PAC 18.4

Updating and digitalization of the Physics Resource Material for secondary school teachers- Stage I

A REPORT

Dr. Raman Namboodiri C. K.

Assistant Professor, DESM, RIE Mysore

Programme coordinator

REGIONAL INSTITUTE OF EDUCATION (NCERT) MYSORE

MYSURU- 570006

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Coordinator.

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1 (A) RESOURCE PERSONS

(i) <u>Internal Resource Persons (IRPs)</u>

1. **Dr. Raman Namboodiri C. K.** **Coordinator**
   Assistant Professor (Physics), DESM,
   RIE Mysore.
2. **Mr. Santosh Kumar,** **Co coordinator**
   Assistant Professor (Physics), DESM,
   RIE Mysore.
3. **Prof. R. Somashekar,**
   Professor (Physics- contractual), DESM,
   RIE Mysore.
4. **Dr. Shalima P.,**
   Assistant Professor (Physics- contractual), DESM,
   RIE Mysore.
5. **Dr. Sudeep Kumara K.,**
   Assistant Professor (Physics- contractual), DESM,
   RIE Mysore.
6. **Mr. Shreekanth S.,**
   Assistant Professor (Physics- contractual), DESM,
   RIE Mysore.
7. **Mr. Noufal P.,**
   Assistant Professor (Physics Education- contractual), DE,
   RIE Mysore.

(ii) <u>External Resource Persons (ERPs)</u>

1. **Mr. V. H. Belvadi,**
   Assistant Professor, Department of Physics,
   St. Philomena's College, Mysuru- 570015.
2. **Dr. K. Padma Prasad,**
   Assistant Professor (Physics),
   J. S. S. College of Arts& Science,
   Mysuru.
3. **Dr. D. Krishnan**
   Retd. Scientist, BARC Mumbai,

A/01/04, 4^{th} Main, AIISH layout,
Bogadi Second Stage, Mysuru- 570026.

4. **Dr. B. V. Sadashivamurthy,**
   Retired Professor, SJCE, Mysore,
   Guest Faculty (Physics), DESM,
   RIE Mysore, Manasagangotri, Mysuru.
5. **Mr. Manohar V. K.,**
   PGT (Physics), JNV Mysore,
   Doddamaragowdanahalli, Mysuru- 571103.
6. **Dr. Pramod Dominic,**
   Assistant Professor, Department of Physics,
   U C College, Aluva,
   Kerala- 683102.
7. **Mr. Suresh kumar J.,**
   PGT (Physics), JNV Galibeedu,
   Madikeri, Kodagu- 571201.
8. **Mr. Laxman Darla.,**
   PGT (Physics), JNV Gollahalli,
   Udigere, Tumakuru,- 572140.
9. **Dr. Rajesh K. P.,**
   Assistant Professor, Department of Physics,
   Government Polytechnic College, Angadippuram,
   Perinthalmanna, Kerala- 679303.
10. **Dr. Biju K. P.,**
    Assistant Professor, Department of Physics,
    Government College, Kodanchery,
    Kozhikode, Kerala- 670580.
11. **Dr. Pradheesh R.,**
    Assistant Professor (contractual), Department of Physics,
    NIT Calicut,
    Kozhikode, Kerala- 673601.
12. **Mr. Suryanarayana.,**
    Teacher (Physics), Sainik School,
    Somwarpet, Kodagu- 571232.

13. **Mr. Santhosha K. J.,**

Lecturer in Physics, BASE PU College,

No. 97/1, 6th Cross, K. R. Vanam, Chamaraja Mohalla,

Mysuru- 570008.

14. **Mr. Kiran Kumar,**

Head of the Department of Physics, JSS PU College,

Ootty Road, Mysuru- 570025.

15. **Mr. Harish M.,**

Lecturer, Department of Physics, JSS PU College for women,

2nd Main Road, Near Swimming pool, Saraswathipuram,

Mysuru- 570009.

16. **Mr. Subrahmania M.,**

Break through Science Society,

Sri parijatha Nilaya, KSRTC Depot Road, Chitradurga.

17. **Mr. K. Arumugam,**

Training Associate (Physics),

Zonal Institute of Education and Training,

Jyoti Nagar Main Road, Siddharthanagar,

Mysuru- 570011.

1 (B) OBJECTIVES OF THIS PROGRAMME

(i) Updating of the Physics Resource Book for secondary school teachers.

(ii) Digitalization of the Physics Resource Book for secondary school teachers.

1 (C) PROGRAMME SCHEDULE AS PLANNED

1	Five days preliminary meeting	June, 2017
2	Five days Workshop- Two stages	August, 2017- January, 2018
3	Digitalization of the material	February, 2018
4	Five days Review Workshop	February, 2018
5	Preparation of report	March, 2018

1 (D) ACTUAL PROGRAMME SCHEDULE

1	Five days preliminary meeting	8th- 12th January, 2018
2	Five days Workshop- First Stages	29th January- 02nd February, 2018
3	Five days Workshop- Second Stages	19th- 23rd February, 2018
4	Digitalization of the material	March, 2018
5	Three days Review Workshop	14th- 16th March, 2018
6	Preparation of report	March, 2018

2 DETAILS OF EACH ACTIVITY

2 (a) Activity I- Initial Planning meeting

A five day workshop was conducted during January 08^{th} to 12^{th}, 2018 to plan the work of 'Updating and digitalization of the Physics Resource Material for secondary school teachers'. The resource material developed by RCE Mysore during 1974 was carefully examined by the resource group. After thorough discussion it has been concluded that the resource material is more suitable to the higher secondary school teachers not at the secondary stage. Since the programme is aimed at the resource material at secondary level, it has been decided to focus on the IX and X standard NCERT text books of Physics and develop the material required. Also it has been agreed that relevant portions from the material of 1974 will be taken and included in the new material after modifications. if needed.

In the planning meeting, it has been decided that as the first stage of this work the focus is to be given on the IX standard Physics topics. The second stage may look into the X standard topics and the two stages together may complete the work.

In order to keep a uniform structure of the resource material a common template has been made as given below.

1. Essential Previous Knowledge
2. Learning Objectives
3. Major Concepts
4. Introduction
5. Concepts
   i. Description
   ii. Activities
6. Exercises
7. Conclusion
8. Concept Map

Other than this, there can be box items on some more related advanced things, Applications, some common misconceptions etc.

2 (b) Activity II- Five days Workshop- Stage 1

The activity II, five days workshop- stage 1, was conducted during January 29th to February 02nd, 2018. Different groups were formed from the resource persons attended the workshop and the five units of the IX standard Physics NCERT text book (Motion, Force and Laws of motion, Work and Energy, Gravitation, and Sound) were assigned to the groups. Considering the pedagogical changes in the last decades it has been decided to give more emphasis on the activities in the material. Almost half of the work was done during this workshop.

2 (c) Activity III- Five days Workshop- Stage 2

The second stage workshop to develop the material was done for five days during February 19th to 23rd, 2018. The remaining part of the work of the first stage workshop was done during this.

2 (d) Activity IV- Digitization of the material

As suggested in the PAC meeting the rationalization of the budget of this programme was done by cutting down the expenditure of this particular activity. The digitization of the material was done at the same time as it was developed and the same resource persons were helping in this.

2 (e) Activity V- Three days Review Workshop

The review workshop was done during March 14th to 16th, 2018. The material developed was carefully examined and modifications were done as suggested by the resource group. The modified material was accepted by the resource group as the final version.

3 RESOURCE MATERIAL
MOTION

INTRODUCTION

One of the most characteristic aspects of the physical world is motion. If we observe our surroundings carefully, we can see that the change in position of objects is a common phenomenon. Movement of the objects are occurring from microscopic to macroscopic level. On the cosmic scale, the galaxies move relative to one another, it appears to be an expanding universe. The sun rotates on its own axis and also it has a motion relative to the nearby stars. Our abode, the earth revolves about the sun and rotates on its own axis. On the surface of the earth we observed a vast variety of motion both natural and man-devised. If we were able to observe individual atoms and molecules directly, we would see the rapid vibrations of atoms in solids and liquids, and the fantastic random motion of molecules in gases. Looking deeper into the atom we would see the motion of electrons about the nucleus and in the nucleus, the motion of the protons and neutrons. So we can see, it is quite apparent that we do indeed live in a physical world that is very much in motion. A description of motion is then a very important part of a science that strives to describe fully our physical universe. We can begin our development of mechanics with a description of motion. The name kinematics is assigned to this segment of mechanics in which we are concerned only with the formal description of motion without explicit reference to the properties of the moving body or the mechanisms by which the motion is produced.

ESSENTIAL PREVIOUS KNOWLEDGE

- State of an object (Rest and Motion)
- knowledge about position or state of body , motion, distance and speed
- plotting graphs with given data
- Interpretation of graphs
- Solving numerical problems based on graph.

LEARNING OBJECTIVES

The student will be able to

- Define reference point
- Differentiate between reference point and origin
- Comprehend about the straight line motion
- Solve problems based on straight line motion
- Explain uniform motion
- Explain non-uniform motion.
- Differentiate between distance travelled and displacement covered
- Differentiate between uniform motion and non-uniform motion
- Identify speed with direction.
- Define rate of change of velocity.
- Plot the graphical representation of motion.
- Differentiate between speed and velocity.
- Differentiate between average speed and average velocity
- Solve problems related to speed and velocity.
- Define Acceleration
- Calculate acceleration from analysing the given parameters
- Plotting the graph when appropriate data is given: Distance-time, Velocity-Time:
- Interpret the graphical representations: Distance-time, Velocity-Time
- Derive the equations of motion by using graphical method.
- Solve the problems by using the kinematic equations of motion
- Comprehend the uniform circular motion

- Identify the daily life situations related to uniform circular motion

MAJOR CONCEPTS

1. Describing motion
2. Motion along a straight line
3. uniform and non-uniform motion
4. Measuring the rate of motion
5. speed with direction
6. Rate of change of velocity
7. Graphical representation of motion
8. Equations of motion by graphical method
9. Uniform Circular motion

Reference point: To describe the position an object we need to specify a reference point called origin.

Example: The distance of the school from the hostel is 1km toward north; here the hostel is reference point.

A body is said to be at rest if it does not change its position with time with respect to its immediate surroundings, while a body is said to be in motion if it changes its position with time with respect to its immediate surroundings.

Distance: The total path length travelled by an object between two positions is called distance.

Activity 1.

- Take a ball place it at a point 'A" on the floor facing the wall
- Hit the ball such that it moves in a straight line and comes back to point 'C" after striking the wall 'B'
- Find the distance covered by the ball (i) from A to B (ii) A to C

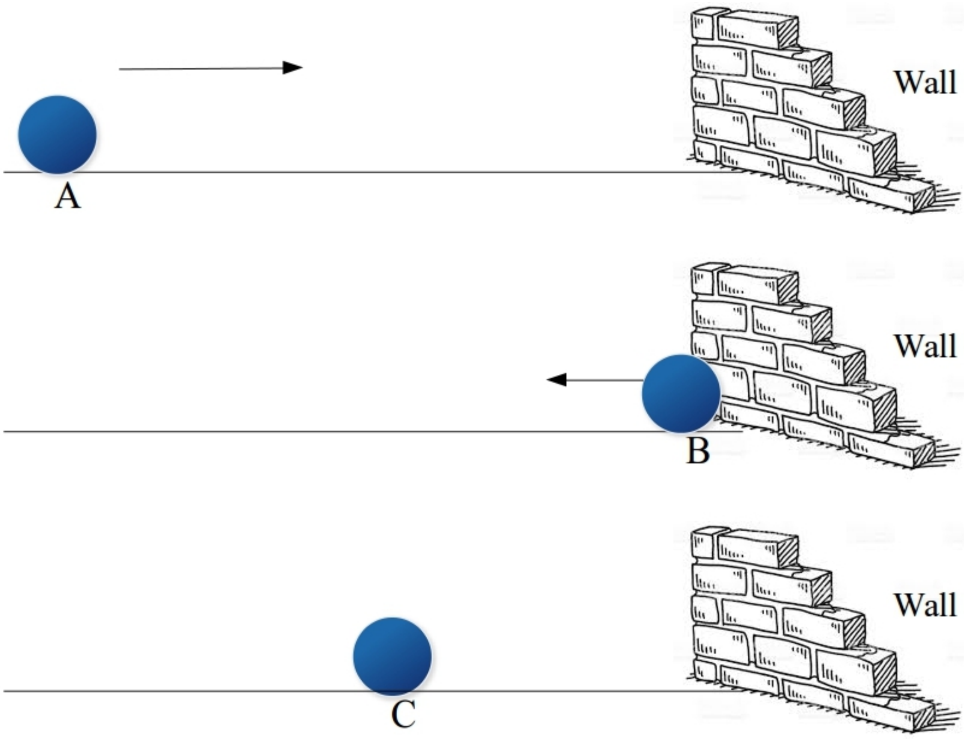


Figure 1.1

Activity: 2 – To find the radius of the bicycle rim

- Take a bicycle rim mark a point on the rim.
- Roll it on the ground along a straight line until the rim completes 5 rotations.
- Measure the distance travelled in 5 rotations.
- Find the radius of the rim.

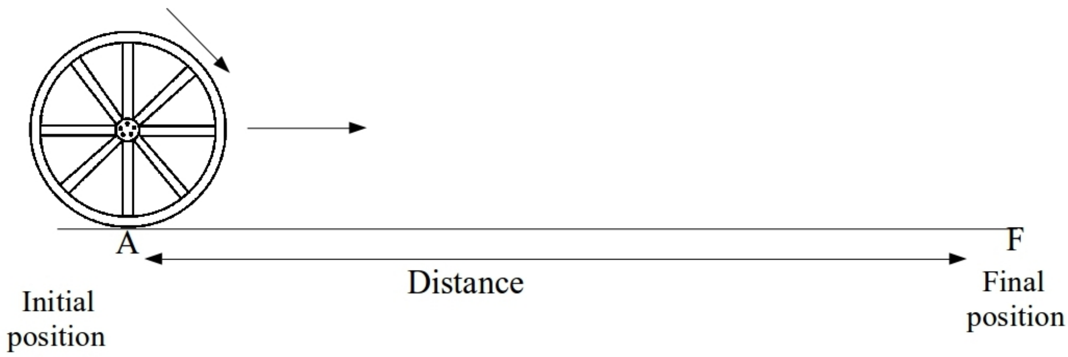


Figure 1.2

Displacement: The shortest distance between initial position to final position of an object is known as displacement.

Activity 3:

- Take a ball place it at a point 'A" on the floor facing the wall.
- Hit the ball such that it moves in a straight line and comes back to point 'C" after striking the wall 'B'
- Find the displacement covered by the ball (i) from A to B (ii) A to C

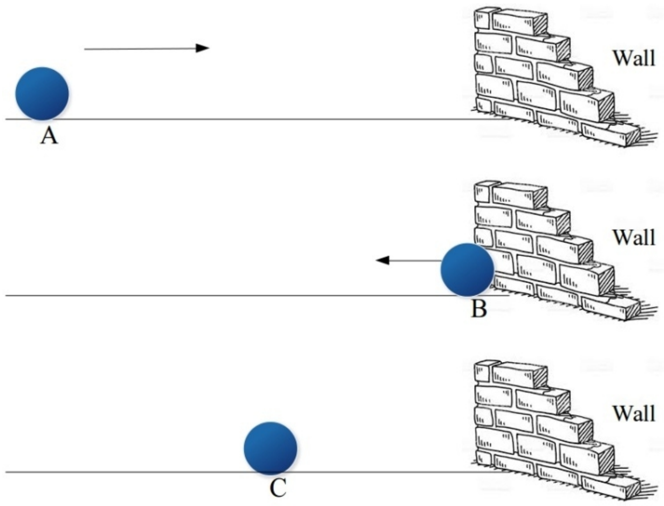


Figure 1.3

Activity 4:

- Take a petri dish and place it on a horizontal table
- place a ball bearing at a point (say 'A")
- Make it to roll and observe the position where it stops. (say the positions 'B' and 'C")
- Find the displacement in each case.

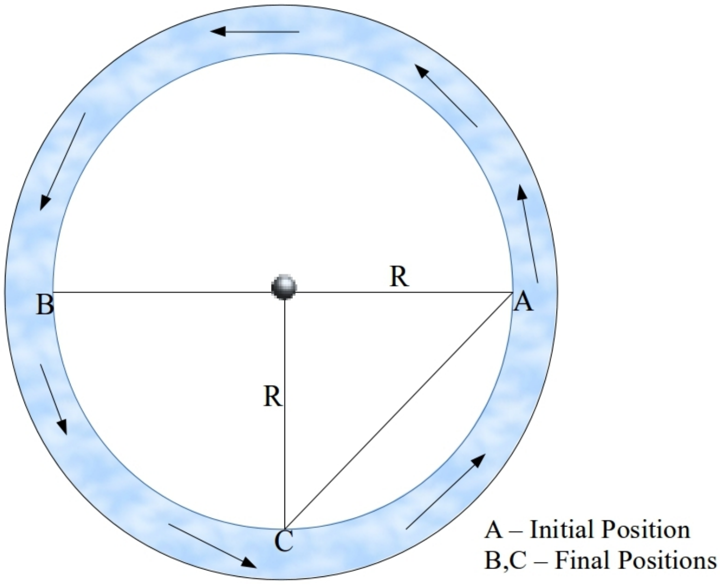


Figure 1.4

Activity 5:

- A cricket player after hitting the ball starts running between the wickets (22 yards)
- What would be the distance and displacement covered by him when he completes one run, two runs and three runs on different occasions?
- Fill the values of distance and displacement in the table given below.

Runs	Distance	Displacement
1		
2		
3		

Distance	Displacement
It is the length of the path travelled by a body in certain interval of time.	It is the shortest distance between the final and initial positions
It depends on the path travelled by the object.	It does not depend on the path travelled by the object.
It is always positive.	It can be positive or negative depending on the direction of motion.
It is not zero even if displacement is zero.	It can be zero even if distance is not zero.

Uniform motion: Any object moving along a straight line which covers equal distances in equal intervals of time (however the small interval may be) is said to be in uniform motion.

Example: The hour hand of a clock it moves with uniform speed completing movement of a specific distance.

Activity 6

- a caterpillar moves on a string tied between two poles.
- It is moving '1'cm per second continuously.
- Infer the motion of the caterpillar.

Non uniform motion: Any object moving along a straight line which covers equal distances in unequal intervals of time or unequal distances in equal time intervals of time then the object is said to be in non uniform motion.

Example: a motion of a car in a crowed street

The motion of a ball on a rough surface

Activity 7:

- Take an inclined plane inclined at an angle of 45 degree

- Allow a solid spherical ball to roll down on an inclined plain from the top.
- Identify the motion of the ball

Speed: It is defined as the ratio of distance travelled by an object to time taken (or) it is the distance travelled per unit time.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

Its SI unit is m/s.

But the speed of an object throughout their motion does not remain constant. Therefore we define average speed of an object as the ratio of total distance travelled to total time taken.

The speed of an object at a particular time is called **instantaneous speed.**

Velocity:

It is defined as the ratio of displacement covered by an object to time taken (or) it is the displacement covered by an object per unit time.

$$\text{velocity} = \frac{\text{displacement}}{\text{time}}$$

Its SI unit is m/s.

If the speed of an object or the direction of the motion or both changes then the object has variable velocity.

The velocity of an object at a particular instant of time is called instantaneous velocity.

If the velocity of an object changes at a uniform rate then the average velocity is the arithmetic mean of the initial velocity and final velocity for a given period.

$$\text{v}_{av} = \frac{u + v}{2}$$

where u is initial velocity and V is final velocity

Activity 9:

- Ask your friend to walk 4m towards east, 2m towards south , 4m towards west and 2m towards north.
- The entire motion lasted in 20 seconds.
- Determine the average speed and average velocity.

Activity 10: In the diagram a skater travels and reverses the direction of travel as shown below. i.e., the skater moves from A to B, then B to C, and then C to D. Determine the average velocity of the skater during these three minutes.

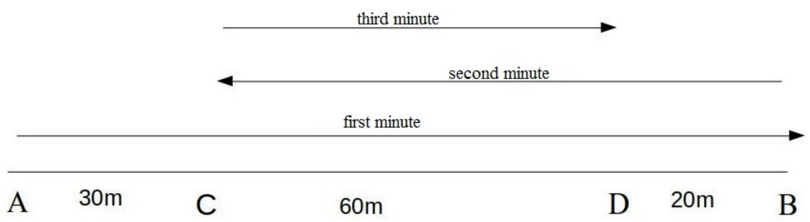


Figure 1.5

Acceleration: If the velocity of an object changes the body gains acceleration**.** It is defined as the ratio of change in velocity to time taken.

$$\text{acceleration} = \frac{\text{change in velocity}}{\text{time taken}}$$

$$a = \frac{v-u}{t}$$

The SI unit of acceleration is m/s^2

- If the velocity of an object is increasing then the acceleration gained by it is positive.
- If the velocity of the object is decreasing then its acceleration is negative or retardation.
- Acceleration has same direction as of velocity if velocity increases.
- Acceleration has opposite direction as of velocity if the velocity decreases.

If the velocity of an object increases or decreases by equal amount in equal intervals of time then the acceleration is uniform. Example: a freely falling body.

Activity 11:

(using ticker tape timer)

- Take a ticker tape timer and connect it to A.C. Mains
- Take a thin strip of paper and place it below the carbon sheet and vibrating pin of ticker tape timer
- Connect the other end of the thin strip paper to slotted masses
- Now, allow the load to fall freely by switching the tape timer on.
- We can see the impressions of vibrating pin on paper strip
- Measure the distance between the successive impressions made by the vibrating pin
- You can find the distance between the impressions goes on increasing proportionately
- From this we can understand that the motion of slotted mass is accelerated.

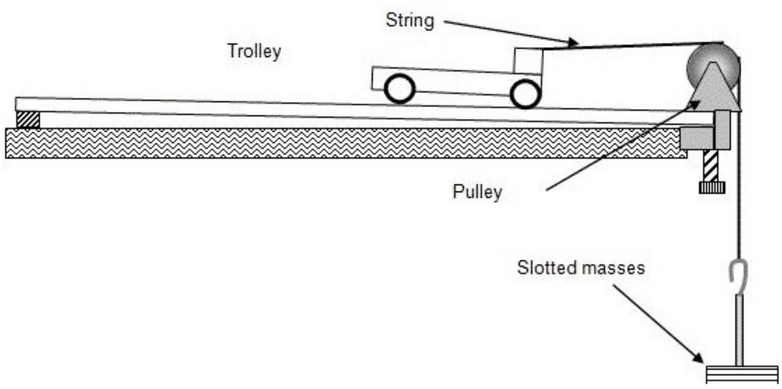
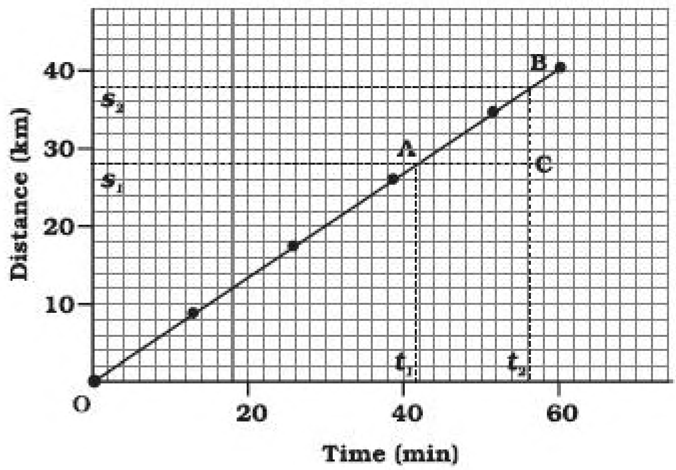


Figure 1.6

Distance - time graph:

It is a graph plotted with time along x-axis and distance travelled along y-axis. The slope of the graph gives the speed of the object.



The distance- time graph of a body moving with same speed.

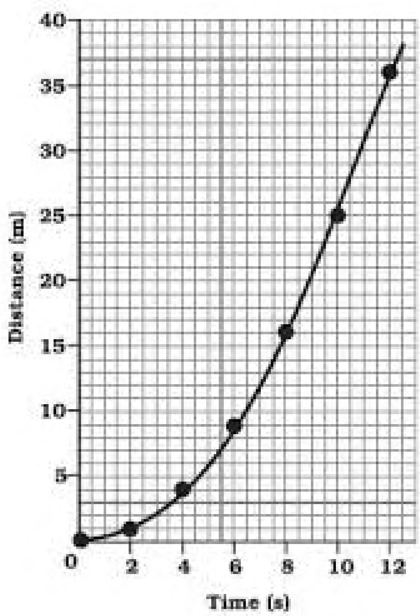


Figure 1.7

The distance- time graph of a body moving with different speed. The slope of the tangent to the curve at any point graph gives the speed or velocity of an object at that instant.

Activity 13:

- Take a ticker tape timer and connect it to A.C. Mains
- take a thin strip of paper and place it below the carbon sheet and vibrating pin of ticker tape timer
- connect other end of the thin strip paper to slotted masses
- Now, allow the load to fall freely by switching the tape timer on.
- We can see the impressions of vibrating pin on paper strip
- Cut the strip paper at successive impressions made by the vibrating pin
- Paste these paper strips on the graph sheet as per the order of impression
- You can find the distance between the impressions goes on increasing proportionately
- Now by using pencil join the impressions on the paper strips which are pasted on graph sheet
- The graph comes out to be a parabola
- From this we can understand that the motion of slotted mass is accelerated.

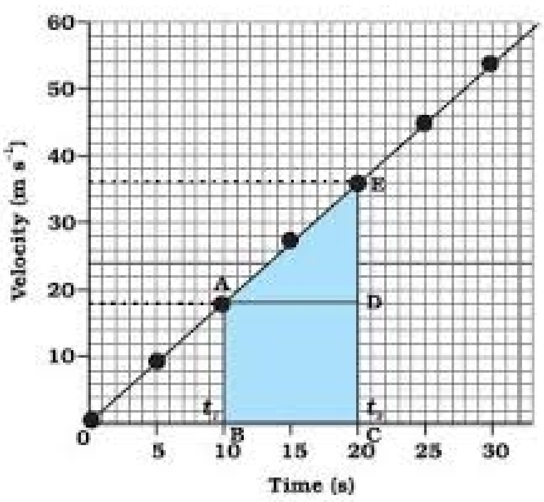


Figure 1.8 The velocity- time graph of a body moving with same acceleration.

Activity 13: Ram left home and drives to school as shown in the graph, on his drive to school he realized that he has forgotten to bring the lunch bag and had to return to the home before going to school for 2 hour class, explain what is happening during different part of the graph.

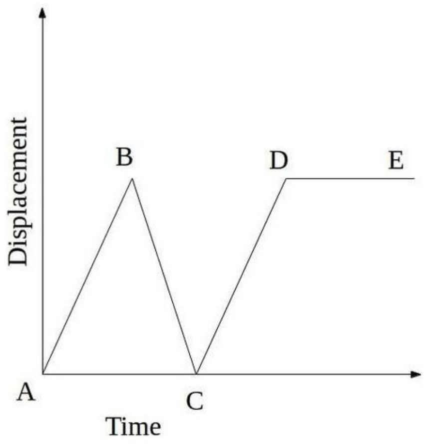


Figure 1.9

Activity 14: When you are standing on the platform of a railway station observe

a) a train entering the platform

b) a train leaving the platform

Write down your observations and plot the graphs between distance- time and identify the nature of motion.

Velocity - time graph:

It is a graph plotted with time along x-axis and velocity along y-axis. From the v-t graph we can determine the displacement of an object and the slope of the graph gives the acceleration of an object at any instant.

The Area under velocity – time graph gives distance or displacement.

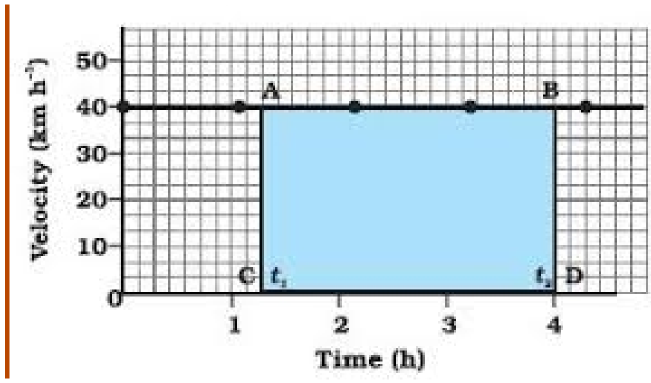


Figure 1.10

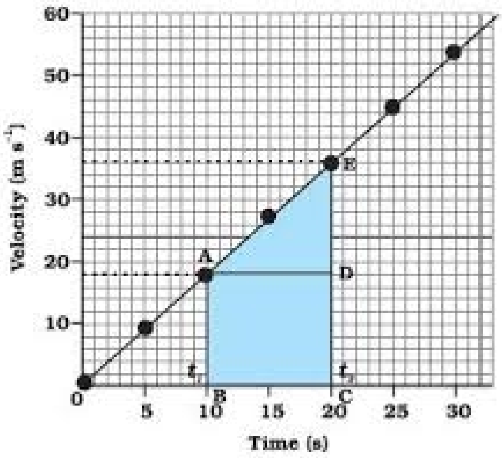


Figure 1.11

Activity 15:

- A ball is dropped from the top of a cliff and its velocity was observed at different intervals of time as given below
- Plot a graph and infer the nature of motion of the body

Time (s)	Velocity (m/s)
0	0
1	10
2	20

3	30
4	40
5	50
6	60

Activity 16:

- A bus moves from the bus stand with an initial velocity of 10m/s for 10 seconds and there after it moves with the velocity of 50m/s in the next 30 seconds. Plot a graph between velocity and time and find out the total distance covered by the bus.

Uniform circular motion:

An object moving along the circumference of a circle with a constant speed is said to be have uniform circular motion.

When the object has uniform circular motion the speed remains constant but its velocity changes, its direction is always tangent to the circular path and the object turns the tangent is always pointing in a new direction.

In uniform circular motion speed is given by,

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{t}$$

Activity 17:

- Take a wall clock whose seconds hand's length is 10cm, minutes hand length is 7cm and hours hand length 4cm.
- Observe the motion of these hands for one complete rotation
- Note down the time taken by each hand for one complete rotation
- Find the speed of each hand for completing one rotation
- We can infer that the motions of these hands of clock are in uniform speed.

- From your observations and calculations fill the following table.

Hand of clock	Time for one complete rotation	Distance travelled in one complete rotation	Speed
Hour hand			
Minute hand			
Second hand			

Activity 18:

- Draw a circle of radius 6cm
- Mark a few points on the circumference of the circle.
- Draw tangents to these points in the direction of motion of your pencil.
- What do these tangents represent?
- We can infer that tangents drawn to the circle represents the direction of the velocity at that instant. Also note that the tangents are perpendicular to the radius of the circle.
- The direction of the tangents changes at different points. It represents the change in direction of motion continuously.

CONCLUSION

- ❖ Motion of an object is change in position with respect to time and it can be expressed in terms of distance travelled or displacement
- ❖ The motion of an object can be uniform or non uniform depending on whether it undergoes equal or unequal displacement in a given time.
- ❖ Speed is distance travelled per unit time and velocity is speed with direction
- ❖ The change in velocity per unit time is acceleration
- ❖ Motion of an object can be shown by plotting distance-time graph and velocity-time graph.
- ❖ For the body which has uniform acceleration along a straight line we can have the three equations of motion namely,

$$v = u + at$$

$$s = ut + \frac{1}{2}at^2$$

$$v^2 = u^2 + 2as$$

- ❖ An object moving along the circumference of a circle with constant velocity is said to be have uniform circular motion.

EXERCISES

1. How to understand that the body under observation is in motion? What parameters will you use? Explain.
2. What is a speedometer or odometer? What is the relevance of this in the society?
3. Does a car's odometer measure position or displacement? Does its speedometer measure speed or velocity?
4. Compare the speeds of tennis ball hit by the player and the cricket ball bowled by a bowler in terms of motion?
5. How velocity is correlated to human metabolism?
6. If you are travelling in a boat upstream and downstream, what changes do you observe?
7. List the highest record speed of (a) flight in India and in world (b) bullet train in India and in world
8. When you observe a person breaking the stone with a hammer , which one you observe first

    (a) Light

    (b) Sound. Justify your answer
9. Mention the importance of time against distance graph? Which one should be along X-axis? Why?
10. Plot the graph for the given data and analyse the behaviour of graph at different

intervals

SI No	Parameter A	Parameter B
1	0	0
2	1	1
3	2	3
4	3	5
5	4	8
6	5	8
7	6	5
8	7	3
9	8	5
10	9	8
11	10	8

11. Speed of light is 3×10^8 m/s and that of sound is 330m/s. Compare the magnitude of light and sound.
12. Mention the role of break in vehicles.
13. Explain what happens to linear velocity in uniform circular motion?
14. The speed of propagation of the action potential (an electrical signal) in a nerve cell depends (inversely) on the diameter of the axon (nerve fibre). If the nerve cell connecting the spinal cord to your feet is 1.2m long, and the nerve impulse speed is 20 m/s, how long does it take for the nerve signal to travel this distance?
15. A football player runs 20 m straight down the playing field in 4 second. He is then hit and pushed 3.00 m straight backward in 2 second. He breaks the tackle and runs straight forward another 21.0 m in 7second. Calculate his average velocity (a) for each of the three intervals and (b) for the entire motion.
16. A car moving 80.5 kmph accelerates to pass a truck 5 s later the car is moving 128.7 kmph what is the acceleration of the car.
17. Brakes are applied suddenly to a racing car travelling at 80m/s. If the car stops after 20 seconds, calculate the retardation of the car.
18. A car travels from a town A to another town B with a speed of 40 km/h and

returns back to the town A with a speed of 60 km/h. What is the average speed of the car during the complete journey?

a) 48 km/h
b) 50 km/h
c) zero
d) None of these.

19. A ball is thrown vertically upwards. It rises to a height of 50 m and comes back to the thrower. Which of the following is correct?

a) the total distance covered by the ball is zero.
b) the net displacement of the ball is zero.
c) the displacement is 100 m.
d) none of these.

20. When a graph of one quantity versus another results in a straight line, the quantities are

a) both constant
b) equal
c) directly proportional
d) inversely proportional

21. When the distance that an object travels is directly proportional to the length of time it is said to travel with

a) zero velocity
b) constant speed
c) constant acceleration
d) uniform velocity

22. The slope of speed-time graph gives

a) speed
b) velocity
c) acceleration
d) momentum

23. A person travels distance πR along the circumference of a circle of radius R. Displacement of the person is

a) R
b) 2R
c) $2\pi R$

d) Zero

24. The velocity of an object is directly proportional to the time elapsed. The object has
   a) uniform speed
   b) uniform velocity
   c) uniform acceleration
   d) variable acceleration

25. In which of the following cases the object does not possess an acceleration or retardation when it moves in
   a) upward direction with decreasing speed
   b) downward direction with increasing speed
   c) with constant speed along circular path
   d) with constant speed along horizontal path

26. If a man walks with a uniform velocity of 2m/s how much time he will take to cover a distance of 4 km

27. With the wind an aeroplane covers a distance of 2400km in 4 hour and against the wind in 6 hr. what are the speeds of the plane and the wind?

28. A train travels at 60kmph and crosses a person in 6 second. Calculate the length of the train?

29. Draw the velocity- time and distance –time graph for a train entering a station, stopping for a while and then leaving the station

30. A bike rider accelerates from rest at a rate of $5m/s^2$ and a traffic signal turns green. The next signal is 300 meter away and turns green in 4.2 s. Is it essential for the bike rider to stop at next signal as well?

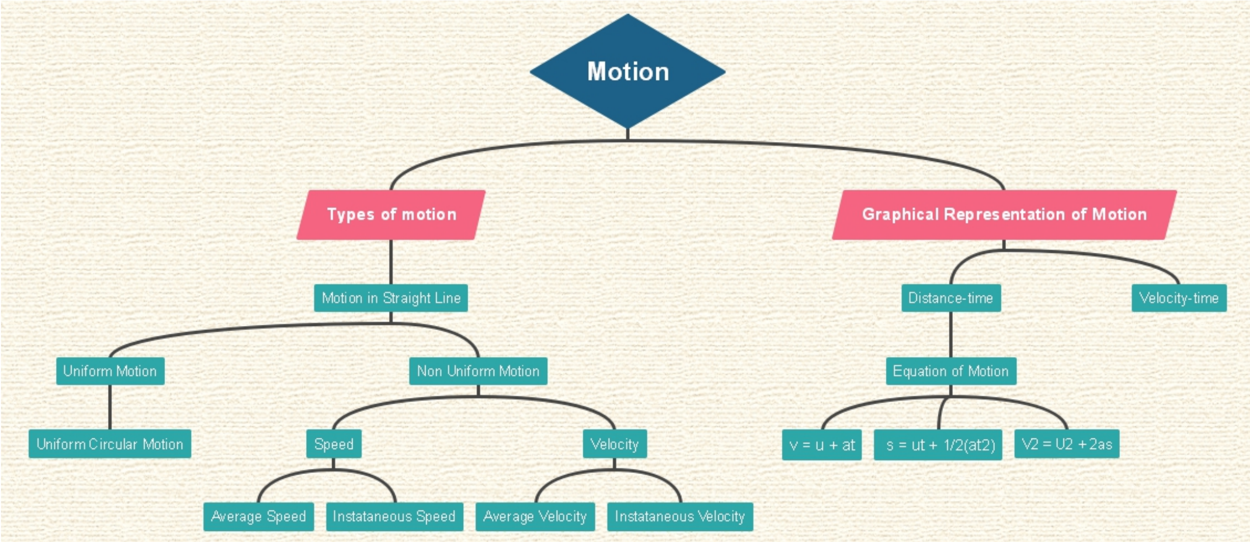
31. Compare the position-time , velocity-time and acceleration-time graph of as cricket ball being hit by a batsman straight back to sore a boundary

32. How long will it take for a 150 m long train running at 60kmph to cross a bridge of 300meter

33. Calculate the speed of rotation of earth and sun if the radius respectively are $6.38\times10^6 m$ and $6.95\times10^8 m$. (period of rotation of sun=27 days)

Velocity in different context
1. **Average breathing velocity of human being during**
Rest 0.79m/s
Deep breath 1.58m/s
Light activity 3.16m/s
2. **Blood flow velocity**
Aorta 21cm/s
Capillaries 0.03cm/s
Venae canal 14cm/s
Small arteries 1.3cm/s
Arterides 0.6cm/s
3. **Electron velocity**
Drift velocity for semi conductors $10^4 m/s$
Root mean square velocity of electron at room temperature for metals $10^5 m$
Fermi velocity of metals $10^6 m$

CONCEPT MAP


Motion
Types of motion
Graphical Representation of Motion
Motion in Straight Line
Distance-time
Velocity-time
Uniform Motion
Non Uniform Motion
Equation of Motion
Uniform Circular Motion
Speed
Velocity
v = u + at
s = ut + 1/2(at2)
V2 = U2 +2as
Average Speed
Instataneous Speed
Average Velocity
Instataneous Velocity

FORCE AND LAWS OF MOTION

INTRODUCTION

In the previous classes children learned about basic idea of force. In Class IX more emphasis is to be given on the concept of inertia, momentum, conservation of momentum, force and different types of forces .Force can be applied on a body in various ways. But the body is said to be in motion only when it overcomes inertia. Inability of a body to change its position by itself is known as inertia. In case of motion of anybody it may be of linear, translational or rotational, force is necessary.

Galileo and Newton proposed laws of motion. These laws are explaining about force. viz., what is force? What does it do? What does a body get when a force is applied on it? In daily life children will come across about all these things. Motion of an object is influenced by both its mass and velocity.

The physical quantity which depends on mass and velocity called momentum of a body plays a big role in motion. The concept of momentum and its conservation helps us to learn many mechanisms of motion of bodies. When same velocity has been imparted on different bodies then the momentum acquired by them is found to be different. It is because of their difference in their masses.

ESSENTIAL PREVIOUS KNOWLEDGE

- Force is a push or a pull.
- To move an object, it has to be pushed or pulled.
- At least two objects must interact for a force to come into play.
- A force can change the state of motion.
- Force can change the shape of an object.
- A force can act on an object with or without being in contact with it.

LEARNING OBJECTIVES

The students will be able to

- Acquire the knowledge of inertia
- Understand Newton's I law
- Understand that without force body cannot change its state of motion.
- Understand that mass and inertia of a body is directly proportional.
- Applies the knowledge of force and understand acceleration.
- Understand that acceleration of a body is inversely proportional to mass present in it
- Understand Newton's second law and measure the quantity of force by using it.
- Understand the meaning of 1N
- Acquires the knowledge about different system of units for force
- Acquires the knowledge about momentum and the law of conservation of linear momentum.
- Acquires the knowledge of Newton's III law
- Understand about action and reaction and how does they act?

MAJOR CONCEPTS

1. Balanced and Unbalanced Forces
2. First law of Motion
3. Inertia and Mass
4. Second law of Motion
5. Mathematical Formulation of second law of motion
6. Third law of Motion
7. Conservation of momentum.

Force:

The first concept of force comes from our everyday experience. If we push an empty box, it moves. If the box is filled with materials, we might push hard to move it or sometime it may not move at all. Similarly if you hit a ball with a bat it moves.

From all these examples the word **"Force"** can be explained as a **push, pull or hit**, basically a muscular activity. By applying a force, an object may or may not move.

Take another example, to move a chair in a long hall from one end to the other, we need to supply a constant push or pull throughout the activity to maintain a constant speed. From this observation, we can infer that, **"a constant force is required to maintain constant speed for an object"**. This was the inference made by **Aristotle** (BC 384-322).

In our previous example of pulling a chair from one end of the hall to other, if we attach small roller wheels to the chair, much lesser force is required to maintain a constant speed. Further if we make the surface of the floor smooth and lubricate the wheels sufficiently, only an initial push is sufficient to move the chair with constant speed. Hence it is clear from this experiment that a **constant force is not required to maintain constant speed**. This idea was first introduced by **Galileo**.

In the example without roller wheels, frictional force played foul to make us pull all the way to maintain a constant speed. Frictional force opposes the motion.

Balanced and Unbalanced Forces

This situation can be visualized with an example of two strings attached to a wooden block and pulled in opposite directions as shown in fig.

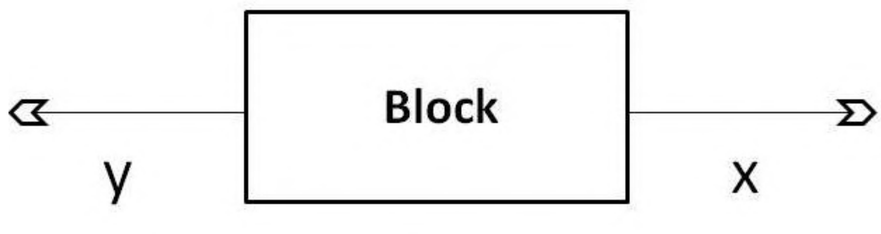


Figure 2.1

If we pull the string X alone, the wooden block move towards right. It will move towards left when we pull the string Y. on the other hand, string X & Y are simultaneously pulled with same force, the wooden block doesn't move at all. If they are pulled with unequal forces, it moves towards the force which is larger. Thus balanced forces don't change the state of motion whereas unbalanced forces change the state of motion.

Again coming back to the example of chair with roller wheels on a smooth floor; an initial unbalanced force is required to start or stop uniform motion. This idea was first introduced by Galileo, he said the following **"when no force is exerted on a body, it stays at rest or it moves in a straight line with constant speed"**.

Activity 1:

Balanced and unbalanced forces.

Place a cardboard making it inclined at a small angle on the table as shown in the figure.

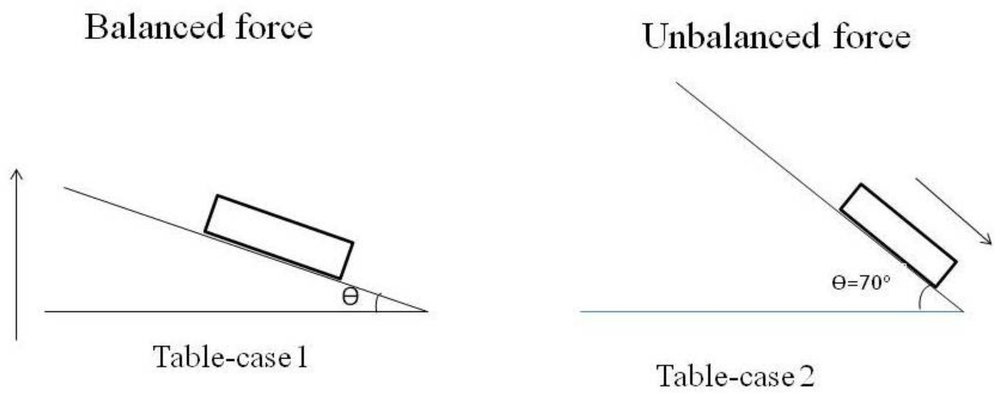


Figure 2.2

- Place a small piece of solid material with a rectangular base (example eraser) on the cardboard
- Adjust the cardboard at small inclination.
- Since the angle of inclination of the cardboard is small, the object placed on the cardboard will not slide down. This is due to the balanced force between gravity and the frictional force.
- Now increase the inclination by raising one side of the cardboard.
- You will notice that after reaching certain angle the object will slide down.

- At this angle the component of gravity along the horizontal has taken over the frictional force. At this stage the body is under an unbalanced force.
- This concludes that the objects move when it is subjected to unbalanced force.
- In other words the object will move if the net force acting on it is nonzero.
- The direction of motion will be along the net force.

Newton's first law of Motion

After Galileo, Newton formulated the laws of Motion. Adding to the inferences made by Galileo, Newton quantified the relations among force, acceleration, Momentum, Action and Reaction. Newton formulated first law (Law of Inertia) as follows- **"Every body continues in its state of rest or of uniform motion along a straight line unless compelled by an external unbalanced force".** Thus an object cannot changes its state of motion without an external force. This inability of an object is known as Inertia.

Activity 2:

- Take a wooden plank and make an inclined plane as shown in fig

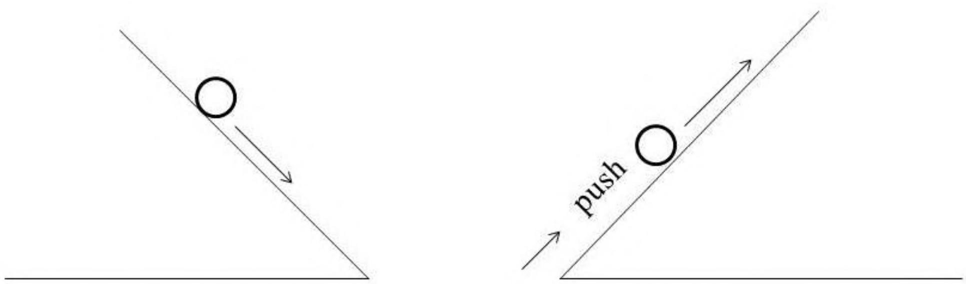


Fig A. Rolls down freely   Fig B. Give a small initial push

Figure 2.3

- Keep the ball on the inclined plane as shown in fig A and release.
- Allow the ball to roll on the inclined plane by giving small initial push as shown in the second part of the above figure (B).
- By observing the two motions, the following conclusions can be made:

If we release the ball at a height on the inclined plane, speed of the ball keeps on increasing (accelerates) which can be attributed to gravitational force.

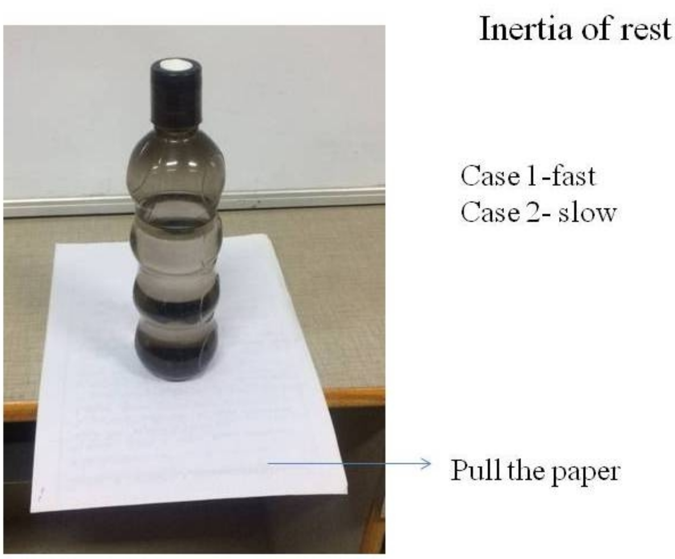
If we roll the ball by giving initial push as in case “B”, speed of the ball keeps on decreasing and finally comes to momentary rest at the top of inclined plane.

- In both these cases unbalanced gravitational force either changes the state of rest or uniform motion.

Activity 3:

Inertia at rest

- Place a rectangular piece of paper near the edge of a table as shown in the figure.
- Place a bottle filled with water on the paper.
- Pull the paper instantaneously.
- Pull the paper slowly.
- You will observe the following for both the cases.
- The bottle will stay on the table when the paper is pulled instantaneously.
- The bottle will fall down as you slowly pull the paper beneath. (You may spill the water if the lid is not closed.)



Note :Bottle filled with water is placed on the paper below

Figure 2.4

- In the first case, when you pulled the bottle instantaneously, the bottle stayed on the table due to its inertia of rest.
- However when the paper was pulled slowly, the bottle fell down.
- In this case the force acted on the paper has transformed to the bottle, (through frictional force) making it to fall.

Caution: Don't use glass bottles of beakers for the experiment. They may break during the experiment.

Activity 4:

Make three tracks as shown in fig ABC. Release the ball in each track as shown in fig. and observe the motion.

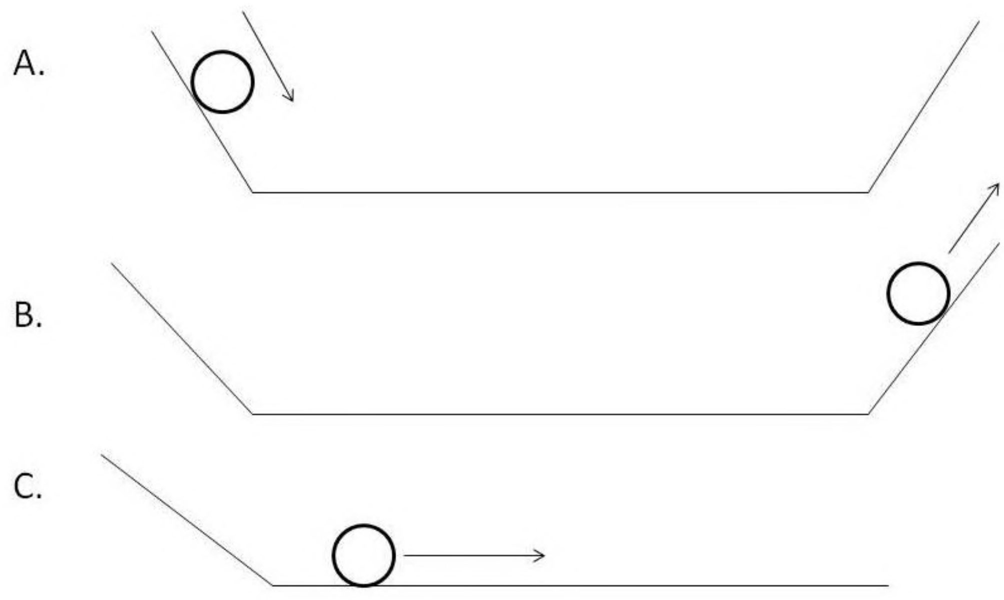


Figure 2.5

- In case A, on both sides the inclinations of the track are same. The ball rolls down, travels straight, and climbs up till it reaches the same height.
- In case B, the slope of the track on the right side is reduced. Thus the ball rolls

down, travels straight, and climbs up covering much more distance (S’) till it reaches the same height when it was released.

- In case C, if we further reduce the slope and finally make it flat on the right side, the ball travels much more distance and tries to reach the same height, thus travels forever. In this case there are no unbalanced forces acting on the ball. It suggests that an unbalanced force is required to change the state of motion of the ball.

Activity 5:

- Place a ball on the cart and move both together.
- Observe the motion of the ball, when the cart was suddenly stopped.

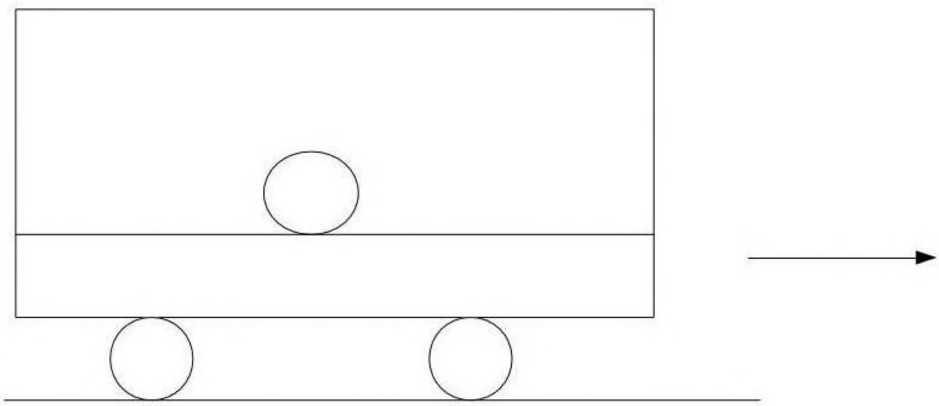


Figure 2.6

- When the cart is suddenly stopped, the ball moves forward and falls off the cart.
- This can be attributed to the inertia of the ball.

THINK

A boy is jumping vertically up on the surface of earth. Let us assume that the boy is in air for 1 second while jumping. By that time the earth might have rotated below him over some distance. But we observe that the boy comes back to his original position after the jump, How can we explain this?

Activity 6:

- A heavy ball is suspended on a rigid stand using a thread X as shown in fig.
- Another thread Y is attached to the bottom of the ball as shown in fig.
- Try to break the thread by pulling Y

  i) Slowly and

  ii) Abruptly

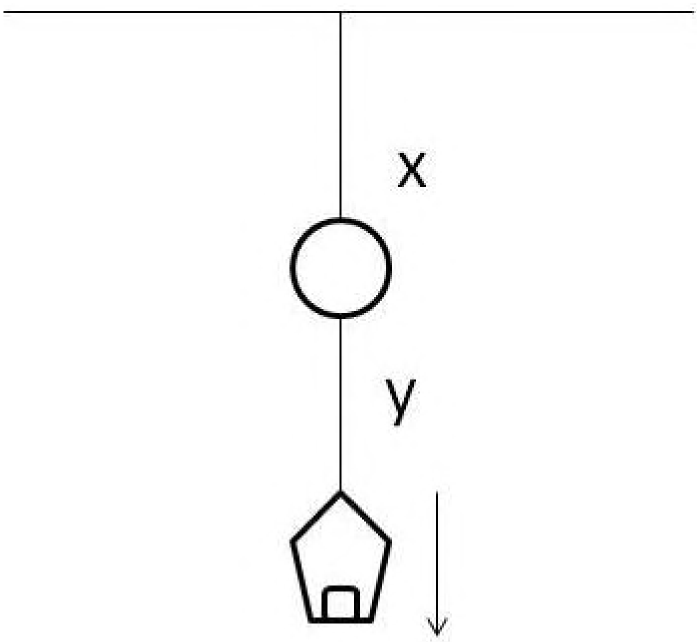


Figure 2.7

- If we do not pull the string Y, there is no tension in string Y and there is a tension in string X which is equal to the weight of the ball.
- If we pull the string Y slowly, the tension in string Y is equal to the pulling force whereas tension in string X is the sum of pulling force and weight of the ball. Hence string X breaks.
- If we pull the string Y abruptly, the pulling force on the string Y is not transferred to the string X because of inertia thus string Y breaks.

Inertia and First law of motion

In everyday life we see that objects come to rest when they are not subjected to constant force in the direction of their motion. However we have learnt that this is not the case. Objects on earth eventually came to rest because of the external forces like drag force and frictional force.

The clear evidence for the first law of motion comes from the observation of heavenly bodies. All planets including earth are in constant motion around the sun from billions of years. Since the outer space is empty, planets won't experience drag or fictional force. And so they are continued to be in constant motion.

Newton’s second law of motion

From first law of motion we concluded that an external unbalanced force induces a change in velocity. Newton tried to obtain an expression for force in terms of change in velocity. We will try to obtain the expression for force through an example of a cricket play.

If a player tries to catch a cricket ball which is moving very slowly, he can easily manage it without any injury to his hand. On the other hand if he tries to catch a hard hit ball (moving with high velocity), it is going to hurt his hand. So we can conclude that as the velocity of the ball increases, the effect of impact is very high. Now if we replace the cricket ball with a tennis ball, even if the player catches a hard hit ball, it is not going to hurt his hand. Thus we can conclude that the effect of impact not only depends on velocity but also on mass. Now let us introduce another concept momentum which is the product of mass and velocity.

$$\text{Momentum } (p) = \text{mass x velocity}$$

Again coming back to the example of catching a hard hit ball, with the fielder pulls his hand gradually with the moving ball while catching; the effect of impact is reduced. By doing this way, the fielder reduces the velocity of the ball to zero not abruptly but by taking sometime, just changing the velocity and thus momentum to zero slowly. If he is able to make this process more slowly, he can reduce the effect of impact further. Thus we can conclude that the force necessary to change the momentum of an object depends on the time rate at which the momentum is changed. Thus Newton's second law can be stated as "the rate of change of momentum of an object is proportional to the force and takes place in the direction of force".

Initial momentum = mu

Final momentum = mv

Change in momentum = mv-mu

Rate of change of momentum = $= \frac{(mv - mu)}{t} = \frac{m(v - u)}{t} = ma$

According to the second law,

$$F \propto ma \text{ or } F = k\text{ma}$$

If we choose the suitable unit system, we can set k=1

$$\text{i.e., } F = ma$$

Now let us understand the meaning of 1N of force. It is the amount of force required to accelerate an object of mass 1Kg to $1\,ms^{-2}$. Now let us consider an example of a metal bob of 1kg which is falling under gravity. Given the information that acceleration due to gravity is $9.8\,ms^{-2}$ you can calculate the force as 9.8N. which is nearly 10N of force. So one Newton's of force is equivalent of the force acted on a mass of 100 grams. Force can also be expressed in CGS units -dyne.

$$1N = 10^5 \text{ dyne}$$

Activity 7: (Second law of motion)

- Take a good quality of spring, wooden plank and the base, a lightweight plastic ball and a heavy metal ball nearly of same size, lock and trigger setup.
- Attach one end of the spring to a rigid plank as shown in the figure.
- Pull the other end of the spring and hold it in place at a particular position

marked on the base. (you can also introduce a lock and trigger system for the sophistication of the experiment)

- Now place a plastic ball with low mass in front of the spring and release the spring.
- Repeat the experiment by replacing the plastic ball with a heavy metal bob.

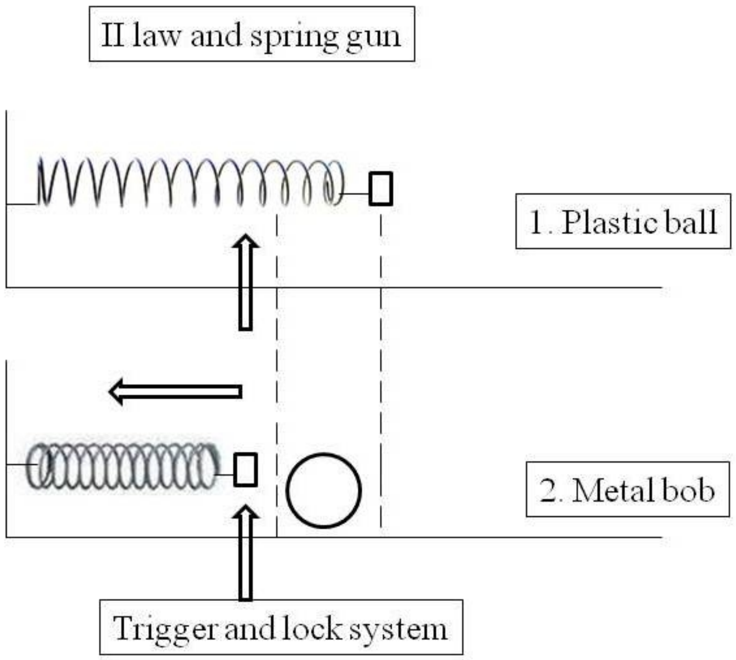


Figure 2.8

- Since the spring is pulled for the same distance, the forces exerted by the spring on both the cases are the same.
- However you will observe that the plastic ball will travel longer distance than the metal bob.
- This is a consequence of Newton's second law. As the mass of the ball increases, the acceleration experienced by the ball will be less.
- This makes the metal bob to exit with lesser velocity than that of a plastic ball.
- As a result the metal bob will travel shorter distance than the plastic ball.

Activity 8:

- Take blocks of different weight, spring, and hooks.
- Attach one end of the spring to the block of 1Kg.

- Place it on the table and pull it with the other end of the spring.
- Now the block starts to move.
- Also you will notice that the spring is stretched.
- Note the length of the spring which is stretched.
- Now replace it with 2Kg block.
- Pull the spring to make it move with the same speed as 1kg mass.
- You may experience that you need to pull it with more effort to make it move as fast as 1kg block. Also you can notice that the spring is stretched more in this case.
- This is a consequence of Newton's second law of motion.
- The amount of stretch on the spring indicates the amount of force exerted on the object. More massive the object, more force is needed to produce the same acceleration.

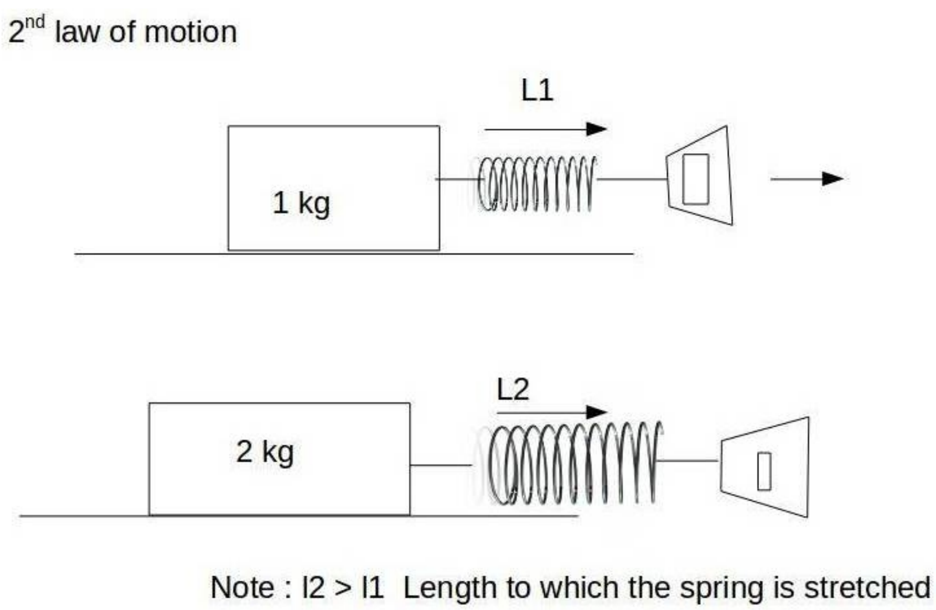


Figure 2.9

Types of forces

Till now we have discussed about the gravitational force and mechanical force. However you may have come across many other kinds of forces such as magnetic force, drag force, frictional force, electrostatic force and so on.

But according to the theoretical understanding, all the kinds of forces are the consequence of only four fundamental forces. Namely gravitational force, electromagnetic force, strong nuclear force and weak nuclear force! (about which you will learn in future classes)

Here you may wonder that mechanical force and frictional force are not listed among the four fundamental forces. This is because the mechanical force and frictional force between the objects has arisen due to the intermolecular repulsions in the matter, attributing electromagnetic force at the atomic level.

The activity of a magnetic spring may help us understand more about the emergence of mechanical force from electromagnetic force. Here you see the magnetic disks acting like a mechanical spring, without touching each other.

Activity 9: (MAGNETIC SPRING)

- Take a pencil, a cardboard disk, five identical ring magnets with the diameter of the inner bore slightly larger than the diameter of the pencil.
- Paste a cardboard disk to the bottom of the pencil and place it firmly on the table as shown in figure.

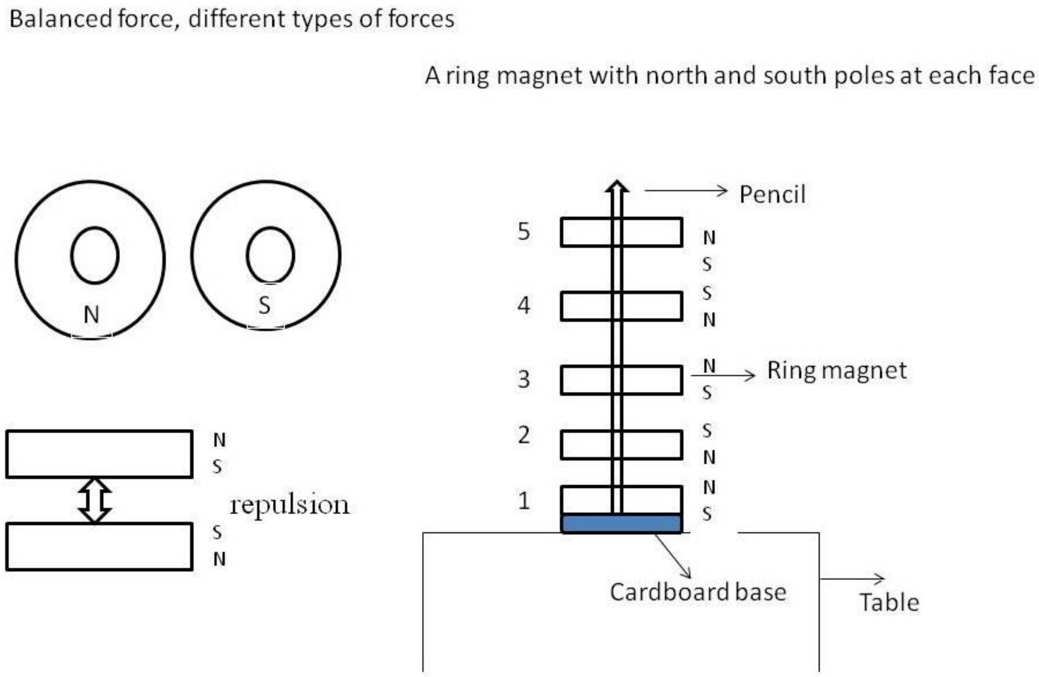


Figure 2.10

A ring magnet will have its North Pole and South Pole at the opposite faces similar to the head and tail of a coin. As you may be familiar, like poles of the magnet repel each other and unlike poles attract each other. Use this principle to test and mark the like pole faces of these ring magnets and keep them ready. Now slide the ring magnets one by one, facing in such a way that only like poles face towards each other.

Observation: After arranging the ring magnets in this way, you will notice that the magnets will settle at different positions subjected to a balanced force between gravity and repulsive force between the magnets. This setup also acts like a spring, so we can name it as a magnetic spring.

Observe carefully the distance between each ring. The distance between bottom rings is much shorter than that of top two rings. Give the explanation of this phenomenon.

Answer: Although the rings are not touching each other, all the weight of the top ring is exerting on to the bottom rings. And so the distance between the bottom rings is short. In contrary the distance between the top rings are more.

Newton's III Law of Motion

From first law of motion, we understood that force is required to change the state of motion of objects. Second law gives quantitative measure for the force. Now consider an example of a ball hitting a thick plank. If we hit the plank with the ball at sufficient speed the plank will fall down and the ball renounces. The plank fall down because of the force exerted by the ball but on the other hand, the ball renounces that means it deviates from its state of uniform linear motion. Thus the force has been applied on the ball too. From this experiment we conclude that when a body applied a force on the other body, the second body applies a force back on the first body. These two forces are called action force and reaction force. They always acting in opposite direction and acts on different bodies.

Take another example of two heavy balls suspended on a rod using thread as shown in the figure.

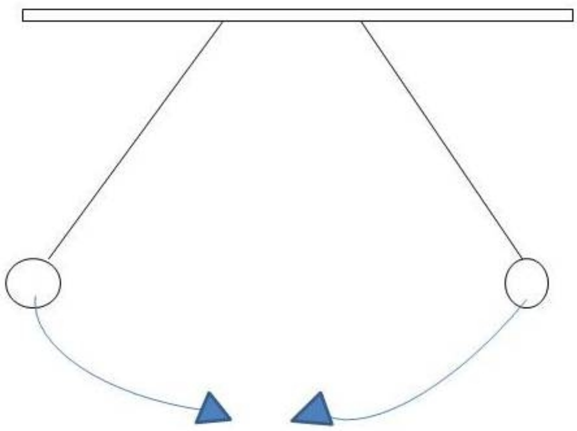


Figure 2.11

Lift the two balls to the same height in such a way that if you release it, it will collide. Release the ball simultaneously and observe the rebounds of the balls. We can observe that the balls renounce to same height. From this experiment, we can conclude that the magnitude of action and reaction are same. Thus, Newton's III law can be stated as "**For every action there is an equal and opposite reaction**"

Activity 10: Balloon Rocket

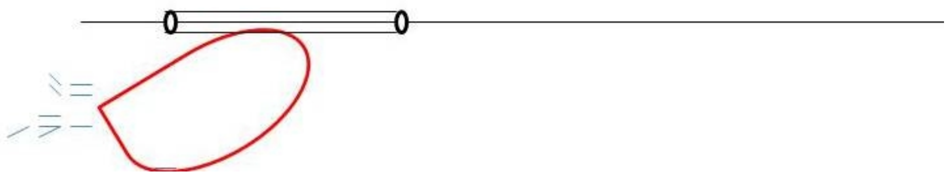


Figure 2.12

Take a long thread tied between the two points which goes through a straw as shown in the figure. Inflate a balloon and tie it at the opening and stick it to the straw. Now untie the opening of the balloon to let the air go out. The balloon and the straw move forward. The effect can be explained by Newton's III law.

Activity 11: [third law of motion]

Materials required:

Plastic ball, plank with a hole, wooden base, nail, candle, matchstick, balloon, and an elastic band.

- Firmly hook one end of the elastic band (rubber band) to the ball.
- Fix the nail and the plank with a hole, on the wooden base. (As shown in the figure)
- Pull the other end of the rubber band through the hole of the plank and tie it to the nail creating the tension in the band.
- You will notice that the ball is firmly held at the plank by the elastic band. As shown in the figure.
- Place the candle below the elastic band and light the candle.

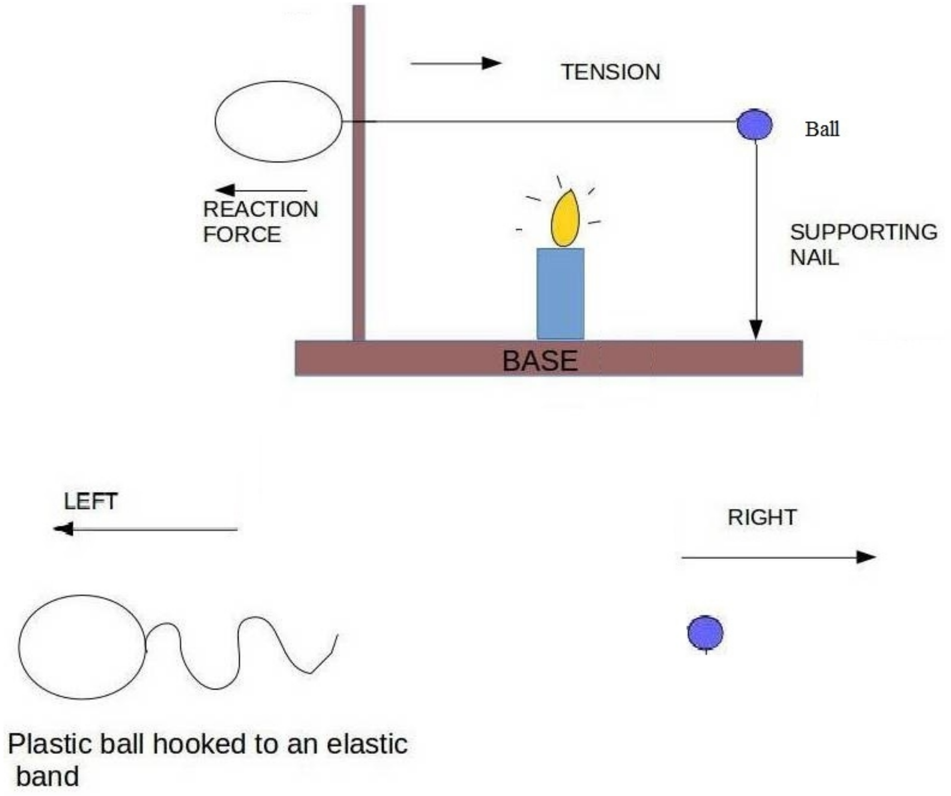


Figure 2.13

Observation:

The ball was firmly held at the surface of the plank before lighting the candle. As the candle was lit, the elastic band was cut and the ball got fired to the left with high speed.

Explanation:

Before lighting the candle, we observed that the ball was firmly held at the plank due to the balanced force between tension of elastic band and the reaction force offered by the surface of the plank on the ball.

After lighting the candle the elastic band got burnt and so the tension in the band vanished instantaneously. However the reaction force offered by the surface of the plank now came to action and forced the ball the fly left in the horizontal direction. This is clearly a consequence of Newton's third law of motion.

Activity 12: Conservation of Linear Momentum

“When no external force acts on a system, the sum of the momentum of the bodies before collision is equal to the sum of the momentum of the bodies after the collision”

Construct a track to roll the metal balls as shown in figure. Take two identical balls. Release the first ball on the track such that it accelerates first and attains a constant velocity when it reaches the plane region. Measure the velocity of the ball by measuring the time taken to travel from A to B. It hits the identical ball B and comes to rest whereas the II ball moves forward. Measure the velocity of the second ball by measuring the time taken from C to D. We will find that the second ball moves with same velocity.

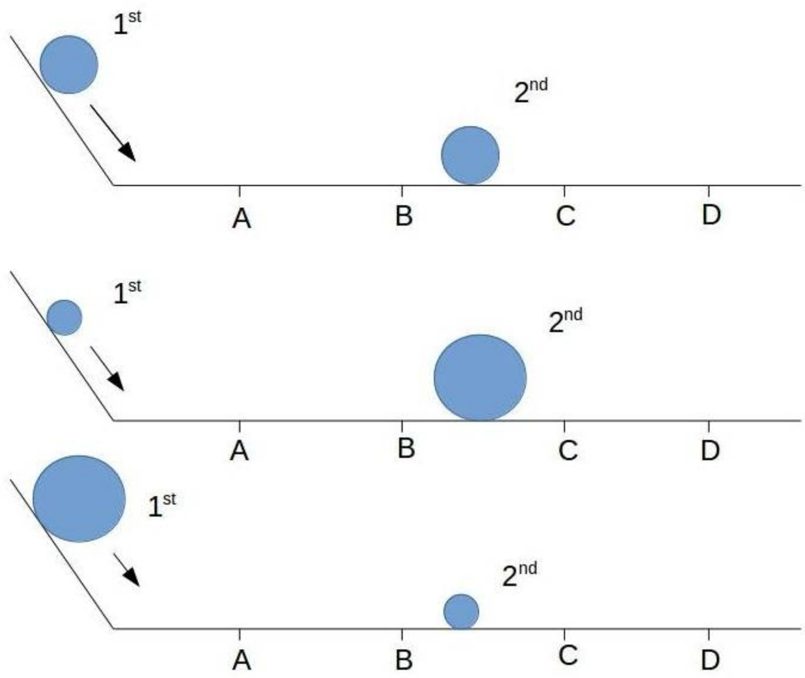


Figure 2.14

Now repeat the experiment with balls of different mass. Replace the second ball in the previous example with a heavy ball. Release the first ball and measure the initial velocity by measuring the time taken to travel from A to B. It hits the 2nd ball which is heavy, 1st ball bounces back and 2nd ball moves forward. Measure the final velocity of 1st ball by measuring time taken to travel from B to A. Measure the velocity of 2nd ball by the time taken to travel from C to D. Now we can verify conservation of momentum.

Again repeat the experiment by interchanging the light and heavy balls as shown in the figure. The heavy ball is released from a height and you can measure its velocity by measuring the time taken to travel from A to B. It hits the light ball and light ball moves very fast. Measure the velocity of light ball by measuring the time taken from C to D. The heavy ball loses some velocity and moves slowly and its final velocity can be measured by noting the time taken by it to travel from C to D. Conservation of momentum can again be verified.

Most of the topics from this chapter which we discussed are the force as something which acts only between two objects in contact, but forces sometimes act at a distance also. Gravitational force is such an example. Earth attracts moon towards its centre which is not in direct contact with the earth. Another example is magnetic force.

The examples for contact forces are: Mechanical force, frictional force, viscous force, air resistance and normal force.

Examples for non contact forces are: Gravitational force, electrostatic force, magnetic force.

CONCLUSION

In physics force is any interaction that, when unopposed, will change the motion of an object. A force can cause an object with mass to change its velocity (which includes to begin moving from a state of rest) i.e., to accelerate. Force can also be described intuitively as a push or a pull. A force has both magnitude and direction making it a vector quantity. It is measured in the SI unit of newton (N). If many forces are acting at a time on an object there can be balanced and unbalanced cases. In case of balanced force net effect is zero. i.e., it does not produce any change in the body due to equal forces are acting from all sides. In case of unbalanced force the body either moves or change its state or shape due to non cancellation of forces. Galileo deduced that objects move with a constant speed when no force acts on them. This means that for a body to move with constant speed or velocity only initial force is required thereafter it is not necessary to continue.

The original form of Newton's second law states that the net force acting upon an object is equal to the rate at which its momentum changes. If the mass of the object is constant, this law implies that the acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object.

Mass and inertia are directly proportional to one another. Larger the mass greater is the inertia. If inertia is large more force is required to apply on it to change its state or shape. In all the three laws of motion which was described by Newton the second law of motion is very important in the sense that both 1st law and 3rd law can be derived from it. Momentum which is the product of mass and velocity is a vector quantity and is measured in $kgms^{-1}$. Large amount of force acts on a body for a small interval of time produces high impulse. That is why while catching a cricket ball which comes with high velocity the fielder moves his hand backwards thereby the time of catching the ball is increased and hence the impulse is gradually reduced to zero. Impulse is numerically equal to the difference in the final and initial momentum of a body. When no external force is acting on a body then the momentum is said to be conserved. i.e., sum of the momentum of bodies before collision is equal to the sum of momentum of bodies after collision. It is applicable in all cases provided no external force is acting on it. It shows that the momentum is due to the internal force present in the system.

EXERCISES AND PROBLEMS

1. Calculate the force required to impart to a car, a velocity of 60m/s in 15 second which is at rest initially. The mass of the car is 2000 Kg.

   HINT: $a = \frac{v-u}{t}$

   a= (60-0)/15 = 4 m/s

   and $F = ma$

   F= 2000 x 4 = 8000 N

2. A base ball of mass 140g moving with a velocity of 1m/s is stopped by a player in 1 second. What is the force applied by the player to stop the ball?

HINT: $F = \frac{m(v-u)}{t}$

F= 0.140(0-1) = -0.14 N (it is the retarding force)

3. A bullet of mass 15g is fired from a rifle. The bullet taken 0.004second to move through its barrel and leaves with a velocity of 300m/s. What is the force exerted on the bullet by the rifle?

HINT: $F = \frac{m(v-u)}{t}$

F = 0.015(300-0)/0.004 = 1125 N

4. A 1500Kg vehicle moving with a speed of 30m/s is brought to rest in a distance of 100m (a) Find the acceleration (b) Calculate the unbalanced force acting on the vehicle. (c) The actual force applied by the breaks may be slightly less than that calculated in case of (b) why? Give reason.

HINT:

(a) $v^2 - u^2 = 2as$

$0^2 - 30^2 = 2a(100)$

$a = -4.5 m/s^2$ (it is the retardation)

(b) now, F = ma

= 1500(-4.5) = -6750 N (it is the retarding force)

c) Due to frictional force, the actual force applied by breaks may be less than that of the calculated value.

5. A bus starting from rest and it takes 40 second to get 15m/s speed. If the bus is full of passengers and its mass is about 12000Kg. Calculate the force applied by the engine of bus to move the bus at the speed of 15m/s?

HINT: F = ma

= 12000(15-0)/40= 4500 N.

6. Ravi bowls a ball at a speed of 150 Km/hr. The batsman (Naveen) hits the ball

and the ball returns back with a speed of 180 km/hour. If the mass of ball is 163g,

a) What is the change in the momentum of ball?

b) If the ball is in contact with the bat for 5 second, with what average force did the bat hit the ball?

HINT: (a) Change in momentum of the ball = $P_{final} - P_{initial} = mv - mu$

$$= 0.163(180 - (-150)) \times (5/18) = 14.94 kg.m/s$$

Average force applied = $= \frac{(P_{final} - P_{initial})}{t} = (14.94 kgm/s)/5s$

7. Suppose you accelerate an object with a steady force and find that the change in speed during a time interval at 1 second amounts to 24m/s. You now repeat the measurement using the same for the second object. It gains 3.3m/s in 0.5s.

   a. Which body has the greater inertial mass?
   b. What is the ratio of the inertial mass of the second object to that of the first?

   HINT: For first body v=24m/s, t=1 s. u=0.

   We know that,

$$V = u + at,$$
$$24 = 0 + a \times 1$$
$$i.e, a = 24 m/s^2$$

   In case of second body, v= 3.3m/s, t= 0.5 s.

$$3.3 = 0 + a \times 0.5$$
$$i.e, a = 6.6 m/s^2$$

   Lesser the acceleration more will be the inertial mass, Hence second body has greater inertial mass. Ratio of inertial masses between second to first = $= \frac{a_1}{a_2} = \frac{24}{6.6} = 3.63$.

8. A force of 5N is applied to a mass of 0.8kg. What is it acceleration?

   HINT: F = ma, Here m= 0.8 kg, F= 5N, Hence a = 5/0.8= 6.25 m/s^2

9. If the distance covered by a moving object varies directly with time, what conclusion could you draw about the motion and force?

HINT: It is said to be that force is acting continuously to make the object to move with uniform motion.

10. A force of 3N is exerted on an object and it accelerates up at $1.5ms^{-2}$.

a. Assuming that this is the only force on the object what is the mass?
b. How do you make an independent measurement of the mass?
c. Suppose this measurement indicate that the mass determined by the first method is greater. What might you suspect?

Answer:

a)

$$F = Ma,$$

$$3 = M \times 1.5$$

$$M = 3/1.4 = 2kg$$

b) By the direct measurement on the weight scale.
c) The object is said to be in an accelerated frame

11. A block of mass 2 kg is pulled on a frictionless table by a force of 6N. The block starts from rest.

a. What is the acceleration of the block?
b. What is the speed of the block after 3 s?
c. How far does the block travel in 2 s?
d. At the end of 3 s, the block splits into two equal pieces- one piece still being pulled by a force of 6N and other free. How far apart will the two pieces be 2 s after the break occur?

Answer:

a. Acceleration = $= 6/2 = 3m/s^{-2}$
b. Speed after 3 s,

$$V = u + at,$$

$$V = 0 + 3 \times 3 = 9m/s$$

c. distance travelled in 2 s is,

$$S = ut + \frac{1}{2}at^2$$

$$S = 0 \times t + \frac{1}{2} \times 3 \times 2^2 = 6m$$

d. At the end of 3 s body has been broken into two equal halves. i.e., each of mass 1kg.

After 2 s, second body moves a distance of $S_2 = ut = 9 \times 2 = 18m$

whereas for first which has been tight by the same force of 6N moves a distance of

$$S_1 = 9 \times 2 + \frac{1}{2} \times 6 \times 2^2 = 30m$$

Hence the distance of separation is 30 – 18 = 12 metre.

12. A car of mass 800Kg moving with some velocity strikes another car of mass 1000 Kg at rest. After this collision both the cars start to move with the velocity of 16 m/s. Find the initial velocity of the first car.

Hint:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

$$800 \times u_1 = 1800 \times 16$$

$$u_1 = 36m/s$$

13. A body is not accelerating or retarding then the net force acting on it will be zero. True/false

Ans: True

14. The net force acting on a stationary body is zero. True/false

Ans: True

15. During tug of war competition neither team is able to gain advantage due to the forces are balanced on both side. True/false

Ans: True

16. When a bus suddenly stops, the passengers in the seat get a forward

jerk. This is due to

a) law of gravitation

b) law of force and acceleration

c) law of inertia

d) law of action and reaction

Ans: (c) law of inertia

17. Which law of Newton describes the relationship between the force and mass?

a) law of gravitation

b) Second law of motion (law of force and acceleration)

c) First law of motion (law of inertia)

d) Third law of motion

Ans: (b) Second law of motion (law of force and acceleration)

18. Which is true in the view of 3^{rd} law of motion of Newton.

a) For every action there is a 25% reaction force in opposite direction.

b) For every action there is equal reaction force in opposite direction.

c) For every action there is a 95% reaction force in opposite direction.

d) It will depend on nature of the bodies involved.

Ans: (b) For every action there is equal reaction force in opposite direction.

19. Why a fielder in cricket game pulls his hands backwards after catching/holding the ball.

a) Keep the ball in hands safely

b) To exert larger force on the ball

c) To reduce the force exerted by the ball

d) It is the rule of cricket game.

Ans: (c) To reduce the force exerted by the ball

20. Which is not true in case of unbalanced force?

a) It can change the direction

b) It can change the momentum

c) It can change the shape of the body

d) It can change the velocity

Ans: (c) It can change the shape of the body

21. A boy tosses a coin in a moving train, and he observed that the coin falls behind him. Then the motion of the train is

a) Retarded

b) Accelerated

c) Uniform

d) unpredictable

Ans: (b) Accelerated

22. Rocket works on the principle of

a) Conservation of velocity

b) Conservation of mass

c) Conservation of momentum

d) Conservation of energy

Ans: (c) Conservation of momentum

23. A tank filled with 70% of water is moving with a uniform speed, on applying sudden breaks the water in the tank would

a) move forward

b) move upward

c) move backward

d) unaffected

Ans: (a) move forward

24. Ravi is travelling on an aeroplane at a constant speed of 700m/hour, also Swaroop is travelling in his car at a constant speed of 70m/hr. Who experiences a less acceleration?

a) Swaroop

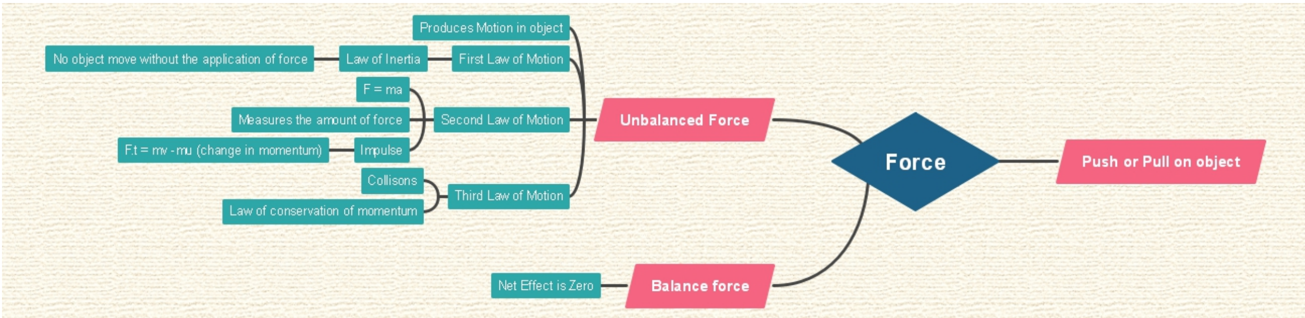
b) Ravi

c) Neither Swaroop nor Ravi

d) Cannot be determined

Ans: (c) Neither Swaroop nor Ravi

CONCEPT MAP



Produces Motion in object
No object move without the application of force
Law of Inertia
First Law of Motion
F = ma
Measures the amount of force
Second Law of Motion
Ft = mv - mu (change in momentum)
Impulse
Collisons
Third Law of Motion
Law of conservation of momentum
Unbalanced Force
Force
Push or Pull on object
Net Effect is Zero
Balance force

GRAVITATION

INTRODUCTION

The ancient Greek philosopher, Aristotle in the 4^{th} century BC, believed that all heavy objects fall because they moved towards the centre of the universe, and they fall due to their inherent heaviness or weight called *gravitas*. Indian astronomer Aryabhatta considered that a force prevents objects from falling when the earth rotates. Brahmagupta another mathematician and astronomer described an attractive force which he called 'gurutvakarshan'. In the 17^{th} century, Galileo observed that objects falling to the earth were accelerating equally irrespective of their weight.

In order to explain the motion of the earth, the Sun and other planets several theories were put forth over centuries. Aryabhatta developed a geocentric model of the Universe with the Earth as the centre and the other objects going round it. Nicholas Copernicus proposed, in 1543, that the earth moved around the Sun.

Kepler believed that heavenly objects obeyed separate laws that were very different from that on earth. His three laws of planetary motion were based on observational data that was compiled over many centuries. However, although fundamentally correct, Kepler's Laws were purely empirical; they facilitated prediction of planetary motion but did not explain why the planets should move in the way they did.

In the 17^{th} century, Sir Issac Newton provided the explanation in his famous inverse square law of gravitation and also gave the explanation of motion on earth. This was based on a suggestion by scientist Robert Hooke that there is a force of gravitation that depends on the inverse square of the distance.

Subsequently, concepts were developed for understanding other complex phenomena such as tides and perturbations. In 1915, Albert Einstein introduced a new theory, “The General Theory of Relativity” that considered gravitational effects to be caused by the curvature in a four-dimensional space-time. Although Einstein's theory explains some observations that Newton's law cannot, the inverse square law has remained an important tool in modern astrophysics and cosmology. Moreover, Newton's and Kepler's laws of gravitation can explain almost all the phenomena of orbits and terrestrial motion with which we will be concerned here.

Introduction to the effect of gravity in day to day life

Gravity is the force by which a body draws objects toward its centre. Some objects have much more gravity than others. The Earth, for example, has more gravity than human beings. This is why an object that falls is drawn to the Earth and returns to the Earth instead of being drawn to a person and flying at that person.

Some examples of the force of gravity include:

- The force that holds the gases in the sun.
- The force that causes a ball you throw in the air to come down again.
- The force that keeps the Earth and all of the planets in line in the proper position in their orbits around the sun.
- The force that propels a child down a slide.
- The force that causes the moon to revolve around the Earth.
- The force from the moon that causes the tides of the ocean.
- The force that causes your drink to rest in the bottom of your glass instead of hovering near the top of your glass.
- The force that keeps you walking on Earth instead of floating away into space.
- The force that causes a pen that rolls off of your desk to fall onto the floor.
- The force that causes a piece of paper that is blowing in the wind to eventually come back down to Earth.
- The force that causes a balloon that is out of helium to come back down to the ground.
- The force that causes a jump rope to come back to the ground after you swing it over your head.

Gravity has the same effect on every object. If you drop a huge elephant or if you drop a small, thin feather, they will fall at the exact same speed. The feather might look like it falls slower and it does so because there is air resistance that interferes with the force of gravity and that can slow it down. However, if you dropped a feather and an elephant in a vacuum where there was no air resistance, they would fall at the exact same speed because there is the exact same amount of force being exerted.

ESSENTIAL PREVIOUS KNOWLEDGE

- Students are familiar with the concept of force, equations of motion
- They are familiar with circular motion
- They are familiar with the basic idea of gravitational force and that it is an attractive force
- They are familiar with centripetal force

LEARNING OBJECTIVES

The students will be able to,

- List some of the examples of gravitational phenomenon
- Identify the role of gravity or gravitational force in day to day life
- A historical development of the subject
- Define Kepler's laws of planetary motion
- Define law of gravitation and make them understand that it is universal
- Explain the effect of gravity on the earth's surface
- Define weight
- Define acceleration due to gravity
- Recall the equation for acceleration due to gravity
- Recall the relation between 'g' with the Earth's gravitational force
- Define thrust and buoyancy
- Recall Archimedes principle
- Define relative density

MAJOR CONCEPTS

1. Gravity
2. Newton's law of gravitation
3. Free fall
4. Kepler's laws of planetary motion.
5. Acceleration due to gravity (g)
6. Mass & weight
7. Thrust & pressure
8. Buoyancy
9. Archimedes principle.
10. Relative density

Description

Gravity is the force by which a planet or other body draws objects toward its centre. Newton's law of gravitation states that every object attracts every other object with a force which is proportional to the product of the individual masses and inversely proportional to the square of the distance between them $F= G\ m_1\ m_2/\ r^2$. The law of gravitation is universal in the sense that it is applicable to all objects in the universe.

Activity 1: Gravitation – dependence on 'r' and mass

Materials required: rope, weighing scale, carry bag, four 250 ml water bottles, and stop watch.

Tie the carry bag at the end of the rope and hold the rope some distance away, say 100cm. Rotate the rope 5 times with the carry bag attached. Measure the time taken and note it down. Also weigh the bag. Now put one bottle inside the carry bag and keeping the distance between the bag and hand as constant rotate the rope five times. Measure the time and weigh the bag. Repeat the experiment by increasing the weight. Note down all the readings and tabulate it. Now fix the weight of the carry bag and do the rotation five times. This time decrease the distance between hand and the bag and do the experiment. Note down the time taken each time. This activity will give the student an idea about the dependence on the distance and mass.

Activity 2:

Given mass of the Sun = 1.989×10^{30} kg

a. Use the table given below and instruct students to calculate the force of gravitation and create a table

b. Using $g = G\,M/r^2$ where M = mass of the planet, r = radius of planet, calculate the value of 'g' for each planet and compare the values.

Planet	Mass of planet ($\times 10^{24}$kg)	Distance from the Sun ($\times 10^{6}$ km)	Radius of planet (km)
Mercury	0.33	57.9	2439
Venus	4.87	108.2	6051
Earth	5.97	149.6	6378
Mars	0.642	227.9	3393
Jupiter	1898	778.6	71492
Saturn	568	1433.5	60268
Uranus	86.8	2872.5	25559
Neptune	102	4495.1	24764

Note: The gas giant planets, Jupiter, Saturn, Uranus and Neptune don't have a solid surface. The radius given here is obtained by specifying a point in the atmosphere of the planet at which the atmospheric pressure is approximately equal to that at the surface of the earth.

- The law of gravitation is universal in the sense that the law is applicable for calculating the gravitational force between all the particles of matter irrespective of their mass and the medium separating them. Kepler's laws are based on observations and they describe the motion of planets around the Sun.

- **Law of orbits:** All planets move about the Sun in elliptical orbits with the Sun as one of the foci
- **Law of Areas:** A radius vector joining the planet to the Sun sweeps out equal areas in equal intervals of time
- **Law of periods:** The square of the period of revolution of the planets are directly proportional to the cube of their mean distance

    - Any object above the earth's surface will tend to fall towards the surface of the earth due to the force of attraction by the earth (gravitational force).

Escape velocity

A stone thrown upwards with a certain velocity will eventually come back to the earth due to gravity. If you increase the velocity the stone will go higher and higher and will still fall back to the earth. Now if you give it a velocity of 11.2 km/s or more what will happen? It will escape from the gravitational pull of the earth. This velocity is called the escape velocity. Similarly for every planetary body there exists an equivalent escape velocity. If the mass of the body is high, the escape velocity required will also be high. For extremely massive objects (with infinitely high densities) not even light can escape from its gravitational pull. Such objects are known as black holes.

Activity 3:

Release a small stone from your hand from a height of about 1m. Observe its speed before it hits the ground. Now release the same stone from a height of about 5 m and again observe its speed just before it reaches the ground. The students may be asked the following questions. Did the stone have the same speed in both the cases? In which case did the stone reach the ground faster? What is the force that accelerated the stone?

Activity 4:

Ask students to drop various objects and see how much time it takes for the objects to fall to the ground. Students can measure time using a stop watch.

Note: Minimum height should be 4.5 m to measure 1 second.

Activity 5:

Ask one of your friends to stand on the upper floor of the building with stones of different masses in his hands. Now let the stones be dropped at the same time. Carefully observe the stones falling. Do they reach the ground at the same time? Ask the students to analyze this and give explanations.

- The acceleration which is gained by an object because of the gravitational force is called acceleration due to gravity 'g'. The average value of 'g' on the earth's surface is 9.8 m s^{-2} and it varies from place to place on the surface of the earth. At a given place, the value of 'g' is same for all objects irrespective of their mass, size, composition and shape.
- Weight of an object is the force with which it is attracted towards the earth and is given by w = mg. Weight of the same object on the moon is only $\frac{1}{6}^{th}$ of its weight on the earth as the value of 'g' on the moon is $\frac{1}{6}^{th}$ of the 'g' value on the surface of earth. Weight of an object on any planetary body can be calculated by knowing the value of 'g' on that planetary body.

Value of 'g' at different heights	
Altitude (h) (km)	**g(m/s^2)**
Sea level	9.8
1000	7.33
2000	5.68
3000	4.53
5000	3.08
8000	1.93
50000	0.13

Activity 6: Direction of gravitational force

Materials needed: A stick, 3 paper clips, neodymium magnets – 3, threads, scale

Take a paper clip and tie it with a thread. Tie the other end of the thread to a stick as shown.

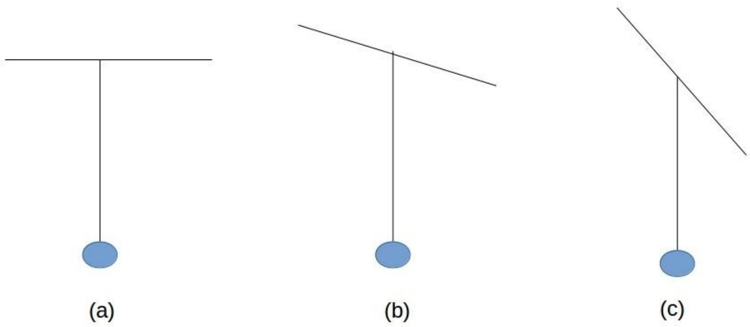


Figure 3.1

Keep the stick parallel to the ground and observe that the paper clip hangs perpendicular to the ground. Now tilt the stick at a small angle with respect to the ground. The paper clip still remains perpendicular to the ground. If you keep on tilting the stick, it can be seen that the paper clip continues to be perpendicular to the ground. This shows that gravitational force is in a direction perpendicular to the earth's surface at any place.

Activity 7: Balancing the force of gravity

(a) Attach 3 magnets on the scale as shown

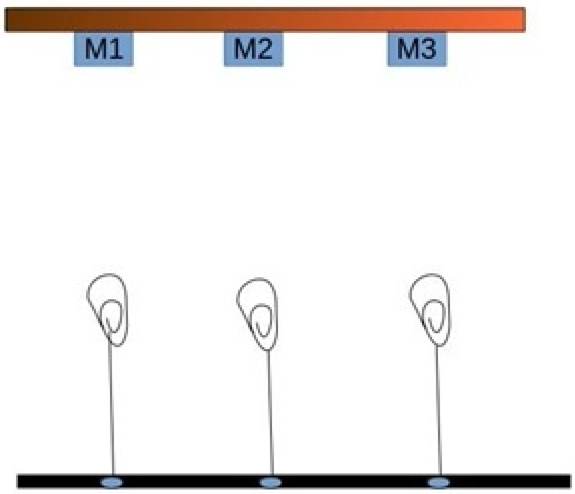


Figure 3.2

Bring the paper clips near the magnet such that it levitates in air. This is because the magnetic force pulls the clips upward and balances the downward gravitational force. Now remove the scale with magnets. See what happens. The paper clips fall down.

- Thrust is the force applied perpendicular to a surface.
- Pressure is the force or thrust applied per unit area.
- All liquids and gases are fluids. Fluids have weight and they also exert pressure on the base and walls of the container in which they are enclosed.
- The pressure applied at a point is transmitted equally in all directions.
- The upward force exerted by a fluid opposing the weight of an immersed object in that fluid is called buoyancy.

How does a scuba diver retain his/her depth under water?

This is done by changing the net weight of the diver by increasing or decreasing the density using air or solid weights. The density can be changed by using an air bladder or vest known as a Buoyancy compensator that can be inflated or deflated depending on the amount of buoyancy needed. The same principle applies to parachutes. In order to keep it afloat, the weight has to be balanced by the buoyancy or upthrust. This shows that buoyancy is a property of not only liquids but all fluids including the air around us.

Figure 3.3 A scuba diver wearing the Buoyancy compensator

Activity 8:

Place the orange on top of water in the glass. Observe that it floats. Now peel off the orange and place it in water once again. It sinks. Ask the students to explain the reason.

Explanation: The orange floats because it displaces a volume of water that is greater than or equal to its weight. The buoyancy of the displaced water overcomes gravity and keeps it afloat. The peel is full of tiny pockets of air and air is less dense than water, so the orange with the peel floats. After the peel is removed, it has a higher density and so the buoyancy of water cannot overcome the gravitational force and keep it afloat.

Activity 9:

Take a large wooden block and put it in a bucket filled with water. What can you observe? The wooden block floats. Now try pushing the block slowly into the water. You will feel an upward push on your hand. This indicates that the water exerts an upward force on the wooden block. Now push the wooden block completely into water and release it. The block bounces back to the surface of water. Ask the students to tell the reason.

Activity 10:

Hold a heavy book in your hand. Can you feel the weight of the book on your hand? Now move your hand quickly downward with some acceleration. What do you feel? Do you feel some decrease in weight of the book? Ask the students to try this experiment and explain the reason.

- Archimedes principle states that when a body is immersed fully or partially in a fluid it experiences an upward force that is equal to the weight of the fluid displaced by it.
- When a body is completely or partially immersed in a fluid it loses weight. It loses maximum weight when it is completely immersed in the fluid.
- When a body is immersed partially or completely in a fluid, the loss in weight of the body = weight of the fluid displaced by the body = buoyant force or upthrust exerted by the fluid on the body
- Volume of the fluid displaced = volume of the body immersed in the fluid.
- Relative density: The relative density of a substance is the density of the substance in comparison that of water.

Activity 11:

Materials required: A transparent glass beaker filled with water, wooden block, kerosene, oil, sugar

Take a beaker filled with water and measure the level of water. Place a wooden block on the surface of water such that it floats. Now once again measure the level of water. Note down the readings and find the difference in water levels. Repeat the experiment with (a) water mixed with sugar (sugar solution) (b) kerosene and (c) oil separately. From the results, what can be inferred about the role of density in this experiment?

Hint: The density of sugar solution is higher than water, while the density of kerosene is less than water.

The case of a ship in salt water and fresh water can be cited as a practical example of this.

Note: Instruct the students to write a short essay on Astronomy in ancient India

How are tides formed?

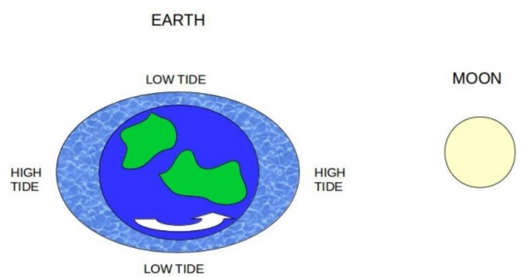


Figure 3.4

The Moon pulls the ocean water on the near side (A) very strongly due to gravitation. Hence you observe the high tide. A high tide is also observed on the opposite side of the earth (B). This is because the force of gravity of the moon on the B side of the ocean is less than its force of gravity on the earth. So the earth is also pulled by the moon towards it, though not as strongly as the A side. Therefore the ocean on the B side also experiences high tide.

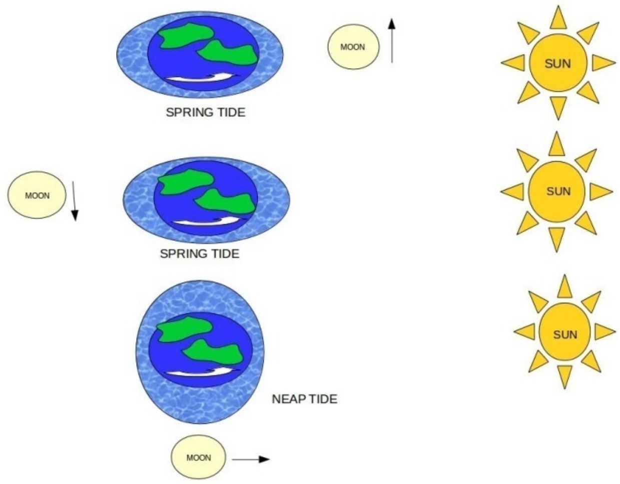


Figure 3.5

When the Sun, Earth and Moon are aligned spring tide occurs. When the Sun is perpendicular to the Earth Moon alignment, neap tide occurs. Spring tides are stronger than neap tides. But tides due to the Sun are weak compared to the effect of the moon.

What are gravitational waves?

When massive objects like black holes accelerate, they created disturbances that radiate away in the form of waves. These waves are known as gravitational waves. They can also be thought of as an invisible but extremely fast ripple in space. They are produced in events such as, when a star explodes asymmetrically, when two big stars orbit each other or when two black holes orbit each other and merge. The first observation of gravitational waves was announced by the ***Laser Interferometer Gravitational Wave Observatory*** (LIGO) on 11th February 2016. The 2017 Nobel Prize in Physics was awarded to three eminent physicists Rainer Weiss, Barry Barish and Kip S. Thorne for this discovery.

CONCLUSION

- The law of gravitation is applicable to objects anywhere in the universe, hence called as universal law.
- Gravitational force is the weakest basic force known in nature.
- Gravity is the gravitational force due to earth.

- Gravitational force varies with altitude, depth & also from poles to equator.
- At a given place gravitational force is the same for all objects.
- Weight of an object at a place is the product of its mass and acceleration due to gravity.
- The weight may vary from place to place but the mass remains constant.
- The normal force acting on surface of contact is called thrust.
- Force acting on a body per unit area is called pressure.
- All objects experience an upward force when immersed in a fluid known as buoyant force.
- If the relative density of the object is less than that of the liquid in which it is immersed, the object floats on the surface of the liquid.
- If the relative density of the object is more than that of the liquid in which it is immersed, the object sinks in the liquid.

EXERCISES

1. Find the force of attraction between two objects with masses, 100 kg and 10kg respectively and separated by a distance of 1m. Also calculate the force if the distance between them are 2m, 10m and 20 m.
2. Calculate the gravitational force of attraction between the masses (a) 10kg and 1kg. (b) 10^8 kg and 10^4 kg separated by 1m. Comment on the result.
3. The distance between the Sun and Jupiter is 778.5×10^6 km. The mass of Jupiter is 1.898×10^{27} kg and the mass of the Sun is 1.989×10^{30} kg. What is the force of attraction between the Sun and Jupiter?
4. A 20kg mass and a 500kg mass are separated by 0.4m. (a) Find the gravitational force between them. (b) If a third mass of 50kg is placed in between and the mass does not experience the gravitational force, calculate the distance at which it should be placed.
5. Two objects attract each other with a gravitational force of magnitude 1×10^{-8} N when separated by 20 cm. If the total mass of the two objects is 5 kg, what is the mass of each?

6. At what height above the earth's surface would a rocket experience half the gravitational force, compared to the value at sea level.

7. Find the weight of a 100kg man on the planets with the following mass and radii.

Planet	**Mass**	**R**
Mars	6.4×10^{23} kg	3.4×10^{6}m
Earth	6.0×10^{24} kg	6.4×10^{6} m
Jupiter	1.9×10^{27} kg	7.2×10^{7} m

8. If a planet of twice the diameter of the earth has a mass six times as the earth. Compare the gravitational field at its surface to the gravitational field at the surface of the earth?

9. A small mass is dropped from an aircraft flying at an altitude of 8000 m. Determine the time required for it to fall. Assume g is constant and there is no air drag. Find the final velocity.

10. Three objects are simultaneously thrown vertically upward with velocities 10 m/s, 50 m/s and 100 m/s. Determine how high it rises before falling back and the total time taken by the object. (Total time is time taken to go up and come down).

11. A stone is allowed to fall from the top of a tower 100 m high and at the same time another stone is projected vertically upwards from the ground with a velocity of 25 m/s. Find the time at which they meet and the corresponding height.

12. A ball (A) is thrown vertically upward with a velocity of 50 m/s. simultaneously another ball (B) is dropped from a tower of height 125m. Find out the distance travelled by the ball in 0.5s, 1s, 2s, 3s, 4s and 5s.

13. A piece of aluminium with mass 1 kg and density 2700 kg/m^3 is suspended from a string and then completely immersed in water. Calculate the weight of the object in water.

14. Three metal blocks of mass 1kg made up of aluminium, iron and gold are immersed in water separately. Which block will displace the maximum amount of water? Or will it be the same in all cases. The densities of the metals are given as Aluminium = 2700 kg/m^3, Iron = 7.87 x 10^3 kg/m^3, Gold = 19.3 x 10^3 kg/m^3.

15. How did Archimedes find out if the crown of the king is pure or not? Suppose you want to determine whether the crown of the king is made up of pure gold or not. Let the crown be weighed first in air and then in water. Suppose the weight was measured as 7.96N and 6.98 N respectively. The density of gold is 19.5 x 10^{-3} kg/m^3.

i. How much is the volume displaced

ii. What was the density of the crown

iii. How can it be found if the crown is made up of pure gold or not.

16. Titanic tragedy: An iceberg floating on sea water is extremely dangerous because much of the ice is below the surface. This hidden ice can damage a ship that is still a considerable distance from the visible ice. What fraction of ice lies below the water level? Assume density of whole ice= 917 kg/m^3, density of sea water = 1030 kg/m^3

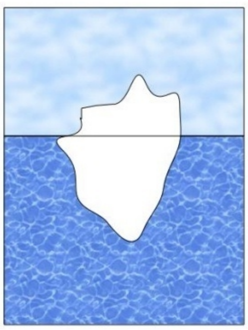


Figure 3.6

Hint: Volume of displaced water is the same as the volume of submerged portion of the iceberg.

Now, when the iceberg is afloat, the weight of the entire iceberg is balanced by the upward buoyant force of water, i.e. weight of the whole iceberg = density (ice) x Volume (whole ice) x g = density (water) x Volume (water displaced) x g.

This gives, Volume (displaced water)/Volume (whole ice) = Volume (submerged ice)/ Volume (ice) = density (ice)/density (water).

17. A frog in a hemispherical pod finds that he just floats without sinking into a sea of blue-green ooze that has a density of 1.35gm/cc. If the pod has a radius of 6cm and negligible mass, what is the mass of the frog?

18. A block of wood floats in fresh water with two thirds of its volume submerged. Place the same wood in oil and kerosene. Find out what percentage of its volume is submerged in the case of oil and kerosene. If the block has 0.90 of its volume submerged in oil, find the density of (a) wood (b) oil. Given the density of water is 1000 kg/m^3.

Hint: Use the equation in problem 15, Volume (submerged wood)/Volume (whole wood) = density (wood)/density (water).

19. Rate of falling object in vacuum is

a. independent of weight
b. dependent on mass
c. independent of mass
d. dependent of weight

20. Acceleration due to gravity on moon is

a. 9.9 ms^{-2}
b. 9.5 ms^{-2}
c. 6.1 ms^{-2}
d. 1.6 ms^{-2}

21. According to Newton's law of universal gravitation, any two particles of finite mass attract one another with a force which is

- Inversely proportional to product of their masses and directly proportional to square of their distance apart

    a. Inversely proportional to product of their masses and directly proportional to their distance apart
    b. Directly proportional to product of their masses and inversely proportional to their distance apart
    c. Directly proportional to product of their masses and inversely proportional to square of their distance apart

22. Point where entire weight of an object acts is

    a. edge
    b. centre of gravity
    c. central point
    d. can be anywhere in body

23. Another name for force of gravity acting on an object is

    a. friction
    b. air resistance
    c. weight
    d. mass

24. Gravitational force of attraction between satellite and earth provides

    a. centripetal force
    b. centrifugal force
    c. resistive force
    d. none of above

25. Earth attracts a body with a force equal to its

    a. weight
    b. area
    c. volume
    d. pollution

26. Natural satellite of Earth is

    a. moon
    b. stars

c. sun

d. mars

27. SI Unit of pressure is

a. Pascal

b. Newton

c. Dyne

d. Barye

28. The upward force exerted by the liquid displaced by the body when it is placed inside the liquid is called

a. Gravitational force

b. Coriolis force

c. Buoyant force

d. Centripetal force

29. The mass of an physical object is

a. Not the same thing as weight of an object

b. The amount of matter contained in the object, independent of the position of object

c. Measure of the extent to which a particle or object resists a change in its direction or speed when a force is applied.

d. All of the above

30. A boat of 8 metre and 40 metre long floats on water. If 125000 N of cargo is added, it will sink

a. 10 cm

b. 4 cm

c. 15 cm

d. 20 cm

31. If weight of an object is greater than upthrust acting on it then object would

a. balance

b. equal

c. float

d. sink

32. Thrust exerted by an iron cuboid when placed on sand is equal to

a. mass of cuboid

b. mass per unit surface area

c. weight of cuboid

d. weight per unit surface area

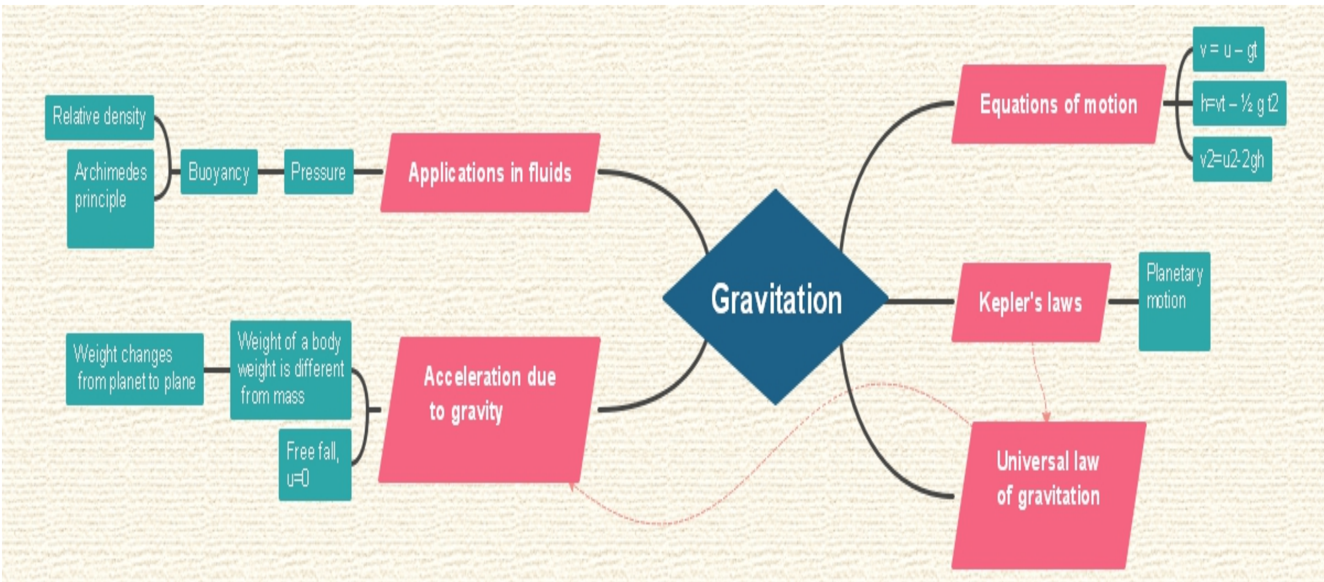
33. A sharp edge blade is more effective in cutting than a blunt blade due to

a. Low force
b. Low pressure
c. Large contact area
d. Small contact area

Answers:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
c	d	d	B	C	A	A	a	A	c	d	b	d	d	d

CONCEPT MAP



WORK AND ENERGY

INTRODUCTION

In our everyday life we use terms like work and energy. Term 'work' is generally used in context to any kind of activity requiring physical or mental effort. But this is not the way how we define work done in physics. When we push or pull a heavy load or lift it above the floor then we are doing work, but a man carrying heavy load and standing still is not doing any work according to scientific definition of work.

Another term we often use is energy. Energy is usually associated with work done in the sense that a person feeling very energetic is capable of doing lot of work. This way energy can be defined as capacity of doing work. There are many forms of energy like chemical energy, mechanical energy, electrical energy, heat energy etc. These forms of energies can be used in number of ways. One form of energy can be converted into another form of energy.

In this chapter we will study about work, relation between work and energy, conservation of energy etc.

ESSENTIAL PREVIOUS KNOWLEDGE

- In the preceding chapters on kinematics, we studied the motion of a particle with no regard to the cause of motion. Now we are familiar with terms like displacement, velocity and acceleration. In dynamics we discussed the causes of motion. Newton's laws help us to handle forces causing the motion of a body and also it tells us about the action and reaction forces.
- In this chapter, we get acquainted with physical quantities like work, energy and power. They provide useful perspective on the motion of particles as well as of extended objects.

LEARNING OBJECTIVES

The students will be able to

- Define the physical quantity called work
- Identify units of work
- Differentiate the work in scientific/general view
- Identify components of work
- Predict whether force is doing positive, negative or zero work.
- Define energy and its correlation to work.
- Define different units of energy
- Mention the types of energy
- Distinguish between potential energy and kinetic energy
- Factors affecting potential and kinetic energy
- Describe the principle of conservation of energy
- Apply the principle of conservation of energy to a variety of physical situation (simple pendulum, Newton's cradle)
- Define power and its unit
- Distinguish between work and power
- Calculate power for different situations
- List several form of energy
- Describe several examples of conservation of energy from one form to another form
- Relate energy and power
- Apply the knowledge of conservation of energy in practical situation (like calculating electric bill)

Major Concepts

1. Work
2. Conditions of work
3. Work done by a constant force
4. Unit of work
5. Unit of energy
6. Different forms of energy
7. Kinetic and potential energy
8. Transformation of energy
9. Principle of conservation of energy
10. Power
11. Unit of power
12. Relation between power and work

Work

Work is said to be done whenever a force acts on a body and the body moves through some distance in the direction of the force.

Conditions of work

Force should act on the object.

Object must be displaced.

Work done=Force x displacement

Unit of work is Nm or J

Definition of unit of work: Work is said to be 1 joule if a force of 1 newton displaces the body through 1meter

Example: work is done when a horse pulls a cart, an engine pulls a train, a man goes up a hill, etc.

Activity 1:

- Push a duster on the table →W≠ 0 (since S≠0)
- Push a table →W≠ 0 (since S≠0)
- Push a wall of the classroom →W= 0 (since S=0)

It is not necessary that the given force that do work all the time.

Work done by a constant force: when the force acts along the direction of motion.

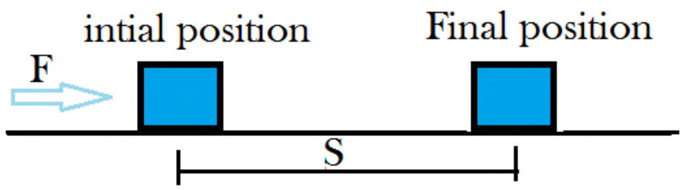


Figure 4.1

$$W = F\,S$$

Work done by a constant force: when the force acting at an angle to displacement.

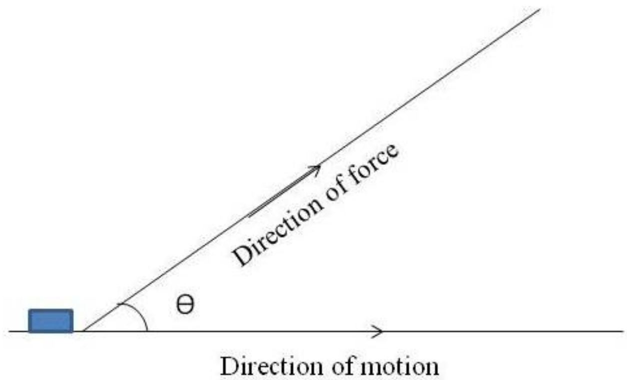


Figure 4.2

Work done by a constant force: when the force acting at an angle to displacement then,

$$W = (F\cos\theta)\, S$$

$$W = FS\cos\theta$$

Special cases:

i. when F is parallel to S, W=+ve
ii. when F is antiparallel to S , W= -ve
iii. when F is perpendicular to S, W=0

Activity 2:

- Take a rubber ball to a height say 'h'.
- Drop the fall and observe the direction of motion of the ball.
- Infer the force acting on the ball.
- The direction of motion of the ball and the direction of force (gravity) are in the same direction.
- Then work is said to be positive.

Activity 3:

- Observe the motion of the rubber ball after hitting the ground.
- Infer the direction of motion and direction of force.https://accounts.google.com/ServiceLowwwgin?service=mail&passive=true&rm=false&continue=https://mail.google.com/mail/&ss=1&scc=1&ltmpl=default&ltmplcache=2&emr=1&osid=1#
- The motion of the ball and the force (due to gravity) are in opposite direction.
- Then the work done by the gravitational force is negative.

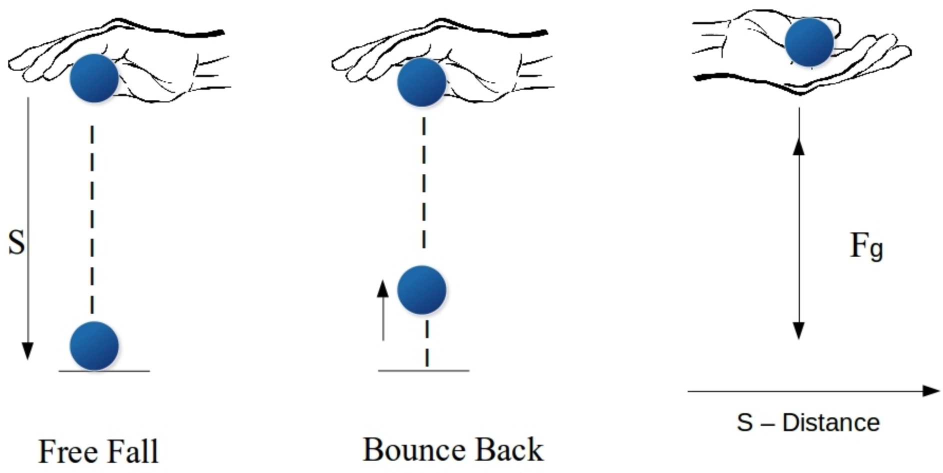


Figure 4.3

Activity 4.

- Place a ball on a table
- Flick the ball to move horizontally on the table.
- Observe the motion of the ball and the force due to gravity.
- Infer the force on the ball due to gravity.
- Since the direction of motion of the ball and force due to gravity are perpendicular work done by the gravitational force is said to be zero.

Activity 5

Take a car toy and toy gun.

a) Trigger the gun in the direction as shown in figure.

Measure the distance covered by the car toy

b) Trigger the gun in the inclined direction as shown in figure.

Measure the distance covered by the car toy.

c) Trigger the gun in the perpendicular direction as shown in figure.

How much distance the car moves?

Inferences

(a) F is parallel to S; as displacement produced is maximum work done will be maximum.

(b) Force is applied at an angle to the car .Displacement produced is less; work done is lesser than the previous case.

(c) F is perpendicular to S; there will be no displacement hence no work done.

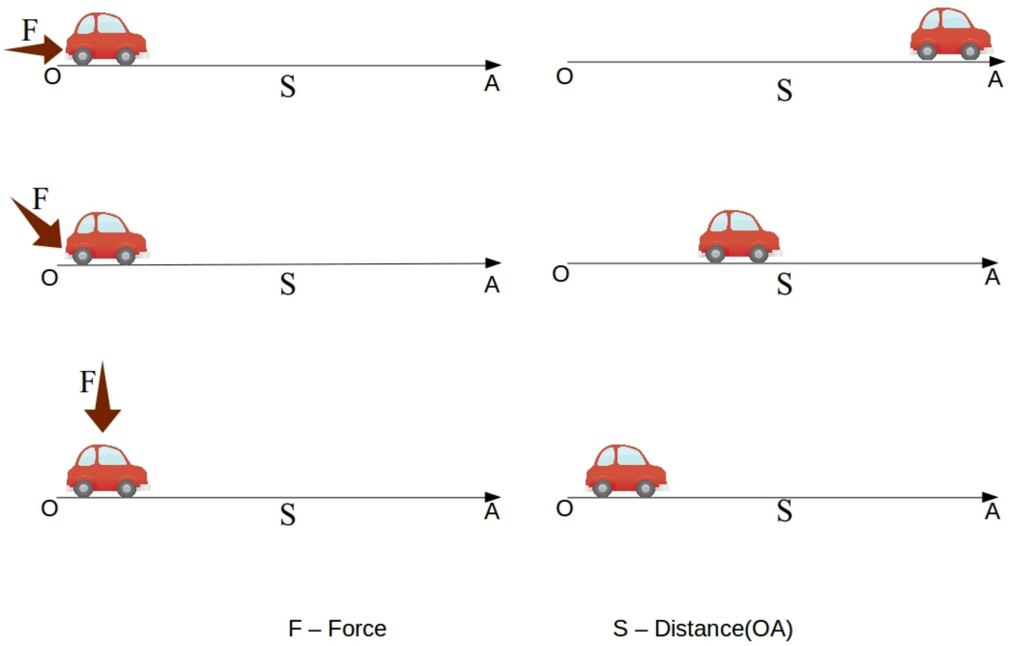


Figure 4.4

Graphical representation of work done by a constant force

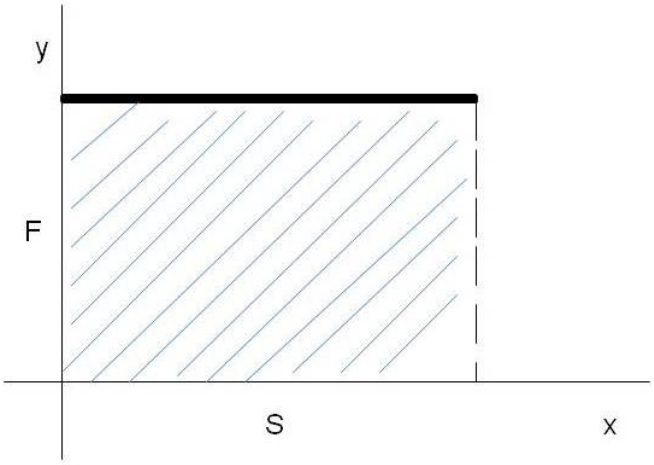


Figure 4.5

Energy

The capacity to do work is called as energy. The sun is the major natural source of energy.

We can also draw energy from nucleus of an atom, the interior of earth etc. SI unit of energy is joule (J). Energy is available in different forms.

Some other units of work or energy

SI. No	Unit	Symbol	Value in SI
1.	Erg	Erg	10^{-7} J
2.	electron volt	eV	1.6×10^{-19} J
3.	Calorie	Cal	4.186 J
4.	kilowatt hour	kWh	3.6×10^{6} J

The energy possessed by a body on account of its motion or position is mechanical energy.

Kinetic Energy

Energy of a body due to its motion is called as kinetic energy.

Kinetic energy = $1/2\,mv^2$

Depending upon its state of motion, a moving body may possess either one or more than on form of kinetic energy simultaneously. For example, a rolling a cylinder in an inclined plane posses both rotational and translational kinetic energies.

Potential Energy

Energy of a body due to its position or configuration is known as potential energy

Potential energy $= mgh$

Examples.

1. Watered stored in a dam.
2. Energy stored in a stretched bow
3. Energy stored in the coiled spring of a watch
4. Stretched rubber band
5. Compressed or elongated spring
6. Any object kept at any height from the ground

An aircraft is being take off from the ground is moving horizontally at an altitude of 1000 meters from the ground. Infer the energy possessed by the aircraft and discuss with your friends.

Potential energy of a body depends only on the initial and final position and it is independent of the path by which it follows.

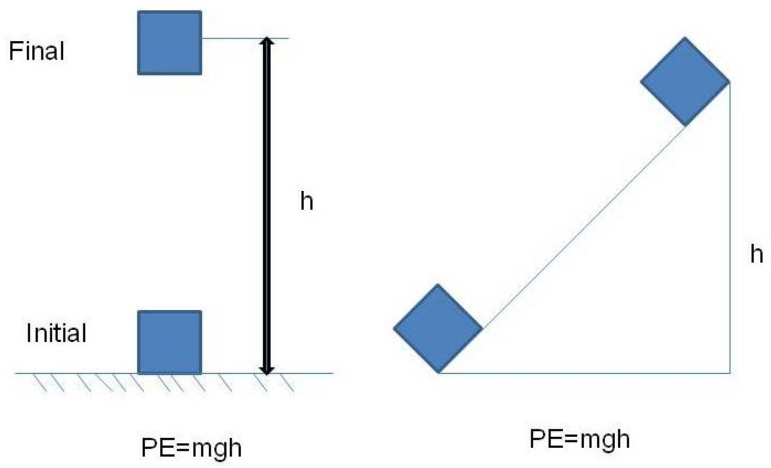


Figure 4.6

Activity 6:

- Take a spring and fix one of its end to rigid support as shown in figure on the table
- Now, the spring is compressed to some extent.
- Place a light weight ball along the axis of spring at point such that distance of ball from the rigid support must be less than the natural length of the spring.
- Then release the compressed spring , we can observe the spring pushes the ball
- Observe the motion (speed) of the ball
- Repeat the activity by keeping the position of the ball at same place and by increasing the length of compression of spring
- As the magnitude of length of compression of the spring increases, it will be noticed that the speed of the ball also increases
- Thus it shows that as the potential energy of the spring increases kinetic energy of the ball also increases.
- Inferences: As potential energy increases, (the work done by the spring force also increases)
- That is, kinetic energy of the body increases.

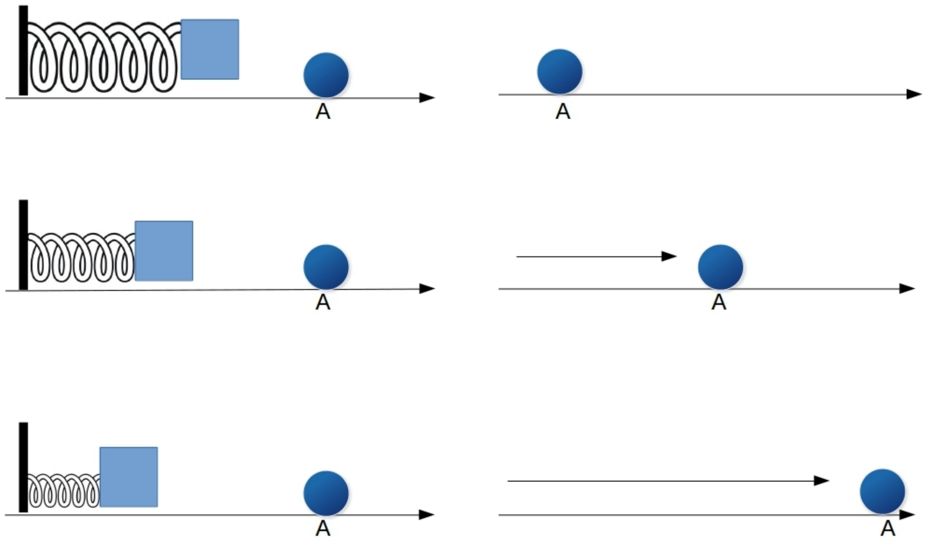


Figure 4.7

Examples:

1. When a moving car hits a parked car and causes the parked car to move, energy is transferred from the moving car to the parked car.

2. Two football players collided on the field, and both went flying backwards. Energy was transferred from each player to the other, sending them in the opposite direction from which they had been running.

3. A ball falls from a height of 2 meters in the absence of air resistance.

Figure 4.8

Conclusion: The ball is losing height (falling) and gaining speed. Thus, the internal or conservative force (gravity) transforms the energy from PE (height) to KE (speed).

In the above descriptions, the only forces doing work upon the objects are internal forces - gravitational and spring forces. Thus, energy is transformed from KE to PE (or vice versa) while the total amount of mechanical energy is conserved. Read each description and indicate whether energy is transformed from KE to PE or from PE to KE.

4. A skier glides from location A to location B across a friction free ice.

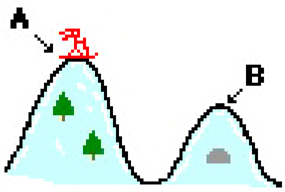


Figure 4.9

Conclusion: The skier is losing height (the final location is lower than the starting location) and gaining speed (the skier is faster at B than at A). Thus, the internal force or conservative (gravity) transforms the energy from PE (height) to KE (speed).

5. The spring of a dart gun exerts a force on a dart as it is launched from an initial rest position.

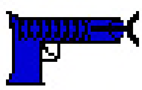


Figure 4.10

Conclusion: The spring changes from a compressed state to a relaxed state and the dart starts moving. Thus, the internal or conservative force (spring) transforms the energy from PE (a compressed spring) to KE (speed).

6. A baseball is travelling upward towards a man in the bleachers.

Figure 4.11

Conclusion: The ball is gaining height (rising) and losing speed (slowing down). Thus, the internal or conservative force (gravity) transforms the energy from KE (speed) to PE (height).

Law of conservation of energy

Energy can neither be created nor to be destroyed. Whenever energy changes from one form to another, the total amount of energy remains conserved or constant. Though there is some loss of energy during conversion, but the total energy of the system remains the same.

Whenever mechanical energy changes to other forms, it is always in the form of kinetic energy and not in the form of potential energy .i.e., the stored potential energy first changes to kinetic energy and then kinetic energy changes to the other form.

Activity 7:

- Take the simple pendulum system, make it to oscillate as shown in the figure.

- Ask students to identify the positions of the ball at which the potential and kinetic energy is maximum and minimum.
- Also infer them about the transformation and conservation of energy.

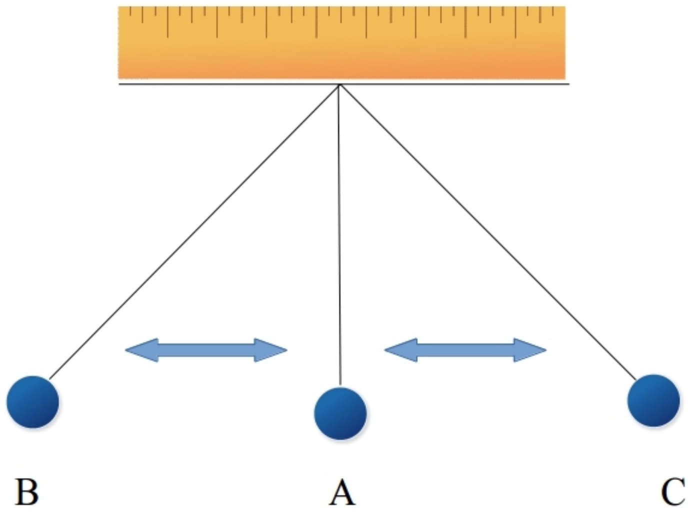


Figure 4.12

Conservation of energy during free fall of a body

A ball of mass m at height h from the surface of the earth has a maximum potential energy =mgh

As the ball falls freely, height decreases as a result potential energy decreases and kinetic energy increase.

Whereas the sum of potential and kinetic energy of the ball remains same at every point during its fall

i.e., PE+KE=constant

Example:

Explain the production of hydro electricity (charts can be used and students are instructed to prepare charts)

Water can produce electricity. Water falls from the sky, converting potential energy to kinetic energy. This energy is then used to rotate the turbine of a generator to produce electricity. In this process, the potential energy of water in a dam can be turned into kinetic energy, which can then become electric energy. Some of the potential energy is also converted into heat energy, due to friction and perhaps some sound energy too.

Power

- Power is defined as rate of doing work. P = work done/time = Energy supplied/time
- $P = W/t$ or $P = E/t$
- Power = Force $\times$ Velocity
- units of power- watt or J/s

Definition of Watt: *Power is said to be 1watt if 1joule of work is done in 1second.*

- The larger unit of power are kilowatt(kW) and horse power (hp)
- 1 kilowatt=1000 watt
- 1 horse power=746 watt
- Joule is the very small unit of energy and it is convenient to use it where a large quantity of energy is involved.
- kWh is the commercial unit of energy.

Differences between work and power	
Work	**Power**
1. Work done by a force is equal to the product of force and displacement in the direction of force. 2. Work done does not depend on time.	1. Power of a source is the rate of doing work by it. 2. Power spent depends on the time in which work is done.

3. S.I. unit of work is joule (J)	3. S.I. unit of power is watt (W).

Activity 8:

Consider your library received two bundles each of 100 new books and each books weighs 0.5 kg. Librarian called Mr. A to help in arranging the books in the shelf which is at a height of 2 m above the floor. Mr. A was given a bundle to arrange in the shelf. Mr. A keeps two books at a time in the shelf and completed the task in 20 minutes. Mr. A was tired after keeping one bundle of books in the shelf. By seeing him Librarian called Mr. B to keep the remaining bundle of books over the shelf. Mr. B keeps four books at a time in the shelf and completed the task in 10 minutes. Find the work done from the given data and infer who has more power?

CONCLUSION

Work done on an object is defined as the magnitude of the force multiplied by the distance moved by an object in the direction of the applied force. The unit of work is joule. Work done on an object by a force would be zero if the displacement of the object is zero.

An object which has capability to do work is said to possess energy. Energy has the same unit as that of work. An object in motion possesses the kinetic energy. An object of mass 'm' moving with a velocity 'v' has a kinetic energy of $1/2mv^2$. The energy possessed by a body due to its change in position or shape is called as the potential energy. Gravitational potential energy of a body of mass 'm' raised through a height 'h' from the surface of the earth is mgh.

According to the law of conservation of energy, energy can only be transformed from one form to another. It can neither be created nor be destroyed. The total energy before and after the transformation always remains constant. Energy exists in several forms like, mechanical energy, nuclear energy etc. The sum of potential energy and kinetic energy of an object is called as mechanical energy.

Power is defined as rate of doing work. Its unit is watt. The energy used in 1hour at the rate of 1kW is known as 1kWh.

EXERCISES

1. A constant force acts on a body does 120 J of work and produces displacement of 5 m. determine the magnitude of force?
2. A body of mass m is dropped from a height of 'h' m. what is the work done by gravity.
3. A force acting on a 20 kg mass changes its velocity from $5m/s$ to $2m/s$ during which the body covers a displacement of 7m. Calculate the magnitude of force.
4. An object of mass 50kg is moving with a uniform velocity of 5m/s. what is the work done to stop the body.
5. A body of mass 20kg is lifted to a height of 10m above the ground. Find the potential energy (given g=9.8 m/s^2).
6. A body of mass 'm' moving with a velocity of 10 m/s. its kinetic energy is 50 J. if the velocity is doubled what is its kinetic energy?
7. A person weighing 60kg climbs up a vertical height of 60m. Calculate the amount of work done by the person. How much potential energy he gains?
8. The electric meter readings of a house hold in consecutive months are 1830 and 1885 respectively. Find the electric bill to be paid by house hold. If the rate per unit is 3.80paise.
9. Compare the work done in lifting a 6kg mass 20m and the kinetic energy of the same mass when it has fallen a distance of 20m from rest.
10. A body of mass 4 kg is thrown up with a speed of 25m/s, find its maximum potential energy?

    HINT: conservation of energy, $KE = \frac{1}{2}mv^2 = 1250J$

11. Is there any work done on a body in uniform circular motion? Justify your

answer.

HINT:

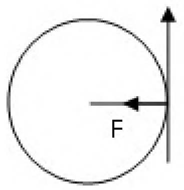


Figure 4.13

12. State in which of the given cases work is said to be done. Give reasons for your answers

    (b) A boy pulling a trolley of about 5m distance.

    (c) A person pushing a huge rock but the rock does not move

    (d) A bullock pulling the cart up to a distance 2km

    (e) A man standing with a heavy bag in his head.

13. Give some examples when energy possessed by a body due to its change in shape?

14. Under what conditions work is said to be done.

15. Is it possible that force is acting on a body but still work done is zero? Explain

16. A ball is dropped from a height of 10 m. find the velocity of the ball before it touches that ground. Do you require the value of mass to find the velocity?

17. Two persons X and Y do same amount of work. The person X does it in t_1 s and the person Y in t_2 s. find the ration of power delivered by them.

18. Give an example for each of the following energy conservation:

    a) Chemical energy to electrical energy

    b) Electrical energy to sound energy

    c) Mechanical energy to electrical energy

    d) Sound energy to electrical energy

19. Differentiate from the following situations into cases of kinetic energy and potential energy.

   a. Running girl
   b. Sitting boy
   c. Oscillating pendulum
   d. Rolling cylinder
   e. Standing man
   f. Fixed rocks
   g. Flying bird
   h. Statue

20. A blacksmith uses a heavier hammer than a goldsmith. Why?

    HINT: Kinetic energy is directly proportional to mass of the body.

21. In winters, rubbing of hands together for some time, causes a sensation of warmth mainly because of

    (a) heat caused by the force of friction
    (b) heat caused by the momentum
    (c) heat caused by the motion
    (d) heat flows from the blood to skin

22. Which of the following does not have unit as Joule?

    (a) Work done
    (b) Kinetic energy
    (c) Potential energy
    (d) Force

23. The commercial unit of energy consumption in households, industries and commercial establishments is

    a) Joule
    b) Watt
    c) kW
    d) KW h

24. A runner, while moving, is facing a wind from the opposite direction. The work done by the wind on runner will be

(a) Zero

(b) negative

(c) Positive

(d) infinity

25. The person will have maximum Potential Energy, when?

(a) he is sleeping on the ground

(b) he is sitting on the ground

(c) he is sleeping on the bed

(d) he is standing on the roof.

26. When we stretch a rubber band, the Elastic Potential Energy of rubber band

(a) remains unchanged

(b) becomes zero

(c) increases

(d) decreases

27. In hydro electricity generation, water stored in a dam possesses:

(a) electrical energy

(b) chemical energy

(c) thermal energy

(d) potential energy

28. An object is displaced by 10 meters in the direction of applied force. If the applied force is 75 N, What is the work done by the force?

(a) 0.75 Joule

(b) 7.5 Joule

(c) 75 joule

(d) 750 joule

29. An object is thrown vertically upward and it reaches to a maximum height 'h' from the ground. During its flight, on reaching 3/4 of height H, it will acquire?

(a) less potential and high kinetic energy

(b) more potential and less kinetic energy

(c) same potential and kinetic energy

(d) only kinetic energy

30. In Force vs. Displacement graph, What does the area under the curve represents:

(a) Velocity

(b) Acceleration

(c) Force

(d) Work done

31. When a body falls freely towards the earth, then its total energy

a) increases

b) decreases

c) remains constant

d) first increases and then decreases

32. A car is accelerated on a levelled road and attains a velocity 4 times of its initial velocity. In this process the potential energy of the car

a) does not change

b) becomes twice to that of initial

c) becomes 4 times that of initial

d) becomes 16 times that of initial

33. In case of negative work the angle between the force and displacement is

a) 0^0

b) 45^0

c) 90^0

d) 180^0

34. An iron sphere of mass 10 kg has the same diameter as an aluminium sphere of mass is 3.5 kg. Both spheres are dropped simultaneously from a tower. When they are 10 m above the ground, they have the same

a) acceleration

b) momenta

c) potential energy

d) kinetic energy

35. A girl is carrying a school bag of 3 kg mass on her back and moves 200 m on a levelled road. The work done against the gravitational force will be (g =10 m s^{-2})

a) 6×10^3 J

b) 6 J

c) 0.6 J

d) Zero

36. Which one of the following is not the unit of energy?

a) joule

b) newton metre

c) kilowatt

d) kilowatt hour

37. The work done on an object does not depend upon the

a) displacement

b) force applied

c) angle between force and displacement

d) initial velocity of the object

38. A body is falling from a height *h*. After it has fallen a height *h/*2, it will possess

a) only potential energy

b) only kinetic energy

c) half potential and half kinetic energy

d) more kinetic and less potential energy

39. How are Joule (J) and ergs (erg) related?

a) $1J = 10^7$ erg

b) $1erg = 10^{-7}J$

c) $1J = 10^{-7}erg$

d) None

Text book exercises – Hints/ solutions

1.

- Suma is doing work. Suma is able to move forward by applying force with her arms and legs in water. Suma is swimming in a pond.
- A donkey is carrying a load on its back. Donkey is not doing any work (in the sense of physics) as the weight he is carrying (the direction of force) and displacement are perpendicular to each other.
- A wind-mill is lifting water from a well. Wind mill is lifting water from a well and doing work against the gravity.
- A green plant is carrying out photosynthesis. No force and displacement are present here, so work done is zero.
- An engine is pulling a train. During the pulling a train, engine does the work

against the friction, present between the railway track and wheels.

- Food grains are getting dried in the sun. During the drying the grains, there is no force as well as displacement is present. So, no work is done.
- A sailboat is moving due to wind energy. Work is done by the wind as it moves the sailboat towards the direction of the force (force of blowing air).

2. When the object moves upwards, the work done by gravity is negative (as the direction of gravitational force is towards the Earth's centre) and when the object come downwards, there is a positive work done. So, the total work down is zero in throughout the motion.
3. Battery converts chemical energy into electrical energy. This electrical energy is further converted into light and heat energy.
4. Kinetic energy is given by the expression,

$$E_k = 1/2mv^2$$

where,

E_k= Kinetic energy of the object moving with a velocity v

Kinetic energy when the object was moving with a velocity $5m/s$

$$E_k = 1/2 \times 20 \times 5^2 = 250J$$

Kinetic energy when the object was moving with a velocity $2m/s$

$$E_k = 1/2 \times 20 \times 2^2 = 40J$$

We know that

Work done=change in kinetic energy $= \frac{1}{2}mu^2 - \frac{1}{2}mv^2 = \frac{1}{2}m(u^2 - v^2)$

$$= \frac{1}{2}20(5^2 - 2^2) = \frac{1}{2}(20)\left(5^2 - 2^2\right)$$

=10(25-4)

=210 J

5. The work down by the gravitational force acting on the body is zero because the direction of force is vertically downward and the displacement is

horizontal i.e. force and displacement are perpendicular to each other.

6. The potential energy of freely falling object decreases and its kinetic energy increases (as its velocity increases) progressively. So, in this way the total mechanical energy (Kinetic energy + potential energy) remains constant. Thus, the law of conservation of energy is not violated and explanation (RHS).
7. The muscular energy of the cyclist is converted into kinetic (rotational) energy of wheels of cycle which is further converted into kinetic energy to run the bicycle.
8. Yes, there is transfer of energy. When we push the rock and fail to move it. Some of our energy is absorbed by the rock in the form of potential energy and the rest of our energy is goes to environment through our muscles and the surface between the rock and out hand.
9. 1 unit of energy is equal to 1 kilowatt hour (kWh).

$$1 unit = 1 kWh$$
$$1 kWh = 3.6\times10^{6} J$$

Therefore, 250 units of energy = $= 250\times3.6\times10^{6} = 9\times10^{8} J$

10. Gravitational potential energy is given by the expression,

W=mgh

Where,

h =Vertical displacement = 5 m

m= Mass of the object = 40 kg

g = Acceleration due to gravity = 9.8 m s^{-2}

∴W= 40 x5 x 9.8 = 1960 J.

At half-way down, the potential energy of the object will be 1960 / 2= 980 J. At this point, the object has an equal amount of potential and kinetic energy. This is due to the law of conservation of energy. Hence, half-way down, the kinetic energy of the object will be 980 J.

11. When a satellite moves around the Earth, the displacement in short interval is along the tangential direction and the force (gravitational force) is towards the centre of the Earth. Since, the force and displacement are perpendicular to each other; the work done by gravitational force is zero.

12. Yes, for a uniformly moving object there can be displacement of an object in the absence of any force acting on it. Suppose an object is moving with constant velocity. The net force acting on it is zero. But, there is a displacement along the motion of the object. Hence, there can be a displacement without a force.

If F=0 then ma=0. That is the object is at rest or at uniform motion along straight line.

eg. in the case of rain droplets, the net force on rain droplets is zero, but they have displacement towards earth.

13. We know, work is done whenever the given two conditions are satisfied

i. A force acts on the body.
ii. ii. There is a displacement of the body by the application of force in or opposite to the direction of force.

When a person holds a bundle of hay over his head, then there is no displacement in the bundle of hay. Although, force of gravity is acting on the bundle, the person is not applying any force on it. Hence, in the absence of force, work done by the person on the bundle is zero.

14. Energy consumed by an electric heater can be obtained with the help of the expression $P = W/T$

where, Power rating of the heater= 1500W= 1.5kW

Time for which the heater has operated, T= 10h

Work done = Energy consumed by the heater

Therefore, energy consumed = Power x Time

= 1.5 x 10 = 15 kWh

Hence, the energy consumed by the heater in 10 h is 15kWh.

15. The law of conservation of energy states that energy can be neither created nor destroyed. It can only be converted from one form to another.

Consider the case of an oscillating pendulum.

When a pendulum oscillates between the mean position P to either of its extreme positions A or B, it rises through a height h above the mean level P. At this point, the kinetic energy of the bob completely converted into potential energy. The kinetic energy becomes zero, and the bob possesses only potential energy. As it moves towards point P, its potential energy decreases continuously as a result the kinetic energy increases. As the bob reaches point P, its potential energy becomes zero and the bob possesses only kinetic energy. This process is repeated as long as the pendulum oscillates.

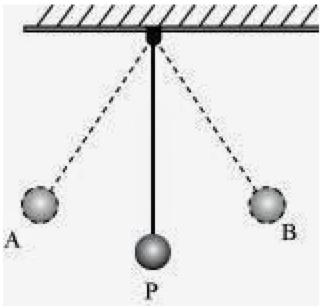


Figure 4.14

The bob does not oscillate forever. It comes to rest because air resistance resists its motion. The pendulum loses its kinetic energy to overcome this friction and stops after some time.

The law of conservation of energy is not violated because the energy lost by the pendulum to overcome friction is gained by its surroundings. Hence, the total energy of the pendulum and the surrounding system remain conserved.

16. Kinetic energy of an object of mass, moving with a velocity v is given by the expression $E_k = 1/2mv^2$

To bring the object to rest, $\frac{1}{2}mv^2$ amount of work is required to be done on the object.

17. Kinetic energy $E_k = \frac{1}{2}mv^2$

where, Mass of car, m= 1500 kg

Velocity of car, $v = 60km/h = 60 \times 5/18ms^{-1}$

Hence, 20.8 x 10^4 J of work is required to stop the car.

18.

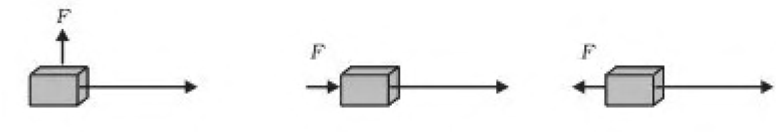


Figure 4.15

Case I

In this case, the direction of force acting on the block is perpendicular to the displacement. Therefore, work done by force on the block will be zero.

Case II

In this case, the direction of force acting on the block is in the direction of displacement. Therefore, work done by force on the block will be positive.

Case III

In this case, the direction of force acting on the block is opposite to the direction of displacement. Therefore, work done by force on the block will be negative.

19. Acceleration in an object could be zero even when several forces are acting on it. This happens when all the forces cancel out each other i.e., the net force acting on the object is zero. For a uniformly moving object, the net force acting on the object is zero. Hence, the acceleration of the object is zero. Hence, Soni is right.

20. Energy consumed by an electric device can be obtained with the help of the expression for power,

$P = W / T$

where, Power rating of the device, P= 500 W = 0.50 kW

Time for which the device runs, T= 10 h

Work done = Energy consumed by the device

Therefore, energy consumed = Power x Time= 0.50 x 10 = 5 kWh

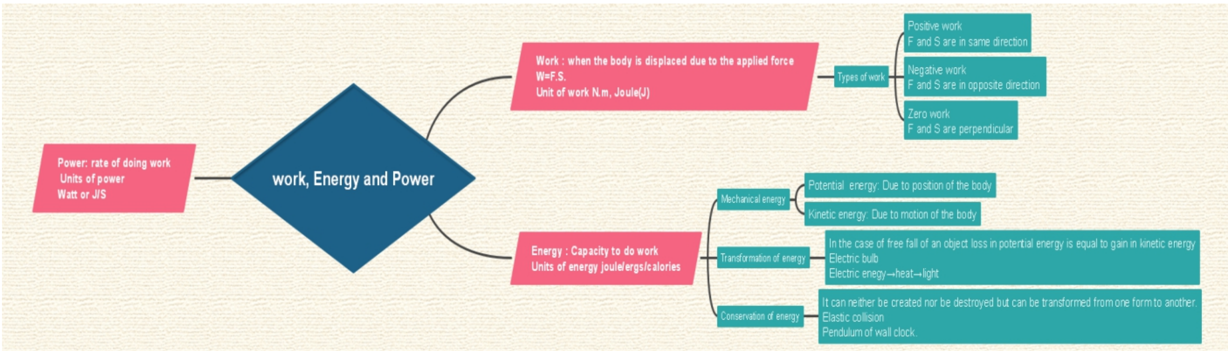
Hence, the energy consumed by four equal rating devices in 10 h will be

4 x 5 kWh = 20 kWh = 20 units.

21. When a freely falling body eventually stops on reaching the ground, its kinetic energy gets converted into heat energy (as the body and ground

become warm due to collision), sound energy and into potential energy (due to change of shape or deformation).

CONCEPT MAP



SOUND

INTRODUCTION

The sound is a carrier of information about the world around us. The information is received by our ears registered in our brain through the sense of hearing. Unlike light, a material medium is essential for the propagation of sound. The atmospheric air which sustains life on our planet also provides the medium for the propagation of sound which is so vital for communication among the planet inhabitants.

Long before man knew what sound was, he had learnt how to use it. He had developed a sophisticated system of communication through speech and an equally sophisticated system of music for his personal enjoyment. Both speech and music are a complex combination of basic elements of sound-music being less complex, though perhaps more enriching than speech. In contrast, the sound produced by vibrating tuning fork is the simplest and purest element of sound. For this reason, we will be using, for the most part, tuning forks to study the characteristics and properties of sound waves in this chapter.

Do we begin the chapter with the discussion on what is sound? And different types of sound. Then, a discussion on the production of sound by vibrating bodies and then proceeds to study the propagation characteristics and effects of medium over the characteristics of sound. Then we examine the role of reflection of the sound wave like the production of echo, reverberation and their applications. Then chapter end with the type of sound waves and their applications.

ESSENTIAL PREVIOUS KNOWLEDGE

- Sound causes sensation of hearing which plays the vital role in communication.
- Oscillatory motion- the to and fro motion of an object.
- Sound is produced by vibrating objects.
- Sound requires a medium to propagate.

- Sound characteristics- Amplitude, frequency and time period.
- Frequency- the number of oscillations per second.
- In humans sound is produced by vibrating vocal cord.
- Audible and non-audible sound.
- Difference between music and noise.

LEARNING OBJECTIVES

The student will be able to:

- Comprehend sound is a wave phenomenon.
- Comprehend sound is capable of doing work.
- Comprehend sound is propagated as a longitudinal mode of vibration.
- Explain the propagation of sound in the air.
- Comprehend sound velocity is different in different medium.
- Solve problems based on velocity of sound.
- Define the process of hearing the sound by humans.
- Comprehend audible and non-audible sound (infrasonic and ultra sonic sound)
- Comprehend and explain the hearing of sound by bats, etc.
- Comprehend the reflection and refraction of the sound.
- Solve problems based on reflection and refraction of sound.
- Define echo.
- Define reverberation.
- Comprehend the hearing of sound by bats, etc.
- Identify and define applications of reflection and refraction of sound.
- Explain working of SONAR.

MAJOR CONCEPTS

1. Sound
2. Production of sound
3. Mode of propagation of sound
4. Characteristics of a sound wave
5. Speed of sound in different medium

6. Reflection of sound
7. Applications of reflection of sound
8. Structure of Human ear

Activity 1: (frequency)

- Take a metal scale of 30cm.
- Fix one end at a rigid support such that the vibrating length of metal scale will be 25cm as shown in figure.
- By using your thumb push the other free end downwards and release it to vibrate vertically
- Observe the vibrations of metal scale.
- Insert 5cm of the scale towards the rigid support such that the vibrating length of metal scale will be 25cm and repeat the activity again to vibrate.
- Observe the vibrations of metal scale.
- In similar way reduce the length of the metal scale by 5cm in steps and notice the vibrations.

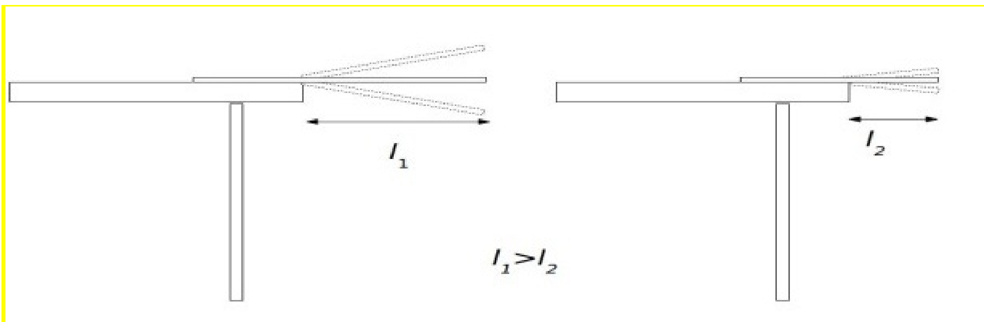


Figure 5.1

It can be noticed that the frequency of vibrations changes as the vibrating length of metal scale changes

The frequency is minimum when vibrating length of metal scale is large.

The frequency is maximum when vibrating length of metal scale is small.

So frequency is inversely proportional to vibrating length.

Activity 2: (Compression and Rarefaction)

- Take few light weight wooden blocks fitted with flexible spring as shown in the figure.
- Fix the free ends of springs on the rigid support.
- Now pull the first block and release it to vibrate.
- Observe the vibrations of all wooden blocks.

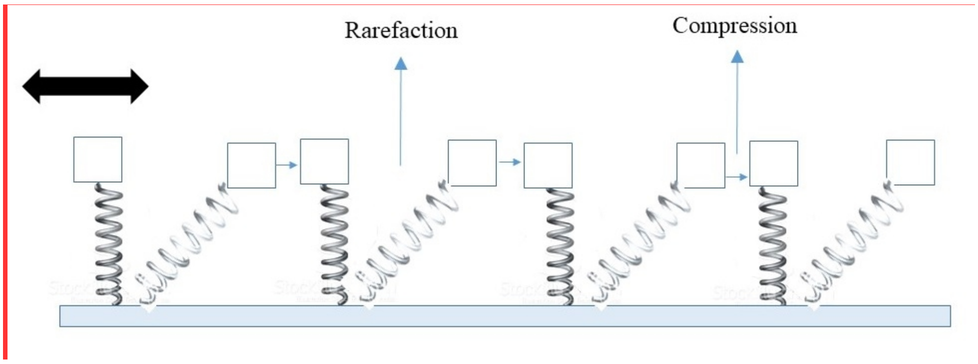


Figure 5.2

It can be noticed that, the first block hits the second block and the second block hits the third block and so on

The energy is transformed from one block to another block; it represents the concept of compression.

After transforming the energy, the block comes back which represents the rarefaction.

Activity 3: (production of sound)

- Take a string of nearly 0.5m
- Stretch a string by holding one end in your mouth under the teeth and the other end in one hand
- Now pluck it near the middle portion you will notice that the string starts vibrating and a sound is heard.
- It can be noticed that the vibrating bodies will produce sound.

Activity 4: (Loudness)

- Drop an empty tin from certain height on to the surface.
- Observe the sound produced.
- Drop the same tin but from more height than the previous.
- Observe the sound produced.

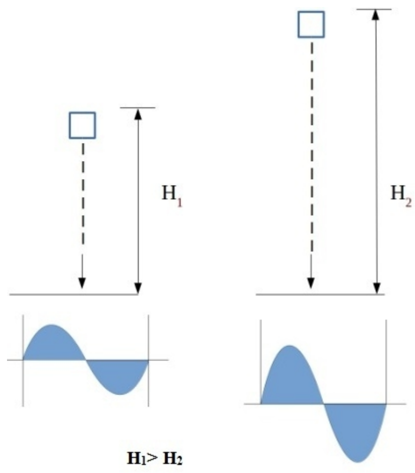


Figure 5.3

- It is observed that the sound is less when height is less and sound is increasing when the height is increased.
- This is because 'as height increases, the energy of the empty tin increases.
- The energy is converted into sound when it falls down.
- Another important observation is only the amplitude of the sound increases when the tin falls from the layer height.
- There is no change in the frequency of sound.
- The natural frequency of the tin remains constant.

Activity 5 (Reflection and sensitivity of ear)

1. Visit a science park near your school as an excursion.
2. You can see the sound reflectors as shown in the figure.
3. Stand at the focus of the one of the reflector and speak few words.
4. Your voice repeats after some time. Infer the reason.
5. Measure the approximate distance between the two concave reflectors.

6. It is always more than 17 m.
7. Discuss reason why the distance is more than 17 m.

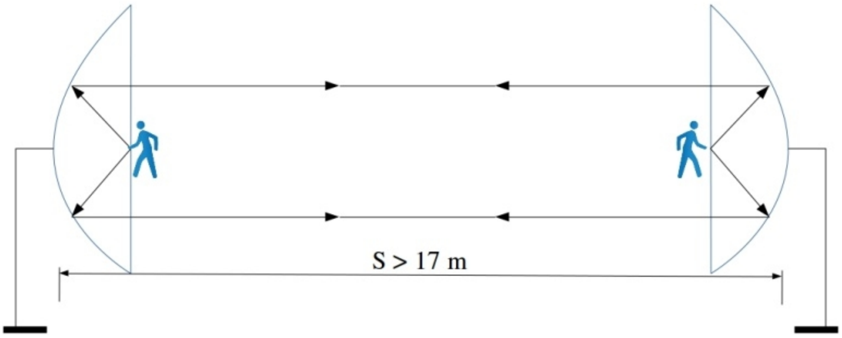


Figure 5.4

Activity 6: (Timber or quality)

1. Go to your school Music room and request your music teacher to play all the instruments and observe the tones.
2. Request you music teacher to bring his music club members and play all the instruments together and listen the pleasant music of all the instruments.
3. Analyse the reason for pleasant music and interpret the following figures.

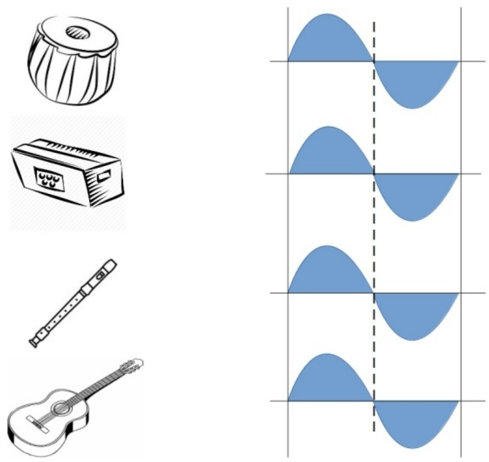


Figure 5.5

❖ The sound produced from all the instruments are of same frequency and same wavelength, but still we can distinguish the tone of the instruments. The reason behind for this is that each instrument has one particular fundamental frequency. It is called timber or quality.

Activity 7: (Noise)

- Request your music teacher to allow the students who do not know how to play Musical instrument properly.
- Then observe the tones, it becomes noise for you.
- Interpret the reason with the following figure.

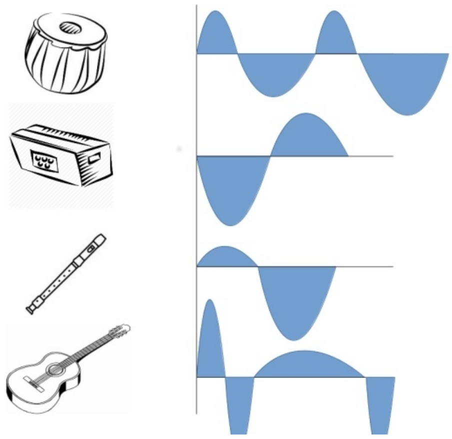


Figure 5.6

- When the amplitude and frequency of the instrument is not matching with other instruments it becomes noise.

Activity: 8 (Reverberation)

- Take an empty metallic tin and beat it with stick or rod.
- Observe the sound produced by the empty metallic tin.
- Cut the empty metallic tin with scissor or knife and make it as a plane sheet.
- Beat the metallic sheet with stick or rod.
- Observe the sound produced now.
- Compare the sound produced in both the cases.
- It can be concluded that in the first case sound is persisting for the ear for some time due to multiple reflection of sound inside the empty metallic tin.
- In the second case there is no persistence of sound for the ear for long time

i.e., in case of the metallic sheet there is no multiple reflections of the sound and it is just travelled away from the source.

- Note: The frequency and amplitude also changes because the shape of the metallic tin is changed.

Activity 9: (Frequency and wavelength are inversely proportional)

1. Take tuning forks of different frequencies (say seven different frequencies).
2. Note down the frequencies which is written on the tuning fork.
3. Calculate the wavelength of the sound produced in each tuning fork by using $v = f \times \lambda$, where velocity "v"= 340 m/s. f-frequency and λ-wavelength.
4. Now plot a graph between frequency on x-axis and wavelength on y-axis.
5. Select any point on the graph and note down its wavelength and frequency value then find the product of them. (i.e., speed of sound wave)
6. Repeat the above said for different points on the graph and verify your result.
7. It can be concluded that the product of wavelength and frequency i.e., speed, remains constant.

Production of sound:

- Sound is produced by vibrating body.
- When a drum or tables is beaten, the sound is produced by the vibrations of the drum membrane.
- In musical instruments like violin or veena, the string under tension will vibrate and produces the sound.
- The human voice box (larynx) is another generator of sound. The vocal cords under vibration can change the frequency and amplitude of the sound.
- The vocal cords and the voice box produce the 'raw' sounds, the lips, the teeth and the tongue helps to make sounds intelligible.

Propagation of sound

Sound is produced by vibrating bodies. The vibrating body sets the particles of the medium around it to vibrate. The particles do not travel all the way from the vibrating body to the ear. A particle of the medium in contact with the vibrating body is first displaced from its equilibrium position then it exerts a force on the adjacent particle. The adjacent particle gets displaced from its position of rest. After displacing the adjacent particle the first particle comes back to its original position. The process continues till the sound reaches our ears.

Compressions and rarefactions

When a body vibrates, it compresses the air molecule surrounded by it and creates the system of high pressure which is called compression. When vibrating body vibrates back after transferring energy it creates the system of low pressure which called the rarefactions. The sound waves transfer energy by forming compressions and rarefactions alternatively. The direction of propagation of sound is changed by the direction of wind. The velocity of sound depends upon the velocity of medium.

Characteristics of sound waves

Frequency

When an object is vibrated, it vibrates the particle of the medium. Then compressions and rarefactions form as the wave travels through the medium. The density of the medium oscillates between the maximum value and the minimum value. The change in the density from the maximum (compression) value to the minimum (rarefaction) value again to the maximum (compression) value makes a complete cycle. The number of such cycles per unit time is called frequency. The SI unit of frequency is hertz (Hz).

Wavelength

The distance between two consecutive compressions or two consecutive rarefactions is called wavelength. In other words, it is the length of one compression and one rarefaction. The SI unit of wavelength is metre. It is represented by the symbol λ.

Time Period

The time taken for one complete cycle (i.e., time taken to complete one compression and one rarefaction) is called time period. SI unit of time period is second (s). It is represented by the symbol T. Relation between frequency (*f*), wavelength (λ), time period (T) and speed of sound (*v*),

$$\text{speed} = \frac{\text{distance travelled by the wave}}{\text{time taken}}$$

$$\text{distance travelled by the wave} = \text{number of cycles} \times \text{wavelength}$$

$$\text{speed of sound} = \frac{\text{number of cycles} \times \text{wavelength}}{\text{time taken}}$$

$$\text{frequency } (f) = \frac{\text{n} \times \lambda}{\text{T}} \qquad (1)$$

where, n = number of cycles

Now,

$$\text{frequency}(f) = \frac{\text{number of cycles (n)}}{\text{time taken (T)}} \qquad (2)$$

from equations 1 and 2,

$$\text{speed of sound (v)} = \frac{\text{number of cycles (n)} \times \text{wavelength } (\lambda)}{\text{time taken (T)}}$$

$$\text{speed of sound (v)} = \text{frequency} \times \text{wavelength}$$

$$v = f \times \lambda$$

The frequency of vibrating string at resonance is given by,

$$f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$$

l = resonating length

T = tension in string

μ = linear mass density

Structure of Human Ear:

- Microphones are most commonly employed as detectors of sound.
- In microphones, the vibrations of the diaphragm can be converted into an identical pattern of voltage variations.
- Like human eye, human ear is a sensitive sensory organ.

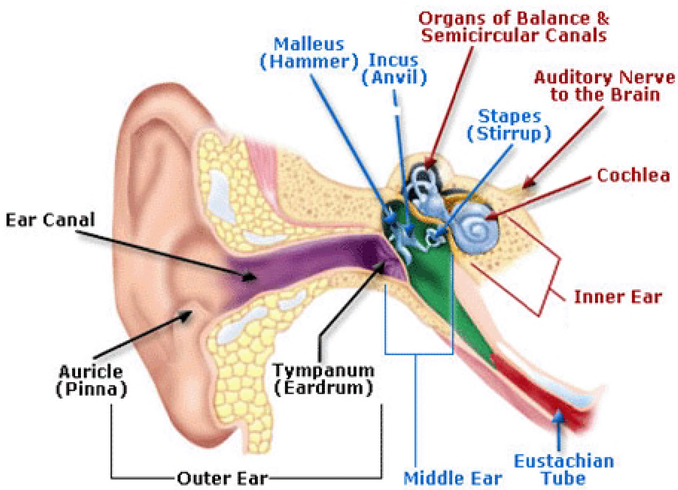


Figure 5.7

- The outer ear collects the incident sound waves and conducts them to the eardrum.
- The bones of the middle ear and eardrum vibrate in response to pressure

variations.

- The vibrations of the ear drum are transmitted as force variations to oval window. The vibrations induce pressure changes in the inner ear.
- The pressure changes transmitted to the inner ear are multiplied between 30 and 60 times three bones hammer, anvil and stirrup.
- In inner ear the pressure variations are turned into electrical signals by the cochlea, which contains 30,000 nerve endings.
- The auditory nerves are stimulated by the changes of pressure in cochlea and carry nerve impulses to the brain.
- The impulses carried by the auditory nerves are interpreted as sound in the brain.

Applications of Ultra sound:

- The frequency of ultrasound waves is high. So they can travel even in the presence of obstacles.
- Ultrasound is used to clean parts located in hard to reach places, as the frequency of ultrasound is high the particles of dust, grease and dirt get detached and drop out.
- Ultrasounds can be used to detect cracks and flaws in metal blocks, the ultrasound gets reflected back indicating the presence of the flaws, defect on passing through the body.
- Ultrasonic waves are made to reflect from various parts of the heart and form the image of the heart. This technique is the “Echocardiography”.
- Ultrasonography: Ultrasonic waves are used to get the images of internal organs like liver, gall bladder, uterus, kidney, etc by the instrument ultrasound scanner. It helps the doctors to detect abnormalities like stones in gall bladder and kidney or tumours in different organs.
- Ultrasound can also used to break small 'stones' formed in the kidneys.

SONAR:

- The full form of 'SONAR' is Sound Navigation Anal Ranging.
- SONAR is a device works by using ultrasonic waves.
- 'SONAR' is used to measure the distance, direction and speed of underwater objects.
- 'SONAR' consists transmitter and detectors

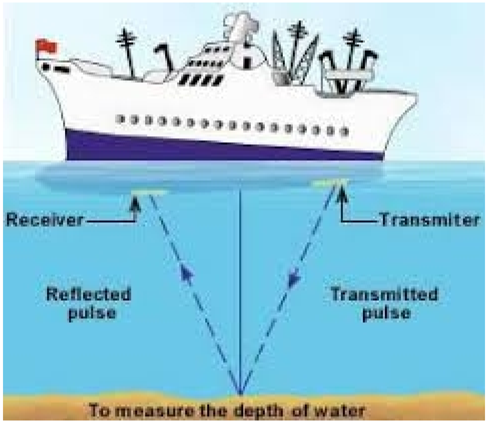


Figure 5.8

The total distance travelled by the ultrasound is,

$$2d = vt$$

$$d = \frac{vt}{2}$$

Refection of sound:

- Sound gets reflected at the surface of a solid or liquid and follows the same laws of reflection followed by light.

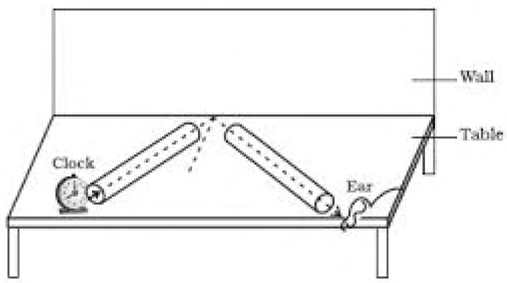


Figure 5.9

Echoes:

- If we clap near a reflecting surface, we will hear the same sound again a little later this sound which we hear later is called echo.
- The sensation of sound persists in our brain for about 0.1 s
- If the speed of sound is 344 m/s, the minimum distance to hear echo is,

$$2d = vt$$

$$d = \frac{vt}{2}$$

$$d = \frac{344 \times 0.1}{2}$$

$$d = 17.2 \text{ m}$$

The minimum distance to hear echo changes with temperature.

Reverberation:

- A reverberation is produced when a sound is reflected causing a large number of reflections to occur and then they decay as sound is absorbed by the reflecting objects.
- To reduce reverberation, the roof and wall of the auditorium, big halls, movie theatres are covered with sound absorbent materials.
- Acoustic fibreglass, Acoustic foam, Acoustic cotton are some sound absorbers.

Uses of Multiple Reflection of Sound:

- Instruments like megaphones, loudhailers, horns, trumpets and shehanais are designed to send sound in particular direction.

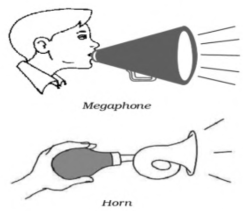


Figure 5.10

- In stethoscopes the sound of the patient's heartbeat reaches the doctors ear by multiple reflection of sound.

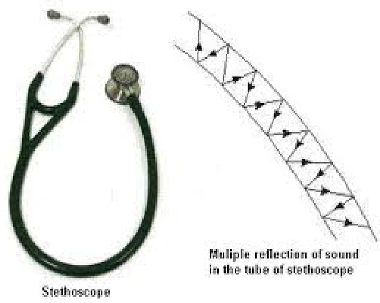


Figure 5.11

Range of Hearing:

- The audible range of sound for human beings is 20Hz to 20,000Hz.d
- Children below 5 years of age and dogs can hear up to 25 KHz.
- The sounds below 20Hz are called Infrasonic sound
- Whales, Rhinoceroses and elephants communicate by infra sound.
- The sound waves of frequency higher than 20 kHz are called Ultrasonic sound or Ultrasound.
- Ultrasound is produced by dolphins, bats, porpoises and rats. Moths of certain families can hear ultrasounds.

Speed of sound in different media:

- Speed of sound is less than the speed of light.
- Sound needs a medium to travel, it can travel through vacuum.
- The speed of sound depends on the properties of the medium through which it travels.

SI No	Animal type	Frequency Range (Hz)
1	Human beings	20- 20000
2	Dogs , children below 5 years	25000
3	Whales, elephants, rhinoceroses	< 20
4	Bats, dolphins, rats	upto100000

Speed of sound in gases medium is given by $v = \sqrt{\frac{P\gamma}{\rho}}$

where,

γ is the ratio of specific heat capacities.

P is the pressure of gas and

ρ is the density of gas.

- Speed of sound in air is 331 m/s at 0^0C and 334 m/s at 22^0C.
- Speed of sound in solids is greater than the speed of sound in liquids which is greater than the speed of sound in gases in general

$$V_{solids} > V_{liquids} > V_{gas}$$

SI No	Substance	Speed (m/s)

1.	Air (at 0°c)	332
2	Hydrogen	1330
3	Water	1486
4	Copper	3810
5	Aluminium	5000
6	Steel	5200

CONCLUSION

Sound gives sense of hearing like light gives sense of vision which is essential for communication. All vibrating bodies can produce sound whereas all sounds produced can't be heard by human beings. Our experience tells us that we can't hear the sound produced in outer space. This is because sound requires a mechanical medium for its propagation. Sound can propagate through a medium like air, water and solid as longitudinal wave. Sound cannot travel through a vacuum. There is no sound in the outer space. In air sound propagates with variation in pressure. A region of increased pressure on a sound wave is called compression and a region of decreased pressure on a sound wave is called a rarefaction. During propagation sound can be reflected, refracted and attenuated by the medium. Sound gets reflected and gives rise to production of echo, reverberation, etc. The applications of reflection of sound are used to measure the depth of the sea, navigation and in search operations.

EXERCISES:

1. A stone is dropped by a girl from the top of a building of height 1000 m vertically downward into a swimming pool filled with water. At what time she heard the sound of the splash?
   Take g= 9.8 ms^{-2} and speed of the sound is 344 ms^{-1}.

(Hint: - First, find the time of fall of the stone under free fall condition. Then, find the time for sound to reach from the swimming pool to the girl. Sum of these two times is the time at she heard the sound of the splash.)

2. A submarine sends out a signal and receives its echo 10s later with SONAR from an object at a distance of 8000m from the submarine. Calculate the speed of the speed of the sound in the water.

   (Hint: - velocity of sound $v = \frac{2d}{t}$).

3. A boy shouting "hurray hurray" near a cliff and heard his echo after 7s. What is the distance of the cliff from the boy? Take the speed of the sound is 344 ms^{-1}.

   (Hint: - velocity of sound $d = \frac{vt}{2}$).

4. A monkey drops a coconut from the top of a coconut tree of height 30m. What time he hears the sound of the coconut hitting the ground after dropping it?

   (Hint: - Fist, find the time of fall of the coconut under free fall condition. Then, find the time for sound to reach from the ground to the monkey. Sum of these two times is time monkey hears the sound of the coconut hitting the ground after dropping it)

5. A metal string vibrating 500 times per second send out a wave at a speed of 350 m/s. What is the period and wavelength of the wave?

   (Hint: - velocity= wavelength x frequency)

6. Calculate the speed of sound at normal temperature and pressure for air.

   (Hint: - Use formula $V = \sqrt{\frac{\gamma P}{\rho}}$).

7. A sonometer wire, 50 cm long, is under tension of 3 kg weight. Find its fundamental frequency if its linear density is 10^{-2} kg/m.

   (Hint: - Use formula $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$)

8. What is the audible range of wavelength of sound for air at normal temperature and pressure?

(Hint:- velocity= wavelength x frequency)

9. Kiran surprised when he listens about echo. To verify it he stood between two building and he given a clap. He heard echo after 0.3 s and 0.5 s respectively from 1^{st} and 2^{nd} building. What is the distance between two buildings if the speed of the sound is 344m/s.

(Hint: - velocity of sound $v = 2\frac{d}{t}$).

10. A tuning fork of frequency 256 Hz produces waves with wavelength of 1cm. What is the speed and period of the wave?

(Hint: - velocity= wavelength x frequency)

11. Classify the following wave characteristics into space variable and time variables.

Frequency, wavelength, period and amplitude.

12. Does the relation $v = f\lambda$ hold good for waves of all types?

(Hint:- Yes)

13. List out some common examples to show that wave transport energy.

(Hint:- communication by radio waves, communication by sound waves, earthquakes, etc.)

14. In what way are the following wave variables affected during a reflection at a fixed boundary?

a) Speed,
b) a wave compression,
c) frequency,
d) direction of propagation,
e) a wave rarefaction.

15. How will you identify the voice of your friend in a singing group, when the song is sung with same pitch and loudness?

16. We know that brain can interpret only electrical signals, but when we interact with others the sound will be in the physical form. How will you justify this?

17. When an empty box is dropped from two building of different heights, we hear two different sounds. State the reason behind it.

18. Ganesh, who is suffering from stomach pain, informed to his father about the problem. His father took the boy to the hospital. By observing the symptoms of pain, Doctor did the medical check-up and reported that the boy has stones in his kidney. After that the boy is given treatment.

a) What are the values shown by the father?

b) What is the technique used by doctor to identify the stone?

19. It can be observed that, there will be a change in the voice of children when they enter into adolescent age. Give the reason behind it.

20. Give any two applications of reflection of sound.

21. What is the mode of propagation of sound wave?

a) Transverse

b) Longitudinal

c) EM wave

d) None of above

22. Voice of a horn and whistle can be recognised by

a) Quality

b) Pitch

c) Velocity

d) Intensity

23. The minimum distance between the source of sound and reflector for producing echo is

a) 34 m

b) 17m

c) 34cm

d) 17cm.

24. The frequency which is not audible by humans is

a) 15 Hz

b) 2000 Hz

c) 25 Hz

d) 15000 Hz

25. An ultrasonic wave is sent from a ship towards the bottom of the sea. It is found that the time interval between the sending and receiving of the wave is 3 s. What is the depth of the sea, if the velocity of sound in the seawater is 1400 m/s?

a) 2100 m

b) 4200 m

c) 5200 m

d) 2600 m

26. The time period of a vibrating body is 0.01 s. The frequency of waves it emits is

a) 1 Hz

b) 10 Hz

c) 100 Hz

d) 1000 Hz

27. The infrasound can be hear by

a) Human beings

b) bat

c) dog

d) none of the above

28. In sonar which types of waves are used to measure the depth of the sea

a) radio wave

b) audible sound wave

c) ultrasound wave

d) infrasound wave

29. The vibration of the veena string gradually dies away. Then what is the affect of it

a) frequency decreases

b) amplitude decreases

c) Time period increases

d) None of the above

30. The velocity of sound in water at room temperature is

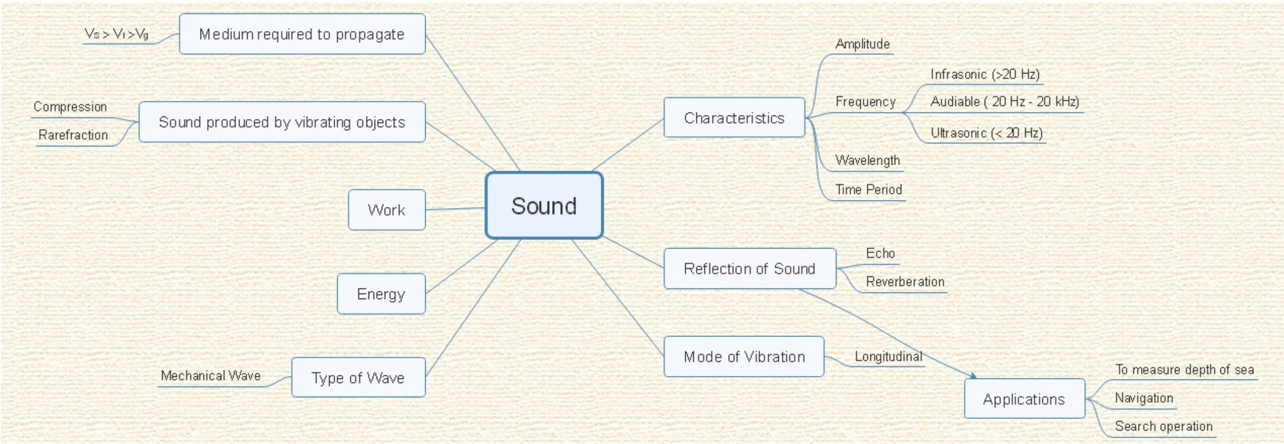
a) 1500 m/s

e) 340 m/s

f) 340 km/s

g) 1500 km/s

CONCEPT MAP



4 FUTURE PLAN

The focus of this programme was on the IX standard topics of Physics the resource material for the secondary school teachers. The material was developed considering the changes happened in the content as well as the pedagogical aspects. The work will be completed once the material for the X standard is also done and it is proposed as a new PAC programme for the financial year 2018-19.