CHAPTER IV

DEVELOPMENT OF INSTRUCTIONAL MATERIAL

4.1 Introduction

Production of the instructional material based on the guidelines described in the earlier chapters forms an important objective of the present study. The earlier discussion highlighted the need for developing specially designed material, as most of the materials in use in the present day schools are neither conceptually clear, nor sequentially well organized, atleast when examined in the perspective of Gagne's conditions of learning. The concept attributes must be made clear with similarities and dis-similarities and limitations well discussed as this forms the pre-requisite for learning of intellectual skills. The basic requirement is that the learner must be told what kind of performance, in general, will show learning has been completed. As a psychologist interested in the training of personnel, Gagne's greatest contribution is in the task analysis and learning hierarchy. Any material developed in this perspective should be based on a proper task analysis. This should be done in a top to bottom fashion and the learning hierarchies should be constructed in a bottom to top approach. These basic requirements in the mapping of learning demands the production of specialised materials as the conventional material available do not necessarily satisfy these needs. The present chapter describes the actual processes involved in developing the learning material. Sample materials are included wherever necessary to illustrate this process. The materials developed could broadly be classified into three categories :

1. Classroom Learning Material (CLM)
2. Home Assignment Material (HAM)
3. Assessment Material (AM).

4.2 Classroom Learning Material (CLM)

After having decided the class and subject for which the material was to be prepared, the main job in the development of material involved the following steps :

1. Selection of topics
2. Formation of topic sequence
3. The task analysis
4. Generation of learning hierarchy
5. Development of instructional material based on the learning hierarchy
6. Evaluation questions to test the capability attainment.

These classroom learning material developed exactly in the order given above were distributed to the students in the form of cyclostylled material just before the class to begin to deal with the topic concerned.

4.2.1 Selection of Topics

The topics included in the physics curriculum of standard IX, as prescribed by the Central Board of Secondary Education, New Delhi, were chosen for the present study. As the experimental validation was to be conducted only for the first semester, the material developed covered about four months course. The main units selected were :

1. Speed and Acceleration
2. Force and Motion
3. Work and Power

They included the following sub-topics :

(1) Speed and Acceleration: Scalar and vector quantities - representation of vectors - their addition and subtraction (paralleagram law-qualitative idea only); resolution of vector graphically; displacement - time graph for uniform motion; velocity - time graph for uniform acceleration in a straight line. Derivation of standard

equations of motion ($v=u+at$, $s=ut+\frac{1}{2}at^2$ and $v^2 = u^2 + 2as$) mathematically and graphically; motion in a circle with uniform speed-relation between linear velocity and angular velocity acceleration due to gravity - standard equations of motion for motions under gravity.

(2) Force and Motion: Types of force; friction - types of friction (sliding and rolling) methods minimising friction, advantages and disadvantages of frictions; Newton's laws of motion; distinction between mass and weight; momentum, conservation of momentum in one dimension, law of gravitation.

(3) Work and Power: Work - definition and unit (joule) measurement of work when force and displacement are (a) collinear and (b) oblique; Power - definition and its unit (watt).

4.2.2 Formation of Topic Sequences

The topics were critically examined with respect to their structure in terms of concepts and rules. As per Gagne's conditions for any meaningful problem solving to take place, the learner should have mastered the related concepts and rules. Fulfilling the above condition, the following order of the topics was decided :

Topic	I	-Speed and Velocity
	II	-Accelerated Motion
	III	-Newton's I & II Laws
	IV	-Newton's III Law
	V	-Conservation of Momentum
	VI	-Gravitation
	VII	-Friction
	VIII	-Work
	IX	-Power

The topic 'speed and acceleration' was selected as the first topic as it contained most basic concepts like time, distance, displacement etc. which are to be later used in the topics to follow. A topic like 'law of conservation of Momentum' which requires treatment of concepts like force and impulse were kept to come after Newton's laws which dealt with force in detail.

4.2.3 Task Analysis

With respect to the content one of the major problem of instruction is how to design the tasks in any topic. For this task analysis maps are to be prepared taking fully into consideration the ideas involved in a given topic and how they are linked together. Some people calls these maps as discovery maps (Fraser, 1975). These maps are even helpful to the students to understand how scientific ideas have developed.

The task analysis was performed intially by identifying all the concepts and rules involved in the topic. This had to be done as according to Gagne concepts must be mastered before the rule capability can be attained. This is a map developed through the identification of concepts and rules and their interrelations. This pyramidal structure developed clearly explains the position of concept or rule in a task analysis map which is illustrated in Fig. 4.1 .

Task analysis map can be broadly divided into three main steps : (1) Concepts, (2) Rules and (3) Problem solving or Higher order rules in problem solving. Problem solving capability forms the highest level in Gagne's learning hierarchy.

In a typical task analysis map, the instructor while preparing the same, looks down from 'above' to the bottom while the learners view the same from the bottom to the top as they find their way in the unfamiliar territory.

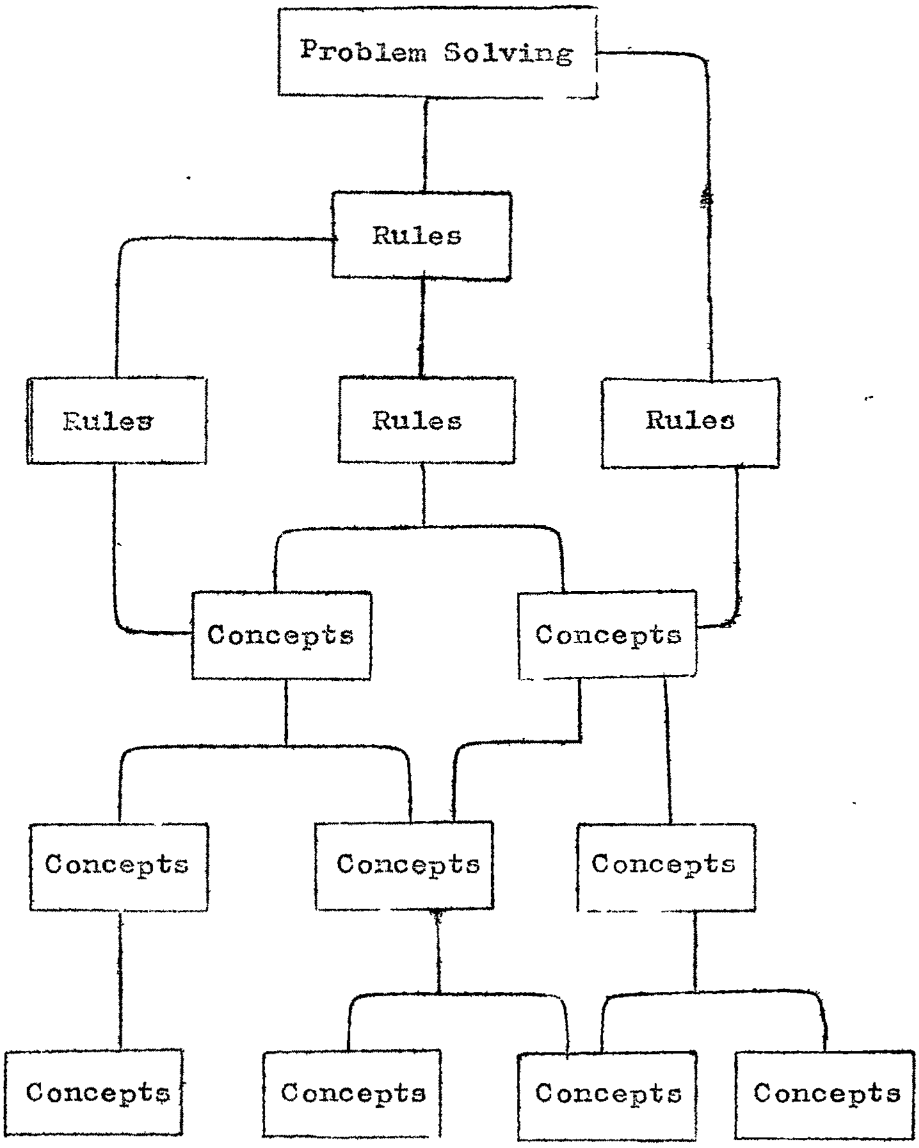


Fig. 4.1 : Task Analysis Map

The topic 'speed and velocity' is discussed here as an example to illustrate how the task analysis maps were developed. Initially rules involved in the topic or the rules required to be covered by the topic were discussed and decided. The two rules were :

(1) S = v.t, i.e. displacement is equal to velocity times

(2) V = rw where is the lenear velocity is equal to radius times angular velocity.

Once the rules were identified search for concept elements were easy. The first rule can be stated in two ways :

(1) Displacement = Velocity x Time

and (2) Distance = Speed x Time

Thus, we straight way come to the following concepts :

(1) Velocity
(2) Time
(3) Displacement
(4) Speed
(5) Distance

The difference between distance and displacement lies in the fact that former is a scalar quantity and the later is a vector

Topic 1 : SPEED AND VELOCITY

Task analysis

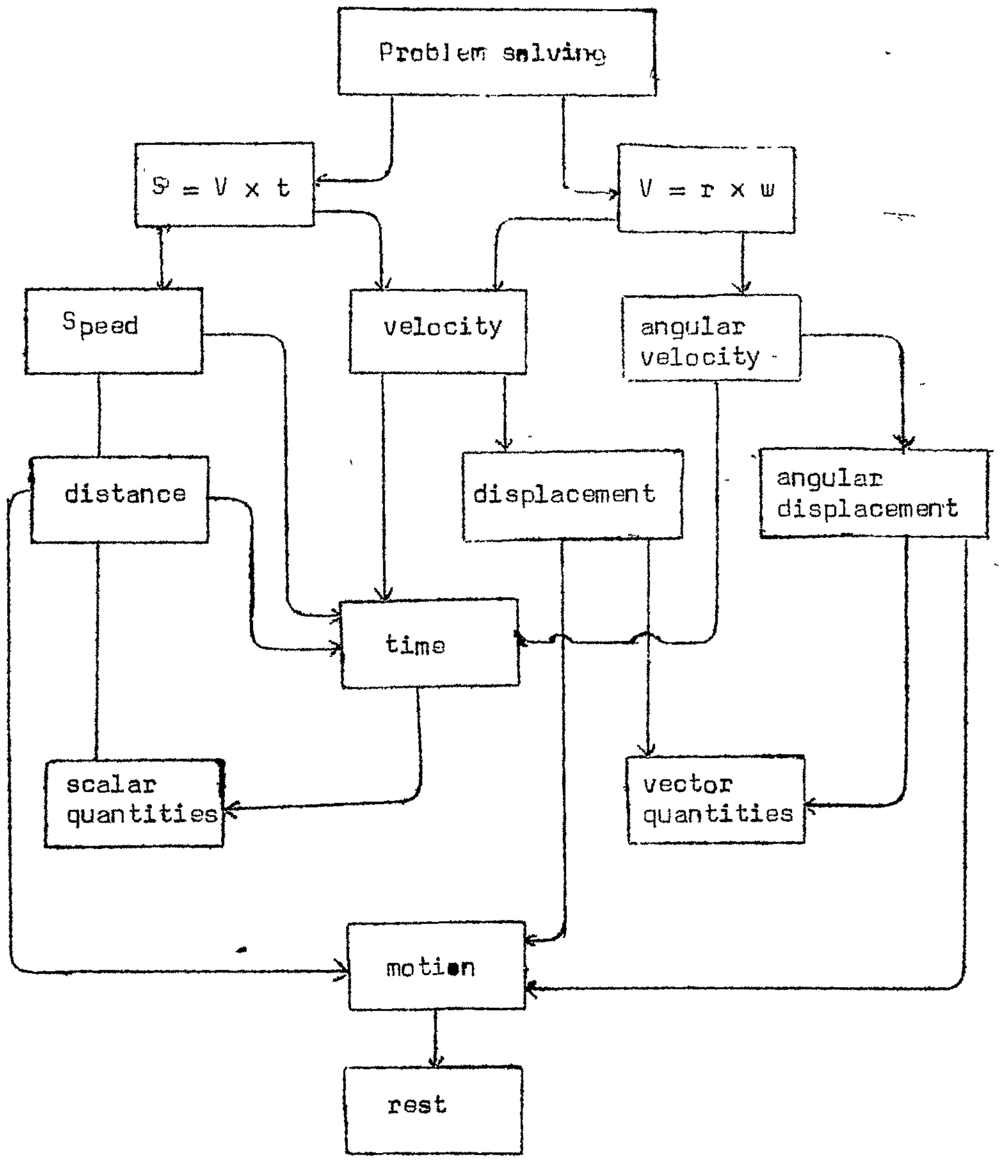


Fig. 4.2 Task analysis map - speed and velocity

quantity. Some have two more concepts in

(6) Scalar quantity

and (7) Vector quantity.

As the displacement is because of the motion of a body we have to define the concept motion and differentiate it from another concept rest.

If we look at the second rule $V = rw$, we have to define velocity, radius and angular velocity. Taking for granted that radius is a concept very familiar with the students of Standard IX. We have to deal with angular velocity and linear velocity.

After having analysed the concepts involved the main thrust was to find the relations between these concepts and bring out a conceptual order. Having determined the order based on pre-requisite requirements, the order of placement of each element in the task analysis map was decided an example of which is shown in Fig. 4.2 .

These task analysis map can be used to depict many more useful things important to the learners. Here we see that elements 1 on the left side of the map are all scalar quantities while those on the right are vector quantities. Even when we deal with laws, the procedures are same; looking down from the top.

4.2.4 Generation of Learning Hierarchies

The key to the design of conditions for effective of learning is the learning hierarchy. (Gagne 1970, pp. 237-276). The learning hierarchy is an arrangement of intellectual skill objectives into a pattern which shows the pre-requisite relationship among them. Beginning with a particular objective say the lesson objective, the learning hierarchy shows which intellectual skills are pre-requisites of each of these in turn indicated and the process continues until one has displayed in a bottom row the most elementary intellectual skill as the pre-requisite.

Having assumed the existence of the hierarchy and the validity of the same, the stages considered for developing the hierarchy were as follows :

(1) Define in behavioural terms the element that is to be the pinnacle of the hierarchy.

(2) Derive the hierarchy by asking Gagne's question, "What must the learner be able to do in order to learn this new element given only instructions?", or each of these elements in turn from the pinnacle element down words (Gagne 1962, p. 358).

Application of this question resulted in the identification of other tasks which one presumed to be subordinate to the final tasks. The same question was applied to each of the task identified inthe first task and the process continued until the tasks described were at level when it could be assumed that they had been mastered as a result of prior instruction.

(3) Define all these elements identified in behavioural terms.

(4) Present these elements described in behavioural terms in an analysis map with interconnections marked.

(5) Check the reasonableness of postulated hierarchy with experienced and subject-matter experts.

As an illustration, the hierarchy, developed for one topic, namely, conservation of momentum is presented here. The objectives framed for the topic are as follows.

The student should be able to;

I.A.identify scalar quantities.

B.define scalars and give examples.

II.A.identify vector quantities.

B.define vectors and give examples.

III. A. define mass.

B. give the unit of mass.

IV. measure time.

V. A. define displacement.

B. distinguish between distance and displacement.

VI. A. define velocity.

B. state velocity in the equation form.

C. give units of velocity.

D. calculate the value of velocity from given data.

VII. A. define momentum.

B. calculate momentum from the given data.

VIII. A. define acceleration.

B. represent acceleration in the equation form.

C. give units of acceleration.

D. calculate value of acceleration from the given data.

IX. A. define force.

B. express force in the form.

$$f = ma = m\left(\frac{v-u}{t}\right)$$

C. define newton.

D. calculate the value of F from the given values.

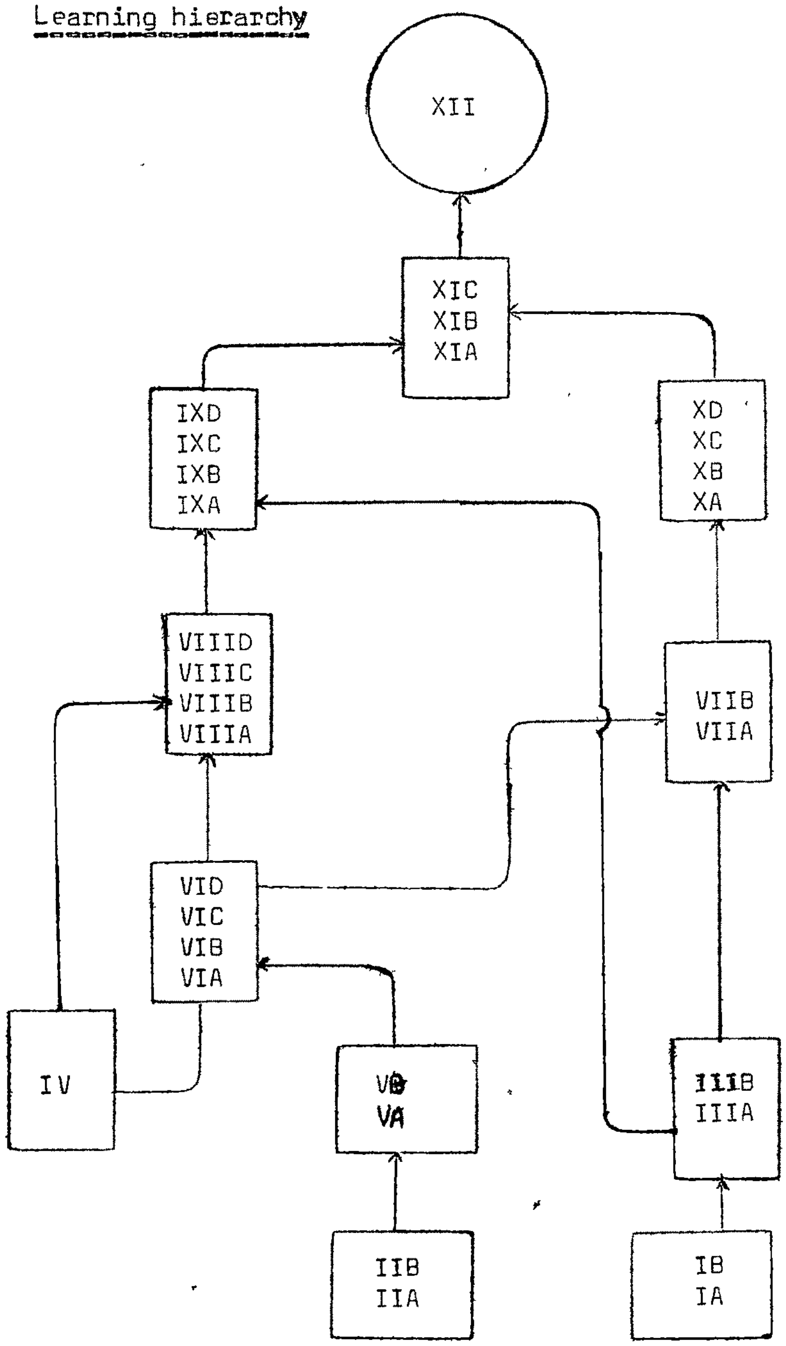


Fig. 4.3 Learning hierarchy map - Conservation of momentum

X.A.define impulse.

B.express impulse as $I = F \times t$.

C.give units of impulse.

D.calculate impulse from the given data.

XI.A.state the law of conservation of momentum.

B.derive the expression.

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

C.explain the significance of the law of conservation of momentum.

XII. solve problems based on the law of conservation of momentum.

In the learning hierarchy map the numbers given i.e. I.A, I.B, etc., refers to the objectives mentioned earlier. While the task analysis goes down from the top task, down to simpler tasks, the learning hierarchy moves up from the simpler objectives at the bottom to complex ones at the top. Evidently the basic concepts like vector and scalar quantities under objective I & II falls at the bottom. While defining a concept like velocity which is complex in itself will have to divided into simpler elements and as such we have four objectives under VI.A, VIB, VIC, VI.D. The concept momentum defined as the product of mass and velocity depends on both objective No.III and VI and as such interrelations are marked. Finally the learning hierarchy map reaches at the top with problem m solving objective at No.XII.

4.2.5 Development of Instructional Material Based on Learning Hierarchy

The learning materials developed were based on the task analysis map and learning hierarchy. These materials were grouped under the tasks marked in the task analysis map. Various concepts and rules were developed bringing out the different attributes clearly.

(a) Development of Concepts

The concept capability of a student greatly depends on his knowledge about the various aspects of a concept. Every concept has a structure which is determined by the complexity of its attributes, how these attributes are linked and in which form they are experienced. Various people might see a concept differently depending upon their conception about the structure of a concept. Let us take the example of a concept from physics-weight. This can be structured with the help of the various points mentioned below.

(i) Definition
(ii) Type of quantity (vector or scalar)
(iii) Written representation
(iv) Specification as to its magnitude and direction
(v) Unit in which it is expressed
(vi) Dimensional formula
(vii) Notes, if any
(viii) Limitation of the concept, if any
(ix) Misconception about the concept.

Apart from these points mentioned above, the development of a concept can also be supported by examples and pictorial representation etc. Is there any particular sequencing order for these attributes which help in the optimization of learning? There is no research finding known to suggest that. An example for the structuring of a concept is illustrated here.

<u>Illustration No.1: Weight</u>

<u>Definition</u>: The force by which the given body is attracted by the earth.
<u>Example</u>: See figure.
<u>Type of Quantity</u>: Vector; but in practice usually treated as a scalar (see specification below).

Written Representation: W

Specification:

(i) Magnitude given by the relation applied to gravitational force and gravitational acceleration of a body or W = Mg.

(ii) Direction: always towards the centre of the earth; hence 'fixed' and need not be considered in all calculations.

Unit: As a force, it is measured in Newton (N).

Dimensional Formula: MLT^{-2}

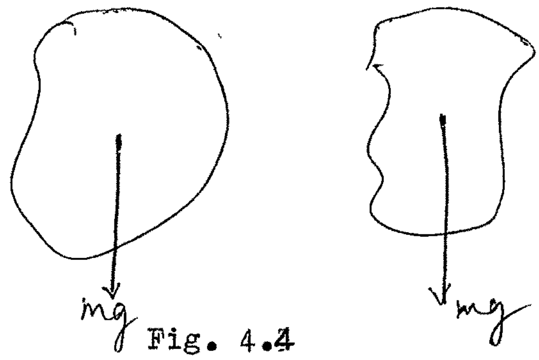


Fig. 4.4

Weight is a vector quantity. Its magnitude is the object's mass times the acceleration due to gravity. It is directed towards the centre of the earth.

Notes:

1. The above definition is also valid for any planet or celestial body other than the earth e.g., Mars, Venus, the Moon, but the value of g is different in each case; (e.g., g of Mars = $3.92ms^{-2}$; g of Venus = $8.82ms^{-2}$; g of Moon = $1.67ms^{-2}$).

2. Sometime unit of weight is also expressed in kilogram weight (kg.wt). At a place, where value of 'g' is taken as $9.8m/s^2$, the Newton and kg.wt. are related by the relation 1 kg.wt = 9.8 N .

Limitation: This unit kg wt and its value in Newton are defined only for measurements on earth. Further,, 1 kg.wt. is not a constant unit; its magnitude depends on the value of the place and as such varies from place to place on earth.

3. The weight of a body in space, where g = 0, is zero. This explains the weighless-ness experienced by astronaughts. Though the bodies experience weightlessness their mass remains unaltered.

<u>Misconception</u>: Weight is often used synonymously with the concept mass which is erroneous. For example, the weight of a person is always expressed as 50 kgs: kg being the unit of mass. Rightly weight should be expressed as 50 x 9.8 = 490 Newton or 50 kg.wt .

The above description of a concept also contains some notes as useful information which is related to the concept and which will enhance the understanding of the concept. The material developed for concept capability also includes small calculations at the concept level. For the above example they are as follows :

<u>Calculation</u>: If the mass of a body is 10 kg then its weight on earth = 10 x 9.8 = 98 Newton and on Moon = 10 x 1.6 = 16 Newton.

Certain other quantities like scalar quantities were developed with lesser number of steps. It may, for instance, contain only the following :

(i) Definition
(ii) Example
(iii) Written Representation
(iv) Diagramatic or Pictorial Representation

The material presented below for the concept scalar quantities illustrates this point.

Illustration No.2: Scalar Quantities

Scalar: A quantity that has only magnitude.
Examples: Mass, time, density, temperature, electric charge
Written Representation: A single magnitude written as either:

(i) a real number multiple of a standard or well-defined unit (e.g., 6.5 kg, 9 s, 136 gcm^{-3}, 273 K, 2°C);

or

(ii) a diagramatic representation of an absolute or a relative magnitude (Fig. 4.5 and 4.6).

4 cms

1 cm

Fig. 4.5: Diagrammatic Representation of Absolute Value.

The shorter line is 1 centimeter long and reprêsents an absolute length of ~~2~~ 1 centimeter. The longer line is similarly 4 centimeters long.

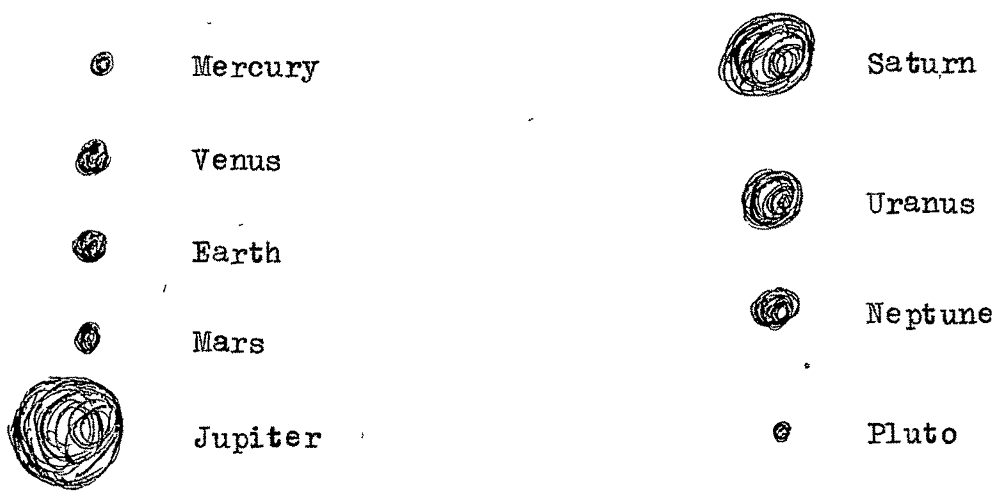


Fig. 4.6: Pictorial Representation of the Relative Size of the Planets.

Size of the planet is proportional to the area of the circle.

Certain concepts which are basically 'defined concepts' require a number of examples to develop proper understanding. Therefore, such concepts as 'inertia' were developed with a good number of examples from every day life, as illustrated below.

Illustration No.3: Inertia

Although two objects can look the same, it might be more difficult to move one than the other. A full box is much more difficult to move than an empty box. This is because of a properly known as Inertia.

The property of all material bodies due to which they naturally tend to continue in a state of rest or of uniform linear motion, is known as inertia.

As is seen above heavier bodies possess more inertia compared to lighter bodies.

Depending on whether the body is at rest or in motion the inertia can be of two types.

(a) Inertia of Rest

If the body is at rest, its inertia is called the inertia of rest.

Examples:

1. A bullet fired on a window glass pane makes a clear hole without breaking the remaining part of the glass. The bullet takes out a part of the glass while the remaining part tends to remain at rest due to its inertia of rest.

2. A coin, placed on a post-card which rests on a tumbler, falls into the tumbler, when the post-card is suddenly knocked with the finger. The coin tends to remain at rest due to its inertia of rest.

3. A person standing in a bus, gets backward push when the bus at rest starts suddenly. His feet start moving suddenly with the bus while the upper portion tends to remain at rest due to inertia of rest. Thus due to this unbalanced motion the person tends to fall backward.

(b) Inertia of Motion

Inertia of a moving body is called the inertia of motion.

Examples:

1. A running person does not stop instantaneously. It is due to the inertia of motion.

2. A person in getting down from a moving bus tends to fall forward. When the bus is in motion, the person in the bus is also in motion. As he gets down, his feet come to rest almost immediately due to friction between the feet and the ground, while his upper portion tends to move in the direction of the motion of the bus. Thus, due to this unbalanced motion, the person tends to fall forward.

3. A cricket bowler runs for some distance before bowling. By doing so he tends to increase the inertia of motion of the ball.

4. An athlete can take a longer jump after running as compared to the jump that he takes after standing.

Note: If a body has large inertia, it will resist a change in its state of rest or of uniform motion to a much greater extent than will a body with a small inertia.

Sometimes a concept in itself may be complex in the sense that it can be divided into different types. For instance the concept force can be different categories like muscular force, magnetic force, electrostatic force, gravitational force, etc. That means these various categories also needs explanation. For example, the concept force is developed with explanation for various categories forces with examples apart from the usual steps previously explained.

Illustration No.4: Force

Any action which alters or tends to alter the state of rest or of uniform linear motion of a body is called force.

Type of Quantity: Vector

Written Representation: F

The cause or agency which produces a change in the state of motion or change in the shape of a body is usually a push or pull which can generally be called a force.

Magnitude: force = mass x acceleration

OR $f = ma$

Unit: Newton.

One Newton is that much force which when acting on a body of mass one kg produces in it an acceleration of 1 ms^{-2}.

Thus, 1 Newton = 1 kg x 1 ms^{-2}

Written Representation: N

Note:

$$\text{Force (Dynes)} = \text{Mass (Grams)} \times \text{Acceleration (cm/sec}^2)$$

$$\begin{aligned} 1 \text{ Newton (N)} &= 1 \text{ kg} \times 1 \text{ m/sec}^2 \\ &= 1000 \text{ gms} \times 100 \text{ cm/sec}^2 \\ &= 10^5 \text{ dynes.} \end{aligned}$$

Examples:

1. We can set a hand cart in motion by merely pushing it.
2. We can change direction of motion of a tennis ball by pushing it.
3. We can change the shape of a plastic mug by simply pressing it.
4. We can elongate a rubber band by pulling it.
5. We can stop the motion of a cricket ball with our hands.

Suppose an acceleration of 5 m/s^2 is produced on a body of mass 10 kgs then the applied force :

$$f = 10 \times 5 = 50 \text{ Netons.}$$

There are various types of forces of which we can discuss a few.

Muscular Force: The push and pull that we exert on a body can be termed as muscular forces.

Examples:

1. Pushing the door open
2. Throwing a cricket ball
3. Pulling the chain
4. Lifting the box

Gravitational Force: A body released from a height falls to the ground; the earth seems to exert a force on the body. This happens because of some constant force exerted by the earth on the body. These forces are called gravitational forces.

Examples:

1. A mango released from the ~~kk~~ tree falls down.
2. Similar falling bodies.

Magnetic Forces: Two magnets placed at distance interact with each other. Similar poles repel each other while dissimilar poles attract each other.

Examples:

1. North pole of one magnet repels the north pole of another magnet.
2. North and south poles attract each other.

Electrostatic Forces: Two electrified bodies placed at a distance, interact with each other. Similar charges repel each other while dissimilar charges attract each other.

Examples:

1. If you rub a plastic comb on your sleeve and hold it near to water trickling from a tap, the water under the influence of a force, will bend towards the comb.
2. The same comb if brought near pieces of small paper it will pick up a few.

(b) Development of Rules

The rule capability depends on the establishment of relations between concept. A rule may have either two or more concept components. Here a learner should be able to respond with a class of relationship among the classes of objects events. The development of a rule consists of :

i. Statement of the rule

ii. A representation of it in an equation form

iii. A derivation to establish the relationship between concepts

iv. Any experimental evidence

v. Illustrations to support the rule

vi. Applications of the rule or its consequences

vii. Evaluation to test the acquisition of rule capability.

To illustrate the various points mentioned above, material developed on Newton's Law of Gravitation is given as follows :

<u>Illustration No.5</u>: <u>Newton's Law of Gravitation</u>

Every body in the universe attracts every other body at all distances with a force directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

If two bodies of masses m_1 and m_2 are kept at a distance r from each other, they attract each other with a force F.

Then,

$$F = m_1 \times m_2$$

and also

$$F = \frac{1}{r^2}$$

$$\therefore F = G \frac{m_1 \times m_2}{r^2}$$

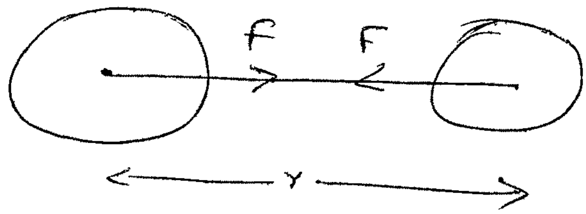


Fig. 4.7: Gravitational Force Between & Two Bodies

G is called the universal gravitation constant. The present accepted value of G in SI system is :

$$6.67 \times 10^{-11} Nm^2/kg^2$$

Illustration No.6:

We have noted in the earlier section that while gravitation refers to gravitational force between any two bodies in the universe gravity is in reference to earth only.

We know that on earth $F = mg$

By Newton's law of gravitation, $F = \frac{GMm}{r^2}$

Where,

M = Mass of earth

m = mass of the body

i.e., $mg = \frac{GMm}{r^2}$

OR $g = \frac{GM}{r^2}$

The immediate consequence of this is that we come to a conclusion the 'g' varies inversely as r^2. The value of 'g' will be zero at large distances and hence the weight 'mg' will also be zero which explains the weightlessness in space.

Certain laws like Newton's 3rd Law required rigorous doubt-clearing exercises. This is because though the laws' statements looked simple, its implications needs thorough understanding. For example, if action and reaction are equal as Newton's 3rd Law says, how does a body move? This needs an analysis as to how action and reaction acts on different bodies. Therefore, keeping such type of intriguing questions in view important points were given under notes while developing the material for rules. Many illustrations were also given wherever possible. To show how this had been done an example on Newton's 3rd Law is given below.

Illustration No.7: Newton's 3rd Law

To every action there is always an equal and opposite reaction.

Here, action = - (Reaction)

The negative sign indicates that the reaction is in the opposite direction as that of action.

Notes:

1. The action and reaction are ~~forces~~ forces.
2. The action and reaction always act along the same straight line but in opposite directions.
3. The action and reaction never act on the same body but always act on different bodies.
4. The action and reaction are always equal in magnitude.
5. The forces always exist in action-reaction pairs.

It is a common experience that if a person hits another person with his palm, the former also experiences a pain. Harder the hit, greater is the pain. Here hitting the person is action while the pain is experienced due to reaction.

It should be borne in mind that there is no formal proof of Newton's third law of motion. Through discussions it could be easily concluded that existence of an isolated force is not possible as for every action (i.e., force). There is always an equal and opposite reaction (i.e., force). Hence forces always exist in action reaction pairs.

However with the help of spring balance experiment it can be established that action and reaction always equal in magnitude. Let us consider a spring balance a being pulled by another spring balance B as shown in the Fig. 4.8. Both the spring balances read equally. This shows that when the balance B pulls the balance A, the balance A also pulls balance B in the opposite direction. The force with which balance B pulls balance A is equal and opposite to the force with which balance A pulls balance B. The force exerted by balance B on balance A on balance B may be

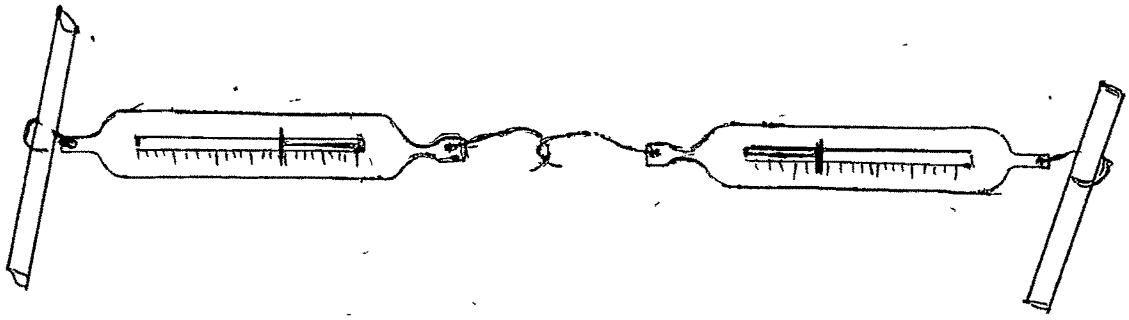


Fig. No. 4.8

termed as 'reaction'. Thus, we see that "for every action there is equal and opposite reaction".

Examples:

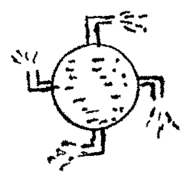
1. Whenever a person steps out from a rowing boat, he pushes backwards on the boat (the action) which moves accordingly whilst the boat pushes the person forward (the reaction) the forces are equal in magnitude, opposite in direction and act simultaneously on the person and the boat.

2. While swimming, a swimmer throws water in a backward direction (action) whereas the reaction of the water moves the swimmer in the forward direction.

3. The birds while flying, push the air downwards with their wings (action). The air exerts an equal and opposite force on the birds inthe upward direction (reaction).

4. In rotating fountain, a central pipe is fitted with four small pipes having fine nozzles at the ends (Fig. 4.9). Water rushes out of the nozzles (action). The pipes move in the opposite direction (reaction). This

Fig. 4.9



principle is used in the foundation to sprinkle water around.

5. When a bullet is fired from a rifle with a certain force (action), there is an equal and opposite force exerted on the rifle in the backward direction (reaction).

6. When a walk on the ground, our feet press the ground backward (action) and the reaction of the ground on our feet moves us in the forward direction.

7. A boatman in order to go away from bank, pushes the bank with a pole (action). The bank pushes the boat away as a result of reaction.

(c) Development of Problem Solving Material

Development of the problem solving capability depends greatly upon the exposure of the pupil to many problem solving situation. The training in problems depends on the students capacity to -

i. understand the problem situation.

ii. translate the problem statements into say equation forms.

iii. computational skills.

iv. recall of the pre-requisite learnings in concepts and rules.

v. internalise problem solving strategies.

The orientation towards the problem solving activities were performed through worked out examples which consisted of the following steps :

1. Problem statement
2. Equations or rules involved in the solution of the problem
3. Substitution of relevant values
4. Calculation of the result

An example given as worked out example is reproduced below :

<u>Illustration No.8</u>: <u>Problem</u>

(a) A car covers a 150 kms with a speed at the rate of 50 kms/hr and another 80 kms at the rate of 40 kms/hr^{-1}. Calculate the average speed for the whole journey.

(i) $S_1 = 150$ kms $\quad S_2 = 50$ kms

$V_1 = 50$ kmsh^{-1} $\quad V_2 = 40$ kmsh^{-1}

(ii) Average speed?

(iii) Average speed = $\dfrac{\text{Total Distance Covered}}{\text{Total Time Taken}}$

$S = S_1 + S_2 \quad t = 1_1 + t_2$

(iv) $S_1 = 150; \quad V_1 = 50$ kmsh^{-1}

$t_1 = \dfrac{S_1}{V_1} = \dfrac{150}{50} = 3$ hrs

$t_2 = \dfrac{S_2}{V_2} = \dfrac{80}{40} = 2$ hrs

$$S = S_1 + S_2 = 150 + 80 = 230 \text{ kms}$$

$$t = t_1 + t_2 = 3 + 2 = 5 \text{ hrs}$$

(v) Average speed $= \frac{S}{t} = \frac{230}{5} - 46$ kms/hr

4.2.6. Evaluation Questions :

Evaluation questions were provided at the end of every element, concept or rule to test the capability attainment. The concept mastery depends on the students memory about the various aspects of it. This can be tested with recall questions. Evaluation questions also included to test the understanding and application of a concept or rule. The evaluation questions framed to test the capability in the concept inertia is given below.

Illustration No.9: Evaluation

1. Define inertia.
2. Give examples for inertia from daily life.
3. Differentiate between inertia of rest and inertia of motion.
4. Explain, why
   (i) a man sitting in a moving car leans forward when the car suddently comes to rest?
   (ii) a person alighting from a moving train should keep running on the platform for some distance before stopping?

(iii) a bullet pierces through a windowpane and makes a small hole, while a stone hitting it shatters it into pieces?

(iv) a man riding a galloping horse keeps his thighs pressed hard against the belly of the horse.

The evaluation questions framed for a rule Newton's 3rd Law of Motion is given below. They involve mostly the recall type to state the law and application level questions.

<u>Illustration No.10</u>: <u>Evaluation</u>

1. State Newton's 3rd Law.
2. If action and reaction are equal then how does a body move.
3. Explain with the help of 3rd Law the action during the lift off of a rocket.
4. Explain what happens when air from a balloonn is allowed to rush out quickly.

To test the capability in problem solving situation is done through various types of problems. For example, the Newton's 2nd Law.

<u>Illustration No.11</u>: <u>Evaluation</u>

1. Find the momentum of a cycle rider of mass 150 kgs moving at 6 ms^{-1} due east.

2. What force is required to give a car of mass 1225 kgs an acceleration of $2ms^{-1}$?
3. A motor car of mass 2000 kgs is moving with a velocity of 36 kms per hour. By the application of brakes it is brought to rest in a distance of 40 metres. Find the average force resisting the motion.

4.3 Home Assignment Material (HAM)

Home assignments of the right kind given under the right conditions promotes learning. It has long been recognized the importance of pupil initiative in learning and the need for helping the pupils to use their out of school time wisely. While designing the following objectives were kept in mind -

1. To stimulate voluntary effort, initiative, independence, responsibility and self direction.
2. To encourage a carry over of worthwhile school activities into permanent leisure interests.
3. To enrich the school experience through related home activities.
4. To reinforce school experience through related home activities.
5. To reinforce school learning by providing the necessary practice, integration and application.
6. To guide towards a self evaluation.
7. To detect areas which needs feedback sessions.

The home assignment material was prepared in two parts :

(i) Self Learning Material (SLM)

(ii) Self Evaluation Material (SEM)

Both these materials were given to the students at the end of instruction of a particular topic as these were prepared topic-wise.

4.3.1 Self Learning Material (SLM)

Self learning material was intended to provide additional information and to reinforce what was learned already in the classroom. It has made use of programmed learning method, which has found its effectiveness as a home work tool, as one of the components. Usually, SLM was prepared with an introduction to the students giving all necessary guidelines for instructions. For instance, the topic No.2 'accelerated motion' had the following introduction.

Illustration No.12: Accelerated Motion (SLM)

To Students:

In the previous topic we have discussed speed and velocity. We often hear of an accelerator in a car or even accelerating motion. Acceleration tells us how quickly the velocity is changing. Without the knowledge of acceleration, we cannot describe the motion of a body completely. We have studied in the class alla about acceleration. Here let us look at it little more minutely. While trying to answer the exercises given you may refer back to the classroom learning material supplied, to supplement your knowledge of a particular concept as and when required or when any difficulty arises.

The introduction to the SLM on Newton's laws I and II presented below has a historical flavour.

Illustration No.13: Newton's Laws I & II (SLM)

To Students:

History of Newton's laws is a long one. The world created by his 'Principia' were inhabited mentally by philosophers and scientists alike.

In the absence of forces, Galileo and Descartes had proposed that a particle continues in uniform motion or remains at rest; this was incorporated by Newton as the first law of motion. In the presence of forces, Newton, generalising the suggestion of Galileo, proposed the 2nd law : the force is equal to mass times acceleration.

These are the raw materials of the Newtonian world. Is it really possible to construct from these few stones a building diverse enough to encompass the marvellous variety of our experiences?

In the programmed learning materials, learning frames were prepared; some of them were of the conventional type-small, others extra large. The frame structure was made up of three components :

1. A bit of information bound between two lines.

2. Soon after this information a sentence which is incomplete indicated by the blank/s. In case of problem situations blanks can be more than one.

3. Answer to the incomplete sentence etc. provided at the end of the material under headings key to SLM.

A few illustfations are given below to explain the types of frames prepared.

Illustration No.14: This is a conventional type small frame.

We know that if we throw a cricket ball it will move in a straight direction. If we apply a force using a bat we can make it in a different path altogether.

Force not only makes a body move but it may also change its_ _ _ _ _ _ _ of motion. ....(9)

Illustration No.15 :

This is with an extra large frame.

So far we have been discussing about bodies at rest and bodies in motion. We have been clearly that the bodies will not move unless a force is applied on it, or we can say that "Every body continues in its state of rest or of uniform linear motion unless an external force acts upon it".

This is known as Newton's First Law (Law of Inertia).

The law can be restated as "Everybody preserves its velocity unless acted upon by an external force". Since velocity is constant either when the body is at rest or when it is moving uniformly in a straight line, this law implies that both these states are preserved due to inertia.

- -

The importance of First Law lies in the fact that -

(i) it defines_ _ _ _ _ _ _ qualitatively.

(ii) it explains the property of_ _ _ _ _ _ _ ....(18)

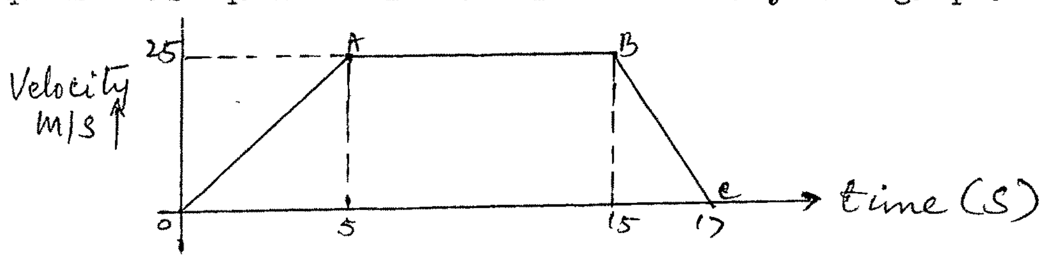
- -

Illustration No.16:

It is an example for graphic problem solving case.

- -

The velocity-time graphs have a very important application. We have already learned in the first topic that the distance travelled = velocity x time taken. If we now look at the graph carefully, we see that the product of velocity and time is actually equal to the area under the graph. That is, we come to conclusion that distance travelled is equal to area under the velocity time graph.



In the graph shown here the distance covered is equal to the area of the trapezium 1 OABC.

- -

$\therefore$ distance travelled $= \frac{AB + OC}{2} \times AE$

$= \frac{- - -}{- - -} \times - - - -$

$= - - -$ ....(10)

Illustration No.17:

This illustrates a guided problem solving exercise.

A bullet of mass 0.005 kg, travelling at a speed of $40ms^{-1}$, penetrates 0.2 m of wood. What is the resistive force offered by the wood, if the retardation is uniform?

We know resistive force f = ma in the opposite direction. The velocity will reduce from 40 m/s to zero wen it stops.

$f = ma$ but $a = \frac{V^2 - u^2}{2s}$ $(u^2 = u^2 + 2as)$

OR $f = m\frac{v^2 - u^2}{2s}$ substitute and calculate.

- - - - - - - - - - - - - - - - - - - -

- ....(20)

4.3.2 Self-Evaluation Material (SEM)

Self evaluation material provided the students a chance to assess himself and perform self correction work. In this material various types of questions which involve all the intellectual skills were provided with answers given at the end to key to SEM. The various exercises included matching, fill in the blanks, statements, derivations reasonings, and problem solving exercises. A few of the illustrations for the type of questions included in the material are given below.

Illustration No.18:

Directions: In the parentheses at the right of each words or expression in the second coloumn write the letter of the expression in the first column which is most closely related.

a. Rate of displacement	displacement	( )1
b. Its graph is a curved line	motion	( )2
c. Rate of motion	linear motion	( )3
d. Distance with direction	speed	( )4
e. Continuous change of location	velocity	( )5
f. Motion along a curved path	uniform velocity	( )6
g. Sum of component velocities	variable velocity	( )7
h. Motion in a straight line	circular motion	( )8
i. Motion about an axis	velocity vector	( )9
j. Represents the magnitude and direction of a velocity	resultant velocity	( )10
k. Its graph is a straight line		

Illustration No.19: Friction

Directions: In the blank space at the right of each statement, write the word or expression which best completes the meaning.

1. Friction is any force that..(1a).. the relative sliding or rolling ..(1b)..of objects that are..(1c).. each other. _ _ _ _ 1a _ _ _ _ 1b _ _ _ _ 1c
2. Some physicists believe that friction is caused by surface..(2).. _ _ _ _ 2
3. If surfaces are made smooth, friction between them..(3).. _ _ _ _ 3
4. Other causes of friction may be ..(4a)..and..(4b).. _ _ _ _ 4a _ _ _ _ 4b
5. Friction acts..(5a)..to the surfaces which are sliding over one another, and in the (same, opposite)..(5b).. direction as the motion. _ _ _ _ 5a _ _ _ _ 5b

Illustration No.20:

1. A body is taken from the earth to the moon. Will its (i) mass, (ii) weight increase, decrease or remain constant?
2. What instruments can be used to measure the (iii) mass (iv) weight on the moon?
3. State Newton's Law of Gravitation.

Illustration No.21:

1. A block weighing 300 N moved uniformly on a horizonal surface by a force of 60 N. (Note here $a = 0$).

   a. What is the force needed to overcome friction ? _ _ _ _1a

   b. What is the normal force pressing the surfaces together ? _ _ _ _1b

   c. What is the coefficient of friction? _ _ _ _1c

These above illustrations show clearly the varied type of questions given under self-evaluation material so that students are exposed to different situations and they can judge their mastery over the topic.

4.4 Assessment Material (AM)

The assessment was done through (i) a criterion test at the end of every topic (ii) a comprehensive test at the end of the planned instruction and (iii) annual examination (question paper from Central Board of Secondary Examinations, New Delhi). The material was prepared for the first two cases. Each assessment paper prepared was divided into three parts: Section A - to test the concepts capability, Section B - to test the rule capability and Section C - to test the problem solving capability. Equal weightage in terms of the marks was given to each part. A few illustrations are given below to show the type of items included in the test which included multiple choice, true-false, fill in the blanks, reasonings, derivations, problem solving exercises etc.

Illustration No.22:

1. Select the most appropriate from the choices given (A/B/C/D).

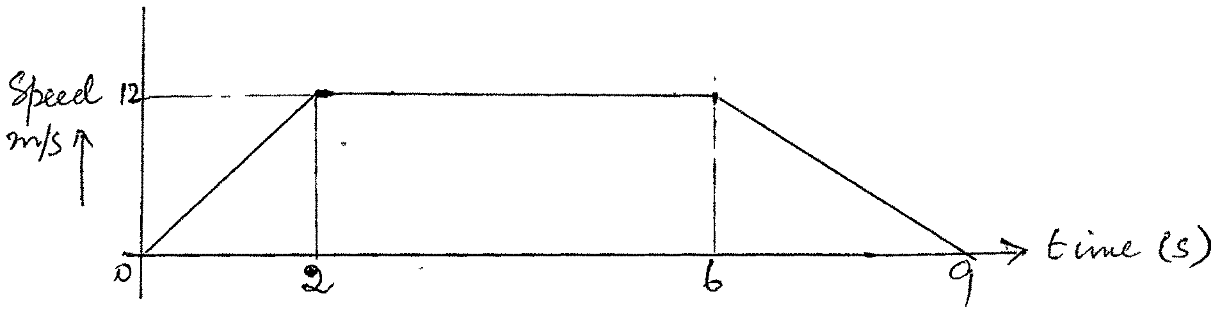
   (a) Acceleration is the rate of change of_ _ _ _ _ _

      A. direction B. speed C. Velocity

      D. none of these

Illustration No.23:

1. The graph represents the motion of a car.



Which statement is true?

(a) The car accelerates, stops, and reverses.
(b) The car accelerates at 6 m/s^2 for 2 seconds.
(c) The car is moving for a total time of 12 seconds.
(d) The car decelerates at 12 m/s^2 for 4 seconds.

Illustration No.24:

I. In the blank space provided write the word which best completes the meaning :

   1. The product of mass and velocity is called..(1).. _ _ _ _ _ _ _ _1
   2. If the acceleration is doubled the force becomes..(2)..times. _ _ _ _ _ _ _ _2

3. When a moving bus suddenly stops the passengers are jerked forward due to..(3).. _ _ _ _ _ _ _ _3
4. A person sitting on a trolley falls backward when it is being pushed forward by some one because of..(4).. _ _ _ _ _ _ _ _4
5. Newton is the unit of..(5).. _ _ _ _ _ _ _ _5
6. ..(6)..is defined as the resistance to acceleration. _ _ _ _ _ _ _ _6
7. Heavy bodies possess..(7).. amount inertia. _ _ _ _ _ _ _ _7

II. Define the following :

(a) Inertia

<u>Illustration No.25</u>:

1. Does a man carrying a luggage on his head on a level road do any work ? Justify your answer.

<u>Illustration No.26</u>:

1. An electron moving with a velocity of 5×10^4 m/s enters an electric field and attains an acceleration of 10^{15} m/s^2 in the direction of its original motion. In how much time will the velocity of the electron become twice its original velocity?

The criterion test items were drawn from the particular topic only while comprehensive test included items from all the nine topics.

4.5 Initial Validation of the Material

Initial validation of the learning material developed was done with the help of 3 experienced teachers who had the necessary experience in dealing with the subject at that particular stage and 5 selected students from Standard X. The Standard X students were selected because they had just finished this particular syllabus in Standard IX and may be in a better position to point out the difficulty level, suitability of the material, level of understanding it can inculcate etc. A detailed questionnaire was prepared to get the opinion of all them in terms of the following :

(i) Clarity of definitions

(ii) Difficulty level of language used

(iii) Familiarity of the terminology used

(iv) Adequacy of the illustrations provided

(v) The approach adopted for the development of the topic

(vi) Any errors etc.

A few illustrations are given below which were part of the questionnaire.

Illustration No.27: Concepts

Tick mark the right. ✓

1. Do you think the learning objectives mentioned are useful? Yes No
2. Are the learning objectives stated clearly? Yes No
3. Concept No.:______ Name:______________________

i. Definition	Clear/Not clear
ii. Units	Mentioned/Not mentioned
iii. Language	Easy/Difficult
iv. The terminology used	Familiar/Not familiar
v. Illustrations	Adequate/Not adequate

Any suggestions : _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Illustration No.28: Rules

i. Definition	Clear/Not clear
ii. Language	Easy/Difficult
iii. Terminology used	Familiar/Not familiar
iv. Do illustrations clearly explain the principle?	Yes/No
v. Are the derivations based on your previous learning?	Yes/No

Any suggestions : _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Illustration No.29: Problem Solving

i. Are the worked out numericals confirm to topic under consideration ? Yes/No

ii. Do the problems require additional information apart from the topic ? Yes/No

iii. How will you rate it?
Easy/Moderate/Difficult/Very Difficult.

Illustration No.30: General

i. Do you like the approach adopted in these materials? Yes/No

ii. Do you wish to make any change in the sequence? Yes/No
If so, please specify._ _ _ _ _ _ _ _ _ _
_ _

iii. Are the illustrations given in general, common to your surroundings ? Yes/No

iv. Do you find any factual errors in the material? Yes/No
If so, specify._ _ _ _ _ _ _ _ _ _ _ _ _ _
_ _

v. Do you think the self-learning material supplied will help the students ? Yes/No

The material, revised based on the responses from experts and students, was used in the experimental validation of the instructional strategy as described in the next Chapter.