AN INVESTIGATION OF THE NATURE, TYPES, AND EFFECTS OF SOME ALTERNATIVE CONCEPTIONS HELD BY GRADE 12 PUPILS IN ELECTROSTATICS IN LUSAKA SECONDARY SCHOOLS.

BY

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DEDICATION

To my father, Field Nsamba, and my mother, Margret Shakola, for their encouragement and support during my school going days. To them I say, "that is the spirit old folks".

To my wife, Agness Bwalya, for the fortitude and patience she showed while I was studying.

To my children, Simon, Subakanya, Field (deceased), Mukanaka (deceased), Maggie, and Janet, all of whom missed parental affection during the course of my studies.

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ABSTRACT

This study investigated the nature, types, trends, patterns, and effects of alternative conceptions held by grade 12 pupils in electrostatics in Lusaka secondary schools.

The study was carried out in three schools in Lusaka; a boys',a girls', and a co-education school. Two groups of pupils in each school were chosen randomly, one to serve as a control and the other as a treatment group. Both groups were first given a pre-test on electrostatics, followed by a tuition period of three months for the treatment group only. At the end of three months, a post test was given to both groups.

The results of the study showed that alternative conceptions in electrostatics are of a certain type, nature, and pattern, and follow a certain trend. Some alternative conceptions were also found to be more persistent and prevalent than others. Uninstructed pupils were found to hold more serious alternative conceptions than instructed ones, showing that instruction is important in the control of alternative conceptions.

Curriculum materials and teachers were cited as not controlling alternative conceptions adequately. Not much attention is paid to listening to pupils' ideas about natural phenomena and correcting these ideas when and where they are at variance with the scientists' ideas.

Teachers and textbooks alike usually ignore the conceptions that pupils come with to a learning situation, and this results in pupils having compartmentalised knowledge; the knowledge they come with from their environment, and the knowledge they learn at school. This usually results in a conflict situation, especially when the two forms of knowledge are at variance with each other and the end result of this process is the development of alternative conceptions about natural phenomena.

It was recommended that teachers should spend more time trying to find out the conceptions their pupils have on each scientific concept before teaching them. This can result in meaningful learning situations for the pupils, in which alternative conceptions can be continuously mitigated against.

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INTRODUCTION

Pupils go to school with their own personal conceptions of the world. Their conceptions of nature are shaped by traditional beliefs, beliefs of their peers and parents, and the way they interpret sensory information from the environment. When they go to school, a new form of knowledge is taught to them; "school knowledge". Vygotsky (1962) agrees with this view and also identifies two sources of knowledge for the individual;- intuitive knowledge and school knowledge. The former, he says, is influenced by language, by culture, and by other individuals. It is the child's own sense making of the environment he observes, tempered and manipulated by his interaction with parents, peers, and television. Its primary characteristic is that it is the child's reality. It is his own belief system. The latter, "school knowledge," is someone else's reality. Its characteristic is authority. It is "science", it is what the book says; or what the teacher says. It is approved by a lot of other people who are usually older and more highly regarded than the child.

According to Pines and West (1983), learners may have the belief that there is 'real knowledge' and 'school knowledge' and very often will avoid integrating them. This, therefore, makes them have compartmentalised knowledge. They learn the school knowledge as a set of symbolic values, and norms, separate from their reality. Often these students know whether to answer a question from one or other of their compartmentalised knowledge.

In school they use 'school knowledge', and with their peers they use their 'real knowledge'. This, therefore, means that the science educator may not easily know which knowledge compartment a pupil is answering questions from, unless he asks for the reasons behind the answers.

The extent to which a student assimilates and accommodates new scientific concepts depends on the degree of integration between the 'real knowledge' and the 'school knowledge'. The process of adapting to new conceptual frameworks can be classified into four situations. The first is a 'conflict situation'. This is a situation where the two types of knowledge are in conflict with each other. Such a situation may be common in Physics where common sense perceptions of the world may be at variance with the scientist's perception of the world (e.g. the concept of the earth going around the sun, when one clearly sees the sun going around the earth everyday).

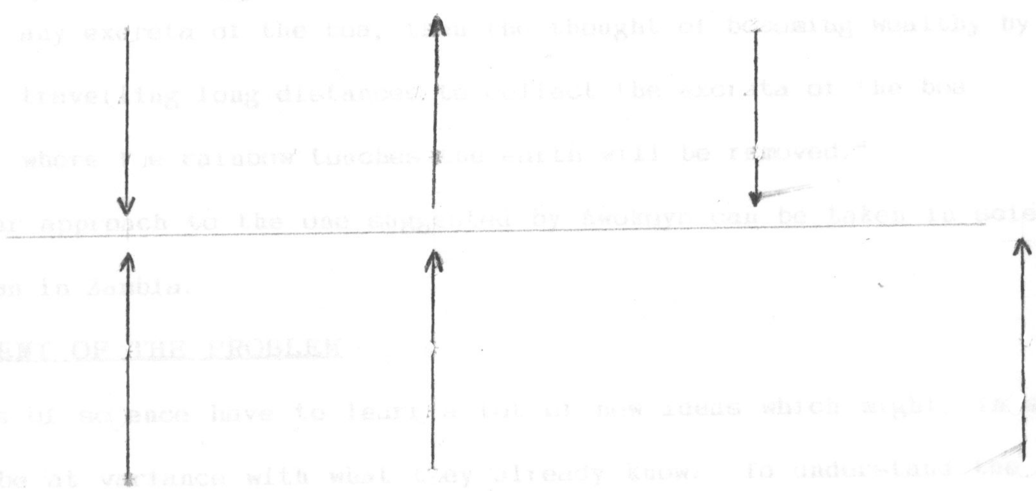
The second is a 'congruent situation'. This is when the student's reality and scientific knowledge can be integrated without any problems. There is no 'reality shock', and no need to abandon old commitments. There is simply an extension, an integration of one's reality into a bigger perspective. In certain topics in Biology, such as plant taxonomy, this may happen. The third is a 'symbolic knowledge' situation. There is hardly any intuitive knowledge to interact with the scientific knowledge.

Some topics such as atomic theory may fall into this category. The fourth case is that of 'un-instructed learning'. This is the case where there is little or no formal science instruction. All the learner's knowledge is based on intuitive learning. The diagram below (Figure 1) shows the four situations that arise:

FIGURE 1:

THE FOUR LEARNING SITUATIONS THAT ARISE WHEN LEARNING SCIENCE:

(After Pines and West, 1983)



Conflict;	Congruent;	Symbolic;	Uninstructed;
e.g. in physics.	e.g. in biology.	e.g. in atomic physics	e.g. fantasy and mysticism.

Alternative conceptions can probably be changed, but first, they have to be identified, and then the approach to them by the science teacher and educator has to be made with great caution and sympathy, so as not to trigger resentment in the learner or his community. Awokoyo (1961,15) writes:

> "A simple plan would be to take the science of things above us, the science of things around us, and then systematically explain off some of the superstitious ideas that people have: For instance, when studying the science of things above us, it is necessary for a rainbow to be demonstrated in the laboratory and for the pupil to produce a rainbow. When they do not find any excreta of the boa, then the thought of becoming wealthy by travelling long distances to collect the excreta of the boa where the rainbow touches the earth will be removed."

A similar approach to the one suggested by Awokoyo can be taken in science education in Zambia.

STATEMENT OF THE PROBLEM

Students of science have to learn a lot of new ideas which might, in some cases, be at variance with what they already know. To understand the new concepts, the students create conceptual frameworks to interpret their perceptions of nature. When these conceptual frameworks they create are at variance with the scientists' interpretation of nature, they are called alternative conceptions, alternative frameworks, misconceptions, or preconceptions.

The purpose of this study was to investigate the nature and effects of alternative conceptions held by grade twelve pupils in electrostatics in Lusaka secondary schools. Specifically the study was an attempt to investigate the following questions:

1. What is the nature of alternative conceptions possessed by students in electrostatics?
2. What are the types of alternative conceptions present?
3. How do students reason when using their alternative conceptions to interpret natural phenomena?
4. Do the types of alternative conceptions in electrostatics follow a certain pattern?
5. What is the effect of instruction in mitigating against alternative conceptions in electrostatics?
6. Do similar types of instruction control alternative conceptions similary in boys and girls?

RATIONALE AND SIGNIFICANCE OF THE STUDY

The way students understand the nature and role of scientific concepts is an important aspect of science education. A study of the alternative conceptions learners come with to the classroom and their effect on learning can, therefore, help science educators appreciate the difficulties students have in understanding scientific concepts (Gowin,1981: Novak,1977).

Identification of the alternative conceptions learners come with can enable the learner and the teacher to have a logical starting point in pedagogy. After all the most important single factor influencing learning is what the learner already knows. If this is properly ascertained, then the learner can be taught accordingly (Ausubel,1968,1978). The unlearning of alternative conceptions might well prove to be the most determinative single factor in the acquisition and retention of subject matter knowledge (Ausubel,1978).

An understanding of the concept of charges and their properties by a pupil can result in a better understanding of an entire class of topics in science, for example, electronics, computer science, solid state physics, quantum theory, nuclear physics, and chemistry. The senior secondary school science syllabus in addition has a lot of topics whose understanding depends on an intimate knowledge of electrostatics. A study of the alternative conceptions associated with electric charges is therefore important.

A Zambian case study on alternative conceptions has not yet been conducted and it is therefore necessary to carry out one since this can enable researchers to compare the Zambian findings with those obtained from other countries. Such a comparison can show whether alternative conceptions in science are cultural universals or are merely isolated pecularities that differ from one society to another.

LIMITATIONS OF THE STUDY.

Three limitations of this study were identified; these were the size of the sample, the geographical distribution of the sample, and the length of time in which the study was carried out.

Relatively few students were used in this study, the total number being one hundred and sixty four. For a study of this type in which it may be necessary to make a generalisation concerning the entire population of students in Zambia a much larger sample than the one used could have been needed for this study. It was however difficult to carry out such a large scale operation due to the limited time in which this study was to be done. It was for the same reason that the sample was selected from only one city, hence introducing another limitation - that of geographical distribution.

The results obtained may therefore be applicable only to the city where the study was carried out. The length of time in which the study was carried out was a third limitation. A study of this type would normally require a long time to yield results which are very dependable. A longitudinal study that would follow pupils conceptions about natural phenomena over several years from kindergarten to college would definitely be better. In spite of these limitations, however, the results of this study would still be quite informative, although in a somewhat limited way.

Other researchers in the same area would probably find the information quite useful and could use it as a basis for further research.

DEFINITIONS OF TERMS.

In this study the following terms will be understood to mean the following:

Alternative conception will refer to an unacceptable but not necessarily 'wrong' interpretation of a concept illustrated in the statement in which the concept is embedded. The terms misconception, preconception, and alternative framework are sometimes taken to mean the same thing as alternative conception, and may be used interchangeably in this study.

Aristotelian ideas will refer to those ideas which are non-Newtonian and are related to the common-sense interpretations of natural phenomena. The idea, for example, that the sun revolves around the earth is an Aristotelian idea because it is based on a common sense interpretation of natural phenomena.

An electric charge will refer to any elementary particle capable of creating an electric current when it moves. It can have a positive or a negative sign. The study of charges is refered to as electrostatics or static electricity.

CHAPTER TWO

REVIEW OF RELATED LITERATURE.

Evidence that people have intuitive ideas about natural phenomena abound in literature. Zambian oral literature gives several examples where interpretation of natural phenomena leads to possession of alternative conceptions. For example a rainbow is interpreted as a snake hanging in the sky, and lightning as a goat or a sheep that falls from the sky to wreck vegeance on earth.

Several studies have been done on alternative conceptions in many parts of the world. These studies are examined in this section in such a way as to inform the present study on the importance and significance of alternative conceptions in science education.

Ivowi (1983), in a Nigerian study, and Helm (1980) in a South African study, examined critically the answer scripts of 'O' level final examinations in physics.

They discovered that alternative conceptions cover a number of concepts in physics and are extremely widespread among students. They also found that similar alternative conceptions occur in all 'O' level physics examinations every year.

Inadequacies in human and material resources were cited as possible causes of the alternative conceptions.

An articulated effort in in-service teacher training programmes, text book production, and equipping physics laboratories , were suggested as solutions that could control the alternative conceptions. These findings seem to suggest that alternative conceptions should be expected wherever there are inadequecies in human and material resources in the teaching of science, such as in Zambia. This, therefore, lends more credence to the need for a Zambian case study.

Kass and Lambert (1983), in a Canadian study, investigated alternative conceptions pertaining to Newton's first and second laws of motion. Forty grade ten beginning students of physics were randomly selected from classes in four high schools. Each student was presented with four tasks in an individual interview setting; horizontal motion along a groove, inertia of a ball in a cart, inertia in space, and acceleration produced by a constant force. Protocol analysis revealed that only approximately one-third of the students expressed conservation of motion or perception of motion relative to an external reference frame. The others exhibited alternative conceptions that reflected Aristotelian ideas. Gravity was used to explain the inertia of a stationary or a moving body in nearly half the instances. The vertical force of gravity was also thought to retard horizontal motion. While girls performed at a significantly lower level than boys on each task, they scored significantly better in end of term tests but not on the concept related criterion test.

This study by Kass and Lambert showed that alternative conceptions also pervade the area of mechanics, an important branch of physics.

Goldberg et. al.(1983) reported an investigation in the area of optics among first year students at Washington University. A sample of ninety students enrolled in both the algebra and calculus based introductory level college physics courses was taken. About half of the subjects had already studied the material in class. They represented the 'post' subjects. The other half, representing the 'pre' subjects had not studied the material in their college physics classes. However, most of them were somewhat familiar with the ideas from either life experiences or from a previous high school physics course. The method of 'individual demonstration interview' was used. Five tasks were **administered** to them individually, and involved the formation of images by plane mirrors and converging lenses. Students' perfomance revealed a number of commonly held alternative conceptions. These are summarised below:

1. Images are seen along one's line of sight.
2. How much of one's body one sees in a mirror depends on one's distance from the mirror.
3. Light from an object can go straight to a screen and form an image on the screen without the presence of a lens.
4. The two special rays, the one leaving the top of the object and travelling parallel to the principal axis, and the one passing through the center of the lens are necessary (and not merely sufficient) to form the entire image on the screen (post students only).

These results from Goldberg's study seem to suggest that when confronted with a task involving manipulation of a physical apparatus, a judgement or prediction about a physical phenomena, students often give responses that are in conflict with the principles of physics.

Hoz and Gorodetsky (1983) investigated the effects of some alternative conceptions of 'speed' and 'time' on the solution of 'velocity problems' in kinematics among high school students in Israel. They found the following alternative conceptions:

1. Speed is an extensive rather than an intensive quantity.
2. Time is not a mediator in situations that involve speed.
3. Replacement of the existing three concept relationship:

   $$ds = v\,dt$$

   (where 'ds' is the differential change in the displacement of a body, 'v', the velocity of the body, and 'dt' the differential change in time).

   by a two-concept direct and inverse (not strictly proportional) relationship.
4. Non-recognition of the distinction between local and global features of concepts and their relationships.

Hoz' and Gorodetsky's findings suggest that some alternative conceptions are caused by misunderstanding of physics concepts in problem situations.

These alternative conceptions may be caused by rote learning of physics materials, without fully understanding the meaning and structure of concepts involved.

Anderson et.al.(1982) carried out a study to determine conceptions of physical and chemical phenomena held by students in grades seven to nine. Children were given a problem to solve and asked their reasoning while they worked on the problem. Results indicated that:

a). Children have intuitive everyday conceptions of physical and chemical phenomena, such as electricity, heat, light, and chemical reactions, before they receive instruction about them.

b). These everyday conceptions can be categorised.

c). Everyday conceptions within a particular field are not predictable but have to be discovered, and each field, therefore, has to be studied separately.

d). Everyday conceptions disrupt and impede the learning of the more adequate concepts contained in school courses.

e). Teachers are little acquainted with these everyday conceptions and their importance for learning.

f). The effect of school instruction in improving children's scientific thinking is not very large.

Anderson's study suggests that alternative conceptions in science are wide ranging and are found not only in physics but also in chemistry. His finding which says that types of alternative conceptions are not predictable phenomena but have to be studied separately is very important.

The finding shows that for every topic in science, a separate study of the alternative conceptions found there should be done.

In a study on alternative conceptions associated with chemical equilibrium, Wheeler and Kass (1978), found six major alternative conceptions among twelfth grade chemistry students. These were; the inability to distinguish between how fast a reaction proceeds (rate), and how far (extent) the reaction goes; uncertainty as to whether the equilibrium constant is in fact a constant; inappropriate use of le Chatelier's principle; and inability to consider all possible factors affecting the equilibrium condition of a chemical system. These findings by Wheeler and Kass imply that when mathematical concepts, like differentiation, intergration, and manipulation of units in algebraic expressions in order to deduce whether the expression reduces to a constant or not, are used to explain phenomena in science, then difficulties in understanding arise and these may develop into alternative conceptions.

In a study to survey the nature of some high school children's understanding of the mole concept in Israel, Novick and Menis (1976) discovered that nearly all children in the sample exhibited an overall poor understanding of the mole concept.

Basically, three main alternative conceptions were identified:

a) The mole is a certain mass and not a certain number.

b) The mole is a certain number of particles of gas.

c) The mole is a property of a molecule.

The authors go on to suggest that a simpler and less involved development of the mole concept in the early part of a chemistry course would be less confusing to most students.

Duncan and Johnson (1973) also found that a very high number of Scottish secondary school children had difficulty in understanding the "mole" and using it in chemical calculations. According to these researchers, the difficuly in teaching the mole concept seems to be:

a). Overcoming the misapprehension that one mole of a compound always reacts with one mole of another regardless of the stoichiometry of the reaction.

b). Balancing equations.

c). Manipulation of the molarity of solutions.

Research on alternative conceptions in electricity has shown that there is considerable confusion on the meaning of common electrical terms like "voltage" and "power" (Russel,1980; Osborne,1981). Instruction in electricity and magnetism also frequently fails to provide students with the ability to reason effectively about electric circuits (Steinberg,1983). The general alternative conceptions are that:

a). When an electric current 'flows' then 'voltage' should be present, and when current is interrupted the voltage disappears.

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

There is also a recurring problem in that both teachers and authors of most school textbooks discuss current 'flow' rather than a flow of charge or electrons.

Alternative conceptions have also been studied in the biological sciences. Fisher (1983) found out that many students believe that amino acids are produced by genetic translation. The concept of osmosis is not also well understood by many. Some students and teachers still view osmotic pressure as arising from a molecular bombardment process (Murray,1983). The theory of evolution also creates a lot of problems to many students. Deadman (1976) reported that children had a firm idea of genetics as the transmission of hereditary characteristics from one generation to another, but beyond that, their understanding was poor. They also tended to use genetics concepts or labels without knowing what these concepts meant.

In another study, Deadman and Kelly, (1978), discovered two major difficulties that are likely to be met when teaching evolution and heredity to young children. These were that children tended to resist explanations of a probabilistic nature, and that they tended to give naturalistic and Lamarkian interpretations of the concepts. Naturalistic and Lamarkian concepts are those that arise intuitively because of a young person's anthropocentric view of the world. Evolutionary changes are conceived as occuring within individual organisms, rather than between generations of organisms.

Some studies have shown that many students do not have a complete understanding of the concept of photosynthesis (Smith and Anderson,1984). Wandersee (1983) studied four aspects of the concept of photosynthesis; the basic function of soil in plant growth, the basic role of photosynthesis in the carbon cycle, the basic roles of the leaf and light energy in photosynthesis, and the primary source of food. Students in grades five, eight, eleven, and fourteen, or at college level were found to harbour alternative conceptions, in varying degrees, on all aspects of the study. Generally, students in lower grades harboured more alternative conceptions than those in higher grades. Some of the alternative conceptions identified were that; the soil loses weight as plants grow in it; the soil is the plants' food; plants eat minerals; roots absorb the soil; plants get vitamins from the soil; plants give off mainly carbon dioxide; water vapour moves into the leaf during photosynthesis; chlorophyll is the plant's blood; plants get their food from the roots and store it in their leaves; trees sleep in winter; leaves change colour because they cannot breathe (just like a person's face does); people put food (fertilizer) in the soil for plants to eat; and that plants produce protein during photosynthesis.

It appears then, that alternative conceptions are found in all the areas of science, in the physical sciences and also in the biological sciences. What circumstances then, lead to such a widespread phenomena? Some alternative conceptions actually result from tuition at elementary and secondary school levels.

Chibesakunda (1984) reported that untrained teachers at primary schools may contribute to the poor teaching of science at that level. He maintained that the untrained teachers may have little or no knowledge of primary school science, and therefore, may retard progress in science learning. Some alternative conceptions may originate from the language and Aristotelian views of a student. Case (1969) pointed out that Bantu languages, as well as most other languages, seemed to be deficient in scientifically precise words. There are no equivalents, for example, in Bantu languages for words such as 'electron', 'charge', 'atom', 'magnet', and 'ion', to name, but a few. Certain alternative conceptions absent from a learner's language may be implanted by the teacher in his attempt to translate certain concepts into the student's local language (Soyibo,1981). In the Zambian case, for example, the expression 'dry Leclanche cell' is translated as "LIBWE" into most dialects. This term "LIBWE" if translated back into English or any other non-Bantu language translates as "stone", and hence may create alternative conceptions on the nature of a Leclanche cell. In the Tonga dialect of Zambia, the word for fertilizer, "BUDO-DODO" can also mean 'vitamins', and 'very appetising food'. A Tonga speaking science student may therefore easily mistake vitamins as being the same thing as fertilizers. Strevens (1976) maintains that a language without equivalents for particular scientific terms is one spoken by people who do not as yet possess a sizeable group of science users, even though such a society may engage in scientific activity. Strevens' claim may actually apply in most countries of the world, Zambia inclusive, where there is a second language interferance in learning science.

Educational psychologists maintain that the internalization of new information by a learner depends on the learner's existing cognitive structure (Piaget and Inhelder,1969). The prior experiences of pupils are generally believed to be pre-requisites to effective teaching and learning of new material. When a pupil employs his alternative framework to interpret a natural phenomena, he is likely to assign it a meaning which is different from or even at variance with what the teacher originally intended to mean. Nussbaum and Novick (1981) postulated that it may be possible for the learner to be ignorant of this disparity and may genuinely think that he has correctly interpreted his teacher's instructions. The teacher frequently attributes the pupils' misrepresentation of facts given in a lesson to a lack of understanding. Nussbaum and Novick, however, feel that it is not a matter of the pupil not understanding but of his understanding differently what was intended.

Garone (1960) pointed out that alternative conceptions could be traced to improper reliance on common sense and to the misinterpretation of one's experiences. Zairour (1975) emphasizes that it requires very thorough teaching to make pupils detach themselves totally from beliefs that appear to be backed by common sense.

This study falls within the theoretical framework that focusses on the interaction between new and existing knowledge. Philosophically, it can come under realism, pragmatism, and the educational theory of social reconstructionism. Existing knowledge under this theoretical framework is said to change, and is in turn changed by new events and experiences.

This theoretical framework is sometimes known as the cognitive account in psychology.

It will now be necessary to explain the different views of the nature of science in order to elucidate clearly which teaching methods may lead to alternative conceptions, and which ones may mitigate against them.

The most simplistic view of the scientific enterprise is, perhaps, the empiricist's view, which holds that all knowledge is based on observation. Scientific laws are reached by a process of induction from the 'facts' of sense data. Taking this view of science, observations are objective and facts immutable. Also, such a position asserts that science will produce a steady growth in knowledge. This position, also known as inductivism was first suggested by Bacon (Driver,1986). This approach, although originally criticised when it first appeared, has reasserted itself this century in the heuristic movement and in some of the naive interpretations of the discovery method adopted by the Nuffield science schemes. Discovery methods in science teaching put pupils in the role of investigator, giving them opportunities to perfom experiments and test ideas for themselves. What actually happens in classrooms when this approach is used? Kuhn (1963), in his work, indicated that once a scientific theory or paradigm becomes established, scientists as a community are slow to change their thinking. Pupils like scientists, view the world through the spectacles of their own alternative conceptions, and many have difficulty in making the journey from their own intuitions to the ideas presented in science lessons.

The heuristic method, which is concerned with allowing children to experience something of the excitement of science - 'to be a scientist for a day', has certain pitfalls when it is put into practice in classrooms and laboratories. Secondary school pupils are quick to recognise the rules of the game when they ask: 'Is this what was supposed to happen? 'or 'Have I got the right answer ?' (Driver,1975, Wellington,1981). The approach is associated with intellectual dishonesty, since two outcomes, which are possibly incompatible, are expected from pupils' laboratory activities. On the one hand pupils are expected to explore a phenomenon for themselves, collect data and make inferences based on it; on the other hand this process is intended to lead to the currently acceptable scientific law or principle. Children may easily fail to abstract and understand these principles from experiments, and this may easily be interpreted as the children's error either for not observing accurately or not thinking logically about the pattern in the results. The inductivist method may therefore be fallacious.

Another view of science is the constructivist or hypothetical-deductive paradigm. In this view, theories are not related by induction to sense data, but are constructions of the human mind whose link with the world of experience comes through the processes by which they are tested and evaluated (Driver,1986). Science is seen as a cooperative exercise, and from a sociological perspective the criteria for the acceptance of a scientific theory is that it has been scrutinized and approved by the community of scientists (Polanyi,1958). It follows from the constructivist philosophy of science that theory is not related in a deductive, and hence unique, way to observations; there can be multiple explanations of events which account for the data. This view of science was subscribed to by Popper (1965). If children are to develop an understanding of the conventional concepts and principles of science, more is required than simply providing practical experiences. The theoretical models and scientific conventions will not be 'discovered' by children through their work. They need to be presented. Guidance is then needed to help children assimilate their practical experiences into what is possibly a new way of thinking about them. Paradigm shifts in children's thinking can therefore come about only through guidance, and finding out what the pupil already knows.

A third view of science is called conventionalism. In this view human brains created or invented certain beautiful structures called laws of nature and then devised special ways, called experiments, of selecting sensory input data so that they would fit into the patterns ordained by the laws. In the conventionalist view, the scientist was like a creative artist, working not with paint or marble but with the unorganized sensations from a chaotic world. Scientific philosophers supporting this position included Poincare (1952),Duhem (1954), and Eddington (1958). From a pupil's point of view, it would be very difficult to learn science using the convetionalist method, since the pupil's mind will have different logical structures from those of scientists, and the result can only be alternative conceptions.

In conclusion it may be said that the literature reviewed here indicates that alternative conceptions permeate all the natural sciences, and the specific way in which they occur can not be predicted but investigated separately. The literature has also shown that these alternative conceptions are tenacious, and impede learning of scientific concepts. Aristotelian ideas based on common sense interpretations of nature, second language interferance, teachers teaching out of licence (unqualified science teachers), and unsuitable textbooks and teachers who do not try to find out what the student already knows before teaching him new information, have all been cited as possible causes of alternative conceptions, amongst others of course. A knowledge of common alternative conceptions related to scientific phenomena can be of extreme value to curriculum developers, science educators and classroom teachers, since this knowledge enables them to know where the learner is (Doran,1972).

CHAPTER THREE

METHOD

This chapter describes the methodology of the study. It deals with how the study was designed and carried out, how the sample was selected, the research instruments used, and how the data was collected.

SELECTION OF THE SAMPLE.

The study was carried out in three secondary schools in the city of Lusaka. The following factors were taken into account in the selection of the sample schools:

1. Availability of apparatus in the science laboratories.
2. Availability of qualified physics teachers.
3. The likelihood that the scheme of work in that particular school could easily be changed in order to incorporate the reseacher's scheme of work.
4. The likelihood of the school administration and the teachers co-operating with the researcher during his research.

After establishing that all the Lusaka secondary schools satisfied these conditions, lots were drawn, and Kabulonga boys', Kamwala, and Matero girls' secondary schools were selected randomly.
The lots were drawn using a raffle method. All the names of the Lusaka schools were written on pieces of paper which were then deposited into a box, thoroughly mixed, and then the first three papers drawn blindly.

The schools selected were also from different locations of Lusaka and sufficiently distant from each other. The schools also represented the three categories of secondary schools found in Zambia. Using gender as a criterion for classification, these are, boys', co-education, and girls' secondary schools respectively.

The reseacher first established that all the students taking part in the study had not yet studied electrostatics at senior secondary school level. In each school two groups of students were chosen, a control and a treatment group. The assignment to control or treatment group was done on purely arbitrary lines, by simply tossing a coin. A total of one hundred and sixty-four pupils took part in the study, eighty-two students in the treatment and eight-two in the control group.

The treatment and control groups were equivalent. This was because they were selected at random, and also the two statistical tests employed in this study showed no significant difference between them in their pre-test scores. The Wilcoxon test, for example, showed no significant difference between the two groups, $Z(81) = -1.6296$, $P < 0.05$. The T-test, showed no significant difference too, $t(81) = 1.64$, $P < 0.05$ (see appendix iii for test scores and appendix iv for statistical tests). The breakdown of the pupils in the schools was as shown in table 1 on the following page.

TABLE 1.

BREAKDOWN OF PUPILS IN THE STUDY ACCORDING TO SCHOOLS.

School	Number of pupils in control group.	Number of pupils in treatment group.	Gender
Kabulonga boys'	28	28	male
Matero girls'	27	27	female
Kamwala	27	27	mixed
TOTALS:	82	82	164

For purposes of this study, Kabulonga boys', Matero girls', and Kamwala secondary schools will be refered to as schools one, two, and three, respectively.

THE RESEARCH INSTRUMENTS.

Classroom lessons, a scheme of work (see Appendix II), and two tests served as the reseach instruments (see Appendix VI). One of the tests served as the pre-test and the other as the post-test. Both tests were prepared by the reseacher, and their content validity was first established before administering them. This was done by consulting some physics teachers in Lusaka Secondary Schools, Science Curriculum Development Specialists, and the Science Inspectorate. The questions in the test papers were verified as being consistent with the 'O' level physics syllabus, and also that they were not ambiguous.

The two tests were very similar to each other in order to test the same concepts. Two similar tests were given, instead of one, in order to avoid a situation where pupils may give correct answers because of the fact that they had extensively revised the test given earlier, and hence merely memorized the answers.

The scheme followed in the teaching and the lesson plans were prepared in such a way as to continually mitigate against alternative conceptions. The constructivist view of science was the theoretical framework used in the design of the scheme and the lesson plans. Ausubel's postulate (Ausubel,1968) that knowledge is structured as a framework of specific concepts, and that meaningful learning occurs only when new knowledge is related by the learner to relevant existing concepts in that learner's cognitive structure, was taken into account in the preparations of both the scheme and lessons.

The component ideas that were to be taught were also carefully chosen, taking into consideration their suitability to pupils of the age group considered in the study. Since the average age of the pupils was eighteen, it was assumed that they were in the Piagetian stage of formal operations. A sample lesson plan is shown in the appendix I.

COLLECTION OF THE DATA

The data collected in this study was of two types. The first type was based on the responses pupils gave during lessons, and those from the question papers. Alternative conceptions that pupils exhibited were obtained from these responses.

The second type of data was based on the test scores from the two tests that were given (the pre-test and post-test). The second set of data was meant to find out whether or not instruction had an effect on mitigating against the alternative conceptions.

This study did not specifically look at the number of each type of alternative conception possessed by pupils, but rather concerned itself with whether the alternative conceptions were present or not, categorising them, and classifying them into degrees of seriousness. The study also examined which groups (uninstructed, or instructed) seemed to possess more alternative conceptions.

The post-test was written three months after the pre-test. A long period such as this one was necessary to preclude rote recall of answers based on the first test (the pre-test), which the pupils could have thoroughly revised by this time. As previously explained, the pre-test was very similar to the post-test, in as far as examining the same concepts was concerned.

ANALYSIS OF DATA:

The data collected was analysed in the following manner:

a). The alternative conceptions found were listed down, together with the attendant students' reasoning.

b). The alternative conceptions were then classified into types on the basis of the reasoning behind them. Explanations were then offered to explain the occurrence of these conceptions.

c). The post-test scores of the control and treatment groups were compared, in order to deduce what effect alternative conceptions may have on performance in electrostatics.

d). Comparison of the alternative conception types found in the control and treatment groups.

e). Comparison of the post-test scores of the girls', boys', and co-education schools, in the treatment group in order to establish the effectiveness of instruction in mitigating against alternative conceptions in the three different types of schools.

Quantitative comparisons were done using statistical tests. A parametric test, the T-test, and a non-parametric test, the Wilcoxon test, were used.

The parametric test was used because it is useful in comparing samples whose population distributions merely approximate the normal Gaussian curve like in this study. The test is also useful where research questions can be cast into hypotheses in the form of Chebyshev's inequalities;

$H_0: U_1 \leq U_0$, and

$H_1: U_1 > U_0$,

such as in this study.

The non-parametric test used could enable a reseacher to say of his subjects that one group has more or less of a certain characteristic than another, without specifying how much more or less. The non-parametric test used in this study , the Wilcoxon test, shows the significance and strength of a statistical relationship (Siegel,1956).

This chapter has looked at the method used. The next chapter will look at the results of this study and their analysis.

CHAPTER FOUR

RESULTS AND DISCUSSION.

The results and their analysis are presented in this chapter.

Six groups of alternative conceptions were found. These were associated with the following concepts:

1). Electrical discharge.

2). Charging and discharging bodies.

3). Force fields.

4). Potential difference and the flow of charge along a conductor or a potential gradient.

5). Cathode rays.

6). Understanding and interpretation of mathematical relationships in electrostatics.

The six groups of alternative conceptions are now presented below.

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH THE CONCEPT OF ELECTRICAL DISCHARGE.

Uninstructed pupils were found to possess the following alternative conceptions on the nature of electrical discharge:

The phenomena of lightning was interpreted in supernatural terms. It was conceptualised as a weapon of vengeance and justice used by the supernatural realm on erring human beings.

The following excerpt shows this trend:

Question: A tall man was running across a plain which had only short grass. There were no other objects around him as tall as he was. If this man was struck by lightning as he was running away from criminal justice, how would you interpret his misfortune?

Answer: The man was struck by lightning because he was a thief and so the spirits or gods punished him.

Lightning conductors on tall buildings were conceptualised as protecting the buildings from lightning by repelling the electrical discharge. They were also conceptualised as being there to warn low flying airplanes of the danger of collision with the tall building; to protect buildings from extreme temperatures; to act as meteorological instruments; and to protect the building from mechanical damage.

The electrical charge that is present on clouds before lightning can occur was conceptualised as being acquired from thunder. The thunder itself was conceptualised as being caused by clouds banging against each other, and the clouds themselves as being massive blocks of ice. The banging naturally led to sparking (hence the lightning), and the loud noise that we call thunder.

The instructed pupils, on the other hand, thought that clouds acquired charges through electrostatic induction and conduction, and that thunder was a result of cold and warm air currents meeting in the atmosphere.

The alternative conceptions possessed by uninstructed pupils as outlined above can be interpreted as forms of egocentric thought that strongly rely on common-sense interpretations of natural phenomena. One of the developmental features of Piaget's theory of cognitive development is the progression from egocentric to more objective thought (Ginsburg and Opper, 1969). Young children have difficult in imagining events from a perspective which differs from their own. Lightning was being understood as an active agent. The lightning was punishing villains in the same way the pupils would punish villains themselves. The lightning conductor was being visualised in personal terms; like a hand for example, in the instance where it wards off or repels lightning, and where it acts as a becone to aircraft; and like a thermometer in the armpit, where it is described as protecting the building from temperature extremes; and like some kind of personal talisman for protection where it is described as protecting the building from damage. This shows that young children see the world with themselves as an agent, and hence tend to explain events in terms of their action on a system, rather than in terms of the properties of the system itself. In this view then, the conceptions of the uninstructed pupils were egocentric.

The alternative conceptions possessed by the instructed pupils were in a different category. Their problem seemed to arise from transfer of training.

The pupils wanted to transfer the concepts they had learned on conduction and induction in electricity, and on convectional rainfall in geography, to electrostatics, in order to explain how clouds acquire charges, and how thunder occurs. These conceptions of the instructed pupils can be described as being non-Aristotelian, since they had no reliance on common-sense interpretations and egocentrism. The alternative conceptions possessed by instructed pupils were therefore a result of problems of transfer and conflict learning, where previous knowledge interferes with new knowledge.

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH CHARGING AND DISCHARGING BODIES.

Uninstructed pupils were found to possess the following alternative conceptions on the concept of charging and discharging bodies; the processes of charging a body by conduction and by induction were mistaken for each other; and the electrification by friction of dielectrics was attributed to the heat produced during the process, and the reason given for this was that it was similar to another process, that of two stones being struck together to produce sparks.

Pupils also classified dielectrics as being good conductors of electricity since the phenomena of sparking can be obtained from them, just as it is obtained from crossed conductors in a short circuit.

Other examples of the responses that were obtained are illustrated below;

Question: Large trucks usually trail a length of chain that just touches the ground behind them while moving. Why is this done?

Pupil 1: The short chain is there for towing other vehicles in case of emergency.

Pupil 2: The chain gives mechanical equilibrium to the vehicle.

Pupil 3: The chain assures the driver that the trailer is still there on account of the rattling noise the chain makes.

Question: Carbon black, a form of powdered graphite, is mixed with molten rubber during the manufacture of rubber tyres for automobiles. Why is this done?

Pupil 1: It gives car tyres their black colour.

Pupil 3: Carbon black increases the durability of the tyres.

Instructed pupils were found with the following alternative conceptions associated with charging and discharging bodies:

1). Heat changes the sign of a charge and this explains why charges on charged bodies change their sign from positive to neutral on heating.

2). Charges are oxidised to carbon dioxide when a charged body is heated, and in the process the body loses its charge.

3). Ebonite rods are good conductors, and so on heating, the charges are conducted away.

4). Heat is a catalyst that speeds up the reaction of discharging.

It appears that after instruction the nature of the alternative conceptions changed from the purely Aristotelian and egocentric type to that based on transfer of training. The excerpts below show this trend. To the questions asking why a short chain is towed behind a vehicle, and why carbon black is mixed with rubber when making tyres, the following responses were obtained:

Pupil X: The chains conduct heat away from the vehicle.

Pupil Y: The carbon black helps in heating the rubber during the process of melting it.

On the use of a bunsen burner in discharging charged dielectrics, uninstructed pupils gave responses of the following type:

1). Heating destroys the regular allignment of charges in a body, and creates a random one, hence discharging the body.

2). Heating destroys magnetism, and since a charged body is a form of magnet, it becomes discharged.

3). Charges of opposite sign flow from the bunsen burner and discharge the dielectric.

The alternative conceptions associated with instructed pupils were of a similar type except that fewer pupils (64% of the instructed pupils) possessed them. These alternative conceptions can be classified as being of the Aristotelian, transfer of training, and conflict variety.

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH FORCE FIELDS.

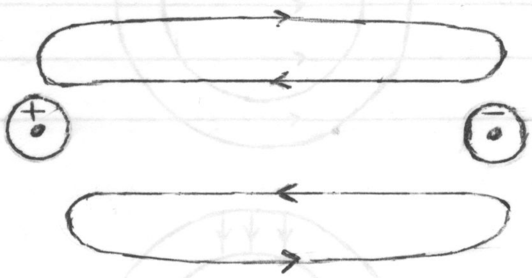
Instructed and uninstructed pupils were both found with the following alternative conceptions. Magnetic fields and electric fields were conceptualised as being the same thing. Flux lines in a force field were thought as being routes along which electric currents flow. Flux lines in the electric field were represented as being continuous in space, and were often drawn pointing in the wrong direction, that is from the negative charge to the positive one.

Figure 11 below shows these alternative conceptions.

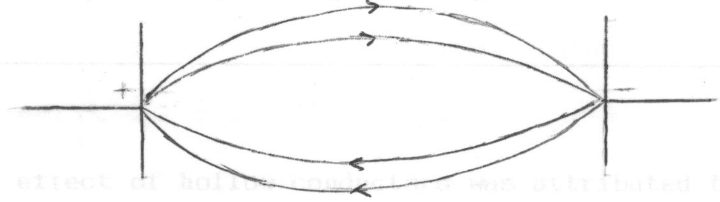
FIGURE 11:

PUPILS' ALTERNATIVE CONCEPTIONS OF THE ELECTRIC FIELD.

(a). Flux lines continuous in space and resembling those in a magnetic field.



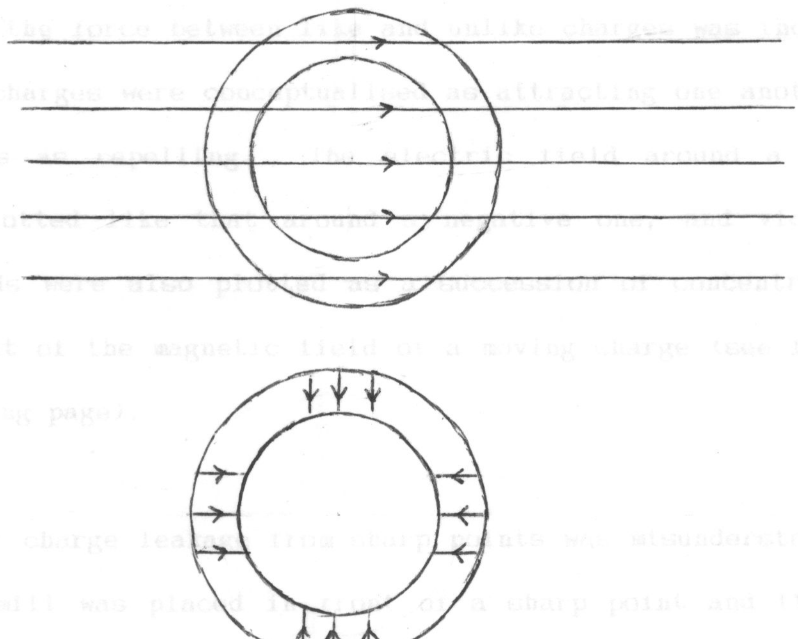
(b). Flux lines drawn pointing in wrong directions.



Electric flux lines were represented as passing right through a hollow conductor (see figure III below), hence the electric field inside had a non-zero value.

FIGURE III:

PUPILS' ALTERNATIVE CONCEPTIONS OF THE ELECTRIC FIELD INSIDE A HOLLOW CONDUCTOR.



The shielding effect of hollow conductors was attributed to factors such as; hollow conductors shield by acquiring a similar charge to that causing the external field; flux lines from an external field bounce off the surface of a hollow conductor; and the surface of the hollow conductor reflects the incident waves.

Force fields associated with stationery and moving charges were mistaken for each other. An electric field was associated with a moving charge, and a magnetic field with a stationery one. The 'static' or crackling noise heard in a radio set was attributed to mechanical wave disturbances (such as those resulting from longitudinal waves), instead of being due to electromagnetic wave perturbation.

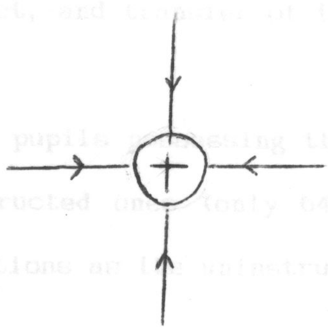
The nature of the force between like and unlike charges was incorrectly given. Like charges were conceptualised as attracting one another, and unlike charges as repelling. The electric field around a positive charge was plotted like that around a negative one, and vice versa. Electric fields were also plotted as a succession of concentric lines similar to that of the magnetic field of a moving charge (see figure IV on the following page).

The concept of charge leakage from sharp points was misunderstood. When a Hamilton's mill was placed in front of a sharp point and thereafter started rotating, pupils interpreted this phenomena in terms of magnetic properties. The mill was construed as being a magnetic compass that was being deflected in the magnetic field of the sharp point. The large charge density on sharp points was attributed to 'their high resistance', instead of being due to leakage of charge. Charge density was defined as the ratio of mass to volume in exactly the same way volume density is defined.

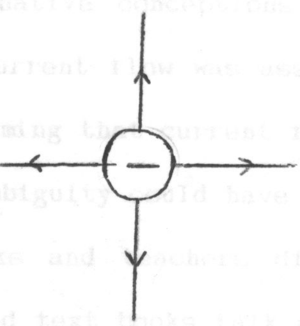
FIGURE IV.

PUPILS' ALTERNATIVE CONCEPTIONS OF FLUX LINES AROUND CHARGES.

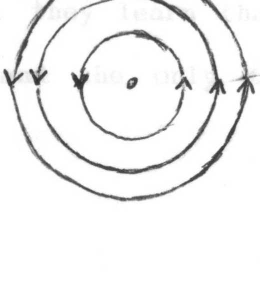
a). Flux lines around a positive charge drawn like that around a negative one.



b). Flux lines around a negative charge drawn like those around a positive one.



c). Flux lines around a charge drawn as concentric circles around it.



Geomagnetism was attributed to gravitational effects instead of being due to the convection currents in the molten magma inside the earth.

The Alternative conceptions found here can be categorised as being of the Aristotelian, conflict, and transfer of training variety.

The number of instructed pupils possessing these conceptions was smaller than that of the uninstructed ones (only 64% of the instructed pupils possessed similar conceptions as the uninstructed ones).

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH POTENTIAL DIFFERENCE AND CURRENT FLOW ALONG POTENTIAL GRADIENTS.

It was found that alternative conceptions regarding the direction of current flow existed. Current flow was assigned the same direction as electron flow, hence assuming that current flowed from a lower potential to a higher one. This ambiguity could have been caused by the fact that both chemistry text books and teachers discuss a flow of electrons, while physics teachers and text books talk about a flow of current. The pupil therefore comes to assume that current flow means the same as electron flow. Matters are made worse by the fact that at later stages in their physics course, they learn that the direction of current is actually conventional, and the only thing that actually moves are charges.

The concept of potential from mechanics frequently interfered with that from electricity. In mechanics the potential energy of a body depends on the position or configuration of that body with respect to an arbitrary reference frame. This means that height could be a measure of mechanical potential. In electricity potential depends on the absence or presence of charge on a body, and on the type of charge present. A body with a positive charge has a higher potential than one with no charge at all, and this body in turn has a higher potential than another with a negative charge. On being asked what was at a higher potential, a negatively charged cloud or the neutral earth? The answer that the cloud was at a higher potential was given because it was higher up was given. This is again a situation where transfer of training results in alternative conceptions.

Prediction of what would happen if two bodies at different electric potentials are connected together by a conductor, and what the relative potentials of two clouds must be if lightning crossed from one to the other were often incorrect. This means that current flow could not be related to change in potential difference and vice versa. It appears that pupils found problems in understanding concepts that involved reversibility of thought. This indicates that pupils may have an inability to think hypothetically in science concepts.

There were also problems associated with electric cells. The anode of a Leclanche cell was labelled as the cathode, and the cathode as the anode. The dissolution of electrodes that accompanies the working life of a Leclanche cell was refered to as 'melting', as the excerpt below shows;

Pupil: The cathode 'melts' faster than the anode as it is slowly eaten away by the eletrolyte.

Pupils may, therefore, confuse the concept of melting with that of dissolving. This is a case where second language interferance may play a role in fostering alternative conceptions. In Zambian dialects only one word,'KU SUNGULUKA' can mean both melting and dissolving. This means that the two processes are thought to be the same phenomena in the local culture.

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH CATHODE RAYS.

There were also alternative conceptions associated with the study of cathode ray tubes found among both instructed and uninstructed pupils. The excerpts that follow illustrate this:

Question: What is a fluorescent screen and how does it work?

Peter: A fluorescent screen fluoresces, and it does so because it is highly polished, and so it acts as a surface of reflection.

Beria: A fluorescent screen is a dark surface that absorbs radiation.

Jessy; Argon, mercury, and magnetic materials are substances that are used for coating fluorescent screens to make them fluoresce.

Ephraim: A fluorescent screen neutralises charges that fall on it, and fluoresces in the process.

Pupils predicted wrongly the direction in which cathode rays are deflected in the electric and in the magnetic fields. The pupils responded that cathode rays are deflected towards the cathode in an electric field, and the deflection in a magnetic field is either absent or occurs in the same plane. In tackling a situation where a deflection is already given, pupils could not predict the sign of the charge on cathode rays. Cathode rays were conceptualised as being merely a beam of light, produced by the filament in the electron gun. The potential difference between the accelerating anode and the filament cathode in a cathode ray tube was predicted as being in the range of 10 to 20 volts. The alternative conceptions associated with this concept were again the Aristotelian variety, the conflict type, and the transfer of training type.

Again fewer instructed pupils, (64%), possessed serious alternative conceptions.

ALTERNATIVE CONCEPTIONS ASSOCIATED WITH UNDERSTANDING AND INTERPRETING MATHEMATICAL RELATIONSHIPS IN ELECTROSTATICS.

Instructed and uninstructed pupils found it difficult to translate verbal statements of physics laws into mathematical ones. Pupils, for example, were asked to work out what form an inverse square law of attraction in electrostatics would take, after being told that the force per unit charge or the field is proportional to charge and inversely proportional to the square of the distance from the charge.

The excerpt below shows the type of answers that were obtained:

Matiya: $E = KQR$

Isaac: $E = KQR^2$

Sobby: $E = KQ^2R$

Where Q stands for charge, R for distance, K is a constant of proportionality, and E stands for the electric field.

Clearly, the pupils did not fully comprehend or comprehended differently the inverse square law. Although they were able to state it verbally, they failed to express it in quantitative terms, showing that they did not appreciate the exact meaning of the law.

Similar responses were given when it came to expressing the law of electric potential in mathematical terms. After being told that the electric potential at a point is proportional to charge and inversely proportional to the distance from the charge, the pupils were asked to translate this into a mathematical statement. The excerpt below shows the typical answers:

Zabuya: $V = - KQ/R^2$

Losson: $V = - KQR$

Alex : $V = - KQR^2$

Where V stands for the electric potential.

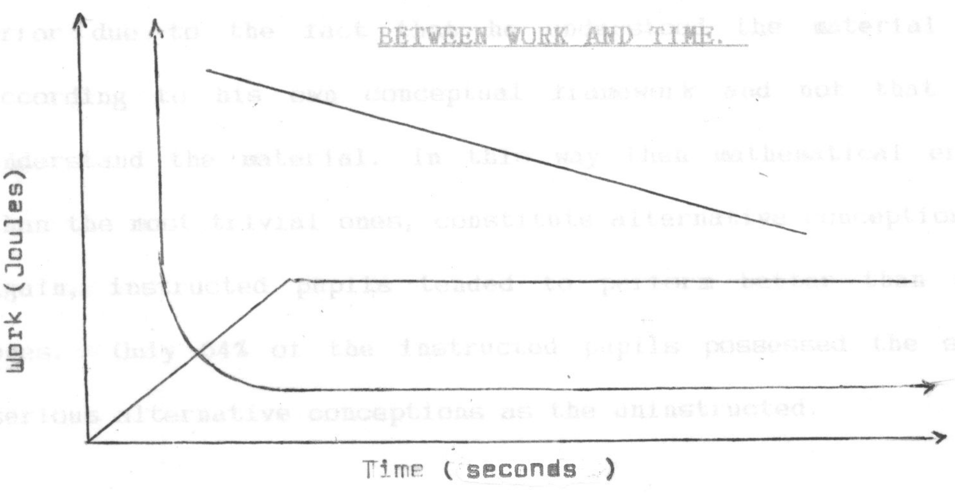
There was a strong resistance of going against common sense views as was evidenced by the reluctance of pupils to accept that the work done along a line of equal potential or an equipotential line was zero. Pupils obviously thought that work was always done whenever a force moved a body regardless of whether the force was applied along an equipotential line or not.

Pupils also found converting mathematical relationships into graphs a problem. A problem where they were to draw the relationship between the work done, W, and the time taken for a current, I, to flow under a potential difference, V, was given. The graphs that pupils drew varied from those showing inverse relationships, hyperbolic relationships, to those showing that work did not vary with time at all. Some of the relationships are shown in figure V below.

FIGURE V:

PUPILS ALTERNATIVE CONCEPTIONS OF THE GRAPHICAL RELATIONSHIP

BETWEEN WORK AND TIME.



Pupils also found problems with derivation of formulae. Where a new mathematical statement has to be derived from simpler ones pupils simply went blank, guessed what the new relationship should be like, or derived it wrongly. For example, pupils found it extremely difficult to derive the relationship:

$R = Wt/Q^2$ from:

$I = Q/t$,

$V = W/Q$, and

$V = IR$ (Ohm's law).

Where V, is the potential, Q, the charge, I, the current, t, the time, W, the work done, and R, the electrical resistance of a conductor.

Failure of a pupil to construct a formula from a verbal statement, or to interpret a formula into a graphical form constitutes an alternative conception because what actually happens is that the pupil made the error due to the fact that he understood the material differently according to his own conceptual framework and not that he did not understand the material. In this way then mathematical errors, other than the most trivial ones, constitute alternative conceptions. Again, instructed pupils tended to perform better than uninstructed ones. Only 64% of the instructed pupils possessed the same type of serious alternative conceptions as the uninstructed.

The alternative conceptions found were classified into degrees of seriousness. The egocentric type was classified as extremely serious, the Aristotelian type as very serious, the conflict learning variety as serious, the interpretation type as tolerable, and the transfer of learning variety as most tolerable.

Thirty six percent of the instructed pupils tended to possess alternative conceptions in the tolerable and most tolerable range.

The test scores of all the pupils, uninstructed and instructed, were classified according to a nine point scale as shown in table II below. The level of seriousness of alternative conceptions possessed by pupils was indicated by position on the nine point scale. Extremely serious alternative conceptions scored one point, conceptions that were neither less serious nor tolerable (average) scored five points, and those that were almost absent scored nine points. Other classifications of the degree of seriousness of the alternative conceptions are shown in table II on the following page.

It was discovered that all the uninstructed pupils possessed alternative conceptions that ranged from less serious to extremely serious. This showed that all the uninstructed pupils possessed alternative conceptions that could be classified as being in the range of seriousness. Among the instructed pupils, only 63.42 % showed alternative conceptions that ranged from less serious to extremely serious (that is, in the serious range), 19.51 % exhibited alternative conceptions which were neither too serious nor tolerable (shown as average in table II), while 14.64 % exhibited alternative conceptions ranging from tolerable to more tolerable (in the tolerable range).and 2.43 % were in the range almost free of alternative conceptions.

TABLE II:

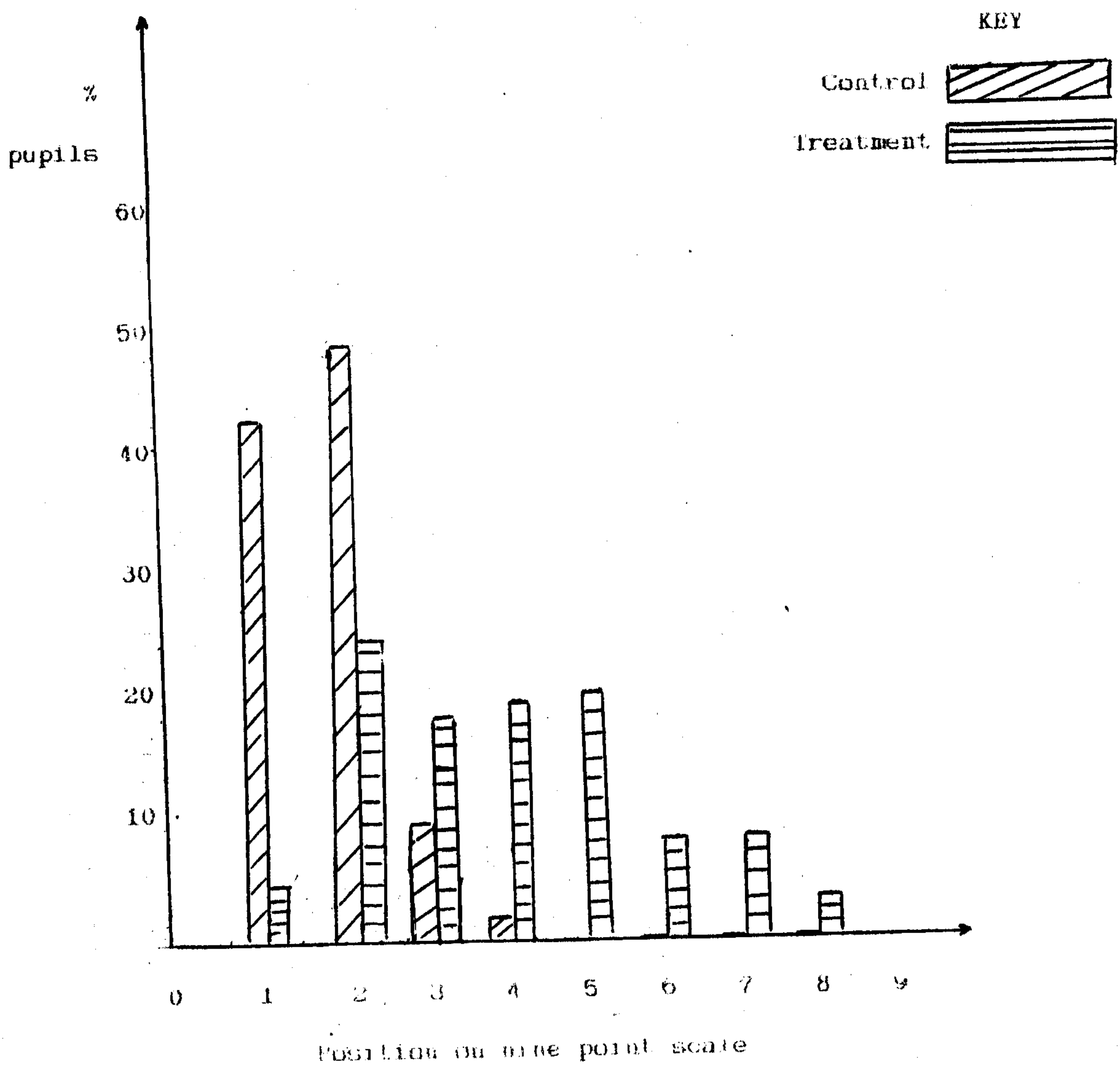
PERCENTAGE DISTRIBUTION OF PUPILS WITH ALTERNATIVE CONCEPTIONS.

DEGREE OF SERIOUSNESS OF ALTERNATIVE CONCEPTIONS.	RANGE OF TEST SCORES. %	SCALE (ON 9-POINT SCALE)	CONTROL %	TREATMENT %
ABSENT	86-100	9	0	0.00
ALMOST ABSENT	76-85	8	0	2.43
MORE TOLERABLE	66-75	7	0	7.32
TOLERABLE	56-65	6	0	7.32
AVERAGE	46-55	5	0	19.51
LESS SERIOUS	40-45	4	1.22	18.29
SERIOUS	35-39	3	8.54	17.07
MORE SERIOUS	20-34	2	47.56	24.39
EXTREMELY SERIOUS	0-19	1	42.68	3.67
		TOTALS	100.00	100.00

The bar graph in figure VI below shows the comparison in visual terms.

FIGURE VI:

BAR GRAPH SHOWING THE PERCENTAGE DISTRIBUTION OF PUPILS WITH ALTERNATIVE CONCEPTIONS.



These results show that all uninstructed pupils possessed mainly serious alternative conceptions in electrostatics, while relatively fewer instructed pupils (63.42%) possessed such serious conceptions. These results indicate that although tuition seems to control the level of seriuosness of alternative conceptions, by reducing them by a certain factor, alternative conceptions are still present after tuition. These conceptions can therefore be described as being tenacious. They are not easily eradicated.

Using the T-test, it was found that the treatment group performed significantly better than the control group; $t(81) = 10.22$, $P < 0.05$, hence showing that fewer instructed pupils possessed alternative conceptions of a more serious nature (see appendix IV).

The Wilcoxon test also showed that the uninstructed pupils possessed more serious alternative conceptions than the instructed ones, since this test also indicated that the treatment group performed significantly better than the control group; $z(81) = -6.9436$, $P < 0.05$.

The post test scores of the boys', girls', and co-education schools were also compared using the T-tests to find out if there were any significant differences in performance among them, and hence if instruction controls alternative conceptions differently among them. Comparison of the girls' and co-education schools showed that there was no significant difference between them, none performed significantly better than the other; $t(27) = 1.01$, $P < 0.05$.

Comparison of the boys' and girls' schools showed that there was a significant difference between them. The boys performed significantly better than the girls; $t(27) = 4.60$, $P < 0.05$.

Comparison of the boys and co-education schools showed that the boys' school performed significantly better than the co-education school, $t(27) = 5.50$, $P < 0.05$ (See appendix V).

The findings of this study could be summarised as follows:

1). Alternative conceptions exist in electrostatics.

2). These conceptions could not have been predictated independently from a study of conceptions in other areas of science, but had to be discovered separately.

3). The alternative conceptions followed a certain pattern; they were associated with the conceptual structure of electrostatics, since each concept had its attendant alternative conceptions.

4). The alternative conceptions could be classified into types:

a). Those resulting from egocentric views of nature.

b). Those resulting from common-sense or Aristotelian ideas.

c). Those resulting from conflict learning situations.

d). Those resulting from problems caused by transfer of training.

e). Those which are a result of faulty interpretation of the meanings of scientific and mathematical statements.

f). Those resulting from a lack of familiarity with scientific equipment.

5). Alternative conceptions were difficulty to eradicate, they were present even after instruction.

6). Alternative conceptions were wide ranging, they covered all the areas of electrostatics.

7). Pupils in boys' schools performed better than those in girls' and co- education schools.

8). Instruction controlled alternative conceptions by reducing them and making them less serious.

CHAPTER FIVE

SUMMARY AND RECOMMENDATIONS

SUMMARY

Pupils harbour alternative conceptions about natural phenomena in electrostatics which cannot be predicted, are difficult to eradicate, (since they may be present even after instruction), have a pattern (since there is an alternative conception associated with each concept), and can be classified into types (the egocentric, Aristotelian, conflict, transfer of training, and faulty interpretation, types). Careful instruction was observed to control alternative conceptions by reducing their degree of seriousness. Instruction in boys' schools seemed to have been more effective in reducing alternative conceptions than in girls', and co-education schools respectively.

Teaching that aims at making the pupils' thinking more consistent with scientifically appropriate ways of thinking about natural phenomena, and induces conceptual change in pupils can control alternative conceptions. Such teaching can be achieved only by the teacher constantly diagnosing students' alternative conceptions, responding to these alternative conceptions, and presenting content in a way that engages the pupils and also makes sense to them. The constructivist view of science, if followed in teaching, can continuously mitigate against alternative conceptions.

DISCUSSION

Underteaching seems to be a general weakness in Zambian schools, and could be a contributing factor to the development of alternative conceptions. Teaching is directed towards examinations, and is characterised by information transmitted by note dictation, and 'teaching by remote control'. The last expression, a term invented by teachers, refers to a situation where teachers, though present in the school compass, delegate their duties to a pupil. The pupil is asked to copy notes straight from a science textbook onto a chalk board, while the teacher is probably warming himself in the sunshine, or playing a game of chess in the staff room, or attending to some other private business. Underteaching may result in alternative conceptions developing among pupils.

Curriculum materials and textbooks may also contribute to the prevalence of alternative conceptions. The inductivist view of science is adopted by some common textbooks of science, such as the more naive interpretations of the discovery method adopted by the Nuffield science schemes (Driver, 1986). One of the features of the science teaching schemes which have been developed over the last 20 or 30 years is a rejection of science as a catalogue of facts. Instead, teaching schemes have been produced which present science as a coherent system of ideas. Focus is on the intergrating concepts or big ideas such as atomic theory in chemistry or kinetic theory in physics. Apart from doing justice to the nature of scientific theory itself, one of the important arguments for such an approach, suggested by Bruner (1963), is that it helps pupils apply ideas to new situations if the connections between those ideas are made explicit in teaching. In short, it encourages 'transfer'. One of the problems with such an argument is that the connections that are apparent to a scientist may be far from obvious to a pupil. It is, after all, the coherence as perceived by the pupil that matters in learning. In developing science teaching material, little attention has yet been paid to the ideas which children themselves bring to the learning task, yet these may have a significant influence on what children can, and do learn from their science lessons (Driver, 1986).

Curriculum materials may also contribute to the development of alternative conceptions due to their reliance on the heuristic method. As was explained in the literature review, this method leads to intellectual dishonesty among pupils since two outcomes which are possibly incompatible are expected from the pupils' laboratory activities. One outcome being that they are expected to derive correct inferences on their own, and the other being that those inferences may possibly be the same as the currently accepted scientific law or principle. This may lead to pupils having compartmentalised knowledge, the first, their own, and the other, the scientifically expected one.

Earlier tuition at elementary and junior secondary school also contributes to the development of alternative conceptions. Primary school teachers can be described as teaching science out of licence, since they do not really specialise in science during their training. A large proportion of primary school teachers are also untrained. In 1984, for example, there was a total of 4,540 assistant and untrained teachers in primary schools out of a total of 12,664 teachers. Such teachers may have little or no knowledge at all of primary school science, and may be a contributing factor to the development of alternative conceptions at that level (Chibesakunda, 1984).

An examination of the records of the ministry of higher education, science, and technology in Zambia shows that the people generally appointed as science lecturers in primary school teacher training colleges, are rarely university graduates in science. Most of them hold qualifications in arts and humanities, yet teach science. Many of them are also underqualified. In 1984, for instance, out of a total of 355 lecturers in all the primary school teachers' training colleges, there were only 71 lecturers who were university graduates. Among the remainder, 53 had full form 5 (grade 12) school certificates as their highest academic qualification, 192 had the general certificate of education, and 39 had either form 2 (grade 9), or form 3 (grade 10) certificates (Educational statistics, Ministry of Higher Education, 1984). Among the graduates, none of the science lecturers had science degrees, but held degrees in other fields. They were all teaching out of licence. Among the non-graduates, those teaching science held either a primary school teachers' certificate, or an advanced primary school teachers' certificate (APC), none of which are explicit qualifications in science education. All this goes to show that even science education lecturers at primary school teacher training colleges were teaching out of licence.

This calls for a careful selection of individuals who are appointed as science education lecturers in teacher training colleges. This would be achieved if teacher training lecturers were recognised as professionals, because, under such circumstances, there would exist a professional body that would recruit new members of the profession, taking into account the academic excellence and performance of the candidates, rather than mere long service as is the case at present.

The ratio of trained science teachers to pupils in secondary schools is quite unfavourable. In 1981, for example, the number of mathematics and science graduate teachers remaining in the teaching service was 65 out of a total of nearly 300 trained graduates (Thomas, 1982). The secondary school enrolment around the same time was about 86,000 pupils. The science teacher to pupil ratio was therefore about 1 teacher for every 1,323 pupils (Stastiscal profile of Zambian education,1978). This kind of imbalance in the teacher-pupil ratio can only mean that teachers may not have enough time to know their pupils well, and hence may not know anything at all about the alternative conceptions the pupils possess. Alternative conceptions may be expected to develop under such conditions.

Some alternative conceptions seem to be a result of second language interference (Soyibo,1981, Strevens,1976, Chibesakunda,1984, Case,1969). Bantu languages lack scientifically precise words, although the people who speak these languages may practice science. An example of this, is that certain natural processes like 'melting' and 'dissolving' may be translated into one Bantu word, such as "KUSUNGULIKA", in most Zambian Bantu dialects. This means that local science may understand 'melting' and 'dissolving' as involving the same scientific processes. Second language interference may lead to Aristotelian, Lamarkian, and naturalistic ideas, because of the intuitive anthropocentric view of the world held by the young person. This means that, a greater emphasis should be put on learning the English language and communication skills as applied in science, than has hitherto been the case.

Apparatus in college and school science laboratories appears to be lacking in general. Colleges and schools were last provided with scientific equipment mostly at their inception, and since that time, that equipment has deteriorated, or is simply missing. In such a situation then, science lecturers and teachers hardly conduct scientific demonstrations and experiments when teaching science. Institutions of learning have also in general been poorly funded. In 1984, for instance, only 1.2% of the total capital expenditure on education of 19.84 million kwacha was spent on teacher training, and out of this small amount, a still smaller amount was spent on science education in teacher training. Secondary schools received a higher amount, 57.6% of the total expenditure on education (Educational statistics, Ministry of higher education, planning unit, 1984). Considering the large number of departments in secondary schools, and the large number of secondary schools in the country (194 at that time), it follows that each school got on average about 100 000 kwacha. If on average, it is assumed that each secondary school has 10 departments, including the administration, then each department was allocated about 10,000 kwacha. As far as scientific equipment goes, this amount of money was not even enough to purchase a supply of chemicals that would last for a week, let alone purchase something like a cathode ray tube for the physics laboratory. Poor funding of colleges and schools could therefore be an additional factor in the prevalence of alternative concetions amomg pupils.

The results of this study also indicate that boys were more successful at controlling alternative conceptions than girls. Sociologists, (Braun,1971, Light and Keller,1986), might argue such a case from two points of view. One point of view being that boys are usually labelled as being fast learners of science, and girls as being slow learners. Using this point of view then, it follows that the differences in perfomance between boys and girls were possibly a consequence of labelling and the self-fulfilling prophecy. Another point of view is that males may be inherently good in problems involving spatial aptitude like those found in science and mathematics, while females may not be as good as the boys. The hypothesis advanced is that during the process of evolution, males being more expendable than females were involved in such dangerous pursuits as hunting, and fighting, all of which required spatial aptitudes. In time this became an inherited trait, and may presently explain the reason why males may perform better than females. The real situation, however, may be that both labelling (nurture or the environment), and inherent qualities (nature or heredity) play a part in determining a pupil's spatial aptitude, and performance in science.

Sociological research evidence also shows that certain categories of people have tendencies to being easily stereotyped and ethnocentric. These categories include the lower economic classes in society, the aged, those with a low standard of education, and women (Braun,1971, Light and Keller, 1986). If alternative conceptions are regarded as a form of stereotyped behaviour (attitudes based on values that are based on limited experience and usually false), or as a form of ethnocentrism (a belief in the superiority of one's existing beliefs, and a reluctance to learn new ones), Then the sociological research evidence is that girls may produce more stereotyped behaviour in resisting changes to their existing conceptions than boys. It must, however, be borne in mind that stereotyped behaviour, and ethnocentrism are themselves results of labelling and the self-fulfilling prophecy.

RECOMMENDATIONS

The following recommendations, or actions to be taken to rectify the alternative conceptions identified in this study, were made:

Theories of instruction and Curriculum planners should pay attention to the ideas which pupils come with to the learning situation, in order to mitigate against alternative conceptions based on 'transfer of training', Aristotelian ideas, and the Larmakian and anthropocentric views held by the pupils. This can be done as an addition to the traditional strategies for improving meaningful learning such as the theories of instruction concerning themselves with how to optimize the acquisition, organisation, and retrieval of new knowledge (Kaiba,1989, Reigeluth,1983).

Teachers and science educators should spend more time studying the reasons pupils give for their alternative conceptions, as this may enable them to correct forms of egocentric thought, irreversible thinking, Aristotelian ideas, and problems associated with transfer of training at an early age.

Curriculum planners, and teachers should also avoid putting too much emphasis on the heuristic method of teaching, which assumes that pupils can derive correct inferences on their own from scientific activities, and that these inferences will at the same time be compatible with currently accepted scientific thought. Instead guided discovery learning must be used, where the pupil is carefully guided to the correct conclusion. In short, the constructivist view of science should be followed in science instruction. This can mitigate against alternative conceptions based on conflict learning.

Teachers who teach out of licence are an important source of alternative conceptions, and so that tendency must be reduced as much as possible. Careful screening of candidates for lecturing in science at colleges must be done to ensure that they have the right qualifications, such as the minimum of a science degree. At secondary schools, science teachers for senior classes should have at least an advanced diploma in the relevant scientific field, and for junior secondary school, at least a secondary school teachers diploma in science education. At primary school teacher training colleges, specialist training for primary school science and mathematics teachers should be introduced, in order to lessen the tendency of primary school science being taught by general practitioners, as is the case at present.

The problem of teaching out of licence is itself dependent on the trained science teacher to pupil ratio. If this ratio became more favourable, there would be little need to resort to 'crisis teachers' to teach science. Hence this calls for a better funding of science and mathematics teacher education to enable teacher training institutes to turn out a greater number of science teachers than at present.

Apparatus, books, and other resources in college and school science laboratories in general, are in short supply. This can be a source of alternative conceptions. An articulated effort in financing science education should therefore be made in order to improve science teaching and learning.

Science teachers should be sympathetic to pupils' alternative conceptions before changing them. In this way, the change may not be resisted. Science teachers should also spend more time with female pupils, giving them the same type of activities as the males, and also desisting from labelling them as slow learners, or in any other negative way.

Supervisors, such as heads of science departments, senior teachers, and the headmasters and their deputies, should ensure that science teachers are efficient and proficient in their duties and do not engage in underteaching strategies such as the "teaching by remote control" mentioned ealier on.

More attention should be paid to teaching the language of instruction well, in this case English, and especially the way it relates to science, than has hitherto been the case, in order to mitigate against alternative conceptions resulting from second language interference.

RECOMMENDATIONS FOR FURTHER RESEARCH

It is recommended that similar studies to this one should be conducted. Such studies should involve more pupils and should cover a wider geographical area than in this study, in order to obtain more generalizable results.

A longitudinal study should also be carried out. Pupils alternative conceptions about natural phenomena should be followed from the time they are in kindergarten to the time they reach college.

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APPENDIX I

LESSON PLAN.

TOPIC ELECTRIC CHARGE. GRADE 12. TIME: 80 minutes.

OBJECTIVES:

At the end of the lesson the pupil should be able to:

1. Give a qualitative defination of charge when asked to do so.
2. Distinguish between positive and negative charge after performing a suitable experiment.
3. Interpret the existence of charges from the atomic view of nature.
4. Design an experiment to show that unlike charges attract and like charges repel.
5. Give examples of ions.
6. Illustrate in simple terms the electronic nature of an atom.
7. Differentiate between sparks produced by friction from those produced by electric discharge.
8. Deduce that lightning is a spark between unlike charges.

BEHAVIOUR CONTENT MATRIX. COGNITIVE DOMAIN.

Knowledge	Understanding	Application	Analysis	Synthesis	Evaluation.
1	2				
	3	4			
	5	6	7	8	

RESOURCES:

1. Electrostatics kit.
2. Electroscopes.
3. Leyden jar.
4. Wimthurst machine.
5. Van De Graaf generator.

TEACHING METHODS:

Constructivist approach.

-Guided discussion, guided demonstration, guided experiment, and guided conclusion and inferences.

CONTENT:

1. Common-sense ideas of charges.
2. Atomic structure.
3. Theory of electric charge.
4. Demonstrations and experiments in electrostatics.

INTRODUCTION.

Ideas on the nature of lightining invited from pupils. The ideas are listed and discussed. The Teacher explains that the lesson is on the causative agent of lightning, the charge.

LESSON DEVELOPMENT

CONTENT	TEACHER ACTIVITY	PUPIL ACTIVITY
Atomic view of nature.	Questions on atomic view nature.	pupils ask and answer questions on topic. class discussion.
Common-sense ideas about	common-sense ideas invited from pupils.	discussion of the common-sense ideas.
Charging by friction.	Teacher demonstration of how to produce charges.	pupil experiment on charge production. guided by Teacher. pupils helped by teacher in making inferences.
Electric discharge.	Teacher demonstrates discharge using electrostatics apparatus.	pupil experiment on discharge using same apparatus as Teacher. pupils assisted in making inferences of how Van De Graaf

		generator, and the Wimthurst machine produce sparks. Conclusions on the action of Leyden jars and Hamilton's mill also arrived at with the teacher's help.
Conclusion	summary of lesson	discussion and comparison of common sense and scientific ideas.

LESSON EVALUATION:

Pupils asked to explain phenomena of lightning using the scientifically accepted concepts they have acquired and also to give reasons why the common sense concepts like lightning is a goat or a sheep falling from the sky are wrong.

Pupils are also asked to perform a lightning discharge experiment using a Van De Graaf apparatus.

APPENDIX II

THE RECORDS AND SCHEMES OF WORK DONE; GRADE 12.LUSAKA SCHOOLS.

WORK PLANNED	WORK DONE	STRATEGY
Electric charge:	-positive and negative charges. Attraction and repulsion of charges. Experiments on field forces. The atom, cations,anions .Electric charges in nature.	-guided experiment and discussion. -guided inference making on the nature of charges. Discussion of the ideas pupils came with to the lesson
ELECTRIFICATION:	-Production of charge by friction. Transfer of charge by conduction and induction. -The electrophorus apparatus. -The Van De Graaf generator. -Conductors and insulators.	-Guided experiments and inference making. -Discussion of pupils conceptions before and after the lesson
ELECTROMAGNETIC FIELDS OF FORCE:	-The electric field and the magnetic field.Geomagnetism and its causes.Ferromagntism. -Comparison of the electric field with the magnetic field. magnetic field.	-Demostration of the electric field using the Van De Graaf generator.

WORK PLANNED	WORK DONE	STRATEGY
ELECTROMAGNETIC FIELDS OF FORCE CONTINUED:	-The inverse square law. -The shapes of electric fields of positive and negative charges.	-Guided discussion inference making.
CHARGE DENSITY:	-Definition of charge density Charge density at sharp points and rounded edges. Leaking of charge from sharp points: the electric wind. Lightning and lightining conductors. Production of thunder during lightning.	-Demonstration of the electric wind using a Hamilton's mill. Construction of a lightning conductor.
ELECTRIC POTENTIAL:	-Absolute potential and potential difference. Current flow. Charge flow.	-Guided discussion Explanation that the concept of current flow was itself originally an alternative conception of the nature of charge flow among early scientists.

WORK PLANNED	WORK DONE	STRATEGY
CALCULATIONS AND FORMULAE IN ELECTROSTATICS:	$I = Q/t$; where I is the current, in amperes. Q, the charge in coulombs, and t, the time in seconds. $V = kQ/r$; where V is the potential in volts, r, the displacement vector, and k, a constant. $W = VQ$, where W is the work done. $W = F.S$, where F is the force, and S, the change in displacement of a given charge. -The work done along an equipotential surface, and around a closed path.	-Discussion of the reasoning involved in the equations. -Plotting graphs from equations.
CATHODE RAYS CANAL RAYS:	-Production of cathode rays and canal rays in the laboratory. Cathode ray tubes and applications to the television tube oscilloscope, and X-ray tubes. Applications of the cathode ray oscilloscope.	Demonstration of Maltese cross experiment, Perrin's experiment, and deflections of cathode rays in electric and magnetic fields.

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APPENDIX III.

TEST-SCORES IN THE PRE-TEST AND POST-TEST

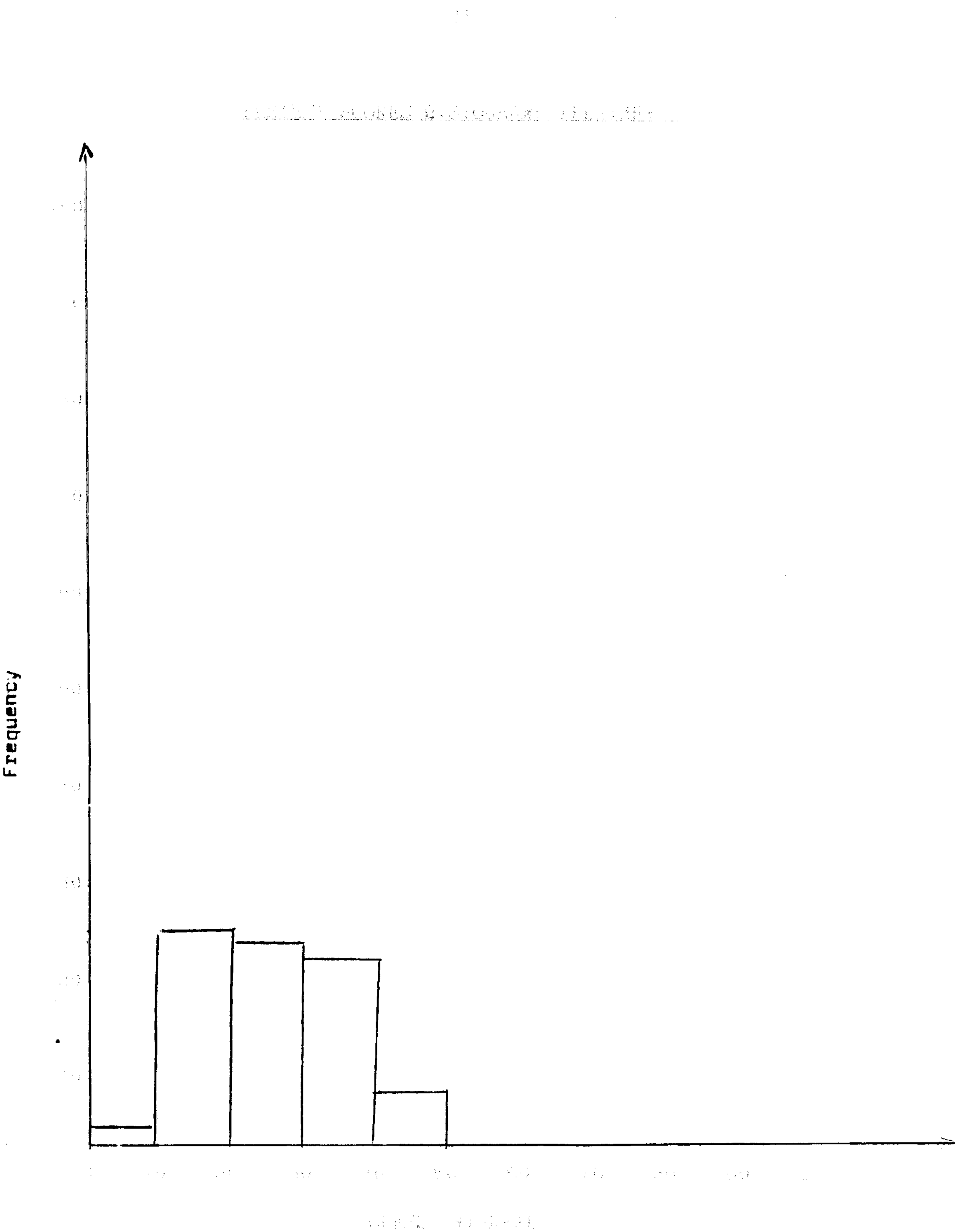
PRETEST SCORES: TREATMENT GROUP.

CLASS INTERVAL	FREQUENCY
0-09	02
10-19	25
20-29	24
30-39	23
40-49	08
50-59	0
60-69	0
70-79	0
80-89	0
90-99	0
TOTAL	82.

MEAN = 25.244.

STANDARD DEVIATION = 10.457.

STANDARD ERROR = 1.150


Frequency

PRETEST SCORES: CONTROL.

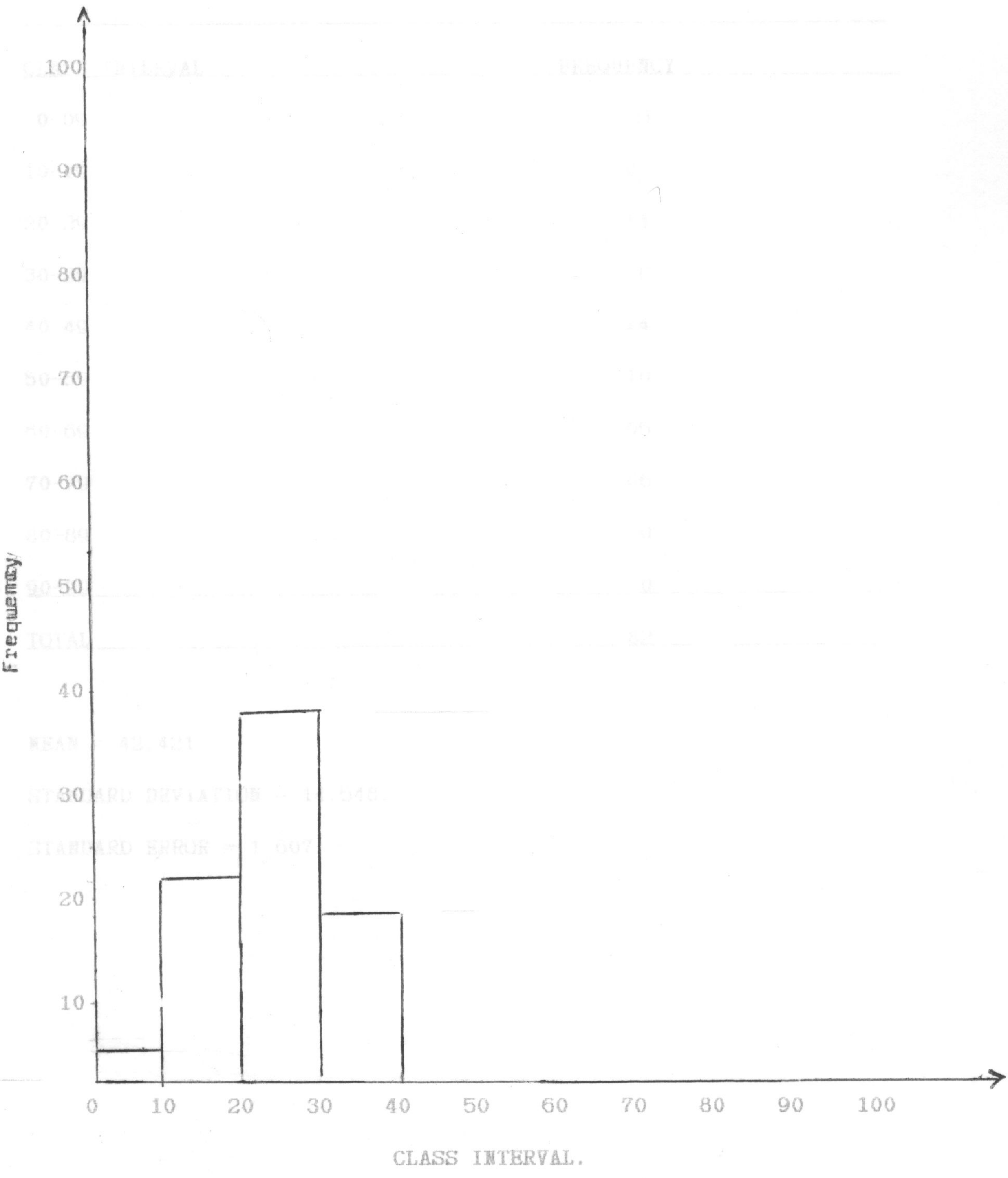
CLASS INTERVAL	FREQUENCY
0-09	04
10-19	21
20-29	38
30-39	19
40-49	0
50-59	0
60-69	0
70-79	0
80-89	0
90-99	0
TOTAL	82.

MEAN = 22.555

STANDARD DEVIATION = 7.503.

STANDARD ERROR = 0.829

PRETEST SCORES HISTOGRAM: CONTROL.



POST-TEST SCORES: TREATMENT.

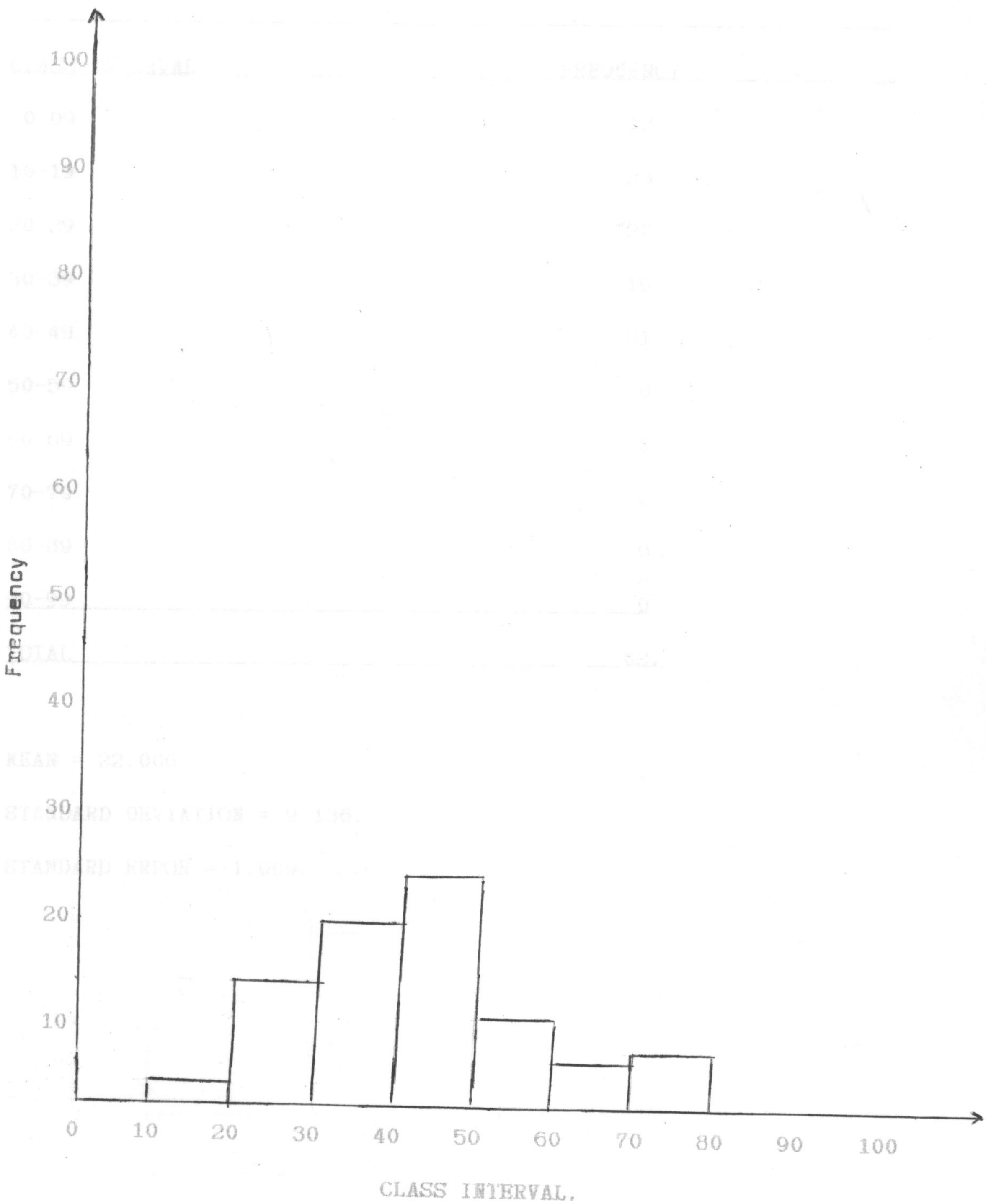
CLASS INTERVAL	FREQUENCY
0-09	0
10-19	03
20-29	14
30-39	20
40-49	24
50-59	10
60-69	05
70-79	06
80-89	0
90-99	0
TOTAL	82.

MEAN = 42.421.

STANDARD DEVIATION = 14.548.

STANDARD ERROR = 1.607.

POST-TEST SCORES HISTOGRAM: TREATMENT.



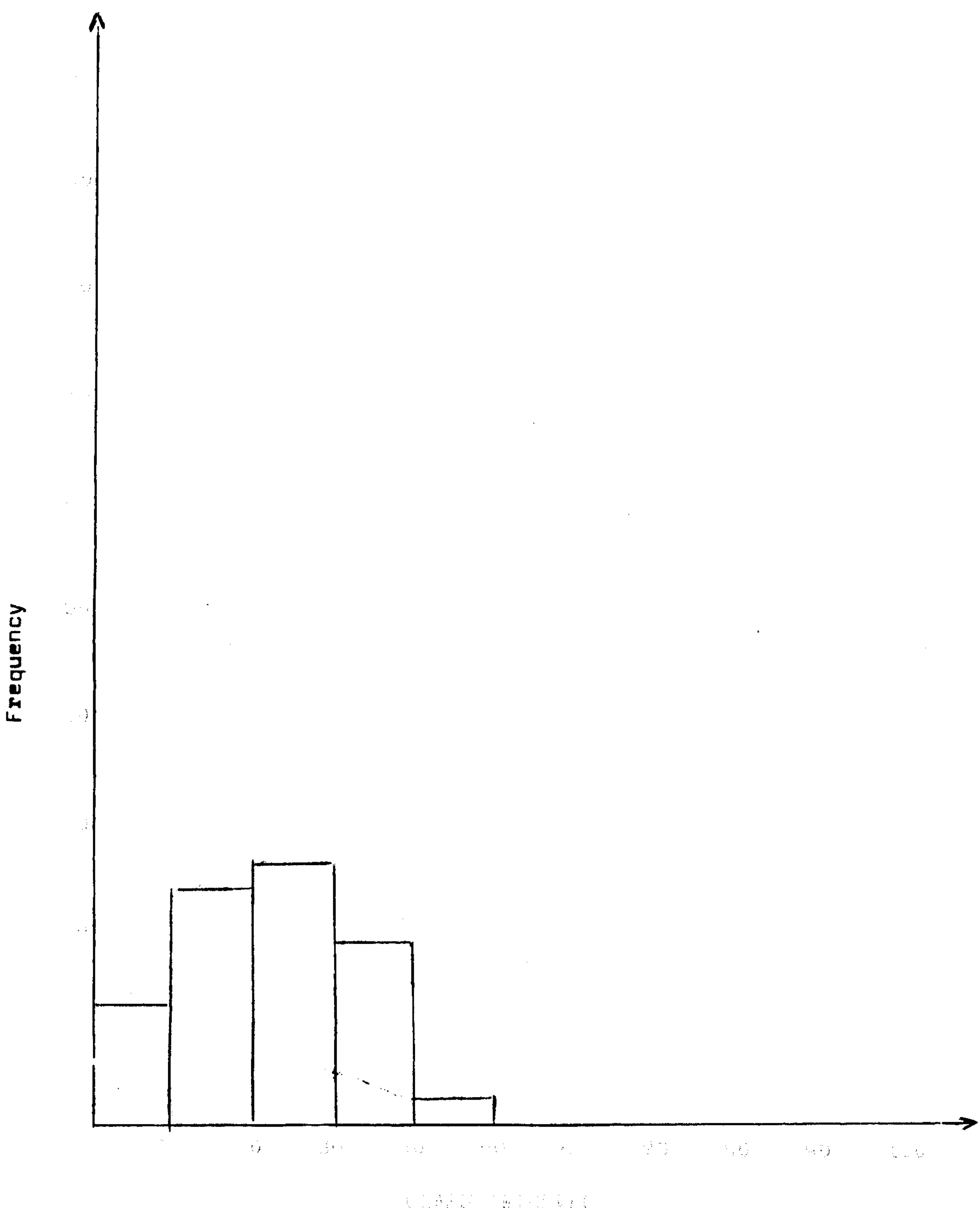
POST-TEST SCORES: CONTROL.

CLASS INTERVAL	FREQUENCY
0-09	12
10-19	23
20-29	27
30-39	19
40-49	01
50-59	0
60-69	0
70-79	0
80-89	0
90-99	0
TOTAL	82.

MEAN = 22.006

STANDARD DEVIATION = 9.136.

STANDARD ERROR = 1.009.


Frequency

APPENDIX IV.

STATISTICAL TESTS

COMPARISON OF PRE-TEST SCORES: CONTROL VERSUS TREATMENT.

WILCOXON TEST:

MEAN RANK	CASES
43.70	47 - RANKS (CONTROL LESS THAN TREATMENT).
35.54	35 + RANKS (CONTROL GREATER THAN TREATMENT).
TOTAL	82

Z = - 1.6296

Z(81) = - 1.6296,   P < 0.05.

CONCLUSION: NO SIGNIFICANT DIFFERENCE BETWEEN THE PERFOMANCE OF THE CONTROL AND TREATMENT GROUPS BEFORE INSTRUCTION.

T-TEST

	NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
TR.	82	25.2439	10.457	1.1555
CR.	82	22.5549	7.503	0.8290

TR = TREATMENT GROUP.   CR = CONTROL GROUP.

t(81) = 1.64,   P < 0.05.

CONCLUSION: NO SIGNIFICANT DIFFERENCE BETWEEN THE PERFOMANCE OF THE CONTROL AND TREATMENT GROUPS BEFORE INSTRUCTION.

COMPARISON OF POST-TEST SCORES: CONTROL VERSUS TREATMENT.

WILCOXON TEST:

MEAN RANK	CASES
44.49	72 - RANKS (CONTROL LESS THAN TREATMENT).
19.95	10 + RANKS (CONTROL GREATER THAN TREATMENT).
TOTAL	82

$Z = -6.9436$

$Z(81) = -1.6296$, $P < 0.05$.

CONCLUSION: SIGNIFICANT DIFFERENCE BETWEEN THE PERFOMANCE OF THE CONTROL AND TREATMENT GROUPS AFTER INSTRUCTION.

T-TEST:

NUMBER OF CASES	MEAN	STANDARD DEVIATION	STANDARD ERROR
TR. 82	42.4207	14.548	1.607
CR. 82	22.0061	9.136	1.009

TR = TREATMENT GROUP. CR = CONTROL GROUP.

$t(81) = 10.22$, $P < 0.05$.

CONCLUSION: SIGNIFICANT DIFFERENCE BETWEEN THE PERFOMANCE OF THE CONTROL AND TREATMENT GROUPS AFTER INSTRUCTION.

APPENDIX V.

COMPARISON OF THE POST TEST SCORES AMONG PUPILS IN THE BOYS',GIRLS', AND CO-EDUCATION SCHOOLS.

SCHOOL	MEAN	STANDARD DEVIATION	STANDARD ERROR
SCHOOL 1. BOYS'.	52.054	14.353	2.712
SCHOOL 2. GIRLS'.	38.786	12.057	2.278
SCHOOL 3. CO-ED.	36.148	11.812	2.273

T-TEST

COMPARISON	T-VALUE	SIGNIFICANCE
SCHOOL 1 VERSUS SCHOOL 2.	t(27) = 4.60, P<0.05.	SIGNIFICANT.
SCHOOL 1 VERSUS SCHOOL 3.	t(27) = 5.50, P<0.05	SIGNIFICANT.
SCHOOL 2 VERSUS SCHOOL 3.	t(27) = 1.01, P<0.05.	NOT SIGNIFICANT.

CONCLUSION:

THE BOYS' SCHOOL PERFOMED SIGNIFICANTLY BETTER THAN THE GIRLS' AND CO-EDUCATION SCHOOLS, WHILE THERE WAS NO SIGNIFICANT DIFFERENCE IN PERFOMANCE BETWEEN THE GIRLS AND CO-EDUCATION SCHOOLS.

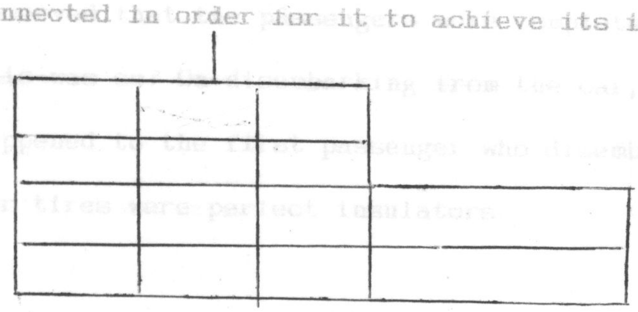
APPENDIX VI:

THE RESEARCH INSTRUMENTS.

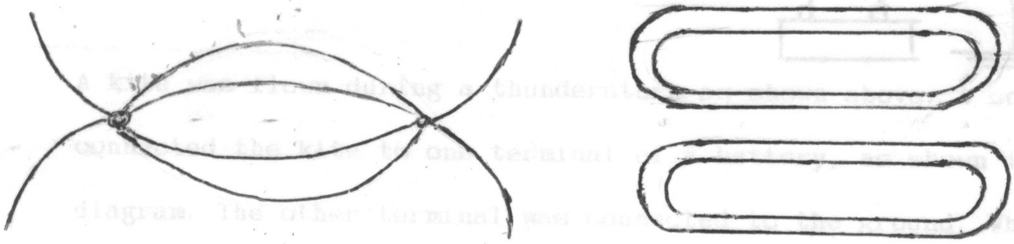
THE PRE-TEST

ANSWER ALL THE QUESTIONS. TIME 90 MINUTES. GRADE 12.

1. Tall buildings sometimes have a long pointed metal rod on their roof tops. What is the function of the metal rod? Where is the metal rod connected in order for it to achieve its intended purpose?

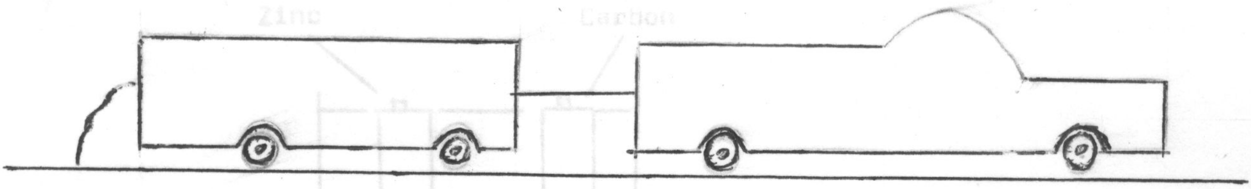


2. Forces can be classified as field forces and as contact forces. Field forces are associated with vector fields in which their effect is felt. Which of the vector fields below represents an electric field?



3. A tall man, suspected of being a criminal, is suddenly struck by lightining while running across a flat plain with no tall trees nearby. Explain this man's misfortune.

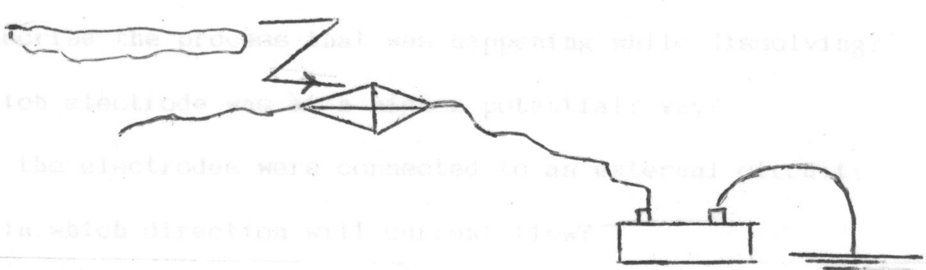
4.



Land trains like the truck and trailer shown above usually trail a chain while moving. Why is this? What happens to the land train while moving which necessitates this precaution?

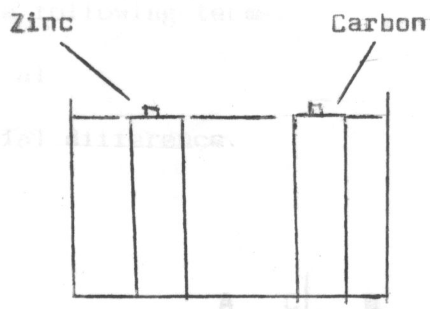
5. A light ning bolt hit a moving car with passengers inside. It was observed that the passengers were completely unharmed. Explain why this was so? On disembarking from the car, what could have possibly happened to the first passenger who disembarked? Assume that the car tires were perfect insulators.

6.



A kite was flown during a thunderstorm as shown above. A conductor connected the kite to one terminal of a battery, as shown in the diagram. The other terminal was connected to the ground. What was the purpose of the experiment? Which had a higher potential, the earth or the clouds? Explain.

What was the sign of the charge that flowed from the cloud to the battery?

7. 

A zinc and carborn electrode were placed in a solution of ammonium chloride electrolyte. It was observed that the zinc dissolved more than the carbon. What is an electrolyte? What is an electrode? Why is ammonium chloride an electrolyte? Which of the electrodes had a negative charge, and which one had a positive charge? Give reasons for your answer.

8. In the question above, both electrodes dissolved, but at different rates.

a) Describe the process that was happening while dissolving?

b) Which electrode was at a higher potential? Why?

c) If the electrodes were connected to an external circuit:

i) In which direction will current flow?

ii) In which direction will electrons flow?

d) Then what could be the definition of electric current?

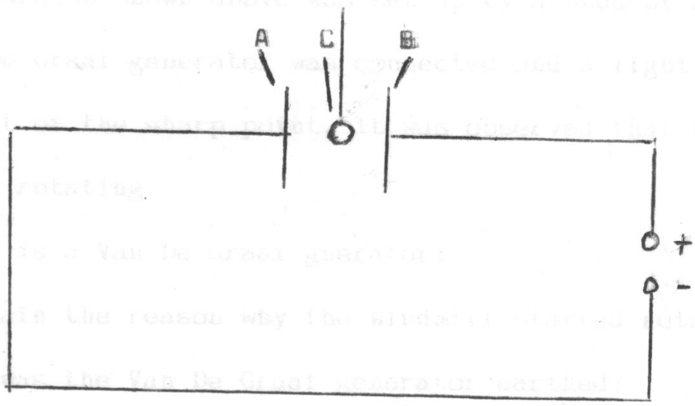
9. Aggie Bwalya, a tailor, noticed that synthetic fibres produced sparks when rubbing against each other. Explain this observation? Are synthetic fibres conductors or insulators? Describe another observation from your experience where something similar occurs.

10. Define the following terms:

a) Potential

b) Potential difference.

c) Charge

11. 

A and B are metal plates. C is a pith ball coated with aluminium. A and B are connected to a 40 Volts source of potential difference.

a) What are the charges on A and on B?

b) Show the charge distribution on the pith ball when it is in the position shown in the diagram.

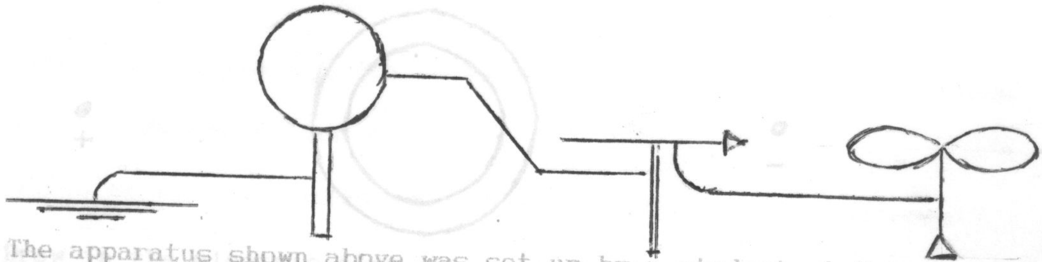
c) If the pith ball is now touched to metal plate A, describe what will happen in terms of its charge distribution on it?

d) What course of events will subsequently occur after the pith ball touches A?

e) What would be observed on an ammeter if plate A was connected to B through an ammeter, during the course of events described in (d) above?

f) What function would the pith ball be playing then?

12.



The apparatus shown above was set up by a student at Matero School. A Van De Graaf generator was connected and a light windmill placed in front of the sharp point. It was observed that the windmill started rotating.

a) What is a Van De Graaf gnerator?

b) Explain the reason why the windmill started rotating?

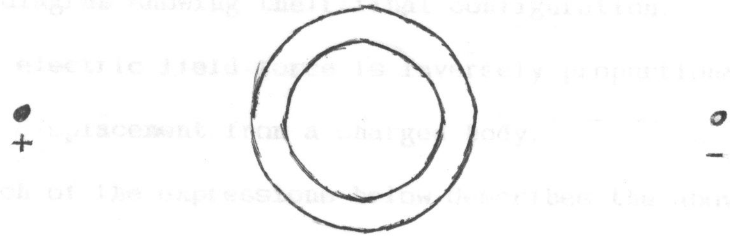
c) Why was the Van De Graaf generator earthed?

d) Supposing the metal rod was not sharp at its arrow end, what could have been observed instead?

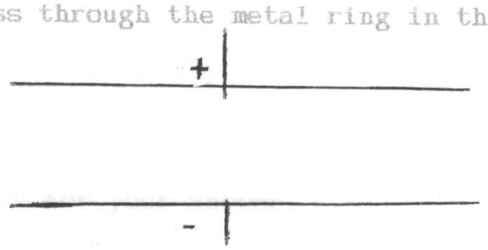
13. A glass rod was rubbed with silk until it acquired a positive charge. What charge was acquired by the silk?
The glass rod was then touched to the cap of a gold leaf electroscope. Draw a gold leaf electroscope, and show the charge distribution in it.

14. A and B are metal spheres. A has a positive charge. Draw a diagram showing the charge distribution on B if B is sufficiently close to A. Metal sphere B was then earthed briefly. Draw a diagram below of the charge distribution on metal sphere B after earthing.
Was sphere B been charged by induction or by conduction? Explain.

15.



a) Draw in the electric flux lines in the diagram shown above, showing how they pass through the metal ring in the middle.



b) Draw the flux lines between the two electrodes in the diagram shown above.

c) Charges A and B are moving in an electric field. A moves parallel to the field and B moves in a perpendicular direction to the field. In both cases a force of 10 Newtons acts on each of them , and both are displaced a distance of 0.5 meters in their respective directions.

i) Calculate the work done on each of the charges A and B.

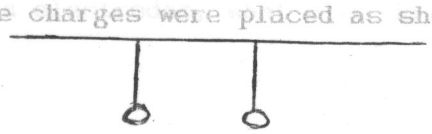
ii) What is the potential difference between the two electrodes?

iii) Calculate the magnitude of charge A in coulombs?

iv) If ten charges similar to A moved between the two electrodes in two seconds, what current flowed?

v) Why is the work done by A different from the work done by B?

16. Two positive charges were placed as shown in the diagram below.



Draw a diagram showing their final configuration.

17. The electric field force is inversely proportional to the square of the displacement from a charged body.

    Which of the expressions below describes the above statement?

    a) $F = -k/r^2$

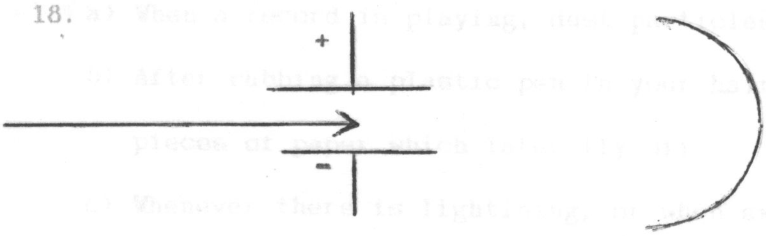
    b) $F = k/r$

    c) $F = kr$

    d) $F = kr^2$

    Give a reason for your answer.

18.



The diagram above shows a stream of electrons passing between two oppositely charged electrodes, and landing on a fluorescent screen.

a) What is a fluorescent screen?

b) Suggest a fluorescent material that can be used to coat it.

c) Complete the diagram by showing the final path of the electron beam.

d) What inference can you make on the sign of the charge on the electron?

e) Other than electrodes, what else do you think can bend electron beams?

f) Give one example of an instrument which makes use of the bending of electron beams in a force field?

19. a) When electrons are stationary, what force field is associated with them?

b) What force field is associated with mobile electrons?

c) Explain the magnetism of a bar magnet in terms of electron movement inside it.

20. Explain the following observations:

a) When a record is playing, dust particles stick to it.

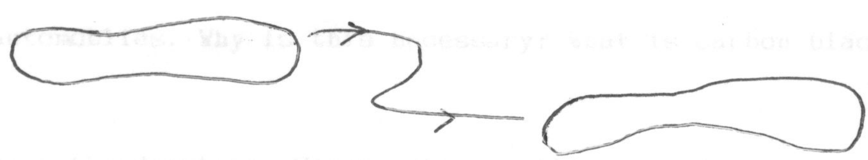
b) After rubbing a plastic pen in your hair, it attracts small pieces of paper which later fly off.

c) Whenever there is lightining, or when switching on or switching off an electric current,'static' is heard in a radio set.

THE POST TEST

ANSWER ALL QUESTIONS. TIME 90 MINUTES. GRADE 12.

1. A flash of **lightning** was observed to move from one cloud to another as shown below. Thunder followed.



a) Which cloud was at a higher potential than the other?

b) How did the clouds acquire the charges?

c) What caused the thunder?

d) What was the direction of the current and the direction of electron flow?

2. Two positive ions of sodium are placed close to each other as shown below.

a) Plot in the electric flux lines between the charges.

b) What is the nature of the force between them?

3. a) What is a positive ion called?

b) Draw the electric field between a positive potassium ion and a negative chloride ion.

4. A trolley is being pushed into an operating theater in a hospital. (The disinfectant used in the theater is flammable). A short metal chain that trails to the floor is attached to the trolley.

What is the function of the short chain?

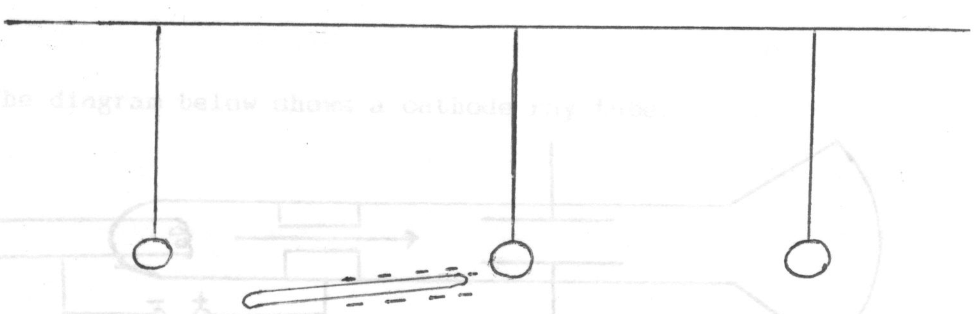
Carbon black, a conductor, is mixed with rubber while manufacturing tyres for automobiles. Why is this necessary? What is carbon black?

5. During a thunderstorm, Simon, while sitting inside a warm and dry room, placed a radio set inside a metal case to protect it.

a) He was protecting it from what?

b) How did the metal container protect the radio?

6. Study the sequence of diagrams below.

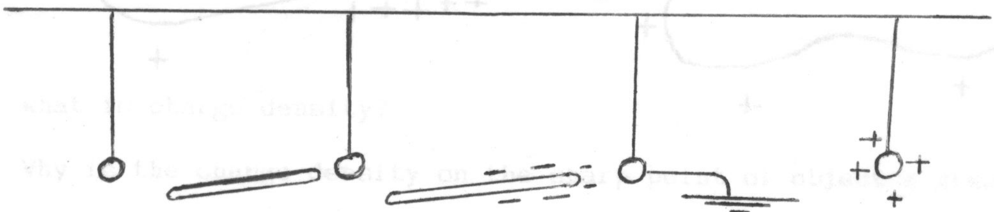


6. A negatively charged ebonite rod is touched to a pith ball, and on removal, a negative charge remains on the pith ball.

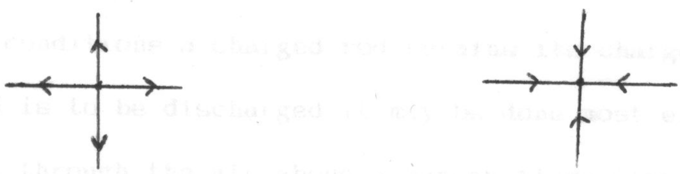
a) Explain how this happened?

b) Is this charging by conduction or by induction?

7. Study the sequence of events in the diagram below. Is this charging by induction or by conduction? Explain what is happening during each stage of the charging process shown in the diagram.

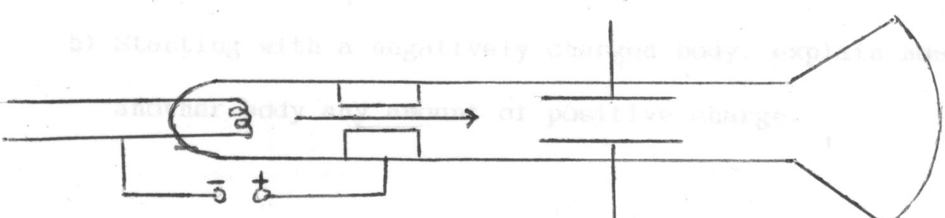


8. The diagram below shows two charges and their attendant electric flux lines.



Identify the negative charge and the positive charge. What is an electric flux line?

9. The diagram below shows a cathode ray tube.

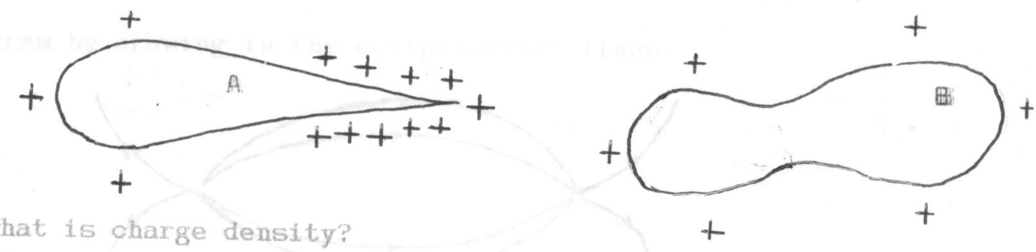


a) What is the function of the hot wire filament?

b) Why is the accelerating plate put at a positive potential with respect to the filament?

c) Which is a likely voltage between the filament and the accelerating plate in the correct working range?

10. Study the diagrams below.



a) what is charge density?

b) Why is the charge density on the sharp point of object A greater than that on the more rounded surfaces of B?

11. Under dry conditions a charged rod retains its charge for a long time. If the rod is to be discharged it may be done most effectively by passing it through the air above a bunsen flame. Give an explanation for this.

12. a) What is an equipotential line? What is electromotive force? What is absolute potential?

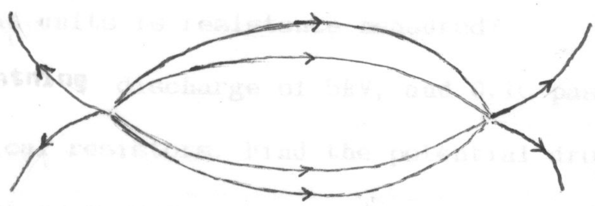
b) Starting with a negatively charged body, explain how you can give another body any amount of positive charge.

13. a) What is the work done when a charge of 0.05 coulomb falls through a potential difference of 10 kilovolts?

b) What current flowed if the charge took 0.02 seconds to pass through the potential difference of 10 kilovolts?

c) Calculate the power.

14. The diagram below shows the electric field of a body. Complete the diagram by drawing in the equipotential lines.



b) The potential difference of a charge 'Q', at a distance 'R', is directly proportional to the size of the charge, and inversely proportional to the distance from the charge.

Which of the expressions below is consistent with the statement above?

i) $V = kQ/R^2$

ii) $V = kQ/R^3$

iii) $V = -kQ/R$

iv) $V = -kQR^2$

15. The diagram below shows a pupil observing a stationary charge.

He was sure that what he was observing was an electric field. If the charge started moving while he remained stationary, what force field would he observe? Supposing he moved at the same constant velocity as the charge, what force field would he observe?

16. When charges pass through a resistor, it becomes hot.

a) What is a resistor?

b) In what units is resistance measured?

c) A lightning discharge of 5kV, and 0.1C passed through three identical resistors. Find the potential drop across each resistor.

17. Study the diagram below showing the cross section of the earth's interior. The magma inside the earth is made of very hot ionised molten rock. Convection currents exist inside the magma.

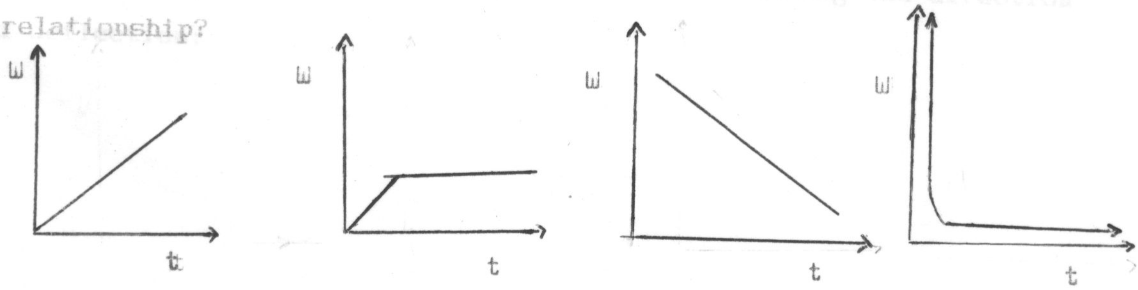
Explain what causes geo-magnetism in terms of the motion of ionised magma in the earth.

How can geo-magnetism be detected in the laboratory?

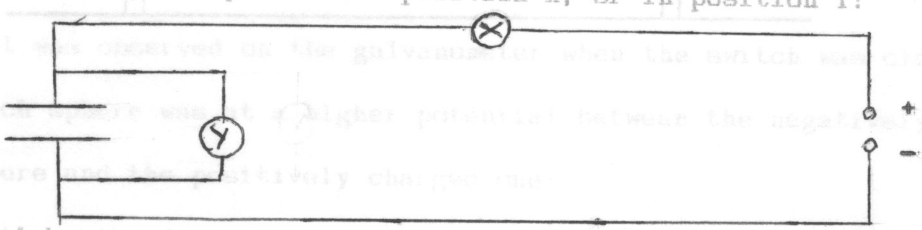
18. The work done, 'W', by a charge, 'Q' coulombs, under a potential difference 'V' volts in time 't' seconds is given by the expression;

$$W = VIt,$$

where I is the electric current. Which of the graphs below shows this relationship?

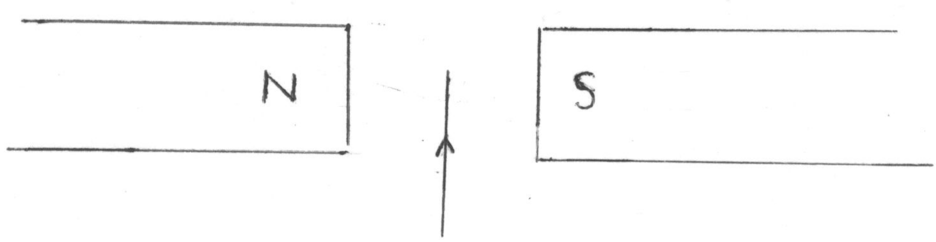


19. Study the circuit diagram below where a cathode ray oscilloscope is being used as an ideal voltmeter since it has a very high resistance. In the diagram, the cathode ray oscilloscope is being used to measure the potential difference across the capacitor plates. Where should the oscilloscope be placed? In position X, or in position Y?



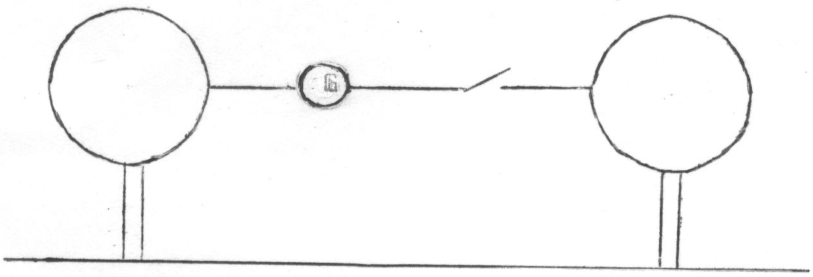
b) A bar magnet was found to move a fluorescent spot on the screen of a cathode ray oscilloscope. What conclusions can make on this observation?

c) In the diagram below, an electron beam was passing between the two unlike poles of two magnets. Complete the diagram by showing the direction in which the electron beam is deflected.



d) What mathematical principle did you use in determining the direction of deflection?

20. Study the circuit diagram below carefully.



a) What was observed on the galvanometer when the switch was closed? Why?

b) Which sphere was at a higher potential between the negatively charged sphere and the positively charged one?

c) What was the direction of the electric current when he switch was closed?

d) Did the spheres remain charged after the switch was closed? Why?