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Integrative Strategy for Effective Teaching of Alternating Circuits in Secondary School Physics: A Guide to Physics Teachers

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Abstract

One of the reasons advanced for the low enrolment and achievement of students in Physics at both secondary and post-secondary schools is poor teaching strategies used by teachers of Physics particularly in teaching Physics concepts classified by students as being difficult. In this paper, integrative strategy for effective teaching of a difficult concept, alternating circuits in secondary school Physics to enhance students' achievement in the subject is proposed. The paper also outlines the principles governing integrative teaching approach. The application of the strategy proposed in

teaching some sub-themes under alternating circuits to guide both teachers and students is shown.

Background of study

According to Ibiok (1998), the problem of many teachers throughout the world is not what to teach but how to teach what. The problem arises from the fact that a school class is a social entity which comprises of students with varying degrees of multidimensional social, academic and psychological problems. The teacher is thus faced with the task of how to reach all the students almost at the same time. This task, no doubt, demands not only adequate knowledge of the concept of what he wants to teach but also an acceptable and effective methodology.

In developing countries like Nigeria, the teaching of Physics in secondary schools now tended to be rigid. The basic flaw in this approach is that it tends to stifle rather than stimulate the interest of the students, particularly those who do not hope to make a career out of science. But these are the very group whom we need to train to develop a continuing interest in and awareness of Physics which is a necessity in the modern world. As Ibiok (1998) maintains, the developing nations should have a high priority for preparing a scientific literate society because without scientific literacy abounding in a sizeable proportion of the society, the effectiveness of introducing modern technology would diminish.

Ibiok (1998) who investigated various methods of teaching Physics in schools found that the conventional lecture method which requires the recipients to listen without attention as the facts are delivered by the teacher was the most commonly used approach. This finding raises the fundamental question of what learning outcomes such instructional method is designed to achieve (Eshiet, 1993). The possible answer to this question calls for the need to reappraise the methods of instruction to adopt the ones most effective in the teaching-leaning process at both the secondary and primary school levels where foundation is laid. This paper addresses itself to some of the ways or appropriate strategies for effective teaching of alternating circuits in secondary schools.

Physics as a science subject, involves both theoretical and practical experiences. For effective teaching and learning of physics, a distinct approach is required. In order to maximize learning teachers are expected to use appropriate strategies bearing in mind the type and academic level of students and the facilities available. Many methods have been advocated by scholars (Ogunneye, 1992, Ibiok, 1998 and Stephen, 2008). Ogunmeye (1992) in particular maintains that learners would achieve significantly higher scores if an integrative strategy is used in teaching the concepts than when a dominative (conventional) strategy is used.

Principles of integrative teaching approach: Integrative teaching strategy is a teaching approach involving practical and theory at the same time. The following principles are involved in integrative teaching approach:

(a) introducing to the students basic apparatus which they will use constantly in the course of practical activities before they are involved in the rigours of how to use them;

(b) where possible, starting the lesson with demonstration activity, involving students and allowing them to observe and draw some conclusions before introducing the day's lesson;

(c) explaining the need for recording and analyzing data obtained accurately.

Sample lesson for teaching alternating circuits using integrative strategies

Subject: Physics

Lesson: Alternating circuits

Class: SS3

Age: Between 15 and 17 years

Duration: 80 Minutes

Objectives Students should be able to:

1. define alternating current and alternating voltage.
2. identify an alternating voltage symbol in a.c. circuits.
3. to set up and draw alternating circuits when alternating voltage is connected across resistor, capacitor and inductor respectively, and when all the three elements are connected together; and
4. to solve simple problems involving capacitor, resistor and inductor.

Materials: Connecting wires, capacitor, inductor, resistor, voltmeter, key, ac source, pendulum bob, thread, ruler and stop watch

Procedure

(1) Introduction

The lesson is introduced by identifying and explaining to students the basic apparatus and terms which they would encounter in the course of learning about alternating circuits thus:

(i). Resistor: This is a device which mainly stores heat energy when current is passed through it. Its circuit representation is thus:

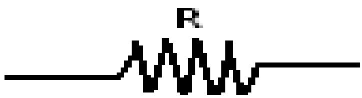


Fig. 1

(ii) Capacitor: This is essentially a device for storing electrical energy or charges. It is generally in the form of two conductors which are insulated electrically from the surroundings. A circuit representation of a capacitor is as shown below.

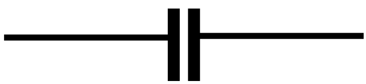


Fig. 2 C

(iii) Inductor: This is a device which mainly stores magnetic energy when a current is passed through it. Its circuit representation is shown below

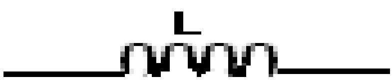
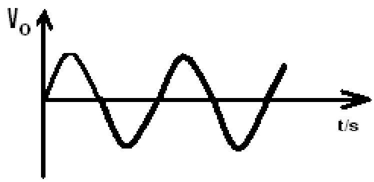


Fig. 3

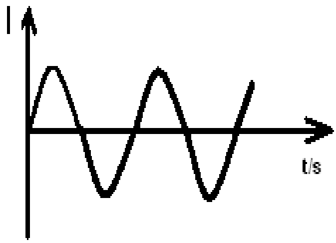
(iv) Alternating Circuit: An alternating circuit is a combination of circuit elements with an ac generator which supplies the alternating current.

(v) Alternating current: An alternating current is the one in which the current changes periodically and it is produced by alternating voltage source.

V against t — I against t



Graph 1



Graph 2

(vi). Alternating Voltage: This is a voltage that varies like sine curve with constant amplitude and frequency. The variation or sinusoidal voltage can be represented as:

$$V = V_o \ \cos \omega t$$

Where V = instantaneous p.d, V_o is the peak p.d or amplitude voltage. $\omega = 2\pi f$ is the circular frequency expressed in radians per second, and f is the frequency in hertz.

(i) AC source: The device that supplies a sinusoidally varying voltage (p.d) V or current (I) is termed an ac source. The usual circuit diagram symbol for an ac source is shown below

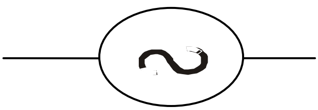


Fig. 4

(2) Students' activity:

Students are divided into four groups and each group is assigned two tasks as follows:

Group A:

Task 1: Students are to perform simple harmonic motion with simple pendulum experiment.

Task 2: In task 2, the students set up alternating circuit with ac source, connecting wires, key, resistor and voltmeter.

Group B:

This group is to repeat the tasks that group one does but in task 2, the students are to use capacitor instead of resistor.

Group C:

This group is to do the same tasks as group 2 but with inductor instead of capacitor in task 2.

Group D:

This group is to set up their tasks as group 3 does but in task 2, the group is to use resistor, capacitor and inductor in setting up the alternating circuit.

Observation:

In task1, it is observed that the velocity changes continuously from zero to maximum. This task 1 as illustrated in the diagram below will give students a fair idea on how both voltage and current attain their maximum, zero and minimum values at the same time when resistor is used in a.c. circuit.

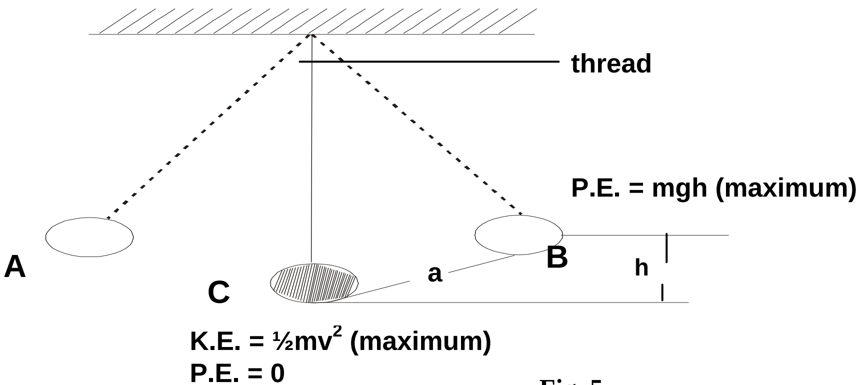


Fig. 5

In task 2, students should be able to draw alternating circuits when resistor, capacitor and inductor are used, noting their different symbols.

Resistor (R) in an AC circuit

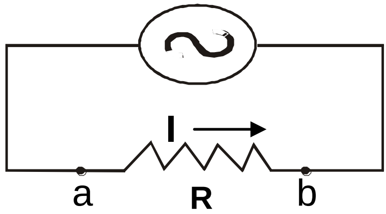


Fig. 6

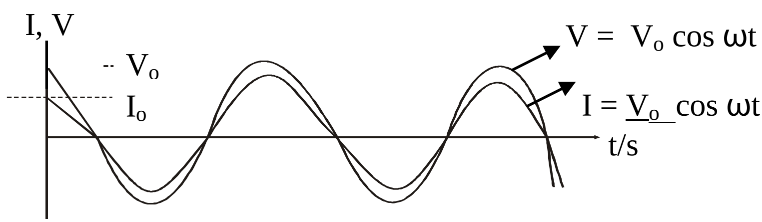
Let's consider a resistor with resistance, R through which there is a sinusoidal current, $I = I_o \cos \omega t$. The positive direction of current is counterclockwise round the circuit. The current amplitude (maximum or peak current) is I_0. From Ohm's law the instantaneous potential, V across the resistor is given by

$$V = IR = (I_oR) \text{ Cos } \omega t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The current I and voltage V, are both proportional to Cos ωt, so the current is in phase with the voltage and the peak current I_o is given by

$$I_o = V_o/R.$$

The graph of I and V for a circuit containing R



Graph 3

By current, 'I' and voltage, 'V' being in phase we mean both attain their peak, zero and minimum values at the same time. The vertical scales for current and voltage are different, so the relative heights of the two curves are not significant. Their projections on the horizontal axis represent the instantaneous current and voltage respectively.

Inductor in an A.C. circuit

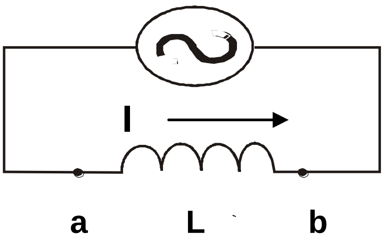


Fig. 7

Next, we replace the resistor in Fig. 6 with a pure inductor with self-inductance L and Zero resistance as shown in Fig. 7. Again we assume that the current is $I = I_o \cos \omega t$, with the positive direction of current taken as counter-clockwise around the circuit.

Although there is no resistance, there is potential difference V_L between the inductor terminals ***a*** and ***b*** because the current varies with time, giving rise to a self-induced emf. The induced emf in the direction of I is given by

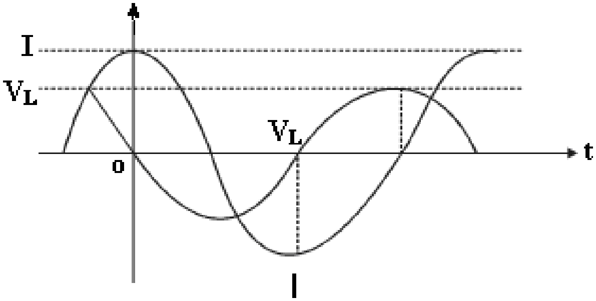
$$V = IR, \quad E = -\frac{LdI}{dt}$$

However, the voltage V is not simply equal to E. To see why, notice that if the current in the inductor is in the positive (counter clockwise) director from ***a*** to ***b*** and is increasing, then dI/dt is positive and the induced emf is directed to the left to oppose the increase in current; hence point ***a*** is at higher potential than is point ***b***. Thus the potential of point ***a*** with respect to point ***b*** is positive and is given by $V_L = +L\, dI/dt$, the negative of the induced emf.

So we have;

$$V_L = +L\, dI/dt = L \frac{d(I_0 \cos \omega t)}{dt} = -I_0 \omega L \sin \omega t \quad \text{.....(2)}$$

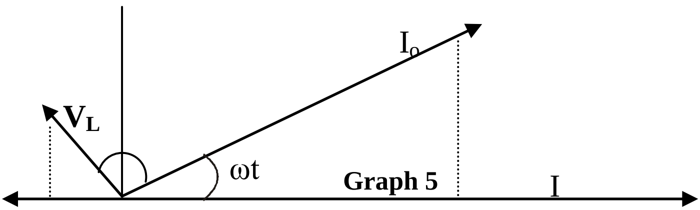
Graph 4



Graphs of instantaneous voltage and current

The V_L a cross the inductor at any instant is proportional to the rate of change of the current. The points of maximum voltage on the graph correspond to maximum steepness of the current curve, and the points of zero voltage are the points where the current curve instantaneously levels off at its maximum and minimum values.

The voltage V_L across the inductor at any instant is proportional to the rate of change of the current.



The voltage and current are 'out of step' or 'out-of-phase' by a quarter – cycle. Since the voltage peak occurs a quarter–cycle earlier than the current peak, we say that the voltage leads the current by 90^0. This is illustrated in the graph of instantaneous voltage and current above. We can also obtain this phase relationship by rewriting eqn (2) using the identity;

$\cos(A + 90^0) = -\sin A$: $V_L = I_0 \omega L \cos(\omega t + 90^0)$..............................(3).

This result shows that the voltage can be viewed as a cosine function with a "head start" of 90^0 relative to the current. As we have done in eqn (3), we will usually describe the phase of the voltage relative to the current, not the reverse. Thus if the current I in a circuit is $I = I_0 \cos \omega t$, and the voltage V of one point with respect to another is: $V = V_0 \cos(\omega t + \phi)$ where ϕ = phase angle which gives the phase of the voltage relative to the current.

For a pure resistor, $\phi = 0$ and for a pure inductor, $\phi = 90^0$ from eqn (3), the amplitude V_L of the inductor voltage is; $V_L = I_0 \omega L$ .... (4).

We define the inductive reactance X_L of the inductor as;

$X_L = \omega L$ .... (5). Using; X_L, we can rewrite (4) in a form similar to (1) i.e. $V = IR$.

$V_L = IX_L$ .... (6) (amplitude of voltage across an inductor, ac circuit).

Because; X_L is the ratio of a voltage and a current, its S.I unit is the ohm (Ω), the same as for resistance.

Capacitor in an AC circuit

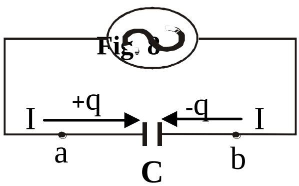


Fig. 8

Finally, we connect a capacitor with capacitance C to the source producing a current

$I = I_0 \cos \omega t$ through the capacitor as shown in the figure 8 above. Again, the positive direction of current is counter clockwise around the circuit.

To find the instantaneous voltage V_c across the capacitor, that is, the potential of point ***a*** with respect to point ***b***, we first let ***q*** denote the charge on the left-hand plate of capacitor as shown in the diagram above.

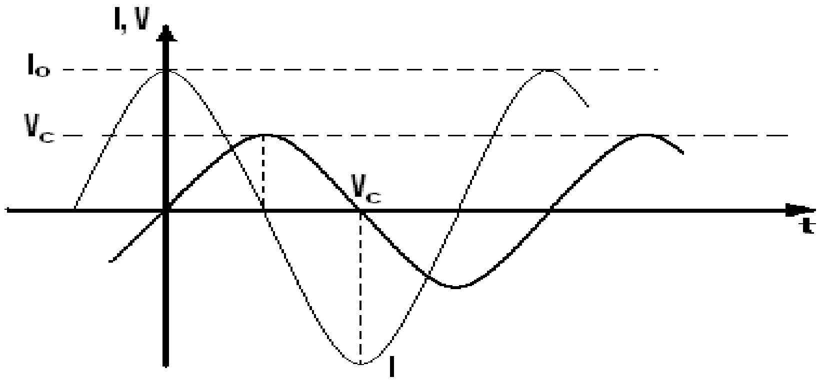
The current, I is related to ***q*** by I = dq/dt, with this definition positive current corresponds to an increasing charge on the left hand capacitor plate. Then

$$I = dq/dt = I_o \cos \omega t \text{ ....(7)}$$

Integrating this, we obtain: $q = {}^{1}/\omega \times \sin\omega t$

Recall: $q = CV_C$ (the charge q = voltage V_C x the capacitance, C)

$$V_C = 1/\omega c \times \sin\omega t \text{ .... (8)}$$



Graph 6: Graph of instantaneous voltage and current.

This figure shows V_c and I as function of t. Because $I = dq/dt = CdV_c/dt$, the current has it's greatest magnitude when V_c curve is rising or falling most steeply and is zero when V_c curve instantaneously levels off at its maximum and minimum values.

The capacitor voltage and current are out of phase by a quarter cycle. The peaks of voltage occur a quarter cycle after the corresponding current peaks and we say that the voltage lags the current by 90^o. We can derive the phase difference by rewriting eqn (8), using the identity

$$\cos (A - 90) = \sin A$$

$V_c = 1/\omega c \cos(\omega t - 90)$………. …………………………………(9)

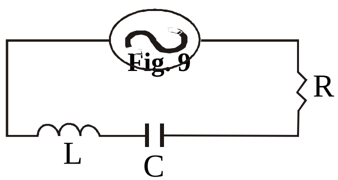
This corresponds to a phase angle $\phi = -90^o$

Eqns (8) and (9) show that the maximum voltage V_c (the voltage amplitude) is: $V_c = 1/\omega c$.

To put this expression in a form similar to V= IR for a resistor, we define a quantity X_c, called the capacitive reactance of the capacitor as: $X_c = 1/\omega c$………….. ……………(10)

Therefore, $V_c = I_o X_c$ (amplitude of voltage across a capacitor, ac circuit).

The L-R-C Series circuit



Many a.c. circuits used in practical electronic systems involve resistor (R), inductor (L) and capacitor (C). A simple case where the three elements are connected in series is shown in figure 9 above. The overall resistance of a mixed circuit containing any two or all the three elements is called ***Impedance***, denoted by Z and defined in the same way as the resistance. If $V_{r.m.s}$ is the effective voltage and $I_{r.m.s}$ the effective current then

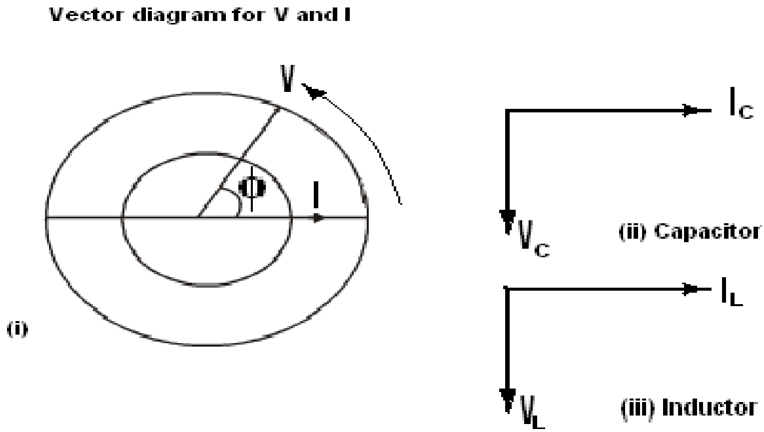
$$Z = \frac{V_{r.m.s}}{I_{r.m.s}}$$

We should expect a phase difference to exist between current and voltage inthe case of a mixed circuit. This is because a phase difference of 90^o ($\pi/2$) between current and voltage exists in both case of a capacitor and inductor.

Vector diagram

Vector diagram is a simple method of analyzing a circuit and in doing so it is convenient to use rotating vectors as shown below. In doing this we take note that in a capacitor, current leads the voltage by or $\pi/2$ or a quarter of a cycle or 90^0 while in an inductor, the current lags the voltage.

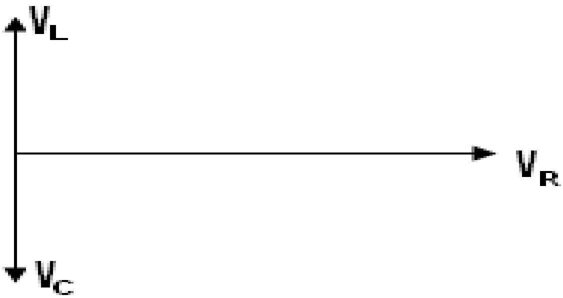
Fig. 10



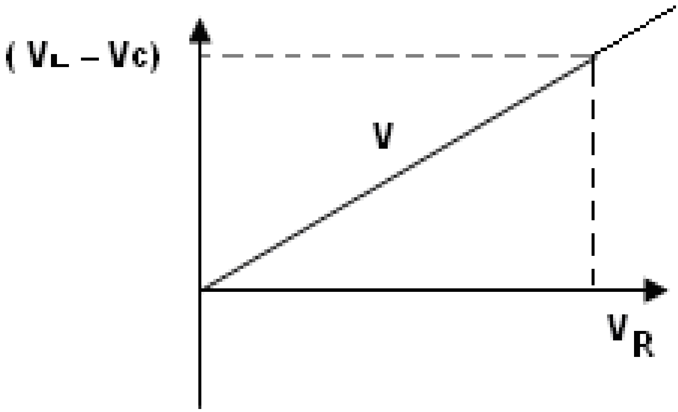
Consider an anticlockwise rotation which is at a phase angle ϕ, the capacitor or inductor is at right angle throughout the rotation as shown in figures 10 (ii) and (iii) above.

In the L-R-C series circuit discussed in this paper, the current is the same for all the circuit components. The voltage is in phase with the current and voltage is therefore used as the reference vector V_R. The voltage vector V_L and current vector V_c are drawn at right angles to V_R as shown below;

Vector diagram for effective voltages



Graph 7



Graph 8

We have shown from the definition of resistance and reactance that

$V_R = IR$; $V_L = IX_L$; and $V_c = IX_c$ then applying Pythagoras theorem to

the figure above $V = \quad V^2_R + (V_L – V_c)^2$

$= \quad I^2 [R^2 + (X_L - X_c)^2]$

$$V = I\sqrt{[R^2 + (X_L - X_c)^2]}$$

$$\text{But } Z = \frac{V}{I} = \sqrt{[R^2 + (X_L - X_c)^2]}$$

Then phase angle ϕ is given by

$$\tan\phi = \frac{V_L - V_c}{V_R} = \frac{X_L - X_c}{R}$$

Hence if X_L is greater than X_c, ϕ is positive and the voltage leads the current but if X_L is less than X_c, ϕ is negative and the voltage lags the current.

From the last two equations, if the circuit contains only R and L, then

$$Z = \sqrt{V_R^2 + X_L^2} \text{ and } \tan\phi = \frac{X_L}{R}$$

$$\text{For R – C circuit, } Z = \sqrt{R^2 + X_c^2} \text{ and } \tan\phi = \frac{X_C}{R}$$

Advantages of integrative teaching approach

The following are the advantages of integrative strategy over the conventional lecture method used by Physics teachers in senior secondary schools:

1. It helps to concretize ideas and concepts and thereby stimulates imagination.
2. It does not only help the teacher to explain the lesson but also makes the lesson practical. This is because the strategy carries along with it appropriate resource materials.

3. The strategy stimulates simultaneous in the learner both the sense of vision and sense of hearing.
4. It creates variety which arouses the learners interest and thereby sustain their attention and retention of the lesson taught.
5. The strategy is student-centered and not teacher-centered.

Class assignment: A capacitor of capacitance 2 μF is used in a radio circuit where the frequency is 500 Hz and current flowing through is 5 mA. Calculate

a) the reactance of the capacitor

b) the voltage across the capacitor.

Conclusion and recommendation

The study was on the use of integrative strategy as an effective approach for teaching alternating circuits in secondary school Physics. In the study, the strategy was used in teaching sample lessons on:

1. Resistor (R) in an ac circuit;
2. Inductor (L) in an ac circuit;
3. Capacitor (C) in an ac circuit; and
4. L-R-C series circuit.

The recommendation is that Physic teachers should adopt integrative strategy as a teaching method.

References

Anyakoha, M. W. & Okeke P. N. (1998). *Senior Secondary Physics (Revised Edition)*. London, Macmillan.

Eshiet, I. T. (1993). *Scientific Concept and Application.* Methodology of Science Teaching (Hisitorical and Conceptual Approach) Abak, Belpot (Nig) Co.

Eshiet, I. T. (1986). The need for innovation and creativity in science teaching as exemplified by the use of water as a source of energy . Science Teachers Association of Nigeria (STAN), 21(1) (pp.64 -71).

Folivi, L. E. & Godman, G (1978). *New Certificate Physics*. London, Butter and Tanner Ltd.

Freeman, R. A & Young, H. D (2004). *University Physics (11th Edition).* New York, Addison Wesley

Ibiok, E. S. (1998). Strategies for teaching difficult concepts in Physics in secondary schools: a guide for teachers. *Nigerian Journal of Vocational Teachers Education (NJOVTE)*, 1(1) (pp78 – 85).

Ogunneye, W. (1992). *Effective Practical Physics for Secondary Schools*. Ijebu-Ode, Jimmy Press Ltd.

Stephen, U. S (2008). Effective teaching and learning of simple machines in primary schools, *Proceeedings of cience eachers association of Nigeria (STAN)* Workshop (pp58-66).