

THE UNIVERSITY OF HULL

A STUDY OF CHILDREN'S MISCONCEPTIONS IN SCIENCE
AND THE EFFECTIVENESS OF A RELATED PROGRAMME
OF TEACHER TRAINING IN PAKISTAN

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by

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on

A Study of Children's Misconceptions in Science and the Effectiveness of a Related Programme of Teacher Training in Pakistan.

The study comprised an investigation of children's misconceptions in science with the intention this should provide a base for further research linked to a wider programme of the improvement of science education in Pakistan.

The investigation was carried out on the concepts of Force, Energy, Light, Work, and Electric Current using Interview-About-Instances approach. It was discovered that children in Pakistan hold misconceptions similar to those held by children in other parts of the world. Then, three groups of science teachers were tested in the concept Force after giving them different levels of information about students' misconceptions. It was found that science teachers also hold misconceptions and performance of the three groups was almost equal on the test.

Next, the teachers of the sample students were trained to re-teach three concepts: Force, Energy, and Light. After re-teaching, students were retested using both IAI and multiple-choice instruments. The results showed that pupils' misconceptions persist despite re-teaching.

Then, in order to confirm or refute these results more widely, a larger number of teachers and students were involved. The purpose of this part of the study was to discover if in-depth teacher training can lead to more effective teaching. A special teacher training programme was developed. The selected teachers were randomly distributed into three groups. Group A was given in-depth training, whilst group B was given simple training. Group C served as a control group. After training, teachers re-taught the concepts Force, Energy and Light in their own schools. Students were tested using multiple choice tests.

It was found that group A was significantly different from groups B and C together only in one subset of test items in the concept Force. Also, the mean scores of students in group A in each test were found to be higher than those of students in groups B and C. From these results it is argued that programmes can be organised for the training of science teachers to tackle effectively problems arising from children's misconceptions. Finally, the study proposes a research project with an overall purpose of improvement of science education in Pakistan.

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CHAPTER I

INTRODUCTION

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INTRODUCTION

1.1. SCIENCE AND NATIONAL DEVELOPMENT

Among the controllable factors that influence the growth and development of a nation; Science Education is possibly the most important. Science in its various forms, represents a way of acquiring and organizing knowledge that contributes significantly to the cultural and intellectual development of a society. Also Science Education provides a sound base for subsequent scientific research and technological development.

Every one of us is aware of the increasing role played by science and technology in the well being of man and his future. The industrial revolution, that the present age has witnessed, is the result of the co-ordinated efforts of scientists and technologists. Science has not only revolutionised man's environment, but has also immensely influenced his thinking. In fact, present day civilization is a direct consequence of the advancement of science and the scientific method.

The application of science and technology has transformed societies; has stabilised economies; has raised the standard of life and living; has provided safety and security and above all has given a sense of dignity and honour to the nations of the world. It has now become immensely clear that the nations, which have used science and its methodology for their development, are today the

more prosperous, the more affluent and the more advanced nations of the world, while the nations, which have not pursued the path of science, have remained poor, insecure and under-developed.

Pakistan needs a strong base of science and technology from which to attack and to solve its problems of food and shelter, fuel and energy, health and security, the exploitation of natural resources and the boosting of agricultural and industrial production. The use of science and technology for development, as well as successful technology transfer depend on an adequate and effective scientific and technological infrastructure. For a self-reliant future, therefore, it is necessary that we, in Pakistan, develop scientific capability and research potential, to be able to solve our problems by ourselves. We must create working conditions and facilities where our own scientists and technologists are encouraged and motivated to tackle problems of national importance and urgency.

According to Kazi (1986), there are three important elements for an effective scientific and technological infrastructure in any developing country. Firstly, it should have laboratories where basic and applied research can be done on vital areas of national development. Secondly it should have at least the critical number of well-qualified scientists and technologists and the training facilities for the continuous production of such manpower. Thirdly, it should have the capacity to use and co-ordinate the findings of research and development and to make a proper selection

of suitable technologies. Once these three elements of the infrastructure are integrated into the production system of the country, it will have the capability to produce technological innovations necessary for the special needs and requirements of the country. For Pakistan, the implication of Kazi's elements are clear, we can acquire and adapt the imported technologies only if we have our own national training and upgrading centres, research institutes and technology units to provide the skilled manpower needed for all three infrastructure components.

Successful and satisfying modern living demands that its citizens should understand and appreciate the part played by science and technology in the development of modern civilization. In a democratic society, citizens need to understand the scientific aspect of their environments and who know with assurance how scientific discoveries, scientific methods and technological advances have affected the society and how the needs of society have constantly stimulated scientific research. Popularisation of science and scientific method, therefore, is a pre-requisite for scientific and technological revolution in a developing country. Making the whole population aware of the benefits of science and technology is imperative and effort must be made to make the Pakistani citizens science minded and science conscious, to be able to appreciate the impact of science and technology on their life and living. Hence, more vigorous and extensive steps will have to be taken for the wider dissemination of knowledge of science and technology in the country.

Again, development in economic spheres can be made only if a systematic emphasis is laid right from the beginning on science education at various levels of our educational system. It is obvious that the demand of an effective science education cannot be met by simple extension of the trends and practices of the past decades. There is urgent need for serious rethinking and reconsidering of the form and the content of science education in the country. An appraisal has to be taken of the newly emerging problems and new programmes designed in response to the requirements of the nation. The new demands of Agriculture, Industry, Trade, Commerce, Engineering, and Medicine must be considered seriously by the course designers. It is, therefore, absolutely essential that the system must be reorganized and reshaped. The reorganized and reshaped system must be fully equipped to execute effectively the needs implied by the future objectives of the country.

As it is widely recognised that science education occupies an important place in the economic and manpower development of a country, it is needless to emphasise that our national survival, both in terms of economy and defence potential, depends in large part on the kind of science education we provide to our children. Although, national development is interpreted as national economic development, yet we know that economic development, in addition to scientific and technological aspects of national growth, is strongly wedged into ideological, ethical and social moorings of a nation. All these elements enter into the

initiation and preparation of a viable educational process. This leads us to the notion that science and technology, national ideology, economic development, and the total education process work *are* interrelated parts of the total system.

1.2. SCIENCE EDUCATION IN THE CURRICULUM

Science Education is regarded by Renner and Ragan (1968) as a process involving two major factors. One of these factors is children—children with great potentialities, with unbound curiosity, and with restless energy. The other factor is the broad field of science, waiting to be explored and understood and used for the enrichment of people's lives. The science curriculum is the instrument used to bring these two factors together in achieving the purposes of science education. If we think of science education as a journey which the teacher and the pupils take in the areas of science, the achievement of objectives is the destination and the science curriculum is the vehicle.

Science is not simply a body of knowledge; more significantly it is also a way of thinking and doing, a mode of looking at things and events and also a strategy of learning how to learn. The teaching of science is a powerful means for developing an attitude of critical inquiry, adaptability and the habit of systematic and hardwork which underlie the creative process of change. The teaching of science, broadly, serves two purposes: First, it is a

cultural and educational discipline, cultivating in the learner, the understanding and the insight of a phenomenon and scientific mode of comprehending it. It is therefore, an essential element of general education. The second purpose is to prepare future scientists and technologists by training young people in the fundamental principles, which govern scientific and technological activities.

Science as a subject serves two distinctive purposes in the school curriculum. First, the school curriculum provides means whereby young people can learn to appreciate and understand important aspects of the culture they inherit and make their own society in which they will have to function both individually and corporately, and the world in which they will live through their adult lives. Formal schooling is an important part of this process of individual growth and development, and science education makes a major contribution to the totality of the individual's general education. Secondly, the school curriculum provides means whereby young people can prepare themselves for more advanced and longer term studies of those aspects of knowledge and experience that interest and excite them as individuals.

In the Policy Statement of the Association for Science Education (1981), the Association argues that in planning and developing the science curriculum teachers and others should note that science should be explored from the viewpoint of:

- i) Science as an intellectual discipline: the pursuit of scientific knowledge as an end in itself which leads to an understanding of the essential principles and processes of science and allied disciplines.
- ii) Science as a cultural activity: the more generalized pursuit of scientific knowledge and culture that takes account of the history, philosophy and social implications of scientific activities, and therefore leads to an understanding of the contribution science and technology make to society and the world of ideas.
- iii) Science and its applications: the development of an appreciation and understanding of the ways in which science and technology contribute to the world of work, citizenship, leisure and survival. This aspect includes an understanding of the way in which scientific and technological ideas are used to create and maintain an economic surplus, facilitate participation in democratic decision making in a technological society, enrich and sustain a wide range of leisure activities and pursuits, and enable the individual to utilize scientific ideas and technological processes in the context of increasing demand for self-sufficiency, the conservation of resources and the utilization of alternative technologies.

The Association has further emphasized that the science curriculum should reflect each of the above contexts if it is to make an effective contribution to general education, prepare young people for their adult life in the community at large, and form a satisfactory base for post school education in science, engineering and technology.

1.3. THE GROWTH OF SCIENCE EDUCATION IN PAKISTAN

At the time of independence in 1947, Pakistan did not inherit a strong background in science and technology. Science teaching at the primary level (age range 5⁺-- 10⁺) was almost absent. Middle school classes (age range 10⁺-- 13⁺) had a weak component of science in the curriculum. Secondary (age range 13⁺-- 15⁺) and higher secondary (age range 15⁺-- 17⁺) stages had science subjects in the form of Physics and Chemistry at the secondary level and Physics, Chemistry, Botany and Zoology at the higher secondary level. Science was elective at these stages. The courses taught were content heavy with a very weak component of practical work. This was concerned only with the verification of pre-taught facts and physical properties of the materials. Those engaged in the teaching of science were themselves often lacking in their knowledge of science.

In spite of some early conferences to consider the state of education in Pakistan, there was practically no change in the pattern and organization of science

education in the country. Science Education as a distinct area was never recognized probably because this concept never emerged in the minds of the planners.

The first noticeable change in the pattern of science teaching came about when the need for continuing instruction in science for all those students who did not study elective science from grade 9 was recognised. This era starts from 1959.

A report of the National Commission on Education published in 1959 and subsequent policies of the Government of Pakistan can be seen as recognising the need for and importance of a viable science and technology education in the country. Worldwide changes in science education starting in the late fifties received attention by the Pakistani science educators in the mid sixties when a massive curricular change was undertaken in the field of science.

A clear cut policy statement by the Government of Pakistan linking science and technology education with socio-economic development, appeared for the first time in the National Education Policy stating thus:

'To promote and propagate scientific and technological training and research in the country and to use this knowledge for socio-economic growth and development thereby ensuring a self-reliant and secure future for the nation.' (Pakistan Ministry of Education, 1978).

Following this recognition that science education plays a vital role in national development, it was decided

in 1978 that a National Centre for Science Education would be established to promote and popularise science and technology among the general population through science fairs, museums, films, etc. The Centre would also improve science teaching through research and innovation. It was further conceived that one Science Education Centre would be established in each province in association with one of the universities (Pakistan Ministry of Education, 1978).

In order to over-come long standing deficiencies and problems in the teaching of science and to establish these centres a comprehensive and long-term Science Education Project has since been developed. The project has the following objectives:

1. To provide physical facilities such as science rooms, science laboratories, equipment and furniture to selected middle and secondary schools where such facilities do not exist.
2. To establish the necessary infrastructure both at federal and provincial levels in order to coordinate research based development efforts in science education and to provide continuity in policy and direction in science education on long term basis.
3. To provide in-service training for all middle and secondary school science teachers and supervisors and to train high level professional manpower in science education.

4. To develop modern science curricula, appropriate teaching learning packages for science teachers, innovative equipment and experimental activities for students and test new assessment procedures for student learning relevant to the needs of Pakistan and in keeping with modern trends in Science Education. (Pakistan Ministry of Education, 1986).

One of the most significant aspects of this project is the establishment of an Institute for the Promotion of Science Education and Training (IPSET) in Islamabad having three aims. First, to coordinate and monitor science education improvement efforts; secondly, to promote research-based development in science education; and thirdly to provide a sound basis for the continuity of policy and direction so as to ensure continued growth and development on a long term basis. This Institute alongwith a network of science education centres will undertake research based development of science curricula, text-books, teachers' guides, teacher training programmes and modules for teachers and inquiry oriented activities for children. It will also develop new assessment procedures for science education, including tests for measurement of understanding, comprehension, scientific attitudes and science process skills.

1.4. RESOURCES FOR SCIENCE TEACHING

The growth and development of a country depends very much on the quality of education in general and science education in particular. The quality of science education depends upon many factors; those which are the most important are: 1) text-books 2) teaching methods, 3) teacher's own knowledge of the subject matter, and 4) teacher training. Unless all of these areas are of the proper composition and quality or importance it is doubtful that science education can have the impact and beneficial outcomes that are so much needed. Some indication of the problems under these four headings will now be given.

1.4.1. TEXT-BOOKS

In Pakistan, the teaching and learning of science in secondary schools takes place mostly through books. Text-books are the most widely used teaching aids and serve also to provide background reading material. Not only do students use the books frequently, but their teachers also rely heavily on the same text-books for information and teaching guidance.

These text-books are not of good quality as far as their role as a teaching aid is concerned. Too many facts are given mostly in general form without much account of their applications. Also, concepts are given in general form without extra pains being taken to reduce such explanations to language easily understood by the students.

Although students depend almost totally on the text-book explanations, these books, because of the inadequate presentation of explanations, do not make things clear to them. Most of the topics are treated rather superficially and with misplaced emphasis. Explanations are rarely accompanied with examples from the common experience of the students.

Generally, everywhere and particularly in Pakistan, text-books serve as the best guide to what is taught in schools. Barrass (1984) stresses that for this reason science educators should feel concerned if text-books for introductory courses contain mistakes (errors), misunderstandings (mis-interpretations of facts) and misconceptions (mis-leading ideas). He claims that some established text-books of biology contain obvious mistakes and gives 15 examples of errors, misconceptions and mis-understandings.

After looking into the faults pointed out by Barrass, the researcher feels that physics text-books might not be very different and may contain many faults. From a brief perusal it seems that in Pakistan also, physics text-books have evident conceptual and linguistic mistakes. This might be confirmed by undertaking some evaluative studies on the existing text-books. It is not unlikely that, as Ivowi (1984) claims, misconceptions in students can be easily traced back to science text-books. For example, in some text-books the impression is given that uniform motion involves only motion with constant acceleration.

The case of a body moving in such a way that its velocity is constant is described in such books as 'a body moving with constant velocity' as if it were not moving uniformly. Ivowi (1984) argues that the misunderstanding of this special case of a uniform motion leads to a misconception about the case of zero velocity.

Similarly, in waves, the distinction between transverse and longitudinal waves is often improperly stated because of the misconception about the response of a medium to a disturbance passing through it. If this is the situation, then as Barrass (1984) argues:

'Pupils rely on text-books, which are used as teaching aids and to provide accurate information and background reading when the teacher is not available (also, when the teacher is available, in Pakistan). They are likely to think that all the new words, which they are expected to learn and understand, are necessary for a proper understanding of biology (and also other sciences). Unfortunately, the pupils are being misled.'

Moreover, pupils are also likely to believe literally what they read in their text-books. They expect science text-books to be scientific and accurate. When text-books treat topics rather superficially or with misplaced emphasis, or contain errors, then dependence on such textbook explanations does not make things clearer to the students (Ivowi, 1984).

Science textbooks with errors serve as deficient teaching aids. Ausubel et al (1978, p. 375) argue that:

'The deficiencies frequently ascribed to textbooks are not really inherent in the medium itself but reflect, rather, deficiencies that are common to all inadequately prepared instructional materials, such as lack of lucidity, ineffective communication, inappropriate level of sophistication, and absence of explanatory and integrative ideas. Relatively few textbooks have ever been written that take into account consideration such as progressive differentiation, integrative reconciliation, sequentiality of subject-matter content, and use of organisers.'

1.4.2. TEACHING METHODS

Most science teaching in Pakistan is content oriented and is dominated by the lecture method. Teaching is done by the teachers authoritatively. There are very few demonstrations with the teacher always 'telling' and the students always 'listening' passively, almost no dialogue takes place between the teacher and the students. This kind of teaching and learning encourages rote-learning on the part of students without understanding of science concepts.

This situation prevails despite the fact that the science syllabuses claim to emphasise the acquisition of process skills such as hypothesising, systematic observation, objective evaluation of evidence and the like. This mismatch between aims of science teaching and actual classroom teaching practices might be due to the scarcity of resource materials, and also to the fact that it is probably easier to organise a content oriented lesson than

to provide practical experience such that each member of the class can develop scientific skills. It may be due to the fact that teachers either do not appreciate the significance of these skills or do not know how to teach them.

1.4.3. KNOWLEDGE OF SUBJECT-MATTER

Teachers constitute an important variable in the learning process. As Ausubel et al (1978, p. 498) argues, it does make a difference from a cognitive standpoint how comprehensive and cogent is the teacher's grasp of his or her subject-matter. His second point is that quite independently of his or her adequacy in this regard, the teacher may more or less be able to present and organise subject matter clearly, to explain ideas lucidly and incisively, and to manipulate effectively the important variables affecting learning. Thirdly in communicating with pupils, the teacher may be more or less capable of translating his or her knowledge in a form appropriate for the pupils' degree of cognitive maturity and subject matter sophistication.

It is self-evident that teachers cannot furnish adequate feedback to students or clarify ambiguities and misconceptions unless they have a meaningful and adequately organized grasp of the subject being taught (Ausubel et. al. 1978, p. 502).

Researches in other parts of the world report

the existence of teachers' inconsistent and naive beliefs (See Section 6.1. Chapter VI). In other words, science teachers generally do not have a completely accurate view of the subject matter they are teaching, and consequently their performance will be less than wholly satisfactory in the science classroom or laboratory.

The teachers' knowledge of his subject matter interacts with the science curriculum and its materials as he or she prepares for teaching. The resultant is the viewpoint presented by the teacher to the pupils. This resultant may be very far from a true (i.e. a scientist's) view of science and may be sufficiently vague or erroneous to inhibit future learning and understanding by the pupils.

1.4.4. TEACHER TRAINING

The teacher's professional role in the educational system is vital, because of his direct involvement in many activities beyond the classroom, such as curriculum development, text-book writing, examinations, etc. This role of the teacher is realized by the Pakistan Government, as is clear from the following statement:

'The educational system of any country hinges on the teacher, who occupies a pivotal position in its evolution. But unless he is made conversant with the latest educational developments and provided upto date training facilities, proper introduction of new curricula and the implementation of the Education Policy is not possible.'
(Pakistan Ministry of Education, 1977)

Worthwhile training of teachers requires sound teacher training programmes. The scope of the science teacher training programmes in Pakistan is limited both quantitatively and qualitatively. Only one Institute in the country, i.e. Institute of Education and Research, Punjab University, Lahore, has been offering science education as an area of specialization in its postgraduate degree programmes since 1971. Recently, this Institute has started offering fulfilled master degree programmes in science education both for in-service and prospective science teachers.

Colleges of Education in the country offer Bachelor degree programmes in teacher education. These programmes include general professional courses common for all the trainees with only two elective courses in pedagogy for school subjects including physics, chemistry, biology and general science. As a matter of fact, the professional training the prospective science teachers receive is not different from those being trained for the teaching of subjects other than science. The result is that the prospective science teachers do not acquire the competencies necessary for their later role in the science classroom and the science laboratory.

Moreover, the teacher training programmes in the country are more theoretical than practical. These programmes seldom make the teachers competent to apply the ideas they get during training. A trained teacher often finds that what he learnt during his/her training was not

applicable in the classroom. This is because teacher training programmes have been planned without keeping in mind the problems and difficulties faced by the teachers in the classroom situations.

Generally speaking, the overall science teaching, curriculum development and teacher training are based on the assumption called 'Tabula Rasa' (Fensham, 1980) in which it is believed that children come to school with blank minds and they have no idea whatsoever about the topics to be taught in the classroom. Moreover, it is believed that whatever the child is told by the teacher in the classroom is spontaneously learnt by them without any difficulty or problem.

The whole system revolves around this assumption. The overall planning of teacher training courses ignores the children, their ideas, and their cognitive levels of understanding. The programme of specialization in Science Education mentioned earlier, no doubt realizes the importance of scientific knowledge and the teaching skills required by the science teachers for their later role in the classroom teaching, but in practice, this programme is also based on the same invalid psychological assumption and needs revision.

Even if some teachers or teacher educators recognise that pupils (especially secondary pupils) do have some prior knowledge, their classroom approach based on 'Teacher Dominance' (Gilbert et al, 1982) is not practically different. This alternative assumption believes

that even though children might have ideas before they come to school, these ideas are not strongly held and can be easily removed or changed by teacher's ideas without special effort.

Work by Osborne and Gilbert (1979) and other researchers have shown (Gilbert et al, 1982) that children have beliefs about how things happen and expectations which enable them to predict future events. The revision of teacher-training must be aware of this knowledge and children's ways of learning.

The views which children bring with them to science lessons are to them logical and coherent and these views have a considerable influence on how and what children learn from their classroom experiences. Moreover, children have clear meanings for words which are used both in everyday language and also in formal science. These are one kind of research findings that must be taken into account when planning the new courses of Science Teacher Education.

These research findings have direct implications for revision of Science Education in general and teacher education in particular. Efforts are being made for the revision of science education in many countries. Some specific examples of attempts to design lessons, or sets of lessons, which build on children's ideas have already been reported in the literature e.g. Nussbaum and Novick (1981), Osborne et al (1981), Schollum et al (1981).

1.5. SIGNIFICANCE OF PRESENT RESEARCH FOR PAKISTAN

Of the four problem areas identified before, namely: 'Textbooks', 'Knowledge of Subject Matter', 'Teaching Methods' and 'Teacher Training', the problem area of 'Teaching Methods' is the most important. Importance of this area lies in the fact that teaching science, as argued by Hurd (1971), requires a teaching method supportive of the way students acquire science concepts. Also, as argued by Victor (1985), the methods of teaching science are the means through which content and process are learned and the objectives of science are achieved. Some methods lend themselves better to a learning situation than do others (Hurd, 1971) and the teacher's task is to use a proper combination of methods to achieve the desired goals of science education (Deighton, 1971).

Recent research in science education, also mentioned in the previous section, suggests that, before any science teaching takes place, children have already acquired considerable knowledge about the natural and technological world. From experience based on a large number of studies (Osborne, 1982), it has been found that children's pre-lesson viewpoints and learning are largely uninfluenced, or influenced in unanticipated ways, by much of our present day teaching. Children often misinterpret, modify or reject the scientific viewpoint as it is presented to them (Gilbert, Osborne and Fensham, 1982) using the way they really think about how and why

things behave. The 'scientific viewpoint' might be rote-learnt and subsequently regurgitated in an examination but it is not the way the pupil actually thinks about the world.

These findings point to the need for a new view of science teaching (Osborne et al 1983). Science teaching, in so far as it is concerned with encouraging students to be aware of, and possibly even adopt, alternative views of the world and meanings for words, needs to build on or to confront, but certainly not ignore, children's viewpoints.

Revision of the programme of Science Education referred ^{to} earlier requires a research base, so that any changes brought in this programme are justifiable. In the past, very little research work had been done in Pakistan to investigate children's prior knowledge and their understanding of basic concepts of science. As a result, the teaching of science in the classroom, science teacher training, and science curriculum development efforts do not take into account children's prior knowledge of the concepts of science.

The present study was undertaken with this background in mind about the status of science education in Pakistan. This study aims at investigating misconceptions of children in selected concept areas in science. The researcher was inspired to undertake this study from the work of Osborne and Gilbert (1979) in Surrey, UK and in Waikato, New Zealand. More specifically,

the study was aimed at forming a base for future research in science education in general and science teacher education in particular. Also, it was envisaged that this study will lead to answers or partial answers to some or all of the following questions:

1. Whether or not Pakistani children have misconceptions similar to those held by children in other parts of the world.
2. Whether or not an investigation technique used in one culture or country can be used in other cultures or countries.
3. Whether or not teachers of science have misconceptions in science.
4. Whether or not informing the teachers about children's misconceptions in science affect their own ideas.
5. Can teacher training be organised to enable the teachers to modify their own misconceptions and to achieve in turn better student concept understanding?
6. Is it possible to modify children's misconceptions in science if the concepts are retaught by specially trained teachers?
7. Whether or not in-depth teacher training can lead to more effective teaching.

It is hoped that this research experience will enable the researcher (and also other science educators)

to: 1) review the existing science education programme at his own Institute in the light of the findings of this study, and 2) to establish a long term research project for the improvement of science teacher education in the country.

It is further hoped that the study will be useful for:

1. The Science Educators - to guide them for better planning of teacher training programmes.
2. The Science Education Researchers - to guide further research in this area.
3. The Curriculum Developers - to guide them to develop curriculum which takes into account children's prior knowledge.
4. The Textbook Writers - to make them cautious of misconceptions they might add to the text-books and to guide the level of explanations of everyday events they should provide.
5. The Science Teachers - to make them aware of both the children's and teachers' misconceptions, and therefore, guide them for better science teaching.

The present study passed through various stages. Firstly, pupils' and teachers' understanding in selected concept areas of science were explored. Secondly, effects of short periods of teacher training and selected re-teaching on teachers' and pupils' conceptions of science

was studied on a small scale. And, thirdly, effects of teacher training on pupils' misconceptions was studied on a larger scale. A detailed time table describing various tasks undertaken in this study is given on the next page. The study has been presented in seven chapters. After the first chapter on Introduction, Chapter II and III review the related literature, Chapter IV, V, and VI describe studies, 1,2, and 3 respectively. Chapter VII presents a summary of the research study, and finally describes a Research Project to be undertaken for the training of teachers and production of materials for the improvement of Science Education in Pakistan.



RESEARCH TIMETABLE

SR.NO.	ACTIVITIES	DATES
1.	Planning, literature search and study.	From November, 1981
2.	Production of Interview cards for 5 concepts (Force, Energy, Light, Work and Electric Current)	September/October, 1982.
3.	Trial Interviews in 5 concepts.	November/December, 1982 and January, 1983.
4.	Modification of Interview Cards.	February, 1983.
5.	Student Interviews using IAI approach, testing 5 concepts.	March, April, May, 1983.
6.	Testing of Teachers in Force using Paper-and-Pencil Test. Group I Group II Group III	April, 1983 October, 1983 August, 1983
7.	Short visit to University of Hull for discussions with the Supervisor, study of literature and further planning.	October, 1983 -- February, 1984.
8.	i. Construction of Multiple choice tests in 3 concepts (Force, Energy, Light) ii. Planning for the workshops. iii. Searching for Teachers to participate. iv. Preparation of Workshop Materials.	Second week of Feb. to 3rd week of March, 1984. " " " " " " " " " " " "
9.	Duplication of Tests.	Last week of March and 1st week of April, 1984.

10.	Test administration for Reliability Test.	Second week of April, 1984.
11.	Formal invitation letter to teachers for the second workshop.	19 April, 1984.
12.	Finalization of MC Tests.	3rd week of April, 1984
13.	Duplication of MC Tests	Last week of April, 1984.
14.	First workshop held for the teachers of the 8th class students.	Last week of April, 1984.
15.	Second workshop for larger group of Teachers.	4th May 1984.
16.	Re-Teaching by the participants of the 1st workshop.	1st week of May, 1984
17.	Re-Testing of students taught by the participants of the 1st workshop using MC Tests.	Second week of May, 1984.
18.	Re-Teaching by participants of the second workshop.	Between 5th May 1984-- 31st May, 1984.
19.	Testing of Students taught by participants of the second workshop using MC Tests.	Between 12th May 1984 & 31st May 1984
20.	Coding of Data	June/July 1984
21.	First draft preparation of Thesis Chapters 2 & 3.	June/July 1984
22.	Preparation of Appendices etc. for the Thesis.	August/Sept. 1984
23.	Re-Testing of Students taught by participants of the 1st workshop using IAI approach.	Sept./Oct./Nov. 1984.
24.	Visit to University of Hull to complete the work.	From December 1984 -- June 1985
25.	Oral examination held	December 1985
26.	Thesis resubmitted after revision in the light of examiners' suggestions.	1989

CHAPTER II

THE TEACHING AND LEARNING OF SCIENCE CONCEPTS

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2.1. WHAT IS A CONCEPT?

The term "concept" does not have a standard meaning the same for all school subjects, nor do the scientists and psychologists use the term in identical ways. One fundamental problem as indicated by Spitzer (1975) in formulating a suitable definition of "concept" is that the term has entered the realm of general language and is commonly used with a very indefinite and flexible meaning. "Concept" has come to refer, in common usage, to any idea, process or thing which cannot be defined readily in another way. Concepts in science typically describe a more complex kind of organization than a simple response to a class of objects.

Webster's New Collegiate Dictionary gives two definitions of concept. The first definition is: "something conceived in the mind, a thought or notion"; the second definition is: "An abstract idea generalized from particular instances." These definitions indicate the notion of "generalization." Certainly there have been many psychological definitions of "concept" which have centred on "generalization", and there is some consensus that some degree of generalization is involved in concept formation. Further, the general agreement among psychologists and educators as

Spitzer (1975) finds is that concept formation is the basis by which man orders his experience; that it represents some sort of cognitive grouping; and that it is an extremely important element of human learning.

One of the most frequently expressed values of concepts is that they allow the individual to form general notions of his world, on the basis of specific experiences with it. According to Hurd (1971), concepts differ from facts at one extreme and from theories or conceptual schemes at the other extreme. To form the simplest concept, at least two facts or observations that agree are needed plus at least one more which does not fit into the classification. These facts do not have to be alike but they must form a meaningful unit, or a class of experience, or a common response that can be generalized. 'Mammal' is an example of the concept; several facts have been brought into a relationship to convey the idea, 'mammal'. This organization of facts also discriminates between animals that are mammals and animals not mammals.

Further, Hurd (1971) views a concept as a synthesis or logical relationship given to relevant information by the student; it is a product of his own imagination, insight or reasoned judgement. A concept is also more than a collection of organized facts. Facts are essentially bits of information whilst concepts are mental constructs resulting from the class identity given to the facts by the learner. Facts are available to all who perceive them; they are public property, whereas concepts are a private possession

and represent a personal grasp of the relatedness of data. Concepts have a logical structure making the facts within the concepts meaningful and therefore useful in thinking. This means concept formation is something more than simply summarizing, sequencing, or grouping items of information. A concept has a cognitive organization transcending the meaning of its several components. For example, in the concept of 'density', as a ratio of mass to volume, density emerges as a relationship formed by the learner. Essentially density represents a conceptual invention that goes beyond the observed data. When a concept such as density becomes a part of the common experience of the people, it acquires a name which makes it possible to share its class identity with others. In this example, a numerical or algebraic expression may be used to more precisely convey its meaning.

Gagné (1966) argues: 'we are also used to referring to the 'content' of school subjects as conceptual, without necessarily considering the nature of behavioural change that may be involved. Thus, we often refer to the body of knowledge called genetics as "the concepts of genetics". If forced to say what we mean by the concepts of physics, we are inclined to reply by naming such things as mass, energy, work, gravitation, and atom. In the case of genetics, the entities named might be genes, chromosomes, DNA, RNA, and perhaps many others. We speak of students learning the concepts of physics and the concepts of genetics, and by so doing we surely mean to imply that what

is learned is conceptual'.

Gagne further argues that despite differences in the language used to describe a concept, there is considerable agreement among research psychologists as to what this word means. The general properties in common in the various definitions as judged by Gagne are:

- i. A concept is an inferred mental process
- ii. The learning of a concept requires discrimination of stimulus objects (distinguishing "positive" and "negative" instances).
- iii. The performance which shows that a concept has been learned consists in the learner being able to place an object in a class.

The most fundamental disagreement (Spitzer, 1975) among theorists concerns the complexity of the construct. On one extreme, there are those who believe that concepts are spontaneous capabilities which the infant can almost immediately master, on the basis of his earliest perceptions (Lewis, 1963; Montessori, 1972; Ricciuti, 1965). On the other extreme, there are others who feel strongly that concepts represent a high level mental process and result from considerable pre-requisite experience and maturity of thought (Gagne, 1965; Tennyson and Merrill, 1971; Vygotsky, 1962).

Another disagreement, according to Spitzer is the conflict between the "pre-language" and the "post-language" positions concerning whether or not language facility is a pre-requisite for concept formation. This controversy

appears to be the most clearly defined area of disagreement.

The pre-language position is supported primarily by experts in early childhood development and child psychologists, who view concepts as being the result of simple learning. Advocates of this position see concept formation as fundamentally a "process of recognition" based on responses to certain perceptual characteristics.

The post-language position tends naturally to place a tremendous importance upon the development of names for concept formation. Brown (1956) views concept formation as the matching of environmental groupings with names. According to this view, groupings already exist in the outside world, but they must be made salient to the individual through language categories. Taba (1967) believes that developing labels for concepts is an important part of concept formation process, and that without names concepts are not concepts. This view highlights a fundamental controversy relating to concepts: do labels come after concepts are formed or are they pre-requisite for concept formation? Vygotsky (1962) believes that, before language, there cannot be true concepts, only "complexes", or "pre-concepts".

Another controversy in the debate over the nature of concepts is between the "associationists" and the "higher level process" advocates. There are a number of theorists who believe that a concept is merely a grouping or category. They would hold that an adequate definition of the term would be similar response to different stimuli;

that stimulus association, or grouping, is the key process in concept formation. Another group believes that a high degree of discrimination ability is required in addition to association. Still another group views concept formation as extremely complex and maintains the belief that, not only is concept formation tied to language development, but it is also linked to such "high level mental processes" as abstraction and logical thinking.

The preceding discussion has shown that several meanings can be given to 'concept' and concept formation. The discussion is by no means exhaustive, there are in the educational literature many other definitions. Among them are Lamb's (1970); Piaget and Inhelder's (1960); Lennenberg's (1967); Gagne's (1970) and Ausubel's et al. (1978). For the present study the definition proposed by Klausmeier et al. (1974) and used by Osborne and Gilbert (1979) seems most useful (Spitzer, 1975).

According to Klausmeier et al. (1974) "a concept is ordered information about the properties of one or more things - objects, events, or processes - that enable any particular thing or class of things to be differentiated from and also related to, other things or classes of things." These writers suggest that there are four levels to concept learning: the concrete level; the identity level; the classificatory level, and the formal level.

According to an interpretation by Osborne and Gilbert (1979), this viewpoint suggests that to understand a concept at a formal level a student must build for himself

an adequate description of concept attributes so that new instances can be correctly classified as examples or non-examples of the concept class. Further, a measure of concept attainment is the ability of an individual to properly categorize instances not previously encountered as instances, or non-instances, of the particular concept. Similarly, Markle and Tiemann (1970, p. 43) state 'to really understand a concept is to be able to generalize to all possible instances that might be presented and to be able to discriminate all possible non-instances including those that bear a strong resemblance to members of a class.' As already mentioned above Gagné (1970) states that if a student can classify new instances, as belonging, or not belonging, to the concept class then he can be said to 'know' the concept.

Using these ideas as a theoretical base, an investigation technique (named as Interview-About-Instances approach) was developed and then used by Osborne and Gilbert (1979) for the investigation of children's understanding of various concepts of science. The same investigation technique was selected by the researcher for the purpose of the present study and is described in Chapter III.

2.2. THE IMPORTANCE OF CONCEPTS IN THE LEARNING OF SCIENCE

The growth of new knowledge in the sciences has been very great in recent years and the rate of increase

has also been accelerating. The very character of science, that is, the fact that each problem solved opens the way to solution of many new problems, results in an accelerating growth in new knowledge (Novak, 1966). There is also the problem of the increasing complexity of everyday life each year with more things to know about and to be able to use, for example, technological achievements and products which are inescapable in the life of each individual. The production of new knowledge in science and its applications in technology is changing the entire pattern of vocational and career advancement. A major problem in career development is the fact that it is no longer possible to prepare oneself or a student for a lifelong career; the knowledge requirements change and many jobs become obsolete (Hurd, 1971).

The number of scientific facts that exist within each discipline has reached explosive and, from a teaching point of view, prohibitive proportions (Pines & Leith, 1981). In addition to the growth in the number of facts, the facts themselves constantly change. The question now for educationists is one of how to design a curriculum that will develop in learners the intellectual skills and attitudes essential for progress within a system of continuous change. Essentially the task is one of providing an education which makes it possible for youth to understand today's world and at the same time be prepared to meet the unknown problems of tomorrow. If we are not able to do this we will always be educating youth for a world that no longer is.

To overcome this difficulty, Pines & Leith (1981) suggest that it makes more sense to view science as a conceptual frame work and to focus science teaching upon helping the student develop a representative and significant reservoir of scientific concepts and to minimize the rote memorization of factual information. If this is accomplished then the teaching of science will be more in harmony with the way science is (Hurd, 1971). Facts constitute the findings of a science, and have little, meaning in isolation from other data. They are needed as a basis for concept development and they provide a skeletal framework, but knowing unstructured facts, however many, does not assure their use or value. Explanations in science arise from concepts, theories and principles and while these explanatory insights arise through a correlation of facts, an explanation of phenomena or events is never found in facts alone. While both facts and concepts are essential for understanding science, teaching limited almost exclusively to the telling, reciting and testing of information does not convey either the meaning or intent of science. To teach only the findings of science is to teach an illusion of scientific knowledge. To be sure one must have an interest in facts since it leads to their discovery, but facts alone are sterile of meaning, unwieldly and uneconomical for teaching purposes. It is the responsibility of science teachers to help young people learn how facts are known and, knowing them, how they can be built from disconnected fragments of data into meaningful structures.

Hurd (1971) further states that while observations and data are basic to science they are neither the means nor the end of science. It is the interaction of theory and logical operations which serves to bring facts together and gives them meaning. Facts become useful and intelligible as parts of verifiable concepts which are in turn illuminated by hypotheses and theories. Concepts and principles, not data, provide the most meaningful units for learning in school for they are a means by which facts and experience can be integrated. Facts outside concepts are blind, concepts without facts are sterile. Facts represent partial answers to problems of the past, but the need in science teaching is for an information organization by which new problems may be met; concepts provide this means since they are generalizable, facts are not. If we expect students to understand the cumulative nature of science it will not be achieved by pyramiding facts, but through understanding how conceptual structures are modified. The meaningful internalization of a scientific conceptual framework according to Pines & Leith (1981) is a far more efficient and adequate way to learn science than the memorization of facts. The acquisition of concepts enables the student to understand phenomena, to ask questions, to carryout investigations, and to generate new instances.

Keeping in view the potential which concepts have for improving problem solving and for learning to learn, Hurd (1971) describes several advantages of concepts in the learning of science. These are briefly described below:

1. A concept provides the best means for getting a lot of data compressed, organized, and into our thinking all at one time. Concepts contain more facts a student can use in a meaningful way, free of the over-burden of details, than most other forms of data communication. Learning concepts is one means of reducing the large volume of scientific knowledge available today and simplifying it for use in thinking.
2. Concepts provide a means for the extension of learning, in other words, to go beyond the initial learning without additional information. It is difficult to do much with isolated facts, for example, knowing the normal body temperature of man to be 98.4°F . is not enough information to extend what has been learned. Whereas, understanding the concept of 'warmbloodedness' makes it possible to describe, hypothesize, or interpret many things about an animal not yet studied by simply identifying it as warmblooded. This is the difference between knowing an interesting fact and possessing useful information. 'Mass' and 'heat' as concepts permit the learner to generalize, but if they exist in the student's mind simply as definitions learned by rote they function as facts and have no value for problem solving. Knowledge enclosed in a concept raises the generalizability of that knowledge. This implies the student is able to use

his generalisations to generate new meanings and make inferences beyond the specific instances he was taught.

3. Knowledge acquired as concepts can be used to build more complex concepts, to formulate principles, to bring new information into a logical structure, to define a problem, to generate new ideas, to provide explanations, to make interpretations, to suggest a hypothesis, to direct observations, to organize data, and to make discoveries. How effectively each of these functions can be carried out depends upon conditions such as, how well the student understands the substance of the concept, whether he is aware of its range of application, whether he has a predisposition and the motivation to apply what he knows, and whether he has had experience using concepts to meet new problem situations. While extensions of knowledge are made possible through concepts they do not occur automatically; knowing a concept is one thing, using a concept in a new context is something else. Concepts inherently possess meaning for more than one situation, awareness of this helps the student to notice relevant events in other contexts and to have some feeling about their plausibility. Forming concepts is one of the best ways for students to understand the intellectual power of scientific knowledge.

The entire structure of science is dependent upon categories of meaning found within its paradigms, concepts, hypotheses, principles, laws, theories and models. Each of these structures represent a meaningful pattern of information. It is these conceptual systems combined with inquiry processes that make it possible to have the knowledge of science work for us.

4. Concepts provide knowledge with a predictive element which tells us what to expect under certain conditions or in particular contexts. In this respect a scientific concept and a theory function in about the same way, since they both allow us to make inferences in areas where we have not previously had specific experience.
5. Concepts are remembered much longer than the facts and specific instances of which they are composed. Factors contributing to concept retention are, first, they have a wider range of associations than facts and therefore are used more frequently and, second, as new bits of information are incorporated, the concept is brought into use and its stability is increased. Remembering is not simply storing a concept in one's mind, nor is it repetitive use, rather it is an integrative process, a continuous reorganization that serves to keep it alive and active. A third reason why concepts are easier to remember is there are fewer of them--they reduce the

volume of information and still allow us to engage in all the intellectual activities required by the facts. With the demands on everyone to know more at every phase of life than at any time in past history we cannot afford learning that will soon be forgotten. The value of concept learning is it reduces the necessity for constant relearning. Rotely learned materials remain isolated and thus have a short tenure in memory. Concepts provide a connecting link between work in school and life outside school through their interpretive power and multi situation application. Thus these are strengthened with use.

6. One function of scientific concepts is to provide the categories into which observations in the laboratory can be fed for coding and possibly turned into information. Without a reservoir of science concepts the student is essentially intellectually helpless in the laboratory, since he can neither identify relevant observations nor provide a means for bringing order to them.

This section has illustrated the extent to which the meaning of science is found in concepts and suggested concept attainment as an efficient and effective way of learning science. The next section describes a learning theory relevant to the present study.

2.3. IDEAS OF LEARNING RELEVANT TO THE PRESENT STUDY

There are three types of learning: Cognitive learning, affective learning, and psychomotor learning. Cognitive processes according to Novak (1976) are those by which we acquire and use knowledge. It is what most people mean when they speak of learning, especially school learning. Cognitive learning results in organized storage of information in the learner's brain and this organized complex is referred to as 'Cognitive Structure'. Affective learning results from signals that arise within the individual and these are identified as pleasure and pain, satisfaction or dissatisfaction, contentment or anxiety and so on. Psychomotor learning involves training of muscular responses through practice, but some cognitive learning is usually an important element in the further development of psychomotor skills through practice and training.

An understanding of how children develop cognitively and also how children learn, is essential to teaching science effectively in the classroom. For guidance in this aspect, science educators have turned to the research and theories of developmental psychologists. Most theories of learning fall into two distinct categories, the so-called behaviourist and cognitive theories (Victor, 1985). Behaviourist psychologists believe that learning consists of making strong connections (or forming strong links) between events called stimuli and appropriate behaviours called responses. This is why this group is often referred to as

S-R (Stimulus Response) psychologists. According to these psychologists the task of teaching is to establish strong connections or associations, between stimuli and the appropriate response reactions of the learner. Thus, when children are presented with a series of questions (stimuli) and supply answers (responses), the correct answers should be reinforced because responses that are reinforced will be strengthened and are most likely to be retained.

Cognitive psychologists are concerned not only with S-R behaviour, but also with the mental processes that cause behaviour. They believe that learning also occurs through the development of new patterns of thought, called insights. Instead of seeing learning as the formation of connections or associations between stimuli and responses, these psychologists view learning as either the gaining of new insights or the changing of previous ideas and perceptions so as to lead to new insights. The task of teaching is to provide situations that encourage insight so that the children can discover ideas on their own.

The theories of two cognitive psychologists have made or seem about to make a tremendous impact on school science. The two theories have broad implications for what should be taught in science, how it should be taught, and the sequence in which it should be taught. For the purpose of the present study the theories of the two psychologists, Jean Piaget and David Ausubel, are first described briefly and then, after a comparison of the theories in the light of their implications for science teaching, an argument will be developed giving the stronger support to Ausubel's ideas.

2.3.1. A BRIEF NOTE ON PIAGET'S THEORY OF INTELLECTUAL DEVELOPMENT

According to Piaget, children develop intellectually in a sequence of stages by age from infancy to post-adolescence. Each stage of learning is necessary for the development of the stages that follow. A child cannot skip a stage because each stage not only utilizes and integrates the one before it but also serves to pave the way for the ones that follow. Although the sequence of stages is the same for all children, the rate at which particular children pass through these stages will depend upon both the children's heredity and their socio-economic environment (Victor, 1985).

Piaget identifies four stages of intellectual development from birth to adolescence. (1) the sensorimotor period, from birth to about two years of age, (2) the period of preoperational thought, from about two to seven years, (3) the stage of concrete operations, from about seven to eleven years, and (4) the formal operations period, from about eleven years to fifteen years.

A brief description (Novak, 1978; Driver, 1983; Victor, 1985; Trowbridge & Bybee, 1986) of each of these stages is given below:

1. SENSORI-MOTOR STAGE

Age

In this stage, (at first) an object exists for the child only when he can see or feel it, and he locates hidden

objects exist even when he cannot see or touch them. For the child there usually is no other time but the present, and no other space than what he now sees. He cannot imagine an act before he carries out the act. Through his senses and motor activities he learns about properties of things, and he begins to develop a practical basic knowledge that forms the foundation for learning in the next stage.

2. PREOPERATIONAL STAGE

Ages

This stage is given its name because the child does not yet use logical operations in his thinking. In this stage the child is egocentric, so his view of the world around him is subjective rather than objective. Because he is egocentric, the child is unable to take into account another person's point of view. Also, the child is perceptually oriented; that is, he makes judgements in terms of how things look to him. He does not think logically, and therefore, cannot reason by implication. Instead he uses an intuitive approach and makes judgments in terms of how things look to him. He depends upon trial and error to make corrections.

He can observe and describe variables (properties of an object or aspects of a phenomenon), but he concentrates or 'centres' on only one variable at a time, usually a variable that stands out visually. He cannot coordinate variables, so he has difficulty in realizing that an object has several properties. Also, he can arrange objects in

simple series, but he has trouble in arranging them in a long series or in inserting a new object in its proper place in a series. To the child space is restricted to his neighbourhood, and time is restricted to hours, days, and seasons.

He has not yet developed the concept of conservation. This means he does not understand that a number of objects can be rearranged and that the size or shape or volume of a solid or liquid can be changed, yet the number of objects and the amount of solid or liquid will be unchanged or conserved.

Also, the child does not yet understand reversibility. His thinking cannot yet reverse itself back to the point of origin. The child does not yet comprehend that action and thought processes can be reversed.

3. CONCRETE OPERATIONS STAGE ^ ^ ^

In this stage the child can now perform logical operations. He can observe, judge, and evaluate in less egocentric terms than in the preoperational stage, and he can formulate more objective explanations. As a result, he knows how to solve physical problems. Because his thinking is still concrete and not abstract, he is limited to problems dealing with actual concrete experiments. He can not generalize, deal with hypothetical situations, or weigh alternative possibilities.

He is capable of decentration, which means that he no longer "centres" his thinking on just one property or

aspect of an object, but can now "centre" on two or more at one time. He can now understand multiple relationships and can combine parts into a whole. He acquires good motor skills and can move objects around to make them fit properly.

He can make multiple classifications, and he can arrange objects in long series and place new objects in their proper place in the series. He begins to comprehend geographical space and historical time. He develops the concepts of conservation according to their ease of learning: first, numbers of objects, then matter, length, area, weight, and volume, in that order. He also develops the concept of reversibility and can now reverse the physical and mental processes when numbers of objects are rearranged or when the size and shape of matter are changed.

4. FORMAL OPERATIONS STAGE

In this stage the child's method of thinking shifts from the concrete to the formal and abstract. He can now relate one abstraction to another, and he grows in ability to think conceptually. He can develop hypotheses, deduce all possible consequences from them, then test these hypotheses with controlled experiments in which all the variables are identical except the one to be tested. When approaching a new problem, the child begins by formulating all the possibilities and then determining which ones are substantiated through experimentation and logical analysis.

After he has solved the problem, he can now reflect upon or rethink the thought processes he used.

Piaget also uses three concepts: Assimilation, Accommodation and Equilibration. A brief description of these concepts follows:

ASSIMILATION

Piaget indicates (Klausmeier, 1985) that individuals continuously interact with their environments. Each interaction always has two adaptive aspects: assimilation and accommodation. Related to cognitive development, assimilation implies incorporating experiences into a person's existing cognitive structure. Each of us has what psychologists describe (Owen et. al, 1978) as a cognitive structure or schema that represents what we know and how we look at our world. Our schemas determine how we respond at a given moment to people, objects, or occurrences, and we try to assimilate new experiences into our schemas. But much information and experience do not fit into our existing schemas, and disequilibrium results. So, we alter our schemas to accommodate the new material.

As a child acquires new experience, events are interpreted according to the mental schema the child has. For example, (Novak, 1978), new instances of dogs that fit the child's schema of dog would be assimilated without any appreciable modification of the schema. However, a very small puppy or bizarre breed of dog might require some

modification of the child's schema and then this experience would be accommodated into the revised schema.

ACCOMMODATION

Accommodation implies changing the cognitive structure to fit new experience (Klausmeier, 1985). As with assimilation, accommodation occurs frequently in the course of learning or the experience of any child. Almost any new learning episode will result in some minor alteration in the child's thought patterns and hence accommodation occurs almost simultaneously with assimilation. In the process of assimilating and accommodating, the cognitive system itself changes and cognitive development occurs.

Cognitive development proceeds in an orderly fashion through four successive stages described earlier. All individuals progress through these four stages in the same fixed order, or invariant sequence.

EQUILIBRATION

Equilibration, or self-regulation, according to Thier (1970) is the factor and the process which is the foundation of and basic to an understanding of Piaget's whole approach to intellectual development.

Piaget holds as illustrated by Novak (1978) that the child constructs general mental schemas to interpret events in the world and these schemas influence the way he

can operate mentally on phenomena to which he is exposed. Schemas are constantly being modified through assimilation and accommodation, and in time, qualitative changes are apparent in the child's schemas. These qualitative changes represent a shift in thought patterns to new levels or stages or a shift in equilibration, with assimilation and accommodation taking on new forms.

2.3.2. THE APPLICATION OF PIAGET'S THEORY TO SCIENCE TEACHING AND LEARNING

As argued by Driver (1983), the main contribution of Piagets' work has not been his general description of the mechanism for ^{the} development of children's structures of thought. Rather, it is the extensive and detailed investigations which he and his collaborators have undertaken to describe the specific characteristics of children's thinking of different ages.

Driver (1983) further describes the cognitive structures which are central to Piaget's theory as of a logical or mathematical nature. They describe the form of a child's thought as opposed to its content. These structures Piaget suggests develop in stages. Piaget's results suggested that children develop formal thought between 11 - 15 years of age. However, surveys undertaken in England by Shayer et. al (1976) and in America by Lawson and Renner (1978) show that the majority of children do not develop formal operations until much later in the secondary school. This, it is argued, has implications for the

science curriculum in secondary schools if what is taught is to be within the grasp of most pupils.

Also, results of surveys (Shayer & Adey, 1983), carried out as part of the science work of the Concepts in Secondary Mathematics and Science Programme (CSMS) based at Chelsea College Centre for Science Education, London show clearly that by age 9 years only about 30 percent of pupils are using concrete operations fully, and one must go to 14 years before this rises above 75 percent. At 14 years only 20 percent are using even early formal operations. The second notable feature of the results is the levelling off at age 14 or 15 of the proportion of pupils who can make use of formal operations. An extrapolation of the results by the researchers suggests that in the adult population only 30 per cent ever make use of theoretical models, or can handle multivariate problems, or can use any of the cognitive strategies characteristic of formal operational thinking. This is contrary to the Piagetian implication that every one attains the stage of formal operations eventually.

Currently, there is some controversy as to the validity and utility of the so called stage theory. It is recognized that the ability of a pupil to use a certain logical operation, for example proportional thinking, depends on his familiarity with the context within which a task is set. Pupils may control variables competently in one task but not in another. This means that it is pupils' behaviours and responses which can be labelled as fitting a

specific stage, not necessarily the pupils themselves. This context effect on performance calls into question the usefulness of applying a 'matching model' to prescribe the teaching materials which are appropriate to the learner's stage of development. Such a matching model, described by Shayer & Adey (1983), has three components:

- 1) the level of cognitive demand of a topic in the curriculum is analysed, and the topic is allocated to a level in the Piagetian stage taxonomy;
- 2) pupils are tested in order to determine their level of cognitive development;
- 3) the curriculum is planned so as to match the level of demand to the level of development of the learner.

This approach can give some guidance in the general planning of science courses over the years 5 - 16. However, there are problems in applying it to particular classes or to individual children. A few of the fundamental problems of curriculum matching have been identified by Driver (1983) and briefly described here.

First, there is the question of adequately analysing the level of demand of a topic in the curriculum. The level of demand of a topic can depend on the way it is taught. For example, a teacher's guide may recommend that a particular topic is treated in a way that demands hypothetico-deductive thought with pupils generating hypotheses and testing them experimentally. The topic could,

however, be treated in a way that did not make these demands and meaningful learning could still take place.

The second problem with the model lies in the assumption about the coherence of the concept of a 'stage'. If a pupil as a result of being tested is allocated to a particular stage, what is the probability of him performing at this level in another context? Studies vary in the answers they give to this question. The studies by Shayer (1979) and Lawson et al (1978) indicate a reasonably high degree of association between levels of performance on one task and that on another. However, the question arises as to whether this is adequate to make educational predictions at the individual level.

The third issue concerns a question of priorities in the curriculum. There is evidence to suggest that particular operations can be taught in the context of teaching a science topic. The necessary proportionality operations can be taught in the context of calculations on mole, the law of moments can be used by pupils who are not assessed as operating at the formal level. Such pupils may not be able to generalize the use of proportional reasoning to other topics, but as science educators we might consider it an important end in itself that these particular scientific principles are understood.

In this debate about the validity of the stage theory it is not the results of Piaget's investigations which are being questioned, it is the interpretation being placed on them which is under review. In this regard,

Driver (1983) presents three interpretations, each with a significantly different implication for the planning of science courses. First, there is the structuralist position which suggests that each stage is characterized by the development in the individual of a set of structures which determine the operations that a person can perform. Developmental factors are identified as the main determinants of the rate of appearance of these structures. According to this analysis, the operations a child can perform, and hence his capacity for learning, are age-dependent. The educational implication of this position is to adopt a 'readiness' model: wait until a necessary stage is reached before teaching a topic.

Another position for which Driver advances some evidence, is that the operations pupils can perform are age-related but the limiting factor is the capacity of working memory--the amount of information a person can keep in mind at any one time.

A third interpretation rejects the idea that there is an age restriction on learning. Instead, it is suggested that the age and sequence in which tasks are successfully performed are simply a function of the complexity of the tasks and the prior experience of the individual.

This position has been argued by Novak (1978), who concludes that the data from a number of studies:

'....support a model of cognitive development that is not 'stage' dependent, but rather dependent on the framework of specific concepts and integrations between these concepts acquired during the life-span of the individual.'

Novak suggests that Ausubel's theory of meaningful learning offers science educators a more useful and valid model of learning than the Piagetian stage model. Ausubel, like Piaget, assumes that each individual organizes and structures his own knowledge. Where the Piagetian model focuses on content independent logical structures or operations, Ausubel postulates that knowledge is structured as a framework of specific concepts. He emphasises the role of verbal learning and distinguishes between rote learning and meaningful learning, where new knowledge is related by the learner to relevant existing concepts in that learner's cognitive structure. The main concepts of Ausubel's theory are described in the following sub-section.

2.3.3. AUSUBEL'S THEORY OF LEARNING

Ausubel's Theory deals primarily with cognitive learning. Miller (1980) has summarised the salient points of his theory saying that there are four key concepts to this theory: Cognitive structure, subsumption, integrative reconciliation, and progressive differentiation.

For Ausubel, Cognitive structure is defined as an individual's organizational stability and clarity of knowledge in a particular subject matter field at any time (Ausubel, 1963). The learner's cognitive structure is

organized in a hierarchical fashion, ideas and concepts are held in such a way that broad over-all concepts have linked to them several related subservient ideas, and so on. When the learner is presented with a new concept it may be received into the cognitive structure and related to the concepts already in place. If there is not a related idea already in the cognitive structure, the length of time the new idea is retained is limited. A relating idea that serves to link new incoming information to the cognitive structure is called a subsumer. 'The process of linking new information to pre-existing segments of cognitive structure is referred to as subsumption.' (Ausubel et al., 1978).

For a period of time, the new information can be recalled almost in its original form, but in time, it will no longer be dissociable from the subsuming concept. In this case 'obliterative subsumption' has occurred. Obliterative subsumption is different from forgetting as it occurs in rote learning. After obliterative subsumption, the residual concept remains and much of the growth that occurred during subsumption is retained and hence this concept remains strengthened and more capable of facilitating new meaningful learning in the future (Novak, 1976). For example, a student may forget the specific examples or the formula for Ohm's law and still recall that there is a definite relationship between voltage, current, and resistance (Novak, 1978). Specific details have been obliteratively subsumed, but a concept's usefulness for

learning new things about electricity remains as a positively functional element in cognitive structure.

If a new concept is introduced to the learner, and a subsumer for the concept is already in place in the cognitive structure, the concept will be linked in by the subsumer and may be integrated into the cognitive structure. If the subsumer is missing, the new concept will be retained for a time and then lost, unless additional ideas are subsequently introduced to allow the new concept to be linked in. 'Integrative reconciliation is the process of meaningful learning where new ideas are related to previously acquired ideas one, or the other, or both are modified' (Ausubel, et al. 1978).

A new incoming idea linked to the cognitive structure by a subsumer will over a period of time fit into the hierarchy of ideas or modify them, this process being helped along by the individual spending mental activity on the new idea. 'Progressive differentiation' describes the hierarchical arrangement of subject matter in the cognitive structure. The most general concept of a subject will be at the apex of a body of knowledge which will be progressively differentiated into less general concepts down through to the least general, most specific, facts.

New concepts are linked to the cognitive structure with 'advance organisers'. An 'advance organiser' as the idea has been introduced by Ausubel (quoted by West and Fensham, 1974) is a verbal statement, presented to the learner before the detailed new knowledge. It attempts to

provide for him an alternative set of anchors or links, if he does not possess appropriate subsumers, or if they are inadequately developed or altered to play their part in the new learning.

In his own words, Ausubel (1960) says: 'the facilitating influence of advance organisers on the incorporability and longevity of meaningful learning material is attributed to two factors: a) the selective mobilization of the most relevant existing concepts in the learner's cognitive structure for integrative use as part of the subsuming focus for the new learning task, thereby increasing the task's familiarity and meaningfulness; and b) the provision of optimal anchorage for the learning material in the form of relevant and appropriate subsuming concepts at a proximate level of inclusiveness.'

Miller (1980) visualises the cognitive structure as ^hcrystal lattice, such as in sodium chloride. At each point in the crystal structure represented by the atoms there may be a subsumer. When a new idea comes in it bounces around the structure and, when striking a point without a subsumer, moves on. If it strikes a subsumer of a completely unrelated concept, it moves on. If it strikes a related subsumer it sticks.

As the individual mulls over a new idea, for instance by doing exercises, it may be categorised under a broader overall concept, or may itself be broad enough to organise several subsumers under it. It may be ranked under a broad concept and interlinked with several other equal

concepts. It may cause a previous concept to be disregarded. The idea is massaged until it fits into the progressively differentiated structure in the logical place, linked to a broader concept above it and having perhaps several narrower concepts linked below it. For example, as a child's concepts of dogs, cats, lions, etc. develop, he may later learn that all of these are subordinate groupings of a more general class mammals. As the concept of mammal is developed, the previously learned concepts of dog, cat, etc. take on a sub-ordinate relationship and the concept of mammal represents 'superordinate' concept learning.

Consider for instance the study of optics in Nuffield Physics. It is preceded by a consideration of wave phenomena, which is a broader concept, helpful in understanding such concepts as diffraction and interference. Later in the course light and other electromagnetic waves are studied and the wave concept provides idea anchorage, and relates the ideas to those previously learned. The student can thus fit the new concepts into the hierarchical structure, preventing physics from becoming a series of unrelated lumps of knowledge that are somewhat unpalatable to the student.

The key concept extracted from Ausubel's theory is that of 'meaningful learning'. Ausubel suggests that learning will only be meaningful when the new idea or concept which is to be learnt can be consciously related to relevant concepts and ideas which have been acquired

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previously. In other words, for meaningful learning to occur the learner must be able to integrate the new idea or concept into his or her existing cognitive structure. In Ausubel's (1978) own words:

'If I had to reduce all of educational psychology to just one principle I would say: the most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly'.

So, Ausubel stresses the importance of relevant prior concepts for meaningful learning. When new knowledge cannot be linked into the existing cognitive structure, 'rote learning' or simple memorization results. The memorized material will carry no meaning for the learner, and will not contribute to understanding or to problem solving ability.

Ausubel categorises the cognitive process on a continuum, with meaningful learning on one end of the continuum and rote learning on the other. A second orthogonal continuum is used by Ausubel to categorise the procedure used to present ideas to the learner. At one end of the continuum is reception learning and at the opposite is autonomous discovery learning. Reception learning is characterised by lecture or text reading where the material is presented to the learner in an organised hierarchical fashion. Autonomous discovery learning is characterised by discovery of random facts that have to be organised by the learner into ^{an} hierarchical scheme.

The distinction between meaningful and rote learning is not so simple there are degrees of meaningfulness. A related but not identical distinction to the rote-meaningful one is that what Biggs (1965) calls "structured" and "unstructured" learning. In structured learning the parts are clearly related to each other, whereas in unstructured learning they are not.

As in the case of rote-meaningful distinction, Howe (1972) considers it wiser to think in terms of a continuum rather than a dichotomy. A similar viewpoint has been put forward by Novak (1978) arguing that: 'Since concepts are acquired idiosyncratically and vary from learner to learner in their degree of differentiation and linkage to other concepts, the rote-meaningful characterization is not a dichotomy but a continuum, with the relative degree of meaningfulness of a learning task influenced both by the learning set and the relevant cognitive differentiation of the learner'.

Ausubel's theory serves as a useful explanatory model to guide science teaching, and as reported by Novak (1976), his emphasis on the central role of concept learning in meaningful learning and problem solving has been supported by a growing number of empirical studies.

Research with children reported by Novak (1978), including studies of cognitive development after specially designed concept oriented audio-tutorial lessons shows that a small proportion of young children (six to seven years) can acquire and use highly formal concepts to

explain phenomena, with explanations at a level ordinarily expected (but not commonly observed) from adult subjects. Both children and adults are highly variable in the accuracy and abstraction of the concepts they possess as evidence in explanations of natural phenomena. Novak (1978) further states:

'We see no evidence of 'stages' of cognitive development over the age range six to twenty-plus, but rather evidence for cognitive development manifested as a broadening array and elaboration of specific concepts. To the extent that broad, widely relevant concepts are differentiated over time, older subjects show more facility for learning new, relevant concepts and hence a generalized increase in competence for abstract reasoning is manifest.'

Novak (1978) goes on to state:

'It is our view that studies designed specifically to detect changes in cognitive development in specific subject matter areas, with or without instructional intervention, point to the highly idiosyncratic and concept specific nature of cognitive development. We believe the growing body of evidence obtained from the more generalized Piagetian tasks also shows approximately the same variability among age groups and for individuals tested across a variety of tasks.'

On the basis of this research evidence Novak supports a model of cognitive development that is not 'stage' dependent but rather dependent on the frame work of specific concepts and integrations between these concepts acquired during the active life-span of the individual. The learning processes involved are adequately

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explained both for contemporaneous learning episodes and developmentally over time, by Ausubel's theory of cognitive learning.

It is widely recognized (West & Fensham, 1974; Miller, 1980) that Ausubel's constant focus is the real classroom situation where teacher and learners are grappling with complex but highly meaningful verbal material. In contrast, Piagetian psychology (described before) has little relevance to the science classroom (Helm & Novak, 1983; Novak, 1988). Further, to quote West & Fensham (1974) again, Ausubel's theory is not one that requires extrapolation from non-human learning, or from the learning by humans of non-sense or very simplified content.

Ausubel's model explains not only how spontaneous concepts are learned, but also how we can alter educational experience to augment the acquisition of specific concepts in any discipline (Novak, 1976) and to teach any idea to a child at any age (Driver, 1983).

The present research concerns with the study of children's concepts of science and the effect of training on students' and teachers' concepts in classroom situations. Because the main emphasis of Ausubel's Theory is on the nature of concepts and the role of concepts in learning (Novak, 1976) in the classroom situation, Ausubel's theory of learning was judged to be the most relevant for the study.

2.4. THE LEARNING OF SCIENCE CONCEPTS

How concepts are learned is basic not only to understanding science but also to the way science is taught. While the research on concept learning provides no well defined strategy which assures every student will acquire a desired concept, there are considerable data providing cues to the more fruitful instructional practices. Forming a concept is an individual affair and is therefore influenced by the range of characteristics distinguishing one student from another: intellectual capacity, motivation, understanding of the teaching materials, background of relevant concepts and information, and conditions for learning (Hurd, 1971).

There is a wide variety of changes in behaviour or capability which can be termed learning. As described earlier in the previous section, Ausubel et al (1978) distinguishes two dimensions to the learning process, the degree of meaningfulness, and the mode in which the material is encountered. Learning is rote if it forms no links with anything but itself, has no ability to help further learning, and is learnt 'by heart'. Entirely meaningful learning fits into a network of other knowledge, extending both what is already known and what can be learnt. Probably no real learning is entirely rote nor entirely meaningful (McClelland, 1982).

Ausubel et al (1978, p. 47) distinguishes further between three basic kinds of meaningful learning:

representational learning; concept learning, and propositional learning. Representational learning concerns the meanings of unitary symbols or words and propositional learning concerns the meanings of ideas expressed by groups of words combined into propositions or sentences. In the first instance (as in naming, labelling, and defining activities), learning the meanings of single words involves learning what they represent (Lennenberg, 1967 quoted by Ausubel, 1978, P. 47). It means learning that particular symbols represent or are equivalent in meaning to particular referents.

Another type of meaningful learning that is prominent in the acquisition of subject matter consists of 'concept learning'. Concepts (unitary generic or categorical ideas) are also represented by single symbols just as other unitary referents are. Except in very young learners, the individual words that are commonly combined in sentence form to constitute propositions actually represent concepts rather than objects or situations, and hence propositional learning largely involves learning the meaning of a composite idea generated by combining into a sentence single words each of which represents a concept.

In 'propositional learning', the meaningful learning task is not to learn what words singly, or in combination, represent, but rather to learn the meaning of new ideas expressed in propositional form. 'Concept learning' being the subject of discussion, is further elaborated here, leaving the other two types of learning.

Ausubel et al (1978, P. 56) defines concepts as objects, events, situations or properties that possess common criterial attributes and are designated by some sign or symbol, and describes two methods of concept learning: 1) Concept formation, which takes place primarily in young children; and 2) Concept assimilation, which is the dominant form of concept learning in school children and adults.

In concept formation the criterial attributes of the concept are acquired through direct experience, through successive stages of hypothesis generation and testing and generalization. Thus young children come to know the concept "dog" through successive encounters with dogs, cats, cows, and so on, until they can generalize those criterial attributes that constitute the cultural concept of "dog". In this case the sign "dog" (or "doggie") is usually acquired before the concept, but the reverse may occur for other concepts, such as "argument" or "mammal". Ausubel calls this a type of discovery learning.

As a child's vocabulary increases, new concepts can be acquired through the process of concept assimilation since the criterial attributes of new concepts can be defined by use in new combinations of existing referents available in the child's cognitive structure. While concrete-empirical props may also aid concept assimilation in young children, it is possible to use existing relevant concepts to accelerate the process of defining the criterial attributes of new concepts. In older children and adults,

very few new concepts are learned by the process of concept formation. These ideas suggest, that much of the task for the teacher then is to look for the processes and conditions that facilitate concept assimilation.

The problem that many students fail to grasp a concept at the time it is considered by a class frustrates the teacher. Why can some students grasp a particular concept while others, of apparently comparable intellectual ability and in the same learning situation, cannot? Assimilation theory suggests that they are missing relevant subsumers in their cognitive structure that would enable them to integrate the abstract ideas into the hierarchy already present.

As argued by Pines and Leith (1981), children are not receptacles into which knowledge can be poured. The reason is not, as many have been led to believe, that children must discover for themselves, in order for meaningful learning to occur (Piaget, 1976). Rather, it is because of the inordinate influence that prior knowledge has on subsequent learning. When two children have different cognitive structures prior to instruction - one with relevant concepts, the other with misconceptions (see Chapter III) - their cognitive structures will diverge further, subsequent to instruction. This is true even if the instruction appears identical for both (Pines, 1977). In other words, what the child hears and learns depends upon which he or she already knows. Thus, there is no such

circumstance as identical instruction where a heterogeneity in cognitive structures exists (Pines & Leith, 1981).

In the presence of the learning difficulties already mentioned, Miller (1980) suggests that the task of the teacher then becomes two fold. First he must diagnose the knowledge of the student about subject matter, and then he must guide the student to the appropriate level in the hierarchy of concepts relative to the student's subject matter knowledge. Another important point to be realised, according to Pines & Leith (1981), is that 'because concepts are complex networks of relations they are acquired over a long period of time.' In fact, it would be more accurate to say that concepts are never wholly acquired. Concepts are not single entities that are learned in an "all or none" fashion. Concepts become differentiated in cognitive structure. That is, as a concept establishes more relations with other concepts it can be said to be more differentiated. A first grade child, a high school student, an undergraduate majoring in physics, and a physicist all have some concept of "energy", but there is an immense difference in the levels and accuracy of differentiation (Pines & Leith, 1981).

An important distinction has been made by Gagné (1965) between concept-learning and principle-learning in the following propositions:

1. There are at least two different, important kinds of phenomena commonly referred to as concept-learning. One refers to the acquiring of a common response, often a

name, to a class of objects varying in appearance. This may best be called concept-learning. The second refers to the combining of concepts into entities variously referred to as "ideas", "facts", "principles", or "rules". This has been called as principle learning by Gagné.

2. The basic reason for the distinction between 'concept' and 'principle' is that they represent two different kinds of learned capabilities.

3. If it is true that knowing a concept and knowing a principle are two different capabilities, then it is also quite possible that the conditions for learning them are also different.

Whether it is the learning of new concepts or new principles, Ausubel's theory implies that it all depends what the learner already knows. Also, the degree to which something new is potentially easy or difficult to learn depends on two factors: the internal complexity of the new material, and the relationship which it bears to what is already known and the way in which that knowledge is organized (McClelland, 1982). Moreover, as suggested by Miller (1980), 'choosing the appropriate level in the hierarchy of subject matter ideas for the student to begin the learning process may in itself be a formidable task'. A 14 year old student will be missing some important subsumers preventing him from studying relativity theory, so where in the hierarchy of ideas should he start? In this context, Ausubel (1978, p. 206) recognises three learning stages on a continuum:

1. The pre-school child cannot understand concepts unless he can spontaneously relate his abstracted criterial attributes to multiple specific but diverse examples of the concept.

2. The elementary school child on the other hand is typically capable of understanding the meaning of a concept by directly relating its presented criterial attributes to cognitive structure, provided he is furnished with concrete-empirical examples of these attributes.

3. Beginning with the junior high school (12 year old) period the learner can understand and manipulate abstract ideas and the relationships between them directly.

Children then learn in much the same manner as adults except for the lack of concrete-empirical experience and many fewer abstract ideas. The very young child will add to its cognitive structure through experience with its environment but will have a limited supply of organising concepts under which to categorise its experience. The fund of organisers will grow with time until the child is able to add to its cognitive structure through verbal as well as experimental means (Miller, 1980).

Further, in order for meaningful learning to take place, three conditions must be met (McClelland, 1982).

1. The material itself must be meaningful, that is, it must make sense or conform to experience.

2. The learner must have enough relevant knowledge for the meaning in the material to be within grasp.

3. The learner must intend to learn meaningfully, that is, must intend to fit the new material into what is already known rather than to memorize it word-for-word.

Once a concept is learned meaningfully by the learner, he is in a fertile position to incorporate new information into the concept with minimal effort. This is one major advantage of conceptualized knowledge; it provides hooks for grasping new knowledge. Then as more information is assimilated the original concept is re-organized, its meaning extended, as well as its discriminatory and predictive powers. The economy of learning concepts results from more coming out than going into the learning; understanding is increased and thought is amplified and memory load reduced.

As the student gains experience in forming concepts he increases his competence for doing so. He shifts from strategies with poor results and adopts others seemingly more profitable (Hurd, 1971). A strategy is a search plan for arriving at a goal with a minimum of effort. In learning science it is an informed guess based upon previous experience tempered by a heuristic behaviour. In helping a student to learn a concept it is as important to know what strategies he is using to code his data as it is to know the extent of his information. This viewpoint suggests that students develop certain skills to learn new concepts, and the condition 3 above described by McClelland (1982) suggests that the students' attitudes

about subject matter may be as important as their knowledge (Miller, 1980) for the meaningful learning to take place. A similar viewpoint has also been put forward by Osborne, Bell and Gilbert (1983). They argue that what applies in relation to scientific knowledge, also applies to scientific skills and attitudes. Children bring to science lessons not only their views of the world and their meanings of words (i.e. children's science, see chapter III), but also their own methods of investigation, their own ideas about what constitutes adequate explanations, and their own outlook on science. All these profoundly influence learning, including the motivation to find out how and why things behave as they do (Tasker, 1980 and 1981; Stead, 1981). These views suggest that for the effective teaching of science concepts, it will be important for the teacher to know a) the prior knowledge of the children, b) their strategies or methods of investigation, and c) their attitude towards the subject matter to be taught. The next section discusses the 'teaching of science concepts', and thus takes into account the necessary conditions for effective teaching of science concepts.

2.5. THE TEACHING OF SCIENCE CONCEPTS

As described earlier, Ausubel et al (1978, p.23) differentiates among various types of classroom learning to make two crucial process distinctions. He makes a

distinction between reception and discovery learning and another between rote and meaningful learning. The first distinction is significant because most of the understandings that learners acquire both in and out of school are presented rather than discovered. And since most learning material is presented verbally, it is equally important to appreciate that verbal reception learning is not necessarily rote in character and can be meaningful without prior non-verbal or problem-solving experience.

Novak (1978) identifies a major confusion concerning meaningful learning and the choice of appropriate teaching methods. In his view, many of the major curriculum projects developed during the 1960s made the fundamental error of equating a rote-meaningful learning dimension with a reception-discovery teaching dimension. In other words rote learning was identified with reception methods (didactic, lecture style presentations) and meaningful learning with discovery methods. However, Novak suggests that these two dimensions should be regarded as independent.

From ^{an} Ausubelian viewpoint, meaningful learning can result from reception or discovery methods, as can rote learning. The key pre-requisite for meaningful learning is that the learner should possess relevant prior concepts so that new knowledge can be consciously integrated into the existing cognitive structure. If these prior, relevant concepts are not present, then rote learning will result independently of whether reception or discovery methods are used. Discovery

methods can be as disastrous as didactic teaching, and conversely, both can be equally effective. According to Ausubel et al (1978) and Novak (1978), it all depends on what the learner already knows. ✓

According to Ausubel's Theory, the crucial test for meaningful learning is the ability to solve relevant novel problems. If a student has learned meaningfully some aspect of gene structure or function, he should be able to solve novel problems of genetics that are relevant to that learning. Novak (1976) suggests that problem-solving ability derives from cognitive structure differentiation and that it is concept specific. To be sure, some broad concepts bear upon a wide array of problems, but usually more specific, subordinate concepts are also needed to solve a given problem. Thus, from an Ausubelian view, there is no general strategy or logic of discovery, except the general strategy of meaningful learning. And meaningful learning is primarily a function of concept development and integrative reconciliation.

Novak (1976) further argues that the act of problem solving is actually a process of meaningful learning. As an individual gathers information from the problem situation, he meaningfully internalizes new elements, thus differentiating some concepts further and forming new associations among subordinate and for superordinate concepts. Problem solving is in reality no more than a special kind of meaningful learning.

Ausubel (1968, P. 455) describes the controversy over "teaching style" as caused by ambiguity in the meaning of terms. For Ausubel, variability in teaching style is both inevitable and desirable. Styles of teaching vary, in the first place, because teachers' personalities vary. What works well for one teacher may be completely ineffective for another. A teacher should therefore adapt his instructional style to strengths, and weaknesses in his background, personality, and preparation.

Further, it is also desirable for teaching styles to vary because of variability in pupil needs and characteristics. Important characteristics are intelligence, anxiety level, interest in subject matter, the prevailing degree of authoritarianism in the adult-child relationship that is typical of a given social class background, and the students' degree of independence and security. Lastly, appropriate teaching style is always relative to the particular educational objective.

The Ausubelian strategy for presenting new material is to develop a stable anchorage as quickly as possible by giving the learner a set of statements at a high level of generality, and then using specific instances to develop their meaning. Initially the general statements have little meaning, so the underlying concepts are vague and limited. Experience with the widest possible range of examples, specifically related to the statements, clarifies and refines them to the point where they can take over. At first the statements act as a clue that something

worthwhile is to be learnt and act as a guide to what that learning will be like (McClelland, 1982).

At another place, McClelland (1982) suggests that when any aspect of science is first introduced, its theoretical ideas will be unfamiliar to children. They will not possess organized knowledge and experience to which the ideas can be related directly. The first task then is to reduce it to key statements in language which is accessible to the learners. This does not mean that every word used must be within the existing vocabulary of the learner, nor does it mean that every word must be in common use in the society. The key statements act as signals that something is to be learnt and act as a linking framework for specific examples and experiences.

The second task is to devise means for exemplifying the statements, showing their power to explain and impose coherence on perceptually different phenomena. The third is to alert the learner to examples in the environment, not contrived for teaching purposes, to which the ideas apply. As the process continues the learner gradually moves from using the examples to give meaning to the key statements, to using the statements to understand new examples.

McClelland (1982) sees three general concepts; 'energy', the 'particulate nature of matter' and 'adaptation' as important at all stages and believes them to be accessible to children before the age of eleven in a form which will enable them to impose coherence on much of their

environment. He summarises a strategy which has been used by him with children in the age range 7 - 8 years. The overall concept of energy was conceived as based on the following hierarchy:

Conservation of energy

energy as an entity (the ability to cause changes)

class names of forms of energy

class names of properties: moving, elastic, hot, etc.

class names of specific objects used in examples.

The key statements used were:

'Energy is the ability to make changes'

'Energy is never lost or destroyed: it is changed from one form to another'.

In addition, a list of forms of energy; kinetic, potential, elastic, chemical, heat, light and sound was provided. It was found that under individualized instruction (audiotutorial) conditions, five lessons each of about fifteen minutes' duration could bring about very satisfactory learning outcomes.

Another example used by McClelland is in the area of 'Particulate nature of Matter'. He considers this area to have the least initial accessibility because the evidence for it is largely by inference and analogy.

Examples of key statements used were:

- Everything is made up of very small pieces called molecules
- What we see, feel, and smell depends on what

sort of molecules there are, and how they are organized

- Different materials are made up of different molecules
- Living things have special large groups of molecules called cells
- Different parts of plants and animals are made up of different cells.

In a similar context, Miller (1980) considers the teaching of physics. Following Ausubel, the broadest concepts should be presented to the learner first. Our task then is to organise the concepts of physics in a hierarchical fashion. Immediately we have a problem because the most general concepts in physics are relativity and quantum theories. Logically this should be taught to the student first but it may not be possible because the student does not have relevant subsumers in his cognitive structure, such as those provided by mathematics or chemistry. Miller suggests that there are at least three different paths we can take to solve this problem.

1. We can come down to the next level of broad concepts and see if the student has the subsumers to link those concepts into his cognitive structure, continuing this process until we reach the level in the hierarchy appropriate to the students we are teaching.

2. We can teach the theories at a level of sophistication appropriate to the student, explaining to the student that they can study the theories in more detail

at a later date when they have acquired the subsidiary subsumers.

3. We can use a combination of (1) and (2), simplifying the more general theories until we have come down in the hierarchy to a level the student can handle rigorously.

Ausubel (1968) presents another important idea for teachers and that is the term "preconception" (see Chapter III). Nussbaum and Novick (1982) report that:

'Preconceptions often interfere with intended learning outcomes. When a student retains and continues to use his preconception to interpret classroom information, he is likely to give it meaning which differs from or even conflicts with the meaning intended by his teacher. It is possible that the learner is not even aware of this gap and that he is perfectly satisfied with his own interpretation, thinking that such was also his teacher's intention. The teacher too can be totally unaware of how the student has internalized the new information and when he does sense that something is amiss, he will often attribute it to the students' "not understanding" but of "understanding differently" from what was intended.'

Quite similarly, Champagne et al (1983) report that their work on mechanics has demonstrated that student's existing knowledge can also adversely affect their ability to learn from science instruction. Their study further indicates that it is not the students' lack of prior knowledge that makes learning mechanics so difficult, but rather their conflicting knowledge. Because of this role of preconceptions, Ausubel et al (1978)

pointed out that "preconceptions are amazingly tenacious and resistant to extinction." He therefore states that:

'... unlearning of preconceptions might prove to be the most determinative single factor in the acquisition and retention of subject matter knowledge.'

These ideas point to the need for a new view of science teaching (Osborne, Bell and Gilbert, 1983). Science teaching, in so far as it is concerned with encouraging students to be aware of, and possibly even adopt alternative views of the world and meanings for words, needs to build on or confront, but certainly not ignore, children's science. These researchers further suggest that if an objective of science teaching is to help children to modify their views of the world and meanings of words, then we need to consider how we might encourage them to change their views. Accordingly to Hewson (1980), children must first find their present conceptions unsatisfactory. For this to occur, the child's present viewpoint has to be recognized by him or her as inadequate; this could happen if the viewpoint failed to anticipate correctly or to control events. The need is for well-chosen learning experiences, which will highlight to the child the inadequacies in a present view. However, dissatisfaction with a present view-point is not a sufficient reason for a child to change a viewpoint. What is also required if a child is to change a view, is access to a new and better idea with which to replace it. This new idea needs to be, according to Hewson (1980):

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- a) intelligible, in that it appears coherent and internally consistent;
- b) plausible, in that it is reconcilable with other aspects of the child's view of the world;
- c) fruitful, in that it is preferable to the old viewpoint on the grounds of perceived elegance, parsimony and economy.

Hewson also emphasizes the dynamic nature of the views children hold, by indicating how dissatisfaction and the status of a particular viewpoint are linked and how these together change with time: 'dissatisfaction comes from loss of fruitfulness and plausibility and the reduction of dissatisfaction comes from increased plausibility and fruitfulness' (Hewson, 1980).

Osborne, Bell, and Gilbert (1983) imply that one of the problems of teaching science is that the scientists' viewpoint may appear to the child to be less intelligible, plausible and fruitful than the child's present view. In practice what does all this imply for what and how we teach children in science classrooms? The Learning in Science Project (1982) offers teachers the following suggestions:

1. We need to identify, and be familiar with, children's current views.
2. We need to design curricula which build on, rather than ignore, children's views.
3. We must provide challenges and encouragement for children to change their views.
4. We must support pupil's attempts to rethink their ideas.

5. We must be sensitive to the possible pupil outcomes of a teaching episode.

In the science education context, Gilbert, Osborne and Fensham (1982), have suggested a set of possible outcomes to a teaching episode. Osborne, Bell and Gilbert (1983) suggest that by being sensitive to these outcomes we may then be better able to appreciate the real effectiveness of our science teaching. These outcomes are:

The new view is

1. simply rejected
2. misinterpreted to fit in with, or even support, present views
3. accepted but in isolation from present views
4. accepted but leads to confusion
5. accepted and forms a coherent view of the world.

Finally, we would again refer to the principle stated by Ausubel et al (1978): 'The most important single factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly.' Also, there is no escape from the fact that all learning is a highly personal activity (Summers, 1982). The total message is clear, if we are to start from what the learner knows and teach him or her accordingly, there is an implication that we must know our students as individuals and explore their ideas and beliefs with them.

2.6. NEW STRATEGIES FOR THE TEACHING OF SCIENCE

In the development of science curricula, the existence of children's science has usually either been ignored or inadequately considered (Fensham, 1980). The two different assumptions (Gilbert et al, 1982) on which previous science teaching has usually been based are: Firstly, the 'Tabula Rasa' or 'Blank-Minded' assumption which by implication underlies many modern curricula (Fensham, 1980). It is assumed that, prior to formal teaching, the learner has no knowledge of a topic. Teaching is based on the supposition that the learner's 'blank-mind' can be 'filled' with teacher's science. The second alternative strategy or assumption is that of 'Teacher Dominance'. In this case, it is assumed that, although learners may have some conceptual view of a new science topic before being taught it, this understanding has little (no) real significance for learning and can be easily replaced. According to this view, if children's science views do exist, they are not strongly held and are easily replaced through science teaching. This assumed that children's views do not affect their understanding of the teacher's message and what children learn is determined solely by the teacher's lesson.

In contrast to these assumptions, evidence that students' naive conceptions are both pervasive and persistent is provided by substantial research in several countries. These studies demonstrate that for several science content areas:

1. people, young and old, have descriptive and explanatory systems for scientific phenomena that develop before they experience formal study of science;
2. these naive descriptive and explanatory systems differ in significant ways from those students are expected to learn in their study of science;
3. the naive descriptive and explanatory systems show remarkable consistency across diverse populations, irrespective of age, ability or nationality;
4. the naive systems are remarkably resistant to change by exposure to traditional instructional methods (Champagne, Gunstone and Klopfer, 1983).

In the light of these findings, there is a need to base the process of curriculum development and the teaching of science on recognition of children's views of science. The assumption on which science teaching could be based has been called by Gilbert et al (1982) as 'Student Dominance' assumption.

As argued by Gilbert et al (1982), for those who operate on the basis of either of the assumptions (Tabula Rasa, Teacher Dominance) the evidence presented here has no implications for science teaching, because its existence will be denied or ignored. But, for others who wish to adopt the alternative assumption, an immediate question will seek information what about the classroom tactics that are needed. In this regard, many suggestions have emerged. Fensham (1980) proposes some new objectives for education, whilst others

suggest teaching strategies for science teaching. Some strategies are presented below under the names of the researchers who have proposed them.

1. Nussbaum and Novick (1980)

These researchers have produced a lesson framework which has been summarised by Gilbert, Watts and Osborne (1982) as follows:

- i. Create a situation, the explanation of which is a central issue in the topic under consideration, which requires the students to evoke their personal views in order to interpret it.
- ii. Encourage the students to present verbally and pictorially their own interpretations of the situation.
- iii. Assist the students in stating their ideas clearly and concisely thereby making them aware of the elements of their personal views.
- iv. Encourage a confrontation in which the students discuss the pros and cons of the different interpretations presented.
- v. Encourage the students to test the ideas contained in their interpretation against experimental observations and thereby realise the need for accommodation in order to eliminate contradictions.

2. Minstrell (1982)

Minstrell argues that there are several things a teacher can do to help students develop a more generally applicable cognitive structure. He proposes a number of

instructional procedures for this purpose: First prepare an engaging social context, one in which students will put their thoughts about the situation up for consideration, free from fear of being chastised for being "wrong". If students are graded down for being "wrong" at this stage, this will add evidence to the belief of some students that science is known only through the knowledge of some authority. Encourage expression of the various alternative explanations. Allow the validity of the explanations to be determined in the light of observational experiences and rational argument.

For example, next, juxtapose several instances of an object at rest; on the solid table, on the out-stretched hand, on the bendable table or spring or rubber band, etc. Third, encourage arguments that explore similarity in effects and explanations across an apparent diversity of instances of objects at rest. Finally, allow students to argue for and choose simplest explanation that explains the most phenomena.

3. Solomon (1983)

Solomon argues that reason for the commonality of children's viewpoints and their persistence is not far to seek. She holds a view that in daily conversation and through the mass media, our children are confronted with implicit assumptions about how things move, their energy and their other properties, which can be directly at odds with the scientific explanation that they learn at school. Outside the school laboratory, these adolescents are

continually being 'socialized' into a whole repertoire of non-scientific explanations. Examination of newspaper reports and every day language makes clear the pervasiveness of this subversive process. Commenting on Duit (1981) and Viennot (1979) she says: although both these authors have correctly traced the source of such popular misconceptions, they still express surprise, and are concerned that means should be found to extinguish them. For Solomon, the logic of the situation determines otherwise.

She believes, such socialized knowledge cannot ever, by its very nature, be extinguished. Whether or not our pupils become successful in science, they must never lose the ability to communicate. It would indeed be a poor return for our science lessons if they could no longer comprehend remarks like 'wool is warm' or 'we are using up all our energy'. What we are asking from our pupils, then, is that they should be able to think and operate in two different domains of knowledge and be capable of distinguishing between them. These domains are: The 'Symbolic Domain' and the 'Life-World Domain'.

These two co-existing spheres, according to Solomon, are very dissimilar both in their genesis and in their mode of operation, and crossing over from one domain of meaning to the other involves an abrupt discontinuity of thought. The movement between the two domains is difficult on two counts. First, the life-world situation-meanings spring too readily to mind, and secondly induction from the

concrete and particular to the abstract and general is always hard and uncertain. For exactly the same two reasons the journey back into the life-world, to find examples of the theory, is always easier.

Moreover, ease of movement between these two domains is not symmetrical for the two different directions. The initial difficulty is often concealed during lessons. We may induct our students so swiftly from concrete examples into the domain of physics that they hardly notice the transition. She further argues that:

'The deepest levels of understanding are achieved neither in the abstract heights of 'pure' physics, nor by a struggle to eliminate the inexact structures of social communication, but by the fluency and discrimination with which we learn to move between these two contrasting domains of knowledge.'

The strategies described in this section offer three guidelines for the science teachers:

- i. Children should be encouraged to express their own views in a free situation.
- ii. Children should be confronted with different situations and be allowed to test their own views against experimental observations.
- iii. It is easier to move children's views from abstract and general to concrete and particular rather than reverse.

Gilbert et al (1982) also express similar views saying that we all need, as teachers, to listen to, be interested in, understand and value the views that children bring with them to science lessons.

CHAPTER III

INVESTIGATING CHILDREN'S CONCEPTS

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3.1. CHILDREN'S CONCEPTS

Ausubel (1978, p. 101) suggests that as a concept is acquired, gradual changes in the characteristics of that concept can be detected. It becomes less diffuse as the learner focuses on critical attributes. A concept becomes more general and hence more widely applicable as the learner separates the concept from particular instances of the concept.

Ausubel further argues that the use of the same terms or concept labels by different persons does not necessarily imply uniformity of understanding of the underlying cognitive content. Because concept learning is based on individual experience, the concepts themselves will tend to have idiosyncratic associations.

Ausubel (1968, 1978) uses the term 'preconception' for the ideas expressed by the individuals which sometimes do not have the status of generalized understandings characteristic of conceptual knowledge. Referring again to Ausubel (1968, p. 335) he suggests that the role of preconceptions in determining the longevity and qualitative content of what is learned and remembered is crucial, and may very well be the most important manipulable factor in the individualization of instruction, and the unlearning of preconceptions might very well prove to be the most

determinative single factor in the acquisition and retention of subject-matter knowledge.

The key idea in Ausubel's theory (See Chapter II) is the nature of meaningful learning as contrasted with rote learning. Ausubel's distinction as illustrated by Novak (1983) is simple and also profound. He defines meaningful learning as the non-arbitrary, non-verbatim, substantive incorporation of new knowledge into a person's cognitive structure, whereas rote learning is described as arbitrary, verbatim, non-substantive incorporation of new knowledge into a person's cognitive structure.

As argued by Novak (1983), the principle of meaningful learning includes the idea that each of us has a unique sequence of learning experiences and hence each of us acquires idiosyncratic meanings for concepts. For this reason, Ausubel chose to use the word subsumer or subsuming concept to designate the functional unit in memory of each person. Each culture has more or less common meanings for the word labels for concepts, but each individual's subsumers are in at least small ways idiosyncratic. In some instances, the idiosyncratic meaning departs widely from the culturally accepted meaning and we say the person has a misconception or alternate framework.

The fact that children tend to develop their own conceptions or preconceptions about certain aspects of the physical world has been known for a long time. Formal research on this topic can be traced back to the earlier

work of Piaget (1929; 1930) in which the clinical interview technique (see later) was employed for the investigation of children's interpretation of natural phenomena. It is only recently that research workers in the field of science education have begun to realize the full educational implications of this form of knowledge (Zylbersztajn, 1983).

Gilbert, Osborne, and Fensham (1982) report that research studies in recent years have shown that children have beliefs about how things happen and expectations which enable them to predict future events. Evidence is accumulating from a wide variety of sources to show that, on the basis of their everyday experiences of the world, they hold these beliefs and expectations very strongly. Moreover, children have clear meanings for words which are used both in everyday language and also in formal science. Such views of the world, and meanings for words, held by children are not simply isolated ideas but rather they are part of conceptual structures which provide a sensible and coherent understanding of the world from the child's point of view.

The research evidence also indicates that children's conceptions, in the form of expectations, beliefs and meanings for words, cover a large range of science concepts (see later). Moreover, as pointed out by Summers (1982), all students of whatever age and even if they have done no science before, will have acquired during their lives their own views of the world, their own cognitive structure. Pines and Leith (1981) suggest, 'what the student

knows prior to instruction may be labelled as "pre-conceptions". Those pre-conceptions that are at odds -- that are inconsistent - with the contemporary scientific framework, are often called "misconceptions". To think however, that these are silly mistakes that can easily be rectified through instruction is naive. Nothing can be further from the truth.'

Hoz (1983) take a similar view and compares the nature of a 'conceptual framework' and that of a 'misconception.' According to Hoz (1983), a conceptual framework (often referred to as a schema or knowledge structure) is a system of interrelated concepts, propositions and procedures. It is designed to account for a knowledge domain, for its parts and aspects, or for the performance on a task within this domain. This neutral (non-evaluative) definition does not judge a conceptual framework as correct or incorrect as long as it apparently accounts for a certain phenomenon. The framework is considered inadequate if it does not fully explain what it is designed to explain. It is considered incorrect when it is incompatible with the current scientific explanation. Hence, for a conceptual framework to be incorrect or improper it is sufficient that either (1) at least one of its concepts or propositions (rules) is incomplete, partial, or has an incorrect or improper meaning, or (2) it is applied either incorrectly or in an improper context.

A misconception is an evaluative term that refers to an improper or incorrect conceptual framework. It

indicates a mismatch between a conceptual framework held by a person (or a group of persons) and the "correct" one.

Driver and Easley (1978) take a different view. They argue that many notions children hold are used in a range of situations and have the characteristics of elementary models or theories. The term 'misconception' is sometimes used in this context, with the obvious connotation of a wrong idea. Research reported on common misconceptions in various areas of science reflects the fact that this term tends to be used in studies where pupils have been exposed to formal models or theories, and have assimilated them incorrectly. A distinction needs to be made between this source of misunderstanding and the situation in which pupils have developed autonomous frameworks for conceptualising their experience of the physical world; these Driver and Easley call 'alternative frameworks.' They further argue that in learning about the physical world, alternative interpretations seem to be the product of pupil's imaginative efforts to explain events and abstract communalities they see between them.

Osborne (1980) suggested the expression "Children's Science" to signify pupils' world views which do not conform with the accepted scientific ones. Osborne et al (1983) illustrate the term further saying that by children's science we mean the views of the world and meanings for words that children tend to acquire before they are formally taught science.' Children's science develops as children

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attempt to make sense of the world in which they live in terms of their experiences, their current knowledge and their use of language. Across a population a range of meanings would exist for a particular word. Every child would employ a range of words, the sum of which would constitute a large part of the individual's 'children's science.' The meaning for a word which was held by a consensus of the scientific community, has been described as being part of 'scientists' science.' A detailed account of children's science and scientists' science appears in the next section which compares the nature of children's ideas and that of the scientists.

To signify children's own ideas or beliefs, Claxton (1982) suggests that children develop "mini-theories," and use them like "gut science" and "lay science" in order to contrast them with "school science" (quoted from Zylbersztajn, 1983).

The discussion in this section has identified that different terms are used to describe children's "ideas" of science but this discussion is not exhaustive. Although different researchers have used different terms for the children's inconsistent ideas e.g. 'Misconceptions' by Doran (1972), Za'Rour (1975), Helm (1978; 1980), Hoz (1983) and Ivowi (1984); 'Preconceptions' by Novak (1977); 'Alternative frame-works' by Driver and Easley (1978), and Watts (1983); 'Children's Science' by Osborne (1980), Gilbert et al (1982) and Zylbersztajn (1983); and 'Naive Conceptions' by Champagne et al (1983), the present study

prefers to use the term 'misconception' whenever reference is to be made to children's inconsistent ideas or when the ideas are at variance with the established scientists' ideas. The selection of this term has been made deliberately keeping in view the aims of the study. As the study aims at identifying children's ideas that are at odds or inconsistent with the contemporary scientific frame-work (Pines and Leith, 1981), wrong ideas (Driver and Easley, 1978), common errors in the popular notions of scientific facts and concepts (Za'rour, 1975), and to help in the design of teacher training programme to modify children's wrong ideas, the term 'misconception' signifies the most appropriate meanings for children's own ideas.

3.2. CHILDREN'S SCIENCE AND SCIENTISTS' SCIENCE

The purpose of this section is to compare and contrast the views of science held by children and those held by scientists. In the previous section, children's science has been described as the views of the world and meanings for words that many children acquire before they receive formal science lessons (Osborne et al, 1983). In this section, scientists' science will mean the generally-accepted viewpoint of the scientific community regarding any particular aspect of science.

In drawing attention to the similarity of nature of views held by young children and scientists, Vicentini-Messori (1980) writes:

'Children like scientists, use similarities and differences to organise facts and phenomena and, in the observation of facts and phenomena, search for elements, and relationships among elements, to build structures of relationships. In addition, children, like scientists, gather facts and build models to explain known facts and make predictions.'

The similarity described here comes about as children (like scientists) attempt to make sense of the world in which they live in terms of their experiences, their current knowledge and their use of language.

In contrast to this indication of similarity of views and processes, Osborne et al (1983) point out there are at least three ways in which children's science differs from that of professional scientists:

1. Young children seem to have difficulty with the kinds of abstract reasoning which scientists are capable of. They tend to view things from a self-centred or human-centred point of view, and they consider only those entities and constructs that follow directly from everyday experience. Quoting Layton (1973), Osborne et al (1983) further argue that the current scientific viewpoint has emerged in just the last 250 years. It has involved the introduction of conceptions for which there are no directly observable instances, e.g. atoms, electric fields, and conceptions which have no physical reality, e.g. potential energy. Such conceptions are outside the child's experience and thus cannot be part of his or her scientific

viewpoint.

2. Children are interested in particular explanations for specific events. Unlike scientists they are not concerned with the need to have coherent and non-contradictory explanations for a variety of phenomena. With their limited experience and concern for a specific explanation only, children can latch on to any one of a number of possible explanations which are reasonable from their more restricted outlook.

The abstract conceptions which have been created by scientists have not only enabled the explanatory and predictive power of science to increase, but have also led to a considerable coherence between scientific theories. However, unfortunately, for the teaching of science, the abstract conceptions and coherent theories are connected to everyday observable phenomena by increasingly complex reasoning: for example, although Maxwell's equations do account for everyday electrical phenomena, e.g. lightning, they do not do so in a simple way. While scientists have become increasingly interested in coherent theories, children are much more interested in simple pragmatic explanations for things that occur in their familiar world and are not too concerned if two theories each explaining a different situation, are mutually inconsistent.

3. The everyday language of a society often leads children to have a view distinctly different to the scientists' view. Such views may not change as the child grows older, or they may even become, with time, increasingly different from scientists' science. In both cases it becomes more difficult to effect a change to the scientists' view as time passes (Osborne, 1981). For example, Bell (1981) has found that young children often have a more scientific meaning for the word 'animal' than do older children.

In developing views of the world, scientists have found it necessary to develop a technical language where words have specific meanings and quantities have unambiguous definitions. This contrasts with the fact that children often do not appreciate the need for precision of language. Unfortunately, many of the words used in science have everyday meanings which are subtly different from their scientific meaning, e.g. work, force, power, friction, energy, animal, plant. This creates great problems for children learning about scientists' viewpoints.

In summary, children and scientists both have views about the how and why things behave as they do and meanings for words used in science. However, children's views and meanings can be quite

different to scientists' meanings. What needs to be remembered from the point of view of science teaching (Osborne et al 1983), is that in terms of the child's mental maturity, experiences and language, the child's view of a particular phenomenon may appear far more sensible and logical to him or her than the scientists' viewpoint. For example, to a child heavy things fall faster than light objects whilst to the scientist they both fall at the same rate but air resistance slows some objects down depending on their shape.

3.3. RATIONALE FOR THE INVESTIGATION OF CHILDREN'S CONCEPTS

According to Ausubel et al (1978, p. 94), 'Concepts serve many purposes in cognitive functioning.... and, one of the principal functions of existing concepts in cognitive structure is to facilitate the acquisition of the new concepts....'. Similarly, Gagne (1977, p. 185) suggests that 'it would be difficult to over-emphasize the importance of concept learning for formal education. The acquisition of concepts is what makes learning possible'.

Also, as discussed before, Ausubel (1968, p. 335) draws our attention to the potent role of preconceptions in inhibiting the learning and retention of scientific concepts and principles. Ausubel (1968) further argues that

'Preconceptions are amazingly tenacious and resistant to extinction....'

An important precondition for Ausubel (1968, p. 337) for instruction in science is 'to ascertain what the more common preconceptions of learners are by means of appropriate pretests, and then to match the suitably tailored organizers with pupils exhibiting corresponding pre-conceptions'.

If these views of concepts on the basis of science teaching and learning are accepted then as argued by Osborne and Gilbert (1980), it would appear desirable to investigate students' understanding of basic concepts for a number of reasons. Firstly, from a learning-theory viewpoint, an analysis of students' conceptual understanding of words used in a particular subject may well need to precede analyses of more complex understandings and skills required of students in that subject, for example problem-solving abilities. Secondly, from a less theoretical viewpoint, an analysis of students' conceptual understanding of words used in a science subject could be used to raise teachers' awareness of the possible perspectives pupils may bring to, and difficulties pupils may have in, ^{the} science classroom. Teachers' greater awareness stemming from the analyses should enable more effective communication to take place.

To fulfil these aims of investigating children's understanding of various concepts of science, requires that appropriate investigation techniques be selected for this

purpose.

The next section reviews the various techniques of investigation used by different researchers whilst later sections justify and describe the particular technique selected for the purpose of the present study.

3.4. REVIEW OF INVESTIGATION TECHNIQUES

Different researchers have employed a variety of approaches in an effort to investigate some aspects of students' ideas and this diversity of approaches has created a proliferation of cognitive commitments. The net results of this situation according to Driver and Erickson (1983) are: considerable confusion over the types of commitments which should be identified and described, a debate over appropriate data gathering and data analysis techniques and difficulties in extending or even replicating studies.

Sutton (1980) suggests that if a teacher can diagnose what is already known, then ways may be found of connecting new knowledge to old and 'school knowledge' with everyday knowledge. Ausubel's theories have helped to articulate this approach and to create a sense of anticipation that the description of 'cognitive structures' will form a new frontier for research in science education.

Sutton further argues that despite the importance and attractiveness of the idea, the difficulties are formidable. Reliable techniques are needed both for finding

out about a person's mental patterns and for representing them on paper and for making use of the information. He surveys the techniques used in attempts to probe the learner's 'structure of ideas' and classifies them into four groups which are briefly described below.

3.4.1. THE CLINICAL INTERVIEW

This is one of the oldest techniques for exploring children's thought. Piaget used it to discern not the content of a child's mind but his habits of mental 'procedure', the dynamics of his thought rather than its statics and thus the mental 'operations', and the inferred 'schemata' on which these might be based. Pines et al (1978) have adapted the method to their own idea of cognitive structure, which gives greater prominence to connections in thought-content, but they retain the basic approach of a conversation with one child around the stimulus of some material or phenomena. The interviewer attempts to combine two almost incompatible features - letting the child talk freely, and yet probing to check the basis of his reasoning. So the interview starts with open questions, and acceptance of all answers, following the child's reasoning wherever it leads. Later, the interviewer may probe more specifically to encourage elaboration of earlier answers, and to get the child to give reasons for his inferences, or make predictions.

Provided the child has a clear understanding of the interviewer's intention, this method does give him the greatest chance to display his reasoning, but it takes a long time, and its interpretation is problematic. How can the information from a lengthy transcript be condensed? Erickson (1977) in her exploration of 'patterns of student beliefs' about heat, summarizes the interview in a 'conceptual inventory'. Pines et al condense their information by translating the interview transcript firstly into a set of propositions and then into diagrammatic form, as a 'semantic network' or 'concept map'.

3.4.2. WORD-ASSOCIATION TASKS

Preece (1978) gives a comprehensive review of work on word associations and related techniques. When a child is presented with a word and then responds with the first word he thinks of, or with a succession of words, going back to the stimulus word each time, there is empirical evidence for some connection in the child's awareness, at least at that moment and in that situation. If this same association is repeatable it might be important for the comprehension of future information. The attraction of this technique is that it allows an operational definition of connectedness, and is amenable to quantification. For example the overlap between response lists triggered by different stimulus words can be used to calculate 'relatedness coefficients' of 'semantic distances'.

3.4.3. WRITING OR SELECTING A DEFINITION

Schaefer (1979) includes writing a definition as a technique in his investigations of the concept of growth. Because the respondent has to compose a statement in his own terms, he has the opportunity to consider all the ideas available to him about the topic. No doubt the act of composition can help to make more firm any incipient structure of the knowledge which is not yet well established.

Kempa and Hodgson (1976) used the technique of allowing the respondent to choose one definition from several all of which can be regarded as correct. This has the advantage that it is accessible to pupils who may find composing their own definition difficult, and therefore, give up and it also lends itself to quantitative processing of the results of the investigation. The results of both these enquiries remind us that an individual's concept matures and changes with time, and in the case of many secondary-school science concepts like oxidation, respiration, or force, the latter versions of these make sense only within a connected set of theoretical relationships.

3.4.4. IDENTIFYING AND USING BIPOLAR DIMENSIONS IN A 'SEMANTIC SPACE'

An altogether different approach to the investigation of personal meanings is to ask pupils to rate a concept in terms of its position on some sort of continuum

(Osgood, 1957). A stimulus word (say bacteria) may be seen as in a certain position on scales of bad-to-good, weak-to-powerful, passive-to-active. The results can be displayed in a two-dimensional or three-dimensional graph. The technique is of course concerned exclusively with personal and private meanings, not public definitions, and with these particular scales the technique may reveal the emotional connotations of the stimulus word rather than its logical connections. Words of very different denotative meaning can appear in similar positions in the 'semantic space'.

In another method described by Fransella and Bannister (1977), which uses Kelly's 'repertory grid' technique, a child may be given three objects, or asked to select three at random from a large number that are offered. He is then asked to consider any two of them which resemble each other in some way and are different from the third, and to say how they are different. Repetition of this procedure creates lists of bipolar dimensions which form the criteria which the child is consciously or unconsciously using in making sense of the information around him.

To repeat Sutton's point here, some means of utilising the information is also required. Whilst the methods of Preece, and of Kempa and Hodgson give quantitative data it is not immediately clear how this can be applied in the classroom.

For the purpose of the present study, a clinical interview methodology known as Interview-About-Instances

approach which was first developed and used by Osborne and Gilbert (1980) was selected. A rationale for the selection of this technique is given in the following section.

3.5. RATIONALE FOR THE SELECTION OF INVESTIGATION TECHNIQUE

For the present study, the clinical interview technique was selected, because as described in the previous section, the individual interview situation not only allows flexibility in discussing reasons or lack of reasons for a particular categorization but it also allows information to be gained about student understanding in situations where the student is unsure how to classify an instance. The interview situation also allows the student to ask questions should he or she wish before attempting to classify perceived or actual ambiguities (Osborne & Gilbert, 1979). It is the only method which allows this level of student-interviewer interaction.

Further, in this method, students cannot easily ignore a question and give no answer, omit to give a reason for an answer, or guess without justification. All these are common practices in written examinations. A further major advantage of the interview technique is that questions can be deliberately imprecise and ambiguous and the student has opportunity to criticize the question. The interview situation also enables investigation of whether the student has given the right answers for the

wrong reasons or the 'wrong' answers for the right reasons. Also, in the interview situation, it is possible to test how committed a student is to a particular view.

Bell and Osborne (1981) argue that the interview technique enables the reasons behind a student's initial answer to be explored by including supplementary and exploratory questions. Listening carefully to the answers given and following them up until you are quite confident that you fully understand the response.

Another important strength of the interview technique pointed out by Mouly (1978) is that it permits the interviewer to help the respondent clarify his thinking on a given point, so that he will give a response where he would normally plead ignorance and, even more important, so that he will give a correct answer instead of a false one.

One of the advantages of the IAI method described further by Bell and Osborne (1981) is that the interview is a mixture of closed and open questions. A balance of closed and open questions, of simple and difficult questions, of superficial and penetrating questions, of neutral and very specific questions is important. In this way it is possible to maintain pupil confidence but at the same time establish clearly the way the pupil thinks about the topic under discussion.

The I.A.I. method has been used for individual interviews in England, New Zealand and Australia (Bell & Osborne 1981). The most extensive use of this method has

been made in the Learning in Science Project (See later in this Chapter). The same technique has also been used in Pakistan by some students of the researcher to investigate children's understanding in various concept areas. For the purpose of the present study, the Interview About Instances approach was selected for both "academic" and "pragmatic" reasons. Earlier research in other parts of the world and by the researcher's students had identified existing misconceptions and hence an "open" method was not needed and would have been wasteful in that it would reduce the opportunities to make comparisons.

Further details about the investigation technique (i.e. IAI) used in this study are described in the next section.

3.6. THE INTERVIEW-ABOUT-INSTANCES APPROACH (IAI)--SOME THEORETICAL CONSIDERATIONS

The Interview-About-Instances (IAI) approach which was developed by Osborne and Gilbert (1979) has been used by them and their colleagues to investigate children's understanding of many concepts e.g. 'work', 'electric current', 'light', 'gravity', 'friction', 'force', and 'energy'. This section describes the theoretical considerations underlying the development of this approach and its application to investigate children's understanding of basic concepts of science.

According to Osborne and Gilbert (1980) the views of Klausmeier et al. (1974) and Markle and Tiemann (1970)

suggest (as already discussed in Chapter II) that concept attainment is closely related to the ability of an individual to categorize instances not previously encountered, as instances or non-instances of a particular concept. This leads to the idea that it may well be practical and effective to investigate a student's understanding of a particular concept using an interview situation (because of the reasons described earlier) and a set of simple line-drawings to depict instances.

Osborne and Gilbert further argue that there are at least two different aspects of concept understanding which may be investigated. Firstly, there is the understanding of a particular concept as evoked in a student's mind by the use of the word in a particular communication, for example via teacher or textbooks. A student may not understand the concept in the way it is intended in the communication; alternatively, the student may understand the intended concept, but the particular context may evoke a different interpretation of the concept. For example, the word 'pen' may evoke a concept of 'a small enclosure' or a 'fountain pen', respectively, rather than 'a writing instrument which usually uses ink'. Apart from the problems of a student not understanding a concept, these additional problems can create hidden learning difficulties. Secondly, there is the student's actual domain of understanding of a particular concept in situations where the concept is explicitly specified by a given formal statement or definition which is accepted by the student as a definition that he 'understands'.

With regard to the first aspect of understanding, what is evoked in a student's mind by the use of a particular instance in an IAI investigation will also depend on the content and nature of the instance. However, alternative procedures for investigating concept understanding either do not eliminate this problem or introduce other difficulties. Provided it is appreciated that in the IAI method particular instances will evoke particular understandings and that, hence, the order of presentation is important, an order can be deliberately chosen that will explore the way in which students tend to use a word. If each categorization of an instance by a student is followed by an interview discussion to establish the reasons for the particular categorization, some idea of the understanding that a student has about the particular concept can be established (Dahlgren and Marton, 1978). With respect to this first part of the investigation in particular, it is important that students are encouraged to express their views without feeling that this will immediately be assessed against an externally defined standard (Driver and Easley, 1978). This helps particularly, if the interviewer is not the students' teacher.

The second part of investigating concept understanding is the analysis of the dimensions and boundaries of a student's concept field where the concept has been explicitly specified by a given or known formal statement. A variety of carefully chosen instances can be presented to the student and his ability to categorize

correctly these instances which he has not previously encountered, as instances or non-instances of a particular concept, can be investigated using this approach. Again, the student should be in an interview situation and be asked to 'think aloud' to show how his decision is reasoned out and how the decision relates to the given or known explicit formal definition of the concept being investigated.

If it is accepted that the best way to explore a student's domain of understanding of a concept is to confront him with instances to categorize as examples or non-examples of the concept class (and for the student to give reasons for each categorization), the key problem is how to select a necessary and sufficient set of instances (see Osborne and Gilbert, 1979) which will clearly explore the dimensions and boundaries of the concept field. The theoretical structure of the concept, the attributes of the concept, the relationships between the concept and other concepts and the various contents associated with the concept, all need to be considered.

3.7. THE MAIN FEATURES OF INTERVIEW-ABOUT-INSTANCES APPROACH

The Interview-About-Instances (IAI) approach consists of a dyadic interview where the focus of attention is a deck of stimulus cards (Watts, 1980). The cards depict situations which the pupil is required to classify as examples or non-examples of a concept. Each act of classification is open for discussion; the interviewer

probes the reasons for the choice. An informal dialogue is allowed to develop around the cards; the conversation is audio-recorded and later transcribed. The data, then, is both structured (focused on a pre-arranged, ordered set of cards) and open ended (the pupils are encouraged to respond freely to each card).

The situations on each card show stick-people line drawings, and carry a question, or two. Between ten and twenty different instances are presented at each interview, the end point depends on the pupils, their ages, the length and detail of their responses. Towards the middle of the session they are asked for their summary, or definition of the concept. This kind of method means that one can study:

- a) their understanding of some of the basic attributes of the concept.
- b) how the common, societal meaning of a word impinges on the pupil's more precise meaning.
- c) the rules of classification they are employing.
- d) how the concept is associated with other concepts — how it is arranged in their framework of ideas.

(Watts, 1980)

The interview tape is transcribed and annotated as faithfully as is possible. It is then divided into several categories depending on the context of the conversation. This helps to highlight the hypothesis, or model, by which a youngster is working.

The interview approach just described is an attempt at gaining some insight into children's scientific ideas. Rather than presenting a critical exposé of the inadequacies of their thinking, it tries to describe the conceptual framework a pupil is using (Watts, 1980).

For other details about ^{the} IAI approach such as choice of concepts for a study, design of deck of cards, the process of elicitation, the transcription of interviews, and the analysis of a transcript, see Osborne and Gilbert (1979); Watts (1981); and Gilbert, Watts and Osborne (1981).

According to Osborne and Gilbert (1979), the method has considerable potential for a variety of reasons:

- i) it enables the student's views to be explored without comparison against external criteria,
- ii) it is applicable over a wide age range and it is non-threatening to students,
- iii) it appears to be more pertinent and penetrating than asking for a definition,
- iv) it has advantages over written examinations in that both the student can ask questions about the questions (e.g. if it is considered ambiguous or it is intentionally ambiguous) and the interviewer can query responses or reasons for lack of student response.

On the other hand there are limitations and difficulties:

- i) Choosing a limited but adequate set of instances so that various aspects of a student's concept can

- be explored,
- ii) choosing a suitable order for the presentation of instances, bearing in mind that particular instances may influence a student's response to later instances.
 - iii) there are difficulties with developing a good interview technique,
 - iv) there is the difficulty of handling, analysing and interpreting qualitative (soft) data.

Another approach which is quite similar to the IAI approach has also been used by Osborne (1980) for investigating children's ideas in science. This approach has been named as Interview-About-Events (IAE) approach and has also been used by others to explore children's views on 'physical change' (Cosgrove and Osborne, 1981), 'chemical change' (Schollum, 1981), the 'particle nature of matter' (Happs, 1981), and the 'changes of state of water' (Osborne and Cosgrove, 1983). This technique involves an event or activity occurring in front of the person being interviewed. Where possible the person is asked to participate in the event, if only to light a burner. Each event is used as a focal point which enables the interviewee's view to be communicated to the interviewer.

The only difference between the IAI and IAE is that the earlier uses instances, and the latter involves an individual discussion with an interviewee about an articulated series of demonstrations called events. The

Interview-About-Events approach is near-equivalent to IAI (in the same way that showing a diagram of apparatus is similar to showing the actual apparatus). The Interview-About-Events approach has at least two difficulties that prevented it from being considered for the present study. The need to set up apparatus--- (as described later) the researcher had to interview under difficult circumstances; and the longer time taken (one-worker problem).

3.8. RESEARCH TEAMS/PROJECTS INVESTIGATING CHILDREN'S CONCEPTS

A summary of studies of children's learning in science that have used Interview-About-Instances approach (IAI) either directly or indirectly as their main techniques of investigation is given below. These have been described in the order of their initiation and the accounts of the work and findings of these teams/projects vary depending upon the information which they published.

3.8.1. THE PERSONAL CONSTRUCTION OF KNOWLEDGE GROUP(U.K.)

The Personal Construction of Knowledge Group (PCKG) is a research group within the Institute for Educational Technology at the University of Surrey. The PCKG have developed ways of identifying alternative conceptions particularly the Interview-About-Instances technique. This technique has been applied to ideas in Physics, Chemistry, Biology, etc.

The main goal is to influence educational practice in a wide variety of ways. To this end continuous observation in classrooms is a central feature of the Group's orientation. The group runs three special activities. These are:

- i) a seminar, weekly in the University term, to which all are welcome. The seminar has a range of forms, including the consideration of papers of common interest.
- ii) discussion, as required, of papers prepared by the individuals.
- iii) the running of a 4 hour workshop, developed jointly with members of the Science Education Research Unit at the University of Waikato, New Zealand. This workshop discusses the concerns of the Group in the context of teaching physics, chemistry or biology.

3.8.2. THE LEARNING IN SCIENCE PROJECT (NEW ZEALAND)

The Learning in Science Project (LISP) was based at the University of Waikato in Hamilton, New Zealand from February 1979 to January 1982. The Project was a research investigation funded by the New Zealand Department of Education. The main aim of the project was to make a study of the teaching and learning of science at the Form 1-4 level, to identify some of the key difficulties in this subject area, and to find ways of overcoming such

the
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difficulties. To this end, a three phase programme was adopted.

In the first phase, the emphasis of the project was on what actually happens in the classrooms rather than on the syllabus and resource materials. Thus, it was decided to seek out the viewpoints of teachers, pupils, science advisers and others about Form 1-4 Science, to observe what teachers are actually teaching (as distinct from what they think they are teaching) and what children are actually learning (as distinct from what teachers think they are learning).

The approach used was not ^{the} usual survey, which tends to be based primarily on answers to questionnaires or tests. Rather a range of methods such as 'unstructured interview', 'observations', and 'structured interviews' were employed to seek out views and make the observations required. In particular, the Interview-About-Instances technique (IAI) developed at the University of Surrey was used by the project team to investigate children's understanding of various concepts of science.

The in-depth phase emphasized interview and classroom observation as methods of investigation. The nature of problems emerged as a result of investigating children's ideas made it an impossible task for the action - research teams to solve them all. The LISP team therefore considered that the best help they could give teachers would be to devise materials which would enable them to become:

- i) aware, and even familiar, with the problems related to at least one specific topic,
- ii) involved in using teaching material specifically designed to overcome these problems, and
- iii) encouraged to seek ways of building on and modifying children's ideas, rather than assuming those ideas to be inconsequential.

Action research was limited to four areas, each area being covered by a group comprised of project team members and practising teachers. The groups were: a physics group, a biology group, a chemistry group, and an activities group.

The common aim of all groups was to produce material useful to and useable by teachers. The work of the project has been published in 54 working papers (See Appendix A) and in various research journals.

3.8.3. THE CHILDREN'S LEARNING IN SCIENCE PROJECT(U.K.)

The project was based at the Centre for studies in Science and Mathematics Education, University of Leeds. This project has undertaken research into the understanding of selected science concepts by 14 - 16 year old pupils based on written tests, interviews and classroom observation studies. The project was funded from 1982-83 by the Department of Education and Science (and from 1983-86, it was being funded by the Schools Council through the Secondary Science Curriculum Review. The project was carried out in two phases:

Phase 1

A content analysis was undertaken of pupils' written responses to questions given as part of the national surveys conducted on behalf of the Assessment of Performance Unit.

The analysis led to a detailed documentation of pupils' understanding in a selected number of concept areas. The kinds of areas included in the investigation were:

The particulate theory of matter

Energy transformation and conservation

Thermal energy: heat, temperature and change of state

Air and air pressure

Simple chemical reactors with oxygen

Conservation of matter

Gas exchange and growth in plants

Light: vision, transmission and reflection

Rates of chemical reactions

The analysis of written responses to questions on these topics was supplemented with interviews with pupils and discussions with local science teachers. Reports of the analysis on each topic area were prepared in a form useful to teachers.

Phase 2

This action research phase involved using the information obtained from the first phase as a basis for developing teaching materials and strategies designed to

improve learning in areas of particular conceptual difficulty. This phase was conceived as a collaboration project involving the research team and practicing teachers and focused on 13-16 year old pupils of all levels of attainment.

The main focus was on the development of some teacher training materials and, development and evaluation of activities, in selected topics, which encourage the active participation of young people in relating school science activities to their own experiences and developing a confidence in using scientific ideas.

3.9. REVIEW OF FINDINGS ABOUT CHILDREN'S CONCEPTS

Until recently the major emphasis in the development of most school science curricula has been directed towards the structure of the knowledge to be taught. However, there is now growing concern about students' 'invented ideas' based upon their interpretations of sensory impressions and the influence these have on the ways in which they respond to and understand knowledge presented in the classroom. Evidence of students' intuitive ideas about natural phenomena abounds in the now extensive journal literature. A summary of findings has been published (Gilbert & Watts, 1983). For the purpose of the present study five concept areas such as Force, Energy, Light, Work, and Electric Current were selected. The basis for the choice of these concepts is described in Section 4.1. Chapter IV. In this section only those concept areas which were selected for the purpose of the

What

present study are described here under broad topic headings restricting the discussion to the elements included in the study.

3.9.1. FORCE

Many of the studies of force have concerned the strong association of force with motion; its interchangeability with the word energy; its separation from the concept of weight. Some of the earliest work on 'misconceptions' was concerned with force. For example, Helm's (1978, 1980) work, which attracted popular attention (Maddox, 1978), shows that students 'fail' conceptual mechanics questions.

In terms of alternative frameworks, force-motion frameworks are widely reported. Some of these have been summarised by Gilbert and Watts (1983) as follows:

- i) If a body is moving there is a force acting on it in the direction of movement.
- ii) Constant motion requires a constant force.
- iii) If a body is not moving there is no force acting on it.

These are not the only frameworks, simply the most commonplace. For example, there are some frameworks that would include forces as being involved with non-movement in contrast to iii) above. Erickson and Hobbs (1978) report students who make a distinction between 'pulling forces' which seem to connote movement with 'holding forces' which do not.

Watts (1983) reports a similar distinction between 'Motive' forces and 'configurative' ones. The association of force and motion, however, has a wide press. Viennot (1979) instigated an important study with physics undergraduates using paper and pencil questions about oscillating masses; Watts and Zylbersztajn (1981) used a similar approach over a variety of situations with 13-year-old students. The findings of both the studies reveal the importance for students of the direction of the force, which is commonly seen as being in the direction of motion. McCloskey, Carmazza and Green (1980) note that the direction need not necessarily be in a straight line. Thus an object set in motion in a curved path (inside a hollow tube) will be predicted as continuing to travel in a curved path when it emerges from the tube. Similar directional points have been made by Laboutet-Barrell (1976); Osborne (1980); Sjoberg and Lie (1981); Narode (1981); Clement (1982); and in the developments of the Watts and Zylbersztajn work by Thomaz (1982) and Wright (1982).

The requirement for constant motion to have a constant force is widespread amongst students. Langford and Zollman (1982), for instance, comment on the strength and persistence of the notion that a force must continue to act on an object if it is to continue in motion even under (simulated) friction-free conditions. Where an object does not receive a constant force, then the force that causes its motion is 'used up' during movement until

other forces (like gravity) take over. These kinds of frameworks are reported by Jira and McClosky (1980); Lawson et al. (1980, 1981); Champagne, Klopfer and Gunstone (1981); Sjoberg and Lie (1981); Watts and Zylbersztajn (1981) and Watts (1983).

The third aspect of the force-motion framework concerns objects in their 'at rest' condition (Minstrell, 1982). Here the absence of motion precludes the possibility of force since (as students say) 'nothing is moving'. As Helm (1981) points out, since in physics a force is deemed to 'act' or 'be exerted' it seems only reasonable to look for the source of such an action or exertion. The corollary to this is that the search is pointless where there is no action. Findings of Osborne (1980), Watts and Zylbersztajn (1981) and Watts (1983) again raise similar issues.

These studies span a variety of ages and aptitudes; consequently it is difficult to glean a clear developmental age-related pattern of change. Erickson and Hobbs (1978), for instance, find few age-related differences, whilst Langford and Zollman (1982) comment on the similarities across aptitude levels. Sjoberg and Lie (1981) suggest there are differences but that 'The only "development" which seems to occur is that some of the mistakes are more clearly expressed by the more mature students. One may argue that they then have the "tools" to express views already developed earlier.....'.

3.9.2. ENERGY

The general framework that can be derived from a review of energy studies has been summarised by Gilbert and Watts (1983) as

- i) energy is to do with living and moving things
- ii) energy makes things work
- iii) energy changes from one form into another.

The first of these represents responses concerning energy that are described as anthropocentric and vitalistic. Stead (1980), for example, discusses the responses of 8 to 13 year old New Zealand students in terms of their strong tendency towards anthropomorphism. She suggests that the youngsters relate the word energy to living things by way of being energetic. Solomon (1982, 1983) makes similar points, noting too that students discuss human energy as being 'rechargeable' - through food or by resting. Watts (1983) calls this a 'human-centred' energy framework, which Gilbert and Pope (1982) also noted during the video-taping of discussions with younger (12 year old) science students. All of these studies also comment on the emphasis given to energy and motion. It seems difficult to imagine any inanimate object as having a lot of energy whilst at the same time being stationary.

The exceptions to this last idea are often couched in terms of 'energy stores' that are concerned with making things work. Batteries, power stations, oil

and coal are all seen as stores of energy, commonly intended for the benefit of humanity through technological appliances (Watts, 1983).

There has been some recent controversy over the 'transformation' framework of energy since it is one that is sometimes explicitly taught. Warren (1982) denigrates this view of energy as emphasising the 'metamorphosis' of energy in a material sense. He suggests that it is appealing to young people who have become conditioned by stories of superman and 'fairy tales in which toads change into princes'. It is a view that sees energy as travelling through machines and wires and changing appearance at different points. In some cases it is thought to be stored in fuel or food. Whatever the merits of such a view (Schmid, 1982, Richmond, 1982) it is a common interpretation of students' responses when discussing energy (Duit, 1981; Solomon, 1982; Gilbert and Pope, 1982; Watts, 1983).

In addition to these general research outcomes, one other feature is worth noting, energy is frequently commented upon as being used by students interchangeably with other terms. Clement (1978), for instance, comments on the lack of differentiation between energy and other terms in college physics students in America. Viennot (1979) makes a similar point: that the concept of energy is 'inextricably mixed with the concept of force in a single undifferentiated explanatory complex'. Duit (1981), using word association tests, also notes the strong

association between force and energy, an overlap of meaning that Watts and Gilbert (1983) discuss in some detail. For Rhoneck (1981) the term energy is closely related to electric current; force being related to 'voltage' in an electric circuit.

3.9.3. LIGHT

As there have been fewer studies in light, it is more difficult to discuss general, widespread findings. However, two particular frameworks are worth noting (Gilbert & Watts, 1983):

- i) (A) reflection is an image on a mirror or surface (and not a process by which light changes direction).
- ii) Light illuminates objects so that they are 'lit up' and can then be seen. The light is local to the scene and need not travel as far as the viewer.

One of the first studies, by Guesne (1978), asked students to respond to some optical experiments in what she calls 'directed' interviews (similar to IAE). These were complemented by 'non-directed', or open-ended questions in a separate set of interviews. She suggested that students (13-14 year olds) talk in terms of reflection for a mirror but not for an illuminated sheet of whitepaper. Lenses are seen as making light bigger and that, in line with the second framework above, candles visible at a distance are not considered to be sending light as far as the observer, but are only capable of 'being seen'.

Stead and Osborne (1980) used an IAI approach and a multiple choice test to consider the relative distances travelled by light from a variety of sources at day and at night. For many interviewees (ranging between 9-16 year olds) the distance travelled depended firstly on the size of the source. The corollary to this is that light from a small source such as a candle could not travel very far. Most 9 year olds did not consider light to travel more than a metre from a source during the day, and only slightly further at night. Jung's (1981) paper comments on a sample of 12 and 15 year olds who suggested that their image was located upon a mirror and not 'behind' it.

In a short study Zylbersztajn and Watts (1982) looked at students' responses to the action of coloured filters placed into a beam of light from a torch. Many of these issues were taken up also by Andersson and Karrqvist (1982; 1983) in a comprehensive study of students' interpretations of optical phenomena.

3.9.4. WORK

Compared to energy, fewer studies have been reported on 'work'. The study by Osborne and Gilbert (1979) reports: there is lot of "typical" everyday language usage of the word 'work' by the children.' Students identify work purely in terms of exertion applied by the person. In the cases where no person was involved,

children change from assuming no work is done because there is not a person present to work is done because there will be a motor (for example) doing the work. Also, students can not see how work could be done when no one was present.

Moreover, children hold a view that nature could not do work, rather work was something done, or attempted against nature. For example, no work is done when a ball drops down, because it is falling freely. A wooden block slowing down on a concrete path does not involve work as it is just natural for it to slow down. Also, the work done by a particular force is sometimes not isolated clearly (in space) from the work done by the reaction force; reactional and frictional forces were frequently confused by the students.

3.9.5. ELECTRICITY

Much of the work on electricity has focused upon simple battery-and-bulb circuits except for three more diverse studies by Preece (1976), Johnstone and Mughol (1978) and Rhoneck (1981). Preece's work consisted of a 'relational' study of concepts concerned with electromagnetism and used a word-association test to explore the semantic proximities of concepts for students who were graduate intending physics teachers. He suggests that the concept of 'electric current' is a pivotal one, in both the structure of the subject matter and within

the structure implied from the students' responses. This suggestion is supported in some of the studies to be considered below. Johnstone and Mughol (1978) concentrated upon electrical resistance in symbolic form. They note that students (at all secondary school age levels) are familiar with basic symbols of electrical circuits but that there is also considerable confusion (again at all ages) for the meaning of common electrical terms like voltage and power. Rhoneck's (1981) study considered such terms in more detail. Using a sequence of interviews, questionnaires and further interviews he explored secondary school students' meanings for electrical voltage and current. Responses indicated a close association between current and energy, voltage and force, and that, whereas voltage and current are related, they are generally not seen to be the same. He presents this relation by saying that a circuit is 'described by the current', and the voltage is 'closely associated' with the current. This kind of framework was supported by Maichle (1981) and is summarised as:

- i) when an electric current 'flows' then 'voltage' should be present; when current is interrupted the voltage disappears.

With the exception of Riley et al (1981) few of the other studies focus on the current-voltage aspects of a circuit, but concentrate on current itself and the components (commonly batteries and bulbs) in the circuit. Osborne and Gilbert (1979) piloted the Interview-about-

Instances technique whilst exploring meanings for electric current. Like Johnstone and Mughol (1978) they comment on the similarities between a group of 7-14 year olds and a group of 16-18 year olds. They note that, for some sixth form physics students, intuitive ideas about electric current (and what happens to it) have not changed since childhood. These and other studies on electric current give rise to the second general framework, which can be described as:

- ii) electric current 'flows' around a circuit in one direction and some of it is used up by each component it meets in turn.

Shipstone (1982) calls this a 'sequence model' and shows that (in his sample) it is very prevalent in the middle years of secondary schooling and persists amongst able students (who had been studying physics for some four years) at A-level. Riley, Bee and Mokwa (1981) describe a similar model developed by students as they worked through sections of a USA Navy electricity and electronics course. These authors refer to it as a 'time-dependent' model of current flow. The same model also features as one of four proposed by Osborne (1981, 1983). All of Osborne's models concern simple circuits (one battery and one bulb) and are, in turn, a 'Unipolar' view that negates the need for a 'return' lead to the battery, from the bulb; a bi-directional 'clashing currents' model; and an 'equal current', scientifically acceptable, model. Osborne has explored

a wide age range of students and again finds that, despite teaching, many of them still use typical 'children's models well into and, in some cases, at the end of the period of formal instruction. Some elements of Osborne's 'clashing' model are to be found in an extract provided by Driver (1983). In this model current 'flows' from both poles of a battery and meets inside the bulb in the circuit, producing light.

3.10. WORLDWIDE VIEW OF CHILDREN'S MISCONCEPTIONS

The findings of the research studies about children's misconceptions in the concept areas described in the previous section, and the findings of the research studies reported by other researchers (see Driver & Easley, 1978; Driver & Erickson, 1983; Gilbert & Watts, 1983) in diverse subject areas show that children of all ages hold misconceptions, and the misconceptions held by children in different parts of the world are similar in nature. The findings are all the more convincing because of the similarity of results from studies using dissimilar (or at least non-identified) methods.

Because of the wide diversity in subject matter, the results of studies cannot readily be synthesized at this stage of our understanding. Being a new area of research in science education, very few studies have been replicated. However, the study on children's conceptions of Earth by Nussbaum and Novak (1976) in America and its replication by Nussbaum (1979)

in Israel; Mali and Howe (1979) in Nepal, and Robina Asmat and Kauser Jabeen (1984) in Pakistan report that children in four countries hold similar conceptions about the Earth. Also, the study of Jordanian and American pupils by Billeh and Pella (1970) concerning the 'Attainment of Concepts of Biological Cell' indicates that neither group was consistently superior to the other group. A series of research studies by LISP and PCKG in various concept areas show similar results. The common patterns in children's misconceptions noted by Gilbert et al (1982) as a result of their studies are:

- i) Use of Everyday Language in daily scientific events,
- ii) Self-Centred and Human-Centred viewpoints of natural events,
- iii) Non-observables do not exist,
- iv) Endowing objects with the characteristics of humans and animals; and
- v) Endowing objects with a certain amount of a physical quantity.

The five common patterns found by Gilbert et al (1982) are a useful summary of the worldwide findings and that for reasons given above, it is difficult to be more specific.

3.11. THE COMMONALITY OF CHILDREN'S MISCONCEPTIONS

The commonness of misconceptions during childhood according to Ausubel et al (1978, P. 101) may

be attributed due to several factors. First, children do not have the cognitive sophistication and the cumulative background of experience necessary for the complete development of many concepts. The pressure on children to use inadequately understood concepts, and at the same time to conceal their lack of understanding, further encourages the development and perpetuation of misconceptions. Second, many of children's misconceptions are derived from erroneous and incomplete information, or from misinterpretation or uncritical acceptance of what they read or are told.

Researchers report different causes/sources of these misconceptions, Johnstone and Mughol (1976) report three main causes of difficulty in Physics concept formation at secondary school level. These are teaching, normal language usage (which tends to confuse and undo teaching) and everyday experience of the material world. Driver and Erickson (1983) have explored the speculations about the possible sources of students frameworks (i.e. misconceptions) in the literature. They argue that the experiences relating to a range of natural phenomena which impinge directly and regularly on human senses (such as pushing, pulling, lifting, sucking, sensations of 'hot' and 'cold') may be built into a system of expectations even before they are made explicit through language. A likely characteristic of ideas, which have been constructed from these sorts of perceptual experiences, is that they are strongly held and resistant to change. It may be, as

Strauss (1981) has suggested, that frameworks which have this perceptual basis are apt to be universal simply because in that most students will have constructed their experiences in similar ways.

The second suggested influence on students' frameworks is that of language and available metaphor (Gilbert et al, 1982; Schaefer, 1979; Sutton, 1980). Driver and Erickson (1983) argue that the commonality in human sensory experiences and possibly in the metaphorical use of language may account for the reported generality of some student frameworks. Indeed, these two sources are often interrelated, with sense experiences and everyday language reinforcing one another, thus increasing the conviction with which certain ideas are held.

Some researchers have also investigated the stability of students' ideas over time after using a cross-sectional sampling design (Driver & Erickson, 1983). A content analysis of the responses of 15 year old students as part of national science assessment programme by Driver et al (1984) indicates that it is only a minority of students who use taught science ideas in response to questions relating to selected topics. Such studies indicate that there is less change in students' conceptualisations during school years than might be supposed. Similar views have been put forward by Pines et al (1981) and Gilbert et al (1982). Gunstone et al (1981) report that in their study, the instruction was less successful than it was hoped in changing students'

world view of force and motion. Despite a number of impressive demonstrated abilities most students had not abandoned an Aristotelian view which shows how strong and enduring these misconceptions are. AA

The science teacher seems to be another important factor, but very few studies have focused on the teachers; as a result, very little is known about the teachers' conceptions of the basic concepts of science. Helm (1980) found the teachers as the major cause of misconceptions in physics amongst South African students, with textbooks, and examination papers also contributing. Ivowi (1984) complementing the findings of Helm (1980) reports a wide spread of some misconceptions in physics amongst secondary school students in Nigeria. He further reports that the teachers of these students seem to have similar misconceptions in some areas of physics, and the main causes of these misconceptions in students can be traced to teachers and some available textbooks. Barrass (1984) reports about 15 major 'misconceptions and misunderstandings' in standard textbooks of Biology. AA

In summary, it can be said that

- i) children's misconceptions is a world wide phenomena,
- ii) children of all ages hold misconceptions,
- iii) the misconceptions held by children are similar in nature,
- iv) these misconceptions are so strong and enduring that it is difficult to remove or modify children's misconceptions. AA

As far as the causes or the sources of children's misconceptions are concerned, everyday experience and everyday language are considered as the main sources. Also, there is some evidence that teachers and textbooks might also be serving as sources of misconceptions which needs further empirical evidence to support. Although, it has to be shown conclusively that teachers are responsible for some of pupils' misconceptions it is known (Helm, 1980; Gilbert et al, 1982; Ivowi, 1984) that teachers themselves have the same common misconceptions as many pupils.

Even if it is agreed only that children develop misconceptions from their everyday experience and language, and if there is evidence that teachers also have misconceptions, then, (at least), it can be said that teachers are less likely to be able to modify children's misconceptions because of their own misconceptions.

In that case, perhaps, there would be a need to think of the teachers first, and, in this respect, we might have to plan special teacher training programmes to enable them to teach the children effectively.

CHAPTER IV

STUDY 1

**THE FIRST INVESTIGATION OF STUDENTS' AND TEACHERS' MISCONCEPTIONS
IN PAKISTAN**

AN OVERVIEW OF THE EMPIRICAL WORK

The empirical work involved in this study was carried out in three stages. In the first stage, described in this chapter, students of the 8th class (age range 11 - 14 years) were tested on the concepts Force, Energy, Light, Work, and Electric Current using the IAI approach. The results confirmed that, broadly speaking, Pakistani students have misconceptions similar to the ones held by children in other parts of the world. With this confirmation it was then relevant to test a sample of 8th grade teachers in order to determine whether or not they have misconceptions in science. Three groups of teachers were tested only in one concept Force using a paper-and-pencil test. It was discovered that in this concept area many of the teachers have misconceptions similar to those of their students.

In Stage 2 of the study, teachers of the 8th class sample students were given extra training relevant to the teaching of the concepts Force, Energy, and Light. The training was aimed at enabling the teachers to remove the misconceptions of the students. Teachers returned to school and retaught the three concepts to their students. The students were re-tested using the IAI approach and also paper-and-pencil tests. It was found that there was no measurable improvement in the children's understanding of concepts.

This was a disappointing result which might have been caused in some unknown fashion by particular characteristics of the small sample of teachers or students used for the Stage 2 Study. Because of its implications for teacher training programmes it was thought desirable to confirm or refute the result more widely; consequently a larger number of teachers and students were involved in a further study using an improved experimental design. The purpose of this third part of the study was to discover if in-depth teacher training can lead to more effective teaching. Three groups of science teachers were selected for training to teach the same concepts of Force, Energy, and Light. Group A was given in-depth training whilst Group B was given simple training about children's misconceptions; no mention of children's misconceptions was made to the teachers of Group C who served as a control group. After all groups of teachers had retaught the three concepts, their students were tested using a specially designed and tested paper-and-pencil instrument.

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CHAPTER IV

STUDY 1

THE FIRST INVESTIGATION OF STUDENTS' AND TEACHERS'
MISCONCEPTIONS IN PAKISTAN

This Chapter deals with the application of Interview-About-Instances (IAI) approach to test students in Pakistan and the testing of the teachers of these students using another method.

4.1. METHODOLOGY FOR TESTING OF STUDENTS

For the purpose of the present study, the concepts Force, Energy, Light, Work and Electric Current were selected.

When selecting the instrument and the concept areas, the researcher had a number of options for the selection of the instrument and the concept areas.

These included:

- i. testing 'new' concept areas and using 'new' instruments,
- ii. testing 'old' concept areas and using 'new' instruments,
- iii. testing 'new' concept areas and using 'old' instruments,
- iv. testing 'old' concept areas and using 'new' instances,

where the labels 'old' and 'new' refer to the previously 'explored' and

'unexplored' concept areas by the researchers, and the same labels refer to the previously 'established' and 'unestablished' instruments respectively.

Instead of any of these the researcher chose to test 'old' concept areas and to use the 'old' instrument and 'old' instances. This decision was made because of the obvious merits of using an established technique. If all researchers continually design new instruments and if (new) instrument is used in only a few studies in one country or institution, then it is not possible to make any meaningful comparative studies. There is the further merit that in using an established instrument in previously explored concept areas, the new research contributes in two ways:

- i. it provides data that can be compared with other data (this aids validity studies), and
- ii. any comparison of results adds to the original research also.

Other features of the IAI approach which were kept in view while selecting the research methodology have already been discussed in Chapter III, Sections 3.6 and 3.7.

For the investigation of concepts Force, Energy and Light, instances used by LISP (Osborne, 1980; Stead, 1980; and Stead and Osborne, 1980) were used. For the investigation of concepts Work and Electric Current,

instances developed at the University of Surrey (Osborne and Gilbert, 1979) were used. The instances were used with only minor changes to a few words to suit local conditions.

Modifications and other such changes were made after trial interviews on a small scale using exactly the same instances developed by the named researchers for each concept. Testing was directed to ensuring that the language used would be clearly understood and the examples used were commonly known to the Pakistani students.

Only a few minor changes were found necessary. For example, for investigation of ^{the} concept of Force, the word Bike was changed to Bicycle; Golf I and II to Cricket I and II; Bowl to Ball I, and Beach Ball to Ball II. For investigation of Energy, the instances 'Hovercraft' and 'Toboggan on Icy Slope' were deleted, again Bike was changed to Bicycle. No change was found necessary to any of the depicted instances of the other concepts.

All the wording on the instances-cards was translated into Urdu. Translation was necessary because during the trial interviews, it was found that children did not participate in discussion easily when given instructions only in English. All the interviews were conducted in Urdu, although the instances on the cards did also carry the English wording. Copies of instances used for interviews in Force, Energy, Light, Work and

Electric Current showing both English and Urdu instructions are given in Appendix B.

4.1.1. TESTING FOR FORCE, ENERGY, WORK AND ELECTRIC CURRENT

For the investigation of all the concepts except Light, interviews were conducted by the researcher himself at the University Laboratory School, Lahore. It is a middle school (pupils age 5⁺ - 14) attached to the Institute of Education and Research, University of the Punjab, Lahore. The school is reasonably typical for the research purposes. The pupils at the school are not just those of faculty (and hence possibly above average ability) but include also children from many other local families.

This school was convenient because of its closeness to the researcher's Institute offices. Also, because all the teachers were ex-students of the Institute, maximum cooperation was easily obtained.

4.1.1.1. SAMPLES

As already stated, pupils in the University Laboratory School are drawn from a wide range of geographical and socioeconomic backgrounds. For the purpose of the present study, samples of pupils were drawn from class 8 in this school. The total year group was 40 with an age range of 11⁺-- 14 years. Class 8 contained only male students. For testing these concepts, a separate group of 20 students was drawn randomly for each concept

from the same class.

4.1.1.2. INTERVIEW TECHNIQUE USED

The students were first individually interviewed (using the method described in Chapter III) on Force, then Energy, Work and finally on Electric Current. Trial interviews were conducted on the class 8 students of the academic session 1982-83, but the actual interviews were conducted in the session 1983-84 during the months of March, April, and May of 1983. Each interview took about half an hour.

Each student was interviewed in a completely isolated room; no person other than the researcher and the student was present. All the interviews were audio-recorded. The instances which were drawn on cards were presented to each student in the same order as in Appendix B one at a time.

In order to encourage dialogue, it was emphasized to each student that there was no one right answer, and the result of the interview would remain confidential and in no way affect his result in the final examination.

While interviewing on Force, the main question for each card and for each student was phrased in the form 'Is there a force on ---?' followed by questions according to need. Similar questions were asked while conducting interviews on Energy, Work and Electric Current.

4.1.2. TESTING FOR LIGHT

For the investigation of the concept Light, interviews were conducted by a trained colleague of the researcher, who was working as a Research Assistant at the Science Education Centre of the Institute of Education and Research, Punjab University, Lahore.

She was selected for this task in view of her professional background and competence. She had B.Sc. and M.A. (Education) qualifications and had specialized in Science Education. Also, she had experience of science teaching at secondary level and possessed all such qualities of a good interviewer as suggested by Mouly (1978). She had integrity and objectivity as well as the tact and the ability to meet people and to make them feel at ease and willing to communicate. She was adept at making an effective primary contact, because as argued by Mouly (1978) the success of an interviewer, frequently depends on the rapport established in the first minute or two.

4.1.2.1. THE TRAINING OF THE INTERVIEWER

Borg and Gall (1983) argue that the interviewer must be trained if reliable and objective information is to be obtained. Borg and Gall (1983) further suggest that training should be carried out in two phases. In the first phase the trainees study the interview guide and learn about the interview conditions, logistics, necessary controls and safeguards, variables being studied, and similar

information. Before conducting any interviews, the interviewer should become so familiar with the interview guide that he/she can conduct the interview in a conversational manner without hesitating, back tracking, or needing to reread or study the guide.

In the second phase, the trainees should conduct practice interviews and receive corrective feedback until their performance becomes standardized and reaches the desired level of objectivity and reliability.

The interviewer selected for this study was also trained in the light of these guide-lines. Before she went out for investigation, she was given a full account of the project and of all background information relevant to the research. After reading and discussing the interview methodology, she undertook some supervised interviews as practice sessions. Only after this training did she set out to hold individual interviews on Light.

4.1.2.2. INTERVIEW TECHNIQUE USED

After the training, trial interviews were held by the interviewer on 30 students (age range 11⁺- 14) drawn from various schools of Lahore City. As before, all the students were interviewed individually one at a time in a special part of their own school. All the interviews were audio-recorded. The main aim of these trial interviews was to judge whether the instances were familiar to and understood by the children. The trial also provided

the opportunity to confirm a reliable interviewing technique. During the trial interviews, frequent discussions were held on interview methodology. These interviews were transcribed jointly by the interviewer and the researcher. Students' responses were also analysed together. The statements of misconceptions thus obtained by the interviewer were compared with those obtained by the researcher during his interviews. The comparison of statements of misconceptions (See Table 4.1.2.2) shows that both the interviewers brought similar results; this similarity shows that the interview technique used by the interviewer was reliable and she was competent to apply the technique. The trial interview results show that a reliable technique of interview and analysis has been established.

For the actual interviews, a separate sample of 30 students was drawn from three different (other than trial) schools in Lahore City. For the purpose of selection of this sample, 10 students were selected on random basis from one class 8 in each school. The sample contained both boys and girls with an age range of 11⁺ - 14 years.

As in the trials, each interview was held in the respective school in a completely isolated room; no person other than the interviewer and the student was present. Each interview took approximately half an hour. All the interviews were audio-recorded as it was done while

investigating other concepts. The instances which were drawn on cards were presented to each student in the same order as in Appendix B one at a time. All aspects of the interview technique were kept the same as for other concepts. All the tapes were transcribed by the interviewer and data thus collected were analysed by the researcher himself.

TABLE 4.1.2.2.

Category Name and Code		Typical Statements Obtained by the trained Interviewer	Typical Statements Obtained by the Researcher
Ideas about Reflection and Emission of Light.	L ₁	"No, it reflects light from the match stick".	"It gets light from the sun, only then, it (moon) emits light". (Moon)
Ego-Centric and Human Centred Viewpoint.	L ₂	"Yes, you can see people moving on the screen, without light, you couldn't see them." (Television)	"The distance to which moon's light can go depends on its strength, when it loses strength it will stop". (Moon)
If you can't see it in the dark, it does not make light.	L ₃	"No, you can't see it in the dark, because it does not rise in the dark, it is not there". (Sun)	"No, you can't see it in the dark, you can see it only when its rays enter our eyes." (Sun)
Everyday Language	L ₄	"It reflects light which it gets from the glowing object". (Painting)	"Yes, it produces light...but not 'electric heater...when 'light' (electric current) passes it emits light". (Heater)
Common Sense Answers	L ₅	"It does not emit light, because it gets changed into colours". (Rainbow)	"It takes light from the wax". (Candle)
Ideas about the distance light travels	L ₆	"If the candle is very large, then its light can go far, but if it is small, it will stay near". (Candle)	"The light from the bigger torch will go farther". (Torch)
Ideas about seeing the objects	L ₇	"You can see it with your eyes, if it is burning". (Candle)	"We can see the painting because of reflection of light of our eyes." (Painting)

4.2. RESULTS (STUDENTS)

The sections which follow discuss the students' responses according to concept.

4.2.1. FORCE

For the purpose of analysis, some of the categories developed by Osborne (1980) were used. These categories have the merit of simplicity of description and therefore of convenience.

The results are presented here in two tables. Table 4.2.1.1. in its Column II presents a typical statement of misconception of Pakistani students under each category. The table also gives the number and percentage (Column III) of similar statements in each category. The Column IV in this table presents statements of misconceptions under each category as explored by Osborne (1980) in his investigation of the concept 'Force'. Column V of this table presents the number and percentage of similar statements in each category obtained by Osborne in New Zealand.

The table 4.2.1.2 presents results showing the number of statements under each category against each instance. These tables indicate that the widely occurring areas of misconceptions are the categories F_5 , F_2 , and F_6 (See Table 4.2.1.1) and the majority of the statements occur in instance 'Cricket I' (Table 4.2.1.2.). These are also the commonest categories reported by Osborne (1980).

The results show that the understanding of the concept of Force by Pakistani students is qualitatively and quantitatively similar to ^{that of} children in other parts of the world. The obvious usefulness of Osborne's Category System devised in New Zealand for classifying results obtained in Pakistan confirms the similarity of children's misconceptions in both the countries. Similarity of children's misconceptions is also confirmed by the nature of statements given by children in both the countries. This similarity is evident from the statements given in Columns II and IV of the Table 4.2.1.1. The finding that the commonest misconceptions in New Zealand are also the most common in Pakistan gives quantitative support to the similarity pattern.

The findings of this concept (Force) show that children living under widely different social and environmental conditions have very similar conception of Force as it occurs in everyday situations.

Category Name and Code I		Typical Statement (Pakistan) II	No. & % of total statements in this category III	Statements in Osborne's Study (NewZealand) IV	No. & % of total statements in this category V
Everyday Language	F ₁	"Yes, he is forcing him to move." (Police)	3 (4.3)	"Yes, he is forcing the car". (Car I)	6 (10.34)
Human-Centred Viewpoint	F ₂	"No, there is no force on the car." (Car I)	14 (20.00)	"No, because no one has to push it". (Car II)	17 (29.31)
Something that can't be observed or felt by humans (or animals) does not exist.	F ₃	"No force is acting on the bicycle". (Bicycle)	7 (10.00)	"No, because it can't feel anything--but there is a force on the man because he has to push it and that puts a force on him". (Car I)	4 (6.90)
Endowing objects with human or animal characteristics.	F ₄	"No, it is moving of its own". (Bicycle)	5 (7.14)	"Yes, it is forcing itself to stop". (Bicycle)	7 (12.07)
The abstract idea being treated as if it had material existence; the force is somehow embedded in the moving object.	F ₅	"Yes, the ball went up because there is force of man's hit". (Cricket I)	17 (24.30)	"I suppose there is because the force from the hit is still on it". (Golf I)	15 (25.87)
Incorrect use of Scientific Terms	F ₆	"Yes, there is force of the inclined plane". (Ball II)	13 (18.6)	"Yes, there is initial energy transferred to the ball". (Golf I)	4 (6.90)
Self-contradictory views	F ₇	"As the man is sitting on the cushion, there is force of weight (not gravity)". (Cushion)	7 (10.00)	"His weight is pushing him down--(but) there is no gravity on the moon". (Moon)	2 (3.45)
There is no gravity on the moon.	F ₈	"No, there is no force on the moon". (Moon)	5 (5.71)	"No, there is no gravitational force on the moon". (Moon)	3 (5.20)

Table: 4.2.1.2.

FORCE

N = 20

Sr. No.	Instances	Categories							
		F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	F ₈
1	Police	1	2	-	-	-	2	-	-
2	Car I	2	1	-	-	-	-	-	-
3	Car II	-	2	-	-	-	-	-	-
4	Car III	-	1	-	-	-	-	-	-
5	Bicycle	-	-	1	1	1	-	-	-
6	Cricket I	-	-	1	1	10	3	-	-
7	Cricket II	-	1	1	-	3	2	1	-
8	Ball I	-	-	1	1	2	1	-	-
9	Box	-	2	2	-	-	1	-	-
10	Ball II	-	1	-	-	1	1	-	-
11	Cushion	-	-	-	-	-	1	5	-
12	Weightlifter	-	4	-	-	-	-	-	-
13	Satellite	-	-	1	2	-	1	1	-
14	Moon	-	-	-	-	-	1	-	4

4.2.2. ENERGY

The results of the investigation of the concept Energy are conveniently presented using tables similar to those used for Force (Tables 4.2.2.1 and 4.2.2.2.).

Energy-misconceptions have been reported by Stead (1980) and Watts (1983). Although they found similar misconceptions, two different systems were used to classify students' misconceptions. For the purpose of the present study, the system used by Stead (1980) was selected for the following reasons:

- i) the category system devised by Stead was self explanatory and also simpler than that used by Watts, and
- ii) the instances used by the researcher in this study were selected also from Stead, therefore, it was reasonable to apply the category system of the same researcher.

The results in Table 4.2.2.1. confirm that the energy misconceptions held by Pakistani students are closely similar to those found by Stead (1980). The obvious usefulness of the Stead's Category System devised in New Zealand for classifying results obtained in Pakistan confirms the similarity of children's misconceptions in both the countries.

The similarity of misconceptions is also confirmed by the nature of statements given by children in both the countries. Some typical statements of Pakistani and

New Zealand children are given in Columns II and IV of Table 4.2.2.1. respectively. Columns III and V present number and percentage of total statements in this category in Pakistan and New Zealand respectively.

The tables show that the majority of the statements of misconceptions of Pakistani children occur in categories E_1 and E_7 (See Table 4.2.2.1.) and misconceptions occurs widely in case of instances 1,2,4,7,11 and 12 as indicated by Table 4.2.2.2. These are some of the commonest categories reported by Stead (1980). Hence there is qualitative and quantitative evidence that children of approximately the same age living in widely different circumstances have very similar misconceptions about energy.

TABLE 4.2.2.1.

ENERGY

N = 20

Category Name and Code I		Typical Statement (Pakistan) II	No. & % of total statements in this category III	Statements in Stead's Study (NewZealand) IV	No. & % of total statements in this category V
Everyday Language	E ₁	"The rock has got no energy since it is a non-living thing". (Rock on Table)	30 (32.60)	"No because it moves the hands itself, it does n't need a human to move it". (Clock)	37 (32.20)
Human-Centred Viewpoint	E ₂	"Yes, it gets energy from man's foot". (Bicycle)	9 (9.78)	"Probably (the moon does use energy), it is just like us, if we want to run around the earth, we'd have to have energy to do it". (Moon)	10 (8.70)
Attribute human or living characteristics to inanimate objects.	E ₃	"Yes, water has got its own energy". (Waterfall)	7 (7.60)	"Yes (the jack's using energy) gravitational--the car wants to come down but the jack's holding it up". (Car on Jack)	7 (6.09)
Everyday use of the word energy.	E ₄	"Potential energy in the clock is being used up slowly". (Clock)	7 (7.60)	"Oh, it is used up as the car goes further along". (Car)	15 (13.04)
Energy as a concrete rather than abstract idea.	E ₅	"Yes, the bird has got energy which it gets from the food (worm) it eats". (Bird)	5 (5.43)	"The sun, the food, the sun makes energy come from--the plant gets energy from the sun, and we get the energy from the plant, from the sun". (Person on Stairs)	22 (19.13)
Conservation of Energy	E ₆	"Energy in the wax turns into heat and light after burning". (Candle)	4 (4.35)	"It's turned into heat and light". (Candle)	9 (7.82)
Confusion between physical phenomena	E ₇	"Yes, it has got energy of gravity". (Moon and Earth)	30 (32.60)	"Yes, (the moon's) using the earth's energy of gravity". (Moon and Earth)	15 (13.04)

Table: 4.2.2.2.

ENERGY

N = 20

Sr.No.	Instances	Categories						
		E ₁	E ₂	E ₃	E ₄	E ₅	E ₆	E ₇
1	Person on Stairs	2	-	-	1	1	-	6
2	Car	1	-	-	-	1	-	6
3	Weightlifter	3	-	-	-	-	-	2
4	Bird	1	2	-	-	1	-	4
5	Rock on Table	3	-	1	-	-	-	-
6	Candle	-	1	1	2	-	1	1
7	Bicycle	5	2	1	1	-	-	1
8	Clock	1	-	-	1	-	-	1
9	Car on Jack	2	-	1	-	-	-	-
10	Yacht	1	2	-	1	1	-	-
11	Waterfall	3	-	1	1	-	1	2
12	Moon & Earth	5	-	2	-	-	-	2
13	Television	-	-	-	-	-	2	5
14	Cow	3	2	-	-	1	-	-

4.2.3. LIGHT

Test results for Light are presented in Tables 4.2.3.1. and 4.2.3.2. The results of the present study were classified under the categories used by Stead and Osborne (1980).

The tables show that the area in which students most commonly hold diverse views is that of 'Reflection and Emission of Light' (Category L_1 in Table 4.2.3.1.), and it is clear from Table 4.2.3.2. that this category of misconceptions is found in case of each instance used in this investigation. The other category of misconceptions which are most commonly held is L_7 . This category is related to 'children's ideas about seeing the objects.'

The results show that misconceptions similar to that reported by Stead and Osborne (1980) are also found in Pakistani students. The similarity of misconceptions is confirmed by the nature of statements given in Columns II and IV of Pakistani and New Zealand children respectively in Table 4.2.3.1. Columns III and V of the same table present the number and percentage of similar statements in Pakistan and New Zealand respectively.

The qualitative and quantitative similarities in the two sets of results confirm that children living under different circumstances have very similar conceptions of Light within physical events.

The results also confirm that the modified research technique for Light (use of an assistant) is valid

and reliable. This is useful-- it means that this sort of study can be extended without need for very specialist manpower, it seems that this work (of studying pupils) can be done at second level of professional expertise i.e. by trained (non-specialist) manpower. It opens the possibility of involving trained teachers in the assessment of the misconceptions of their own pupils.

TABLE 4.2.3.1.

LIGHT

N = 30

Category Name and Code		Typical Statement (Pakistan)	No. & % of total statements in this category	Statements in Stead and Osborne's Study (NewZealand)	No. & % of total statements in this category.
I		II	III	IV	V
Ideas about Reflection and Emission of Light.	L ₁	"No, it reflects light from the match stick". (Candle)	42 (40.78)	"No, it just reflects light from the sun". (Moon)	15 (13.76)
Ego-Centric and Human Centred Viewpoint.	L ₂	"Yes, you can see people moving on the screen, without light, you couldn't see them". (Television)	6 (5.83)	"Yes, you can see the screen. It lights up so you can see what's on it". (Television)	9 (8.26)
If you can't see it in the dark, it does not make light.	L ₃	"No, you can't see it in the dark, because it does not rise in the dark, it is not there". (Sun)	11 (10.68)	"If you take the painting into the dark--it won't make light". (Painting)	7 (6.42)
Everyday Language	L ₄	"It reflects light which it gets from the glowing object". (Painting)	4 (3.88)	"No, it glows--it's light in itself but it doesn't make light on earth". (Moon)	14 (12.84)
Common Sense Answers	L ₅	"It does not emit light, because it gets changed into colours". (Rainbow)	11 (10.68)	"Yes, because it's got heat". (Candle)	4 (3.67)
Ideas about the distance light travels	L ₆	"If the candle is very large, then its light can go far, but if it is small it will stay near". (Candle)	11 (10.68)	"It stays on the heater". (Heater)	18 (16.51)
Ideas about seeing the objects	L ₇	"You can see it with your eyes, if it is burning". (Candle)	18 (17.46)	"He can see it with his eyes". (Television)	42 (38.53)

Table: 4.2.3.2.

LIGHT

N = 30

Sr.No.	Instances	Categories						
		L ₁	L ₂	L ₃	L ₄	L ₅	L ₆	L ₇
1	A Candle	8	-	-	-	-	2	2
2	The Sun	5	-	6	-	1	1	1
3	The Moon	3	-	4	-	1	-	-
4	A Torch	7	-	-	-	-	2	-
5	An Electric Heater	3	-	1	-	1	2	1
6	Television	5	1	-	-	2	1	2
7	Bright Red Painting	2	2	-	1	-	1	4
8	Mirror	4	1	-	1	2	-	4
9	A Movie Screen	2	1	-	1	2	2	2
10	A Rainbow	3	1	-	1	2	-	2

4.2.4. WORK

Osborne and Gilbert (1979) who investigated this concept chose to present their results other than by categories. Data were presented by these researchers according to instances. To preserve the pattern of presentation adopted for the concepts Force, Energy, and Light, categories were derived from the Osborne and Gilbert study. These categories were used to group the responses of the Pakistani students and the statements of misconceptions obtained by Osborne and Gilbert. The results are given in Tables 4.2.4.1. and 4.2.4.2.

Categories were derived from Osborne and Gilbert's data without making any change or modifications in the statements of misconceptions presented by them. After a thorough study of the statements, the commonest statements of misconceptions in the data were termed as categories and data was organised under these categories as shown in Table 4.2.4.1. The only difference in the presentation was that Osborne & Gilbert made an instance-wise presentation, whilst the researcher organised the same data according to categories.

The results obtained in Lahore are in complete agreement with the Osborne and Gilbert study. This agreement is evident from the similarity in the nature of statements of misconceptions given by Pakistani and British children. These statements are given in Columns II and IV of the Table 4.2.4.1. The number and percentage of

similar statements of Pakistani and British children are given in Columns III and V of the same table respectively. In this table all the derived categories of misconceptions are present and those most commonly used are W_1 , W_5 , W_7 , and W_2 . Table 4.2.4.2. shows that statements occur mostly under instances 2,9 and 11.

These results demonstrate two things:

1. Children living in different parts of the world hold similar misconceptions, and
2. The data presented by one group of researchers under one system can be presented successfully by another researcher under a different system.

TABLE 4.2.4.1

WORK

N = 20

Category Name and Code		Typical Statement: (Pakistan)	No. & % of total statements in this category	Statements in Osborne and Gilbert's Study. (U.K.)	No. & % of total statements in this category.
I		II	III	IV	V
Everyday Usage	V ₁	"Yes, because studying is working". (Doctor)	21 (25.00)	"Yes, because he is trying his hardest to study a medical report". (Doctor)	15 (39.47)
Work done in terms of exertion applied by the person.	V ₂	"Yes, man is using his strength to go up". (Person on Stairs)	12 (14.29)	"Yes, because he is trying to get it moving and once he has got it going it would be easier". (Car I)	3 (8.00)
Work done if no person is involved.	V ₃	"Yes, work is done by the machinery". (Coal)	6 (7.14)	"Yes, work is done because there will be a motor doing the work". (Coal)	4 (11.00)
Work done when no one was present	V ₄	"Yes, flame produces heat, and heating is working". (Steel Block)	7 (8.33)	"Yes, because the flame is going something to the block". (Steel Block)	3 (8.00)
Nature could not do work	V ₅	"No work is being done, because the block is moving of its own". (Wooden Block on Ice)	13 (15.48)	"No, because it simply slides down". (Wooden Block on Ice slope)	3 (8.00)
Difficulty in isolating a force doing work	V ₆	"Yes, work is being done due to potential energy". (Steel Ball)	12 (14.29)	"Yes, it is gaining potential energy as it moves up--there is no force as such on it as it is moving at a constant velocity...." (Coal)	4 (11.00)
Relationship between work and movement	V ₇	"Yes, work is being done because it is moving". (Trolley)	13 (15.48)	"Well, he would be doing more work if it was moving up". (Weight Lifter)	6 (16.00)

Table: 4.2.4.2.

WORK N = 20

Sr.No.	Instances	Categories						
		W ₁	W ₂	W ₃	W ₄	W ₅	W ₆	W ₇
1	Weightlifter	4	-	-	-	-	-	1
2	Doctor	9	-	-	-	-	-	-
3	Man and Girl	5	-	-	-	-	-	-
4	Car I	-	4	-	-	-	-	-
5	Car II	-	4	-	-	-	-	-
6	Car III	-	3	-	-	-	-	-
7	Coal	-	-	3	-	-	-	-
8	Steel Block	-	-	-	4	-	-	-
9	Steel Ball	-	-	-	-	4	3	1
10	Wooden Block on ice	-	-	-	-	1	-	2
11	Wooden Block on ice slope	-	-	-	-	2	3	1
12	Wooden Block on Concrete Path	-	-	-	-	1	-	1
13	Trolley	-	-	-	-	1	1	1
14	Escalator	1	-	2	-	-	-	1
15	Ball rolling down slope	-	-	-	-	1	2	2
16	Person on Stairs	2	1	-	-	-	-	1
17	Halley's Comet	-	-	-	-	1	1	-
18	Pendulum	-	-	1	-	-	2	1
19	Roller Coasters	-	-	-	2	2	-	1
20	Yacht	-	-	-	1	-	-	-

4.2.5. ELECTRIC CURRENT

Osborne and Gilbert (1979) who investigated this concept chose, as in the case of Work, to present their results other than by categories. However, as before, the researcher derived categories of misconceptions in Electric Current from the Osborne and Gilbert study and used these to group the responses of the Pakistani students. It is stressed that as before, no changes to original statements were made in the course of this reorganisation of the data. The results from both the studies are given in Tables 4.2.5.1. and 4.2.5.2.

Again it is clear that the results from the two studies are in complete agreement both qualitatively and quantitatively. This agreement is evident from the nature of statements of misconceptions given by Pakistani and British children, (these statements are given in the Columns II and IV of the Table 4.2.5.1.) and the number and percentages of similar statements of misconceptions of Pakistani and British children (presented in Columns III and V of the same Table respectively). In this table, all the derived categories are present and the most commonly used are EC_1 and EC_2 . Table 4.2.5.2. shows that misconceptions under category EC_1 are found in all the instances except 5, 10, 12, and 13, and instance 1 contains more of the statements of misconceptions as compared to other instances used in the investigation.

These results also demonstrate that:

- i. children living in different circumstances hold similar conceptions of the physical phenomenon, and
- ii. the change in the style of presentation i.e. into categories is reliable.

TABLE 4.2.5.1.

ELECTRIC CURRENT

N = 20

Category Name and Code		Typical Statement (Pakistan)	No. & % of total Statements in this category	Statements in Osborne & Gilbert's Study (U.K.)	No. & % of total Statements in this category
I		II	III	IV	V
Common Sense	EC ₁	"There is no current, but, if you put a bulb, then there will be current in the wires". (Bare Wires)	29 (41.43)	"No, (There is no current) it has to have the lamp connected". (Bare Wires)	28 (32.55)
Everyday Situation	EC ₂	"Yes, there is electric current... because, battery is charged... if you put it in the car, the car will start". (Battery I)	19 (27.14)	"Yes, if it has not all been used up". (Battery I)	27 (31.39)
Confusion about the flow of electric current in a circuit.	EC ₃	"There is electric current in one of the wires". (Bare Wires)	4 (5.71)	"Yes, but the electric current would not be doing anything useful ...the electric current would flow up to the ends of the wires...but there would not be any electric current coming out...it would flow around in the wires...perhaps back again". (Bare Wires)	13 (15.11)
Relationship between the switch and the electric current.	EC ₄	"Electrons come from the switch, when it is turned on". (Lamp II)	7 (10.00)	"It goes into the lamp and then comes out and around to where the switch is". (Lamp I)	3 (3.48)
Electric current is used up	EC ₅	"It is used up in producing light". (Lamp I)	4 (5.71)	"Electric current goes into the bulb and shines up". (Lamp I)	11 (12.79)
Difficulty in defining the electric current.	EC ₆	"Something which makes the bulb glow and flows through wires". (Definition)	7 (10.00)	"Light is electromagnetic waves and electric current is a flow of electrons therefore, light must be a flow of electrons". (Definition)	4 (4.65)

Table: 4.2.5.2.

ELECTRIC CURRENT

N = 20

Sr.No.	Instances	Categories					
		EC ₁	EC ₂	EC ₃	EC ₄	EC ₅	EC ₆
1	Battery I	7	5	-	-	-	-
2	Battery II	4	1	-	-	-	-
3	Bare Wires	2	-	3	2	-	-
4	Neon Lamp	3	2	-	1	-	-
5	Lamp I	-	-	-	-	3	-
6	Sun	1	3	-	1	-	-
7	Lightning	3	2	-	-	-	-
8	Person	2	-	-	-	-	-
9	Compass	2	3	-	1	-	-
10	Liquid	-	-	1	-	-	-
11	Torch	2	-	-	-	-	-
12	Fence	-	-	-	1	-	-
13	Definition	-	-	-	-	-	7
14	Lamp II	1	2	-	1	1	-
15	Path of Electron	1	-	-	-	-	-
16	Model	1	1	-	-	-	-

4.3. SUMMARY (STUDENTS)

The results of investigations of Force, Energy, Light, Work, and Electric Current show a strong agreement that misconceptions are held by the majority of the children. These results also show that Pakistani students hold misconceptions similar to those held by children in other parts of the world. The similarity of results is evident from the qualitative aspect of the statements given by students in these studies. This similarity is based on qualitative data because of the nature of the cards. Each set of cards was intended to elicit information about specific misconceptions held by pupils in Europe, New Zealand, etc. When used in Pakistan, the students responded with the same misconceptions. The similarity of results is also evident from the quantitative aspect, because of frequencies of misconceptions in different countries.

On the basis of these results it can be said that the phenomena of misconceptions do not seem to be unique to any one country or culture, rather it seems that it is a universal phenomenon and children in every culture seem to think in the same fashion with a similar understanding of the physical phenomena. On the basis of this evidence, culture or social background does not seem to be a primary variable among the influences affecting the way children understand these phenomena.

These investigations not only support the results of other studies in the relevant areas, but the results of

these investigations also show that the technique, i.e. the IAI approach which was used in Urdu and by different interviewers in Pakistan, can be applied successfully, and it is no doubt an effective technique to explore children's misconceptions irrespective of their culture and of the fine details of presentation. The general agreement between the results (for each separate concept) in different countries and the similarities across different concepts also provide strong evidence for the validity of the study and hence of the research methodology. In particular because the results for Light match so closely to results for other concepts, the use of a trained assistant staff is justified. Further, the results offer evidence that children's misconceptions appear equally strongly when presented in different forms; thus they are not an artifact of a data analysis technique.

4.4. METHODOLOGY FOR TESTING OF TEACHERS

After confirming the students' misconceptions, it is now interesting to seek an explanation of or the sources of these misconceptions. As described earlier in Chapter III both the science teachers and the text-books have been suggested as possible sources of children's misconceptions. Keeping in view the key role of the teacher in the educational system in general, and his role in the classroom teaching, curriculum planning, and text-book writing the present study sought additional information about the teacher's role in determining pupils'

misconceptions.

4.4.1. SAMPLES

Three groups of secondary school teachers were selected; each group contained both male and female subjects, a majority held M.Ed. degrees. Group I teachers (N = 29) were the participants of a workshop which was held in April 1983 at the Institute of Education and Research, University of the Punjab, Lahore. Group II teachers (N = 19) were the students of the new class of M.Ed. programme at the Institute whilst Group III teachers (N = 26) were the outgoing students of M.Ed. programme of the session 1982-83 also at the same Institute. The three groups were equivalent in that

- i. all the subjects in each group were trained science teachers, and
- ii. all of them were holders of B.Sc. and B.Ed. degrees.

All the three groups were tested on the concept Force but prior to the tests different teaching sessions were given to the three groups. Each group was given one lecture. The duration of each lecture was one hour. Group I teachers were told nothing about the research nor

M.Ed. is a post-graduate degree in Education offered to trained in-service teachers.

about children's misconceptions. Group II teachers were told about the research and children's misconceptions in Light. The teachers of Group III were told about the research, and children's misconceptions in Light and children's misconceptions in Force. To enable others to replicate this portion of the research, a synopsis of the talks given to the three groups is given in Appendix C. The table 4.4.1. summarises the information held by the three groups.

TABLE: 4.4.1.

Groups	N	Test Subject	Group information concerning children's misconceptions and research studies *		
			Generally	In Light	In Force
I	29	Force	No	No	No
II	19	Force	Yes	Yes	No
III	26	Force	Yes	Yes	Yes

* Post lecture and pre-test in Force misconceptions.

4.4.2. INSTRUMENT USED

Keeping in view some difficulties in interviewing the groups of teachers, it was decided not to use the IAI method for this part of research. The main difficulties were:

1. The study groups consisted of experienced teachers and many of them were well-known to the researcher. Due to this reason it was felt that it would be difficult to establish dialogue and elicit information properly.
2. Some of the teachers in all three groups came from far off places. Particularly, the teachers of group I and group III were available at the Institute only for a limited time. It was therefore, difficult to retain them any more for interviewing nor was it possible for the interviewer to travel to their home-districts.
3. Interview is a time-consuming method of eliciting information, therefore, it was difficult to interview so many teachers particularly within a limited period of time.

Because of these difficulties in using the IAI method, it was decided to use a paper-and-pencil instrument for this study. The questionnaire on Force used by Zylbersztajn and Watts (1980) was chosen as the instrument. (The merits of using an existing, tested, instrument have been discussed in Section 4.1.). The questionnaire consists

of 12 multiple choice questions with a short space left for the respondents to explain the reasons for their answers. The free responses allowed, resulted in a degree of open-endedness in the character of the data. The openness of the response format helped to off-set the "test" nature of the questionnaire.

Zylbersztajn and Watts designed two types of cards for this questionnaire - "Description Cards" in which the basic drawings are repeated, showing arrows representing, in each alternative, different directions or magnitudes of forces acting in the situation. Each of the question cards presents, besides the "scientifically correct" alternative, at least one inspired by an alternative pupil framework found by researchers.

In this questionnaire, description cards 1 (question cards 1,2,3) and 2 (question cards 4,5,6) were designed by Zylbersztajn and Watts to survey the association between force and motion; description card 3 (question cards 7,8) the idea of unequal action and reaction pairs with one overcoming the other in the direction of motion; description cards 4 (question card 9) and 5 (question card 10) the idea that heaviness increases when something is raised up; description card 6 (question card 11) the conception that there is no gravity in space, and description card 7 (question card 12) the idea that a greater force acts on a torch when it is switched on.

The questionnaire was used in English in the same pattern as given in the Appendix D. / Because English

version was used, no prior testing was undertaken. Informal discussion with the teachers after the test confirmed they had no language-problems of understanding the questions.

4.5. RESULTS (TEACHERS)

The results were analysed in two parts, in quantitative form in Part I and, in Part II, in qualitative form. Table 4.5.1. gives the percentages of incorrect responses to each question by the teachers of each of the 3 groups. The figures in this table show that the majority of the teachers in each group responded incorrectly to the majority of the questions. The means of the incorrect responses of all these groups show that the three groups of teachers performed almost equally (badly) on the test. This was confirmed by a t-test on the means.

Table 4.5.2. shows the results of applying the t-test to pairs of experimental groups. The test shows that all the groups have essentially the same level of factual knowledge and hence (presumably) the same level of misconceptions. These results show that there is no difference among the groups of teachers as far as their performance on the Force-test is concerned.

This result leads^{us} to conclude that the effect of the limited information given to the teachers in the one hour pre-test lecture was not significant.

Next, responses given to each question were grouped to indicate the misconceptions held by the teachers. The analysis was carried out using the categories of Zylbersztajn and Watts and given on page 181. It was interesting to note during the analysis that the same misconceptions as reported by Zylbersztajn and Watts (1980) for students are present in the statements of the majority of the teachers. Table 4.5.3. presents the number and percentage of these statements given by teachers in response to each question.

The analysis of these statements as presented in the tables also makes evident that teachers hold misconceptions similar to those held by the students in Pakistan. Although, different testing techniques were used, still similar results were obtained. As the results of students and teachers on the tests in Force are very close to each other, the system used to classify students' results (See Section 4.2.1) was also used to present the teachers' results. Table 4.5.4. presents results under this system. Statements of Pakistani teachers in Column II and that of British students in Column IV in this table indicate that misconceptions among teachers are similar to those of both Pakistani and British students. To show that teachers and students in Pakistan hold similar misconceptions, Table 4.5.5. compares the statements of misconceptions of Pakistani teachers and students. Columns II and IV present typical statements of misconceptions of Pakistani Teachers

and students respectively. Columns II and V of the same table present number and percentage of similar statements in each category. No statement was found under the category 'Everyday Language'. This might be due to the difference in the testing techniques, because the tests of students and teachers used different instances; or more likely it may be due to the more sophisticated language available to the older teachers who will be accustomed to using technical terms in their everyday teaching work.

Table: 4.5.1.

INCORRECT RESPONSES OF TEACHERS IN DIFFERENT GROUPS(INPERCENT)

Questions	Group I N = 29	Group II N = 19	Group III N = 26
1	79.3	89.5	84.6
2	51.7	57.9	57.6
3	13.7	5.3	3.8
4	75.8	89.4	84.6
5	51.7	73.7	53.8
6	51.7	68.5	53.7
7	82.7	47.4	65.4
8	55.2	42.1	65.4
9	58.6	63.1	73.1
10	75.9	78.9	73.1
11	51.7	42.1	23.0
12	34.4	31.6	38.4
Mean	56.86	57.45	56.37

Table: 4.5.2.

T- tests of factual knowledge scores of groups.

Groups Compared	Basic data of Groups		df t-value Significance level
	N	\bar{X}	
III	26	5.15	53 0.27
I	29	4.76	
III	26	5.15	43 0.47
II	19	4.05	
II	19	4.05	46 0.49
I	29	4.76	

Table: 4.5.3.

Summary of teachers' responses

FORCE (TEACHERS)

N = 74 (all groups)

Category of Misconceptions	Description Card	Question Card	No. of statements and % of teachers giving such statements containing misconceptions
"If a body is moving there is a net force acting upon it in the direction of the movement. If a body is not moving there is no net force acting upon it."	1	1	52 (70.27)
		2	35 (47.29)
		3	60 (81.08)
	2	4	38 (51.35)
		5	31 (41.89)
		6	42 (56.76)
"If two bodies interact generating a state of movement one of these must be exerting a greater force upon the other."	3	7	43 (58.11)
		8	47 (63.51)
"Heaviness increases when something is raised up."	4	9	37 (50.00)
	5	10	61 (82.43)
"There is no gravity in space."	6	11	38 (51.35)
"A greater force acts on a torch when it is switched on."	7	12	39 (52.70)

TABLE: 4.5.4.

FORCE (TEACHERS) N = 74 (All Groups)

Category Name and Code I		Typical Statements of Pakistani Teachers II	No. of similar statements in this category III	Statements of students in Zylbersztajn and Watt's Study. (U.K.) IV
Everyday Language	F ₁	-	-	-
Human-Centred Viewpoint	F ₂	"Because the ball is thrown straight up in the air, so the direction of the ball will be upwards". (Question 1)	21	"I think that the force is upwards because the person is throwing the ball up and putting all the force underneath the ball to move it up". (Question 1)
Something that can't be observed or felt by humans (or animals) does not exist.	F ₃	"The person on the left has applied more force..... (no other force)". (Question 7)	31	"Because the size of the force from the person on the left is greater than from the person on the right". (Question 7)
Endowing objects with human or animal characteristics.	F ₄	"The cannon ball wants to go straight but due to the centripetal force, it goes lightly down and use curve path". (Question 4)	15	"Because it shows that the ball has to travel forwards to reach the next point". (Question 4)
The abstract idea being treated as if it has material existence; the force is somehow embedded in the moving object.	F ₅	"Person's hand applied the force on the stone. Under this force stone is going upward in the air". (Question 1)	17	"The force comes from the person's hand throwing it upwards. Forcing the ball up". (Question 1)
Incorrect use of Scientific Terms.	F ₆	"The torch which is lit, there is more force of electricity which is acting on it". (Question 12)	11	"A torch which is lit needs more force than a torch which is not lit because it needs power to light". (Question 12)
Self-Contradictory Views	F ₇	"There will be no force on the spanner, but the spanner will move downward due to force of gravity".(Question 11)	5	"....Because if the man is on the moon the gravity will pull the spanner up". (Question 11)
There is no gravity on the moon.	F ₈	"There is no gravitational force on the moon, so the spanner is at the same position". (Question 11)	11	"Because there is no gravity on the moon, there is no force to pull it towards the ground". (Question 11)

TABLE 4.5.5.

FORCE (TEACHERS)

N = 74 (All Groups)

Category Name and Code		Typical Statements of Pakistani Teachers	No. & % of total statements in this category	Typical Statements of Pakistani Students	No. & % of total statements in this category.
I		II	III	IV	V
Everyday Language	F ₁	-	-	"Yes, he is forcing him to move." (Police)	3 (4.3)
Human-Centred Viewpoint	F ₂	"Because the ball is thrown straight up in the air, so the direction of the ball will be upwards." (Question 1)	21 (18.9)	"No, there is no force on the car." (Car I)	14 (20.00)
Something that can't be observed or felt by humans (or animals) does not exist.	F ₃	"The person on the left has applied more force (no other force)". (Question 7)	31 (27.9)	"No force is acting on the bicycle". (Bicycle)	7 (10.00)
Endowing objects with human or animal characteristics.	F ₄	"The cannon ball wants to go straight but due to the centripetal force, it goes lightly down and use curve path". (Question 4)	15 (13.5)	"No, it is moving of its own". (Bicycle)	5 (7.14)
The abstract idea being treated as if it had material existence; the force is somehow embedded in the moving object.	F ₅	"Person's hand applied the force on the stone. Under this force stone is going upward in the air". (Question 1)	17 (15.3)	"Yes, the ball went up because, there is force of man's hit". (Cricket I)	17 (24.30)
Incorrect use of Scientific Terms.	F ₆	"The torch which is lit, there is more force of electricity which is acting on it". (Question 12)	11 (9.9)	"Yes, there is force of the inclined plane". (Ball II)	13 (18.6)
Self-Contradictory Views	F ₇	"There will be no force on the spanner, but the spanner will move downward due to force of gravity."(Question 11)	5 (4.5)	"As the man is sitting on the cushion, there is force of weight (not gravity)". (Cushion)	7 (10.00)
There is no gravity on the moon.	F ₈	"There is no gravitational force on the moon, so the spanner is at the same position". (Question 11)	11 (9.9)	"No, there is no force on the moon." (Moon)	5 (5.71)

4.6. SUMMARY (TEACHERS)

The results of the investigations of teachers' misconceptions show that teachers in Pakistan hold misconceptions similar to those reported by researchers in other countries (Zylbersztajn and Watts, 1980). The Pakistani teachers hold misconceptions similar to those held by Pakistani students. These findings support the validity of these studies. Previous researches have drawn attention to the importance of books and teachers in forming children's conceptions in Science. It was also shown that the three groups of teachers performed almost equally on the test, although they had been given different levels of information about students' misconceptions.

4.7. SUMMARY AND DISCUSSION

The investigation of children's misconceptions in the concepts of Force, Energy, Light, Work and Electric Current shows that Pakistani students hold misconceptions similar to those held by children in other parts of the world. The investigation of teachers' misconceptions in the concept of Force shows that Pakistani teachers hold misconceptions similar to those held by Class 8 students in Pakistan.

The results of these investigations are also supported by two other research studies conducted in Pakistan - one on pupils and the other on teachers. Both the studies were conducted to explore misconceptions in

Force using the same questionnaire (Zylbersztajn and Watts, 1980). The study on pupils by Bushra Pargeen (1984) shows that pupils of all ages in the sample hold similar misconceptions. The study on teachers by Saira Saeed and Waqar-Un-Nisa (1984) shows that science teachers and teacher-trainees hold similar misconceptions in Pakistan. The results of both these studies also indicate that there is no significant difference in the kind of misconceptions held by students and experienced teachers.

The similarity of misconceptions held by children in different countries as reported here and elsewhere indicates that the formation of misconceptions appears to be a universal and culture free phenomenon. This viewpoint is taken also by Billeh and Pella (1970) who compared the achievement of American and Jordanian pupils in grades 3-6 on various tests. The results of their study indicated that neither group was consistently superior to the other, indicating that culture did not appear to be an over-riding factor in concept learning. The study by Mali and Howe (1979) in Nepal and a study by Rubina Asmat and Kausar Jabeen (1984) in Pakistan yielded similar results; children in both countries had similar views about ^{the} Earth and Gravity. Again, studies on children's conceptions of the changes of states of water by Osborne & Cosgrove (1983) in New Zealand and by Farhat Shaheen and Riffat Shaheen (1984) in Pakistan show similarity of ideas. A wider Piagetian study by Karplus et al (1975) showed that a large percentage of secondary-age children in each of seven sample countries

did not have an operationally efficient grasp of proportional reasoning and control of variables.

Osborne, Bell and Gilbert (1983) argue that the similarity in the children's views is perhaps not so surprising, because as pointed out by Vicentini-Messori (1980):

'Many experiences are shared among all the people of the world: living in a three dimensional space with a vertical privileged direction, immersed in air and standing on a land where different species of plants grow, different kinds of animals live, the sun shines and warms, rises and sets with a quasiperiodical rhythm, the wind blows and rain falls, there are things that are "continuous", like water, and things that are "discrete," like sand and people, experiences of similarities and differences, the experience of the passing of time scanned by the periods of stars but also by birth and death of living beings, (cyclic returns and irreversibility together), by the need to breathe, to eat, by alternating warm and cold periods, the feeling of a "time" which perceptually is essentially "present" with the possibility of remembering and learning from the "past" and of projecting experiences and acquisitions into the "future."

The present study of teachers also leads to another very important result. It appears likely that simply telling teachers of children's misconceptions does not affect the teachers' performance on a test of their own misconceptions. It seems that this level of information is not sufficient to make the teachers cautious of their own misconceptions. It can be further deduced that if mature teachers cannot/ do not change their conceptions easily, the same will be true of pupils. Telling pupils or teachers that the 'old' is wrong and the 'new' is correct

will not be sufficient. These results suggest that a more substantial programme of teacher training will be required to enable the teachers to modify their own misconceptions as the first step in helping them to achieve better student concept-understanding.

CHAPTER V

STUDY 2

TEACHER TRAINING AND RE-TESTING OF STUDENTS

CHAPTER V

STUDY 2

TEACHER TRAINING AND RE-TESTING OF STUDENTS

Studies carried out by the other workers described in Chapters II and III have shown that students and teachers in several parts of the world hold misconceptions about science phenomena. The experimental findings of Study 1 reported in the previous chapter establish that both students and teachers in Pakistan have similar misconceptions about certain physical science concepts.

This statement is both valid and reliable. The reliability of the measurements is shown first by the close similarity between results for the different concepts. The agreement between the results obtained by the principal researcher for the concepts Force, Energy, Work, Light, and Electric Current and the assistant researcher for Light argues strongly that the results are not simply a characteristic of one person's interpretation of students' and teachers' answers. The validity of the research, i.e. the extent to which the results of the study are determined by misconceptions rather than some extraneous factor (s), is confirmed by the extent to which Pakistan results fit into the world-wide pattern.

The central role played by teachers in determining students' learning has been stated earlier. Because of this powerful central role, and because the teachers as a group

held misconceptions in all the concepts studied, it was felt unlikely that minor changes of teaching patterns would lead to elimination of students' misconceptions. It was judged important to train teachers to deal with misconceptions in the concept areas. Therefore, a special programme was planned to train teachers to deal specially with the problem of student misconceptions in chosen concept areas.

It was a brief programme in which only a small number of teachers was involved. A brief programme was deliberately chosen for two reasons. First, for the sake of general economy, a long programme should not be used if a short one will suffice. Second, because science teacher training time is short, a module devoted to this topic has to be short if it is to be located in the teacher training course. If the brief programme is successful in bringing positive changes in students' misconceptions, it is intended to be incorporated as a complete 'module' in a project to be set up for the purpose of improvement of science education in Pakistan.

This chapter describes the content and methodology of the brief teacher training programme designed to alert teachers to problems of students' misconceptions. The chapter describes how after training sessions, the teachers retaught selected topics in their schools and how the retaught students were again tested using both the IAI and the paper-and-pencil methods.

5.1. THE EXPERIMENTAL WORKSHOP

For the purpose of testing the teacher training* module, a workshop was planned for 2 teachers of the 8th class sample students. The module content and methodology were aimed at enabling the two teachers to remove misconceptions of the students in the concepts of Force, Energy, and Light. The hypothesis formulated for this part of the study (Stage 2) was that after receiving the specially designed training, teachers would be able to reduce the level of misconceptions of their students.

The workshop was held at the Science Education Centre of the Institute of Education and Research, University of the Punjab, Lahore in the last week of April 1984. Because the teachers could not spare one full day for the workshop, it was held on three consecutive days from 9.00 a.m. -- 11.00 a.m. each day. A synopsis of the workshop programme and the description of the materials used are given in Appendix G.

In the first session (two hours) the participants were introduced to current research work in science education in general and research on concept understanding in particular. They were told about the techniques being used to explore children's understanding of concepts. Later, the IAI approach was explained in detail and the way it was being used for the purpose of the present study was described. The methodology and purpose of the present study

* Teacher Education in Pakistan is described in Appendices E & F.

were also explained.

Participants were informed of the significant results of the student interviews. Each instance of each concept and students' responses were shown to the participants. They were encouraged to discuss the examples and to ask questions in order to clarify their own understanding of the research and of the concepts. In asking these questions teachers could correct some of their own misconceptions of the concepts. At the end of this session, the teachers would know about the purpose of the research, know students' particular misconceptions in the concepts and, possibly, have corrected some of their own misconceptions.

On the second day of the workshop, the participants were told the methodology of testing the teachers and the results obtained in Stage 1. As on the previous day, the teachers were encouraged to discuss and ask questions about all features of this phase of the study. There was a second chance to discuss the science concepts at the end of the second session.

On the third day of the workshop, the results of the present study were linked to Ausubel's theory of learning; both 'meaningful' learning and 'rote' learning were discussed. After that, outcomes of interactions of students' and teachers' ideas were discussed from Gilbert et al (1982). It was then linked to an example of a lesson (James, 1983) in order to show how a wrongly planned lesson taught by teachers who themselves have misconceptions, can make pupils' misconceptions worse.

Then, an exercise was given so that participants could practise the diagnosis of children's misconceptions. This exercise was adapted from Nussbaum* (1980, 1981). In this exercise teachers learnt to look for a (correct) explanation and not simply long "interesting" accounts. Afterwards, for the purpose of generating discussion, and as a further exercise, worksheets which were adapted from LISP (Schollum et al 1981; Osborne, 1981) were used. From these exercises, the teachers learnt to explore the range of views they and their pupils hold about the related concepts. Participants' responses and ideas were then discussed. After this, the group of teacher-students and the researcher discussed examples showing differences between children's ideas and scientists' ideas of 'force'. This study was based on LISP material (Osborne, et al, 1981). Finally, to close the workshop sessions, a summary of ideas discussed during the three day workshop was presented.

The teachers were requested to re-teach their class 8 students the concepts of Force, Energy, and Light spending at least two 40 minute lessons on each concept. The teachers were also told that after their teaching, the students would be re-tested by the IAI approach and by written paper-and-pencil tests; the tests would be administered by a person not from the school. Teachers knew of the IAI approach as it was discussed in the workshop, but they were not told the content or format of the other test. In particular, they were not aware of the questions that would be posed to the students. This was thought necessary

* A photo-reduced 'diagram' of Nussbaum materials is given on page 193.

The following question is taken from a physics test given to fourteen year-old pupils. Two individual answers are cited.

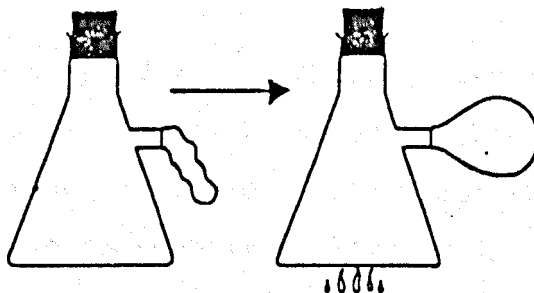


Figure 1

Question : In a certain experiment a flask full of air had a deflated balloon attached to a side pipe coming out of the flask. As the flask was heated by a flame the balloon inflated (see figure 1).

Explain this phenomenon using the particle theory.

Answer A: There is air in the bottle which fills it and also fills some of the balloon which is not blown up. If someone places the bottle with the molecules of the air above the flame then it becomes hot in the bottle and the air expands. The molecules move from the bottle to the balloon and this makes the balloon blow up.

Task 1 : Write a short evaluation of answer A and insert an appropriate numerical grade (out of 10 points) in the box

Answer B: There is air in the bottle which fills it and also fills some of the balloon which is not blown up. Scientists discovered that the air which is in the bottle contains very small particles which are very great in number. These small particles, which they also found to be like tiny balls, can move and reach every place in the air of the bottle. Scientists called these particles molecules. If someone places the bottle with the molecules of the air above the flame, then it becomes hot in the bottle and the air expands and blows up the balloon. This happens because of the law which says that things expand when they are heated and also because when it becomes hot in the bottle then the very tiny molecules tend to go away from the hot place and so they move from the bottle to the balloon and this makes it blown up. If someone would like to see what would happen if the bottle were cooled down, he would find that the balloon would shrink again because of the law which says that things shrink when they are cooled. But with water it does not happen so since when water is cooled below 4°C then, amazingly enough, it would expand. This is what they call the anomaly of water.

Task 2 : Write a short evaluation of answer B and insert an appropriate numerical grade (out of 10 points) in the box

As a teacher, which of the two answers (the short one or the long one) would you prefer to receive from your students?

.....Explain why.....

to avoid any kind of reflection by the teachers about the test information during teaching.

5.2. SAMPLES

The sample of the study consisted of students of 8th class of the University Laboratory School who had already left the school after taking their final examination. Because of unrest in schools earlier in the year, the workshop had to be organised hurriedly at a time when the sample students had left the school. So, the main difficulty involved was to recall the students, re-teach the concepts, and re-test them.

Fortunately, the teachers who had participated in the workshop had very good rapport with the students and their parents, and were able to approach them through correspondence and personal contact at their new schools. As a result of the teachers' considerable efforts, about 20 students from the total strength of 40 in that class were finally contacted. The students agreed to report at the Institute three days before the teaching started.

5.3. STUDENT TEACHING BY THE TRAINED TEACHERS

When the students reported at the Institute, one of their teachers had a talk with them in a classroom and the purpose of inviting them was also explained. All the students who reported readily agreed to attend the teaching

programme. During this orientation session, a schedule was also settled between the students and their teachers. This was necessary, because students had to come to the Institute after their school hours (and sometimes between the school hours) to attend the teaching programme.

The teaching was done during one week (6 days) starting on Saturday and ending on Thursday. On each day, teaching lasted for about 40 minutes. Three concepts Force, Energy, and Light were taught again by the teachers. In order to keep uniformity of content to be covered under each concept, a summary sheet listing the sub-concepts of Force, Energy, and Light was developed after consulting the Pakistan Elementary Science Curriculum reports for classes I - V (1973) and VI - VIII (1974). A copy of this summary sheet is given in Appendix H. This summary sheet was given to the teachers for their guidance. Although the content of the lessons was suggested by the summary sheet, teachers were completely free to choose their own teaching approach and exemplars. At the same time, they were also reminded that the main aim of the whole activity was to remove the misconceptions of the children as had been discussed in the workshop.

The researcher visited the classrooms where the teaching was going on, but only for a very short period for the purpose of ensuring that no organisational problems interfered with the teaching. The intention was to avoid interruptions and to create a free atmosphere for teacher-student discussions. Teachers were encouraged to discuss

their lesson plans and students' reactions with the researcher before and after the class. These discussions were held approximately for half an hour daily.

After this one week of teaching, the students were tested using a written test on the next working day. Only 18 students were allowed to take the test; the other two students had failed to attend the teaching programme regularly. On this occasion, only the written tests on Force, Energy, and Light were taken. These were multiple-choice tests developed separately to test these concepts. Each test consisted of 10 items. The tests are given in Appendices I & J. Some other information concerning these tests will be described in Chapter VI. The results of these tests will be presented later in this chapter.

The same students were tested using the IAI approach. The procedure adopted, and the problems faced by the researcher during this part of the study are described in the next section.

5.4. RETESTING OF STUDENTS USING IAI APPROACH

It will be recalled that the IAI approach requires a lengthy (30 mins. approx.) interview with each individual student. Shortly after the written tests were taken, the schools closed for the summer vacation. It was not possible to interview students before the vacation started because of the short time available and some other problems. During the vacation period, interviewing was not possible because

students dispersed to follow their own vacation programmes.

Just after the vacation, when schools re-opened in September, the students have to take examination. So, again, students were not available and could not spare time for interviews. However, immediately after the examinations were over, the researcher with the help of one of the teachers started searching for them either at their schools or at their homes in the evening. Very few students could be contacted on the first visit, for the rest, the researcher had to visit their schools and homes many times. Only three came to the Institute for interview.

By making many such visits, it was possible to interview all 18 students who had taken the paper-and-pencil tests. Interviews were conducted by the researcher himself as in the same manner as it was done for the Study 1 described in Chapter IV. Each student was interviewed in Force, Energy, and Light (in that order) on the same occasion. This was necessary because it was not feasible to meet the students three times. It took approximately one hour to interview each student on the three concepts. Interviews were audio-recorded using a separate tape for each student. Data for each concept were collated after transcription of the eighteen tapes.

5.5. RESULTS

The results of students obtained after using the IAI approach and paper-and-pencil tests have been presented in separate sections according to the concepts. It will be argued that these results show that misconceptions similar to those explored in the first investigation of students' misconceptions (Study 1 described in Chapter IV) persist after re-teaching the concepts Force, Energy and Light.

5.5.1. THE IAI RESULTS

As the misconceptions explored in this study were similar to that of students in Study 1, the analysis procedures and categories described in Chapter IV have been used for these data also. The results of Force, Energy, and Light obtained from the IAI interview tapes are presented (in that order) in the following sections.

5.5.1.1. FORCE

The results in the concepts area Force for Study 2 are presented in Tables 5.5.1.1. (a), 5.5.1.1. (b), 5.5.1.1. (c) and 5.5.1.1. (d). Table 5.5.1.1. (a) presents typical statements of students under each category of misconception. This table also presents the number and percentage of similar statements under each category. The table shows that the human-centred viewpoint is held by the majority of the students. Table 5.5.1.1. (b) presents the

number of statements under each category of misconception against each instance. Table 5.5.1.1. (c) presents typical statements of misconceptions of students of Study 1 and Study 2 for qualitative comparison. Finally, Table 5.5.1.1. (d) compares statistically the statements of misconceptions of students in Study 1 and Study 2.

The qualitative comparison of statements in Table 5.5.1.1. (c) shows that there is great similarity in the nature of statements given by students under each category of misconception. The only difference which was noticed in this concept area was that the students used different terminology in their statements. For example, the terms 'momentum', 'reaction', 'air friction', 'reaction due to gravity', and 'acceleration', were used by them indiscriminately.

If statements of category F_3 are selected from the Table 5.5.1.1. (c), students of Study 1 hold a view that "No force is acting on the bicycle" while it is slowing down. Whereas, students of Study 2 hold a view that "there is no force on the man" who sits in a satellite. Afterwards, the same students realise that "there is a force on the satellite, but no force on the man in the satellite." In both of these statements a common difficulty faced by the students seems to be that they are unable to identify the forces acting on an object; whether it is a bicycle or a satellite. The underlying difficulties facing the students both in Study 1 and 2 are that if they cannot observe or feel something; they do not realise its

existence. This problem leads students to hold many mistaken ideas, for example, in category F_5 , the students of Study 1 hold a view that after hitting the ball, "the ball went up because there is force of men's hit". Whereas, the students of Study 2 after re-teaching hold a view that "there is a force of the cricketer, air friction, and gravity." In this instance students were able to identify other forces, such as air friction and gravity, but in addition to that they have also wrongly identified "the force of the cricketer." Although slightly different words have been used by the students of both the studies, the main structures of their misconceptions remain the same. Students did use the technical vocabulary (e.g. gravity, air friction) which they heard during re-teaching, but they could not assimilate these new words. It seems that teachers had not conveyed the concepts in a meaningful way.

In fact, the new terminology did not change the main structures of the students' concepts which were previously held by them. But, the use of new terminology does indicate their maturity, because the mistakes were expressed by them more clearly. This result is in agreement with Sjoberg and Lie (1981), described earlier in Chapter III, wherein, they state that the use of new terminology in a naive fashion indicates that the only "development" which seems to occur is that they have the "tools" to express the views already developed earlier

For the statistical comparison of statements of misconceptions of students in Study 1 and Study 2, categories (see Table 5.5.1.1. (d)) which were less than 5 were added (and also recoded) to their adjacent categories. For example, F_1 and F_2 were recoded as F_{1+2} , and F_7 and F_8 as F_{7+8} after addition.

When the results for Force were compared using the Chi-Square test, the value of χ^2 obtained from these data was equal to 11.25 with $df = 5$ compared with a value 11.07 needed to reach the 0.05 level of significance. Thus the results show that the students of Study 1 and 2 gave significantly different responses ($P = 0.05$). Examination of the table shows the value of χ^2 is caused by reteaching the concept, because a large increase in the number of statements in Study 2 was found in case of the categories F_2 and F_6 .

TABLE 5.5.1.1.(a)

FORCE

N = 18

Category Name and Code		Typical Statement	No. and % of total statements in this category
Everyday Language	F ₁	"Yes, there are two forces, one is gravity and the other is that of the policeman who is forcing the man." (Police)	2 (1.72)
Human-Centred Viewpoint	F ₂	"There is no force, as he is just sitting on it." (Cushion)	44 (37.93)
Something that can't be observed or felt by humans (or animals) does not exist.	F ₃	"No, there is no force on the man there is a force on the satellite but not on the man." (Satellite)	5 (4.31)
Endowing objects with human or animal characteristics	F ₄	"Yes, there is a force of the man and that of the car (any other) force of friction". (Car II)	5 (4.31)
The abstract idea being treated as if it had material existence; the force is somehow embedded in the moving object.	F ₅	"There is a force of the cricketer, air friction and gravity." (Cricket I)	15 (12.93)
Incorrect use of Scientific Terms	F ₆	"There is a force of man's hand, gravity and the reaction due to gravity." (Car I)	32 (27.59)
Self-Contradictory views	F ₇	"There is air friction and gravity but no force on the satellite". (Satellite)	7 (6.03)
There is no gravity on the moon.	F ₈	"There is no force on the moon." (Moon)	6 (5.17)

TABLE: 5.5.1.1.(b)

FORCE N = 18

Sr. No.	Instances	Categories							
		F ₁	F ₂	F ₃	F ₄	F ₅	F ₆	F ₇	F ₈
1	Police	1	9	-	-	-	1	-	-
2	Car I	1	5	-	1	-	3	-	-
3	Car II	-	7	-	1	-	4	-	-
4	Car III	-	2	-	1	-	2	-	-
5	Bicycle	-	2	-	-	4	3	-	-
6	Cricket I	-	-	-	-	6	4	-	-
7	Cricket II	-	3	-	-	1	3	-	-
8	Ball I	-	2	1	-	2	1	-	-
9	Box	-	1	-	-	-	3	-	-
10	Ball II	-	4	-	-	2	4	-	-
11	Cushion	-	4	-	-	-	-	5	-
12	Weightlifter	-	3	-	-	-	2	1	-
13	Satellite	-	2	4	2	-	1	1	-
14	Moon	-	-	-	-	-	1	-	6

TABLE: 5.5.1.1.(c)

FORCE

Category	Typical Statement Study 1	Typical Statement Study 2
F ₁	"Yes, he is forcing him to move". (Police)	"Yes, there are two forces, one is gravity and the other is that of the policeman who is forcing the man". (Police)
F ₂	"No, there is no force on the car". (Car I)	"There is no force, as he is just sitting on it". (Cushion)
F ₃	"No force is acting on the bicycle". (Bicycle)	"No, there is no force on the man there is a force on the satellite but not on the man". (Satellite)
F ₄	"No, it is moving of its own". (Bicycle)	"Yes, there is a force of the man and that of the car (any other).... force of friction". (Car II)
F ₅	"Yes, the ball went up because there is force of man's hit". (Cricket I)	"There is a force of the cricketer, air friction and gravity". (Cricket I)
F ₆	"Yes, there is force of the inclined plane". (Ball II)	"There is a force of man's hand, gravity and the reaction due to gravity". (Car I)
F ₇	"As the man is sitting on the cushion, there is force of weight (not gravity)". (Cushion)	"There is air friction and gravity but no force on the satellite". (Satellite)
F ₈	"No, there is no force on the moon". (Moon)	"There is no force on the Moon". (Moon)

TABLE: 5.5.1.1.(d)

IAI RESULTS

FORCE

Category Code	Study 1 N = 20	Study 2 N = 18	Category Codes after addition	Study 1 N = 20	Study 2 N = 18
F ₁	3	2	F ₁₊₂	17	46
F ₂	14	44			
F ₃	7	5	F ₃	7	5
F ₄	5	5	F ₄	5	5
F ₅	17	15	F ₅	17	15
F ₆	13	32	F ₆	13	32
F ₇	7	7	F ₇₊₈	11	13
F ₈	4	6			

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right]$$

$$\chi^2 = \underline{11.25}$$

For df = 5, the table value is 11.07 at 0.05 level.

5.5.1.2. ENERGY

The results of the concept Energy for Study 2 are presented in Tables 5.5.1.2 (a), 5.5.1.2 (b), 5.5.1.2 (c) and 5.5.1.2 (d). As in case of Force, Table 5.5.1.2 (a) presents typical student statements about energy along with the number and percentage of such statements. The table shows that the word 'energy' was used by the students most frequently in the 'everyday language' sense. The table also shows that most of the students confuse various physical phenomena. Table 5.5.1.2 (b) presents the number of misconceptions under each category of misconception against each instance used in the study. Table 5.5.1.2 (c) compares the typical statements of students of Study 1 and 2 qualitatively under such category of misconception; whilst Table 5.5.1.2 (d) compares the statements of students of both the studies statistically.

The qualitative comparison between the statements of students of Study 1 and 2 also shows that students in both the studies hold similar misconceptions. The similarity in the statements of students of Study 1 and Study 2 in the concept Energy is evident from the Table 5.5.1.2 (c). Referring to category E_3 , the students of Study 1 hold a view that in a waterfall "Water has got its own energy", whereas students of Study 2 say that "Moon and Earth both have got their own energies." These statements show that the students in both the studies are unable to point out the kind of energies in the instances "waterfall" and "Moon and Earth". Students in both the studies attribute human

or living characteristics to inanimate objects.

Also, in category E₇, a few students in Study 1 hold a view that "Moon and Earth" have got "energy of gravity." The students in Study 2 hold a view that "weight has got potential energy which is there due to gravity." Students of both the studies have confusions between physical phenomenon. They have equally confused energy with the 'force of gravity'.

For the statistical comparison, Chi-Square test was used. Wherever, it was found necessary, the categories were added and recoded (See Table 5.5.1.2 (d) as it was done in Force. In this case, categories E₅ and E₆ were recoded as E₅₊₆ after addition. The value of χ^2 obtained from these results was 2.17 with df = 5, and was not significant. The statistical comparison of the results of this concept shows that there was no difference between the students of Study 1 and 2.

The results from Studies 1 and 2 are not significantly different in the case of Energy; but in case of Force significant difference was found from the results of Studies 1 and 2. The difference between the results of Force and Energy might be due to the fact that in case of Energy, students in Study 1 had some technical language such as "energy", "potential". No new technical language was added in re-teaching, hence the non-significance of the Chi-Square Test.

From the results it is evident that the students' misconceptions persisted even after re-teaching which shows that re-teaching the Study 2 sample students could not bring any positive change in their misconceptions. It seems that teachers could not convey the concepts in a meaningful way.

TABLES: 5.5.1.2.(a)

ENERGY

N = 18

Category Name and Code		Typical Statement	No. & % of total statements in this category
Everyday Language	E ₁	"Yes, the man is using his energy to lift the weight." (Weightlifter)	45 (35.16)
Human-Centred Viewpoint	E ₂	"Yes, it gets energy from the wind when the wind blows energy is produced in it." (Yacht)	17 (13.28)
Attribute human or living characteristics to inanimate objects	E ₃	"Yes, moon and earth both have got their own energies." (Moon & Earth)	11 (8.59)
Everyday use of the word Energy	E ₄	"It is using up the energy given by the man." (Bicycle)	7 (5.47)
Energy as a concrete rather than abstract idea.	E ₅	"Yes, the man uses his energy which he gets from the food he eats." (Person on stairs)	8 (6.25)
Conservation of Energy	E ₆	"The wax turns into heat energy of the candle after burning." (Candle)	7 (5.47)
Confusion between Physical phenomena	E ₇	"Weight has got potential energy which is there due to gravity." (Weightlifter)	33 (25.78)

Table: 5.5.1.2.(b)

ENERGY

N = 18

Sr.No.	Instances	Categories						
		E ₁	E ₂	E ₃	E ₄	E ₅	E ₆	E ₇
1	Person on Stairs	2	1	-	1	1	-	2
2	Car	5	-	-	1	2	-	6
3	Weightlifter	6	-	-	-	-	-	3
4	Bird	5	1	-	-	1	-	3
5	Rock on Table	4	-	2	-	-	-	-
6	Candle	1	5	2	2	-	1	-
7	Bicycle	5	5	-	2	-	-	6
8	Clock	-	-	-	1	-	-	-
9	Car on Jack	2	-	1	-	-	-	-
10	Yacht	-	4	1	-	3	-	1
11	Waterfall	4	-	1	-	-	3	2
12	Moon & Earth	8	-	4	-	-	-	6
13	Television	-	1	-	-	-	3	3
14	Cow	3	-	-	-	1	-	1

TABLE: 5.5.1.2.(c)

ENERGY

Category Code	Typical Statement Study 1	Typical Statement Study 2
E ₁	"The rock has got no energy since it is a non-living thing." (Rock on Table)	"Yes, the man is using his energy to lift the weight." (Weightlifter)
E ₂	"Yes, it gets energy from man's foot." (Bicycle)	"Yes, it gets energy from the wind when the wind blows energy is produced in it." (Yacht)
E ₃	"Yes, water has got its own energy." (Waterfall)	"Yes, moon and earth both have got their own energies." (Moon & Earth)
E ₄	"Potential energy in the clock is being used up slowly." (Clock)	"It is using up the energy given by the man." (Bicycle)
E ₅	"Yes, the bird has got energy which it gets from the food (worm) it eats." (Bird)	"Yes, the man uses his energy which he gets from the food he eats." (Person on Stairs)
E ₆	"Energy in the wax turns into heat and light after burning." (Candle)	"The wax turns into heat energy of the candle after burning." (Candle)
E ₇	"Yes, it has got energy of gravity." (Moon and Earth)	"Weight has got potential energy which is there due to gravity." (Weightlifter)

TABLE 5.5.1.2(d)

IAI RESULTS

ENERGY

Category Code	Study 1 N = 20	Study 2 N = 18	Category Codes after addition	Study 1 N = 20	Study 2 N = 18
E ₁	30	45	E ₁	30	45
E ₂	9	17	E ₂	9	17
E ₃	7	11	E ₃	7	11
E ₄	7	7	E ₄	7	7
E ₅	5	8	E ₅₊₆	9	15
E ₆	4	7			
E ₇	30	33	E ₇	30	33

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right]$$

$$\chi^2 = \underline{2.17}$$

For df = 5, the table value is 11.07 at 0.05 level.

5.5.1.3. LIGHT

The results of retaught students obtained from IAI tapes in this concept area are presented in Tables 5.5.1.3. (a), 5.5.1.3 (b), 5.5.1.3 (c) and 5.5.1.3 (d). As before, Table 5.5.1.3. (a) presents typical statements of misconceptions along with the number and percentage of such statements under each category of misconception. The table shows that students hold misconceptions most frequently about the phenomena of reflection and emission of light. Table 5.5.1.3. (b) presents the number of misconceptions explored in Study 2 under each category of misconception against each instance. Table 5.5.1.3 (c) compares the statements of students of Study 1 and Study 2 qualitatively; whilst the Table 5.5.1.3 (d) compares the statements of misconceptions of students in both the studies statistically.

The qualitative comparison of typical statements of misconceptions of students in Study 1 and 2 shows (See Table 5.5.1.3 (c)) that students in Study 1 and Study 2 hold similar misconceptions. The similarity of misconceptions is evident from the nature of statements given in the Table. In both the studies, students do not understand the phenomena of 'Reflection and Emission of Light.' The students of Study 1 hold a view that a burning candle "reflects light from the match stick." Similarly, the students of Study 2 say that the moon "gets light from the sun, only then, it (moon) emits light." Both the statements show that students do not discriminate between

'emission' and 'reflection', and this difficulty is common in students of both the studies.

Also, students both in Study 1 and Study 2 hold a view that the distance to which light can travel is connected to the size of the object emitting light. Students of Study 1 hold a view that "if the candle is very large, then its light can go far, but if it is small, it will stay near." The students of Study 2 give a similar statement saying that "light from the bigger torch will go farther."

This comparison of selected statements of students of Study 1 and Study 2 in this concept area shows that qualitatively, misconceptions held by the students in both the studies are similar. Re-teaching by the trained teachers did not change their misconceptions which were previously held by them.

For the statistical comparison, Chi-Square test was used. For this purpose, categories which were less than 5 were added (and recoded) to the adjacent categories. In this case, category L_4 and L_5 were added and recoded as L_{4+5} as it was done in case of Force and Energy. The value of χ^2 obtained from these data was 8.14 with $df = 5$, and not significant. When the results of students of Study 1 and Study 2 were compared using Chi-Square Test, it was found that the students of Study 1 and 2 were not significantly different from each other.

The results in this concept area are similar to that of Energy, but different from the concept area of

Force. Again, as in case of Energy, this result might be due to the fact that for Light, even in Study 1 students had some technical language such as "light", "reflect", "glow", "emit", etc. No new technical language was added in re-teaching, hence the non-significance of the Chi-Square Test.

As referred in Chapter IV, Section 4.1.2., the concept Light was investigated by a colleague of the researcher. But, in Study 2 the same concept was investigated by the researcher himself. The qualitative agreement between the statements of misconceptions of students in Study 1 and 2 as well as the statistical comparison, is further evidence to support that the two interviewers obtained similar results using the same interviewing technique.

TABLE: 5.5.1.3.(n)

LIGHT

N = 18

Category Name and Code		Typical Statement	No. & % of total statements in this category
Ideas about Reflection and Emission of light	L ₁	"It gets light from the sun, only then, it (moon) emits light." (Moon)	60 (53.09)
Ego-Centric and Human-Centred viewpoint	L ₂	"The distance to which moon's light can go depends on its strength, when it loses strength, it will stop." (Moon)	7 (6.19)
If you can't see it in the dark, it does not make light.	L ₃	"No, you can't see it in the dark, you can see it only when its rays enter our eyes." (Sun)	5 (4.42)
Everyday Language	L ₄	"Yes, it produces light but not 'electric' heater when 'light' (electric current) passes, it emits light." (Heater)	4 (3.54)
Common Sense Answers	L ₅	"It takes light from the wax." (Candle)	11 (9.73)
Ideas about the distance light travels	L ₆	"The light from the bigger torch will go farther." (Torch)	16 (14.16)
Ideas about seeing the objects	L ₇	"We can see the painting because of reflection of light of our eyes." (Painting)	10 (8.85)

TABLE: 5.5.1.3.(b)

LIGHT

N = 18

Sr. No.	Instances	Categories						
		L ₁	L ₂	L ₃	L ₄	L ₅	L ₆	L ₇
1	A Candle	10	-	-	-	3	2	-
2	The Sun	10	-	1	1	1	2	-
3	The Moon	5	1	1	-	-	-	1
4	A Torch	11	-	-	-	1	4	1
5	An Electric Heater	6	2	-	2	3	3	-
6	Television	5	2	-	-	1	2	-
7	Bright Red Painting	2	-	1	-	-	-	2
8	Mirror	5	1	1	-	-	1	2
9	A Movie Screen	2	-	-	-	-	1	3
10	A Rainbow	4	1	1	1	2	1	1

TABLE: 5.5.1.3.(c)

LIGHT

Category Code	Typical Statement Study 1	Typical Statement Study 2
L ₁	"No, it reflects light from the match stick." (Candle)	"It gets light from the sun, only then, it (moon) emits light." (Moon)
L ₂	"Yes, you can see people moving on the screen, without light, you couldn't see them." (Television)	"The distance to which moon's light can go depends on its strength, when it loses strength it will stop." (Moon)
L ₃	"No, you can't see it in the dark, because it does not rise in the dark, it is not there." (Sun)	"No, you can't see it in the dark, you can see it only when its rays enter our eyes." (Sun)
L ₄	"It reflects light which it gets from the glowing object." (Painting)	"Yes, it produces light.... but not 'electric' heater when 'light' (electric current) passes it emits light." (Heater)
L ₅	"It does not emit light, because it gets changed into colours." (Rainbow)	"It takes light from the wax." (Candle)
L ₆	"If the candle is very large, then its light can go far, but if it is small, it will stay near." (Candle)	"The light from the bigger torch will go farther." (Torch)
L ₇	"You can see it with your eyes, if it is burning." (Candle)	"We can see the painting because of reflection of light of our eyes." (Painting)

TABLE: . 5.5.1.3.(d)

IAI RESULTS

LIGHT

Category Code	Study 1 N = 30	Study 2 N = 18	Category Codes after addition	Study 1 N = 30	Study 2 N = 18
L ₁	42	60	L ₁	42	60
L ₂	6	7	L ₂	6	7
L ₃	11	5	L ₃	11	5
L ₄	4	4	L ₄₊₅	15	15
L ₅	11	11			
L ₆	11	16	L ₆	11	16
L ₇	18	10	L ₇	18	10

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right]$$

$$\chi^2 = \underline{8.14}$$

For df = 5, table value is 11.07 at 0.05 level.

5.5.2. THE PAPER-AND-PENCIL TEST RESULTS

The results obtained from the paper-and-pencil tests in Force, Energy, and Light are presented in Table 5.5.2.1. This table gives the scores or the number of questions responded correctly by each student in the sample of Study 2. The table also gives the mean scores (\bar{X}) and the variance (σ_t^2) in case of each test.

The reliability co-efficient (r_{tt}) of each test was calculated using Kuder - Richardson Formula KR - 20 which is stated as below:

$$r_{tt} = \frac{n}{n-1} \times \frac{\sigma_t^2 - \sum pq}{\sigma_t^2}$$

Where

- r_{tt} - reliability coefficient of the whole test
- n - number of items in the test
- σ_t^2 - the variance of the test scores
- p - the proportion of the group answering a test item correctly
- q - the proportion of the group answering a test item incorrectly

(Garrett & Woodworth, 1967, p. 341)

For the calculation of r_{tt} for each test, the number of correct and incorrect responses, p , q and the product pq were obtained. These data are presented in Table 5.5.2.2, 5.5.2.3 and 5.5.2.4 for the tests on Force, Energy, and Light respectively. The reliability coefficients thus obtained for the tests on Force, Energy, and Light were 0.68, 0.10, and 0.26 respectively.

These values are rather lower than the usual values quoted for norm-referenced tests. In the present case, the tests are criterion-referenced tests, prepared for the special purpose of finding what students could perform (Gronlund, 1982, p. 14) without reference to the performance of others.

As argued by Gronlund (1982, p. 16), for criterion - referenced tests the traditional procedures for estimating reliability (and also the traditional standards) are inappropriate due to limited score variability. As the criterion - referenced tests are prepared to measure different attributes, the use of conventional (KR-20) reliability measures is probably not appropriate. Moreover, as described in Chapter VI, the tests consist of items with high difficulty levels. The test items were difficult because they were designed to test exact perceptions, or small differences between exact (correct) and inexact (erroneous) conceptions.

In the test on Force, items 8 and 10 were found to be easy, whilst items 2,4,6, and 7 were most difficult. In the test on Energy, items 2,3,9 and 10 were found to be

easy, whilst item 1 and 7 were the most difficult. In the test on Light, items 1,4,5,6,7,8 and 9 were found to be easy, whilst items 3 and 10 were the most difficult. The remaining items in each test i.e. (items 1,3,5 and 9 in Force, items 4,5,6, and 8 in Energy and item 2 in Light) were of intermediate difficulty.

The results obtained from these tests show that generally, the performance of students was very low. In case of the test on Force, the range of questions answered correctly by the students was 0-7; whilst it was 2-7 in Energy, and 3-8 in Light out of 10 in each test. As far as individual test items are concerned; only 2 items in Force (Table 5.5.2.2); 4 items in Energy (Table 5.5.2.3) and 7 items in Light (Table 5.5.2.4) were answered correctly by more than 50% of the students in the sample.

TABLE: 5.5.2.1.

PAPER-AND-PENCIL TEST RESULTS

N = 18

Students	Scores of Students on the three Tests		
	Force/10	Energy/10	Light/10
1	4	7	3
2	1	5	5
3	1	6	3
4	7	6	4
5	7	3	7
6	3	4	9
7	6	4	5
8	2	3	5
9	3	5	5
10	6	2	5
11	4	3	8
12	3	5	6
13	3	6	7
14	4	4	6
15	0	7	6
16	1	4	5
17	6	2	8
18	3	5	6
\bar{x}	3.5	4.5	5.7
σt^2	4.6	2.38	2.65

TABLE: 5.5.2.2.

PAPER-AND-PENCIL TEST RESULTS
FORCE (N = 18)

Question Nos.	No. of Correct Answers	Proportion of Correct Answers (P)	Proportion of Incorrect Answers (q = 1 - p)	pq
1	7	0.38	0.62	0.24
2	1	0.05	0.95	0.05
3	7	0.38	0.62	0.24
4	0	0	1.00	0.00
5	7	0.38	0.62	0.24
6	4	0.22	0.78	0.17
7	5	0.27	0.73	0.21
8	15	0.83	0.17	0.14
9	9	0.5	0.5	0.25
10	10	0.55	0.45	0.25

$$\sum pq = 1.79$$

Using the Formula KR-20

$$rtt = \frac{n}{n-1} \times \left(\frac{\sigma_t^2 - \sum pq}{\sigma_t^2} \right)$$

$$\text{or } rtt = \frac{10}{9} \times \frac{4.6 - 1.79}{4.6}$$

$$rtt = \underline{0.68}$$

TABLE: 5.5.2.3.

PAPER-AND-PENCIL TEST RESULTS

ENERGY (N = 18)

Question Nos.	No. of Correct Answers	Proportion of Correct Answers (p)	Proportion of Incorrect Answers (q = 1 - p)	pq
1	4	0.22	0.78	0.17
2	10	0.55	0.45	0.25
3	12	0.66	0.34	0.22
4	7	0.38	0.62	0.24
5	8	0.44	0.56	0.25
6	8	0.44	0.56	0.25
7	1	0.05	0.95	0.05
8	9	0.5	0.5	0.25
9	11	0.61	0.39	0.24
10	11	0.61	0.39	0.24

$$\sum pq = 2.16$$

Using the Formula KR-20

$$rtt = \frac{n}{n-1} \times \left(\frac{\sigma_t^2 - \sum pq}{\sigma_t^2} \right)$$

$$\text{or } rtt = \frac{10}{9} \times \frac{2.38 - 2.16}{2.38}$$

$$rtt = \underline{0.10}$$

TABLE: 5.5.2.4

PAPER-AND-PENCIL TEST RESULTS

LIGHT (N = 18)

Question Nos.	No. of Correct Answers	Proportion of Correct Answers (p)	Proportion of Incorrect Answers (q = 1 - p)	pq
1	12	0.66	0.34	0.22
2	8	0.44	0.56	0.25
3	5	0.27	0.73	0.21
4	11	0.61	0.39	0.24
5	14	0.77	0.23	0.18
6	14	0.77	0.23	0.18
7	15	0.83	0.17	0.14
8	10	0.55	0.45	0.25
9	11	0.61	0.39	0.24
10	3	0.16	0.84	0.13
				$\sum pq = 2.04$

Using the Formula KR-20.

$$rtt = \frac{n}{n-1} \times \left(\frac{\sigma t^2 - \sum pq}{\sigma t^2} \right)$$

$$\text{or } rtt = \frac{10}{9} \times \frac{2.65 - 2.04}{2.65}$$

$$rtt = \underline{0.25}$$

5.6. SUMMARY AND DISCUSSION

The retest results show that students of Study 1 and 2 hold similar misconceptions in Force, Energy, and Light. This similarity has been established by the qualitative and quantitative comparison of statements of students' misconceptions in both the studies. The retest results demonstrate that students' misconceptions persist despite re-teaching of the concepts by the informed teachers. It appears from these results that informing the teachers about students' misconceptions fails to help them achieve correction of these misconceptions.

Although, in general, few differences were found in the Stage 2 results, children did seem to be a little more specific in their responses than they did in Study 1. In the re-test interviews, they made more use of scientific terms rather than their own words to describe various situations. Because of this, the number of statements given by students in certain categories of misconceptions in each concept area had increased due to wrong use of new terms by them in a variety of ways. This increase caused significant difference between the statements of students of Study 1 and 2 in the concept area of Force; but the difference was not significant in other areas because of comparatively smaller increase in the number of statements using technical words.

Setting aside the possibility this reflects the greater maturity of the students, the difference appears to stem from re-teaching the concepts. It is possible that during re-teaching, scientific terms were stressed by the teachers perhaps in their efforts to remove the misconceptions. Students used the new terms which they have come to know during re-teaching in a manner that showed lack of understanding. They applied new terms to their 'old' misconceptions. This is further illustrated by the low performance of students on paper-and-pencil tests.

From the results of Study 2, it appears that little meaningful learning took place. The new scientific terms which the students have come to know during re-teaching could not be assimilated by them. As argued by Miller (1980), these students are missing relevant subsumers in their cognitive structures that would enable them to integrate the (new) abstract ideas into the hierarchy already present. Because as argued further by Summers (1982) learning will only be meaningful when the new idea or concept which is to be learnt can be consciously related to relevant concepts and ideas which have been acquired previously. In other words, for meaningful learning to occur the learner must be able to integrate the new idea or concept into his or her existing cognitive structure.

Further, it appears from the results that the students of Study 2 applied the new words to their incorrect concepts. The new terms were integrated into the

existing (wrong) structures, because without some form of integration, it is doubtful if the technical terms would have been retained in the period from teaching to testing. The retention of new technical terms argues for integration, the results argue for integration into the "wrong" schema.

It was due to the integration of new terms into the existing (wrong) structures that students of Study 2 demonstrated lack of understanding. Students used the new scientific terms indiscriminately, and it seems that students do not understand what they do (Sjoberg and Lie, 1981). The only "development" which seems to occur is that some of the mistakes were expressed more clearly by the more mature students and the re-teaching gave the pupils the tools to express their views.

Although, the teacher training programme used in Study 2 was short (6 hours only) and the null result is based on a study of 2 teachers and 18 students only, it may nevertheless be significant. The result is significant in the sense that a null effect was obtained despite the fact that much of the study was conducted under very favourable conditions. The teachers selected were not ordinary teachers, both had a strong academic and professional background and were known in their schools for their dedication and hard work. These better than average teachers are more likely than others to be able and willing to apply results of Ausubel's work, the new

teaching techniques etc. Also, almost every kind of physical facility was available for classroom teaching. Moreover, they were keener to tackle the children's misconceptions after they were told about these misconceptions during the workshop. The students in the sample were also very motivated because of the interactions they had during interviews on various instances. Attendance for re-teaching and re-testing shows this. But, inspite of all this, the study failed to show a decrease in the level of students misunderstandings of basic concepts.

This result might have been caused either due to the inexact teaching of the technical terms (if the technical term is not taught precisely it can appear to fit a range of phenomena not just the correct one), or failure of teachers to pick up students' inexact use of the terms. This is the sort of thing that Nussbaum's exercise might have picked up if the teachers had done this exercise with their students. It seems that teachers did not benefit from Nussbaum and LISP exercises used in the training sessions.

As described earlier in section 5.4 of this Chapter, the two tests (IAI and paper-and-pencil) were conducted on the sample students of Study 2 with an approximate time interval of five months from the time of re-teaching. First the paper-and-pencil tests were used immediately after re-teaching, whereas the same students were tested again using IAI technique after a period of five months. This appears to have the problem that students

would have forgotten what they have learnt during re-teaching. Although, testing the students after such a long time period was a necessity, probably this proved to be an advantage to seek long term changes in the students' cognitive structures and give time for rote-learnt material to be forgotten (Ausubel et al, 1978). The students were re-taught the concepts one year after they had their first IAI tests; and re-tested using the same technique five months after re-teaching. In this manner, there was approximately 17 months time difference between the first testing and re-testing. But, the IAI technique brought the same results which clearly indicates that the IAI approach does probe the concept structures.

The fact that pupils gained additional technical vocabulary suggests that the two teachers did stress new ideas during re-teaching, i.e. the teacher-training programme did have some effect. But either

- i) the effect was too weak to alter the strongly held students' views, or
- ii) the teacher training was not of the right kind.

This small experiment leads one to conclude that merely informing teachers about children's misconceptions does not prove to be effective. Once again there is evidence that the misconceptions held by children are strong, enduring and resistant to change.

As the sample was small and the programme was short, any attempt to generalise the results must be treated with caution. However, the lack of success may be confirmed in a larger study.

CHAPTER VI

STUDY 3

TEACHER TRAINING AND LARGE SCALE TESTING OF STUDENTS

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STUDY 3

TEACHER TRAINING AND LARGE SCALE TESTING OF STUDENTS

The results of the second study strongly suggest that merely informing teachers about children's misconceptions does not enable them (the teachers) to bring about changes in these conceptions. Study 2 showed that there was almost no reduction in the children's misconceptions and that, more disappointingly, some additional inconsistent ideas were introduced as a result of the reteaching. We conclude with Osborne and Gilbert (1980) and Champagne et al (1983) that children's misconceptions are strong, enduring and are not removed by simply telling the teachers about these misconceptions. Further, it has been shown that it is comparatively easy to cause students to apply new technical vocabulary to their existing ideas without requiring these to be modified.

Since only two teachers were trained and the number of students who were involved in re-teaching and re-testing was only 18, the researcher had to consider a means of training teachers and the testing of students on a larger scale. Such a study would be for the purpose of obtaining more detailed information about the nature of the problem.

The larger scale programme of teacher training and testing of students was necessary, because the researcher was interested to incorporate this programme and

the methodology so established in a project to be set up for the purpose of improvement of science education in Pakistan. As mentioned in Chapter 1, this project has as one of its objectives the improvement of science education through changes in science teacher education in the country.

Because a larger number of students was to be involved in the new study it was not feasible to use the IAI technique. For this reason, paper-and-pencil instruments which were similar to IAI Cards were devised, tested for reliability and finalized for testing children in groups. Concurrently, workshop materials were developed for the training of teachers for re-teaching the concepts of Force, Energy, and Light in their own schools. The teacher-training programme, the workshop, and the results obtained are the subject of this chapter.

6.1. THE TEACHER TRAINING PROGRAMME

As described earlier in Chapter III, the main focus of the researchers in the field of pupils conceptions has been the learner; comparatively very little attention has been paid to the teachers. The majority of studies do mention the importance of the knowledge of pupils' misconceptions by the teachers, but few report work done to investigate and to subsequently modify teachers' behaviours.

This section after taking into account the previous research work describes the need for a new programme and the organisation of this programme.

6.1.1. REVIEW OF PREVIOUS WORK

Recent research work ignores the teachers in two ways. Firstly, no direct testing of the teachers has been done. Secondly, very little effort has been made to help the teachers correct possible misconceptions. However, a few of the researchers do mention some of the teachers' naive ideas. For example, Viennot (1979) referring to an earlier study (Viennot, 1977) says that teachers tend to make mistakes similar to those of their pupils when they answer in a hurry. Helm (1980) identified the teachers as the major cause of misconceptions in Physics amongst South African students, with textbooks and examination papers contributing their fair share.

Hope and Townsend (1983) studied the extent to which accurate scientific conceptions in certain physical and biological concepts are held by first year teacher trainees, using the LISP survey in Physics (Osborne, et al 1981) and biology (Bell, 1981). The subjects were first year students training as primary school teachers. It was found that biological concepts were relatively well understood by student teachers although some scientific misconceptions still occurred, particularly for the animal and living categories. Also, it was found that student teachers held a number of inaccurate or false conceptions about physical science and their general performance was more similar to a fourth form level than a sixth form level.

Ivowi (1984) reports that teachers (in Nigeria) seem to have similar misconceptions to their students. He claims that in some areas of physics the main causes of these misconceptions in students can be traced to teachers and some available textbooks. Barrass (1984) identifies 15 major 'misconceptions' and 'misunderstandings' in standard textbooks of biology. These books have no doubt been written mostly by teachers. James (1983) came to realise her own misconceptions at the end of a lesson saying that 'not only were students' preconceptions important to consider, but also a teacher's own preconceptions should be taken into account.'

According to Gilbert et al (1982), 'just as by children's science we mean those views of the natural world and the meanings for scientific words held by children before formal science teaching teachers undoubtedly have a wide variety of viewpoints ranging from almost children's science to scientists' science'.

Zylbersztajn and Watts (1980) designed a study to investigate both the occurrence of some specific ideas about the concept of 'Force' among secondary school students and the teachers' awareness concerning this occurrence. In this study, students were tested using a questionnaire (described earlier in Chapter IV); while the teachers were interviewed using the questionnaire as a focus. The teachers were asked to write below each alternative the percentages of their students they thought would choose it. Teachers seemed to be aware of the students' choices in some of the cases, but their predictions were not very good

in the others.

Osborne and Gilbert (1979) as a part of their investigation of the concepts 'Work' and 'Electric Current' explored the relevance of the Interview-About-Instances (IAI) approach to the classroom. In this connection, a workshop was held with the teachers on the concept 'Electric Current'. This workshop formed part of a one day in-service course for teachers who were involved in teaching an A-level physics course. The main aims of the workshop were:

- i. to help teachers clarify their own ideas about 'electric current'
- ii. to make teachers more aware of the understandings some students have about 'electric current'.
- iii. to suggest and discuss ways that 'instances' might be used to diagnose student understanding and to teach concepts.

The workshop consisted of four sessions and was reported to be useful within the limitations of its aims.

A few studies have attempted to modify children's ideas by designing instruction for pupils instead of training the teachers. Nussbaum and Novick (1981) designed two lessons on the particle model. The strategy used was a 'brainstorming' exercise based on the (British) Science Teacher Education Project. Lesson I was planned for 'Exposing alternative frameworks and creating cognitive dissonance', and Lesson II dealt with 'Inventing a model through accommodation'. The researchers suggest that the

lessons contributed to the pupils' cognitive understanding. The whole activity was watched by the pupils' own classroom teachers. No follow-up study of the teachers was reported.

Gunstone et al (1981) designed 6 sessions of special activities in an effort to modify students' Aristotelian views about force and motion. The programme had only limited success in changing students' world views of the concepts.

Minstrell (1982) investigated the "at rest" condition of an object with two physics classes at a high school. As a part of his investigation, he suggests the following instructional factors that apparently aid in the development of the students' concept of force:

- i. an engaging, free thinking, free speaking social context, in which students are encouraged to articulate their beliefs,
- ii. a juxtaposition of a variety of first-hand experiences with static objects, and
- iii. encouragement to search for the simplest, consistent, rational argument that will explain the similarity of effects in an apparent diversity of experiences.

It appeared that some students did change their conceptual understanding. At the very least, as a result of instruction, the students were more willing to hold and use the physicists' view of forces on static objects in subsequent problem solving.

Osborne (1983) tried to modify children's ideas about electric current by exposing them to experimental evidence that was at variance with their ideas. Also, an analogy was given that supported the scientists' ideas and pupils' reaction to this was sought. It was found that although most children had modified their views with respect to the simple battery, bulb, and wires circuit, they retained their pre-lesson model for situations where the return path was not obvious.

Some of the researchers/research teams tried to help the teachers either by devising activities to be done as part of their training or by preparing materials for them to use with the pupils. Nussbaum (1981) investigated student teachers' competency to diagnose pupils' answers for possible misconceptions. The materials consisted of two supposed explanations of a given physical phenomena. These explanations constructed by the author, were based on findings of a previous study in which individual pupils' explanations of certain demonstrated physical phenomena were analysed. This exercise, in which two worksheets were used, was done by the student teachers as part of their programme.

Nussbaum argues, 'diagnosing a pupil's misconceptions appropriately is but the first step to be taken by the teacher towards helping the pupil to replace his persistent preconceptions with the scientific concepts'. He finds that most student teachers participating in this study before receiving any relevant training were not ready to make appropriate diagnosis of misconceptions. They rather

tended to make general descriptive remarks which did not have any interpretative quality. The need for specific training activities, to develop diagnostic competency is clear.

Northfield and Gunstone (1983) while reviewing activities from a one-year Teacher Education Programme regarded three concerns as necessary in any programme incorporating the outcomes of 'alternative frameworks' research. These concerns are the student teachers'

- i. Science background
- ii. Understanding of their own learning
- iii. Understanding of children's learning.

The authors felt that making student teachers aware of the existence of alternative frameworks in their own and their pupils' thinking is not a difficult task; but dealing with the implications for their later teaching roles provides a further (and perhaps greater) challenge. No follow-up study of the teachers is reported.

The Learning in Science Project (LISP) in its Action-research phase, had as one of its aims the finding of ways to solve some of these problems. The team considered that the best help it could give teachers would be to devise materials for them. The groups (Physics, Chemistry, Biology) developed materials in their own subject areas.

The physics group developed two papers for teachers. The first of these papers (No. 33), titled 'Force, Friction and Gravity -- Notes for Teachers' (Osborne et al 1981) provided background information on children's and scientists'

ideas about force, friction and gravity. The paper states that to teach ideas about a concept (e.g. force) successfully, it is necessary (for the teachers) to know three things:

- i. what physicists mean by the term 'force'.
- ii. what children typically mean by the term and, more importantly,
- iii. what your own (teacher) views are of 'force', and how these views compare with (i) and (ii) above.

The paper consists of three parts. Part I gives survey questions for investigating teacher's own views, and the physicists' answers to the survey questions are given. Part 2 gives a summary of contrast between children's ideas and scientists' ideas. Part 3 describes scientists' views of force in detail and contrasts them with children's views about 'force'.

The second paper (No. 34) titled 'Teaching about Force - Suggested teaching Activities' (Schollum et al, 1981) provides a set of teaching activities suitable for the Form 1-4 level. The activities were designed to modify children's views about 'force' toward the scientific view by taking into account the findings of the in-depth phase. Pre-tests and Post-tests were also provided so that teachers could evaluate the success of their teaching approach. In addition to this, the Activities group also produced some videotapes showing the strategies being used in the classroom.

6.1.2. NEED FOR A NEW PROGRAMME

Results of the present study already described have shown that teachers also hold misconceptions similar to those held by their students, and simply telling or making teachers aware of children's misconceptions does not affect the teachers' performance on the test. With these results in mind, the need for a fresh approach to training of teachers in science concepts is evident.

A decision was taken to plan a fresh teacher training programme. Existing programmes were considered unsuitable because:-

- i. Some were planned in a limited context, e.g. Nussbaum (1981) and focused only on the diagnostic ability of the teachers, but, the researcher looked for a detailed programme for in-depth training of teachers.
- ii. Others were not feasible being too long, e.g. Northfield and Gunstone (1983) describe a one-year programme, but for the present study, only a one-day programme was feasible.
- iii. Most mainly dealt with student teachers. In contrast, the present study involves in-service teachers holding B.Sc. and M.Ed./M.A. Edu. degrees.

Briefly, it can be said that the previous programmes do not meet the requirements of the programme intended for the present study. The main considerations underlying this teacher training programme were, that

- i. it should be short, so that it is easily useable in the Colleges of Education and does not require large scale changes as far as the contents of the existing courses and the college time table is concerned.
- ii. it should be suitable for teaching by Teacher Educators with limited special training; otherwise, it would be difficult for them to use the programme.
- iii. its ideas should be easily implemented by experienced teachers in the classrooms. If teachers face too great difficulties in the implementation of new ideas, then the impact of training cannot reach the child, the ultimate aim of teacher education.

The programme had the following objectives:
After attending this programme, the teachers should

- i. have a general background of the recent research work concerning children's understanding of basic concepts of science, and the techniques used for this purpose.
- ii. have a knowledge of children's misconceptions.
- iii. know how to diagnose pupils' misconceptions.
- iv. have a knowledge of their own and other teachers' possible misconceptions and those in textbooks.
- v. be able to contrast children's/teachers' ideas and scientists' ideas.

- vi. understand the interaction of children's and teachers' ideas.
- vii. be able to relate research findings to selected topics of Educational Psychology.
- viii. be aware that a wrongly planned lesson can establish the misconceptions more firmly.

While planning this programme, maximum utilization was made of the work already described of other researchers. In this regard, the works of Osborne and Gilbert (1979); Zylbersztajn and Watts (1980); Nussbaum (1981); Osborne and Gilbert (1981); Schollum et al (1981); Gilbert et al (1982); James (1983); Osborne (1983); Northfield and Gunstone (1983) and the Learning in Science Project as a whole (Osborne and Freyberg, 1981) have been used as sources of guidance to plan the activities of this teacher training programme. As an overall plan, this programme was designed following the strategy suggested by LISP that: 'the participants should be told the differences between the views of the students and that of scientists'.

6.1.3. ORGANIZATION OF NEW PROGRAMME

For the execution of the teacher training programme a one-day workshop was planned for the teachers. The workshop programme was planned to consist of two parts: Lecture I and Lecture II. The workshop programme and methodology are described in more detail in section 6.6

of this Chapter. Although described as 'Lecture' each session also included demonstrations and discussions.

The main aim of Lecture I was to make the teachers generally aware of the science misconceptions of both pupils and science teachers. It was planned that during this lecture, teachers would be told about the recent research work concerning children's understanding of various concepts of science and the techniques being used (in particular IAI) for the purpose of these investigations. This lecture was also planned to discuss the misconceptions of children in the concepts of Force, Energy, and Light; and the misconceptions of teachers in the concept of Force along with the correct conceptions of these concepts.

Lecture II was generally aimed at providing a theoretical background and opportunities for teachers to think about classroom teaching in order to tackle children's misconceptions. In this connection, it was planned that this lecture would include discussion on Ausubel's Theory of Learning as it related 'Meaningful' and 'Rote' learning; and interaction of children's ideas and teacher's ideas making use of the main ideas from Gilbert et al (1982). Then, it was planned to discuss an example of a lesson which was adapted from James (1983) that made children's misconceptions worse, which would then be followed by an exercise adapted from Nussbaum (1981) to diagnose children's misconceptions.

This was followed by use of some worksheets from the LISP team for discussion and further exercises to

contrast children's ideas and scientists' ideas. Part 2 of the programme concluded with a summary/discussion of the ideas discussed in the workshop.

This teacher training programme is feasible in the light of its aims because of having an adequate length and the contents selected for the programme. Moreover, it does not require much staff for the programme to be implemented. Briefly, it can be said, that the programme is simple and easily useable by others without causing many practical difficulties. If the programme is successful, it could be implemented in the Teacher Education Colleges and Institutes of Education and Research in Pakistan.

6.2. THE EXPERIMENTAL DESIGN

The sample of the study consisted of a group of 21 volunteer secondary school science teachers having B.Sc. and M.A. Education or M.Ed. degrees with specialization in Science Education. The selection procedure and other related matters are described in section 6.6. of this Chapter.

As shown later in diagram 6.6.1., the group of 21 teachers was distributed to three equal groups (A, B and C) on random basis to undergo different training and to follow the Post-Test only control Group Design of Campbell and Stanley (1963, P. 25). The modified design to meet the present purpose is shown in Fig. 6.2.1.

R	X	O ₁ (Experimental Group)
R		O ₂ (Experimental Group)
R		O ₃ (Control Group)

where R = Random assignment to separate treatment groups

X = treatment

O₁, O₂, O₃ = Observations/Post tests.

Fig. 6.2.1.

In this design, the symbol R indicates that at a specific time prior to X (treatment) the groups were made equivalent by a random sampling assignment. According to Campbell (Kirk, 1972, P. 192), the sampling procedures employed assure us that at time R the groups were equal, even if not measured. R provides a point of prior equality just as does selection based on results of a pre-test. The range of uniformity obtained by random selection depends upon the size of the sample selected.

As shown by Campbell and Stanley (1963, P. 8), this design provides for control on the majority of sources affecting internal and external validity of experiments. In the light of the aims of the present study, this design was found to be most useful because, in particular, it controls-although it does not measure - the main effects of history, maturation, and pre-testing (Van Dalen, 1979, P.256).

Campbell and Stanley (1963, P. 5) describe these variables as follows:

1. History, the specific events occurring between the first and second measurement in addition to the experimental variable.
2. Maturation, processes within the respondents operating as a function of the passage of time per se (not specific to the particular events), including growing older, growing hungrier, growing more tired, and the like.
3. Pre-testing, the effects of taking a (pre) test upon the scores of a second testing.

This design is also superior to some other designs, because no interaction effect of pre-testing and treatment can occur. Pre-testing may alert subjects to features of the experimental treatment they would otherwise have ignored or not observed. This sensitisation may affect both control and experimental groups but not necessarily to the same degree. Thus the differential effect of the testing rather than the treatment may be responsible for the whole or part of any observed differences at the post-test stage.

After the formation of groups, a different treatment was given to each of the three groups (See Section 6.6). After the treatment, the science teachers went to their schools to re-teach the concepts chosen for this study. Each teacher re-taught the contents in his/her own school to an intact class of students. No random assignment was

possible with these classes because of some practical problems. Because the teachers in the sample belonged to schools situated at large distances from Lahore, and were volunteer teachers, it was not possible to send them to different schools or to arrange different treatments in any school.

As far as the size of the sample is concerned, it looks to be small i.e. only 7 teachers in each group as compared to usually recommended sample size. Garrett and Woodworth (1967, P. 208) suggest that if the sample is less than 25, say then there is often little reason for believing such a small group of persons to be adequately descriptive of any population. The authors further state that the larger the sample the larger the standard deviation of the sample and more inclusive (and presumably representative) the sample becomes of the general population. From the results of many trials based on computer-generated data, Petrinovich and Hardyck (Kirk, 1972) conclude that tests based on groups of less than 10 individuals lack sensitivity.

Notwithstanding the statistical merits of large samples, it is evident that the size of the sample in the present study was limited by the time and resources available to the single part-time investigator. Because of this limitation 30 teachers were invited to take part in the study; 24 turned up; 3 were dropped from the sample; as a result only 21 were left.

As described earlier, re-teaching was planned to be done in intact classes, and as argued by Peckham, Glass and Hopkins (1969) 'if the unit which is randomly assigned to treatment is the intact class, the logic of the situation may demand that the classroom be the unit of analysis.' Although, in the present study, the teachers and not the classes were randomly assigned to treatment; and since all the members of one class received the same treatment, therefore, they must be treated as one unit. Hence, the class (the least unit) received different treatment.

After reteaching, these classes of students were tested using multiple-choice test items (see later). In order to carry out the statistical analysis, means of each class would be obtained in each concept area and comparison would be made between classes taught by teachers in groups A, B and C.

The comparison of groups is fundamental to the experimental method. When only two groups are involved it is customary to apply a t-test to compare the two means. However, when more than two groups are involved repeated application of the t-test to all possible pairwise comparisons may not be justified.

For the comparison of groups in the present study, the Scheffe test was selected because it is appropriate for making any and all comparisons of interest on a set of K means (Edwards, 1968, P. 150). The method uses the criterion that the probability of rejecting the null

hypothesis when it is true (a Type I error) should not exceed 0.01 or 0.05, for example for any of the comparisons made.

The Scheffe's method is more rigorous than other multiple comparison methods with regard to Type I error (Ferguson, 1976, P. 296). It leads to fewer significant differences. According to Petrinovich and Hardyck (Kirk, 1972, P. 314), Scheffe's test is extremely conservative and will always produce extremely low Type I error rates when comparisons are limited to all possible pairs.

As argued by Ferguson (1976, P. 296) the Scheffe test has other merits too. It is easy to apply; no special problems arise because of unequal n's, and it uses the readily calculated F statistics. The criterion it employs in the evaluation of null hypothesis is simple and readily understood. It is not seriously affected by violations of the assumptions of normality and homogeneity of variance, unless these are gross.

Because of these strong points, the test was used to compare the three groups, as shown in the table 6.2.2., first on the mean scores of the whole test, and then on subsets of items in each test. The subsets of items are described later in this chapter.

In addition to the application of the Scheffe test, it was decided that a Chi-Square test would test the significance of the difference between the mean scores of the groups after obtaining the frequencies of right (R) and Wrong (W) answers to each test item. The results are

TABLE: 6.2.2

Concept Area	Subsets	A Means	B Means	C Means
Force	TFS	---	---	---
	FS1	---	---	---
	FS2	---	---	---
Energy	TES	---	---	---
	ES1	---	---	---
	ES2	---	---	---
Light	TLS	---	---	---
	LS1	---	---	---
	LS2	---	---	---
	LS3	---	---	---

presented in Section 6.9. of this Chapter.

6.3. NEED FOR NEW TEST INSTRUMENTS

As explained earlier, it is not usually feasible to use the IAI approach to test a large sample, because of the time and manpower resources that would be required. Therefore, it was decided to develop objective test instruments for the testing of students' misconceptions. Objective tests have the following characteristics (Macintosh and Morrison, 1969) relevant to this study.

They are:

- i. reliable,
- ii. easy to administer to a large sample,
- iii. easy to mark, and to interpret the results.

According to Deale (1975), the most familiar form of objective test is the multiple-choice, where pupils have to mark the one correct answer out of several possible answers. Also, as argued by Marshal and Hales (1971), a multiple-choice test is the most flexible and versatile of all the selection-type assessment instruments and can be used to measure both knowledge outcomes and various types of intellectual skills (Gronlund, 1982). It was decided to construct a test of multiple-choice items for the purpose of the present study.

6.4. DESIGN OF MULTIPLE-CHOICE TESTS

As the main purpose of this study was to extend the pilot study of Stage 2, the same concepts Force, Energy and Light were selected. Therefore, three separate tests were required for the experiment. The main consideration which formed the basis for the objective test construction was that maximum similarity was maintained between the instances used for IAI interviews and in these tests.

Where-ever possible the tests used the same instances as used in the interviews. Because 20 items were required initially to construct the test, more than were available from the IAI cards, further instances of the 3 concepts were selected from other sources (See Table 6.4.1.). While selecting the sets of questions for each test, care was taken to ensure that items from all "themes" were included for which IAI cards were designed. The full lists of test items are included in Appendices I and J.

Each item had four responses from which students make their choice of response. Depending upon the situation, some items have more than one correct response. Approximately 50% items in the test on Force had more than one correct response. The test on Energy had only two such items, whilst each item in the test on Light had only one correct response.

The question part in the stem of the question clearly mentions that students have to give all correct responses out of the four responses given in each item;

Table: 6.4.1.

Concepts	Sources from where instances were selected for Mc Tests
Force	Osborne (1980), Zylbersztajn and Watts (1980), Osborne et al (1981), Schollum et al (1981), and Watts (1983)
Energy	Stead (1980), and Watts (1983)
Light	Stead and Osborne (1980), Andersson & Karrqvist (1982; 1983) and Personal Construction of Knowledge Group

the instructions also made it clear that in each item there is a possibility that more than one response might be correct.

The students selected to take the tests had no prior experience with the multiple-choice tests, and were to be exposed for the first time with this test format, so the format adopted in the construction of these tests was not disturbing for them as it might have been for students familiar with the 'one-correct answer' format.

For marking the tests, it was decided that '1' mark would be assigned to an item which is answered totally correctly, and '0' mark would be assigned otherwise. To obtain a '1' mark students must indicate all correct responses and no incorrect responses.

This answer format had two effects. First it made the items more difficult for the students. In contrast to the four option single-correct answer format in which there is a 25% chance of selecting the correct response by guessing only, the present format effectively reduced the 'guessing score' to zero. Students had to demonstrate 100% knowledge of both exemplars and non-exemplars, i.e. in order to answer an item correctly, students must know all the correct and in-correct responses. For example, if a student has to answer A, B, C and leave D in order to answer the following item correctly, he can not answer it unless he recognises all the correct and incorrect responses.

A	B	C	D
1	1	1	.

Second, machine scoring of responses was made necessary and more restrictive. Whereas descriptive statistics showing percentages of students choosing a particular response are valuable for the usual type of multiple-choice item, it is only combinations of responses that are of interest in the present test.

All the test items were first developed in English and were seen by three Science Education lecturers. After incorporating their suggestions, the tests were translated into Urdu and were examined again by the same colleagues. Students used the tests in Urdu without seeing the English version.

6.5. RELIABILITY TEST OF NEW INSTRUMENTS

Each set of items was pilot tested in a school. For this purpose, the Government High School Township, Lahore was selected, because it had an adequate number of 8th class students. Only one school was used for the pilot testing because the researcher did not want to lose schools from the main experiment.

Each of the 3 tests was administered to a different group of 100 students. The tests were administered

during the second week of April 1984 in two visits to the school. On the first visit, the test on Force was given, and on the second visit, tests on Energy and Light were given simultaneously to two groups of students.

Prior to administration of the tests, the multiple-choice test format and how it is answered was explained on the chalkboard. In his explanation, the researcher used two examples from general knowledge and one example from science. This example was made very similar to the design of the items of the present tests but was not from the concept area relevant to the group. For example, the group taking the test on Force was given an example in Light. The explanation of the multiple-choice test was necessary, because as explained earlier, the students were not familiar with this type of question.

Students were told to ask, if they had any difficulty in understanding the questions. No time restriction was imposed on answering the test items. Student collaboration was not allowed.

The reliability of each item was estimated using the procedure described by Brown, Hitchman and Yeoman (1971). They state that tests should consist of items of medium difficulty ($F = 0.3$ to 0.7) and of discrimination value 0.4 or better. Using these criteria, 10 items were selected for each concept. The F and D values of the selected and non-selected items in each test are given in Appendix I under each item of the English version. The F values are rather lower than the normal values, this is

accepted in light of the criterion-nature of the tests and the lack of guessing score as previously explained.

6.6. THE EXPERIMENTAL WORKSHOP

As already stated the teacher training workshop was planned to train a group of science teachers to reduce the number of misconceptions held by children about the concepts of Force, Energy, and Light. Because of the nature of teacher education in Pakistan, attendance at the workshop was restricted to volunteer teachers who were ready to travel at their own expense, participate in the workshop during leisure time and who were ready to teach in their own schools by making special adjustments to the time-table.

Instead of selecting a random sample of science teachers, the researcher selected a sample of volunteer science teachers. This was done keeping in view the demands to be made on the subjects. As argued by Borg and Gall (1983) random sampling of broad populations is possible for survey research in which slight demands are made on the subjects. For educational studies that employ other methods than survey, such as correlational or experimental research, the demands on the subjects are usually much greater, and consequently it is virtually impossible to obtain the cooperation of all subjects selected by random sampling. Even if the researcher selects a random sample, he can rarely get cooperation from all the subjects selected.

When some subjects refuse to participate in a study, the remaining subjects no longer constitute a random sample because persons who agree to participate are likely to be different from those who do not.

For the selection of sample the teachers were approached in either of two ways. A few of the teachers were contacted at their home or school addresses through post or through friends and colleagues; about 50% of the teachers who took part in the workshop were approached in this way. Other teachers were contacted personally at the Punjab Education Extension Centre, Lahore whilst they were participating in another workshop organised by the Government.

About 30 teachers agreed to help with the workshop, but only 24 were able to do so. Of these 24, three had only B.Sc. and B.Ed. qualifications, so they were excluded from the sample; the remaining 21 teachers held both B.Sc. and M.A. Education/M.Ed. degrees with specialization in science education.

After a half hour introductory session on the workshop day, the 21 participants were divided into three equal groups. Group-wise distribution of teachers is given in Appendix K. Grouping was done randomly to follow the overall plan of Study 3 (See Table 6.6.1.) as explained in Section 6.2.

*M.A. Education is a two year degree programme after B.A. or B.Sc; M.Ed. is a one year degree programme after B.A./B.Sc. plus B.Ed. M.A. Education and M.Ed. are considered equal for all teaching and education purposes.

According to this plan, group A was the Experimental Group I to undergo in-depth training. Group B was the Experimental Group II to undergo simple training. Group C was the Control Group, who received only a general lecture on Science Education with no discussion about children's misconceptions. Groups A and B were taught by the researcher and Group C was taught by one of the colleagues of the researcher.

On the workshop day, Group A and B received a common Lecture I before the lunch break (See Workshop Programme in Table 6.6.2). During this lecture, discussion was encouraged as in the workshop organised for the earlier study (Stage 2).

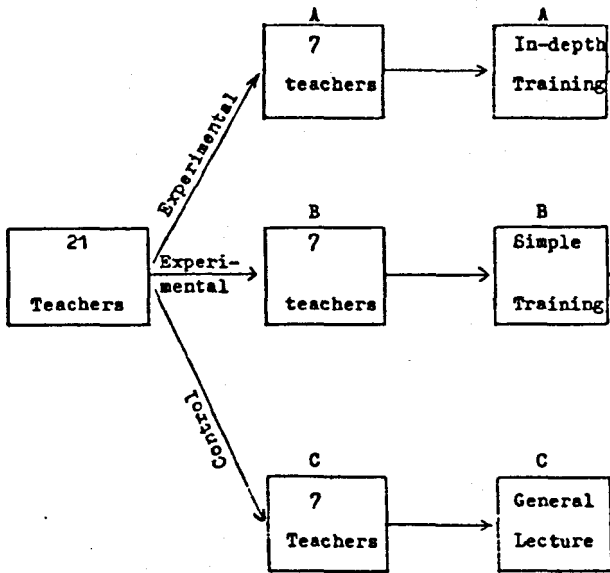
The participants of Group B and C had no further sessions whilst, after the lunch break, Group A received a further Lecture II. This lecture was the same as that delivered on the 3rd day of the earlier workshop. The main aims and general features of Lectures I and II have been described in Section 6.1. The topics covered in these lectures is given in Table 6.6.3. For more details about the workshop programme and the materials used during the workshop, see Appendix G.

After the lectures, all the participants (Group A, B, and C) were requested to teach concepts of Force, Energy and Light to the students of 8th class in their schools. As previously, a summary sheet of topic content (See Appendix H) was given to the teachers in order to ensure uniform and complete coverage of the three concepts.

Table 6.6.1

← One day workshop →				
Selection of Teachers	Grouping of Teachers	Groups of Teachers	One day teacher training	Type of training

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OVERALL PLAN OF STUDY 3

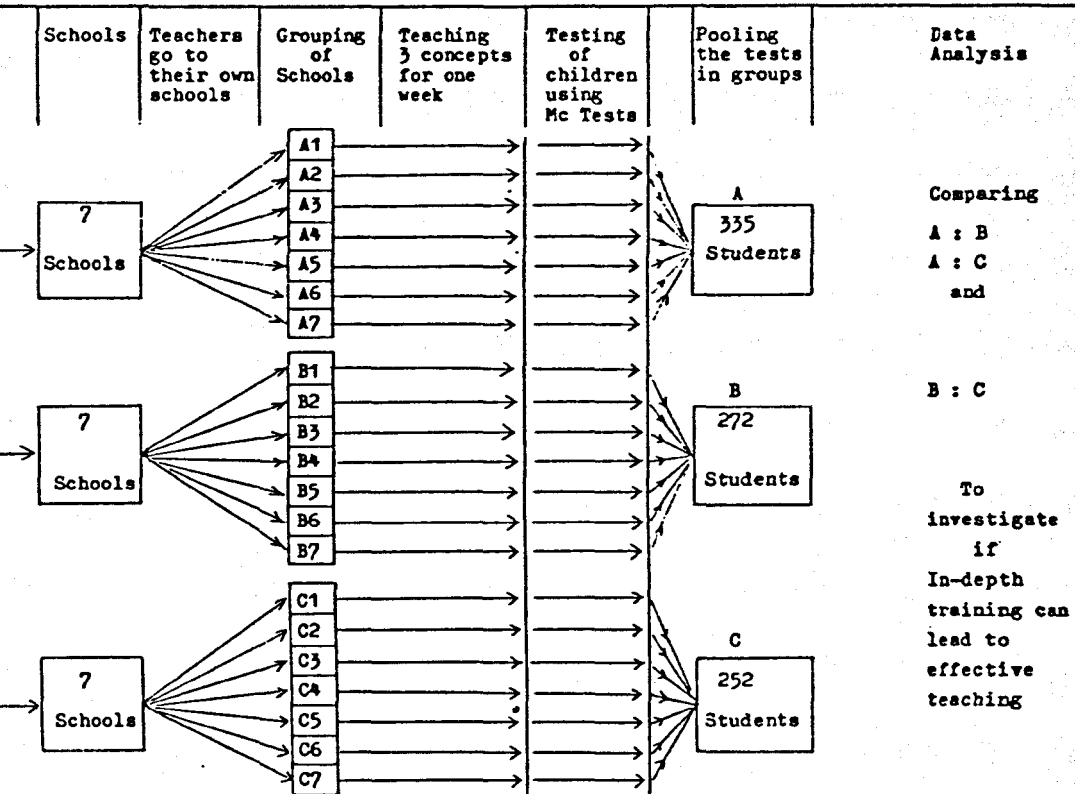


Table: 6.6.2.

THE WORKSHOP PROGRAMME

4th May 1984

1.	8.30 a.m.	-	9.00 a.m.	Welcome to the participants and formation of Groups A, B, C.	
2.	9.00 a.m.	-	10.30 a.m.	1st Session	Common
3.	10.30 a.m.	-	11.00 a.m.	Tea Break	Lecture (I)
4.	11.00 a.m.	-	12.30 p.p.	2nd Session	for Group A, & B, and General Lecture for Group C
5.	12.30 p.m.	-	3.00 p.m.	Lunch Break and Friday Prayer	
6.	3.00 p.m.	-	4.30 p.m.	3rd Session	Special
7.	4.30 p.m.	-	5.00 p.m.	Tea break	Lecture (II)
8.	5.00 p.m.	-	6.30 p.m.	4th Session	for Group A only.

TABLE: 6.6.3

Lectures	Groups Participated	Topics covered in Lectures
Lecture I	Experimental Group I (A) and Experimental Group II (B)	<ol style="list-style-type: none"> 1. Introduction to recent research work in science education with special emphasis on concept understanding. 2. Introduction to techniques of exploring children's understanding of basic concepts in Science. 3. Introduction to the Interview-About-Instances Approach. 4. Description of modification of the Instances used in Pakistani situation. 5. Presentation of Students' results for each concept (i.e. <u>Force</u>, <u>Energy</u>, <u>Light</u>). 6. Methodology of Testing the science teachers. 7. Description of the test instrument used. 8. Presentation of Results (Teachers). 9. Summary and discussion of ideas presented.
Lecture II	Experimental Group I (A)	<ol style="list-style-type: none"> 1. Ausubel's Theory of Learning. 2. Outcomes of Interaction of students' and Teachers' ideas. 3. A lesson that made misconceptions worse--An example. 4. An exercise to Diagnose pupils' misconceptions. 5. Further exercise to Diagnose misconceptions. 6. Differences between children's ideas and Scientists' ideas. 7. Discussion and summary of ideas presented during the one-day workshop.
General Lecture	Control Group(C)	<p>There was no mention of misconceptions research in this lecture. It was a general lecture concerning problems of science education in Pakistan.</p>

6.7. THE FOLLOW-UP PROGRAMME

In the final session of the workshop, participants agreed a schedule of dates for them to teach the concepts ready for the student tests. As in Study 2, the teachers were unaware of the details of the test format.

Each teacher re-taught the concepts in his/her own school by making special adjustments in the school time-table. Every teacher was asked to teach the three concepts to one group of students during a 6 day period, spending as nearly as possible equal times on each concept.

6.8. TESTING OF STUDENTS

Despite some problems and the scattered locations of the schools, every school was visited by an outside examiner to carry out the student tests.

Test administration was completed shortly after the agreed teaching period in all but one school. The teacher in that school was assigned to other duties; because he could not teach according to his schedule he was dropped from the Group B sample.

A special instruction sheet was also developed for the guidance of the examiners incharge of the tests. (An English version of the Urdu text is given in the Appendix L). Based on field experience of the researcher described in Section 6.4., an example of a multiple-choice test item was also given in this sheet in order to

illustrate the multiple-choice test format. The same example was used by all the examiners to illustrate the format. Also, the same sequence was adopted to present the tests. The test on Force was presented first, then the test on Energy, and finally the test on Light was administered. Students gave their answers to the three tests on separate answer sheets.

6.9. RESULTS

The results of the paper-and-pencil tests in Force, Energy and Light were analyzed in two parts using different statistical methods.

In Part I, for the purpose of comparison, in order to locate difference between the groups, items in each test were grouped with respect to the frameworks they were constructed to measure. For example, in case of the Test on Force (See Table 6.9.1.1.) two groups of items were drawn which were named as subset 1 (FS1) and subset 2 (FS2); for Energy, the two subsets were ES1 and ES2; and similarly, for Light, there were three subsets, LS1, LS2 and LS3.

Next, mean scores were obtained of each school on the total number of items on each test which were called as TFS, TES, and TLS for Force, Energy and Light respectively. Mean scores were also obtained for each subset of items in each test, then, the comparison was made between groups using the Scheffe Test.

In Part II, the groups A, B and C were further compared on the basis of the number of right (R) and wrong (W) answers of students in each group to each item of the 3 tests. A Chi-Square test was used to test the significance of the between-group differences in the right (R) and wrong (W) scores.

6.9.1. PART I

In this part, the mean scores of each school on the total test, and on the subsets of items in each test are presented in tables given in the Appendix M. The groups were then compared using the Scheffe Test. The results are presented in Table 6.9.1.2. This table shows that there is no significant difference between the groups in all the tests in each comparison except one. Groups were found significantly different from each other in only one subset of test items namely FS2. Group A performed significantly better than the other two groups on this test only.

TABLE: 6.9.1.1.

TABLE: SHOWING SETS OF ITEMS IN THE VARIOUS TESTS

Test on	Frameworks	Test items	Subsets & code
Force	i. Association between Force and Motion.	1,2,4, 6,7,10	Subset 1 (FS1)
	ii. Force embedded in the object	3	Subset 2
	iii. No gravity on the Moon	5,9	(FS2)
	iv. Greater force acts on a lit torch	8	
Energy	i. Energy Conversion	1,4,5, 7	Subset 1 (ES1)
	ii. Association between energy and living things	2,3	Subset 2 (ES2)
	iii. Kinds of Energy	6,8	
	iv. Energy and State of Matter	9	
	v. Association between shining and energy	10	
Light	i. Emission and Reflection of Light	1,4,5	Subset 1 (LS1)
	ii. Distance light travels	2,3,6,8	Subset 2 (LS2)
	iii. Propagation of Light-Seeing	9	Subset 3 (LS3)
	iv. Propagation of Light-Refraction	10	
	v. Dispersion of Light	7	

TABLE: 6.9.1.2.

COMPARISON OF GROUPS ON SCHEFFE TEST

Test	Variables	A		B		C		F Value	Scheffe Test
		M	Sd	M	Sd	M	Sd		
Force	TFS	1.499	0.207	1.086	0.384	1.125	0.499	2.400	NS
	FS1	0.845	0.306	0.668	0.370	0.703	0.369	0.484	NS
	FS2	0.796	0.355	0.417	0.084	0.422	0.159	5.788	Sig.*
Energy	TES	2.422	1.098	1.869	0.986	2.187	1.087	0.438	NS
	ES1	1.126	0.436	0.988	0.436	1.116	0.467	0.186	NS
	ES2	1.296	0.676	0.881	0.558	1.071	0.646	0.702	NS
Light	TLS	3.218	1.320	1.815	1.004	2.684	1.498	1.881	NS
	LS1	1.019	0.383	0.575	0.316	0.788	0.455	2.070	NS
	LS2	1.438	0.593	0.916	0.575	1.286	0.676	1.195	NS
	LS3	0.760	0.417	0.325	0.248	0.608	0.412	2.224	NS

NS = Not significant at $P = 0.05$

*There was a significant difference between Group A and Groups B & C together at the 0.05 level of significance.

6.9.2. PART II

In this part, the results of Force, Energy, and Light are presented in different tables. These are discussed here in the following sections separately for each concept.

6.9.2.1. FORCE

The results of the groups (A, B, C) in the concept of Force are given in summary Table 6.9.2.1.a. This Table presents the percentages of right (R) and wrong (W) responses of students in each group.

Using Chi-Square Test, the comparison of results of groups A and B (See Table 6.9.2.1.a.) shows that there was significant difference at 0.01 level between the groups in case of four questions only (Questions 5, 6, 9 and 10), whilst there is no difference in results in case of remaining six questions. All the significant differences favour the 'A' group.

The comparison of groups A and C (See Table 6.9.2.1.c.) shows that there is significant difference between groups in four questions (Questions 5, 6 and 9 at 0.01 level and question 8 at 0.05 level). No significant difference was found in other questions. All the significant differences favour the 'A' group.

The comparison of results of groups B and C (See Table 6.9.2.1.d.) shows that there is significant difference in two questions (No. 1 and 9) only at 0.05 level.

One of the significant differences (Q.1) favours the 'B' group of students, whilst the other (Q.9) favours the 'C' group.

TABLE: 6.9.2.1.a.

FORCE

Questions.	R/W	Group A (N = 335) %	Group B (N = 272) %	Group C (N = 252) %
1	R	11.94	15.80	9.52
	W	88.05	84.19	90.47
2	R	8.65	6.98	5.15
	W	91.34	93.01	94.84
3	R	8.35	10.29	10.31
	W	91.64	89.70	89.68
4	R	8.95	9.92	10.31
	W	91.04	90.07	89.68
5	R	19.40	8.08	5.55
	W	80.59	91.91	94.44
6	R	16.41	8.45	7.93
	W	83.58	91.54	92.06
7	R	17.01	14.70	17.46
	W	82.98	85.29	82.53
8	R	14.32	13.23	8.33
	W	85.67	86.76	91.66
9	R	26.56	8.82	15.07
	W	73.43	91.17	84.92
10	R	21.19	11.76	16.66
	W	78.80	88.23	83.33

TABLE: 6.9.2.1.b.

FORCE

Questions	R/W	Group A N = 335	Group B N = 272	χ^2 (Sig. level)
1	R	40	43	1.88 (NS)
	W	295	229	
2	R	29	19	0.56 (NS)
	W	306	253	
3	R	28	28	0.38 (NS)
	W	307	244	
4	R	30	27	0.15 (NS)
	W	305	245	
5	R	65	22	15.47 (0.01)
	W	270	250	
6	R	55	23	8.50 (0.01)
	W	280	249	
7	R	57	40	0.58 (NS)
	W	278	232	
8	R	48	36	0.13 (NS)
	W	287	236	
9	R	89	24	31.17 (0.01)
	W	246	248	
10	R	71	32	9.44 (0.01)
	W	264	240	

TABLE: 6.9.2.1.c.

FORCE

Questions	R/W	Group A N = 335	Group C N = 252	χ^2 (Sig.level)
1	R	40	24	0.85 (NS)
	W	295	228	
2	R	29	13	2.64 (NS)
	W	306	239	
3	R	28	26	0.64 (NS)
	W	307	226	
4	R	30	26	0.28 (NS)
	W	305	226	
5	R	65	14	23.66 (0.01)
	W	270	238	
6	R	55	20	9.25 (0.01)
	W	280	232	
7	R	57	44	0.01 (NS)
	W	278	208	
8	R	48	21	4.97 (0.05)
	W	287	231	
9	R	89	38	11.18 (0.01)
	W	246	214	
10	R	71	42	1.87 (NS)
	W	264	210	

TABLE: 6.9.2.1.d.

FORCE

Quest-ions	R/W	Group B N = 272	Group C N = 252	χ^2 (Sig. Level)
1	R	43	24	4.61 (0.05)
	W	229	228	
2	R	19	13	0.74 (NS)
	W	253	239	
3	R	28	26	0.00 (NS)
	W	244	226	
4	R	27	26	0.02 (NS)
	W	245	226	
5	R	22	14	1.3 (NS)
	W	250	238	
6	R	23	20	0.04 (NS)
	W	249	232	
7	R	40	44	0.72 (NS)
	W	232	208	
8	R	36	21	3.22 (NS)
	W	236	231	
9	R	24	38	4.89 (0.05)
	W	248	214	
10	R	32	42	2.58 (NS)
	W	240	210	

6.9.2.2. ENERGY

The summary of results of all the groups (A, B, C) in the concept of Energy are presented in Table 6.9.2.2.a. which gives the right and wrong responses to each question in percent.

The comparison of results of groups A and B shows (See Table 6.9.2.2.b.) that there is significant difference between the groups at 0.01 level in 6 questions (No. 2,3,5,6, 9 and 10) and at 0.05 level in one question (No. 7), whilst no significant difference in the group means was found in the remaining four questions. Six out of seven significant differences (Qs. 2,3,5,6, 9 and 10) favour the 'A' group of students, whilst the other(Q.7) favours the 'B' group.

The comparison of results in Table 6.9.2.2.c. shows that there is significant difference between the groups A and C in three questions (Question 2 at 0.01 level and Questions 9 and 10 at 0.05 level) only. All the significant differences favour the 'A' group.

But, in case of groups B and C, significant difference was found (See Table 6.9.2.2.d.) only in questions 6 and 7 at 0.01 and 0.05 levels respectively. No difference was found between these groups in the results of the other eight questions. One of the significant differences (Q.7) favours the 'B' group of students, whilst the other (Q.6) favours the 'C' group.

TABLE: 6.9.2.2.a.

ENERGY

Questions	R/W	Group A (N = 335) %	Group B (N = 272) %	Group C (N = 252) %
1	R	34.62	27.20	32.53
	W	65.37	72.79	67.46
2	R	23.28	13.23	9.12
	W	76.71	86.76	90.87
3	R	36.11	25.36	32.53
	W	63.88	74.63	67.46
4	R	32.83	26.10	33.33
	W	67.16	73.89	66.66
5	R	32.83	23.16	27.38
	W	67.16	76.83	72.61
6	R	36.11	25.36	35.31
	W	63.88	74.63	64.68
7	R	9.25	15.07	9.12
	W	90.74	84.92	90.87
8	R	16.71	17.64	18.25
	W	83.28	82.35	81.74
9	R	26.26	14.33	18.65
	W	73.73	85.66	81.34
10	R	21.19	8.08	13.49
	W	78.80	91.91	86.50

TABLE: 6.9.2.2.b.

ENERGY

Questions	R/W	Group A N = 335	Group B N = 272	χ^2 (Sig. level)
1	R	116	74	3.82 (NS)
	W	219	198	
2	R	78	36	9.92 (0.01)
	W	257	236	
3	R	121	69	8.07 (0.01)
	W	214	203	
4	R	110	71	3.23 (NS)
	W	225	201	
5	R	110	63	6.8 (0.01)
	W	225	209	
6	R	121	69	8.05 (0.01)
	W	214	203	
7	R	31	41	4.83 (0.05)
	W	304	231	
8	R	56	48	0.085 (NS)
	W	279	224	
9	R	88	39	12.89 (0.01)
	W	247	233	
10	R	71	22	19.86 (0.01)
	W	264	250	

TABLE: 6.9.2.2.c.

ENERGY

Questions	R/W	Group A N = 335	Group C N = 252	χ^2 (Sig. level)
1	R	116	82	0.26 (NS)
	W	219	170	
2	R	78	23	20.21 (0.01)
	W	257	229	
3	R	121	82	0.80 (NS)
	W	214	170	
4	R	110	84	0.014 (NS)
	W	225	168	
5	R	110	69	2.00 (NS)
	W	225	183	
6	R	121	89	0.034 (NS)
	W	214	163	
7	R	31	23	0.004 (NS)
	W	304	229	
8	R	56	46	0.22 (NS)
	W	279	206	
9	R	88	47	4.68 (0.05)
	W	247	205	
10	R	71	34	5.78 (0.05)
	W	264	218	

TABLE: 6.9.2.2.d.

ENERGY

Questions	R/W	Group B N = 272	Group C N = 252	χ^2 (Sig. level)
1	R	74	82	1.75 (NS)
	W	198	170	
2	R	36	23	1.15 (NS)
	W	236	229	
3	R	69	82	3.27 (NS)
	W	203	170	
4	R	71	84	3.27 (NS)
	W	201	168	
5	R	63	69	1.22 (NS)
	W	209	183	
6	R	69	89	8.99 (0.01)
	W	203	163	
7	R	41	23	4.3 (0.05)
	W	231	229	
8	R	48	46	0.025 (NS)
	W	224	206	
9	R	39	47	1.77 (NS)
	W	233	205	
10	R	22	34	3.79 (NS)
	W	250	218	

6.9.2.3. LIGHT

The results of groups A, B and C in the concept of Light are presented in the summary Table 6.9.2.3.a. Using the Chi-Square Test, the results of the groups A and B show (see Table 6.9.2.3.b.) that there is significant difference between these groups at 0.01 level in case of 8 questions and at 0.05 level in case of a further question. There was only one question the results of which show that there was no significant difference between groups. All the significant differences favour the 'A' group.

The comparison of results of groups A and C shows (Table 6.9.2.3.c.) that there is significant difference between groups in three questions (Questions 5 and 6 at 0.01 level and question 10 at 0.05 level) only. No difference was found in the results of majority of the questions. All the significant differences favour the 'A' group.

The comparison of the results of groups B and C shows (See Table 6.9.2.3.d.) that there is significant difference in the results in six questions (Questions 2, 5, 7, and 9 at 0.01 level and question 1 and 6 at 0.05 level). No difference was found in the results of the remaining questions. All the significant differences favour 'C' -- the control group.

TABLE: 6.9.2.3.a.

LIGHT

Questions	R/W	Group A (N = 335) %	Group B (N = 272) %	Group C (N = 252) %
1	R	26.56	12.13	19.84
	W	73.43	87.86	80.15
2	R	32.83	17.64	28.57
	W	67.16	82.35	71.42
3	R	26.86	20.22	25.39
	W	73.13	79.77	74.60
4	R	17.31	11.39	12.69
	W	82.68	88.60	87.30
5	R	59.40	30.14	42.06
	W	40.59	69.85	57.93
6	R	60.59	39.33	48.80
	W	39.40	60.66	51.19
7	R	27.46	12.13	24.20
	W	72.53	87.86	75.79
8	R	17.91	9.92	15.07
	W	82.08	90.07	84.92
9	R	19.10	4.77	13.49
	W	80.89	95.22	86.50
10	R	26.86	12.5	18.65
	W	73.13	87.5	81.34

TABLE: 6.9.2.3.b.

LIGHT

Questions	R/W	Group A N = 335	Group B N = 272	χ^2 (Sig.level)
1	R	89	33	19.46 (0.01)
	W	246	239	
2	R	110	48	17.97 (0.01)
	W	225	224	
3	R	90	55	3.62 (NS)
	W	245	217	
4	R	58	31	4.18 (0.05)
	W	277	241	
5	R	199	82	45.54 (0.01)
	W	136	190	
6	R	203	107	27.14 (0.01)
	W	132	165	
7	R	92	33	21.55 (0.01)
	W	243	239	
8	R	60	27	7.79 (0.01)
	W	275	245	
9	R	64	13	27.79 (0.01)
	W	271	259	
10	R	90	34	19.03 (0.01)
	W	245	238	

TABLE: 6.9.2.3.c.

LIGHT

Questions	R/W	Group A N = 335	Group C N = 252	χ^2 (Sig. level)
1	R	89	50	3.58 (NS)
	W	246	202	
2	R	110	72	1.21 (NS)
	W	225	180	
3	R	90	64	0.188 (NS)
	W	245	188	
4	R	58	32	2.33 (NS)
	W	277	220	
5	R	199	106	17.3 (0.01)
	W	136	146	
6	R	203	123	(8.07) (0.01)
	W	132	129	
7	R	92	61	0.68 (NS)
	W	243	191	
8	R	60	38	0.80 (NS)
	W	275	214	
9	R	64	34	3.24 (NS)
	W	271	218	
10	R	90	47	5.41 (0.05)
	W	245	205	

TABLE: 6.9.2.3.d.

LIGHT

Questions.	R/W	Group B N = 272	Group C N = 252	χ^2 (Sig.level)
1	R	33	50	5.81 (0.05)
	W	239	202	
2	R	48	72	8.83 (0.01)
	W	224	180	
3	R	55	64	1.98 (NS)
	W	217	188	
4	R	31	32	0.19 (NS)
	W	241	220	
5	R	82	106	8.05 (0.01)
	W	190	146	
6	R	107	123	4.74 (0.05)
	W	165	129	
7	R	33	61	12.94 (0.01)
	W	239	191	
8	R	27	38	3.18 (NS)
	W	245	214	
9	R	13	34	12.14 (0.01)
	W	259	218	
10	R	34	47	3.77 (NS)
	W	238	205	

6.10. SUMMARY AND DISCUSSION

The application of the Scheffe Test (Table 6.9.1.2.) on the mean scores in the tests of Force, Energy, and Light shows that groups A, B and C are not significantly different from each other in each test. However, group A was found significantly different from groups B and C together in the Subset FS2.

The application of Chi-Square test on the results of Force, Energy and Light brings some kind of mixed results. The results of Force show that there is no difference in groups in most (6 in case of groups A and B; 6 in A and C and 8 in B and C) of the questions. But, the results of Energy show that groups A and B were significantly different in most (7 out of 10) of the questions. No difference was found in groups A and C in most of the questions (7 in this case), and also, the groups B and C were not significantly different in case of 8 questions. In case of Light, the results have shown that there was significant difference in groups A and B in 9 questions. No difference was found in groups A and C in the majority of the questions (7 in this case). Again, groups B and C were significantly different in 6 out of 10 questions.

A summary of Chi-Square Test results is presented in Table 6.10.1. The table shows that the ratio of significant differences between groups A and B is 19:1. The single difference in favour of B is at the 0.05 level; one such difference will be found on average in every 20 tests even with random results. Thus the finding of one

TABLE: 6.10.1.

Summary Table of χ^2 Test Results

Concept Areas	Comparison Groups											
	A V B				A V C				B V C			
	Favours A		Favours B		Favours A		Favours C		Favours B		Favours C	
	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01	0.05	0.01
Force (Tables 6.9.2.1.b 6.9.2.1.c 6.9.2.1.d)	0	4	0	0	1	3	0	0	1	0	1	0
Energy (Tables 6.9.2.2.b 6.9.2.2.c 6.9.2.2.d)	0	6	1	0	2	1	0	0	1	0	0	1
Light (Tables 6.9.2.3.b 6.9.2.3.c 6.9.2.3.d)	1	8	0	0	1	2	0	0	0	0	2	4

19:1

A > B

10:1

A > C

2:8

B=C(F,E)

C > B

(Light only)

such difference in 30 trials (10 tests for each concept) is well within the grounds of chance and may be dismissed. The summary table shows very clearly that at the individual question level, students taught by teachers in Group A do significantly better than students taught by Group B teachers.

The same superiority (10:1 ratio) is shown in the sets of comparisons between students taught by Group A and Group C teachers.

The summary table shows a different result in case of B to C comparisons. The table shows that on the concepts Force and Energy, there is an equal small number of significant differences in favour of each group. Again we note that the number of these differences is no greater than we might expect by chance alone in the 20 comparisons. We conclude therefore, that on Force and Energy, the treatment given to Group B teachers was no different in its effect to the treatment given to Group C.

In Light, the comparison favours pupils of Group C teachers. The superiority of Group C teachers might have occurred due to some unknown reasons.

Having discussed between-group differences at the individual question level, we now return to the results of the Scheffe Test. Why is it that this test shows only one between-group difference? Part of the answer undoubtedly lies in the conservative nature of the test itself. This coupled with the small sample size (only seven classes in each) makes it very difficult for a significant result to be

found. Another factor is the low scores on the tests, as we know tests lose their discriminating power when they are either very easy or, as in this case, rather difficult. This is not an argument in favour of easier tests. The tests have to remain "true" to the concepts being tested. Although the results would be more convincing if the Scheffe test results were different, they could not be expected to be so in this experiment.

The results of Study 3 show that the over all performance of students in each group was very low. This low performance might have been caused due to many factors.

Firstly, the teachers might have not been able to use the information from the workshops to teach the students more effectively. In other words, it can be said, that they might have been unable to transfer the ideas properly to the students under the conditions of the experiment. Many factors might have hindered their classroom teaching. Also, the time devoted to each concept was very short; only two periods, each of about 40 minutes, were spent on each concept.

Secondly, when the students were retaught, the summer vacation was about to start. Therefore, it was possible that students did not take this teaching activity as seriously as they would have done at another time.

Thirdly, the students were not used to the objective test questions. Although every effort was made to explain the test pattern, yet many might have difficulty in

answering the questions. As a result, they might have ticked any of the responses without any understanding.

Fourthly, there was a possibility of non-seriousness of students while taking the tests. Similar problem has also been reported by Watts (1983), when he tried to gather students' written responses to the frameworks. Watts writes: "the responses received in this way were cursory, often in the extreme. Few gave any other response other than a 'yes' to each of the questions (some simply ticked each one)." A similar pattern was noticed in the present study in the case of a few students.

Fifthly, the tests might have been difficult (as said earlier) for this level of students, and this is clear from the low F and D values (see Appendix I) of the test-items selected for these tests. The difficulty might have been caused by the content used in the test items, or it may be due to the entirely new test format.

Sixthly, there was a possibility that the science textbooks which were used by students might be containing misconceptions. Although concepts were retaught by the teachers with an aim to modify children's misconceptions, classroom teaching might have been less effective as compared to the impact of textbooks on children's ideas. This is because of the fact that they rely heavily on textbooks.

Although, the performance of students in each group has been very low, the significant difference between groups A and B and A and C in favour of 'A' group at the

individual question level on Chi-Square Test (Table 6.10.1.); and the significant difference between groups A and B and C together in Subset FS2 on Scheffe Test (Table 6.9.1.2.) is very encouraging. If we consider groups of items in Table 6.9.1.1., Subset FS2 consists of items constructed to test the misconceptions: 1) the force is embedded in the objects (one item), 2) there is no gravity on the moon (2 items) and 3) greater force acts on the lit torch (one item). The significant difference between groups shows that the treatment (i.e. training) could cause difference in performance only in one small set of items. This result shows that it is comparatively easier to modify this set of misconceptions as compared to other misconceptions which seem to be more strongly linked to the cognitive structures of students because of their common experience, that is why it is so difficult to dissociate them from their main structures.

Further, the performance of group C which was found to be higher (although on Light only) than the group B looks strange. This result might have been caused by some "random events" (Peckham, Glass and Hopkins, 1969) both internal and external to the groups.

As described earlier in section 6.2. of this chapter, only 21 teachers were involved in this study and there were only 7 teachers (or schools) in each group. The results are based on a very small sample as compared to the usual recommended size. Garrett and Woodworth (1967)

suggest 25; Petrinovich and Hardyck (1972) suggest 10 as the minimum sample size. The researcher feels that for this type of study, it was quite a reasonable sample; because as described earlier, it was not possible to increase the size of the sample and handle a larger group of teachers and students.

Moreover, educationally speaking, we should not feel so much concerned with large sizes of the samples for the validity or the statistical significance of the results. Rather we should be interested in the improvement of instruction towards the better understanding of concepts of science in each and every school i.e. the educational significance of the findings. The aim should be to obtain educationally worthwhile improvements on each member (teacher) of every sample.

Even if some technique or methodology is successful only in one school, we should try to make use of it in other schools, because sometimes it might not be possible to get support from the statistical results for very good techniques only because appropriate size of the sample could not be managed by the researcher. Here, in the present study, the better performance of the experimental group (A) as compared to groups B and C does indicate the significance of results educationally.

These educationally significant results based on the empirical study suggest that teacher training programme developed for the purpose of present study has been successful, although to a limited extent. However, as

pointed out earlier in this section, if the factors which might have caused low performance are controlled, there is a possibility to get better results.

Also, the participants of the workshop could not see the demonstration of ideas discussed in the workshop. As a result, teachers might have faced difficulty in the application of these ideas. The researcher feels that if the demonstration of ideas is also arranged as part of the teacher training programme, ability of teachers to apply the ideas in the classroom might be increased.

The problems related to the administration of tests in special situations for the purpose of research might be controlled by integrating these tests with the normal school examinations. As far as the difficulty level of these tests is concerned, it was restricted by the criterion nature of these tests, therefore, as said earlier, easier tests might have lost their significance.

The results of the present study proved a limited success of the teacher training programme. These results show that Study 2 was reliable. However, the study has shown that teacher training programmes can be organized for science teachers with an aim to enable them to modify children's misconceptions in science. On the basis of these results the researcher strongly feels the need of a more systematic and organised research programme, using the present study as a base, for the improvement of science teacher education and science education in the country.

CHAPTER VII

DISCUSSION AND IMPLICATIONS OF RESEARCH FINDINGS FOR SCIENCE

EDUCATION IN PAKISTAN

CHAPTER VII

DISCUSSION AND IMPLICATIONS OF RESEARCH FINDINGS FOR SCIENCE
EDUCATION IN PAKISTAN

7.1. SUMMARY

The study involved investigation of Pakistani children's misconceptions in selected concept areas in Physics. The investigations were carried out using the IAI approach on the concepts of Force, Energy, Light, Work and Electric Current. The samples were the 8th class students with an age range of 11 - 14 years. The results of these investigations (Study 1) showed that Pakistani children of this age hold misconceptions in the chosen areas that are qualitatively and quantitatively similar to those held by children in other parts of the world.

In order to determine whether or not science teachers in Pakistan have misconceptions in science, three groups of teachers were tested using a paper-and-pencil test. It was shown that a majority of the teachers hold misconceptions similar to those of their students.

Later on, a sample of teachers of 8th class students were given extra training and asked to re-teach three concepts: Force, Energy and Light to their students. After the re-teaching, students were retested using both the IAI approach and specially designed multiple-choice tests (Study 2). The IAI results have shown that similar

misconceptions were retained by the students despite re-teaching. Statistically, no significant difference was found in the statements given by them during interviews held before and after re-teaching the concepts Energy and Light. However, some negative difference was found in the statements given by sample of Study 2 students in case of the concept Force. The results of the paper-and-pencil tests show that most of the questions were answered wrongly by the majority of the students thus confirming the continued existence of incorrect or only partially correct concept patterns after the re-teaching.

From this preliminary study, a teacher training programme was developed to train a larger number of teachers for re-teaching the 3 concepts (Study 3). This part of the study was aimed at discovering whether an in-depth one day teacher training on children's misconceptions can lead to more effective teaching. As part of this experiment, over 800 students were tested using multiple choice paper-and-pencil tests. The results of Scheffe Test showed that there was no significant difference between the groups in each comparison except one. The group A which was given in-depth training, was found significantly different from groups B and C together in one of the subsets of test items in the concept area Force. The results of Chi-Square Test have shown that there was significant difference between groups A and B and A and C in favour of 'A' group at the individual question level. Also, a little training (Group B)

shows no improvement over no training (Group C). Indeed, it seemed worse on Light. Although, it was limited success, but the study has shown that it is possible to organise teacher training on children's misconceptions in science.

The present study is consistent with the Ausubelian strategy that the most important single factor influencing learning is what the learner already knows. The study attempted to explore children's misconceptions, trained the teachers to reteach chosen concepts when children's misconceptions are known. This study also confirms Nussbaum's (1981) findings that without specific training to deal with children's misconceptions, teachers cannot apply their knowledge in the classroom, even when they are experienced (in contrast to Nussbaum's pre-service teachers) and motivated.

The present study suggests that i) teachers require specific training to deal with children's misconceptions; ii) programmes of longer duration will be required to impart this training, because as shown by Study 3, a short programme of teacher training does not prove to be entirely successful in bringing about the desired changes; and, iii) demonstration of the ideas should be incorporated as an integral part of the teacher training programme; so that teachers can apply the ideas effectively after training. Attention has also been drawn to this important point by Northfield and Gunstone (1983) saying that 'making student teachers aware of the existence of alternative frameworks

in their own and their pupils' thinking is not a difficult task; but dealing with the implications for their later teaching roles provides a further (and perhaps greater) challenge. Keeping this challenge in view, the researcher strongly feels the need of a better research programme for the training of teachers. A project to devise, trial and evaluate such a programme of teacher training is a matter of some importance.

7.2. DIRECTIONS FOR SCIENCE EDUCATION IMPROVEMENT IN PAKISTAN

The proper training of science teachers is important because of the teachers' role not only in direct classroom teaching, but also in other educational activities such as curriculum development, text-book writing, examinations, etc. There is not just one problem area but three which need attention if children's alternative views/misconceptions are to be taken into account. These are, 1) the science textbooks, 2) teacher's own conceptions of the science concepts, and 3) the methodologies used in the classroom.

Although, textbook writing is done one way or the other by the teachers, only a few are involved in this job. The other two problem areas, however, are directly related to each and every teacher and have a direct impact on children's understanding of new concepts. Only if the teachers are made aware of children's naive ideas and beliefs, and if their own knowledge of the subject matter

and teaching methods are improved, is there a possibility of improvement in the teaching and learning of science in Pakistan as elsewhere.

This upgrading of teachers is not likely to be an easy task. It will require planned, directed and organised effort supported at national level and sustained over several years. Keeping this challenge in view, the researcher strongly feels the urgent need of a project with the overall purpose of helping the teachers of science in Pakistan.

7.2.1. AIMS OF THE PROJECT

Within the overall purpose of helping the science teachers, three broad aims for a Science Teacher Training Programme can be identified:

1. Improvement of teachers' subject matter knowledge
2. Dissemination of knowledge about effective alternative teaching methods.
3. Revision of curriculum materials.

In order to achieve these broad aims, the proposed project will need to follow a phased programme emphasizing mainly on teacher training. Curriculum materials will be produced at each stage on the basis of the feedback obtained from the teacher training programmes and classroom teaching. After a period of use of the materials on a sufficiently large scale, new or revised school textbooks will be required.

A project such as that described could be based at the Science Education Centre, Institute of Education and Research, University of the Punjab, Lahore. As described earlier in Section 7.1. of this chapter, the present study has shown that Pakistani children hold misconceptions similar to those held by children in other parts of the world. Therefore, for this project, a useful composition of the project team will be a few consultants from overseas and some local science educators. The presence of the overseas consultants on the project team will be most helpful for three main purposes:

- 1) they will provide expertise to the project;
- 2) they will bring the latest materials with them which is useful for the project implementation and for the guidance of the local staff;
- and 3) they will be a source of motivation for the local science educators, and because of this motivation they might initiate other useful activities later on.

The presence of the local science educators on the team will be necessary because these are the persons who will be responsible for further dissemination of the materials and programmes.

An overview of the project programme with the proposed aims might be phased as follows.

7.2.2. AN OVERVIEW OF THE PROJECT

As stated earlier, the overall purpose of this project will be to help the teachers of science in Pakistan. In order to achieve its broad aims, the proposed project will follow a phased programme consisting of three stages (see Table 7.2.2.).

In Stage 1, the project team consisting of local science educators and foreign experts will be divided into three groups - the Research group, a group to deal with Teacher Training and a third group to produce materials. The project team will, first or all, hold a seminar for local science educators for their orientation about the project plan and the recent research work in the field of children's misconceptions in science.

After that, a training workshop will be held for the science educators involving science teachers as participants.

In Stage 2, the trained science educators will organise workshops for the training of science teachers. Curriculum materials will be developed and revised on the basis of the feedback obtained from these workshops.

The science teachers who have participated in the workshops will go for classroom teaching; science educators will observe the activities. Materials will be revised in the light of the feedback obtained from the classroom teaching.

TABLE: 7.2.2.

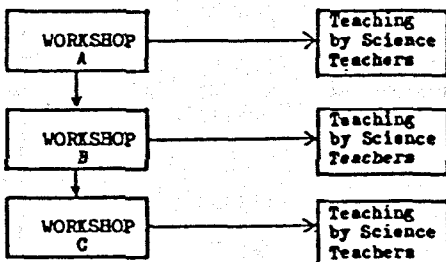
<p>STAGE 1</p> <p>SCIENCE EDUCATION PROGRAMME</p> <p><u>Aim:</u> To organise a programme for the training of Science Educators</p>	
<p>Research Seminar for Science Educators</p>	<p>Training Workshop for Science Teachers</p>
<p><u>Outcomes:</u></p> <ol style="list-style-type: none">1. A team of Science Educators to run workshops.2. A research team to further use IAY etc.3. An Evaluation group.	

THE PROJECT PROGRAMME

STAGE 2

WORKSHOPS FOR THE SC. TEACHERS

Aim: To organise workshops for the training of Sc. Teachers and development of curriculum materials



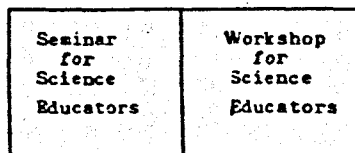
Outcomes:

1. Trained Science Teachers
2. Basis for developing curriculum materials.

STAGE 3

DISSEMINATION

Aim: To disseminate the T.T. programme and the Materials to other centres



Outcomes:

1. Trained science educators to train the teachers further.
2. Tryout of the material developed at Stage 2.

In Stage 3, the project team will hold a seminar and a workshop (like Stage 1) for local science educators at a new centre, using the materials developed in Stage 2. The local science educators will organise workshops for the training of local science teachers.

7.2.3. THE PROJECT PROGRAMME

The project programme consists of three stages: These are described as below:

STAGE 1 - SCIENCE EDUCATORS PROGRAMME

This programme will consist of two parts - a Research Seminar and a Training Workshop for the science educators.

THE RESEARCH SEMINAR

In the first instance, the project team will organise a seminar for the local science educators involved both in the pre-service and in-service teacher education. Only those science educators will be involved who are experienced and have adequate background of educational psychology. The main aim of this seminar will be to make the selected science educators aware of the recent advances in science education and to identify local needs. This seminar will also explain the nature as well as the activities of the project.

THE TRAINING WORKSHOP

The next step in the programme should be a workshop organised by project team for the training of Science Educators. They will not participate in the workshop activities, but instead only observe the workshop sessions just to see how the activities are organised. Participants of the workshop will be the science teachers from the local schools. The duration of this workshop should be one week. This length is necessary because the empirical evidence from the research studies described earlier indicates that any short programme of teacher training does not suffice. Study 2 showed that a short teacher training programme, and thereafter shorter reteaching programmes for the students even under the most favourable conditions does not improve their conceptions. The one day programme (Study 3) showed some significant difference between the three groups of students. Better student results of fully informed group of teachers do indicate some positive effect of teacher training. These findings show that a longer teacher training programme is needed to enable teachers to deal with the children's misconceptions more effectively.

The main aims of this one week workshop will be to make the science educators aware of the recent research work, its implications for the teaching of science, and to enable the teachers to deal with the children's ideas effectively.

During this one week workshop, the main teaching strategy used by the project team will be based on Lectures with practical demonstrations and participatory discussion. Within this overall strategy, the general guidelines described in the previous section will also be followed.

Mainly, the lecture programmes of this workshop will be similar to the one used by the researcher and described in Chapter VI. However, as it will be a more extensive programme, more time will be available to the participants to improve their subject matter knowledge and the knowledge of the more effective teaching strategies for improving the children's ideas.

Main themes to be discussed in the workshop are given in Table 7.2.3. (See page 304)

TABLE: 7.2.3.

THE WORKSHOP THEMES

Sr.No.	Themes
1.	Recent research concerning children's misconceptions-general background and methods/techniques used worldwide and in Pakistan to explore children's ideas.
2.	Worldwide effort to improve children's ideas with special reference to Personal Construction of Knowledge Group, LISP, CLISP and other selected research studies including Pakistan.
3.	Review of research findings related to children's ideas in various concept areas.
4.	Review of research findings related to teachers' ideas.
5.	Ausubel's Theory of Learning as it related 'Meaningful' Learning and 'Rote' Learning.
6.	The Teaching and Learning of Science Concepts.
7.	Interaction and outcomes of children's and teachers' ideas along with examples of lessons that worsen children's misconceptions.
8.	Diagnosis of children's misconceptions.
9.	Contrasting children's ideas and Scientists' ideas.
10.	Implications of recent research for future science education in Pakistan.

OUTCOMES OF THE STAGE 1 PROGRAMME

The outcomes of this programme will be

- i. a team of Science Educators trained to run workshops for the science teachers.
- ii. a research team to further apply IAI and other such techniques.
- iii. a group to evaluate the training workshops and classroom teaching.

After the workshop, the science educators will go back and organise similar workshops for the science teachers.

STAGE 2 - WORKSHOPS FOR THE SCIENCE TEACHERS

In this stage, the trained science educators will hold three workshops - A, B and C.

The workshop A will be organised on the similar lines as it was done in the workshop organised in Stage 1. Science teachers from the local schools will participate in this workshop. Although it will be a teacher training workshop, it will also provide a basis for the development of curriculum materials. This workshop will be of one week duration and will be observed by the experts from the project team. The trained teachers will go to their schools for classroom teaching and use the materials supplied to them. The preparation of materials in this stage will involve:

- 1) background materials, 2) diagnostic/survey materials,
- 3) Materials containing activities for the teachers/trainees,
- 4) Materials containing activities for the participants/students,
- 5) Evaluation materials.

The background materials should include some background reading concerning the recent advances in science education, research findings, research methodology, etc. The diagnostic (as used by Nussbaum, 1981)/Survey (as used by LISP Teams) materials will contain questions/items to diagnose the preconceptions of the participants/students whatever the case may be. Wherever possible, materials will be adopted from the work of LISP, CLISP, and other researchers. The purpose of these materials will be to help the trainers/teachers to diagnose/survey the misconceptions of the participants/students, or to use them as pre-tests and post-tests (Schollum, et al, 1981) so that they could evaluate the success of their teaching approach. The materials will contain less IAI, more written and more oral questions.

The materials containing activities (similar to those used by LISP teams) for the teachers/trainers or students/participants will be useful for them in their own teaching and training programmes later on.

As the project will include formative (on-going) evaluation, the evaluation materials will consist of instruments such as tests, questionnaires, observation schedules or interviews. As argued by Gronlund (1981), the

formative evaluation is used to monitor learning progress during instruction. Its purpose is to provide continuous feedback to both pupil and teacher concerning learning successes and failures. Feedback to pupils provides reinforcement of successful learning and identifies the specific learning errors that are in need of correction. Feedback to the teacher provides information for modifying instruction and for prescribing group and individual remedial work. For the purpose here, the main aim of formative evaluation is to provide feedback to the project team, so that the teacher training programme and the materials developed for this purpose could be revised.

Keeping in view the purpose of evaluation, the instruments developed will be criterion-referenced, because as argued by Gronlund (1981) again, the functions of formative evaluation are likely to be best served by criterion-referenced instruments. Here also the instruments used by other researchers will be utilized wherever possible.

The trained teachers will go to their schools after the workshop for classroom teaching. They will use the materials supplied to them for the purpose. Classroom teaching will be observed by the members of the project team.

In the light of the feedback obtained from the Workshop organised by the Science Educators and the classroom teaching by trained Science Teachers, the project team will revise the lecture plans and the materials produced.

With the revised lecture plans and the materials another Workshop (B) will be organised by the Science Educators for another group of science teachers. After the workshop, trained teachers will go for teaching in their own schools. Both the workshop and the classroom teaching will be observed by the project team. Again, the materials and lecture plans will be revised on the basis of the feedback.

The revised materials and lecture plans will be used in another workshop (C) to undergo another cycle of revision. At the end of this stage, materials will be ready for the Science Educators to hold Science teaching workshops, and for Science teachers for classroom teaching. After a use of these materials on a sufficiently large scale, the existing textbooks will be revised using these materials.

STAGE 3 - DISSEMINATION

When the materials are ready at the end of Stage 2, the programme of teacher training and the materials developed under the project will be disseminated to other centres. Like Stage 1, seminars will be held to introduce the materials developed in Stage 2. Talks/discussions will be held by the visiting Science Educators of the project team.

Then, a workshop will be organised for the science educators similar to the one organised in Stage 1. Those Science educators who participated in this programme

will organise workshops for the training of science teachers.

Similar programmes will be held at other centres. The project team will follow up. After the materials have been used sufficiently, the project team will revise the textbooks again. Afterwards, there will be a programme of continuous follow up either by the government or the project team.

The programme described appears to offer a practicable, cost-effective means of tackling the training of science teachers.

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APPENDIX A

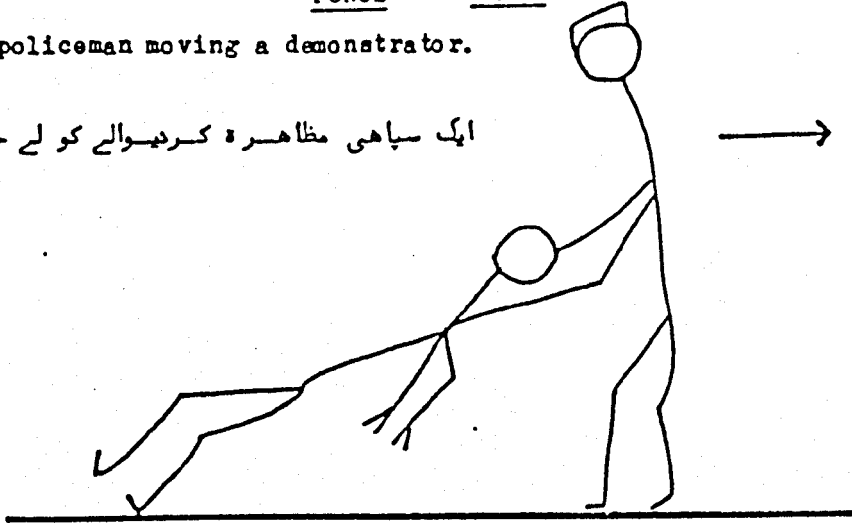
WORKING PAPERS OF THE LEARNING IN SCIENCE PROJECT

(1979 - 1982)

- | | | | | |
|--------------------------------|---------------------------------|--|--|--|
| 1. An initial framework | 14. Reconsidering the framework | 28. The framework: Toward Action Research | 39. Visit to a classroom No.2 | 51. Video: Animals |
| 2. Focus on Experiments | 15. Living | 29. Toward Solutions: The work of the Biology Action-Research Group | 40. Visit to a classroom No.3 | 52. Video: Electric current |
| 3. Focus on Knowledge | 16. Force | 30. Animals, Plants and Living: Notes for Teachers | 41. Visit to a classroom No.4 | 53. Video: Force |
| 4. Focus on Topics | 17. Energy | 31. Teaching about Animal, Plant and Living, Part I/II (2 papers) | 42. Portraying children's classroom experiences | 54. Video: Activities |
| 5. Focus on the Teacher | 18. Particles | 32. Toward Solutions: The Work of the Physics Action-Research Group | 43. Children's views and classroom experiences | |
| 6. Focus on the Learner | 19. Friction | 33. Force, Friction and Gravity: Notes for Teachers | 44. Working in classrooms | <u>NOTES</u> |
| 7. Focus of Process Skills | 20. Gravity | 34. Teaching about Force | 45. Interviewing children | (a) Papers of direct relevance to practising teachers, No.31,32,33,34, 36-38,45,47-49. |
| 8. Focus on the Syllabus | 21. Weather | 35. Towards Solutions: The Work of the Chemistry Action-Research Group | 46. Toward solutions: The work of the Activities-Action Research Group | (b) Paper 30 covers aspects of Papers 15, 22 and 24. |
| 9. Focus on Attitudes | 22. Animals | 36. Burning | 47. Science Activities: the Problem | Paper 33 covers aspects of Papers 16, 19 and 20. |
| 10. Focus on the Classroom | 23. Light | 37. Reactions | 48. Science Activities: specific problems, some solutions | Paper 36 covers aspects of Papers 18 and 27. |
| 11. Focus on Written Resources | 24. Plants | 38. Heating and Cooling | 49. Science Activities: Wider issues, some considerations | Paper 38 covers aspects of Paper 26. |
| 12. Focus on Equipment | 25. Electric current | | 50. Outlook on Science | |
| 13. Visit to a Classroom | 26. Physical change | | | |
| | 27. Chemical change | | | |

1. Police A policeman moving a demonstrator.

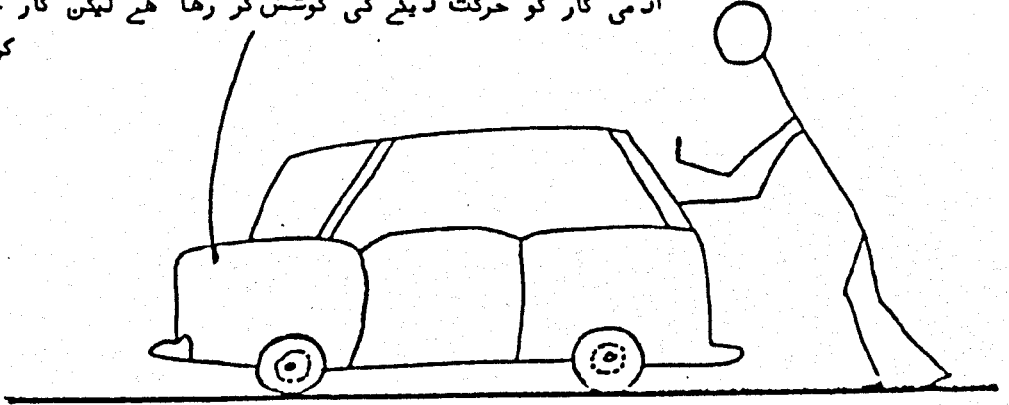
ایک سپاہی مظاہرہ کر دیوالے کو لے جا رہا ہے۔



کیا مظاہرہ کرنے والے پر کوئی قوت عمل کر رہی ہے؟

2. Car I A man is trying to move the car but the car is not moving.

آدمی کار کو حرکت دینے کی کوشش کر رہا ہے لیکن کار حرکت نہیں کر رہی۔



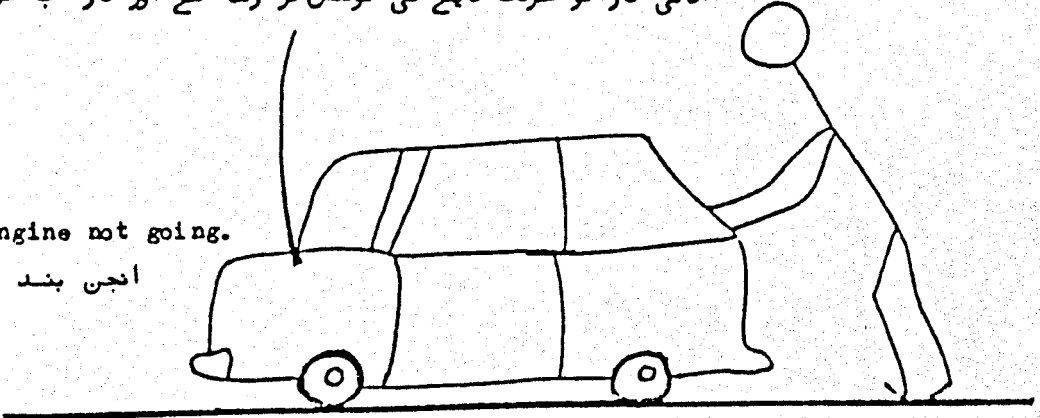
کیا کار پر کوئی قوت عمل کر رہی ہے؟

3. Car II

The man is trying to move the car and the car is now moving.

آدمی کار کو حرکت دینے کی کوشش کر رہا ہے اور کار اب حرکت کر رہی ہے

Engine not going.
انجن بند ہے

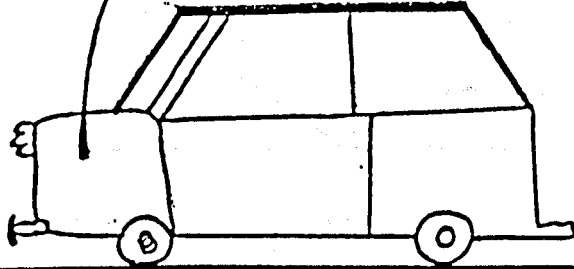


کیا کار پر کوئی قوت عمل کر رہی ہے؟

4. Car III

The car is speeding up from the traffic lights.

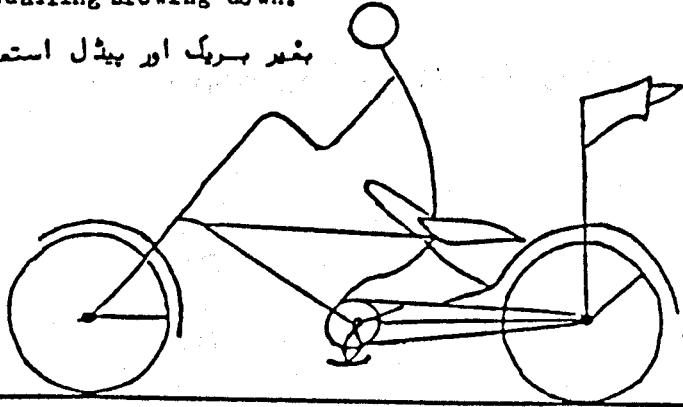
کار کی رفتار چڑھانے کی باتوں کے پاس سے گزرنے کے بعد تیز ہو رہی ہے -



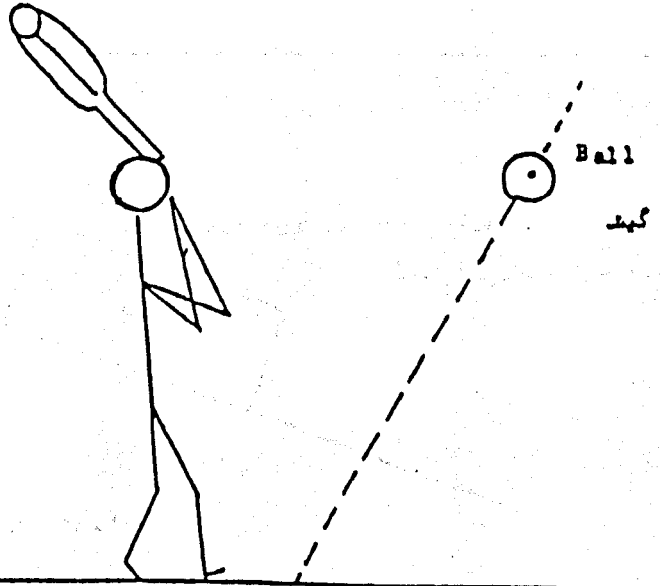
Is there a force on the car? کیا کار پر کوئی قوت عمل کر رہی ہے ؟

5. Bicycle No brakes no pedalling slowing down.

بغیر بریک اور پیڈل استعمال کئے سائیکل کی رفتار کم ہو رہی ہے -



Is there a force on the bicycle? کیا سائیکل پر کوئی قوت عمل کر رہی ہے ؟

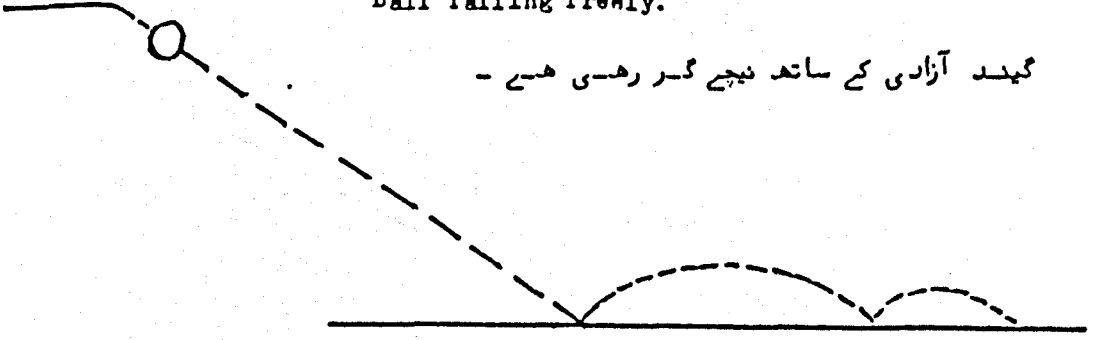
6. Cricket I

Is there a force on the cricket ball? کیا گیند پر کوئی قوت عمل کر رہی ہے ؟

Cricket II

Ball falling freely.

گیند آزادی کے ساتھ نیچے گر رہی ہے۔



Is there a force on the cricket ball? کیا گیند پر کوئی قوت عمل کر رہی ہے ؟

Ball I

گیند پکسان رنٹار کے ساتھ لڑھک رہا ہے۔ Ball rolling at a steady speed.

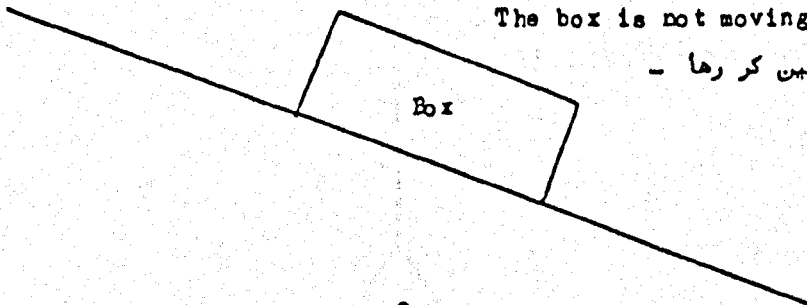


Is there a force on the ball? کیا گیند پر کوئی قوت عمل کر رہی ہے ؟

Box

The box is not moving.

ٹپہ حرکت نہیں کر رہا۔



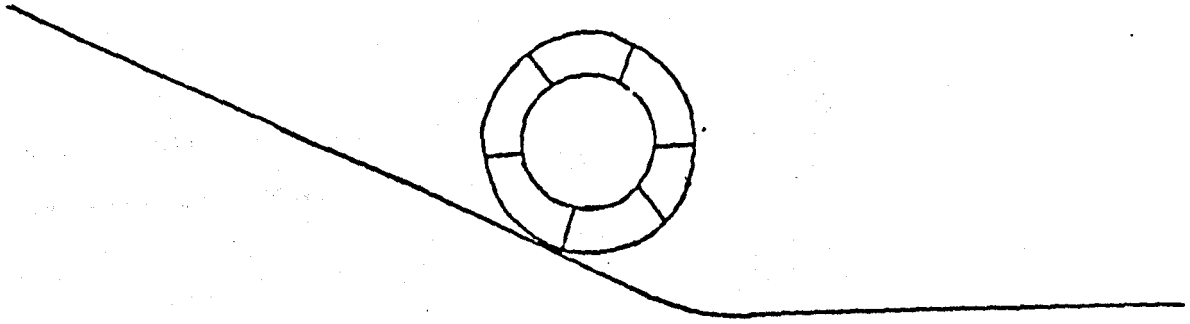
Is there a force on the box?

کیا ٹپہ پر کوئی قوت عمل کر رہی ہے ؟

Ball rolling down slope and speeding up.

10. Ball II

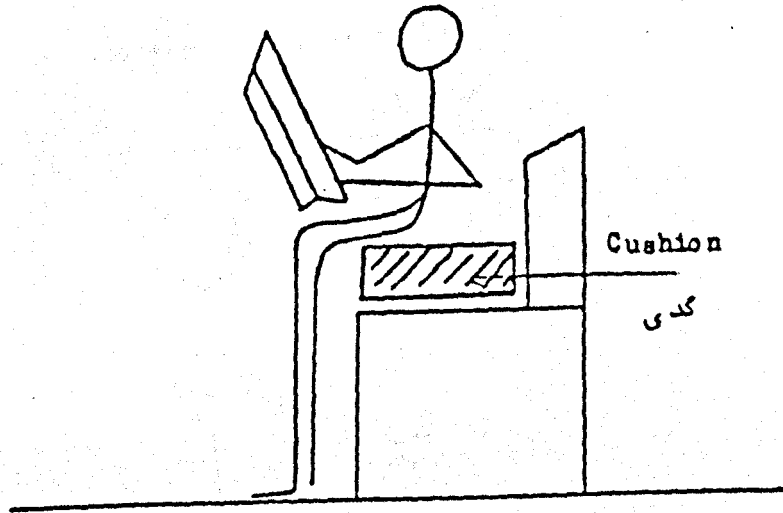
گیند ڈھلوان سطح پر سے نیچے لڑھک رہا ہے۔



Is there a force on the ball?

کیا گیند پر کوئی قوت عمل کر رہی ہے؟

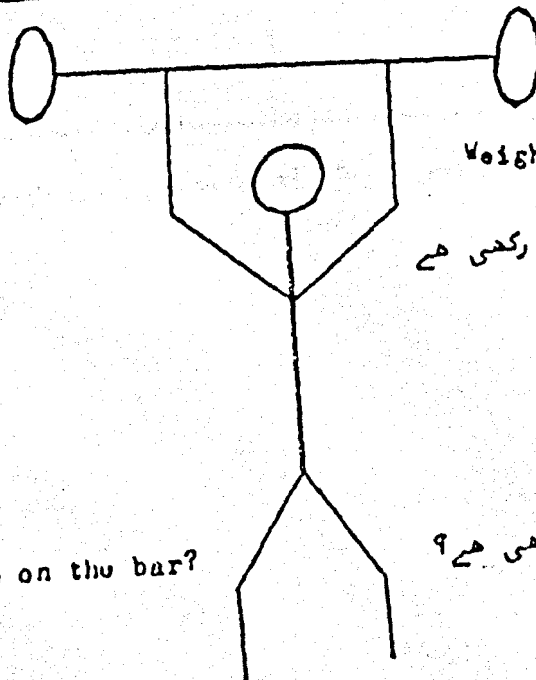
11. Cushion



کیا گدی پر کوئی قوت عمل کر رہی ہے۔

Is there a force on the cushion?

12. Weight Lifter



Weight lifter holding bar steady

ویٹ لفٹر نے ساکن وزنی سلاخ اٹھا رکھی ہے

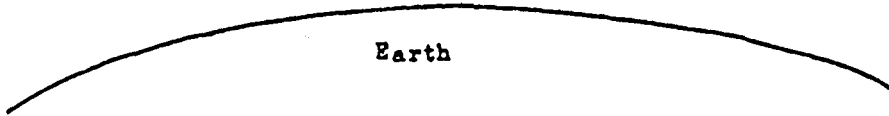
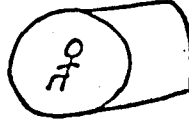
Is there a force on the bar?

کیا سلاخ پر کوئی قوت عمل کر رہی ہے؟

13. Satellite

Man in a satellite going around the earth.

ایک آدمی مصنوعی سیارے میں زمین کے گرد حرکت کر رہا ہے۔



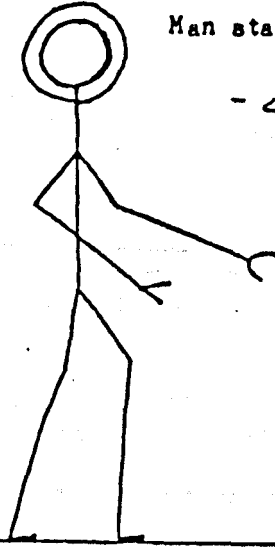
Is there a force on the man in the satellite?

کیا سیارے پر موجود آدمی پر کوئی قوت عمل کر رہی ہے؟

14. Moon

Man standing on the moon.

آدمی چاند پر کھڑا ہے۔

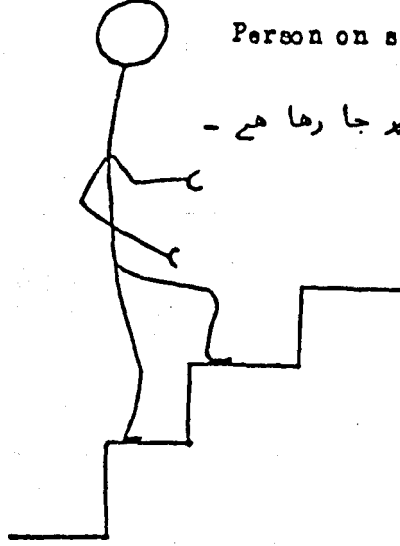


Is there a force on the man? کیا آدمی پر کوئی قوت عمل کر رہی ہے؟

1. Person on stairs

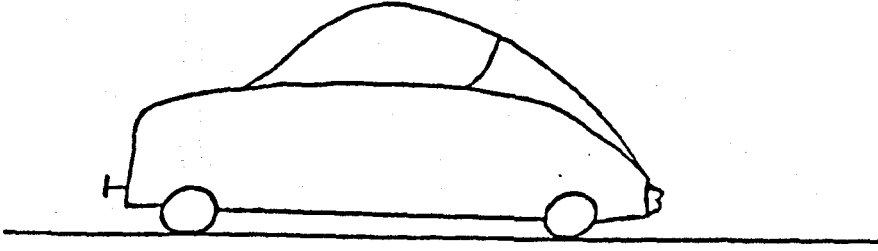
Person on stairs.

آدمی سیڑھیوں پر جا رہا ہے۔

2. Car

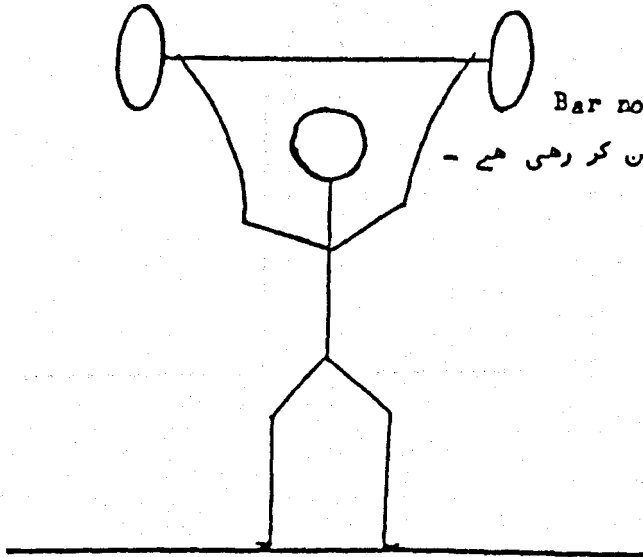
Car moving along the road.

ر سڑکی پر جا رہی ہے۔

3. Weightlifter

Bar not moving.

بار حرکت نہیں کر رہی ہے۔



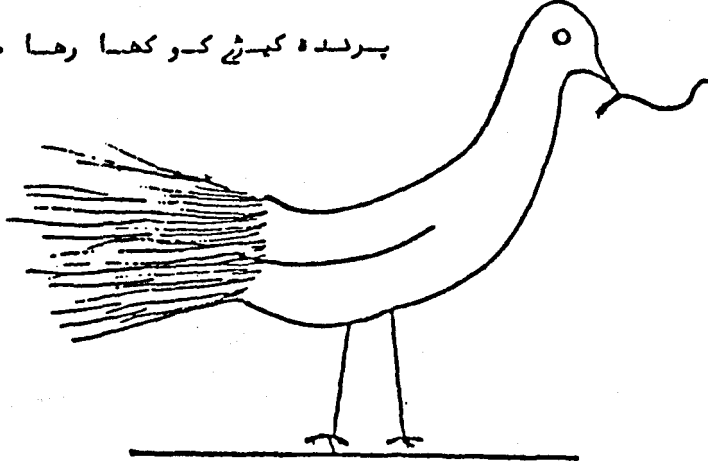
Weightlifter holding a bar stationary over his head.

وہٹ لفٹر نے ساکن بار سر سے اوپر اٹھا رکھی ہے۔

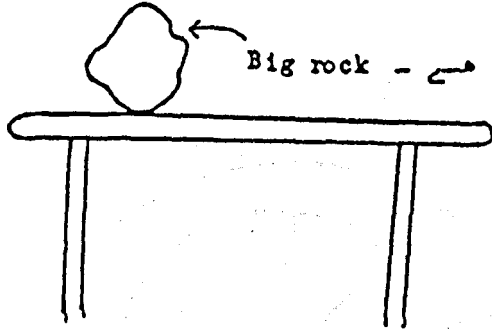
Bird eating worm.

4. Bird

پرندہ کبڑے کو کھا رہا ہے۔

5. Rock on Table

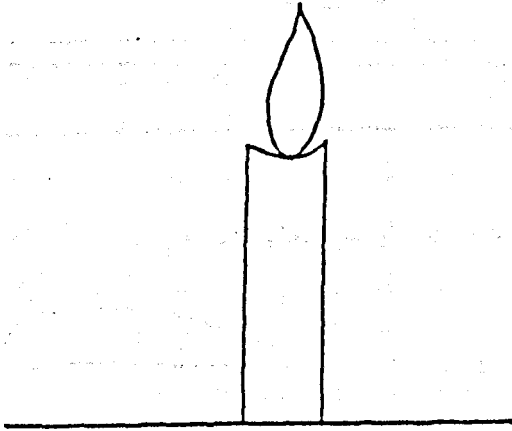
Rock on table.



مذکے اید ایک پتھر کا عڑا پڑا ہے۔

6. Candle

Burning candle۔ سووم ہتی جمل رہتی ہے



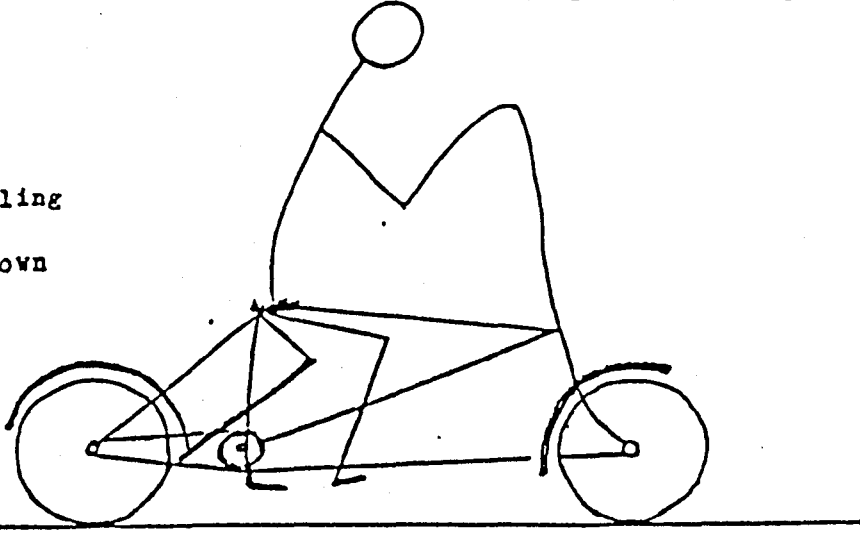
7. Bicycle

Bicycle slowing down.

ہائیکل کی رفتار کم ہو رہی ہے۔

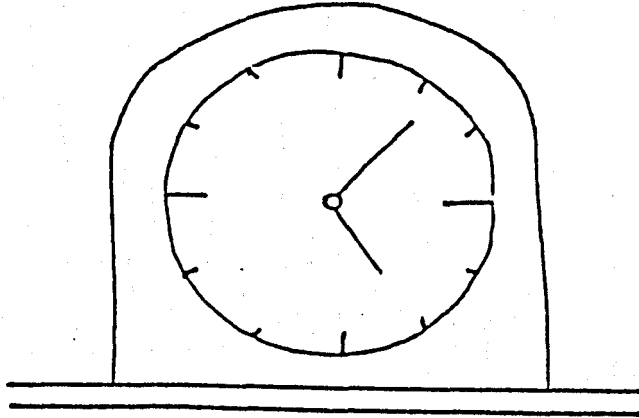
No pedalling
No Brakes
Slowing down

ہائیکل کے پدال تو ہریک
استعمال ہو رہے ہیں
تہ ہیل استعمال ہو
رہے ہیں لیکن ہائیکل
کی رفتار آہستہ ہو رہی

3. Clock

Wind up clock.

چاسی والی گھنٹی

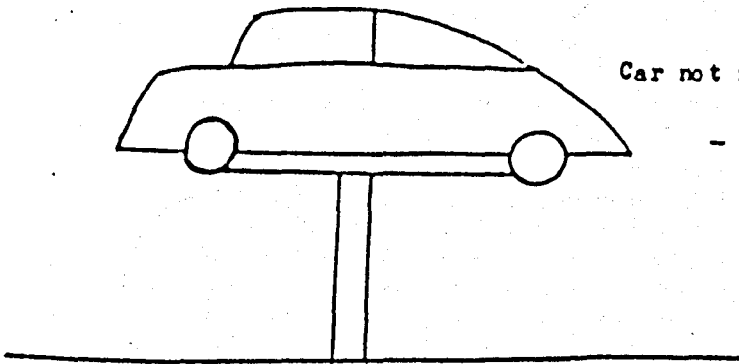
9. Car on Jack

Car on Jack.

گاشی کو جیک کی مدد سے اوپر اٹھایا گیا ہے۔

Car not moving.

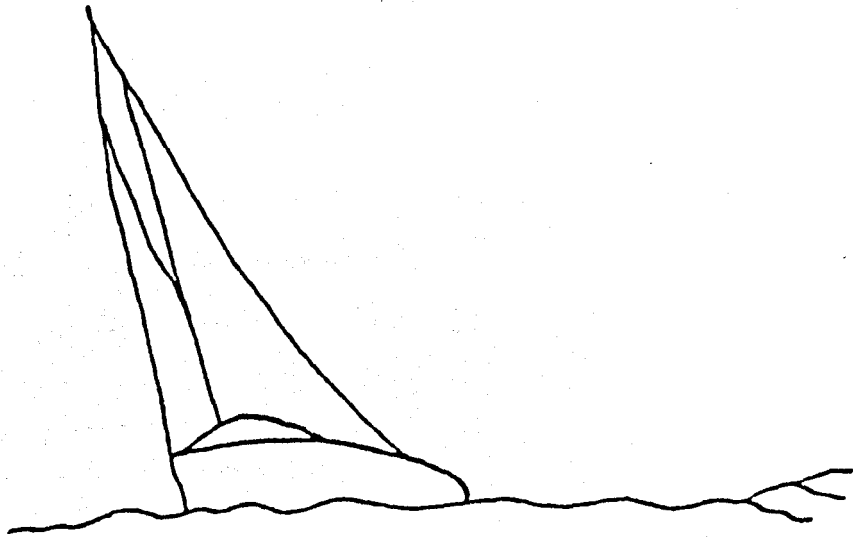
گاشی حرکت نہیں کر رہی ہے۔



10. Yacht

Yacht

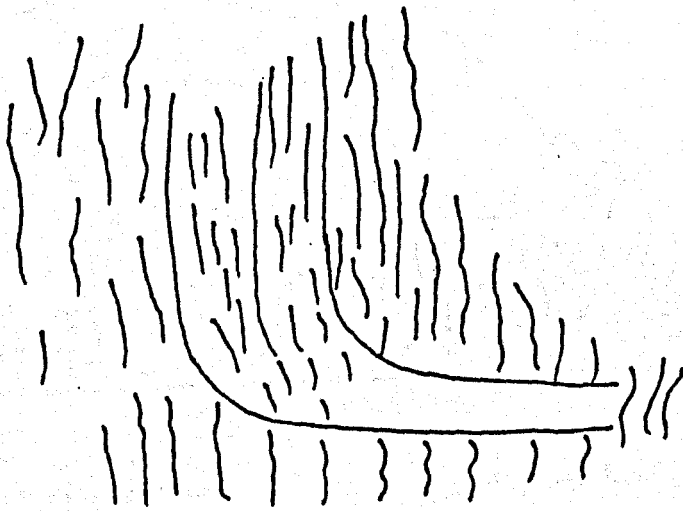
کشتی



11. Waterfall

Water Fall

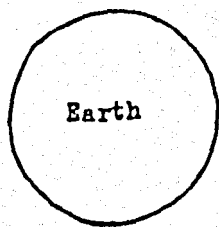
آبشار



12. Moon & Earth

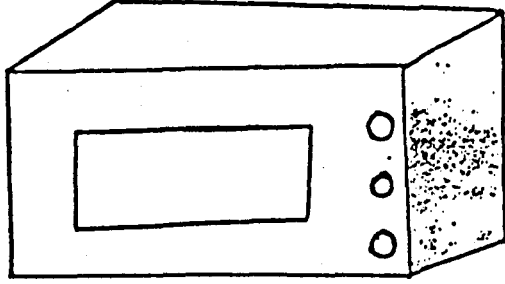
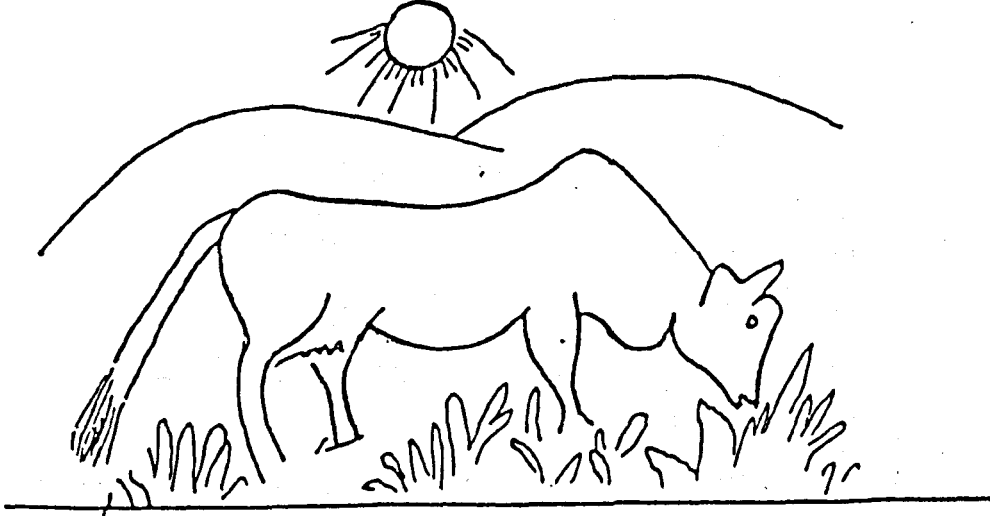
Moon and Earth.

چاند اور زمین



13. Television

Television. ٹیلی ویژن

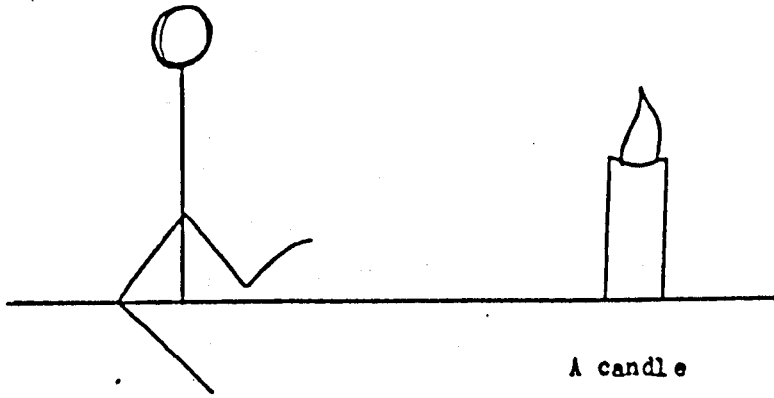
14. Cow

Cow eating grass.

گائے گھاس کھا رہی ہے -

1. A Candle

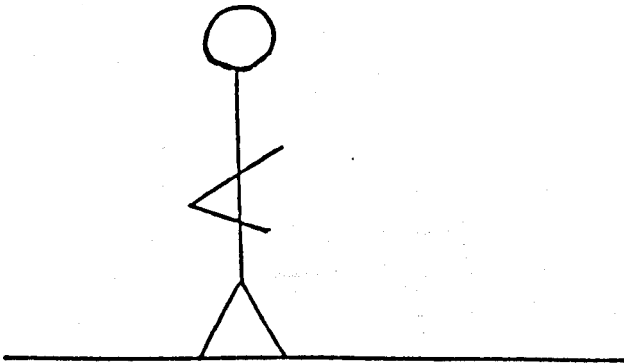
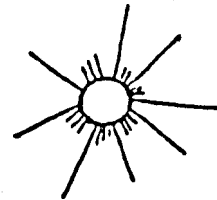
روشنی



A candle

موم ہتی

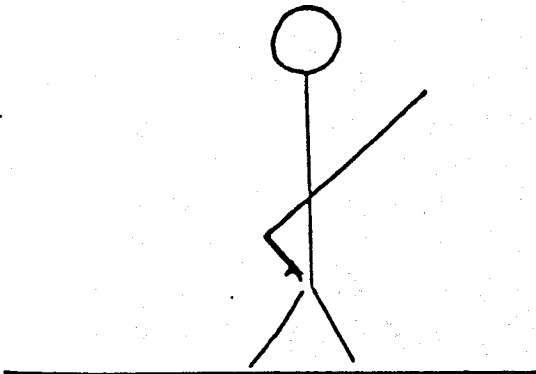
2. The Sun



The Sun

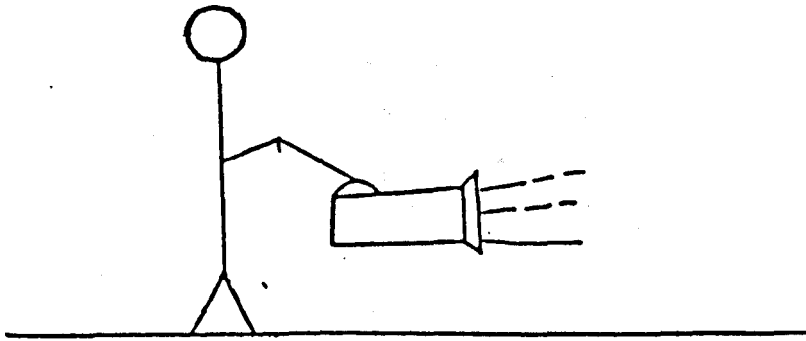
سورج

3. The Moon

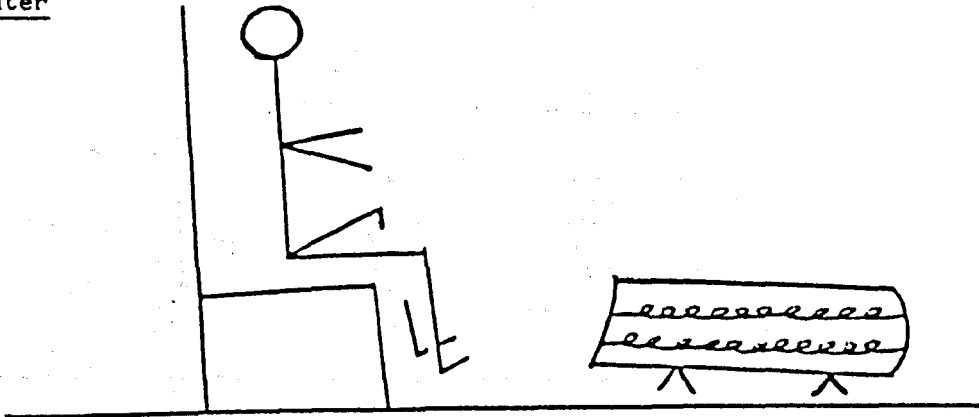


The Moon.

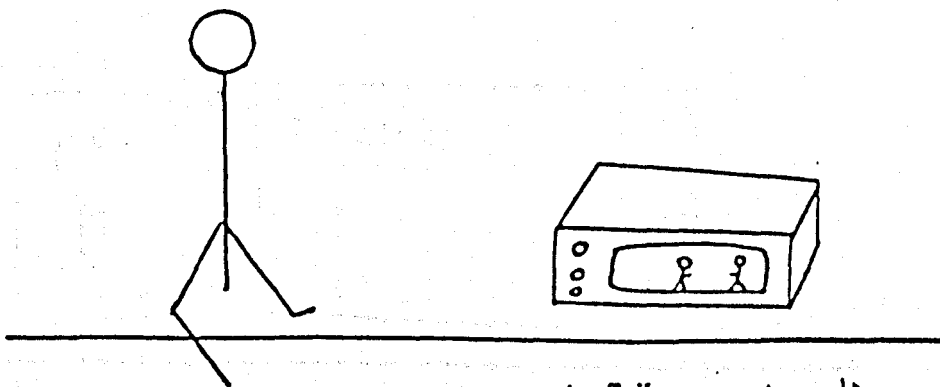
چاند

4. A Torch

A Torch. تارچ

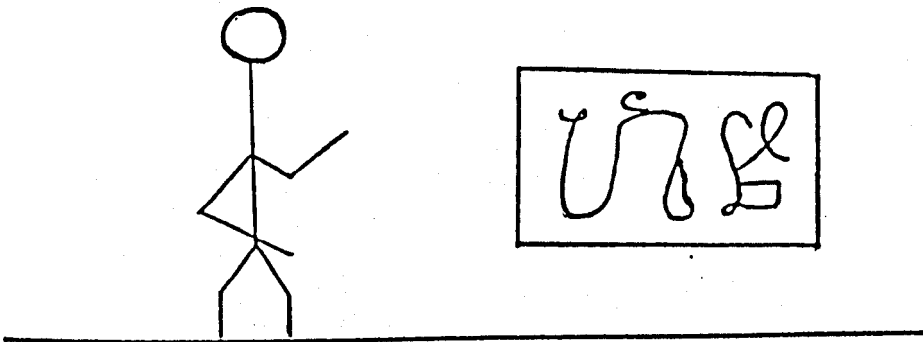
5. An Electric Heater

بجلی کا ہیٹر An Electric Heater

6. Television

A T.V. ٹیلیوژن

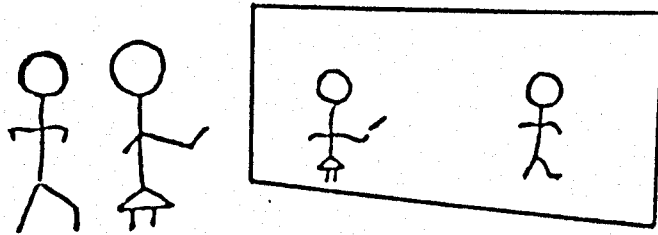
7. Bright Red Painting



A Bright Red Painting.

تصویر

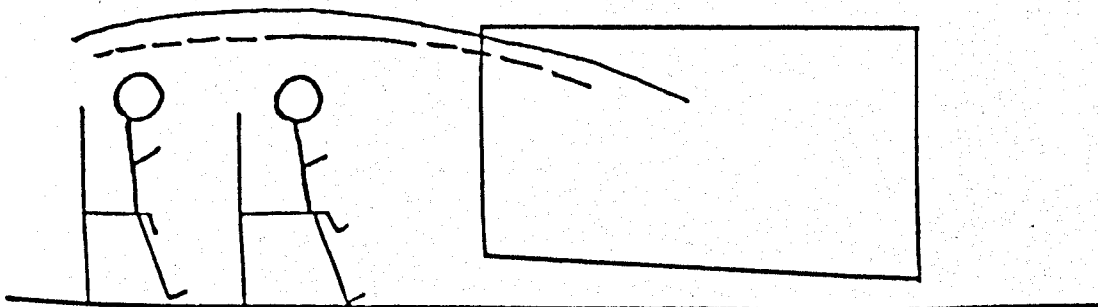
8. Mirror



A Mirror.

آئینہ

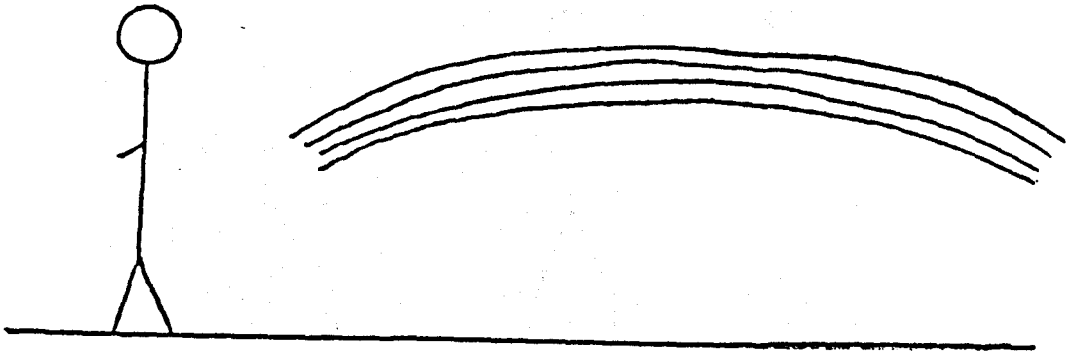
9. A Movie Screen



A Movie screen.

فلم سکرین

10. A Rainbow

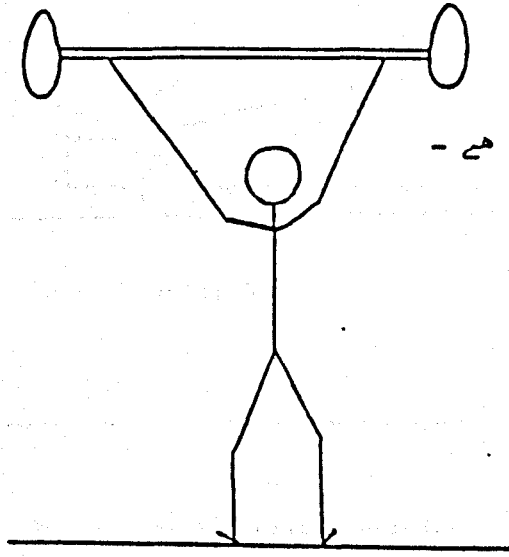


A Rainbow.

قوس قزح

Work

کام

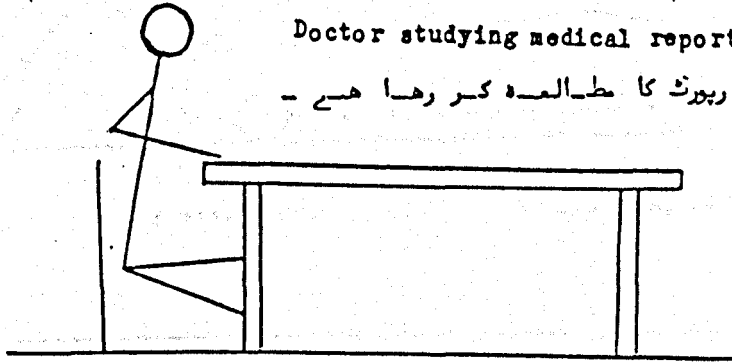
1. Weightlifter

The Bar is not moving.

بار حرکت نہیں کر رہا ہے -

Is the weightlifter doing work?

کیا ویٹ لفٹر کام کر رہا ہے ؟

2. Doctor

Doctor studying medical report.

ڈاکٹر میڈیکل رپورٹ کا مطالعہ کر رہا ہے -

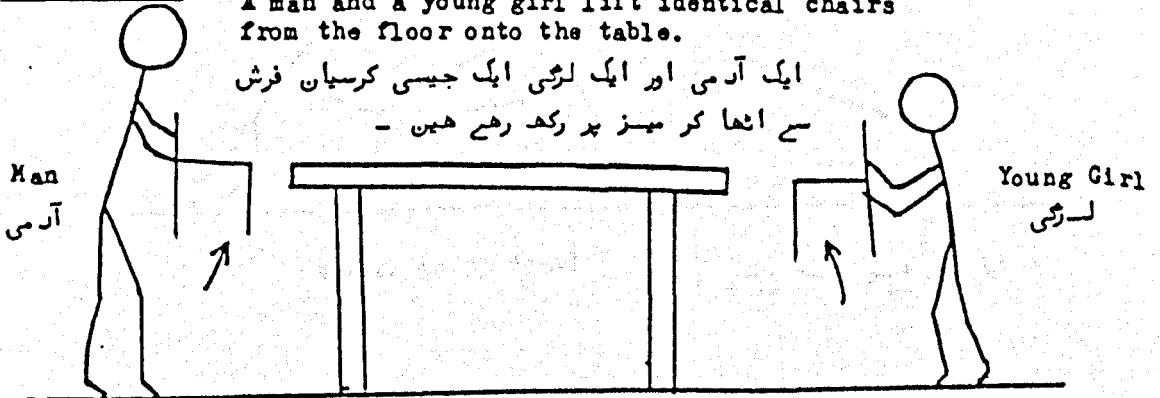
Is the doctor doing work?

کیا ڈاکٹر کام کر رہا ہے ؟

3. Man and girl

A man and a young girl lift identical chairs from the floor onto the table.

ایک آدمی اور ایک لڑکی ایک جیسی کرسیاں فرش سے اٹھا کر میز پر رکھ رہے ہیں -

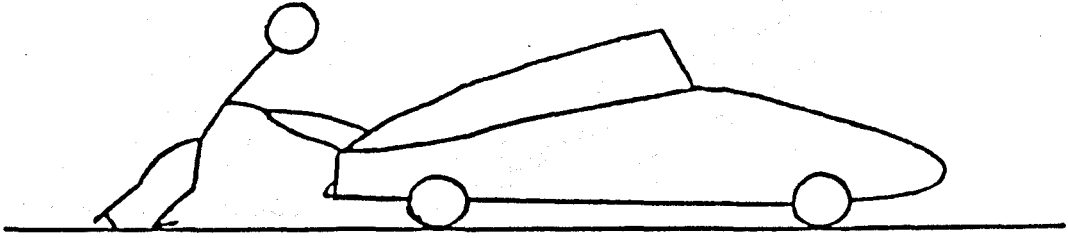


Are they each doing work? If so, who is doing the most work?

کیا وہ دونوں کام کر رہے ہیں - اگر ایسا ہے تو کون زیادہ کام کر رہا ہے ؟

کار حرکت نہیں کر رہی ہے۔ - The car is not moving.

4. Car I.

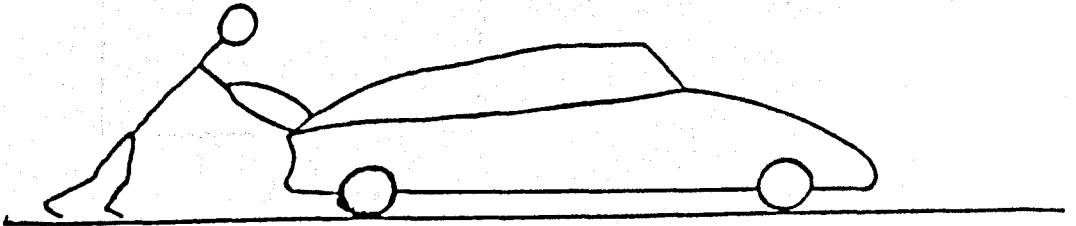


Is work being done?

کیا کام ہو رہا ہے؟

5. Car II.

کار کی رفتار بڑھ رہی ہے۔ - The car is increasing speed.



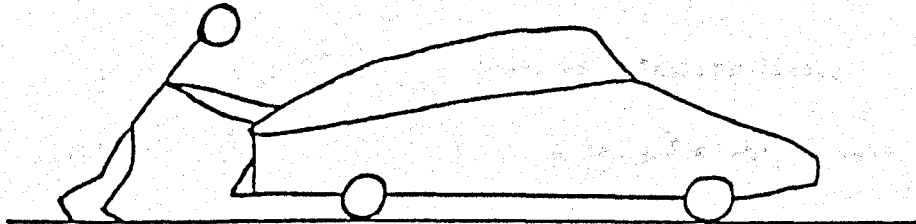
Is work being done?

کیا کام ہو رہا ہے؟

6. Car III.

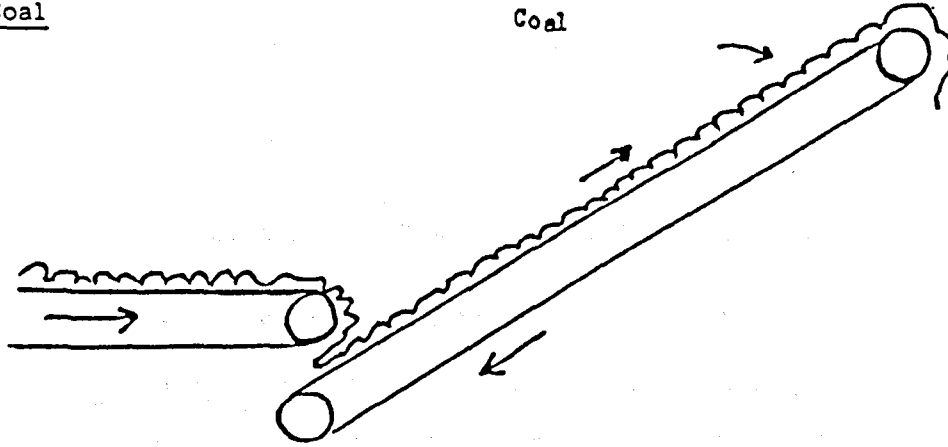
The car is moving at a steady speed.

کار یکساں رفتار سے حرکت کر رہی ہے۔ -



Is work being done?

کیا کام ہو رہا ہے؟

7. Coal

Is work being done as the coal moves up?

کیا کوئلہ اُپر لے جاتے وقت کام کیا جا رہا ہے ؟

8. Steel Block

Steel Block

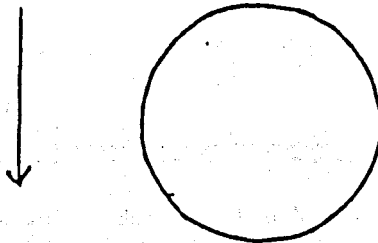
سٹیل بلاک

Flame

شعلہ

Is work being done as the flame heats the block?

جب شعلہ بلاک کو گرم کرتا ہے تو کیا کام کیا جا رہا ہے ؟

9. Steel Ball

Steel ball falling freely.

سٹیل بال آزادانہ گر رہا ہے

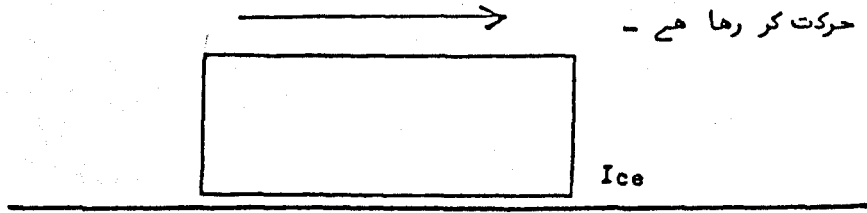
Is work being done as the ball falls down? کیا بال کے نیچے گرتے وقت کام ہو رہا ہے ؟

10. Wooden Block on Ice.

Wooden block moving steady speed.

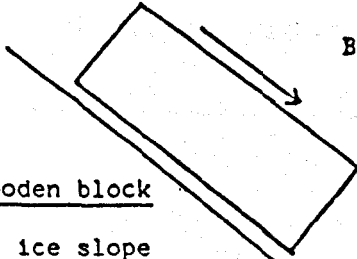
لکٹی کا بلاک پکسان

رفتار سے حرکت کر رہا ہے -



Is work being done as the block slides along?

کیا جب بلاک نیچے سرگتا ہے تو کام کیا جا رہا ہے ؟

11. Wooden block
on ice slope

بلاک کسی رفتار بڑھ رہی ہے - Block increasing speed

A smooth block of wood slides down a slippery ice slope.

Is work being done as the block slides down?

لکٹی کا ایک ہموار ٹکڑا برف کی ٹھلوان سطح پر پھسل رہا ہے -

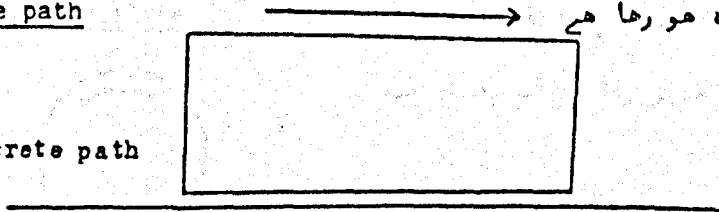
کیا جب بلاک نیچے جا رہا ہے تو کام ہو رہا ہے -

12. Wooden block on
concrete path

Wooden block slowing down.

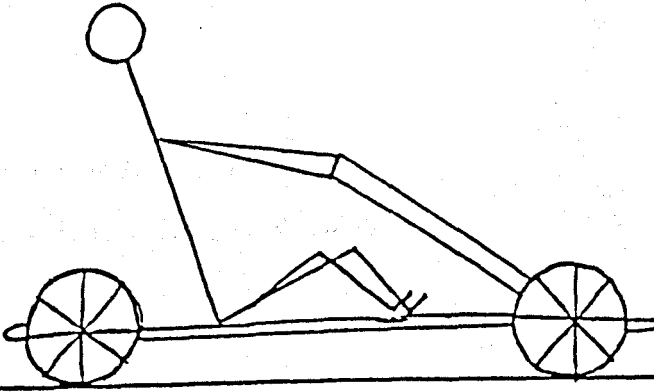
لکٹی کا بلاک آہستہ ہو رہا ہے

concrete path



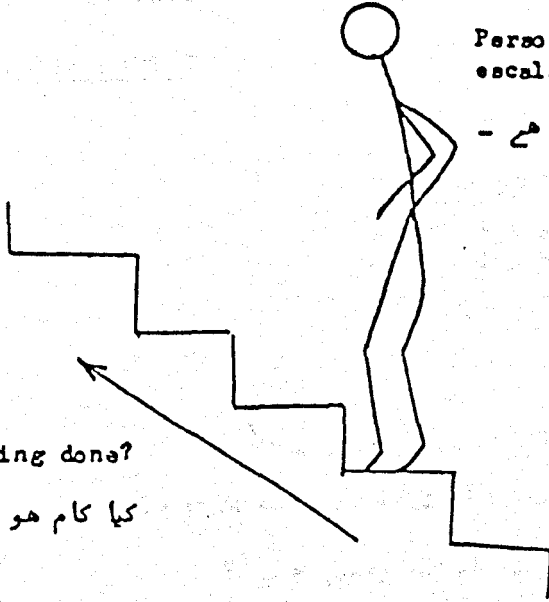
Is work being done as the block slides along?

کیا جب بلاک آہستہ ہوتا ہے تو کام ہوتا ہے -

13. Trolley

Is work being done?
کیا کام ہو رہا ہے ؟

Trolley moving but slowing down. ٹرالی حرکت کر رہی ہے لیکن آہستہ ہو رہی ہے۔

14. Escalator

Person standing on a steadily moving escalator

آدمی ایک متحرک سیڑھی پر کھڑا ہے۔

Is work being done?

کیا کام ہو رہا ہے ؟

15. Ball rolling down slope

Ball rolling down slope, no slipping.



بال نیچے کی طرف حرکت کر رہا ہے۔ پھل نہیں رہا ہے۔

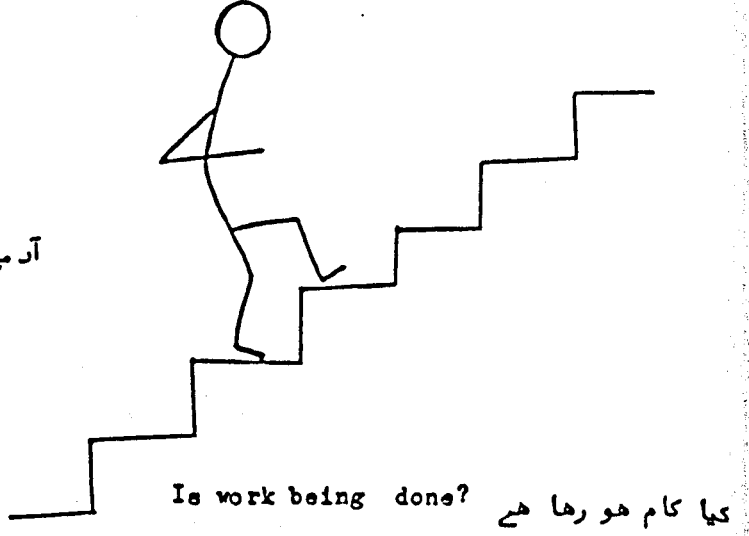
Is work being done?

کیا کام ہو رہا ہے ؟

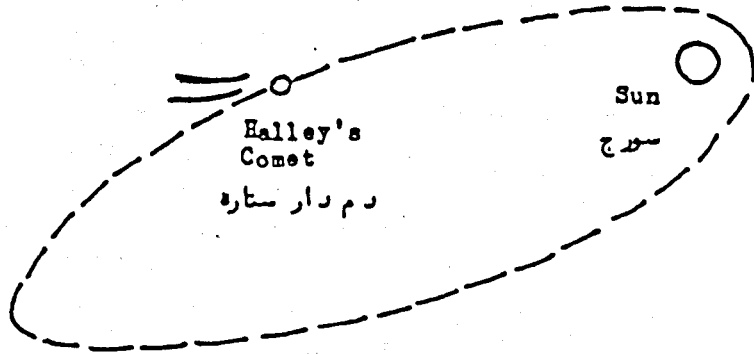
16. Person on stairs

Person climbing stairs.

آدمی سیڑھیوں پر چڑھ رہا ہے۔



Is work being done? کیا کام ہو رہا ہے

17. Halley's Comet

Is work done on Halley's comet by the sun's gravitational force?

کیا سورج کی قوت تجاذب دم دار ستاروں پر کام کر رہی ہے؟

Swinging pendulum bob.

جھولتا ہوا شاقول

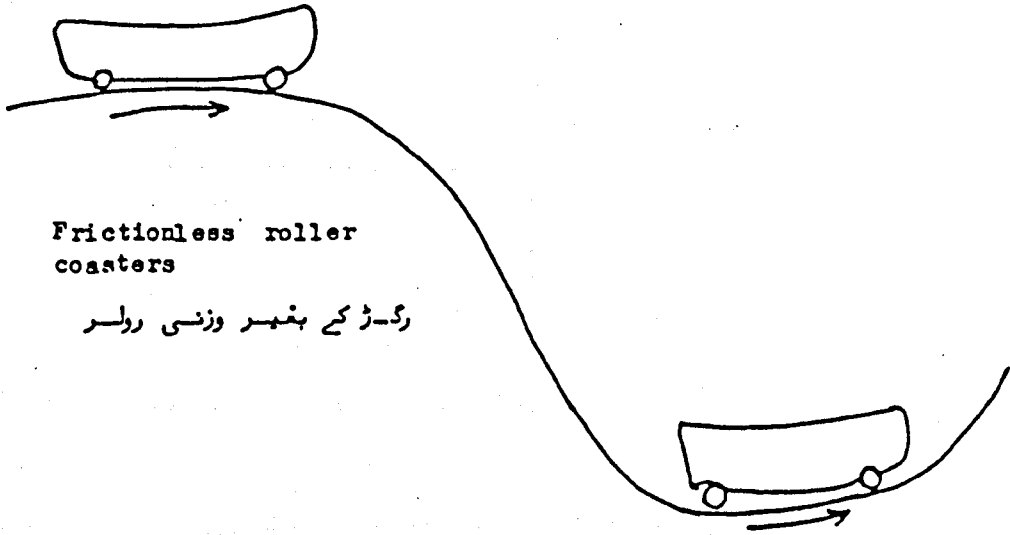
18. Pendulum String

رسی

Bob
شاقول

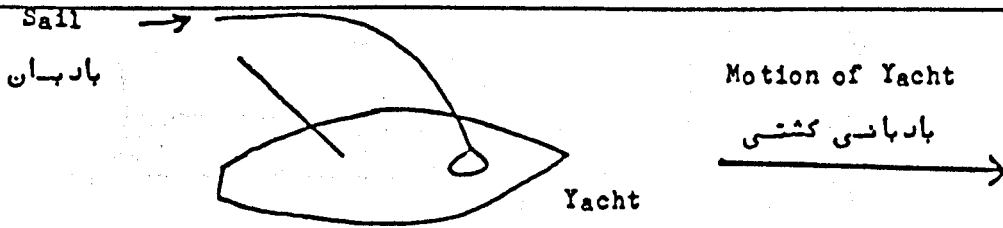
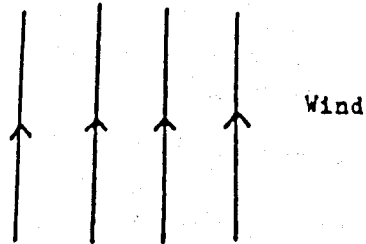
Is work being done on the pendulum bob by the force of the string?

کیا رسی کی قوت کے ذریعے شاقول پر کام ہو رہا ہے؟

19. Roller coasters

Is work done on the roller coasters by the forces from the rail?

کیا وزنی رولر پر ریل کی قوت سے کام کیا جا رہا ہے ؟

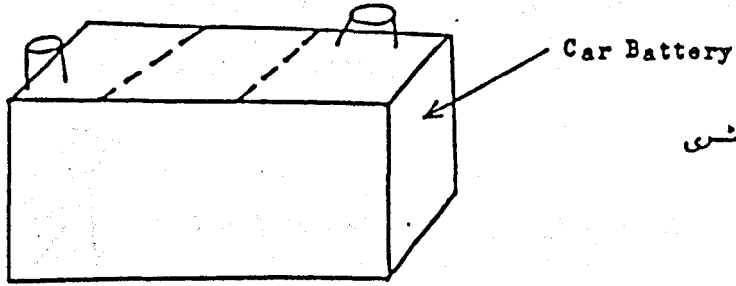
20. Yacht

Is work done on the yacht by the force of the wind?

کیا ہوا کی قوت سے بادبانی کشتی پر کام ہو رہا ہے ؟

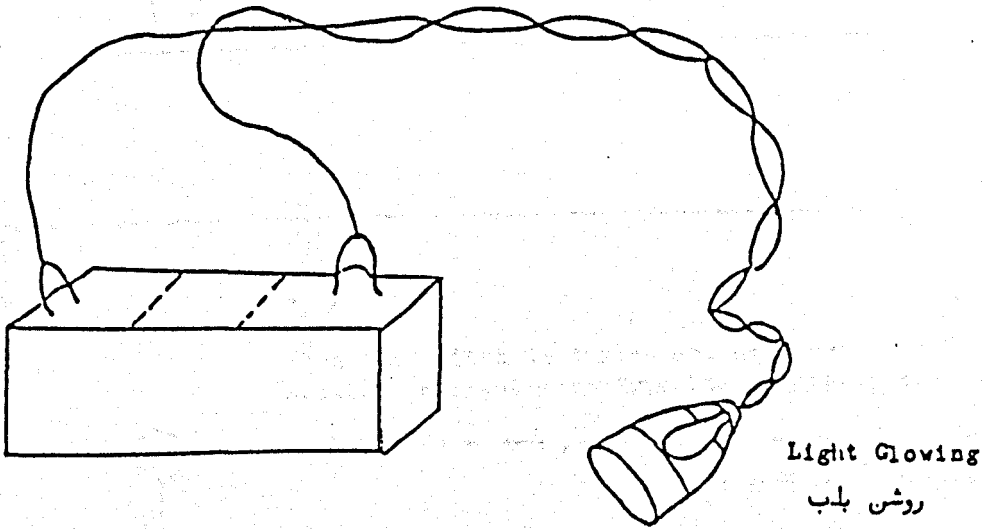
ELECTRIC CURRENT.

برقی رو

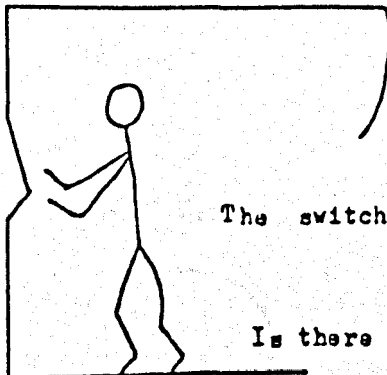
1. Battery I

کار کی بیٹری

Is there an electric current in the Battery? کیا بیٹری میں برقی رو موجود ہے ؟

2. Battery II

Is there an electric current in the Battery? کیا بیٹری میں برقی رو موجود ہے ؟

3. Bare wires

Bare Wire ننگی تاریں

Lamp to be connected

لیکن بلب نہیں لٹایا گیا ہے -

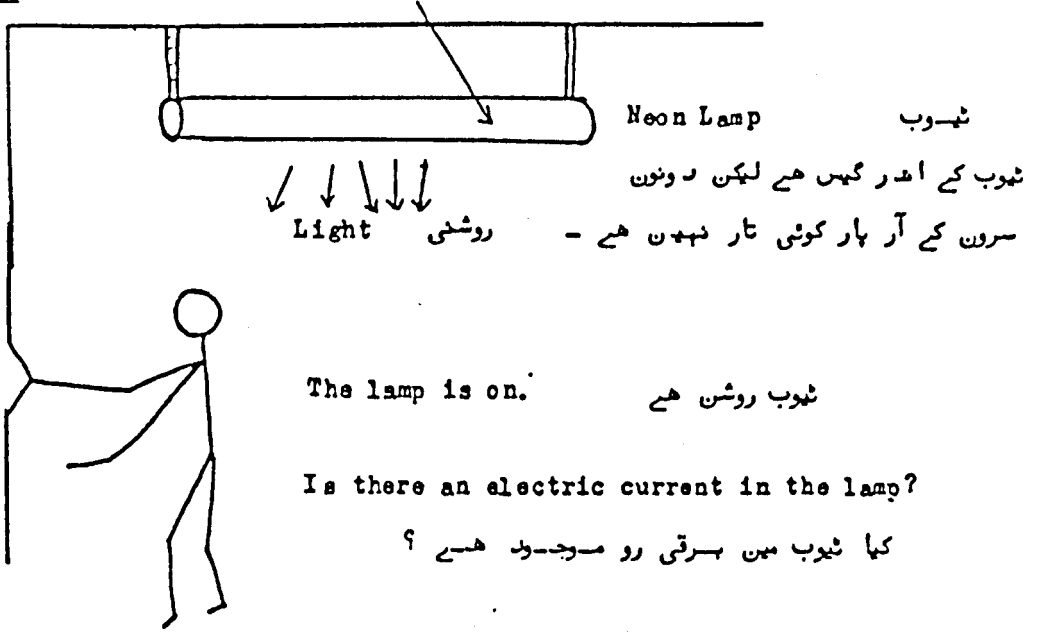
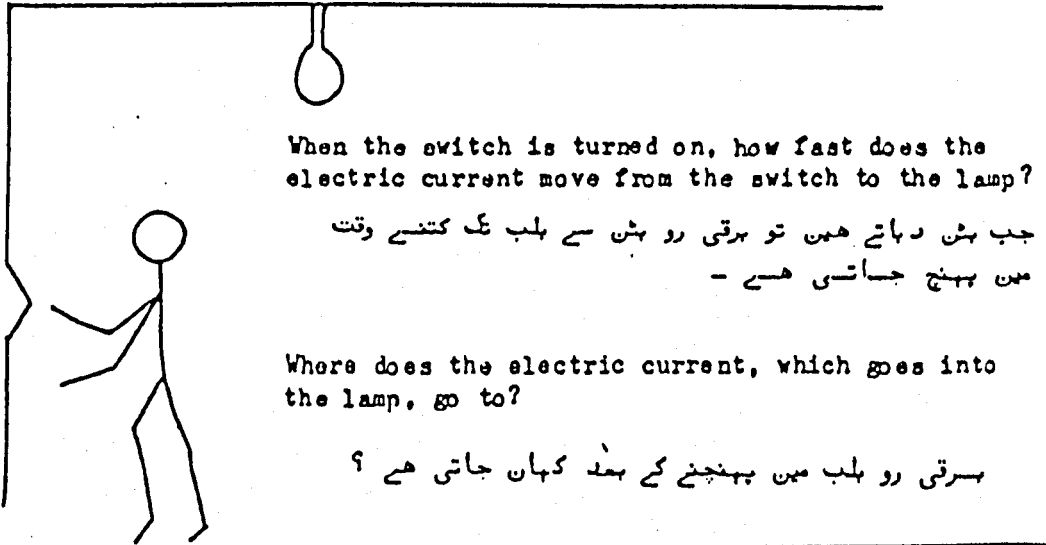
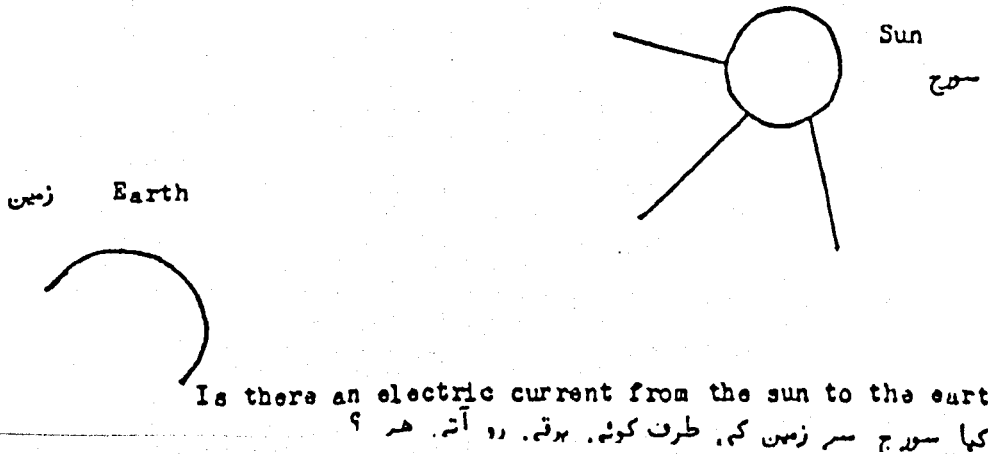
The switch is on - بٹن دبا ہوا ہے -

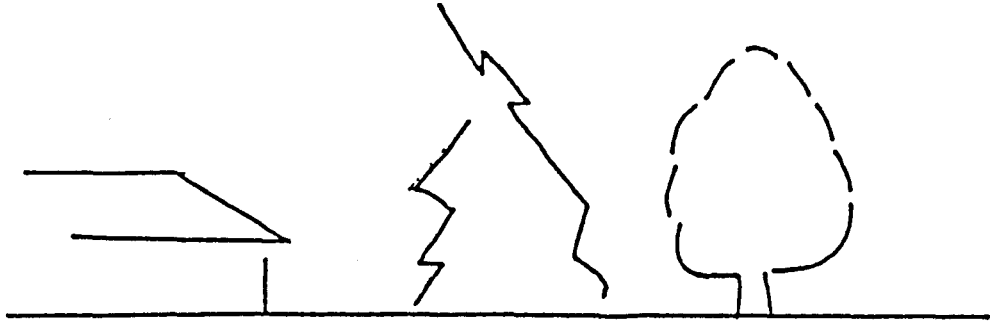
Is there an electric current in the bare wires?

کیا ننگی تاروں میں برقی رو موجود ہے ؟

4. Neon lamp

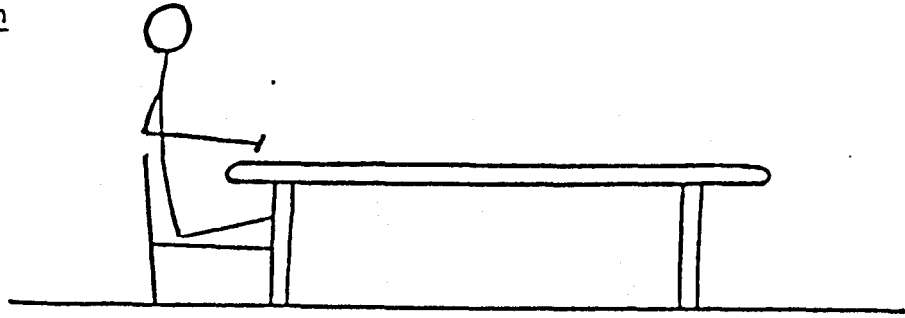
Gas (No wires through tube)

5. Lamp I6. Sun

7. Lightning

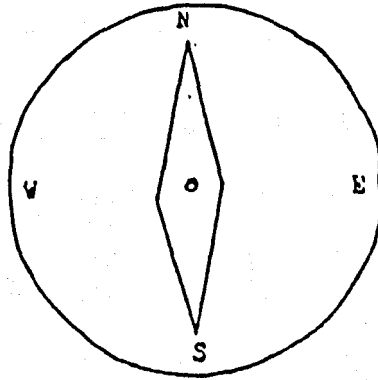
Is there an electric current in the lightning?

کیا آسمانی بجلی میں کوئی برقی رو ہوتی ہے ؟

8. Person

A person is writing at a desk. Is there an electric current in the writer's arms?

کسی میز پر بیٹھا کام کر رہا ہے - کیا اسکے بازو میں برقی رو موجود ہے ؟

9. Compass

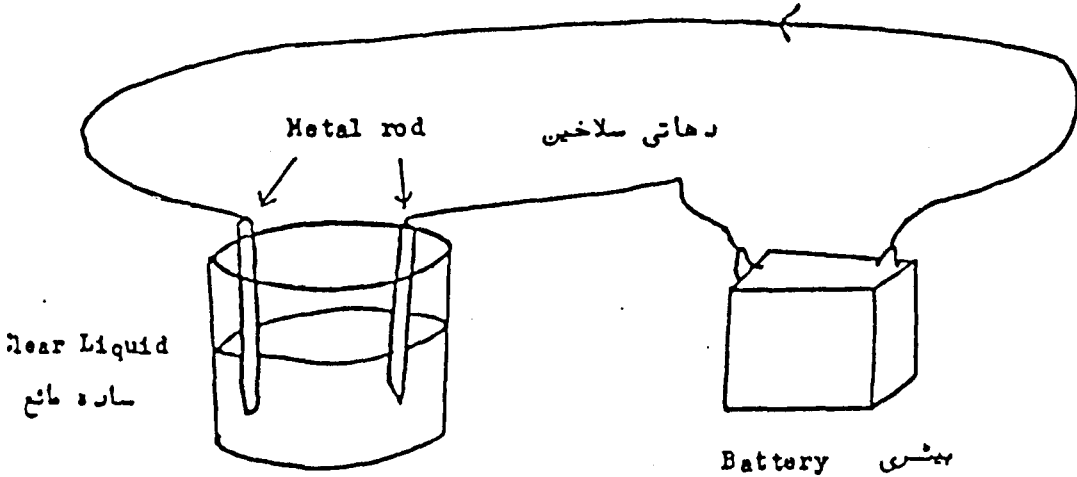
Is there an electric current in the compass needle?

کیا قطابھی سوئی میں برقی رو موجود ہے ؟

10. Liquid

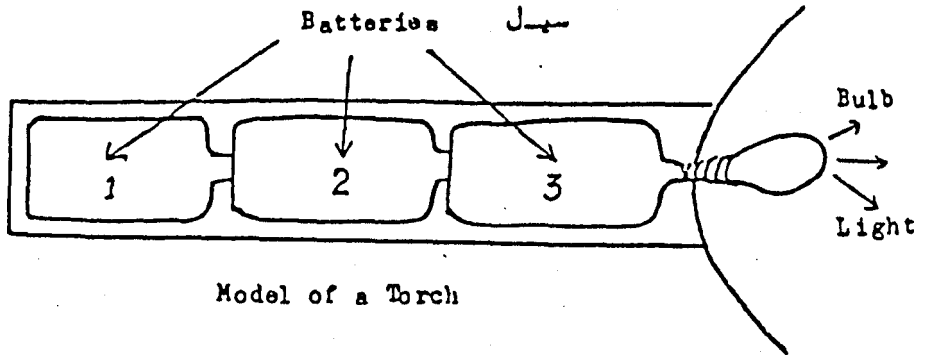
Electric current in wire

تار میں برقی رو ہے -



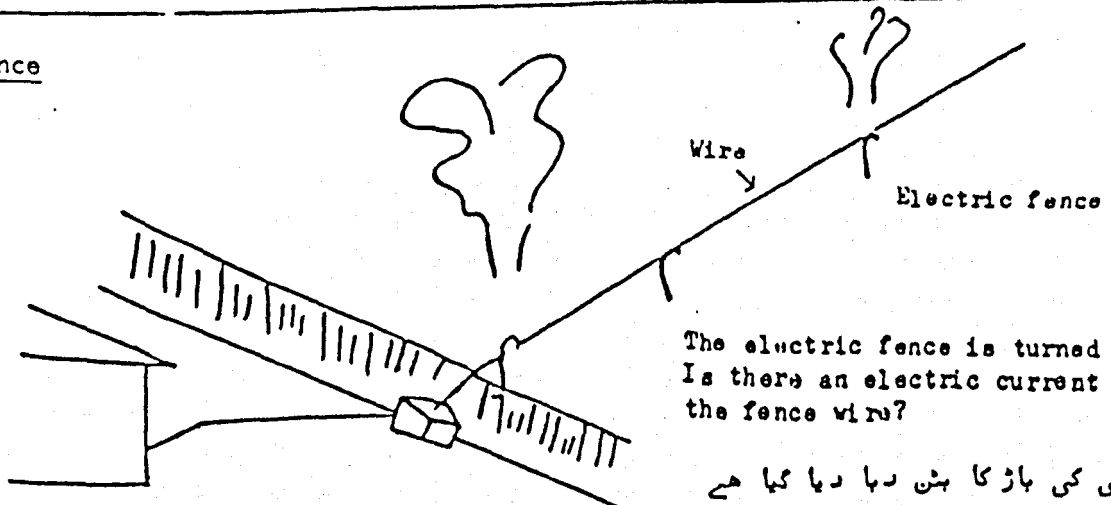
There is a current in the wire. Is there an electric current in the liquid?

تار میں برقی رو ہے - کیا مائع میں برقی رو موجود ہے ؟

11. Torch

The torch is switched on and the lamp is glowing. Is there an electric current through the batteries? Which battery has the most current through it (identical batteries-different batteries)

ٹارچ کا بٹن دبا یا ہوا ہے اور اس کا بلب روشن ہے کیا اسکے اندر موجود سیلون میں سے برقی رو گزرتی رہی ہے کس سیل میں سے زیادہ برقی رو گزرتی رہی ہے (ایک جیسے سیلون میں سے - مختلف سیلون میں سے)

12. Fence

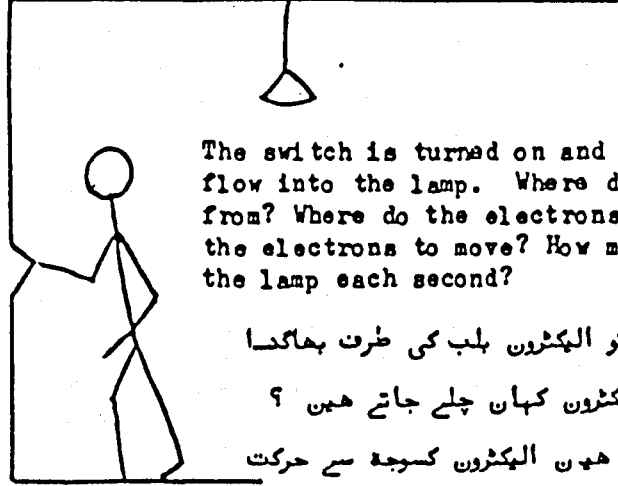
The electric fence is turned on. Is there an electric current in the fence wire?

بجلی کی باڑ کا بٹن دبا دیا گیا ہے کیا باڑ کی تار میں برقی رو موجود ہے ؟

13. Definition

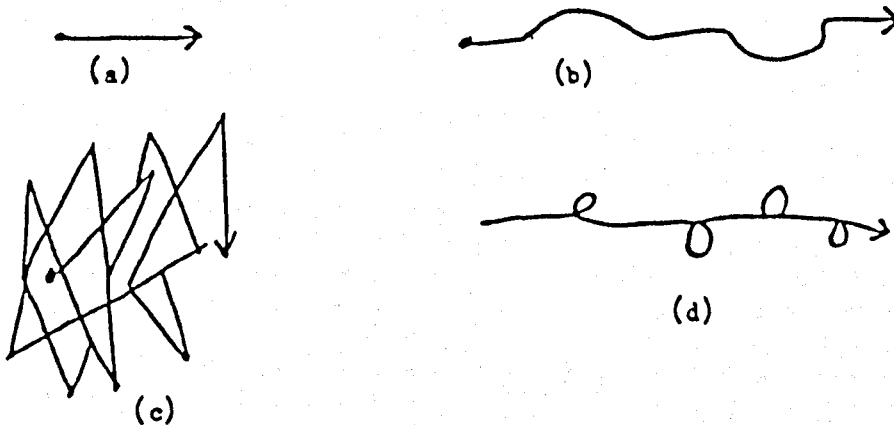
How would you define an electric current?

برقی رو کیا ہے اس کی تعریف کریں -

14. Lamp II In a metal an electric current is a flow of electrons.

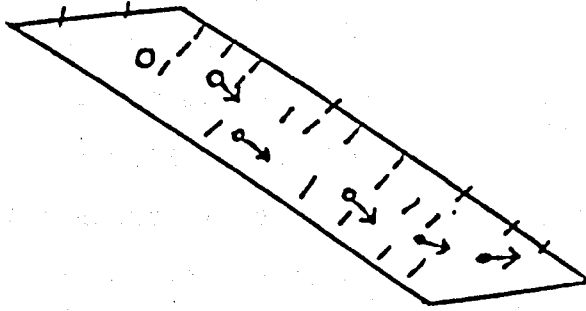
The switch is turned on and electrons start to flow into the lamp. Where do the electrons come from? Where do the electrons go to? What cause the electrons to move? How many electrons enter the lamp each second?

جب بٹن دباتے ہیں تو الیکٹرون بلب کی طرف بھاگتا
شروع کر دیتے ہیں الیکٹرون کہاں چلے جاتے ہیں ؟
الیکٹرون کہاں سے آتے ہیں الیکٹرون کسوجہ سے حرکت
میں آتے ہیں ایک سیکنڈ میں کتنے الیکٹرون بلب میں
داخل ہوتے ہیں -

15. Path of electron

What is the path of an electron like in a metallic conductor if an electric current is present?

اگر کسی دھاتی موصل میں برقی رو موجود ہو تو الیکٹران کے بہاؤ کا راستہ کیا ہوگا ؟

16. Model

This model of an electric current in a metal uses nails to represent atoms and steel marbles to represent electrons. The marbles roll down the slope, stopping temporarily each time a nail is hit. How is this similar to, or different from, an electric current in a metal?

دھات میں برقی رو سے متعلق اس ماڈل میں کیل ایٹموں کو ظاہر کرتے ہیں اور سٹیل کی گولیاں الیکٹرونوں کو ظاہر کرتی ہیں۔ گولیاں ڈھلوان سطح سے نیچے پھسلتے وقت جب کیل سے ٹکراتی ہیں تو وقتی طور پر رک جاتی ہیں۔ یہ بات دھات میں موجود برقی رو سے کثیر مشابہت رکھتی ہے اور کس طرح محفوظ ہے۔

APPENDIX C

SYNOPSIS OF TEACHER TRAINING PROGRAMME IN STUDY 1

As described in Chapter IV, Section 4.4. three equivalent groups of teachers were tested on Force using a paper-and-pencil test. Before testing them, the three groups of teachers were given different levels of information. This information is described briefly as under:

Group I

It was a control group. No information about the research, nor about the children's misconceptions was given. During one-hour lecture, problems concerning the teaching of science, problems of science teachers and students, and how the teaching of science may be improved in Pakistan were discussed. Before the questionnaire was distributed, teachers were told that the purpose was not to test them, but instead, it was just to obtain their opinions in response to the items in the questionnaire. They were further told that the results will not affect the teachers in any way.

Group II

This group of teachers was told about recent research work in Science Education particularly in the field of concept learning. In this regard, the work of 'Personal Construction of Knowledge Group' in UK and 'Learning in Science Project' in New Zealand were discussed in detail. Researcher's own research work was also

explained. This was done by showing the Instance-cards used in the study. After that, teachers were told about the patterns of children's misconceptions explored through recent research. Specifically, they were told about children's misconceptions in the concept of Light. These results were discussed from the work of LISP and also from the researcher's own work. Similarity in the results was also explained. As for group I, the teachers of this group were tested in Force using the same paper-and-pencil instrument used for Group I.

Group III

This group was given the same details of information about research as it was done to the group II teachers. The teachers of this group were informed (as for group II) about children's misconceptions in Light. In addition to that, this group was also informed about children's misconceptions in Force. Results of LISP and that obtained by the researcher were also explained. After giving all this information, the teachers were tested in Force using the same paper-and-pencil instrument used for Groups I & II.

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APPENDIX 'D'
QUESTIONNAIRE ON FORCE

We are trying to find out what people think of some ideas in physics.
These cards are about FORCES.

It is not a test! We want your opinions so it doesn't matter if you
have'nt done this work in class.

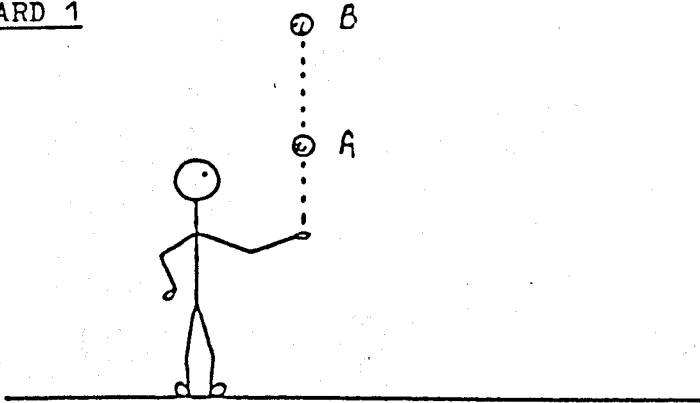
We don't want your names. No one will see your answers, or know who
wrote them.

Please try hard to answer all the questions as best as you can.

Thank you very much for your ideas.

INSTRUCTIONS

1. There are two different types of cards: description cards and question cards.
2. In a description card a situation is described but no question is asked.
3. Following a description card you will find one or more question cards referring to the situation.
4. In order to answer the question you will have to choose amongst different drawings. Tick the one you think is best in the box near the drawings.
5. In the bottom of each question card there is a blank space. Please, explain the reasons for your choice in this space. If there is not enough space continue on the back of the card.
6. Answer the cards, please, in the order they are placed.

DESCRIPTION CARD 1

A stone is thrown straight up in the air.

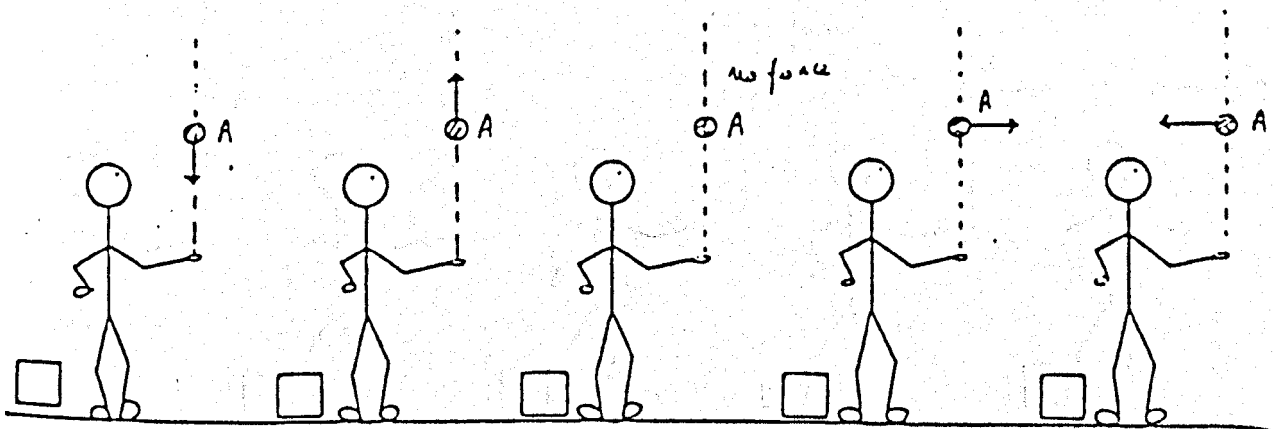
It leaves the person's hand, goes up through point A, gets as high as B and then comes back down through A again.

The following three cards refer to this situation.

Q.1

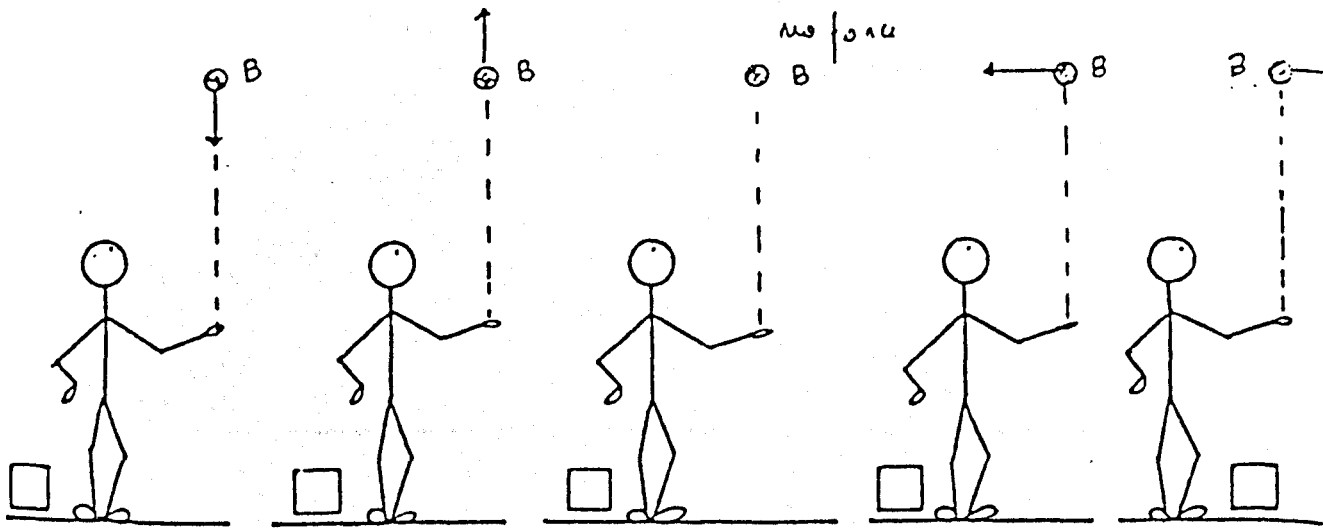
The arrows in the pictures are supposed to show the direction of the force on the the stone.

Which picture do you think best shows the force on the stone on its way up through A ?



Explanation:

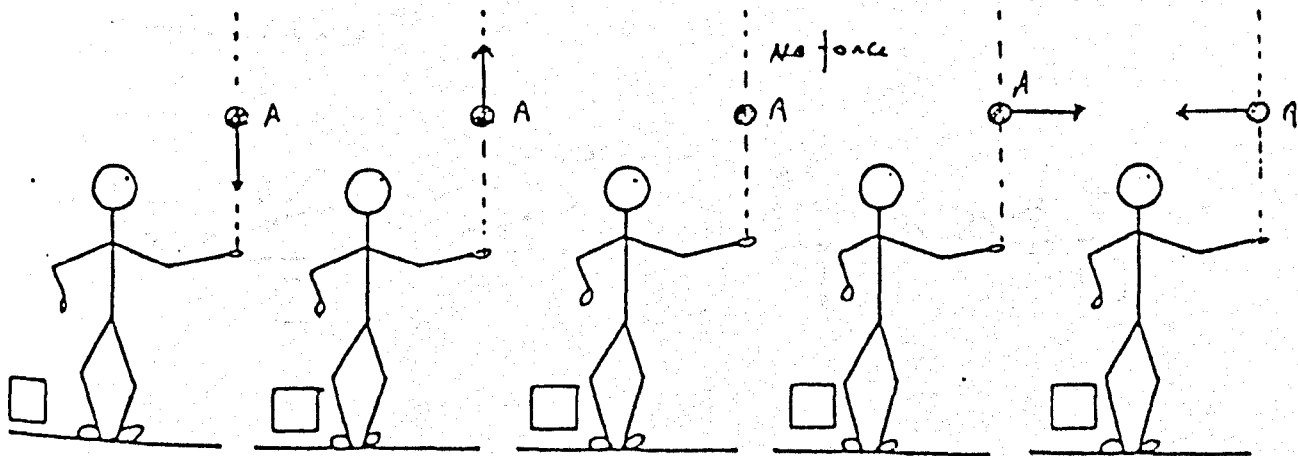
Q. 2. Now, which pictures do you think best shows the force on the stone when it reaches the point B (Maximum height)?



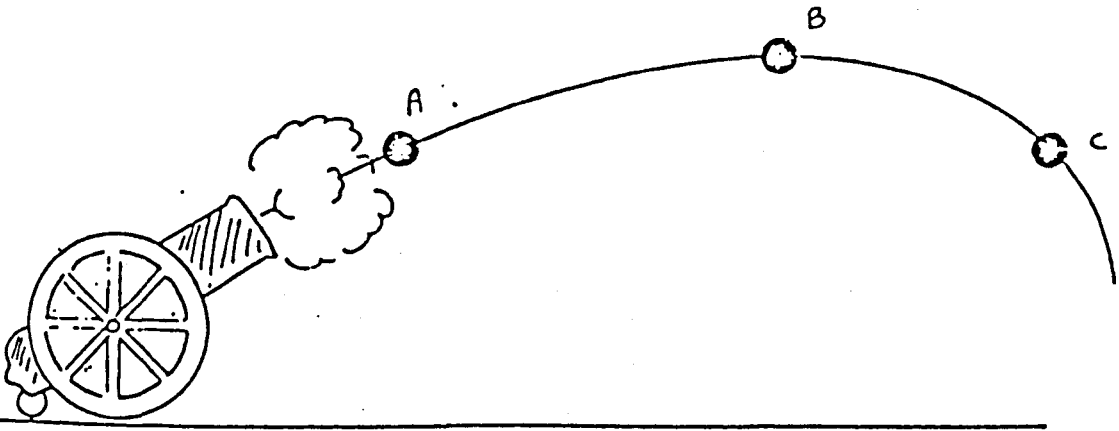
Explanation:

Q. 3

Now, which picture do you think best shows the force on the stone when it is passing through the point A on its way down?



Explanation:

DESCRIPTION CARD 2

A cannon ball is fired from a cannon.

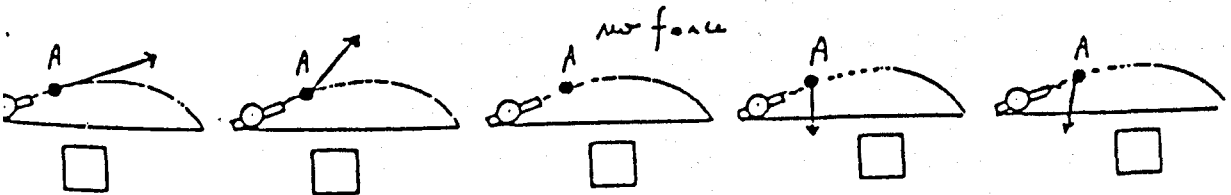
Points A, B and C are three different positions on the path of the ball.

The following three cards refer to this situation.

Q.4

The arrows in the pictures are supposed to show the direction of the force on the cannon ball.

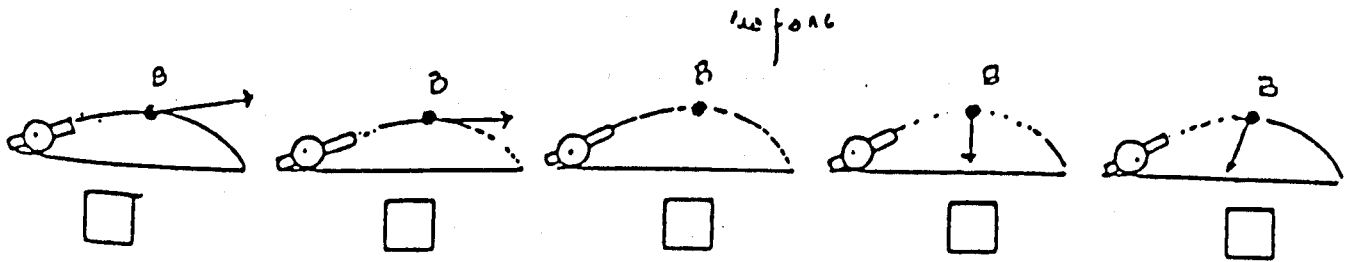
Which picture do you think best shows the force on the ball as it is passing through point A ?



Explanation:

Q.5

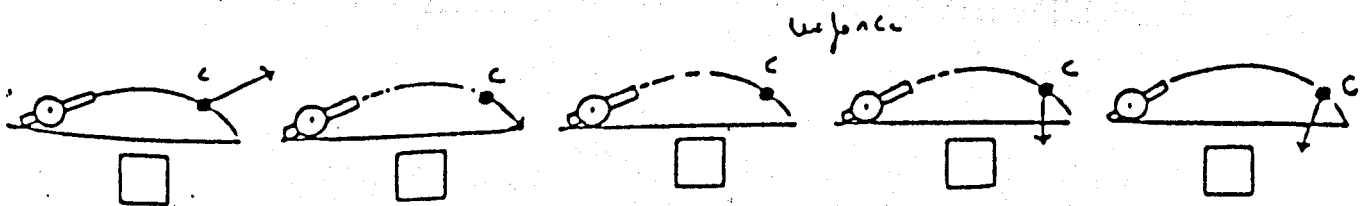
Now, which pictures do you think best shows the force on the ball as it is passing through point B (Its highest point)?



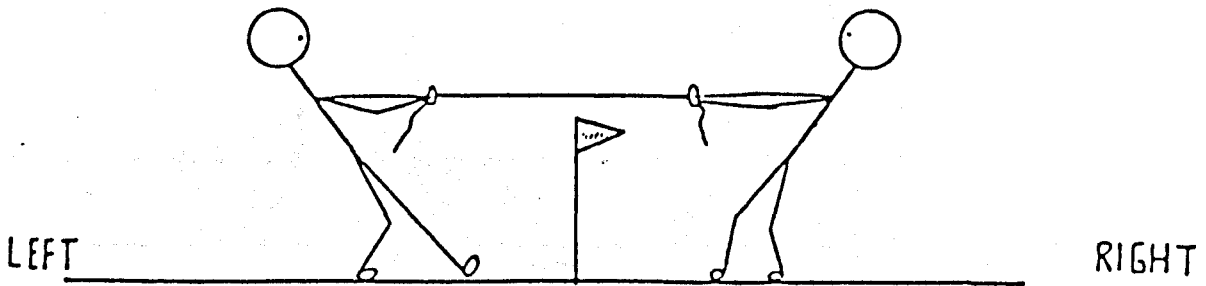
Explanation:

Q.6

Now, which picture do you think best shows the force on the ball as it is passing through point C?



Explanation:

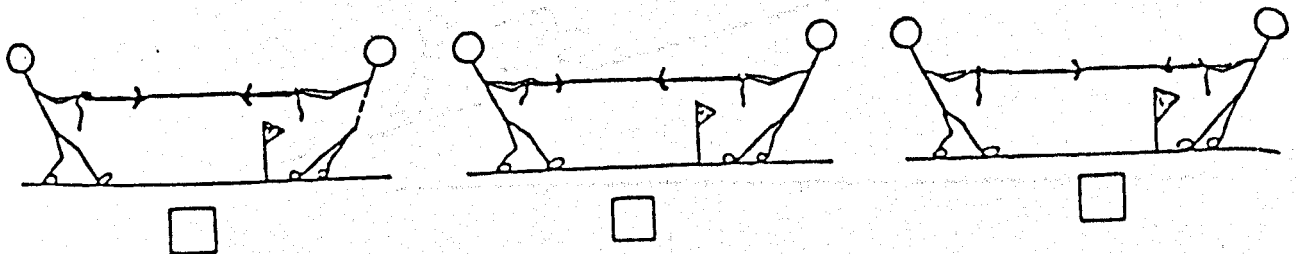
DESCRIPTION CARD 3

This is a tug-of-war between two people.
The flag shows the half-way line.

The following two cards refer to this situation.

Q.7

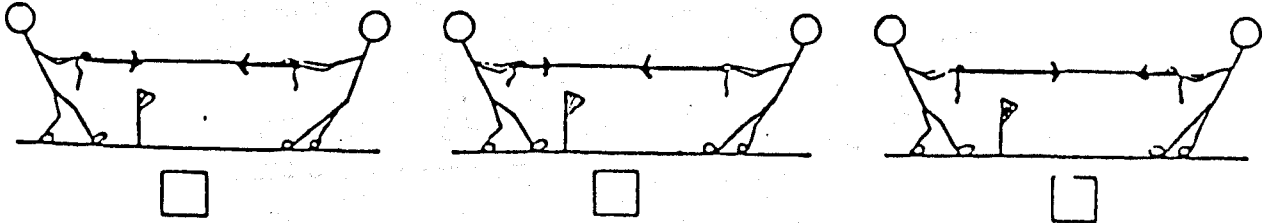
The person on the left is winning.
Which of the following drawings do you think best shows what is happening? The size of the arrows are supposed to show the size of the force that each person exerts on the other.



Explanation:

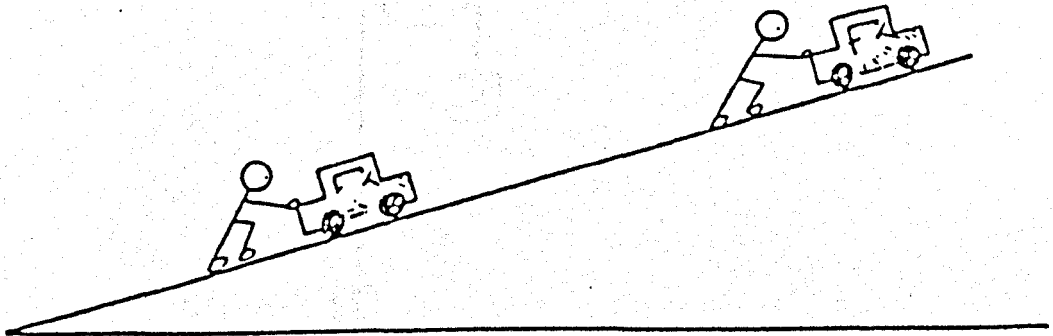
Q. 8. Now, the person on the right is winning.

Which of the following drawings do you think best shows what is happening ?



Explanation ?

DESCRIPTION CARD 4



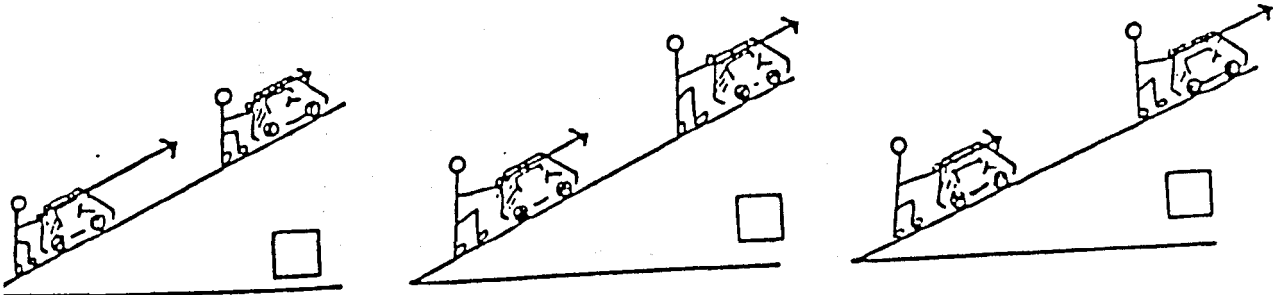
These two people are stopping the cars rolling down the hill.

Both cars are the same and have the hand brake off.

The following card refers to this situation.

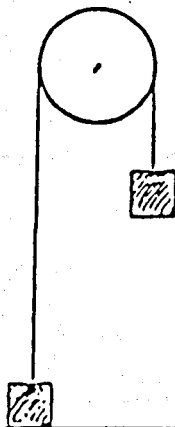
Q.9. Here, the size of the arrows are supposed to show the size of the forces exerted by the people on the cars.

Which drawing do you think best shows what is happening ?



Explanation:

DESCRIPTION CARD 5



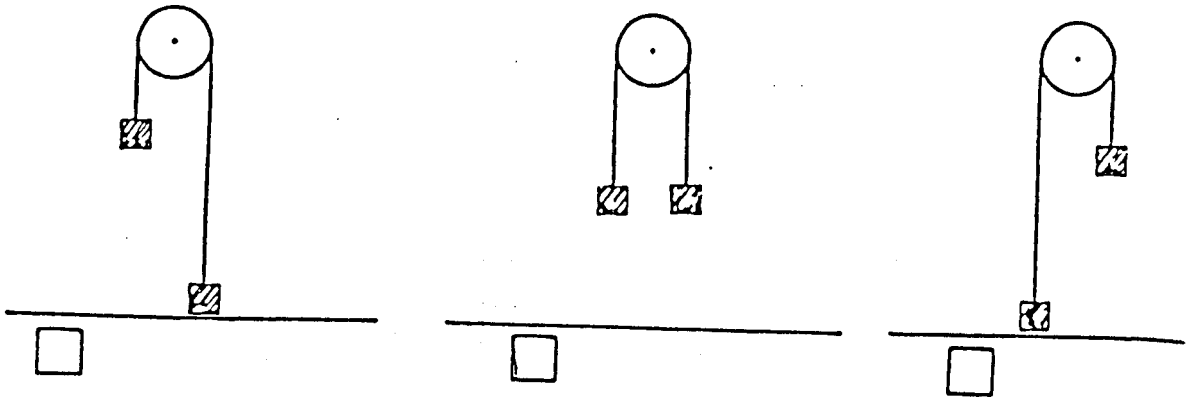
Two equal objects are linked by a piece of string.
The string is placed lightly over a pulley.

The following card refers to this situation.

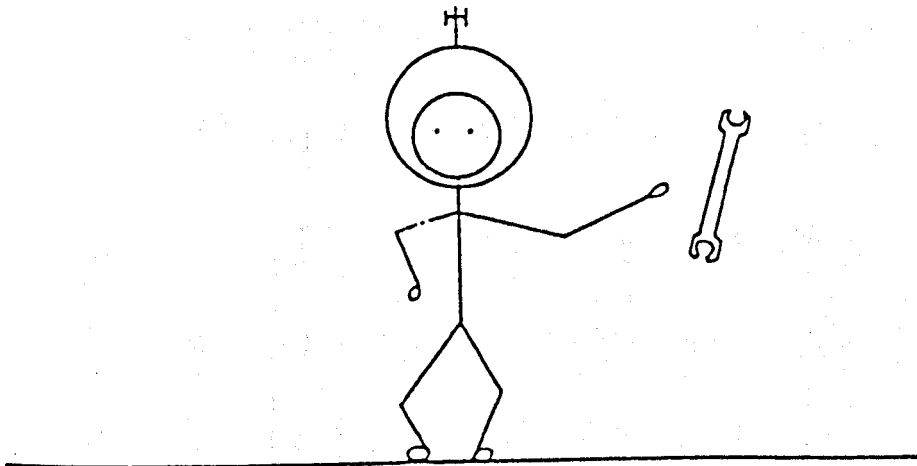
Q.10.

Here, it is one minute later.

Which picture do you think best shows the position of the blocks now?



Explanation:

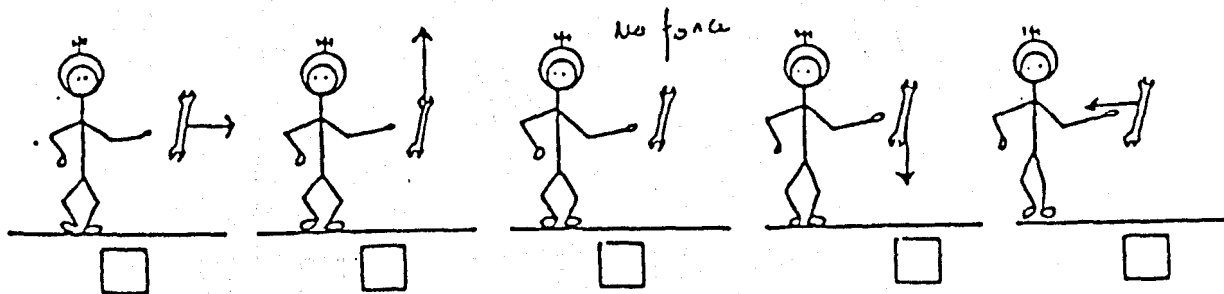
DESCRIPTION CARD 6

Here is an astronaut on the moon.
He has gently let go of his spanner.

The next card refers to this situation.

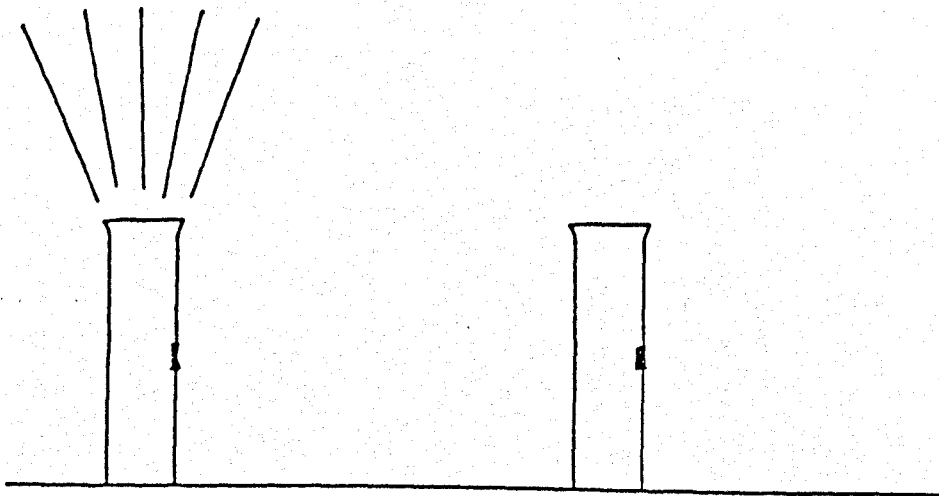
Q. 11. The arrows are supposed to show the direction of the force acting on the spanner.

Which drawing do you think best shows the force on the spanner ?



Explanation:

DESCRIPTION CARD 2

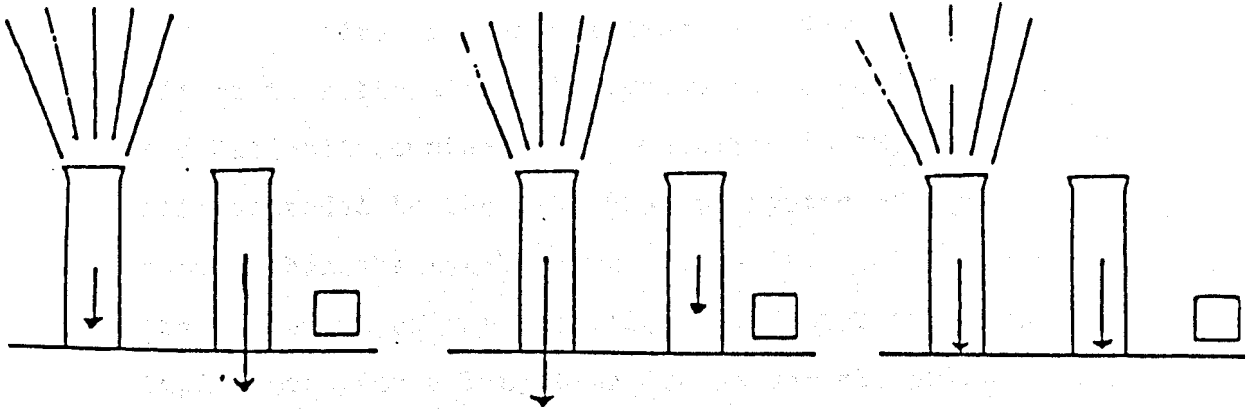


Here are two torches. One is lit, the other switched off.

The following card refers to this situation.

Q.12. The size of the arrows are supposed to show the size of the forces on the torches.

Which drawing do you think best shows the forces on the torches ?



Explanation :

APPENDIX E
TEACHER EDUCATION IN PAKISTAN

After the independence in 1947, the first serious effort to rationalise the system of education was made by the National Commission on Education in 1959 which inter alia conceded to the fact that no system of education is better than the teachers who serve it. But, unfortunately, the decisions of the Education Commission could not be implemented for a long time due to social, political, and economic problems in the country.

With the revision of the curricula at all levels at different times keeping in view the changing needs of the society, the need to provide sound basic education and adequate professional training to teachers becomes all the more apparent. For the purpose of teacher training in order to prepare teachers to teach at different educational levels various teacher training institutions have been established.

Institutions preparing primary school teachers are called Elementary Teachers Training Colleges; those institutions which prepare teachers for secondary schools are called Colleges of Education and those preparing teachers for post-graduate degrees i.e. M.A. Education/ M.Ed./Ph.D. degrees are called Institutes of Education and Research and are affiliated to the Universities in the country.

In service education is taken care of by the Education Extension Centres and the National Institute of Teacher Education at Provincial and Federal levels respectively. Non-formal media are also being utilized to train teachers through correspondence courses and radio/T.V. programmes under the auspices of the Allama Iqbal Open University. In order to meet the growing demand of teachers in the country, "Education" has been introduced as an elective subject from Matriculation to graduation level.

The basic educational qualifications required for various teacher training courses and other such details are given in Appendix F.

The Institute of Education and Research, University of the Punjab, Lahore which was established in 1960, offers the following post-graduate degree programmes in the field of Education:

- i. M.A. Education (Elementary) - Two-year programme after B.A./B.Sc.
- ii. M.Ed. (Elementary) - One-year programme after B.A./B.Sc. and B.Ed.
- iii. M.A. Education (Secondary) - Two-year programme after B.A./B.Sc.
- iv. M.Ed. (Secondary) - One-year programme after B.A./B.Sc. and B.Ed.
- v. Master of Business Education (M.B.E.) - Two-year programme after B.A./B.Sc.

- | | | | |
|-------|--|---|--|
| vi. | M.A. Industrial Arts
Education | - | Two-year programme
after B.A./B.Sc. |
| vii. | M.Ed. Industrial Arts
Education | - | One-year programme
after B.A./B.Sc. and
one year diploma in
Industrial Arts
Education. |
| viii. | Master of Science
Education (M.S.Ed.) | - | Two-year programme
after B.Sc./B.S.Ed
or B.Sc. and B.Ed. |
| ix. | M.Ed. Science | - | One-year programme
after B.Sc., B.Ed.
or B.S.Ed. |
| x. | Ph.D. in Education | | |

This Institute offers the following specializations in the Elementary and Secondary Education degree programmes:

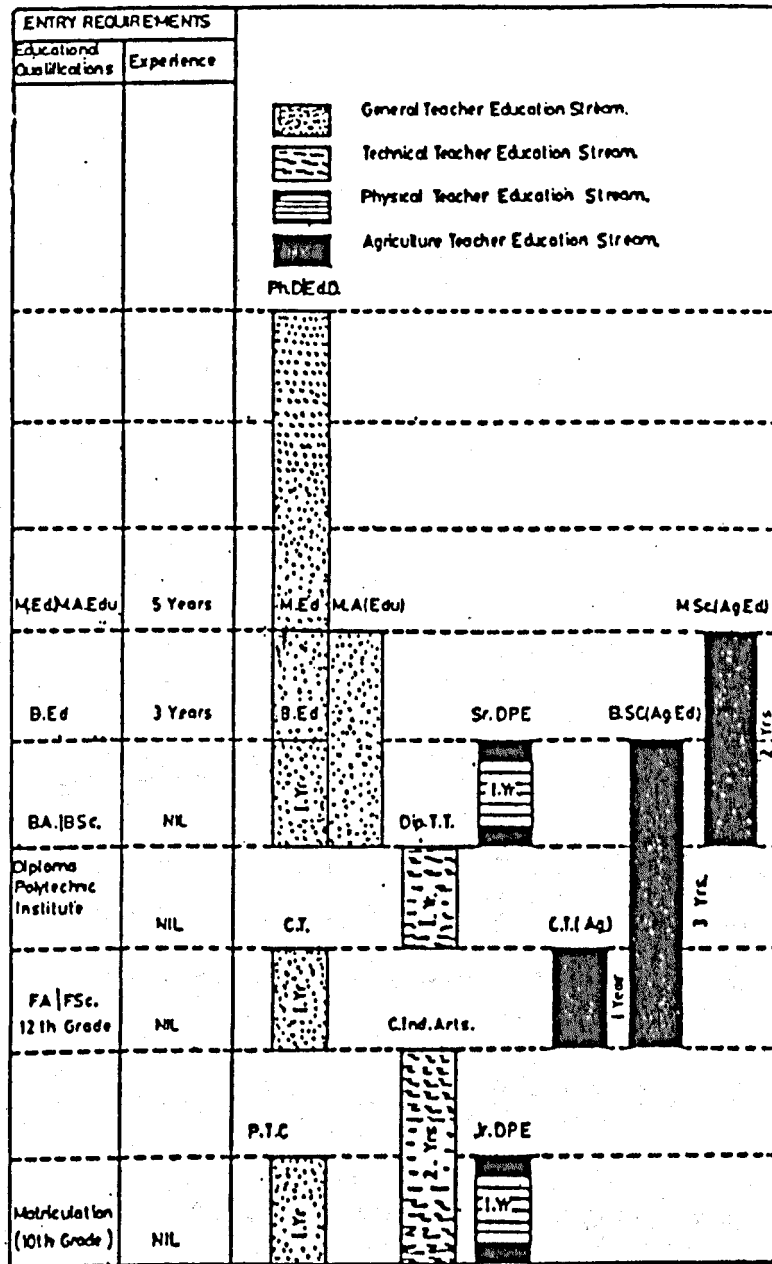
- i. Language Education
- ii. Mathematics Education
- iii. Social Studies Education
- iv. Educational Psychology
- v. Educational Guidance
- vi. Educational Administration
- vii. Curriculum
- viii. Teacher Education
- ix. Islamic Education
- x. Science Education

All the other post-graduate institutions in the country offer one-year degree programme which is called Master of Education (M.Ed.) degree in general education.

The National Institution of Education, Islamabad was established in 1974 to train key education personnel in methods and techniques of teaching and to provide orientation in new curricula and its implementation programme. Summer courses are also conducted there (and also at other institutions) in Science, Mathematics, English, and other subjects with the assistance of the British Council, UNESCO, USAID and other international agencies.

APPENDIX F

STRUCTURE OF TEACHER EDUCATION IN PAKISTAN



Taken from: Pakistan Ministry of Education, Teacher Education in Pakistan, Government of Pakistan, Curriculum Wing, Islamabad, 1977.

APPENDIX G

WORKSHOP PROGRAMME AND DESCRIPTION OF MATERIALS USED

As described in Section 5.1. Chapter V, a workshop was planned for the training of teachers. The workshop was aimed at enabling the teachers to remove misconceptions of students in the concepts of Force, Energy, and Light. It was held on three consecutive days from 9.00 a.m. to 11.00 a.m. each day. The three day programme of the workshop is outlined below along with the description of the materials used:

1. FIRST DAY

On the first day of the workshop, the following topics were discussed:

- i. Introduction to recent research work in science education with special emphasis on concept understanding.

The trainee-teachers were told the world-wide research efforts of researchers in the field of concept understanding. In particular, the work of the Personal Construction of Knowledge Group and the Learning in Science Project were discussed as described in Chapter III Section 3.8.

- ii. Introduction to techniques of exploring children's understanding of basic concepts in science

Under this topic, techniques used by various researchers to explore children's understanding of certain

concepts were explained. The discussion was limited to the Section 3.4 of Chapter III. M

iii. Introduction to the Interview-About-Instances Approach

This topic was discussed in the similar detail as described in Chapter III Sections 3.6. and 3.7. Rationale to select this technique was also explained. /

iv. Description of modification of the Instances used in Pakistani Situation

The trainee-teachers were told about the changes made in few of the instances. These changes have been described in Chapter IV, Section 4.1. Rationale for the modification of selected instances was also explained. /

v. Presentation of Students' Results for each concept. (i.e. Force, Energy, Light)

All the instances used in the investigation were shown to the teachers one by one. Students' responses were told according to the instances. Similarity in the views held by Pakistani students and that of other countries was also explained. Moreover, common patterns of students' misconceptions as described in Chapter III Section 3.10. were explained.

vi. Discussion to clarify and to sum up the ideas

The discussion was aimed at clarifying any of the problems or questions raised by the trainees. Although, the trainee-teachers were free to ask any question at any time during the three day workshop, this opportunity was provided to the teachers specially for the exchange of views at the end of one-day programme. Finally, the ideas discussed during the first day were summed up by the

researcher.

2. SECOND DAY

The following topics were covered on the second day of the workshop:

i. Summary of ideas discussed on the First Day of the workshop

At the beginning of the second day programme, the ideas discussed on the first day were reviewed briefly, and the programme of the second day was explained.

ii. Methodology for testing the science teachers

The trainees were told that after testing the students, teachers of these students were tested using a paper-and-pencil test. The over all methodology of testing the teachers as described in Chapter IV, Section 4.4 was explained.

iii. Description of the test instrument used

The nature and main features of the test were explained to the trainees. Reasons to select this test instrument were also explained as in the same manner as described in Section 4.4.2 of Chapter IV. To make the teachers fully aware of the test, photocopies of the test were also provided.

iv. Presentation of Results

After the description of the test, results were presented. This presentation was made by taking the test items one by one. These results were also compared with

those of the students'. Similarity of results was also explained.

- v. Discussion to clarify and to sum up the ideas presented on the second day.

As on the first day, the trainees discussed important points and ideas they wished to clarify. Finally, a summary of ideas discussed on the second day was presented.

3. THIRD DAY

The programme of the third day of the workshop included the following topics:

- i. Ausubel's Theory of Learning

Salient points of the Assimilation theory were discussed as described in Chapter II, Section 2.3.3. Particularly, the process of learning, 'rote' learning and 'meaningful' learning as viewed by Ausubel were discussed with due emphasis.

- ii. Outcomes of Interaction of Students' and Teachers' ideas

Under this topic, trainees were told that when the students' and teachers' ideas interact; this interaction results in various patterns of outcome as seen from the teacher's point of view. These ideas were adopted from Gilbert et al (1982), and a synopsis of these ideas is given in Appendix G-I. A handout containing these ideas was also provided to the trainees.

iii. A lesson that made misconceptions worse - An example

In order to explain the interaction of students' and teachers' ideas further, an example of a lesson was presented which was adopted from James (1983). A synopsis of this lesson is given in Appendix G-2.

iv. An exercise to Diagnose pupils' misconceptions

Then, in order to enable the trainees to diagnose their pupils' misconceptions, they were given an exercise to practice the diagnosis of misconceptions. This exercise was adopted from Nussbaum (1980, 1981) and is given in Appendix G-3.

v. Further exercise to diagnose misconceptions

For a further exercise to diagnose misconceptions, trainees were provided with worksheets. This was done to enable the teachers to assess their own understanding, and through this practice, to enable them to assess their pupils' understanding of basic concepts of science. Worksheets were adopted from Schollum et al (1981) and Osborne (1981) and are given in Appendices G-4 and G-5.

vi. Differences between children's ideas and scientists' ideas

In order to enable the trainees to contrast between the children's ideas and those of the scientists' ideas, and what needs to be changed to bring children's ideas close to the scientists' ideas, a study was adopted from Osborne et al (1981). A copy of the worksheet used is given in Appendix G-6.

vii. Discussion and Summary of ideas presented during the three day workshop

As before, the trainees were invited to ask questions related to the ideas discussed during the three day workshop. Finally, before closing the workshop, a summary of ideas was presented. Before dispersing, a programme of re-teaching and re-testing the concepts of Force, Energy, and Light was finalized with the teachers. This programme was prepared according to the convenience of the teachers.

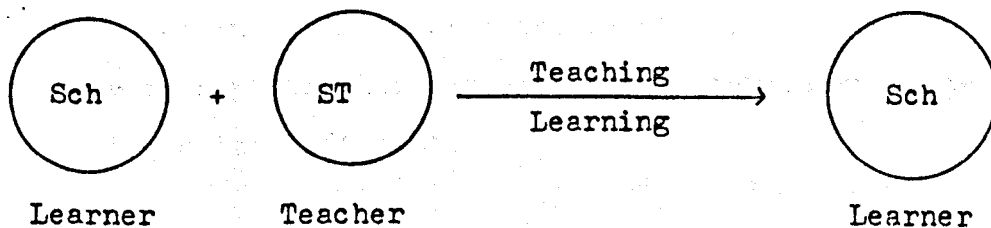
APPENDIX G-I

OUTCOMES OF INTERACTION OF STUDENTS' AND TEACHERS' IDEAS

On the basis of the data collected by the IAI method from students who have been taught science, Gilbert et al (1982) suggest that there are at least five patterns of outcomes, as seen from the teacher's point of view, when students' ideas interact with teacher's ideas:

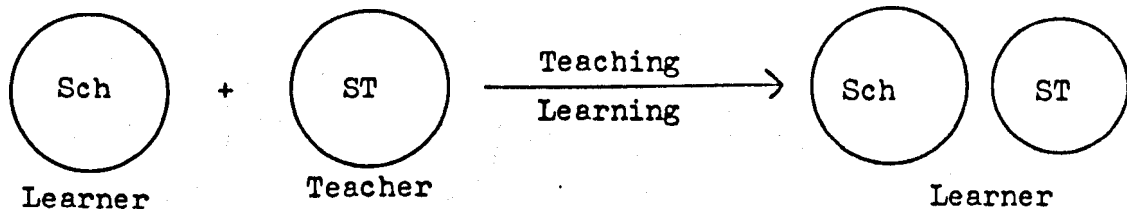
1. Undisturbed Children's Science Outcome

Some students have viewpoints which appear to be quite uninfluenced by formal teaching. However, although the viewpoint is essentially unaltered, often some language of science is now used to describe the viewpoint. The interaction that has occurred is presented in the figure below:



2. Two Perspective Outcome

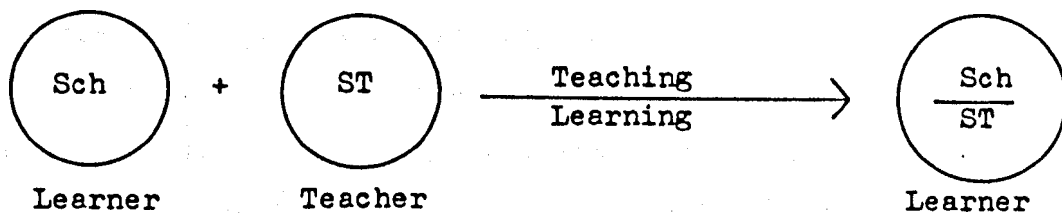
It is possible for the student basically to reject the teacher's scientific view of the world but to consider it as something that must be learnt, e.g. for assessment purposes. The student, therefore, has two views but the learned science viewpoint is not one that is used outside the formal learning situation. The interaction that has occurred is presented in the figure below:



3. Reinforced Outcome

The dominance of the students' prior understandings and meanings for words can, as suggested earlier, often lead to quite unintended interpretations of what is being taught. As one example of this, quantities defined in science in a particular way can be misinterpreted to mean something quite different.

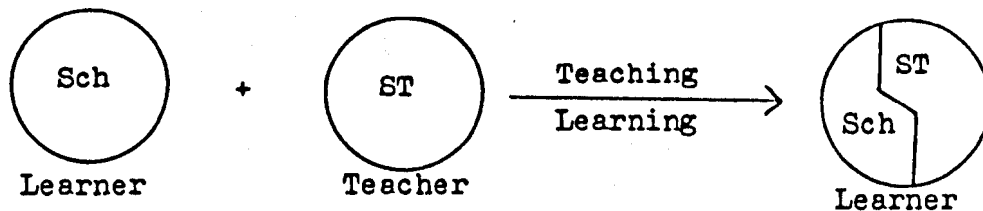
The student's own viewpoint is maintained following teaching but scientific concepts are put forward to explain or underpin a particular viewpoint. Many young children who have not been taught formal physics consider that there is a force in the direction of motion. The interaction that occurs is presented in the figure below:



4. Mixed Outcome

In many cases scientific ideas are learnt, understood and appreciated by learners. However, these ideas are interrelated in many different ways and at any one time only a certain amount can be learnt. Frequently, this results in students holding ideas that are not integrated and may be self-contradictory. In this outcome the learners' views are a mixture or amalgam of children's science views and teacher's views.

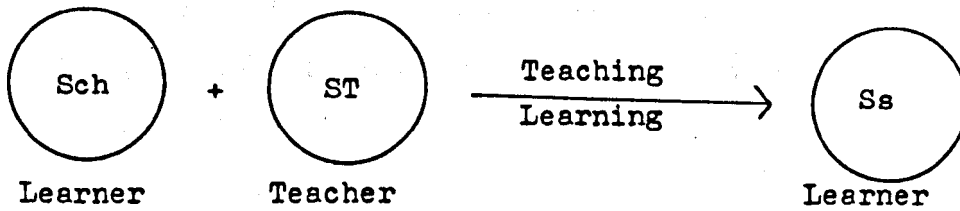
The interaction that has occurred is presented in the figure below:



5. Unified Scientific Outcome

An aim of science education is that a learner should obtain a coherent scientific perspective which he understands, appreciates and can relate to the environment in which he lives and works. Students can be found who have this view in relation to specific words and view points. Sometimes, the learned viewpoint is in fact more closely aligned to scientists' science than to the teachers' views of the science.

The interaction that has occurred is presented in the figure below:



If such interactions produce the outcomes illustrated, then teachers seem called upon to anticipate them.

APPENDIX G - 2

A LESSON THAT MADE MISCONCEPTIONS WORSE

Teacher's Objective

To help the students appreciate the concept of "adaptation" by allowing them to see a practical example of how it was beneficial to an animal to be adapted to its environment.

Experiment Selected

Title: Why do some animals have very large ears?

Investigation: Which bag of hot water loses heat more rapidly?

Equipment Used: Two plastic bags, thermometer, jug.

Procedure as directed to children

1. Add an equal volume of very hot water to each bag so that each is about one eighth full.
2. Tie one bag so that the water is in an almost spherical container.
3. Lie the other bag on the bench so that the water spreads over as great an area as possible.
4. At the end of ten minutes, measure the temperature of the water in each bag.

Questions Raised by the Teacher

1. Which bag of water cooled down more quickly?
2. Why did this happen?
3. How does having big ears help an animal survive in very hot areas?
4. In what other ways do animals behave in order to keep cool?

Due to circumstances at the time the experiment was copied from a blackboard by each student and instructions were given for the investigation to be carried out at home. A week later, practical reports were collected, after which a class discussion was held. Testing of the concept of adaptation occurred at the end of term, some 1½ months later.

The teacher used this analogy with the following reasons in mind:

1. The teacher felt that the model would be a mechanism by which students "school knowledge" of the concept of adaptation would become part of their "action knowledge." "School knowledge" is defined as that knowledge which some one else presents to us and is partly grasped, but does not become part of our working knowledge, whereas "action knowledge" is that knowledge which one can call one's own in that it can be drawn upon to help cope with some of the needs of everyday living. To achieve this transformation, it was hoped that students would be led to make connections between what they already know, what they were learning at the time and the more abstract idea of adaptation, i.e. from the known to the unknown.
2. The teacher felt that the experiment would interest his students enough for them to want to do the experiment. It certainly had an impact on them when they read the title question on the blackboard. Very few of the students did not attempt the experiment.

The answers to the worksheet questions by the children can be seen in tables 1 and 2 below:

Table 1: Students' answers to the question. "Why did the flat bag of hot water cool down more quickly than the rounded bag of hot water."

Answer	N = 28	Number	Percentage
1. More surface area -- more space to cool down.		20	71.2
2. Other responses		8	28.8

Table 2: Student's answers to the question: "How does having big ears help an animal to survive in very hot areas?"

Answer	N = 28	Number	Percentage
1. Cool down more quickly.		7	25.0
2. Hear better for pray, and cool down quicker.		2	7.1
3. Cool down and act as a fan.		3	10.6
4. Cooler because heat is spread more evenly around them.		2	7.1
5. Flat bag corresponds to large ears corresponds to cooling quicker.		2	7.1
6. Other Responses		9	32.4

While planning the lesson the teacher hoped that the students would go through the following processes of thought:

- Step 1: Complete the experiment, "Why Do Some Animals Have Large Ears?"
- Step 2: Find that the flatter bag cooled quicker than the spherical bag.
- Step 3: Reason that this occurred because the flatter bag had more of its surface area exposed to the surroundings than the spherical bag and so the rate of cooling was faster (greater surface area to volume ratio).
- Step 4: Extend this through to animals with large ears--can be one way for animals to lose heat.

The biggest jump which the students had to make was from step 3 to step 4. When the equipment for the experiment was listed, many students asked, "what have plastic bags got to do with large ears?" "Wait and see," the teacher told them. The analogy between the flat bags and large flat ears was not clear to some students. Much of the problem stemmed from the fact that step 1 did not correspond to his students' setp 1 i.e. the students' preconceptions affected the way they looked at the question.

Looking at their answers to the question, "How does having big ears help an animal to survive in very hot areas? 11 out of 28 students replied that:

1. the ears were needed for shade,
2. to hear prey better,
3. to be used as a fan to cool down,
4. to swat flies.

or a combination of these answers. These responses were associated with students' previous experience and learning, and were firmly entrenched, probably, in their "action knowledge".

When the teacher asked one of his students why she thought that large ears were used as a fan. "In all those Tarzan movies," she replied, "the elephants are always flapping their ears. That keeps them cool since it's so hot in Africa -- the ears are just like fans." This seemed logical to her.

At that moment, the teacher realized that not only were students' pre-conceptions important to consider, but also a teacher's own pre-conceptions should be taken into account.

After looking at this investigation we should stop and think about what we are teaching and our own misconceptions as well as our students'. It is often too easy to say a student is not a good learner, but often a teacher is just as imperfect. One must also look closely at the teaching strategies one employs to help students learn -- we can see that they may confuse students rather than clarify things, even though a teacher feels that it is a great way of getting across a scientific concept.

APPENDIX G-3

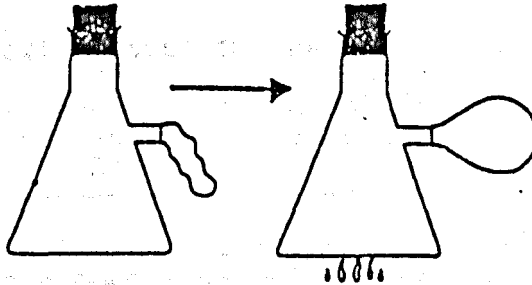
AN EXERCISE TO DIAGNOSE PUPILS' MISCONCEPTIONS

(These pages are a full version of Nussbaum's exercise, shown on Page 193)

Question

In a certain experiment a flask full of air had a deflated balloon attached to a side pipe coming out of the flask. As the flask was heated by a flame the balloon inflated.

Explain this phenomenon using the particle theory.

Administration

1. Read, the following answer given by a pupil:
"These is air in the bottle which fills it and also fills some of the balloon which is not blown up. If someone places the bottle with the molecules of the air above the flame then it becomes hot in the bottle and the air expands. The molecules move from the bottle to the balloon and this makes the balloon blow up."
2. Write a short evaluation of this answer and insert an appropriate numerical grade (out of 10 points) in the box.

3. Read and evaluate the following answer by a pupil.

"There is air in the bottle which fills it and also fills some of the balloon which is not blown up. Scientists discovered that the air which is in the bottle contains very small particles which are very great in number. These small particles, which they also found to be like tiny balls, can move and reach every place in the air of the bottle. Scientists called these particles molecules. If some one places the bottle with the molecules of the air above the flame, then it becomes hot in the bottle and the air expands and blows up the balloon. This happens because of the law which says that things expand when they are heated and also because when it becomes hot in the bottle then the very tiny molecules tend to go away from the hot place and so they move from the bottle to the balloon and this makes it blown up. If some one would like to see what would happen if the bottle were cooled down, he would find that the balloon would shrink again because of the law which says that things shrink when they are cooled. But with water it does not happen so since when water is cooled below 4°C then, amazingly enough, it would expand. This is what they call the anomaly of water."

Do the following steps further:

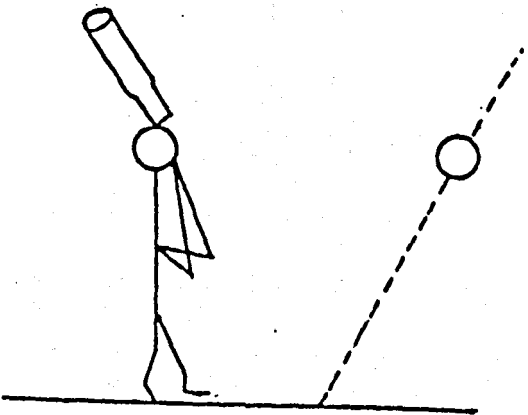
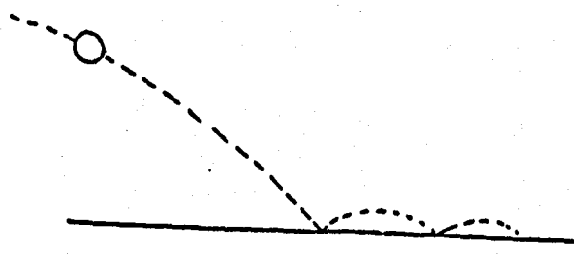
4. Read answer B again and identify various misconceptions which you think exist in the pupil's mind. Explain briefly the nature of each mistake

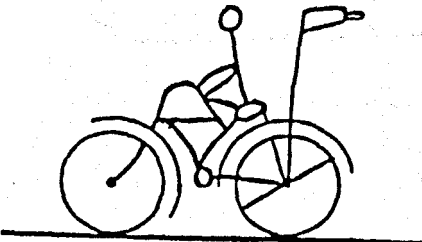
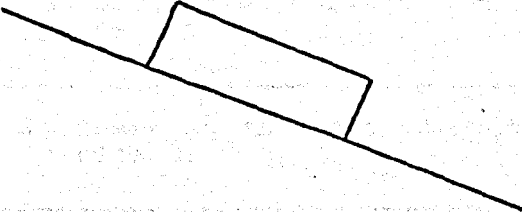
5. What is in your opinion the possible source for these conceptual mistakes?
6. Suppose the answers which indicate these types of misconceptions had been received from only 5 pupils out of the 30 pupils you have in your class. Following is a list of possible ways in which you could react as a teacher. Discuss with your peers the advantages and disadvantages of each:
- taking off a few points from the pupils' scores.
 - requiring the pupils to re-read the relevant chapter in the book.
 - requiring the pupils to look at the right answer in a classmate's test.

- d. talking to the pupils and explaining the correct answer.
- e. talking to the pupils and asking them additional questions.
- f. devoting 20 minutes of the next session to discuss the test and its difficulties.
- g. -----
- h. -----

APPENDIX G-4

WORK SHEET 1

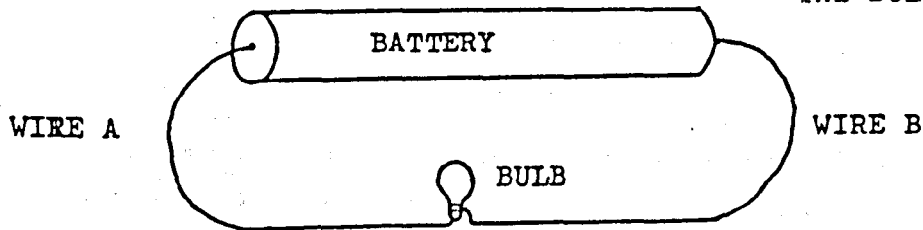
Instances	Yes/ No	Why you think that way
<p>1.</p>  <p>Are there any forces on the cricket ball?</p>		
<p>2. CRICKET BALL FALLING FREELY</p>  <p>Are there any forces on the ball?</p>		

Instances	Yes/ No	Why you think that way
3.  Are there any forces on the bicycle?		
4. THE BOX IS NOT MOVING  Are there any forces on the box?		

APPENDIX G-5

WORK SHEET II

THE BULB IS GLOWING



Question	Yes/ No	Why do you think that?
1. Is there an electric current in the bulb?		
2. Is there an electric current in wire A?		
3. Is there an electric current in wire B?		
4. Is the current in wire B less than the current in wire A?		
5. Does the electric current in wire B go from the bulb to the battery?		

APPENDIX G-6

A CONTRAST BETWEEN CHILDREN'S IDEAS AND SCIENTISTS' IDEAS

FORCE

Children's Science	Needs changing in terms of the Scientists' meaning of force.	Scientist's Science
Force is making some one do something against their will.	Force is <u>not</u> making some one do something.	Force is a push or pull.
Force is a thing <u>in</u> a moving body (e.g. a moving cricket ball)	Force is not a thing in a body; it acts <u>on</u> a body.	A moving body has <u>momentum</u> . The faster it moves the greater the momentum.
There must be a force on, or in, a body moving at a steady speed.	If a body is moving at a steady speed there is <u>no</u> total force acting on it.	The total force on a body, moving at steady speed, is zero.
Force is a thing put into a body causing it to move.	If a force is acting on a body, then something is pushing or pulling on the body.	Force on one body means there is an opposite force on another body.
Force is a change of position.	Force is only indirectly a change of position.	Force is a change of momentum (or speed or velocity).
Force is the same as momentum.	Force is not equal to momentum.	Force is the rate of change of momentum.

APPENDIX H

A SUMMARY SHEET OF CONCEPTS OF FORCE, ENERGY, AND LIGHT

FORCE

1. Material objects can be moved.
2. A force is necessary to make things move and make the moving things stop.
3. Force is push or pull.
4. It takes greater force to move heavy objects than light ones.
5. Force of running water and moving air can move objects.
6. Force of human muscles, animal muscles, engines can be used to make things move.
7. Force of gravity pulls the objects towards earth.
8. Force of friction stops motion.
9. An object at rest tends to stay at rest and an object in motion tends to stay in motion unless some outside force is applied.
10. Magnetic force helps to move certain things.
11. During the interaction of two material objects the action and reaction forces are equal and opposite.
12. The reaction of forces help to move certain things much as aeroplane, jets, rockets.

ENERGY

1. Changes are due to energy. Energy is the ability to do work.
2. There are different forms of energy--mechanical, heat, light, electrical and atomic energy.
3. Heat energy produces some changes--change of temperature, change of state, change of volume.

4. Heat energy is produced in burning.
5. Kinetic energy is the energy possessed by a body because of its motion.
6. Potential energy is the energy possessed by a body because of its position.
7. Heat is the energy due to molecular motion.
8. Energy is involved in chemical changes, which may be exothermic or endothermic.
9. Light is a form of energy and it can be converted into other forms of energy.

LIGHT

1. Sun is a source of heat and light.
2. Light is screened off by the intervention of an opaque object. Light passes through transparent objects.
3. We get more light from a source at shorter distance and less at a longer distance.
4. Shadows are cast in opposite direction to the source, they are formed because light travels in a straight line.
5. Light bounces off when it strikes objects--called reflection.
6. We can see things when light is either emitted by them or reflected from their surface.
7. The moon is a nonluminous body. Moonlight is reflected sunlight.
8. Sunlight consists of seven colours.
9. Transparent materials allow most of the light striking them to pass through. Translucent materials allow some light to pass through and some light to be absorbed. While opaque materials do not allow any light to pass through them, but absorb and reflect the light instead.
10. A material appears coloured because when light strikes the material all the coloured lights are absorbed except the one which is reflected to the eye.

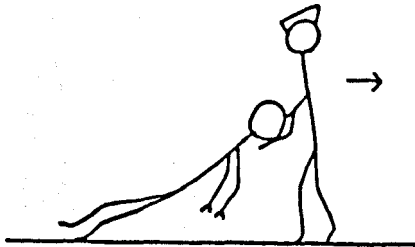
11. An image is seen in a plane mirror because almost all light striking its surface is reflected.
12. The image in a plane mirror is as large as the object in front of it and is laterally inverted.
13. Reflection is regular from a smooth surface and irregular from a rough surface.
14. When a beam of light passes from one medium into another it is bent in its path. This bending of light is called refraction.
15. Refraction produces many optical effects.
16. When a beam of light passes through a prism a band of colours called spectrum is obtained. This splitting up of light is called dispersion.
17. Rainbow is a spectrum that is produced when the sun shines during or immediately after a shower.
18. Any coloured transparent material looks coloured because it allows only one coloured light to pass through and absorb all the rest.
19. Red, blue and green are called primary colours of light.
20. Light is a form of energy and can be converted into other forms of energy.
21. Light can be reflected by spherical mirrors and are two types concave and convex.
22. Parallel rays of light striking a concave mirror are so reflected that all the rays converge at one point called the focus of the mirror.
23. A convex mirror diverges the rays of light passing through it.
24. Images can be formed from spherical mirror whose distance depends upon the distance of object.
25. Light can be refracted by the lenses. They are of two types concave and convex.
26. Parallel rays after passing through a convex lens converge at a point called the focus of the lens.

27. Concave lens diverges the rays of light passing through it.
28. Images can be formed by lenses. The distance of the image depends upon the distance of object.
29. Spherical mirrors and lenses are used in many optical instruments.

APPENDIX I

TEST ON FORCE

Q. 1. A Policeman is moving a Demonstrator.

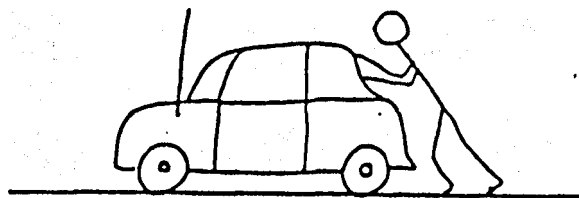


Tick () all the forces that act on the demonstrator.

1. Pull of Gravity
2. Policemen's Pull
3. Friction of the ground
4. Another force not mentioned

(F = 58.64, D = 0.26, Selected)

Q. 2. The man is trying to move the car but the car is not moving. The brakes are off.

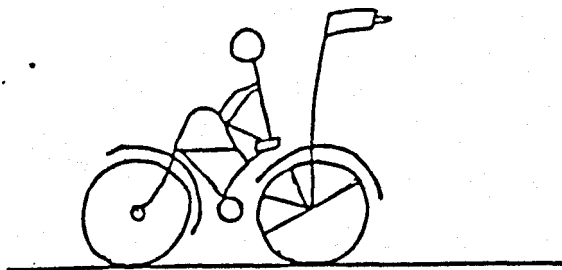


Tick () all the forces acting on the car.

1. Man's Push
2. Friction
3. Pull of Gravity
4. Inertia of the car

(F = 38.88, D = 0.17, Selected)

- Q. 3. A cyclist is moving along. He stops pedalling, does not use the brakes. The bicycle slows down.

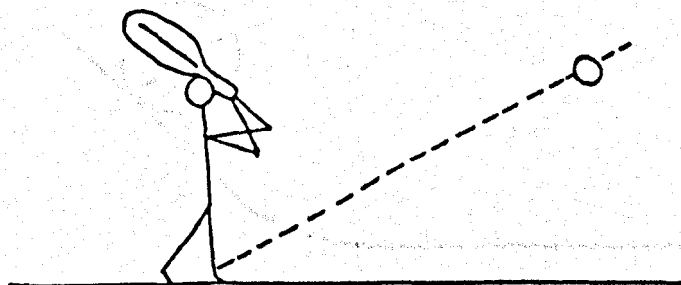


Tick () all the forces acting on the bicycle.

1. Pull of Gravity
2. Friction
3. Man's Force
4. Another force not mentioned

(F = 19.44, D = 0.17, Selected)

- Q. 4. A cricketer hits the ball and the ball now moves freely.

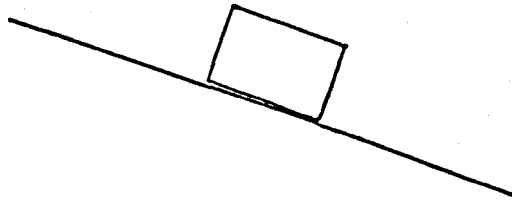


Tick () all the forces acting on the cricket ball.

1. Force of the cricketer
2. Pull of Gravity
3. Force of Air
4. Another force not mentioned

(F = 9.25, D = 0.06, Not Selected)

- Q. 5. There is a box on an Inclined Plane. The box is not moving.

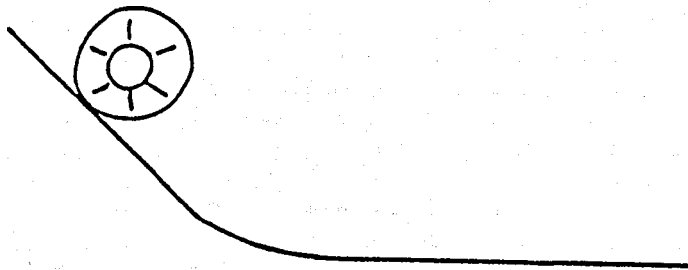


Tick () all the forces acting on the box.

1. Pull of Gravity
2. Friction
3. Reaction of the Inclined Plane.
4. Another force not mentioned

(F = 57.41, D = 0.21, Selected)

- Q. 6. A ball is rolling down a hill and speeding up.



Tick () all the forces acting on the ball.

1. Force of Air
2. Pull of Gravity
3. Reaction of the Hill
4. Another force not mentioned

(F = 58.64, D = 0.21, Not Selected)

- Q. 7. There is a cushion on the chair.
A man is sitting on the cushion.

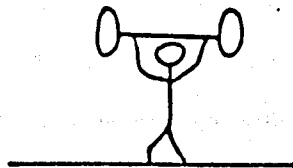


Tick () all the forces acting on the cushion.

1. Man's force
2. Force of air
3. Pull of gravity
4. No force

(F = 40.74, D = 0.074, Not Selected)

- Q. 8. A weight lifter is holding a bar and the bar is steady.

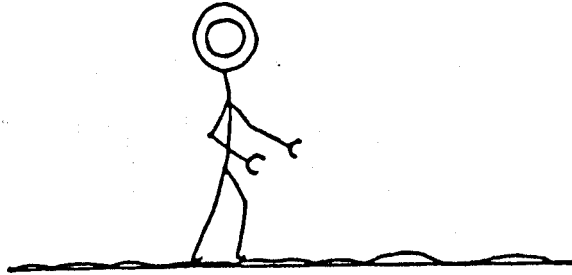


Tick () all the forces acting on the bar.

1. Man's force
2. Pull of gravity
3. Force of air
4. Another force not mentioned

(F = 50.93, D = 0.06, Not Selected)

Q. 9. A man is standing on the moon.

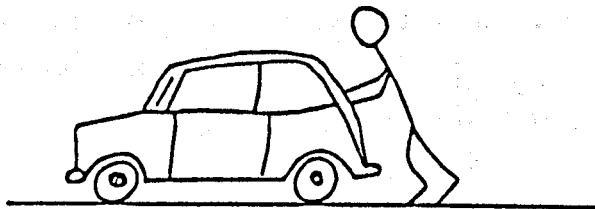


Tick () all the forces acting on the man.

1. Pull of Earth's Gravity
2. Pull of Moon's Gravity
3. Force of Air
4. Reaction of Moon's surface

(F = 36.11, D = 0.24, Selected)

Q. 10. The man is pushing the car and the car is moving.

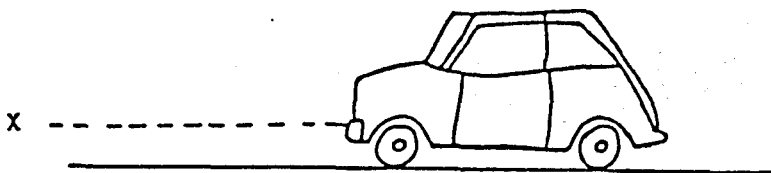


Tick () all the forces acting on the car.

1. Friction
2. Man's Push
3. Pull of Gravity
4. Reaction of the Earth

(F = 51.39, D = 0.21, Selected)

- Q. 11. A car is travelling along a flat road when the engine stops going. The car slows down and stops at X.

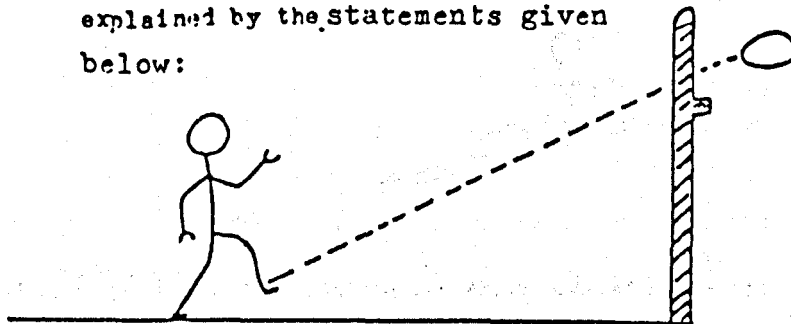


Tick () all the forces acting on the car which can be explained as

1. Gravity caused the car to stop
2. Friction caused the car to stop
3. The car just stopped naturally
4. The car ran out of force

(F = 7.40, D = -0.074, Not Selected)

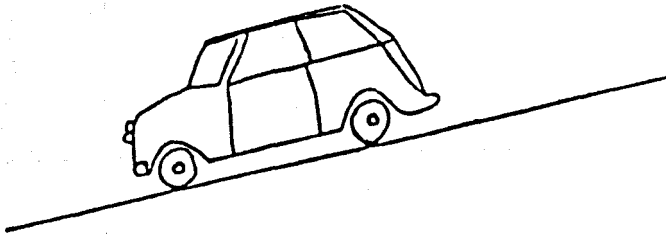
- Q. 12. A football has been kicked toward the goalpost. As it moves through the goal post, the forces acting on the ball can be explained by the statements given below:



Tick () all the forces acting on the foot ball.

1. The force of gravity
2. The force of friction
3. The force of the kick
4. Another force not mentioned

- Q. 13. A car is parked on a hill. It is not moving. Brakes are on!

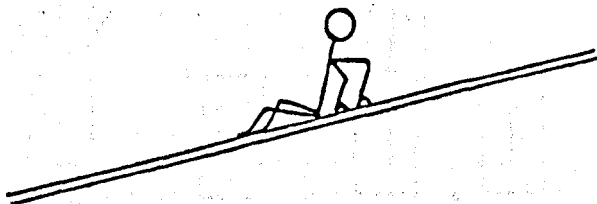


Tick () all the statements which explain the forces on the car.

1. There are many forces on the car but the total force is zero.
2. There are many forces on the car and the total force is downwards.
3. There is no force on the car at all.
4. Gravitational force is acting on the car.

(F = 11.11, D = 0.00, Not Selected)

- Q. 14. A person is on a slide but is not moving.

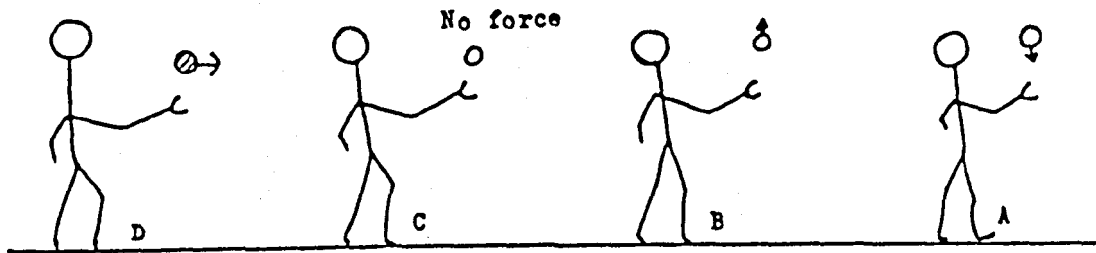


Tick () all the statements which explain the forces on the person.

1. Many forces are acting on the person but the total force is zero.
2. Many forces are acting on the person but the total force is downward.
3. The person is using his own force
4. No force is acting on the person at all

(F = 7.40, D = 0.00, Not Selected)

Q. 15. A person throws a tennis ball straight up into the air just a small way. If the ball is on the way up, then the force on the ball is shown from the following figures:

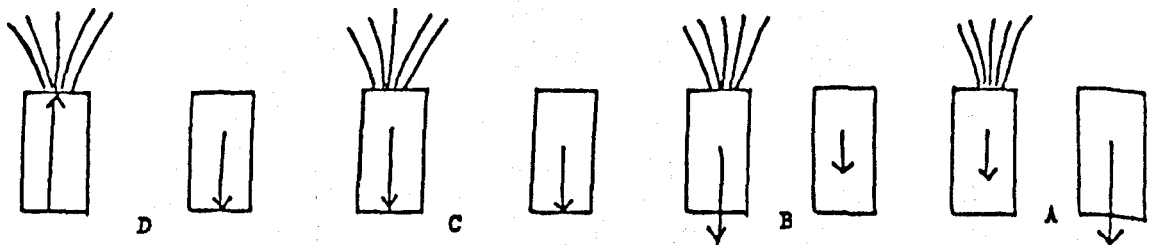


Tick () all the statements which explain the forces on the ball.

1. A. The force is acting downward because the force of gravity acts on the ball downward.
2. B. The force acts upward because the ball is moving upward.
3. C. There is no force on the ball because the upward force and the force of gravity balance each other.
4. D. The force is acting towards right away from the person.

(F = 9.25, D = 0.11, Selected)

Q. 16. Here are two torches. One is lit, the other switched off. The size of the arrows are supposed to show the size of the forces on the torches.

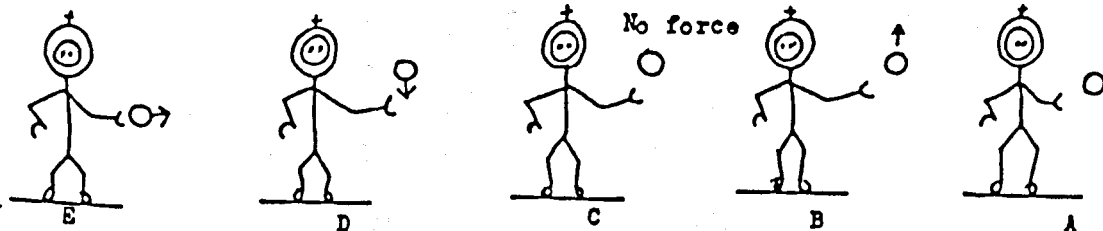


Tick () all the statements which explain the forces on the torches.

1. A is correct because more gravitational force is acting on the unlit torch.
2. B is correct because lit torch has more gravitational force than the unlit one.
3. C is correct because equal force of gravity acts on both the torches, no matter the torch is lit or not.
4. D is correct because the lit torch has more force upward because it is lit.

(F = 12.95, D = 0.11, Selected)

- Q. 17. Here is an astronaut on the moon. He has gently let go a ball (Fig. A). The arrows are supposed to show the direction of the force on the ball in the figures below:

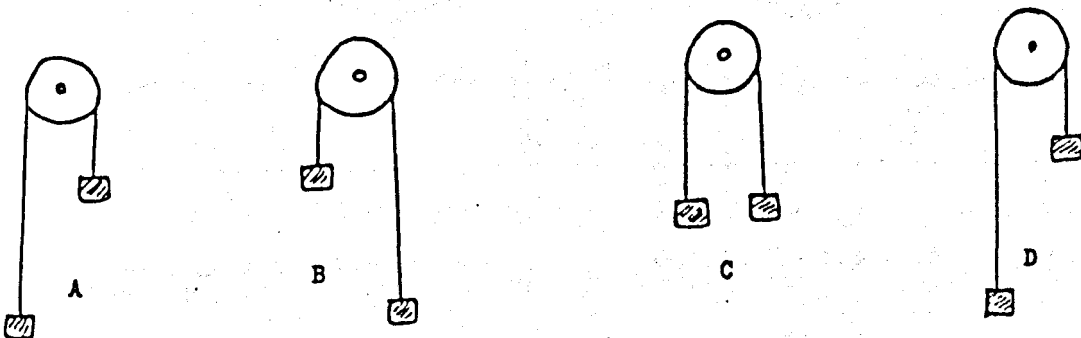


Tick (/) all the statements which explain the forces on the ball.

1. B is correct because there is no force acting on the ball, so it goes up.
2. C is correct because there is no force on the moon's surface so the ball is suspended in the space.
3. D is correct because gravitational force of the moon is acting on the ball, so the ball falls down towards the moon's surface.
4. E is correct, because the force of the astronaut pushes the ball towards right.

(F = 12.95, D = 0.26, Selected)

- Q. 18. Two equal objects are linked by a piece of string as in Fig. A. The string is placed lightly over a pulley. Here is a picture one minute later shown in B, C, and D.

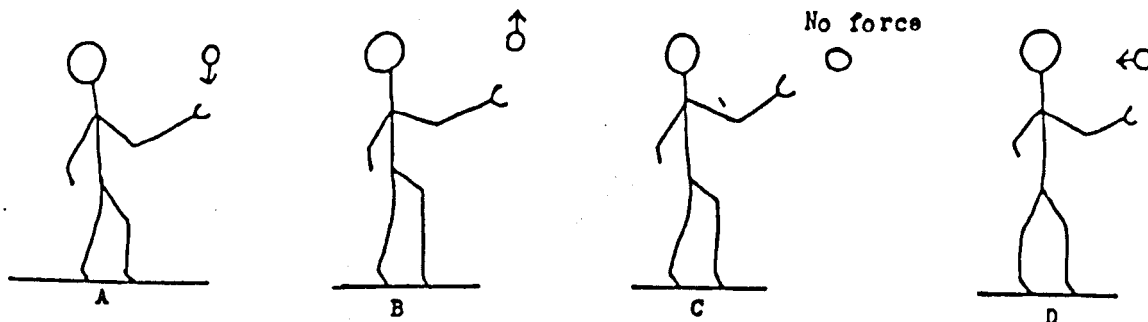


Tick (/) all the statements which explain the forces on the objects.

1. B is correct, because more force of gravity acts on the higher object, so the higher object comes down.
2. C is correct, because the weights are equal, so they move to adjust themselves at equal height.
3. D. As the weights are equal, so no one pulls the other, and, do not move from their positions.
4. Another reason not mentioned.

(F = 2.70, D = 0.00, Not Selected)

- Q. 19. A person throws a tennis ball straight up into the air just a small way. If the ball is on the way down, then the following figures show the force on the ball.

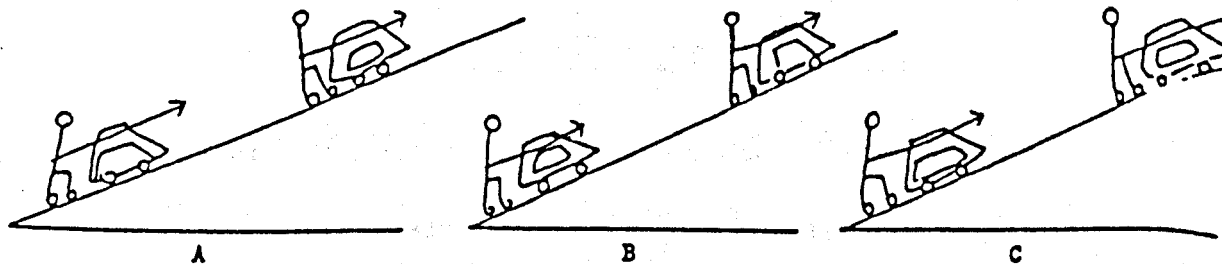


Tick () all the statements which explain the force on the ball.

1. A is correct because the pull of the gravitational force acts on it downwards.
2. B is correct because the person has thrown it upwards.
3. C is correct because the upward force of the person and the downward force of gravity balance each other.
4. D is correct because the force on the ball acts towards the person himself.

(F = 12.95, D = 0.11, Selected)

- Q. 20. Two persons are stopping the cars rolling down the hill. Both cars are the same and have the hand brake off. Here, the size of the arrows are supposed to show the size of the forces exerted by the persons on the cars. Following figures explain the forces on the cars.



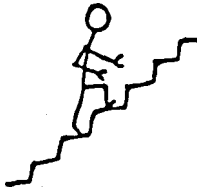
Tick () all the statements which explain the force of the persons on the cars.

1. A is correct because the man near the bottom has to use more force against gravity.
2. B is correct, because both of them use the same amount of force to stop the same size cars.
3. C is correct because the person at the top has to put in more force to stop the car rolling down. He has to put more force because he is higher.
4. Another force not mentioned.

(F = 1.85, D = -0.04, Not Selected)

TEST ON ENERGY

Q. 1. A person is climbing up the stairs.



Tick () all the correct statements from the following:

1. He is using his chemical potential energy to climb up.
2. He is making use of his kinetic energy.
3. He is using his gravitational potential energy.
4. He is making use of no energy.

(F = 7.41, D = 0.15, Not Selected)

Q. 2. A car is moving along the road.

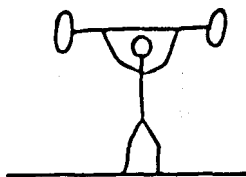


Tick () all the correct statements from the following:

1. Car is moving because of its own kinetic energy.
2. Car is moving because of its potential energy.
3. Car is moving because of its engine's force which gets energy from the chemical potential energy in the fuel.
4. Car has no energy, it is moving of its own.

(F = 37.04, D = 0.44, Selected)

Q. 3. A weight lifter is holding a bar stationary over his head.

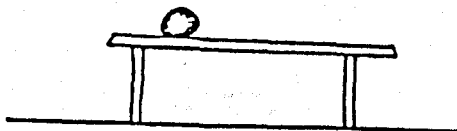


Tick () all the correct statements from the following:

1. Weight lifter is holding the stationary bar because of the gravitational energy of the bar.
2. Weight lifter is using energy of his hands while holding the bar in this position.
3. Weight lifter is using his heat energy for holding the bar in this position.
4. Weight lifter is using his chemical potential energy which he gets from the food he eats to hold the bar in this position.

(F = 9.26, D = 0.19, Not Selected)

Q. 4. A rock is lying on the table.

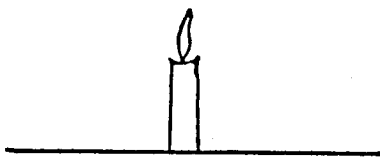


Tick () all the correct statements from the following:

1. There is no energy because the rock is just lying on the table.
2. The rock has gravitational potential energy which has been stored in it when it was lifted to this position.
3. The rock possesses kinetic energy.
4. The rock gets energy from the table.

(F = 16.67, D = 0.33, Selected)

Q. 5. A candle is burning.

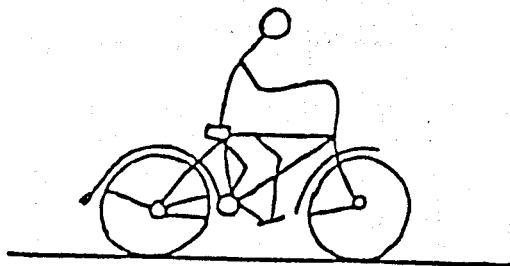


Tick () all the correct statements from the following:

1. The candle gets energy from carbon dioxide.
2. The candle uses kinetic energy.
3. The chemical energy changes to heat energy when the candle burns.
4. The candle uses chemical potential energy of the wax and converts it into heat and light energy.

(F = 14.81, D = 0.30, Not Selected)

Q.6. Bicycle is slowing down. The person uses no pedals, no brakes, but is slowing down.

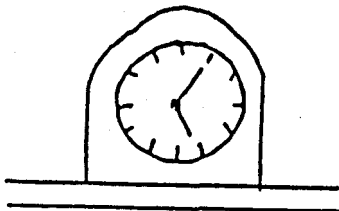


Tick () all the correct statements from the following:

1. The bicycle is moving because of its kinetic energy, but is slowing down because of friction.
2. The bicycle has potential energy that is why it is moving.
3. The bicycle is moving because of the potential energy of the cyclist.
4. The bicycle is moving because of the energy of the pedals.

(F = 22.22, D = 0.44, Selected)

Q. 7. Here is a wind-up clock.

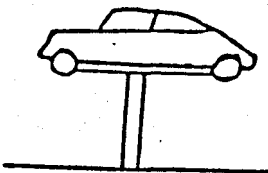


Tick () all the correct statements from the following:

1. The clock works because of gravitational energy.
2. The clock works because of chemical energy.
3. The clock gets energy from the spring where potential energy has been stored by a person by using his kinetic energy.
4. Any other energy not mentioned

(F = 29.63, D = 0.37, Selected)

Q. 8. A car has been lifted up by a jack and is stationary.

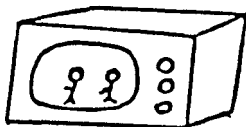


Tick () all the correct statements from the following:

1. Car has potential energy.
2. Car has kinetic energy.
3. Car has no energy.
4. The energy of the jack is keeping the car up there.

(F = 3.70, D = 0.07, Not Selected)

Q. 9. Here is a television which is 'on'.

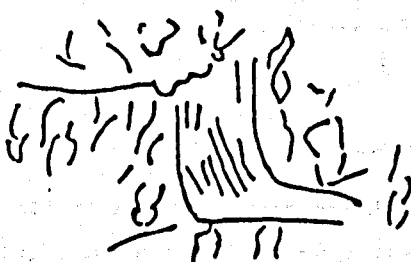


Tick () all the correct statements from the following:

1. The picture in the television is formed because of the chemical energy in the T.V.
2. The television has light energy that is why we can watch picture on it.
3. The television has sound energy that is why we can hear the sound from it.
4. Television works on electric energy and this energy is then converted to light, sound and some heat energy.

(F = 31.48, D = 0.49, Selected)

Q. 10. Here is a water fall.

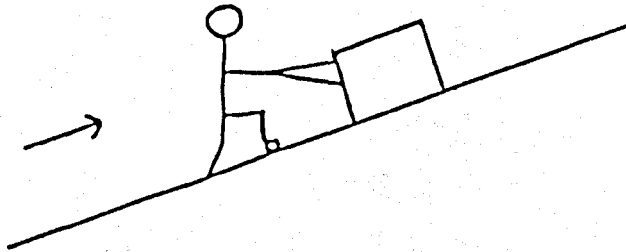


Tick () all the correct statements from the following:

1. Water falls down because of gravitational pull.
2. Water falls down because of greater height.
3. Water falls down because the gravitational potential energy of water is converted into its kinetic energy.
4. Water falls down because of its chemical energy.

(F = 11.11, D = 0.22, Not Selected)

Q. 11. A man is pushing a heavy box up a hill.

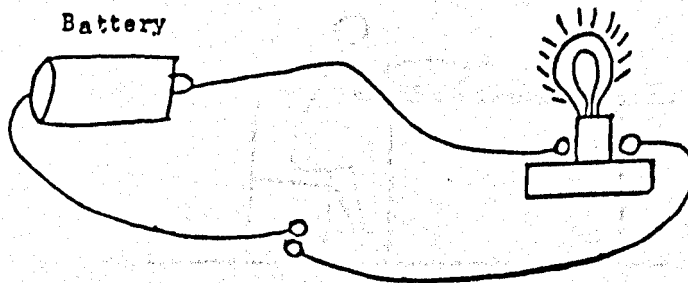


Tick () all the correct statements from the following:

1. The man is using his kinetic energy to push the box up.
2. The man is using his potential chemical energy to push the box up.
3. The man and the box both have potential energy.
4. Any other reason not mentioned.

(F = 0.00, D = 0.00, Not Selected)

C. 12. A battery, bulb and a switch have been put in a circuit. The bulb is 'on'.



Tick () all the correct statements from the following:

1. The bulb has electric energy that is why it gives off light.
2. The battery has chemical energy that is why the bulb gives off light.
3. The battery has kinetic energy that is why the bulb gives off light.
4. Neither the bulb nor the battery has any kind of energy.

(F = 9.26, D = 0.19, Not Selected)

Q. 13. There is some hot water in the beaker.

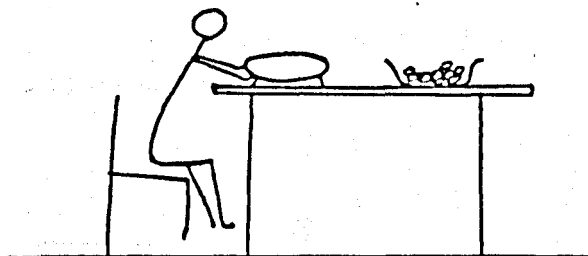


Tick () all the correct statements from the following:

1. The water has heat energy in it.
2. The water has chemical energy in it.
3. The water has potential energy in it.
4. Any other reason not mentioned

(F = 27.78, D = 0.33, Selected)

Q. 14. A person is eating a meal.

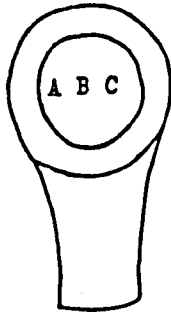


Tick () all the correct statements from the following:

1. The person is using his kinetic energy.
2. There is chemical potential energy in the meal.
3. The person is taking in the chemical energy while eating meal.
4. Any other reason not mentioned.

(F = 64.81, D = 0.41, Selected)

Q. 15. A person is using hand lens to read small letters.

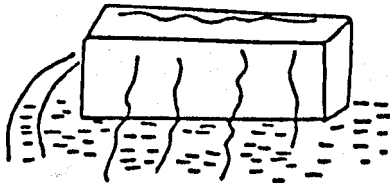


Tick () all the correct statements from the following:

1. The person can read the letters because of the mechanical energy in the lens.
2. There is light energy in the lens, that is why the person can read the letters.
3. There is chemical energy in the lens, that is why the person can read the letters.
4. The person is reading because of the light in the surroundings; using his own chemical potential energy and with the help of the lens.

(F = 25.93, D = 0.30, Selected)

Q. 16. A block of Ice is melting.

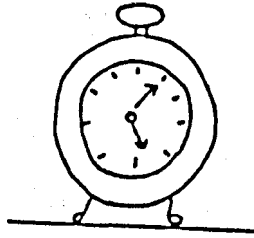


Tick () all the correct statements from the following:

1. Ice melts because it has heat energy in it.
2. Ice melts because of absorbing heat energy from the surroundings.
3. Ice melts because of the chemical energy stored in it.
4. Any other reason not mentioned.

(F = 18.52, D = 0.37, Selected)

Q. 17. There is an alarm clock with a luminous dial.



Tick () all the correct statements from the following:

1. There is no emission of energy here.
2. There is light energy emitted by the luminous dial.
3. The clock has potential energy stored in its spring when it was wound.
4. The clock has gravitational potential energy.

(F = 11.11, D = 0.15, Not Selected)

Q. 18. A person is sledging down hill in the snow.

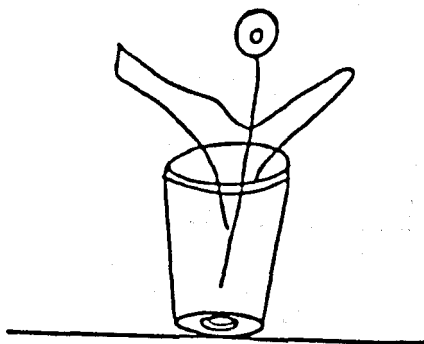


Tick () all the correct statements from the following:

1. The person is using his own energy while sledging down.
2. The person is sledging down because of gravitational potential energy.
3. The person is sledging down because he gets energy from the snow.
4. Any other reason not mentioned.

(F = 1.85, D = 0.04, Not Selected)

Q. 19. There is a flower plant in a pot.

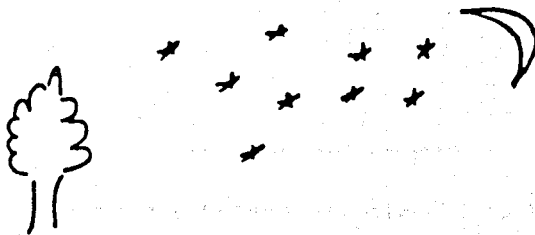


Tick () all the correct statements from the following:

1. The flower gets energy from the sun and the soil for its growth.
2. The flower gets energy from the earth for its growth.
3. Light energy falls on the flower that is why the flower is alive.
4. The flower plant gets energy only from the soil.

(F = 14.81, D = 0.30, Not Selected)

C. 20. The stars are shining at night.



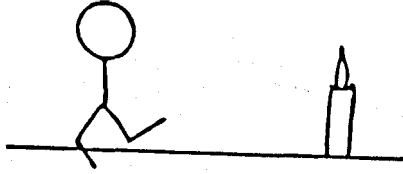
Tick () all the correct statements from the following:

1. There is no energy because there is no sun.
2. Stars shine because of the light energy emitted by themselves.
3. Stars get some energy from the moon as well.
4. Any other reason not mentioned.

(F = 31.48, D = 0.55, Selected)

TEST ON LIGHT

Q. 1. A Candle is burning.

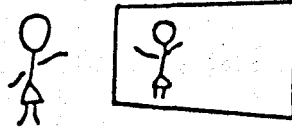


How do you see the candle?

1. Because of the surrounding light.
2. Because of light coming out of the candle.
3. Because of light coming out of your own eyes.
4. Because of reflection of light by the candle.

(F = 3.70, D = 0.074, Not Selected)

Q. 2. A person looks at himself in the Mirror.



How does a person see himself in the Mirror?

1. One can see himself because the light which falls on him when falls on the mirror is reflected by it.
2. One can see himself because of light in the surroundings.
3. One can see himself because this is the property of the mirror.
4. Any other reason not mentioned.

(F = 11.11, D = 0.22, Selected)

Q. 3. A person is looking at a rainbow.

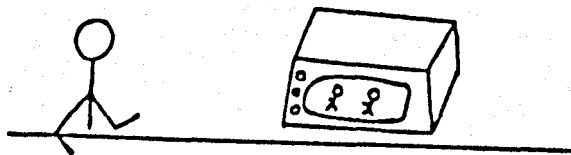


The colours in the rainbow are formed because of

1. Reflection of sunlight by the rain drops.
2. Dispersion of sunlight by the rain drops.
3. Transmission of sunlight through the rain drops.
4. Refraction and Reflection of sunlight by the rain drops.

(F = 5.60, D = 0.11, Not Selected)

Q. 4. A person is watching a television programme.

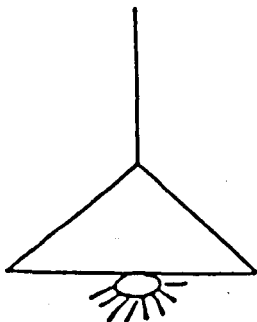


Do you think that the light from the T.V. Screen

1. Comes out about a metre.
2. Comes out to the person watching.
3. Travels a long distance and goes all over the room.
4. Just fades away about two or three metres away from the T.V.

(F = 22.22, D = 0.30, Selected)

Q. 5. A Light Bulb is switched 'on' during the day.

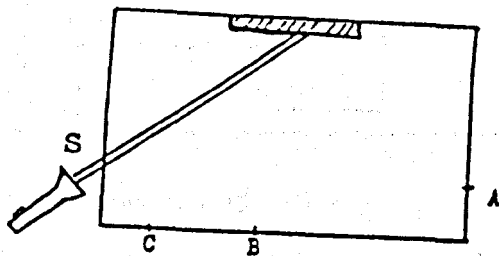


Do you think that the light from the light bulb

1. Stays on the light bulb.
2. Comes out about halfway towards you.
3. Comes out as far as you but no further.
4. Comes out until it hits something.

(F = 33.33, D = 0.66, Selected)

Q. 6. A torch is being shone through a hole in the wall of a room at S towards a mirror on another wall.



Where would you have to stand to see the reflection of the Light?

1. At A
2. At B
3. At C
4. Some where else.

(F = 20.37, D = 0.26, Selected)

Q. 7. An Electric bar heater is 'on' at night.

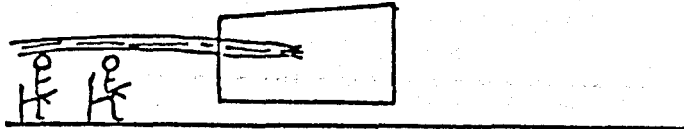


When the heater is 'on'

1. It produces 'light'.
2. It produces 'heat'.
3. It produces 'heat' as well as 'light'.
4. It produces light only at night.

(F = 3.70, D = 0.074, Not Selected)

Q. 8. A pupil is watching a film.

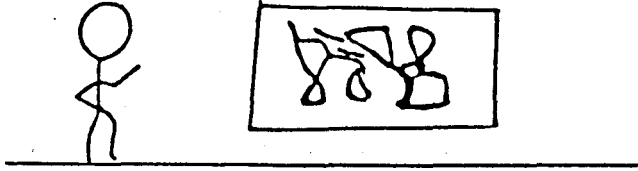


How can he see the film?

1. He can see the film because of reflection of the light falling on the screen.
2. He can see because of light coming out of the screen.
3. He can see because of the light coming out of his own eyes.
4. Any other reason not mentioned.

(F = 3.70, D = 0.074, Not Selected)

Q. 9. A Bright Red Painting.

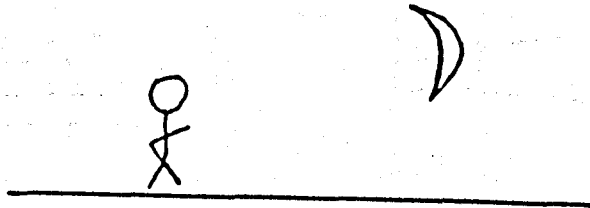


How do you see the painting?

1. Because of surrounding light.
2. Because of the light coming out of the painting.
3. Because of light coming from your own eyes.
4. Because of reflection of light by the painting.

(F = 1.85, D = 0.037, Not Selected)

Q. 10. Moon is shining.

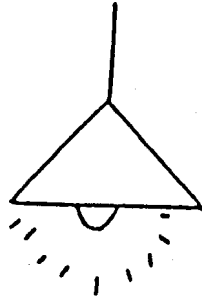


How does the moon shine during the night?

1. Because of its own light.
2. Because of reflection of sunlight.
3. Because of light from the other sources.
4. Any other reason not mentioned.

(F = 40.74, D = 0.74, Selected)

Q. 11. A light bulb is 'on' during the night.

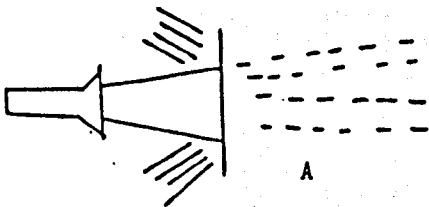


Do you think that the light from the bulb

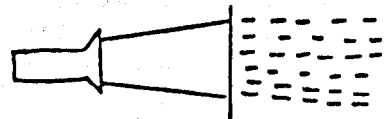
1. Stays on the light bulb.
2. Comes out about halfway towards you.
3. Comes out as far as you but no further.
4. Comes out until it hits something.

(F = 53.70, D = 0.85, Selected)

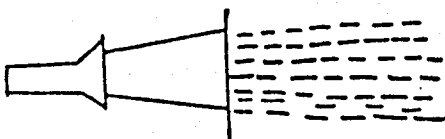
Q. 12. A torch is shone at a coloured filter.



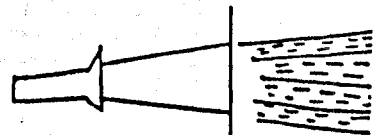
A



B



C

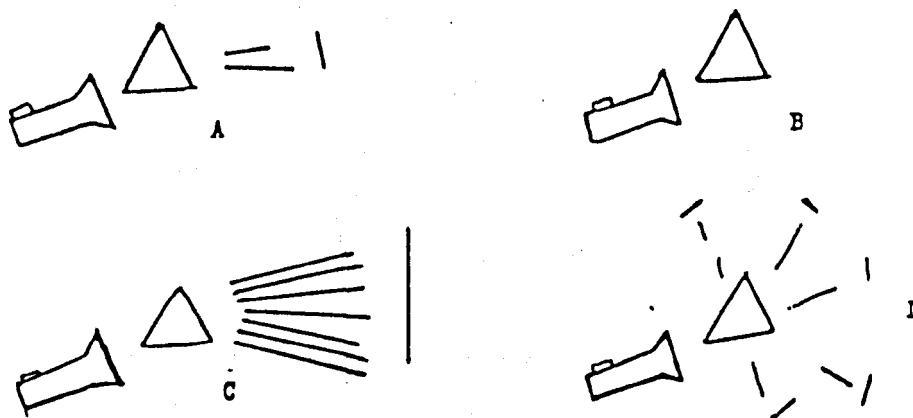


D

Which picture do you think best shows what happens when the light reaches the filter?

1. (A) The filter reflects some light and lets through a bit of coloured light.
2. (B) The filter absorbs some light and only lets through the coloured light.
3. (C) The white light from the torch pushes coloured light out of the filter.
4. (D) The filter dyes the white light of the torch

Q. 13. A torch is being shone at a glass prism

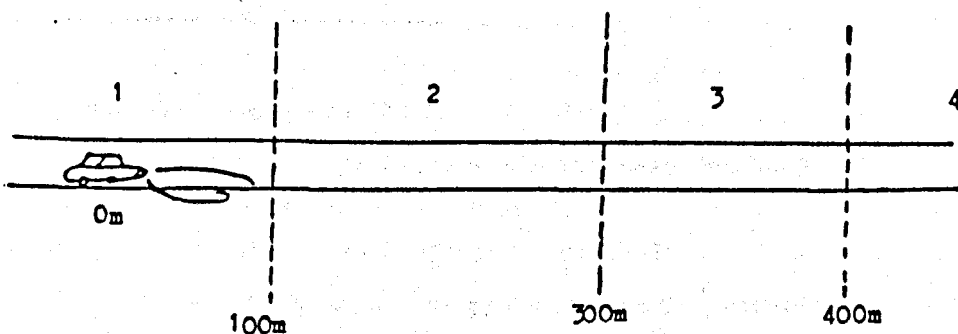


Which pictures do you think best show what happens with the light and the prism?

1. (A) Two sides produce two spots of light.
2. (B) The three sides produce three primary colours.
3. (C) A range of colours is produced which join up with each other.
4. (D) The prism sparkles and produces many spots of light

(F = 16.66, D = 0.33, Selected)

C. 14. A car is standing parked on a straight, flat road with its head lights dipped. A pedestrian, who is standing in the road, is able to see the headlights.

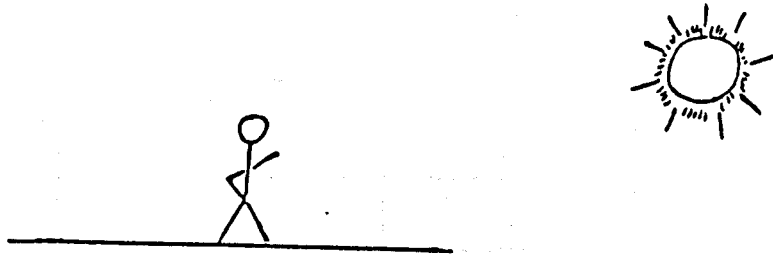


In which sections is there light?

1. There is light only in Section 1, because, headlight reached this far.
2. There is light in Section 2, because batteries are not strong enough.
3. The pedestrian can see the light, therefore there is light in 1, 2 and 3.
4. Possibly, light can go up to 4 and even beyond that.

(F = 9.26, D = 0.185, Not Selected)

Q. 15. The Sun is Shining.

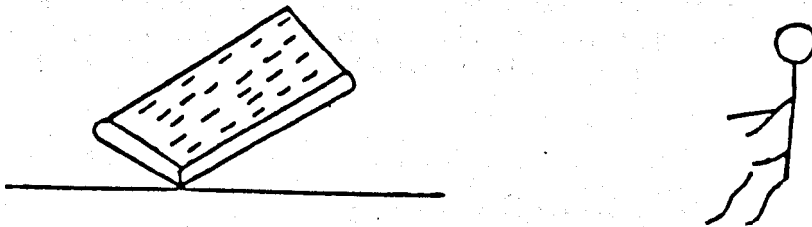


How far does the light from the sun go?

1. It goes up to the Earth.
2. It goes up to the Earth and the Moon.
3. It can go a little beyond our Earth.
4. It goes up to infinite distance.

(F = 12.96, D = 0.26, Selected)

Q. 16. A person is looking at the book.

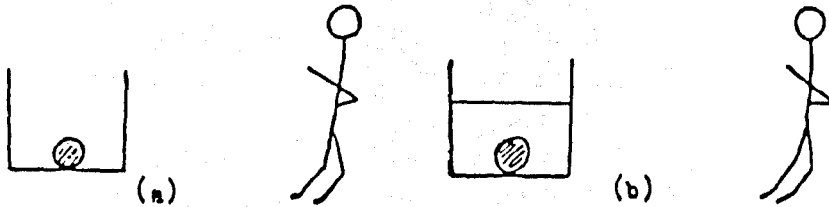


The person can see the book because:

1. Some kind of eye waves go between the book and the eyes.
2. Light shines in the surroundings.
3. The book gives off light, which is perceived by the eye.
4. The book reflects light. This light then hits the eye.

(F = 9.26, D = 0.186, Selected)

- Q. 17. A person is looking down into a bucket in fig (a). There is a glass marble on the bottom. He can not see the marble. When the bucket is filled with water as in fig. (b) the person is able to see the marble. Neither the person, nor the bucket has moved.

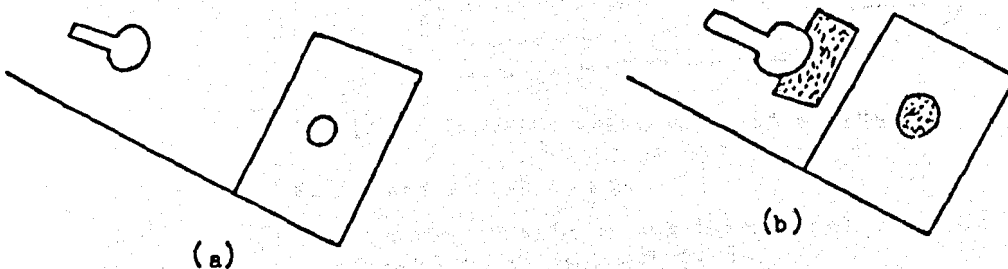


The reason that he can see the marble may be.

1. That the marble appears to have moved.
2. That the marble is reflected by the water in the bucket
3. When the light rays from the marble meet the surface of water, they are bent and that is why he can see it.
4. The water makes the marble clearer to see the bucket.

(F = 22.22, D = 0.37, Selected)

- Q. 18. A torch is shone on a door (Fig.a). A spot of white light can be seen on the door. When a plate of transparent red glass is placed in front of the torch, a spot of red light is seen on the door.(Fig.b)



The plate of red glass changes the colour of the spot from white to red due to the reason that.

1. The red glass plate gives red light.
2. The light goes through the red glass plate, which colours it red.
3. The plate of glass lets only red light through and the rest is absorbed.
4. When the light reaches the plate of red glass, the rays are bent and they change the colour.

(F = 0.00, D = 0.00, Not Selected)

Q. 19. There is a flower plant in a pot.

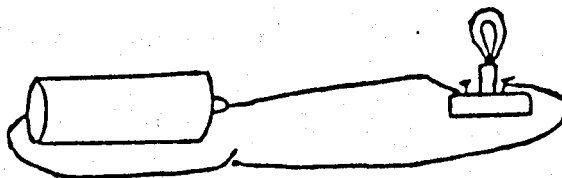


The colours in the flower can be seen

1. Because of the light in the surroundings.
2. Because of the reflection of light falling on the flower surface.
3. Because of absorption of some of the light waves and reflection of the other.
4. Any other reason not mentioned.

(F = 7.40, D = 0.148, Not Selected)

Q. 20. A battery, bulb and switch put in a circuit.



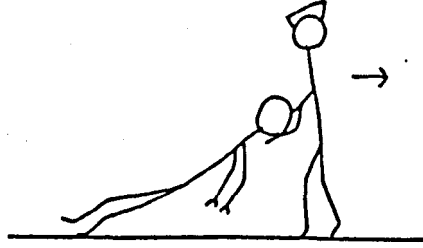
The light from the bulb comes out because

1. The switch is on.
2. Current heats up the filament of the bulb and the bulb then gives off light.
3. Of the gas already filled in the bulb.
4. Any other reason not mentioned.

(F = 7.40, D = 0.148, Not Selected)

FORCEقوت کا ٹیسٹ

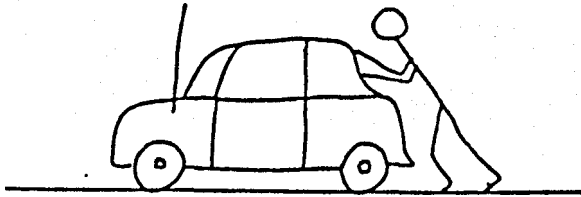
سوال نمبر ۱ - ایک سپاہی مظاہرہ کرنے والے کو لے جا رہا ہے -



مظاہرہ کرنے والے پر عمل کرنے والی قوتوں پر یہ (/) نشان لگائیں

- الف - ثقلی قوت
 ب - سپاہی کے کھینچنے کی قوت
 ج - زمین کے ساتھ رگڑ کی قوت
 د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

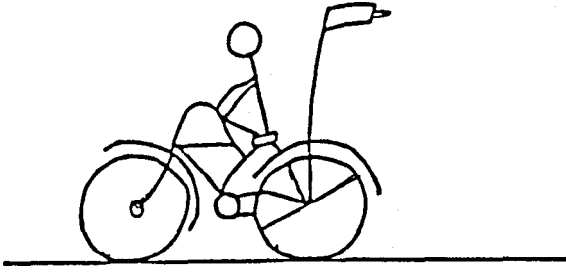
سوال نمبر ۲ - آدمی کار کو حرکت دینے کی کوشش کر رہا ہے لیکن کار حرکت نہیں کر رہی - جبکہ بریک بھی نہیں لگائی گئی -



کار پر عمل کرنے والی قوتوں پر یہ (/) نشان لگائیں -

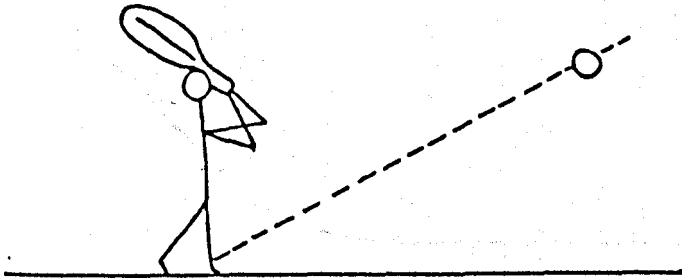
- الف - آدمی کے دھکیلنے کی قوت -
 ب - رگڑ کی قوت
 ج - ثقلی قوت -
 د - کار کی جمودی قوت -

سوال نمبر ۳ - ایک سائیکل سوار جا رہا ہے - وہ پیڈل کا استعمال نہیں کر رہا ،
 وہ ہی بریکیں استعمال کر رہا ہے - سائیکل کی رفتار کم ہو رہی ہے -



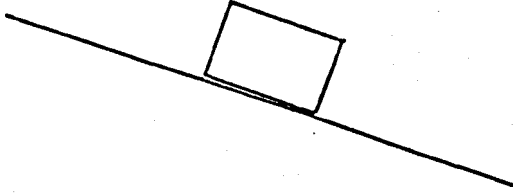
- ہائیسیکل پر عمل کرنے والی قوتوں پر یہ (/_) نشان لگائیں -
- الف - ثقلی قوت -
- ب - رگڑ کی قوت
- ج - سائیکل سوار کی قوت -
- د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۴ - کرکٹ کے ایک کھلاڑی نے گیند کو ہٹ (Hit) لگائی ہے اور اب گیند
 آزادانہ حرکت کر رہی ہے -



- گیند پر عمل کرنے والی قوتوں پر یہ (/_) نشان لگائیں -
- الف - کھلاڑی کی قوت
- ب - ثقلی قوت -
- ج - ہوا کی قوت -
- د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۵ - ڈھلوان سطح پر ایک ڈبہ پڑا ہے - ڈبہ حرکت نہیں کر رہا ہے -



ڈبہ پر عمل کرنے والی قوتوں پر یہ (/_) نشان لگائیں -

الف - ثقلی قوت -

ب - رگڑکی قوت -

ج - ڈھلوان سطح کا ردعمل -

د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۶ - ایک گیند پھائی سے نیچے کی طرف حرکت کر رہا ہے اور اسکی رفتار بڑھ رہی ہے -



گیند پر عمل کرنے والی قوتوں پر یہ (/_) نشان لگائیں -

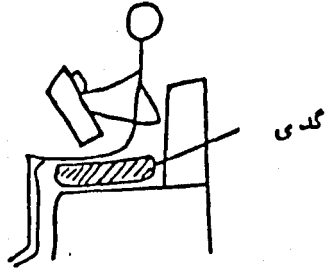
الف - ہوا کی قوت -

ب - ثقلی قوت -

ج - پھائی کی سطح کا ردعمل -

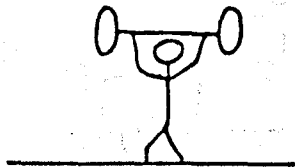
د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۷ - کرسی پر گدے بیٹھی ہے اور ایک آدمی گدی پر بیٹھا ہے -



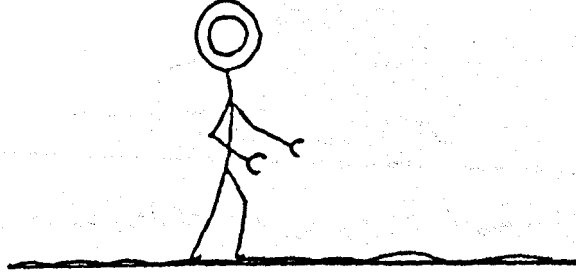
- گدی پر عمل کرنے والی قوتوں پر یہ (/) نشان لگائیں -
- الف - آدمی کسی قوت
ب - ہوا کسی قوت
ج - ثقلی قوت
د - کوئی بھی قوت نہیں -

سوال نمبر ۸ - ایک وزن اٹھانے والے آدمی نے بھاری سلاخ اٹھا رکھی ہے اور سلاخ حرکت نہیں کر رہی ہے -



- سلاخ پر عمل کرنے والی قوتوں پر یہ (/) نشان لگائیں -
- الف - آدمی کسی قوت -
ب - ثقلی قوت
ج - ہوا کسی قوت
د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۹ - ایک آدمی چاند کی سطح پر کھڑا ہے -



آدمی پر عمل کرنے والی قوتوں پر ہمہ (/) نشان لگائیں -

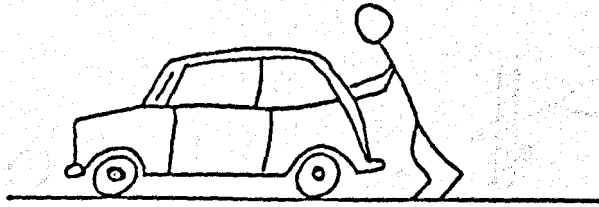
الف - زمین کی کشش

ب - چاند کی کشش

ج - ہوا کی قوت

د - چاند کی سطح کا ردعمل

سوال نمبر ۱۰ - ایک آدمی کار کو دھکا لگا رہا ہے اور کار حرکت کر رہی ہے -



کار پر عمل کرنے والی قوتوں پر ہمہ (/) نشان لگائیں -

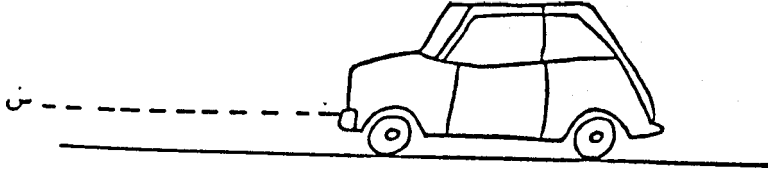
الف - رگڑ کی قوت

ب - آدمی کے دھکیلنے کی قوت

ج - ثقل کی قوت

د - زمین کا ردعمل -

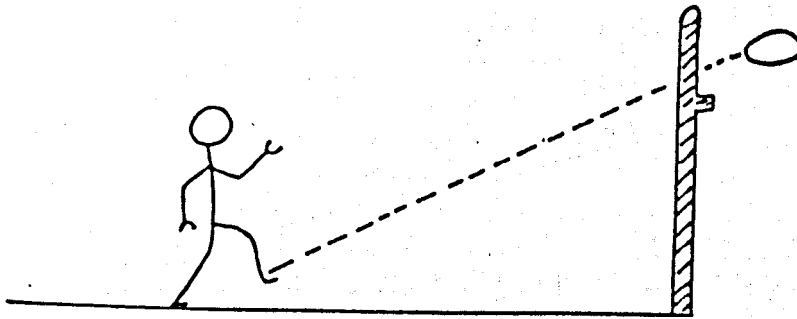
سوال نمبر ۱۱ - ایک کار کھلی سڑک پر جا رہی ہے لیکن کار کا انجن بند ہو جانے کی وجہ سے اسکی رفتار آہستہ آہستہ کم ہو گئی ہے - حتیٰ کہ کار مقام "س" پر رک گئی ہے -



مندرجہ ذیل بیانات میں کار کے رکنے کی وجوہات بتائی گئی ہیں آپ صحیح بیان / بیانات پر یہ (/) نشان لگائیں -

- الف - کار ثقلی قوت کی وجہ سے رک گئی ہے -
- ب - کار رگڑ کی قوت کے زیر اثر رک گئی ہے -
- ج - کار قدرتی طور پر رک گئی ہے -
- د - کار کسی قوت ختم ہو گئی ہے -

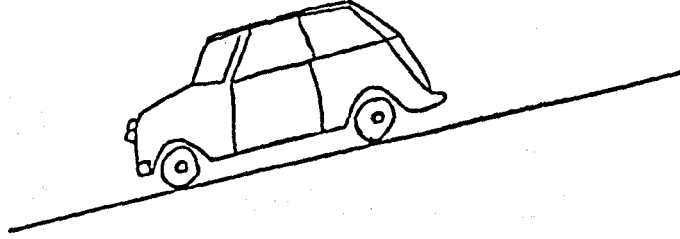
سوال نمبر ۱۲ - فٹ بال کو " گول پول " کی طرف " ہٹ " لگائی گئی - فٹ بال جس وقت " گول پول " میں سے گزر رہا ہے - اس پر عمل کرنے والی قوت کو درج ذیل بیانات سے واضح کیا گیا ہے -



فٹ بال پر عمل کرنے والی قوتوں پر یہ (/) نشان لگائیں -

- الف - ثقلی قوت
- ب - رگڑ کی قوت
- ج - ہٹ لگانے کی قوت
- د - کوئی اور قوت جس کا ذکر نہ کیا گیا ہو -

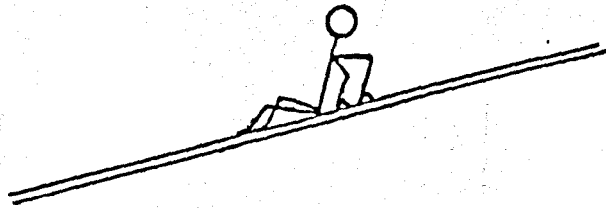
سوال نمبر ۱۳ - ایک کار پہاڑی پر کھڑی ہے یہ حرکت نہیں کر رہی ہے - بریکن لگی ہوئی ہیں -



ایسے تمام بیانات پر یہ (/_) نشان لگائیں جو کار پر عمل کرنے والی قوتوں کو واضح کرتے ہوں -

- الف - کار پر بہت سی قوتیں عمل کر رہی ہیں لیکن مجموعی قوت صفر ہے -
 ب - کار پر بہت سی قوتیں عمل کر رہی ہیں لیکن مجموعی قوت نیچے کی طرف عمل کر رہی ہے -
 ج - کار پر کوئی بھی قوت عمل نہیں کر رہی ہے -
 د - کار پر ثقلی قوت عمل کر رہی ہے -

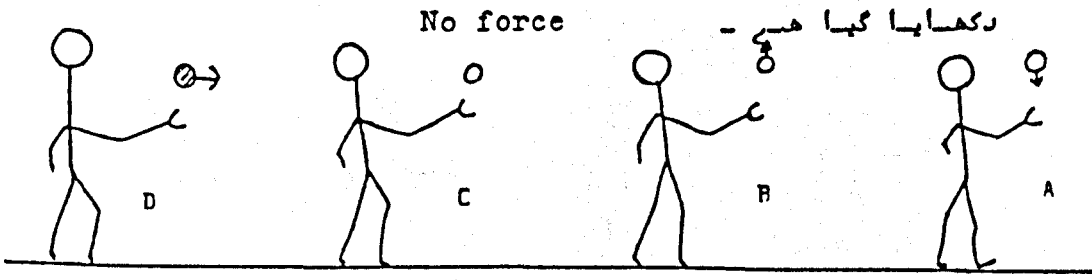
سوال نمبر ۱۴ - ایک آدمی ڈھلوان سطح پر کھڑا ہے لیکن حرکت نہیں کر رہا -



ایسے تمام بیانات پر یہ (/_) نشان لگائیں جو آدمی پر عمل کرنے والی قوتوں کو واضح کرتے ہوں -

- الف - آدمی پر بہت سی قوتیں عمل کر رہی ہیں لیکن مجموعی قوت صفر ہے -
 ب - آدمی پر بہت سی قوتیں عمل کر رہی ہیں لیکن مجموعی قوت نیچے کی طرف عمل کر رہی ہے -
 ج - آدمی خود اپنی قوت استعمال کر رہا ہے -
 د - آدمی پر کوئی بھی قوت عمل نہیں کر رہی ہے -

سوال نمبر ۱۵ - ایک آدمی ٹیبل کی گیند کو ہوا میں اوپر کی طرف پھینکتا ہے گیند ابھی اوپر جا رہی ہے - اس پر عمل کرنے والی قوت کو دی گئی اشکال کے مطابق



ایسے تمام بیانات پر یہ (/_) نشان لگائیں جو گیند پر عمل کرنے

والی قوتوں کو واضح کرتے ہیں -

الف - (A) قوت نیچے کی طرف عمل کر رہی ہے کیونکہ ثقلی قوت گیند

پر نیچے کی طرف عمل کرتی ہے -

ب - (B) قوت اوپر کی طرف عمل کرتی ہے کیونکہ گیند

اوپر کی طرف حرکت کر رہا ہے -

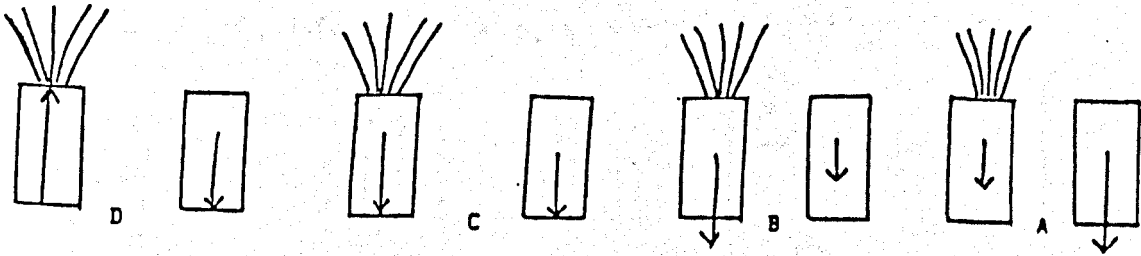
ج - (C) گیند پر کوئی قوت عمل نہیں کر رہی کیونکہ اوپر

والی قوت اور ثقلی قوت ایک دوسرے کے برابر ہیں -

د - (D) قوت آدمی کی دائیں جانب عمل کر رہی ہے -

سوال نمبر ۱۶ - یہاں پر دو نارچ دکھائے گئے ہیں ایک روشن ہے دوسرا روشن نہیں ہے

تیسرے نشان نارچ پر عمل کرنے والی قوت کی مقدار کو ظاہر کرتے ہیں -



ان تمام بیانات پر یہ (/_) نشان لگائیں جو نارچ پر عمل کرنے

والی قوتوں کو واضح کرتے ہیں -

الف - (A) درست ہے کیونکہ غیر روشن نارچ پر ثقلی قوت زیادہ عمل کر رہی ہے

ب - (B) درست ہے کیونکہ روشن نارچ پر غیر روشن نارچ کے مقابلہ میں

ثقلی قوت زیادہ عمل کرتی ہے -

ج - (C) درست ہے کیونکہ دونوں نارچوں پر یکساں ثقلی قوت عمل

کرتی ہے اس سے کوئی فرق نہیں پڑتا کہ نارچ روشن ہے یا نہیں -

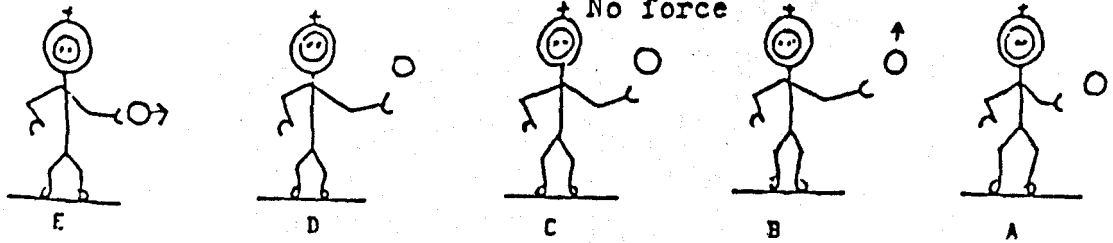
د - (D) درست ہے کیونکہ روشن نارچ پر اوپر کی طرف قوت عمل کر رہی

ہے جو کہ اسے روشن ہونے کی وجہ سے ہے -

سوال نمبر ۱۷۔ چاند پر کھڑے ایک خلا باز نے آہستہ سے ایک گیند کو گرایا (شکل A)

نیچے والی شکلوں میں تیسرے نشان " گیند " پر عمل کرنے والی قوت

کی سمت کو ظاہر کرتے ہیں -



ان تمام درست بیانات پر ہمہ (/) نشان لگائیں جو کہ گیند پر قوت

کو واضح کرتے ہیں -

الف - (A) درست ہے چونکہ گیند پر کوئی قوت عمل نہیں کرتی - اسلئے

ہمہ اوپر کی طرف حرکت کرتا ہے -

ب - (C) درست ہے - چونکہ چاند کی سطح پر کوئی قوت نہیں ہے -

اسلئے گیند خلا میں رک جاتا ہے -

ج - (B) درست ہے کیونکہ چاند کی کشش گیند پر عمل کر رہی ہے

اسلئے گیند چاند کی سطح کی طرف گرتا ہے -

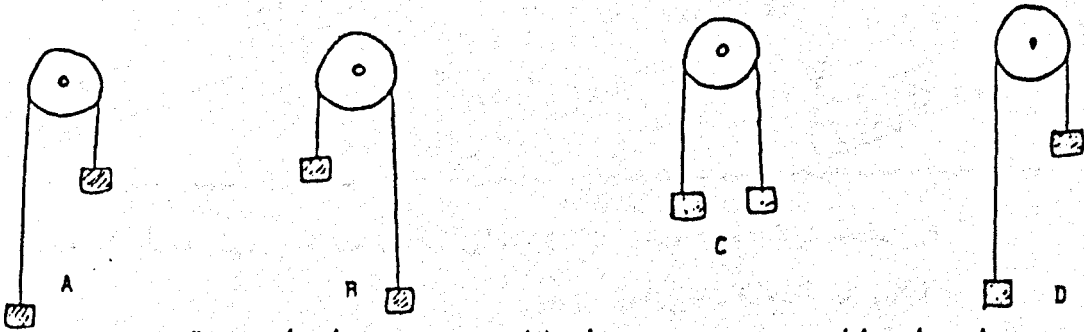
د - (E) درست ہے - کیونکہ خلا باز کی قوت کے باعث گیند دائیں طرف

گرتا ہے -

سوال نمبر ۱۸۔ دو ایک جیسے اجسام کو رسی کے ایک ٹکڑے کے ساتھ جوڑا گیا ہے جیسا کہ

شکل A میں دکھایا گیا ہے - رسی کو چرخے کے اوپر رکھا گیا ہے ایک منٹ

کے بعد دونوں اجسام کی حالت شکل B, C اور D میں دکھائی گئی ہے -



ان تمام بیانات پر ہمہ (/) نشان لگائیں جو دونوں اجسام پر قوت

کو واضح کرتے ہوں -

الف - (B) درست ہے کیونکہ اونچائی والے جسم پر ثقلی قوت زیادہ عمل کرتی

ہے اسلئے وہ جسم نیچے جاتا ہے -

ب - (C) درست ہے - چونکہ وزن برابر ہیں - اسلئے دونوں اجسام ایک

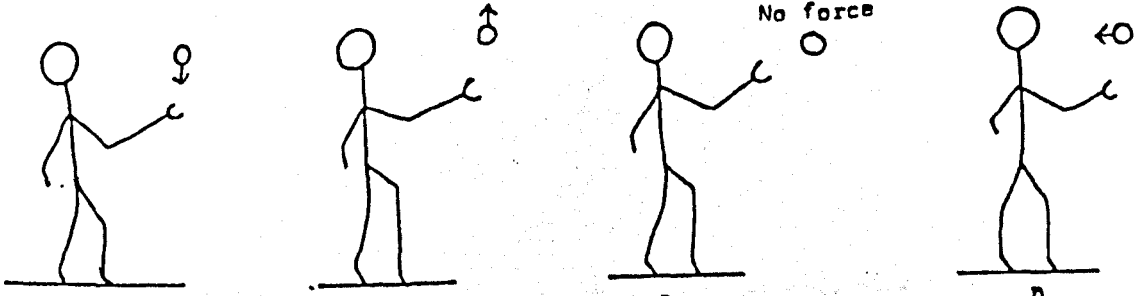
جیسی اونچائی پر پہنچ کر رک جاتے ہیں -

ج - (D) چونکہ وزن برابر ہیں اسلئے وہ ایک دوسرے کو کھینچتے

ہوں اور وہ ہی اپنی پہلی حالت سے حرکت کرتے ہیں -

د - کوئی اور وجہ جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۱۹ - ایک آدمی ٹھہس کی گھبت کو ہوا میں تھوڑا سا اوپر پھینکتا ہے گھبت اس وقت نیچے کیطرف آ رہی ہے - دی گئی اشکال گھبت پر عمل کرنے والی قوتوں کو ظاہر کرتی ہیں -

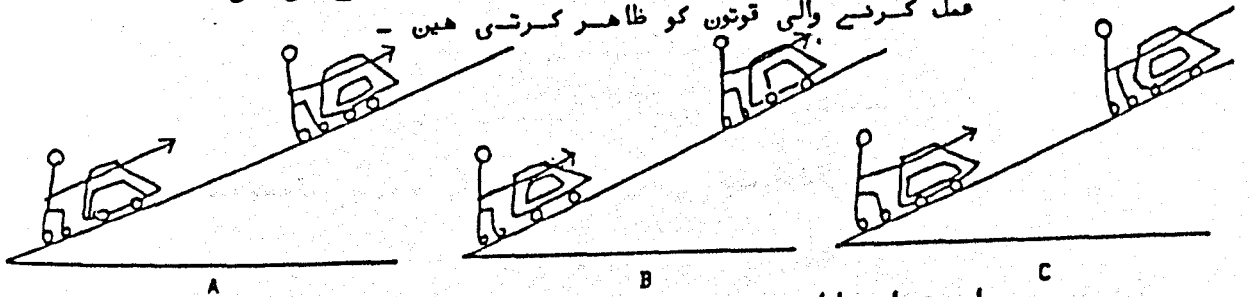


ان بیانات پر بہ (/) نشان لگائیں جو گھبت پر عمل کرنے والی قوت کو واضح کرتے ہوں -

- الف - (A) درست ہے - کیونکہ ثقلی قوت اس پر نیچے کیطرف عمل کرتی ہے -
 ب - (B) درست ہے کیونکہ آدمی نے اسکو اوپر کی طرف پھینکا ہے -
 ج - (C) درست ہے کیونکہ آدمی کی اوپر کی جانب عمل کرنے والی قوت اور نیچے کی طرف عمل کرنے والی ثقلی قوت ایک دوسرے کے برابر ہیں -
 د - (D) درست ہے کیونکہ گھبت کی قوت آدمی کے اپنی جانب عمل کرتی ہے -

سوال نمبر ۲۰ -

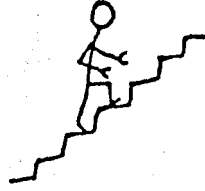
دو آدمی کاروں کو نیچے آنے سے روک رہے ہیں - دونوں کاریں ایک جیسی ہیں اور ان کو برہمیں نہیں لگائی گئیں - تیسرے کی لمبائیاں آدمیوں کی اس قوت کو ظاہر کرتے ہیں جو وہ کاروں پر لگا رہے ہیں - نیچے دی گئی اشکال کاروں پر عمل کرنے والی قوتوں کو ظاہر کرتی ہیں -



ان تمام بیانات پر بہ (/) نشان لگائیں جو کاروں پر عمل کرنے والی قوتوں کو واضح کرتے ہوں -

- الف - (A) درست ہے - کیونکہ نیچے والے آدمی کو ثقلی قوت کے خلاف زیادہ قوت لگانی پڑتی ہے -
 ب - (B) درست ہے - کیونکہ دونوں ایک جیسی کاروں کو روکنے کیلئے ایک جیسی قوت استعمال کر رہے ہیں -
 ج - (C) درست ہے - کیونکہ زیادہ اونچائی پر موجود آدمی کو کار کو نیچے آنے سے روکنے کیلئے زیادہ قوت لگانی پڑتی ہے -
 د - ایسی کوئی قوت جس کا ذکر نہ کیا گیا ہو -

سوال نمبر ۱ - ایک آدمی سیڑھیاں چڑھ رہا ہے -



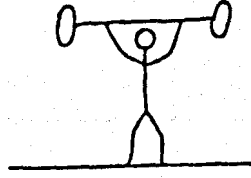
- مندرجہ ذیل بیانات میں سے کون سا بیان بالکل صحیح وضاحت کرتا ہے -
- ۱- آدمی اپنی مغنی کیمیائی توانائی خرچ کر رہا ہے -
 - ۲- آدمی اپنی حرکی توانائی استعمال کر رہا ہے -
 - ۳- آدمی ٹنٹی ثقلی توانائی کی وجہ سے اوپر چڑھ رہا ہے -
 - ۴- آدمی کوئی بھی توانائی استعمال نہیں کر رہا ہے -

سوال نمبر ۲ - ایک کار سڑک پر جا رہی ہے -



- مندرجہ ذیل بیانات میں سے کون سا بیان بالکل صحیح وضاحت کرتا ہے -
- ۱- کار اپنی حرکی توانائی کی وجہ سے حرکت کر رہی ہے -
 - ۲- کار اپنی مغنی توانائی کی وجہ سے حرکت کر رہی ہے -
 - ۳- کار اپنے انجن کی توانائی کی مدد سے چلتی ہے جو وہ پٹرول میں موجود مغنی کیمیائی توانائی سے حاصل کرتا ہے -
 - ۴- کار میں کوئی توانائی موجود نہیں ہے یہ خود بخود چل رہی ہے -

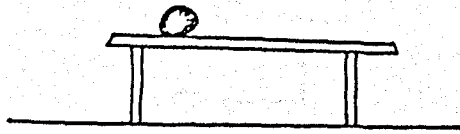
سوال نمبر ۳ - وزن اٹھانے والا ایک آدمی بھاری سلاخ کو اپنے سر سے اوپر ساکن حالت میں رکھے ہوئے ہے -



مندرجہ ذیل میں سے کون سا بیان صحیح وضاحت پیش کرتا ہے -

- ۱- اس نے سلاخ کو اس میں موجود مخفی توانائی کی وجہ سے اٹھا رکھا ہے
- ۲- اس نے اپنے ہاتھوں کی توانائی کو استعمال کر کے سلاخ کو اس حالت میں اٹھایا ہوا ہے -
- ۳- وہ سلاخ کو اس حالت میں اٹھائے رکھنے کے لئے اپنی حرارتی توانائی استعمال کر رہا ہے -
- ۴- وہ سلاخ اٹھائے رکھنے کیلئے مخفی کیمیائی توانائی استعمال کر رہا ہے جو وہ اپنی خوراک سے حاصل کرتا ہے -

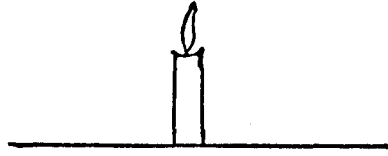
سوال نمبر ۳ - پتھر کا ایک ٹکڑا میز پر پڑا ہے -



مندرجہ ذیل میں سے کون سا بیان صحیح وضاحت پیش کرتا ہے -

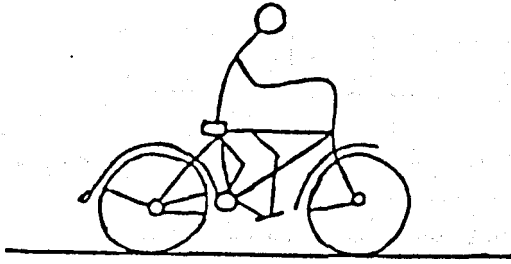
- ۱- یہاں پر کوئی توانائی عمل نہیں کر رہی - کیونکہ پتھر کا ٹکڑا بالکل ساکن حالت میں پڑا ہے -
- ۲- پتھر میں مخفی توانائی موجود ہے جو اس میں اس وقت پیدا ہوئی جب اسے نیچے سے اٹھا کر میز پر رکھا گیا -
- ۳- پتھر میں حرکتی توانائی موجود ہے -
- ۴- پتھر میز سے توانائی حاصل کرتا ہے -

سوال نمبر ۵ - ایک موم ہتی جل رہی ہے -



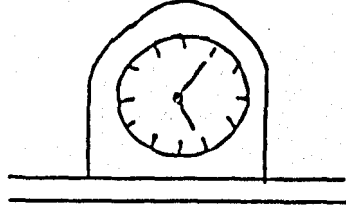
- مندرجہ ذیل میں سے کون سا بیان موم ہتی کے جلنے کے عمل کی صحیح وضاحت کرتا ہے -
- ۱- موم ہتی جلنے کیلئے کاربن ڈائی آکسائیڈ سے توانائی حاصل کر رہی ہے -
 - ۲- موم ہتی جلنے کیلئے اپنی حرکی توانائی استعمال کر رہی ہے -
 - ۳- موم ہتی کے جلنے کے عمل میں کیمیائی توانائی حرارتی توانائی میں تبدیل ہو رہی ہے -
 - ۴- اس عمل میں موم میں موجود مخفی کیمیائی توانائی حرارت اور روشنی میں تبدیل ہو رہی ہے -

سوال نمبر ۶ - ایک سائیکل سوار دہ تو پیڈل چلاتا ہے اور نہ ہی بریک لگاتا ہے لیکن سائیکل چل رہی ہے مگر آہستہ ہوتی جا رہی ہے -



- مندرجہ ذیل میں سے کون سا بیان صحیح وضاحت کرتا ہے -
- ۱- سائیکل میں حرکی توانائی موجود ہے جسکی وجہ سے یہ چل رہی ہے اور آہستہ ہونے کی وجہ سے رگڑ کی قوت ہے -
 - ۲- سائیکل میں مخفی توانائی موجود ہے جسکی وجہ سے یہ حرکت میں ہے -
 - ۳- سائیکل سوار میں مخفی توانائی موجود ہے جسکے باعث سائیکل چلتی جا رہی ہے -
 - ۴- سائیکل پیڈلون میں موجود توانائی کی وجہ سے چلتی جا رہی ہے -

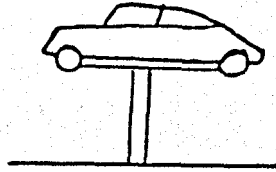
سوال نمبر ۷ - تصویر میں چابی والا کلاک دکھایا گیا ہے -



درج ذیل بیانات میں سے کون سا بیان صحیح ہے ؟

- ۱- کلاک ثقلی توانائی کی وجہ سے کام کرتا ہے -
- ۲- کلاک کیمیائی توانائی کی وجہ سے کام کرتا ہے -
- ۳- چابی دہنے والے شخص کی حرکی توانائی سے کلاک کی سونیاں حرکت کرتی ہیں -
- ۴- کوئی اور توانائی جس کا ذکر نہیں کیا گیا -

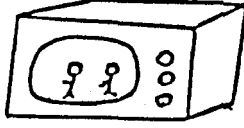
سوال نمبر ۸ - ایک کار کو جیک کسی مرد سے اوپر اٹھایا گیا ہے اور کار ساکن ہے -



درج ذیل بیانات میں سے کون سا بیان صحیح ہے -

- ۱- کار میں مخفی توانائی موجود ہے -
- ۲- کار میں حرکی توانائی موجود ہے -
- ۳- کار میں کوئی توانائی موجود نہیں ہے -
- ۴- جیک کسی توانائی سے کار کو اوپر اٹھایا ہوا ہے -

سوال نمبر ۹۔ تصویر میں ٹیلیویژن دکھایا گیا ہے۔



کون سا بیان صحیح وضاحت کرتا ہے۔

- ۱۔ ٹیلیویژن اپنے اندر موجود کیمیائی توانائی کی وجہ سے تصویر دکھاتا ہے۔
- ۲۔ ٹیلیویژن کے اندر روشنی کی توانائی موجود ہے جسکی وجہ سے ہم تصویر دیکھ سکتے ہیں۔
- ۳۔ ٹیلیویژن کے اندر آواز کی توانائی موجود ہے جسکی وجہ سے ہم اس سے نکلتی آواز سن سکتے ہیں۔
- ۴۔ ٹیلیویژن بجلی کی توانائی سے پروگرام دیتا ہے یہ توانائی روشنی، آواز اور حرارت میں تبدیل ہو جاتی ہے۔

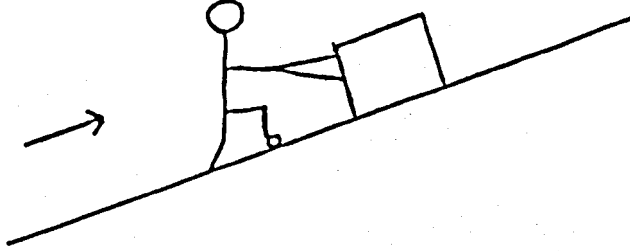
سوال نمبر ۱۰۔ تصویر میں ایک آہٹار دکھائی گئی ہے۔



کون سا بیان صحیح وضاحت کرتا ہے۔

- ۱۔ ہائی ٹرنی قوت کے اثر کی وجہ سے گرتا ہے۔
- ۲۔ ہائی زیادہ بلندی کی وجہ سے گرتا ہے۔
- ۳۔ ہائی اعلیٰ گرتا ہے کیونکہ ہائی میں موجود مخفی توانائی حرکتی توانائی میں تبدیل ہو جاتی ہے۔
- ۴۔ ہائی اپنی کیمیائی توانائی کی وجہ سے گرتا ہے۔

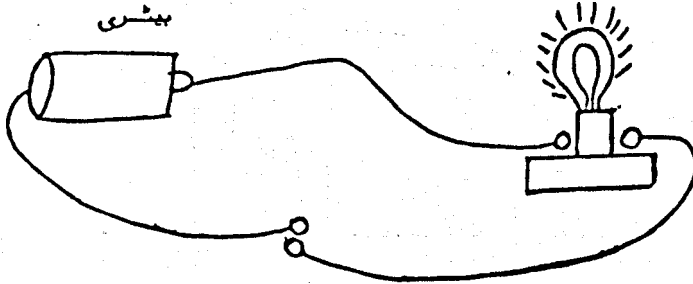
سوال نمبر ۱۱۔ ایک آدمی ایک وزنی صندوق کو دھکیل کر پہاڑی گدیے اوپر لے جا رہا ہے۔



کون سا بیان صحیح وضاحت کرتا ہے۔

- ۱۔ آدمی اپنی حرکتی توانائی کو استعمال کر رہا ہے۔
- ۲۔ آدمی اپنی مخفی کیمیائی توانائی استعمال کر رہا ہے۔
- ۳۔ آدمی اور صندوق دونوں میں مخفی توانائی موجود ہے۔
- ۴۔ کوئی اور وضاحت جو کہ بیان نہیں کی گئی۔

سوال نمبر ۱۲۔ ایک بیٹری، بلب اور سوئچ ایک سرکٹ میں جوڑے گئے ہیں اور بلب روشن ہے۔



کون سا بیان صحیح وضاحت کرتا ہے۔

- ۱۔ بلب میں برقی توانائی موجود ہے اسلئے یہ روشن ہے۔
- ۲۔ بیٹری کے اندر کیمیائی توانائی موجود ہے اسلئے بلب روشن ہے۔
- ۳۔ بیٹری کے اندر حرکتی توانائی موجود ہے اسلئے بلب روشن ہے۔
- ۴۔ نہ تو بلب کے اندر کوئی توانائی موجود ہے اور نہ ہی بیٹری میں۔

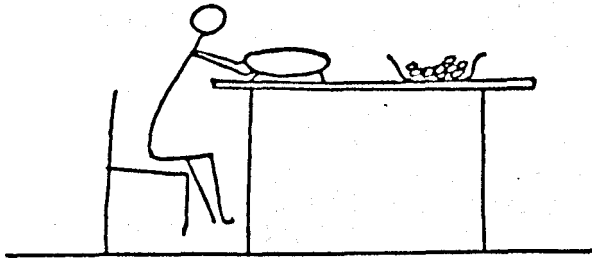
سوال نمبر ۱۳- ایک بیکر میں گرم پانی ہے -



کون سا بیان صحیح ہے -

- ۱- پانی میں حرارتی توانائی موجود ہے -
- ۲- پانی کے اندر کیمیائی توانائی موجود ہے -
- ۳- پانی کے اندر مخفی توانائی موجود ہے -
- ۴- کوئی اور وضاحت جس کا ذکر نہیں کیا گیا -

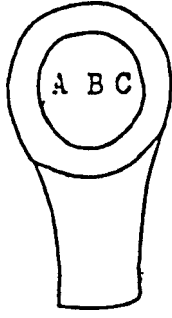
سوال نمبر ۱۴- ایک آدمی کھانا کھا رہا ہے -



صحیح وضاحت کیا ہے ؟

- ۱- آدمی اپنی حرکی توانائی استعمال کر رہا ہے -
- ۲- کھانے کے اندر مخفی کیمیائی توانائی موجود ہے -
- ۳- آدمی کھانا کھاتے وقت اپنے اندر کیمیائی توانائی جمع کر رہا ہے -
- ۴- کوئی اور وضاحت جس کا ذکر نہیں کیا گیا -

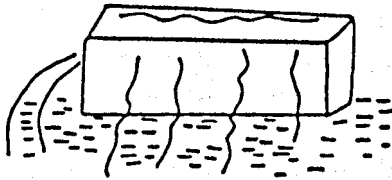
سوال نمبر ۱۵۔ ایک شخص عدسہ کی مدد سے الفاظ پڑھنے کی کوشش کر رہا ہے۔



کون سا بیان درست ہے۔

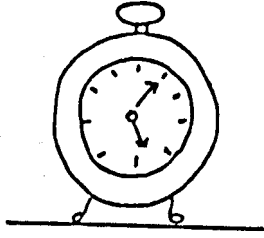
- ۱۔ عدسے میں مکانی توانائی موجود ہے اسلئے وہ شخص الفاظ پڑھ رہا ہے
- ۲۔ عدسے میں روشنی کی توانائی موجود ہے اسلئے وہ شخص الفاظ پڑھ رہا ہے۔
- ۳۔ عدسے میں کیمیائی توانائی موجود ہے اسلئے وہ شخص الفاظ پڑھ رہا ہے۔
- ۴۔ وہ شخص روشنی اور اپنی مخفی کیمیائی توانائی استعمال کرکے عدسہ کی مدد سے الفاظ پڑھ رہا ہے۔

سوال نمبر ۱۶۔ برق کا ہلاک ہونے پڑے پڑے پگھل رہا ہے۔



- ۱۔ برق اسلئے پگھل جاتی ہے کیونکہ اس میں حرارتی توانائی ہوتی ہے۔
- ۲۔ برق اسلئے پگھلا شروع کر دیتی ہے کیونکہ یہ ارد گرد سے حرارتی توانائی جذب کرتی ہے۔
- ۳۔ برق اپنی کیمیائی توانائی کی وجہ سے پگھلا شروع کر دیتی ہے۔
- ۴۔ کوئی اور وجہ جس کا ذکر نہیں کیا گیا۔

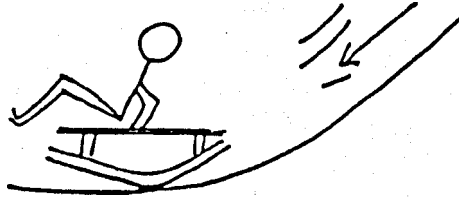
سوال نمبر ۱۷ - ایک الارم کلاک جس کا ڈائل خود بخود چمکتا ہے -



مندرجہ ذیل میں سے کون سا بیان صحیح ہے -

- ۱- یہاں پر کسی قسم کی توانائی خارج نہیں ہو رہی -
- ۲- چمکنے والے ڈائل پر سے روشنی کی توانائی خارج ہوتی ہے -
- ۳- کلاک میں مخفی توانائی موجود ہے -
- ۴- کلاک میں ثقلی توانائی موجود ہے -

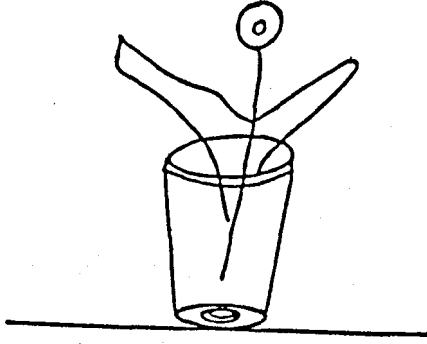
سوال نمبر ۱۸ - کوئی شخص برف پر پھسل کر پہاڑی سے نیچے آ رہا ہے -



مندرجہ ذیل میں سے کون سا بیان صحیح ہے -

- ۱- پھسلنے وقت وہ شخص اپنی توانائی استعمال کر رہا ہے -
- ۲- وہ شخص مخفی توانائی کے باعث پھسل رہا ہے -
- ۳- اس شخص کو برف سے توانائی مل رہی ہے -
- ۴- کوئی اور وجہ جس کا ذکر نہیں کیا گیا -

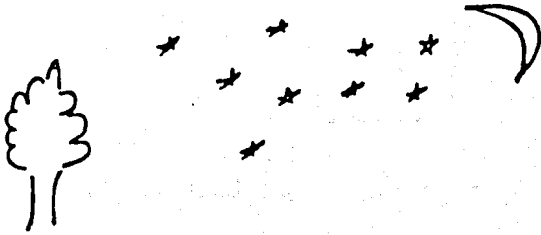
سوال نمبر ۱۹۔ ایک گلے میں پھول کا پودا لگا ہوا ہے۔



مدرجہ ذیل میں سے کون سا بیان صحیح وضاحت کرتا ہے۔

- ۱۔ پھول کا پودا اپنی نشو و نما کیلئے توانائی سورج اور مٹی سے حاصل کرتا ہے۔
- ۲۔ پھول کا پودا اپنی نشو و نما کیلئے توانائی زمین سے حاصل کرتا ہے۔
- ۳۔ روشنی کی توانائی پھول کے اوپر پڑتی ہے اسلئے پودا زندہ ہے۔
- ۴۔ پھول کا پودا صرف مٹی سے توانائی حاصل کرتا ہے۔

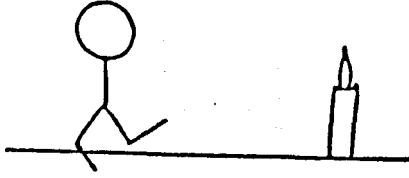
سوال نمبر ۲۰۔ رات کے وقت ستارے چمک رہے ہیں۔



مدرجہ ذیل بیانات میں سے کون سا بیان صحیح وضاحت کرتا ہے۔

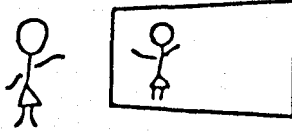
- ۱۔ چونکہ سورج چمک نہیں رہا اسلئے کوئی توانائی موجود نہیں ہے۔
- ۲۔ ستارے اس توانائی کے باعث چمکتے دکھائی دیتے ہیں جو وہ خود خارج کرتے ہیں۔
- ۳۔ کچھ توانائی ستارے چاند سے بھی حاصل کرتے ہیں۔
- ۴۔ کوئی اور وضاحت جس کا ذکر نہیں کیا گیا۔

سوال نمبر ۱ - ایک موم بتی جلا رہی ہے -



- آپ جلتی ہوئی موم بتی کو کس طرح دیکھتے ہیں -
- ۱- ارد گرد موجود روشنی کی وجہ سے -
 - ۲- موم بتی سے نکلیے والی روشنی کی وجہ سے -
 - ۳- آنکھوں سے نکلیے والی روشنی کی وجہ سے -
 - ۴- موم بتی سے منعکس ہونے والی روشنی کی وجہ سے -

سوال نمبر ۲ - ایک شخص آئینے میں اپنی تصویر دیکھ رہا ہے -



- یہ شخص آئینے میں اپنے آپ کو کس طرح دیکھ لیتا ہے ؟
- ۱- اس شخص پر پڑنے والی روشنی جب منعکس ہو کر آئینے پر پڑتی ہے تو آئینہ دوبارہ اس کو منعکس کر دیتا ہے -
 - ۲- یہ شخص اپنے آپ کو ارد گرد کی روشنی کی وجہ سے آئینے میں دیکھ سکتا ہے -
 - ۳- آئینے کی یہ ایک خصوصیت ہے کہ کوئی شخص جب اس کی طرف دیکھے تو وہ اپنے آپ کو دیکھ سکتا ہے -
 - ۴- کوئی اور وجہ جس کا ذکر نہ کیا گیا ہو -

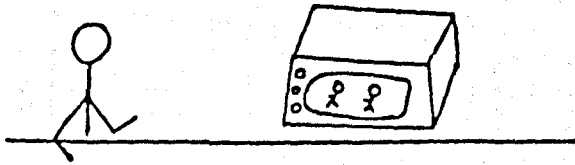
سوال نمبر ۲ - ایک آدمی قوس قزح دیکھ رہا ہے -



قوس قزح میں موجود رنگ مندرجہ ذیل وجوہات کی بناء پر ہوتے ہیں -

- ۱- ہائی کے قطروں سے سورج کی روشنی کے منعکس ہونے کی وجہ سے -
- ۲- ہائی کے قطروں سے سورج کی روشنی کے انتشار کیوجہ سے -
- ۳- ہائی کے قطروں میں سے سورج کی روشنی کے گزرنے کیوجہ سے -
- ۴- ہائی کے قطروں میں سے سورج کی روشنی کے انعکاس کی وجہ سے -

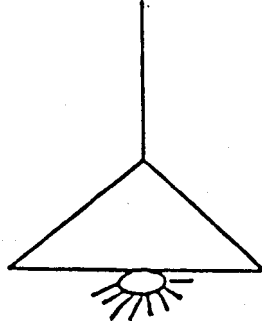
سوال نمبر ۲ - ایک آدمی ٹیلیویژن پر پروگرام دیکھ رہا ہے -



آپ کے خیال میں ٹیلیویژن کی سکرین سے آنے والی روشنی

- ۱- ایک میٹر تک آتی ہے -
- ۲- دیکھنے والے آدمی تک آتی ہے -
- ۳- بہت زیادہ فاصلے تک سفر کر سکتی ہے اور سارے کمرے میں پھیل جاتی ہے -
- ۴- ٹیلیویژن سے ۲ یا ۳ میٹر تک سفر کرنے کے بعد ختم ہو جاتی ہے -

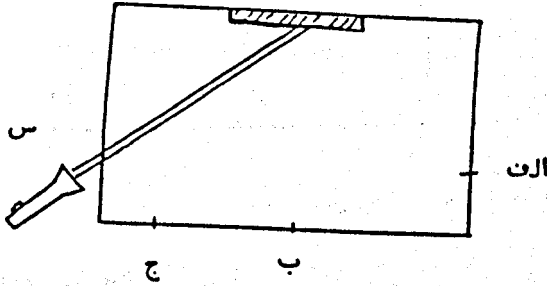
سوال نمبر ۵- روشنی کا ایک ہلب دن کے وقت روشن ہے۔



آپ کے خیال میں ہلب سے آئے والی روشنی

- ۱- صرف ہلب تک محدود رہتی ہے۔
- ۲- آپ سے آ رہے فاصلے تک آتی ہے۔
- ۳- آپ تک آتی ہے۔
- ۴- اس وقت تک چلتی رہتی ہے جب تک کسی چیز سے ٹکرا دے جائے۔

سوال نمبر ۶- کمرے کی ایک دیوار کے سوراخ "س" میں سے نارچ کسی مدد سے روشنی ایک آئینے پر ڈالی گئی ہے جوکہ کمرے کی ایک دوسری دیوار پر رہے۔



آئینے پر سے منعکس ہونے والی روشنی کیلئے آپ کس مقام پر

- کھڑے ہوں گے۔
- ۱- مقام "الٹ" "
- ۲- مقام "ب" "
- ۳- مقام "ج" "
- ۴- کسی اور جگہ پر

سوال نمبر ۷ - بجلی کا سلاخ والا ہیٹر رات کے وقت آن (on) ہے -



- جس وقت ہیٹر آن (on) ہو -
- ۱- یہ روشنی پیدا کرتا ہے -
 - ۲- یہ حرارت پیدا کرتا ہے -
 - ۳- یہ حرارت کے ساتھ ساتھ روشنی بھی پیدا کرتا ہے -
 - ۴- صرف رات کے وقت روشنی پیدا کرتا ہے -

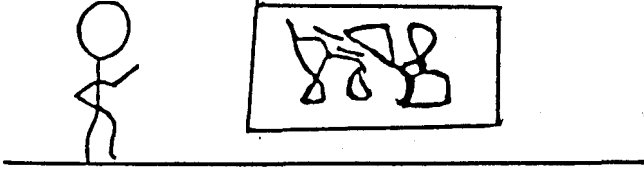
سوال نمبر ۸ - ایک طالب علم فلم دیکھ رہا ہے -



طالب علم فلم کس طرح دیکھ رہا ہے ؟

- ۱- سکرین پر پڑنے والی روشنی کے انعکاس کی وجہ سے -
- ۲- سکرین میں سے نکلنے والی روشنی کی وجہ سے -
- ۳- اپنی آنکھوں میں سے نکلنے والی روشنی کی مدد سے -
- ۴- کوئی اور وجہ جس کا ذکر نہیں کیا گیا -

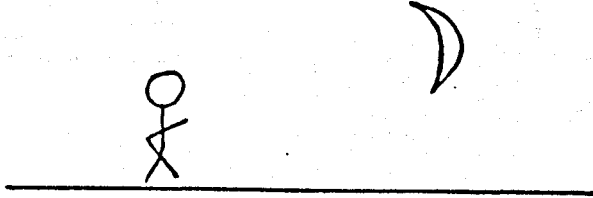
سوال نمبر ۹ - شکل میں ایک تصویر بنائی گئی ہے -



اس تصویر کو آپ کس طرح سے دیکھتے ہیں ؟

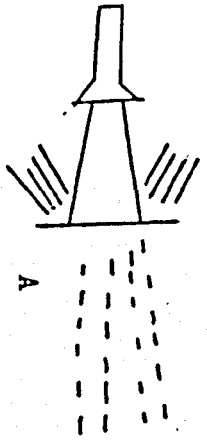
- ۱- ارد گرد موجود روشنی کی وجہ سے -
- ۲- تصویر سے خارج ہونے والی روشنی کی وجہ سے -
- ۳- آپ کی آنکھوں سے خارج ہونے والی روشنی کی وجہ سے -
- ۴- تصویر سے روشنی کے انعکاس کی وجہ سے -

سوال نمبر ۱۰ - چاند چمک رہا ہے -

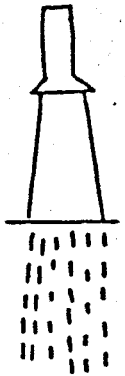


رات کے وقت چاند کس طرح چمکتا ہے ؟

- ۱- چاند اپنی روشنی کی وجہ سے چمکتا ہے -
- ۲- چاند سورج کی روشنی کے انعکاس کی وجہ سے چمکتا ہے -
- ۳- چاند کئی دوسرے مٹیوں سے آنے والی روشنی کی وجہ سے چمکتا ہے -
- ۴- کوئی اور وجہ جس کا ذکر نہیں کیا گیا -



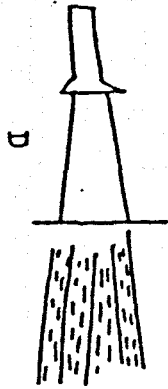
A



B



C



D

آپکے خیال میں جب روشنی اس فلٹر پر پڑتی ہے تو کون سی شکل سب سے

بہتر وضاحت کرتی ہے۔ -

۱- (A) فلٹر سے کچھ روشنی منعکس ہو جاتی ہے اور کچھ گزر جاتی

ہے جو رگددار ہوتی ہے۔ -

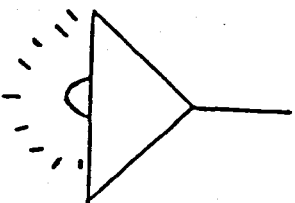
۲- (B) فلٹر کچھ روشنی جذب کر لیتا ہے اور کچھ گزرنے دیتا ہے۔ -

جو رگددار ہوتی ہے۔ -

۳- (C) سفید روشنی فلٹر پر پڑنے کے بعد رگددار روشنی کو باہر

دھکیل دیتی ہے۔ -

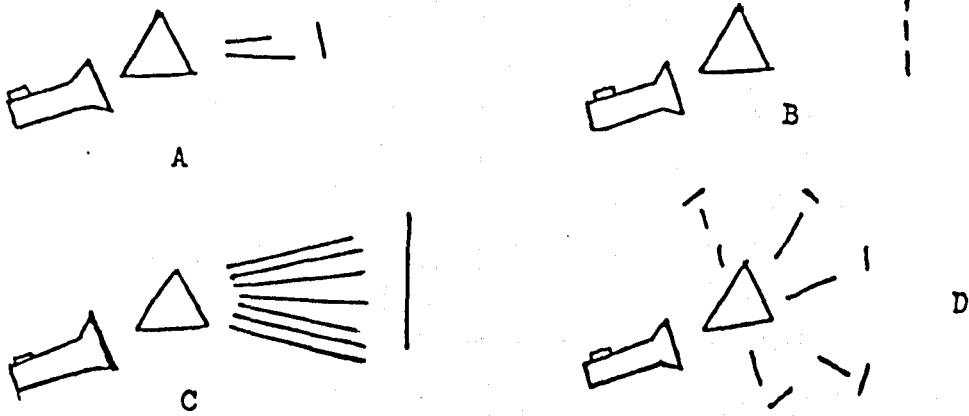
سوال نمبر ۱۱- رات کے وقت بھلسی کا بلب روشن ہے۔ -



آگے خیال میں بلب سے نکلنے والی روشنی

- ۱- بلب کے اوپر ہی رہتی ہے۔ -
 - ۲- آپ سے آگے نکلے گی آتی ہے۔ -
 - ۳- صرف آپ کی پہنچتی ہے اور اس سے زیادہ دور نہیں جاتی۔ -
 - ۴- اس وقت تک چلتی رہتی ہے جب تک کسی چیز سے ٹکرا نہیں جاتی۔ -
- سوال نمبر ۱۲- ایک خارج کی روشنی رفتار فضا پر ڈالی گئی ہے۔ -

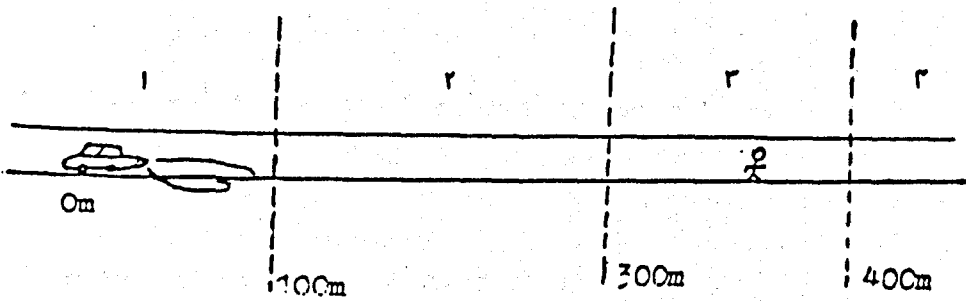
سوال نمبر ۱۲ - نارچ سے آنے والی روشنی شیشے کے ایک منشور پر پڑ رہی ہے -



آپکے خیال میں کون سی تصویر منشور پر پڑنے والی روشنی کو واضح کرتی ہے -

- ۱- (A) منشور کی دو اطراف روشنی کی دو شعاعیں پیدا کرتے ہیں -
- ۲- (B) منشور کی تین اطراف روشنی کے تین رنگ پیدا کرتے ہیں -
- ۳- (C) منشور میں سے بہت سے رنگ گلتے ہیں جو ایک دوسرے کے ساتھ ملے ہوتے ہیں -
- ۴- (D) منشور چمکتی ہے اور اس سے بہت سی شعاعیں گلتی ہیں -

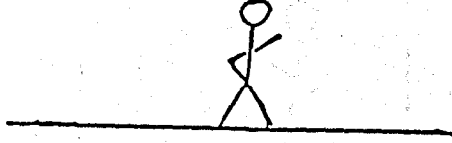
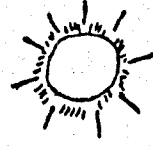
سوال نمبر ۱۳ - ایک کار سیدھی اور ہموار سڑک پر گھسی ہے کار کی بتیاں مدہم ہیں ایک شخص سامنے سڑک کے درمیان کھڑا ہے اور کار کی بتیوں کو دیکھ سکتا ہے



آپکے خیال میں کار کی روشنی شکل کے کس حصے تک آنے گی ؟

- ۱- روشنی صرف حصہ ۱ میں ہوگی کیونکہ کار کی روشنی صرف یہاں تک پہنچ سکتی ہے -
- ۲- روشنی حصہ ۲ میں ہوگی کیونکہ کار کی بیسی طاقتور نہیں -
- ۳- وہ شخص چونکہ روشنی دیکھ سکتا ہے اسلئے روشنی حصہ ۱، ۲ اور ۳ میں ہے -
- ۴- اس بات کا امکان ہے کہ روشنی حصہ ۳ تک جائے یا اس سے بھی آگے تک چلی جائے -

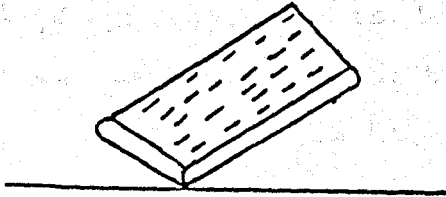
سوال نمبر ۱۵ - سورج چمک رہا ہے -



سورج کسی روشنی کتنی دور تک جاتی ہے ؟

- ۱- زمین تک جاتی ہے -
- ۲- زمین اور چاند دونوں تک جاتی ہے -
- ۳- زمین سے کچھ زیادہ فاصلے تک جاتی ہے -
- ۴- لامحدود فاصلے تک جاتی ہے -

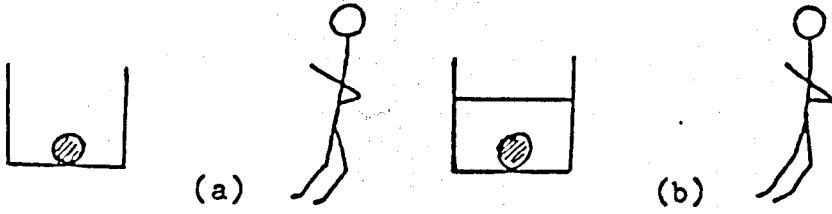
سوال نمبر ۱۶ - ایک شخص کتاب کو دیکھ رہا ہے -



یہ شخص کتاب کو اسلئے دیکھ سکتا ہے کیونکہ

- ۱- آنکھوں سے ایک طرح کی لہریں خارج ہوتی ہیں جو کتاب تک جاتی ہیں -
- ۲- ارد گرد روشنی موجود ہے -
- ۳- کتاب میں سے ایک طرح کی روشنی خارج ہوتی ہے جو پھر آنکھوں پر پڑتی ہے -
- ۴- کتاب روشنی کو منعکس کرتی ہے اور یہ روشنی پھر آنکھوں کے ساندھن جاتی ہے -

شکل (۳) میں ایک شخص بالٹی کے اھر پٹی ہوئی شیشے کی گولی کو دیکھنا چاہتا ہے لیکن وہ اسے دیکھ نہیں سکتا - شکل (b) میں جب بالٹی کو پانی سے بھر دیا جاتا ہے تو وہ شخص اسے دیکھ سکتا ہے اس دوران میں وہ تو وہ شخص اپنی جگہ سے ہلا اور وہ ہی بالٹی کو حرکت دی گئی -



وہ شخص جس وجہ سے گولی کو دیکھ سکتا ہے وہ یہ ہو سکتی ہے -

۱- کچھ گولی اپنی جگہ سے ہل گئی ہے -

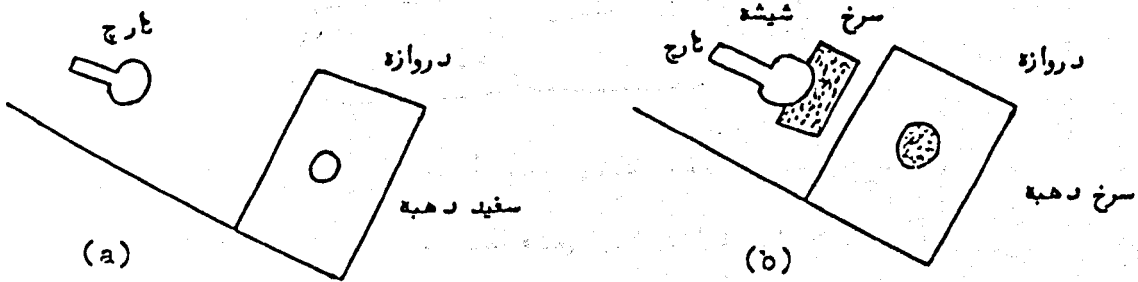
۲- پانی گولی کا عکس بناتا ہے -

۳- روشنی کی شعاعیں جب گولی کی سطح سے منعکس ہو کر پانی کی

سطح پر پہنچتی ہیں وہ مڑ جاتی ہیں -

۴- پانی کی وجہ سے دکھائی دیتی ہے -

ٹارچ کی روشنی دروازے پر ڈالی گئی ہے دروازے پر بننے والے سفید روشنی کے نشان کو آسانی سے دیکھا جا سکتا ہے شکل (۶) ٹارچ کے سامنے جب ایک شفاف اور سرخ رگ کا شیشہ رکھا جاتا ہے تو دروازے پر سرخ رگ کا ایک نشان بنتا ہے - شکل (b)



شیشے کی سرخ پلٹ دروازے پر پڑنے والی سفید روشنی کو سرخ رگ

کی روشنی میں تبدیل کر دیتی ہے کیونکہ

۱- یہ سرخ روشنی خارج کرتی ہے -

۲- سفید روشنی جب اس میں سے گزرتی ہے تو شیشہ اسے سرخ

رگ دے دیتا ہے -

۳- یہ صرف سرخ روشنی کو گزرنے دیتی ہے اور باقی تمام رنگوں کو

جذب کر لیتی ہے -

۴- جب روشنی اس پر پہنچتی ہے تو شعاعیں مڑ جاتی ہیں اور اس وجہ

سے ان کا رنگ تبدیل ہو جاتا ہے -

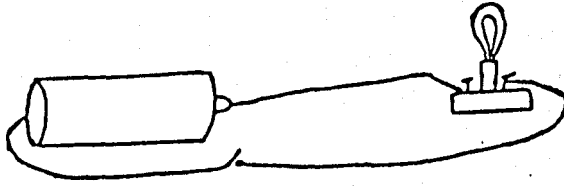
سوال نمبر ۱۹ - ایک گلسے میں پھول دار پودا ہے



پھول کے رنگ کیونکر دیکھے جا سکتے ہیں ؟

- ۱- ارد گرد کسی روشنی کسی وجہ سے -
- ۲- پھول پر پڑنے والی روشنی کے انعکاس کی وجہ سے -
- ۳- کچھ روشنی کو جذب کرنے اور کچھ روشنی کے انعکاس کی وجہ سے -
- ۴- کوئی اور وجہ جس کا ذکر نہیں کیا گیا -

سوال نمبر ۲۰ - ایک بیٹری - بلب اور سوئچ ایک سرکٹ میں جوڑے گئے ہیں -



بلب سے روشنی کیونکر نکلتی ہے ؟

- ۱- سوئچ کو دبانے کی وجہ سے -
- ۲- بلب کے اندر کسی تار کے گرم ہونے کی وجہ سے -
- ۳- بلب میں موجود گیس کی وجہ سے -
- ۴- کوئی اور وجہ جس کا ذکر نہیں کیا گیا -

APPENDIX K

List of Teachers (in groups): their respective Schools and the No. of children involved in the study.

School No.	Name of the Teacher	No. of Children	M/F	School Address
<u>Group A (Total No. of Students: 335)</u>				
I.	Miss Khalida Adeb	45	F	Government Girls Comprehensive High School, Sargodha.
II.	Miss Khaliqa Islam	40	F	Government Girls Comprehensive High School, Sargodha.
III.	Mr. Masood Ahmad Bhatti	50	M	Government High School Ghoray Shah, Lahore.
IV.	Mr. M. Mansha Saleemi	50	M	Government Islamia High School, Vehari.
V.	Mohammad Zaman Chughtai	50	M	Government Islamia High School, Cantt, Lahore.
VI.	Miss Sarwat Hameed	50	F	Government Girls Comprehensive High School, Wahdat Road, Lahore.
VII.	Mr. M. Ashraf Naz	50	M	Government Muslim Model High School, Lower Mall, Lahore.
<u>Group B (Total No. of Students: 272)</u>				
I.	Mr. Fayyaz Ahmad Ghauri	28	M	Government Comprehensive High School, Bahawal Nagar.
II.	Rana Abdul Latif Khan	50	M	Muslim High School, Lahore Cantt.
III.	Miss Sajida Khatoon	50	F	Government Girls High School, Chichawatni.
IV.	Mr. Khalid Latif Khan	50	M	Government High School Noor Shah, Distt. Sahiwal.
V.	Ammad-ud-Din Khan	44	M	Government High School, Niaz Baig, Lahore.
VI.	Abdul Majid	50	M	Government Arif High School, Mustafabad, Lahore.

VII. Syed Mohammad Ijaz Shah (Dropped from sample) Government High School Bolani, Tehsil, Kharian District. Gujrat.

Group C. (Total No. of Students: 252)

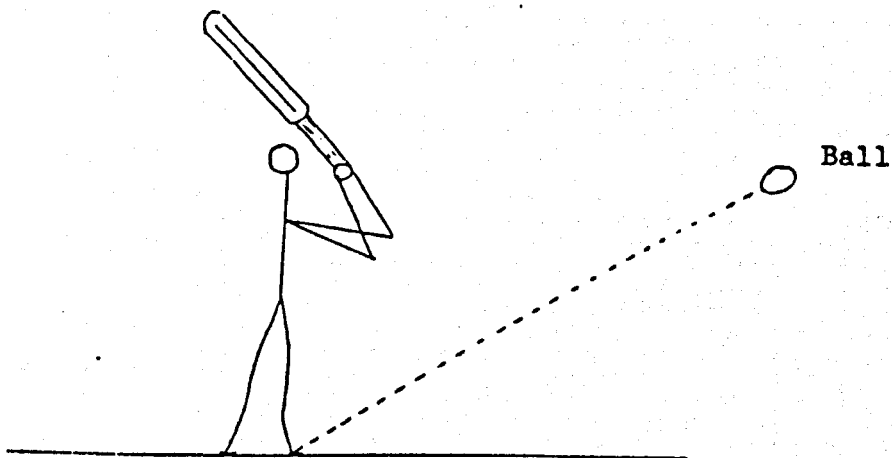
I.	Miss Najma Parveen	34	F	F.G. Girls High School, Multan Cantt.
II.	Muhammad Hussain Azad	55	M	Government Islamia High School, Mohani Road, Lahore.
III.	Abdul Rashid Bhatti	50	M	Government High School, Kanganpur, District. Kasur.
IV.	M. Atta-ul-Haq	23	M	Government High School, Khushab.
V.	Manzoor Ahmad	39	M	Government High School, Satiana, District, Faisalabad.
VI.	Ghulam Mustafa Shah	28	M	Government High School Rajar, Tehsil and District Khushab.
VII.	Asghar Ali Sheikh	23	M	Government High School, Mandi Sadiq Ganj, District. Bahawal Nagar.

APPENDIX LGUIDELINES FOR THE EXAMINERS

While taking the tests, please take care of the following points.

1. Seating arrangements may be such that students are not able to collaborate.
2. Before distributing the copies of the tests, it may be made clear to the students that the marks obtained in these tests will not in any manner affect their school results.
3. Students may not write their names and should not do any writing on the test sheets.
4. Each student will take 3 tests. First, the test on Force, then Energy and, lastly Light will be taken. The same sequence may be followed in each school.
5. Before the students start answering the questions, the following example may be used to explain the test format and how to answer the questions.

Example: A cricketer hits the ball and the ball now moves freely.



Tick (✓) all the forces acting on the cricket ball

1. Force of the cricketer
2. Pull of gravity

3. Force of air

4. Another force not mentioned.

5. Every question has four responses. A student can answer as many correct responses as he wants out of these four responses by ticking (✓) them. There is a possibility of more than one correct response in some of the questions.

7. Answers may not be given on the test copies; a separate answer sheet is provided for this purpose. In order to answer a question, the student should tick (✓) all the responses he thinks correct. For example, if a student feels that response 3 in answer to question 5 is correct, he will answer the question as follows.

Question 5 : 1 2 3[✓] 4

8. If students feel any difficulty in reading the questions, they may be helped. Please do not give explanations.

9. No time restriction may be put on students.

THANKS

APPENDIX M

TABLE: SHOWING CLASS MEANS OF EACH SCHOOL IN ALL GROUPS.

FORCE

Group	School	Force TFS/10	FS1 /6	FS2 /4
A 1	1	1.356	0.689	0.667
1	2	1.500	0.850	0.650
1	3	1.640	0.700	0.940
1	4	1.820	1.120	0.700
1	5	1.320	0.860	0.460
1	6	1.240	0.380	0.860
1	7	1.620	1.320	0.300
Means		1.499	0.845	0.796
B 2	1	0.679	0.214	0.464
2	2	1.000	0.540	0.460
2	3	1.580	1.040	0.540
2	4	0.700	0.380	0.320
2	5	1.500	1.159	0.341
2	6	1.060	0.680	0.380
Means		1.086	0.668	0.417
C 3	1	1.441	0.882	0.559
3	2	0.873	0.509	0.364
3	3	1.280	0.940	0.340
3	4	1.043	0.696	0.348
3	5	0.744	0.308	0.436
3	6	0.500	0.286	0.214
3	7	2.000	1.304	0.696
Means		1.125	0.703	0.422

TABLE: SHOWING CLASS MEANS OF EACH SCHOOL IN ALL GROUPS ENERGY

Group	School	Energy TES/10	ES1 /4	ES2 /6
A 1	1	3.333	1.378	1.956
1	2	4.125	1.825	2.300
1	3	2.460	1.260	1.200
1	4	2.100	1.000	1.100
1	5	1.760	0.960	0.800
1	6	2.480	1.060	1.420
1	7	2.700	0.400	0.300
Means		2.422	1.126	1.296
B 2	1	3.500	1.714	1.786
2	2	2.000	1.000	1.000
2	3	2.380	1.180	1.200
2	4	1.480	0.920	0.560
2	5	0.977	0.636	0.341
2	6	0.880	0.480	0.400
Means		1.869	0.988	0.881
C 3	1	3.441	1.412	2.029
3	2	1.236	0.727	0.509
3	3	1.440	0.760	0.680
3	4	2.000	1.087	0.913
3	5	2.333	1.231	1.103
3	6	1.036	0.643	0.393
3	7	3.826	1.957	1.870
Means		2.187	1.116	1.071

TABLE: SHOWING CLASS MEANS OF EACH SCHOOL IN ALL GROUPS

LIGHT

Group	School	Light TLS/10	LS1 _{/3}	LS2 _{/4}	LS3 _{/3}
A 1	1	3.911	1.444	1.667	0.800
1	2	4.775	1.150	2.400	1.225
1	3	3.140	1.060	1.260	0.820
1	4	3.080	1.040	1.360	0.680
1	5	1.820	0.720	0.800	0.300
1	6	4.540	1.380	1.860	1.300
1	7	1.260	0.340	0.720	0.200
Means		3.218	1.019	1.438	0.760
B 2	1	3.214	1.000	1.464	0.750
2	2	1.900	0.880	0.600	0.420
2	3	2.780	0.580	1.820	0.380
2	4	0.880	0.240	0.520	0.120
2	5	1.318	0.500	0.614	0.205
2	6	0.800	0.240	0.480	0.080
Means		1.815	0.575	0.916	0.325
C 3	1	4.706	1.382	2.059	1.265
3	2	1.182	0.309	0.600	0.273
3	3	2.000	0.660	0.860	0.480
3	4	2.043	0.696	1.043	0.304
3	5	3.026	1.077	1.462	0.487
3	6	1.179	0.179	0.679	0.321
3	7	4.652	1.217	2.304	1.130
Means		2.684	0.788	1.286	0.608