Can you understand Physics without sketching pictures?

By

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DEDICATION

To my parents

To my husband

To my children

Abstract

This study presents data showing some of the problems that students in Qatari high school (age~ 16-18) encountered when learning about forces electricity and magnetism. Then suggest ways by which the situation might be improved. The second aim is to explore whether the visual spatial ability is important to achieve better in physics or not.

At the first stage, the data have been collected through three surveys. These were applied in Qatar using students enrolled in secondary schools: first, second and third year students (age 16-18). The surveys reflected the syllabuses at each level, covering the specific physics topics relevant to each year group. The sample was 542 students from five schools. The topics which seemed to be causing the greatest problems were matter and its mechanical characteristics, particularly fluid pressure, Pascal's principle, Archimedes's principle and the electric energy and electric power topics were perceived as difficult by the students, in the first year. In the second year group the topics that were noted as difficult were mechanics (Newton's laws & stability), gravitational force and its field, electric potential and capacity, dielectric constant, impulse-momentum theorem and conservation of momentum

At the second part of first stage of this study, following from the result of the first part two tests were conducted to examine students understanding and misconception in particular topics. This was conducted by using communication structural grids, open-ended question and some problems. The first test was given to 242 first year students in three high schools, and the second test was conducted using 153 students of second year in five high schools. From the result obtained it was found that students in both year one and two in Qatar high schools had difficulty understanding the basic concepts such as density, mass, weight, force, acceleration and pressure. There was another misunderstanding that appeared. Students could solve formula in general state but when it was given to them in different ways they could not give a correct answer. To attain the second aim to investigate the visual spatial ability in relation to achievement in physics, an individual paper-and-pencil test was designed for the first and second years of Qatari high school to measure the visual-spatial ability in the context of physics. The participants were the same as in the difficulties test. The results suggest that in both groups there were significant positives correlations between visual spatial performance and performance in physics.

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Chapter One

Introduction

1.1 Background

This study focuses on some aspects of physics education at high school level in the State of Qatar although it is expected that the conclusions drawn have a relevance to physics education in general at school level. This chapter explains why students have to study physics in Qatar and gives a brief description of the structure of education in Qatar. In addition, some information is given about teaching science and physics at school level in general and an outline of the aims and objective of the study are offered.

Physics continues to be widely regarded by students in most countries as difficult; it is often classified as the hardest subject at the school level because it involves many abstract concepts such as sound, light, electricity, magnetism, and energy. These are ideas which cannot be seen but which have to be visualized in the mind. Physics deals with solving problems which are not only linked to the science curriculum but also to real life. Many people may claim that only scientific and academic people can understand physics. However, Einstein has argued that it should be possible to explain physics to a barmaid (Einstein and Lightman, 1994).

This thesis presents data showing some of the problems that students in Qatar high schools encountered when learning about forces, electricity and magnetism. The data clarify the complexity of the task that students face and reveal some difficulties that have received little attention in the literature.

Physics topics have proved to be difficult and troublesome in several countries. For example, in 2000, Zapiti found that Mechanics, Electricity, Magnetism, Thermodynamics, Waves and Radiation contained the most difficult topics in physics in Cyprus and Scotland. Many years before, Johnstone explored similar results at secondary level (Johnstone and Mughol, 1976) while, recently, Chen (2004) obtained parallel results at junior high school level in Taiwan (Chen, 2004). Peters (1981) concluded that kinematics, dynamics, electricity and magnetism were difficult concepts to the students in an introductory honors physics course at University level.

1.2 Why teach physics?

These reasons might be grouped under the following headings:

(a) Physics can help the learner to make more sense of the world around;
(b) Physics offers essential underpinning principles for major societal advances;
(c) Physics allows opportunities to develop useful cognitive skills;
(d) Physics is a key subject for many areas of employment;
(e) Physics offers cultural insights and understandings.

It is interesting to conjecture what education provision would be like if physics, as a subject, was totally absent from the curriculum. It is also interesting to speculate how society might be different without the contribution from physics. Such analyses might give an insight into the importance of physics in the education provision.

1.3 Background to Qatar

Qatar has been an independent state since 1971. It is situated in the middle of the western coast of the Arabian Gulf. The land area is approximately 11,437 km^2 on a low-lying limestone peninsula sticking out toward the north about 160 km into the Gulf. The coastline is about 550 km long and surrounds the country to the west, north and east. Islam is the official religion of the country, and the Islamic Law (Shariah) is the main source of legislation in the country. The official language of the State is Arabic but English is also widely spoken.

Qatar has a desert climate with a short, moderate winter with little rain and a long, hot summer. The inland humidity is lower than that in neighboring countries in the Arabian Gulf. The geography of Qatar generally contains flat, rocky surfaces with some limestone outcrops in the Dukhan area in the west and the Fuwairit area in the north. It includes some hills which reach an altitude of 40m above sea level in both the western and northern parts of the country (mofa.gov.qa).

1.4 Structure of the Education System in Qatar

The system of general public education in Qatar is compulsory for all children and is divided into three stages: primary (ages 6-12), secondary (ages 12-15) and high school (ages 15-18) Figure 1.1 (overleaf) illustrates the system. Education in Qatar is completely free for all Qatari people during all levels from primary until they finish the university.

In the final two years in the high school, students can choose their major between three branches: science, mathematics and French. There is no need to pass any exams to enter any of these branches. Finally, all students can move into a university level by taking exams in all subjects they have studied in the final year of school, students have to get 75% in the final exam in the science branch and 80% in the other branches to enter the university free of charge; otherwise they have to pay for university education.

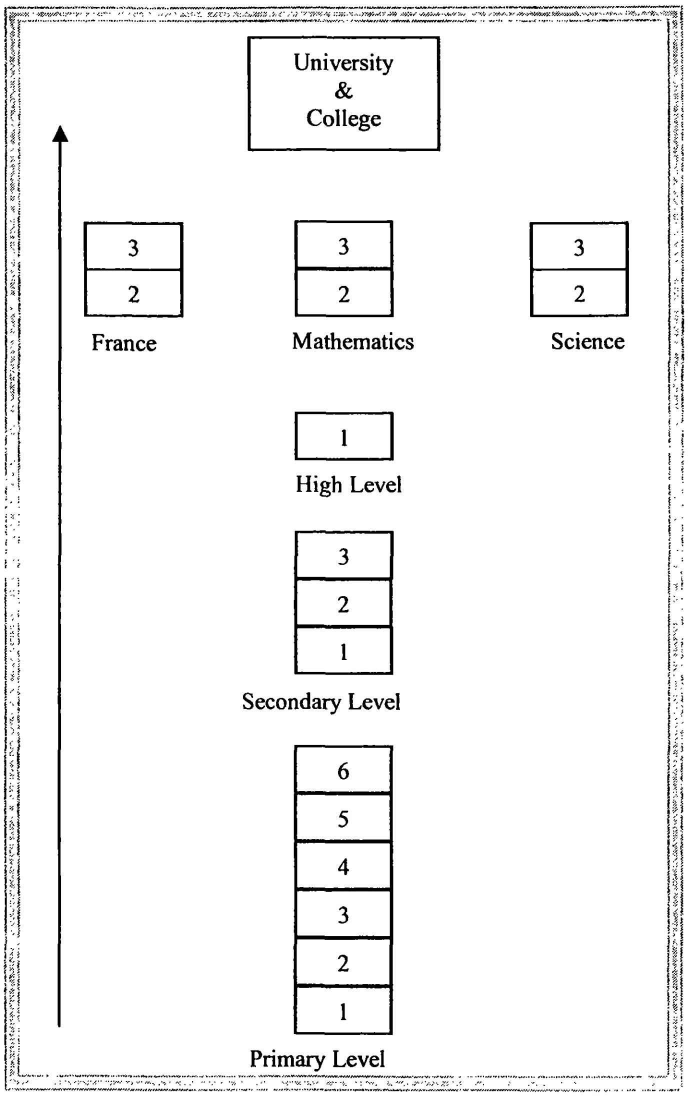


Figure. 1.1 Qatar Education System

In September 2004, Qatar built a modern, world-class public-school system involving Independent Schools. In 2004-2005, twelve Independent Schools were established and in the academic year 2005-2006, there is a plan to open twenty new schools covering the three levels (primary, secondary and high) as well as the pre-primary level for 4-6 year olds. This new system offers creative and special education environments for students and more choices for parents, because these schools offer a variety of systems and instructional programmes allowing parents to choose the schools which fit their children's needs. In addition, the new system has had a direct positive impact on the contribution of parents and the community (planning Council, State of Qatar, 2006).

1.5 Science Education in School

Science education in Qatar is started in year one of the primaries level and continues until the end of the high school, except in the French branch. Students study science as integrated science from primary one until the first year of the high school. In the second year of high school, science is taught as separate subjects: Physics, Chemistry and Biology. Science is still taught in the mathematics branch as general science.

1.6 The Physics Curriculum in the Secondary Stage

The secondary stage consists of three grades: the first, second and third secondary grades (16-18). In the first secondary grade, a student studies physics as a part of science for five sessions a week. Each session is about 45 minutes. The content of physics is Matter and its Mechanical characteristics, Energy Conservation, Thermal energy and Electrical Energy.

Physics in the second year of secondary occupies four sessions a week and the content includes Vectors, Linear motion, Newton's Laws of motion, Uniform Circular motion, Energy Conservation law, Kinetic Energy Conservation, Collisions, Thermal Behaviour of gases, Law of thermodynamics, Universal Gravitation Field and Electric Fields.

The third year of secondary physics is five sessions a week. The content includes Oscillations and simple Harmonic Motion, Wave motion Characteristics, Force and Magnetic Fields, Electromagnetic Induction, Sinusoidal Alternating Current, Electronics, Semiconductor and Transistor, Communication, Modern Physics and Atomic model development and Nuclear physics.

1.7 Aims and objectives of the present study

This study seeks to look again at the areas of perceived pupil difficulty in Physics and see how these relate to other studies in other countries. The main task, however, is to make an initial exploration of visual-spatial ability and to see how this relates to performance and understanding in Physics topics.

1.8 Research Methodology

Different approaches could be used to achieve the above aims. This research will depend upon the following approaches in gathering information.

1. Three questionnaires were prepared to investigate the difficult topics that students encountered in the three years in high school level and, based on this gathered information from the questionnaires, two tests were designed for the first and the second year's students to examine the difficult topics further and explore students' misconceptions and misunderstandings.

2. Visual spatial ability was examined by a test conducted only on first and second years in high school level. Finally, the results obtained from the previous tests were correlated with the marks in physics to explore any relationship between visual spatial ability and performance in physics.

1.9 Structure of the thesis

This thesis has been divided into six main chapters. This chapter introduces the education system in Qatar and the place of science and physics in the school levels, with outlines of the study's aims.

The second chapter attempts to provide some information about learning models, the nature of difficulties in understanding Physics. Imagery, visual spatial ability and the visual learner are also discussed. Chapter three moves on to consider some of the fundamental reasons causing difficulty in learning Physics in order to see the nature of problems.

Chapter four will identify and analyze the results obtained from the questionnaires and the tests which were prepared to explore the difficult topics in specific area among the high school students in physics and discover the particular difficulties in these topic.

Chapter five then moves on to consider the way the visual-spatial test results relate to performance in Physics.

Finally, in chapter six, a general summary of the findings of the study is offered. This is related to the limitations of the study. Suggestion for teaching will be made.

Chapter 2

Learning Models

2.1 Cognitive Development Theories

Cognitive development refers to the changes happening in an individual's cognitive structures, abilities, and processes. Cognitive development was defined by Driscoll as the change of the child's undifferentiated, unspecialized cognitive abilities into the adult's conceptual competence and problem-solving skill (Driscoll, 1994).

Cognitive theories are described as approaches to the goal of understanding human thinking (Bruner, 1960; Ausubel, 1963). These theories agree that the learner's acquisition of clear, stable, and organized bodies of knowledge is the goal. They also maintain that *"these bodies of knowledge, once acquired"*, compose in their own right structures that influence the meaningful learning and retention of new subject-matter material (Ausubel and Anderson, 1965).

Education theory has generally moved historically through three general principal theories, behaviorism, information processing, and constructivism (Good and Brophy, 1977) although it is possible to argue that constructivism is merely one aspect of information processing (see, for example, Johnstone, 1997).

The discussion here will start with Piaget, looking at the nature of human cognitive development, because he is one of the most influential of modern thinkers (Pulaski, 1980). Ausubel (1969a) claimed that *"Any discussion of stages of intellectual development must, of necessity, begin with Piaget's outstanding contributions to this problem"*.

2.2 Jean Piaget's Learning Models

Jean Piaget (1896-1980) was a Swiss biologist who originally studied molluscs (twenty scientific papers were published on them by the time he was 21). In the 1920s, Piaget became interested in psychology and he spent more than 50 years (from 1920 to 1970) observing children from birth to adolescence to see how they responded to a variety of tasks. He had enormous impact on the field of cognitive development (Flavell, 1963). Kitchener (1986) maintained that Piaget's theory of development was based on his astute observations of young children in Geneva. Piaget believed children's schemes or logical mental structures change with age (Driscoll, 1994). He also supposed that the child was very much the active learner in an age-stage progression where each stage was characterized by certain operations on knowledge (Herron, 1996). In addition, Kitchener (1986) said Piaget always considered himself a natural scientist, not a psychologist.

2.2.1 Stages of Development

Piaget described tasks that are completed effectively at various ages, and he developed a theory to describe these age-related differences (Herron, 1996). He tried to separate the effects of declarative knowledge such as word meaning, conceptual and propositional knowledge as a basis for his stage model. Piaget's model identifies four developmental stages and how children's cognitive processes move through them. It is noted by Piaget (1974) that young children cannot connect between eye and object until a later stage when they commonly think of vision as 'a passage from the eye to the object' The nature of this link was studied further by Guesne (Herron, 1996; Jonathan *et al*, 1993). The four stages are:

1. Sensor motor stage (infancy 0-2): During this period children progress into 6 stages listed as following: intelligence is demonstrated through motor activity without the use of symbols. Knowledge of the world is limited but developing because it is based on physical interactions and experiences. Children obtain object permanence at about 7 months of age (the dawning of memory). Physical development (mobility) allows children to begin developing new intellectual abilities. Some symbolic (language) abilities are developed at the end of this stage (Wohlwill, 1973).
2. Pre-operational stage (toddler and Early Childhood 2-7): children's intelligence demonstrated by using symbols, language matures, and memory; and developed

imagination. However, the child thinks in an a logical and nonreversible manner (Kitchener, 1986, McNally, 1974).

3. Concrete operational stage (elementary and early adolescence 7-11): This stage is characterized by 7 categories of conservation which are number, length, liquid, mass, weight, area and volume. The child begins to develop structures to explain his physical experiences (Piaget, 1969; McNally, 1974).

4. Formal operational stage (adolescence and adulthood 11- 15): During this stage, the children's cognitive structures progress to become like adult thinking. By this point, the child is able to think abstractly, hypothesize, generalize and develop ideas. Moreover, the child can begin to solve complex and hypothetical problems which involve abstract operation (Kitchener, 1986; Piaget and Inhelder, 1968). Pulaski (1980) claimed that not all adults fully achieve the highest stage of intellectual development. However, certainly such thinking is characteristic of scientists and researchers who work with atoms, quarks, and nuclear fission. *"As Einstein is reputed to have said of Piaget's theory, It is so simple that only a genius could have thought of it".* (Pulaski, 1980)

It becomes obvious that Piaget views development as continuous and constant. In other words, each stage evolves out of the one before it and contributes to the following one. In addition, some children grow up faster than others, but the sequence is unchanging (Pulaski, 1980).

Hyde (1970) pointed out that ideas linked to the formal education of physics become important at the latter two stages with the beginnings of thinking logically and finding relationships. In many countries, abstract ideas of physics (ideas like those related to forces, energy and electricity) do not really appear in the curriculum until these two stages (Hyde, 1970). Before these stages are reached, success in physics in schools mainly depends in memorization rather than understanding. In 1946, Piaget described an investigation into the development of children's understanding of movement and speed (Piaget, 1970). Piaget's work on velocity focused largely on the development of the concept within the Piagetian stages of development structure. He found that the child is unable to link velocity to time and distance until nine or ten years old (Pulaski, 1980). It is a relatively difficult concept to grasp until the period of formal operations, perhaps at eleven or twelve. Furthermore, Piaget claims that children under nine or ten are unable to discern between and coordinate dissimilar possible perspectives accurately (Pulaski, 1980).

As a biologist, Piaget was interested in children's adaptation to their environment and their behavior as controlled through mental organizations. This adaptation is driven by a biological incentive which Piaget called schemata. These are reflexes that are available from birth and the child uses them to represent the world and designate action to acquire balance between schemes and the environment (equilibration) (Flavell, 1963, Kitchener, 1986).

How do children's cognitive structures progress during the stages? What are the basic abilities that allow a sensorimotor child to change to the preoperational stage, or a concrete-operational child to transit to the formal-operational stage? Piaget hypothesized two invariant mechanisms: assimilation (internal processes) and accommodation (external processes). These invariants, according to Piaget, provide the important link between biology and intelligence because they hold equally for both (Flavell, 1963; Lee, 2000; Kitchener, 1986).

Assimilation is the process by which a person takes material into their mind from the environment, and this may mean changing the evidence of children's senses to make it fit (Good and Brophy, 1977). Accommodation is the process of changing cognitive structures in order to accept something from the environment (Furth, 1970).

Assimilation and accommodation should work together but not be conceived as two separate processes working one after the other *"assimilation and accommodation constitute two poles, and not two distinct behaviors"* (Piaget, 1975/77) .

How do these two processes work together to drive children's growth? Piaget proposed that necessarily both processes include every behaviour event by the infant (Good and Brophy, 1977). Successful adaptation reflected a balance between accommodation and assimilation (Lee, 2000; McNally, 1974; Herron, 1996). Good and Brophy (1977) claim that Piaget's theory became popular with advocates of discovery learning, because he was one of the first psychologists to recognize clearly that human are born as active, exploratory, information-processing organisms.

2.3 Neo-Piagetian Theories

Neo-Piagetian theories mix elements of Piaget's theory with concepts from information processing theory. Demetriou *et al* (1994), mentions that many researchers were concerned to produce an explanation for Piaget's theories. One of the first of these was Pascual-Leone. He builds his assumption on Piaget's theory rather than totally rejecting it. Indeed, he rejects only Piaget's proposal that children acquire a single system of logical operations. Instead, he suggests that children obtain several more specific systems of concepts and thinking skills relevant to particular satisfied domains. These systems develop in a stage-like manner, with slowly growing information processing mechanisms (working memory capacity that will discussed later in detail) setting an upper limit on the complexity of thinking and reasoning skills that can emerge during infancy and childhood (Pascual-Leone, 1974).

One of the central ideas developed by Pascual-Leone's model is the evaluation of the M-demand of a problem (Niaz, 1989). This model suggests that student's performance was a function of three parameters which illustrate the psychological system: repertoire H (the mental strategy that applied to the task), M-demand (a maximum number of steps (schemes) that the subject must mobilize simultaneously in the course of executing a task), and M-space (central computing space) (Pascual-Leone, 1974; Serumola, 2003). According to Pascual-Leone (Niaz, 1989) training or situational treatment of the content of a task can reduce the M-demand of a task.

Pascual-Leone claims that the student must have the following abilities in any science courses at the secondary level:

1. Process and transform data in different ways to produce solutions.
2. Process concurrently a large number of steps or facts in a problem.
3. Separate relevant from irrelevant information.
4. Gaining previous knowledge of particular concepts and facts. (Niaz, 1989)

Mental strategies are used to execute any task. Case (1974a) puts these strategies into three main categories: figurative schemata, operative schemata, executive schemata. Moreover, he recommends that context and children's prior knowledge can solve the problem of what he calls schemata (a strategy to use with encoding complex information). This relates new information to students' prior knowledge (Baddeley, 1986), and this recommendation is similar to Pascual-Leone's idea. Pascual-Leone and Case were distinguishing between schemata and students mental capacity which were limited and developed with age. However, Case suggested a task's M-demand may possibly be reduced by giving students a mental strategy appropriate to the learning experiences (Case, 1974b). Additionally, Niaz pointed out that M-demand might change without changing the logical structure (Niaz, 1987).

2.4 Bruner

Bruner's model is a general framework for teaching based upon the study of cognition. Much of the model is connected to child development research (especially Piaget). Bruner and his colleagues produce data that seemed to show that children at various ages could learn things that Piaget and his colleagues said they could *not* learn (Good and Brophy, 1977). The ideas outlined in Bruner (1960) focused on science and mathematics learning for young children (Bruner, 1973). Learning is an active process in which learners construct new ideas or concepts based upon their present and past knowledge: the main idea in the theoretical structure of Bruner. Bruner (1966) declares that cognitive structure provides meaning and organization to experiences and allows the individual to *"go beyond the information given"* (Bruner, 1966).

Bruner and Ausubel differ in their conception of the function of cognitive structure: Bruner emphasized discovery as the cognitive process while Ausubel referred to reception learning where the teacher played a dominant role (Ausubel, 1963; Bruner, 1959, 1960). Bruner (1973) claims that learning by steps (discovery learning) lead children to understanding and recognizing the tasks. Moreover, Bruner argues that discovery is necessary for "real possession" of knowledge, has certain unique motivational advantages, organizes knowledge effectively for later use, and promotes long-term retention (Ausubel and Anderson, 1965). However, Ausubel (1961) rejects some of these specific claims, but agrees that some unique pedagogic advantages is offered by the discovery method, is a useful adjunctive technique under certain educational conditions, and is necessary for the development of problem-solving abilities (Ausubel and Anderson, 1965).

Science progresses by means of the empirical and this might suggest that discovery learning is an appropriate way to learn science. However, the learning of science is not the same thing as the process of science although it is important that in learning science pupils do gain an understanding of that process.

2.5 David Ausubel

Ausubel was influenced by Piaget's cognitive development theory. He was very active in his field in the 1950s to 1970s. He developed his instructional models based on cognitive structures.

Cognitive theories maintain that meaningful verbal learning is a normal human mechanism. This kind of learning offers excellence balance for acquiring and storing the enormous quantity of ideas and information represented in any body of knowledge (Ausubel and Anderson, 1965).

Ausubel (1968) suggests that the process of learning breaks down into three steps: what will the person learn, what does the person want to learn, and what did the person learn? He proposed that all classrooms can be located along two independent dimensions the rote-meaningful dimension and the reception-discovery dimension. Furthermore, he considered that children have a natural tendency to organize information into a meaningful whole. Children should first learn a general concept and then move toward specifics, not inductively as Bruner recommended.

Teachers can facilitate learning by organizing information presented so that new concepts are easily relatable to concepts already learned. Ausubel's model suggests how teachers or instructional designers can best arrange the conditions that facilitate learning for students by the following ideas: teachers need to remember that inputs to learning are important, learning materials should be well organized, new ideas and concepts must be potentially meaningful to the learner, attaching new concepts into the learner's already existing cognitive structure will make the new concepts recallable (Ausubel, 1969b).

Two processes are involved in Ausubel's model:

1. Reception, which is employed in meaningful verbal learning, and rote learning
2. Discovery, which is involved in concept formation and problem solving.

He obviously distinguishes how these processes connected to each others. The Figure (2.1) below shows the relationship between Ausubel's rote and meaningful learning related to reception and discovery learning (Ausubel *et al*, 1978).

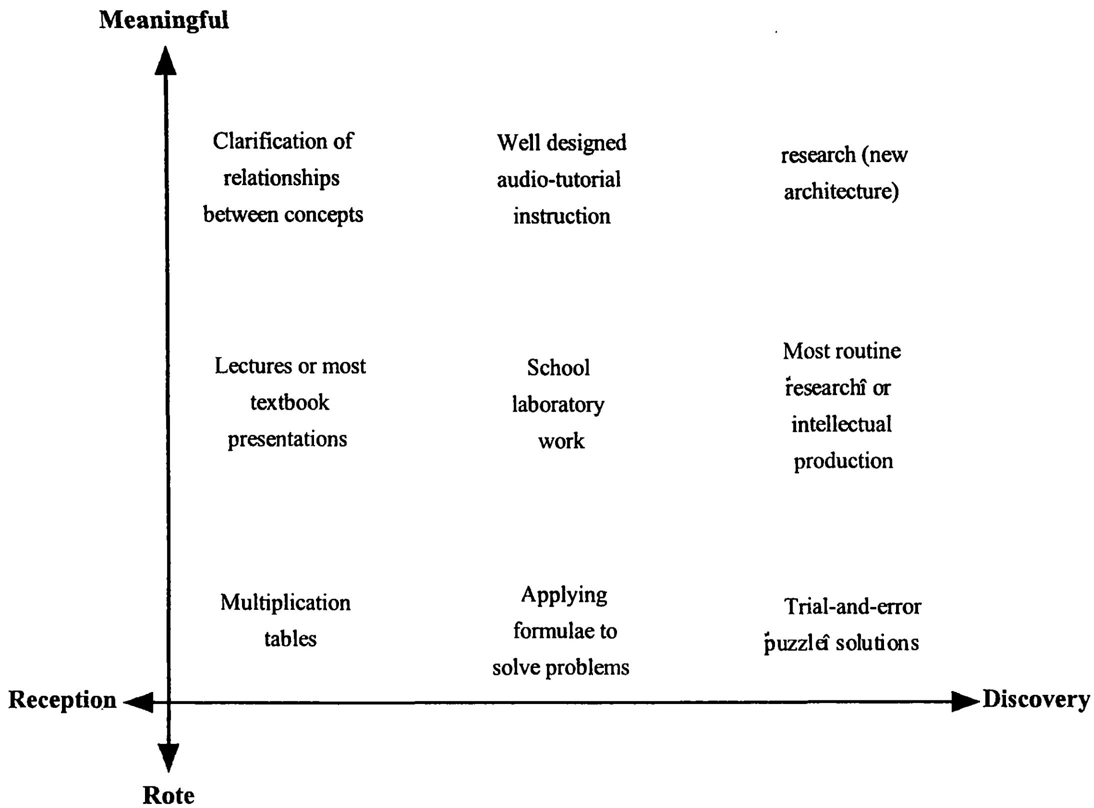


Figure 2.1 Reception learning and discovery learning are on a separate continuum from rote learning and meaningful learning

2.5.1 Meaningful and Rote learning

Meaningful learning involves the acquisition of meanings, new meanings and understandings. Thus, the emergence of new meanings in the learner reflects the completion of a meaningful learning process (Ausubel *et al,* 1978).

According to Ausubel *et al* (1978), meaningful learning is a process in which new information is related to an existing relevant aspect of an individual's knowledge structure, and which, in the same way, must be the result of an obvious action by the learner. In Ausubel's model, he contended that the most important single factor influencing learning is what the learner already knows *"If I had to reduce all of educational psychology to one principle, I would say this: the most important single* *factor influencing learning is what the learner already knows. Ascertain this and teach him accordingly" (*Ausubel *et al*, 1978).

To acquire meaningful knowledge, the learner can approach the task in two different ways (Good and Brophy, 1990). If a person attempts to memorize her driver's certificate number without relating the numbers to anything more than a random series, that is rote learning. On the other hand, if a person attempts to create some relationship to something that they already know, they experience meaningful learning (Ausubel, 1962). A good illustration for this might be: a *student could learn Ohm's law, which indicates that current in a circuit is directly proportional to voltage. However, this proposition will not be meaningfully learned unless the student already has meanings for the concepts of current, voltage, resistance, direct and inverse proportion, and unless he or she tries to relate these meanings as indicated by Ohm's law* (Ausubel *et al*, 1978).

Ausubel places a great deal of importance on the difference between rote and meaningful learning. He stresses meaningful learning, as opposed to rote learning or memorization; and reception, or received knowledge, rather than discovery learning. However, is meaningful learning just what rote learning is not? This may be true only if the learner keeps in mind that meaningful learning is strongly connected to the process of knowledge retention within cognitive structures. He suggests that meaningful learning occurs when the learner's appropriate existing knowledge interacts with the new learning. Rote learning occurs when no such interaction takes place (Ausubel et al, 1978).

Ausubel (1969b) describes the most likely circumstances which result in rote learning and meaningful learning (Table 2.1).

Rote learning	Meaningful learning
1. The material to be learned lacks logical meaning.	*1. The material itself must be related to some hypothetical cognitive structure in a non arbitrary and substantive fashion.*
2. The learner lacks the relevant ideas in his own cognitive structure.	*2. The learner itself must possess relevant ideas to which to relate the material.*
3. The individual lacks a meaningful learning set (a character to connect new concepts, propositions, and examples, to previous knowledge and experience).	*3. The learner must possess the intent to relate these ideas to cognitive structure in a non arbitrary and substantive fashion.*

Table 2.1 The result in rote learning and meaningful learning

In short, in reception learning (rote or meaningful) the learner has to be presented with what is to be learned in its final form (Ausubel, 1978, 1969a).

2.5.2 Reception and Discovery Learning

Reception learning and discovery learning are not on the same level of importance as meaningful learning. The overall aim is meaningful learning. The mechanisms for learning may be by means of discovery or reception. Discovery learning is not as important as meaningful learning (Ausubel and Anderson, 1965). However, Bruner is a leading supporter of discovery learning and has said that the most meaningful learning takes place when it is exploration (Good and Brophy, 1977).

Ausubel maintains that a key feature essential in discovery learning is that the principal content of what is to be learned is not given but must be independently discovered by the learner before he can internalize it (Ausubel, 1969b; Ausubel and Anderson 1969). Moreover, his most common analysis of discovery learning is that although it can be effective in certain situations, for the most part it is cumbersome and overly time-consuming (Langford, 1989). Additionally, unless the teacher provides a greater context, the learning is unorganized and will have no better chance of retention than rote memorization of a procedure. Instead, expository teaching can be made to be meaningful if the teacher is conscientious about how the material is presented.

2.5.3 Summary

One key feature of Ausubel's model is that it concerns itself primarily with intentional or "school" learning. In that way, his model differs from behaviorism and cognitive information processing, which attempt to explain aspects of all human learning or memory. He focuses on how an individual learns meaningful information (Ausubel, 1968). Consequently, Ausubel's theory suggests how teachers or instructional designers can best arrange the conditions that facilitate learning for students. In addition, he focuses on how an individual learns *the maximum amount* of meaningful information.

In summary, according to Ausubel, students acquire knowledge primarily through reception rather than through discovery. Concepts, principles, and ideas are presented and understood, not discovered. The more organized and focused the presentation, the more methodically the individual will learn. In additional, he stresses meaningful learning and he sought to encourage meaningful rather rote reception learning.

2.6 Information Processing Models

Information processing is an approach to the purpose of understanding human thinking. This approach arose in the 1940s and 1950s. Information processing theories have become a general theory of human cognition in psychology (Solso, 1991; Tulving, 2000).

The basic idea of these models is that humans take information in, process it, put it in storage and then retrieve it later when it is needed. In more detail, information is input. This input has to take some form that can be recognized by one or more of the senses (visual, auditory, tactile, kinesthetic, and oral) (encoding). Information may take time to be processed, for the processing of information possibly passes through a number of stages, each stage with its own characteristics, limitations, and parameters (Bourne *et al*, 1979). When people pay attention to information picked up by the sensory registers, it goes into the working memory; if they do not pay attention it is lost. Once in working memory it needs to be processed or practiced within 5 to 20 seconds for it to be transferred to the long-term memory (from where it can be retrieved) (Child, 2004; Johnstone and Su, 1994; Baddeley, 1999).

Not surprisingly, the information processing model became much more popular with the advent of computers. Sensory memory is like a temporary buffer in a computer that stores information briefly (like a cache in a web browser). Then working memory comes which is very much like a file being worked on, before it is saved (a bit like RAM). Finally, long-term memory is certainly similar to a hard drive (Johnstone, 1984).

2.6.1 Memory

The study of psychology of memory has been enormously active, having changed and developed in the last ten to fifteen years (Baddeley, 1997). Memory, as a property of the human mind, is the ability to return and recall information from something that has been learned or experienced, as acquired through our senses (Child, 2004; Tulving and Donalson, 1972; Tulving, 2000).

Memory is a vital part of the learning process, since if a person is unable to remember anything from the past, (s)he could not learn anything new. Baddeley (1997) suggests that memory is not one system but all the parts operate in harmony. In the case of the psychological study of memory, there is considerable agreement that it can broadly be divided into three separate types of memory store: (1) sensory memory; (2) short-term memory; and (3) long-term memory (Baddeley, 1999, Shanks, 1997). In 1960 Atkinson and Shiffrin formulated an understanding named the modal model. This can be summarizing by: information passed to the sensory memory and then supplied to the short term memory which in turn communicates with long term memory (Baddeley, 1990).

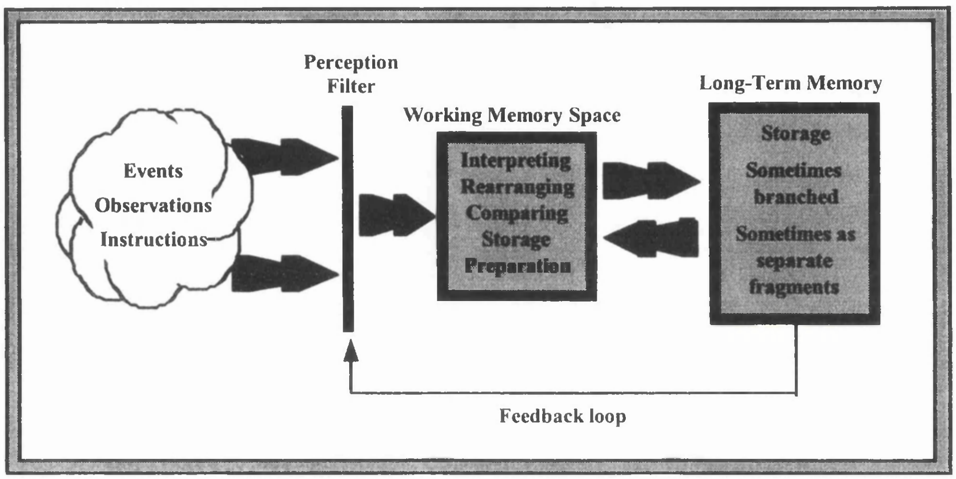


Figure. 2.2 Model of learning and memory organization in information processing (Johnstone, 1997)

Johnstone presents an additional model of information processing, (Figure 2.2) which draws in the ideas of Ashcraft who, with his colleague Shiffrin, treated many problems of conceptualizing the memory system (Shanks, 1997). In the Johnstone model, the Perception Filter (sensory memory) receives signals from the outside world and admits some of them to the working memory. Clearly the perception filter is constantly bombarded by stimuli, but an individual is able to select or filter out certain signals for further considerations. This filtering process is influenced by what is already held in the long term memory, aiding the selection of important from unimportant information. Meanwhile, the working memory, of limited capacity, is the space where information is held for decoding, interaction (with information drawn from the long term memory) and encoding (for storage in the long term memory). New information is most efficiently stored if it is linked to that already held in the long term memory (Johnstone, 1993).

2.6.2 Sensory memory

Sensory memory is the immediate, initial recording of sensory information in the memory system. It is responsible for the encoding (take information and convert it to a practical mental form) of information (Klatzky, 1975). Baddeley (1997) claims that sensory memory is the earlier stage in the processes, in order for something to get into long-term memory; it must first "register" with sensory memory.

Sensory memory is the part of the memory in which information enters the human information processing system using a variety of channels linked with the different senses, so there are many sensory memory systems, one associated with each sense (Baddeley, 1997). Many researchers hypothesized three registers: *"Iconic or visual memory, echoic or auditory (or verbal) and semantic memory"* (Child, 2004).

In 1991, the sensory memory was described by Johnstone as a perception filter, and he gave an idea about how this filter is affected by earlier knowledge, following the ideas of Ausubel. The meaning a person assigns to sensory impressions depends on both the background knowledge and the context in which the person experiences something (Johnstone, 1991).

Sensory memory is still considered to operate automatically within approximately less than 1 second and certainly no more than 2 seconds (Ashcroft, 1994) and so can be seen to be very short lived; for example, when looking at a photograph, sensory memory occurs as the image of the picture enters your eyes and is transmitted to the brain. This entire process takes less than a second (Baddeley, 1999). Even though retaining information for a very short period if time, it is not to be confused with short term memory *"which typically lasts 10-15 seconds without rehearsal of the remembered material)"* and is so named to distinguish it from long term memory which can store information for as long as a lifetime (Klatzky, 1975).

2.6.3 Short-term memory

Short-term memory is the stage between sensory memory and long-term memory. The information held in short-term memory may be a recently processed sensory input, items recently retrieved from long-term memory or the result of recent mental processing (Klatzky, 1975).

Short-term memory is also called working memory. If the emphasis is on remembering, then the term 'short-term memory' is appropriate. If the emphasis is on the fact that this part of the brain is where a person holds information, thinks about information and solves problems then the phrase 'working memory' is more useful (Baddeley, 1986; Johnstone, 1997). Reflecting this, the standard definition of working memory is more limiting, however, and refers *"to the temporary storage of information that is being processed in any of a range of cognitive tasks"* (Baddeley, 1986; 1997). Atkinson and Ashiffrin's (1968) model mentions that working memory is able to hold and perform operations on information while subjects perform other more complex cognitive tasks, such as learning and comprehending (Shanks, 1997).

Johnstone (1997a) proposed that working memory has two main functions: the first is holding ideas while processing them; The second is sharing the information it holds and has processed with the long-term memory. According to Baddeley and Hitch (1974), working memory plays a significant role in supporting a whole range of complex daily cognitive activities (Gathercole and Baddeley, 1993). Baddeley (1986) presents a model of working memory and hypothesizes a central executive and two slave systems: an articulator loop and a visual-spatial scratch pad (Baddeley, 1990, 1997; Child, 2004).

On the one hand, a vast amount of evidence indicates that working memory is an entirely different process from long-term memory (Baddeley, 1986). The capacity of working memory appears to be quite limited: it stores a *"limited amount* of information for a *limited amount of time"* (roughly 30-45 seconds). People are different in the limit of their working memory; some people are better than others at remembering what they have just seen (Johnstone, 1993). Baddeley describes this as *"holding mental pictures in mind from moment "* (Baddeley, 1986).

Working memory contains information that we are actively using. There are four possibilities: firstly it might be forgotten almost immediately; secondly, it may possibly be held briefly through simple attention and repetition; thirdly it may be held for a little longer (for a few minutes) through frequent repetition or simple *"chunking"* of the information into *"larger"* items; finally, through "elaborative practice" reorganization and repetition, it becomes part of our long-term memory. In other words, a piece of information can be held in working memory for as long as it is actively thought about until it is either lost or placed in long-term memory (Child, 1993).

Miller has provided two ideas that are fundamental to the information processing framework and cognitive psychology more generally. The first concept is *"chunking"* breaking down the information into manageable units (Baddeley, 1986), and the capacity of short term (working) memory. Miller (1956) found that short-term memory could only hold 5-9 chunks of information (seven plus or minus two) chunks of information. These could be numbers, letters, words, and could refer to digits, words, chess positions, or people's faces. The concept of chunking and the limited capacity of short term memory became a basic element of all later models of memory.

The second concept is that information processing uses the computer as a model for human learning. Like the computer, the human mind takes in information, performs operations on it to change its shape and content, stores and locates it and generates responses to it. Thus, processing involves gathering and representing information, or encoding; holding information or retention; and getting at the information when needed, or retrieval.

Miller *et al* (1960) believed that information processing models can assist in developing cognitive theories, and in general they can be applied to instruction by following these guidelines:

- Make sure you have the students' attention;
- Aid students focus on the most important details and separate less essential information;
- Help students make connections between new information and what they already know;
- Provide for repetition and review of information; Present instruction in a clear, organized, way;
- Focus on meaning, not on memorization of information.

Baddeley notes that working memory has limited space to hold and operate on information while Miller found that people could hold 7 ± 2 chunks of information (Miller, 1956). As a result, this part of the memory can be easily overloaded (Johnstone, 1997b) if there is too much information and limited space to operate on it. *"If the information we are connected with reaches the upper limits of our working space, an overloading in the capacity of working memory could occur. A loss in productivity may arise"* (Barber, 1988).

There are some differences between working memory and sensory memory in several ways. First, the capacity of the sensory memory is almost unlimited, whereas the capacity of the working memory is limited. The information in the sensory memory is unprocessed, while the information in the working memory has been encoded. The information in the working memory does not fade away as quickly as information in the sensory memory. However, the information in the working memory will be lost in about twenty or thirty seconds, unless it is processed further. Recent research has shown that working memory does not consist of a single general capacity, but rather consists of several subsystems that can be relied on to complete various types of tasks (Baddeley, 1986).

2.6.4 Long-Term Memory

Long-term memory is the final component in the information processing model. Information is transferred from working memory in a few seconds then it is stored in long term memory up to a lifetime. Therefore, long term memory storage is permanent and does not suffer loss through time (Driscoll, 1994, Bourne *et al*, 1979). It is the part of memory which has an unlimited capacity and can hold information for an indefinite period (Child, 1993).

Information enters long-term memory from working memory. If the information has been repeated in some way, recall from long term memory is easier. Equally, if the information is associated with some emotion, it may well also be easily recalled. For example, friends and family will be remembered for a long time, while someone you only meet once will not. Similarly, the events surrounding a distressing experience are remembered, while the typical day-to-day events leading up to it are usually not (Child, 1993; Driscoll, 1994).

In meaningful learning, new information is transferred to long term memory and it is linked in some way to previous knowledge already in long term memory. Information is translated into some meaningful form (encoded) and retrieved through a process of identification and recall for a particular purpose (Baddeley, 1999). Atkinson & Shiffrin (1968) argue that information can be stored in long term memory only after it has been stored in short term memory, and even then, storage in long term memory is a probabilistic event.

Long term memory is a unitary system which consists of two types of memory: episodic and semantic long term memory (Bourne *et al*, 1979). Tulving (2000) is a psychologist who made a useful distinction between the two types of long term memory: episodic memory represents our memory of events and experiences in a serial form. It is from this memory that a person can reconstruct the actual events that took place at a given point in our lives *"such as going to the dentist a week ago"*. Semantic memory, on the other end, is a structured record of facts, concepts and skills that we have acquired. The information in semantic memory is derived from that in our own episodic memory, such that we can learn new facts or concepts from our experiences (Tulving, 2000). *" Knowing the meaning of a word or the chemical formula for salt or the capital of"* Qatar all are good illustration of semantic memory (Baddeley, 1999).

In addition there is a third type of long term memory described as procedural memory(Bourne *et al,* 1979), and this type is concerned with 'knowing how' as opposed to 'knowing that'. Examples include knowing how to drive a car or cook a meal.

2.6.5 Summary

Information processing theory mainly focuses on how a person receives, thinks about, mentally modifies, and remembers information, and how such cognitive processes change over the course of development.

Long-term memories are maintained by more stable and permanent changes in structure. Some psychologists, however, argue that the difference between long-term and working memories is only a reflection of differing levels of activation within a single store (Baddeley, 1999). Many researchers claim that children remember better as they grow older. Of course, the working memory grows with age to age 16 at roughly on unit each two years. However, of greater importance is the fact that more knowledge and experience allow the possibility that meaningful learning can be enhanced as more links can be formed in long term memory. Also, older children might focus on what the researcher wants them to remember (Bourne *et al*, 1979).

No matter how learning occurs, thinking takes place in working memory and this can be a rate-determining step in the process because of the limited size of working memory. This concept is critical to the understanding of some learning difficulties.

Most models of learning are dominated by the views of Piaget, who argues that a growing child passes from stage to stage during development, with each stage characterized by a different set of cognitive processes. There is agreement that there are enormous changes from infancy to adulthood. Moreover, cognitive development is jointly determined by the biological characteristics of the individual and the type of environment in which the person grows (Bourne *et al*, 1979): for example *"Piaget's development stages*; *Ausubel's inadequacy of previous knowledge for meaningful learning*; and *Pascual-Leone's ideas of limited space related to age and information processing models"*. Features of these models have been absorbed into the information processing model developed by Johnstone (1991). This will be discussed later.

2.7 Imagery

Visual imagery is a flow of thoughts which you can see, hear, feel smell or taste. An image is an inner representation of your experience as your mind codes, stores, and expresses information. Imagery is the language of the arts, the emotions, and most important, of the deeper self.

Visual imagery has become a popular research issue after much neglect through the early years of the last century. In fact, much of the current excitement in the field of mental imagery arises from Shepard and his colleagues who were in 1971 carrying out their study of rotating mental images in the memory linked to time (Baddeley, 1997). They concluded from their study that visual imagery was based on an analogue medium, involving the gradual manipulation of the image. It appears to play a major role in problem-solving and creativity; it also appears to help sensory-motor skills by allowing mental rehearsal of task or activity (Miller, 1984).

Bourne and his colleagues (1979) found that the mere process of creating images or viewing pictures dramatically increases recall. It has been argued that the way information is encoded in memory is represented by two codes: imaginal and verbal. These two codes exist in long term memory (Solso, 1991, Bourne *et al*, 1979). Paivio believes that the imagery code seems more adjusted to concrete information than abstract information, whereas the verbal code seems more adjusted to processing abstract information. However, this does not suggest that all words link with abstract and all picture with concrete information. Sometimes visual stimuli are better represented by imaginal codes than verbal codes or vice versa (Solso, 1991).

As mentioned earlier Baddeley's model represented two slave systems of working memory: one of them is a visual-scratch pad which is responsible for setting up and manipulating visuo-spatial images, but not responsible for the enhanced memorability of highly imaginable words, and as such is useful in taking advantage of imagery for learning (Baddeley, 1990). Additionally, to see relationships between concepts we have represented either literally or symbolically by our images is the most important meaning of imagery in the visual-spatial scratch pad. Therefore, it would be like prose without metaphor if a person does not have imagery (Baddeley, 1986).

Undoubtedly, imagery offers powerful assistance to memory, and visual information can be stored in long-term memory. Indeed, many researchers have discussed how images are stored in memory, and their theories can be classified into three categories: *"picture-analogy theories, symbolic representation theories, and surface representation theories"* (Bourne *et al.*, 1979). There are separate visual and spatial components of imagery, with different anatomical structures within the brain (Baddeley, 1997).

The idea of capacity limits has a long been fundamental to theories of imagery (Klosslyn, 1980), and working memory as well (Baddeley, 1986; Miyake and shah, 1999).

2.8 Visual Spatial Ability

Cognitive psychology has added importantly to our understanding of how humans encode and remember. The ability to visualize does seem to enhance understanding and subsequent recall. For a long time, spatial abilities have been demoted to a minor status in accounts of human intelligence. Typically, tests of spatial ability are viewed as measures of practical and mechanical abilities that are useful in calculating success in technical occupations, but not as measures of abstract reasoning ability (Smith, 1964). Shepard (1978) mentions that this is in disagreement with the important role afforded to spatial imagery in accounts of creative thinking, and with the practical correlations between spatial tests and other measures of intelligence.

In point of fact, there are many views in the literature about human spatial abilities. Indeed, many of those who have studied spatial abilities have noted it with reactions that range from amusement to annoyance (Paivio, 1971; Smith, 1964). On the one hand, some of the tests of spatial abilities were used to measure giftedness "*especially performance tests that use blocks or form boards or pieces of paper that must be folded and unfolded*". Furthermore, spatial abilities are regularly concerned in accounts of creative and higher-order thinking in science and mathematics (Shepard, 1978; West, 1991). On the other hand, spatial abilities are often connected with concrete, lower-level thinking. Thus, they are used to predict success in various practical and technical occupations, such as carpentry, auto mechanics, and the like.

Olkum (2003) claims that, in recent times, spatial abilities are understood as important for higher-order thinking in science and mathematics, for the ability to create and realize figure in language, and for creativity in many fields. The sciences involve many situations where there are opportunities for representing and manipulating information in learning and problem solving. Douglas and Battista (1992) propose that spatial thinking is important for scientific work. In addition, it is required in many intellectual endeavors such as solving problems in physics, mathematics and engineering design (Smith, 1964; Pellegrino *et al*, 1983)

The concept of spatial ability is used for the abilities related to the use of space. Burnet and Lane (1980) define visual spatial ability using the following ideas: visual spatial ability is the ability to mentally rotate, retain, retrieve, and transform well-structured visual images or figures in two or three dimensions.

There are, in fact, a number of spatial abilities, each emphasizing different aspects of the process of image generation, storage, retrieval, and transformation. According to Shepard (1978) and West (1991), spatial abilities are essential constructs of all models of human abilities and high levels of spatial ability have normally been linked to creativity, not only in the arts, but in science and mathematics as well. For example, on several occasions Albert Einstein reported that verbal processes appeared not to play a role in his creative thought. He claimed to achieve insights by means of thought experiments on visualized systems of waves and physical bodies in states of relative motion. Others demonstrated high levels of spatial abilities and noted that they played an important role in their most creative activities. They came from many disciplines, for example, physicists (such as

James Clerk Maxwell, Michael Faraday, and Herman Von Helmholtz), inventors (such as Nikola Tesla and James Watt), and others (such as Benjamin Franklin, John Herschel, Francis Galton, and James Watson).

There are four different types of test used to measure spatial abilities: *"performance tests, paper-and-pencil tests, verbal tests, and film or dynamic computer-based tests"*. Much research shows that spatial ability is essential and may possibly be enhanced through appropriate activities (Lohman, 1986).

Many theorists (e.g. Just & Carpenter, 1992) emphasize the exchange between storage and transformation tasks in a unitary working memory system. By this explanation, mental rotation problems are good measures of spatial ability because they place substantial demands on both storage and transformation functions, and require subjects to manage the exchange between them (Miyake and Shah, 1999).

2.8.1 The Visual-spatial learner

Silverman (2000) has established the concept of the *"visual-spatial learner"*. Visual-spatial learners are individuals who think in pictures rather than in words. They have multi-dimensional perception, which means that they can transform images in their mind's eye, considering them from many viewpoints. Visual-spatial learners require more time to translate their mental pictures into words, and word retrieval may be problematic, so time is a problem to the visual-spatial learner (Silverman, 2002). Table 2.2 shows a comparison of characteristics between these two types of learner.

According to Silverman (Table 2.2), visual-spatial thinkers are individuals who think in pictures rather than in words, who have good long-term memory, enjoy geometry and physics, think creatively, technologically, mechanically, and emotionally, are natural mathematicians and scientists, have trouble with spelling, reading, and memorizing, can learn all-at-once rather than step-by-step, and who learn better visually than auditorally. However, some visual-spatial learners are excellent at auditory-sequential processing. They can deal with both systems, and can resort to sequential methods of problem solving if they do not gain an immediate understanding when looking at a problem. Indeed, many researchers agree that these students are usually highly gifted with well-integrated abilities (Silverman, 1999).

The Auditory-Sequential Learners	The Visual-Spatial Learner
Thinks primarily in words	Thinks primarily in images
Has auditory strengths	Has visual strengths
Relates well to time	Relates well to space
Is a step-by-step learner	Is a whole-part learner
Learns by trial and error	Learns concepts all at once
Progresses sequentially from easy to difficult material	Learns complex concepts easily; struggles with easy skills
Is an analytical thinker	Is a good synthesizer
Attends well to details	Sees the big picture; may miss details
Follows oral directions well	Reads maps well
Does well at arithmetic	Is better at math reasoning than computation
Learns phonics easily	Learns whole words easily
Can sound out spelling words	Must visualize words to spell them
Can write quickly and neatly	Much better at keyboarding than handwriting
Is well organized	Creates unique methods of organization
Can show steps of work easily	Arrives at correct solutions intuitively
Excels at rote memorization	Learns best by seeing relationships
Has good auditory short-term memory	Has good long-term visual memory
May need some repetition to reinforce learning	Learns concepts permanently; does not learn by drill and repetition
Learns well from instructions	Develops own methods of problem solving
Learns in spite of emotional reactions	Is very sensitive to teachers' attitudes
Is comfortable with one right answer	Generates unusual solutions to problems
Develops fairly evenly	Develops quite asynchronously (unevenly)
Usually maintains high grades	May have very uneven grades
Enjoys algebra and chemistry	Enjoys geometry and physics
Masters other languages in classes	Masters other languages through immersion
Is academically talented	Is creatively, technologically, mechanically, emotionally or spiritually gifted
Is an early bloomer	Is a late bloomer

Table 2.2 Characteristics Comparison between the Visual Spatial and Auditory Sequential Learners (Silverman, 1999)

Sword suggests the spatial and sequential thinking are two different mental organizations that affect the way people view the world (Sword, 2000). Therefore, teachers have to consider that there is a different way of learning than that they may be using in the normal classroom.

In the next chapter, a brief view of the current researches on conceptual understanding and the difficulties of understanding physics concepts will be given.

Chapter Three

Difficulties in learning physics

3.1 Introduction

Physics is sometimes portrayed as one of the most difficult subjects for students to excel in. This need not necessarily be a correct evaluation. For example, in looking at the difficulty levels of subjects in the Scottish curriculum at Standard Grade (sat around age 15-16), data from relative ratings shows that physics, in performance terms, is a subject of average difficulty (Reid, 2005). Nonetheless, the Scottish patterns do not seem to be repeated in too many countries.

This chapter seeks to present data showing some of the misconceptions and difficulties that learners encounter when learning physics, particularly in areas like forces, electricity and magnetism, in order to investigate why students classify some topics as difficult, as well as an exploration of possible ways to solve some of these problems consistent with findings from educational research.

3.2 Common Difficulties in Physics

It is clear that a number of concepts traditionally introduced into secondary physics courses are troublesome to school and university students (Driver, 1989). This type of work has received strong attention over the last two decades in learning science (Saxena, 1992), particularly in research into context and content (for example, Doran, 1972; Driver, 1973; Archenhold, 1980; Sutton and West, 1982; Driver, 1982; McDermott, 1984; Gilbert and Watts, 1983).

Based on teaching experience, it has been observed that students very often face difficulties in coping with physics, and many people would agree that physics is a difficult subject to learn (Jones and Mooney, 1981).

3.3 Specific Difficulties in Physics

The literature describes a quite enormous amount of work which has been carried out in an attempt to identify and analyze student difficulties in understanding physics ideas. The results show that students have encountered problems in understanding in many areas of physics: mechanics, such as vectors; Newton's Laws, forces; circular motion, energy, acceleration and so on (Goldberg and Anderson, 1989; McLoskey *et al*, 1980; McDermott *et al*, 1987), electricity and magnetism such as electrostatics and magnetostatics (Maloney, 1985), DC circuits (Fredette and Lochhead, 1980; Cohen *et al.* 1983; McDermott and Shaffer, 1992), electric and magnetic fields (Viennot and Rainson, 1992), light and optics, such as the nature of light, color and vision (Watts, 1985; Saxena, 1991), geometrical optics (Goldberg and McDermott, 1986), heat, temperature, and thermodynamics (Warren, 1972; Erickson, 1979), pressure, density, and the structure of matter (McKinnon and Geol, 1971; Griffiths and Preston, 1992).

It might be thought, looking at the above list, that almost everything in physics learning was a problem. However, these studies are based on specific curricula, teaching approaches and text-books which operate in specific countries and the pattern of results may well not apply equally in all contexts.

In Scotland, a study was carried out among students at both school and university levels to assess their perceptions of the difficulties. This study was conducted over two years; in 1974-75, working with 115 first year university students, 550 post-O-grade and 211 pre-O-grade and, in session 1975-76, with 414 post-O-grade and 499 pre-O-grade pupils in Glasgow. Students indicated topics that they encountered as difficult, this being defined to them in terms like: 'I found this difficult to understand and I still do not understand it'. The most difficulties topics were found to be in three categories: motion, energy and electricity. This included topics like the difference between mass and weight, the idea of uniform motion, pressure, conservation of momentum, elastic and inelastic collisions, energy and power, heat and temperature, latent heat, heat transfer, current ac and dc, resistance induction field and E.M.F. (Johnstone and Mughol, 1976).

The following section gives a brief overview of these difficulties by looking at same of the investigations on students understanding forces, electricity and magnetism.

3.3.1 Forces

Science and technology play an increasingly significant role in everyday life. Of all the topics encountered in science, force is one that pervades all walks of life. The concept of forces is therefore introduced into most syllabuses at a somewhat early stage. In most countries the topic of force is included in most syllabuses.

Below are some common student difficulties and misconceptions about the concept of forces. The majority of students believe the following ideas: objects will move in the direction of their velocity; the fall of objects over the earth is typically related to their weight; heavier objects fall faster than light objects; faster-moving objects have a larger force acting on them; and objects only move when a force is exerted upon them (Halloun and Hestenes, 1985). Students believe that the direction of force is the same as the direction of motion (Watt and Zylbersztajn, 1981). In addition, Dejong (1988) and Smith (1992) noted that each semester, a high percentage of students who attended their class had misconceptions concerning the concept of force.

Many studies have been conducted in a bid to find the difficulties that students experience in understanding force. Hellingman (1992) declares that many researchers believe that misconceptions about force are not the students' problem only but also exist among professional physicists.

In an investigation by Gilbert and Watts (1983) on concepts, misconceptions and alternative conception, they noted that much research, such as Helm (1980) and Maddox (1978), had indicated that students confuse force and motion, and hold misconceptions concerning the words 'energy' and 'weight'.

The lack of understanding of frictional force was observed from the studies that were carried out by Paulo and Adriano in 2005 to explore misconceptions among schools teachers and students in Portugal. An investigation was administrated to a sample of 15 school physics teachers and students of physics education courses, using written diagnostic questions involving direction of frictional force, the normal forces at an interface and Newton's third law. The results showed that most of participants knew that frictional force does not always have the same direction as the motion, and that the teachers sometimes do not perceive the contribution of the torques of frictional and normal forces related to body motion. Finally, the concept of free body diagrams in such contexts involves a general lack of understanding and a variety of misconceptions.

A series of studies (Brown, 1999; Gamble, 1989; Gunstone & Watts, 1985; Hellingman, 1989; Maloney, 1984; Osborne, 1985; Savage and Williams, 1989; Watts & Zylbersztajn, 1981) has been conducted on students about finding the difficulties that they encounter in learning physics. It was found that Newton's laws of motion are especially difficult for beginner students and teachers.

Newton's third law, defined according to Newton as: *to every action there is always opposed an equal reaction: or, the mutual actions of two bodies upon each other are always equal, and directed to contrary parts* (Newton, 1682) is extremely important and it was appears that it is causing a misunderstandings in many students in many countries. Brown (1999) suggested that this law should be emphasized in teaching physics and should comprise a significant part of the unit on forces and Newton's laws, because he believed that there is a correlation between understanding the concept of force and Newton's third law. This result has been demonstrated from a study which looked at the relation between Newton's third law and understanding physics; he collected his data from a study involving oral, and multiple choice tests.

Studies were performed in many countries (e.g. Maloney 1984) which showed that a high percentage of students do not understand Newton's laws and that misconception abounds not only among students but in text books as well.

Boyle and Maloney (1991) performed a study to investigate the understanding of Newton's third law among 100 university students. Half of them were provided with a hand-out describing forces with clear statements of the third law. All the students who had not been given the hand-out did *not* answer correctly, while, surprisingly, less than half of those who were offered the hand-out answered correctly.

Hellingman (1989) noted that the common phrasing of Newton's third law fosters confusion between the two forces that arise from a single interaction and two forces that balance. Moreover, not only are the terms in which Newton's third law is commonly couched confusing, the central meaning of the law is generally ignored in that most teachers or text-books concentrate on the first part of Newton's third law, which is that the action force and reaction force are equal and opposite. However, they ignore that because these forces are acting upon different bodies, the result of these forces is not equal to zero.

Hellingman (1992) continued his study to investigate difficulties students have understanding the concept of force, and he found that the third law is central to the definition of a force. Furthermore, it is essential to help students to see the difference between force and 'not a force'. However, Newton's third law is ignored in most textbooks at secondary level.

Savage and Williams (1989) carried out a study to find how and why students have confusions with the concept of centrifugal force, and how the situation could be manipulated. They examined first year science and engineering undergraduates in the University of Leeds using a mechanics questionnaire. They noted that problem solving in mechanics requires the adoption of a regular approach in which Newton's second law is applied to bodies in rest frames and subject only to Newtonian forces. In addition, they found how Newtonian mechanics can be used to investigate the effect on the human body due to both contact and body forces and provide a normal explanation for students' individual experience of accelerated motion.

McDermott and Trowbridge (1980, 1981) carried out two studies using students from the University of Washington studying a variety of introductory physics courses: these studies aimed to investigate students' understanding of the concepts of velocity and acceleration in one dimension. Among many interesting findings in these two studies, it is clear from the data collected that students have misconceptions of the concepts of position, velocity, and acceleration. Many students believe that a particle which has no velocity at an instant cannot be accelerating. This misconception arises because they may not understand the ratio $\Delta v/\Delta t$. A similar outcome was found from the second study: students encountered some difficulties in learning about acceleration. In short, a large number of students believe that if the object has a larger velocity, it also has a larger acceleration, or vice versa, that acceleration equals zero when the object is stable, and students fail to see acceleration as the ratio $\Delta v/\Delta t$.

Research in Nigerian secondary schools that aimed to explore the misconceptions in these areas of physics was conducted with 258 students from eight schools with different systems. The results indicate that most of the students had difficulties in learning physics, particularly in understanding uniform motion, which arises from misconceptions regarding cases of zero velocity, and that they also had misconceptions about contact force, mutual potential energy, and kinetic energy, and the definition of the Kelvin temperature (Lavowi, 1984). Helm (1980) found similar results in his study of South African students.

3.3.2 Electricity

Much research has been conducted looking at the main difficulties in understanding the concepts linked to electricity (Pfundt and Duit, 1994). Several results appearing from these studies show that there is a lack of understanding of basic concepts in electricity such as current, voltage (Shipston, 1984; Psillos and Koumaras, 1988; Webb, 1992), and electric circuits (Black and Solomon, 1987). The outcomes from this area of research will now be summarized.

Johnstone and Mughol (1978) explored the growth of understanding of the concept of electric resistance. This topic was selected because it was indicated as difficult in 1976 when they carried out a study to classify difficult topics in physics among secondary level students (Johnstone and Mughol, 1976). The data were collected using a comparison interview and test.

1. Pupils find that basic symbols of electrical circuits were familiar.
2. All pupils believe that current only appeared in closed circuits.
3. There was confusion between voltage and power.
4. Many students recognize the practical difference between E.m.f and P.D. but only a small portion of them understood why this should be.

In a study conducted among Australian primary science teachers, third year education students, and South African primary science teachers (Webb, 1992), it was found that participants (students and teachers) had a confused understanding of electric current, which is a flow of electrical charge carriers, usually electrons or electron-deficient atoms (Johnson, 2001b), through a wire from negative to positive: they would forget that a potential difference across the wire is needed. They also thought that current flow was equal and flowed in the same direction in both wires.

McDermott and Shaffer (1992) conducted a study to investigate the conceptual understanding of electric circuits. They pointed out that students had misconceptions in understanding current: they believed that the batteries were a constant current source and that current is 'used' in the circuit, which is wrong because voltage is merely the energy enabling electrons to flow in a circuit (Johnson, 2001b) and does not supply any charge.

Shipstone and his colleagues introduced a study to investigate the students understanding of electricity. This was administrated to more than 1200 students aged 15-17 year-old (grade 10) from five European countries (England, France, The Netherlands, Sweden and West Germany) and indicated misunderstandings related to the concept of voltage. The majority of students thought of a battery as a constant current source not as a constant voltage source (Shipstone *et al*, 1988).

Another study related to students' misconceptions in electricity in simple DC circuit was carried out by Shipstone (1984) on students in the age range of 12 to 18 years. He produced a pencil and paper test with of ten questions testing ideas relating to current, voltage and the effect of resistance upon these. Four models of electricity were distinguished as follows (these models were first named by Osborne in 1981): the first model was the *clashing current model* which sees current leaving the battery at both terminals and being used up within the circuit element. The second was called the *attenuation model* which considers current traveling in one direction only, becoming gradually weakened as it goes so that later lamps will be least bright. The third one considered *electric current* as being divided amongst the component of the circuit. Finally, *the scientifically acceptable model* which is similar to the second model (*attenuation model)*, in which the current is the same throughout the circuit. Shipstone noted that many students use an incorrect model of current flow, and, because of this, it was concluded that many electric principles cannot be assimilated.

In 1988, Psillos and Koumaras introduced a study based on the electrical phenomena to investigate pupils' understanding of concepts of voltage at secondary school level. They designed two questions on voltage, and 147 students age 13-15 were involved in this study. They were asked to indicate whether they were familiar with the term 'volt' and they were asked to give examples. The results represented that the majority of pupils have difficulties and were confused between the terms 'volt' and 'current' as well as 'energy' and 'electricity'. The researchers found that the approaches offered by textbooks caused these confusions. They then went further in this study and offered some essential steps in introducing the voltage model. Here are some of these features:

1. Using one concept to define voltage is much better than using two or three; for example, many textbooks at secondary level use PD (potential difference), EMF, and voltage to interpret DC circuits, which may be a root misunderstanding in the concept of voltage.
2. Voltage refers to ordered pairs in space rather than one point, as presented in many textbooks. This approach would be more comprehensible for learning about batteries and voltmeters.

Miller and Beh (1993) reported a study which looked at 15 years old school students with electricity. They investigated the understanding of simple parallel electric circuits. Misconceptions in voltage appeared because students were unable to recall basic facts about voltages in parallel circuits-part of the basic data for which any mental model of voltage must be able to account.

Saxena (1992) mentioned that in 1987 Dominguez performed research to solve misinterpretations related to electricity using instruction. He concluded that learners' misconceptions and related cognitive structures were so well established that it was extremely difficult to dislodge wrong ideas. This emphasizes the importance of establishing correct ideas at the outset and it presents a clear warning against the teaching of these fundamental ideas too early using teachers from other disciplines (e.g. primary teachers teaching physics ideas or teachers qualified in chemistry or biology teaching physics as part of an integrated science course). Wrong conceptions established early may prove close to impossible to change later.

Indeed, looking at the research evidence overall, electricity may perhaps be classified as one of the most difficult phenomena in physics. Part of this problem lies in being unable to 'see' electrical phenomena but only to see the outcomes and effects. Part of this lies in the conceptual base of many ideas (like energy and voltage) which are difficult to grasp with holding many underlying ideas clearly in mind at the same time.

3.3.3 Magnetism

As stated by Pfundt and Duit (1999), the last twenty years has seen a substantial number of studies being carried out to address the difficulties in the field of physics related to kinematics and dynamics (e.g. velocity, acceleration, force). On the other hand, in relation to the area of mechanics, rather less research has been established in magnetism (Bar and

Zinn, 1997, Galili, 1995, Seroglou *et al*, 1998) but there were some studies in secondary education. In recent times, some studies have considered the university and postgraduates levels (Borger and Gilbert, 1999)

Many cases in the literature on the area of magnetism have focused on students' misconceptions in the interactions between magnets at primary school level and to lesser extent at secondary level (Bar *et al*, 1997). However, a small number of studies deal with the analyzing magnetic field and magnetic force, not with the students' ideas of magnetic field and its relation to the magnetic force (Guisasola *et al*, 2004).

Student entering high school have an unclear and confused picture of electricity. Then they come across magnetic fields and they need to understand a mechanistic model of magnetic field and flux. Many people may agree that students frequently have difficulties in understanded magnetic field and flux (Ali, 2004). Nonetheless, magnetic field and flux need to be familiar to the students for the reason that it is the basis of electromagnetic phenomena. Guisasola *et al* (2004) performed a study among 235 university engineering and physical science students. The aim of the study was to discover misconceptions of the nature of magnetic field. The results showed that majority of the students have a nonscientific model to explain magnetic phenomena. He recommended some suggestions: for example, more attention should be considered on the conceptual aspect particularly at the microscopic level. In addition, the ampere model and the problems that appear from this model, such as attraction and repulsion between two spirals of current and interactions between two magnetic fields, should be introduced to the students. That allows students to distinguish between current running in the wire and the electrostatic charge in the same wire. It also demonstrates that students believe lines of magnetic field are real, so student must be taught that these lines are imaginary and that human intellect and imagination are often used by scientists to describe and explain natural phenomena.

Another study in magnetism was carried out by Maloney in 1985. His study intended to explore students' confusion about forces on charges moving in magnetic field. The investigation identified that there were misunderstanding between interactions between electric charges (positive and negative charge) and magnetic fields; they believe the charges sitting on the two ends of magnets (minus on the South Pole and positive on the North Pole).

3.4 The difficulties of understanding physics concepts

Numerous educators (e.g. Lovell, 1961; Beard, 1971; Gangé, 1970; Rogers, 1970) are in agreement that concepts are very important in teaching science. Lovel1 (1961) give a definition to concepts *"Concepts enable words to stand for a whole class of objects, qualities or events and are of enormous help to us in thinking"* (Johnstone and Mughol, 1978).

The complex and abstract nature of Physics makes the subject difficult to understand. However, complexity is not the only difficulty to understanding Physics. There are many others that are related to the mind of the learner: language, working memory overload, and lack of mathematic language. These issues are now discussed.

3.4.1 The nature of science concepts

It seems that physics is the most abstract subject in science. McDermott and Redish (1999) reported on a study which looked at students understanding of important topics in science and they recognized many students have serious gaps in understanding of important topics. These gaps refer to the complex and abstract nature of science making the subject difficult to understand.

The nature of science has become a fundamental factor of science education programmes. Johnstone (1982, 2000) pointed out that the very nature of science makes it inaccessible to many learners. Much cannot be understood by the normal use of the sense of sight and touch. For example, an element cannot be distinguished from a compound using the senses while acceleration can be 'felt' when in a car but the way to describe it in physics terms may be very different from what the person can sense (Johnstone, 1991).

In the same paper, Johnstone expresses his view that physics is like chemistry in being presented at three levels in teaching and learning. He describes these three levels as multi level thought processes which can be thought of as corners of a triangle (Figure. 3.1) which he called: descriptive and functional, representational and explanatory.

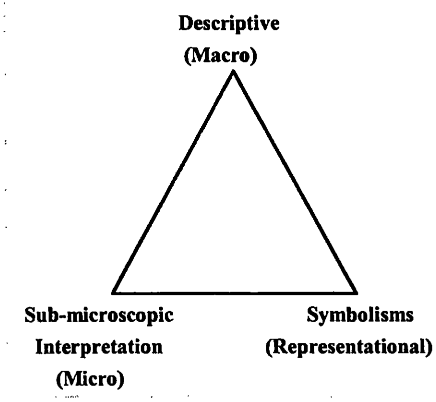


Figure 3.1 The Physics Triangle (Johnstone, 1991)

1. Macro (descriptive and functional): in this level students could see, smell, touch, and describe their observations: such as a light bulb, a motor spinning, a bell ringing and color.
2. Sub-micro level (representational): this level deals with invisible concepts such as forces, reactions, and atoms (electrons). Students should draw a mental picture of what they were taught at this level because they could not sense these concepts they only can see their reactions.
3. Symbolic (explanatory): in this level symbols, formula, equations, mathematical manipulation and graph were represent to explain why such phenomena happens.

From a study by Bat-Sheva and Uri (1990), it was concluded that the macro level is the easiest level for learners and they lacked a consistent picture of the explanatory mechanisms, When the students were asked to give explanations of phenomena from microscopic level they could not provide an accurate discussion.
Johnstone (1991) noted that any successful education must include all three levels. They cannot be separated totally. However, moving from level to other level is very difficult for the novice learner. Learning starts at macro level while teachers are more likely to move easily between these levels. If the teacher starts to move between levels when presenting topics, it is highly likely that the learner will suffer information overload and understanding will not occur.

Thus, it is important that teachers do not introduce too many levels at the same time. The learners must gain confidence at one level and then systematically build on this to develop the other levels, thus avoiding information overload. In addition, if the learners face too many concepts at the same time, they are unable to distinguish the more important ideas. Consequently, students should be taught how exactly to learn by guiding them how to handle the information successfully (Johnstone, 1991). Overall, the evidence shows that students learn by concrete concepts (images) more than abstract concepts (Johnstone, 1991; Paivio, 1971).

3.4.2 The Language Barrier

Language has been shown to be one cause of difficulties in understanding physics (Johnstone, 1984, 1991). There is a broad range of literature on the diagnosis of students misconceptions linked to language (e.g. Doran, 1972; Helm, 1980).

Language is the medium of learning and physics contains many words such as *force, energy* and *acceleration* which are often used in 'non-physics' talk. These words have different meanings compared to physics. Therefore, students who do not understand the physics meaning of these words will not be able to process and store the new information (Baddeley, 1990).

Misconceptions and confusions do not only appear in the language that teachers used but also in the language of the text book. Voltage may be a good illustration in that it is addressed in the textbooks in the secondary level by using three symbols PD, EMF and V (Psillos and Koumaras, 1988) which definitely cause a problem when pupils seek to distinguish between them.

Johnstone and Cassels (1978) and Cassels and Johnstone (1979) looked at the problems caused by language in student's responses to test questions. Of course, there are technical words relevant in any discipline but the main problem occurs with words where there are meanings in the use of non-science talk which are different (often in subtle ways) from scientific usage. There are also problems with language structure, and students found complexity and confusion with multiple choice questions when the statement contained negatives.

Research investigating the conceptions, misconceptions and conceptual change related to the language complexity for second language learners of science in South Africa has been carried out by Rutherford and Nkopodi (1990) and Rollnick and Rutherford (1993). Selepeng threw much light on the nature of the problem when she measured the working memory space of the pupils twice, one using the first language and the once using the second language. She was able to show that the measured working memory space fell with the second language, showing that some of this space was being used in processes like translation (Johnstone and Selepeng, 2001). This also offers explanations of wider problems of the way language use up valuable working memory space, leaving less for thinking. Figure 3.2 serves to illustrate this.

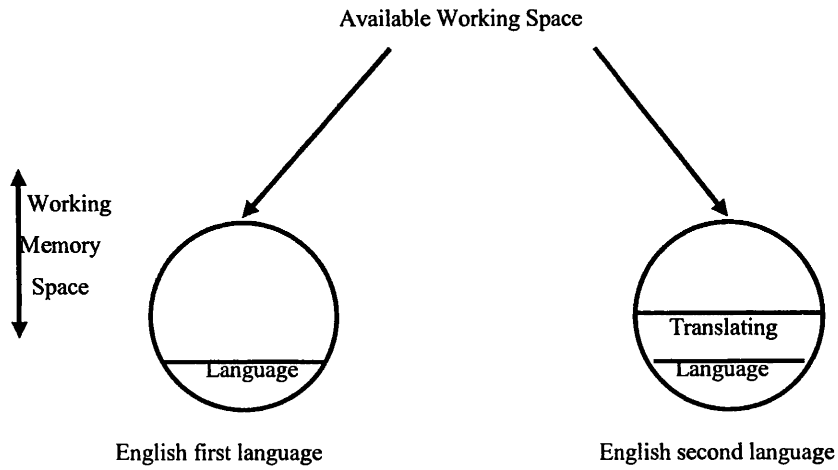


Figure: 3. 2 Reduction of available working space due to a second language
(Johnstone and Selepeng, 2001)

All cognitive structure models contain the idea that learners are controlled by limits. Specifically in working memory space that language is stored in memory uses two types of encoding which are visual or verbal forms, and the unfamiliar (new or other language) concepts or phrase can cover much more space than familiar words (Johnstone, 1991).

Saxena (1992), Shipstone (1984), Borger (1999) and Webb (1992) tried to create a picture of the electrical current and circuits, assisting students to visualize these microscopic concepts. This may reduce the difficulties in learning such abstract concepts by using many ways in which the students were involved at the learning processes. For example, Saxena (1992) tried to give students an opportunity to experiment and verify their predictions and reasoning. Shipstone (1984) tried to encourage students to consider the models that they hold and to challenge the inadequate models experimentally. Kibble (1999) offered situations when the students were invited to generate explanations in relating to electricity, in order to enhance understandings through dialogue.

It is clear from previous work that teachers should give students a chance to explain the phenomena in their own words to avoid rote memorized teachers' language without understand what they memorized (Johnstone and Selepeng, 2001). In other words, to achieve progress in students' understanding of principles in the physical world and in a systematic view of physics, students have to understand in their own words and realize what the relevant objects and properties are. They should have the ability to manage a particular situation and to construct investigations and predict events when properties of subjects are combined.

3.4.2 Mathematical Language

Mathematics provides the proper tools for learning with the precisely defined quantities that science uses. Physics combines mathematics with physics principles to explore everyday problems. Therefore, it is not enough to be excellent at mathematics to explain physics problems. The learner must be able to manipulate given equations through the given information in each problem. The most important fact in this state is how to transfer information from one field (e.g. Mathematics) to another (e.g. Physics). This may be too difficult according to Reid and Yang (2002). Indeed, this may be yet another example of working memory overload, the pupil not being able to hold the mathematical ideas alongside the physics ideas at the same time. As the mathematical ideas become more established, they will occupy less space and application to physics situations may become increasingly possible.

Students at all levels lack sufficient confidence in the mathematical language used to describe the fundamental laws of physics because it is too difficult to explain and cannot be linked with life's experiences easily (Breiteberger, 1991; Clement *et al*, 1981). Therefore, students may possibly find that applying algebra in solving physics problem (e.g. DC circuits, thermodynamics, and optics) is too difficult (Rebmann and Viennot, 1994). Knight (1995) completed a study involving about 300 university engineering students after mathematics and physics courses in high school and a semester of college calculus explored their understanding of vectors. From the data collected, he concluded that many students (one-third which is a big ratio) were unfamiliar with finding the problems solutiȯns or recognizing vector components.

3.5 Summary

It is clear that studies show consistently that students do have difficulties in learning Physics. There is some consistency in the topics which have proved most troublesome and this chapter has offered some broad interpretations of the difficulties which have been found. Overall, the evidence of the previous studies shows that students develop numerous misconceptions and there may be several reasons for these:

(a) Physics, as a discipline, is often abstract and highly conceptual;

(b) Accepted Physics understandings and experiences from life may seem to be inconsistent;

(c) Physics teaching often involves the descriptive, the sub-microscopic interpretation and the representation of ideas in symbols. Handling all three levels is simply too demanding in terms of information for the novice learner;

(d) Words and ideas are developed in non-physics situations which are inconsistent with the physics use of words.

(e) Learners often have to use mathematical ideas along with physics ideas: this may cause information overload again;

(f) Physics textbooks, in attempts to cover the topics properly, can offer too many ideas too fast or can simplify to the point of loss of inadequate meaning.

(g) Many very complex ideas are taught quite early in most curricula (e.g. forces, electricity). If taught by teachers who are not physicists, wrong ideas may be established which may prove almost impossible to dislodge later.

Ausubel (1968) sums up the most important aspect in learning effectively that teacher must know what is the learners already know then teach them accordingly. This principle could possibly avoid the overloading of working memory space. Building new ideas onto ideas that are well established allows the learner to develop more valid understandings. Almost certainly, the Physics curriculum needs re-structuring and the outcomes form the numerous research studies need to be applied. This requires a bridge to be built between curriculum planners so that the curriculum and this pedagogy can be developed in the light of the well established research evidence.

This research study will seek to investigate difficulties in understanding physics in particular areas that are encountered in Qatar's high school level and to explore, in particular, the visualization aspects of physics learning.

Chapter Four
Difficulties in Physics
Methodology and Results

4.1 Introduction

This chapter describes how the surveys and the tests were carried out in this study, and discusses the data obtained. The methods used will first be outlined. Then, the data obtained will be summarised and discussed. Finally, there is an attempt to draw conclusions to offer insights into the situation in Qatar but also to show patterns which might have wider applicability in the successful learning of physics.

4.2 The Aims

This study seeks to explore the learning of physics with secondary pupils (ages 16-18) in Qatar. There are two main stages:

1. The identification of the main areas of difficulties in the current physics curriculum in Qatar from age 16-18 and the presentation of some insights into the nature of these difficulties and the reason for their existence. This will point, hopefully, to some potential solutions.
2. It seems from many studies that visual-spatial ability relates to performance. This study seeks to explore how visual spatial ability related to physics ideas might be connected to student success in those topics which are causing most difficulty as well as with overall physics performance.

4.3 Methodology of the Research

The methodology of this study is divided into a three main stages:

1. Three surveys were designed to investigate the first aim.
2. Two tests were conducted to explore the difficulties in more detail.
3. Two tests were applied to determine the relationship between the students' visual spatial abilities and achievement in physics.

4.4 Methodology of the First Stage

The data were collected through a survey. This was applied in Qatar using students enrolled in high schools: first, second and third year students (age 16-18). The survey reflected the syllabuses at each level, covering the specific physics topics relevant to that year group

The overall aim of this part of the research is to seek to investigate the topics in physics which are causing most difficulty with 16-18 years old Qatari students from grade 10-12 and to suggest ways by which the situation might be improved.

A survey was prepared for each year of secondary school. The data for the first and second years was gathered at the start of the following year, asking the students to look back while the data for the third year was gathered as late in the third year course as possible.

The surveys covered three main areas of the content of the current physics syllabus (forces, electricity and magnetism). Samples were chosen to reflect typical pupils at each stage: 202 first year students from three high schools, 187 second year students from five schools, and 153 third year students from four schools. The surveys were applied by high school teachers in Qatar. Students were asked to indicate by tick in the appropriate columns (Figure 4.1) headed 'Easy', 'Moderate', 'Difficult' and 'Not studied' how well they understood each topic.

Easy:	**I understand it without difficulties**
Moderate:	**I had difficulties but I understand it now**
Difficult:	**I still do not understand the topic**
Not studied:	**I have never studied this topic or I forget that I studied it before**

Figure 4. 1 The keys of categories.

Written comments were invited if students picked the 'Difficult' column in order to see the course through the eyes of the students.

An enormous amount of information was collected from the students' answers. In order to specify the topics that were considered to be most troublesome for the students, it was decided to select the topics that were more difficult to students (which had percentage of difficulty of 8% and over for the first class, 15% and above for the second class and the third class). The 8% and 15% are arbitrary. They merely give a small numbers of the most difficult topics.

4.5 The Results

The following sections will discuss the results obtained from the Qatari high schools for first, second and third year. Only the more important findings will be described, the results being analyzed using simple statistics and tables, followed by an overview of the outcomes from the tests as a whole, with a discussion of their probable significance. The distributed surveys and results are shown in full in Appendix A.

4.5.1 Result for the First Year

From the data collected, five topics out of thirteen were considered as difficult by the first year students, and these are shown in Table 4.1:

Qatar / First year	
Difficult Topics	**% Difficulty**
4. Fluid Pressure	15.4
5. Pascal's Principle	9.4
6. Archimedes's Principle	12.9
12. Electric Energy	8.4
13. Electric Power	11.4

Table 4.1: Difficult Topic encountered the First Year Students

It seems that matter and its mechanical characteristics, particularly fluid pressure, Pascal's principle, Archimedes's principle, and the electric energy and electric power topics were perceived as difficult by the students. Similar finding were obtained by McGuire and Johnstone (1987) who pointed out that force, energy and current electricity were the most complex topics facing students in Glasgow.

The findings were analyzed related to students' comments about why they had classified some topics as difficult. Table 4.2 shows examples of students written comments on the topics that they specified as difficult, and which, as a result, they still do not understand or even, somewhere, remember studying.

The students tend to blame the teacher or the textbook for many of their problems. However, some of the comments refer to confusion or complication. In addition, the use and application of formulae seems difficult for them. All this is consistent with information overload but the problem may be quite complex.

Qatar / First year	
Difficult Topics	**Typical Written Comment**
4. Fluid Pressure 15.4 %	• Poorly Taught because teachers' major is biology • Difficult concept • Formula can be confusing and applying them to problems was difficult • No good textbook
5. Pascal's Principle 9.4 %	• Not taught well by the teacher • Difficult to understand • Not enough examples to explain the formula • Complicated textbook and formula • The way of teaching
6. Archimedes's Principle 12.9 %	• Complicated formula • Complicated textbook • The way of teaching • Difficult memorizing details
12. Electric Energy 8.4 %	• The teacher could not control the student which cause difficult to understand • Lack of information from textbook
13. Electric Power 11.4 %	• Textbook • The way of teaching • Need more work on it • Remembering formulas

Table 4.2 **First Year Students Written Comments for the Topics Indicated as Difficult**

4.5.2 Results for the Second Year

The topics that are perceived as difficult by the second-year students are shown in Table 4.3. The following topics were noted as difficult in the second year course: mechanics (Newton's laws & stability), gravitational force and its field, electric potential and capacity, dielectric constant, impulse-momentum theorem and conservation of momentum.

Gamble (1989), Osborn (1985), McDermott and Shaffer (1992), and McDermott(1993) all identified Newton's Third Law as most difficult and they carried out studies to explore the misconceptions. Moreover, Lawson and McDermott (1987) mention that the work-energy and impulse-momentum theorems were difficult for students at high school level.

Qatar / second year	
Difficult Topics	**% Difficulty**
5. Inertial mass and gravitation mass	15.5
6.Newton's Third Law	16.0
7.Force of friction	16.6
8. Application on Newton's Laws	22.4
9. Stability	10.7
11. Gravitation force	12.3
13. The gravitation field	16.6
17. Electric potential for spherical conductor	12.3
19. Electric capacity	11.8
20. Dielectric constant	13.4
22. Impulse – momentum Theorem	14
23. Conservation of momentum	15

Table 4.3: Difficult Topic encountered the Second Year Students

Table 4.4 shows examples of student written comments for the topics that they specified as hard.

As before, teachers and textbooks come in for criticism. The students also pinpoint complicated ideas and many sources of confusion. The abstract nature of many ideas was mentioned many times. Again, all this is consistent with information overload, the difficulties in memorisation again suggesting this.

The impulse - momentum theorem was identified as difficult because formulas can be confusing and applying them to problems is very difficult. This finding is similar to the Lawson and McDermott finding in 1987 that students were unable to relate the algebraic formalism to motion, suggesting that the students were lacking in mathematical language.

Qatar / second year	
Difficult Topics	**Typical Written Comment**
5. Inertial mass and gravitation mass 15.5%	• Teaching time was not enough • Hard to understand diagrams • Complicated – Textbook
6.Newton's Third Law 16%	• Too much concept and theory • Complicated diagrams • Solving complicated problems • The way of teaching • Hard to understand- textbook
7.Force of friction 16.6%	• Too many complicated diagrams , theory and problems • Difficult concepts • Complicated –text book • Not taught well by the teacher • Formulas can be confusing • Difficult to remember every thing
8. Application of Newton's Laws 22.4%	• Teaching time was not enough • Too many cases and complicated • Solving complicated problems • Difficulty because of textbook • Too much math
9. Stability 10.7%	• No comments
11. Gravitation force 12.3%	• Poorly taught
13. The Gravitation field 16.6%	• Difficult – Complicated formula • The way of teaching
17. Electric potential for spherical conductor 12.3%	• Confusing with the capacity • Complicated diagrams- textbook • The way of teaching- cannot imagine • Calculation difficult
19. Electric capacity 11.8%	• Not taught well by the teacher • Confusing -Difficult to understand • Lack of information because of textbook
20. Dielectric constant 13.4%	• Difficult diagram • Complicated - difficult to understand and learn • The way of teaching
22. Impulse – momentum Theorem 14%	• Formulas can be confusing and applying them to problems is difficult • Difficult memorizing details
23. Conservation of momentum 15%	• The way of teaching • Complicated problems and formula do not understand • Hard to understand – textbook

Table 4.4 Second Year Students Written Comments for the Topics Indicated as Difficult

4.5.3 Results for the Third Year

The topics that are perceived as difficult by the third year students are shown in Table 4.5.

Qatar Third Class	
The Topic	**%Difficulty**
10. Force between Parallel conductors	13.7
11. Generated Induced Current	15.0
12. Electromotive Force	13.1
13. Motional Electromotive Force	13.1
15. The Electric Dynamo	15.0
16. Self Induction	14.4
17. Multual Induction	15.7
18. Transformer	13.1
19. Alternating E.M.F. & Alternating Current	12.4
20. R.M.S. Value	10.5
21. The R-L-C Series Circuit	17.7
22. Series Resonance	24.2

Table 4.5: Difficult Topic encountered the Third Year Students

From the results obtained, it is clear that students in the third year had trouble understanding electromotive force and its application, along with alternating current and circuits. Current and circuits were identified as difficult in many earlier studies, as mentioned above (for example: Shipston, 1984; Psillos and Koumaras, 1988; Webb, 1992).

Table 4.6 presents a summary of students' written comments on the topics that students in third year selected as hard. Students comments indicate that the topic of Series Resonance, The R-L-C Series Circuit and Generated Induced Current because they are very complicated, too many cases and hard to understand diagrams.

Self Induction and Multual Induction are a cause of confusion because they involved the concept of E.M.F (electro motive force) which is not well explained in the standard text-book. For reasons which are far too complex to go into here an E.M.F is measured in volts, which students have seen previously in connection with batteries and potential differences across resisters. The connection with mechanical forces and E.M.Fs is never explained.

Although Series Resonance is an application of previously mentioned data in the textbook, it is classified as the most difficult topic at this level because it contains complicated problems, formulas, and diagrams.

Qatar / Third year	
Difficult Topics	**Typical Written Comment**
10. Force between Parallel conductors 13.73%	• Hard to understand diagrams • Difficult concept • Not enough examples to explain the formula
11. Generated Induced Current 15.03%	• Too much concept and theory • Hard to remember every thing • Not taught well by the teacher • Hard to understand- textbook and Diagrams
12. Electromotive Force 13.07%	• Difficult concepts • Complicated –Text book • Need to revise • Formulas can be confusing
13. Motional Electromotive Force 13.07%	• Too many cases and complicated • Solving complicated problems • Difficulty because of textbook • Need more time • Too much math
15. The Electric Dynamo 15.03%	• Hard to understand diagrams • Difficult to remember every thing • Complicated- Difficult to understand &learn • Difficult memorizing details • Too many parts and different diagrams Confusing
16. Self Induction 14.38%	• Confusing with Multual Induction • Hard to understand – textbook
17. Multual Induction 15.69%	• Difficult – Complicated formula • Not taught well by the teacher • Complicated- Difficult to understand & learn
18. Transformer 13.07%	• Confusing formula • The way of teaching • Difficult to learn Efficiency of a Transformer
19. Alternating E.M.F. & Alternating Current 12.42%	• Not taught well by the teacher • confusing E.M.F with voltage • Confusing text-book -Difficult to understand
20. R.M.S. Value 10.46%	• Difficult diagram • No good textbook • Formulas can be confusing and applying them to problems is difficult • The way of teaching
21. The R-L-C Series Circuit 17.65%	• Difficult memorizing details • Complicated- Difficult to understand and learn • The way of teaching • Too many cases and complicated
22. Series Resonance 24.18%	• Complicated problems and formula do not understand • Teaching time was not enough • Complicated diagrams

Table 4.6 Third Year Students Written Comments for the Topics Indicated as Difficult

In brief, this study highlights some of difficult topics in physics, as perceived by Qatari high schools students. The aim of this study is to identify the topics of physics that encountered as difficult by students. The major areas that cause problems are lack of previous knowledge, understanding diagrams, teaching time, textbooks, and mathematics skills.

4.6 Methodology of the second stage

The second stage aimed to explore students' misconceptions and misunderstandings in particular topics. The topics were chosen from the results obtained from first stage for first year high school (16 years old) and second year high school (17 years old) students. The topics for first year students were related to matter and its mechanical characteristics (Fluid Pressure, Pascal's Principle, and Density). Because the survey was conducted on students who had studied the topics last year but the exams were conducted on other students who had studied the topics this year, this led to some topics not being examined (e.g. electrical energy and electric power) because the students had not yet studied them at this stage of the enquiry.

In the second year results, twelve topics were identified as difficult topics at the first stage of the result but half of them have not been studied at the time of this study. Thus topics in mechanics and dynamics were chosen: linear motion and Newton's laws of motion (Newton's third Law, application of Newton's laws and force of friction).

The tests were applied at the middle of the year with first and second year high school Qatari students by high school teachers in Qatar. The students' selected answers in the tests providing information about conceptual difficulties. The types of questions were new to the students in both groups. Despite the students being informed by the teachers and the questions that there may be more than one correct answer, many of them gave only one correct answer.

4.6.1 First year result

The first test was given to 242 first year students in three high schools. The structural communication grid, open-ended questions (short answers), and multiple choice questions were used in an attempt to check how well the student grasped the previous topics.

Question 1

Question 1 was about density. In this question students should understand that the substances with larger density will sink in the substances that have smaller density and vice versa.

(1) Below are some substances and their densities.

	Substance			Density	
No.	Solid	liquid	Gas	Kg/ m^3	gm/c m^3
A	Gold			19 000	19
B		Mercury		14 000	14
C	Lead			11 000	11
D	Iron			8 000	8
E		Water		1 000	1
F	Ice			920	0.9
G		Petrol		800	0.8
H			Air	1.3	0.0013

Select the substances to answer the following questions.
Substances may be used as many times as you wish.
Use the letter to show your answers. (You can use this formula $\rho = m / v$)
There may be ***one or more*** *answers to each question*

Referring to the above table, which of those substances will?

(a) Sink in water ....

(b) Float on water. ....

(c) Sink in mercury. ....

(d) Float on mercury. ....

Figure 4.2 Question 1 (a, b, c, and d)

For such a straightforward question, it is surprising that so few managed all four answers (A, B, C and D) (Table 4.7). The majority of the pupils selected A (Gold) and some managed to select Lead and Iron. Very few selected mercury. It is likely that the poor answers reflect a lack of experimental experience; had they ever seen mercury in a laboratory situation? 11% chose one or more wrong answers along with the right answers.

Table 4.7		1(a) Which will sink in water			N= 242
	Number	%		Number	%
One correct	112	46	A only	61	25
Two correct	38	16	A, D only	33	14
Three correct	28	12	A,C, D only	28	12
four correct	10	4			
Correct +wrong answer(s)	26	11			
Wrong answer(s)	10	4			
No answers	18	7			

In part (b) (the answers were F, G and H), as in the previously results, most students (56%) responded with only one correct answer. Nearly 60% of them chose F (Ice). Just 7% gave all three right answers. It seems that students experienced ice with water in their life and they knew it would float. Also, they may have experienced that oil might float on water but they had difficulty to imagine the air with water. The results are shown in Table 4.8.

Table 4.8		1(b) Which will float in water			N= 242
	Number	%		Number	%
One correct	136	56	F only	82	34
Two correct	27	11	F,G only	17	7
Three correct	18	7			
Correct +wrong answer(s)	34	14			
Wrong answer(s)	43	18			
No answers	10	4			

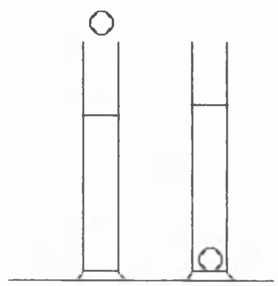
In part c, there is only one correct answer that A (Gold). More than half (67%) of the students picked the incorrect answers, only 36% selected the correct answers (Table 4.9). The most popular incorrect answers were lead and iron. It may be students understood lead and iron to be heavy so they might sink but they did not consider the mercury.

Table 4. 9	1(c) Which will sink in mercury	N=242
	Number	%
Correct answer	87	36
Wrong answer(s)	163	67
Correct answer+ wrong answer	22	9
No answers	12	6

Table 4.10 shows the result of question d. The correct answers are C, D, E, F, G and H. Only 8 of the students gave all correct answers; 155out of 242 gave one acceptable answer, which in 82 of cases was H (air).

Table 4.10	1(d) Which will float in mercury			N= 242	
	Number	%		Number	%
One correct	155		Wrong answer(s)	18	
Two correct	20		No answers	15	
Three correct	3		Most common correct answer (H)	82	
Four correct	1		Most common wrong answer (A)	36	
Five correct	3				
Six correct	8				
Correct +wrong answer(s)	19				

Look at the diagram below.



A ball of gold (mass 5g) is dropped into a cylinder of water and the water level rises.

Suppose the experiment was repeated using a 5g ball of lead instead.

If the experiment is repeated using a lead ball instead of a gold ball, to what height will the water in the cylinder rise when the lead ball is dropped?Tick one box

☐ 1. The same as with the gold

☐ 2. Higher than with the gold

☐ 3. Lower than with the gold

Figure 4.3 Question 1. Part e

Figure 4.3 shows the part e in question 1, which there was a diagram showing an experiment of dropping two balls into different liquids and the student have to find out the solution by choosing it from the multiple choice question.

To answer this question correctly students should know the relationships between mass, volume and density. In another words the students must understand that if the mass is constant and the density was raised the volume should be decreased.

The answer of this question is number 2. As can be seen from the Table 4.11, surprisingly, although the formula and values of density were given in the question, only one third of students selected the correct answer and 46% of the total indicated wrong answer number 3 (lower than with gold) this answer may have been chosen because they thought gold's density larger than lead so it is heavier than lead, therefore, the water has to be higher in the case of gold ball but they forgot that they have same mass 5 g.

Table 4.11	**To what height will the water in the cylinder rise when the lead ball is dropped?**	**N=242**
	Number	**%**
Correct answer	36	15
Wrong answer(s)	199	48
Wrong answer(3)	111	46
No answers	6	2

Overall, it is noted from the result that the students did not really understand the concepts of density and mass. Students only answered correctly what they had experienced. They did not recognize that the substances that have the larger density will sink in the less dense liquids and float on the higher density liquids. There was another misunderstanding that appeared. Students did not understand the relationships between the mass volume and density (***$\rho = m / v$***). For example, when the mass is constant, if the density increases the volume will decrease and vice versa. In other words, even though the formula was given in the question and they did not have to remember it, they did not understand the inverse relationship between density and volume. McKinnon and Geol (1971) found from their study that students even among university level had difficulties with concept of density.

Question 2

Students' understanding of the characteristics of matter was investigated in two sub-questions (a and b) in question 2 as can be seen from the Figure 4.4. In part (a), students were asked to draw the liquid state of matter. The answer is illustrated in Figure 4.5.

(3) If Figure 1 represents a **solid** state and figure 3 represents a **gas** state:

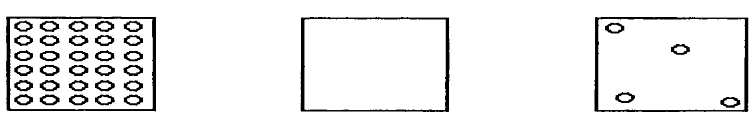


Figure 1 Figure 2 Figure 3

a) Draw what a liquid might look like in figure 2.

b) If the substance in figure 3 is cooled down, its molecules move at a speed which is....................

Figure 4.4 Question No. 2 (a and b)

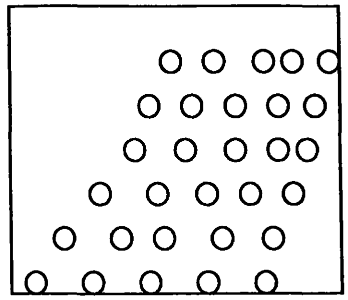


Figure 4.5 The answer of question 2 (a)

There is a possible misunderstanding in this question in that the question did not specify that the pictures have intended to show the 'side view' of the containers; in a side – view the distinguishing feature of a liquid is that it has a surface. In fact, according to the Table 4.12, only 5% of all students (11 out of 242) answered correctly. This is small proportion compared with those who drew an incorrect diagram (93%).

Table 4.12	Question(2)			N=242
	A		B	
	Number	%	Number	%
Correct answer	11	5	122	50
Wrong answer(s)	226	93	108	44
No answers	5	2	11	4

It seems that the students did not have a clear notion of the characteristics of the matter at a molecular level. They did not appreciate that the liquid state has almost the same amount of molecules as solid state but a non-definite shape (because the liquid take the shape of the container, without total ordering of the molecules) while all students who drew incorrect answers had drawn a similar shape that in Figure 4.6. This shape may correct if we talking about liquid in general not in particular situation.

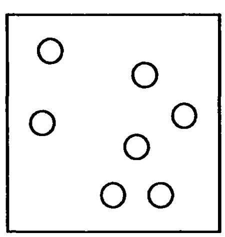


Figure 4.6. The most answer that was indicated by first year students in question 2 (a)

In part (b) of the question 2 (see Figure 4.4), half of the participant wrote the correct answer which is less, slower or the like. However, 45% wrote incorrect answers, most of those choosing to write more or increase. Almost half of the students did not know the relationship between the temperature and molecules' speed, although this concept is taken in primary level from grade 3. However there is might another basis that they maybe did not recognize the word <u>cooled down</u>, they may be thought <u>*if heated up*</u> (see Table 4.12).

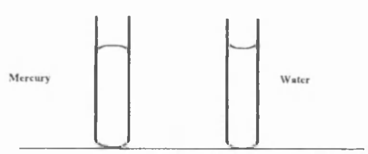
Question 3

Table 4.13	(3) Why a stiletto heel is more likely to mark the floor than an elephant foot.				N=242
	Number	%		Number	%
Correct answer	83	34	Half correct answer	27	11
Wrong answer(s)	100	41			
No answers	32	13			

Table 4.13 shows that 34% wrote two reasons and 11% wrote one reason. The expected reasons were that the elephant exerts a larger force (because it is heavier) but the girl's heel exerts a larger pressure (because of its smaller area) so her heel would sink farther into the ground. On the other hand, more than 40% wrote incorrect answers, most of them relating the reason to the weight alone. It seems that the majority of students had confusion between the concepts of weight, force and pressure.

Question 4

(4) a) Here are two pictures showing two glass tubes the first one contains mercury and the other one contains water.



b) Explain, *in two sentences,* why the surface takes a different shape in each tube.

....

....

....

Figure 4.7 Question No. 4

The expected right answer is along the lines of: the shape of the surface comes about because the adhesion (the force between water and glass molecules) is greater than the cohesion (the force between water molecules) at the surface and vice versa in mercury.

From the results in Table 4.14, 59% answered wrongly. They knew there are two forces and they wrote the expression correctly but they were confused between the two substances. Nonetheless, they had not indicated Surface Tension as difficult in the survey.

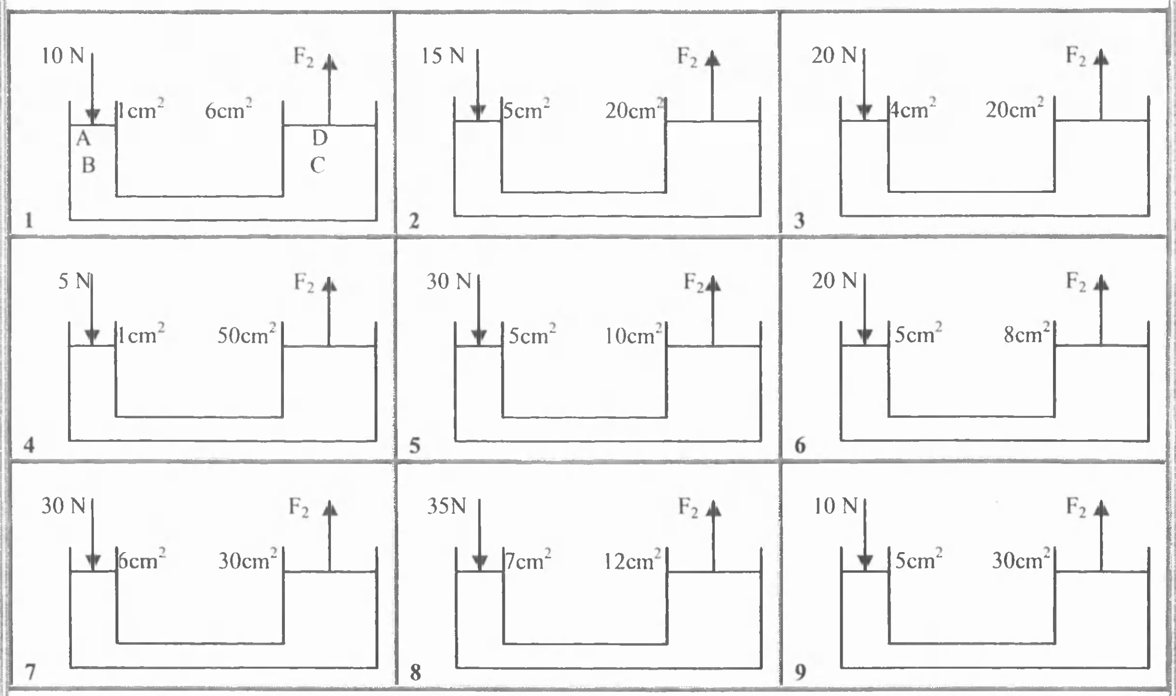
They may simply have memorised ideas and not appreciated that they did not understand the phenomenon.

Table 4.14	(4) why the surface takes a different shape in each tube.				N=242
	Number	**%**		**Number**	**%**
Correct answer	59	24	Half correct answer	21	8
Wrong answer(s)	143	59			
No answers	19	7			

Question 5

Question 5 is a structural communication grid related to Pascal's Principle in which the pressure is transmitted from one piston to the other and the pressure is the same at both ends; this question is divided into five sub-questions, a, b, c, d and e (Figure 4.8).

(5) In the grid below, there are 9 Hydraulic disc brakes. In each box, the force and pistons' areas are shown.



Select the box(es) to answer the following questions. Boxes may be used as many times as you wish. Use the box numbers to show your answers.(You can use this formula $F_1/A_1 = F_2/A_2$*).*

(a) In which box(es) does F_2 have the same value as that in box 1 ? ....

(b) In which box(es) does F_2 have the largest value? ....

(c) In which box(es) does F_2 have the smallest value ? ....

(d) In which box(es) does the pressure of the left hand side have the same value as box 3 ? ....

(e) Look at box 1 where is the pressure greatest?*(Tick one box)*

☐ A	☐ D	☐ A&D	☐ B&C	☐ B,C&D	☐ A, B, C&D
1	2	3	4	5	6

Figure. 4.8 Question No. 5

In part a, the question asked the students to indicate the box(es) where F_2 has the same value as that in box 1. Only 15% of students correctly identified all of the boxes, which are 2, 5, 8 and 9. 75 out of 242 chose answer number 9: when referring to Figure 4.7, it can be seen that the force on the right hand side in box 9 has the same value as that in box 1, so they perhaps chose this answer for that reason and not because they understood it. This evidence emerged because the students who answered this question correctly did not also correctly answer the second question, which carried a similar idea. However, it is evident from Table 4.15 that students had difficulty in understanding Pascal's Principle, particularly at identifying the force, even though the equation was offered in the question along with the values of the areas, and at the same time, it also provided another force. Table 4.15 shows the pattern of student responses.

Table 4.15	**5(a) In which box(es) does F_2 have the same value as that in box 1 ?**	
N=242	**Number**	%
One correct	30	12
Two correct	4	2
Three correct	7	3
four correct	37	15
Correct +wrong answer(s)	10	4
Wrong answer(s)	74	30
No answers	46	19

In question 5 (b), students were asked to select the box(es) in which F_2 has the largest value: the correct answer is 4. Only 44% correctly identified the answer: it was no surprise to obtain the previous result because those who answered this question correctly did not correctly answer the first question. On the other hand, the number of students who answered incorrectly is still high at 92 out of 242 students. Table 4.16 presents the pattern of student answers.

Table 4.16	**5(b) In which box(es) does F_2 have the largest value?**	N=242
	Number	**%**
Correct answer	107	44
Wrong answer(s)	92	38
Correct answer+ wrong answer	4	1
No answers	39	16

As can be seen in Table 4.17, in question 5(c), only one-third of participants were able to pick the smallest F_2 (box 6) from the diagram shown in Figure 4.7, while a similar proportion indicated the wrong answer, which was box number 1. It seems that they chose these two boxes because they had the smallest areas.

Table 4. 17	5(c) In which box(es) does F_2 have the smallest value ?	N=242
	Number	**%**
Correct answer	73	30
Wrong answer(s)	126	52
Correct answer+ wrong answer	2	1
No answers	41	17

In part d, students were asked to indicate the box(es) in which the pressure on the left-hand side has the same value as box 3. Disappointingly, from the 16 students who were able to give the correct answers, only 1 student gave all of the correct answers, which were 4, 7 and 8. However, 65% selected wrong answers. Table 4.18 shows the pattern of student responses. From this result, we identified that 83 students selected the wrong answer 6, which they possibly chose because the value of F_1 is the same as F_1 in box 3. There is thus evidence that students have misconceptions about pressure and force.

Table 4.18	5(d) In which box(es) does the pressure of the left hand side have the same value as box 3 ?	N= 242
	Number	**%**
One correct	13	5
Two correct	2	1
Three correct	1	0.5
Correct +wrong answer(s)	2	1
Wrong answer(s)	158	65
No answers	58	24

A similar level of confusion emerged in question 5(e) (Figure 4.8). The students were asked to choose the box that shows the greatest pressure. From the students' responses (Table 4.19), it can be seen that the students had difficulty with Pascal's Principle and the pressure inside liquids. The majority of those who answered incorrectly chose box 3, in which the answer is A & D. From this result, we could conclude that the students did not understand Fluid Pressure. In addition, the students did not recognize that the pressure may increase with depth because they chose A & B not C & D. However, students should have chosen A, B, C & D because the pressure will be transmitted from one piston to the other, so the pressure is the same at both ends and at every point.

Overall, in looking in the results of question 5 and 3, it can be concluded that students have serious difficulty in understanding Fluid Pressure and Pascal's Principle and are confused between pressure and force.

Table 4.19	5(e) Look at box 1 where is the pressure greatest?				N=242
	Number	%		Number	%
Correct answer	34	14	Box number 3	58	24
Wrong answer(s)	172	70			
No answers	37	15			

This evidence comes from the high percentage of non answered questions which were between 15% and 24%. Looking at the students' answer sheets, it is clear that most students who tried to use the formula gave correct answers. However, on average more than 45% of students could not apply Pascal's Principle although the formula was given to them in the question.

In brief, the results suggested that students did not really understand the basic concepts in first year physics such as Density, Surface Tension and Fluid's Pressure although they have been taught these topics on several occasion.

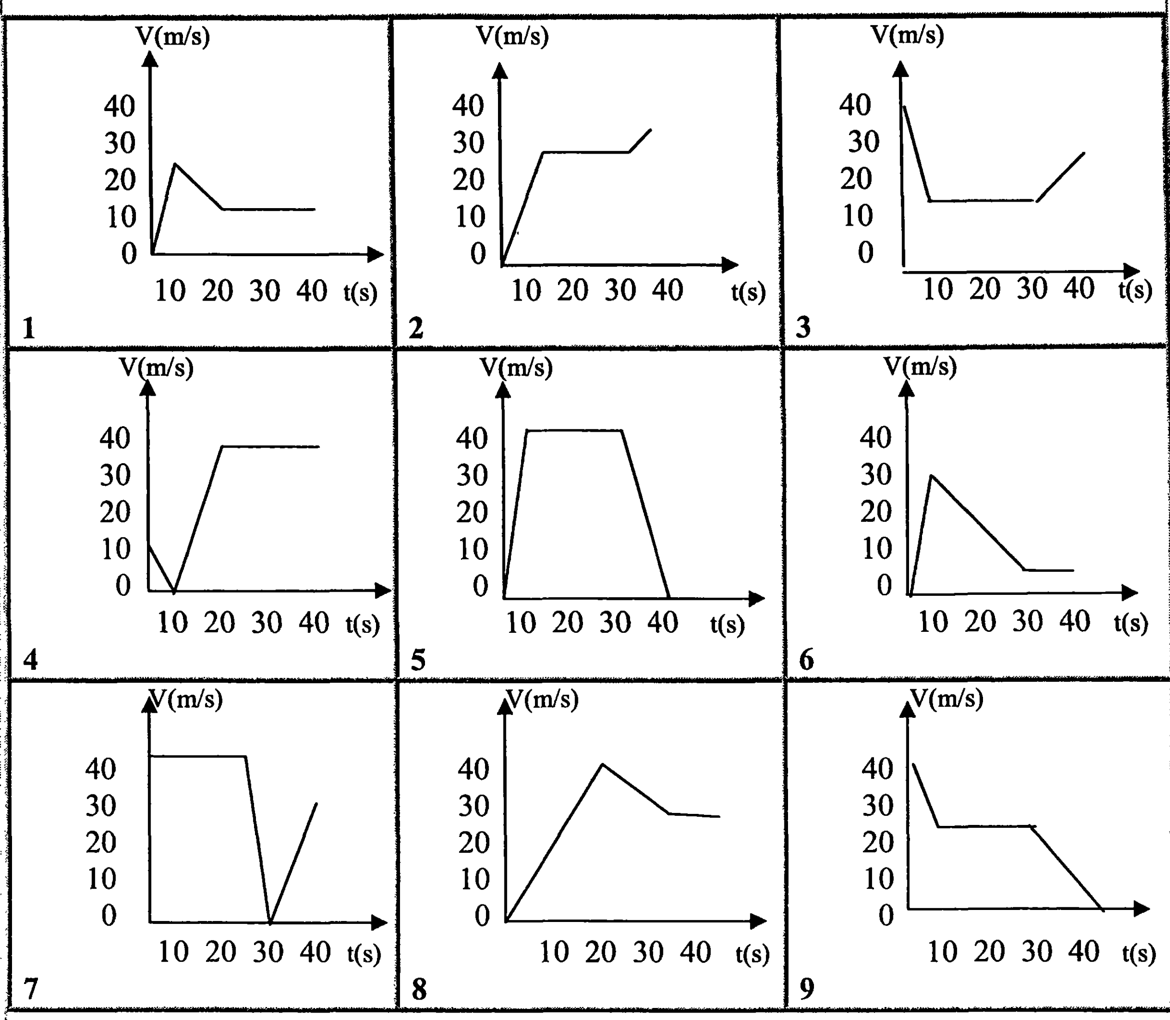
4.6.2 Second year results

The second test was conducted using 153 students of second year in five high schools. The structural communication grid (Q1 and Q 2), and open-ended questions (Q3) (short answers) were applied in an attempt to check how well the students understand some topics which were identified as difficult (see Table 4.3).

Question 1

Question 1 (Figure 4.9) was linked to linear motion. It attempted to investigate how well the students cope with the concept of velocity (increase, decrease, constant and stop) and with reading velocity-time graphs. There were four sub-questions a, b, c and d and the results of each are discussed in turn.

(1) Below are nine box(es). In each of them, there is graph representing a car motion:



Select the box(es) to answer the following questions.
Boxes may be used as many times as you wish.
Use the box numbers to show your answers.

(a) In which box(es) the car does not stop at the end of motion? ....

(b) At 20 second, which box(es) show the car travelling fastest? ....

(c) Which box(es) represent the motion of a car in where there is an increase in velocity, followed by decrease, followed by constant velocity? ....

(d) In which box(es) does the driver never use the brake? ....

Figure 4.9 Question 1 (a, b, c and d)

Table 4.20	**1(a). In which box(es) does the car not stop at the end of motion?**	**N= 154**
	Number	**%**
One correct	22	15
Two correct	7	5
Three correct	27	18
Four correct	8	5
Five correct	10	6
Six correct	8	5
All correct	46	30
Correct +wrong answer(s)	16	10
Wrong answer(s)	8	5
No answers	2	1

In part (a), 84% of students chose one or more correct answers, but only 46 of them gave all of the correct answers, which are 1, 2, 3, 4, 6, 7, 8 (Table 4.20). Most of them knew that the car will stop when the velocity equals zero. The problem here may be that they were confused by some graphs in which the velocity became zero before the end of the motion.

Table 4.21	1(b) At 20 second, which box(es) show the car travelling fastest?	
N=154	Number	%
One correct	55	36
Two correct	20	13
Three correct	27	17
four correct	16	10
Correct +wrong answer(s)	25	16
Wrong answer(s)	7	4
No answers	4	2

In part (b), the answers are in boxes number 4, 5, 7 and 8. Students should know when the velocity is the largest at 20 sec in this question. As can be seen from Table 4.21, more than one-third of all students indicated one correct answer. Only a few students selected four answers correctly. The majority of the students selected boxes numbers 8 and 7, just a small number choosing box number 4. Perhaps box number 4 was not chosen because the students misread the graph at 20 sec.

Table 4.22	1(c)) Which box(es) represent the motion of a car in where there is an increase in velocity, followed by decrease, followed by constant velocity?	N= 154
	Number	%
One correct	37	24
Two correct	19	12
Three correct	67	44
Correct +wrong answer(s)	17	11
Wrong answer(s)	13	8
No answers	1	1

In part (c), the correct answers are 1, 6 and 8. To answer this question correctly students should understand the velocity-time graph and know how the velocity is changing with time. According to Table 4.22, which illustrates the students' responses, although 44% answered correctly, there is a similar percentage who omitted one or more correct answers. This result suggests that most students understand the relationship between velocity and time but they may need to concentrate more on the questions because the graphs were very obvious and clear.

Table 4. 23	1(d) In which box(es) does the driver never use brake?	N=154
	Number	**%**
Correct answer	48	31
Wrong answer(s)	72	47
Correct answer+ wrong answer	24	16
No answers	10	6

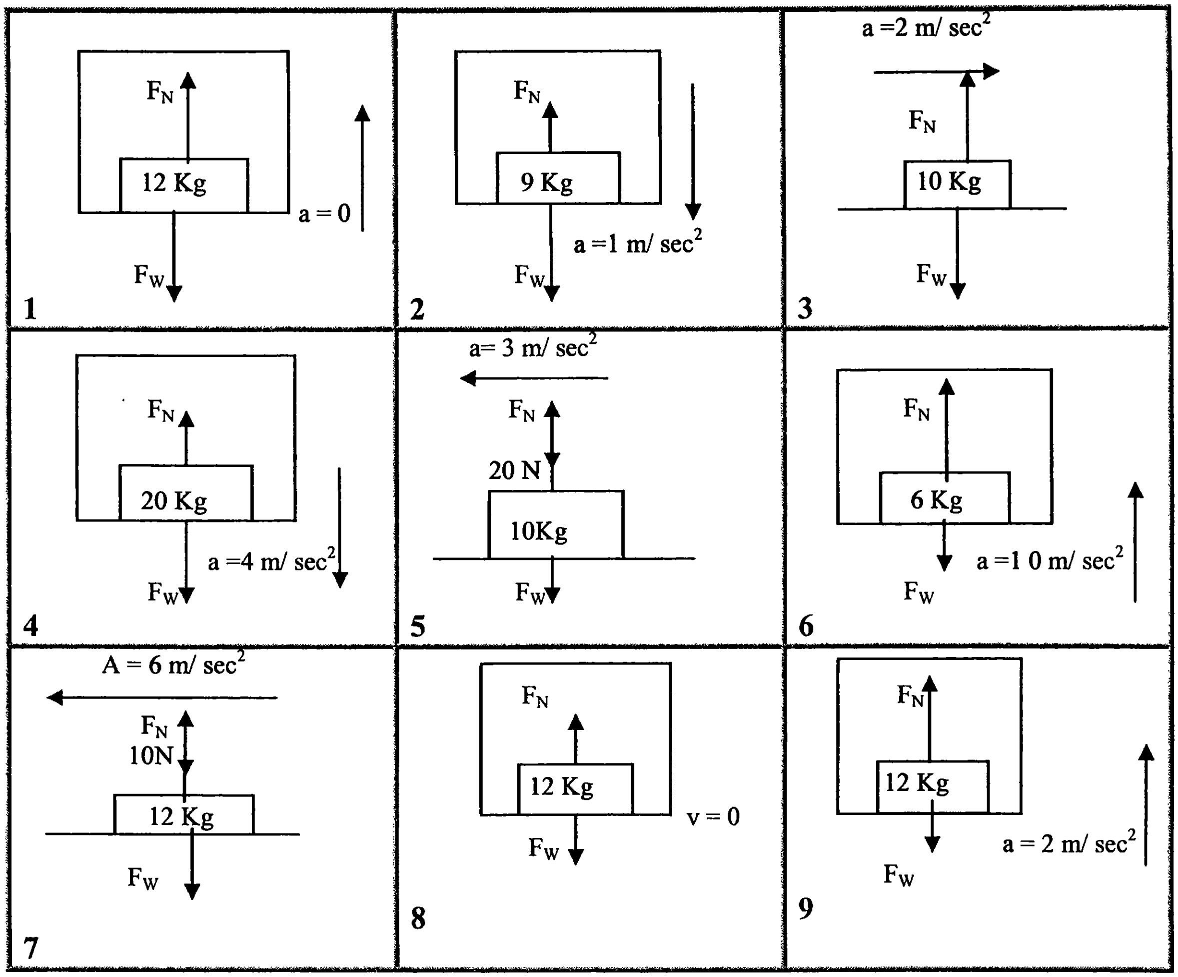
In part (d), most students selected the wrong boxes (nearly 72%), and 16% chose both correct (box 2) and incorrect answers. There is only one correct answer: 2. On the other hand, only one third of all selected the correct answer. The most common wrong answers indicated were 3, 4 and 7. The result is shown in Table 4.23.

Previous work suggested that interpreting graphs was not easy (Brasell, 1987; McDermott *et al*, 1987) and the results here would support this. Students do seem to be confused by velocity-time graphs and lack of understanding of velocity, especially when the velocity is changing. They may understand that the car will stop when the velocity equals zero. However, it is possible that some students did not perform well because this type of question was not familiar to them.

Question 2

In question 2, a structural communication grid question was used to explore students' understanding of Newton's Laws, especially the second and third laws, and the Force of Friction.

(2) Here are 9 pictures showing different objects moving (inside lift or above flat surfaces). In each motion, the mass, acceleration, some of the forces and the direction of movement are shown.



Select the box(es) to answer the following questions.
Boxes may be used as many times as you wish.
Use the box numbers to show your answers.

- F = mass * its acceleration
- F in opposite directions = big force – small force
- Acceleration due to gravity g = 10 m/s^2

a) In which box(es) is the object moving with constant vertical velocity? ....
b) In which box(es) is $F_N = F_w$?
....
c) In which box(es) does F_N have the same value as it has in box 1?
....
d) In which box(es) is the object acted upon by a force of friction. ....
e) For each answer to question 4, mark the direction of the force of friction on the pictures.

Figure 4.10 Question 2 (a, b, c, d and e)

This question (Figure 4.10) was divided into five sub-questions, a, b, c, d, and e, and the results from each are discussed in turn.

Table 4. 24	2(a) In which box(es) is the object moving with constant vertical velocity?	N=154
	Number	**%**
Correct answer	78	51
Wrong answer(s)	26	17
Correct answer+ wrong answer	43	28
No answers	7	5

In question 2(a), the answers is 1. (Table 4.24) it can be seen that the majority of students (approximately 50 %) indicated the correct box (78 students). This result shows that half of the students understand that the acceleration equalling zero when the velocity equals zero.

Table 4.25	2(b) In which box(es) is $F_N = F_w$	N= 154
	Number	**%**
One correct	99	64
Two correct	26	17
Three correct	3	2
Correct +wrong answer(s)	11	7
Wrong answer(s)	7	5
No answers	8	5

In part b, boxes 1, 3 and 8 were the answers. Surprisingly, only 2% of all students indicated the three boxes correctly. However, the majority of students chose only one correct answer, which was number 8 (102). There were a small number of students who selected box 3 (14 out of 154). The reason for these results might be that box 8 has a similar state to box 1. On the other hand, a small number of students selected box 3 perhaps because the object has a different direction of motion (see Figure. 4.10).

Table 4.26	2(c) which box(es) does F_N have the same value as it has in box 1?	
N=154	**Number**	**%**
One correct	61	40
Two correct	2	1
Three correct	0	0
four correct	0	0
Correct +wrong answer(s)	35	23
Wrong answer(s)	40	26
No answers	16	10

To answer part (c), students must apply Newton's second law to find the value of the force (Table 4.26). The correct answers are 4, 5, 6, and 8. This question may be categorized as leading the student to make an incorrect selection because no one provided the complete answer correctly. In looking at the pattern of choices, it has to be noted that 74 students selected box 8, 49 students selected box 9 and 23 students chose the box 7. As can be seen from Figure 4.10, the mass in these all boxes are the same as the mass in box 1, so they might be chose these boxes according to the mass, and they ignored the other forces, acceleration, and the way of motions.

Table 4.27	2(d) In which box(es) is the object acted upon by a force of friction.	N= 154
	Number	**%**
One correct	23	15
Two correct	31	20
Three correct	54	35
Correct +wrong answer(s)	11	7
Wrong answer(s)	16	10
No answers	19	12

In part (d) (Figure 4.10), 35 % could indicate the correct boxes which are 3, 5 and 7. By using their answers, it would be extremely simple to note that there were a large number of students who indicated one or more correct answers. This may suggest that many students knew that any object will meet the force of friction when it moves in horizontal way. On the other hand, nearly one third of students could not give the right answers. This might be because the students did not understand the question or they may use to connect between the rough surfaces and the force of friction because many of them asked: where the rough surface is. All results are shown in Table 4.27.

Table 4.28	2(e) mark the direction of the force of friction on the Pictures	N= 154
	Number	**%**
One correct	7	5
Two correct	8	5
Three correct	45	29
Correct +wrong answer(s)	3	2
Wrong answer(s)	11	7
No answers	80	52

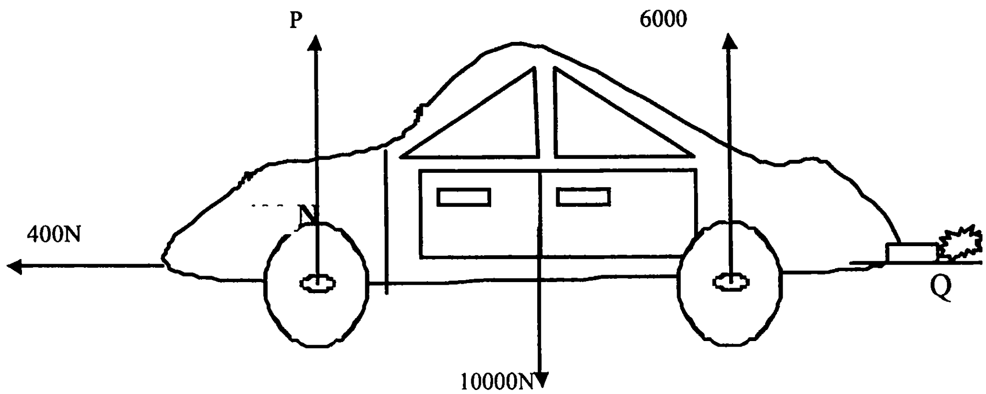
Students in part (e) were asked to mark the direction of the force of friction on the pictures for each answer to question d. Comparing their results for questions d and e (Table 4.27 and Table 4.28 respectively), it was obvious that all those who answered question d correctly could also mark the direction of the force of friction.

In addition, there were 9 students unable to do it successfully. And over half students could not offer any answer. However, from the results acquired the number of students who indicated the right answers from question d less than in question e. For example, 104 students were be familiar with indicating the force of friction upon the object placed in box 7, but only 58 of them could act this force acceptably.

From the results, it appears that students in second grade have problems connecting force with motion. Similar findings emerged from Helm (1980) and Maddox (1978). Furthermore, it is clear that there are misunderstandings of Newton's Laws, and confusion between the mass of an object and its weight. This finding resembled what many researches have found previously (see chapter three). In many cases, it is obvious that students suffered from the lack of mathematical conceptions, since they were unable to apply the formula even though the two formulas were given in the question (only a small portion could apply these formulas correctly). They have also misconceptions regarding case of zero velocity; about concept of the free body diagram (see the result of question 2(a). McDermott *et al* (1987) studied student difficulties in connecting graphs and physics. She investigated students' difficulties in connecting graphs to physical concepts and in connecting graphs to the real world. In addition according to Table 4.25 and 4.26, the lack of understanding of frictional force is noticeable from the results particularly where the force of friction is acting on moving objects. Paulo and Adriano (2005) and Caravalho and Sousa (2005) found similar results.

Question 3

(3)



A front-wheel drive car is traveling at constant velocity. The forces acting on the car are shown in the diagram above. Q is the force of the air on the moving car. P is the total upward force on both front wheels.

(a) Explain why: (i) P= 4000 N

(ii) Q= 400 N

....

....

....

....

(b) If the acceleration due to gravity = 10 m/s^2 calculate the mass of the car.

....

....

....

(c) If the driver starts to brake the car describe what happens to the acceleration?

....

....

....

Figure 4.11 Question 3

Question 3 (Figure 4.11) is about stability and acceleration. It was open-ended questions in which students were asked to give a short answer explaining some phenomena. In this question students should understand that if the object is influenced by many forces, it only could move at constant velocity when the resultant of forces equals zero. In addition, students have to know how to calculate the resultant of forces.

Table 4.29	3(a) Explain why: (i) P= 4000 N (ii) Q= 400 N				N=154
	Number	%		Number	%
Correct answer	15	10	Half correct answer	18	11
Wrong answer(s)	38	25			
No answers	83	54			

In part a (Figure11) the reason for both (i) and (ii) is essentially the same: the underlying reason is net constant velocity implies no net resultant force. Students were required to produce an explanation of why the force named P equal 4000 N and the force named Q equal 400N. The answer of this question is: because the car moves at constant velocity so the resultants of forces should be equal zero. As can be seen from the Tables 4.29 most students chose not answering the questions a few were able to give a completely correct answers, and a small portion gave only one reason. Moreover, those who answered correctly did not provide a good explanation. For example, many of the students simply mentioned the word 'stability' without further explanation.

In part b, students were asked to calculate the mass of the car (Figure 4.11). In this question students have to apply the equation of weight (F= mg) to calculate the mass. In this case students have to know the relationship between the parameters to calculate the mass. As can be seen in the Table 4.30, over 40% did not answer the question and 27% answered incorrectly. Only a small portion (21%) could answer correctly and 17% could write the formula or gave the correct answer with the wrong formula.

Table 4.30	3(b) If the acceleration due to gravity = 10 m/s2 calculate the mass of the car.				N=154
	Number	%		Number	%
Correct answer	33	21	Half correct answer	17	11
Wrong answer(s)	41	27			
No answers	63	41			

In part (c) (Figure 4.11), students were asked to give an explanation of what happens to the acceleration if the driver starts to brake the car. In this question, students should understand that braking means negative acceleration and reduced velocity. As can be seen in Table 4.31, only one-third of the students could answer correctly and the others gave wrong explanations or left the question without any answer.

Table 4.31	3(c) If the driver starts to brake the car, describe what happens to the acceleration?	N=242
	Number	**%**
Correct answer	54	35
Wrong answer(s)	55	36
No answers	45	29

It is obvious that the second year students did not understand the meaning of stability or how to deal with a simple diagram showing this idea. It is easy to distinguish that they were unable to calculate the mass of the car although, its weight and acceleration due to gravity were given in the question and this formula has been taught from primary level. In addition, many students do not understand that acceleration equals zero when the object is moving at constant velocity, and students fail to visualize acceleration as the ratio $\Delta v/\Delta t$, because only one-third of them understand that when the car is braked, the velocity declines, so the acceleration will decrease as well. The previous results are similar to those of McDermott and Trowbridge (1981).

Overall, the high school students not only have difficulties related to misunderstanding algebraic relations in physics equations, but also have difficulties communicating with diagrams. A parallel result was attained by Johnson (2001a).

It could be suggested that teaching in a simple way without unnecessary information or complicated equations may help the students to achieve more, and to understand and apply formulas to solve such problems. In addition, students have to learn the basic ideas for solving any problem at the beginning of the year. The redundant and random data overload students' working space memory limited capacity. Simple graphs and visual pictures may help them to reduce overloading working space memory space. Teachers should keep the content of information at a minimum and within the capacity of students (Johnstone, 1993).

An attempt to investigate the visual spatial ability in relation achievement in physics will be argued next chapter.

Chapter Five

Visual-spatial

Methodology and Results

5.1 Introduction

This chapter discuses the second part of the methodology used in this study. In this, the results from the visual-spatial test are discussed and their relationship to performance in Physics is explored. Performance in Physics is assessed by a test devised to test Physics understanding as well as by the marks the students gained in their schools in the first semester of the year 2004-2005. A description is given of how the statistics were collected, analyzed and presented. Correlations between working memory space, performance in physics tests, and visual spatial ability are discussed.

5.2 The Aim of the second part of research

Many ideas in Physics can be understood in terms of diagrams, models and representations. These may be physical or mental models. The aim was to try to measure the influence of visual-spatial ability on students' success in some topics which were causing most difficulty and compare it with their marks in physics examinations to find the kind of correlation between visual spatial ability and achievements in physics (both in terms of recall and understanding).

5.3 Methodology of the second stage

This stage is divided into three main parts:

1. Measurement of visual-spatial ability.
2. Measurement of working memory space.
3. Analysis of the influence of visual spatial ability on achievement in physics and having working memory space.

5.4 The Results

The results obtained from the Qatari high schools for first and second years will be discussed. A huge amount of information was collected from the students' answers. For clarity, only the more important findings will be described in detail: the results will be analyzed using simple figures and tables, followed by a summary of the outcomes from the tests as a whole, with a discussion of their probable importance. The tests are shown in full in Appendix B.

5.4.1 The Result of the Visual-Spatial Test

To explore the visual-spatial ability of the students, an individual paper-and-pencil test was designed for the first and second years of Qatari high school to measure the visual-spatial ability in the context of physics. However, the test was applied at the same time with the difficulties tests and using the same participants. This was done so that the participants should be the same in the two exams in order to compare their results, this approach minimizing any disruption to the school schedule. The test took about 20 minutes. It consisted of nine questions in which the easy tasks come first and more difficult ones come later. The test was the same in both years, and applied as a part of difficulties tests so the orders of questions were different in the two years (the first year began with question number 6, whereas the second year began with question number 4). The test contains four elements: visual memory, block rotation, mental animation and perspective.

In following questions (6, 7, 8 and 9 in the first year and 4, 5, 6 and 7 in the second year) students were asked to solve mechanical reasoning problems that involved inferring the motion of workings of a mechanical system from a static diagram. Three different kinds of mechanical reasoning problems were identified: Complex Animation (Figure 5.1), Linear Animation (Figure 5.2 and Figure 5.3), and Three-dimensional Animation (Figure5.4). The questions illustrated in Figures 5.1, 5.3 and 5.5 were taken from Hegarty and Kozhevnikov (1999).

Hegarty and Kozhevnikov (1999) carried out a study to examine a student's mental animation using a wider selection of mechanical systems. They concluded from their study that the ability to simultaneously store and process a lot of spatial information is essential for mentally animating machines. Also, they provided new evidence related to simulating the behavior of different types of machines. In particular, the ability requires a variety of viewpoints in space in three dimensions. This takes a large space in working memory because it is needed to imagine the performance of the machine from different perspectives. In addition, they mentioned in their study that linear mental animation tasks involve the subject to process visual information in sequence, as one processes verbal information.

In the following analyses it will be used one table in each question to state the result of both groups: first year using N=242 and N=154 at the second year.

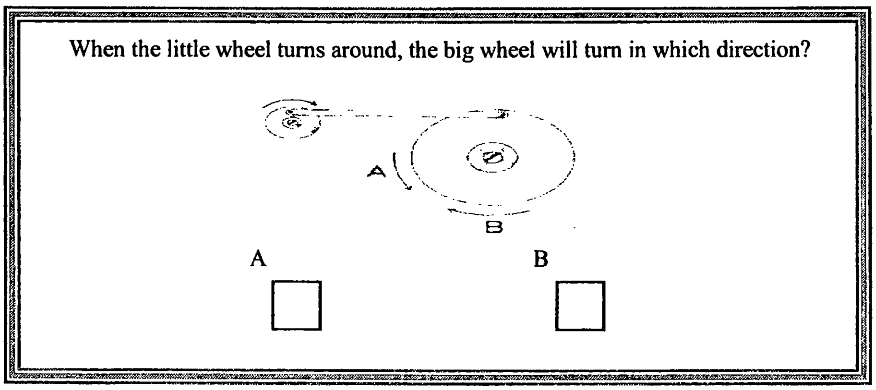


Figure 5.1 Wheel Problem: question 6 in the first year and 4 in the second year

In the first question students were asked to identify the direction of the big wheel when the little wheel was turned around the direction shown in Figure 5.1. In this case students should visualize the whole system at once.

Table 5.1	**N = 242**		**N = 154**	
	No.	**%**	**No.**	**%**
Correct Answer	189	78	142	92
Wrong Answer	51	21	12	8
No Answers	2	1	0	0

The answer of this question was B. As can be seen from the Tables, 5.1, students in second year achieved much better than students in first year. The percentage of correct answers in second year was nearly 92%, while in first year it was about 78%.

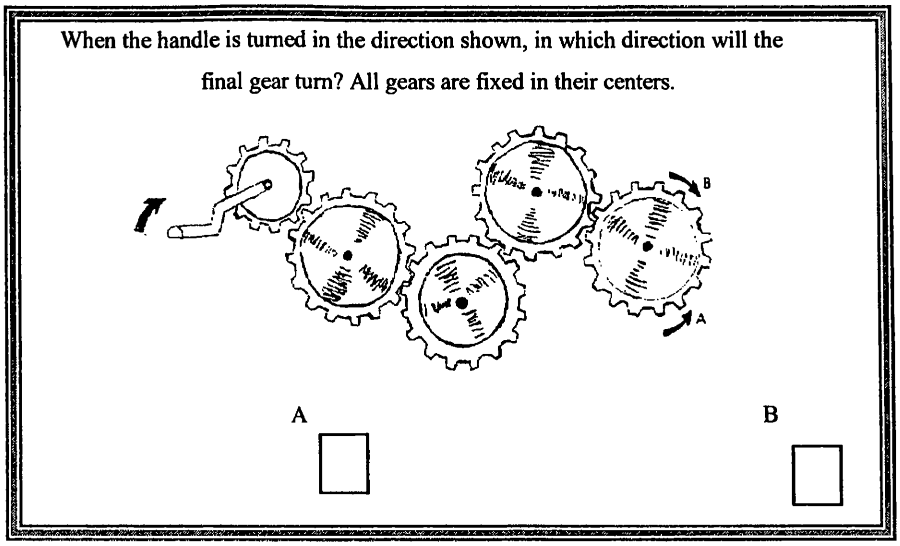


Figure 5.2 Gear problem: question 7 in the first year and 5 in the second year

The second question (7 in the first year and 5 in the second year) asked students to determine in which direction the final gear will rotate when the handle is turned in the direction shown in Figure 5.2. The answer was in B direction.

The pattern of students responses in this question (Table 5.2) is similar to that in the last question. But the percentage decreased almost 10 % in the correct answers and increased in similar proportion in the incorrect answers. This result appeared because the number of wheels was increased so it will need more processing in mind to find the sitution.

Table 5.2	N = 242		N = 154	
	No.	%	No.	%
Correct Answer	159	66	127	83
Wrong Answer	83	34	27	18
No Answers	0	0	0	0

In third question, students were asked to note the direction of the final gear when the first one turns in the direction (see Figure 5.3). The correct answer is A. This question is not different in nature from the second question except that this question is three dimensional whereas the second one is two dimensional.

When the first gear is turned in the direction shown, in which direction will the final gear turn?
All gears are fixed in their centers.

☐ A ☐ B

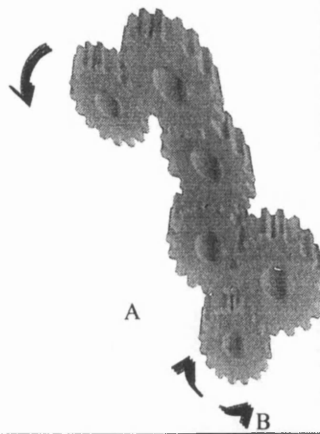


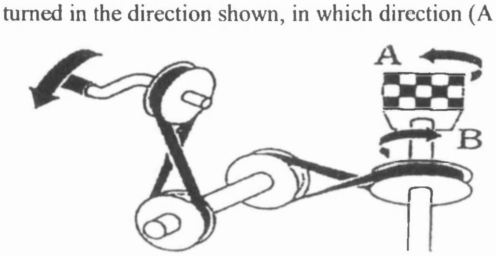
Figure 5.3 Gear problem: question 7 in the first year and 5 in the second year

Table 5.3	N = 242		N = 154	
	No.	%	No.	%
Correct Answer	125	52	88	57
Wrong Answer	113	4	64	42
No Answers	4	2	2	1

Table 5.3 shows the results. The two years perform similarly. However, the performance is much less than in the previous question, suggesting that students find the visualisation of three dimesnions more difficult than two dimensions.

In question four (9 in the first year and 6 in the second year), students were asked to identify the direction the box will move when the handle is turned in the direction presented in the Figure 5.4, the correct answer being A

When the handle is turned in the direction shown, in which direction (A or B) will the box turn?



A ☐ B ☐

Figure 5.4 Gear-and-belt problem: question 8 in the first year and 6 in the second year

The two years performed similarly and the level of sucess is similar to the previous question which was also three dimensional in nature.

Table 5.4	N = 242		N = 154	
	No.	%	No.	%
Correct Answer	157	65	99	64
Wrong Answer	90	37	51	33
No Answers	5	2	4	3

In the question shows in Figure 5.5 students were asked to imagine the shape when they see it from the backside. The correct answer was the shape number B.

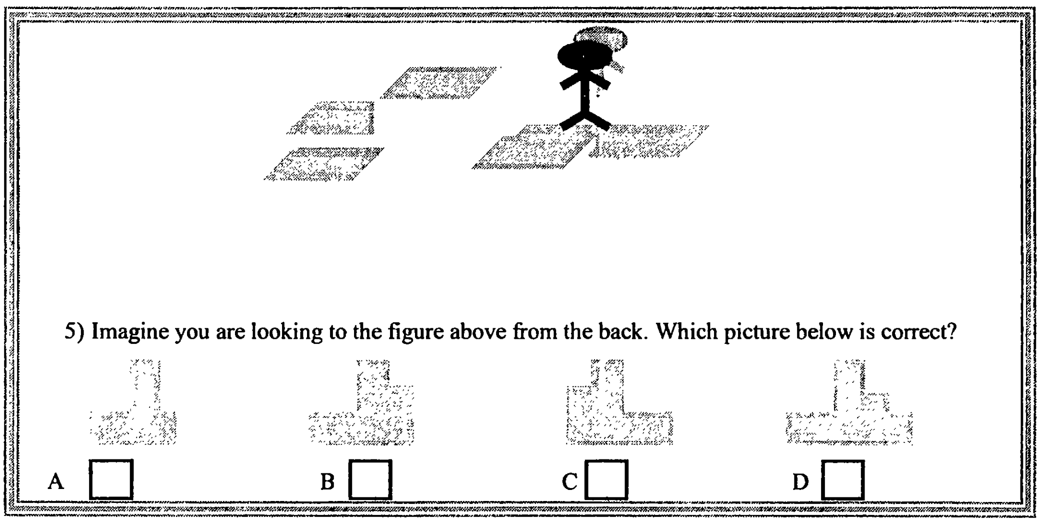


Figure 5.5 Question 10 in the first year and 8 in the second year

As can be seen from the Tables 5.5, only 28 % students from the first year and 36% from the second year could answer correctly which was B. Answer number C had the biggest percentages in both years which almost 50% from all students choosing it. It seems that students could not visualize the back view since the half of participant chose the picture viewing the front side not the back.

Table 5.5	N = 242		N = 154	
	No.	%	No.	%
Correct Answer	68	28	55	36
Wrong Answer	164	68	94	61
No Answers	9	4	5	3

Mental rotation tasks were used in the next question (Figure. 5.6).

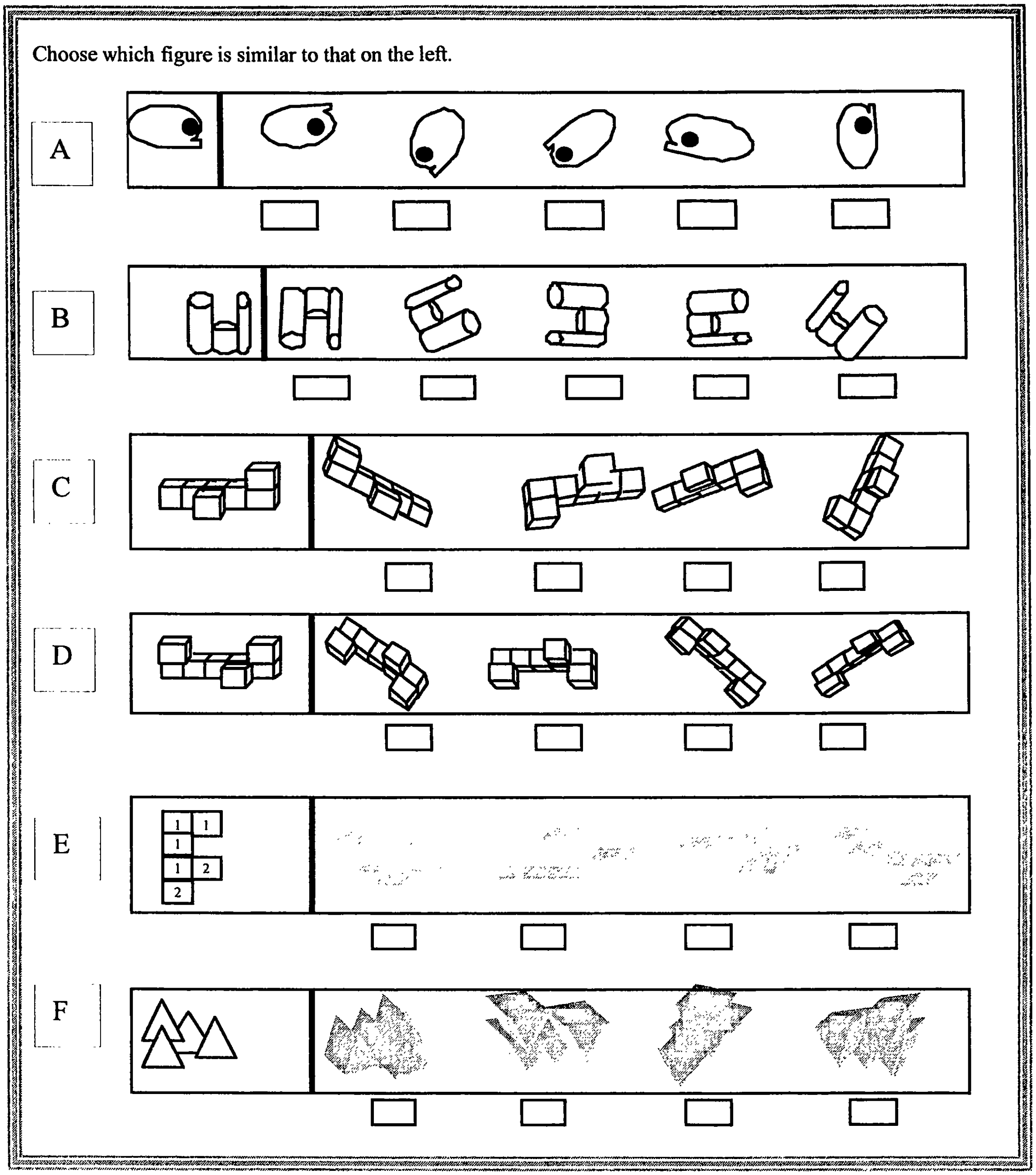


Figure 5.6 Question 11 in the first year and 9 in the second year

Block Rotation

Just and Carpenter (1992) stress that mental rotation problems are good measure of spatial ability because they place considerable demands on both storage of the mind and transformation functions, and require subjects to control the exchange between them. In this question a set of two-dimensional and three-dimensional figures were prepared. These figures involved different shapes, with cubes, cylinder and other objects, and students have to recognize which of these remaining figures is the same as the model figure when rotated in space. There were several types of spatial relation task such as parts A, B, C, D and F, and spatial visualization task using rotations tasks, by via 2D to

3D transformation such as part E. The figures are ordered from two dimensions to three dimensions.

Table 5.6		N = 242			N = 154		
		Correct Answer	Wrong Answer	No Answers	Correct Answer	Wrong Answer	No Answers
A	No.	123	119	0	90	63	5
	%	51	49	0	58	41	3
B	No.	108	129	5	76	74	4
	%	45	53	2	49	48	3
C	No.	102	134	6	82	64	8
	%	42	55	2	53	42	5
D	No.	67	169	6	61	84	9
	%	28	70	2	40	55	6
E	No.	56	177	9	49	103	12
	%	23	73	4	32	67	8
F	No.	105	129	8	77	65	12
	%	43	53	3	50	42	8

In part A (Table 4.6), students were required to rotate mentally a two dimensional shapes. The correct answer was number 3 which is rotated at about 100 degrees. Almost half of the students in the first year were able to select the correct shape in part A, and 58% students from the second year.

In part B students were asked to rotate the figure in two dimensions; the teachers explained this point to students at the time of test. Otherwise, all the answers could be correct.

Parts B and D looked at mental rotation task but the objects were rotated in different angles (around 90° and 300° in B and D respectively). As can be seen from the Table 5.6, there is an interesting difference between the responses to the two questions, with significantly lower correct responses rates on the D question in both years. It suggested that students in both years achieved less when the figure rotated in a larger angle.

This is confirmed by parts C and F where students indicated almost the same correct answers in both questions in every year. It can be clearly seen that correct figures in both question C and F rotated at the same angle, although the shapes are very different.

In part E, students should be able to distinguish the figure that is transformed from two dimensions to three dimensions. 23% from all students in the first year could indicate the figure successfully, whereas 32% of students in the second year answered correctly.

The results suggest the following effects:

(a) Tasks involving mental rotation of two dimensional figures is much easier to cope with than three dimensions tasks;

(b) When the angle of rotation became greatly bigger, the tasks turned out to be extremely difficult.

These two results it could possibly be related to working memory space, more space being required for three dimensions than two and more working memory space being required for larger angles. The first result is similar to that obtained by Hegarty and Kozhevnikov (1999) while the second result is related to the Shepard and Matzler (1971) finding on mental rotation and imagery. They found that there was a linear relationship between the angle of rotation of an object and the time it took the subject to answer. They concluded from their study that people need more time for increased rotation of an object.

A further factor which might be important is that students in both years performed better in mental rotation questions than in transforming two dimensions to three dimensions. This may be because the students required more space from working memory to transfers the figure from two dimensions to three dimensions in limited time. This result may be as a result of overloading of working memory since these diagrams involved a considerable amount of processing (in three-dimensions). This places a high demand on working memory.

A boat started traveling from Doha harbor sailing east for 10 km. It then changed its direction traveled for 20 km due North. After that, it stopped for about 2 hour. Next the boat sailed to the south and traveled for 30 km before going west for 10 km. Finally it stopped.

How far was the boat from its starting position? ....

You may use the space below for drawing

Figure 5.7 Question 14 in the first year and 12 in the second year

In the question shown in Figure 5.7 the participants were asked to solve a problem that included an explanation of boat direction to find the boat position at the end of the motion. They have to visualize the direction of motion and the distances in their mind to solve this problem. The correct answer is 10 km. The responses were almost the same in both years. Although a large number of students tried to draw a picture of the movement, only one third of the students in the first year answered correctly, and two third of the total were unable to give the correct answer. Half of them left the question without any answer. Most of the incorrect answers given were 70 m, because they summed up the distances without consideration of the boat's direction. The Table 5.7 shows the pattern of students' responses.

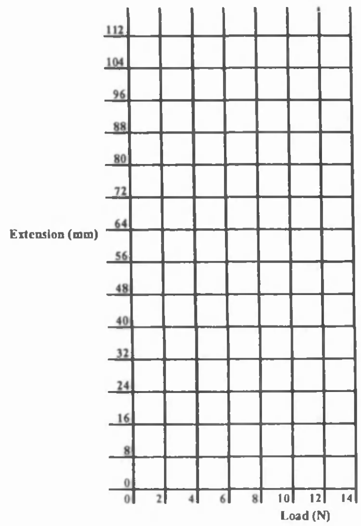
Table 5.7	N = 242		N = 154	
	No.	%	No.	%
Correct Answer	73	30	50	32
Wrong Answer	94	39	60	39
No Answers	74	31	44	29

It is clear from the previous results there is a differences on performance in the visual spatial test between the two groups. As might be expected, the mean performance of the second year students tended to be better than the first year students. Nippold and Duthie (2003) asserted that adults produce a larger percentage of figurative images than children. Crum (1999) mentioned in his reviews that Camp claimed the mental imagery is strongly related to personal experiences. Using the result above, it is possible to conclude that students in the second year experienced more in science (and in life, in general) than students in the first year. In addition, the students' major in the second year was a science, while the first year students studied general science.

It was decided to consider the following two questions (Figure 5.8 and Figure 5.9) as part of both tests (visual-spatial and difficulties) because at the same time students have to visualize the graph using the points given, glance at some point on the graph, and visualize the equation.

The results of an experiment are shown in the table. One of the readings is incorrect.

Load (N)	0	2	4	6	8	10	12	14
Extension (mm)	0	16	32	58	64	80	96	112



(a) Use these results to plot a graph.

(b) Use your graph to find:

1.The extension when the load is 3 N

....

2.The load, which produces an extension of 40 mm.

....

(c)Label the incorrect point on the graph with the letter E

Figure 5.8 Question 12 in the first year and 10 in the second year (a, b and c)

At part (a) Figure. 5.8, students were asked to plot a graph using the results from an experiment. One of the readings is incorrect. Only 31% in each group could plot it correctly. On the other hand, 49% and 92% of all students from the first and the second year respectively could identify the points correctly. Tables 5.16 and 5.17 show the pattern of students' answers.

N=242		**Students' responses in question 12 part a**			**Table 5.8**
%	No.		%	No.	
10	24	Wrong(points & graph)	31	74	Correct (points & graph)
1	3	Wrong(points)	49	119	Correct (points)
48	117	Wrong (graph)	1	2	Correct (graph)
			11	26	Not answer

N=154		**Students' responses in question 10 part a**			**Table 5.9**
%	No.		%	No.	
1	1	Wrong(points & graph)	1	47	Correct (points & graph)
1	1	Wrong(points)	92	142	Correct (points)
68	105	Wrong (graph)	29	44	Correct (graph)
			5	8	Not answer

In parts b and c, students were required to find some points on the graph they had plotted (Figure 5.8). It was decided to measure the average of the two questions 1 and 2, because they included similar ideas. By comparing the results of both groups, it could be concluded that students in the second year performed much better than the first year group (Tables 5.8 and 5.9). In addition, 75% of first year students were unable to pick the points correctly. Although the other group achieved much better results, there was a considerable proportion (29%) who could not give accurate answers.

N=242	Students' responses in Question 12 parts b(1,2) and c	Table 5.10
%	**No.**	
26	62	Avrage of correct answers
36	87	Avrage of wrong answers
39	95	Avrage of not answers

N=154	Students' responses in Question 10 parts b(1,2) and c	Table 5.11
%	**No.**	
63	97	Average of correct answers
17	26	Average of wrong answers
12	19	Average of not answers

It is clear from the result above, that the participants had problem in drawing and read the graphs and this problem appeared more in the general students (the yengest group) than in science once (the oldest group). In addition, they could not visualize the graph although they indicated the points correctly and at the same time, they were unable to glance the unappeared points using their graphs.

Look at the formula: P = F/A

Now answer the following questions:

(a) What will happen to the value of A when P is increased and F is constant?

☐ Increased ☐ Decreased ☐ Constant

(b) When A is decreased and P is constant, what will happen to the value of F?

☐ Increased ☐ Decreased ☐ Constant

Figure 5.9 Question 13 in the first year and 11 in the second year

In the question shown in Figure 5.9, students were asked to manipulate the formula to find what happened to the subject if you changed the other values. It was decided to calculate the average of the students' answers in the two parts of this question since they tested the same skill. Similar findings were indicated from their results that in average of 61% and 75% of all students from the first and the second year respectively answer this question correctly and nearly 33 students from both groups left the question without any answer. Tables 5.12 and 5.13 show the pattern of students' responses.

N=242	Students' responses in question 13	Table 5.12
%	**No.**	
28	67	Average of correct answers
61	148	Average of wrong answers
11	28	Average of not answers

N=154	Students' responses in question 11	Table 5.13
%	**No.**	
21	32	Average of correct answers
75	116	Average of wrong answers
4	6	Average of not answers

To conclude, students had a problem in solving problems because they did not know how to carry out the formula to find the relation between the parameters. In addition, a rotation skill is very important to solve problem. The generation and manipulation of mental rotation figures is an essential cognitive method for problem solving (Cohen *et al*, 1996)

5.4.2 The Result of the Correlation

N=242 First year	Visual spatial	Difficulties	Physics Marks
Visual spatial		0.38**	0.22**
Difficulties			0.20**

N=154 Second year	Visual spatial	Difficulties	Physics Marks
Visual spatial		0.47**	0.17*
Difficulties			0.29**

** Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.05 level (2-tailed).

Table 5.14 Correlation between the three marks

Three sets of data were obtained for each year group. Results from a test of visual-spatial ability, results form a test of physics difficulties, and the students overall examination performance. Any relationship between these was tested using Pearson correlation, the data being scale data with approximately normal distributions (see Appendix c).

The overall physics mark reflected test material which largely was based on recall. The difficulties test was designed to explore understanding. As can be seen from the results shown in Table 5.14, in both groups there are significant positives correlations between visual-spatial performance and performance in physics, whether recall or understanding. However, this significance was far more apparent between visual-spatial ability and understanding physics rather than memorizing (the test in the school). This leads to the suggestion that visual-spatial ability may be important to the understanding of physics.

5.5 Working Memory Space

This part of the result was not considered at the beginning of this study but after gathering information from the questionnaires and exams, it was decided to conduct a test measuring the space of the working memory, and to find if there is any correlation between working memory space and performance in physics, and also with visual-spatial ability.

It was only possible to gain access to 51 students from the second year in Qatar, drawn from the same group involved the previous measurements. The Figural Intersection Test (F.I.T), which was designed by Pascual-Leone and Smith (1969), was used to examine the individual working memory space. The test was conducted at the end of the term.

As can be seen from Figure 5.9, which illustrates a sample of the test which every question contained two sets of simple geometric shapes, the set of figures on the right acting the presentations' set and those on the left are the tests' set. Students were asked to shade the overlap area between the figures; there are 36 items on the test as shown in Appendix B.

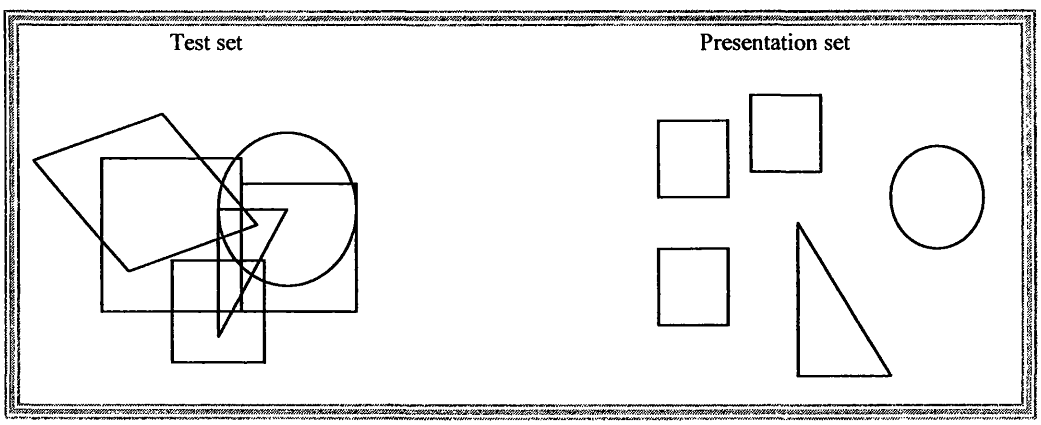


Figure 5.10 Figurative Intersection Test

The number of shapes involved in the 30 items varied form two to eight. The aim was merely to place the students in order on the basis of their working memory. No attempt was made to measure the working memory absolutely. The time allowed was 20 minutes. With such a small sample, it is recognized that drawing conclusions with confidence will be difficult.

Correlations were carried out using the Pearson Correlation to explore any relationships with the previous measurements. Table 5.16 shows the results obtained.

N=51 Second year	Visual spatial	Difficulties	Working memory	Physics marks
Working memory	0.10	0.20		0.33*

5.15 Correlation between working memory and the three marks

5.6 Summary

Summing up, it was found that visual-spatial ability offers more links to long-term memory and a much better way to conceptualize many physics topics. It therefore seems that visual-spatial ability is a very important skill in the understanding of science. This is similar to the findings of Lohman (1993), who mentioned that visual-spatial abilities are important for higher-order thinking in science and mathematics (Lohman, 1993). Visual-spatial learners have good long-term memory and enjoy geometry and physics. Furthermore, Silverman (1999) said that visual-spatial learners are creative, technological, mechanical, and emotional, and that they are natural mathematicians and scientists. Visual-spatial ability is also related to the working memory space, which is a very important feature for success in physics because according to many researchers in this field, any question or formula has to be manipulated in this space; this was discussed in detail in Chapter two in this study.

Chapter six

Conclusion

6.1 Introduction

This chapter seeks to bring together the findings from this study. This study sought to look again at the areas of perceived pupil difficulty in Physics in Qatar and see how these relate to other studies in other countries. The main task, however, was to make an initial exploration of visual-spatial ability and to see how this relates to performance and understanding in Physics topics.

6.2 Consequences from the First Part

The following conclusions can be drawn:

1. From the questionnaires, it was found that students in the first year had problems understanding some topics such as Matter and its Mechanical characteristics (Fluid's Pressure, Pascal's Principle, and Archimedes's Principle), Electric Energy and Electric Power. However, from the difficulties test results, it can be seen that the most difficult area for students in first year is related to confusion concerning fluid pressure, force and mass. Moreover, although only 7 out of 202 students claimed that the Surface Tension is difficult to understand, it was found that 66% of them were unable to give an explanation of the phenomena. In addition, students in the second year classified Newton's Laws as difficult, similar result was found after applying the exam particularly in the third law. The emphasis in teaching and assessment in Qatar is on recall of information or conducting routine procedures correctly. Pupils may be able to cope with some of these but may not understand the ideas.

2. It was observed that students at Qatar high schools level (especially the first and second years) had considerable difficulty in applying formulas, even when these formulas were given to them. This might reflect a problem with mathematics and algebraic symbols. However, students do not find it easy to apply the skills of one

subject area (mathematic) in another area (physics). A lack of experience and confidence in either area may lead to them having to hold too many ideas at the same time, a typical example of working memory overload.

3. Students have trouble understanding the concepts of stability, acceleration and pressure and linking them to their own experiences. This may reflect a problem with some physics topics in that experience is either not present or the experience does not appear to relate to what they are being taught. This offers support for the idea of an applications-led curriculum (see Reid, 1999)

4. Students, especially in the first year, faced some problems with reading some graphs and linking them to their own experiences, especially the velocity-time graphs. In addition, from the 337 out of 396 students who identified the points correctly only 126 students could plot a correct graph.

5. Students in the second year have problems sketching the force of friction on to diagrams. In general, students in both groups were poor at picking out information from the diagrams.

6. According to the results gained from the questionnaires that students in all groups wrote similar comments for the topics indicated as difficult; for example, lack of resources in teaching (such as experiments), difficult concepts (abstract concepts to be visualized such as pressure), formulas and unclear textbooks, difficult to apply formulas, too many concepts and theories in one lesson and no time for revision and solve new problems which related to the subject (Tables 4.2, 4.4, 4.6).

Bearing in mind that the students tested were actually at the high end of the ability range as tested by the school examination, this picture is quite depressing. It would appear that these students have learned to pass examinations quite well, but without gaining very much understanding, or 'feel', for the subject. When given a simple formula as part of the data of a question, they were unable to use it. It appeared that they have learned to use formulas in a mechanical, or algorithmic, fashion, but have no conception of their use as a guide to thinking. Similar remarks could be made about most of the other topics tested here.

6.3 Consequences from the Second Part

Looking at the outcomes from the visual spatial test:

1. Both groups had difficulties in rotating figures, in particular the three dimensional ones and these difficulties increased when the angle of the rotation rose as well.

2. Students found it difficult to transfer two dimensional figures to three dimensional ones. This is a major problem in that textbooks, blackboards and displays are, inevitably in two dimensions. However, the students have to translate these two dimensional representations into three dimensional reality. This is a well established problem (see, for example, Johnstone *et al*, 1977). Part of the answer lies in offering the students experiences in handling and manipulation three dimensional objects or models for themselves and relating this experience to two-dimensional representations.

3. Most of the participants examined had difficulty visualizing overturned pictures.

4. The majority of the students could not visualize the graph although they determined the points on the sheet correctly. Additionally students were unable to visualize some points in graphs.

5. Students at the high school level, even in the science branch, had difficulty to transpose formulas.

6. The actual marks in both the Visual Spatial test and the test relating to understanding were very much lower than the marks in the Physics examination used in the schools. The reasons for poor achievement in the understanding test and the visual spatial test might be the time of the exams (after the fourth period), the students did not prepare for the exams, students did not review for the exams and the topics examined were learned two months before the exams. Hence these exams examine understanding not recall as the Physics exam at the school.

7. Those good at visual-spatial also good at Physics understanding ($r = 0.38, 0.47$), those good at visual-spatial also good at recall of Physics ($r = 0.22, 0.17$).

8. Most of our findings agree with those of the research mentioned in previous chapters.

6.4 Suggestion for teaching

Visual-Spatial abilities are essential for understanding physics, considering diagrams and solving problems. Furthermore, visual spatial ability offers more links in long term memory; it also offers a much better way to conceptualize many Physics topics. It could be developed (from the literature).

The results indicate that most students in Qatar's high schools have difficulties in learning physics and these difficulties arise for several reasons. For instance, many concepts and abstract ideas were provided to the students in one session which may overload their working memory. In addition, the diagrams were complex and text-books as well. Therefore, students need different teaching approaches from traditional methods which probably reduce the overloading working memory. Pre-lecture could be useful for decreasing the new concepts.

The following recommendation may helpful for solving problems: read the questions many times, drawing simple diagrams to illustrate the questions (problems), write down the formulas outlines using algebraic symbols.

Due to student's difficulties and misconceptions regarding to the velocity, acceleration and time, we suggest that students have to be taught these concepts using graphs, and these graphs should be presented it all together to find the differences between them.

Some suggestions for the teaching of physics in schools include presenting information in textbooks in a simple way using important information, taking into consideration studies in the field of curriculums and obtaining from students the reasons for their difficulty understanding textbooks rather than guessing the reasons. In addition, simple diagrams and graphs, and relating abstract facts to the students' lives may be useful to help understanding and reduce misunderstandings.

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Appendix A

General Physics Level of Difficulty Questionnaire

Please tick an appropriates your opinion about each physics topic

> **Easy: I under stand it without difficulties**
>
> **Moderate: I had difficulties but I understand it now**
>
> **Difficult: I still do not understand the topic**
>
> **Not studied: I have never studied this topic or I forget that I studied it before**

The topic	*Easy*	*Moderate*	*Difficult*	*Not studied*	*If difficult, please say why?*
Electromagnetism Force	52%	36%	6%	6%	----------------------------------
Hook's Law	48%	40%	8%	4%	----------------------------------
Surface Tension	56%	39%	3%	2%	----------------------------------
Fluid's Pressure	24%	43%	15%	18%	----------------------------------
Pascal's Principle	57%	31%	9%	2%	----------------------------------
Archimedes's Principle	41%	40%	13%	6%	----------------------------------
Electric Current	79%	18%	3%	0%	----------------------------------
Current Intensity	80%	15%	5%	0%	----------------------------------
Potential Difference	76%	18%	5%	0%	----------------------------------
Ohm's Law	62%	33%	4%	0%	----------------------------------
Resistors in Series and Parallel	59%	34%	6%	1%	----------------------------------
Electric Energy	51%	38%	8%	2%	----------------------------------
Electric Power	43%	43%	11%	2%	----------------------------------

General Physics Level of Difficulty Questionnaire

Please tick an appropriates your opinion about each physics topic

Easy:	I under stand it without difficulties
Moderate:	I had difficulties but I understand it now
Difficult:	I still do not understand the topic
Not studied:	I have never studied this topic or I forget that I studied it before

The topic	*Easy*	*Moderate*	*Difficult*	*Not studied*	*If difficult,please say why?*
Force and Motion	59%	34%	4%	2%	----------------------
Newton's First Law	69%	24%	7%	0%	----------------------
Newton's Second Law	57%	34%	9%	1%	----------------------
Weight and Mass	53%	37%	7%	2%	----------------------
Inertial mass and Gravitational Mass	18%	35%	16%	32%	----------------------
Newton's Third Law	49%	32%	16%	4%	----------------------
Force of Friction	37%	44%	17%	3%	----------------------
Application on Newton's Laws	33%	44%	22%	1%	----------------------
Stability	14%	32%	11%	43%	----------------------
Moment of Force (Torque)	10%	15%	9%	67%	----------------------
Gravitational Field	37%	39%	12%	11%	----------------------
The Law of Universal Gravitational	12%	13%	6%	70%	----------------------
The Gravitational Field	25%	37%	17%	22%	----------------------
Electric Force	59%	33%	6%	2%	----------------------
The Electric Field	64%	28%	7%	1%	----------------------
Electric Potential	64%	28%	9%	0%	----------------------
Electric Potential for Spherical conductor	59%	29%	12%	0%	----------------------
Equality Voltage Surfaces	62%	29%	6%	2%	----------------------
Electric Capacity	52%	35%	12%	2%	----------------------
Dielectric Constant	41%	42%	13%	4%	----------------------
Capacitors in Series and Parallel	64%	26%	7%	3%	----------------------
Impulse-Momentum Theorem	47%	37%	14%	2%	----------------------
Conservation of Momentum	40%	41%	15%	4%	----------------------

General Physics Level of Difficulty Questionnaire

Please tick an appropriates your opinion about each physics topic

Easy: I under stand it without difficulties

Moderate: I had difficulties but I understand it now

Difficult: I still do not understand the topic

Not studied: I have never studied this topic or I forget that I studied it before

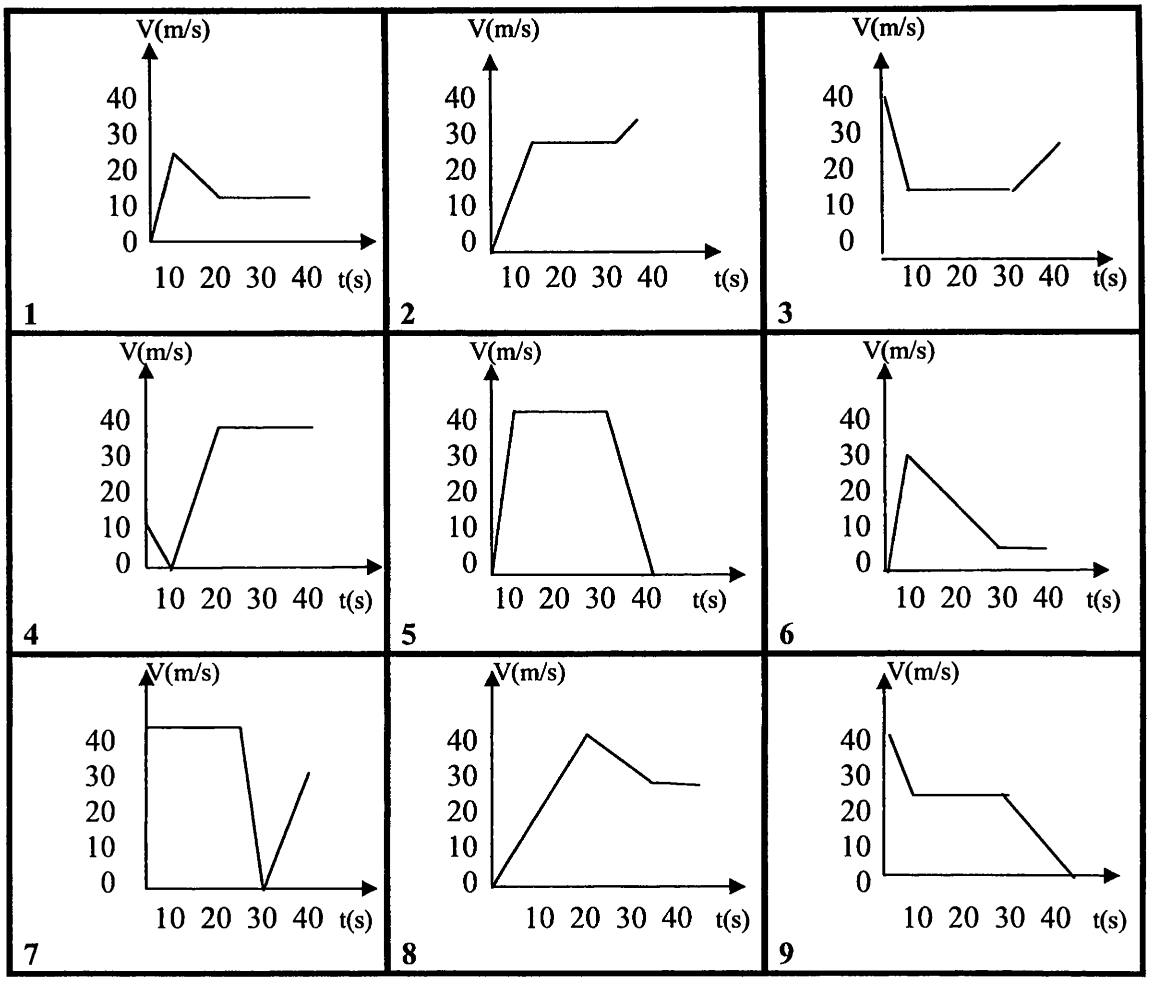
The topic	*Easy*	*Moderate*	*Difficult*	*Not studied*	*If difficult, please say why?*
Magnetic Field	86%	14%	0%	0%	----------------------------
Magnetic Flux	84%	16%	0%	0%	----------------------------
Magnetic Force	78%	19%	2%	1%	----------------------------
Mass Spectrometer	6%	30%	3%	1%	----------------------------
Magnetic Field of Moving Charge	56%	38%	5%	1%	----------------------------
The Simple Electric Motor	47%	42%	10%	1%	----------------------------
Loud Speaker	62%	31%	3%	4%	----------------------------
Magnetic Field of a current element	48%	45%	5%	2%	----------------------------
Cassette Tape-recorder	50%	40%	3%	7%	----------------------------
Force between Parallel conductors	31%	40%	14%	15%	----------------------------
Generated Induced Current	40%	40%	15%	5%	----------------------------
Electromotive Force	34%	44%	13%	9%	----------------------------
Motional Electromotive Force	33%	40%	13%	14%	----------------------------
Faraday's Law	56%	32%	9%	13%	----------------------------
The Electric Dynamo	35%	47%	15%	3%	----------------------------
Self Induction	39%	45%	14%	2%	----------------------------
Mutual Induction	33%	48%	16%	3%	----------------------------
Transformer	39%	45%	13%	3%	----------------------------
Alternating E.M.F & Alternating Current	38%	44%	13%	5%	----------------------------
R.M.S. Value	43%	42%	10%	5%	----------------------------
The R-L-C Series Circuit	37%	41%	18%	5%	----------------------------
Series Resonance	39%	33%	24%	4%	----------------------------
Nuclear Forces	53%	26%	3%	18%	----------------------------
Nuclear Potential Barrier	41%	20%	7%	32%	----------------------------

Appendix B

Thinking About Physics

Answer all questions
The marks will not be used for your grades in physics

(1) Below are nine pictures. In each of them, there is graph representing a car motion:



Select the box(es) to answer the following questions.
Boxes may be used as many times as you wish.
Use the box numbers to show your answers.

(i) In which box(es) does the car stop at the end of motion? ....

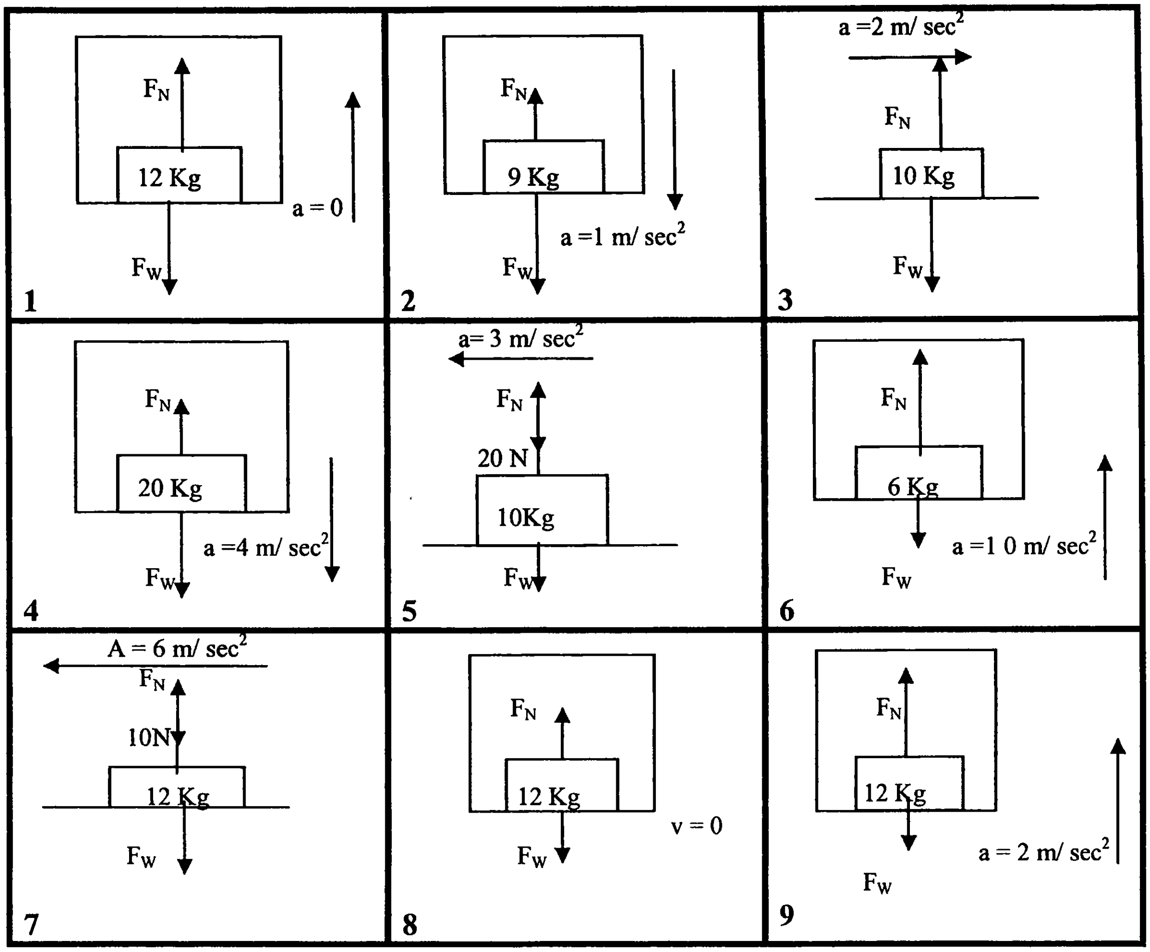
(ii) At 20 second, which box(es) show the car traveling fastest? ....

(iii) Which box(es) represent the motion of a car in where there is an increase in velocity, followed by decrease, followed by constant velocity?

....

(iv) In which box(es) does the driver never use brake? ....

(2) Here are 9 pictures showing different objects moving (inside lift or above flat surfaces). In each motion, the mass, acceleration, some of the forces and the direction of movement are shown.



Select the box(es) to answer the following questions.
Boxes may be used as many times as you wish.
Use the box numbers to show your answers.

(i) In which box(es) is the object moving with constant vertical velocity? ....

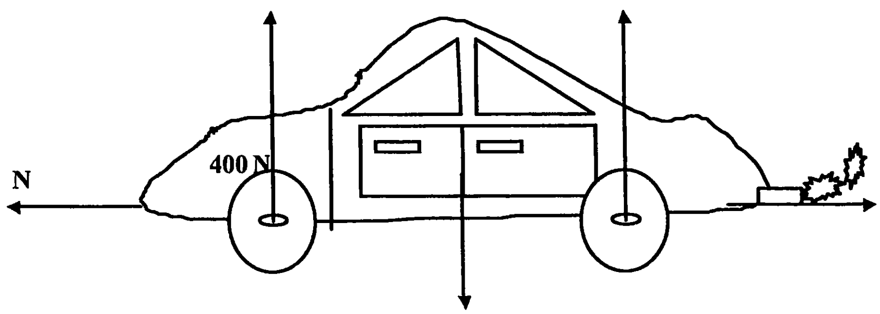
(ii) In which box(es) is $F_N = F_w$ ....
(the acceleration due to gravity $g = 10$ m/s^2)

(iii) In which box(es) does F_N have the same value as it has in box 1? ....

(iv) In which box(es) is the object acted upon by a force of friction. ....

(v) For each answer to question 4, mark the direction of the force of friction on the pictures.

(3)



A front-wheel drive car is traveling at constant velocity. The forces acting on the car are shown in the diagram above. Q is the force of the air on the moving car. P is the total upward force on both front wheels.

(a) Explain why: (i) P= 4000 N

(ii) Q= 400 N

....

....

....

....

(b) If the acceleration due to gravity = 10 m/s^2 calculate the mass of the car.

....

....

....

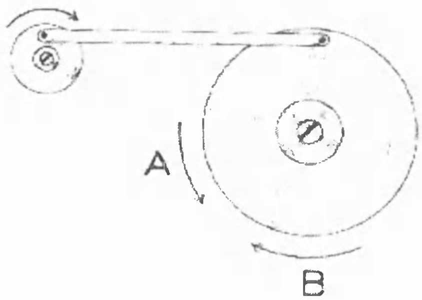
(c) If the driver starts to brake the car describe what happens to the acceleration?

....

....

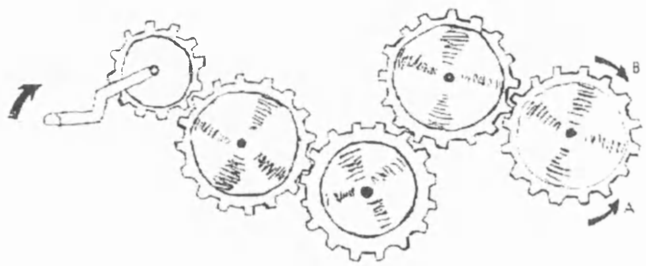
....

(4) When the little wheel turns around, the big wheel will turn?



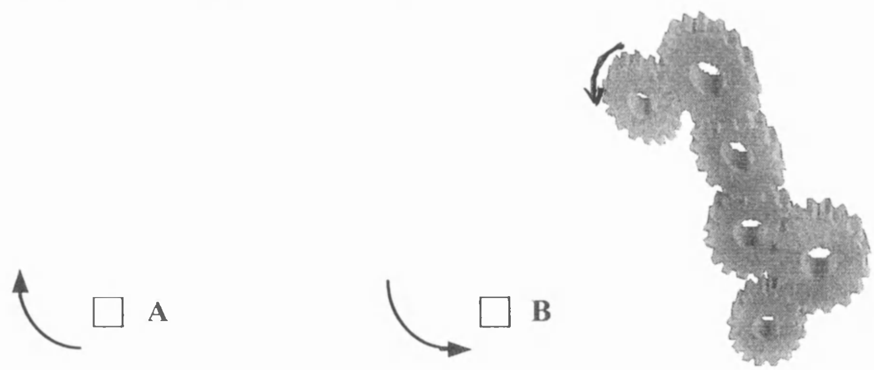
☐ A ☐ B

(5) When the handle is turned in the direction shown, in which direction will the final gear turn? All gears are fixed in their centers.



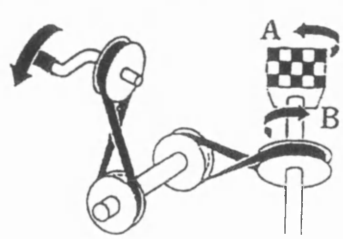
☐ A ☐ B

(6) When the first gear is turned in the direction shown, in which direction will the final gear turn?



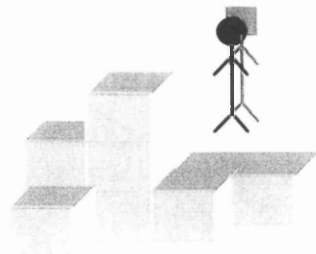
☐ A ☐ B

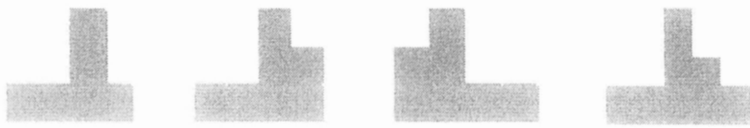
(7) When the handle is turned in the direction shown, in which direction (A or B) will the box turn?



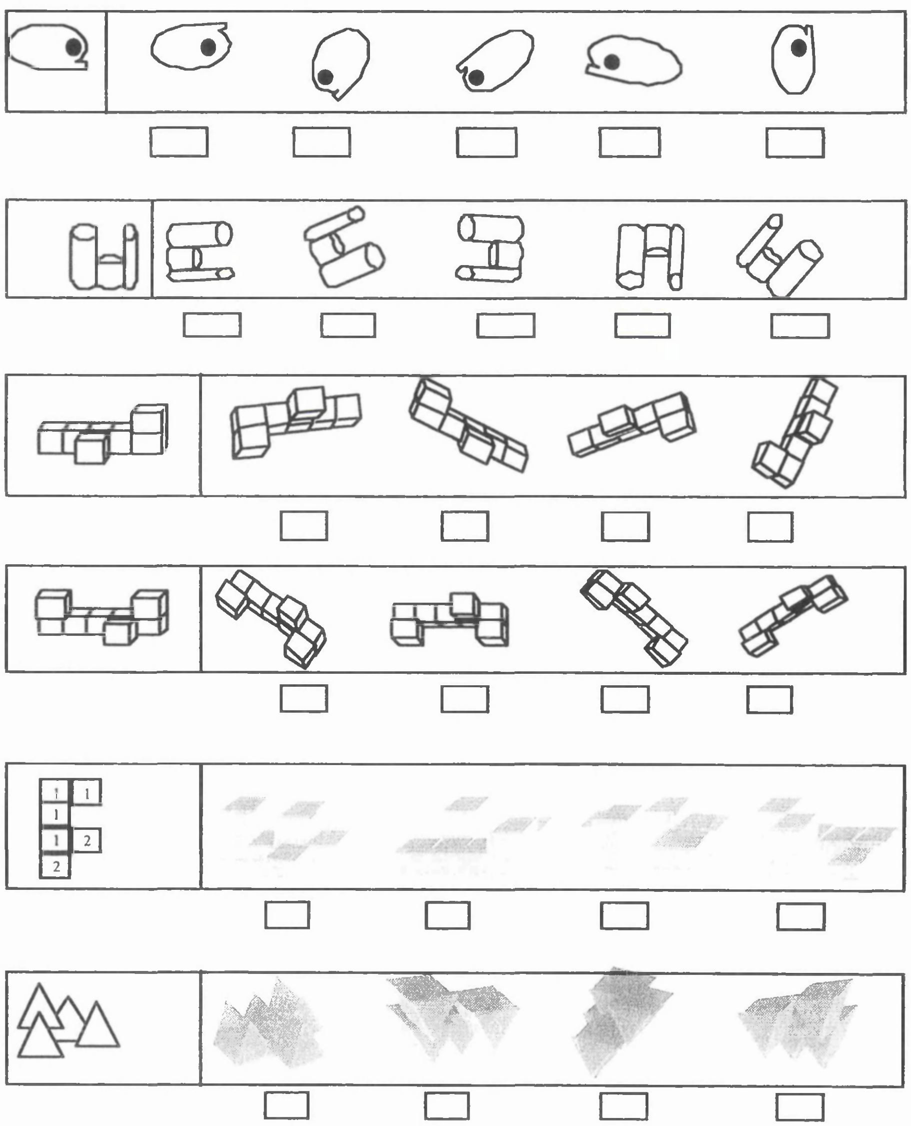
☐ A ☐ B

(8) Imagine you are looking to the figure above from the back. Which picture below is correct?





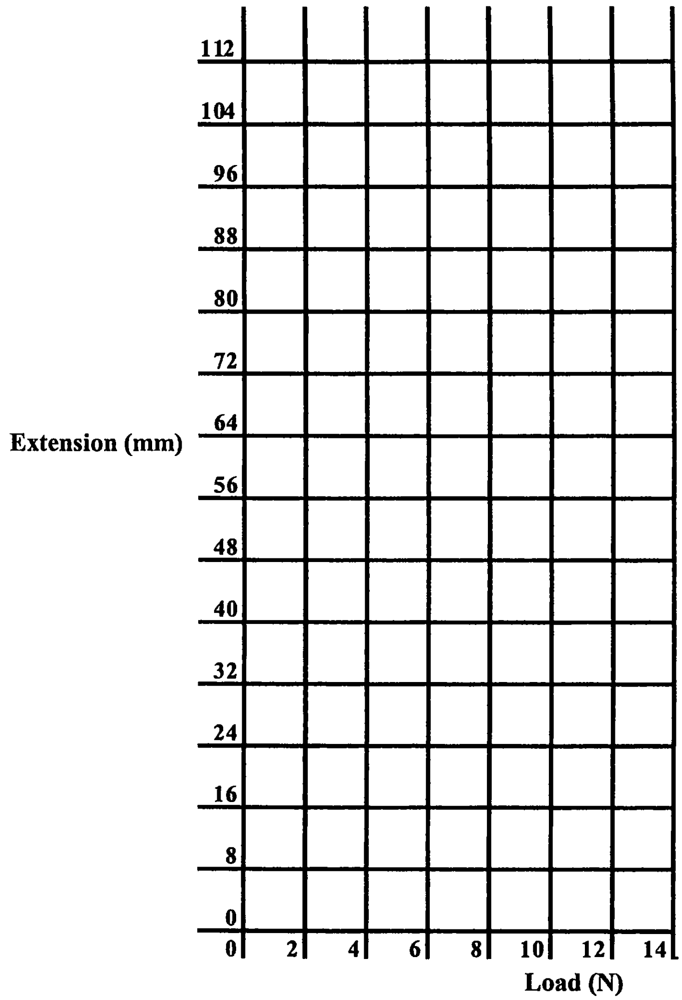
(9) Choose which figure is similar to that on the left.
(Tick one box on each line)



(10) The results of an experiment are shown in the table. One of the readings is incorrect.

Load (N)	0	2	4	6	8	10	12	14
Extension (mm)	0	16	32	58	64	80	96	112

(a) Use these results to plot a graph.



(b) Use your graph to find:

i) The extension when the load is 3 N. ....

ii) The load, which produces an extension of 40 mm. ....

(c)Label the incorrect point on the graph with the letter E. (10)

(11) Look at the formula: $P = F/A$
Now answer the following questions:

(a) What will happen to the value of A when P is increased and F is constant?

☐ Increased ☐ Decreased ☐ Constant

(b) When A is decreased and P is constant, what will happen to the value of F?

☐ Increased ☐ Decreased ☐ Constant

(12) A boat started traveling from Doha harbor sailing east for 10 km. It then changed its direction traveled for 20 km due North. After that, it stopped for about 2 hour. Next the boat sailed to the south and traveled for 30 km before going west for 10 k. Finally. it stopped.

How far was the boat from its starting position? ....…

You may use the space below for drawin

Centre for Science Education
University of Glasgow

Thinking About Physics

Answer all questions
The marks will not be used for your grades in physics

(1) Below are some substances and their densities.

	Substance			Density	
No.	Solid	liquid	Gas	Kg/ m^3	gm/c m^3
A	Gold			19 000	19
B		Mercury		14 000	14
C	Lead			11 000	11
D	Iron			8 000	8
E		Water		1 000	1
F	Ice			920	0.9
G		Petrol		800	0.8
H			Air	1.3	0.0013

Select the substances to answer the following questions.
Substances may be used as many times as you wish.
Use the letter to show your answers. (You can use this formula $\rho = m / v$)
*There may be **one or more** answers to each question*

Referring to the above table, which of those substances will?

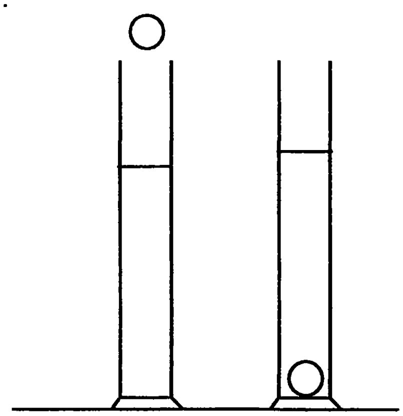
(i) Sink in water ....

(ii) Float on water. ....

(iii) Sink in mercury. ....

(iv) Float on mercury. ....

Look at the diagram below.



A ball of gold (mass 5g) is dropped into a cylinder of water and the water level rises.

Suppose the experiment was repeated using a 5g ball of lead instead.

(v) If the experiment is repeated using a lead ball instead of a gold ball, to what height will the water in the cylinder rise when the lead ball is dropped?
Tick one box

☐ The same as with the gold
☐ Higher than with the gold
☐ Lower than with the gold

(2) If Figure 1 represents a **solid** state and figure 3 represents a **gas** state:

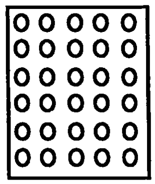


Figure 1

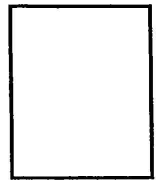


Figure 2

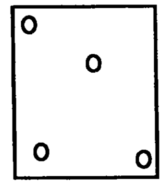


Figure 3

(i) Draw what a liquid might look like in figure 2.

(ii) If the substance in figure 3 is cooled down, its molecules move at a speed which is

....

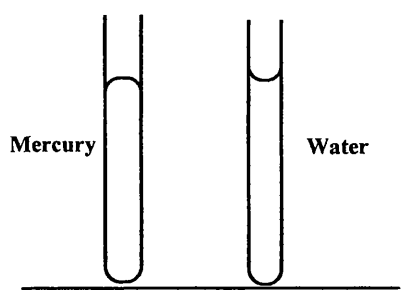
(3) Explain, *in two sentences,* why a stiletto heel is more likely to mark the floor than an elephant foot.

....

....

....

(4) Here are two pictures showing two glass tubes the first one contains mercury and the other one contains water.



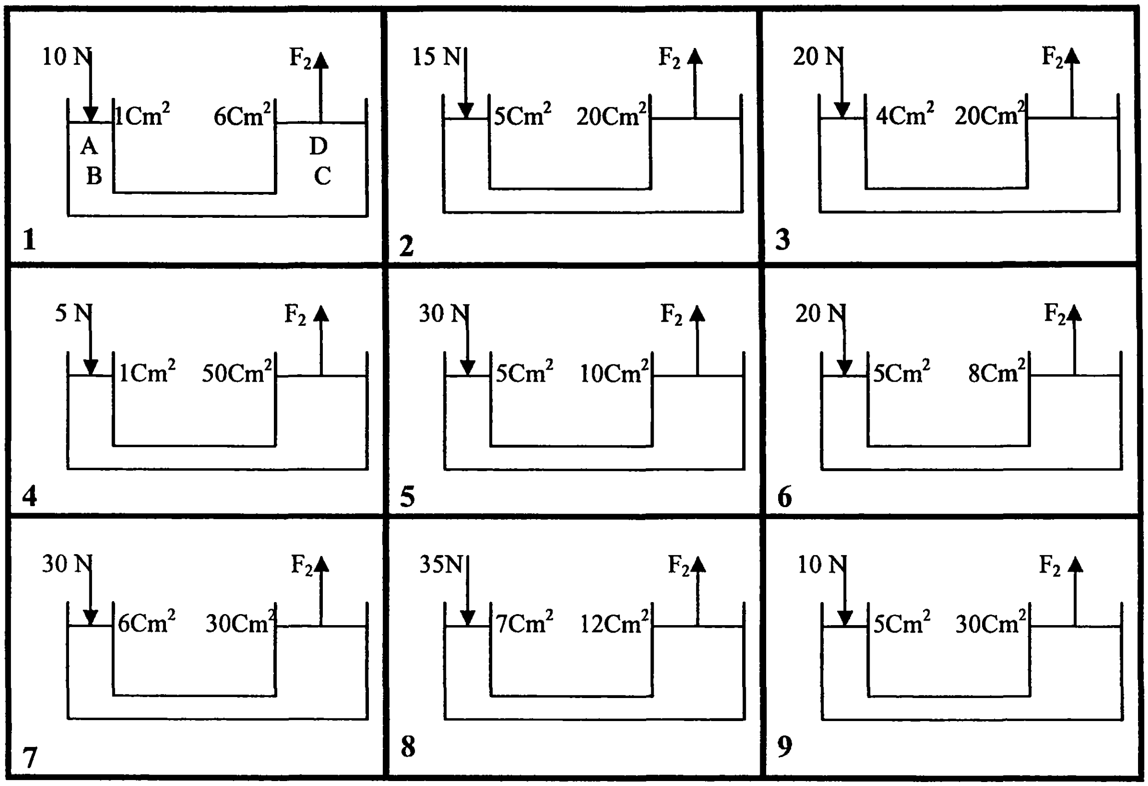
Explain, *in two sentences,* why the surface takes a different shape in each tube.

....

....

....

(5) In the grid below, there are 9 Hydraulic disc brakes. In each box, the force and pistons' areas are shown.



Select the box(es) to answer the following questions.
Boxes may be used as many times as you wish.
Use the box numbers to show your answers.
(You can use this formula $F_1 / A_1 = F_2 / A_2$*).*

(i) In which box(es) does F_2 have the same value as that in box 1 ? ....

(ii) In which box(es) does F_2 have the largest value? ....

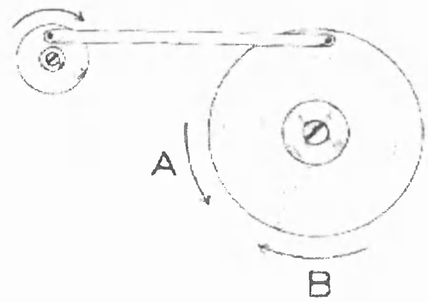
(iii) In which box(es) does F_2 have the smallest value ? ....

(iv) In which box(es) does the pressure of the left hand side have the same value as box 3 ? ....

(v) Look at box 1 where is the pressure greatest?
(Tick one box)

☐ A ☐ D ☐ A&D ☐ B&C ☐ B,C&D ☐ A, B, C&D

(6) When the little wheel turns around, the big wheel will turn?



☐ A ☐ B

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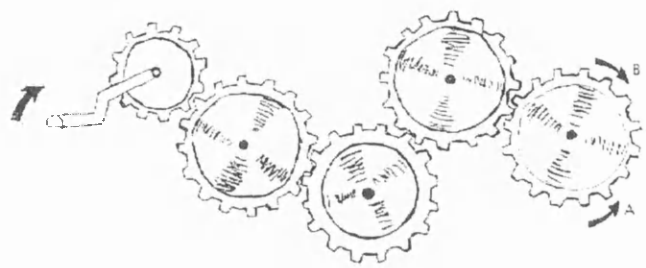

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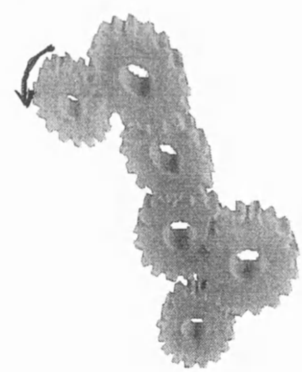
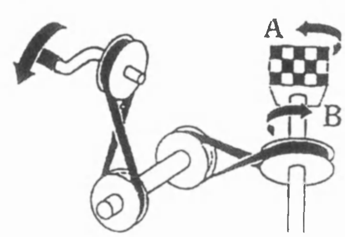
(8) When the first gear is turned in the direction shown, in which direction will the final gear turn?



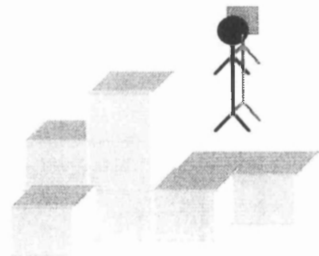
☐ A ☐ B

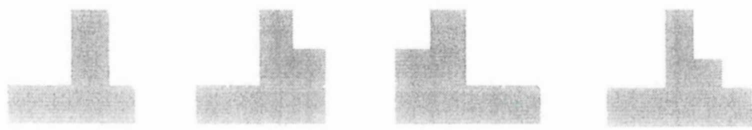
(9) When the handle is turned in the direction shown, in which direction (A or B) will the box turn?



☐ A ☐ B

(10) Imagine you are looking to the figure above from the back. Which picture below is correct?





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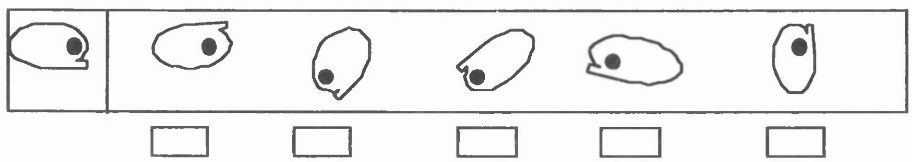
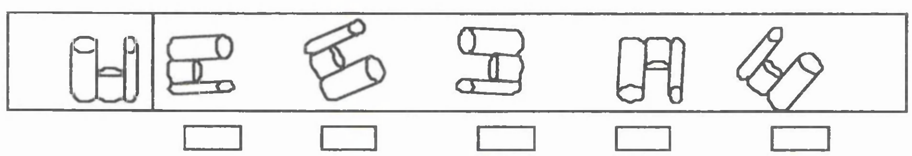
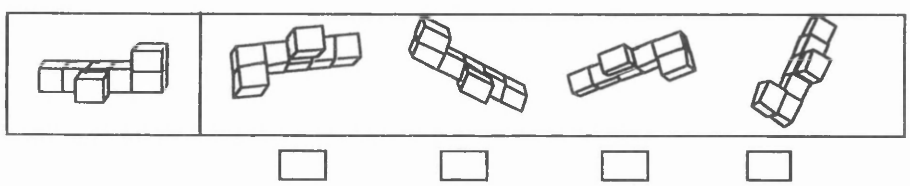
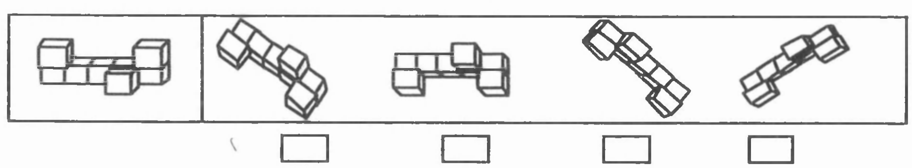
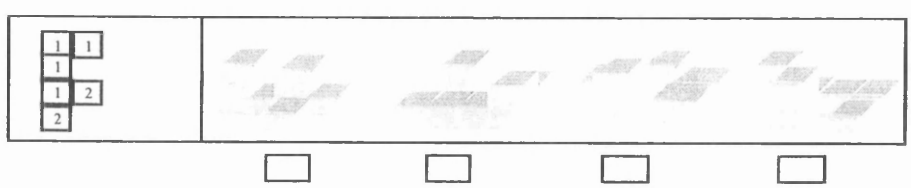
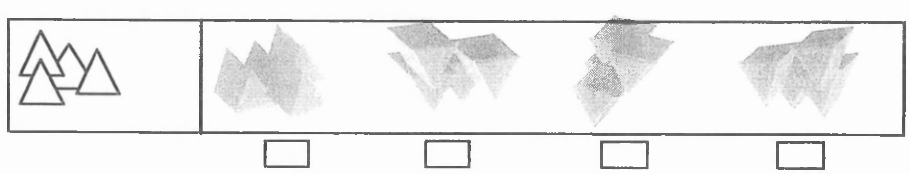












(13) Look at the formula: P = F/A
Now answer the following questions:

(a) What will happen to the value of A when P is increased and F is constant?

☐ Increased ☐ Decreased ☐ Constant

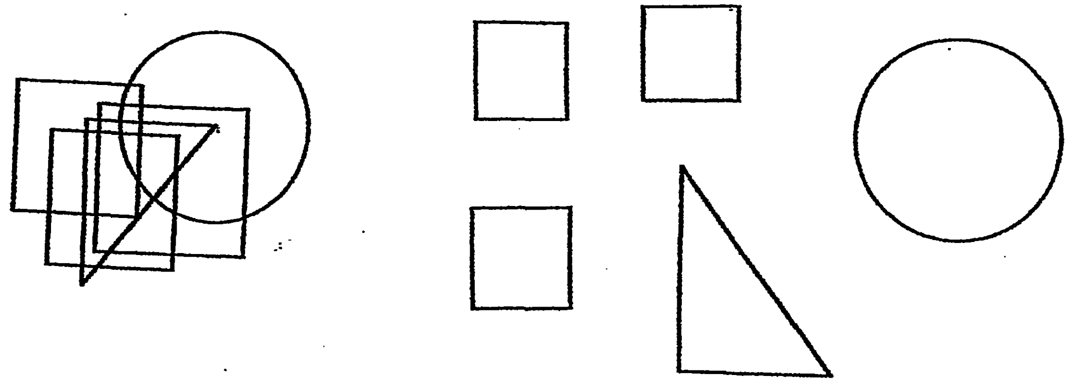
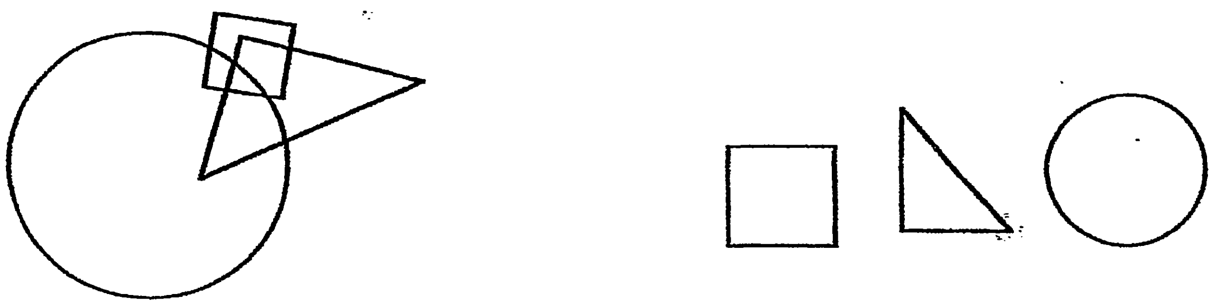
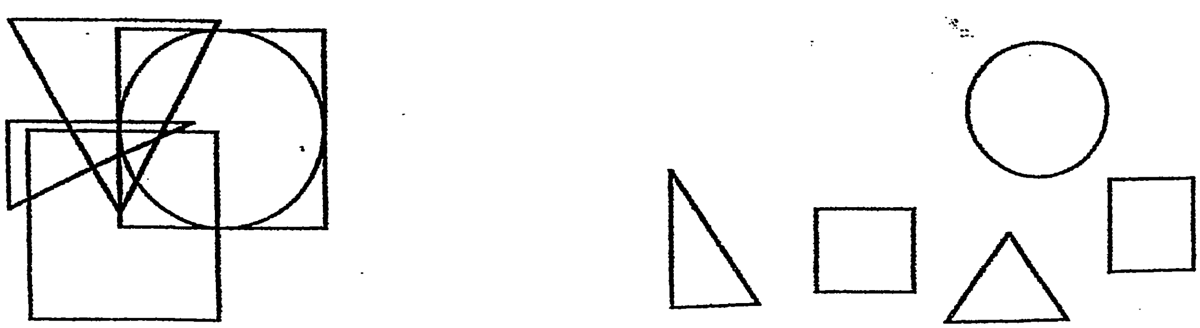
(b) When A is decreased and P is constant, what will happen to the value of F?

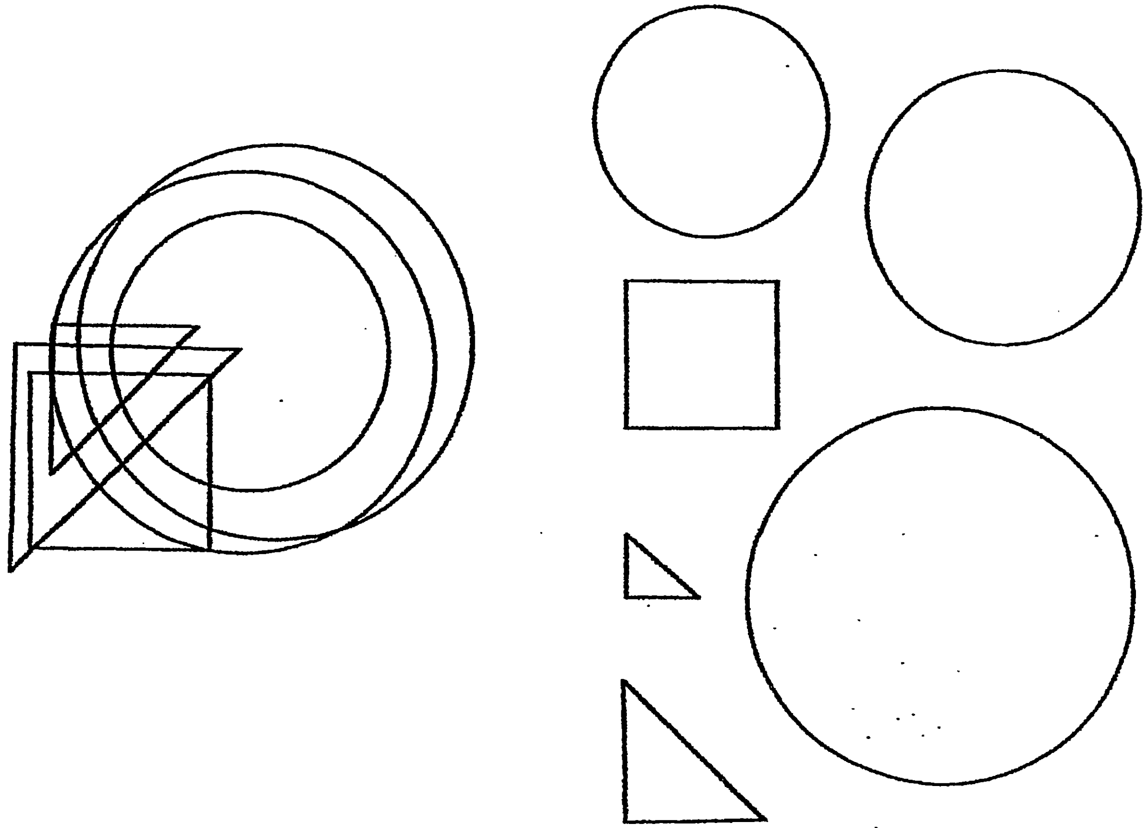
☐ Increased ☐ Decreased ☐ Constant

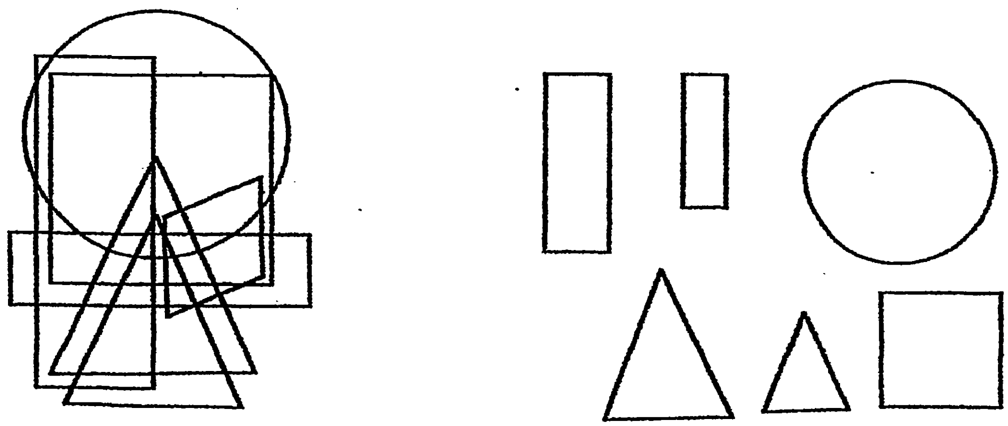
(14) A boat started traveling from Doha harbor sailing east for 10 km. It then changed its direction traveled for 20 km due North. After that, it stopped for about 2 hour. Next the boat sailed to the south and traveled for 30 km before going west for 10 k. Finally. it stopped.

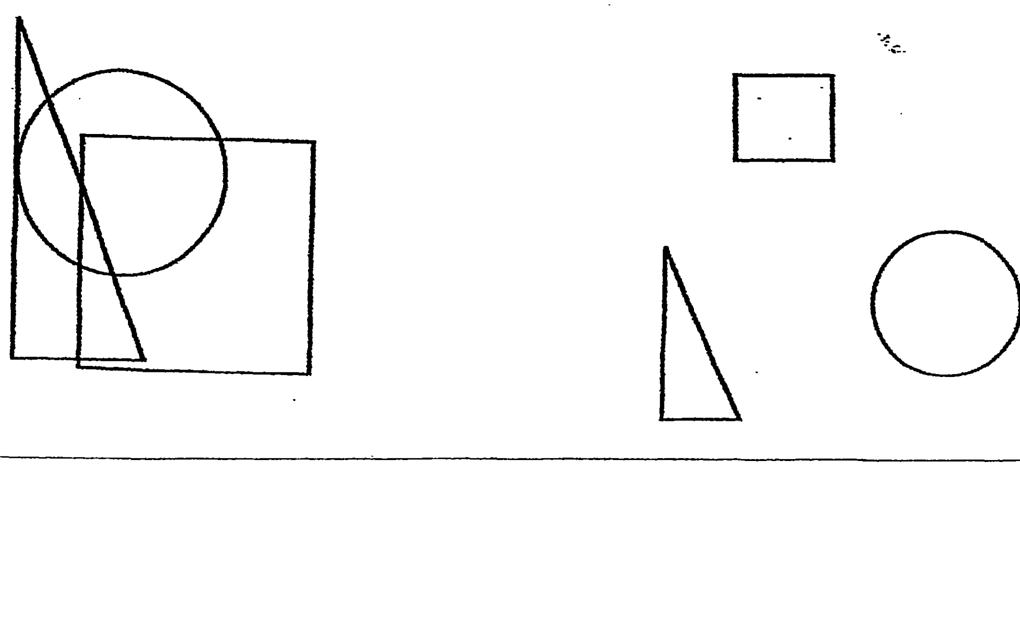
How far was the boat from its starting position? ....

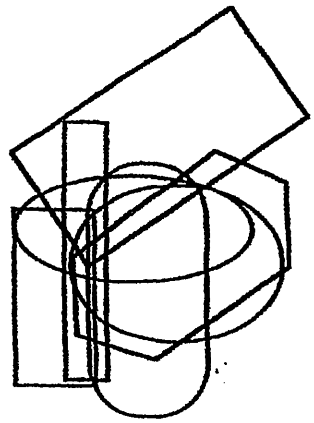
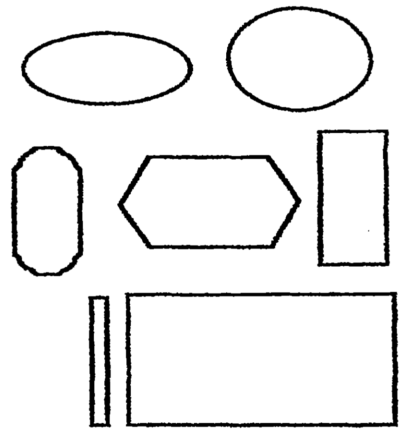
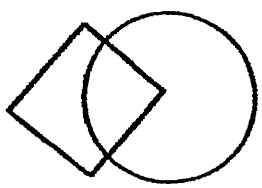
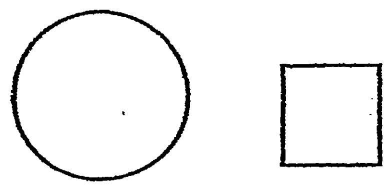
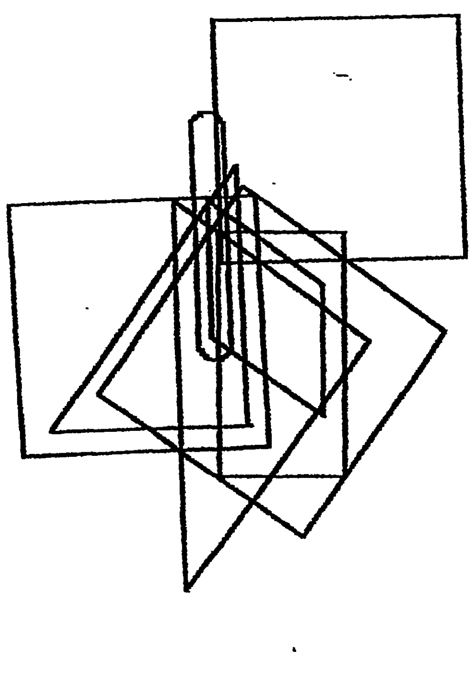
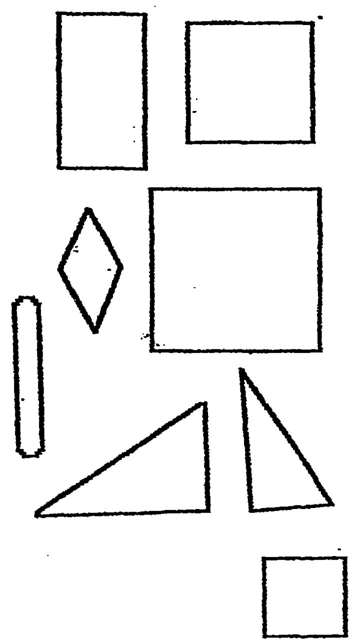
You may use the space below for drawing:

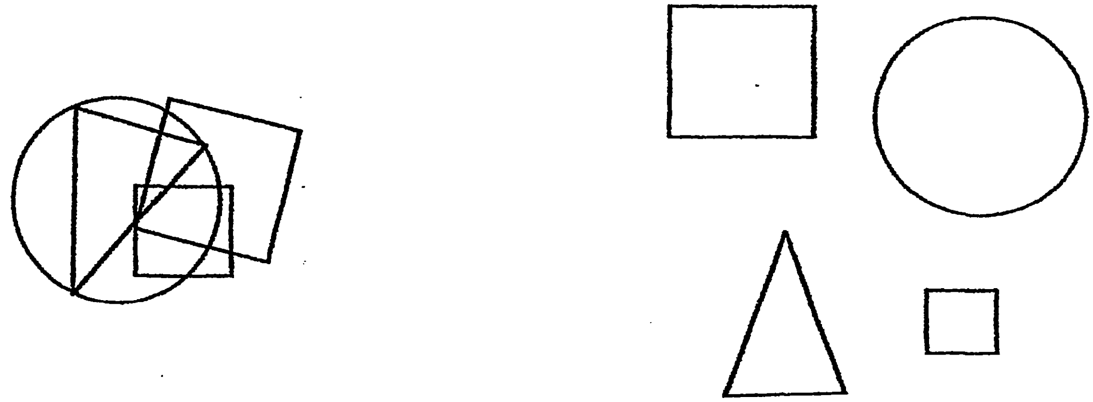
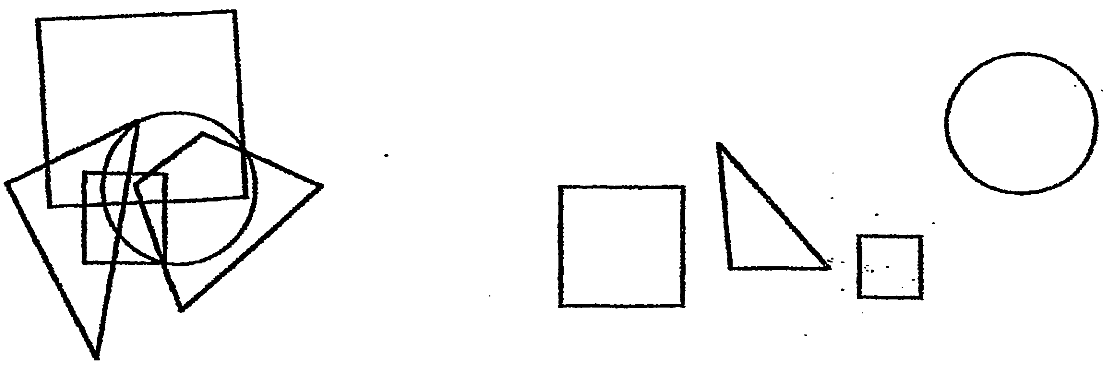
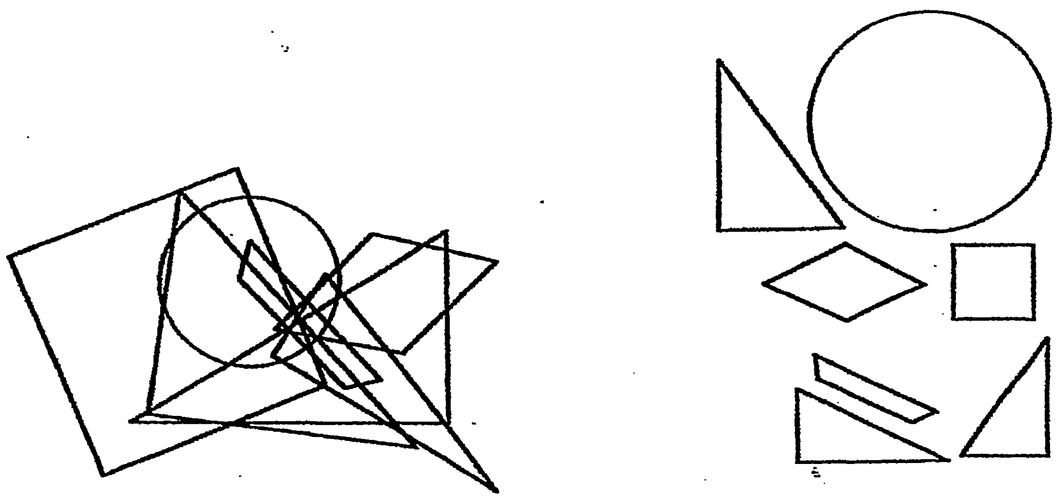
1	
2	
3	
4	

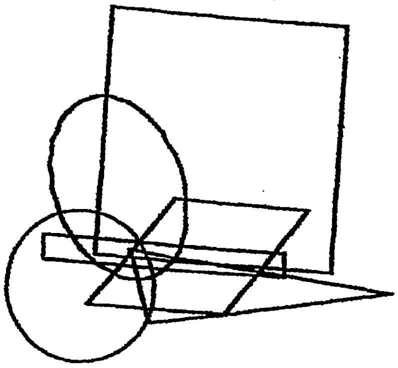
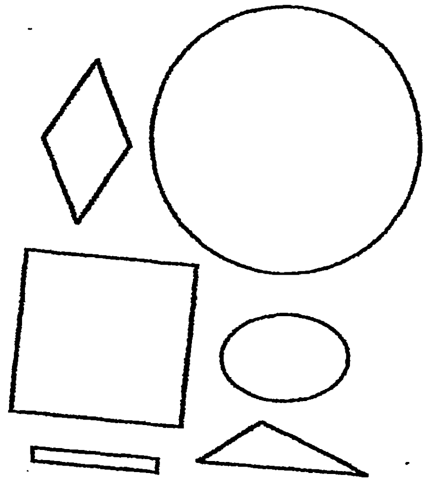
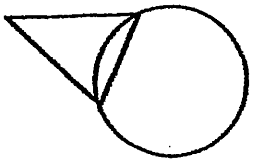
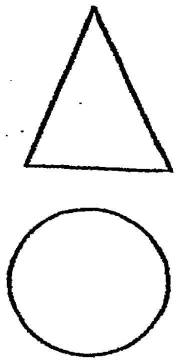
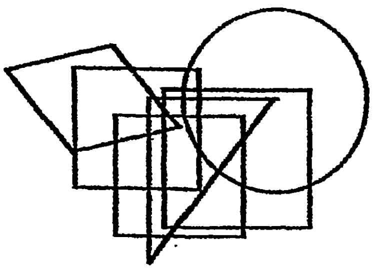
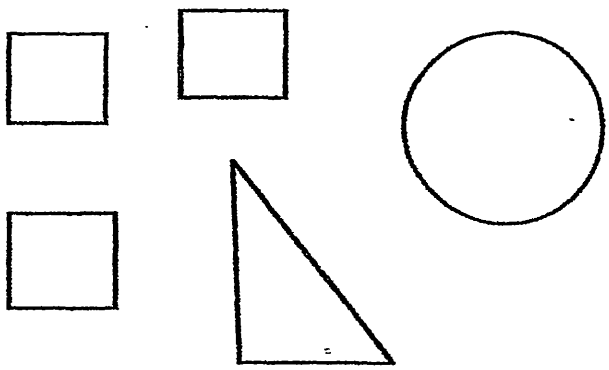
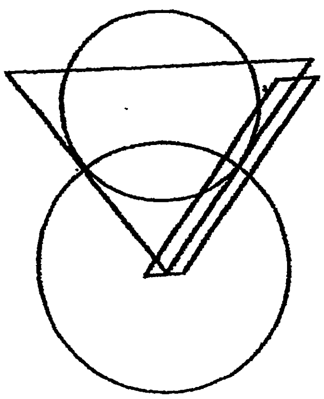
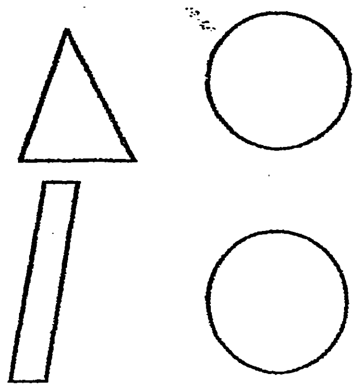
5 

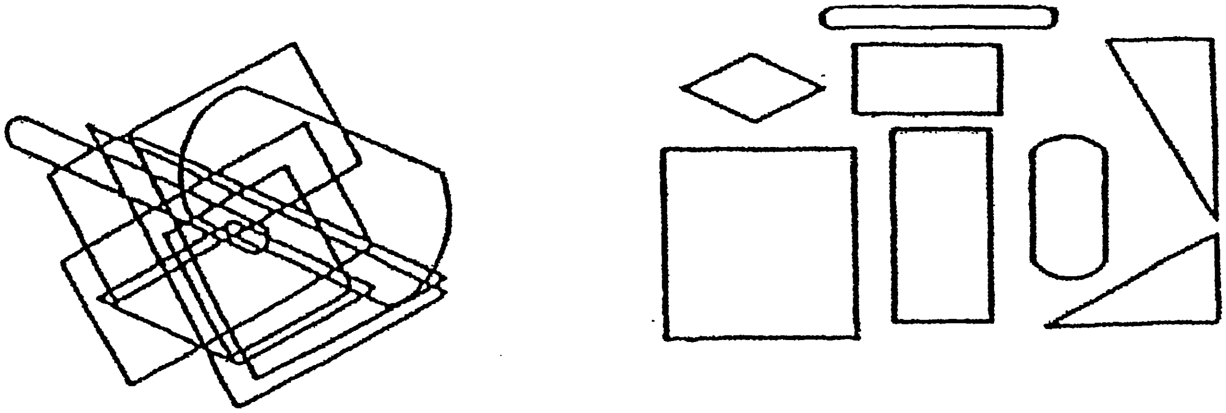
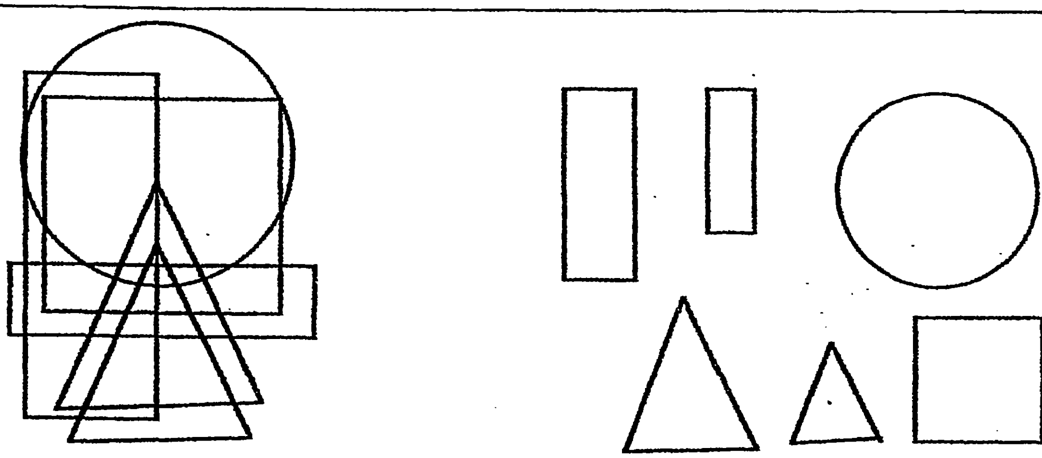
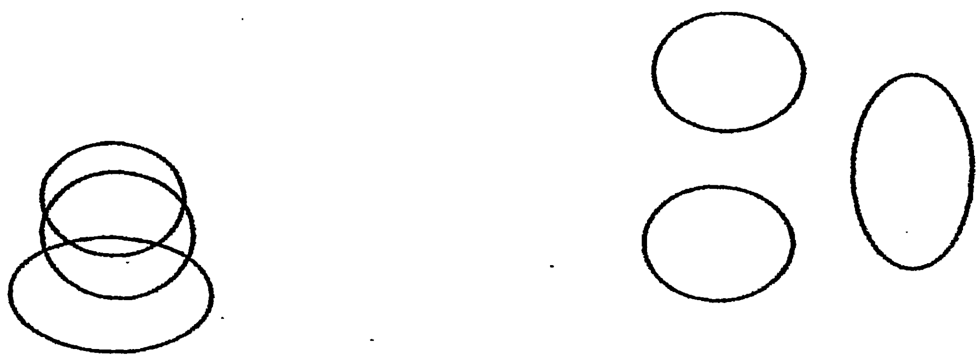
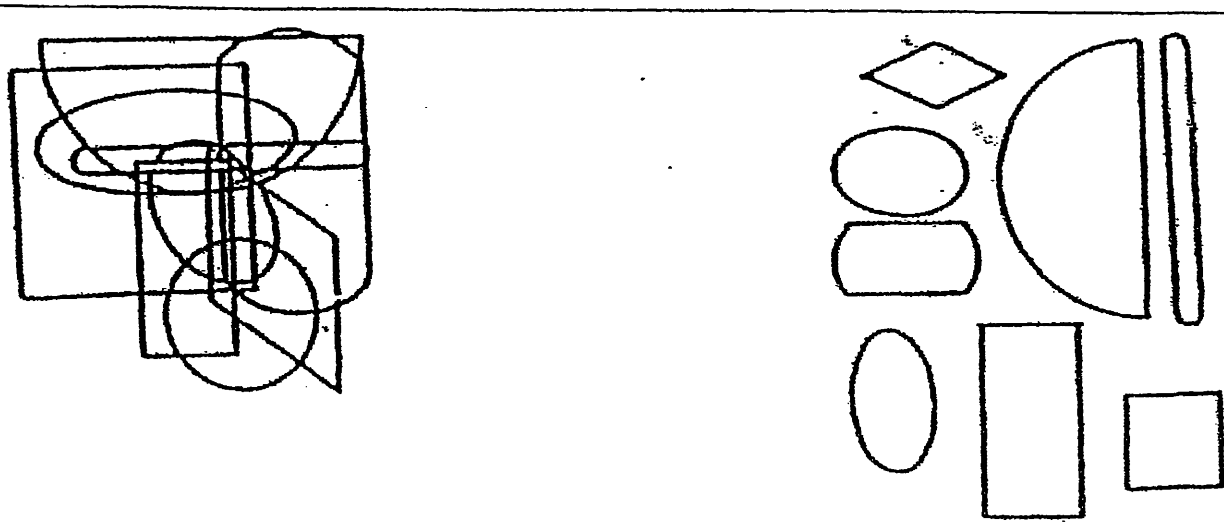
6 

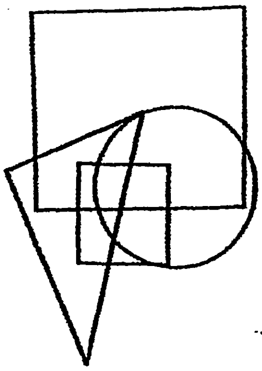
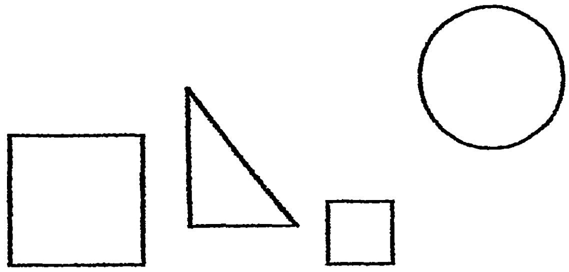
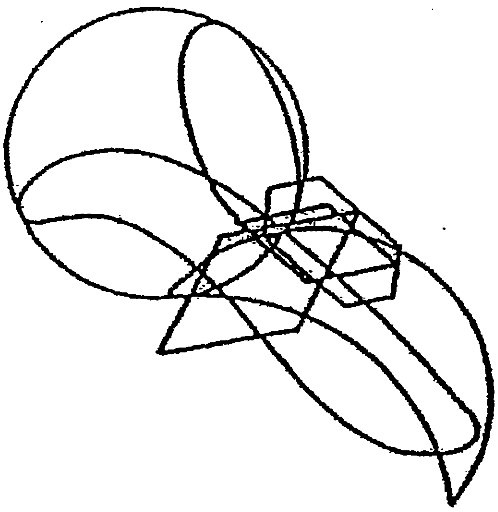
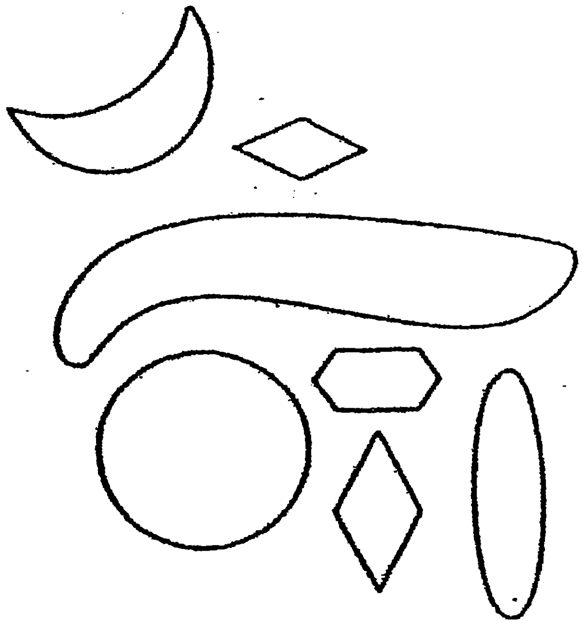
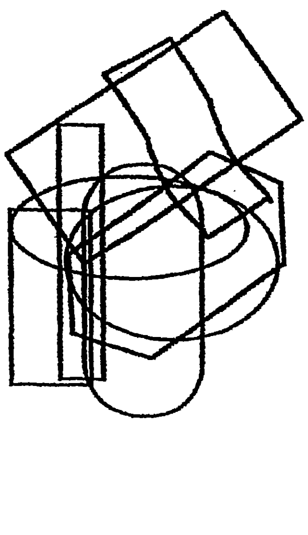
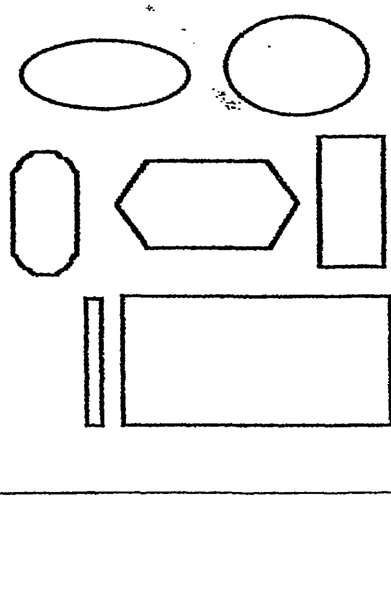
7 

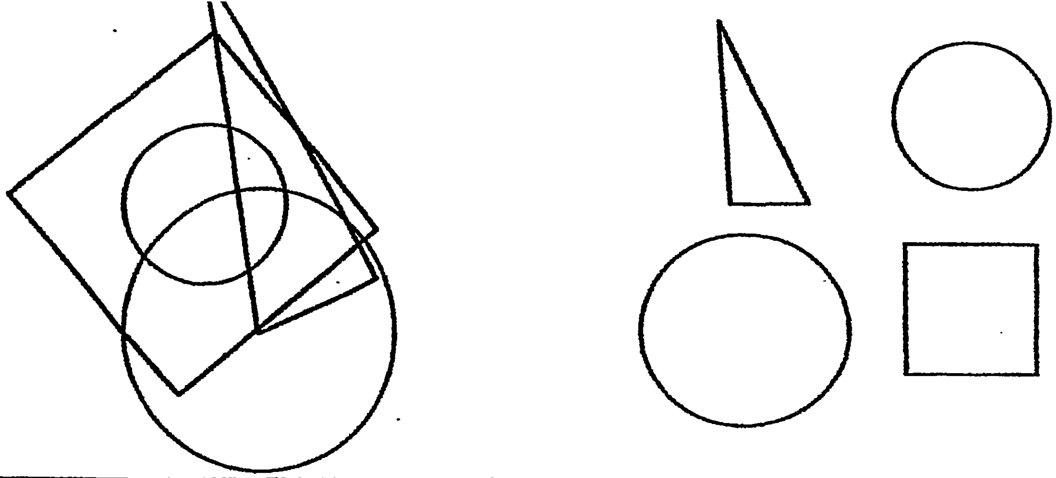
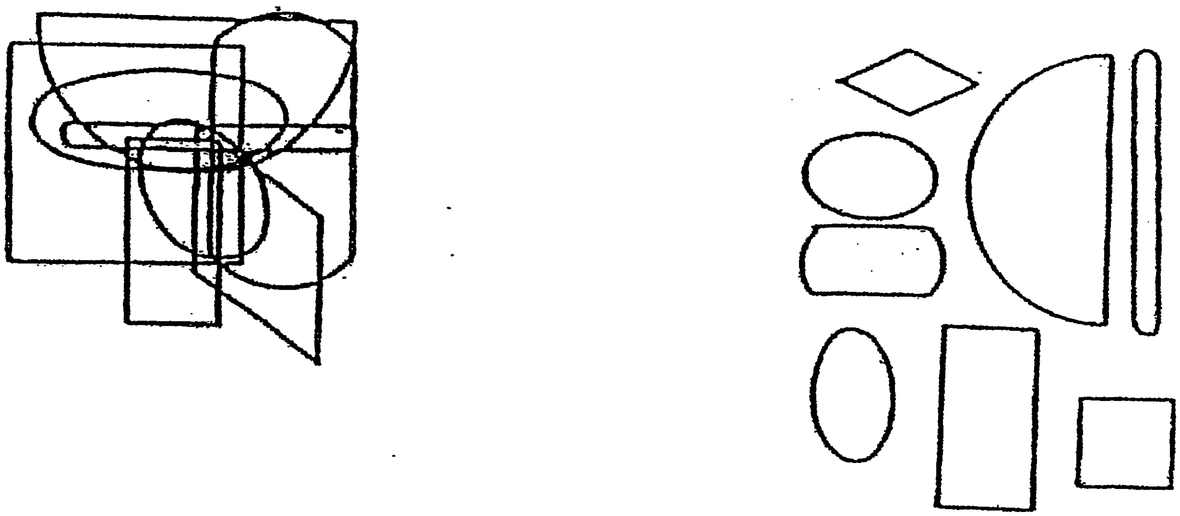
8		
9		
10		

11	
12	
13	
14	

15		
16		
17		
18		

19	
20	
21	
22	

23		
24		
25		

26	
27	
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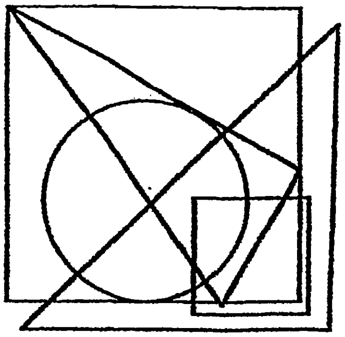
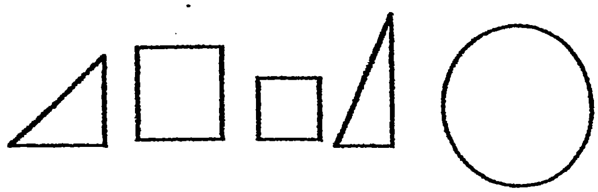
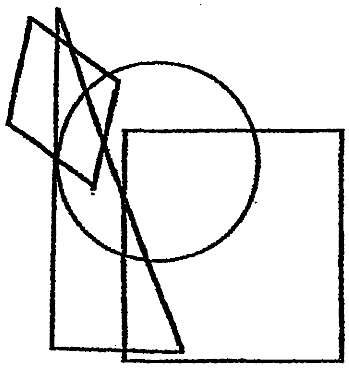
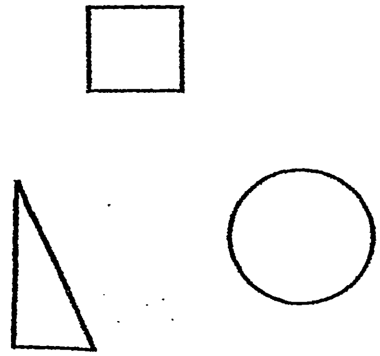
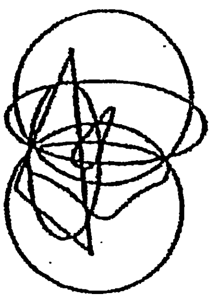
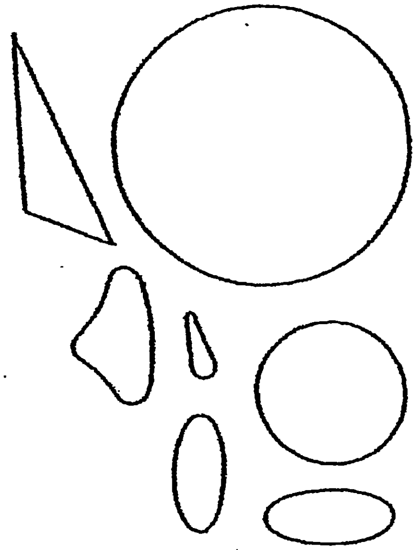
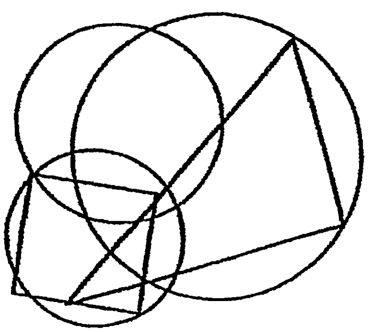
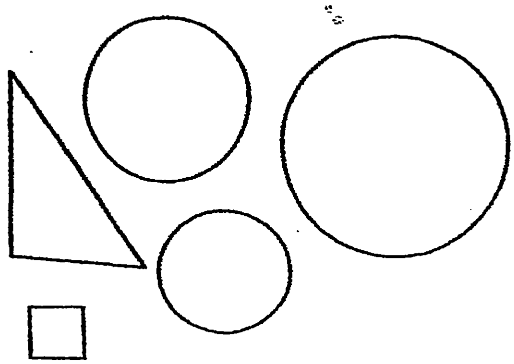
30		
31		
32		
33		

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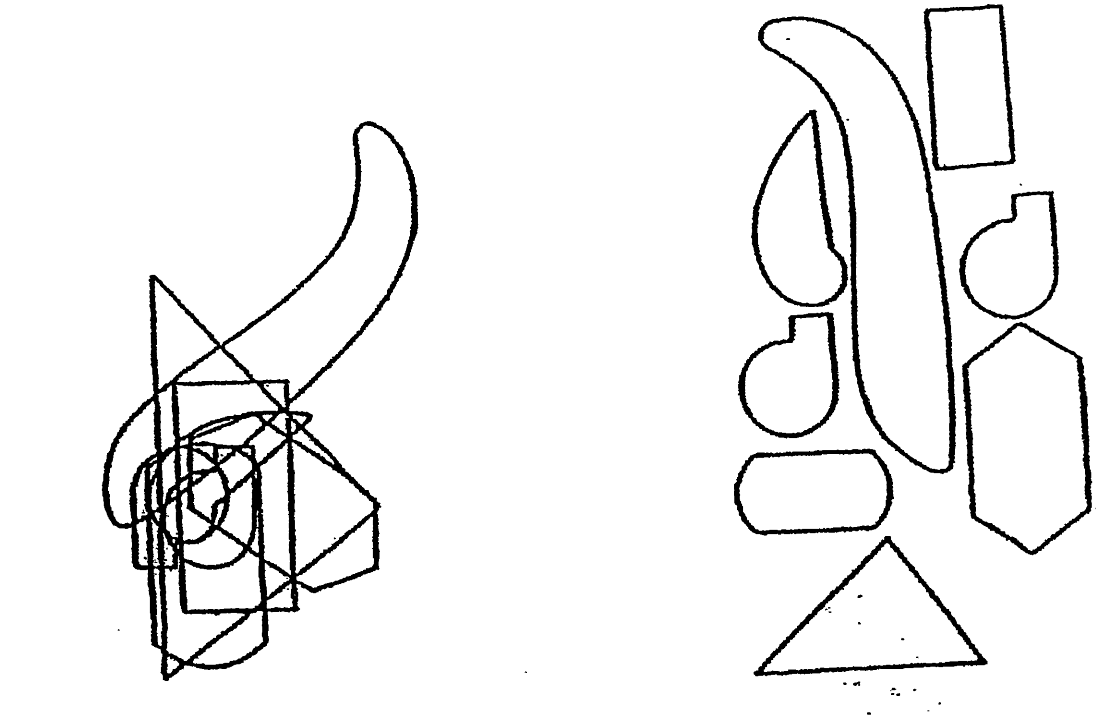

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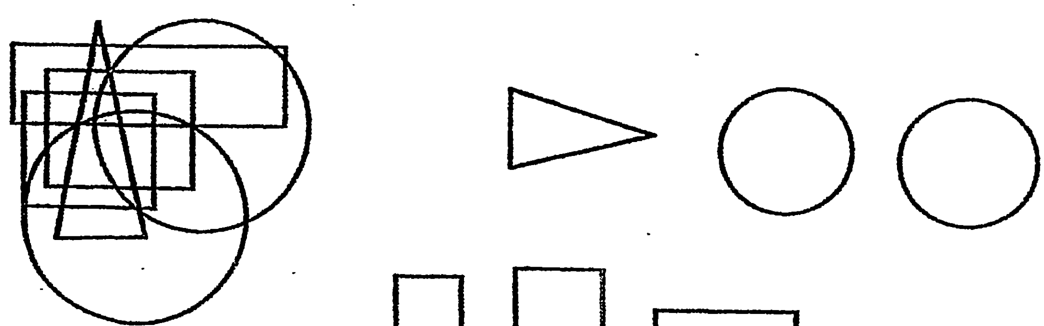

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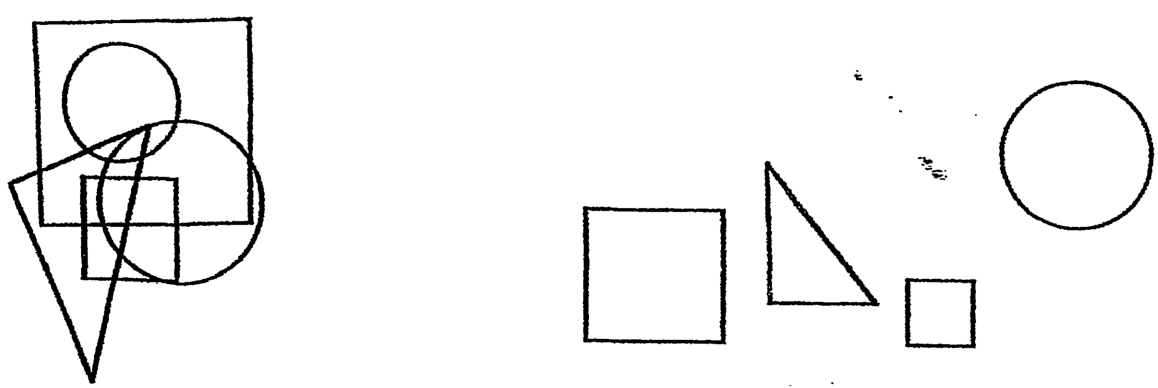

Appendix C

Comparing between the result of mid term test, difficulties and visual spatial test first class/Qatar

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
1	9	22.5	8	20	32
2	8	20	4.5	11.25	47.5
3	5.5	13.75	7	17.5	39.5
4	7	17.5	7.5	18.75	49.5
5	6	15	5.5	13.75	43.5
6	5.5	13.75	5.5	13.75	49
7	6	15	2.5	6.25	32
8	4	10	8.5	21.25	48.5
9	5	12.5	4	10	44
10	5	12.5	3.5	8.75	36
11	9	22.5	5.5	13.75	37.5
12	12	30	8	20	40.5
13	5	12.5	3.5	8.75	27
14	14	35	3.5	8.75	41
15	9	22.5	8.5	21.25	45
16	5	12.5	6.5	16.25	35.5
17	8	20	7	17.5	49
18	8	20	7	17.5	36.5
19	7	17.5	5	12.5	48
20	7	17.5	3.5	8.75	41
21	12	30	12	30	49.5
22	11	27.5	9	22.5	48
23	7.5	18.75	5.5	13.75	36.5
24	6	15	4.5	11.25	41.5
25	6	15	5.5	13.75	41.5
26	8	20	5.5	13.75	33.5
27	8	20	4.5	11.25	33
28	6	15	3.5	8.75	38.5
29	9	22.5	75	187.5	48.5
30	16.5	41.25	7	17.5	49
31	7	17.5	4	10	24
32	5	12.5	4.5	11.25	29.5
33	4	10	5	12.5	39.5
34	6	15	6	15	40
35	7	17.5	4	10	30.5
36	9	22.5	8.5	21.25	48.5
37	6	15	5.5	13.75	43
38	8	20	3.5	8.75	41
39	3	7.5	12.5	31.25	49.5
40	6	15	4	10	28.5
41	4	10	3	7.5	44
42	11	27.5	4.5	11.25	49.5
43	13	32.5	7	17.5	36.5
44	13	32.5	15.5	38.75	50

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
45	7	17.5	6	15	49
46	16.5	41.25	9	22.5	47
47	6	15	8	20	46.5
48	10	25	4.5	11.25	34.5
49	4	10	5	12.5	44.5
50	5	12.5	3	7.5	47
51	11	27.5	10.5	26.25	50
52	5	12.5	2.5	6.25	40.5
53	4	10	6	15	50
54	6	15	2.5	6.25	38.5
55	13	32.5	8.5	21.25	48
56	6	15	7	17.5	49.5
57	7	17.5	4.5	11.25	30
58	6.5	16.25	1	2.5	47
59	16.5	41.25	9	22.5	49.5
60	11.5	28.75	7	17.5	49.5
61	4	10	3	7.5	37
62	8	20	6	15	48
63	9	22.5	6	15	45
64	6	15	1	2.5	38
65	6	15	1.5	3.75	43.5
66	10	25	12	30	50
67	6	15	3.5	8.75	34
68	10	25	4	10	37.5
69	16	40	13	32.5	49.5
70	8	20	6	15	34
71	8	20	5.5	13.75	32.5
72	11	27.5	8	20	31
73	11.5	28.75	5	12.5	47
74	12	30	4	10	
75	15	37.5	12.5	31.25	50
76	7.5	18.75	5	12.5	42.5
77	11	27.5	5.5	13.75	42
78	11	27.5	11	27.5	50
79	11	27.5	7	17.5	34.5
80	6	15	4	10	41
81	6	15	3.5	8.75	39.5
82	9	22.5	7.5	18.75	49.5
83	10	25	8	20	48.5
84	1	2.5	2	5	34.5
85	9	22.5	5.5	13.75	32
86	6	15	1	2.5	43
87	4	10	3	7.5	45
88	10	25	1.5	3.75	43.5
89	4	10	3.5	8.75	50
90	6	15	6	15	45.5
91	2	5	5	12.5	45
92	8	20	6.5	16.25	49
93	12	30	10	25	48.5
94	7	17.5	7.5	18.75	47.5
95	5.5	13.75	2.5	6.25	43.5

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
96	9	22.5	9	22.5	12.5
97	8	20	4	10	34.5
98	10	25	4.5	11.25	36
99	6	15	3.5	8.75	22
100	1	2.5	4.5	11.25	19
101	6	15	6	15	42
102	9	22.5	4	10	41.5
103	6	15	2.5	6.25	45
104	10	25	2	5	33.5
105	6	15	1	2.5	45
106	6	15	3	7.5	33
107	5	12.5	1.5	3.75	
108	6	15	9	22.5	40.5
109	7	17.5	4	10	24
110	7	17.5	6.5	16.25	29
111	7	17.5	6	15	17
112	10	25	4	10	38
113	10	25	8	20	46
114	12	30	5.5	13.75	27.5
115	7	17.5	5.5	13.75	43.5
116	8	20	4.5	11.25	50
117	7	17.5	4.5	11.25	37.5
118	5	12.5	3	7.5	40.5
119	12	30	6.5	16.25	46.5
120	8	20	5.5	13.75	23.5
121	8	20	6.5	16.25	33.5
122	8	20	9	22.5	48
123	7	17.5	5	12.5	36
124	11	27.5	2.5	6.25	37
125	6	15	5.5	13.75	21.5
126	5.5	13.75	3.5	8.75	48
127	8	20	9	22.5	50
128	8	20	3	7.5	29.5
129	5	12.5	5	12.5	23.5
130	8	20	6.5	16.25	46.5
131	4	10	4.5	11.25	37.5
132	8	20	4	10	33
133	8	20	4	10	41.5
134	8	20	6.5	16.25	32.5
135	4	10	1.5	3.75	39.5
136	3	7.5	2.5	6.25	23.5
137	7	17.5	4.5	11.25	33.5
138	4	10	5	12.5	25.5
139	8	20	7	17.5	49.5
140	12	30	2.5	6.25	29
141	7	17.5	4.5	11.25	46.5
142	10	25	7.5	18.75	44.5
143	3	7.5	2	5	29.5
144	5	12.5	3.5	8.75	13
145	2	5	4.5	11.25	28.5
146	7	17.5	1.5	3.75	33.5

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
147	9	22.5	6.5	16.25	49.5
148	8	20	1.5	3.75	33
149	3	7.5	2.5	6.25	39.5
150	13	32.5	6	15	50
151	6	15	2.5	6.25	29
152	13	32.5	3.5	8.75	48.5
153	6.5	16.25	2	5	30.5
154	7	17.5	6	15	44
155	10	25	6.5	16.25	46.5
156	14	35	9	22.5	48
157	9	22.5	13.5	33.75	33.5
158	17	42.5	15	37.5	47
159	7	17.5	7	17.5	27.5
160	7	17.5	11	27.5	29
161	9	22.5	13	32.5	47.5
162	5	12.5	7.5	18.75	27.5
163	8	20	1	2.5	33
164	10.5	26.25	12.5	31.25	40.5
165	8	20	7.5	18.75	36
166	9	22.5	8	20	44
167	13	32.5	9.5	23.75	33
168	6	15	13.5	33.75	49.5
169	14	35	10.5	26.25	28
170	14	35	8.5	21.25	49.5
171	14	35	8	20	15.5
172	3	7.5	5.5	13.75	30.5
173	13	32.5	13.5	33.75	30.5
174	6	15	5.5	13.75	40
175	9	22.5	6.5	16.25	48.5
176	12	30	8.5	21.25	39
177	13	32.5	8.5	21.25	26.5
178	5	12.5	7	17.5	31
179	15	37.5	7	17.5	49.5
180	12	30	8	20	22
181	12	30	8.5	21.25	40.5
182	10	25	8	20	32
183	9	22.5	15.5	38.75	25.5
184	11	27.5	8.5	21.25	41.5
185	9	22.5	5	12.5	18.5
186	8	20	10	25	32
187	17	42.5	10	25	46.5
188	12	30	8.5	21.25	48.5
189	9	22.5	7	17.5	33
190	6	15	16	40	50
191	12	30	9	22.5	49
192	12	30	5	12.5	39.5
193	8	20	3.5	8.75	46
194	6	15	8.5	21.25	23.5
195	7	17.5	7	17.5	45
196	9	22.5	7.5	18.75	41
197	8	20	5	12.5	43

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
198	7	17.5	4	10	37
199	7	17.5	1.5	3.75	28
200	9	22.5	8.5	21.25	38.5
201	5	12.5	1.5	3.75	37
202	6	15	7.5	18.75	41
203	11	27.5	10.5	26.25	23.5
204	7	17.5	6.5	16.25	49
205	10	25	9	22.5	48.5
206	12	30	5.5	13.75	31
207	9	22.5	8	20	33
208	7	17.5	7	17.5	39.5
209	8	20	5.5	13.75	47.5
210	11	27.5	10.5	26.25	43.5
211	5	12.5	9	22.5	49.5
212	10	25	7	17.5	44
213	6	15	5	12.5	24
214	11	27.5	10	25	41.5
215	12	30	8.5	21.25	39
216	5	12.5	4.5	11.25	44
217	6	15	5.5	13.75	32.5
218	7	17.5	4.5	11.25	46.5
219	6	15	2.5	6.25	45.5
220	12	30	4.5	11.25	43
221	10	25	2	5	32
222	4	10	4	10	40.5
223	13	32.5	7	17.5	50
224	4	10	2.5	6.25	19.5
225	3	7.5	4.5	11.25	26
226	8	20	5	12.5	43
227	11	27.5	6	15	45
228	10	25	3	7.5	42
229	5	12.5	4.5	11.25	36
230	4	10	1	2.5	33.5
231	5	12.5	4	10	24
232	7	17.5	1.5	3.75	31
233	11	27.5	6	15	38
234	8	20	7	17.5	25
235	15	37.5	9.5	23.75	50
236	7	17.5	5.5	13.75	23.5
237	4	10	2	5	35.5
238	5	12.5	3	7.5	39.5
239	2	5	2.5	6.25	41.5
240	6	15	3	7.5	32.5
241	5	12.5	3	7.5	24
242	5	12.5	5	12.5	21.5

V.S. m. visual spatial test marks **V.S. m. * 2.5 visual spatial test marks times by 2.5**

Diff.. m. difficulties test marks **Diff.. m.* 2.5 difficulties test marks times by 2.5**

Phy.m. school physics test marks

Comparing between the result of mid term test, difficulties and visual spatial test Second class/Qatar					
No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
1	18	45	10.5	26.25	47.5
2	14	35	14.5	36.25	41
3	17	42.5	16.5	41.25	50
4	15	37.5	11	27.5	36.5
5	11	27.5	5	12.5	46
6	16	40	14.5	36.25	49
7	14	35	14.5	36.25	50
8	19	47.5	13.5	33.75	44
9	15	37.5	13	32.5	48
10	15	37.5	11.5	28.75	42.5
11	15	37.5	15.5	38.75	48.5
12	15	37.5	7.5	18.75	36.5
13	15	37.5	17	42.5	46
14	14	35	12.5	31.25	43.5
15	20	50	14.5	36.25	41
16	15	37.5	15	37.5	45
17	7	17.5	8	20	36.5
18	13	32.5	12.5	31.25	45
19	11	27.5	11.5	28.75	42.5
20	10	25	7.5	18.75	30.5
21	11	27.5	11	27.5	44
22	14	35	4	10	41
23	16	40	7	17.5	48.5
24	17	42.5	13	32.5	44
25	14	35	13.5	33.75	49.5
26	12	30	7	17.5	45.5
27	10	25	11.5	28.75	47.5
28	9	22.5	7.5	18.75	33.5
29	11	27.5	7.5	18.75	34.5
30	11	27.5	10	25	35.5
31	11	27.5	12.5	31.25	39.5
32	6	15	9.5	23.75	21.5
33	5	12.5	8	20	48.5
34	10	25	13	32.5	40.5
35	11	27.5	7	17.5	39
36	13	32.5	8.5	21.25	19
37	12	30	8	20	15.5
38	14	35	6.5	16.25	35
39	11	27.5	13	32.5	20.5
40	9	22.5	4.5	11.25	17.5
41	12	30	13.5	33.75	38.5
42	13	32.5	15	37.5	45
43	12	30	10.5	26.25	30
44	12	30	13	32.5	48

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
45	12	30	5.5	13.75	43
46	10	25	9.5	23.75	31
47	14	35	8.5	21.25	40
48	12	30	4.5	11.25	23.5
49	14	35	11.5	28.75	22.5
50	13	32.5	9.5	23.75	45
51	11	27.5	6	15	40
52	14	35	10	25	48
53	8	20	5	12.5	48.5
54	8	20	7.5	18.75	50
55	12	30	4	10	43
56	10	25	7	17.5	43.5
57	9	22.5	2	5	30
58	6	15	3	7.5	46
59	8	20	2.5	6.25	48
60	8	20	5.5	13.75	49
61	4	10	5.5	5.5	49.5
62	11	27.5	8	20	49
63	12	30	9.5	23.75	44.5
64	7	17.5	5.5	13.75	47
65	13	32.5	6	15	48.5
66	9	22.5	9	22.5	46.5
67	9	22.5	8	20	49.5
68	13	32.5	5	12.5	48.5
69	9	22.5	11.5	28.75	49.5
70	11	27.5	2	5	48
71	10	25	3	7.5	30.5
72	9	22.5	8	20	41
73	9	22.5	6.5	16.25	39.5
74	13	32.5	12.5	31.25	50
75	12	30	7	17.5	30
76	12	30	8.5	21.25	49.5
77	12	30	9.5	23.75	42
78	3	7.5	5	12.5	39
79	8	20	12.5	31.25	36
80	10	25	5.5	13.75	38
81	2	5	5.5	13.75	36.5
82	15	37.5	7	17.5	21.5
83	15	37.5	10	25	45
84	11	27.5	8.5	21.25	42
85	8	20	8.5	21.25	40
86	14	35	7.5	18.75	46.5
87	11	27.5	2	5	42
88	0	0	6	15	49.5
89	7	17.5	2.5	6.25	23.5
90	12	30	6.5	16.25	28
91	3	7.5	6	15	41.5
92	8	20	5	12.5	42
93	14	35	11.5	28.75	47.5
94	8	20	8	20	45.5
95	2	5	7	17.5	38.5
96	9	22.5	4.5	11.25	48

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
97	6	15	4	10	44
98	12	30	14.5	36.25	46.5
99	5	12.5	6.5	16.25	22
100	11	27.5	6	15	37
101	9	22.5	6.5	16.25	48.5
102	11	27.5	11	27.5	39
103	5	12.5	3	7.5	30.5
104	8	20	13.5	33.75	29
105	14	35	16	40	49.5
106	8	20	3	7.5	48
107	7	17.5	8	20	38
108	8	20	9.5	23.75	40.5
109	8	20	8	20	41
110	12	30	15.5	38.75	49.5
111	7.5	18.75	12.5	31.25	49.5
112	15	37.5	15	37.5	46
113	12	30	17.5	43.75	48.5
114	10	25	2	5	43
115	13	32.5	6.5	16.25	35
116	13	32.5	8	20	47
117	10	25	4	10	30
118	9	22.5	4	10	21
119	12	30	6.5	16.25	36.5
120	9	22.5	3	7.5	21.5
121	5	12.5	5	12.5	27.5
122	11	27.5	5	12.5	34.5
123	12	30	10	25	42
124	5	12.5	10.5	26.25	43
125	11	27.5	2.5	6.25	33.5
126	15	37.5	14	35	47.5
127	12	30	6	15	37
128	8	20	2.5	6.25	45.5
129	11	27.5	7.5	18.75	44.5
130	7	17.5	3.5	8.75	46w
131	12	30	5	12.5	42.5
132	10	25	11.5	28.75	50
133	13	32.5	4	10	34
134	20	50	12	30	39.5
135	10	25	2	5	45
136	15	37.5	10.5	26.25	46
137	10	25	8.5	21.25	36
138	10	25	6.5	16.25	46.5
139	15	37.5	11	27.5	49
140	14	35	6.5	16.25	48
141	10	25	6	15	39
142	9	22.5	15	37.5	42.5
143	12	30	11.5	28.75	45.5
144	10	25	7	17.5	44.5
145	9	22.5	7	17.5	44
146	13	32.5	3	7.5	46.5
147	7	17.5	1	2.5	24
148	13	32.5	7.5	18.75	47

No.	V.S. m.	V.S. m. * 2.5	Diff.. m.	Diff.. m.* 2.5	Phy.m.
149	10	25	6	15	34
150	7	17.5	8	20	42
151	7	17.5	3	7.5	36
152	9	22.5	3	7.5	28
153	13	32.5	6.5	16.25	41.5
154	10	25	11	27.5	39

No.	V.S. m.	Phy.m.	Diff. m	Wm
2	35	41	24.5	5
5	27.5	46	8.5	2
6	40	49	24.5	5
7	35	50	24.5	5
9	37.5	48	22	4
11	37.5	48.5	26	5
12	37.5	36.5	12.5	3
13	37.5	46	28.3	6
14	35	43.5	21	4
15	50	41	24	5
16	37.5	45	25	5
17	17.5	36.5	13.5	3
18	32.5	45	21	4
19	27.5	42.5	19.5	4
21	27.5	44	18.5	4
22	35	41	7	1
23	40	48.5	12	2
24	42.5	44	22	4
25	35	49.5	22.5	5
26	30	45.5	12	2
27	25	47.5	19	4
28	22.5	33.5	12.5	3
29	27.5	34.5	12.5	3
51	27.5	40	12	2
52	35	48	17	3
53	20	48.5	9.5	2
54	20	50	13.5	3
55	30	43	7	1
56	25	43.5	12	2
57	22.5	30	3.5	1
58	15	46	5	1
59	20	48	4.5	1
60	20	49	9.5	2
61	10	49.5	9.5	2
62	27.5	49	13.5	3
63	30	44.5	17	3
65	32.5	48.5	10	2
66	22.5	46.5	15	3
67	22.5	49.5	13.5	3
68	32.5	48.5	8.5	2
69	22.5	49.5	19.5	4
70	27.5	48	3.5	1
71	25	30.5	5	1
72	22.5	41	13.5	3
73	22.5	39.5	11	2