

METHODOLOGY OF Science Teaching (HISTORICAL AND CONCEPTUAL APPROACH)



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THE USE OF MODELS IN PHYSICS TEACHING

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Models that have direct bearing in the teaching and learning of physics are of varied nature. They may be mechanistic, mathematical or heuristic but each must of a necessity function and have resemblance in certain ways to occurrences either in real or hypothetical world. For instance, the Kinetic Energy Kit is a mechanistic model used in illustrating the collision of molecules of a gas with each other and with the walls of the container. This, at the microscopic level, shows how pressure is exerted by the gas molecules. Mathematical models include mathematical expressions and symbolisms. These include Maxwell-Boltzmann's expression for molecular velocity and energy distribution; equations of state etc. The use of heuristic models in the teaching of Physics basically applies to the use of problem-solving models in solving practical and theoretical problems in Physics. The role of models in the process of learning in science is receiving increasing attention (Pella and Zeigler, 1968).

It is worthwhile to note that while mechanistic models aid in proper internalization of physics concepts, mathematical models help in the quantification of concepts. Heuristic models, however, help in provoking relevant actions that can be harnessed into solving problems in Physics. Of these three models, the emphasis of this section of the chapter is on the use of mechanistic models in the teaching of Physics concepts. The areas of Physics covered are waves, mechanics, heat and electricity.

Wave Model:

The wave theory of light, for instance, suggests that light energy is transported from place to place in a wave-like manner. This explains why characteristics such as reflection, refraction and interference are associated with light. So a wave provides a satisfactory model for light. In this regard, it could be preferable to talk of "wave model" rather than the theory of light (Wenham et al, 1978). Propagation of sound energy also require the use of wave model. Under this, phenomena such as reverberation, echo, hearing around corners and doppler effect, can be explained. In all these, light and sound behave as waves.

Considering the varied areas of usefulness of this model in proper conceptualization of Physics, it is imperative to search for models that will foster proper conceptualization of 'waves'.

Model for Teaching the Concept of Wave:

(a) **Waves on Strings:** To illustrate this, tie a string or spring to a fixed support and stretch it taut above the floor. Then jerk the far end rapidly up and down rhythmically to make vertical waves or to the left and to the right to make horizontal waves. Observe that a pulse travels along and rebounds. Fig. 7.05 shows the movement of pulse during vertical displacement of the string.

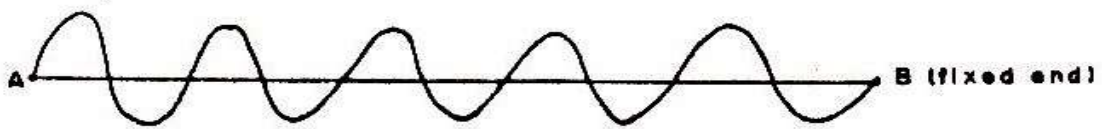


Fig. 7.05: Movement of Pulse During Vertical Displacement of a String.

The jerking is done at A-end. A similar effect can be observed by using a heavy rope or long, floppy rubber tube. If both A and B ends are superposition of waves can be observed.

(b) **Water Waves:** It has become usual to illustrate water wave and its characteristics with a ripple tank. However, in the absence of ripple tank, a wide basin with clean water could be used for illustrations.

(i) **Circular Pulse:**

Start a single ripple by dropping a smooth pebble in the midst of water in the basin; then make several ripples using a finger or a pencil to touch the water. Fig. 7.06 shows circular water waves produced in a basin.

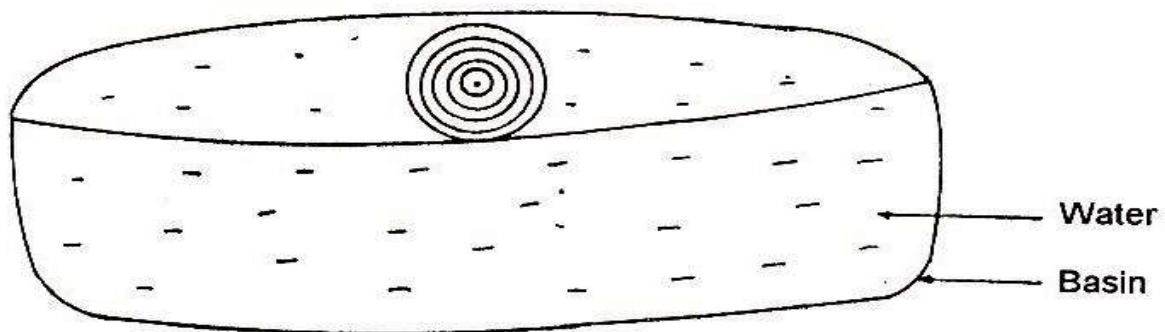


Fig. 7.06: Circular Water Waves.

The pulses spread out from the point of disturbance maintaining their circular shape and having increasing radii of curvature. This uniform and circular spread of disturbance in water is useful in the process of fishing. Casting nets within the circumference of the waves could result to a greater catch compared to situation with straight pulses.

(ii) **Straight Pulse:**

Use a cylindrical wooden rod to make a sharp roll forward and backward in the basin. To have continuous waves, continue this motion. The ripples are rather wide near the rod but become sharper as they move away. Straight pulses are like ridges or roofing sheets and remain straight as they travel, having little dispersion. This form of waves is of great significance in the sea as they affect the speed and smooth movement of boats and canoes. Many lives are often lost in the sea due to this form of waves. It is always safer to sail in a direction against the direction of waves than sailing in the same direction with the waves, especially when the speed of wave is very high.

Wave Properties:

Depending on the width of the basin, properties such as reflection on curved and straight barriers, can be illustrated. Observe that in the reflection of straight pulse from a straight barrier, angle of incidence equals the angle of reflection. In the reflection of circular pulse at a straight barrier, the reflected part has the same shape as the incident pulse.

Moreover, the centres of curvature of the incident and reflected waves are equidistant from the reflecting surface and the line joining them is perpendicular to the surface.

Interference of Waves:

To illustrate this phenomenon with the water in the basin, gently drop two similar pebbles from the height but at two different positions into the water. Observe what happens with the two sets of circular pulses formed. Figure 7.07 shows the result. Also release the pebbles from different heights and compare the result to that shown in Figure 7.07.

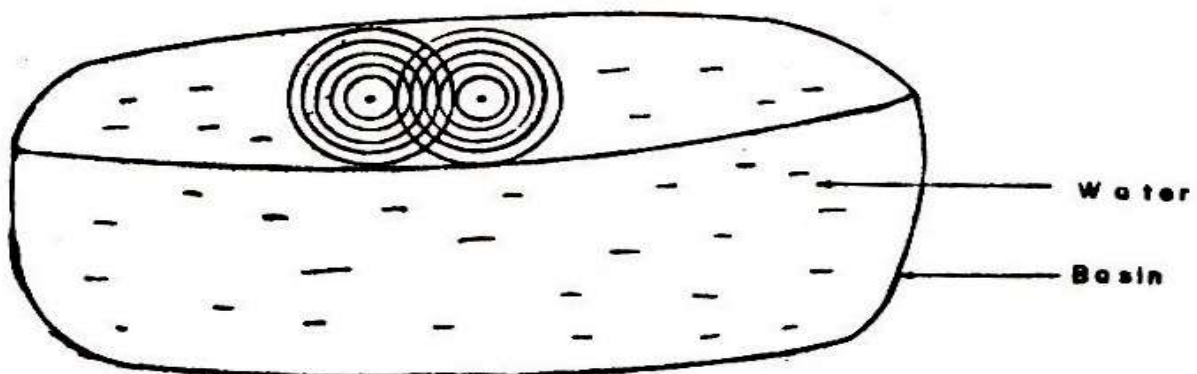


Fig. 7.07: Interference of Circular Waves in Water.

Although, the outcome may not be exactly as that obtained with a ripple tank due to the problem of not being able to produce continuous waves in the basin, this model will in no small way foster the child's understanding of the concept and properties of waves.

Models in Mechanics:

Chosen for discussion here is the model for teaching "GAS PRESSURE" Often students get confused in considering pressure gases exert, having been acquainted with pressure in solids as the distribution of force over a unit area of the spread. For proper conceptualization, a cylinder with a movable piston is used. Inside the cylinder are spherical lead balls of very few millimetres in diameter. These approximate to "molecules" in a gas. The other end of the cylinder is connected to an electric motor to provide the required agitation and collisions of the "molecules" in the cylinder, as shown in Figure 7.08 (a).

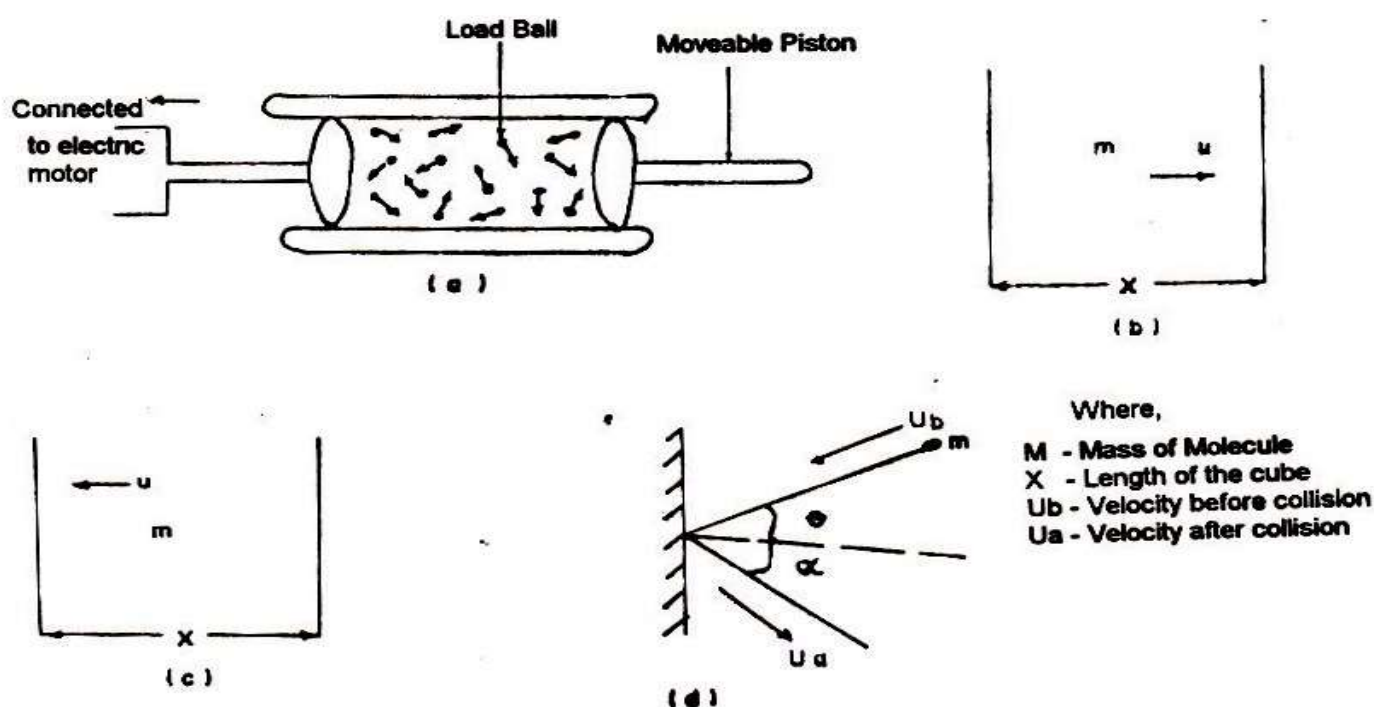


Fig. 7.08: Model of How a Gas Exerts Pressure

With this model, the random motion of molecules in the gas can be illustrated from the random motion of the lead balls as shown in figure 7.08 (a). Moreover, it would be easy to form the concept of gas pressure originating from the collisions between molecules as well as of molecules with the walls of the containing vessel. Elastic collisions of molecules is illustrated in Figures 7.08(b) and (c) by using a particular molecules of mass m and moving with a velocity u between two opposite walls of the vessel, of distance x apart. The vessel is approximated to a box of equal sizes:

From figure 7.08 (d), it can be illustrated, considering the elastic impact of a single particle on the face of the box, and applying the law of conservation of energy and momentum that:

$$MU_b \sin \theta = MU_a \sin \alpha \quad MU_b \cos \theta = MU_a \cos \alpha$$

$$\text{So, } \frac{1}{2} MU_b^2 = \frac{1}{2} MU_a^2$$

$$U_b = U_a \text{ and } \theta = \alpha$$

Moreover, with this model, quantitative expression of gas pressure as well as equation of state can be obtained.

Model of a Bridge:

To construct this model, use two cement blocks vertically placed at a distance x apart. Then place a wooden plank on the blocks such that the two edges of the plank rest respectively on each block.

This is as shown in figure 7.09 below:

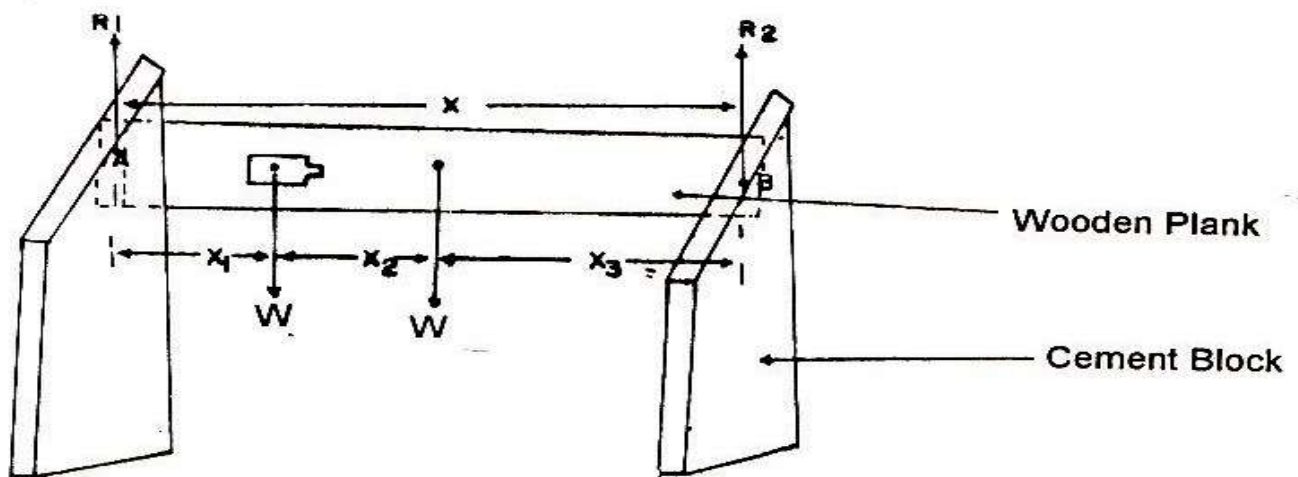


Fig. 7.09: Model of a Bridge with a Car.

This single model can be used in teaching quite a number of concepts in mechanics. It aids the teaching and conceptualization of "Action and Reaction Forces", "Equilibrium of Forces", "Moment of Forces" and "Principle of Moment".

- (i) **Action and Reaction Forces:** These forces are observed at points A and B. The action forces w_1 and w_2 are those exerted at the edges of the plank on the blocks. The reaction forces as shown in Figure 7.09 are R_1 and R_2 . According to Newton's third law of motion, action and reaction are equal and opposite. Thus $w_1 = -R_1$ and w_2

= - R_2 . Where the negative sign indicates direction.

- (ii) **Equilibrium of Forces:** The model clearly shows the situation of having forces at equilibrium condition. If a car, C of weight W comes into the "bridge" as shown in Fig. 7.09, without any breakdown or excessive strain on any part of the 'bridge', equilibrium condition will still be maintained. Considering the weight W of the car and the weight w of the plank acting at the centre of it; if the forces acting at A and B are recorded and examined, it will be found that:-
Total forces at A and B = $w + W$

This is because the two supports take the whole downward forces due to gravity. It can also be observed from measurement that in the absence of the car, the force is evenly divided between the two supports. This even distribution ceases to hold in the presence of the car in the 'bridge'. To determine this distribution, moments of forces should be taken respectively from A and B.

- (iii) **Principle of Moment:** This principle states that at equilibrium, the sum of the clockwise moments equals that of the anti-clockwise moments. In order to determine the values of R_1 and R_2 in Fig. 7.09 take moments of forces as follows:

- (a) Suppose the block B were removed, the plank would turn about the other support at A. The plank is then subject to the turning moments about A of:
- (1) the weight, W of car and weight w of plank - clockwise
 - (2) R_2 at A - anti-clockwise.

The thrust R_1 at A has no effect on rotation about A. Since these turning moments must be equal;

$$R_2 \times (\text{anti-clockwise}) = (Wx_1 + wx_2)$$

$$\therefore R_2 = (Wx_1 + wx_2)/x$$

Similarly, suppose that the support given by block A were removed, the plank would then turn about the other support at B; so taking moment at

- (b)
- 1) R_1 at B - clockwise;
 - 2) W and w at B - anti-clockwise;
- It also follows that
- $$R_1 x = Wx_1 + wx_3$$

$$\therefore R_1 = (Wx_1 + wx_3)/x$$

Note: Basically, a bridge consists of at least three parts, namely, two

supports, called "abutments", one at each end, and a 'span' to connect them together. There could be more than one span in a bridge. There are many types of bridges but girder bridge is one of the commonest modern types.

The mechanical characteristic of girder bridges is that the weight is carried by vertical supports that are subject to downward compression. When the vertical supports are able to produce normal reaction equal and opposite to the weights and stresses to which the bridge is subjected, there will exist an equilibrium. As soon as the supports are not able to produce the required reactions, the state of equilibrium will cease and the resultant force will act in a downward direction thus causing the bridge to collapse.

It is to avoid such collapses that some bridges carry information restricting vehicles of certain weights from going through them. For general purpose bridges, many factors are integrated and strength of materials used are properly considered high enough to withstand all the weights and stresses to which they possibly will be subjected.

Model for Teaching the Concept of Friction:

The model chosen is that of a bicycle. This is because a bicycle in its simplicity of operation, provides both the merits and demerits of friction. Friction is a force that opposes the motion of two or more surfaces in contact with one another. This force emanates from imperfection in smoothness of surfaces of solid bodies. Opposition to motion implies that friction acts in opposite direction to the force which causes or intends to cause motion. Such opposition to motion is analogous to resistances to the flow of electric current and heat. In fluids, friction exists as a viscous force.

Types of Friction:

Mechanically, there are three types of friction in solids, namely:

- (1) **Static or Limiting Friction, F' :** This is a force which has to be applied to initiate motion. To illustrate this, place a wooden block of known weight on a table. Tie a light cord to the block and pass the cord over a smooth pulley to a scale-pan or weight hanger whose weight is known. Place a small standard weight in the scale pan. This weight, together with the weight of scale-pan or weight hanger provides an horizontal force on the block.

This force is intended to move the block. So, the frictional force will act in the direction against that of intended motion. Gently increase the weight in the scale-pan until the block starts to slide. The total weight in the scale-pan (including the weight of the pan or weight hanger) equals the limiting or static friction. The term "limiting" is used because this type of friction has a limited value. That is, it increases as the weight of the scale-pan increases (as in the illustration above); but at a point, it could not further increase. It is at this point that the block starts to slide. The term "static"

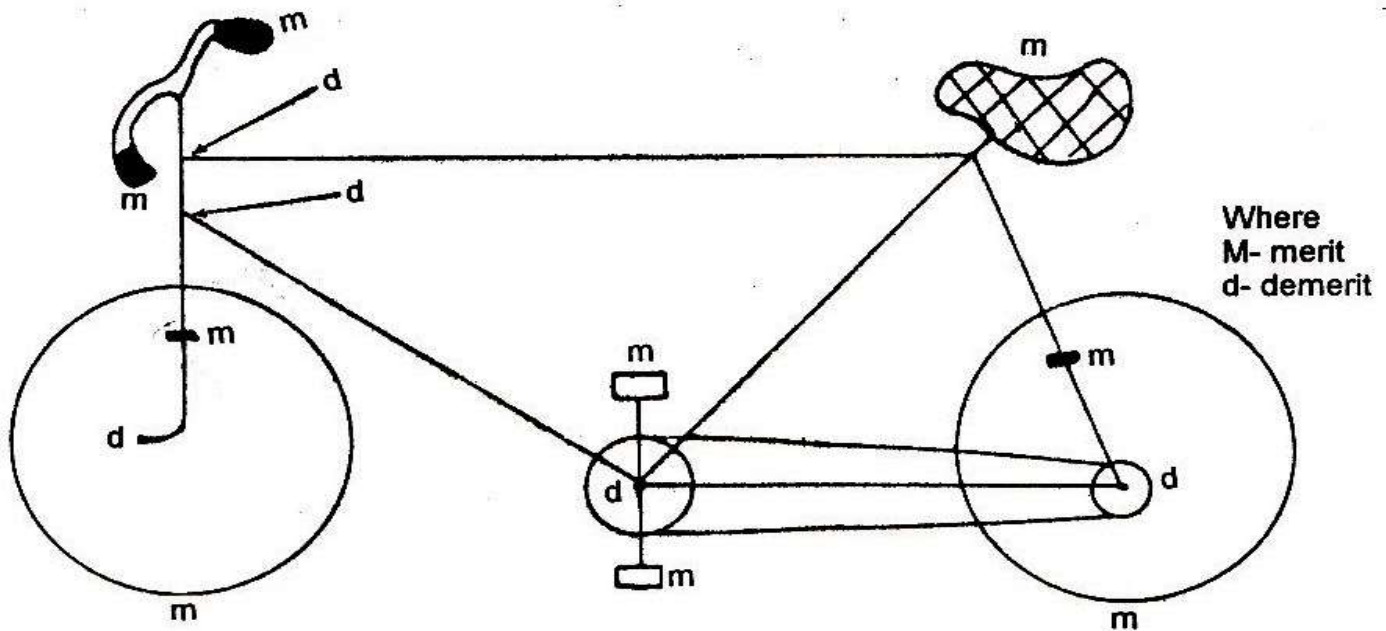


Fig. 7.10: Model of a Bicycle.

At every point labelled 'm' friction is useful while at others, labelled 'd' it is hazardous. Some usefulness of friction can be summarized as follows:

1. Walking, running and jumping: It would have been difficult, if not impossible to propel a body forward in walking, running or jumping without friction existing between the soles of our shoes or feet and the ground. It is friction that prevents us from falling as we carry out these activities.
2. Sitting on chairs, car and bicycle seats: Friction exists between the sitting portions of the chairs and our bottoms. Without this force, it would have been uncomfortable to sit on chairs or other seats.
3. Handling of knives and matchets: Friction exists between the wooden or metal portions of knives or matchets and human palms. It is this force that makes for a good grip.
4. Holding objects generally: It will be difficult to have a firm hold on objects if friction between the objects and palms is very small. This can be seen in holding a slippery fresh fish or winding a wrist watch with a worn out winder.
5. Driving of Cars and Bicycles: It would be difficult if not impossible for vehicles to move about if there was no friction between the moving tyres and the ground. Frictional force here is useful in enabling vehicles to negotiate bends (friction provides the centripetal force required) and to come to rest when required. This is why worn out tyres are not allowed by the traffic wardens. The frictional force between such tyres and the ground is very much reduced.

6. Friction also helps in wearing caps or hats and in tying scarfs, If the hairs are slippery, the caps or scarfs would not remain firmly on the head.
7. Friction also helps in producing electric charges. This is obtained by rubbing say ebonite rod with fur.
Contrary, some common disadvantages are:
 1. Wearing out of metal joints: As shown in Fig. 7.10 above, friction provides troublesome effects on areas labelled 'd'.
 2. Wearing out of vehicle tyres and soles of shoes.
 3. Requires much expenditure of energy in riding a bicycle.

Reducing Friction:

Due to some troublesome effects of friction, attempts are made to reduce it in the following areas.

1. Friction existing between the piston and cylinder of a car is reduced by oil being splashed up by the rotation of the crank shaft.
2. Friction between any rotating wheel and ball bearing is reduced by using grease.
3. Friction existing between a drilling pin and the metal being drilled is reduced by lubrication.
4. Friction between metal joints as in Figure 7.10 above is reduced by applying grease on the joints.
5. Modern hovercrafts operate with air tracks to reduce friction between them and the ground.
6. Modern trolleys used in the laboratory are made to stand on ball bearing wheels to reduce friction between them and the table on which they are used.

In each of the above cases, something which can cause motion to occur easily between two moving bodies is used (Ashworth and Rayan). For instance, oil causes one layer to slide easily on the other.

Model For Energy Conversion:

Ideally, in illustrating the conversion of energy from one form to the other, Energy Conversion Kit is usually used. However, in the absence of this Kit, a model can be used that consists of a kerosine stove, aluminium kettle with lid and water. Fill the kettle up to about two-third of its volume with water and place it on the kerosine stove to be heated up. The following energy conversion could be illustrated with this model:

- (i) **Chemical energy to heat energy:-**
From the burning of kerosene, chemical energy is converted into heat energy which is used in heating up the water in the kettle.
- (ii) **Heat energy to Mechanical Energy:-**
By heating the water in the kettle, steam is produced that forces the kettle's lid open. This shows a conversion of heat energy to Mechanical energy.
- (iii) **Mechanical Energy to Sound Energy:-**
The kettle's lid forced open does not fall off. It rather moves up and down vibrating and producing sound.

These processes are summarised as follows:-

Chemical energy \longrightarrow Heat energy \longrightarrow Mechanical energy \longrightarrow Sound energy.

Model For Internal Combustion Engine:

The two main types of internal combustion engine are gasoline and diesel engines. In both types, a gas or mixture of gases, known as working substances, contained in the cylinder, undergoes cycle. In gasoline engine, the cycle is made up of six processes, four of which involve motion of a piston and are called strokes.

Since these processes occur internally, there is often a problem in conceptualization. To aid understanding therefore, the model, as shown in Figure 7.11 (a) - (f) can be used. The model is made up of a cylinder with adiabatic walls and movable piston, placed in either isothermal or adiabatic contact with a source of heat, for an ideal gasoline engine. The processes are discussed as follows:

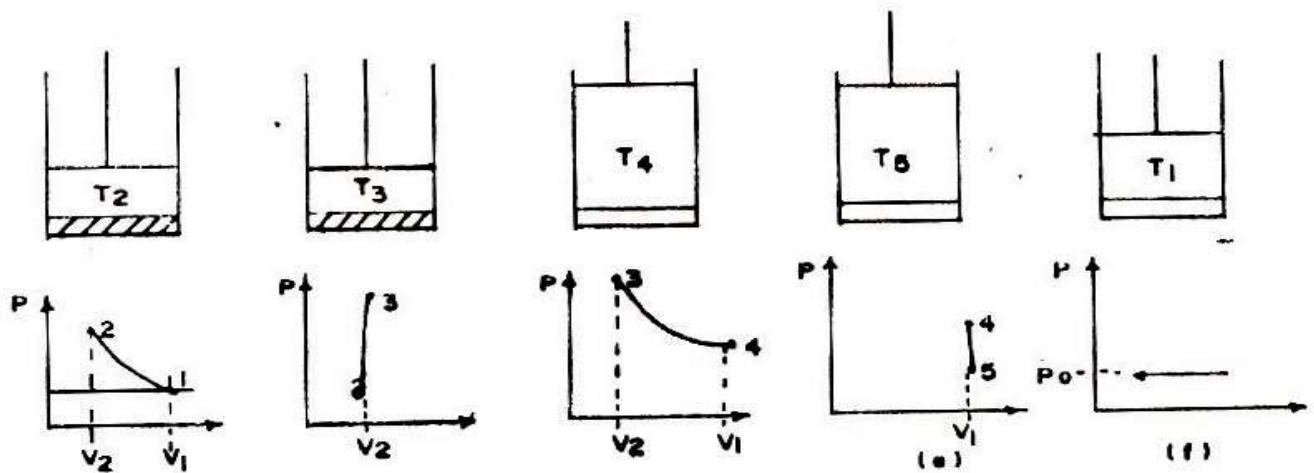


Fig. 7.11: Model of an Internal Combustion Engine.

- (i) **Intake Stroke:** The first movement of the piston is to draw in a mixture of gasoline vapour and air into the cylinder by suction stroke. There is an isothermal contact between the cylinder and the source of heat, as shown in Figure 7.11 (a).
- (ii) **Compression Stroke:** The mixture in the cylinder is compressed until its temperature and pressure rise considerably. The volume of the working substance at this stage is less than the initial volume. Both the model and the corresponding PV diagram are shown in Figure 7.11 (b).
- (iii) **Explosion:** The piston is stationary at this stage. Using electric spark (by turning on an ignition key, in a car) causes the combustion of the hot mixture to take place very rapidly. The combustion products attain a very high temperature and pressure at a constant volume (see Figure 7.11 (c)).
- (iv) **Power Stroke:** Once again, the piston moves due to the expansion of the hot combustion products. This results to a drop in pressure and temperature of the products (see Figure 7.11 (d)).
- (v) **Valve Exhaust:** The temperature and pressure at the end of the power stroke still exceed that of the atmosphere. In this process, some gas is allowed to escape until the pressure drops to that of the atmosphere. So, unlike during explosion when heat is allowed into the system, heat is given out during valve exhaust. However, the volume of the cylinder remains the same as the piston remained motionless (see Figure 7.11 (e)).
- (vi) **Exhaust Stroke:** The piston moves and pushes almost all the combustion products out of the cylinder. This shows the return of the system to its initial stage. (See figure 7.11 (f)).

It should be noted that the underlying assumption in using this model is that the working substance behaves like an ideal gas and all the six processes considered are quasi-static (that is, slow-moving frictionless processes).

Model for Electricity:

One of the commonest models for teaching concepts in electricity is a Circuit Board. It is made up of piece of hardboard or plywood of about thirty square centimetres used as a base (UNESCO, 1973). On the board are fixed clips for holding cells, and metal strips for providing connections between cells.

In order to make electric circuits on the board, brass curtain and rod holders are screwed into the base as shown in Figure 7.12 below. Connecting wires with crocodile clips as well as copper strips are used for connections.

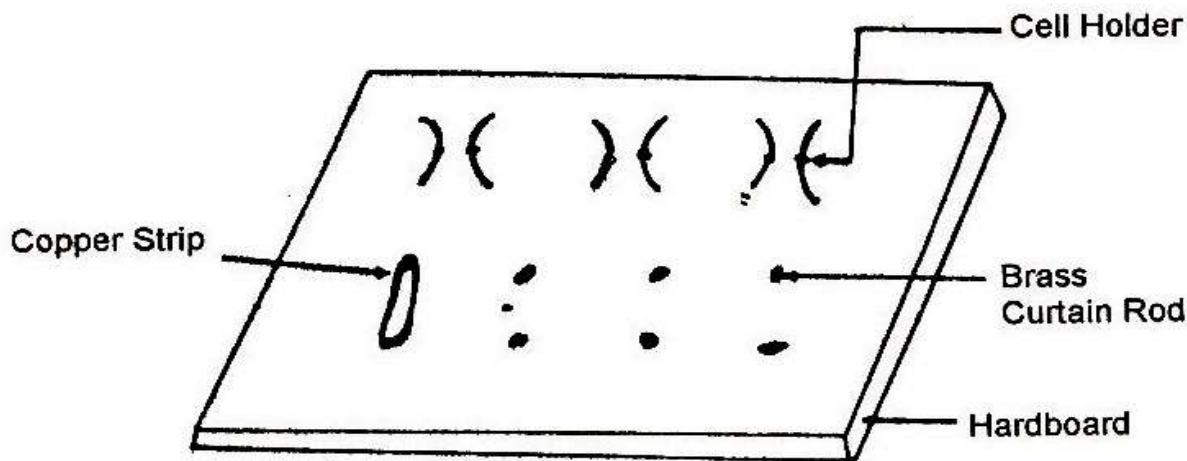


Fig. 7.12: Circuit Board Model.

The use of circuit diagrams could be a bit confusing to beginners. Circuit Board can be used to reduce this confusion. Practically, it is used for identifying conductors and non-conductors of electricity, illustrating different types and effects of circuit connections with resistors or cells in series or parallel. The main advantage of this model is that it affords a learner an opportunity of watching and comparing the intensity of glow in bulbs for each pattern of connection. When this observation is matched with quantitative expressions for effective current and voltage in the circuit, proper conceptualisation can be fostered.

Conclusion:

This section of the book has tried to employ mechanical models in the teaching of some concepts in different areas of school physics. While it is true that models used are limited in scope, functioning and generalizability, it is worth emphasizing that these models aid proper understanding of physics concepts.