IDENTIFICATION OF ERRORS IN PHYSICS AND EFFICACY OF A REMEDIATION PACKAGEAMONG SECONDARY SCHOOL STUDENTS IN ZARIA, KADUNA STATE, NIGERIA

BY

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NIGERIA

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OCTOBER, 2015

DECLARATION

I declare that the work in this dissertation titled “Identification of Errors in Physics and efficacy of a Remediation Package among Secondary School Students in Zaria, Kaduna State, Nigeria” has been carried out by me in the Department of Science Education of faculty of Education, Ahmadu Bello University Zaria, Nigeria. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertationwas previously presented for another degree or diploma at this or any other Institution.

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Mohammed Kabir FALALU	**Signature**	**Date**

CERTIFICATION

This dissertation titled "Identification of Errors in Physics and efficacy of a Remediation Package among Secondary School Students in Zaria, Kaduna State, Nigeria" by Mohammed Kabir FALALU, PhD/EDUC/08176/2008-09, meets the regulations governing the award of the degree of Doctor of Philosophy (PhD) in Science Education of Ahmadu Bello University, Zaria, Nigeria and is approved forits contribution to knowledge and literary presentation.

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DEDICATION

I wish to dedicate this work to the memory of my late parents Alhaji Falalu Nuhu and Hajiya Rabiatu Shitu who made me to be the first to acquire Western Education in the family despite all odds. May their gentle souls rest in perfect peace.

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ABBREVIATIONS USED

WAEC	West African Examination Council
WASC	West African School Certificate
SSCE	Senior Secondary Certificate Examinations
G SS	Government Secondary School
STAN	Science Teachers Association of Nigeria
NPE	National Policy on Education
EDT	Error Diagnostic Test
PPMCC	Pearson Product Moment Coefficient of Correlation
SS II	Senior Secondary Class Two
NECO	National Examination Council
RP	Remediation Package
PAT	Physics Achievement Test

OPERATIONAL DEFINITION OF TERMS

Error: Incorrect response made by a student to stimulus in form of written test

Error-types: Various types of incorrect responses classified based on their nature and subject topic where the incorrect responses occur.

Error frequency The number of occurrence of incorrect responses in examination

Remediation: Correction of identified students' errors in Physics Examination.

DiagnosisIt is the identification of the nature and cause of errors committed by Students in Physics examination

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ABSTRACT

This study identified the errors committed in Physics Examinations and tested the efficacy of a Remediation Package developed and tested among Senior Secondary School Students in Zaria Education Zone, Kaduna State, Nigeria .Two coeducational schools participated out of nineteen senior secondary schools in the zone. 122 students, comprising of 92 males and 30 females out of 1831 senior secondary school students were used in the study. The study design was in two folds; Diagnostic test for identification errors was survey while the remediation part wasQuasi experimental in nature. The instruments used were Error Diagnostic Test (EDT), Physics Achievement Test (PAT) and Remediation Package for Identified Errors in Physics (RP).During the diagnostic segment seventeen errors were identified and a Remediation Package for Identified Errors in Physics (RP) was developed based on identified error topics. At the remediation segment, experimental group was exposed to the remediation package using problem solving approach while the control group was taught using lecture method. Six research questions were raised and five null hypotheses were developed for testing. Frequencies and percentages of errors and achievement scores were used in answering the research questions while Chi-square, Pearson Product-Moment correlation Coefficientand t-test were the statistical tools used for testing the hypothesis at 0.05 level of confidence. After analysing the data, the following were the major findings; four error-types were identified with factual error having the highest and communicative error having the least frequency. There was significant difference in the frequency of different error-types committed by the SSII students in Physics examination, there was significant difference in the academic achievement of SSII students between those exposed to the Physics remediation package and those taught using lecture method and there was an inverse relationship between frequency of errors and academic achievement scores of subjects. As error increased the achievement score decreased. This shows that the remedial package developed based on diagnosed errors and taught using problem solving method during remediation was effective in reducing error frequency and improving students' academic achievement. Recommendations were made for using the developed package to address similar situations too and Physics teachers should be trained and retrained with use of problem solving teaching strategy and on how to use the remediation package used in the study.

CHAPTER ONE

THE PROBLEM

1.1 Introduction

Science education is an essential part of education of all people growing up in a fast changing and increasingly complex technological world. Yakubu (2003) captures this succinctly when he used the analogy that Science and Technology are to modern life of what hands are to the body. Science and Technology are used to harness the forces of nature and transform the raw resources with which nature endows man into goods and services for better quality of life.One of the broad aims of National Policy on Education in Nigeria is to equip students to live effectively in the age of modern science and technology (FME 2013). To concretize the policy aim, science subjects amongst which is physics, are made core subjects being taught in Nigerian secondary schools. According to Atadoga (2000) the teaching of Physics is expected to achieve certain aims. Such aims include:-Training to specialize to a science-based career,Broadening the horizon of non-technical students by giving them some familiarity with the content and discipline of the subjects,training of technical manpower such as research scientists, applied scientists and engineers.

Atadoga (2000) further observed that the objectives of teaching Physics in the secondary school include the following:

i. Learning of the fundamental facts and principles of science.

ii. Development of the abilities and skills needed to engage in the processes of science.

iii. Inculcation of positive attitude about and appreciation for science and consequences of science.

The objectives of teaching Physics were drawn with some expected consequences. Three of the consequences of learning science according to Roth and Lawlers (2002) include coping effectively with everyday life in a society that is highly influenced by technology; learning science as a way by which scientific knowledge and skills can be deployed and integrated with other types of knowledge and skills in a technological and environmental context. The third dimension of the consequences of acquiring scientific knowledge is the belief in the assumptions of the dynamic nature of scientific knowledge.All these aims and objectives were designed to help fashion out a curriculum that is relevant for the development of a nation that is technologically and economically vibrant (Atadoga 2000).

Yakubu(2003) asserted that in the modern world of science, the technological potentials of any nation could be more accurately gauged by the quality of its science education programmes.Science education programmes usually consist of scientific processes and products. Science education is a process of teaching, training and learning to acquire scientific knowledge and skills by the learner. Scientific processes are the tools required by learner to acquire scientific literacy and the vehicle through which teachers teach science content (Santa& Alvermann1991). Science educational processes refer to teaching, learning, exercises, testing, procedure, methods and verification of science knowledge (Santa & Alvermann 1991). InfactWolf (1999) sees the processes having three major elements namely, objectives, learning experiences and appraisal procedures. Science educational objectives represent the desired performance or behaviours that individuals in a programme are supposed to acquire. Learning experiences are those activities and experiences that the learner acquires in order to attain the desired behaviors e.g. defining a problem, hypothesising and making observation. Another element of educational processes is appraisal procedures and which are usually called evaluation. Scheerens, Glas, & Thomas(2003) described educational evaluation as a systematic collection and interpretation of evidence leading, as part of the process, to a judgment of value with a view to taking action. They considers evaluation as the act of gathering information and juxtaposing it with some set of criteria to make judgments regarding the strengths and weaknesses, merits or worth of an educational innovation, programme, or product.

Since Education prepares future generations to take their place in their societies(Sanders, 1999), educators and other members of the society cannot afford to retain substandard performance of students, materials and methods of instruction. There is therefore the need to evaluate and assess the quality in all aspects of teaching and learning strategies in order to identify and possibly reduce the general problems leading to substandard performance among science students generally and Physics in particular. Evaluation is normally intended to lead to better policies and practices in education (Sanders, 1999).Evaluation is a feedback mechanism which provides students and other stakeholders with information on how learners are meeting set targets and expectations. Evaluation also provides teachers with feedback on how well the students are learning and also helps to gauge the quality of the instructional strategies employed. Evaluations also provide information to the educational administration on the effectiveness of the teachers, the educational programmes, and how well the educational programmes are working.

School evaluation is in different forms. Formative evaluation is one conducted when a course of study or a lesson is in progress. Continuous assessment (CA) tests are usually given to students during the course of a programme. CA tests are examples of formative evaluation. When courses are completed, performances of students are usually evaluated. This kind of evaluation is known as summative evaluation. Leaving school certificate examinations, junior secondary school certificate examinations, (JSCE) and senior secondary school certificate examinations (SSCE) are some other examples of summative evaluation (Glickman, Gordon and Rose-Gordon 2009).

A general evaluation of students' performance in science at Senior Secondary School Examination in Nigeria has been reported in one of the WAEC statistical bulleting which could be used for different purposes such as guidance and counseling, designing of remediation package and review of teaching strategies in use. The result is as follows;

Table 1.1 Students' Performance in SSCE Science 2005—2011 in Nigeria.

Year	Total Number sat	Pass with credit	Percentage Passwith credit
2005	1745904	697026	39.92
2006	1893106	838720	44.31
2007	2079437	788292	37.91
2008	2093496	813935	38.87
2009	2274388	810559	35.64
2010	2229816	1159448	51.99
2011	2634052	1219778	46.31

Source: WAEC, Test Division, Lagos (2013)

The result of the percentage pass of Nigerian students shows that the performance in science is not encouraging with about two thirds of the secondary school students failing their examinations in sciences. The persistent poor performance of students in science at the secondary schools level is creating worries on the future of science and technological development which is a perceived visionary Nigerian national goal. The persistent poor performance of students in science needs to be addressed by further studies on the problems students face during examination which may have been affecting students' performance in science. Another result of students' performance in Physics for Senior Secondary School Student in Nigeria for last five years is also not encouraging**.**

Table 1.2 StudentsPerformance in SSCE Physics from 2005 to 2010 in Nigeria

Year	Total Number sat	Number with credit	Percentage with credit
2005	344411	142943	41.50
2006	375824	218199	58.05
2007	418593	180797	43.19
2008	415113	200345	48.26
2009	465636	222722	47.83
2010	463755	237756	51.27

Source: WAEC, Test Division, Lagos (2011)

From the information presented on students" performance in science in general and Physics in particular, the consensus is that there is consistent poor performance in senior secondary school examinations in Physics. There is therefore the need to conduct further studies in order to diagnose some of the problems and errors committed by the students with a view to remediate the identified errors.

Diagnostic assessment tests are usually designed to identify weaknesses in learning processes. It is usually designed and administered by trained professionals. It can be conducted at any point during learning depending on the aim it is intended to achieve. The outcome of such evaluation could be useful to the teacher in the design, teaching, learning and assessment strategies of a programme. Diagnostic evaluation is also used to gain fuller understanding of students' grasp of key concepts of a subject of study. It is also used for determining qualitative measure of learning gained from different types of instructions. It is used to measure where a student is in terms of his knowledge, skills and ability to solve problem or answer questions as required in a subject area. In diagnostic evaluation records of students' performance are usually collected and the discrepancies between expected correct responses and actual students' responses are recorded. The possible causes of such discrepancies, if any, are also considered. From the outcome of the evaluation, remedial treatment could be proffered (Voltz 2010). Some forms of diagnostic evaluation include misconception studies and error analysis of students' responses to given tasks. Present study will involve diagnosing students' errors on senior secondary school Physics Mock Examinations, designing a remediation package based on the identified errors and a test for the efficacy or otherwise of the package.

Shaibu(1987) was of the view that remediation package could take different designs and approaches. It could be made in a formof training in the method of correcting the identified challenges using a designed programme to be handled by a professional on the chosen method. He went on to say that remediation could take the form of guidance and counseling on the identified area where errors are prominent. As a means of remediation, an instructional material could be designed containing lecture notes and exercises, to be delivered to students with identified challenges using a teaching method suitable to the cognitive level of erring students and nature of errors committed by the students. Teaching with a remediation package designed based on the identified errors committed by students was the approach employed in present research. Remediation based on identified errors was the approach adopted from Shaibu(1987).Errors committed werefirstidentified in the diagnostic segment of error analysis studiesand then the remediation was carried out.

The errors identified were classified based on classifications made by some researchers like Inekwe(1984), Melle(1996)and some Examination bodies like WAEC.Hornby (2000) defined error as a mistake especially one that cause problems or affects result of an activity. Inekwe (1984) defined error as a wrong process carried out by students in problem solving which leads to a wrong solution after one has been taught the right process. Inekwe (1984) also viewed mistake as an oversight that may lead to an error in problem solving which is not due to one's lack of knowledge of the correct algorithm. Melle (1996) defined error as mistake or incorrect responses made by a student to given stimuli in form of oral or written test. Errors could be procedural or conceptual in nature (Fong-lok, 1995). Errors committed in the procedure of solving given numerical exercises are referred to as procedural errors while conceptual errors are called misconceptions. Misconceptions are terms ascribed to individual thinking pattern that create problems with respect to science learning and teaching. Error analysis is defined as the study of the kind and quantity of errors that occur in a field of study. Error analysis in the present study is diagnosing students' error-types, nature and frequency of errors committed by secondary school Physics students with a view to finding the possible causes of the errors and designing a remediation package to help remediate the errors or misconceptions. Error analysis could involve studying students' school work such as homework, class work and sometimes diagnostic tests could be designed to identify the major errors the students commit and the possible sources of such errors. (Postelethwaite1999). In this study diagnostic test was used to identify the students' error.

The basic techniques of error analysis according to (Postelethwaite 1999) involve going through students' test, examination scripts, homework or assignment books and making frequency counts of the errors committed. Information about the most frequent errors committed can be obtained and possible causes of the errors could be identified. According to Postelethwaite(1999) the information about causes of the errors could be obtained using questionnaire from teachers and students about the problem they have had with the programme, tests or with the teaching strategy. The outcome could be used to design a remediation package to reduce or, if possible eliminate instances of the errors committed by the students. In the present study a diagnostic test was designed to determine students' error-types, nature and frequency of errors committed by secondary school Physics students a remediation package wasadministered to the errors committed which could lead to reduction in performance

Several studies have been conducted in errors and misconceptions that students commit in various academic disciplines. Examples of some of the studies in errors include those in Biology (Lawal, 1995, 2010), Mathematics (Inekwe, 1984; Isa, 1990) and Chemistry (Melle, 1996)Ajibola(1998). Students' errors in these studies cited were classified according to their nature, and type. Newbury (1965) classified errors, involving theoretical examinations in chemistry, into the following categories: spelling, grammar, factual statement, mistakes of using equations, result, conclusion and carelessness. Ajibola (1988) identified six error-types as follows: factual errors, algorithmic errors, diagrammatic error, wrong equation, inferential errors, blunder or carelessness. In Mathematics, Inekwe (1984) and Isa (1990) identified four types of error categories, namely; wrong operation, error of computation, algorithm error and random error. Some of the misconception studies conducted includes the initial knowledge state of college physics student Halloun & Hestenes (1995,) and some misconceptions in Newtonian mechanics. These studies identified allot of misconceptions that students have on areas studiedwhich could make students commit errors when answering questions in examinations.The Chief Examiners' report in WAEC (2004) also highlighted some students' errors in physics theory paper such as wrong explanation of quantities and concepts, wrong units, wrong diagrams, poor expression and poor application among others. Out of the research studies on error earlier mentioned, only Inekwe (1984) used diagnostic assessment on the teachers and students to ascertain the sources of the errors in Mathematics. Others did not seek the views of the teachers and students on the possible causes of the students' errors on the subject studied. Secondly the researchers only identified and classified the errors with a view to improving students' academic achievement. However improvement of students' academic achievement may not be attained without providing a remediation package to correct the identified errors. This study intends to fill these gaps.

A remediation package was designed based on the identified error–typesand possible reasons that prompted students to commit such error. The package was designed to alleviate the underlining problems that prompted the students to commit the often avoidable errors. Ado (2010) defined performances as how well an individual is able to demonstrate desired abilities. Usman (2000) defined performance as the extent to which students have learnt, acquired certain information, and mastered skills usually as a result of planned instruction or training. The senior secondary school students' performance in SSCE examinations in science and Physics in particular, has been rated as poor by many schools. Asim, Bassey and Essien (2005) for example conducted a five –year trend analysis of WAEC/SSCE results aimed at determining the level of students' performance in O' level Science, Technology and Mathematics (STM) subjects and the suitability of the students to pursue STM based courses in tertiary institutions. The consensus of the study indicated that the students' performance in science was poor with Physics having the worst quality of performance. In the same vein Onwiduki (1996) found that about 77.42% of Physics concepts were considered to be difficult by students leading to the committing of errors in examinations.

Several factors have been identified that lead to poor performances of students in science generally and Physics in particular. Some of the factors reported by Onah &Ugwu(2010) include teachers qualification, availability of laboratory facilities and gender. Usman (2000) reported on lack of use of practical activities and teaching strategies employed by the teachers. Owolabi's (2004) study on a diagnosis of students' difficulties in Physics revealed that poor performance of students in Physics could have emanated from students' lack of full understanding of Physics concepts. Some other studies have been conducted on factors on factors affecting students' academic performance with a view to finding lasting solutions to the incidence of poor performances of students' in science. Therefore to improve students' academic performance in science in general and Physics in particular, there is the need to identify the prevailing misconceptions and errors committed with a view to providing a package for remediation. The efficacy and gender dimension if any, of the packagecould be tested because the issue of gender effects on students' performance is not a concluded research concern.

Results of studies into gender-related factors in students' academic performance in science are still controversial. Researchers like Kennedy (2000), James (2000),Croxford(2003),Erinhoso(2005),Kolawole(2007) Ariyo(2006&,2011)have shown that boys achieve higher in science than girls. James (2000) cited an International Association for Evaluation ofEducational Achievement (IEA) report which showed that the gender-related differences in achievement were largest in Physics and smallest in Biology. Kelly (1987), Welch (1985), Lauzon (2001) however found that boys are not achieving as highly as girls in science. Shuaibu and Ameh (1982), Voyer and Voyer (2014) also found that female students perform better than their male counterpart in integrative processes and Biological science. Similarly, James (1991) found that female students performed better than their male counterpart in science when exposed to inquiry methods. The issue of gender-related differences in science is still a controversy. In this study therefore a remediation package involving problem solving skills was employed for correcting errors committed by O level Physics students and to determine whether or not if the remediation package is gender friendly. In all the studies earlier cited, the authors, for example Inekwe (1984),Melle (1996) did not identify the frequency of errors committed by the students on the basis of gender related differences. Lawal (1995) however found out errors committed in SSCE Biology practical have gender dimension; female students committed more errors than male students in the study. The gender dimension controversy was addressed in present study so as to fill the gap.

1.1.1 Theoretical Framework

The working principle that underlie the design of the error remediation package in this study was the generally accepted view that diagnosis presupposes remediation. The

Remediation Package for Identified Errors in Physics was designed considering the constructivists' view of knowledge proposed by Piaget (1977). Piaget(1977) developed the cognitive developmental theory. The three basic components of the theory are the schemas, processes that enable transition from one cognitive level to another and the four stages of cognitive development.

According to Cherry(2012) the schemas describes both mental and physical actions involved in understanding and knowing. The schema is the building block of knowledge. When a child's schema is capable of explaining what it can perceive around the child, the child is in a cognitive balance or equilibrium. When the child's schema is not capable of explaining what it can perceive, it is in disequilibrium. The child at this stage could display some kinds of misconceptions and also commit errors on some tasks given. On the processes of transition through the cognitive levels Cherry (2012) identified assimilation and accommodation as the processes. When a child takes in new information into his existing schema to move to equilibrium he is assimilating. Changing or altering existing schema in the light of new knowledge or experience is known as accommodation. Striking a balance between assimilation and accommodation is known as the equilibrium. The diagnostic approach of present study attempted to find out the nature and frequency of errors students commits when they are at a disequilibrium cognitive stage in the schema of knowledge on Physics theory. The instructional materials in the remediation package servedto reduce the level of disequilibrium so that a learner can easily emulate them easily or influence the restructuring of the learning cognitive structure to accommodate the learning materials as the process ensures areas where there are conflicts are resolved. The package served as new schemas on the identified challenging areas to assist students in assimilation and accommodation of new experiences to serve as remediation to identified errors.

Equally important is the Ausubel (1968) learning theory which states that the learner's previous knowledge is the most important factor that influences learning. According to Ausubel (1968) pupils organise knowledge by themselves and that meaningful learning occur when new knowledge is acquired by linking new information to learners cognitive structures.According to the theory, sets of new information known as advanced organisers are set to compare new knowledge with existing information for the new knowledge to be subsumed.In compliance with Ausubel's theory, the initial or previous knowledge and errors committed by students was diagnosed upon which a remediation package was designed. The treatment administered involved some activities to give the students opportunity to participate actively in constructing and developing their knowledge to correct the identified error. In designing the error correction package, Gagne's Learning Theory (1977) that describes the organisation of intellectual skills and concepts in a hierarchical order from simple to complex and from known to unknownwas employed.Gagne identified five major categories of learning: verbal information, intellectual skills, cognitive strategies motor skills and attitudes. (Gayne, Brigges& Wager, 1992).

Gagne suggested that learning tasks for intellectual skills can be organised in a hierarchy according to complexity: Stimulus recognition, response generation, procedure following, use of terminology, discriminations, concepts formation, role application, and problem solving. (Gagne, Briggs& Wager, 1992). The teaching and learning materials in the remediation package were organised based on the learning tasks suggested by Gagne(1977).

Gagne's Learning Theory outlined nine instructional events and corresponding cognitive processes:

- Gaining attention (reception)
- Informing learners of objective (expectancy)
- Stimulating recall of prior learning (retrieval)
- Presenting the stimulus (selective perception)
- Providing learning guidance (semantic encoding)
- Eliciting performance (responding)
- Providing feedback (reinforcement)
- Assessing performance (retrieval)
- Enhancing retention and transfer (generalization)

(Gagne, Briggs& Wager, 1992)

Based on Gagne's theory the learning materials in the remediation package werearranged in hierarchical order from simple to complex. The instructional strategy used in remedial teaching involved all the nine instructional events outlined by Gagne (1977) and the four stages in the four steps for remediation outlined by Shaibu (1987).

1.2 Statement of the Problem

In Nigeria, research and some statistical information from some examination bodieslike WAEC (2013)indicated a persistent failure of about two third of candidates that have sat for SSCE WAEC examination in science (Table 1.1 and 1.2). A statistics of entries and results for Physics in Nigeria; May/June WASSCE for 2005 to 2011 indicated an average pass of about 48% for the country and 34% for Kaduna State, the area of present research. The information on percentage pass in science and Physics in particular is an indication of the state of poor performance of students in science.Several efforts have been made by researchers to evaluate teaching and learning of science with a view to finding out the factors that affects or influence students' performance in science. The factors identified have been clustered into student-related, teacher-related and systemic factors. Some of the teacher-related factors include teachers' qualification, experience and teaching strategies often employed when teaching. Some of the student-related factors include gender(Onah & Ugwu 2011), misconceptions, errors committed in tests and examination(Owolabi 2004, Lawal 2009), and cognitive ability of students and performance of practical(Usman 2000). Some of the systemic problems include non-availability of teaching and learning materials, nature or type and location of schools (Ariyo 2006). All these factors have been fairly investigated in relation to students' performances in science.

Available literature indicated a number of studies in error analysis in relation to students' performance in science. Examples include Inekwe (1984) Mathematics; Hestenes and; Halloun (1985) in Physics Isa (1990) Mathematics, Lawal (1995) Biology, and Melle (1996) Chemistry.These researchers concentrated on identifying error- types and determination of possible relation between error frequency and students' performances. There was no attempt to design a remediation package to reduce the frequency and types of errors committed by students more especially in senior secondary school Physics. The problem of failure to identify types of errors and misconceptions by

Science educators and Physics teachers at secondary school level and designing a remediation package to address the errors could still keep the level of students' understanding of Physics concepts at a low level and thus increase the chance of committing errors in school certificate examination in Physics. Specifically this study investigates the type and frequency of errors committed by students of physics in senior secondary school examinations. The study also involves the designing of a remediation package to see its effect on reducing, if not eliminating the predisposing factors that prompt students to commit such errors and possibly improve students' performance in Physics at senior secondary school level.

Most of the research works conducted in Physics such as those of Thomas (2002), Foster (2004) concentrated more on determining errors and their remediation on practical aspects of Physics in relation to academic achievement without considering the theory aspect of Physics on which the Physics practical are designed to provide an opportunity for verification of theories, principles and lawsmade. The effort to diagnose and remedy the poor performance in Physics will not be comprehensive and all-encompassing if the study is not conducted on the theory aspect. Theaspects of Physicstheory constitutes 50% of the total marks awarded for the assessment and grading of students' performance in Physics subject in WAEC examinations. If the problem of error committed in practical is solved without considering the errors committed in Physics theory, students' poor performance may still not be fully addressed. Therefore, there is need to identify some of the errors committed by students in Physics theory and provide possible remediation package to address the identified errors which could possibly improve students' performance in Physics. The present studytherefore identified the nature and types of errors students commit in PhysicsMock and WAEC examination. A remediation package was designed and used to minimize, if not eliminate possibilities of further committing such errors in future.

1.3 Objectives of the Study

The aims of this study are to:

i. determine error types and the frequency of such errors committed by SSII Senior Secondary School students in Physics theory examinations .

ii.analyse the nature of the errors and the possible causes of the errors committed by students in Physics senior secondary school examinations.

iii.determine whether there is any relationship between frequency of error-types committed by students and their academic achievement in Physics examinations.

iv.design a remediation package with an aim to remedy the pre-disposing factors leading to the committing of the errors and misconceptions.

v.determine the effect of remediation package on senior secondary school Physics students' academic achievement in theory test.

1.4 Research Questions

Based on the research problem highlighted above, the following research questions were raised and answers sought for them in this study:

i. What types of errors do Senior Secondary School Students commit in Physics theoryExaminations?

ii. What is the frequency of error-types committed by SSII students in Senior Secondary School Examination in Physics theory papers?

iii. Is there any difference in the frequency of the error-types committed by SSII male and female students in Senior Secondary School Examination in Physics theory papers?

iv. Does the administration of the remediation package reduce the frequency of Error-types Senior Secondary School SSII students commit after exposure to the Remediation Package?

v. Is there any relationship between the frequencies of error-types committed by Students and theirAcademic Achievement in Senior Secondary School PhysicsExamination?

vi. What are the causes of errors committed by Students in Senior Secondary School Examination in theory Physics papers?

1.5 Null Hypotheses

Based on the stated research questions, the following null hypothesis were formulated for testing at 0.05 level of significance.

i. There is no significant difference in the frequency of different error-types committed by SSII students in Senior Secondary School Examination in Physics theory papers.

ii. There is no significant difference in the frequency of error-types committed by the subjectsexposed to Physics Remediation package and thoseexposed to lecture method.

iii. There is no significant difference in the frequency of error-types committed by male and female subjectsexposed to Physics Remediation package and those exposed to lecture method.

iv. There is no significant difference in Academic Achievement between the subjects exposed to remediation package and those exposed to lecture method only.
v. There is no significant relationship in the frequency of errors committed by the subjects exposed to the remediation package and their academic achievement in Physics.

1.6 Significance of the Study

The findings of this study will hopefully be significantto the following persons;

a. The teachers

The result of this study is expected to help give an assessment of the progress of the students and could indicate areas of Physics courses which are not well understood by the students. The findings could possibly help the teacher make adjustments in the teaching strategies and sequencing of concept to improve on students' academic performance and correcting errors being committed.

b. The students:

The findings from this study will hopefully help the students to be curios of how errors come so that they can avoid them especially the areas in which they are most prone to making such errors.

c. The Curriculum designers

The findings of this study could help the curriculum planners in adopting the remediation package for the improvement of teaching and learning of O' level Physics.

d. Senior School Certificate Examiners.

The result from this study will hopefully help to guide examiners to be aware of errors committed and think on how to improve in framing questions in a manner that might reduce the risk of students making unintentional errors visa-vie improving students' performance in both theory and practical O' level Physics.

e. Professional bodies

Professional bodies that have interest in identification and remediation of errors students commit in science subjects could adapt some effective strategies employed in present study.

f. Researchers

Researchers could critique, adapt, adopt and use the research approach on other subject areas and subjects.

1.7 Delimitation of the Study

The target subjects for this study were students offering Physics in Senior Secondary School in Zaria Education Zone of Kaduna State. Zaria Education Zone consists of 44 public secondary schools out of which 16 are senior secondary schools situated in Zaria, Sabon Gari, and Soba Local Government Area of Kaduna State. Schools located within these three local governments areas are designated by the state ministry of education as Zaria Educational Zone. Since Physics is the subject area of the present study and it is only taught at senior secondary schools, 19 senior secondary schools were the focus of the study. Zaria Education Zone was selected for the study because it is cosmopolitan in nature, where students come from different political, economic, cultural and religious groupings. Only two coeducational Senior Secondary Schools were used for present study for logistical reasons.

The students used in this study were the senior secondary school students offering Physics in the public schools in Zaria Education Zone. Considering that SS I students are just being introduced to Physics subject and may have succeeded in completing only about one third of the senior secondary school Physics syllabus and SSIII students have almost completed the syllabus but they are very busy preparing for external examinations. Thus SSII students were chosen for the study. The SSII students are expected to have been exposed to most of the Physics SSCE syllabus.

The topic used for the present research was mechanics. Mechanics is the most frequently studied subject area in Physics which include subtopics like Kinematics, Dynamics, Vectors, force and wave which appear in most other topics in Physics which contributes to Students' performance (Eryilmaz, 2002). A successful grasp of content of mechanics requiresan understanding of relevant concepts and sufficient problem solving techniques.

1.8 Basic Assumptions

The study has the following assumptions;

i. That the SS II students, have covered at least two third of the WAEC Physics syllabus.

ii. That the teachers of Physics teach the subject in senior secondary schools as required by the curriculum using appropriate methods of teaching.

iii. That students' answers are a true reflection of what they know.

iv. The students are exposed to physics practical lessons as required by senior secondary school curriculum

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter the literatures relevant to the study were reviewed, under the following subheading:-

- Teaching Physics in Senior Secondary Schools in Nigeria.
- Students' Academic Performance in Physics at SSCE
- Concept of Error
- Classification of Errors
- Error Analysis and its Significance
- Models of Error Analysis
- Gender Issues in Science
- Science Teaching Methods
- Remediation, Meaning, Strategies and Approaches to Remediation
- Overview of Similar Studies
- Implication of Literature Reviewed for the Present Study.

2.2 Teaching of Physics at the Senior Secondary Schools in Nigeria

. Physics is one of the basic science subjects taught in schools and its concepts and techniques underpin the progress of all other branches of science (Murenzi 2009).Physics generates fundamental knowledge needed for the future technological advances that will continue to drive the economic engine of the world. It is an element in the education of Chemists, Engineers, Computer Scientists as well as practitioners of other Physical

Biological Sciences (Jayden 2013) .Some of the importance of Physics mentioned above justifies the teaching and learning of Physics at the secondary level of evaluation.

Themain aim of teaching Physics at the Secondary School level is to contribute to the achievement of the general objectives of Science teaching, and to emphasise the specific nature of Physics and its relations with other Science disciplines. The other aims of teaching Physics as cited by Adeyemo (2010)include the following:

i. Giving the students a scientific knowledge throughenlarging their scope of knowledge; interpreting their scientific observations; understanding laws, models and theories of natural phenomena; andrelating physical laws to technological applications.

ii. Preparing students for scientific careers based on Physics and to awaken their scientific vocations.

iii. Making students aware of the scientific methods with all the rigour, intellectual honesty and critical thinking it requires. This consists of practicing the experimental methods in order to develop the skills of observation, data collection and analysis;the Mathematical formulation of the laws of Physics and the construction of modelsandthe resolution of concrete problems.

iv. Making students understand the scientific messages contained in diagrams, graphs and media.

v. Training students to express themselves scientifically through the use of the appropriate terminology and abstract representation.

From research and some statistical data obtained from some examination bodies like WAEC indicating the poor performance of student in science one can say that the aims and objectives of teaching Physics are yet to achieved. A diagnosis of students' learning difficulties, such as the errors they commit in examination with expected learning objectives could provide a framework for designing a remediation package to address the students' errors in examination which could improve students' performance. The diagnosis and remediation in Physics is what is intended in the present study with a view to improving the quality of teaching learning of physics in the schools.

2.3 Students' Academic Performance in Physics

Several studies were carried out on students' academic achievement. Ado(2010) view academic achievement as the students' overall learning experience resulting in an observable and measurable behavioral change which includes the acquisition of specific skills and technique at the end of a teaching-learning event. Usman (2000) defined academic performance as the extent to which students have learnt or acquired certain information, and mastered skills usually as a result of planned instruction or training. The senior secondary school students' performance in SSCE examinations in science and Physics in particular, has been rated as poor by many researchers. Asim , Bassey & Essien (2005) for example conducted a five–year trend analysis of WAEC/SSCE results aimed at determining the level of students' performance in O' level Science, Technology and Mathematics (STM) subjects and the suitability of the students to pursue STM- based courses in tertiary institutions. The consensus of the result from studies indicated that the students' performance in science was poor with Physics having the worst quality of performance. In the same vein a statistical data on entries and results for Sciences in Nigeria for WASSCE May/June 2006 to 2010 revealedthe poor state of students' performance in Physics. The data obtained from Shaibu (2014) showed a declining percentage pass 41.50, 58.05, 43.1, 48.26, 47.83, 51.27% of candidates with credit in Physics for the years 2005 through 2010.The results show a mean of 48.34% credit pass over the six years which is not impressive and thus justify the need for further diagnostic studies of students' problems or errors that have hindered commendable academic achievement in Physics on the part of the students concerned.

Similar situation of poor performance was observed in Kaduna State with percentage pass of 62.04, 34.05, 45.23, and 49.77% for the years 2006 through to2010 (WAEC Test Division Lagos 2011).The meanpercentage ofperformanceofthe students inthe SSCE WASSCE Physics Examination results reported was also poor. The unsatisfactory performance justifies the need for further studies with a view to identifying the factors that hinder effective performance of students in Physics. Several studies were carried out to address the issue of students' poor performance in science, one of which found out that students' performance in MOCK Examination is predictor to students' performance in Senior Secondary School Examinations (Ajayi, Lawani & Muraina 2011).With this view in mind presentstudy diagnosed students' errors in Physics at the Mock Examination stage with a view of cutting the nub at the pod. The identified errors served as indicators on where and how remediation package was designed to address the identified errors.

2.4Concept of Errors.

The term error has different meaning to different researchers. Inekwe(1984) defined error as a wrong process carried out by students in problem solving which leads to a wrong solution after one has been taught the right process. Melle (1996) defined error as mistake or incorrect responses made to stimulus in form of written or oral test. The views of the two researchers cited above differ because Inekwe(1984) view mistake as an oversight that may lead to an error in problem solving which is not due to ones lack of knowledge of the correct algorithm while Melle(1996) view error and mistake to be an incorrect responses made to stimulus. Mistakes, according to Corder(1981) are deviations such as slip of tongue caused by inattention and stress. In another dimension both error and mistakes are seen as a wrong action attributable to poor judgment, ignorance, or inattention (http://www.differencebetween.net). Error in a scientific measurement does not mean a mistake or blunder. Instead the term 'error' and 'uncertainty' both refer to avoidable imprecision in measurements (http://phy.colmbia.edu) visited on 30/8/2013.

According to Corder (1967); errors occur systematically and consistently when a learner is trying to use the knowledge he/she acquired in the subject of study, which may be as a result of memory lapse, brain fatigue, slip of pen and many other sources. According to Mohammed (2000) errors which are due to wrong processes tend to persist.This means that errors can be identified and corrected by the learner and the learner would need to be assisted to correct the wrong processes usually employed in solving problems. Errors could be conceptual as a result of learners' interaction with specific phenomena and that conception formed during this process constitute personal explanatory knowledge of the phenomena in question. Where the conception of a learner does not agree with scientific ideas, error or misconception occurs.According to Piaget (1977) concepts formed by the learner usually form the foundation on which new knowledge are anchored.The position of conception in developing knowledge made it necessary in this study to feature some test items in Error Diagnostic Test (EDT) to feature some tests on misconception of some terms in Mechanics.

2.5 Classification of Errors

Researchers on students'errors have identified and classified errors into different classes. Etherton (1977) observed that classification of errors varies from individuals to individuals. Sudam (1985) for example classified errors into five categories as follows:-

1. Random errors e.g. an error without a particular pattern
2. Errors related to sequencing steps within procedures
3. Errors related to conceptual learning
4. Errors related to selection of information or procedure.
5. Errors related to recording work.

Newbury (1965) classified error – types for written work in Chemistry into seven categories listed below:

i. Spelling errors e.g. wrong spelling of scientific terms or concepts
ii. Grammar errors .e.g. misuse of plural term in place of singular
iii. Factual errors e.g. when facts like laws, theories or definition are wrong
iv. Drawing error. This could be in form of wrong drawing of graphs or diagrams
v. Wrong equation which could occur when an equation is used at a wrong place.
vi. Wrong result and conclusion which may occur when there is wrong substitution or wrong arithmetic
vii. Carelessness such as disobeying simple mathematical operations

Ajibola(1988) proposed six error – types. These are:

i. Factual error such as stating wrong rules, theories or definitions

ii. Algorithmic error which could be inform of wrong arithmetic of substituted data.
iii. Diagrammatic error such as incorrect drawing or labeling of diagram
iv. Wrong equation, Inferential errors are using a wrong equation when solving problems and wrong conclusion.
v. Blunder or carelessness.

Inekwe(1984) and Isa(1990) reported separately but similar categorization of errors namely;

i. Wrong operation such as wrong usage formulae or basic operations
ii. Error of computation which could be in form of wrong arithmetic
iii. Algorithmic random errors.

Inekwe(1984) and Isa(1990) classification were for identified errors committed by students in Mathematics.Melle (1996) adapted the classification of Newbury(1965) and Ajibola (1988) in analyzing errors committed by students in Nigeria certificate in Education (NCE) Chemistry theory paper.

The West African Examination Council (WAEC) in their Chief Examiners report (WAEC2004) highlighted some students' errors in Physics theory examination as follows:

i. Wrong explanation of concepts such as wrong definitions of terms
ii. Wrong units of fundamental and derived quantities
iii. Poor expression in terms of language usage
iv. Poor explanation

In the present study, Ajibola'(1988) approach with some modificationwere adopted for the theory Physics examination errors under study. The error classifications used are;

i. Wrong explanation of concepts
ii. Use of Wrong units
iii. Poor expression
iv. Spelling errors for example wrong spelling of scientific terms or concepts
v. Grammar errors for example misuse of plural term in place of singular
vi. Factual errors e.g. when facts like laws, theories or definition are wrong
vii. Drawing error. This could be in form of wrong drawing of graphs or diagrams
viii. Wrong equations which could occur when an equation is used at a wrongplace.
ix. Wrong result and conclusion which may occur when there is wrongsubstitution or wrong arithmetic
x. Carelessness such as disobeying simple mathematical operations

The WAEC classification of errors was chosen because when students grow to the level of graduating from Senior Secondary School they arelikely going to write WAEC SSCE Examinations which when passed at credit level would qualify them to pursue science and technology careers. Thusidentifying and treating some of the errors highlighted by the examination body will go a long way in easing and possibly reducing errors committed by students during examinations. This kind of effort could improve students' performance in Physics.

2.6 Error Analysis and its significance

Error analysis is the study of the kinds and quantity of errors committed by students in a subject of study (http:/en.wikipedia.org). Taylor, (1997) defined error analysis as the study and evaluation of uncertainty in scientific measurements. Error analysis is significant in many respects; a study of students' school work, such as homework, class work, tests and examination to identify errors committed by students gives the teacher a fair ideas of the progress of the students and an indication of which part of the subject taught were not well understood. A good record of types of errors committed by students could guide the teacher when preparing future lessons. Stating the importance of error analysis to the teacher, Olayemi (1980) observed that Error analysis may show a teacher the areas where his/her teaching has not been effective enough and can provide data for preparation of teaching materials when extensive errors analysis is replicated.

According to Mohammed (2000), error analysis could indicate the state of the learner and show areas where remediation is needed. To the learners, it is psychologically important to indicate to them their errors, not as a sign of failure but as a positive source of improvement. Corder (1967), stated that errors are indispensable aspect of learning since the learner learns through their errors and discovers the acceptable from the unacceptable. Similarly error analysis is an indirect way of consulting the learner to find out their needs for the purpose of planning their curriculum (Corder 1967). This could be done by interviewing the students on tasks given to them with a view to identifying students' areas of weakness and strength which could be used in reviewing and planning students' curriculum

Etherton (1977) was of the view that error analysis based on adequate data would show:

a. common weakness with which pupils need help.

b. inadequacies in an official syllabus, faulty sequence of units or commission of essential materials.

c. weakness or errors which may be entirely new to the teacher or of which the teacher may be only dimly aware.

d. problem which are unknown to some textbook writers.

e. a form of self-education to the teacher, as the errors may show a teacher area where his teaching has not been effective.

Wyatt (1973), claimed that an error analysis may be undertaken in an attempt to find out the final remedial work that would be necessary before an end of course examination.

2.7 Models of Error Analysis

Students' errors are in different forms and classes, as such approaches of treating the different forms of errors may differ. The different theoretical approaches or stages of analysing errors are known as models of error analysis. Mohammed (2000) identified two major types of models for error analysis. These are descriptive and analytical models. Descriptive model centers on the structure and context of subject of study while analytical model advocates for the study of psychology of why and how errors occur.

Corder (1974)), one of the proponents of analytical model gave three stages for analysing of errors. The stages are:

1st Recognition Stage

2nd Description stage

3rd Explanation stage

At the recognition stage, the analyst tries to interpret the learners' intended meaning in the context with the aim of arriving at authoritative interpretation. Where the learner cannot be consulted, the analyst is left to interpret and reconstruct the message the learner intended to convey. During the second stage i.e. description stage the original students' response is compared with expected correct responses. This gives the description of the error committed .The last stage is the explanation of error. At this stage the why and how of committed errors are given..

Etherton (1997) also suggested two steps to guide the classroom teacher in making an error analysis. The first stage is copying the errors exactly as the learner makes them in an exercise book or on cards. The second stage is to identify the errors and classify them using appropriate headings. Mohammed (2000) in her study employed a synthetic model containing identification, classification and explanation stages as proposed by Corder(1974). Omojuwa(1979) used the three stage model proposed by Corder(1981) but however expanded the third stage of explanation by providing strategies for elimination of the identified errors.The three stage model suggested by Corder(1981) and employed by Mohammed (2000) with the addition of providing remediation strategy added by Omoguwa(1979) is what the present study employed in the present study.

2.8Gender Issues and Science Education

Gender is sometimes referred to as the roles assigned to different sexes i.e. males and females while sex refers to the biological differences existing between males and females (SMASE 2005). The role of gender in academic achievement in science has been a major concern to science educators. A good number of studies have been carried out to find out the influence of gender factor on academic achievement. A vast array of literature concerning gender differences favouring males in mathematics and science have been published over the past decades. For example Miller andHeripern(2014), Mari (1988) and Aigboman, (2002), reported significant gender differences in performance and achievement in science and science related tasks in favour of the males.Recent analyses suggest that observed gaps in gender-related achievement tend to be strongest in Physics and earth sciences than in Biology and 'life science' or general science (Stein and Machr, 1984; Lauzon 2001) Similarly Nwogwu , Ugwuanyi and Nworgu (2014) pointed out that the enrolment of women in tertiary institution has increased at a slower rate than male enrolment. They also observed that females tend to enroll in humanities and are found to be underrepresented in science subjects and mathematics where males dominate. Perhaps this could be as results of the fact that girls still have difficulty in understanding the physical sciences notably physics as observed by Aigboman (2002).A considerable effort has been made in a variety of studies to explain the observed gender-related gaps in science education. This trend was attributed by Miller (2012) to historical gender stereotyping of science as a "male realm" while to Nworgu (1988), the significant gender differences is due to content area interaction in science achievement, implying that males are more inclined to science than females.

Good, Julie and Lylan (20100supporting the claims of Miller (1983) observed that gender stereotyping which assigns sciences as male domain is a major cause of female low participation in science. On a similar note, Okeke (2001) agreed that this perception may have also contributed to the poor enrolment and achievement of girls in science and technology in tertiary institution. This trend, he claimed, can be traced back to history. It was formerly believed that certain subjects are not meant for women, and this tends to influence their attitudes toward such subjects. Historically formal education system was established by the missionary churches and colonial government with a belief that boys but not girls would benefit from an academic form of education (Ndirika, 2007). Girls generally remained illiterate and were encouraged to remain in the home (Hydeand Mertz2009). According to Hydeand Mertz, (2009), gender stereotyping permeates the school system manifesting in both direct and indirect ways. Biological explanations have been presented suggesting that there are some innate differences between the sexes that imply differential performance on assessments.

Oakes (1990) provided a useful summary of the individual, school and societal factors thought to explain differences in the way boys and girls participate and achieve in mathematics and science. Individual factors can be loosely grouped into cognitive and affective classes. With respect to cognitive differences, much has been written about gender differences, though there still exists debates about the extent of these cognitive differences, and whether they translate into differences in standardized achievement tests, and whether there is evidence that they can be overcome by training.

While some researchers such asWhiteleg (1997) ,Voyer and Voyer (2014) showed that girls perform better than boys in science, others, like Uhumuavbi *et al* (2003),Usman(2009) show on the contrary that sex (gender-factors) plays no significant role in achievement in science and technology. Similarly Olajide (2002) in a study investigating the influence of gender and other factors on the achievement of students in Biology reported that there were no gender-related differences in students' performance. AlsoSahranavard and Hassan (2013), Tobin (1993),Good, Julie and Lylan (2010), Abubakar, and Alao (2010), reported no significant differences in boys' and girls' scores in science. Usman(2000) reported that there was no difference in the performance of male and female students in Integrated Science practical activities when taught using NISEPT mode of instruction. Daramola (1983) also reported no significant difference in male and female student's scores in a study of influence of location and sex difference on the knowledge of basic Physics by form III students in Kwara State secondary schools. In line with the belief that gender factors may have influence on students' achievement, Ogunboyede (2003) conducted a study and found out that boys are not better than girls in terms of achievement in Science.

From the foregoing, it can be said that while the results from the studies on the existence of cognitive difference in science is inconclusive, it does seem clear that girls exhibit more negative attitudes toward science. However, there is little conclusive evidence that these negative attitudes cause lower academic achievement in girls (Oakes, 1990). The issue of the role of gender in academic achievement thus appears to be inconclusive; hence this study intends to investigate as aspect of the study gender-related issue, as it relates to errors that students commit in examinations which affect their achievement.

Ogunsola-Bandele and Lawan (1996) conducted research on error patterns and gender. The results of the study showed that the errors students committed in ordinary level in practical Biology were gender biased with female students committing more errors. The area in the subject of research was Biology practical only without due consideration to the theory segment of the subject. The information on error patterns in Biology subject would only be complete when similar studies are conducted into the theory part of the subject. It is also the aim of this study to fill this gap.

2.9 Science Teaching Methods

It was observed that what a learner learns depends not only on what the learner is taught but also on how the learner is taught as well as his/her developmental level, interest and experiences (Okebukola 1997). For this reason science education researchers believe that much closer attention needs to be paid to methods to be chosen for presenting learning materials to learners (Okebukola1997,Clement2003).Some of the methods advocated by science educators include inquiry method, discussion method, demonstration method, project method, fieldtrip, cooperative learning, simulation, concept mapping etc. Balogun (1982),Okebukola (1994), Okebukola (1997), Okebukola (2002), Clement (2003), Okafor and Okeke (2004). From the findings of the above listed science educators it appears obvious that the method the teacher uses to convey the content to the learner helps to create the learning environment and to specify the nature of the activity in which the teacher and the learner will be involved during the lesson.

Research findings of science educators like Jegede and Taylor (1998), Okebukola (2002), Tavi and Treagust (2002), reveal that those teaching methods that are activity-oriented and that involve the learner taking active role in the teacher/learning process result in better learning and understanding of science concepts on the part of the learner. However, teachers of physics and other sciences generally resort to the use of the popular “talk-chalk” method to teach in their classrooms. This method of teaching is popularly known as the traditional (lecture) method of teaching, Traditional method has been in use for a number of decades now, for teaching. Olerewaju (1994) stated that it was an old system of teaching, and that it was as old as teaching itself. This approach according to Jegede and Brown (1980) relied to a large extent on the learning of facts and the acceptance of these facts as proven beyond all doubts. Akusoba and Alao (1988) described traditional method of instruction as comprising of two approaches. The first was referred to as oral (lecture) approach, where the teacher does most of the talking and used the chalkboard occasionally, while the learner remains passive listener. This they also called "talk-and-chalk" method. The second approach in their classification was referred to as the use of printed materials like textbooks, science magazines etc to teach science concepts. Akusoba and Alao (1988) contended that lecture method could be used in place of the use of the printed materials where students are made to read these texts and in most cases committ the contents to memory without fully understanding the principle being learnt.

Olarewaju (1994) described traditional method of teaching as a "one way traffic" type of classroom interaction. Here, the teacher talks and writes notes on the board while the students listens and copy down notes. The teacher talks directly to the students and the students are not given any opportunity to ask questions or give feedbacks to the teacher. In traditional methods of classrooms interaction, minimum participation on the part of the student in the lesson takes place. The teacher is the all-knowing, and only comes to the class to deliver lesson while the learner listens and writes down key points dictated by the teacher. No active learning goes on in such learning. In fact, Abdullahi (1982) contended that ninety percent of scientific information or principles that students receive from their teachers come through lecture method. This he said is as a result of the emphasis the educational system placed on paper qualification, which are obtained through public examinations. Science teachers thus use lecture method since it leads to easy coverage of the school syllabus, which unfortunately is the main concern of science teachers and the society generally. The method leads to coverage of large amount of materials to a large class size in a single period. The method has indeed been found to be very useful in the area of content coverage. However, Abdullahi (1982) warned that for effective usage of lecture method in teaching, two teaching skills must be used by the teacher. These include clear and good command of language as well as ability to write clearly and boldly on the chalkboard.

Researches in science education have shown the inadequacy of lecture method in the teaching and learning of science concepts. The overall picture resulting from the use of this approach is that students tend to come out with large number of mistakes and errors in examinations and tests. These errors are simple indicators of misunderstanding of what has been taught and students' poor skills of responding to given tasks which could result in poor performance in science and science-related courses. Jegede and Brown (1980) reported that if the frontiers of scientific knowledge are to be extended, students of science at all levels have to be allowed to ask questions and not just accept concepts as being dictated by the teacher only. It is thus clear that the role of students' personal experiences in the construction of knowledge is necessary and important for effective and meaningful learning to take place. The interactive role of the learner is in line with the view of Kuhn (1970), who recognizes the role of personal construction in the development of scientific knowledge. Therefore there is the need to use activity-based teaching approaches in remediation of students' errors in Physics theory and practical examination. Activity-based approach was employed in the remediation strategy to be used in this study.

2. 10 Remediation, Meaning and Strategies

2.10.1 Meaning of Remediation

Remediation means different things to different experts. Perin (2003) defined remediation as a class or activity intended to meet the needs of students who initially do not have the skills, experience or orientation necessary to perform at a level that the institutions or instructors recognize as 'regular' for the students. The American Heritage (2000) defined remediation as an act or process of correcting a fault or deficiency. A dictionary website www.your.com defined remediation as an act or process of remedying or overcoming learning disabilities or problems. The website definition appears suitable for what remediation is considered in present study.

2.10.2 Strategies for Remediation

Remediation of identified errors may require some short or long -term plan to achieving the intended goal of correction. The plan for achieving the required corrections is the remediation strategy. Callaway and Moore (2007) presented an empirical approach to selecting a remediation strategy and opined that the success of a remediation depends on content of remediation and selecting the right strategy at the right time. They presented many competing learning theories upon which some remediation strategies were built upon.Vanlehn Silver,Mrray,Yamarchi and Bagget (2003) in Callaway and Moore (2007) proposed that students learn when they experience an impasse, such as getting stuck, they may be correct but uncertain and could have made a known type of error. This view may be the basis for conflict approach or strategy (Sleeman, Kelly Martinak, Ward, Moore 1989).Posher et al (1982) in Callaway and Moore (2007)who believe that cognitive dissonance or disagreementoccurs when a student is forced to confront an inconsistency between a strongly held but inaccurate expectation and an actual outcome. The teacher in this case shows what is wrong and the reason why the method is wrong. The remediator shows how to solve the problem. The entire task is done and practice tasks are given. (Sleeman et al 1989).

Wolf, Crosson and Resnik(2005) were of the view that when students are given an opportunityto give an "accountable talk" when attempting to solve a given task, valid examples and reasoning strategies of the student could be deduced which could give guide on areas of error. This view could be the reason why some remediation strategies require students to verbalize their problem solving procedures with a view to giving account of every step taken to solve a given problem. In other words students need to account for every step or action taken. This is the basis for corpus of human – human tutoring dialoque a computer assisted remediation programme designed by (Wolf et al 2005). Thomas and Rohwer (1993) in Callaway and Moore (2007) explained learning gains by the extent to which students apply cognitive effort or engagement when processing the new material. Here the teacher may ask the students verbally to show how and why they followed their chosen procedure for solving a given problem. After an assessment, the teacher shows the correct way on the board and reason for each step of solving the problem when students' earlier responses were wrong. The teacher re – present the task and ask for 'how' and 'why' for each step on solving the problem. If there is any error, the teacher correct on the spot and more practice tasks are given later (Sleeman, Kelly, Martinak, ward and Moore 1989).Reteaching is another remediation strategy in which students are given task to work out and where they are wrong, it is mentioned to them that they are wrong. The teacher then re-teaches the subject area where the students have committed errors in. The students are then re tested to see whether the remediation is successful or not (Sleeman et al 1989).

Several studies have been conducted to compare the effectiveness of the approaches for remediation of students' errors. Martinak, Schneider and Sleeman (1987) compared approaches for correcting algebra errors via an intelligent tutoring system. The aim of the study was to compare effectiveness of targeted remediation and reteaching or feedback approach. The subject of study were 15 9^{th} and 10^{th} grade equivalent JSII and SSI algebra students from high – achievement math class and 24 students from a low – achievement algebra class. The instrument used was intelligent tutoring computer system (RPIXIE) and statistical tool used was percentages. The result showed that the targeted and reteaching groups in the low – achiever class, scored higher than the evaluative group.The result showed that the computer intelligent tutoring system was effective correcting algebra errors

Swan (1983) in Sleeman et al (1989) reported that a conflict approach of error remediation was more effective than simple re-teaching. Conflict approach is another term for the cognitive dissonance approach to remediation.Bonderson & Olsen (1983) found no difference between error – specific remediation and re-teaching error remediation approaches. Error-based, model-based, (MBR) are used in describing a remediation strategy designed based on students' identified error pattern or model. Sleeman, Kelly, compared error – based or model – based remediation (MBR) with reteaching in algebra. The results showed that MBR and reteaching were both more effective than no tutoring; however MBR was not clearly more effective than reteaching.The literature reviewed so far has given some knowledge on different types of strategies of remediation and the relative effectiveness of some of the strategies. The intention of present research is to identify students' errors in Physics, design remediation package, and use re-teaching strategy to administer the remediation package. The re-teaching strategy was tried in error remediation of algebraic errors and was found to be effective.

2.10.3 Approaches to Remediation

Remediation approach is refers to particular ways of treating remediation of identified errors or challenges faced or experienced by students in given tasks. Shaibu(1987) identified four ways of treating problems experienced by students with problem solving difficulties. These approaches are training in the method of correcting identified challenges, guidance and counseling, lecture method and printed instruction approaches.

In the training approach the trainer prepares instruction on the general skill of problem solving procedure .This approach will require a lot of time and pedagogical skills to effective the required skills and strategies.The guidance and counseling approach will require verbal exchange between the teacher and the student on how to correct identified challenges. This will also involve the teacher asking the student to adopt or drop certain skills that may be related to students' identified problems. Mutual confidences, good rapport, follow up and time will be required for the success of this approach.Lecture method usually contain structured lecture on the identified problems with a view to promote understanding of the difficult concept or strategy. Verbal communication styles, classroom management skill, time, expertise in pedagogical skills are all required to succeed with this approach.

The printed instruction approach usually contains organised textual material of instruction organised in relevant area of difficulty. The structure and format of the text will depend on the nature, scope and theoretical assumptions on which the remediation is designed. This approach was used by Shaibu(1987) and found the approach simple, adaptable and time saving.

2.11.0 Overview of similar studies

In this section of the review, error analysis studies conducted in a number of subjects such as Mathematics, Chemistry, Biology, Physics and other related subjects were reviewed and critiqued. The review was presented according to subjects.

Mathematics has enjoyed appreciable number of error analysis studies. Hall (2002) for example investigated and analysed the errors students'committed in the processes of solving of lineal equations. Poor process skills in clearing square roots signs, fractions, and incorrect transposition of letters/symbols or numbers from one side of an equation to the other have been found as the great causes of error. Hall(2002) was of the view that the knowledge that an answer is wrong is not the same as the knowledge of how the student arrived at the answer, and that every problem does not provoke the same type and degree of thinking. He opined that it is not possible to account for students' guess of correct answers. Diagnostic interview and written tests were the strategies employed in collecting data.Blair and Brick (2010) were of the view that interview technique was a very important tool in diagnosing students' mathematically thinking and in analysis of written responses to a test or examination.

Sulvan (2012) however highlighted some shortcomings of the teacher conducting interview with the students to identify some of their errors. Some of the short coming are:

i. the use of interview takes more time than the use of written test.

ii. the class teacher or researcher may not have sufficient time for an in – depth interview as might be required for effectiveness.

From the various views expressed above, one is tempted to say that both the use of written examination and the diagnostic interview have their strength and weakness. The purpose of study, sample size and the time available for the researcher, to a large extent, determined the method employed. In the present study students' written examination answer scripts was the instrument used. Oral interview was not employed due to shortage of time.

Newman (1996) conducted an error analysis research using a combination of examining students' scripts and interviews. 917 grade 6 pupil, equivalent to primary pupil in class six in Nigeria, were the subjects of his study and the instrument used comprised 40 Mathematics test items. After the test, the students' scripts were marked and the five lowest performing children in each of the classes were interviewed by the researcher and his assistants. The interview was structured according to a guideline drawn by the researcher. The guideline consisted of instruction in which the pupils were asked to:

Attempt the question once again and wait for students to attempt the questionunassisted.

Response to the following:

- Please read the questions to me. If you don't know a word leave it out.
- Tell me what the question is asking you to do.
- Tell me how you are going to find the answer.
- Show me what to do to get the answer. Tell me what you are doing as you work.
- Now write down the answer to the question

Newman's (1997) guideline became a model for error analysis. Newman (1997) found out that error can occur at any of the stages; however he found out that more than fifty percent of errors occur at transformation stage when learning mathematics. He also identified the influence of language in learning mathematics pointed to the appropriateness of remediation. These sequences and features have shown additional dimension of areas where students can commit error in their attempt to read and work out given tasks

Newman's model has given the present researcher some useful strategies for diagnosing students' errors which was employed in present research. Newman (1997) devised error classification and a model of how a child goes about solving a problem. The model contained a description of sequence of steps, and failures at different stages. The sequences of steps are reading the question, comprehension, transformation, process skills and encoding and the major causes of errors are carelessness and motivation.

White (2010) explained Newman's sequence and features as follows:

i. Reading ability – This is to test whether the students can read questions. Possible errors could occur in word and symbol recognition.

ii. Comprehensive – This is to test students understanding of the questions. Errors could occur in understanding terms, symbol and general understanding.

iii. Transformation – Students' ability to select Mathematics process required to obtain correct solution to a given problem.

iv. Process Skills – This is to test the students' ability to perform mathematical operation needed for the task. Error could occur due to random responses, wrong operation, faulty algorithm, faulty computation or even when there is no response at all.

v. Encoding – this referring the students' ability to write the answer in acceptable form.

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Sleeman, Kelly, Martinak, Ward and Moore (1989) conducted studies into the diagnosis and remediation of high school students in Algebra. The first study was to compare the effectiveness of model – based remediation MBR and re-teaching. 44 second and third year, equivalent to JS II and JSIII mathematics students were randomly assigned to MBR or re-teaching groups. 20 items pretest 20 – items posted tutoring scripts for MBR and re-teaching were some of the materials used for the study. In MBR group students first rework items marked incorrect on the pretest. The procedure was repeated two or more times for each items marked as wrong. In the re-teach team students' earlier work were collected before re-teaching to avoid comparisons. Standard deviation was the statistics used for result analysis. Results of the study showed that there was a significant difference in the overall mean score between pretest and posttests and no significant difference by condition. The experience showed that MBR and re-teaching were comparable even with students with low scores.

The second study by Sleeman et al (1989) compared cognitive dissonance (CD), cognitive engagement (CE) with MBR and reteaching. 48 students from two second and third year Mathematics classes were used for the study. 20– Items pretest was administered and anyone who scored below 80% was seen for tutoring. Any student with 80% or less is assumed to have committed some error that needs to be reviewed. The students were randomly assigned to MBR, reteaching, MBR + CD and MBR + CE groups. Results of the study showed that analysis of variance indicated no significant difference among the conditions on the pretest. It was also observed that, there was a general posttest gain and no significant difference between the conditions on posttest scores. Following strongest stability criterion where error for a given task was traced from pretest through tutoring and posttest, only about 20% of the error appeared stable.

In order to test the effectiveness of MBR and re-teaching in the context of stable error, a third study was designed by Sleem et al (1989). A 51 – items stability measure was the instrument used. 96 students participated. .Students in treatment groups were individually seen for a 50 minute period. Each student was asked to work out the first six items in the pretest to establish stable errors. Stable errors were tutored before the unstable errors. The control group simply took the pretest and posttest. General post test was administered one week after tutoring. Post Ad-hock analysis using Scheffe test showed no difference between MBR and re-teaching, but both being better than the control group on the posttest. (Sleem et al 1989). Riccomini (2005) studied the ability of elementary teachers' to identify error patterns in subtraction.20 teachers were used in this research. The teachers were given sets of completed subtraction exercises and were asked to identify problem areas and state the one they would address first to correct students' misconceptions. Analysis of the data indicated that teachers were able to describe some specific error pattern but did not base their instructional focus on error pattern identified. The report of Riccomini's work indicated the need to consider students' errors when planning for any remediation strategy of which this is the plan of present research.Present study identified students' errors and a remediation package was designed based on the identified errors.

In another study conducted, Ekwueme and Ali(2012) examined the effect of the four identified process errors (arbitrary, structural, executive and clerical errors) in mathematics on students' academic achievement in Senior Secondary Certificate Examination (SSCE). The instrument used for this study was the students' scripts and redesigned marking scheme for those scripts in mathematics. Four hundred SS3 students were used as the sample. The data collected were analysed using simple proportion, frequency count, chi-square test and Analysis of variance (ANOVA). The result of the study showed that students committed more of structural error which has to do with the conceptual knowledge of the basic concepts in mathematics. Also girls committed more of the identified process errors than their male counterparts. The mean achievement score of students classified as committing more of structural and arbitrary errors differed significantly from the other two errors. Structural and arbitrary errors had more negative effects on students' academic achievement than executive and clerical errors. This research has similar of assessing error-type in terms of frequency and relating to achievement

Chemistry is another subject in which several error analysis studies were conducted. Savoy (1988) investigated how senior secondary school students in Botswana understood chemical equations within the framework of atom, atomicity, molecule, valence, radial, brackets, subscripts and stoichiometric coefficient concepts. From the students' responses some errors were identified, some of which were:

i. Inability to differentiate between atom and molecule.

ii. Not knowing the atomicity of elements.

iii. Inability to represent more than one atom or molecule of an element.

iv. Incorrect use of bracket and omission of bracket when they are required.

v. Inability to write the formula of a compound from its name, especially complex radicals.

vi. Inability to construct an equation from the wording for an equation.

These error categorisation was an attempt to identify students' errors which is part of the plan of present research. However, there was no attempt to find out the possible cause(s) of the error or proposal for remediation of the error of which present research did.Bello(1979) in Melle (1996) carried out investigation on some factors affecting students' understanding of a mole concept in chemistry examination among senior secondary school students. The result of the study indicated that:

i. Students found the mole concepts difficult to understand.

ii. Gender affected achievement in learning mole concept.

iii. School factor affected students' performance.

iv. Most students lacked clear problem – solving strategies of chemistry problem.

v. Students committed avoidable errors due to carelessness and insufficient mathematical skills.

Recommendations were made to improve on teacher's teaching strategies in and good use of students' previous knowledge. This study identified some errors and possible causes as intended in present study. Gender issue as it relates to students' performance in science featured just as the present study. However no remediation strategy was proposed or designed as is the case in present study

.Melles (1996) identified error – types made by NCE III Chemistry students from selected colleges of Education in Nigeria. One hundred and one students were used for the study. Students' examination scripts for three years were used. Errors from the scripts were identified, classified and their proportions computed. Simple percentage was the statistical tool used for data analysis. Results of the study indicated that:

i. Factual error was the most frequent error – type.
ii. Significant relationship between frequencies of errors in Physical and Inorganic Chemistry was observed.
iii. Differences in the frequency of errors in Physical and organic Chemistry has gender dimension with girls having higher frequencies.
iv. There was no significant difference in the frequency of error – type found during each of the four year studied.
v. There was no significant difference in the frequencies of the error – types committed by the students per year level.
vi. No relationship was established between frequencies of errors made and the academic achievement of the NCE III Chemistry students in the colleges studied.

Melle (1996) used students' scripts to identify the errors. He assumed that what the student wrote in their scripts were true reflection of the students' thinking and procedure of solving problems. He did not attempt interviewing the students so as to get more correct interpretation of learners' intentions and the problem solving strategies which is needed for remediation. No attempt was also made to propose remediation of identified errors. In the present study, remediation strategy was designed and implemented. The efficacy of the remediation package was tested amongthe study subjects.

Shaibu(1987) conducted a study on problem solving difficulties in mechanistic organic Chemistry among students of school of Basic Studies in Nigeria. The study had two major components, diagnosing the nature, causes of difficulties in problem solving and the remediation of the identified challenges. The sample of the study comprise of 190 students from five out of thirteen colleges in Nigeria. The research design of the diagnostic part is survey. The instruments consisted of three test; Test A for testing prerequisite conceptual knowledge, Test B for investigating students problem solving behaviours. The third test was Think Aloud Problem Solving (TAPS) with same as Test B. Chi-square statistical tool was used. Result indicated catalogue of chemical misconceptions and problem solving behaviours, which were major sources of students' solving difficulties.

The research design for the remediation section was experimental with pretest and posttest. The experimental group was treated with a remediation package designed based on the identified students' difficulties in the diagnostic stage while control group had no treatment. t-test statistical tool was used for analysing data collected. The outcome indicated that the remediation programme employed using structured text was effective. The structured text was also found to be suitable for remediation of the identified problems. Recommendation was made to employ teaching approach that will provide students with opportunity to interact with learning materials for better enhancement in learning required concepts and skills.Considering the age level of study subjects, there may change in the outcome of the study. The experimental design, pattern of remediation package and the statistical tools used by Shaibu (1987) were adapted for present study.

Some related literatures on error analysis in Biology were reviewed. Sorunke and Olafimihan (1988) carried out an error analysis of science teachers in practical Biology. 64 science teachers were the sample of study. The study subjects were given two different leaves, two different plants, a fruit and a fish to draw and label fully. The scripts were marked and identified errors were classified or categorized based on the criteria of assessing drawing in Biology examinations. Result of the study showed proportion, accuracy of drawing, accuracy of labels as most frequent errors identified. Soyimbo (1992) conducted error analysis research using 50 NCE and 60 B.Sc Ed students. The research instrument comprised five labeled diagram some of which were wrong in three categories of drawing errors. Result of the study showed that knowledge of the three categories of errors in Biological diagrams among the pre – service teacher was poor. No attempt was made by Sorunke to identify the causes of the errors or to design a remediation package Identification and classification of errors makes of the study to be similar in some respect to the present research.

Lock (1985) conducted a study on error types in Biology. Two sets composed of high ability and low ability third year biology students with age ranging from13 – 14 years in a co-educational school were used for the study. Both set were taught Biology by the same teacher after which the students were asked to copy a passage from the board. The students were requested to compose their note in answer to given questions as a second assignment. The three approaches were compared and the errors were collected analyzed according to the following error-types; spelling, punctuation, presentation, morphological and factual errors. The result of the study showed that the high ability group made less error than the low ability, and the graduation of errors was from dictation to copying from board to self–composed notes. Lock's work was on theory aspect of biology.

The methods used in Lock's study appear to be that of testing the students' language ability than the learners' grasp of knowledge of biology theory. What the students have written in the second and third task may have been dictated by situational and contextual variable such as pressure to meet up with teachers demand but not a true reflection of learners' intention and ability on given task.

Lawan (1995) determined the nature of errors secondary school students commit in practical Biology and the effect of such on academic achievement. The instrument used was selected questions and possible error types from WAEC practical questions and regulations. 317 final year Biology student in Zaria metropolis were the sample of the study. One way ANOVA and Chi-square were the statistical tools used in analysing the data collected. The result of the study showed that:

i. There was a significant difference in error types between schools.
ii. There was difference in the order with which schools committed the error.
iii. Significant relationship was identified between errors committed and achievement of the students. The more error the poorer the students' achievement.
iv. Error committed was gender – related Girls committing less error than boys

The instruments used by Lawan were from a reliable source, WAEC, which is one of the authorities saddled with responsibilities of preparing and conducting examinations for

Senior Secondary School students in Nigeria and West Africa. Lawan's study was restricted to biology practical alone, leaving the theory, making the knowledge on error incomplete about Biology. Present study was on Physics theory and a remediation package was used to address identified students' errors and gender dimension of errors wereaddressed as was tackled in Lawan's study.

Mohammed (2011) conducted a research with the aim of determining frequency of errors committed science and non-science Biology students and its effect on biology achievement. The result indicated that there significant differences in the error frequency between science and non-science students. There was also a significant difference achievement between science and non-science students. The categorization of errors and relating them to achievement is similar to what was done in present study but it is short of a remediation package.

Oyekan(2013) investigated the effect of diagnostic remedial teaching strategy on students' achievement in Biology. The purpose of the study was to diagnose and remedy identified students' weaknesses in Biology by comparing their performances in Conventional Teaching Method (CTM) and Diagnostic Remedial Teaching (DRT) strategy. A sample of 12 teachers and 427randomly selected SS2 students was drawn from three secondary schools in each of the four selected Local Government Areas in Osun and Oyo States of Nigeria. A pretest-posttest control group design with the students randomly assigned into experimental, conventional teaching and control groups was utilized for the study. Two instruments titled Error Patterns among Biology Students (EPABS), and Test of Achievement in Biology (TAB) were developed, validated and used for data collection. The findings of this study largely showed that the use of DRT is more effective in improving the students' achievement and retention than the CTM in Biology classroom practices. Hence, the diagnosis, knowledge and correction of identified students' weaknesses can strengthen Biology teachers with necessary teaching competence, behaviour and innovation required to rescue the students from learning difficulties.The use of diagnosis and remediation teaching strategy with a view to testing whether some remediation may be achieved makes the study similar to present study.

One of the few relevant literatures in Geography is the study conducted by Adesoji (2003). He reported that female students enjoy drawing exercises better than male students. Male students took more accurate measurements and solve more accurate mathematical computation of map scale, distance gradients and contour reading than female. Adesoji's research indicated that female students made more errors with mathematical computation on map data than the male and the male students were more careless with drawing errors. This study identified types of error and established gender linkage with some particular errors. Determination of students' error and possible linkage with gender was part of what present research addressed.

Lyon, (1976)dealing with data identified mistakes in Learning Topographic Maps: Leaning and Teaching with Maps. http://books.google.com assessed March, 2009reviewed and summarized error of topographic studies in the following order:

Error Type	**Source**
1. Personal (P)	The map reader or observer
2. Instructional (I)	The Instrument in use
3. Environmental (E)	The environment of learning
4. Concept (C)	The concept under study

5. Data (D)	The data required
6. Methodology (M)	Method of instruction
7. Computational (C)	The computations

This error classification in association with their sources has added more knowledge on error classification which one of the issues of concern in present study.

Abdu (1987) administered series of map reading exercises to a group of senior secondary school students in Kano Nigeria. When given topographic map of Kano. S.E.(1:50,000) the students were requested to identify lakes, ponds, escarpment, calculate length of river Ririwai and its general flow, the total area of Palgore forest reserve and describe features of interest on the map. The following errors were noted from the students' responses.

i. A mix up in the direction of flow of the river.
ii. Wrong measurements and use of scale.
iii. Mix up in the position of lakes with ponds, conical hills, with escarpment.
iv. Poor communication skills
v. 80% wrong measurement of the length of river Ririwai.
vi. 90% gross errors in calculating the total areas of Palgore forest reserve.
vii. 20% returned the map without attempting any of the questions and with no explanation.

In an attempt to establish the limit of the errors, the complexity of the task was rearranged using map with higher ratio scale. More errors were recorded using map 1:100,000, students failed in identification and description of land form, drainage and settlement relationship. Abdu's research identified error types without proposal on interviewing the students and proposing remediation strategy which present study intends to do.

Abdulkarim(2011) conducted a study on errors on topographical map reading among secondary school students in Zaria.Error Identification Presentation and Interpretation (EIPI) instrument was developed and used. 100 scripts for students' MOCK examination were used. Wilcoson rank test was employed. Result showed that that errors on presentation was highest while interpretation error was least with 15%. Relation between errors of identification was significant and positive. The remediation approach employedshowed that it was effective. The study pattern of identification and use of a remediation instrument makes the work similar and relevant to present work.

Very few Physics literature relevant to present study was found by the researcher. These are hereunder highlighted. Thomas (2002) in http://www.medinellonline.net/ visited on 21/06/2012 presented a report of study focused on the design of an error correction package (ECIP) for senior secondary school Physics practical. The experimental design was quasi experimental with pre–test, post–test and control group design. 60 students from selected government colleges were the sample of study. The instrument used was a package titled error correction instructional package made up of past examination questions of the West Africa Examination Council (WAEC) covering mechanics, light, electricity and heat. One way ANOVA was the statistical tool used. Result of the study indicated that ECIP has positive effect on students' performance and reduction in errors committed by students during Physics practical. Thomas's work is relevant to present study because it was an attempt to provide a remediation strategy to reduce students' error in Physics which is similar to what present study plans to designs.

Forster (2004) conducted a study on how student draw graph in Physics. The aim of the study was to find out the processes and sources of error in qualifying examination into tertiary institutions in Western Australia. Forster explored the interpretation and construction processes called upon in questions with graphical component in Physics Tertiary Entrance Examination. Errors made by students were reported by examiners and explanation for the errors were offered and sources of challenge in graph drawing skills such as requirement to calculate gradients and analysed experimental data were highlighted. Question structures that could be barrier to students' understanding of the examination were identified. Report showed that there were significant errors noted in drawing graphs. This is a report of work on identification of errors which is part of what present study has investigated.

Kim and Pack (2001) investigated the relationship between traditional physics textbooks problem solving and conceptual understanding of physics. 27 first year students in Physics education in Seoul were used. Two tests and one questionnaire were used. Result of the study showed that students had many well-known conceptual difficulties with basic mechanics and there was little correlation between number of problems solved and conceptual understanding. This work has great relevance to present work in terms of design and some type of instruments used.

Thompson and Sokoloff (1997) assessed students; learning of Newton's Laws. Multiple choice instrument was designed to probe conceptual understanding of Newtonian mechanics. Result indicated that students were little affected by the traditional approach. Two active learning microcomputer programmes were designed and used. Application of the programmes showed that students developed functional understanding of the first and second laws. This study probed misconception and remediation strategy. The topic and research design has similarity to present study.

Halloun and Hestenes (1985) studied the initial knowledge state of college physics students. Mathematics and Physics diagnostic tests were used. 1500 college and 80 high school students participated in the study. Result showed that students' initial knowledge has a large effect on his performance but conventional instruction produces small improvement in basic knowledge. The use of physics diagnostic test to determine conceptual understanding makes the study relevant to present research.

Halloun and Hestenes (1985) conducted a study on the common sense about motion. Common sense beliefs of college students about motion and its causes were surveyed and analysed. A taxonomy of common sense concepts which conflict with Newtonian theory was developed as a guide to instruction. Some of the students; conceptual beliefs are reflected in misconception test to be used in present study.

Akinsola, and Ifamuyiwa,(1990) conducted a research on the effect of two methods of remediation in High school Physics classes. This study examined the effects of teacher-directed and student-oriented remediation methods in high school physics classes in Nigeria. Students (N = 121) from three Nigerian high schools were assigned randomly to three conditions: teacher-directed remediation, student-oriented remediation, or no treatment. Results of formative, intelligence, and achievement tests indicated that the teacher-directed remediation approach was more effective for increasing performance. Educational implications, especially for developing countries, are discussed. This research has given encouragement to employ teacher directed remediation approach in present research.

Beichner(1994) developed a test for analysing students' understanding of Kinematics graphs. He used 895 high school and college students as subjects of study. Problems identified include misinterpreting graphs as picture, slope height confusion, problem of finding the slopes of lines not passing through the origin and inability to interpret the meaning of the area under various graph curves. This research has addressed area of which is part of the present research.

A survey ofInteractive-engagement versus traditional methods was conducted by Hake(1998)on pre/post test data using the Halloun Hestenes Mechanics Diagnostic test or more recent Force Concept Inventory is reported for 62 introductory physics courses enrolling a total number of students *N* 6542. A consistent analysis over diverse student populations in high schools, colleges, and universities is obtained if a rough measure of the average effectiveness of a course in promoting conceptual understanding is taken to be the average normalized gain *g*. The latter is defined as the ratio of the actual average gain (% post % pre) to the maximum possible average gain (100% pre). Fourteen ''traditional'' (*T*) courses (*N* 2084) which made little or no use of interactive-engagement IE methods achieved an average gain *g* *T*-average 0.230.04 std dev. In sharp contrast, 48 courses (*N* 4458) which made substantial use of IE methods achieved an average gain *g* IE-ave0.480.14 standard deviation, almost two standard deviations of *g* IE-average above that of the traditional courses. Results for 30 (*N* 3259) of the above 62 courses on the problem-solving Mechanics Baseline test of Hestenes–Wells imply that IE strategies enhance problem-solving ability. The conceptual and problem-solving test results strongly suggest that the classroom use of IE methods can increase mechanics-course effectiveness well beyond that obtained in traditional.Outcome of Hake's(1997) result has given some high light on methods of conducting remediation which is useful to present research.

A studyto find out the types of error committed and influence of gender onthe type of error committed by senior secondary school physics students in metropolis was conducted by Omosewe and Akanbi(2013). Six (6) schools were purposively chosen for the study. One hundred and fifty five students' scripts were randomly sampled for the study. Joint Mock physics essay questions (JMPEQ) for SS3 physics students, and researchers prepared error identification and classification and index (REICI) were used as the instruments. The reliability coefficient of REICI scores was 0.78. Frequency counts,means percentages and chi-square were used to analyze the data collected. The findings of thestudy revealed that four types of errors were committed by students which include Operational defective Algorithms, Random and Computational errors. The frequency of errorscommitted by male students was significantly higher than that of their female students. This study has some similarity with diagnostic part of present study which center around identification of error-types committed by students in Physics. However the classification of errors as defective algorithm, operational and computational errors appears to be the same kind of error classified differently. Present study used classication of errors that is distinctive.

Aderonmu and Nte (2014) conducted a study to diagnose error patterns of Physics students in solving problems using progressive wave equation. 92 SSII students were sampled for the study. Diagnostic Test of Error Pattern Using Progressive Wave Equation instrument was used. Finding revealed Computational error being the highest followed by Translational then Conceptual error. It was also found that significant difference existed between the different error types committed. The researchers did not bother on the issue of remediation determination of the possible causes of the identified error which present studied treated.

2.12Summary and Implication of Literature Reviewed forthis Study

The reviewed literature contains definition and models of error analysis. Descriptive model proposed by William (1990) and Wood (1995)is concerned with structural and context of subject of study while analytical model proposed by Corder (1974)suggests findings onthe nature, why and how errors occur. This implies that the present study is one form of analytical model because nature and causes of errors were studied. TheLiterature also indicated that after diagnosis, remediation is expected to follow. In this study therefore remediation package was designed and administered based on the kind of error identified. Several remediation approaches have been reported in the literature reviewed whichimplied that any one out of the four identified approaches could be adopted. Some identified approaches for remediation are training on the method of correction of errors, guidance and counseling, lecture method and the use of printed instructional approach.ThePrinted textual material approach alongsideteach and re-teach strategy was adopted for the study.

In error analysis, four major stages of identification and remediation were identified by Omojuwa (1979). The stages are recognition, description, explanation of errors and providing remediation strategies for the identified error. The four stages were adopted in present study. When remediating students' errors on examinations, some remedial strategies such as re-teaching, cognitive engagement and dissonance were been found in the literature to have been used by some researchers. Re-teaching featured in the present study.Some principles of error correction were identified by Rajeswari(2010) are selection of effective techniques, consideration of students' effective factors toward the remediation and making the remediation appealing to the student.

The literature so far reviewed has given some direction and guidance for designing and conducting the present study. Based on the insight derived from the literature, the diagnostic part of the study employedanalytical model design as was used by Omojuwa(1979) involving identification, classification explanation and remediation. In the remediation strategy, a teachingand re-teaching strategy was used where students were taught on topics where errors were identified using problems solving method, exercises and activities. Where there was a further challenge, the problem areas were re-taught. The Experimental group was treated with a remediation package containing printed texts, exercises and activities while the control group receivedlectures without reference to the content of the package. Present studyhas addressed gender issues on errors committed and achievement. This approachwasdifferent from the methods employed by Inekwe(1984) and Mohammed (2003) who did not addressthe gender issue in their studies.The present studywas focused on Physics errors in theory which is different from errors in practical as addressed by Lawal (1995) and Ogunsola.(2004). In order to have effective remediation, students' initial errors were diagnosed from which a remediation package was designed to address the identified errors. Considering the cognitive level of senior secondary school students, the approach of using printed textual materials, teaching and re-teaching strategy was employed during the remediation stage, as they appear quite appropriate.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

In this chapter, the methodology of the study is presented. It is and arranged according to the following sub-headings.

- Research Design
- Population
- Sample and Sampling Techniques
- Procedure for Identification of Errors
- Instrumentation
- Pilot Testing
- Data Collection Procedure
- Procedure for Data Analysis

3.2 Research Design

The study is two folds.First is the identification oftypes of errors senior secondary school students commit in Physics examinations and then testing the efficacy of a prepared remediation package aimedat reducing errors committed by the students via treatment. The design of the first part was in a form of a survey study where a paper and pencil method was used. Itinvolved diagnostictestto identity the types of errors students commit in Physics theory Senior Secondary School examinations.For the second phase of the study, which was the remediation segment, a quasi-experimental approach was employed and involved pretest -posttest experimental- control group design. This design was a form of between-group comparison with pretest and posttest measures to determine the efficacy of the remediation package. From the result of the first part of the study, students who commit particular errors were selected and grouped into control and experimental groups. The Experimental group was exposed to a prepared remediation package which was designed based on the identified errors. Problem solving instruction method was used to treat the experimental group while the control group was exposed to similar topics taught to the experimental group using lecture method. The remediation package is called Remediation Package for Identified Errors in Physics. A pretest was given to bothexperimental and control groups to determine the comparability of the two group'sability level before treatment. A posttest was administered after treatment to determine the efficacy or otherwise of the remediation package. The design of this study is represented in figure 3.1.

CGO_1 ⟶ X_0 O_2 ⟶ ⟶

EG O_1 ----------→--------→ X_1 -------------------→O_2

Fig.3.1 Flow chart of Research design

Where CG = Control group

EG = Experimental group

X_0 = Lecture on topics taught to experimental group

X_1 = Remediation Package content administered using problem

Solving method

O_1 = Pretest

O_2 = Posttest

3.3Population

The population for this study was all SSII students offering Physics in Public schools in Zaria Educational Zone of Kaduna State.Zaria Education zone comprise of secondary school located in Zaria and Sabon Gari local government areas of Kaduna State. The Education zone comprise of suburban areas like Samaru, Sabon Gari, Tudun Wada, Wusasa and Zaria City. Zaria Education Zone is heterogeneous with people coming from different parts of Nigeria. It is cosmopolitan in nature comprising people of different backgrounds .There are nineteen senior secondary government schools in the zone with students offering Physics at the Senior Secondary School levelNine schools are withinSabon-Gari Local Government and twelve schools from Zaria Local Government areas. Five schools are male schools, five schools for females while the remaining nine schools were co-education schools.The SSII students were chosen for the study because SSI students have learnt about two third of SSCE Physics content and are more steady not preparing for external examinations like the SSIII Students. The study subject had an average age of seventeen years.SSIII students were not used because of their preparation for Senior Secondary School examinations which maynot give them proper attention for participating effectively in the study. The student population offering Physics in public schools in the study area was 1,831 comprising of 1,204 male and 627 female distributed within 19 secondary schools. The distribution of the population according to schools is presented in Table 3.1

Table 3.1 Population for the Study

S/N	Name of School	Type of School	M	F	Total
1	Barewa College	Boys	300	-	300
2	Alhudahuda College	Boys	100	-	100
3	GSS Zaria Snr	Boys	200	-	200
4	GGSS Zaria	Girls	-	75	075
5	GSS Dakace	Coeducation	61	13	074
6	GGSS Pada	Girls	-	75	075
7	GSS Magajiya	Coeducation	59	21	080
8	GGSS Kofan Gayan	Girls	-	101	101
9	GGSS Dogon Bauchi	Girls	-	183	183
10	GSS Muchia	Coeducation	41	29	070
11	GSS Chindit	Girls	-	48	048
12	GSS Chindit	Boys	41	-	041
13	Aminu GSS	Coeducation	29	18	047
14	GSS Tudun Saibu	Coeducation	57	19	076
15	GSS Likoro	Coeducation	24	16	040
16	Kufena College	Boys	177	-	177
17	GSS Tudun Jukun	Coeducation	72	48	120
18	GSS Kaura	Coeducation	26	12	038
19	GSS Yakasai	Coeducation	17	14	031
	TOTAL		1,204	627	1,831

Source: Inspectorate Division, Ministry of Education, Kaduna (2012)

3.4 Sample and Sampling Technique

The School sample used for the error diagnostic test comprised six co-educational Secondary Schools.Names of schools in the population were written on pieces of papers and folded. The folded papers containing names of school were randomly picked without replacement. Names of selected schools were therefore generated.The schools are Government Secondary Schools Dakace,Tudun Juukun, Tudun Saibu, Magajiya, Muchia and Aminu.The sixschools were chosen based on school status that is coeducational as well as different school locations of the schools such as Zaria city, Tudun Wada, Sabon Gari, and Soba area. Six Schools chosen are more than ten percent minimum sample size recommended by Frankel, Wallen and Hyon (1993).The details of the selected schools are presented in Table 3.1

In the sampled schools six classes were selected using stratified random sampling to form the study team.Pretest was administered to the selected subjects to determine which of the schools were comparable in their ability levels using Analysis of Variance (ANOVA) statistical tool at $p \leq 0.05$. The result is presented in post study appendix D. After the pretest the result showed there was significant difference in which Scheffe's test was conducted to determine the Schools that were not significantly different. GSS Dakace and GSS Tudun Jukun showed no significant difference and were picked for the study. GSS Dakace had 47 male and 13 female totaling 60 subjects while GSS Tudun Jukun had 45 male and 17 female totaling 62 study subjects selected using stratified random sampling. The total number of sample size is 122 viable for this study in line with the central limit theorem recommendation that a minimum of 30 sample size is viable for experimental study Tuckman (1975). The two schools were later grouped into experimental and control groups using simple random sampling technique involving balloting method one of the schools picked from the two schools was used as the control group while the second was the experimental group. The schools are GSS Dakace as the control group and GSS Tudun Jukun as the experimental group. The detail of the schools and sample selected is shown in Table 3.2

Table 3.2Selected School Sample for the Study

S/N	Name of School	Group	Male	Female	Total
1	GSS Dakace	Control	47	13	60
2	GSS Tudun Jukun	Experimental	48	17	62
	Total		92	30	122

3.5 Topic Selected for the Study

The topics used for the present study was Mechanics selected from the Senior Secondary School Physics syllabus. Mechanics topic was selected for this study because students perceive it more difficult to learn the topic than other Physics topics (Okpala 1978). The topic is also one of the most frequently studied subject area in Physics, which include such subtopics as kinematics, dynamics and vector which usually appear in most other topics in Physics such as Electricity, Magnetism and Waves. West Africa Examination Chief Examiners (2006 and 2007) for example reported the topic (mechanics) as one major area in whichsecondary school students face serious academic challenges in learningof Physics and also in achievement at examinations (WAEC 2006, 2007).The subtopics selected for use in the study as earlier stated are Kinematics, Dynamics and Vectors. These subtopics are required for learning other related concepts such moment, work in motion and properties of matter.

Table 3.3 Specification of Items of the Instrument measuring various dimensions of thesub-topics

Sub-Topic	Item	Total
Scalar and Vector Quantities	1, 2, 3,	03
Distance and Displacement	4, 5, 6,	03
Speed and Velocity	7, 8, 9, 10	04
Acceleration	11, 12, 13	03
Motion Graph	14, 15, 17	03
Momentum	17, 18, 19, 20	04
Impulse	21, 22, 23	03
Potential Energy	24, 25, 26	03
Projectile	27, 28, 29	03
Vectors	30, 31, 32	03
Dynamics	33, 34, 35	03
	Total	35

The information in Tables 3.3 is the distributions of test used in EDT items based on subject subtopics. There are 35 test items in all.

3.6 Instrumentation

Instrument is a generic term that researchers use for a measurement device. The nature and type of instrument for a research are usually chosen based on the aim of the research, research design, reliability and validity of the instrument. The aim of presentresearch was to identify errors students commit and find out how effective was a remediation used in reducing the error. Based on the stated aims of the research, two instruments were chosen for gathering of information for the study; diagnostic and achievement test.

Diagnostic test was used to find out the types of errors students committed and the area where the errors were committed in Physics examination. This part of the study was for diagnosing students' errors and locating where the errors were committed. The achievement test was for determinationof the achievement level of study subjects at entry level and to determine the effect or otherwise of the remediation package on possible errors in terms of better achievement was also determined. Effect or otherwise of remediation on students' achievement was chosen as a good measure of efficacyof the remediation package.

3.6.1Construction of Error Diagnostic Test (EDT)

Error diagnostic test (EDT) was designed and used to identify errors and types of errors students committed in a Physics Error Diagnostic Test. Test requiring free-response to agiven task was suggested as suitable for the diagnostic test (Sahare 2013).

Before designing the Error Diagnostic Test (EDT), the researcher surveyedsome areas in which students problems in learning Physics manifested. Consequently an investigation was conducted into the following;

(i) WAEC Chief Examiner's reports for a period of four years (2007-2012).

(ii) SSCE Mock examinations scripts of Physics for randomly selected students (2008-2013)

(iii) Findings from literature of related studies.

The brief surveyconducted was found to be appropriate in producing more objective assessment of the background problem. This assessment method was also used and found to be successful by Shaibu(1987). The brief reports of the short survey are presented below;

The WAEC Chief Examiners reports generally highlighted on students' showing unacceptable level of weakness in the following areas;

- Definition, explanation and description of required given terms
- Drawing complete and well labeled diagrams
- Describing experiments logically and sequentially
- Recall and application of correct formulae to solve numerical problems
- Computational skills
- Skills to represent information graphically and interpret graphs
- Understanding of some given concepts and Physics theories
- Conversion of units

Some the examiner's reports are presented in Appendix 13.This justifies the fact that students have some problems in learning Physics at ordinary level.

A survey of SSCE Mock Examination scriptsfor students in Physics for five years (2008-2013) was conducted. Fifty scripts for five year were requested from EducationalResource Centre (ERC) Kaduna. The area where student had challenges in the examination was noted using the marking guide provided. Scripts for students from Zaria Education Zone were used in the survey. The aim of the survey was to have an insight on topics and skills where study subjects had problems on which was used in designing the diagnostic test EDT. The outcome of the survey indicated some students' difficulties which include;

- Lack of adequate knowledge required to answer some questions set in Physics examinations.
- Lack of capability in problem solving skills.
- Committing factual, algorithmic and factual errors

A survey of related literature indicated that Mechanics was one of the most frequently studied topic and sometimes difficult to understand by students. The survey also identified some common errors students committed inexaminations to include factual, algorithmic and diagrammatic.

Based on the outcome of the short survey as highlighted above, the error diagnostic test (EDT) was designed to diagnose common errors that senior secondary school students frequently committed in the process of learning Physics generally.

The test comprise of thirty five (35) free response theory questions on the concepts of Kinematics, Dynamics and Vectors. The test was designed by the researcher and the following procedures were followed:

i. Preparation for the Design of Error Diagnostic Test

Weighting to objectives, content and types of questions were decided based on the initial outcome of the survey on sampled mock examination scripts, chief examiners reports and survey of relevant literature. The objectives given weighting are Knowledge, Application and Skills.

The weighting to content considered subtopics under major topics of Kinematics, Dynamics, and Vectors. The weighting of objectives and content for the diagnostic test (EDT) is presented in Table 3.5

Table3.4Weighting of Objectives and Contentsof Error Diagnostic Testitems.

Content	Knowledge	Application	Skills	Total	Type of questions
Scalar and Vector Quantities	1	1	1	03	Free response
Distance and Displacement	1	1	1	03	✓
Speed and Velocity	2	1	1	04	✓
Acceleration	1	1	1	03	✓
Motion Graph	1	1	1	03	✓
Momentum	2	1	1	04	✓
Impulse	1	1	1	03	✓
Potential Energy	1	1	1	03	✓
Projectile	1	1	1	03	✓
Vectors	1	1	1	03	✓
Dynamics	1	1	1	03	✓
Total	12	11	10	35	✓

ii. Construction of questions for EDT

Test items were prepared based on the topics chosen for study testing knowledge, application and skills of subject matter. The test consisted of 35 free response questions subject content as outlined in Table 3.5. Text books, past question papers and textual materials from internet such as tutorials and diagnostic tests on Physics and other subjects were consulted during the design of EDT.The sample of EDT is attached in the appendixB.

iiiPreparation of Marking Scheme for EDT

Marking Scheme containing outline answers and division of marks for each part of the questions were developed. For every question, two marks were allocated for correctly answering the questions giving a total mark of seventy for the35 item EDT test. The marking guide for EDT is attached in the appendix C

3.6.2Validation of Error Diagnostic Test (EDT)

The validity of EDT was determined by a team of three experts comprising of a senior lecturer in Science Education with a PhD in Science Education, a senior lecturer from Physics Department at Ahmadu Bello University Zaria with a PhD in Physics and a senior Physics teacher with degree in Physics Education from a Senior Secondary School with more than 15 years teaching experience in Senior Secondary School Physics. The experts were requested verbally to study the test items and comment on the following:

i. Do the test items conform to the subject specification?

ii. Are the test items within the reading level of the students?

iii. Do the content tally with the topic of research?

iv. Are the instruments clear?

v. Are the suggested answers correct?

The validators passed the following comments on the test:

i. The test items are valid, that is, they conform to the subject specification they are to test.

ii. The test items are clearly stated and appropriate in terms of reading difficulty level of the students

iii. The content tally with the topic of research

iv. Fourty out of fifty statements in the instrument learning materials are clear

v. Thirty eight out of fifty suggested answers are correct.

Fifty (50) items were prepared for the test but only thirty five (35) passed the test of the validators and the thirty five (35) items were selected as items for the instrument, thus making a total of thirty five (35) items for the EDT.

3.6.3 Physics Achievement Test (PAT)

The Physics Achievement test (PAT) was designed by the researcher. The aims of designing PAT were to evaluate the students' achievement levels at the beginning of study and after implementation of the remediation package. It was expected that the differences of the achievement mean scores could be a good measure of efficacy or otherwise of the remediation package administered.

In designing the Physics Achievement Test (PAT) the cognitive level of subjects and the expected level of coverage in the senior secondary school Physics syllabus were considered.Study materials suitable to senior secondary school Physics were selectedsince the study subjects were selected.The following steps were followed in the construction of the achievement test;

The weighting of content of the achievement test, and the types of questions according to the objectives of study were prepared. Multiple choice questions were used in the test because they are considered suitable for an achievement test. The multiple choice test items comprised of a stem and four variables. The distribution of the test items of the Physics Achievement Test(PAT) according to the set objective and subject content are presented in Figure 3.5

Table 3.5 Weighting of Objectives and Contents of the Achievement Testitems.

Content	Knowledge	Application	Skills	Total	Type of questions
Scalar and Vector Quantities	1	1	1	03	Free response
Distance and Displacement	1	1	1	03	✓
Speed and Velocity	2	1	1	04	✓
Acceleration	1	1	1	03	✓
Motion Graph	1	1	1	03	✓
Momentum	2	1	1	04	✓
Impulse	1	1	1	03	✓
Potential Energy	1	1	1	03	✓
Projectile	1	1	1	03	✓
Vectors	1	1	1	03	✓
Dynamics	1	1	1	03	✓
Total	12	11	10	35	✓

The achievement test initially contained fifty questions but after validation thirty five (35) multiple choice items selected from major concepts under the topic Mechanics. The specifications of items of the instrument are presented in Table 3.6. The test items were sourced from relevant Physics text books like Ordinary level Physics by Nelkon and some tutorial material from Physics tutorial web sites on the internet.

A marking guide was prepared by the researcher which was used to mark the achievement test. Two marks were allocated to each test item correctly answered. The marking scheme containsoutline of answers and divisions of marks for each part of the questions.

3.6.4 Validity of Physics Achievement Test (PAT)

The validity of PAT was determined by a team of three experts comprising of a senior lecturer in Science Education with a PhD in Science Education, a senior lecturer from Physics Department at Ahmadu Bello University Zaria with a PhD in Physics and a senior Physics teacher with degree in Physics Education from a Senior Secondary School with more than 15 years teaching experience in Senior Secondary School Physics. The experts were requested to check for clearity of questions set, tallying with topic of research and whether the answers were correct or not. The experts validated and passed the following comments on the test:

i. The test items conform to the subject specification they are to test.

ii. The test items are clearly stated and appropriate in terms of reading difficulty level of the students

iii. The content tally with the topic of research

iv. Thirty six out of fifty statements in the instrument learning materials are clear

v. Thirty four suggested answers are correct.

Based on the validators' comments, corrections were made and thirty five (35) items were selected as items for the instrument, thus making a total of thirty five (35) items for the PAT. The aim of PAT was to determine students' level of pass in the given test.

3.7 Pilot Study

The Pilot Study for the purpose of present study was carried out using two schools out of the nine Coeducational Secondary Schools in Zaria Education Zone. The coeducational schools used for the pilot test were Government Secondary School Likoro and Government Secondary School Kaura.The two schools were suitable to the ten percent of sample size for pilot test as recommended by Baker (1994) for a pilot study.

The aims of pilot study were to;

i. identify items that have weak construction so as to discard and replace

ii.determine degree of difficulty of test items.

iii.examine the plausibility of detractors

iv.determine suitable time limit for the test.

Physics Achievement Test (PAT) was administered to the sampled subjects from Government Secondary School Kaura and Government Secondary School Likoro. Intact class of senior secondary school comprising of 26 male and 12 female students was used for the test. The PAT test was administered to subject by the researcher to avoid unnecessary interactionsthat may affect the quality of the test. The test was marked using the marking scheme prepared for the test. PAT was re-administered after two weeks for determination of reliability of the test. The scores obtained by study subject were used to determine facility indices of the PAT test.

For determination of reliability and facility indices for Error Diagnostic Test (EDT)intact class comprising of 24 male and 16 female students from Government Secondary School Likoro and Kaura were used. The EDT test was administered using test re-test approach between an interval of two weeks. The test was repeated at two weeks interval of the first test given as recommended by Tuckman (1975). Frequency of commitment of error types and achievement scores of the sample students were determined using a marking guide prepared by the researcher.

3.7.1 Reliability of Physics Achievement Test (PAT)

The PAT instrument was subjected to reliability test using test-re-test method. Thirty eight (38) SSII students comprising of twenty six (26) male and twelve (12) females from G.S.S. Kaura Zaria were used for the test. Intact class of study subject was used as the sample the pilot test. The PAT was administered twice with an interval of two week and the data collected was analysed using Pearson-Product –Moment Correlation Coefficient statistics. The reliability of the instrument which is a measure of what the instrument is expected to measure with consistency was determined to be 0.70.

3.7.2 Reliability of (EDT)

The reliability of Error Diagnostic Test (EDT) was determined using one of the schools which is not part of the sample i.e. G.S.S. Likoro. Fourty (40) SSII students comprising of sixteen (16) female and twenty four (24) males were used as the sample. Test-re-test method was used. The tests were administered within an interval of two weeks (Topman 1978). The reliability coefficient of EDT was determined using the Pearson-product-moment-coefficient (PPMC) formula. The coefficient of reliability value of r = 0.72 was obtained showing that the instrument is reliable (Kerlinger 1973) and could be used in data collection in this study.

3.7.3 Facility Indices of the Items

Facility index of a test item is a measure of percentage of candidates that got a test item right vis-à-vis the total number of the candidates (Usman 2000). The facility indices of the items in the error diagnostic test (EDT) were determined using Satterly (1986) who recommended the formula expressed below:

$$FI = \frac{R}{T}$$

Where, FI = facility index.

R = number of students who answered the test item correctly

T = Total number of students tested.

Satterly (1986) recommended that items with 30-70% facility indices represent suitable test items in assessing achievement. Furst (1958) recommended the use of test items with facility index ranging from 0.30 to 0.75. Usman (2000) used test items with FI of the range 0.35 to 0.75 and were considered appropriate. As such items with FI within the range of 0.35 to 0.75 were selected for use in present research (Appendices H).

3.7.4 Discrimination Indices of the Items

Furst (1974) in Olororukooba (2001) gave the discrimination index formulae as follows:

$$DI = \frac{(RU - RL)}{T}$$

Where

DI = Discrimination Index

RU = Number among upper 27% who responded correctly to the test item

RL = Number among lower 27% who responded correctly to the test items

Discrimination index values are usually within the range of -1.0and + 1.0 (Kelly, Ebel, and Linacre 2002). The DI is usually expressed in decimal positive value. When the discrimination index is highly positive it implies that large proportion of competent students more than poor ones got the test items right. Zero value of the DI indicates that the test could not discriminate between competent and poor students. When the value of the index is negative, it means that more of the poorer students got the test items right compared with more students that are competent. Lawal (2010) and Usman (2000) used test items with DI within the range of 0.30 to 0.70. Items within the range of 0.30 to 0.70 were selected for present study (Appendix H).

3.8Procedure for Identification of Errors

. The aim of the diagnostic test was to identify what the students do not understand in learning Physics at ordinary level. It is a study of learning difficulties. Three steps were followed in the diagnostic test which included identification of students who are having trouble or need help with their learning, locating the errors and discovering the causal factors of the errors.

For the identification of errors and error-types that students committed, the six coeducational schools randomly selected and indicated in Table 3.6 were used. 250 randomly sampled study subjects out of 467 students offering Physics from the six selected school participated in the error identification test. The EDT was administered to study subjects by the researcher with the assistance of subject teachers in the various schools used. The test comprised of 35 free response test items. No time limit was set for the diagnostic test because the test was not for speed but for error identification. However the test lasted for two hours.

Table 3.6 Coeducation Schools selected for Error Diagnostic Test

SN	SCHOOL	Male in Class	Female in Class	Total students in Class	Selected Male Students	Selected Female Students	Total Sampled Students
1	GSS Magajiya	59	21	080	30	20	50
2	GSS Muchia	41	29	070	30	15	45
3	Aminu GSS	29	18	047	20	10	30
4	GSS Dakace	61	13	074	30	20	50
5	GSS Tudun Saibu	57	19	076	20	15	35
6	GSS Tudun Jukun	72	48	120	40	20	60
	TOTAL	319	148	467	150	100	250

At the end of the test, the answer scripts were marked and collected according to the prepared marking scheme. Every correct answer to a question attracted two marks while wrong response to a question attracted zero mark.The errors committed by students on each question were identified based on the given tasks on each question. For example where a student was asked to draw, calculate or define and could not accomplish the task the subject was considered to have committed error on drawing, calculation and on definition. The frequency of identified errors were determined and recordedaccording to gender.

The identified errors (Table 4.01) were later classified into error-types. Error-types are errors classified based on their similarities in nature, and subject topic. Four error-type as was proposed by Ajibola(1988) were used in the classification. These error-types are Factual, Algorithm, Communicative and Diagrammatic Error-types. Frequency of the classified error-types for subjects were calculated based on gender and recorded.

3.9.1 Remediation Package (RP)

From the identified errors and error-types, a remediation package was designed. Remediation packages were found effective for remediation of problems solving difficulties in mechanistic organic Chemistry by Shaibu (1987). Thomas (2007) also found remediation effective in minimizing errors Secondary School students committed in Physics practical. The error remediation package is an instructional material containing lesson notes, hands-on activities for the subjects prepared by the researcher on the topics where errors were identified. It was prepared to address and correct the identified errors.

The package contains textual material and numerical exercises on subject content and instructional strategies employed in addressing the identified challenges. Some of the contents of the remediation package were obtained from some Physics text books, developed activities acquired in relevant workshops and from tutorial materials from the internet. The package was arranged into seven units. Each unit has an introduction stating the objective and the content of the unit, followed by some textual materials on topics where students' errors were identified, Questions inform of numerical exercises and some expected responses from students on given exercises were also made available to permit individual rates of progress which could be used for other level grades.

Instructions on hands-on and minds-on activities from the identified errors, a remediation package was designed to test for the efficacy of the package. The measure of the efficiency or otherwise of the remediation package would be a measure of how the students' academic achievement improved relative to their achievement in the diagnostic test. The remediation approach adopted for present study is the use of printed instructional material in form of a package.

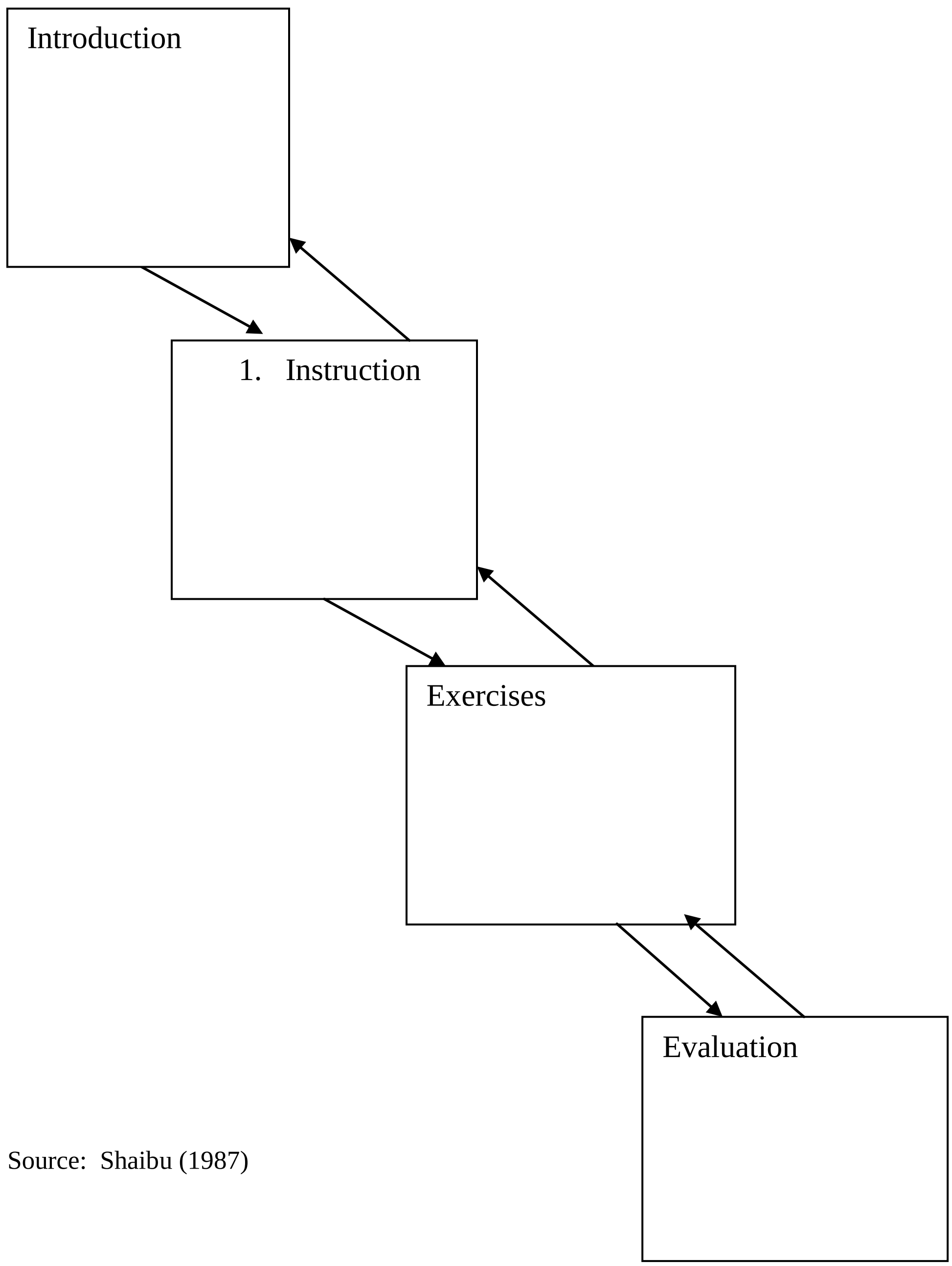
The theoretical framework for writing the remediation package was based on Shaibu's flow chart for remediation treatment containing Introduction, Instruction, Exercises and Evaluation.The textual materials in the remediation package were presented in hierarchical order of simplicity in line with Gagne's (1977) view that concepts and skills to be learnt are to be arranged in hierarchical order, from simple to complex and from known to the unknown. Ausubel's (1968) learning theory emphasising the importance of learners' prior knowledge on learning was also considered when designing the package. Some useful hands-on and minds-on activities featured prominently in the lesson plans of the remediation package so as to make the leaner actively involved in construction of knowledge to be learnt in agreement with the constructivist view of knowledge as was proposed by Piaget (1977). Problem solving method was used as instructional method in presenting the package to address identified errors. The remediation package is attached as appendix A'

The materials in the remediation package (RP) were validated by two senior lecturers, one from Physics department and the other from Science Education department of Ahmadu Bello University Zaria, Nigeria. The package was certified to be suitable for addressing the students' errors identified at the diagnostic stage of the research. My team of supervisors saw and approved of the use of the remediation package as suitable instrument for remediation of the identified errors.

3.9.2 Implementation of the Remedial Instructional Programme

In order to implement the remedial instructional package on the experimental group, a remediation flow chart adopted from Shaibu (1987) was used. Shaibu's flow chart was adopted because identification of problem solving difficulties and remediation package was the study strategy used then which is similar to present approach of error identification followed by administration of remediation package.

Fig 3.2A Flow Chart for Remediation Treatment



Source: Shaibu (1987)

The subjects in the experimental group comprised48 male and 17 female totaling 62 subjects from GSS Tudun Jukun as presented in Table 3.2. The subjects who participated in the EDT test were selected using stratified random sampling technique while the school was selected using simple random sampling technique involving balloting method.The study subjects were made into a class.

The researcher and study subjects agreed on the day of Saturday at 9:00 am to be the interaction time so as not to interfere with the usual school time table. In order to motivate study subjects for continuousattendance to the remediation programme a transport ticket was provided to the study subjects.

At the introduction stage of remediation, the experimental group subjects were intimated with the rationale for designing the remediation session and some possible benefits the subjects may gain if they effectively and consistently attend and participated in the remediation sessions. The subjects were told about how the remediation sessions were to be conducted. When the remediation sessions fully started the topic to be treated during each session and the procedure of the session were given to the study subjects in experimental group. At the instructional stage, subtopics on the topic mechanics were treated with the subjects using materials in the remediation package. The problem solving instructional approach was used for the experimental group. During instructions, areas of identified errors were highlighted and how to address the errors were treated. Each subtopic was treated per week.

During interaction with the experimental group series of activities were employed. First step of the lesson involved review of background knowledge of subjects and linking the previous knowledge with topic of lesson. The reviews were made because learning is like a scaffolding process. Students build new understanding on what they know earlier. The review was in form of questions and posers. After the review, contexts were usually created to motivate students to prepare for learning concepts and skills embedded in the lesson. The motivators were in form of questions, statement of objective of lesson or explanation of the procedure of activities conducted by students in the lesson. The motivation stage was to create a hook intended to direct the learner towards effective learning of content of the lesson. Hands-on and minds-on activities were provided in the lesson to enrich the lesson and to enhance remediation of identified students' errors. During the remedial treatment the researcher:

a. referred indirectly to the errors
b. reaffirmed the correct procedure of addressing the identified errors
c. gave additional instruction using the remediation package.
d. used problem solving approach.
e. gave practice items prepared in the remediation package.
f. evaluated students' performances in given exercises

Activities a-e are in line with the instructional flow chart in Fig. 3.2 adopted from Shaibu (1987). The timeframe for the remediation was arrived at based on the number of topics and duration used which was 2hours period per topic per week.

. At the end of every topic, unit of remediation package or interaction stage, questions and exercises were provided to assess the students on what they have learnt and level of error remediation. The questions were given in form of class work, homework or assignment for submission during preceding classes. The exercises were to give subjects the opportunity to test and confirm their level of grip to subject materials treated during the instruction stage.

At the evaluation stage the students' attempts on the given exercises were assessed by the researcher to see the areas of their strength and weakness with respect to the remediation. Where the subjects had challenges it was discussed with reference to the materials treated in the instructional stage. The relationship between the introduction, instruction, exercises and evaluation stages in the remediation flow chart was mutual in the sense that each stage precedes the next stage and when there was any challenge in a stage, material or activities in the previous stage were revisited to relate and address the identified challenge for successful overall achievement the remediation exercise.Interaction with experimental group lasted seven weeks.

After the experimental group was treated with the remediation package the posttest, comprising of EDT was administered for the second time in order to determine whether or not the remediation package (RP) was effective in remedying the errors commonly and frequently committed by the subjects. Similarlyin order to find out whether exposure to the remediation package had effect or not on study subjects' academic achievement Physics Achievement Test (PAT) was administered to subjects the second time.

After administration of the two tests, the scripts for each of the tests were marked according to the marking developed in the pretest. The scripts for EDT and PAT had 35 items and each was awarded 2 marks because they were free response type. The scores were recorded separately and grouped into experimental and control group as well as male and female for gender testing. For error identification, students' errors and error-types were identified and classified based on error types committed in frequency and percentage form. The data collected from the two tests were subjected to statistical analysis as described in subsection 3.10.0

3.9.3 Teaching of the Control group

The subjects in the control group comprised 47 male and 13 female totaling 60 subjects from GSS Dakace as presented in Table 3.2. The study subjects who participated in the EDT test were selected using stratified random sampling technique while the school was selected using simple random sampling technique involving balloting method. The study subjects were made into a class.

The researcher and the subjects agreed to meet on Friday at 4:00 am to be the interaction time so as not to interfere with the usual school time table. In order to motivate the subjects for continuous attendance to the remediation class a transport ticket was provided to the subjects for regular and easy attendance to the class.

The interaction with thecontrol group was teaching topics on which students errors were identified using lecture method without any reference to the content of the remedial package. The teaching session comprised of Introductory, Instruction, Exercise, and Evaluation stages. In each of the stages emphasized on exposition with zero problem solving approach and hands-on and minds-on activities as contained in the Remediation Package used with Experimental group. The teaching lasted for seven weeks with two periods per week. . During teaching in the control group the researcher

a. did not use the remediation package but used lecture note from text books not arranged with examples in the same pattern with remediation package.

b. referred indirectly to the errors without telling the subjects that those are some errors they committed in EDT test.
c. gave working exercises different in frequency and setting pattern from those in remediation package
d. used lecture method instead of problem solving method

After the control group was taught with the lecture method on study topics, the posttest, comprising of EDT and PAT were administeredseparatelyin order to determine whether or not the errors commonly and frequently committed by the subjects have changed or not. The Physics Achievement Test (EDT) was administered to control group subjects for the second time in order to determine study subjects' academic achievement after exposure to the lectures on subject topics.

At the end of administration of the two tests, the scripts for each of the tests were marked. The scripts for EDT and PAT had 35 items each was awarded 2 marks because they were free response type. The scores were recorded separately and grouped into experimental and control group as well as male and female for gender testing. For error identification, students' errors identified from their scripts were classified based on error-types committed in frequency and percentage form. The data collected from the instruments were subjected to analysis as described in subsection 3.10.0

3.10.0 Data Analysis

For analysing the data collected, the research questions and the hypotheses stated in chapter one are hereunder restated and suitable statistical tools for their analyses are presented as follows;

Hypothesis 1:

There is no significant difference between the frequencies of the error-types committed by the subjects in Senior Secondary School Physics theory Examination. The nature of data to be collected for testing above hypothesis was in frequency form. To test for the significant difference, Chi-square test was used to test the hypothesis at $p \leq 0.05$

Hypothesis 2:

There is no significant difference in the frequency of error-types committed by subjects exposed to physics remediation package and those that are not exposed to remediation package. Chi-square test was used in analysing the data collected for testing Ho_3 at $p \leq 0.05$

Hypothesis 3:

There is no significant difference in the frequency of error-types committed by male and female subjects exposed to Physics Remediation package. Chi-square test was used in analysing the data collected for testing Ho_4 at $p \leq 0.05$

Hypothesis 4:

There is no significant difference in Academic achievement between subjects exposed to remediation package and those not who were not directly exposed to it. t-test statistical tool was used in testing the hypothesis Ho_{at} $p \leq 0.05$

Hypothesis 5

There is no significant relationship in the frequency of errors committed by the subjects exposed to the remediation package and their academic achievement in Physics.Pearson-product-moment-correlation-coefficient statistical tool was used to test the hypothesis at $p \leq 0.05$

CHAPTER FOUR

DATA ANALYSIS, RESULTS AND DISCUSSION

4.1 Introduction

This chapter contains the presentation of results and discussion of the results from this study. For the purpose of data collection for the survey part of the study, Error Diagnostic Test (EDT) was used to identify the errors and types of such errors committed by Senior Secondary School Students in Physics. Frequency and percentages were used in answering research questions while Chi-square, t-test and Pearson Product moment coefficient correlation were used in testing stated hypotheses. Statistical Package for Social Science (SPSS)software programme was used for analysing the data collected.

4.2 Results of the Diagnostic Test

The results of EDT was analysed and used to answer the research questions raised.

4.2.1 Answering the Research Questions

The survey test was conducted in order to find answers to three research questions and test two null hypotheses. The research questions are as follows:

Research Question 1. What types of errors do SSII students commit in senior SecondarySchoolPhysics examinations?

From the result of the EDT test administered on the subjects, the following errors were identified and presented in Table 4.01

Table 4.01 Identified Errors

S/N	IDENTIFIEDERRORS	FREQUENCY
1	Wrong determination of distance travelled in linear motion graph	23
2	Inability to locate position of given points on linear motion graph	19
3	Wrong determination of displacement in linear graph	28
4	Wrong drawing of positions of given points on displacement time graph	17
5	Incorrect drawing of displacement of object on displacement time graph	38
6	Wrong identification and description of patterns of movement time graph	41
7	Incorrect understanding of the concept of acceleration	16
8	Wrong calculation of acceleration from given data	15
9	Wrong understanding of impact of Inertia	19
10	Incorrect determination momentum of a body when relevant variables are given	41
11	Incorrect description of projectile displacement	19
12	Wrong determination of potential energy of a body	39
13	Inability determine the impulse of a force	38
14	Improper description of forces acting on a moving body	34
15	Wrong description of speed of falling body at different locations	32
16	Wrong description of velocities of falling body at different locations	29
17	Incorrect drawing of Vector diagrammes	40
	Total	488

The errors were identified based on the nature of tasks embedded into the questions designed in the Error Diagnostic Test (EDT). Seventeen errors were identified from the students' scripts. The seventeen identified errors were the main focus for designing the remediation package.

Research Question 2. What is thefrequency of error types-committed by SSII Students in Physicsexaminations?

To analyse the data collected for answeringresearch question two, Identified errors were classified into Errors-types and descriptive statistics inform of frequency and percentage of the classified Error-types were used. The errors identified in Table 4.01were classified into error-types using Ajibola(1988). Errors 1,2,3,6,14,14,15 and 16 were categorized as Factual errors while Algorithmic error-types comprise of errors 8, 10, 12 and 13 Communicative error-type comprise errors on description, definitions and explanations of terms and concepts. Diagrammatic error-type comprise of errors on drawings of graphs and model and presented in Table 4.02.

Table 4.02 **Frequency and Percentage of Error-Types committed by Student in Senior Secondary SchoolPhysics Examination**

S/N	Error-type	Frequency	Percentage
1	Factual- Errors	205	42.03
2	Algorithm-Errors	137	27.97
3	Communicative- Errors	052	10.67
4	Diagrammatic-Errors	094	19.23
	Total	488	100.00

From the result in Table 4.02 the most frequent Error-type committed was Factual errors with 205(42.03%) followed by Algorithm errors with 137(27.97%). The third high percentage error committed was on Diagrammatic errors with 94 (19.23%). The Factual error-typesare errors inform of misconceptions of some concepts like acceleration, and impulse. Wrong definitions and wrong procedure for performing a given task such as describing change of velocity and projectile of falling bodies are other forms of Factual errors.Factual errors could be due to misunderstanding of the concept which could be due to the method of teaching the concept (Melle 1996, Allchim 2000b). Algorithm errors are errors that occur when solving problems in form of failure to substitute, use the required formulae or correct arithmetic. Poor Mathematics background and inadequate problem solving skills have often been associated with algorithm errors.The error-type with lowest frequency was Communicative error with 52(10.87%). Communicative error involved wrong usage of technical terms which could be due to poor proficiency in language such as wrong definitions and concepts (Ajibola 1988, Ado 2010). From the percentage of errors committed on different tasks on the diagnostic test shown in Table4.2, all errors within the range 40-100% have been featured in the remediation package used as the treatment.

Research Question3. Is there anydifference in the frequency of the Error-types committed by male and female students in senior secondary school examination in Physics theory paper?

The statistics used to analyse data collected for answering the research question was a descriptive statistics in form of frequency and percentageof the classified Error-types. The result is presented in Table 4.03

Table 4.03 Frequency and Percentage of Error-typesidentified inSenior Secondary School Physics Diagnostic Test onGender

S/N	Error-type	N	Freq.	Male Freq.	Mean Male Freq.	Female Freq.	Mean Female Freq.
1.	Factual Error		205	90(43.8%)	0.98	115(56.2%)	3.8
2.	Algorithm		137	48(34.5%)	0.52	89(65.5%)	3.0
3.	Communicative	122	052	28(53.1%)	0.30	24(46.9%)	0.8
4.	Diagrammatic		094	59(63.2%)	0.64	35(36.8%)	1.2

From the result in Table 4.03 the fourError-types were shown to have differences between male and female students. Factual Error- types has a frequency 90(43.8%) for male and 115(56.2%) for females. The femalesubjectscommittedmore of the factual error-types than the male subjects.The male subjects committed 48 (34.5%) of the Algorithmic error-types against 89(65.5%) for female subjects. This indicates that female subjects committed more algorithm errors than the male subjects. For communicative,28

(53.1%) of the error was committed by male subjects while 24 (46.9%) the females committed similar error.Here males committed more of communication errors than the female subjects.The Female subjects had59 (63.2%) of Diagrammatic errors against35 (36.8%) for the malesubjects. This therefore showed that males committed less of the diagrammatic errors than the female. From the result in Table 4.03 it was observed that the mean percentage error for female is slightly higher than the male percentage score. There istherefore difference in the frequency of errors committed by the subjects inexamination on the four identified Error-types.

Research Question 4. Does the administration of Remediation package reduce the frequencyof the Error-types SSII students committed after exposure to the remediation package?

To answer research question 4, the frequency of error-types committed by members of experimental and control groups in posttest was collected and analyzed. The result of the analysis is presented in Table 4.04.

Table 4.04Frequency of Errors at Pretest and Posttest levels on EDT

Error-Type	N	Pretest Freq.	Mean Pretest Freq.	Posttest Freq.	Mean Post test Frequency	Mean difference
Factual Error		260	2.1	195	1.6	0.5
Algorithmic Error		178	1.5	127	1.1	0.4
Communicative Error	122	134	1.1	072	0.6	0.5
Diagrammatic Error		148	1.2	084	0.7	0.5

From the result in Table 4.04, the frequency of Error- types on pretest and posttest of the subjects on EDT presented. The subjects in the experimental group had mean score of 2.1 in pretest and 1.6 on posttest for factual error while 1.5 and 1.1 were mean for algorithmic errors at pre and posttests respectively. 1.1and 0.6 were the mean frequency for communicative error at pretest and posttest respectively. Diagrammatic error has a mean frequency of 1.2 and 0.7 at pretest and posttest respectively. The frequencies of all the error types were higher at the pretest than at the post test level. The differences in thescores could be attributed to exposure of subject to the remediation package given to the experimental group.

Research Question 5. Is there any relationship between the frequencies of errors-typescommitted by the subjects andtheir academic achievement in senior secondary school Physics examination?

The data usedfor finding answers to research question 5 were percentagesof Error-types and achievement for the study group in posttest. .The data collected ispresented inTable 4.05.The descriptive statistical tool used in describing the relationship between Error-types and Achievementis a graph of frequencyof Error-types against achievement test scores. Graph is a tool of describing relationship between variables(Kerlinger 1973). The graph of percentage error against Academic achievement tests scores is presentedin Fig. 4.1.The data in Appendix 8 containing Students Error and Achievement Scores was used forplotting the graph in Fig 4.1

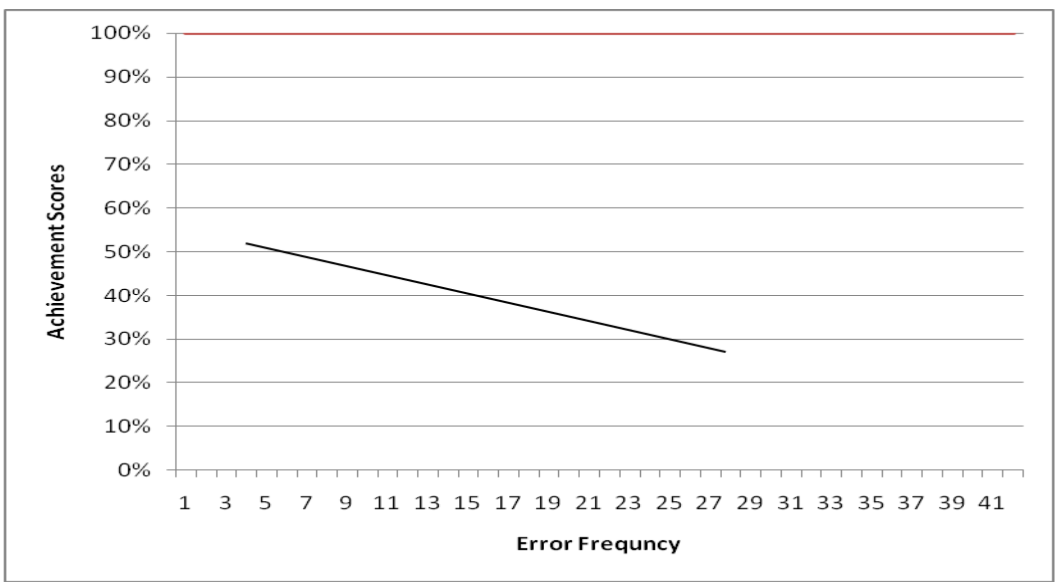


Fig 4.1 Graph of frequency of Error against Achievement Scores

The graph of Academic Achievement Scores against Frequency of Errors committedis a straight line graph inclining to the left. This implies that the gradient was negative which also implies that the relationship between the error frequencyin X-axis and achievement scores of Y-axis is negative. This means that as one variable increases the other decreases. From the graph in Fig.4.1 as Academic Scoresincreases along the Y-axis, Frequency of Error decreases along the X-axis. To determine the coefficient of correlation between the Academic Achievement Scores and Frequency of Errors Pearson-Product- Moment-Correlation-Coefficient(PPMCC) statistics was used when testing null hypothesis five.

Research Question 6. What are the underlying courses of Errors committed bystudents in SSII Physics test?

In order to answer this research question, some of the wrong or incorrect actions taken by the subjects in the Error Diagnostic Test (EDT) under the identified error were assessed from their test scripts and highlighted for each error identified in Table 4.01. Possible causes were outlined based on expected actions for each task in the EDT. The highlight is presented in Table 4.05.

Table 4.05: Some Causes of IdentifiedErrors.

s/no	Errors	Possible cause(s)
1	Wrong determination of distance travelled in linear motion graph	• Incorrect reading of axes scale • Incorrect matching of coordinate axes • Incorrect reading of location
2	Inability to: locate position of given points on linear motion graph	• Misconception of distance • Incorrect identification of time interval • Wrong calculation of distance
3	Determine displacement in linear graph	• Misconception of displacement • Wrong reading of data from graph • Incorrect calculation of displacement
4	Draw positions ofgivenPoints on displacement Timegraph	• Incorrect reading on X, Y axis • Wrong drawing of position
5	Draw displacement ondisplacementtime graph	• Incorrect reading on X, Y axis scale • Wrong usage of data to draw
6	Identifyand describe pattern of time graph movement displayed on motion graph	• Reading X, Y axes • Misconception on nature of motion graph • Incorrect identification of graphs
7	Show understandingof the concept of acceleration	• Unclear concept of velocity change
8	Carryout calculation involving acceleration	• Unclear concept of velocity change • Incorrect recall of formula • Incorrect substitution of data • Incorrect arithmetic
9	Show understanding of The concept of Acceleration	• Misconception of change in velocity • Misunderstanding of Newton's 2^{nd} Law of motion
10	Determine momentumof a Bodywhen other relevantVariablesare given	• Misconception of momentum • Correct recall of formula • Correct substitution • Correct arithmetic
11	Describe projectile Displacement	• Misconception of impulse • Recall of formula • Substitution of data • Correct arithmetic
12	Determine potentialenergy ofbodywhenrelevant variablesare given	• Misconception of potential energy • Wrong recall of Potential Energy formula • Wrong arithmetic
13	Determine theimpulse of a force	• Misconception of force • Types of forces • Resolution of force
14	Describe forces acting on a moving body	• Misunderstanding of speed • Velocities at different locations
15	Describe speed offalling bodyatdifferent locations	• Theory of resolution • Misunderstanding of task
16	Describe velocities of falling bodyat different locations	• Misunderstanding of velocities in relation to position
17	Poor drawing of Vector Diagrammes	• Misconception of vector • Wrong representation of vector • Addition of vector using tail to tail

From the presentation in Table 4.05 most causes of identified errors centeredaround misconceptions of some given terms, wrong procedure of solving numerical exercisesand poorrecall of some required facts,concepts or formula. All the seventeen errors were classified into four error-types and the possible causes of each error-type identified were sought in the available literature. Some factual error-types were seen to occur as a result of rushing to complete syllabus by teachers which usually lead to concept, ideas, formula not properly put across to students (Rufai 1987). Intellectual developmental level of the students has been seen by Savoy (1988) and Melle (1996)as another cause for factual errors. In present study subjects of study were at similar intellectual level and the cause of theirfactual error may be due to the teaching strategy their teachers used which was taken care of in present research using problem solving method in the remediation strategy.

Algorithmic errors are caused by carelessness in problem solving processes according to (Melle 1996). Ammeh (1980) attributed the cause of Algorithm error to students' poor background in Mathematics. In present study carelessness in form of wrong substitution, wrong arithmetic has featured prominently. Problem solving strategies were emphasised in the remediation package to reduce algorithm errors.Communicative error-type has been associated with poor proficiency in English language (Olayemi ,1980) and carelessness in correct reporting and discussion with students. To address the communication error, group activities where student-student, student-teacher interactions and reporting featured to enhance communication skills.On Diagrammatic error-type lack of constant practice been described as the major cause by Newbury (1977).Isa (1990) attributed non appreciation of meaning of diagrammes as important feature in displaying scientific information was another cause for the error in diagrammes. Diagrammatic exercises have featured prominently in the remediation package.

4.2.2 Test of Null Hypotheses

The fivehypothesesstated for the study were tested and the results are presented bellow:

$H0_1$ Null hypothesis One

There is no significant difference in the frequency of different error-types committed by SSII students in senior secondary school Physics examination.

In order to test null hypothesis one, the mean frequencies of the different error-types identified were collated and subjected to a Chi-Square test and the result is presented inTable 4.06

Table 4.06: Chi-Square Analysis of Test on Frequencies of differentError-Types.

S/N	Error-type	N	% freq.	df.	P	Remark
1	Factual Error	4	42.03	3	0.011	Significant
2	Algorithm Error		27.97			
3	Communicative Error		10.67			
4	Diagrammatic Error		19.23			

Significant at $P \leq 0.05$,

From the result in Table 4.06, the number of Error-types N=4, and the degree of freedom for a 4 cell data is 3. The P value obtained was 0.011 which is lower than the significant level set at $p \leq 0.05$ the null hypothesis is therefore rejected. This indicated that the difference between the frequencies of different Error-types was significant. The null hypothesis is therefore rejected.

$H0_2$ Null Hypothesis Two

There is no significant difference in the frequency of error-types committed by subjects exposed to Physics Remediation Package and those exposed to lecture method only.

The data collected for analysing H_{03} were the frequencies of error-types committed by SSII students in control and experimental groups during the post test. The frequencies were subjected to a Chi-square test for any possible difference or otherwise. The result is presented in table 4.07.

Table 4.07: Chi-squareTest Result on Frequencies of Error-types Committed by study subjectsin Post test

Variables	N	Mean freq.	df	P	Remark
Experimental	62	40.42	1	*0.04	*Significant
Control	60	59.58			

*Significant at $P \leq 0.05$

The result in Table 4.07 indicated that the mean scores for control and experimental groups were 59.58 and 40.42 respectively. The P value of 0.04 was obtained which is less than the level of significance set at $P \leq 0.05$. The null hypothesis three is therefore rejected. This indicated that thereis significant difference in the frequency of error-types committed by the experimental and control groups in favour of experimental group.

$H0_3$ Null Hypothesis Three

There is no significant difference in the frequency of Error-types committed by male and female subjects exposed to the Physics Remediation package.

The frequency of error-types committed by experimental group and gender in the post test was calculated. The data was analysed using Chi-squaretest of difference. The result is presented in Table 4.08.

Table 4.08 Chi-square Analysis in Error Types and Gender Among Experimental Group.

Variables	N	Mean Freq.	df	P	Remark
Male	45	41.14	1	*0.4	*Not significant
Female	17	39.70			

*Significant at P≤0.05

The result in Table 4.08 shows that the mean scores for male and female subjects were 41.144 and 39.7 respectively. The P valueobtained was 0.4. The P value isgreater than the set level of significance i.e. p ≤0.05.The null hypothesis is therefore retained indicating that there is no significant difference in frequency of error-types committed by male and female subjects in experimental group. The indifference could be attributed to similar exposure to remediation packageshowing that both male and female subjects benefited equally from the remediation package.

$H0_4$ Null Hypothesis Four

There is no significant difference in the academic achievement between the subjects exposed to the remediation package and those exposed to lecture teaching method only.

The achievement test scores for control and experimental groups were collected after the posttest. The scores were subjected to a t-test analysis for significant different if any. The result of the t-test is presented in table 4.09.

Table 4.09 Result of Pearson Product Moment Coefficient of Correlation (PPMCC) Test on Percentage of Error and Achievement Scores between control and experimental groups

Variables	N	X	SD	Df	P	Remark
Experimental		60.94	13.34			
				120	*0.03	*Significant
	122					
Control		39.06	13.34			

*****Significant at P≤0.05

From the results in Table 4.09, the achievement mean scores on achievement for experimental and control groups were 60.94 and 39.06 respectively. The degree of freedom for the data was 120. The P value is 0.01which is lower than the significant level set at p≤ 0.05.The null hypothesis is therefore rejected indicating that there is significance difference in academic achievement between control and experimental groups. The null hypothesis is therefore rejected.

$H0_5$Null Hypothesis Five

There is no significant relationship between students' frequency of errors and academic performance among Senior Secondary School Students' exposed to the remediation Package

In order to test null hypothesis six the frequency of errors and achievement score were expressed in percentages and were subjected Pearson Product Moment Correlation test. The result of the data analysis is presented in Table 4.10

Table 4.10Result of Pearson Product Moment Coefficient of Correlation (PPMCC) Test on Percentage of Error and Achievement Scores

Variable	N	SD	r_{value}	P	Decision
Error	62	13.54			
			-0.67	*0.04	*Significant
Achievement	62	13.38			

*Significant at P≤ 0.05

From the result in Table 4.10 the calculated coefficient of correlation obtained is - 0.67 and with a p value of 0.04 which is lower than the significant level value set at p≤ 0.05. The null hypothesis is therefore rejected. This indicated that there is a significant relationship between error and achievement scores. The negative value of coefficient of correlation indicated that the relationship between percentage error score and percentage achievement score was an inverse one which implies that as error increased the achievement score decreased.

4.3 Summary of Major Findings

Based on the outcome of the analysis of data collected for present study, the following are the major findings of the research:

i. Seventeen errors were identified with different frequencies ranging from 15 to 41.

The error with least frequency was wrong calculation of acceleration, while error on identification of nature of motion graph and determination of momentum had the highest mean frequency of 41.

iiThe errors were classified into four error-types namely factual 205(42.03%), algorithm 137(27.97%), communication 52(10.67%)

and diagrammatic 94(19.23%) error-types.

iiiThere was significant difference in the frequency of different error-types committed by the SSIIstudents in Physics theory examination. $\square^{2}$ calculated was 21.49 within a degree offreedom of 3 and P value of 0.01 obtained at P≤0.05.

ivThere was significant difference in the frequency of error-types committed by SSII between experimental and control group students. At df of 1 a P value of 0.04 was obtained at significant limit at P≤0.05. The mean score forcontrol was 59.58 and the score for experimental was 40.42.

ivThere was no difference in the frequency of error-types committed by male and female subjects exposed to the Physics Remediation Package. The valueofP calculated was 0.4 at significant value of P≤0.05. The mean scores for male and female were 41.14 and 39.70 respectively.

V There was significant difference in the academic achievement of subjects between those exposed to the Physics remediation package and those not so exposed. The calculatedvalue of t was 1.26 with df =2 and a P value of 0.03 obtained at significant level P≤0.05. The mean score for experimental group was 60.94 and the score for control was 39.06 at a standard deviation of 13.34.

viThere was a significant inverse relationship between the percentage of errors and the percentage of academic achievement. The correlation coefficient r calculated was -0.67 and the p value obtained was 0.04 at significant level of p ≤0.05. As percentage of error increased the percentage of achievement score decreased.

4.4 Discussion of the Results

. The discussion of the results of the present study is presented in relation to the research questions and hypotheses stated for the research.

The result of statistical analysis relating to research question one, indicated in Table 4.01showed that seventeen different errors were identified to have been committed by study subjects with different frequencies. The errors were identified based on the tasks given to the study subjects in the diagnostic tests. The frequencies of the errors were indication of the level of difficulty embedded in each given task. Thefrequency of the errors guided the researcher in selecting topics for discussion in the design of the Physics remediation package used as treatment for the experimental group.The different errors identified is in agreement with the view of Allchin (2000a),Collins & Pinch (1993), Darken (1998)who stated that error is common in Scientific practice. The finding is in agreement with the view of Allchin(2000a) that errors in science range along a spectrum from those relatively local to the phenomena to those more conceptually derived.

The identified errors were classified into factual, algorithm, communication and diagrammatic error-types based the classification of Ajibola(1988).Frequencies of error-types indicated in Table 4.02 showed factual error has the highest frequency and diagrammatic error having the least.The factual errors and algorithmic error are due to several causes related to the concept that is being learnt the teaching method, the students' previous knowledge and ability.The factual error being the highestin frequencywas in agreement with the findings of Ekwueme &Ali(2012) and Omosewo but in disagreement with the findings of Zakaria, Ibrahim & Maat (2013) who identified algorithm error as the highest occurring in learning quadratic equations.The finding also disagrees with finding of AderonmuandNte(20014)who found computational errors highest Error in whatever form or type causes some anomaly in teaching and learning of science which is needed for development as such studying error-types with a view to remediating them is highly required.

The resultindicated in Tables 4.02 and 4.06were presentedto answer research question two and the result of testing null hypothesis one respectively. The results of the analysis revealed that there was significant difference in frequency of occurrence between different error-types identified as indicated in the test of significance of null hypothesis one. The differences in the frequencies of the error-type were due to level of difficulty of tasks and exposure to the remediation package. This finding is in agreement with the findings of Lawan (1996), Melle(1996), Mohammed (2000) and Ekwueme & Ali (2012) Aderonmu and Nte (2014) who found significant differences between the error types they identified in their separate studies. According to Allchine (2000a) all errors are related because they hinder proper acquisition of scientific knowledge, as such all effort must be put towards studying and correcting the identified errors.

The analysis of data for answering research question threepresented in Tables 4.03 showed that the frequency of error-type between gender is different. However when the significance of the difference in frequency and gender was tested as proposed in hypotheses three, result in Table 4.08 indicated no significance difference in the frequency. . This finding is in disagreement with the finding of Lawan (1996), Melle (1996), Ekwueme and Ali (2012), Hyde and Martz (2009) who found that there was significant differences in frequencies of error-types committed between maleand female with girls having higher frequencies than the male on errors committed . The result is in disagreement with the findings of Harding and Whiteleg (1997), Omosewo & Akanbi (2013) who found that male student committed more errors than female students in science. The commitment of more error by female subjects in the study was expected because most studies tend to show that female students performed poorly than male students in Physics due to the abstract nature of the subject(Madsen, Mckagan, Sayre 2013).The finding is in agreement with findings of Olajide(2002),Uhumauviv et al(2003), Usman(2009), Sahranavad and Hassan(2013) who found that there was no significant difference in academic performance between male and female students in science. The result of no difference in frequency of error-types may be as a result of subjecting the study subjects to the same training content and using the same problem solving approach.

The outcome of the analysis of result for testing null hypothesis four as presented in Table 4.09 and the result presented in Table 4.04 for answering research question four indicated that remediation reduced frequency of errors committed by subject.. The result also indicated that there was significant difference in academic achievement between control and experimental groups.The reduction in errors committed and significant difference in frequency of error-types was as a result of exposure to the remediation package administered to the experimental group. This shows that the remediation package was effective in addressing or correcting students' misconceptions of some terms like momentum and incorrect problem solving skills and strategies that lead to errors in response to examination items. This result is in agreement with the work of Shaibu (1987), Battistain et al (2010) who found that diagnostic prescriptive instruction significantly and positively influences science achievement.The finding is in consonance with outcome of the findings of Oyekan (2013) who showed that subjects exposed to diagnostic Remedial Teaching have higher achievement and retention than those not exposed to remedial package in science. Adelman (1998) and Deil-Amen and Rosenbaum (2002) documented a contrary result showing that students who took remedial courses had markedly lower graduation rate than those not exposed to the remediation.The difference achievement was expected as students who have learnt concepts meaningfully are expected to commit less errors than those not exposed to similar opportunity.

The outcome of the test for relationship between frequency of errors and academic achievement as captured in hypothesis five and results indicated in Table 4.10showed that the coefficient of correlation between frequency of errors and achievement was -0.67. The correlation was negative indicating that the relationship was an inverse one which implies that as error increased the achievement score decreased. The inverse relationship between achievement and error-type frequencies was also depicted in a linear graph obtained when frequency of error was plotted against achievement scores in Fig4.1. The inverse relationship agreed with the findings of Norris (1995) who revealed an inverse relation between pragmatic errors and reading achievement in his study. The finding is in agreement with the work of Melle (1996) who found an inverse relationship between frequency of errors committed and academic achievement of study subjects.

In an attempt to find out some of the possible causes of the identified error-types, as was stated in research question six, the students'responses on given questions in the Physics remediation package was examined. Test showed some misconception of terms such as acceleration, inability to read out data from given numerical exercises, wrong choice of scales,wrong drawingof motion graphs. Other causes included wrong usage of formula, improper substitution, wrong arithmetic and units of quantities. The observations were made on the marked study scripts on error diagnostic test and achievement tests.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter contains the summary of the research problem, research questions and hypotheses, procedure of the research as well as the major findings from the study. Conclusion and recommendations were made based on the findings of the study.

5.2 Summary

This study was aimed at identifying the errors committed in Physics examinations by Senior Secondary School Students and also to determine the efficacy of a remediation package designed to minimize committing such errors in future. The study was in two parts: diagnosing the types of errors committed by the students, andthe designand determination of the efficacy of a remediation package.From a population of one thousand eight hundred and thirty one students offering Physicsin Zaria Education Zone..122 randomly selected senior secondary school students participated in the study.Sixty students were in the control group and sixty two in the experimental group. The sample comprised, ninety two malesand thirty female students.The research design was Quasi- experimental involving pretestposttest approach.

Six research questions and fivenull hypotheseswere statedfor answering and testing respectively.An Error Diagnostic Test on Physics (EDT) was used to identify errors frequently committed by physics students at the senior secondary school level.. Based on the identified errors, a remediation package for correcting of the identified errors was developed.The remediation package was administered for eight weeks on the experimental group using problem solving approach while the control group was taught the sameconcepts using lecture method only..A posttest comprising the **Error Di**agnostic Test (EDT)and Physics Achievement Test (PAT) were administered. Data collected from the pretest and posttests were analysed as reported in chapter four.

5.3 Summary of Findings

The following comprise themajor findingsfrom the study:

1. Seventeen errors were identified with different frequencies ranging from 15 to 41. The error with least mean frequency was wrong calculation of acceleration(15), while error on calculation of momentum of force(41).

   mean frequency of 67.75%.

2. When the errors were classified into four error-types, factualerrors constituted (42.03%), algorithm(27.97%), communication (10.67%)and diagrammatic(19.23%)

3 There was significant difference in the frequency of different error-types committed by the SSII students in Physics theory examination. Null hypotheses one was therefore rejected.

4There was significant difference in the frequency of error-types committed by the subjects in theexperimental and control groupsnull hypotheses two is therefore rejected. This shows that the treatment was effective in remediation of identified errors committedby students.

5. There was nosignificant difference in the frequency of error-types committed by male and female subjects exposed to the Physics Remediation Package. Null hypnosis three was therefore rejected.

6. There was significant difference in the academic achievement of subjects between those exposed to the Physics remediation package and those not so exposed. Null hypotheses four was rejected.
7. There was an inverse relationship between the frequency of errors committed by the subjects and their academic achievement. Null hypotheses number five was rejected.

5.4 Conclusion

Based on the findings from the study, the following conclusion aredrawn:

Students committed seventeen errors in the error diagnostic test and when classified into error-types, factual error had the highest frequency while communicative error had the least frequency. Significant difference was observed in thefrequency of error-types identified .It was observed thatthe remediation package was effective in improving students' achievement,lowering the frequency of errors committed by students and the package was not gender biased. An inverse relation between frequency of errors and achievement scores was established. It was found that major causes of error-types committed centers on inability to recall facts, wrong algorithmic procedures which could be adequately handle by using problem solving approach teaching approach.

5.5Recommendations

Based on the findings from this study the following recommendations are made:

1.Science teachers are encouragedto diagnose their students' errors after instructions to identify common errors and use effective remediation package to correct them. This will help improve students' performance in Physics.

2.The use of printed instruction material containing organized textual material Organized aroundidentified area of errors and using problem solving approach for remediationis recommended for Science Teachers and researcher for remediation of error frequency committed by Physics students.

3.The use of physics remediation package for identified errors developed for present study is recommended to science teachers for use in the teaching and learning of Physics at senior secondary school level for possible improvement in the performance of students in Physics.

4.Science teachers should regularly evaluate the teaching and learning of science in an effort to incorporate the mode of diagnosing misconceptions and development of remediationapproaches used in this study for effective performance of students in science.

5.Textbook publishersshould adopt the patternof arrangement of textbooks to contain lesson notes, hands-on and minds-on activities, numerical exercises, solution to numerical exercises as employed in the design of the diagnostic and remediation package for possible better improvement of learning and achievement in Physics.

6.Physics students should find time to go through the instructional remediation package so as to learn some Physics skills and knowledge presented in problem solving approach which serve as supplement and booster to their usual Physics lessons. The package could enhance better achievement scores and less commitment of errors in Physics examinations as was found in present study.

7.Literate parents should endeavor to enlist the tested remediation package in their libraries so as to assist their children foe better achievement in Physics.

5.6 Limitation of the Study.

1. The schools used for the study were state government schools. Federal and private schools were not involved. Federal and private schools have different setting interns of teachers and equipment.Thisdifferent settings could create some difference which can affect the generalizationto be made from theoutcome of present research.
2. Only Mechanics topic was used among many other Physics topics.Other topics may have their peculiarities which may be different from that of mechanic. The possible difference couldlimit the generalisability of present findings from the study.
3. The study was conducted on Physics theory not includingpractical which takes about 50% of overall assessment at public examinationsof thesubject. This restriction may have an effect on thegeneralisation scope of findings of present research.

5.7Suggestion for Further Studies

1. The present study restricted participation of subjects at ordinary level only. It is recommended that similar studies should be replicated at tertiary , university levels,other states and the nation as a whole in order to obtain a more comprehensive and generalisable outcome on study topic.

2.It is suggested that similar study should be conducted on both theory and practical Physics combined so as to have a combined effect outcome for better and wider generalisation.

3. Present diagnostic study and the design of remediation package was restricted to ordinary .level Physics only. It is therefore recommended for further studies on other science subjects at different levels and different topics so as to obtain a wider base for generalization and contribution to knowledge on impact of remediation on achievement in science.

5.8 Contributions to Knowledge

The studyhas contributed to knowledge in the following ways:

1. The designing of an Error Diagnostic Test(EDT)and a remediation package are contribution toward addressing students' challenges in learning and achievement in Science.
2. The remediation package developed was found to be effective and gender friendly. Therefore it could be used for addressing identified errors for male and female Physics and perhaps Science students generally at the secondary schools in Kaduna State
3. The Error Diagnostic Test (EDT) developed could be used by other researchers for the purpose of diagnosing students' problems associated with teaching and learning difficulties in secondary school Physics.

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APPENDIX 1

REMEDIATION PACKAGE

A REMEDIATION PACKAGE FOR IDENTIFIED ERRORS IN ORDINARY LEVEL PHYSICS

Using Problem Solving Method

By

Mohammed Kabir FALALU

Introduction

Mechanics is a branch of Physics that deals with the study of motion and itss causes. Materials in this package started with Kinematics which is a study of motion without regard for the cause. The conditions required for object to accelerate, concepts of force, moments, momentum and vectors as consequence of force were introduced.

The textual material is designed to assist you understand the basic concepts, principles, theories and skills needed in ordinary level mechanics.The package is made up of several topics. Each topic contains introduction, lesson note, exercises and answers to the given exercises.

By the time you successfully go through the package, your understanding of the basic concepts, knowledge and skills to answer questions in mechanics would have been enhanced.

M. K. Falalu

TABLE OF CONTENT

UNIT 1

LINEAR MOTION

1.1 Technical Language of Kinematics

Kinematics is the science of describing the motion of objects using words, diagrams, numbers, graphs, and equations. Kinematics is a branch of mechanics. The goal of any kinematics lesson is to develop sophisticated mental models that serve to describe (and ultimately, explain) the motion of real-world objects.

In preceding lessons words used to describe the motion of objects will be investigated. The aim is to gain a comfortable foundation with the language that is used throughout the study of mechanics. Terms such as scalars, vectors, distance, displacement, speed, velocity and acceleration will be treated. These words are used with regularity to describe the motion of objects.

1.1.1 Scalars and Vectors

The motion of objects can be described by a person without a background in physics using a collection of words and phrases such as *going fast*, *stopped*, *slowing down*, *speeding up*, and *turning* provide a sufficient vocabulary for describing the motion of objects. In physics, we use these words and many more words such as *distance*, *displacement*, *speed*, *velocity*, and *acceleration*. As we will soon see, these words are associated with mathematical quantities that have strict definitions. The mathematical quantities that are used to describe the motion of objects can be divided into two categories. The quantity is either a vector or a scalar. These two categories can be distinguished from one another by their distinct definitions:

- Scalars are quantities that are fully described by a magnitude (or numerical value) alone.
- Vectors are quantities that are fully described by both a magnitude and a direction.

Some examples of scalar quantities are distance, temperature, speed and mass of a body. Velocity, force, acceleration are some examples of vector quantities. The remainder of this lesson will focus on several examples of vector and scalar quantities (distance, displacement, speed, velocity, and acceleration). As you proceed through the lesson, give careful attention to the vector and scalar nature of each quantity. As we proceed through other units at the Remediation package and become introduced to new mathematical quantities, the discussion will often begin by identifying the new quantity as being either a vector or a scalar.

Exercise 1

1. Categorize each of the following quantities as being either a vector or a scalar quantity in table 1

Table1. Categorisation of quantities.

Quantity	Category
a. 5 m	
b. 30 m/sec, East	
c. 5 m, North	
d. 20 degrees Celsius	
e. 256 bytes	
f. 4000 Calories	

1.2 Distance and Displacement

Distance and displacement are two quantities that may seem to mean the same thing yet have distinctly different definitions and meanings.

- Distance is a scalar quantity that refers to "how much ground an object has covered" during its motion.
- Displacement is a vector quantity that refers to "how far out of place an object is"; it is the object's overall change in position.

To test your understanding of this distinction, consider and draw the following motion depicted in Fig 1. A physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North. What is the Distance covered and the Displacement made by the teacher?

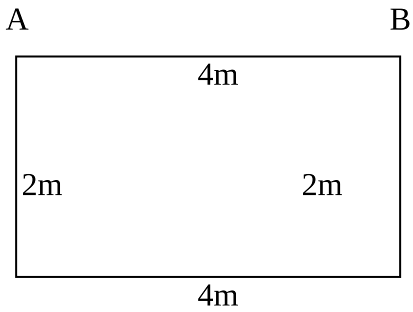


Fig. 1

The physics teacher has walked a total distance of 12 meters, her displacement is 0 meters. During the course of her motion, she has "covered 12 meters of ground" (distance =+4m+2m+4m+2m = 12 m). Yet when she is finished walking, she is not "out of place" - i.e., there is no displacement for her motion (displacement = +4+2m-4m-2m=0 m). Displacement, being a vector quantity, must give attention to direction. The 4 meters east *cancels* the 4 meters west; and the 2 meters south *cancels* the 2 meters north. Vector quantities such as displacement are *direction aware*. Scalar quantities such as distance are ignorant of direction. In determining the overall distance traveled by the physics teachers, the various directions of motion can be ignored.

Consider another example. The diagram in Fig. 2 shows a car runs beside a long straight wall which has marks at metre intervals.. The aerial on the car acts as a convenient indicator of the position of the car. The positions of the car at clock readings of t = 0 s, t = 1 s, t = 2 s, etc. are shown in Fig. 2. Note that at the instant (clock reading) t = 3 s the car on reaching the 13 m position "goes into reverse".

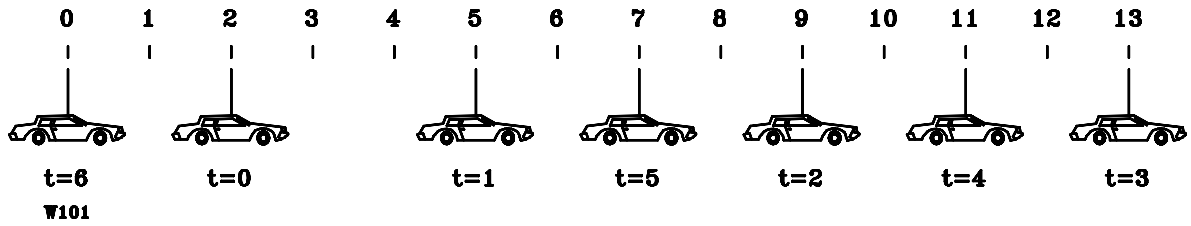


Fig.2

Exercise 2 What is the car's result

ing displacement and distance of travel from t=0 to the various times stated in table 2?

Table2. Determination of Distance and Displacement

Time(s)	Distance(m)	Displacement
4		
5		
2		
6		

To understand the distinction between distance and displacement, you must know the definitions. You must also know that a <u>vector quantity</u> such as displacement is *direction-aware* and a <u>scalar quantity</u> such as distance is *ignorant of direction*. When an object changes its direction of motion, displacement takes this direction change into account; heading the opposite direction effectively begins to *cancel* whatever displacement there once was.

EXERCISE 3

1. Calculate the displacement of the cross-country team if they begin at the school, run 100 km and finish back at the school?

2. Calculate the distance and the displacement of a 100m race sprinter?

1.3 Speed and Velocity

Speed is a scalar quantity that refers to "how fast an object is moving." Speed can be thought of as the rate at which an object covers distance. A fast-moving object has a high speed and covers a relatively large distance in a short amount of time. Contrast this to a slow-moving object that has a low speed; it covers a relatively small amount of distance in the same amount of time. An object with no movement at all has a zero speed.

Velocity is a vector quantity that refers to "the rate at which an object changes its position." Imagine a person moving rapidly - one step forward and one step back - always returning to the original starting position. While this might result in a frenzy of activity, it would result in a zero velocity. Because the person always returns to the original position, the motion would never result in a change in position. Since velocity is defined as the rate at which the position changes, this motion results in zero velocity.

Velocity being a vector quantity is *direction aware*. When evaluating the velocity of an object, one must keep track of direction. It would not be enough to say that an object has a velocity of 45m/s. One must include direction information in order to fully describe the velocity of the object. For instance, you must describe an object's velocity as being 45 m/s, **East**. This is one of the essential differences between speed and velocity. Speed is a scalar quantity and does not *keep track of direction*; velocity is a vector quantity and is *direction aware*.

The task of describing the direction of the velocity vector is easy. The direction of the velocity vector is simply the same as the direction that an object is moving. It would not matter whether the object is speeding up or slowing down. If an object is moving rightwards, then its velocity is described as being rightwards. If an object is moving downwards, then its velocity is described as being downwards. So an airplane moving towards the west with a speed of 300 m/S has a velocity of 300 m/s, west. Note that speed has no direction (it is a scalar) and the velocity at any instant is simply the speed value with a direction.

As an object moves, it often undergoes changes in speed. For example, during an average trip to school, there are many changes in speed. Rather than the speed-o-meter maintaining a steady reading, the needle constantly moves up and down to reflect the stopping and starting and the accelerating and decelerating. One instant, the car may be moving at 50 mi/hr and another instant, it might be stopped (i.e., 0 mi/hr). Yet during the trip to school the person might average 32 mi/hr. The average speed during an entire motion can be thought of as the average of all speedometer readings. If the speedometer readings could be collected at 1-second intervals (or 0.1-second intervals or ...) and then averaged together, the average speed could be determined. Now that would be a lot of work. And fortunately, there is a shortcut.

1.4 Calculating Average Speed and Average Velocity

The average speed during the course of a motion is often computed using the following formula:

Average Speed = Distance Traveled/ Time of Travel

In contrast, the average velocity is often computed using this formula

Average Velocity = Change in position/Time taken = Displacement/Time taken

Let's begin implementing our understanding of these formulas with the following problem:

Question; Adams traveled from Zaria to Sokoto for 8 hours on his motorcycle. The distance between Sokoto and Zaria is 440km. What was his average speed?

To compute her average speed, we simply divide the distance of travel by the time of travel.

Average Speed = Distance traveled/ Time for travel
= 440km/8hrs = 55km/hr
=440km/360x 8 = 0.153 km/sec

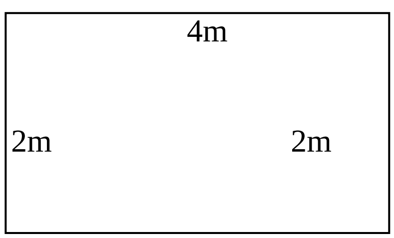
Adams averaged a speed of 55 miles per hour or 0.15km per second. He may not have been traveling at a constant speed of 55 km/hr. He may have stopped at some instant in time to rest or eat and may have reached a speed of 65 km/hr at other instants in time. He ended up with an average speed of 55 km per hour. The above formula is a shortcut method of determining the average speed of an object.

1.5 Average Speed and Instantaneous Speed

It is common to distinguish between the average speed and the instantaneous speed. The distinction is as follows.

- Instantaneous Speed - the speed at any given instant in time.
- Average Speed - the average of all instantaneous speeds; found simply by a distance/time ratio.

Instantaneous speed is the speed that the speedometer reads at any given instant in time and the average speed is the average of all the speedometer readings during the course of the trip. Since the task of averaging speedometer readings would be quite complicated (and maybe even dangerous), the average speed is more commonly calculated as the distance/time ratio.



4m Fig 3

Now let's consider the motion of that physics teacher again in Fig 3. The physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North. The entire motion lasted for 24 seconds. Determine the average speed and the average velocity based on diagram Fig.3.

i Average speed= Distance traveled/time ratio

= (4m+2m+4m+2m)/24s= 12m/24 = 0.5m/s

ii Average velocity = Displacement / time taken

= (+4m+2m-4m-2m)/24s =0/24= 0 m/s

The teacher walked a distance of 12 meters in 24 seconds; thus, her average speed was 0.50 m/s. However, since her displacement is 0 meters, her average velocity is 0 m/s. Remember that the displacement refers to the change in position and the velocity is based upon this position change. In this case of the teacher's motion, there is a position change of 0 meters and thus an average velocity of 0 m/s.

In conclusion, speed and velocity are kinematic quantities that have different definitions. Speed, as a scalar quantity, is the rate at which an object covers distance. The average speed is the distance (a scalar quantity) per unit time. Speed is *ignorant of direction*. On the other hand, velocity is a vector quantity; it is *direction-aware*. Velocity is the rate at which the position changes. The average velocity is the displacement or position change (a vector quantity) per time ratio.

1.6 Acceleration

Acceleration is a vector quantity that is defined as the rate at which an object changes its velocity. An object is accelerating if it is changing its velocity.Sports commentators/announcers occasionally say that a person is accelerating if he/she is moving fast. Yet acceleration has nothing to do with going fast. A person can be moving very fast and still not be accelerating. Acceleration has to do with changing how fast an object is moving. If an object is not changing its velocity, then the object is not accelerating. The data in table 3 below are representative of a northward-moving accelerating object. The velocity is changing over the course of time. Anytime an object's velocity is changing, the object is said to be accelerating; or it has acceleration.

Table3. Velocities of moving object at given times

Time (s)	0	1	2	3	4	5	6	7	8	9	10
V m/s, North	20	20	20	22	24	26	26	26	23	20	17

EXERCISE 4

Use the values in Table 3 and answer the following questions.

(i) Is the car accelerating at the instant t = 1 s?

(ii) Is the moving body changing velocity when t = 4 s

(iii) What is the acceleration of the car at the instant t = 7s?

1.7 The Meaning of Constant Acceleration

Sometimes an accelerating object will change its velocity by the same amount each second. The readings in Table 4 are showing movement of a body with a uniform increase in velocity of 5m/s. This is referred to as a constant acceleration since the velocity is changing by a constant amount each second. An object with a constant acceleration should not be confused with an object with a constant velocity. Table4. Velocity of a body displaying uniform acceleration.

Time(s)	Velocity, m/s, South
0	0
1	5
2	10
3	15
4	20

Note that if an object is changing its velocity, whether by a constant amount or a varying amount, then the body is an accelerating object. And an object with a constant velocity is not accelerating. The data in Tables 5 & 6 below shows motions of objects with a constant acceleration and a changing acceleration. Note that each object has a changing velocity.

Table 5 Motion with constant acceleration

Time (s)	Velocities, m/s, North
0	0
1	3
2	6
3	9
4	12

Table 6 Motion with changing acceleration

Time(s)	Velocity, m/s, West
0	0
1	2
2	5
3	7
4	8

Since accelerating objects are constantly changing their velocity, one can say that their speed is not a constant value. A falling object for instance usually accelerates as it falls.

1.8 Calculating the Average Acceleration

The average acceleration (a) of any object over a given interval of time (t) can be calculated using the equation

Average Velocity =Change in Velocity/ Time = (Final Velocity – Initial Velocity)/ Time

This equation can be used to calculate the acceleration of the object whose motion is depicted by the velocity-time data tables above. The velocity-time data in the table shows that the object has an acceleration of 10 m/s/s. The calculation is shown below.Acceleration values are expressed in units of velocity/time. Typical acceleration units include the following m/s/s , m/s^2 These units The reason for the units becomes obvious upon examination of the acceleration equation.

Acceleration = Change in velocity/Time ==(m/s)/s =m/s/s

Since acceleration is a velocity change over a time, the units on acceleration are velocity units divided by time units - thus (m/s)/s or (mi/hr)/s. The (m/s)/s unit can be mathematically simplified to m/s^2.

1.9 The Direction of the Acceleration Vector

Acceleration is a vector quantity; as such it has a direction associated with it. The direction of the acceleration vector depends on two things:

- whether the object is speeding up or slowing down
- whether the object is moving in the positive (+) or negative(-) direction

The general RULE OF THUMB is:

If an object is slowing down, then its acceleration is in the opposite direction of its motion.

The RULE OF THUMB can be applied to determine whether the sign of the acceleration of an object is positive or negative, right or left, up or down, etc. Consider the two data in Tables 7a and 7b below. In Example 7A, the object is moving in the *positive* direction (i.e., has a *positive* velocity) and is speeding up. When an object is speeding up, the acceleration is in the same direction as the velocity. Thus, this object has a positive acceleration. In Example 7B, the object is moving in the *negative* direction (i.e., has a negative velocity) and is slowing down. According to our RULE OF THUMB, when an object is slowing down, the acceleration is in the opposite direction as the velocity. Thus, this object also has a positive acceleration.

The RULE OF THUMB can be applied to the motion of the objects represented in the two data tables below. In each case, the acceleration of the object is in the *negative* direction. In Example 8A, the object is moving in the *positive* direction (i.e., has a *positive* velocity) and is slowing down. According to our RULE OF THUMB, when an object is slowing down, the acceleration is in the opposite direction as the velocity. Thus, this object has a negative acceleration. In Example 8B, the object is moving in the *negative* direction (i.e., has a *negative* velocity) and is speeding up. When an object is speeding up, the acceleration is in the same direction as the velocity. Thus, this object also has a negative acceleration.

Table 7a Positive change in velocity

Time (s)	Velocities, m/s, North
0	0
1	3
2	6
3	9
4	12

Table 7b Positive change in velocity

Time (s)	Velocity (m/s)
0	0
1	-7
2	-5
3	-4
4	-2

Table 8a Negative change in velocity

Time(s)	Velocity, m/s
0	0
1	-2
2	-5
3	-7
4	-8

Table 8b Negative change in velocity

Time(s)	Velocity, m/s
0	0
1	8
2	7
3	5
4	2

In physics, the use of positive and negative always has a physical meaning, positive and negative describe a direction. Positive often means movement to the right or up and negative often means to the left or down. So to say that an object has a negative acceleration as in Examples 8a and 8b is to simply say that its acceleration is to the left or down. Negative accelerations do not refer acceleration values that are less than 0. An acceleration of -2 m/s/s is an acceleration with a magnitude of 2 m/s/s that is directed in the negative direction.

Exercise 5

Use the equation for acceleration to determine the acceleration for the following motions.

Time(s)	Velocity, m/s ,	Acceleration
1	2	
2	5	
3	7	
4	8	

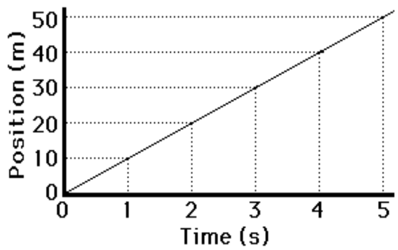
Time (s)	Velocity, m/s, East	Acceleration
1	8	
2	7	
3	5	
4	2	

UNIT 2

MOTION GRAPHS

2.1 The Meaning of Shape for a p-t Graph

Fig. 4



In representing motion of object, words, diagrams, numbers, equations, and graphs are used. Present lesson focuses on the use of position vs. time graphs to describe motion. As we will learn, the specific features of the motion of objects are demonstrated by the shape and the slope of the lines on a position vs. time graph. The first part of this lesson involves a study of the relationship between the shape of a p-t graph and the motion of the object.

To begin, consider a car moving with a constant, rightward (+) velocity - say of +10 m/s.

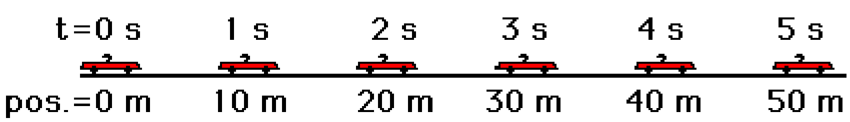


Figure 5

If the position-time data for such a car were plotted, then the resulting graph would look like the graph in Fig. 4. Note that a motion described as a constant, positive velocity results in a line of constant and positive slope when plotted as a position-time graph.

Now consider a car moving with a rightward (+), changing velocity - that is, a car that is moving rightward but speeding up or *accelerating.*

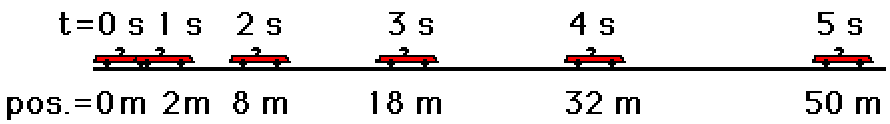


Figure 7

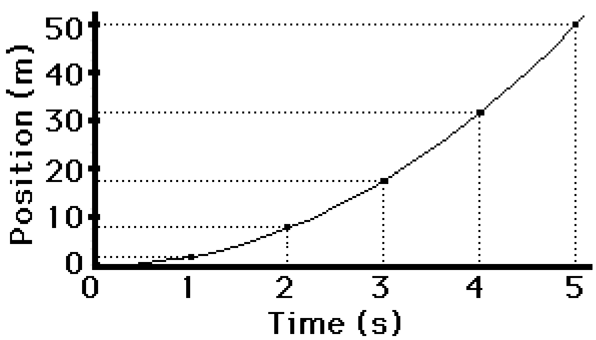


Fig.6

If the position-time data for such a car were graphed, then the resulting graph would look like the graph in Fig. 6. Note that a motion described as a changing, positive velocity results in a line of changing and positive slope when plotted as a position-time graph.

The position vs. time graphs for the two types of motion - constant velocity and changing velocity (acceleration) - are shown as follows in Fig. 8a and 8b..

Constant Velocity

Positive Velocity

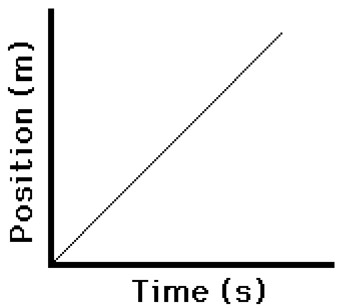


Figure 8a

Positive Velocity

Changing Velocity (acceleration)

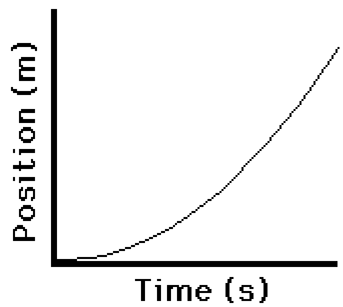


Figure 8b

2.2 The Importance of Slope

The shapes of the position - time graphs for these two basic types of motion - constant velocity motion and accelerated motion (i.e., changing velocity) - reveal an important principle.

The slope of the line on a position-time graph reveals useful information about the velocity of the object. It is often said, "As the slope goes, so goes the velocity." Whatever characteristics the velocity has, the slope will exhibit the same (and vice versa). If the velocity is constant, then the slope is constant (i.e., a straight line). If the velocity is changing, then the slope is changing (i.e., a curved line). If the velocity is positive, then the slope is positive (i.e., moving upwards and to the right). This very principle can be extended to any motion conceivable.

Consider the graphs below (Fig. 9a,b,10a,b) as example applications of this principle concerning the slope of the line on a position versus time graph.

The graph on Fig 9a, is representative of an object that is moving with a positive velocity (as denoted by the positive slope), a constant velocity (as denoted by the constant slope) and a small velocity (as denoted by the small slope).

The graph on Fig.9b has similar features - there is a constant, positive velocity (as denoted by the constant, positive slope). However, the slope of the graph on Fig.9b is larger than that on Fig 9a. This larger slope is indicative of a larger velocity. The object represented by the graph on the right is traveling faster than the object represented by the graph on the left. The principle of slope can be used to extract relevant motion characteristics from a position vs. time graph. As the slope goes, so goes the velocity.

Slow, Rightward(+)
Constant Velocity

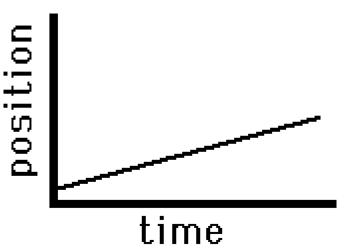


Figure 9a

Fast, Rightward(+)
Constant Velocity

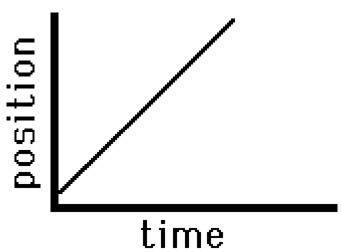


Figure 9b

Consider the graphs below in Fig. 10 as another application of this principle of slope.

Slow, Leftward(-)
Constant Velocity

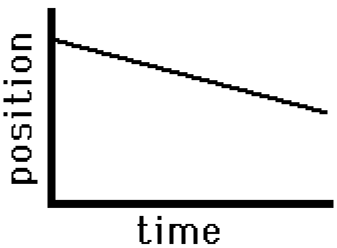


Figure 10a

Fast, Leftward(-)
Constant Velocity

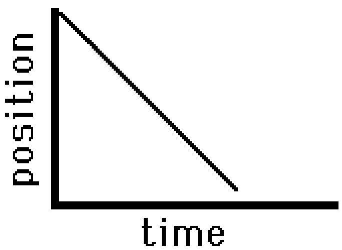


Figure 10b

As a final application of this principle of slope, consider the two graphs in Fig. 11a,b below. Both graphs show plotted points forming a curved line. Curved lines have changing slope; they may start with a very small slope and begin curving sharply (either upwards or downwards) towards a large slope. In either case, the curved line of changing slope is a sign of accelerated motion (i.e., changing velocity). Applying the principle of slope to the graph on Fig. 11a, one would conclude that the object depicted by the graph is moving with a negative velocity (since the slope is negative). Furthermore, the object is starting with a small velocity (the slope starts out with a small slope) and finishes with a large velocity (the slope becomes large). That would mean that this object is moving in the negative direction and speeding up (the small velocity turns into a larger velocity).

Negative (-) Velocity

Slow to Fast

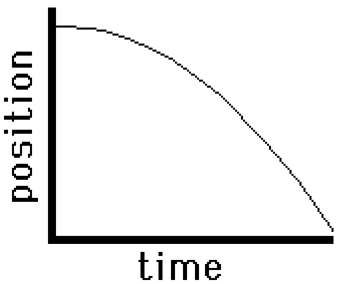


Figure 11a

Leftward (-) Velocity

Fast to Slow

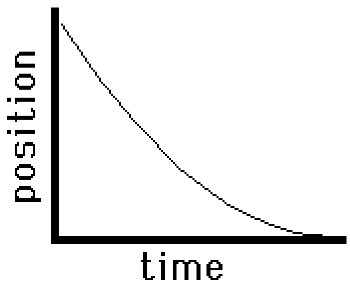
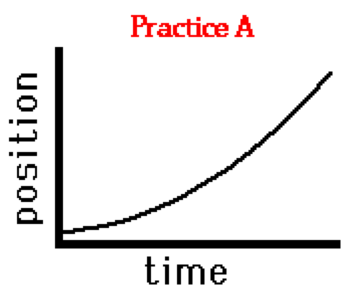


Figure 11b

The principle of slope is an incredibly useful principle for extracting relevant information about the motion of objects as described by their position vs. time graph. Once you've practiced the principle a few times, it becomes a very useful means of analyzing position-time graphs.

Exercise 6

(a) Use the principle of slope to describe the motion of the objects represented by the two plots below. In your description, be sure to include such information as the direction of the velocity vector (i.e., positive or negative), whether there is a constant velocity or an acceleration, and whether the object is moving slow, fast, from slow to fast or from fast to slow. Be complete in your description.



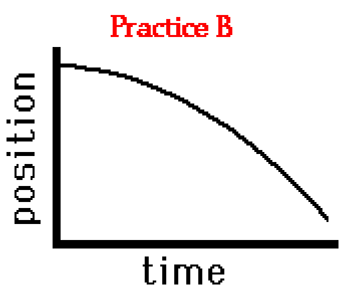


Fig. 12b

Fig.12a

(b) Consider a car moving with a constant velocity of +10 m/s for 5 seconds. Draw the graph of the motion

2.3 The Meaning of Slope for a position – time graph

The slope of a position –time graph reveals important information about an object's velocity. For example

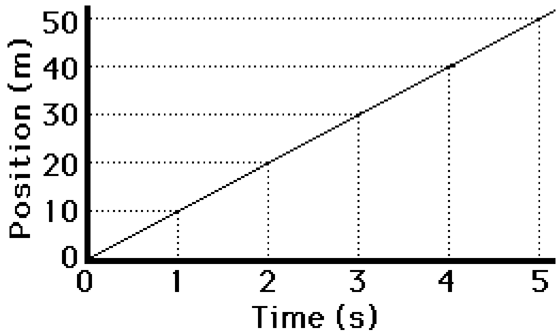
A small slope means a small velocity

A negative slope means a negative velocity

A constant slope (straight line) means a constant velocity

A changing slope (curved line) means a changing velocity

Thus the shape of the line on the graph is descriptive object's motion. In this segment of the lesson we will examine how the actual slope value of any straight line graph is the velocity of the object.



Consider a car moving with a constant velocity of +10 m/s for 5 seconds (Fig. 15). The diagram below depicts such a motion.

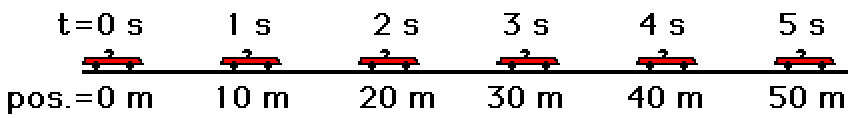


Figure 13b

The position-time graph would look like the graph in Fig 15

Figure 15. Note that during the first 5 seconds, the line on the graph slopes up 10 m for every 1 second along the horizontal (time) axis. That is, the slope of the line is +10 meter/1 second. In this case, the slope of the line (10 m/s) is obviously equal to the velocity of the car. We will examine a few other graphs to see if this a principle that is true of all position vs. time graphs.

Now consider a car moving at a constant velocity of +5 m/s for 5 seconds, abruptly stopping, and then remaining at rest (v = 0 m/s) for 5 seconds.

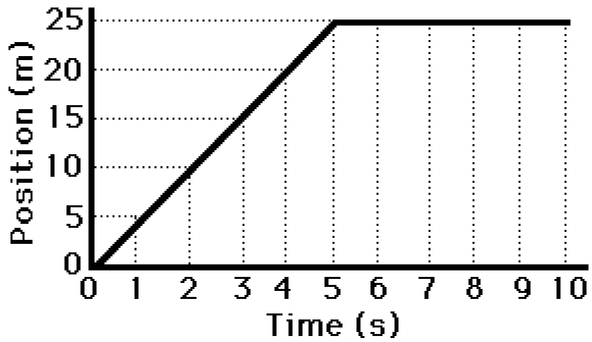


Figure 14

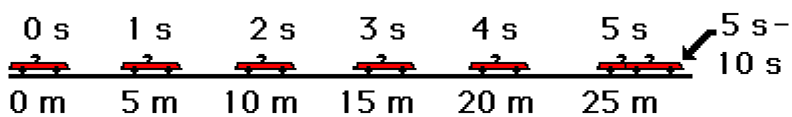


Figure 16

If the position-time data for such a car were plotted, then the resulting graph would look like the graph in Fig. 14. For the first five seconds the line on the graph slopes up 5 meters for every 1 second along the horizontal (time) axis. That is, the line on the position vs. time graph has a slope of +5 meters/1 second for the first five seconds.

Thus, the slope of the line on the graph equals the velocity of the car. During the last 5 seconds (5 to 10 seconds), the line slopes up 0 meters. That is, the slope of the line is 0 m/s - the same as the velocity during this time interval. Both of these examples reveal an important principle. The principle is that the slope of the line on a position-time graph is equal to the velocity of the object. If the object is moving with a velocity of +4 m/s, then the slope of the line will be +4 m/s. If the object is moving with a velocity of -8 m/s, then the slope of the line will be -8 m/s. If the object has a velocity of 0 m/s, then the slope of the line will be 0 m/s.

EXERCISE 7

A train is given a test run on a track which has numbered markers every kilometre. Using the following information, mark the appropriate points on the Figure 17 below and then draw your version of the position-time graph.

(i) The train starts at t = 0 from the 4 km mark.

(ii)It speeds up and passes the 7 km mark 1 min later.

(iii) Still speeding up, the train travels 5 km during the next 2 min.

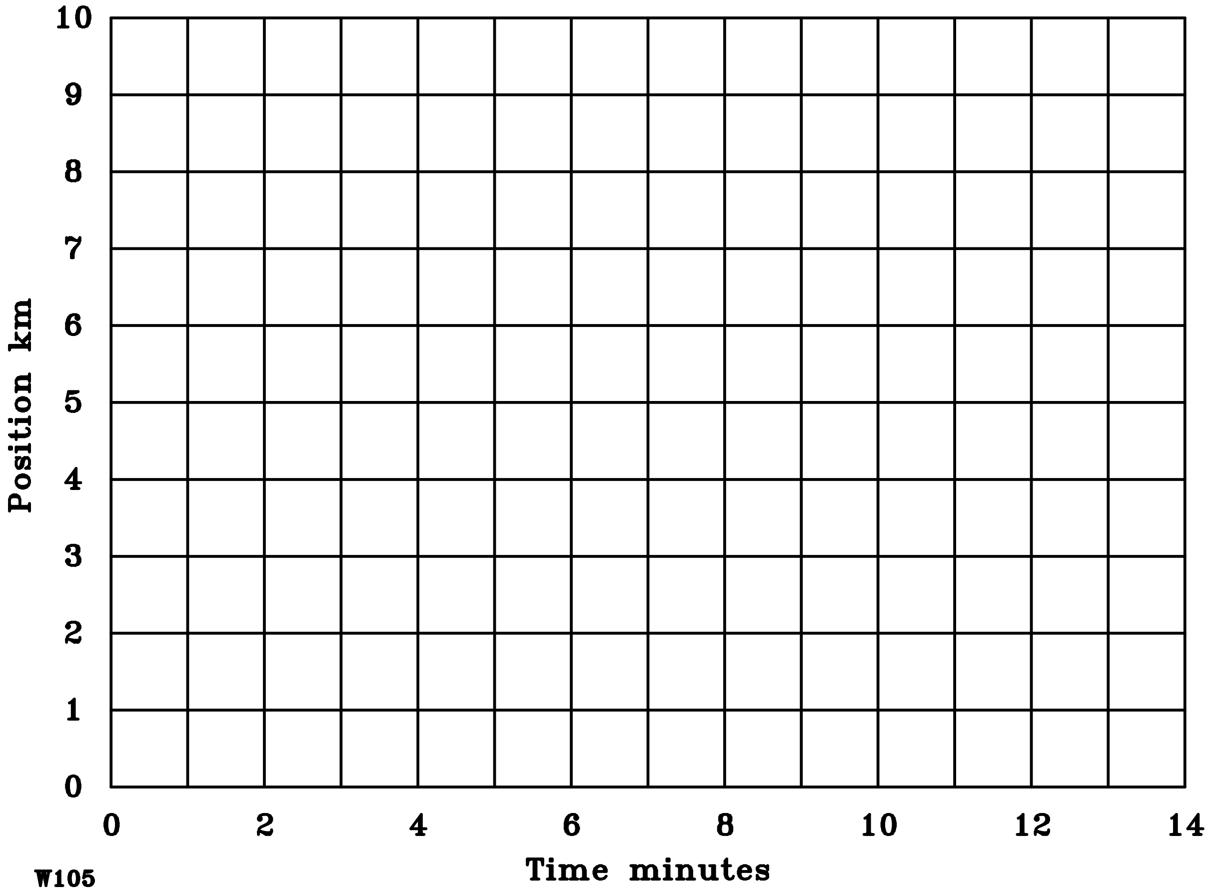


Figure 17

2.4 Determining the Slope on a p-t Graph

It was learned earlier that the slope of the line on a position versus time graph is equal to the velocity of the object. If the object is moving with a velocity of +4 m/s, then the slope of the line will be +4 m/s. If the object is moving with a velocity of -8 m/s, then the slope of the line will be -8 m/s. If the object has a velocity of 0 m/s, then the slope of the line will be 0 m/s. The slope of the line on a position versus time graph tells it all.

Let's begin by considering the position versus time graph below (Fig.18).

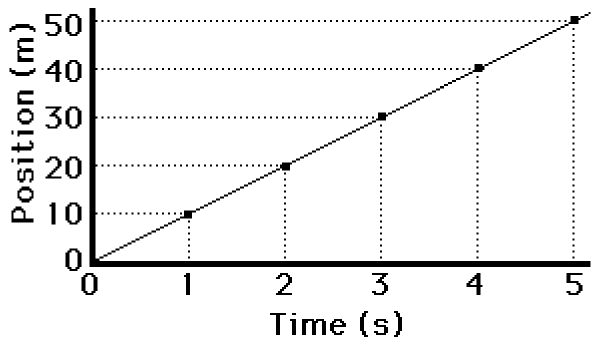


Figure 18

The line is sloping upwards to the right. But mathematically, by how much does it slope upwards for every 1 second along the horizontal (time) axis? To answer this question we must use the slope equation.

Slopes = $\frac{\Delta y}{\Delta x}$= (Y2 – Y1)/ (X2 – X1) = rise / run

The slope equation says that the slope of a line is found by determining the amount of rise of the line between any two points divided by the amount of run of the line between the same two points. In other words,

- Pick two points on the line and determine their coordinates.
- Determine the difference in y-coordinates of these two points (*rise*).
- Determine the difference in x-coordinates for these two points (*run*).
- Divide the difference in y-coordinates by the difference in x-coordinates (rise/run or slope).

The diagram below shows this method being applied to determine the slope of the line. Note that three different calculations are performed for three different sets of two points on the line. In each case, the result is the same: the slope is 10 m/s.

For points (5 s, 50 m) and (0 s, 0 m):

$$\text{slope} = \frac{50\,\text{m} - 0\,\text{m}}{5\,\text{s} - 0\,\text{s}} = 10\ \text{m/s}$$

For points (5 s, 50 m) and (2 s, 20 m):

$$\text{slope} = \frac{50\,\text{m} - 20\,\text{m}}{5\,\text{s} - 2\,\text{s}} = 10\ \text{m/s}$$

For points (4 s, 40 m) and (3 s, 30 m):

$$\text{slope} = \frac{40\,\text{m} - 30\,\text{m}}{4\,\text{s} - 3\,\text{s}} = 10\ \text{m/s}$$

Consider the graph below (Fig. 19). Note that the slope is not positive but rather negative; that is, the line slopes in the downward direction. Note also that the line on the graph does not pass through the origin. Slope calculations are relatively easy when the line passes through the origin since one of the points is (0,0). But that is not the case here.

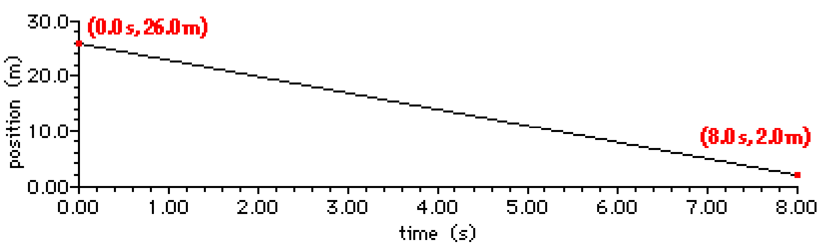


Figure 19

Exercise 8

1. Determine the slope of the object as shown by the graph in Fig. 19.

2 Calculate the slope representing about the moving object in Fig. 20

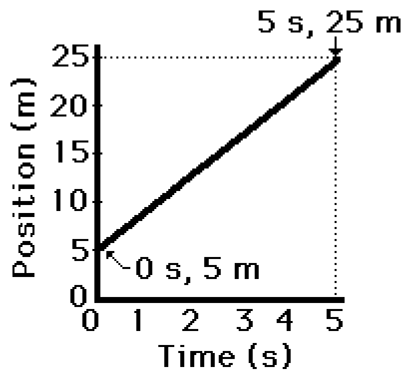


Figure 19

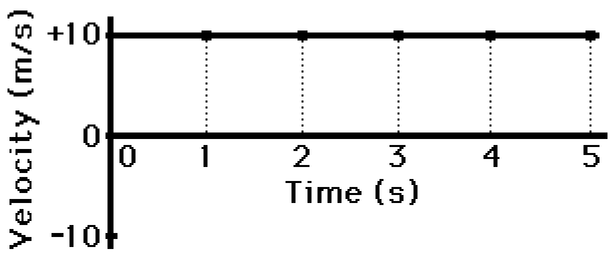


Figure 20

2.5 The Meaning of Shape for a v-t Graph

This lesson focuses on the use of velocity - time graphs to describe motion. You will learn, the specific features of the motion of objects are demonstrated by the shape and the slope of the lines on a velocity vs. time graph. The first part of this lesson involves a study of the relationship between the shape of a v-t graph and the motion of the object.

Consider a car moving with a constant, rightward (+) velocity - say of +10 m/s(Fig. 21). As learned earlier a car moving with a constant velocity is a car with zero acceleration.

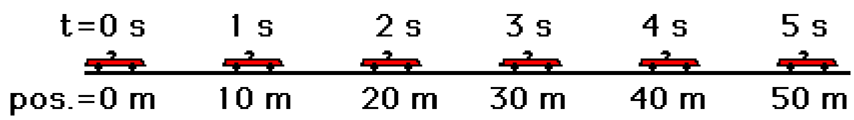


Figure 21

If the velocity-time data for such a car were plotted, then the resulting graph would look like the graph at the in Fig 23. Note that a motion described as a constant, positive velocity results in a line of zero slope (a horizontal line has zero slope) when plotted as a velocity-time graph. Furthermore, only positive velocity values are plotted, corresponding to a motion with positive velocity.

Now consider a car moving with a rightward (+), changing velocity - that is, a car that is moving rightward but speeding up or accelerating. Since the car is moving in the positive direction and moving fast, the car is said to have positive acceleration.

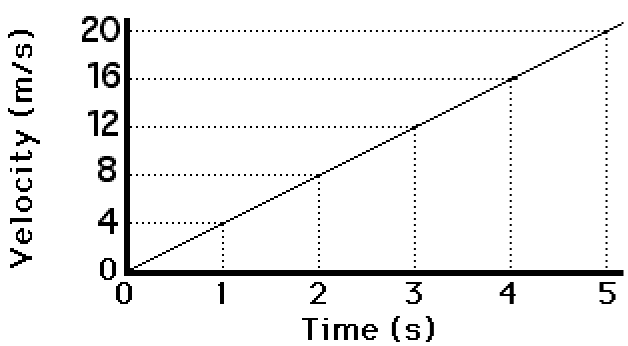


Fig 23

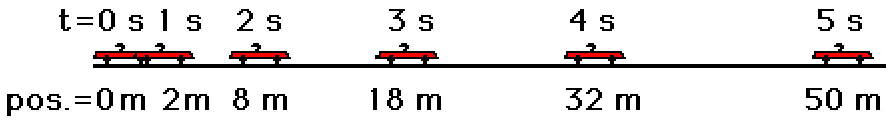


Figure 24

If the velocity-time data for such a car were graphed, how will the resulting graph look like?

 Note that A motion described as a changing, positive velocity results in a sloped line when plotted as a velocity-time graph.

The slope of the line is positive, corresponding to the positive acceleration. Furthermore,

Only positive velocity values are plotted, corresponding to a motion with positive velocity

Positive Velocity
Zero Acceleration

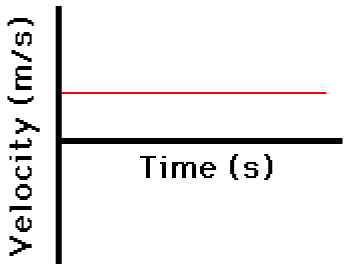


Figure 25a

Positive Velocity
Positive Acceleration

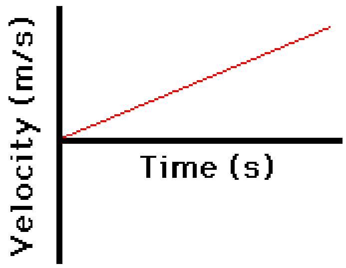


Figure 25b

2.6The Importance of Slope

The shapes of the velocity - time graphs for these two basic types of motion - constant velocity motion and accelerated motion (i.e., changing velocity) - reveal an important principle. The principle is that the slope of the line on a velocity-time graph reveals useful information about the acceleration of the object.

If the acceleration is zero, then the slope is zero (i.e., a horizontal line).

If the acceleration is positive, then the slope is positive (i.e., an upward sloping line).

If the acceleration is negative, then the slope is negative (i.e., a downward sloping line). This very principle can be extended to any conceivable motion.

But how can one tell whether the object is moving in the positive direction (i.e., positive velocity) or in the negative direction (i.e., negative velocity)?

The velocity would be positive whenever the line lies in the positive region (above the x-axis) of the graph. Similarly,

The velocity would be negative whenever the line lies in the negative region (below the x-axis) of the graph. Fig. 26a

A positive velocity means the object is moving in the positive direction;

A negative velocity means the object is moving in the negative direction. So one knows an object is moving in the positive direction if the line is located in the positive region of the graph (whether it is sloping up or sloping down. Fig.26b

An object is moving in the negative direction if the line is located in the negative region of the graph (whether it is sloping up or sloping down). Fig. 26d

If a line crosses over the x-axis from the positive region to the negative region of the graph ,(or vice versa), then the object has changed directions.

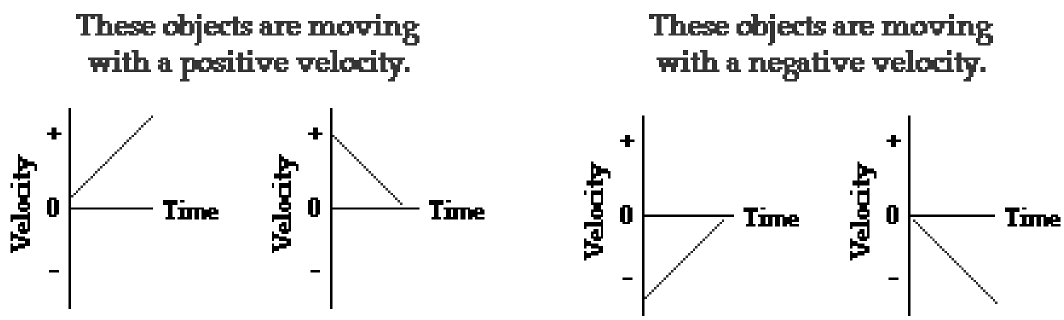
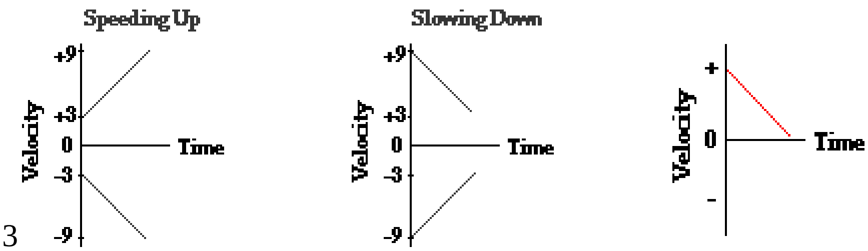


Figure 26a,b,c,d

2.7 How can one tell if the object is speeding up or slowing down? Speeding up means that the magnitude (or numerical value) of the velocity is getting large. For instance, an object with a velocity changing from +3 m/s to + 9 m/s is speeding up. Similarly, an object with a velocity changing from -3 m/s to -9 m/s is also speeding up. In each case, the magnitude of the velocity (the number itself, not the sign or direction) is increasing; the speed is getting bigger. Given this fact, one would believe that an object is speeding up if the line on a velocity-time graph is changing from near the 0-velocity point to a location further away from the 0-velocity point. That is, if the line is getting further away from the x-axis (the 0-velocity point), then the object is speeding up. And conversely, if the line is approaching the x-axis, then the object is slowing down.



3

Fig.27a, b, c,

Exercise 9

1. Draw the graph of a moving object whose motion has the following descriptions

1. moving in the positive direction.
2. moving with a constant velocity.
3. moving with a negative velocity.
4. slowing down.
5. changing directions.
6. speeding up.
7. moving with a positive acceleration.
8. moving with a constant acceleration.

2.8 The Meaning of Slope for a v-t Graph

In this part of the lesson, we will examine how the actual slope value of any straight line on a velocity-time graph is the acceleration of the object.

Consider a car moving with a constant velocity of +10 m/s. A car moving with a constant velocity has an acceleration of 0 m/s/s. Fig.28

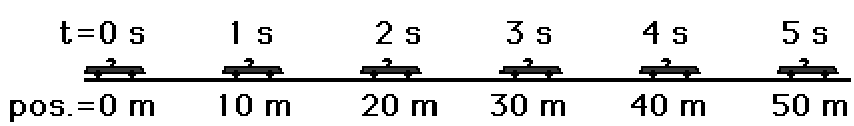


Figure 28

The velocity-time data and graph would look like the graph below. Note that the line on the graph is horizontal. That is the slope of the line is 0 m/s/s. In this case, it is obvious that the slope of the line (0 m/s/s) is the same as the acceleration (0 m/s/s) of the car.

Time (s)	**Velocity (m/s)**
0	10
1	10
2	10
3	10
4	10
5	10

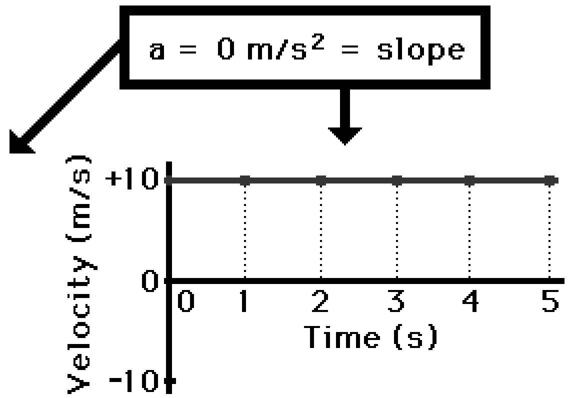


Figure 29

So in this case, the slope of the line is equal to the acceleration of the velocity-time graph. Now we will examine a few other graphs to see if this is a principle that is true of all velocity versus time graphs.

Now consider a car moving with a changing velocity. A car with a changing velocity will have an acceleration.

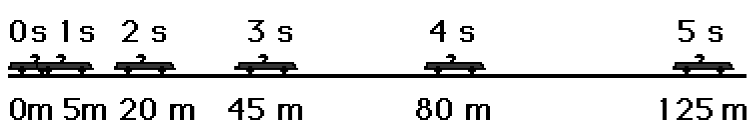


Figure 30

The velocity-time data for this motion show that the car has an acceleration value of 10 m/s/s. The graph of this velocity-time data would look like the graph below Fig. 31. Note that the line on the graph is diagonal - that is, it has a slope. The slope of the line can be calculated as 10 m/s/s. It is obvious once again that the slope of the line (10 m/s/s) is the same as the acceleration (10 m/s/s) of the car.

Time (s)	**Velocity (m/s)**
0	0
1	10
2	20
3	30
4	40
5	50

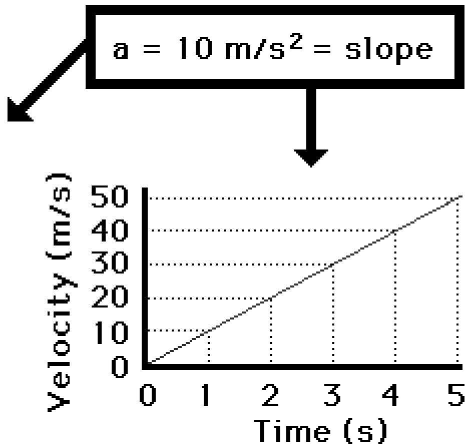


Figure 31

In both instances above, the slope of the line was equal to the acceleration.

Consider the motion of a car that first travels with a constant velocity (a=0 m/s/s) of 2 m/s for four seconds and then accelerates at a rate of +2 m/s/s for four seconds. That is, in the first four seconds, the car is not changing its velocity (the velocity remains at 2 m/s) and then the car increases its velocity by 2 m/s per second over the next four seconds. The velocity-time data and graph are displayed below (Fig. 32). Observe the relationship between the slope of the line during each four-second interval and the corresponding acceleration value.

Time (s)	Velocity (m/s)
0	2
1	2
2	2
3	2
4	2
5	4
6	6
7	8
8	10

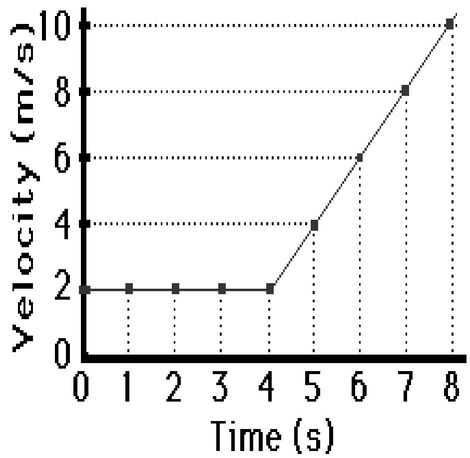


Figure 32

From 0 s to 4 s: slope = 0 m/s/s
From 4 s to 8 s: slope = 2 m/s/s

A motion such as the one above further illustrates the important principle:

The **slope** of the line on a velocity-time graph is equal to the **acceleration** of the object. This principle can be used for all velocity-time in order to determine the numerical value of the acceleration.

Exercise 10

The velocity-time graph for a two-stage rocket is shown below Fig 33. Use the graph and your understanding of slope calculations to determine the acceleration of the rocket during the listed time intervals.

1. t = 0 - 1 second
2. t = 1 - 4 second
3. t = 4 - 12 second

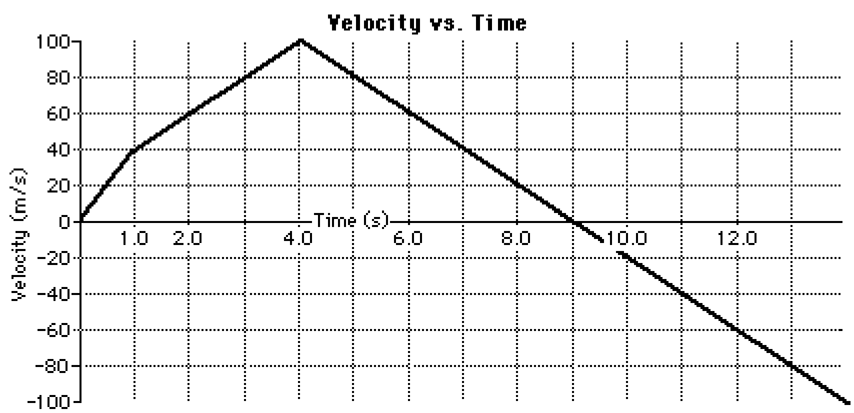


Figure 33

2.9 Relating the Shape to the Motion

As discussed earlier, the shape of a velocity vs. time graph reveals pertinent information about an object's acceleration. The shape of the line on the graph (horizontal, sloped, steeply sloped, mildly sloped, etc.) is descriptive of the object's motion. This principle can be extended to any motion conceivable. In this part of the lesson, we will examine how the principle applies to a variety of types of motion. In each diagram below (Fig. 34a,b,c), a short verbal description of a motion is given (e.g., "constant, rightward velocity") and an accompanying *ticker tape* diagram is shown. Finally, the corresponding velocity-time graph is sketched and an explanation is given.

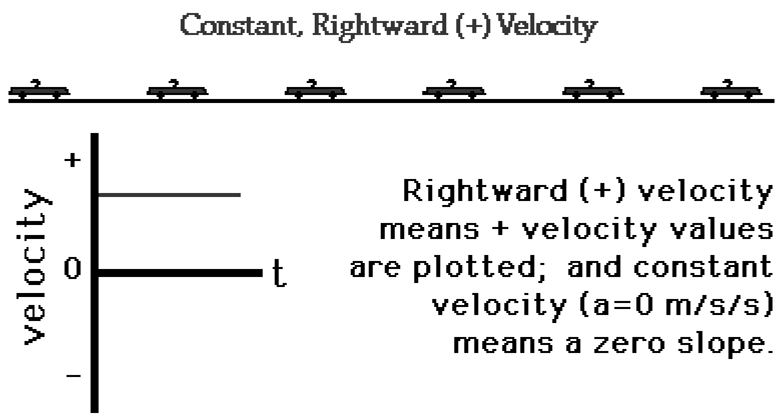


Figure 34a

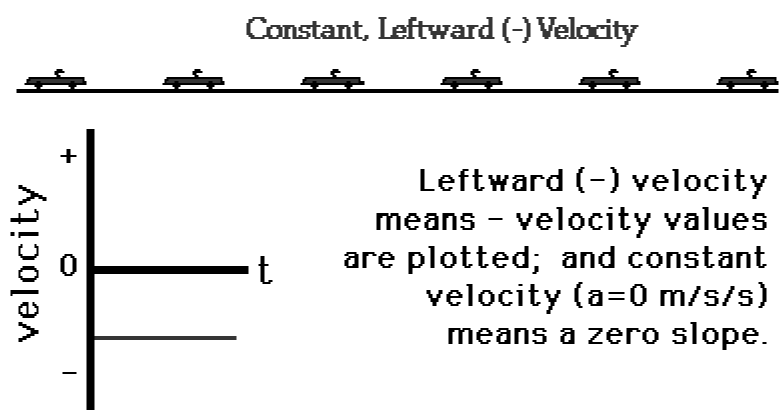


Figure 34b

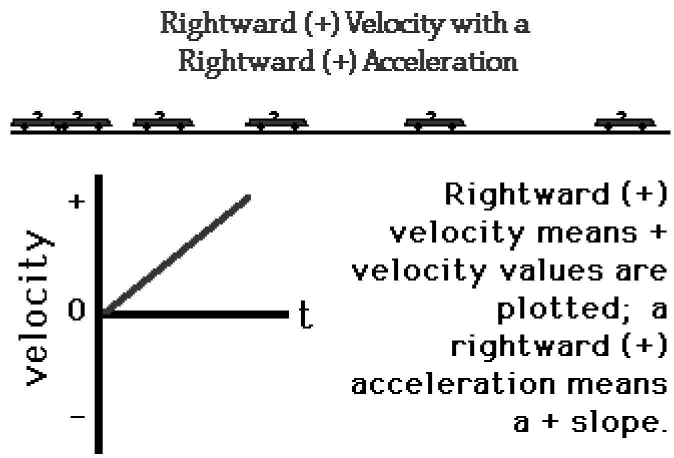


Figure 34c

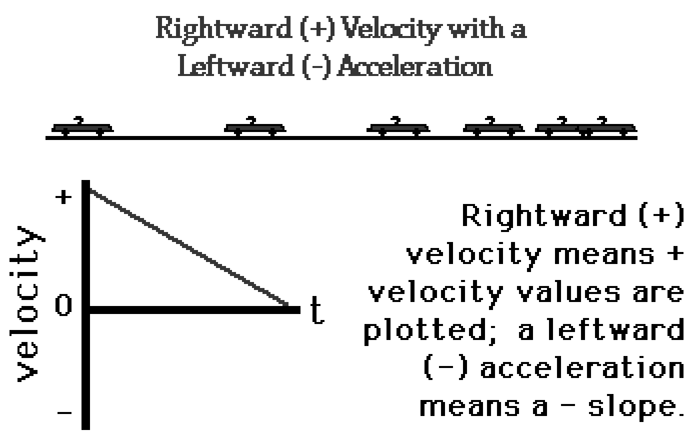


Figure 35a

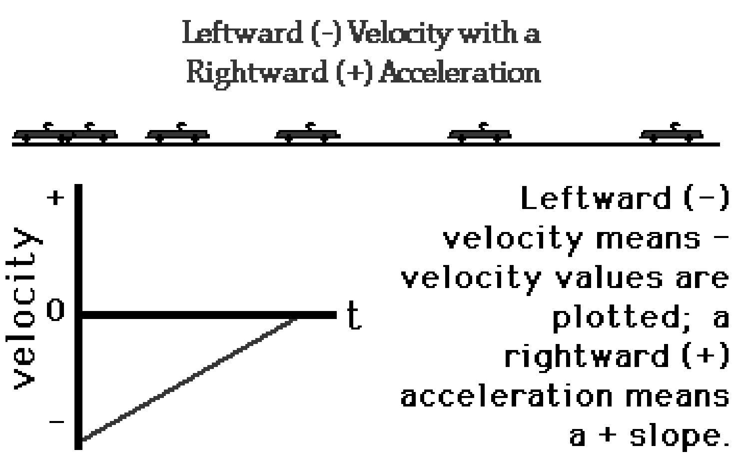


Figure 35b

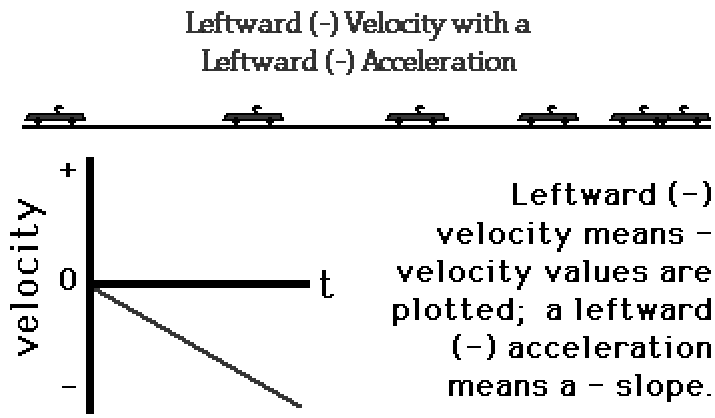


Figure 35c

EXERCISE 10

Describe the motion depicted by the following velocity-time graphs Fig 10a,b,c. In your descriptions, make reference to the direction of motion (+ or - direction), the velocity and acceleration and any changes in speed (speeding up or slowing down) during the various time intervals (e.g., intervals A, B, and C).

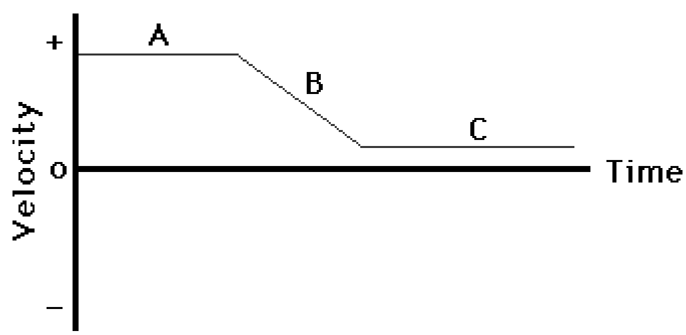


Figure 36a

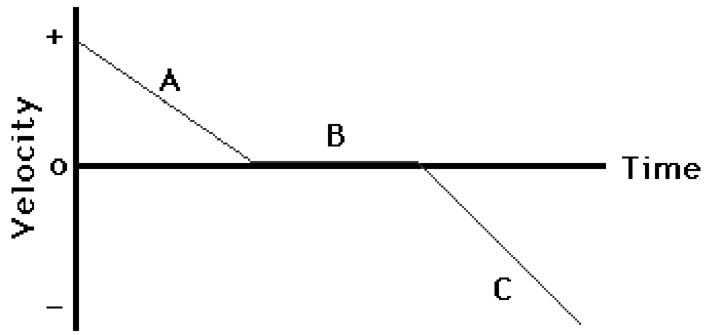


Figure 36b

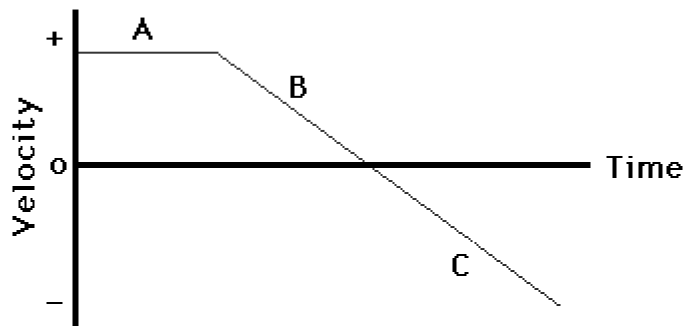


Figure 36c

UNIT 3
MOMENTUM AND IMPULSE

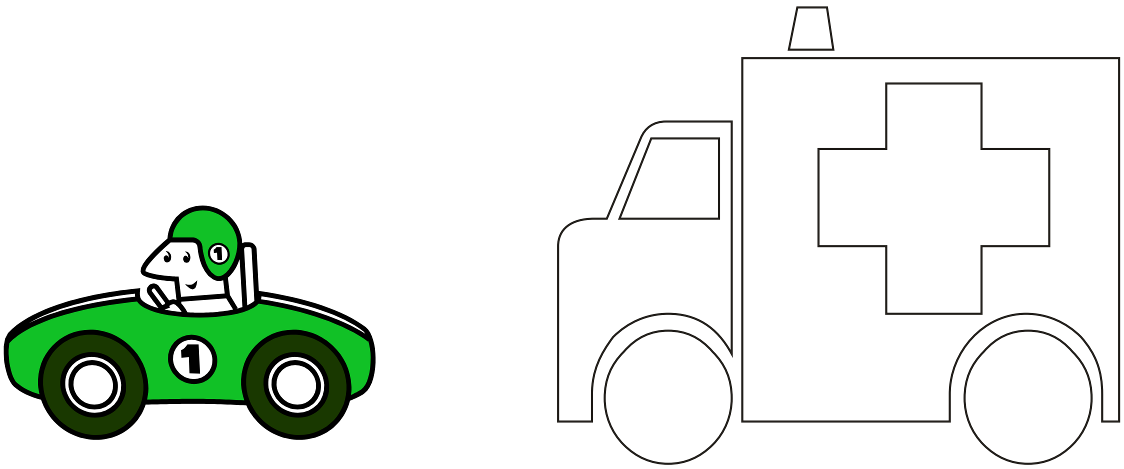


Fig. 38

3.1 MOMENTUM

Look at the given pictures. If both the car and the truck have same speed, which one can be stopped first? Of course all you say, it is hard to stop truck relative to car. Well, what is the reason making car stop easier? They have same speed but different masses. Can mass effect the stopping time or distance? The answer is again YES! It is hard to stop heavier objects. What we are talking about so far is **momentum**.

Momentum is a physical concept that is affecting or related to “moving body”. In other words for talking about momentum we must have moving object, it must have both mass and velocity. Let me formulize what we said;

Momentum=Mass X Velocity

We show momentum in physics with “p”, mass with “m” and velocity with “v”.

Then equation becomes;

p=m.v

Since velocity is a vector quantity and multiplied with mass (scalar quantity) momentum becomes also vector quantity. It has both magnitude and direction. Direction of momentum is the same as velocity. From the definition and given equation we can change momentum by changing its mass or changing its velocity.

Unit of the momentum is kg m/s as you can guess from the equation.

Example: Calculate the momentum of the give objects.

- A basketballball having 2kg mass and 6m/s velocity moves to the east
- A car having 15m/s velocity and 1500kg mass moves to the north
- A child having mass 25kg and velocity 2m/s moves to the west

a. Momentum of basketball;

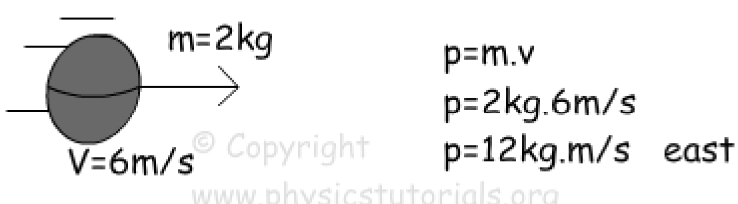


Figure 39

b. Momentum of car**;**

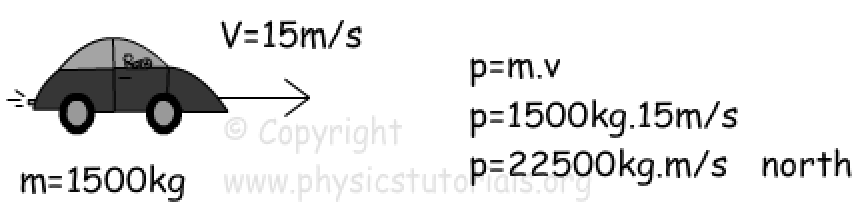


Figure 40

c. Momentum of boy;

Figure 41

Momentum can be defined as "mass in motion." All objects have mass; so if an object is moving, then it has momentum - it has its mass in motion.

The amount of momentum that an object has is dependent upon two variables: how much mass of the body is moving and how fast the body is moving.

Therefore Momentum depends upon the variables mass and velocity.

In terms of an equation, the momentum of an object is equal to the mass of the object multiplied by the velocity of the object.

Momentum = mass • velocity

In physics, the symbol for the quantity momentum is the lower case "p". Thus, the above equation can be rewritten as

$$p = m \cdot v$$

Where **m** is the mass and **v** is the velocity. The equation shows that momentum is directly proportional to an object's mass and directly proportional to the object's velocity.

The units for momentum would be mass unit multiplied by velocity unit. The standard metric unit of momentum is the kg•m/s.

Momentum is a **vector quantity** that is fully described by both magnitude and direction. To fully describe the momentum of a 5-kg bowling ball moving westward at 2 m/s, you must include information about both the magnitude and the direction of the bowling ball. It is not enough to say that the ball has 10 kg•m/s of momentum; the momentum of the ball is not fully described until information about its direction is given. The direction of the momentum vector is the same as the direction of the velocity of the ball. In a previous unit, it was said that the direction of the velocity is the same as the direction that an object is moving. If the bowling ball is moving westward, then its momentum can be fully described by saying that it is 10 kg•m/s, westward.

From the definition of momentum, it becomes clear that an object has a large momentum if either its mass or its velocity is large. Both variables are of equal importance in determining the momentum of an object. Consider a Truck and a motor cyclist moving down the street at the same speed. The considerably greater mass of the Truck gives it a considerably greater momentum. Yet if the Truck were at rest, then the momentum of the least massive Cyclist would be the greatest. The momentum of any object that is at rest is 0. Objects at rest do not have momentum - they do not have any "mass in motion." Both variables - mass and velocity - are important in comparing the momentum of two objects.

The momentum equation can help us to think about how a change in one of the two variables might affect the momentum of an object. Consider a 0.5-kg physics cart loaded with one 0.5-kg brick and moving with a speed of 2.0 m/s. The total mass of *loaded* cart is 1.0 kg and its momentum is 2.0 kg•m/s. If the cart was instead loaded with three 0.5-kg bricks, then the total mass of the *loaded* cart would be 2.0 kg and its momentum would be 4.0 kg•m/s. A doubling of the mass results in a doubling of the momentum.

EXERCISE 12

Express your understanding of the concept and mathematics of momentum by carrying out the following activities.

1. Determine the momentum of a

a. 60-kg halfback Lorry moving eastward at 9 m/s.

b. 1000-kg car moving northward at 20 m/s.

2. A car possesses 20 000 units of momentum. What would be the car's new momentum if its

Velocity was doubled.

.

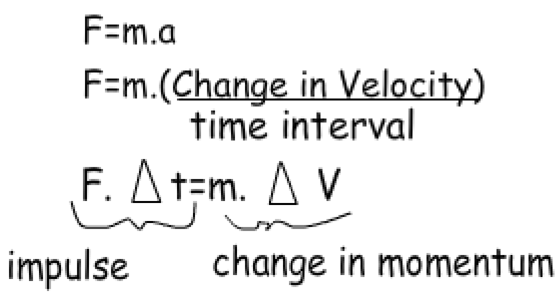
c. its mass was doubled (by adding more passengers and a greater load)

3.2 IMPULSE

If velocity changes then acceleration occurs. We are also aware that force causes acceleration, in other words change in the velocity is the result of applied net force. Change in the velocity is proportional to the applied net force. If it is big then change is also big. Another important thing is the time of applied force. How long does it act on an object? It is linearly proportional to the change in velocity. If you apply a force on an object 1 s then you see small change in the momentum. However, if you apply force on an object long period of time then you see the amount of change in momentum is bigger than the first situation. In summary, **impulse** is the multiplication of applied force and time interval it applied. Impulse is also a vector quantity having both magnitude and direction. It has the same direction with applied net force.

Impulse=Force .Time Interval

Impulse and momentum are directly related to each other. Let's find this relation now.



As you can see, we found that impulse is equal to the change in momentum. In examples we will benefit from this equation.

Impulse=Change in Momentum

Example: If the time of force application is 5s find the impulse of the box given below.

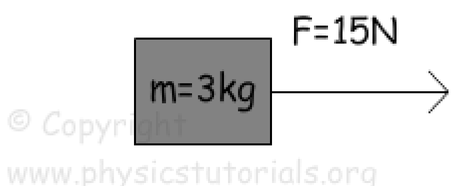


Figure 42

Impulse=Force Time Interval

Impulse=15N.5s

Impulse=75N.s

Example: Find applied force which makes 10m/s change in the velocity of the box in 5s if the mass of the box is 4kg.

Impulse=Change in momentum

F.t=p2-p1

F.t=m. (V2-V1)

F.t=4kg.10m/s=40kg.m/s Impulse of the box is 40kgm/s

F=40kg.m/s/5s=8N Applied force

In a collision, an object experiences a force for a specific amount of time that results in a change in momentum. The result of the force acting for the given amount of time is that the object's mass either speeds up or slows down (or changes direction). The impulse experienced by the object equals the change in momentum of the object. In equation form, $F \bullet t = m \bullet \Delta v$.

EXERCISE 13

Use the impulse-momentum change principle to fill in the blanks in the following rows in Table 9. As you do, keep these three major truths in mind:

- The impulse experienced by an object is the force time.
- The momentum change of an object is the mass velocity change.
- The impulse equals the momentum change.

Table 9

	Force (N)	Time (s)	Impulse **(N*s)**	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
1.		0.010			10	-4
2.		0.100	-40		10	
3.		0.010		-200	50	
4.	-20 000			-200		-8
5.	-200	1.0			50	

There are a few observations that can be made in the above table that relate to the computational nature of the impulse-momentum change theorem.

First, observe that the answers in the table above reveal that the third and fourth columns are always equal; that is, the impulse is always equal to the momentum change.

Observe also that if any two of the first three columns are known, then the remaining column can be computed. This is true because the impulse=force • time. Knowing two of these three quantities allows us to compute the third quantity.

And finally, observe that knowing any two of the last three columns allows us to compute the remaining column. This is true since momentum change = mass • velocity change.

There are also a few observations that can be made that relate to the qualitative nature of the impulse-momentum theorem.

An examination of rows 1 and 2 show that force and time are inversely proportional; for the same mass and velocity change, a tenfold increase in the time of impact corresponds to a tenfold decrease in the force of impact.

An examination of rows 1 and 3 show that mass and force are directly proportional; for the same time and velocity change, a fivefold increase in the mass corresponds to a fivefold increase in the force required to stop that mass.

Finally, an examination of rows 3 and 4 illustrate that mass and velocity change are inversely proportional; for the same force and time, a twofold decrease in the mass corresponds to a twofold increase in the velocity change.

EXERCISE 14

Express your understanding of the impulse-momentum change theorem by answering the following questions..

1. A 0.50-kg cart (#1) is pulled with a 1.0-N force for 1 second; another 0.50 kg cart (#2) is pulled with a 2.0 N-force for 0.50 seconds. Which cart (#1 or #2) has the greatest acceleration? Explain.

Which cart (#1 or #2) has the greatest impulse? Explain.

Which cart (#1 or #2) has the greatest change in momentum? Explain.

3. If a 5-kg object experiences a 10-N force for duration of 0.10-second, then what is the momentum change of the object?

UNIT 4

POTENTIAL ENERGY

4.1 POTENTIAL ENERGY

Objects have energy because of their positions relative to other objects. We call this energy as **potential energy**. For example, apples on the tree, or compressed spring or a stone thrown from any height with respect to ground are examples of potential energy. In all these examples there is a potential to do work. If we release the spring it does work or if we drop the apples they do work. To move the objects or elevate them with respect to the ground we do work. The energy of the objects due to their positions with respect to the ground is called **gravitational potential** energy.

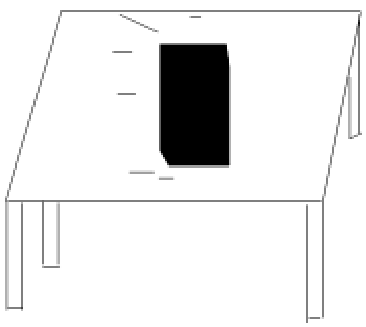


Figure 43a,b

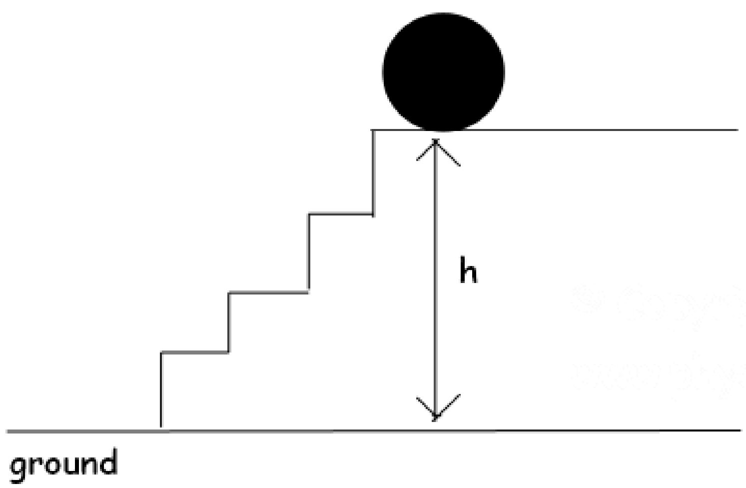


Figure 44

The pictures given above are the examples of gravitational potential energy. They both have a height from the ground and because of their positions they have energy or potential to do work. Look at the given examples below. They are a little bit different that of given above.

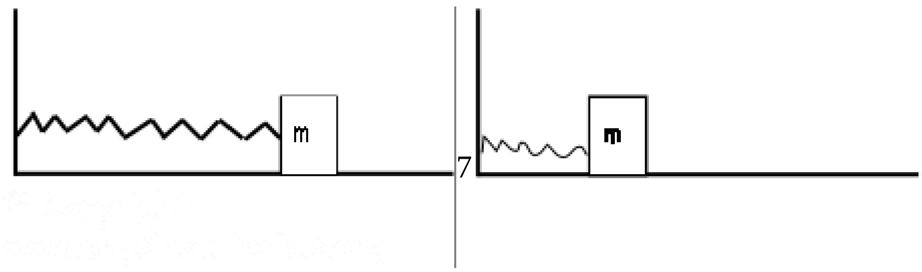


Fig.45

In the first picture, system including a spring and a box is at rest. However, in second picture the box compresses the spring and loads it with potential energy. If we release the box spring does work and pushes the box back. These two examples of gravitational and spring potential energy are calculated differently. Let me begin with the calculation of **gravitational potential energy**. We will look at which factors effects the magnitude of potential energy or which does not effect. Work done against to the earth to elevate the objects is multiplication of its **weight** and distance which is **height**. Thus, as we said before energy is the potential of doing work.

Then, gravitational potential energy becomes;

PE=mg.h

Now, look at the given picture and try to calculate the potential energies of the given ball in three situations.

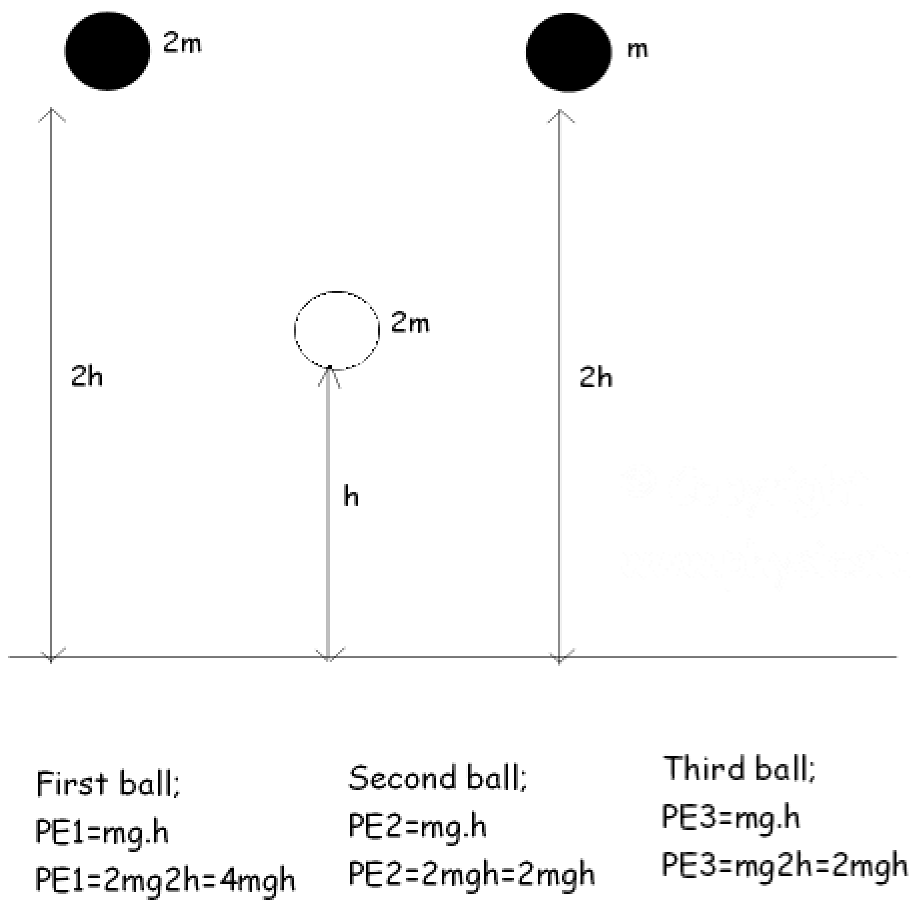


Figure 46

We see that gravitational potential energy depends on the weight and height of the object. Now let’s solve some more examples related to this topic before passing to the kinetic energy.

Example: In the pictures given below, if the potential energy of the ball in the first picture is P find the potential energy of the ball in second situation in terms of P.

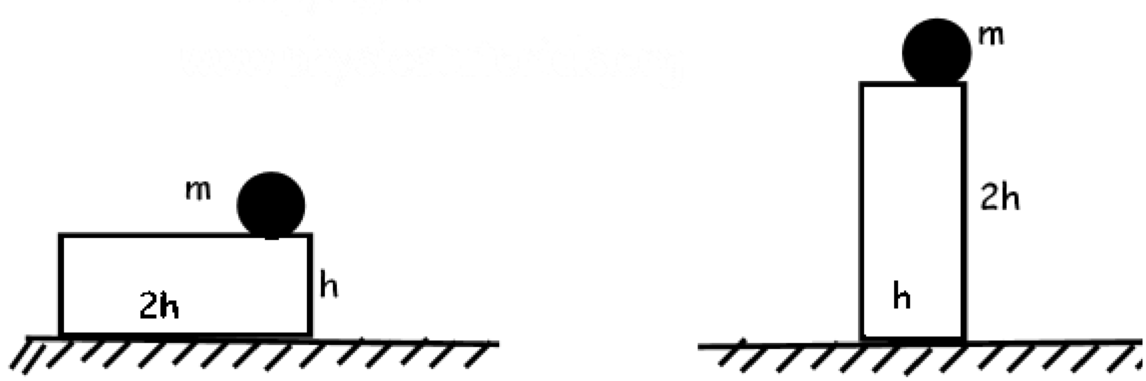


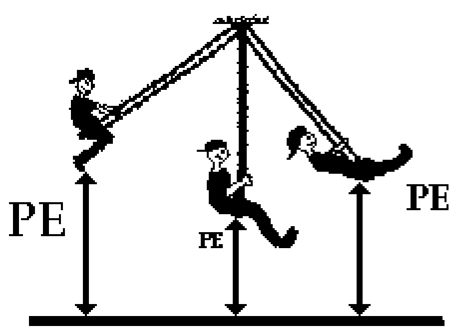
Figure 47

Situation 1 : **P=m.g.h=mgh**

Situation 2: **P'=m.g.2h=2mgh=2P**

An object can store energy as the result of its position. For example, the heavy ball of a demolition machine is storing energy when it is held at an elevated position. This stored energy of position is referred to as potential energy. Similarly, a drawn bow is able to store energy as the result of its position. When assuming its *usual position* (i.e., when not drawn), there is no energy stored in the bow. Yet when its position is altered from its usual equilibrium position, the bow is able to store energy by virtue of its position. This stored energy of position is referred to as potential energy while energy stored elastic stretch is elastic potential energy.

4.2 Gravitational Potential Energy



. Gravitational potential energy is the energy stored in an object as the result of its vertical position or height. The energy is stored as the result of the gravitational attraction of the Earth for the object.

The gravitational potential energy of the massive ball of a demolition machine is dependent on two variables - the mass of the ball and the height to which it is raised.

Fig.48

There is a direct relation between gravitational potential energy and the mass of an object. More massive objects have greater gravitational potential energy. There is also a direct relation between gravitational potential energy and the height of an object. The higher an object is elevated, the greater the gravitational potential energy. These relationships are expressed by the following equation:

$$\mathbf{P.E._{grav} = mass \bullet g \bullet height}$$

$$\mathbf{P.E_{grav} = m *\bullet g \bullet h}$$

In the above equation, **m** represents the mass of the object, **h** represents the height of the object and **g** represents the gravitational field strength (9.8 N/kg on Earth) - sometimes referred to as the acceleration of gravity.

To determine the gravitational potential energy of an object, a *zero height position* must first be arbitrarily assigned. Typically, the ground is considered to be a position of zero height. But this is merely an arbitrarily assigned position that most people agree upon.

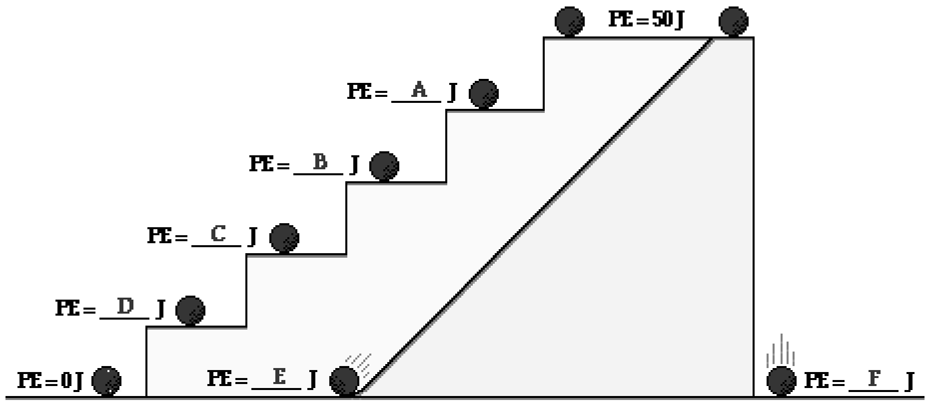


Figure 49

4.3 Elastic Potential Energy

The second form of potential energy that we will discuss is elastic potential energy. **Elastic potential energy** is the energy stored in elastic materials as the result of their stretching or compressing. Elastic potential energy can be stored in rubber bands, bungee chords, trampolines, springs, an arrow drawn into a bow, etc. The amount of elastic potential energy stored in such a device is related to the amount of stretch of the device - the more stretch, the more stored energy.

Springs are a special instance of a device that can store elastic potential energy due to either compression or stretching. A force is required to compress a spring; the more compression there is, the more force that is required to compress it further. For certain springs, the amount of force is directly proportional to the amount of stretch or compression (x); the constant of proportionality is known as the spring constant (k).

$$F_{spring} = k * x$$

Such springs are said to follow Hooke's Law. If a spring is not stretched or compressed, then there is no elastic potential energy stored in it. The spring is said to be at its *equilibrium position*. The equilibrium position is the position that the spring naturally assumes when there is no force applied to it. In terms of potential energy, the equilibrium position could be called the zero-potential energy position. There is a special equation for springs that relates the amount of elastic potential energy to the amount of stretch (or compression) and the spring constant. The equation is

$$PE_{spring} = \frac{1}{2} * k * x^2$$

where k= spring constant
x= amount of compression
(relative to equilibrium pos'n)

In summary, potential energy is the energy that is stored in an object due to its position relative to some zero position.

An object possesses gravitational potential energy if it is positioned at a height above (or below) the zero height.

An object possesses elastic potential energy if it is at a position on an elastic medium other than the equilibrium position

EXERCISE 15

1. A cart is loaded with a brick and pulled at constant speed along an inclined plane to the height of a seat-top. If the mass of the loaded cart is 3.0 kg and the height of the seat top is 0.45 meters, then what is the potential energy of the loaded cart at the height of the seat-top?

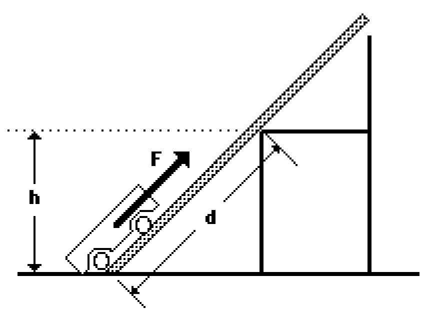


Fig. 50

UNIT 5

PROJECTILE

5.1 Definition of Projectile

A projectile is an object upon which the only force acting is gravity.

There are a variety of examples of projectiles. An object dropped from rest is a projectile (provided that the influence of air resistance is negligible). An object that is thrown vertically upward is also a projectile (provided that the influence of air resistance is negligible). And an object which is thrown upward at an angle to the horizontal is also a projectile (provided that the influence of air resistance is negligible).

A projectile is any object that once *projected* or dropped continues in motion by its own inertia and is influenced only by the downward force of gravity.

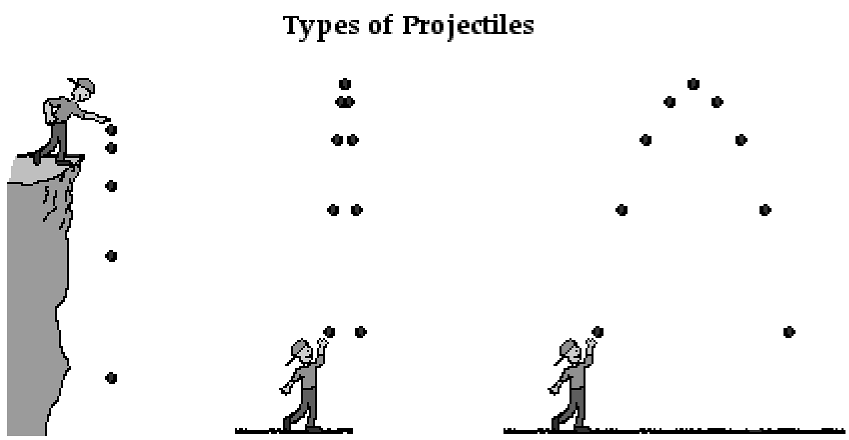


Figure 51

By definition, a projectile has a single force that acts upon it - the force of gravity. If there were any other force acting upon an object, then that object would not be a projectile. Thus, the free-body diagram of a projectile would show a single force acting downwards and labeled force of gravity (or simply F_{grav}). Regardless of whether a projectile is moving downwards, upwards, upwards and rightwards, or downwards and leftwards, the free-body diagram of the projectile is still as shown in Fig. K . By definition, a projectile is any object upon which the only force is gravity.

Fig. 52

5.2 Projectile Motion and Inertia

Consider a cannonball shot horizontally from a very high cliff at a high speed.Fig.53 And suppose for a moment that the *gravity switch* could be *turned off* such that the cannonball would travel in the absence of gravity? What would the motion of such a cannonball be like? How could its motion be described? According to Newton's first law of motion, such a cannonball would continue in motion in a straight line at constant speed. If not acted upon by an unbalanced force, "an object in motion will ...". This is Newton's law of inertia.

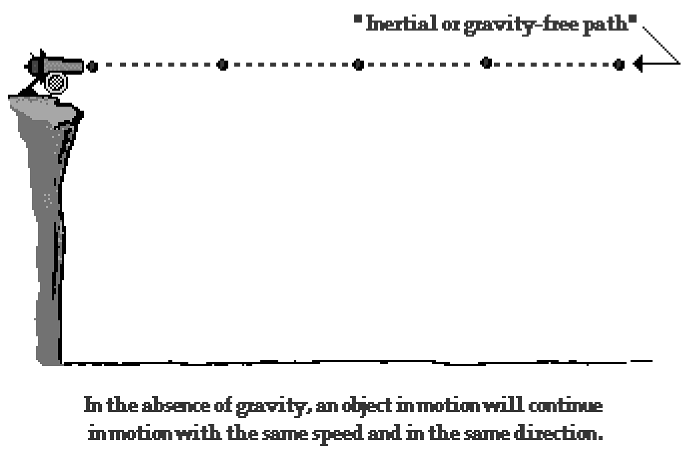


Figure 53

Now suppose that the *gravity switch* is turned on and that the cannonball is projected horizontally from the top of the same cliff. What effect will gravity have upon the motion of the cannonball? Will gravity affect the cannonball's horizontal motion? Will the cannonball travel a greater (or shorter) horizontal distance due to the influence of gravity? The answer to these questions is "No!" Gravity will act downwards upon the cannonball to affect its vertical motion. Gravity causes a vertical acceleration. The ball will drop vertically below its otherwise straight-line, inertial path. Gravity is the downward force upon a projectile that influences its vertical motion and causes the parabolic trajectory that is characteristic of projectiles.

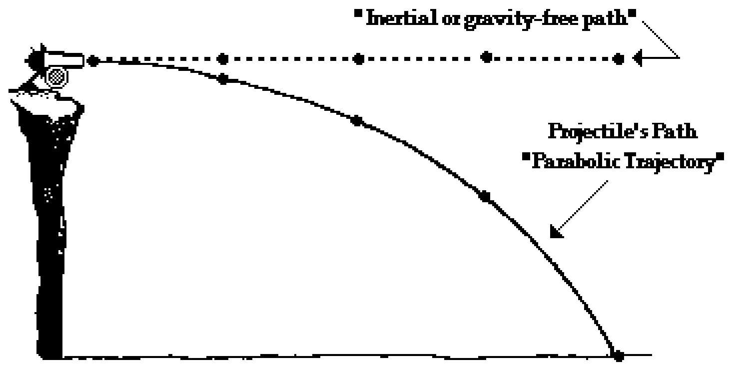


Figure 54

A projectile is an object upon which the only force is gravity. Gravity acts to influence the vertical motion of the projectile, thus causing a vertical acceleration. The horizontal motion of the projectile is the result of the tendency of any object in motion to remain in motion at constant velocity. Due to the absence of horizontal forces, a projectile remains in motion with a constant horizontal velocity. Horizontal forces are not required to keep a projectile moving horizontally. The only force acting upon a projectile is gravity!

5.3 Horizontally Launched Projectile Problems

There are two basic types of projectile problems that we will discuss in this course. While the general principles are the same for each type of problem, the approach will vary due to the fact the problems differ in terms of their initial conditions. The two types of problems are:

Problem Type 1:

A projectile is launched with an initial horizontal velocity from an elevated position and follows a parabolic path to the ground. Predictable unknowns include the initial speed of the projectile, the initial height of the projectile, the time of flight, and the horizontal distance of the projectile.

Examples of this type of problem are

a. A pool ball leaves a 0.60-meter high table with an initial horizontal velocity of 2.4 m/s. Predict the time required for the pool ball to fall to the ground and the horizontal distance between the table's edge and the ball's landing location.
b. A soccer ball is kicked horizontally off a 22.0-meter high hill and lands a distance of 35.0 meters from the edge of the hill. Determine the initial horizontal velocity of the soccer ball.

Problem Type 2:

A projectile is launched at an angle to the horizontal and rises upwards to a peak while moving horizontally. Upon reaching the peak, the projectile falls with a motion that is symmetrical to its path upwards to the peak. Predictable unknowns include the time of flight, the horizontal range, and the height of the projectile when it is at its peak.

Examples of this type of problem are

a. A football is kicked with an initial velocity of 25 m/s at an angle of 45-degrees with the horizontal. Determine the time of flight, the horizontal distance, and the peak height of the football.

b. A long jumper leaves the ground with an initial velocity of 12 m/s at an angle of 28-degrees above the horizontal. Determine the time of flight, the horizontal distance, and the peak height of the long-jumper.

Three common kinematics equations that will be used for both type of problems include the following:

$$\mathbf{S = ut + \tfrac{1}{2}at2}$$

$$\mathbf{V = u + at}$$

$$\mathbf{V2 = u2 + 2as}$$

S = Distance, U = initial velocity, V = final velocity, a = acceleration, t = time

The above equations work well for motion in one-dimension, but a projectile is usually moving in two dimensions - both horizontally and vertically. Since these two components of motion are independent of each other, two distinctly separate sets of equations are needed, one for the projectile's horizontal motion and one for its vertical motion. Thus, the three equations above are transformed into two sets of three equations for the horizontal and the vertical components of motion,

5.4 Solving Projectile Problems

To illustrate the usefulness of the above equations in making predictions about the motion of a projectile, consider the solution to the following problem.

Example
A pool ball leaves a 0.60-meter high table with an initial horizontal velocity of 2.4 m/s. Predict the time required for the pool ball to fall to the ground and the horizontal distance between the table's edge and the ball's landing location.

The solution of this problem begins by equating the known or given values with the symbols of the kinematic equations - x, y, v_{ix}, v_{iy}, a_x, a_y, and t. Because horizontal and vertical information is used separately, it is a wise idea to organized the given information in two columns - one column for horizontal information and one column for vertical information. In this case, the following information is either given or implied in the problem statement:

Horizontal Information	Vertical Information
x =??? $\mathbf{v_{ix}}$ = 2.4 m/s $\mathbf{a_x}$ = 0 m/s/s	y = -0.60 m v_{iy} = 0 m/s a_y = -9.8 m/s/s

As indicated in the table, the unknown quantity is the horizontal displacement (and the time of flight) of the pool ball.

An organised listing of known quantities (as in the table above) provides cues for the selection of the strategy. For example, the table above reveals that there are three quantities known about the vertical motion of the pool ball.

Since each equation has four variables in it, knowledge of three of the variables allows one to calculate a fourth variable. Thus, it would be reasonable that a vertical equation is used with the vertical values to determine time and then the horizontal equations be used to determine the horizontal displacement (x). The first vertical equation ($y = v_{iy} \cdot t + 0.5 \cdot a_y \cdot t^2$) will allow for the determination of the time. Once the appropriate equation has been selected, the physics problem becomes transformed into an algebra problem. By substitution of known values, the equation takes the form of

$$-0.60 \text{ m} = (0 \text{ m/s}) \cdot t + 0.5 \cdot (-9.8 \text{ m/s/s}) \cdot t^2$$

Since the first term on the right side of the equation reduces to 0, the equation can be simplified to

$$-0.60 \text{ m} = (-4.9 \text{ m/s/s}) \cdot t^2$$

If both sides of the equation are divided by -5.0 m/s/s, the equation becomes

$$0.122\ s^2 = t^2$$

By taking the square root of both sides of the equation, the time of flight can then be determined**.**

$$t = 0.350\ s\ (\text{rounded from } 0.3499\ s)$$

Once the time has been determined, a horizontal equation can be used to determine the horizontal displacement of the pool ball. Recall from the given information, v_{ix} = 2.4 m/s and a_x = 0 m/s/s. The first horizontal equation ($x = v_{ix} \bullet t + 0.5 \bullet a_x \bullet t^2$) can then be used to solve for "x." With the equation selected, the physics problem once more becomes transformed into an algebra problem. By substitution of known values, the equation takes the form of

$$x = (\mathbf{2.4\ m/s}) \bullet (0.3499\ s) + 0.5 \bullet (0\ m/s/s) \bullet (0.3499\ s)^2$$

Since the second term on the right side of the equation reduces to 0, the equation can then be simplified to

$$x = (\mathbf{2.4\ m/s}) \bullet (0.3499\ s)$$

Thus,

$$x = 0.84\ m\ (\text{rounded from } 0.8398\ m)$$

The answer to the stated problem is that the pool ball is in the air for 0.35 seconds and lands a horizontal distance of 0.84 m from the edge of the pool table.

The following procedure summarizes the above problem-solving approach.

1. Carefully read the problem and list known and unknown information in terms of the symbols of the kinematic equations. For convenience sake, make a table with horizontal information on one side and vertical information on the other side.
2. Identify the unknown quantity that the problem requests you to solve for.
3. Select either a horizontal or vertical equation to solve for the time of flight of the projectile.
4. With the time determined, use one of the other equations to solve for the unknown. (Usually, if a horizontal equation is used to solve for time, then a vertical equation can be used to solve for the final unknown quantity.)

Exercise 16

A soccer ball is kicked horizontally off a 22.0-meter high hill and lands a distance of 35.0 meters from the edge of the hill. Determine the initial horizontal velocity of the soccer ball.

UNIT 6

VECTORS

6.1 Vectors and Direction

A vector quantity is a quantity that is fully described by both magnitude and direction. On the other hand, a scalar quantity is a quantity that is fully described by its magnitude.

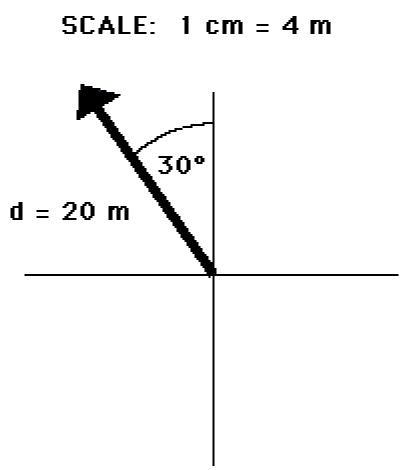


Figure 55

The emphasis of this unit is to understand some fundamentals about vectors and to apply the fundamentals in order to understand motion and forces that occur in two dimensions. Fig.55

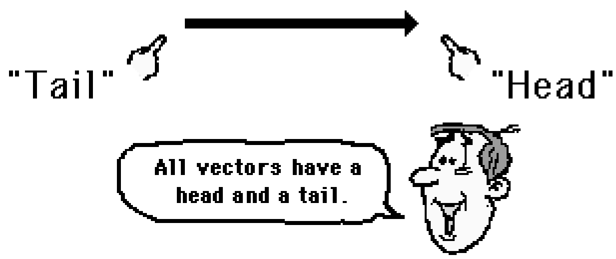
Examples of vector quantities that have been discussed include displacement, velocity, acceleration, and force. Each of these quantities is unique in that a full description of the quantity demands that both a magnitude and a direction are listed.

For example, suppose your teacher tells you "A bag of gold is located outside the classroom. To find it, displace yourself 20 meters." This statement may provide yourself enough information to pique your interest; yet, there is not enough information included in the statement to find the bag of gold. The displacement required to find the bag of gold has not been fully described. On the other hand, suppose your teacher tells you "A bag of gold is located outside the classroom. To find it, displace yourself from the center of the classroom door 20 meters in a direction 30 degrees to the west of north." This statement now provides a complete description of the displacement vector - it lists both magnitude (20 meters) and direction (30 degrees to the west of north) relative to a reference or starting position (the center of the classroom door).

Vector quantities are not fully described unless both magnitude and direction are listed.

Vector quantities are often represented by scaled vector diagrams. Vector diagrams show a vector by use of an arrow drawn to scale in a specific direction. Vector diagrams were introduced and used in earlier units to depict the forces acting upon an object. Such diagrams are commonly called as free-body diagrams. An example of a scaled vector diagram is shown in the diagram at the right. The vector diagram depicts a displacement vector. Observe that there are several characteristics of this diagram that make it an appropriately drawn vector diagram.

- a scale is clearly listed
- a vector arrow (with arrowhead) is drawn in a specified direction. The vector arrow has a *head* and a *tail*.
- the magnitude and direction of the vector is clearly labeled. In this case, the diagram shows the magnitude is 20 m and the direction is (30 degrees West of North).



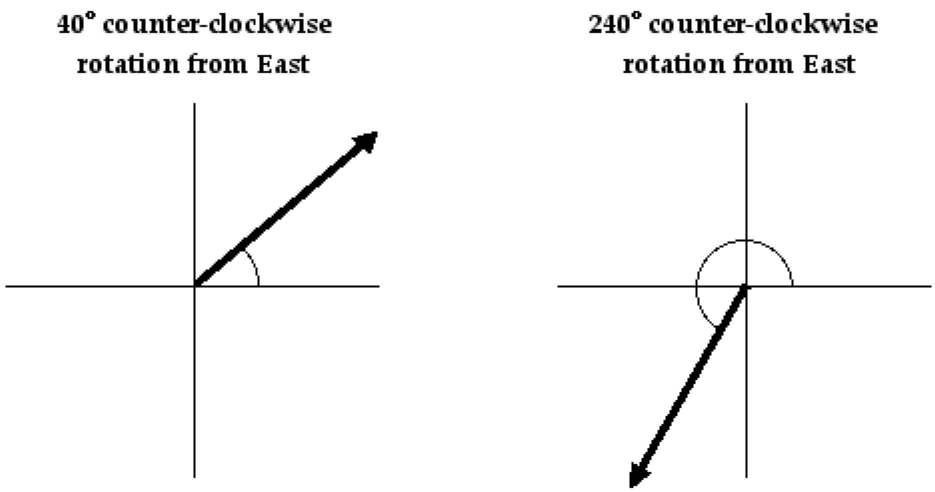
Format for Describing Directions of Vectors

Vectors can be directed due East, due West, due South, and due North. But some vectors are directed *northeast* (at a 45 degree angle); and some vectors are even directed *northeast*, yet more north than east. There are a variety of conventions for describing the direction of any vector. The two conventions that are used are described below:

1. The direction of a vector is often expressed as an angle of rotation of the vector about its "tail" from east, west, north, or south. For example, a vector can be said to have a direction of 40 degrees North of West (meaning a vector pointing West has been rotated 40 degrees towards the northerly direction) of 65 degrees East of South (meaning a vector pointing South has been rotated 65 degrees towards the easterly direction).
2. The direction of a vector is often expressed as an anticlockwise angle of rotation of the vector about its "tail" from due East. Using this convention, a vector with a direction of 30 degrees is a vector that has been rotated 30 degrees in an anticlockwise direction relative to due east. A vector with a direction of 160 degrees is a vector that has been rotated 160 degrees in a counterclockwise direction relative to due east. A vector with a direction of 270 degrees is a vector that has been rotated 270 degrees in a counterclockwise direction relative to due

east. This is one of the most common conventions for the direction of a vector and will be utilized throughout this unit.

Two illustrations of the second convention (discussed above) for identifying the direction of a vector are shown below.



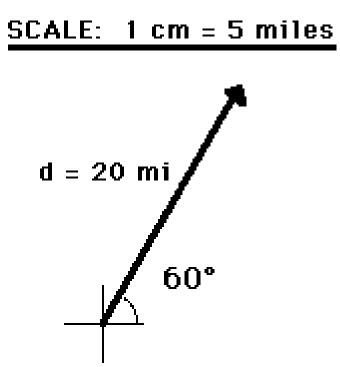
Observe in the first example that the vector is said to have a direction of 40 degrees. You can think of this direction as follows: suppose a vector pointing East had its tail pinned down and then the vector was rotated an angle of 40 degrees in the counterclockwise direction.

Observe in the second example that the vector is said to have a direction of 240 degrees. This means that the tail of the vector was pinned down and the vector was rotated an angle of 240 degrees in the counterclockwise direction beginning from due east. A rotation of 240 degrees is equivalent to rotating the vector through two quadrants (180 degrees) and then an additional 60 degrees *into the* third quadrant.

6.2 Representing the Magnitude of a Vector

The magnitude of a vector in a scaled vector diagram is represented by the length of the arrow. The arrow is drawn a precise length in accordance with a chosen scale. For example, the diagram Fig F shows a vector with a magnitude of 20 miles. Since the scale used for constructing the diagram is <u>1 cm = 5 miles</u>, the vector arrow is drawn with a length of 4 cm. That is, 4 cm x (5 miles/1 cm) = 20 miles

Fig. 56



Using the same scale (1 cm = 5 miles), a displacement vector that is 15 miles will be represented by a vector arrow that is 3 cm in length. Similarly, a 25-mile displacement vector is represented by a 5-cm long vector arrow. And finally, an 18-mile displacement vector is represented by a 3.6-cm long arrow. See the examples shown below.

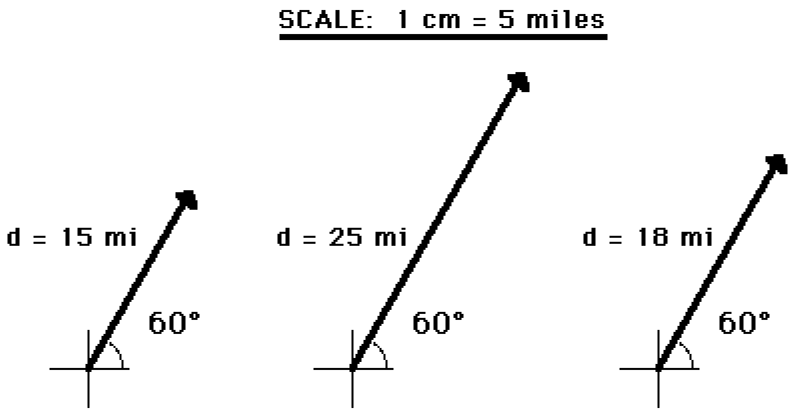


Figure 57

In conclusion, vectors can be represented by use of a scaled vector diagram.

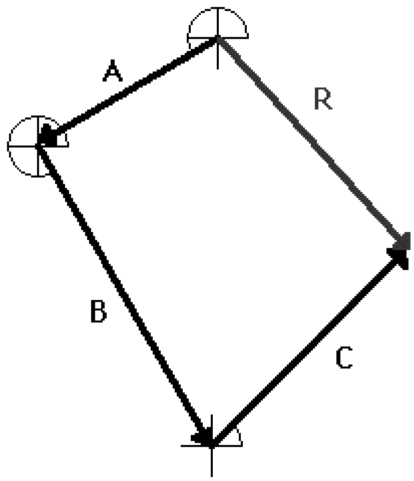
On such a diagram, a vector arrow is drawn to represent the vector. The arrow has an obvious tail and arrowhead.

The magnitude of a vector is represented by the length of the arrow. A scale is indicated (such as, 1 cm = 5 miles) and the arrow is drawn the proper length according to the chosen scale. The arrow points in the precise direction.

Directions are described by the use of some convention. The most common convention is that the direction of a vector is the counterclockwise angle of rotation which that vector makes with respect to due East.

6.3 Resultants

The **resultant** is the vector sum of two or more vectors. It is *the result* of adding two or more vectors together. If displacement vectors A, B, and C are added together, the result will be vector R. As shown in the diagram, vector R can be determined by the use of an accurately drawn, scaled, vector addition diagram.



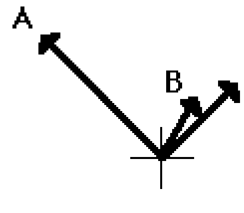


Figure 58 Figure 59

To say that vector R is the *resultant displacement* of displacement vectors A, B, and C is to say that a person who walked with displacements A, then B, and then C would be displaced by the same amount as a person who walked with displacement R. Displacement vector R gives the same *result* as displacement vectors A + B + C. That is why it can be said that

$$A + B + C = R$$

The above discussion pertains to the result of adding displacement vectors. When displacement vectors are added, the result is a *resultant displacement*. But any two vectors can be added as long as they are the same vector quantity. If two or more velocity vectors are added, then the result is a *resultant velocity*. If two or more force vectors are added, then the result is a *resultant force*. If two or more momentum vectors are added, then the result is ...

In all such cases, the resultant vector (whether a displacement vector, force vector, velocity vector, etc.) is the result of adding the individual vectors. It is the same thing as adding A + B + C + ... "To do A + B + C is the same as to do R." As an example, consider a football player who gets hit simultaneously by three players on the opposing team (players A, B, and C). The football player experiences three different applied forces. Each applied force contributes to a total or resulting force. If the three forces are added together using methods of vector addition , then the resultant vector R can be determined. In this case, to experience the three forces A, B and C is the same as experiencing force R. To be hit by players A, B, and C would result in the same force as being hit by one player applying force R. "To do A + B + C is the same as to do R." Vector R is the same result as vectors A + B + C!!

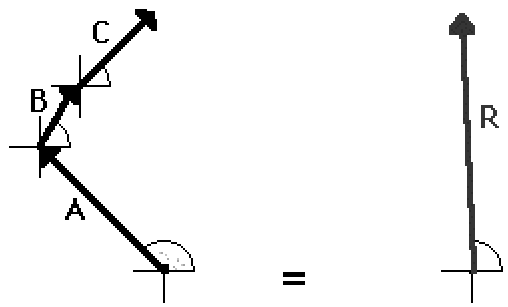


Figure 60

In summary, the resultant is the vector sum of all the individual vectors. The resultant is the result of combining the individual vectors together. The resultant can be determined by adding the individual forces together using vector addition methods.

6.4 Vector Addition

Two vectors can be added together to determine the result (or resultant). Recall that the *net force* experienced by an object was determined by computing the vector sum of all the individual forces acting upon that object. That is the net force was the result (or resultant) of adding up all the force vectors. During that unit, the rules for summing vectors (such as force vectors) were kept relatively simple. Observe the following summations of two force vectors:

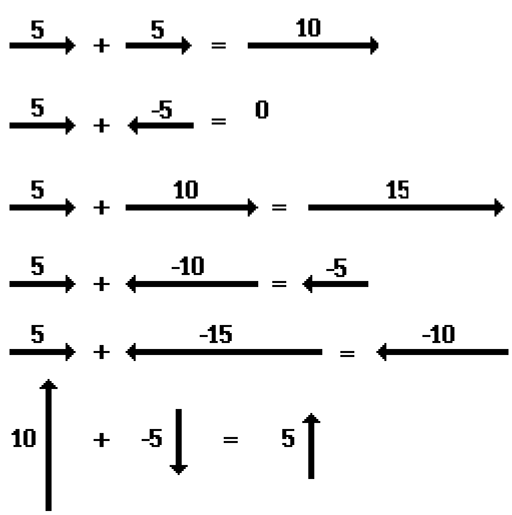


Figure 61

These rules for summing vectors were applied to free-body diagrams in order to determine the net force (i.e., the vector sum of all the individual forces). Sample applications are shown in the diagram below.

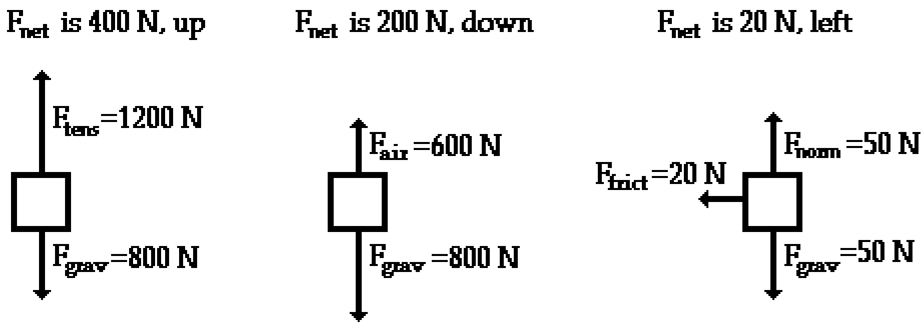


Figure 62

In this unit, addition of vectors will be extended to more complicated cases in which the vectors are directed in directions other than purely vertical and horizontal directions. For example, a vector directed up and to the right will be added to a vector directed up and to the left. The *vector sum* will be determined for the more complicated cases shown in the diagrams below.

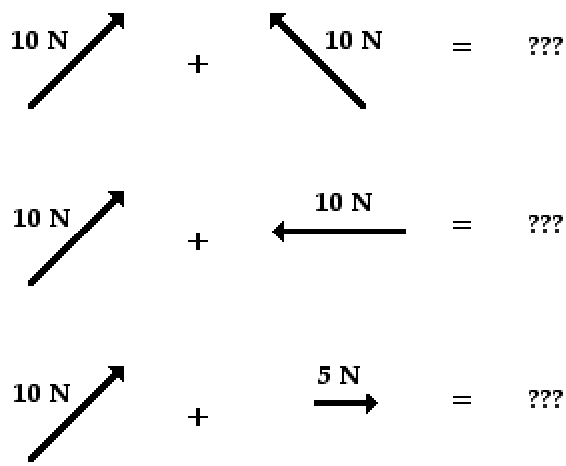


Figure 63

There are a variety of methods for determining the magnitude and direction of the result of adding two or more vectors. The two methods that could be used are:

- the Pythagorean theorem and trigonometric methods
- the head-to-tail method using a scaled vector diagram

6.5 Use of Scaled Vector Diagrams to Determine a Resultant

The magnitude and direction of the sum of two or more vectors can also be determined by use of an accurately drawn scaled vector diagram. Using a scaled diagram, the **head-to-tail method** is employed to determine the vector sum or resultant.

The head-to-tail method involves

Drawing a Vector to Scale on a sheet of paper beginning at a designated starting position.

Where the head of this first vector ends, the tail of the second vector begins (thus, *head-to-tail* method).

The process is repeated for all vectors that are being added.

Once all the vectors have been added head-to-tail, the resultant is then drawn from the tail of the first vector to the head of the last vector; i.e., from start to finish. Once the resultant is drawn, its length can be measured and converted to *real* units using the given scale.

The direction of the resultant can be determined by using a protractor and measuring its counterclockwise angle of rotation from due East.

A step-by-step method for applying the head-to-tail method to determine the sum of two or more vectors is given below.

1. Choose a scale and indicate it on a sheet of paper. The best choice of scale is one that will result in a diagram that is as large as possible, yet fits on the sheet of paper.
2. Pick a starting location and draw the first vector *to scale* in the indicated direction. Label the magnitude and direction of the scale on the diagram (e.g., SCALE: 1 cm = 20 m).
3. Starting from where the head of the first vector ends, draw the second vector *to scale* in the indicated direction. Label the magnitude and direction of this vector on the diagram.
4. Repeat steps 2 and 3 for all vectors that are to be added
5. Draw the resultant from the tail of the first vector to the head of the last vector. Label this vector as **Resultant** or simply **R**.
6. Using a ruler, measure the length of the resultant and determine its magnitude by converting to real units using the scale (4.4 cm x 20 m/1 cm = 88 m).
7. Measure the direction of the resultant using the counterclockwise convention

An example of the use of the head-to-tail method is illustrated below. The problem involves the addition of three vectors:

20 m, 45 deg. + 25 m, 300 deg. + 15 m, 210 deg.

SCALE: 1 cm = 5 m

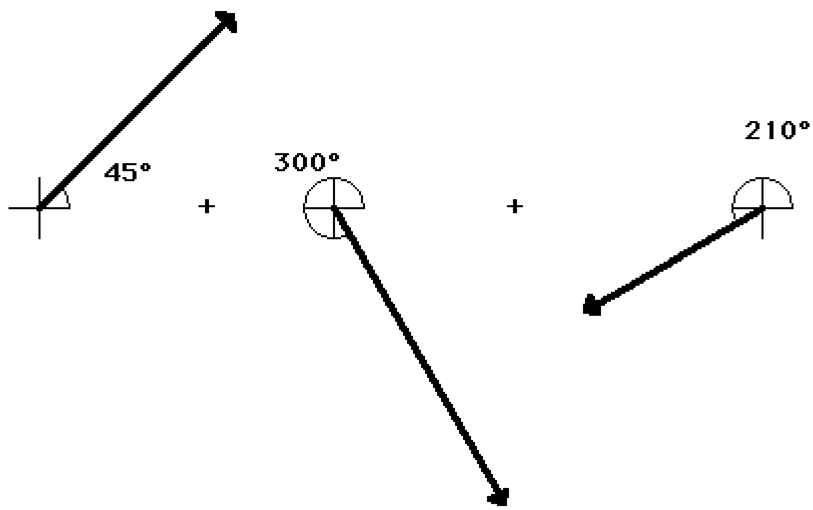


Figure 64

The head-to-tail method is employed as described above and the resultant is determined (drawn in red). Its magnitude and direction is labeled on the diagram.

SCALE: 1 cm = 5 m

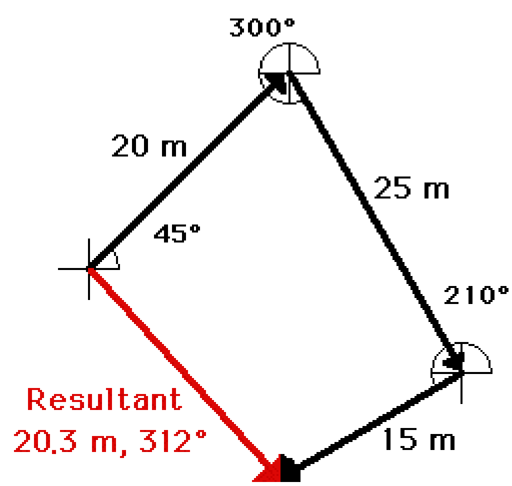


Figure 65

The order in which three vectors are added has no affect upon either the magnitude or the direction of the resultant. The resultant will still have the same magnitude and direction. For example, consider the addition of the same three vectors in a different order.

15 m, 210 deg. + 25 m, 300 deg. + 20 m, 45 deg.

SCALE: 1 cm = 5 m

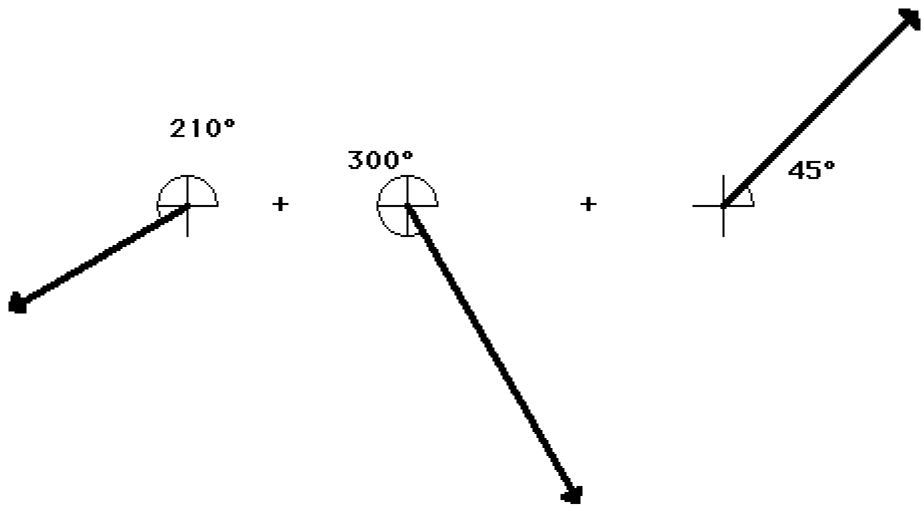


Figure 66

When added together in this different order, these same three vectors still produce a resultant with the same magnitude and direction as before (20. m, 312 degrees). The order in which vectors are added using the head-to-tail method is insignificant.

SCALE: 1 cm = 5 m

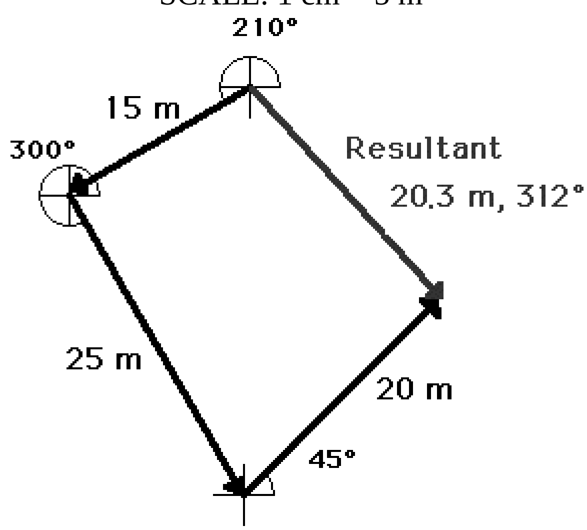


Figure 67

6.5 Vector Components

When an object had an acceleration and we described its direction, it was directed in *one dimension* - either up or down or left or right. Now in this unit, we begin to see examples of vectors that are directed in *two dimensions* - upward and rightward, northward and westward, eastward and southward, etc.

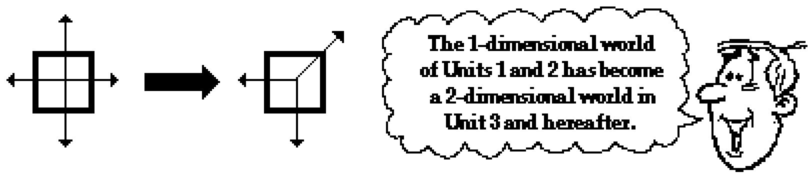


Figure 68

In situations in which vectors are directed at angles to the customary coordinate axes, a useful mathematical trick will be employed to *transform* the vector into two parts with each part being directed along the coordinate axes. For example, a vector that is directed northwest can be thought of as having two parts - a northward part and a westward part. A vector that is directed upward and rightward can be thought of as having two parts - an upward part and a rightward part.

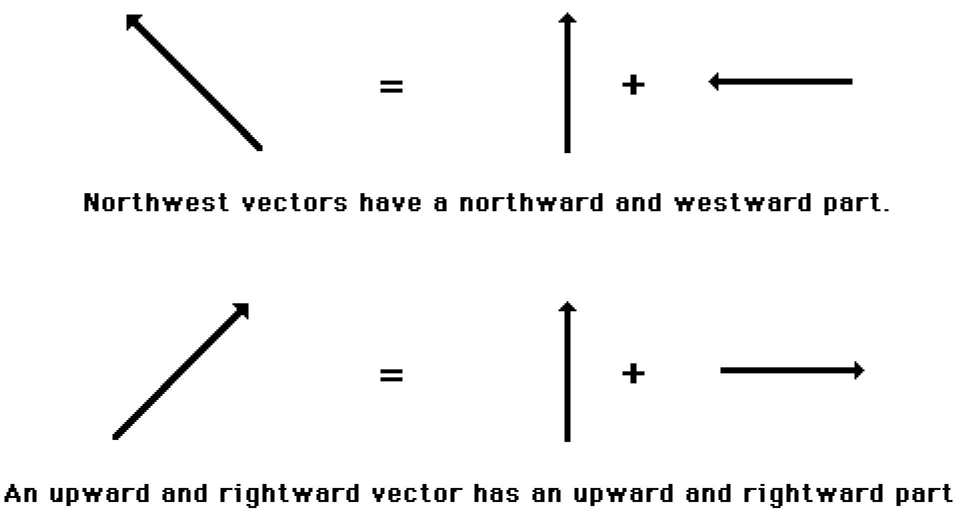


Figure 69

Any vector directed in two dimensions can be thought of as having an influence in two different directions. That is, it can be thought of as having two parts. Each part of a two-dimensional vector is known as a **component**. The components of a vector depict the influence of that vector in a given direction. The combined influence of the two components is equivalent to the influence of the single two-dimensional vector. The single two-dimensional vector could be replaced by the two components.

If Ado's dog chain is stretched upward and rightward and pulled tight by his master, then the tension force in the chain has two components – an upward component and a rightward component. To Ado, the influence of the chain on his body is equivalent to the influence of two chains on his body – one pulling upward and the other pulling rightward.

If the single chain were replaced by two chains. With each chain having the magnitude and direction of the components, then Ado would not know the difference. This is not because Fido is *dumb* (a quick glance at his picture reveals that he is certainly not that), but rather because the combined influence of the two components is equivalent to the influence of the single two-dimensional vector.

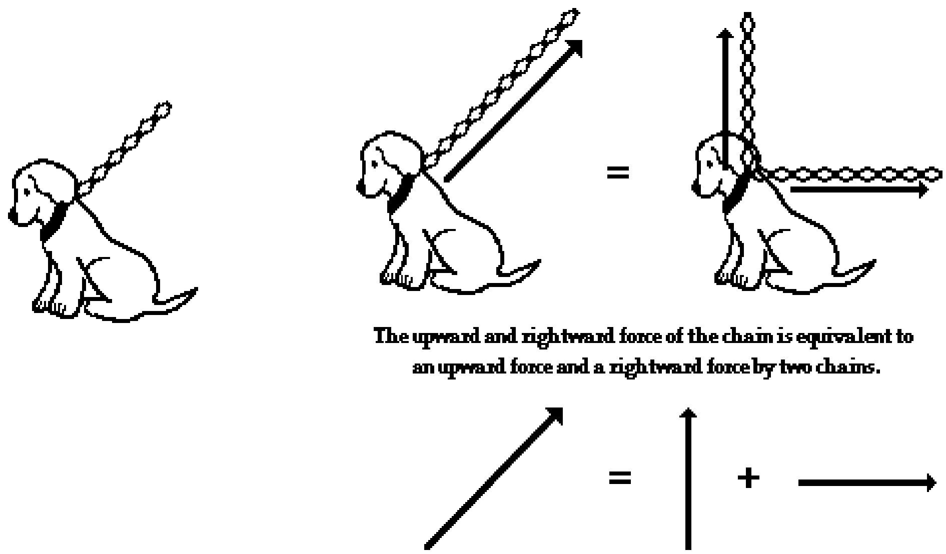


Figure 70

Any vector directed in two dimensions can be thought of as having two different components. The component of a single vector describes the influence of that vector in a given direction.

6.6 Vector Resolution

Any vector directed at an angle to the horizontal (or the vertical) can be thought of as having two parts (or components). That is, any vector directed in two dimensions can be thought of as having two components. For example, if a chain pulls upward at an angle on the collar of a dog, then there is a tension force directed in two dimensions. This tension force has two components: an upward component and a rightward component. As another example, consider an airplane that is displaced northwest from O'Hare International Airport (in Chicago) to a destination in Canada. The displacement vector of the plane is in two dimensions (northwest). Thus, this displacement vector has two components: a northward component and a westward component.

In this unit, we learn two basic methods for determining the magnitudes of the components of a vector directed in two dimensions. The process of determining the magnitude of a vector is known as **vector resolution**. The two methods of vector resolution that we will examine are

- the parallelogram method
- the trigonometric method

6.7 Parallelogram Method of Vector Resolution

The parallelogram method of vector resolution involves using an accurately drawn, scaled vector diagram to determine the components of the vector. A step-by-step procedure for using the parallelogram method of vector resolution is:

1. Select a scale and accurately draw the vector to scale in the indicated direction.
2. Sketch a parallelogram around the vector: beginning at the tail of the vector, sketch vertical and horizontal lines; then sketch horizontal and vertical lines at the head of the vector; the sketched lines will meet to form a rectangle (a special case of a parallelogram).
3. Draw the components of the vector. The components are the *sides* of the parallelogram. The tail of the components starts at the tail of the vector and stretches along the axes to the nearest corner of the parallelogram. Be sure to place arrowheads on these components to indicate their direction (up, down, left, right).
4. Meaningfully label the components of the vectors with symbols to indicate which component represents which side. A northward force component might be labeled F_{north}. A rightward velocity component might be labeled v_x; etc.
5. Measure the length of the sides of the parallelogram and use the scale to determine the magnitude of the components in *real* units. Label the magnitude on the diagram.

The step-by-step procedure above is illustrated in the diagram below to show how a velocity vector with a magnitude of 50 m/s and a direction of 60 degrees above the horizontal may be resolved into two components. The diagram shows that the vector is first drawn to scale in the indicated direction; a parallelogram is sketched about the vector; the components are labeled on the diagram; and the result of measuring the length of the vector components and converting to m/s using the scale.

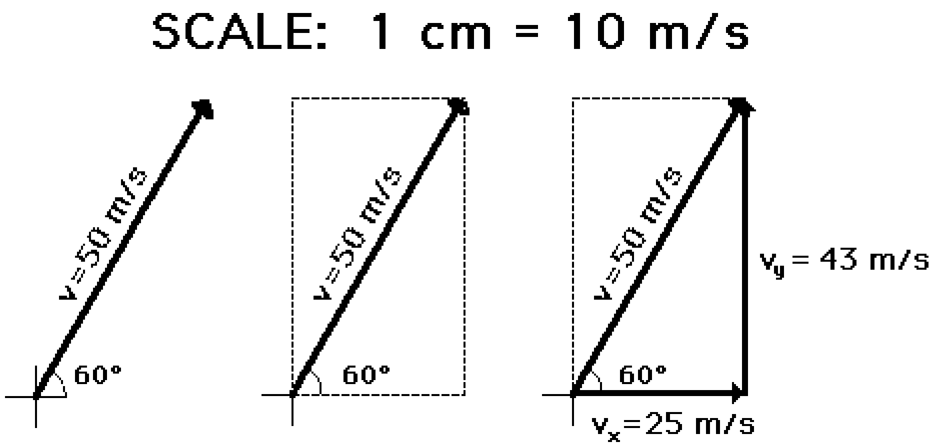


Figure 71

6.8 Trigonometric Method of Vector Resolution

The trigonometric method of vector resolution involves using trigonometric functions to determine the components of the vector. The use of trigonometric functions to determine the direction of a vector was described. Now, trigonometric functions will be used to determine the components of a single vector. Recall that trigonometric functions relate the ratio of the lengths of the sides of a right triangle to the measure of an acute angle within the right triangle. As such, trigonometric functions can be used to determine the length of the sides of a right triangle if an angle measure and the length of one side are known.

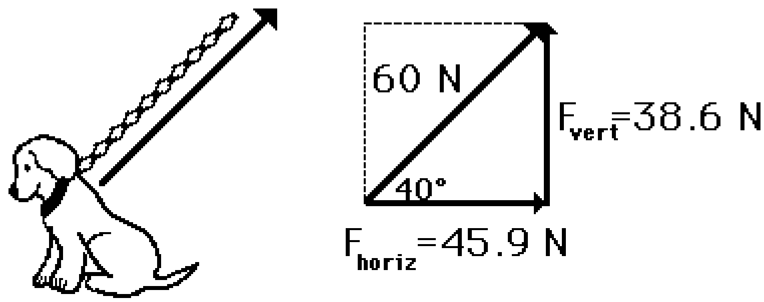
The method of employing trigonometric functions to determine the components of a vector are as follows:

1. Construct a *rough* sketch (no scale needed) of the vector in the indicated direction. Label its magnitude and the angle that it makes with the horizontal.
2. Draw a rectangle about the vector such that the vector is the diagonal of the rectangle. Beginning at the tail of the vector, sketch vertical and horizontal lines. Then sketch horizontal and vertical lines at the head of the vector. The sketched lines will meet to form a rectangle.
3. Draw the components of the vector. The components are the *sides* of the rectangle. The tail of each component begins at the tail of the vector and stretches along the axes to the nearest corner of the rectangle. Be sure to place arrowheads on these components to indicate their direction (up, down, left, right).
4. Meaningfully label the components of the vectors with symbols to indicate which component represents which side. A northward force component might be labeled F_{north}. A rightward force velocity component might be labeled v_x; etc.
5. To determine the length of the side opposite the indicated angle, use the sine function. Substitute the magnitude of the vector for the length of the hypotenuse.

Use some algebra to solve the equation for the length of the side opposite the indicated angle.

6. Repeat the above step using the cosine function to determine the length of the side adjacent to the indicated angle.

The above method is illustrated below for determining the components of the force acting upon Fido. As the 60-Newton tension force acts upward and rightward on Fido at an angle of 40 degrees, the components of this force can be determined using trigonometric functions.



$$\sin 40° = \frac{F_{vert}}{60\ N} \qquad \cos 40° = \frac{F_{horiz}}{60\ N}$$

$$F_{vert} = 60\ N \times \sin 40° \qquad F_{horiz} = 60\ N \times \cos 40°$$

$$F_{vert} = 38.6\ N \qquad F_{horiz} = 45.9\ N$$

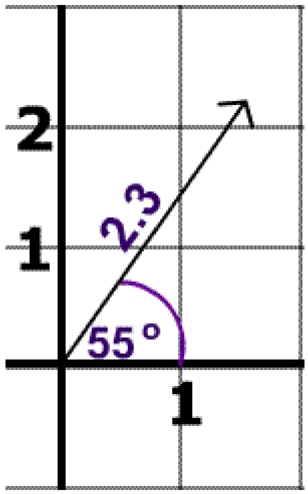
Figure 72

In conclusion, a vector directed in two dimensions has two components - that is, an influence in two separate directions.

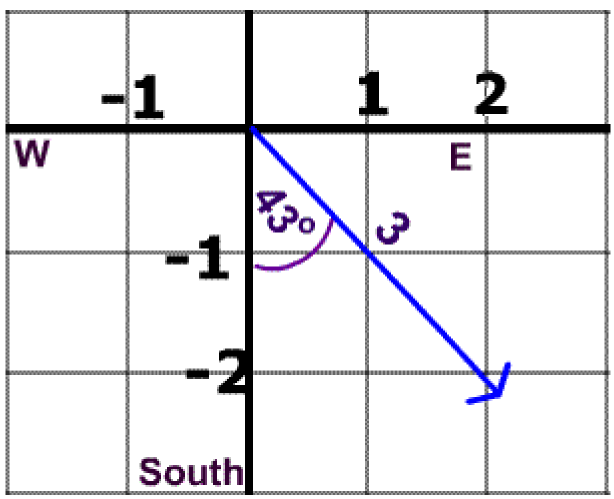
The amount of influence in a given direction can be determined using methods of vector resolution. Two methods of vector resolution have been described here - a graphical method (parallelogram method) and a trigonometric method.

Vectors Exam1 and Problem Solutions

1What is the magnitude and direction of the vector below?



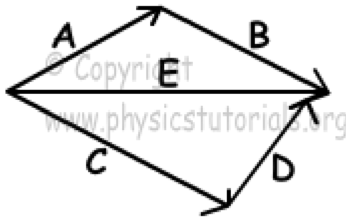
2. Find the magnitude and direction of vector in the diagram below.



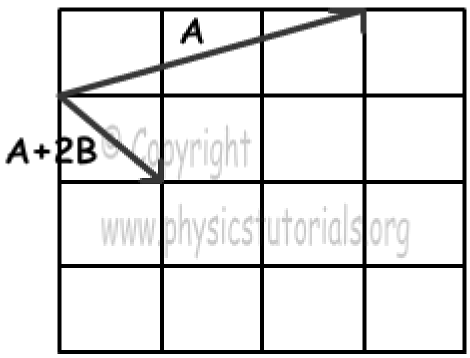
3

,

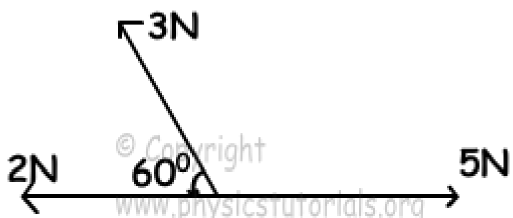
2. Find resultant vector.



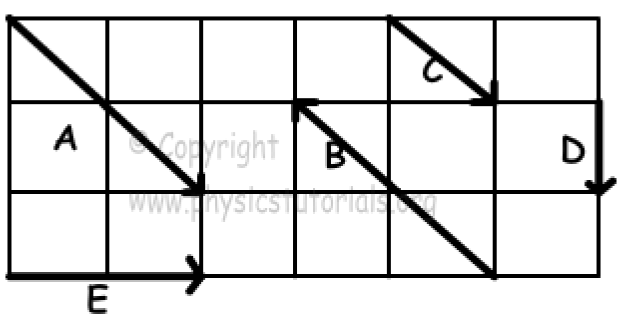
3. A and A+2B vectors are given below. Find vector B.



4. Find resultant vector.



5. Which one of the following statements is true?



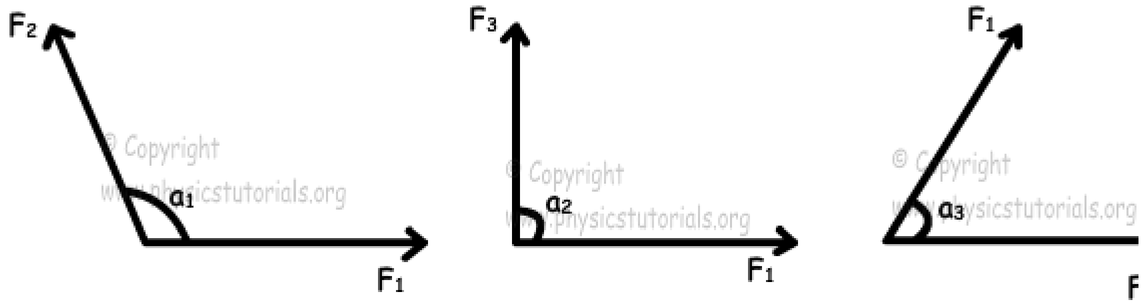
I. A=B in magnitude

II. A=2C

III. E=2D

IV. A=B

6. If α3<α2<α1 and R1=R2=R3, find the relation between F1, F2 and F3.

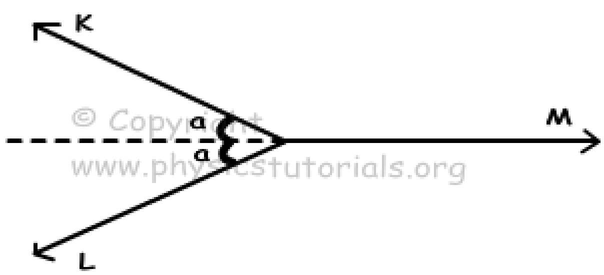


Decreasing in the angle between forces increases the resultant force.

If α1=α2, then R1>R2 and F2>F3

If α2=α3, then R2>R3 and F1>F2 **F1>F2>F3**

7. Resultant vector of K, L and M is zero.

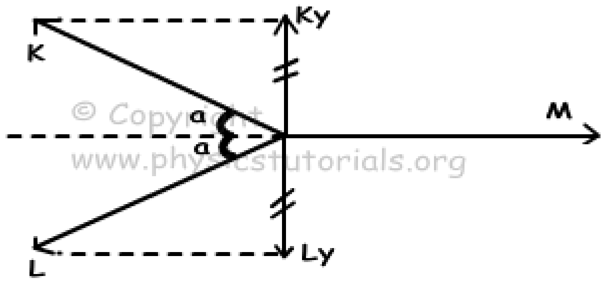


Which one of the following statements given below is definitely false?

I. Ky and Ly components are equal vectors

II. K+L=M

III. $\alpha=60^0$



I. Ky=-Ly, they are equal in magnitude but opposite in directions, thus they are not equal vectors .I. is false.

II. Magnitude of K+L=M, but directions are opposite, thus II is also wrong.

III: $\alpha=60^0$ is possible .III is not exactly false.

UNIT 7

SOLUTION TO GIVEN EXERCISES

Exercise 1

Quantity	**Category**
a. 5 m	Scalar
b. 30 m/sec, East	Vector
c. 5 m, North	Vector
d. 20 degrees Celsius	Scalar
e. 256 bytes	Scalar
f. 4000 Calories	Scalar

Exercise 2

Time(s)	Distance(m)	Displacement
4	15m	11m forward
5	19m	7m forward
2	9m	9m forward
6	26m	2m forward

Exercise 3

No.1. Displacement = 100m from School to End of cross country—100m back to school

= 100m-100m= 0m

No 2. Distance=100m

Displacement =100m forward

Exercise 4 (i) No velocity change

(ii) Yes , a = (24-22)/4 = 0.5m/s

(iii) At t=7 , no acceleration

Exercise 5

Time(s)	Velocity, m/s ,	Acceleration m/s/s
1	2	0
2	5	1.5
3	7	0.7
4	8	03

Time (s)	Velocity, m/s, East	Acceleration m/s/s
1	8	0
2	7	-0.5
3	5	-0.7
4	2	-1.0

Exercise 6

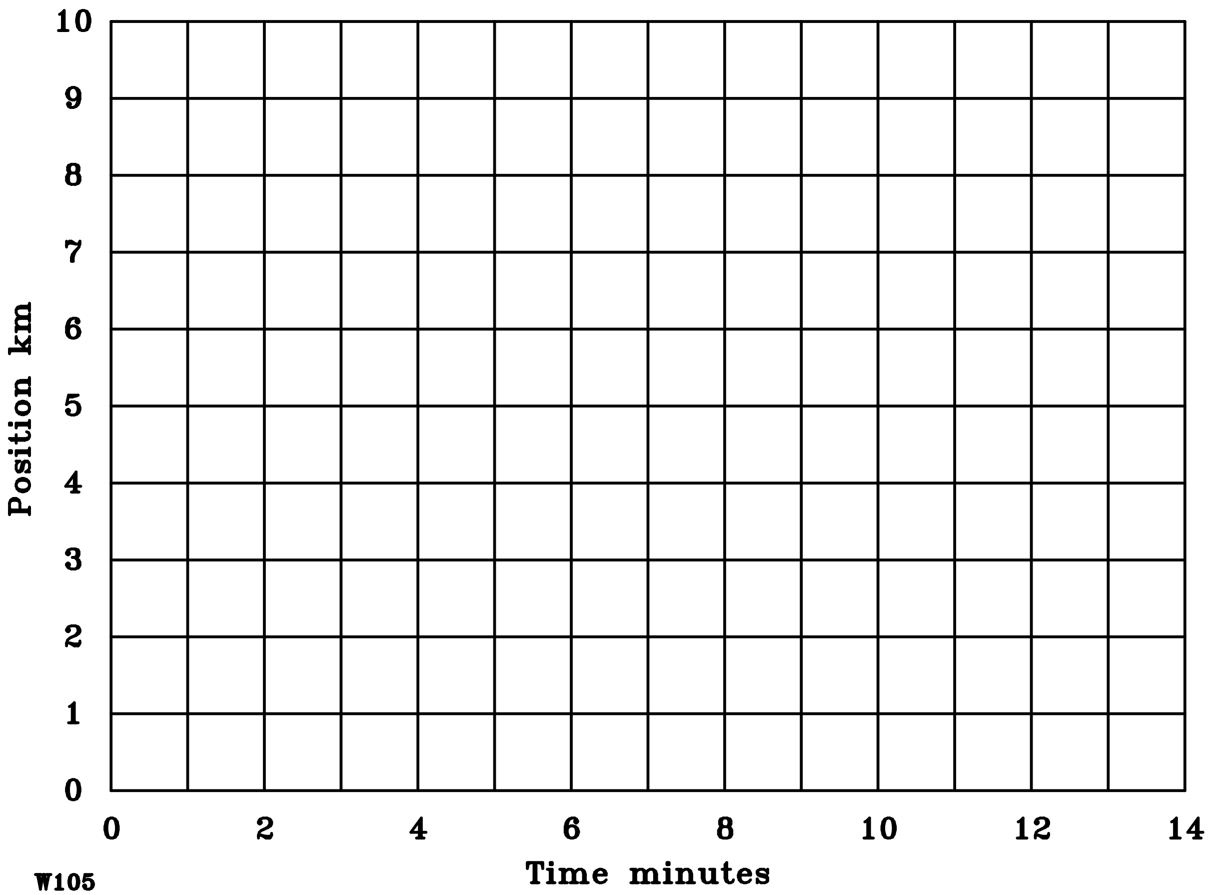
(A) Fast to slow, + ve velocity, velocity not constant

(B) Slow to fast velocity, - ve velocity

(C) Diagram to follow

Velocity								
12								
10	-----	----------	--------	-------	------			
8								
6								
4								
2								
00	1	2	3	4	5	time		

Exercise 7



Exercise 8

(1) Slope = (y’’ – y’)/ (x’’ – x’)

= (26.0 – 2.0)/(0.0 – 8.0)

= 24/(-8)

= - 3.0 m/s

(2) Slope = SPEED of the motion

Exercise 9

(i) 40m/s/s

(ii) 20 m/s/s

(iii) – 20m/s/s

Exercise 10

(a) There is constant velocity at A, + ve velocity change on B, constant low velocity on C

(b) At A there is fast + change in velocity, At B velocity constant=0, At C sharp –ve change in velocity

(c) At A there is constant + ve velocity, At B –ve change in velocity, At C –ve change in velocity

Exercise 12

1 A 540kgm/s

B 20,000kgm/s

2 a. 10,000 Units

b. 40,000 Units

Exercise 13

	Force (N)	Time (s)	Impulse **(N*s)**	Mom. Change (kg*m/s)	Mass (kg)	Vel. Change (m/s)
1.		0.010	-40	-4000	10	-4
2.		0.100	-40		10	
3.	-200	0.010		-200	50	
4.	-20 000			-200		-8
5.	-200	1.0		-200	50	

Exercice 14

Q1

(i) Acceleration #1= 2 and acceleration fo#2=4

#2 has greater acceleration than #1

(ii) Impulse for #1=1x1=1.0Ns

v For #2= 2x1/2=1.0Ns

Same impulse

(iii) Ft= m(v-u)= same

Q2. Momentum change= Fxt= 10x0.1= 1Ns

Exercice 15

M=3.0kg, h=0.45m, g= $10ms^{-1}$

Potential Energy = m g h = 3x10x0.45 = 13.5 J

Exercise 16

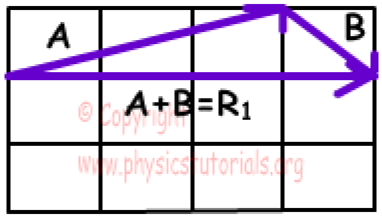
S= 35m, height = 22m

$V^2 = u^2 + 2as$

$0 = u^2 + 2x10x35$

Exercise 17 Vector EXAM 1

(Q1)



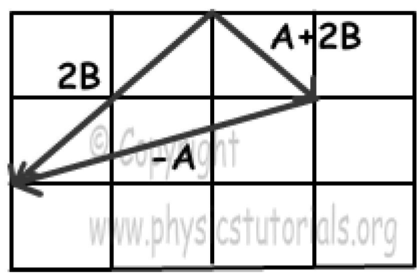
(Q2) **Since; A+B=E and C+D=E**

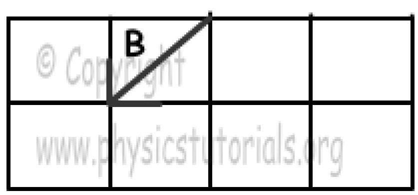
R=A+B+C+D+E

R=E+E+E=3E

(Q3)We use vector addition properties.

A+2B-A=2B

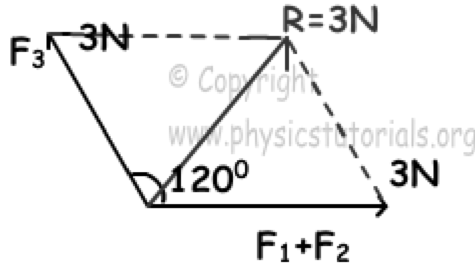




(Q4)To get vector B, we multiply 2B with 1/2.

F1+F2=5-2=3N

(Q5)



F1+F2+F3=R=3N

As you can see in the figure given above, A and B are equal in magnitude, so I. is true. If you multiply C with 2, you get A, this means that II. is also true E =2D in magnitude but not in direction. Thus; III. is false.

APPENDIX 2

ERROR DIAGNOSTIC TEST ON THEORY (EDT)

NAME--
SCHOOL---

GENDER	TICK
Male	
Female	

Dear students, the following are questions on subtopics in Mechanics. You are to answer all the questions on plane sheet provided. Answer the questions carefully and show the working where possible. The questions are set to find out how much you know and areas of challenges on the topic. Thank you very much for your cooperation.

Attempt all questions **Time 2hrs**

Q1 Categorise each of the following quantities as being either a vector or a scalar quantity.

Quantity	Temperature	Mass	Moment	Acceleration	Density	Weight
Category						

Q2 What is the vector sum of the following forces acting at a point ; 50N North,50N South, 20N West.

Q3 A Physics teacher walks 4m East, 2m South, 4m West and finally 2m North. What is the
displacement made by the teacher?

Read the following for question 4,5 and 6

A car runs beside a long straight wall which has marks at <u>metre intervals</u>. The aerial on the car acts as a convenient indicator of the <u>position</u> of the car. The positions of the car at clock readings of t = 0 s, t = 1 s, t = 2 s, etc. are shown in the Figure 1. Note that at the instant (clock reading) t = 3 s the car on reaching the 13 m position "goes into reverse".

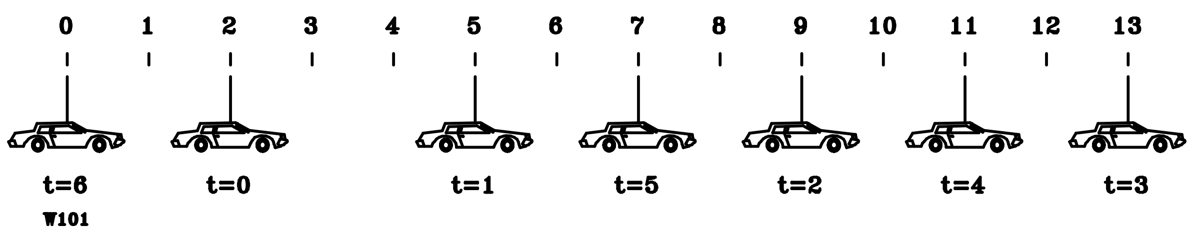


Figure 1

Q4.What is the position of the car at the instant of time t = 2 s?

.

Q5. Starting from t = 0 s what is the distance travelled by the car at t = 4 s?

Q6 At the instant t = 4 s, what is the displacement of the car from its original t = 0 position?

.

In questions 7 to 9 you are required to draw a position-time graph on the basis of information given

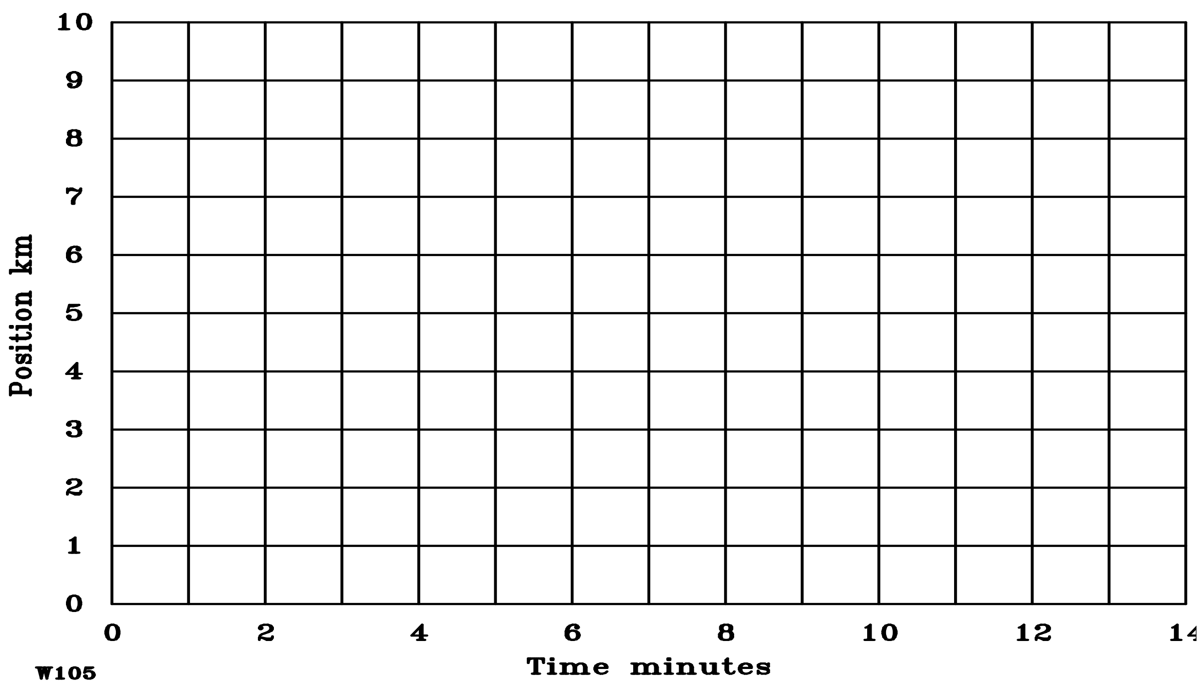


Figure 2

A train is given a test run on a track which has numbered markers every kilometre. Using the following information, mark the appropriate points on the Figure 2 above and then draw your version of the position-time graph.

Q7.The train starts at t = 0 from the 2 km mark.

Q8. It speeds up and passes the 3 km mark 1 min later.

Q9. Still speeding up, the train travels 5 km during the next 2 min.

Q10. Adams travelled from Zaria to Sokoto for 8 hours on his motor bicycle. The distance between

Soskoto and Zaria is 440km. What is the average speed?

The table below is a record of the velocity of a car (v ms^{-1}) at times(t) second (s). The car was travelling initially at a velocity of 20 $ms^{-1.}$. Use the record for questions 22 and 23

t s	0	1	2	3	4	5	6	7	8	9	10
V m	20	20	20	22	24	26	26	26	23	20	17

Q11. Is the car accelerating at the instant t = 1 s?

Q12. Is the car accelerating at the instant t = 4 s?

Q13. Determine the acceleration for the following motions

Time(s)	Velocity(ms^{-1})	Acceleration(ms^{-2})
1	2	
2	5	
3	7	

Seven position-time graphs (A-G) are shown in Fig 3. Which of these graphs best represents?

:

Q14. A car travelling at a constant 60 km per h our?

Q15. A car slowing down with the brakes applied?

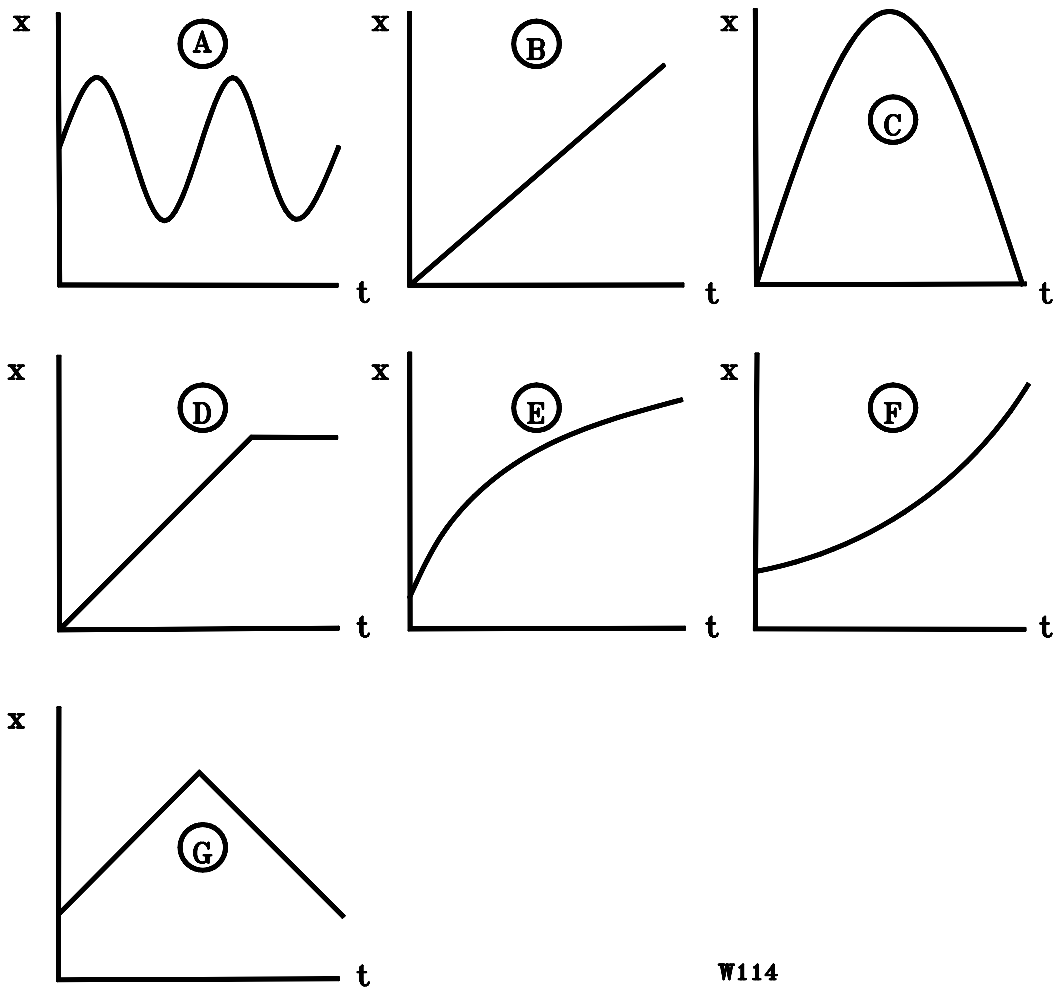


Figure 3

Q16. A heavy lorry has high inertia, how difficult is it to start it moving and to stop it moving

Q17. A particle is dropped from a vertical height h and falls freely for a time t. With the aid of a
sketch explain how h varies with t.

Q18. Explain linear momentum of a force.

Q19. Determine the momentum of a60kg halfback lorry moving eastward at $20ms^{-1}$.

Q20.Two toy railway trucks A and B collide. The masses and velocities of the trucks are as shown
in the figure 5.

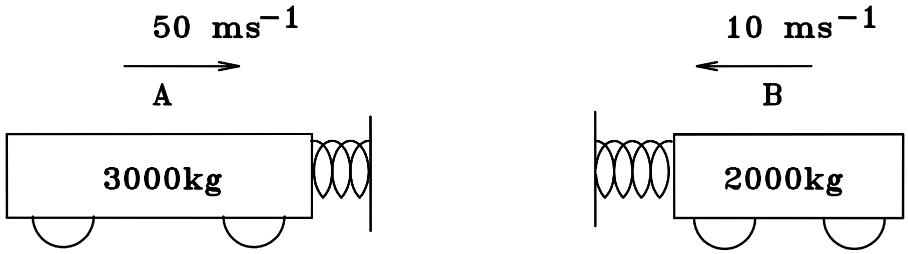


Figure 5 W200

What is the total momentum of the system before the collision?

Q21. Explain Impulse of a force.

Q22. Consider an object of mass 2 kg initially at rest which is acted on by a constant force of 15 N
for a period of 2 s. What is the impulse of this force?

Q23. What is the physical quantity that has same dimensions as impulse?

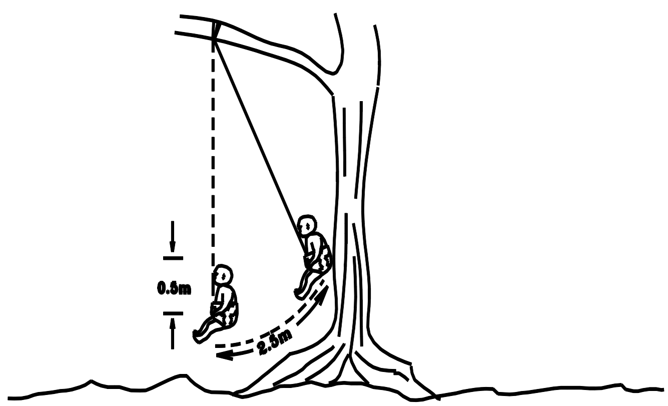
Q24. A carpenter on top of a roof 20.0m high left a hammer of mass 1.5kg. What is the potential

energy of the hammer?

Q25. A child of mass 30 kg swings on a rope as shown, starting from rest at point P and passing

through the lowest point of its swing at Q. What is the child's change in potential energy

between P and Q if separation between P and Q is 0.9m?



S925

Figure 6.

Q26 What are the factors that influence the potential energy of abody?

Q27. What is a projectile motion?

Q28. A particle is projected horizontally at $15ms^{-1}$ from a height of 20m. Calculate the horizontal distance covered by the particle.

Q29. A ball is swinging pendulum-fashion on the end of a string. While the ball is swinging to the right the string breaks as shown in the Figure 7.

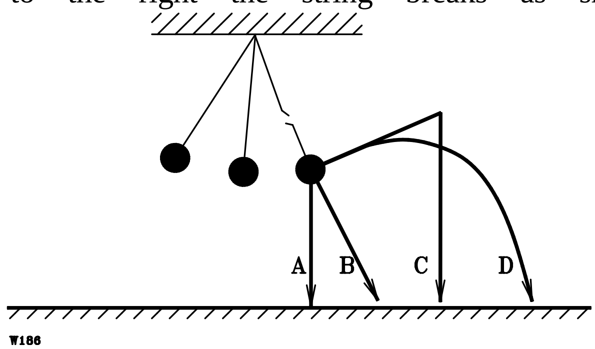


Figure 7.

Which of the four paths A, B, C or D most closely resembles the path of the ball?

The diagram in Fig 8 shows two vectors A and B.
Use the diagram in Fig. 8 for questions 30 to 33

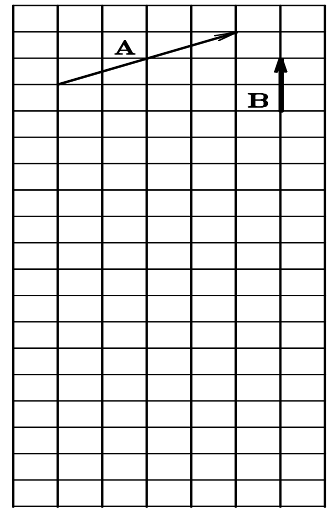


Figure 8

Q30 Draw the vector -B.

Q31 Using the "tip to tail" method construct the vector A+ (-B).

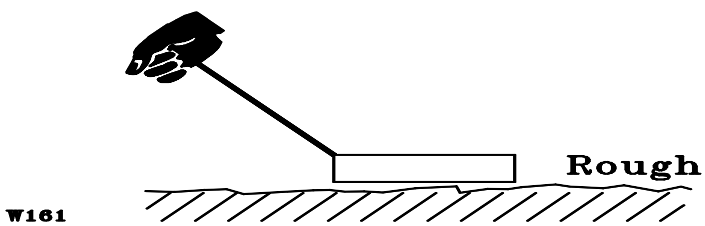


Figure 9

Q32. John pulls on a rope to move a sledge of mass m across rough horizontal ground with acceleration**a** in Figure 9. Which of the following are forces acting on the sledge?

A The force which John exerts on the rope.
B The weight of the sled.
C The tension in the rope acting on the sledge.
D A friction force due to the rough ground.
E A vector force **F** = m**a** necessary to keep the sled accelerating.
F A vertical force exerted by the ground on the sled.

A ball bounces up and down continually. It falls from position 6 and strikes a steel plate at position 0, rebounds and travels vertically upwards to position 6 where it reverses its direction of motion; falls again strikes the plate and so on. It is assumed that there are no frictional effects so that the motion goes on forever. Position 6 is the highest position attained.

Q33 At which of the positions (1-6) is the ball falling in Figure 10 with the greatest speed?

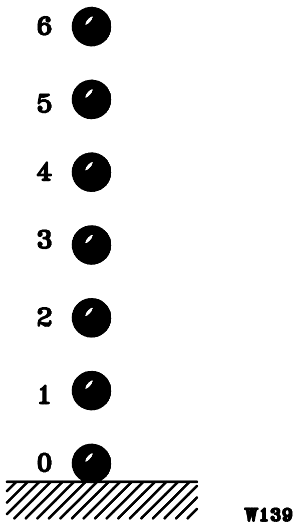


Figure10

Q34. At which of the positions (1-6) in Figure 10 is the ball at rest?

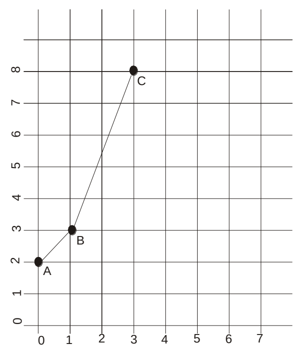
Q35 Draw the forces which are acting on a load suspended on an elastic spiral spring**.**

APPENDIX 3

MARKING SCHEME FOR EDT

Quantity	Temperature	Mass	Moment	Acceleration	Density	Weight
Category	scalar	scalar	scalar	vector	Scalar	vector

1. +50N South – 50N North 20N West = +20N West
2. 4mE+2Ms-4Mw-2Mn=0m
3. At t=2s position is 9m
4. Distance travelled at t=4s=11-2=9m
5. Displacement 11-2 = 9m forward
6. A.
7. B.
8. C.



9. T=8hrs, s= 440km. v = ?

$V = \frac{displacement}{Time} = \frac{440000}{8*360} = 152.28ms^{-1}$

11.Not accelerating at t=1s

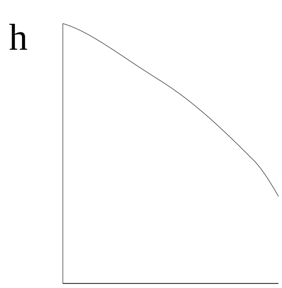
12, Accelerating at t=4s

13.

Time (s)	Velocity(ms^{-1})	Acceleration(ms^{-2})
1	2	0
2	5	1
3	7	1

14. B
15. G
16. Difficult to start
    Difficult to stop

17



18. Momentum of a force is product of mass and velocity of body.

19. Momentum= m x v

$= 60kg \times 20ms^{-1}$

$= 1200kgms^{-1}$

20. $M_a \times V_a = 3000kg \times 50ms^{-1} = 150000kgms^{-1}$

$M_b \times V_b = 2000kg \times (-10)ms^{-1} = -20000kgms^{-1}$

21. Impulse is the product of force and time taken for application of force

Or momentum change for moving body

22. m=2kg, F= 15N, t= 2s, Impulse = ?

Impulse = F x t

15N x 2s = 30NS

23. Momentum

24. P. E. = mgh

= 1.5 x 10 x 2.0

= 30 Joule

25 Difference in potential energy = mgh

= 30 x 10 0.90

=270 Jouls

26. P.E. = mgh

P.E. α mass of body

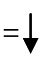
α height of body above ground level

27. Motion of a body under the influence of gravity only is projectile motion.

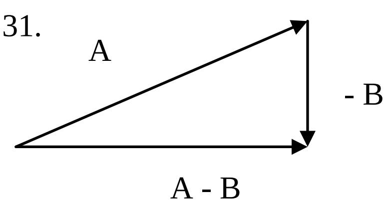
28 $u=15ms^{-1}$, h = 20m, $g = 10ms^{-2}$

$H= U^2/ 2g = 15^2/(2 \times 10)= 11.25m$

29. D

30. –B = 

31.

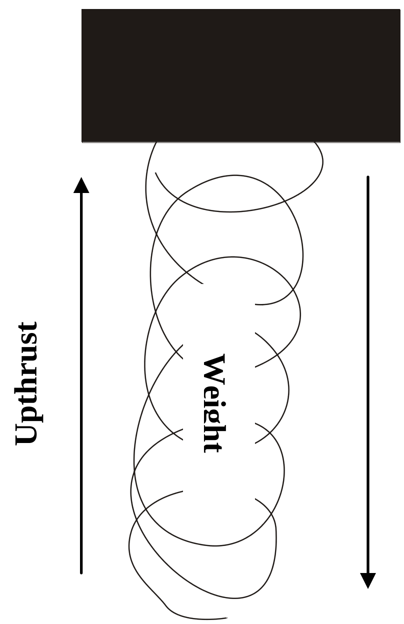


32. B, C, D.

33. Position 1

34. Position 6

35.



APPENDIX 4
PHYSICS ACHIEVEMENT TES (PAT)

NAME---
SCHOOL---

GENDER	TICK
Male	
Female	

Dear students, you are to answer all the questions provided. Answer the questions carefully and show the working where possible. The questions are set to find out how much you know and areas of challenges on the topics with a view towards improving the situation. Thank you very much for your cooperation.

Attempt all questions **Time 2hrs**

1 Which of the following is not a vector

a. Velocity b. Force c. Time d. Acceleration

2 You walk 31 m south and 31 m west. What is your displacement ?

a. 22m SW b. 44m SW c. 44m NW d 62m SW

3. Two football players hit a blocking sled. One hits it with a force of 350 N, East, and the other hits it with a force of 270 N, South. The resulting force is:

A .442 N, SOUTH EAST, B. 620N SOUTH EAST C. 80N SOUTH EAST D 20 N SOUTH EAST

4. Velocity is a ……………………............................

(a) Scalar quantity (b) Vector quantity (c) Scalar vector (d) Displacement

5. Average velocity can be define as ………………………………

(a) $\frac{distance\ travelled}{time\ of\ travel}$ (b) $\frac{displacement}{time\ travel}$ $(c)\ Forcee \times Aceleration$ $(d)\ speed$

6. A passenger sitting by the window of a train moving with a velocity of 72km/h sees for 10s a train moving with a velocity of 32.4km/h in the opposite direction. Find the length of the second train

(a) 2.9m (b) 290m (c) 1.44m (d) 29m

7. …………………………. Is always required to set objects in motion

(a) Energy (b) Force (c) Velocity (d) Power

8. A force of 5N acting in the direction of displacement of an object through 20m does…..

(a) 100J (b) 10J (c) 1000J (d) 200J

9. Force of gravity on a body is called……………..

(a) Mass of the body (b) Force of the body (c) Weight of the body (d) energy

10. A body whose weight is 100N walks up a flight of stairs 8m height in 32s. What power has he developed?

(a) 25W (b) 30W (c) 20W (d) 35W

11The tendency of a body to remain at rest or, if moving, continue its motion in a straight line is describe as
(a) Momentum (b) Inertia (c) Vector (d) recoil velocity

12. A car of mass 1000kg travelling at 36km/h is brought to rest over a distance of 20m. Find theaverage retardation.
(a) $2.5m/s^2$ (b) $-2.5m/s^2$ (c) $-20m/s^2$ (d) $25m/s^2$

13. Workdone is defined as the product of …………………………….
(a) Displacement in the direction of force and the force
(b) Distance covered and Acceleration (c) Displacement and Distance covered (d) Power and Energy

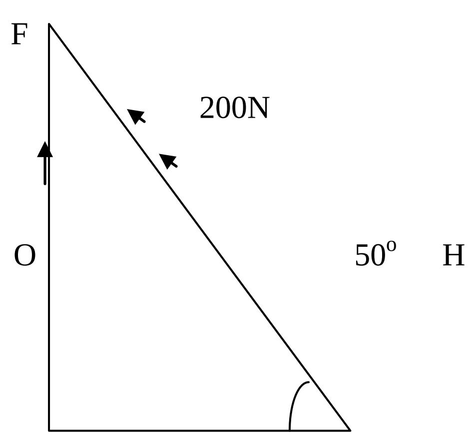
14. The work done when a force of 10N moves an object through 10m in the direction of the force is
(a) 100NM (b) 1000NM (c) 10NM (d) 100N

15. The energy possessed by an object due to its position or state when it is at rest is known as
(a) Kinetic energy (b) Potential energy (c) Mechanical energy (d) Internal energy

16. Kinetic energy depends on both its …………… and………………………
(a) Mass and Displacement (b) Speed and Mass (c) speed and Velocity (d) Mass and energy

17. Calculate the power of a pump which can lift 200kg of water through a vertical hight of 6m in 10s. (take $g = 10m/s^2$)
(a) 10KW (b) 1.20KW (c) 1.20W (d) 10KW

18. A garden roller is pulled with a force of 200N acting at an off 50^0C with ground level. Find the effective force pulling the roller along the ground.



(a) 129N (b) 0.64N (c) 128N (d) 12.9N

19. A motor car is uniformly retarded and brought to rest from a velocity of 108km/h in 15s. Find its acceleration.

(a) $2m/s^2$ (b) $-2m/s^2$ (c) $30m/s^2$ (d) $20m/s^2$

20. The rate at which the velocity of a moving body is changing is known as …………

(a) Speed (b)Velocity (c) Acceleration (d) Power

21. A body is said to remain in a state of rest or uniform motion in a straight line unless it is acted by an………

(a) Internal force (b) External energy (c) External force (d) Velocity

22. A stone is thrown horizontally from the top of a cliff 100m height with a velocity of 40m/s. Find its velocity on reaching the ground.

(a) 40m/s (b) 60m/s (c) 80m/s (d) 20m/s

23. When a body falls freely under gravity, the sum of its potential and kinetic energies remain

(a) Constant (b) Dynamic (c) at rest (d) Variables

24. The time rate of change of momentum of a body is

(a) Inversely proportional to the applied force and takes place in the direction in which the force acts

(b) Proportional to applied force and takes place in the direction in which the force acts

(c) Linear in relation to the velocity of the body and power

(d) Changes with energy of the body

25. A stone is thrown vertical upward with an initial velocity of 14m/s. Neglecting air resistance. Find the maximum height. ($g = 9.8m/s^2$)

(a) 19.6m (b) 9.4m (c) 10m (d) 11m

26 An object is thrown upward with an initial velocity of 14m/s..and the maximum height is 10m. Neglecting air resistance, calculate the time taken before reaching the ground ($g = 9.8ms^{-2}$)

(a) 2.4s (b) 14s (c) 1.4s (d) 14.3s

27. Sketch a velocity-time graph for a moving with uniform acceleration from 5m/s to 25m/s in 15s. Use the sketch graph to calculate the value of acceleration.

(a) $1.33m/s^2$ (b) $13.33m/s^2$ (c) $133m/s^2$ (d) $11.33m/s^2$

28. A 5g mass is placed on a straight air track sloping at an angle of 45^o to the horizontal. Calculate the acceleration as it slides down. (take $g = 10m/s^2$)

(a) $7.1ms^{-2}$ (b) $0.14ms^{-2}$ (c) $0.5ms^{-2}$ (d) $7.0ms^{-2}$

29. What force is required to accelerate an electron with mass of 9.1g from rest to a velocity of 6m/s in 10s.

(a) 5.46N (b) 54N (c) 4.1N (d) 5.64N

30. A mango of mass 2g fallen from a height of 20m above the ground, calculate the potential energy of the mango.
(a) 40J (b) 400J (c) 4J (d) 45J

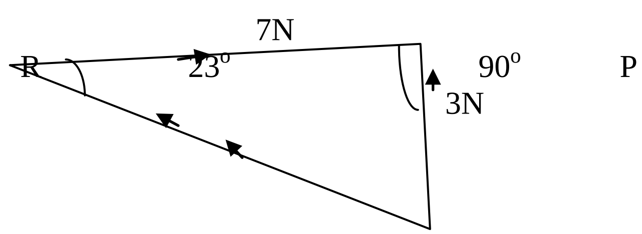
31. A lorry of mass 60kg falls freely from a height of 2m at 10m/s. Calculate the kinetic energy of the lorry.
(a) 300J (b) 3000J (c) 30J (d) 3J

32. A projectile motion moves along the curve path under the action of
(a) Force only (b) Gravity only (c) Acceleration only (d) Power and Force

33. In projectile motion, the horizontal and vertical motion are …………………………
(a) Independent of each other (b) Dependent of each other (c) Related to each other (d) Linear in motion

34. The total time for which the projectile remains in the air is called……………………
(a) Time of flight (b) Vertical time (c) Object time (d) Time to reach the ground

35. Object is attracted by the earth and this force of attraction or pulling force is called?
(a) Attraction force (b) Pulling force (c) Gravitational force (d) Force of the body



(a) 7.6N (b) 58N (c) 6.7N (d) 5.8N O

APPENDIX 5
MARKING SCHEME FOR PAT

1. C

2. A

3. A

4. B

5. B

6. A

7. B

8. C

9. A

10.A

11.B

12.B

13.A

14.A

15.B

16.B

17.B

18.D

19.B

20.B

21.B

22.B

23.A

24.B

25.A

26.B

27.C

28.A

29.A

30.B

31.D

32.B

33.C

34.A

35.C

APPENDIX 6
LESSON PLANS FOR EXPERIMENTAL GROUPS

LESSON PLAN ONE

Lesson Topic: Linear Motion:
Class: SS 2
Time: 80 minutes
Topic: Speed, Velocity & Acceleration

Behavioural Objectives: By the end of the lesson students should be able to:
(1) Measure linear distance, time and calculate velocity.
(2) Plot graphs to show: speed versus distance and
(3)Plot graph of velocity versus distance

Instructional Materials:

2 meter sticks per group of 6 students
2 stop watches or watches with second hands per group
1 Pencil and data sheet per group

Introduction

Students to measure a distance of 100m using the metre rules provided and mark positions 0, 25, 50, 75 and 100m.

Presentation of lesson

Step I

Select 5 students each to stand at 0,25,50,75 and 100m positions,:
Start the battery powered toy car placed along the 100m line drawn
Student at Start position
Indicate the vehicle being timed by Saying "GO"
Waving arm or flag as it crosses the start position.
Student at 25 meters position - begin timing at the "Start" command and stop timing as vehicle crosses the 25 meter position.
Student at 50 meters position - begin timing at the "start" command and Stop as the vehicle crosses the 50 meter position.
Student at 75 meters position - begin timing at the "start" command and Stop as the vehicle crosses the 75 meters position.
Student 100 meters position - begin timing at the "start" command and stop as the vehicle crosses the finish line (100 position).

Step II

The data collected in activities in step I be collated on board by the students. Students will be grouped into five each group consisting one of the timers in step I.
(i)Students will use the collated data and to calculate the average speed and the average velocity for each group using the following formulae:

Speed = distance/time

Velocity = distance & direction/time

(ii) Student will be guided to plot a graph velocity Vs time and speed Vs time.

(iii) Students will use the measured time for the movement of vehicle at the five distances from "0" to 100 meters and plot the acceleration of the vehicle on a graph.

Evaluation: The students will report the outcome of their exercises and teacher will assess the outcome

Conclusions:

1. Students learned the difference between speed and velocity by measuring distances and times and using formulae to calculate speed and velocity.
2. Students learned how to use data from a table to plot a graph showing the information.
3. Students learned that motion is defined in relative terms.
4. Students learned that acceleration is a rate of change in speed or velocity (increase or decrease).

Home Work: Students to attempt Exercises 2, 3 and 4 from the remediation package

LESSON PLAN TWO for Experimental group
Topic: Straight Line Motion in Two Parts
Class: SS 2
Time: 1 hr.
Behavioural Objectives: By the end of the lesson students should be able to

(1) Observe both constant and accelerated (changing) motion.
(2) Calculate speed from distance and time measurements.
(3) Graph distance vs time for constant and accelerated motion
(4) Observe that the two motions look different when graphed.

Previous Knowledge: Students have learnt about speed, acceleration and drawing graph.

Instructional Materials:

Battery powered toy car, Stopwatch, Meter Rule, Toy car (not powered), a long slope.

Introduction:
Students are shared into groups of fives. Instructional materials shared.
Step I
Let Students to start the powered car.

Ask the following questions, in writing:
Describe the motion of the car as it rolls along the table.
How can you tell what it is doing?
What do you need to know to find the speed of your moving car?
Find the average speed of your car over a distance of 1 meter using given materials.
What can you measure? How many trials have made in the Measurement ?
Record your measurements and calculations.
Is this a constant speed? How can you tell?
Find the average speed for 2 meters.
Was it the same as the average speed for 1 meter?
What about 3 meters?
Step II
Plot the Graph of the Distance Traveled vs. the Time Taken for 1, 2 and 3 meters.
Describe this graph. Is it straight?
Is this constant motion or changing motion?
What is the relationship between the Distance Traveled and the Time Taken?
Look at the slope (rise over run) of the graph, and calculate this slope.
What does this tell you?

Step III

Let students create a hill on table.

Start your car at the top of the hill.

Ask your students the following questions, also in writing.

Describe the motion of the moving car.

Is it constant motion? Or is it accelerated (changing) motion?

Find the average speed of your car for 1/2 meter.

Record your measurements and calculations.

Repeat for 1 and 1 1/2 meters (or the end of the hill)

what do these speeds tell you? Is it constant motion, or accelerated motion?

Step IV

Graph the Distance Traveled vs the Time Taken.

Describe this graph. Is this a straight line?

What does this graph tell you about the motion of the car rolling down the hill?

Evaluation:

Teacher draws graphs of some motions, and ask for a description of the motions from the students.

Conclusions:

Students have been able to measure distance, time and be able to combine them to find speed. They have learnt how plot of graph distance vs time, and to find the slope and speed. They also learnt to recognise the difference between constant motion and accelerated motion.

Home work: Students attempts exercises 6,7,8,9and 10 in the Remediation package

LESSON PLAN THREE for Experimental group
Topic: Momentum And Colliding Spheres
Class : SS 2
Time : 1 Hr

Objective: By the end of the lesson students should be able to :
(1)Identify that mass x velocity equals momentum.
(2)Realise the impacts of collisions and their results.
InstructionalMaterials: Paper, Chalk, Iron Spheres, Marker, Meter Rule and String.
Students' previous knowledge: Students have learnt about velocity and seen colliding objects
Introduction:

The students are asked to think about the content of an object. The student will be requested to say what the weight and mass of a body is.
Step I
Students are asked if a heavy lorry and a light car are moving with the same velocity which of them will easily be stopped and why?

The idea of mass in motion is introduced which leads to the concept of momentum. The students are told that when we think of mass and velocity together, we call this action momentum. Momentum refers to mass in motion.

The moment of a body is the product of mass of an object and the velocity of the moving body.
Step II
Two spheres are shown with the same amount of mass.
The student are asked what would happen if both spheres were moving at the same speed toward a wall?
The students try rolling the spheres and note their observations.
The students are asked what would happen if the two spheres were moving toward each other at the same speed?
At this point, the teacher demonstrates a collision using spheres of equal mass.
The students record their observation
Evaluation.

Students would be asked the meaning and formula for momentum of a body. What is the impact collusion on moving bodies?

Conclusion:
The student learnt the meaning of force and is introduced to mass. The students would

have learnt that momentum is mass multiplied by velocity. When moving bodies collide their speed and velocity changes.

Home Work: Students to attempt exercises in 12, 13 and 14 in Remediation Package.

LESSON PLAN FOUR for EXPERIMENTAL Group

Topic: VECTORS
Time: 80minutes
Behavioural objectives: By the end of the lesson, the students should be able to:

(i) Define a vector and state some its rules.
(ii) use head to tail rule in addition of vectors.

Students' previous knowledge : The students have knowledge of displacement, direction and angle measurements
Instructional Materials:
Three pieces of heavy yarn of different colours, preferably blue, orange, and green, Three pieces of chalk of different colors, blue, orange, and green, A large blackboard protractor, Several meter rules and 2-meter meter sticks, Three bricks wrapped in plastic, A side clamp for the front desk,
Four large pieces of paper with East, West, North, South printed on them.
Introduction

Post the four large signs representing the directions on the four opposite walls in the classroom. Ask a student to move a brick from the front desk to his seat. Make it known to the class the direction that the brick
was moved and that it might represent the change in position of any object from one position to another. Ask the class to enter into the description of this change in position of the brick (to elicit an answer of "displacement").
Step I
Have students take out a sheet of paper and pencil to record a simple data table you place on the board, having length in meters and angle in degrees for each of the three sides of the triangle. Label the sides A,B,C respectively. Also the angles are labeled as alpha, beta, and gamma.
Step II
Group the into groups of fives. Challenge each group to find one of the sides and angles, then record them on the board. Then graphically have the students record them on their graph paper.
Step III
Show students how to graphically add vectors "head to tail", by putting the head of the second vector to the head of the first vector and so forth until all vectors for that problem have been added.

While writing vector equations remind the students to indicate above each algebraic symbol a small arrow representing a vector.
Evaluation The teacher go over some of the vector addition exercises and also ask for definition of a vector quantity
Conclusion After graphing, a chalk and talk review of vectors takes place. At this point the students would be advised to record these notes for future reference. The main

concepts revealed here were the addition of parallel vectors (positive or negative) depending on their direction, then adding two vectors at 90 degrees was shown.

Home Work Student attempt exercises 15,16 and 17 in the Remediation package

LESSON PLAN FIVE for Experimental group
Topic: Effect of Height on Potential Energy
Class: SS 2
Time : 45 minutes
Behavoural Objective : By the end of the lesson students should be able to;
Demonstrate a reinforced concept of potential and kinetic energy.
Instructional Materials:
Toy car, 6 Text books, Tag board or other material for track, 3 - 1 cup milk cartons, Meter stick or tape measure
Introduction

1. Place the track so that one end is on top of one of the books and track slants down to the floor. Tape the track to the floor so that it does not move.
2. With the cartons, build a tower at the lower end of the track: two cartons on the bottom, one on top.

Step I
3.Let the students Place the car at the top of the track and allow the car to roll down the track (do not push the car).
4. Measure the distance from the bottom of the track to the carton the car was knocked off. Measure the distance from the lower end of the track to the edge of the carton that is farthest away from the track. (if the car did not knock over the cartons, record this information.)

Step II
5. Raise the track by placing 3 books total under the first book. Then rebuild the tower of cartons.
6. Place the car at the top of the track and allow the car to roll down the track. Measure how far the carton traveled. Repeat this 3 times and record information.

Step III
7. Repeat the activity with the ramp six books high.
Recording and Analyzing the Data:
**Make a chart or graph in your notebook that will organize the results of your trials.

Evaluation
The students should provide answers to the following:
1. How did the height of the hill change in your demonstrations?
2. What kind of energy did the car have at the top of the hill?
3. What kind of energy did the car have as it was rolling down the hill?
4. When did the car have the least energy... at one book? three books? six books? When did the car
have the most energy?
5. How does the height of the hill affect the amount of potential energy in the car?
6. How did this demonstration show that energy is converted to other forms?
7. Write the outcome of the demonstration and its results. Be sure to use as many of the vocabulary words as you can, that you have learned in studying this unit. Underline any vocabulary words that you use.

(some words may include: potential energy, kinetic energy, acceleration, speed, momentum, heat energy, sound energy, mechanical energy, velocity)
Conclusion: Review major information and skills acquired in the lesson.
Home Work: Students to attempt exercise 15 in the remediation package

APPENDIX7

LESSON PLANS FOR CONTROL GROUPS

LESSON NOTE ONE

Lesson Topic: Linear Motion:
Class: SS 2
Time: 80 minutes
Topic: Speed, Velocity & Acceleration

Behavioural Objectives: By the end of the lesson students should be able to:
(1) Describe linear distance, time and calculate velocity.
(2) Plot graphs to show: speed versus distance and
(3)Plot graph of velocity versus distance

Students' previous knowledge Student have learnt about types of motions

Teaching aids:
1 Pencil and data sheet per group

Introduction
Students are asked to give the definition of speed and velocity of a moving body and state their formulae.

Presentation of lesson

Step I
The teacher solves the following exercise to the students in class;
A car moved in a straight road and the time and distances covered were recorded as follows:

Distance(m)	Time (s)	
0	00	
20	25	
40	53	
60	70	
80	95	
100	121	

(i) Calculate the speed and velocity the car the various distances covered.
(ii) Determine the average speeds and velocity of the car.

Step II

Student will be shown to plot a graph velocity Vs time and speed Vs Time and to determine acceleration using answers in step I.

.

Evaluation: Students to give definition of velocity, speed and show their class work for assessment

Conclusions:
Students are reminded on velocity and graph

LESSON PLAN TWO for control group
Topic: Straight Line Motion in Two Parts
Class: SS 2

Time: 1 hr.
Behavioural Objectives: By the end of the lesson students should be able to

(1) Calculate speed from distance and time measurements.
(2) Graph distance vs time for constant and accelerated motion
(3) Observe that the two motions look different when graphed.

Previous Knowledge: Students have learnt about speed, acceleration and drawing graph.

Instructional Materials:

Graph sheet an mathematical set

Introduction:
Students are asked to describe the motion of the car as it moves along a given road.

What do you need to know to find the speed of your moving car?

Step I The teacher plot the Graph of distance traveled against the time taken from a given data. The teacher describe the nature of the graph

Step II Teacher draws graphs of some motions, and describe the motions for the students.

Evaluation:

Teacher asks students how to calculate speed and draw distant time graph

Conclusions:
Teacher review on how to calculate speed.

LESSON PLAN THREE for Control group
Topic: Momentum And Colliding Spheres
Class : SS 2
Time : 1 Hr

Objective: By the end of the lesson students should be able to :
(1)Identify that mass x velocity equals momentum.
(2)Realise the impacts of collisions and their results.
InstructionalMaterials: Paper, Chalk, Iron Spheres, Marker, Meter Rule and String.
Students' previous knowledge: Students have learnt about velocity and hve seen object colliding
Introduction:

The students are asked to think about the content of an object.
Step I
Students are to be told that the moment of a body is the product of mass of an object and the velocity of the moving body.
Step II
A numerical exercise is be solved by the teacher on momentum
Evaluation.

Students would be asked the meaning and formula for momentum of a body. What is the impact collusion on moving bodies?

Conclusion:
The students will be reminded about the meaning of momentum and its formula

LESSON PLAN FOUR for control Group

Topic: VECTORS
Time: 80minutes
Behavioral Objectives: By the end of the lesson, the students should be able to;
(i) Define a vector and state some its rules.
(ii) Use head to tail rule in addition of vectors.

Students' Previous Knowledge : The students have knowledge of displacement, direction and angle measurements
Teachingmaterials:
Three pieces of chalk of different colors, blue, orange, and green, blackboard protractor

Introduction
Students to state the four cardinal points and describe a triangle
Teacher define a vector for the student
Step I
The teacher draws a triangle on theboard using the different colours showing angles and sides
Step II
Teacher show students on the board how to add vectors "head to tail"..
Evaluation The teacher go over student' note and also ask for definition of a vector quantity
ConclusionStudents are given home

LESSON PLAN FIVE for Experimental group

Topic: Effect of Height on Potential Energy

Class: SS 2

Time : 45 minutes

BehavioralObjective : By the end of the lesson students should be able to;

(i)Define potential and kinetic energy

(ii)State the effect of height on potential energy.

Instructional Materials:

Chart of a ball on top of a slanted edge

Introduction

Teacher asks for definition of potential and kinetic energy from student

Step I

Teacher display chart of object on edge of slanted slide

Teacher explains where the object has potential and kinetic energy

Step II

Teacher ask student to state position of maximum kinetic energy

Evaluation

The students to be asked the effect height on potential energy

Conclusion: Review major information learnt in the lesson.

APPENDIX 8

ERROR FREQUENCY, AVERAGE ACADEMIC SCORES OF STUDY SUBJECTS

AND GENDER

Number of Subject	Sex Male=M Female=F	Academic Scores (%)	Error Frequency		
1	M	56.00	15		
2	M	50.83	24		
3	F	49.50	18		
4	F	46.5	19		
5	M	46.5	19		
6	F	46.83	18		
7	M	43.50	20		
8	M	45.83	19		
9	M	41.5	20		
10	M	62.83	13		
11	M	61.17	13		
12	F	54.83	16		
13	M	59.33	14		
14	F	53.17	16		
15	M	52.33	16		
16	M	51.00	17		
17	M	41.83	20		
18	F	49.5	18		
19	F	43.33	20		
20	F	44.67	19		
21	M	55.38	16		
22	M	37.83	22		
23	M	44.5	19		
24	M	53.83	16		
25	M	48.67	18		
26	M	56.00	15		
27	M	36.33	22		
28	M	53.33	13		
29	M	38.33	22		
30	M	35.17	23		
31	M	51.83	16		
32	M	49.00	18		
33	M	43.00	20		
34	M	51.00	17		
35	F	46.17	9		
36	M	42.17	20		

37	M	41.9	20		
38	M	43.4	20		
39	F	47.37	18		
40	F	47.37	18		
41	M	45.03	19		
42	M	43.70	20		
43	M	39.10	21		
44	M	37.20	22		
45	F	43.43	20		
46	M	41.43	21		
47	F	35.83	19		
48	F	24.97	26		
49	M	56.33	15		
50	M	50.50	17		
51	F	41.67	20		
52	M	50.67	17		
53	M	47.50	18		
54	M	50.83	17		
55	M	38.17	21		
56	M	42.17	20		
57	M	42.50	20		
58	M	30.33	25		
59	M	53.00	16		
60	M	59.83	14		
61	F	50.33	18		
62	M	48.17	18		
63	F	47.83	18		
64	M	44.17	20		
65	M	39.50	21		
66	F	56.67	16		
67	M	46.17	19		
68	F	50.00	17		
69	M	52.50	16		
70	M	53.33	16		
71	M	48.67	18		
72	M	42.00	20		
73	M	47.33	19		
74	M	42.67	20		
75	F	44.83	19		

76	M	48.00	18		
77	M	42.00	20		
78	M	40.50	2 1		
79	F	42.50	20		
80	F	41.50	20		
81	F	36.67	22		
82	F	29.33	25		
83	M	43.17	20		
84	M	50.00	18		
85	M	54.32	16		
86	M	40.33	21		
87	M	45.5	19		
88	M	37.83	22		
89	M	47.67	19		
90	F	44.67	18		
91	F	49.17	19		
92	M	55.33	16		
93	F	44.50	19		
94	F	26.50	27		
95	M	32.17	24		
96	M	60.17	14		
97	F	39.67	21		
98	F	35.17	22		
99	M	35.50	23		
100	M	28.83	25		
101	M	41.67	20		
102	M	39.67	21		
103	M	60.17	14		
104	M	42.17	20		
105	M	26.50	26		
106	M	44.50	19		
107	M	55.33	16		
108	M	49.17	18		
109	M	44.67	19		
110	M	47.67	19		
111	M	45.50	19		
112	M	54.32	16		
113	M	29.33	25		
114	M	42.50	19		

115	M	36.67	23		
116	M	42.50	20		
117	M	48.00	18		
118	M	42.00	20		
119	M	53.33	16		
120	M	54.32	16		
121	F	67.53			
122	M	43.15			

APPENDIX 9

ANOVA test result of PAT on Coeducational Schools in study area

	Sum of squares	df	Mean Square	F	Sig.
Between groups	828.725	3	276.242	4.064	0.009
Within groups	6457.113	96	67.970		
Total	7285838	98			

Significant at $p \leq 0.05$

APPENDIX10

Scheffe's test on three groups' least significant difference

(i)Schools	(J) Schools	Mean Differences (I- J)	Std. Error	Sig.	Lower Bound	Upper Bound
A	B	1.40000	2.33186	.948	-5.2371	8.0371
	C	7.35667*	2.35602	.025	0.6508	14.0625
	D	5.00000	2.33186	.211	-1.67371	11.6371
B	A	-1.40000	2.33186	.948	-8.0371	5.2371
	C	5.95667	2.35602	.101	-0.7492	12.6625
	D	3.60000	2.33185	.500	-3.0371	10.2371
C	A	-7.35667*	2.35602	.025	-14.0625	-0.6508
	B	-5.95667	2.35602	.101	-12.6625	0.7492
	D	-2.35667	2.35602	.801	-9.0625	4.3492
D	A	-5.00000	2.33186	.211	-11.6371	1.6371
	B	-3.60000	2.33186	.500	-10.2371	3.0371
	C	2.35667	2.35602	.801	-4.3492	9.0625

*The mean difference is significant at the 0.05 level

APPENDIX11

Item analysis for Error Diagnostic Test on Theory (EDT)

Item Number	FI=R/T	DI=(RU-RL)/0.5N
1	0.64	0.35
2	0.45	0.40
3	0.65	0.52
4	0.64	0.53
5	0.40	0.33
6	0.80	0.40
7	0.42	0.40
8	0.38	0.63
9	0.52	0.57
10	0.48	0.67
11	0.35	0.42
12	0.55	0.47
13	0.75	0.30
14	0.40	0.60
15	0.54	0.41
16	0.65	0.45
17	0.64	0.68
18	0.78	0.40
19	0.60	0.40
20	0.50	0.52
21	0.60	0.36
22	0.67	0.51
23	0.67	0.47
24	0.60	0.55
25	0.77	0.58
26	0.47	0.47
27	0.67	0.55
28	0.47	0.46
29	0.57	0.58
30	0.53	0.53
31	0.41	0.47
32	0.46	0.41
33	0.55	0.39
34	0.47	0.49
35	0.57	0.50

APPENDIX12

Item analysis for Error Diagnostic on Physics Achievement Test (PAT)

Item Number	FI=R/T	DI=(RU-RL)/0.5N
1	0.65	0.35
2	0.44	0.43
3	0.66	0.52
4	0.65	0.53
5	0.40	0.39
6	0.76	0.40
7	0.47	0.42
8	0.40	0.63
9	0.54	0.55
10	0.48	0.66
11	0.39	0.46
12	0.55	0.47
13	0.72	0.30
14	0.46	0.61
15	0.53	0.41
16	0.67	0.44
17	0.64	0.68
18	0.78	0.43
19	0.60	0.40
20	0.52	0.52
21	0.60	0.36
22	0.67	0.51
23	0.67	0.47
24	0.60	0.55
25	0.77	0.58
26	0.47	0.47
27	0.67	0.55
28	0.47	0.46
29	0.57	0.58
30	0.53	0.53
31	0.41	0.47
32	0.46	0.41
33	0.56	0.42
34	0.48	0.49
35	0.57	0.55
36	0.67	0.54
37	0.45	0.68
38	0.50	0.55
39	0.56	0.60
40	0.61	0.57
41	0.45	0.46

APPENDIX 13
WAEC CHIEF EXAMINERS' REPORT

candidates weakness/remedies

The inadequacies in the performance of candidates were attributed to the following weaknesses:

1. poor expression; inability to interpret correctly the demands of test items framed with some key words such as: explain; define; describe;
2. inability to differentiate between diffusion and osmosis;
3. lack of the skill to represent information graphically and interpret graphs;
4. lack of competence to describe experimental procedure satisfactorily;
5. inability to state precautions taken to ensure accuracy in the experiment;
6. failure to use appropriate concepts of physics to explain observations in everyday life;
7. poor handling of arithmetical calculations.

The suggested remedies were as following:

- Re-training of teachers should be organized by State Ministries of Education in collaboration with WAEC;
- Efforts should be made by teachers to emphasize understanding of basic principles and their applications;
- Schools should put in more effort into the teaching of mathematics so as to improve the students' computational skill;
- Teachers should make greater effort to ensure adequate coverage of the syllabus;
- School principals should monitor coverage of the syllabus by handling the "weekly diary" more purposefully;
- Class room instructions should be related to the students' environment.
- The teaching of Physics should be practical-based.

candidates weakness/remedies

The inadequacies in the performance of candidates were attributed to the following weaknesses:

- poor interpretation of questions
- poor skill in arithmetic
- inadequate knowledge of basic concepts in Physics
- inability to apply knowledge sufficiently

The suggested remedies were as follows:

- physics teachers should strive harder to ensure adequate coverage of the syllabus at all times.
- meaningful test items should be administered from time to time, and matched with true assessments.
- enough time should be allocated for physics on schools time table.
- teachers adequacy should be examined by seasoned and more experienced physics teachers to create rooms for improvement in delivery.
- physics teachers should participate in WASSCE coordination exercise.
- WAEC should make impromptu inspection of schools’ laboratories in order to checkmate inadequacies.
- school libraries should be stocked with enough recommended physics textbooks.