

TECHNOLOGICAL DEVELOPMENT THROUGH EFFECTIVE SCIENCE TEACHING

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Preamble: I am sincerely grateful to the Workshop Director for inviting me to be a part of this very important workshop. It is true that unless there is an action there cannot be a reaction. We cannot expect something new and better while still doing things the old way. In other words, we cannot use old methods to get new results. That is why the theme of this workshop is apt. If we must acquire and develop our indigenous technology, science teaching must be done differently from what is going on now. In 1957, for instance the Russian went into space for the first in the history humanity with a spacecraft called SPUTNIK. This posed a lot of challenges to nations of the world, particularly America who promised to get to space before the end of next decade. In order to actualize this they had to restructure their science curricula as well as adopt new and eventful methods and strategies for teaching science. With these, they were able to actualize their dream in 1969.

Science:

The importance and the role of science cannot be overstated. It is through science people receive awareness and understanding of the environment, make discovery and embark upon technological development. To realize this noble role, the teaching of science has to be done effectively. Admittedly, the teaching of science could be very challenging due to its nature and the low scientific literacy of our society.

Science has two major types of concepts, namely, empirical and theoretical (abstract). Empirical concepts are directly perceivable, quantifiable and measureable, while theoretical concepts mostly exist in abstraction and cannot be directly and simply measured and quantified. Moreover, science has two major

dimensions, namely Process and Product. As the name implies, the process dimension has to do with the methods, strategies and approaches utilized in obtaining scientific facts, principles, theories and concepts which are collectively referred to as the product of science. The two dimensions are mutually related and inseparable. Effective teaching of science should therefore incorporate and emphasize these dimensions. Students should be taught the same way scientists practice science.

Technology:

While science focuses on the discovery and generation of knowledge about the environment (immediate and remote), technology focuses on the utilization of these knowledge in producing skills, materials, tools, machines and gadgets capable of enhancing human life and comfort. In between Science and Technology are Mathematics and Engineering. The development of technology often draws and harnesses many fields of human endeavors that include science, Engineering, Mathematics, cultural and linguistic knowledge to better off human dignity and longevity.

The world has witnessed and is still witnessing lots of technological development. The invention of the printing machine made it possible for scientists, politicians and researchers to communicate their ideas findings with ease. This led significantly to the age of enlightenment and communication until the invention of integrated circuit that culminated in the modern computer.

By the middle of 20th century, scientific knowledge was so harnessed and applied that man could be able to overcome gravitation pull and to leave the earth atmosphere to explore space for the first time. Today, automobile and aeronautical technologies have tremendous impacts on transportation. Within the last few months there have been reported cases of flying cars and bicycles.

Information technology has been extensively developed. Now you can stay in the comfort of your house to watch events and to communicate with anyone anywhere in the world. All these will be utopic if science is not effectively taught in our institutions of learning.

Effective Science Teaching:

Just as science has two major dimensions, the teaching of science equally has two dimensions, namely the content; that is, **what to teach**, which is synonymous with the product of science; and **how to teach**, which has to do with pedagogy and is analogous with the **process of science**. It is therefore necessary for science teachers to be fully acquainted with the two components for meaningful and effective teaching of science. The science teacher is expected to have an in-depth knowledge and understanding of the concept to be taught, the skills involved and possible areas where the knowledge involved could be applied. In the same way he/she must know how best a particular concept could be taught. There are many methods, strategies and approaches to the teaching of science. These are chosen based on criteria that include:

- The nature of the concept
- The available facilities and teaching/learning materials
- Entry behaviors of learners
- Resourcefulness of the teacher

Appropriate teaching approach/method.

Central to most psychological theories applicable to science teaching is the emphasis on the structuring of learning materials. In making physics real, there must be proper structuring of teaching/learning materials. While Ausubel (1968) prefers a structuring from the most inclusive to the least inclusive, Gagne, Briggs and Wagor (1992) prefer from the least inclusive to the most inclusive. Whichever structure is preferred, the principles enshrined in the structure should be followed to avoid haphazard delivery of lessons.

For instance, Ausubel learning theory emphasizes the incorporation of the new material into the cognitive structure for learning to be made meaningful. The meaningfulness referred to here is analogous to making it real. It is the duty of

the teacher therefore to effectively plan his/her lesson. On the other hand, Gagne emphasizes **task analysis** which is cored on prerequisite learning.

Moreover, besides structuring emphasized by Gagne, guided discovery (enquiry approach) is equally emphasized. **Students should be taught science in the same way scientists practice science.**

Among the recommended ways of teaching science effectively are:

- ❖ Enquiry approach
- ❖ Demonstration method
- ❖ Integration of practical work in the teaching/learning process.
- ❖ The use of multimedia approach

Enquiry-based teaching/learning:

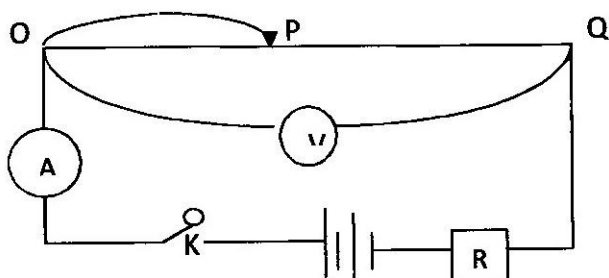
This approach is learner-centered. The intention is to develop in the learner scientific attitudes such as inquisitiveness, objectivity and the ability to undertake an objective observation of the environment and natural phenomena. Furthermore, Enquiry approach in science teaching is capable of enhancing the acquisition of creative, critical and reflective thinking skills in the learners which are considered crucial for entrepreneurship. In an Enquiry approach, learners are encouraged to initiate teaching/learning process by asking questions based on what they observe practically in a particular concept.

Alternatively, the process can start with the teacher assisting the learners to observe certain phenomena and then asking them to explain each. The fundamentals of Enquiry approach are objective observation and questioning.

Enquiry approach, although very taxing and involving, is efficient in the development of skills. As students are provided with certain information and are guided to discover some additional information, the subject will become real and useful to them.

Being a laboratory-oriented in most cases, this approach should affect the type of practical questions teachers present. Some physics teachers, for example, are still adherence to cookbook practical physics.

Case Study I



You are provided with a potentiometer, an ammeter, a voltmeter, a standard resistor and other necessary apparatus. Using the circuit diagram above as a guide, carry out the following instructions:

- (i) Connect the circuit as shown in the diagram above.
- (ii) Close the key, K read and record the Ammeter reading I_0 and Voltmeter reading, V_0 when Jockey J is not making any contact with potentiometer wire OQ.
- (iii) Using Jockey, J, make a contact with the potentiometer wire OQ at a point P such that $OP = 10\text{cm}$
- (iv) Read and record the current, I and the corresponding value of the voltage, V .
- (v) Repeat the procedure for other values of $OP = 20\text{cm}, 30\text{cm}, 40\text{cm}, 50\text{cm}$ and 60cm .
- (vi) Tabulate your readings.
- (vii) Plot a graph of V against I , starting both axes from the origin.
- (viii) Determine the slope S , of the graph.
- (ix) Determine the value of V when $I = 0$
- (x) State 2 precautions taken to obtain accurate results.

Alternative case.

1. Connect up the circuit as shown in the diagram.
2. Starting with V_0 , make a contact with the potentiometer wire OQ at a point P such that $OP = 10\text{cm}$
3. Make other similar contacts, taking the corresponding values of V and I in each case.
4. Determine the resistance R of the potentiometer wire.

By reducing the details from 10 to 4, students are given the opportunity to think. For example the problem of determining the resistance of the wire, given the clues, should lead the student to look for the following: that

- (i) $R = V/I$
- (ii) to determine R a slope is needed.
- (iii) to have a slope, a graph is needed.
- (iv) to have a graph there is need to have more readings than for the length of 10cm. He/she will now use his/her discretion to determine the intervals.
- (v) there is need to arrange the readings in a table.

Case Study 2.

You are provided with a water bath (beaker) copper block, stirrer, polyethylene cup calorimeter, retort stand/clamp, a piece of thread and water.

- (i) Firmly support one end of the thread provided on the clamp of the retort stand and tie the copper block to the other free end of the thread.
- (ii) Heat the copper block in boiling water for at least 10minutes.

- (iii) Weigh the polyethylene cup calorimeter empty and again when about 2/3 filled with water at room temperature. Record the water temperature.
- (iv) Bring the calorimeter close to the bath and quickly transfer the copper block into it. What is your reason for the quick transfer?
- (v) Stir the water gently with the thermometer and carefully record the highest temperature of the mix (Note: The highest temperature is reached within about 30seconds of transferring the block).
- (vi) Weigh the copper block after it has cooled completely.

Alternative case:

You are provided with a water bath (beaker), copper block, stirrer, polyethylene cup calorimeter, retort stand/clamp, a piece of thread, water and a thermometer.

- i. Heat up the copper block in water to a certain temperature before transferring it to the polyethylene cup calorimeter with water.
- ii. With this arrangement determine the amount of heat transferred by the copper block to water and the calorimeter.

Demonstration method:

Another effective way of teaching science is by practically demonstration the concept involved. Demonstration can be carried out in the following forms:

- ✓ Teacher demonstration
- ✓ Student demonstration
- ✓ Teacher-Student demonstration
- ✓ Student-Student demonstration

It should be noted that a lesson in science does not, necessarily need to start with definitions; it could better start with demonstration. In other words, an effective science lesson could start with practical sessions.

The teaching/learning of scientific concepts: Integration of theory and practical work

The tradition of separating physics practical from the theory classes does not seem to help much. It is time to begin to see that there exists no dichotomy between theory and practical work in science. Every topic or concept in science has practical orientation.

In making science real and its teaching effective, practical work must be incorporated into the theory. A more effective teaching starts with practical work in most cases. This fosters better understanding than starting it theoretically.

Case studies:

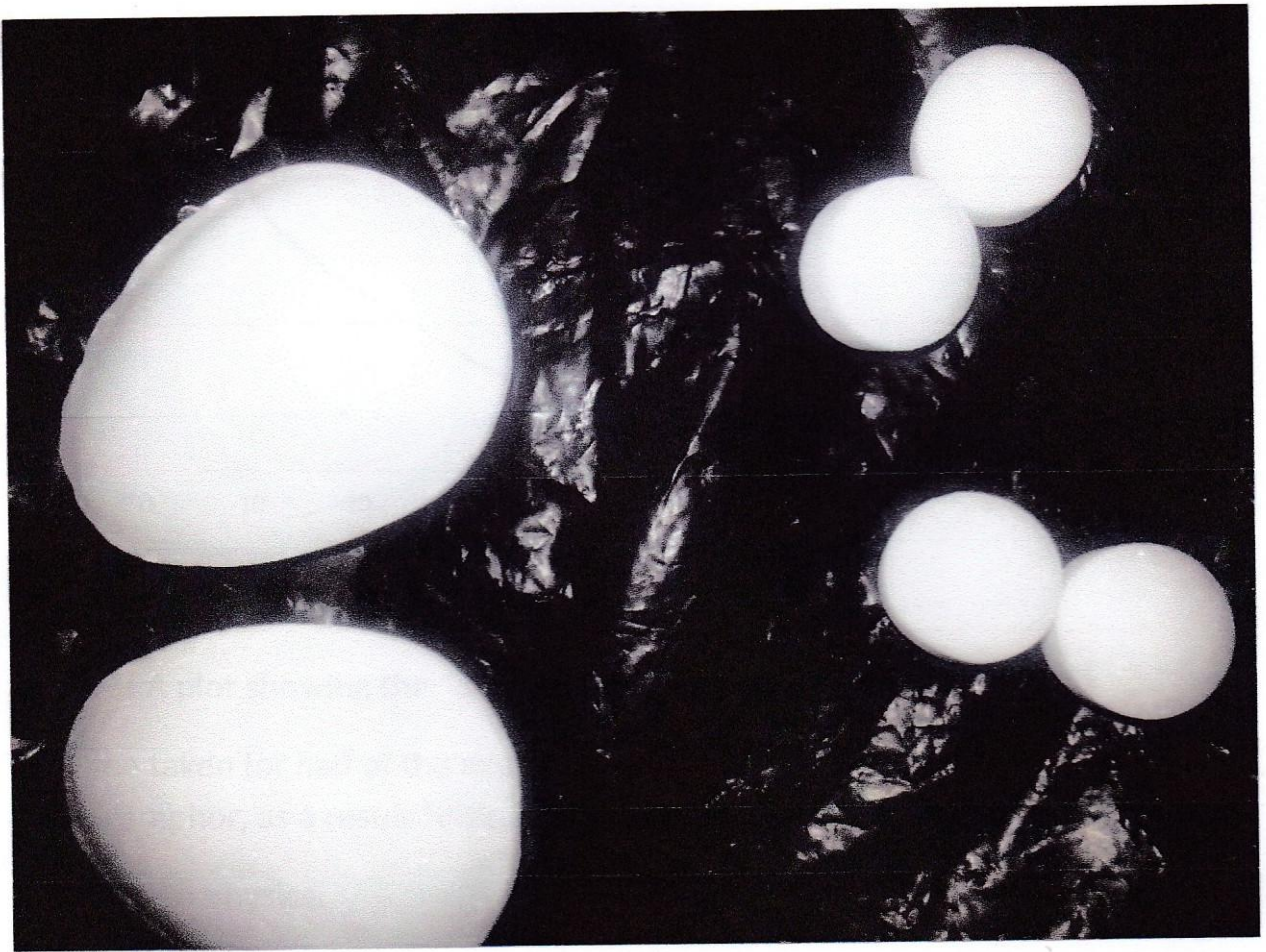
1. For instance, many teachers approach the concepts of heat capacity and specific heat capacity by defining what they mean. The next thing is to give their equation and then begin to solve numerical problems, when the actual conceptualization of the concept is not fully grasped.

What would happen if the lesson starts with say 4 similar beakers containing the same volume of, say, water, kerosene, palm oil and groundnut oil and same amount of heat from a steady flame is applied to each beaker and its content for say 5 minutes after the initial temperature of each was taken? Taking the temperature of the liquids after the said time will indicate that within the same time frame, the temperature of the liquids rose up differently. That is, same amount of heat given to those substances caused their temperature to rise differently. Then find the time required for each liquid to have its temperature risen for 1°C . This will give different time durations which shows different amounts of heat transferred to the system.

In the same way, lessons on Faraday's laws of electrolysis, in Chemistry, can start with experimentation to end up with the statements of the laws and the quantitative level of the concept. Equally in Biology, lessons on cell and cell theory should proceed from learners' observation of cells both with their naked eyes and with the eyes aided.

2. Radioactivity is a theoretical concept. The practice has been that we teach it mathematically as one cannot use a radioactive substance for practical. But we could use **camphor** to aid students understanding of the concept of half-life of a

radioactive substance. The mass of the camphor can be observed periodically over time and a graph of mass with time plotted.



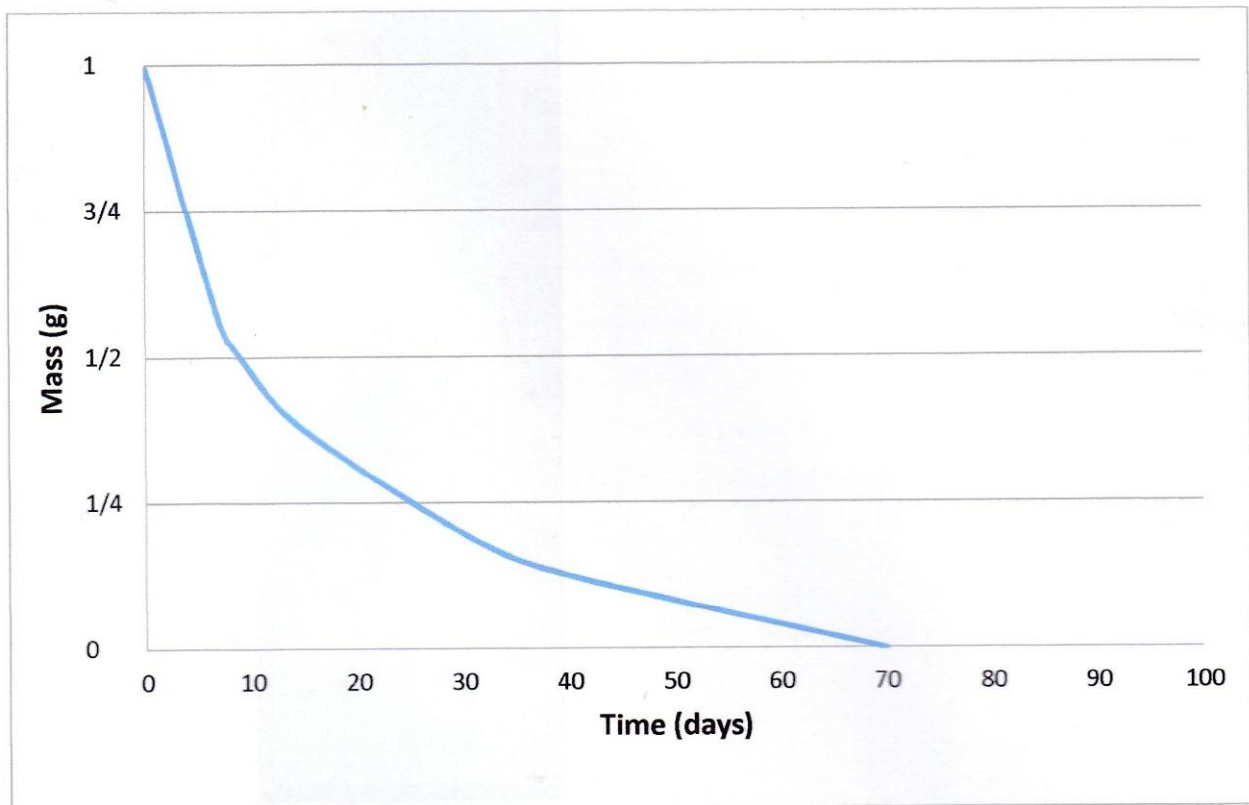


Figure 1: A plot showing the “disintegration” of camphor with time.

The time taken for half of the mass of camphor to remain denotes the “half life” of the camphor, as a result “disintegration”.

Multimedia physics.

Another primary way of making physics real is by using a multimedia facility either through simulators or animations. My experience with physics students has shown that the great majority of them do not understand the concepts they are taught in physics, especially when the concept is a theoretical one. By using animation, the students will be able to see by multimedia arrangement the activities involved and will have their understanding and comprehension enhanced.

1. Free fall of objects: - It seems unimaginable ordinarily to believe that an elephant for instance can fall to the ground from a certain height using the same time with a feather from the same height.

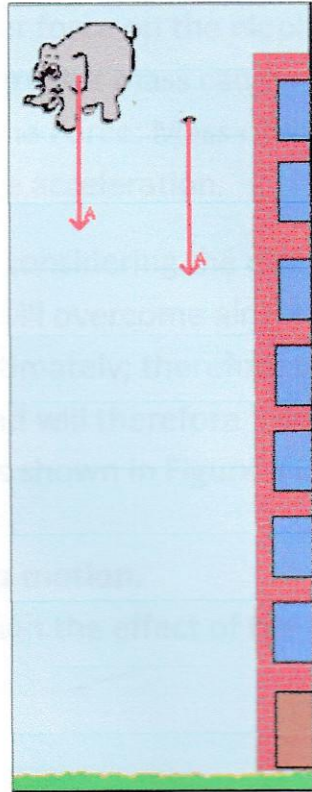


Figure 2: Elephant and feather in a free fall.

Source: <http://www.physicsclassroom.multimedistudio>

Reasons:

It is known that all objects irrespective of their masses will experience the same pull towards the earth if air resistance is neglected. This acceleration known as acceleration of free fall has a magnitude of 9.8m/s^2 .

Generally

$$F = ma$$

$$a = F/m$$

Note:

- i. The force on the elephant is greater than that on the feather.
- ii. The mass of the elephant is greater than that of the feather.

iii. The greater force on the elephant is expected to cause it to accelerate more but its greater mass causes the Force: Mass ratio for the elephant to be the same as the Force: Mass ratio of the feather, thereby causing the two to have the same acceleration.

However, considering the effect of air resistance, the greater weight of the elephant will overcome air resistance much more than is the case with the feather ultimately; therefore the elephant will accelerate more than the feather and will therefore take a shorter period of time to land the earth surface, as shown in Figure 3 (Elephant and feather in a non-free fall).

2. Projectiles motion.

By extension the effect of the force of gravity is seen in the motion of projectile.

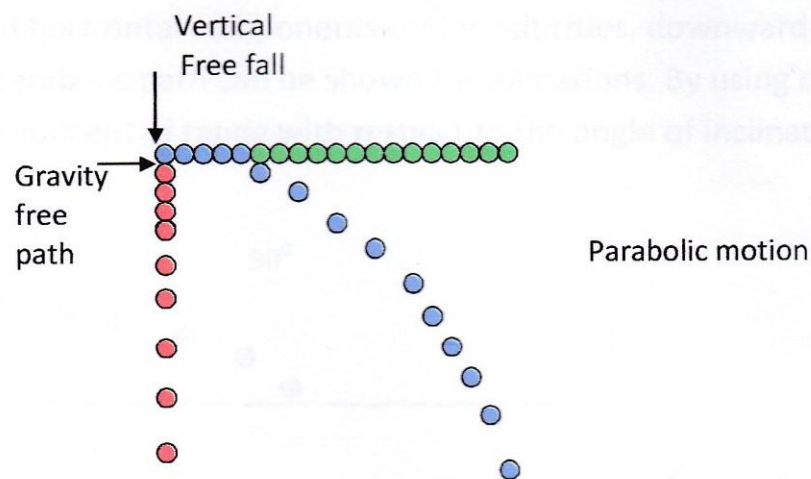


Figure 4: Effect of gravity on projectiles.

Source: <http://www.physicsclassroom.multimediasudio>

A projectile is an object upon which the only force is gravity. Although gravity attracts the projected downward, it does not affect its horizontal velocity. The

only effect of gravity on the horizontally moving object is to alter its direction such that the path becomes parabolic.

For a horizontally launched projectile, using cannon ball

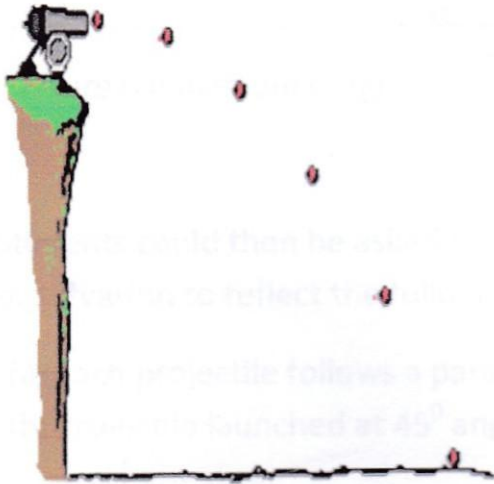
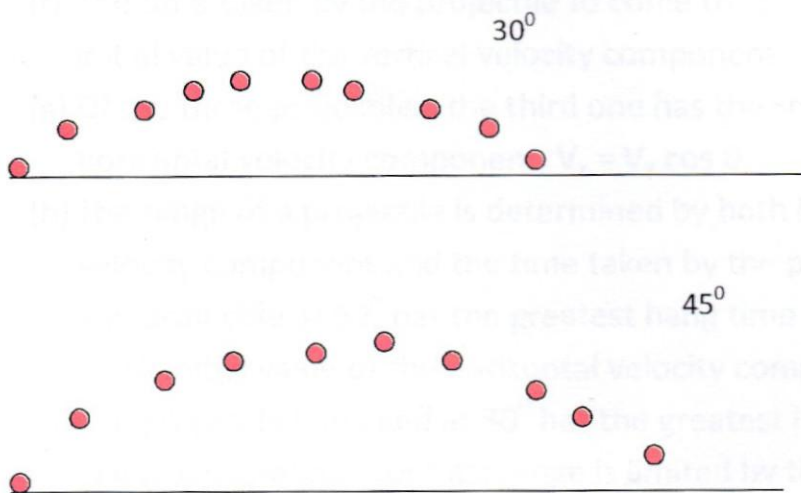


Figure 5: Horizontally launched project

The vertical and horizontal components of the velocities, downward acceleration as well as the parabolic path can be shown by animations. By using different projectiles, the concept of range with respect to the angle of inclination can be demonstrated.



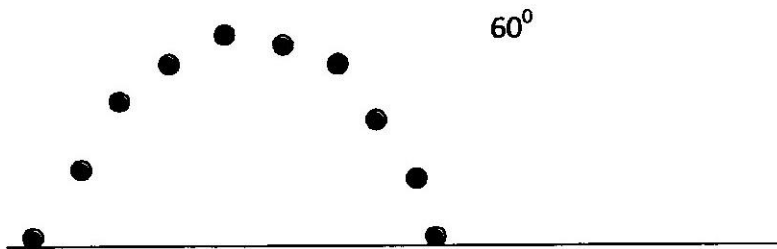


Figure 6 maximum range

Students could then be asked to observe and analyze by the initial value their observation to reflect the followings:

- (a) Each projectile follows a parabolic path.
- (b) Projectile launched at 45° angles had the greatest range, medium peak height and hang time.
- (c) The projectile launched at 60° angle had the highest peak height before falling, but the smallest range and highest hang time (reach the ground last).
- (d) The projectile launched at 30° angles reached the ground first and has the smallest peak height.
- (e) The peak height of a projectile is determined by the initial value of the vertical velocity component. The higher V_y , the greater the peak height, $V_y = V_x \sin \theta$
- (f) The time taken by the projectile to come to rest is also determined by the initial value of the vertical velocity component.
- (g) Of the three projectiles, the third one has the smallest initial value of the horizontal velocity component, $V_x = V_y \cos \theta$
- (h) The range of a projectile is determined by both its initial value of horizontal velocity component and the time taken by the projectile to come to rest.
- (i) The projectile at 60° has the greatest hang time but it's range is limited by the small initial value of the horizontal velocity component.
- (j) The projectile launched at 30° has the greatest initial value of the horizontal velocity component but it's range is limited by the very short hang time.

3. Wave's motion: Standing waves.

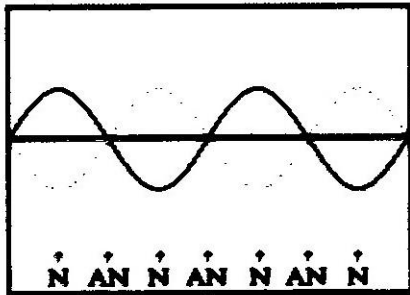


Figure 7: Standing Wave

Source: <http://www.physicsclassroom.multimediastudio>

With this we can demonstrate:

- (k) Standing waves.
- (ii) Interference of waves.
- (iii) Nodes – location where two waves interfere such that one is displaced upward and the other downward to the same amount.
- (iv) With this type of interference, there is no displacement and is therefore called destructive interference.

Students should identify the blue and green waves in the animation moving in opposite directions; blue to the right and green to the left, and the black wave that shows the resultant wave. They should also observe that the interference is as the result of the two waves moving in opposite direction with same frequency, added together in accordance with the principle of superposition. There are a variety of patterns which could be produced based vibration at certain frequencies.

Each pattern corresponding to vibration at a particular frequency is known as harmonic. The lowest frequency of vibration to bring about standing wave is what is seen in Figure 7 and is referred to the first harmonic.

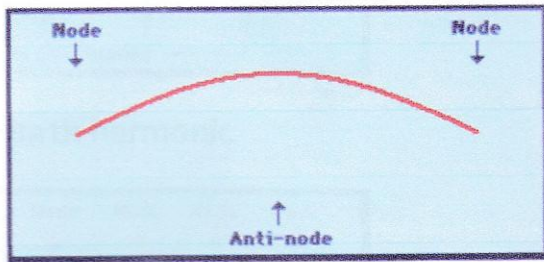


Figure 8a: First harmonic

Then we can then show the animation of second, third and fourth harmonics.

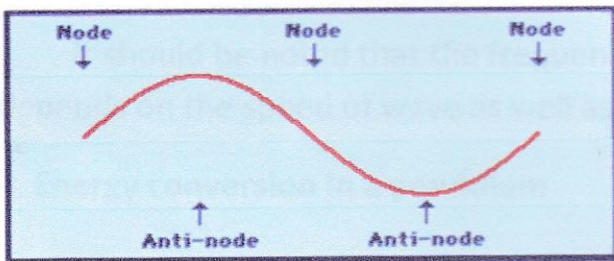


Figure 8b: second harmonic

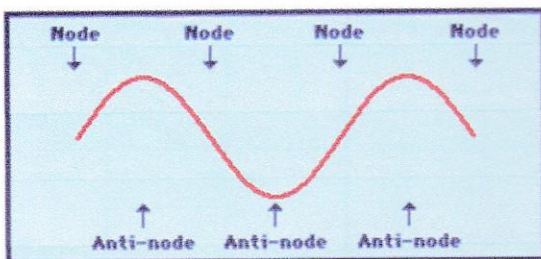


Figure 8c: third harmonic

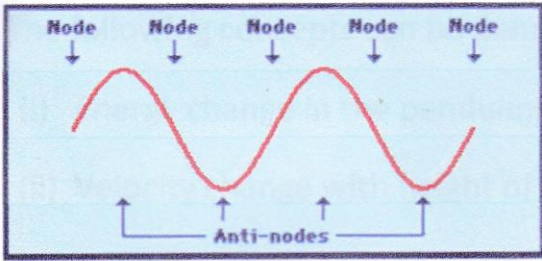


Figure 8d: fourth harmonic

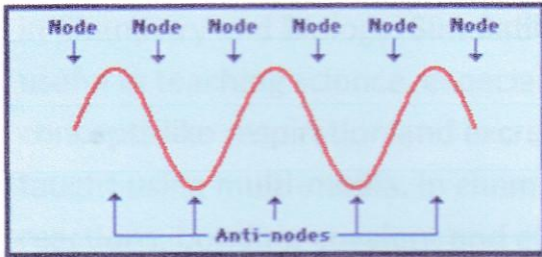


Figure 8e: fifth harmonic

It should be noted that the frequency associated with each harmonic depends on the speed of wave as well as the wavelength in the medium.

4. Energy conversion in a pendulum

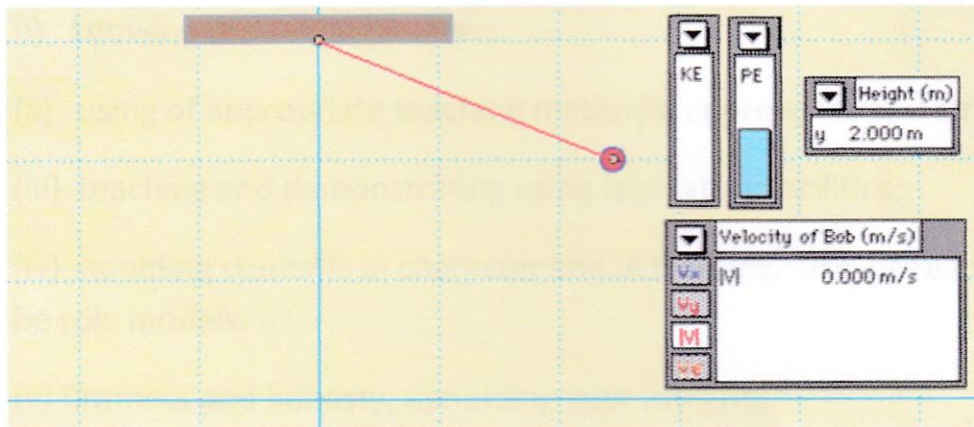


Figure 9: Energy conversion in pendulum

Source: <http://www.physicsclassroom.multimediasudio>

The following concepts can be demonstrated thus animation

- (i) Energy change in the pendulum
- (ii) Velocity change with height of the pendulum.
- (iii) Energy conversion in the system.

You will notice that I have only used multimedia physics. The same is applicable in Chemistry and Biology. Simulations, using multi-media approach are very useful in teaching science, especially theoretical concepts. In biology, for instance concepts like respiration and excretion in organisms could be more effectively taught using multi-media. In chemistry, concepts such as rates of chemical reactions, bonding-covalent and electrovalent are better taught using simulations.

Commitment to work.

Let me round off by emphasizing that fundamental to all the areas we have considered in teaching science effectively is our commitment to work.

Teaching is different from lecturing. It is more demanding than other forms of professions. As science teachers we are expected to be committed to:

- (i) knowing the subject matter;
- (ii) using of appropriate teaching methods, approaches and strategies;
- (iii) teaching and demonstrating using laboratory facilities;
- (iv) moulding students in character and in learning. To succeed in this, we must be role models.
- (v) firmness and honesty, upholding your integrity.

It should be noted that teachers are like pastors. They do not only teach what they know but also who they are. While the first part is often carried out consciously and overtly in the classrooms/ laboratories, the second is done unconsciously within and outside the institution. Failing in any of these aspects of

teaching will amount to a complete failure in our callings as teachers. So you do not only impart your knowledge to your students but also your life.

It is indisputable that organismic factors in the students have significant impact on their performance, but it has been observed that environmental and teacher factors are stronger than organismic.

Conclusion:

Let me say in conclusion that this crucial workshop is very timely and is expected to equip science teachers with skills and techniques in the teaching of science. It is also expected that resource persons so carefully selected will make a workshop and not a talk shop.

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