TEACHER'S HANDBOOK

STELLAR LEARNING

Physics

9

On Board! BOOKS

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Motion

Checkpoint (Page 6)

1. What is the SI unit of length?

Ans. The SI unit of length is metre (m).

2. What is rectilinear motion?

Ans. Rectilinear motion is a type of motion in which an object moves along a straight line, for example, a fruit falling down from a tree or a cyclist moving along a straight road.

3. The distance between two stations is 240 km. A train takes 4 hours to cover this distance. Calculate the speed of the train.

Ans. Distance, d = 240 km; time taken, t = 4 hours

Let the speed of the train be s km/h

Since, $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

Therefore, $s = \frac{d}{t} = \frac{240\text{ km}}{4\text{ h}} = 60$ km/h

4. Zubeida takes 15 minutes to cycle from her home to her school. If her bicycle has a speed of 2 m/s, calculate the distance between her home and her school.

Ans. Speed, s = 2 m/s;

time, (t) = 15 min

= 15 × 60 s = 900 s

Let the distance between Zubeida's home and her school be d m.

Since, distance = speed × time

Therefore, $d = s \times t$ = 2 m/s × 900 s

= 1800 m = 1.8 km

5. A car moves with a speed of 40 km/h for 15 minutes and then with a speed of 60 km/h for the next 15 minutes. Calculate the total distance covered by the car.

Ans. First period of time, t_1 = 15 minutes = $\frac{15}{60}$ h

= 0.25 h

Second period of time, t_2 = 15 minutes = 0.25 h

Speed of the car during t_1, s_1 = 40 km/h

Speed of the car during t_2, s_2 = 60 km/h

We know that distance = speed × time

Therefore, distance covered during t_1,

$d_1 = s_1 \times t_1$

= 40 km/h × 0.25 h = 10 km

Distance covered during t_2,

$d_2 = s_2 \times t_2$

= 60 km/h × 0.25 h = 15 km

Therefore, total distance covered by the car,

$d = d_1 + d_2$ = 10 km + 15 km

= 25 km

6. The odometer of a moving car shows that it covers 15 km in 20 minutes. Calculate the speed of the car in km/min during this time. Express the speed in km/h also.

Ans. Distance covered by the car, d = 15 km;

time, t = 20 min

Since, $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$

Therefore, speed (in km/min)

$= \frac{d}{t} = \frac{15\text{ km}}{20\text{ min}} = 0.75$ km/min

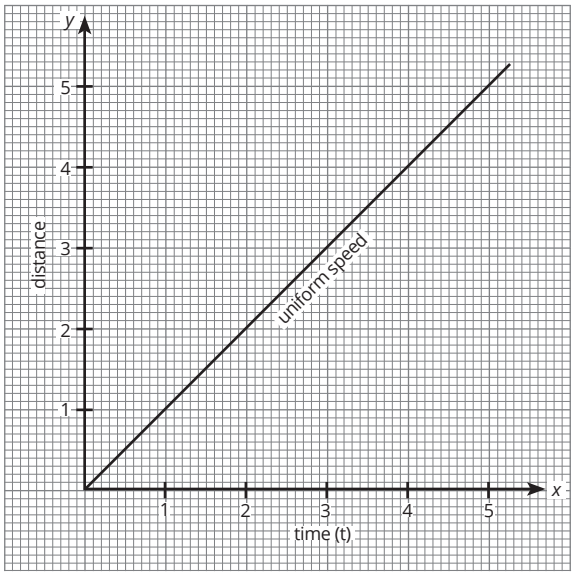
Speed (in km/h) = Speed (in km/min) × (60 min/1 h)

= 0.75 km/min × 60 min/h

= 45 km/h

7. What is the nature of the distance–time graph for the motion of an object moving with a constant speed?

Ans. The distance–time graph for the motion of an object moving with a constant speed is a straight line with a constant slope.



8. Name the device that records the speed of a vehicle in km/h.

Ans. The device that measures the speed of a vehicle in km/h is known as a speedometer.

9. The distance between Mona's and Lisa's house is 9 km. Mona has to attend Lisa's birthday party at 7 pm. She started from her home at 6 pm on her bicycle and covered a distance of 6 km in 40 minutes. At that point she met John and the two spoke for 5 minutes. If Mona still manages to reach the party at 7 pm, with what speed did she cover the remaining 3 km? What was her average speed for the entire journey?

Ans. The one-hour period between 6 pm (when Mona starts from her home) and 7 pm (when she reaches Lisa's party) can be divided into 3 time periods t_1 (= 40 min), t_2 (= 5 min), and t_3.

The total time taken, t = 1 h = 60 min

Since, $t_1 + t_2 + t_3 = t$

Therefore, $t_3 = t - (t_1 + t_2)$

$= 60 \text{ min} - (40 \text{ min} + 5 \text{ min})$

$= 15 \text{ min}$

Mona covers 3 km during t_3

Thus, speed with which she covers 3 km,

$$s_3 = \frac{\text{Distance}}{t_3} = \frac{3 \text{ km}}{15 \text{ min}}$$

$= 0.2$ km/min

Average speed, s_{av}

$$= \frac{\text{Total distance covered}}{\text{Total time taken}}$$

$$= \frac{9 \text{ km}}{60 \text{ min}} = 0.15 \text{ km/min}$$

10. Give an example of an oscillatory motion.

Ans. An example of oscillatory motion is the pendulum of a wall clock moving from one end to another about its mean position.

Milestone 1

(Page 10)

Multiple-Choice Questions

1. The SI unit of distance is

(a) metre. (b) kilometre.

(c) centimetre. (d) millimetre.

Ans. The SI unit of distance is (a) metre.

2. Which of these is a scalar quantity?

(a) Displacement (b) Distance

(c) Force (d) Velocity

Ans. Out of the four options given, only (b) distance is a scalar quantity.

3. A car travels from one city to another city 50 km away and then comes back to its initial point by the same route. What is the total distance covered for the car?

(a) 50 km (b) 100 km

(c) 0 km (d) 150 km

Ans. The correct answer is (b) 100 km.

Total distance covered = distance covered while travelling from the first city to the second + distance covered while travelling from the second city to the first = 50 km + 50 km = 100 km

4. In the above example, what is the total displacement of the car?

(a) 50 km (b) 100 km

(c) 0 km (d) 150 km

Ans. The correct answer is (c) 0 km.

Total displacement of the car = Distance between the initial position and the final position

Since the car starts and ends its journey at the same point, the distance between the initial position and the final position is 0.

Therefore, displacement is also 0.

5. Which of the following can have a negative value?

(a) Distance (b) Displacement

(c) Mass (d) Length

Ans. The correct answer is (b) Displacement.

The other three quantities are scalar in nature, while displacement is a vector quantity. Since

scalar quantities cannot have negative values, the only correct option is displacement.

Very Short Answer Type Questions

6. If you are walking towards a tree, is the tree in motion relative to you or is it at rest in relation to you?

Ans. If I am walking towards a tree, then the tree is moving towards me in relation to me.

7. What is the displacement of the moon after completing one revolution around the earth?

Ans. After completing one revolution around the earth, the moon reaches its initial position. Therefore, its displacement is 0.

8. If time and change in position are two of the three parameters needed to define motion, what is the third?

Ans. The third parameter needed to define motion is the reference point or origin.

9. Is it possible for the magnitude of displacement of an object to be greater than the distance covered by it?

Ans. No, it is not possible for the magnitude of displacement of an object to be greater than the distance covered by it.

10. If object A is moving in relation to object B, is object B also moving in relation to object A?

Ans. Yes, if object A is moving in relation to object B, then object B is also moving in relation to object A.

Short Answer Type-I Questions

11. John is driving his car on the road. Is the car in motion with respect to all reference points? Is there any reference point with respect to which it is at rest?

Ans. No, the car is not in motion with respect to all reference points. If John is taken as a reference point, the car is at rest relative to him.

12. For an object moving in a straight line, in what case will the distance be different from its displacement?

Ans. If the object moving in a straight line changes its direction of motion, i.e. instead of continuing to move forward, it moves backward for some time, then the distance will be different from the displacement.

13. Give an example where we feel the presence of motion through indirect evidence.

Ans. The movement of leaves because of wind (or air particles) is an example of presence of motion through indirect evidence.

14. Among the following positions of an object that can move in a horizontal plane, which two denote identical positions?

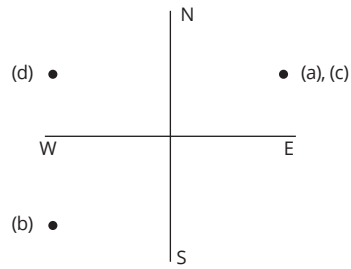
(a) 10 m, 30° north of east

(b) 10 m, 60° south of west

(c) 10 m, 60° east of north

(d) 10 m, 30° north of west

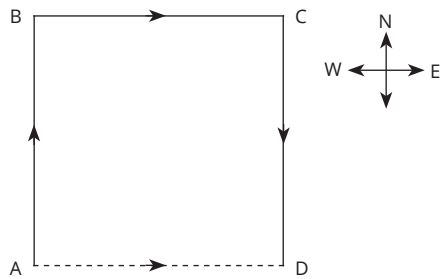
Ans. (a) 10 m, 30° north of east and (c) 10 m, 60° east of north denote identical positions.



Short Answer Type-II Questions

15. A car moves 500 m due north, then 500 m due east and then 500 m due south. What is the distance covered by the car? What is the displacement?

Ans. The solid line in the figure below represents the distance covered by the car and the broken line represents its displacement.



The total distance = 500 m + 500 m + 500 m

= 1500 m = 1.5 km

Total displacement = distance between initial point and the final point = 500 m due east

(Note that the direction is given here because displacement is a vector quantity. A displacement of 500 m due east is different from a displacement of 500 m due west.)

16. What do we mean when we say that motion is relative? Give an example to support your answer.

Ans. It means that the motion of any object depends on the frame of reference of the observer. For example, suppose person A sitting in a moving car looks at person B standing at rest beside the road. For person B, person A is in motion. For person A, person B is in motion in the opposite direction.

17. Classify the following into scalar and vector

quantities:

(a) Length

(b) Time

(c) Weight

(d) Energy

Ans. (a) Length – Scalar

(b) Time – Scalar

(c) Weight – Vector

(d) Energy – Scalar

18. Give an example each of oscillatory motion, vibratory motion, curvilinear motion and multiple motion.

Ans. (a) Oscillatory motion – Motion of a swing

(b) Vibratory motion – Motion of a tuning fork on being struck

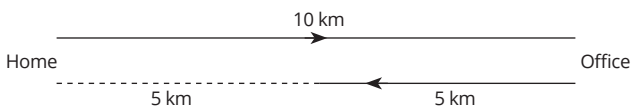
(c) Curvilinear motion – Motion of a paper plane thrown into the air

(d) Multiple motion – Motion of the wheels of a car moving forward

Long Answer Type Questions

19. Jasleen rides her bike from home to her office in the morning. The office is 10 km from her home. In the evening, she takes the same route to ride back home, but the petrol runs out halfway and she has to leave her bike and take a taxi. What is the distance covered by her bike during the day? What is the displacement?

Ans. The figure below shows Jasleen's movement through the day. The solid line represents her motion on her bike and the broken line represents her motion in a taxi.



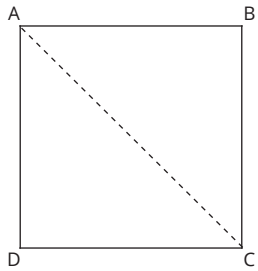
The distance covered by the bike

= 10 km + 5 km = 15 km

The displacement of the bike = distance between its initial position (home) and final position (half way between home and office) = 5 km

20. A person starts running along the boundary of a square field with each side measuring 200 m. What is the maximum displacement she can have at any point if she starts from one corner of the square?

Ans. The figure below shows a square field where the person starts running from point A.



As we can see, the maximum displacement from point A is possible when the person is at point C. In this case, the displacement = length of the diagonal of the square of side 200 m

$= 200\sqrt{2}$ m

= 282.84 m

Milestone 2

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Multiple-Choice Questions

1. If an object covers equal distances in equal intervals of time, it is said to

(a) be at rest.

(b) move with uniform speed.

(c) move with uniform velocity.

(d) move with uniform acceleration.

Ans. The correct answer is (b). Since we are talking about distance and not displacement, this is motion with uniform speed and not uniform velocity.

2. If the unit of a quantity is cm/s, it is likely to be a measure of

(a) displacement. (b) velocity.

(c) acceleration. (d) force.

Ans. The correct answer is (b) velocity.

3. The SI unit of retardation is

(a) m/s^2. (b) km/h^2.

(c) m/s. (d) m^2/s.

Ans. The correct answer is (a) m/s^2.

4. If an object is moving with constant velocity, its acceleration is

(a) positive. (b) negative.

(c) zero. (d) could be any of these.

Ans. Since acceleration is the rate of change of velocity, if there is no change in velocity, the acceleration is zero. The correct answer is (c).

5. If a runner takes '*t*' seconds to complete one lap round a circular path of diameter '*d*', her speed is given by

(a) $\frac{\neq d}{t}$. (b) $\frac{\neq d^2}{4t}$.

(c) $\frac{2\neq d}{t}$. (d) $\frac{t}{\neq r^2}$.

Ans. The correct answer is (a).

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Here, distance = 1 lap = circumference of the circle of diameter $d = \pi \times d$

Therefore, speed = $\frac{\neq d}{t}$

6. Train A is standing at a platform of a railway station with its front towards the east. Roshan is running at the speed of 1 m/s inside Train A towards the front of the train. Train B passes by slowly on the tracks beside Train A at the speed of 3.6 km/h from west to east. Reema is sitting inside Train B. Which of these statements would be true from Reema's perspective?

(a) Roshan is stationary.

(b) Roshan is running towards the east with the speed of 2 m/s.

(c) Train A is stationary.

(d) Train A is moving towards the east with the speed of 1 m/s.

Ans. The correct answer is (a).

Roshan is moving at 1 m/s (= 3.6 km/h) from west to east inside Train A. Since Train B is also moving from west to east at 3.6 km/h, the relative motion of Roshan with respect to Train B is zero. Since Reema is stationary inside Train B, Roshan's relative motion with respect to Reema is also zero.

Very Short Answer Type Questions

7. When are the magnitudes of the speed and the velocity of a moving object equal?

Ans. The magnitudes of the speed and the velocity of a moving object are equal when it is moving along a straight line in the same direction.

8. Is there any situation where the speed of an object is negative?

Ans. No, the speed of an object cannot be negative.

9. If the velocity of an object is changing, but its magnitude is not, what other property must be changing?

Ans. In the given case, the direction of velocity must be changing.

10. If the displacement of an object over a 10-minute interval is zero, is its velocity at every instant in this interval necessarily zero?

Ans. No, the velocity can be positive, negative, or zero during the 10-minute interval.

11. What does the odometer of a car measure?

Ans. The odometer of a car measures the distance covered by the car.

12. What is the direction of velocity of an object in circular motion?

Ans. In circular motion, the velocity of the object is directed towards the tangent to the circular path.

Short Answer Type-I Questions

13. A train travelling due north on a straight railway track covers a distance of 5 km in 10 minutes. What is the speed and the velocity of the train expressed in SI units?

Ans. Distance covered = 5 km = 5000 m;

time taken = 10 min = 10 × 60 s = 600 s

Speed = Distance/Time = 5000 m/600 s = 8.33 m/s

Since the train travels along a straight railway track, the displacement = distance covered

$$\text{Velocity} = \frac{\text{Displacement}}{\text{Time}} = \frac{5000\ \text{m}}{600\ \text{s}} = 8.33\ \text{m/s}$$

14. A car travels a certain distance at a speed of 30 km/h and returns at a speed of 10 m/s. What is the average speed over the entire journey for the car?

Ans. Speed on the onward journey, s_1 = 30 km/h;

speed on the return journey, s_2 = 10 m/s = 36 km/h

Let the distance covered in one direction = d km

Time taken on the onward journey = t_1

Time taken on the return journey = t_2

$$t_1 = \frac{d}{s_1} = \frac{d\ \text{km}}{30\ \text{km/h}} = \frac{d}{30}\ \text{h}$$

$$t_2 = \frac{d}{s_2} = \frac{d\ \text{km}}{36\ \text{km/h}} = \frac{d}{36}\ \text{h}$$

$$\text{Average speed} = \frac{\text{Total distance}}{\text{Total time}} = \frac{d+d}{\frac{d}{30}+\frac{d}{36}}\ \text{km/h}$$

$$= \frac{2}{\frac{1}{30}+\frac{1}{36}}\ \text{km/h}$$

$$= 32.7\ \text{km/h}$$

15. If a property of an object's motion is given as –20 m/s, it would be its speed or velocity? Give a reason to support your answer.

Ans. This would be the object's velocity. It cannot be the speed because speed is a scalar quantity and it cannot be negative.

16. In the case of uniform circular motion of an object, name one property that

(a) remains constant.
(b) changes continuously.

Ans. (a) The speed remains constant;
(b) The velocity changes continuously

17. If a ball is thrown vertically upwards, what can you say about its velocity and acceleration at its highest point?

Ans. For a ball thrown vertically upwards, its velocity at the highest point is zero and acceleration is the acceleration due to gravity (9.8 m/s^2) directed downwards.

Short Answer Type-II Questions

18. In a hare-tortoise race, the hare ran for 5 minutes at a speed of 5 km/h, slept for 50 minutes, and then ran for 5 minutes at a speed of 7.5 km/h. What is the average speed of the hare in the race?

Ans. Given, $t_1 = 5 \text{ min} = \frac{5}{60}$ h, $s_1 = 5$ km/h;

$t_2 = \frac{50}{60}$ h, $s_2 = 0$;

$t_3 = \frac{5}{60}$ h, $s_3 = 7.5$ km/h

$d_1 = s_1 \times t_1$

$= 5 \text{ km/h} \times \frac{5}{60} \text{ h} = \frac{25}{60} \text{ km}$

$d_2 = s_2 \times t_2 = 0 \times \frac{50}{60} \text{ h} = 0 \text{ km}$

$d_3 = s_3 \times t_3 = 7.5 \text{ km/h} \times \frac{5}{60} \text{ h}$

$= \frac{37.5}{60} \text{ km}$

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

$$= \frac{d_1 + d_2 + d_3}{t_1 + t_2 + t_3}$$

$$= \frac{\frac{25}{60} + 0 + \frac{37.5}{60}}{\frac{5}{60} + \frac{50}{60} + \frac{5}{60}} \text{ km/h}$$

$$= \frac{25 + 37.5}{5 + 50 + 5} \text{ km/h}$$

$= 1.04$ km/h

19. A motorcyclist takes 1 h 25 minutes to ride from his home to his friend's house with a uniform speed of 45 km/h. What is the distance between his house and his friend's house?

Ans. Speed, $s = 45$ km/h,

time, $t = 1 \text{ h } 25 \text{ min} = 1 + \frac{25}{60} \text{ h} = 1.42$ h

Distance $= s \times t = 45 \text{ km/h} \times 1.42 \text{ h}$
$= 63.9$ km

20. The maximum speed of a bus is 100 km/h. If it takes 8 hours to cover a trip of length 500 km, what is the ratio of its maximum speed to its average speed?

Ans. Maximum speed, $s_{max} = 100$ km/h

Distance covered, $d = 500$ km, time taken, $t = 8$ h

Average speed, $s_{av} = \frac{d}{t} = \frac{500}{8} = 62.5$ km/h

Therefore, $\frac{s_{max}}{s_{av}} = \frac{100 \text{ km/h}}{62.5 \text{ km/h}} = 1.6$

21. Zafar starts running along a circular path of radius 100 m for his morning exercise. What is his average velocity at the end of one lap if he takes 5 minutes to complete one lap?

Ans. Average velocity $= \frac{\text{Total displacement}}{\text{Total time}}$

Since total displacement at the completion of one lap of the circular path = 0

Therefore, average velocity $= \frac{0}{5 \text{ min}} = 0$

Long Answer Type Questions

22. A train is moving at 80 km/h. On applying brakes, it slows down to 10 m/s in 10 seconds. What is the acceleration experienced by the train in these 10 seconds?

Ans. Initial velocity, $u = 80$ km/h $= 22.2$ m/s;
final velocity, $v = 10$ m/s; time, $t = 10$ s

$$\text{Acceleration} = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$$

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

$$= \frac{10 \text{ m/s} - 22.2 \text{ m/s}}{10 \text{ s}}$$

$= -1.22$ m/s^2

23. Zubin covers one lap of a circular track of radius 14 m in 22 seconds.
(a) If he keeps moving around the track, what is his displacement at the end of 1 minute 17 seconds?
(b) If he runs in a straight line with the same speed, what distance will he cover in 5 minutes?

Ans. Zubin covers one lap in 22 seconds. This means he covers half the lap in 11 seconds.
(a) Total time = 1 min 17 s
$= 77 \text{ s} = 3 \times 22 \text{ s} + 11 \text{ s}$

Therefore, Zubin has completed 3 full laps in this time and has covered half of the 4th lap. He is at a point diametrically opposite to his starting point.

The displacement at this point = The diameter of the circular path
$= 2 \times \text{radius} = 2 \times 14 \text{ m} = 28$ m

(b) Zubin's speed along the circular path,

$$s = \frac{\text{Circumference}}{\text{Time}} = \frac{2 \times \pi \times 14 \text{ m}}{22 \text{ s}} = 4 \text{ m/s}$$

Distance covered in 5 minutes = $s \times$ time

$= 4 \text{ m/s} \times 5 \times 60 \text{ s} = 1200 \text{ m}$

24. Starting from rest at one station, a train attains a velocity of 40 km/h in 60 seconds. Then it applies brakes and the velocity comes down to 5 km/h in 5 seconds. What is the acceleration of the train in both these cases?

Ans. **Case 1:** initial velocity of the train, $u = 0$, final velocity, $v = 40$ km/h = 11.11 m/s; time, $t = 60$ s

$$\text{Acceleration, } a = \frac{v-u}{t} = \frac{11.11 \text{ m/s} - 0}{60}$$

$= 0.185 \text{ m/s}^2$

Case 2: initial velocity, $u = 11.11$ m/s; final velocity, $v = 5$ km/h = 1.4 m/s; time, $t = 5$ s

$$\text{Acceleration, } a = \frac{v-u}{t} = \frac{1.4 \text{ m/s} - 11.11 \text{ m/s}}{5 \text{ s}}$$

$= -1.942 \text{ m/s}^2$

25. The distance between Delhi and Agra is 200 km. A train travels the first 100 km at a speed of 50 km/h. How fast must the train travel for the next 100 km so that its average speed at the end of the journey is 70 km/h?

Ans. $d_1 = 100$ km, $s_1 = 50$ km/h;

$d_2 = 100$ km, $s_2 = ?$;

$s_{av} = 70$ km/h

$$t_1 = \frac{d_1}{s_1} = \frac{100 \text{ km}}{50 \text{ km/h}} = 2 \text{ h}$$

$$t_2 = \frac{d_2}{s_2} = \frac{100 \text{ km}}{s_2 \text{ km/h}} = \frac{100}{s_2} \text{ h}$$

$$s_{av} = \frac{d_1 + d_2}{t_1 + t_2} = \frac{100 \text{ km} + 100 \text{ km}}{2 \text{ h} + 100/s_2 \text{ h}}$$

or $\quad 70 \text{ km/h} = \dfrac{200}{2 + 100/s_2} \text{ km/h}$

or $\quad 2 + \dfrac{100}{s_2} = \dfrac{200}{70} = 2.857$

or $\quad \dfrac{100}{s_2} = 2.857 - 2 = 0.857$

or $\quad s_2 = \dfrac{100}{0.857} = 116.6 \text{ km/h}$

Milestone 3

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Multiple-Choice Questions

1. For a train starting from one railway station, increasing its speed at 20 m/s^2 for 30 minutes and then decreasing it at 20 m/s^2 for 30 minutes to come to a halt at the next railway station, what are the values of u and v?

(a) $u = 20$ m/s, $v = 20$ m/s

(b) $u = 0$, $v = 0$

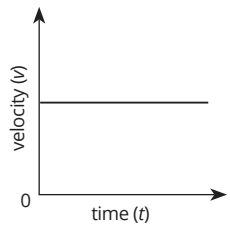
(c) $u = 0$, $v = 10$ m/s

(d) $u = 10$ m/s, $v = 0$

Ans. Since the train starts from rest from the first railway station, the initial velocity (u) = 0. Since it comes to a halt at the next railway station, its final velocity (v) = 0.

Therefore, the correct answer is (b) $u = 0$, $v = 0$

2. The figure below shows the velocity–time graph of an object moving in a fixed direction.



The object

(a) is at rest.

(b) is moving with variable velocity.

(c) is moving with constant velocity.

(d) is moving with nonzero acceleration.

Ans. We can see in the graph that the velocity of the object does not change with the increase in time. This constant value of velocity is not 0. Therefore, there is a displacement taking place, i.e. the object is not at rest. This also means that the acceleration (rate of change of velocity) is 0.

Therefore, the correct answer is (c).

3. The acceleration of an object is equal to

(a) $\dfrac{u-v}{t}$. (b) $\dfrac{v-u}{t}$.

(c) $(v - u)\,t$. (d) $(u - v)\,t$.

Ans. We know that acceleration is defined as the rate of change of velocity with respect to time.

This means, acceleration

$$= \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$

Therefore, the correct answer is (b).

4. If the velocity–time graph for an object's motion is not a straight line, its acceleration is

(a) constant. (b) negative.

(c) zero. (d) variable.

Ans. If the velocity–time graph is not a straight line, it means that the velocity is changing. Therefore, the

acceleration is not zero. This eliminates option (c). For acceleration to be constant, the velocity–time graph would be a straight line with a constant slope. Since this is not the case, we can eliminate option (a). Since we do not know if the velocity is increasing or decreasing, we cannot say with certainty if the acceleration is positive or negative. The only thing we can say about the acceleration is that it is (d) variable.

5. The unit that represents the area under a velocity–time graph is

(a) m.

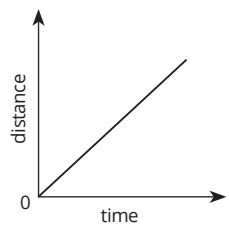
(b) m^2.

(c) m/s.

(d) m/s^2.

Ans. We have studied that the area under a velocity–time graph is the displacement. The unit of displacement is metre. Therefore, the correct answer is (a).

6. The figure below shows a distance–time graph for an object moving in a fixed direction. We can say that the object



(a) is moving with a constant velocity.

(b) is moving with a variable velocity.

(c) is moving with a constant acceleration.

(d) is at rest.

Ans. The slope of the distance – time graph represents the speed (or, in this case, velocity). Since the slope is constant, the correct answer is (a).

Very Short Answer Type Questions

7. What property of an object is described by the slope of a distance–time graph?

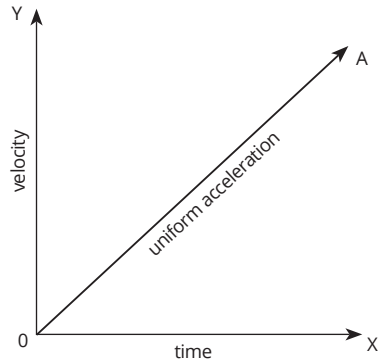
Ans. The property of an object described by the slope of a distance–time graph is speed.

8. Name the property which is measured by the area under the velocity–time graph.

Ans. The property measured by the area under the velocity–time graph is displacement.

9. Draw the velocity–time graph for an object in motion with uniform acceleration. The object starts moving from rest.

Ans. Given below is the velocity–time graph for an object in motion with uniform acceleration.



Note that the slope is constant and the graph starts from origin as the object starts moving from rest (initial velocity = 0).

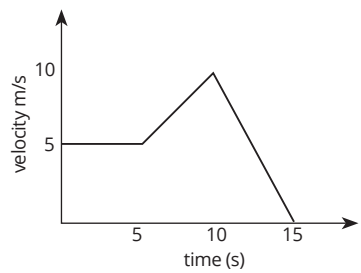
10. The velocity–time graph for non-uniformly accelerated motion, with increasing velocity, is a curve. Does this curve move upwards or downwards?

Ans. Since the velocity is increasing, it means that the acceleration is positive. Therefore, the slope of the velocity–time graph is increasing, i.e. the curve moves upwards.

Short Answer Type-I Questions

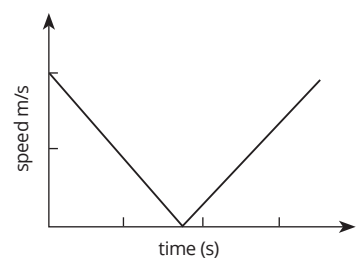
11. Draw a graph for an object that moves at 5 m/s from t = 0 to t = 5 s, then speeds up uniformly to 10 m/s from t = 5 s to t = 10 s and then slows down to 0 m/s from t = 10 s to t = 15 s.

Ans. The graph given below shows the required motion:



12. A ball thrown upwards rises to a height and then falls back to the ground. If you neglect the air resistance, how will its speed–time graph look like?

Ans. The figure given below shows the speed–time graph of the ball:

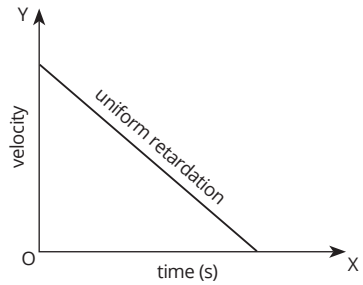


13. If the slope of a graph gives us information of an object's acceleration, what are the properties likely to be described by the two axes?

Ans. If the slope of a graph gives us the acceleration of an object, the x-axis represents time and the y-axis represents velocity of the object.

14. Draw the velocity–time graph for an object experiencing uniform retardation.

Ans. The figure below shows the velocity–time graph of an object experiencing uniform retardation:



Short Answer Type-II Questions

15. A tiger running along in the forest at constant velocity of 8 km/h notices a deer and starts running after it. If it accelerates uniformly at 2 km/h^2, how much distance will it cover in 30 seconds?

Ans. Initial velocity of the tiger, u = 8 km/h;
acceleration, a = 2 km/h^2;

$$\text{time, } t = 30 \text{ s} = \frac{30}{3600} \text{ h} = \frac{1}{120} \text{ h}$$

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

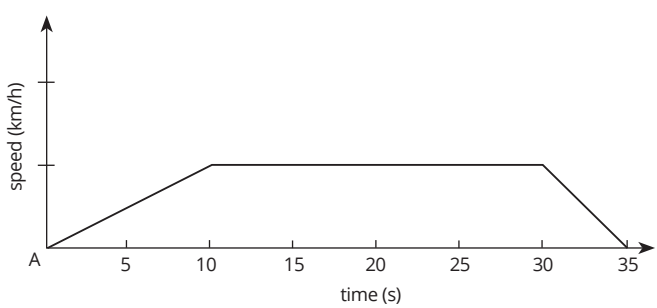
Therefore, distance covered by the tiger, s

$$= (8 \text{ km/h})\left(\frac{1}{120} \text{ h}\right) + \frac{1}{2} (2 \text{ km/h}^2) \left(\frac{1}{120} \text{ h}\right)^2$$

$$= 0.0667 \text{ km} = 66.7 \text{ m}$$

16. Draw the speed–time graph for an object where the speed increases uniformly from rest for 10 minutes, stays constant for 20 minutes and then decreases to zero in 5 minutes.

Ans. The figure below shows the required speed–time graph:



17. If the retardation caused by the brakes of a car is 3 m/s^2, calculate the initial velocity at which the car would be travelling to come to stop in 15 seconds.

Ans. Final velocity of the car, v = 0;
acceleration, a = –3 m/s^2; time, t = 15 s

We know that $v = u + at$, where u is the initial velocity

Therefore, $0 = u + (-3 \text{ m/s}^2)(15 \text{ s})$

or $u = 45$ m/s

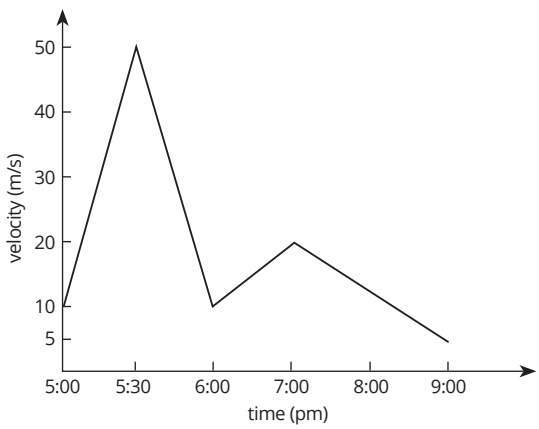
18. Draw a velocity–time graph for a car that shows the following motion:

Time (s)	5:00 pm	5:30 pm	6:00 pm	7:00 pm	9:00 pm
Velocity	10 m/s	50 m/s	36 km/h	72 km/h	5 m/s

Ans. The given table can be rewritten as:

Time (s)	5:00 pm	5:30 pm	6:00 pm	7:00 pm	9:00 pm
Velocity	10 m/s	50 m/s	10 m/s	20 m/s	5 m/s

Given below is the velocity–time graph for the car:



19. If an object moving in a straight line is accelerating at 8 m/s^2, reaching a final velocity of 10 m/s over a distance of 4 m in a specific time, what was its initial velocity?

Ans. Acceleration, a = 8 m/s^2; final velocity, v = 10 m/s; distance, s = 4 m

We know that $v^2 = u^2 + 2as$, where u is initial velocity

Therefore, $(10 \text{ m/s})^2 = u^2 + 2 (8 \text{ m/s}^2) (4 \text{ m})$

or $100 \text{ m}^2/\text{s}^2 = u^2 + 64 \text{ m}^2/\text{s}^2$

or $u^2 = 36 \text{ m}^2/\text{s}^2$

or u = 6 m/s

20. A particle starts from a point with a velocity of 6 m/s and moves with an acceleration of –2 m/s^2. Show that after 6 s the particle will be at the starting point.

Ans. Initial velocity, u = 6 m/s; acceleration, a = –2 m/s^2; time, t = 6 s

We know that displacement, $s = ut + \frac{1}{2}at^2$

$= (6 \text{ m/s})(6 \text{ s}) + \frac{1}{2}(-2 \text{ m/s}^2)(6 \text{ s})^2$

$= 36 \text{ m} - 36 \text{ m}$

$= 0$

Since the displacement is 0 after 6 seconds, it shows that the particle has reached its starting point during the course of its motion.

Long Answer Type Questions

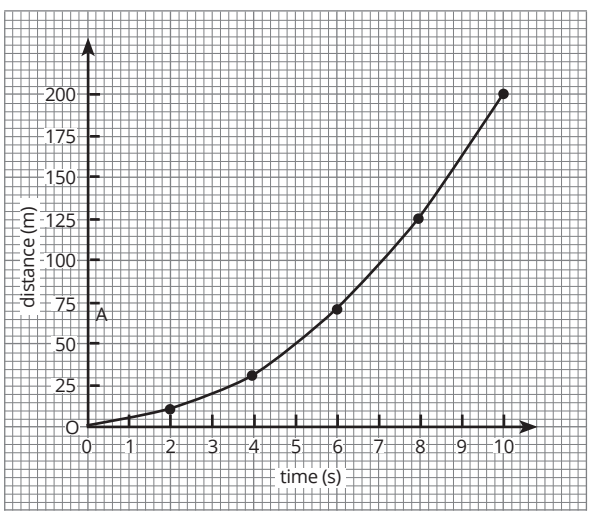
21. A car starting from rest accelerates at 4 m/s^2 for 10 seconds. Plot a distance–time graph for the car's motion using the distances covered by it in 2, 4, 6, 8 and 10 seconds.

Ans. Acceleration, a = 4 m/s^2; initial velocity, u = 0

Using the equation $s = ut + \frac{1}{2}at^2$, the distance covered by the car for each interval can be given as:

Time (s)	0	2	4	6	8	10
Distance (m)	0	8	32	72	128	200

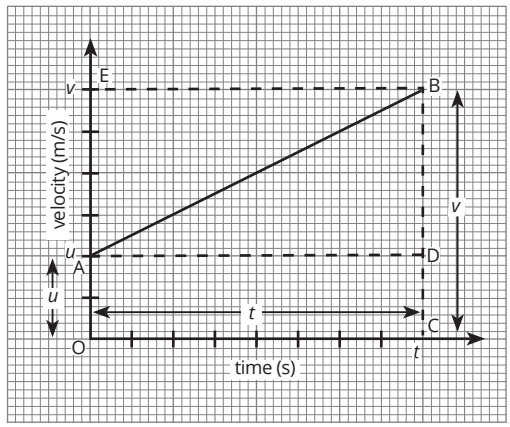
The figure given below is the distance–time graph for the above table:



22. Derive the three equations of motion with the help of graphs. Assume constant acceleration.

Ans. (a) Derivation of $v = u + at$

Consider the velocity – time graph for an object moving with uniform acceleration as shown in the figure below. Initial velocity at point A is u (u is not equal to 0). Final velocity after time t is v at point B.



We draw perpendicular BC on x-axis from point B, perpendicular BE on y-axis from point B, and perpendicular AD on BC from point A.

Acceleration of the object = slope of line AB

or $a = \frac{BD}{AD} = \frac{BC - DC}{AD}$

Since, BC = v, DC = OA = u, and AD = OC = t

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

or $v = u + at$

(b) Derivation of $s = ut + \frac{1}{2}at^2$

We know that distance travelled by an object is given by the area under the velocity – time graph.

Thus, distance travelled = Area of trapezium OABC

or s = Area of ΔABD + Area of rectangle OADC

$= \left(\frac{1}{2} \times AD \times BD\right) + (OC \times OA)$

From the figure,

$AD = OC = t$

$BD = BC - DC = v - u = u + at - u = at$

$OA = u$

Therefore, $s = \left(\frac{1}{2} \times t \times at\right) + (t \times u)$

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

(c) Derivation of $v^2 = u^2 + 2as$

Distance travelled = Area of trapezium OABC

or $s = \frac{1}{2}$ × (sum of parallel sides) × (height)

$= \frac{1}{2} \times (OA + BC) \times OC$

$= \frac{1}{2} \times (u + v) \times t$

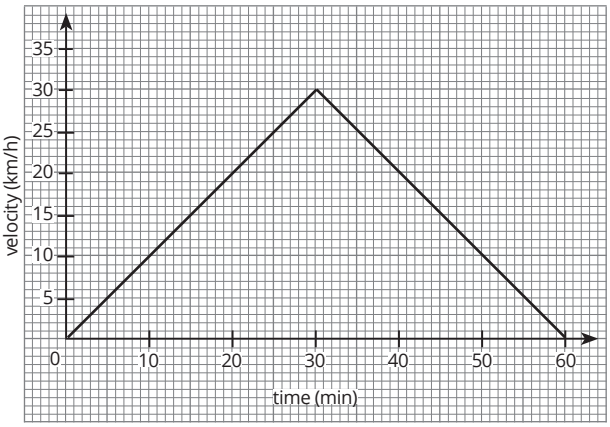
$= \frac{1}{2} \times (u + v) \times \frac{v-u}{a}$

or $2as = (v + u)(v - u)$

or $2as = v^2 - u^2$

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

23. The following figure shows the velocity–time graph of a car.



(a) In which period is the car accelerating?

(b) In which period is it decelerating?

(c) What is the distance covered during acceleration?

(d) What is the distance covered during deceleration?

(e) What is the average speed of the car over the entire journey?

Ans. (a) The car is accelerating from $t = 0$ to $t = 30$ min

(b) The car is decelerating from $t = 30$ min to $t = 60$ min

(c) Distance covered = Area under the graph

$$= \frac{1}{2} \times 30 \text{ min} \times 30 \text{ km/h}$$

$$= \frac{1}{2} \times 0.5 \text{ h} \times 30 \text{ km/h} = 7.5 \text{ km}$$

(d) Distance covered = Area under the graph

$$= \frac{1}{2} \times 30 \text{ km/h} \times (60 - 30) \text{ min}$$

$$= 7.5 \text{ km}$$

(e) Average speed = Total distance/Total time = (7.5 km + 7.5 km)/(0.5 h + 0.5 h) = 15 km/h

Higher Order Thinking Skills (HOTS) Questions

(Page 23)

1. If you are sitting in a stationary train, is there a situation possible where it appears to move? How?

Ans. Yes, it is possible. If another railway train on an adjacent track is running, then we feel that our train is moving in a direction opposite to that train.

2. Under what condition(s) are the three equations of motion applicable?

Ans. The conditions are that the acceleration is uniform and the motion is in a straight line.

3. What is the numerical ratio of the average velocity to average speed when an object is moving along a straight line?

Ans. The numerical ratio of average velocity to average speed in such a condition is 1.

4. Can an object have acceleration even at rest? If yes, give an example.

Ans. Yes, an object can have acceleration even at rest. An example is the acceleration due to gravity acting on a book kept at rest on a table.

5. Can there be a situation where the acceleration of an object is positive, but the velocity is negative? If yes, give an example.

Ans. Yes, this is possible. Consider a frame of reference where east to west is positive direction and west to east is negative direction. If a car is moving from west to east its velocity is negative. Now, if the car's brakes are applied, since the acceleration works in a direction opposite to the velocity, it is positive. Thus, the velocity is negative while the acceleration is positive.

6. If an object covers one round about a circular path of diameter d metres in t seconds, what is its speed?

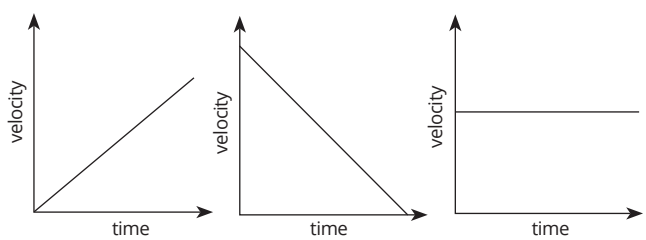
Ans. Speed = Distance covered/Time

$$= \frac{\text{Circumference of circular path}}{\text{Time}} = \frac{\pi d}{t}$$

7. Is it possible to stop a fast-moving automobile instantaneously?

Ans. No, it is not possible to stop a fast-moving automobile instantaneously. It will always take some time, depending on the deceleration, to bring its velocity to 0.

8. Interpret the behaviour of velocity as depicted in the three separate velocity–time graphs shown in the following figures:



Ans. (a) Velocity increases with time at a constant rate.

(b) Velocity decreases with time at a constant rate.

(c) Velocity remains constant with time.

9. The following table represents the distance of a car with time in a fixed direction:

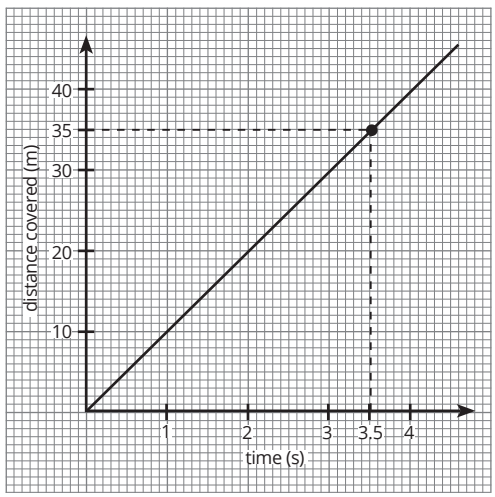
Time (s)	0	1	2	3	4
Distance (m)	0	10	20	30	40

Draw a distance–time graph to find

(a) the distance travelled by the car in 3.5 seconds.

(b) the speed of the car.

Ans.



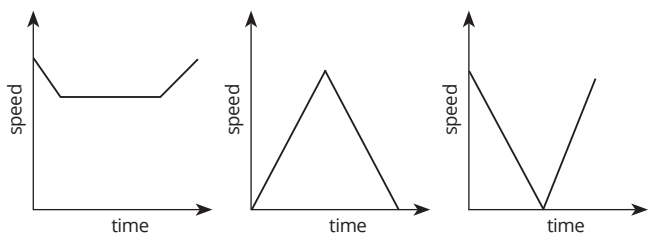
The distance – time graph is given above.

(a) Drawing a straight line from 3.5 s on the *x*-axis to the graph and extending it horizontally to meet the *y*-axis, we get the distance travelled in 3.5 s, which is 35 m.

(b) The speed of the car is given by the slope of the graph.

$$\text{Slope} = \frac{30\text{ m} - 20\text{ m}}{3\text{ s} - 2\text{ s}} = 10\text{ m/s}$$

10. Which of these three speed–time graphs represent these cases?



(a) A cricket ball thrown vertically upwards and then coming down into the hands of the thrower.

(b) A trolley decelerating to a constant speed and then accelerating uniformly after some time.

Ans. (a) Speed – time graph (b) corresponds to the motion of the cricket ball.

(b) Speed – time graph (a) corresponds to the motion of the trolley.

Self-Assessment

(Page 24)

Multiple-Choice Questions

1. The distance between New Delhi and Chandigarh is 250 km, and the distance between Chandigarh and Amritsar is 230 km. Which of these statements is true for the distance between New Delhi and Amritsar?

(a) It has to be equal to 480 km.

(b) It can be greater than 480 km.

(c) It can be less than 480 km.

(d) We can't say anything from the given information.

Ans. New Delhi, Chandigarh, and Amritsar either form a straight line or can be seen as vertices of a triangle. If they fall on a straight line, then the distance between New Delhi and Amritsar will be 480 km, but this is not necessary. If the three cities form a triangle, 480 km is the sum of the length of the New Delhi-Chandigarh side and the Chandigarh-Amritsar side of the triangle. The sum of two sides of a triangle is always greater than the sum of the third side. Thus, New Delhi-Amritsar can be less than 480 km. Therefore, the right answer is (c).

2. A body is thrown vertically upward with a velocity *u*. The greatest height to which it will rise is

(a) $\frac{u}{g}$. (b) $\frac{u^2}{2g}$.

(c) $\frac{u^2}{g}$. (d) $\frac{u}{2g}$.

Ans. At the greatest height, the final velocity (v) = 0.

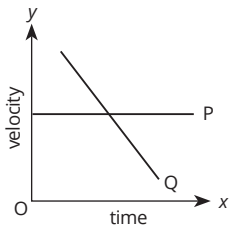
Using $v^2 = u^2 + 2as$, we have $0 = u^2 + 2(-g)s$, where g is the acceleration due to gravity acting in the opposite direction on the body.

Therefore, $s = \frac{u^2}{2g}$

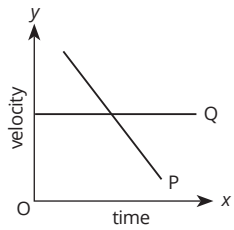
The correct answer is (b).

3. A body P moves with a uniform velocity and another body Q moves with uniform retardation. The correct velocity–time graph for the two bodies is

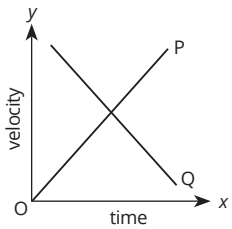
a.



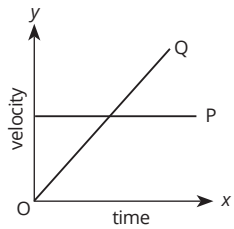
b.



c.



d.



Ans. The correct answer is (a).

4. A motorcycle is being driven at a speed of 20 m/s when brakes are applied to bring it to rest in 5 seconds. The deceleration produced by the brakes is

(a) 4 m/s^2.

(b) – 4 m/s^2.

(c) 0.25 m/s^2.

(d) – 0.25 m/s^2.

Ans. Initial velocity, u = 20 m/s; time, t = 5 s; final velocity, v = 0

If the acceleration acting on the motorcycle is a m/s^2, we have

$$v = u + at$$

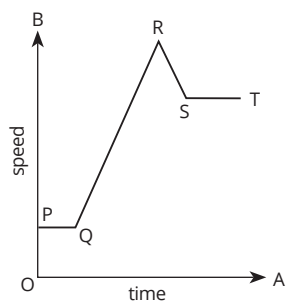
or $$= 20 \text{ m/s} + (a \times 5 \text{ s})$$

or $$a = -4 \text{ m/s}^2$$

If the acceleration is – 4 m/s^2, the deceleration is 4 m/s^2.

Therefore, the correct answer is (a).

5. In the speed–time graph for a moving object shown below, the part that indicates uniform deceleration is



(a) ST. (b) QR.

(c) RS. (d) PQ.

Ans. The correct answer is (c) RS.

Assertion–Reason Type Questions

For question numbers 6 to 15, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of the assertion.

(b) Both A and R are true but R is not the correct explanation of the assertion.

(c) A is true but R is false.

(d) A is false but R is true.

6. **Assertion:** The sun appears to be moving around the earth to people residing on the surface of earth.

Reason: For people on earth's surface looking at the sun, the reference point is the earth, which is in motion.

Ans. (a)

7. **Assertion:** The wheels of a car moving on a straight road exhibit multiple motion.

Reason: The centre of each rotating wheel of a car moving on a straight road exhibits rotatory motion.

Ans. (c)

8. **Assertion:** An object in uniform circular motion experiences zero acceleration.

Reason: An object in uniform circular motion moves along a circular path with a constant speed.

Ans. (d)

9. **Assertion:** An object is momentarily at rest when it is reversing its direction of motion.

Reason: At any instant of time, an object can have acceleration even if its velocity is zero.

Ans. (b)

10. **Assertion:** The displacement of an object can be zero even if the total distance covered by it is not zero.

Reason: Distance is a scalar quantity, while displacement is a vector quantity.

Ans. (a)

11. **Assertion:** An object can never have variable velocity when its speed is constant.

Reason: Speed is a scalar quantity, while velocity is a vector quantity.

Ans. (d)

12. **Assertion:** When an object being rotated in uniform circular motion is let go, it moves along a straight line tangential to the circular path.

Reason: The velocity of an object in uniform circular motion is directed towards the centre of the circle at any given moment.

Ans. (c)

13. **Assertion:** Even if the acceleration of a moving object is positive, it is possible that the object may be slowing down.

Reason: Both velocity and acceleration are vector quantities.

Ans. (b)

14. **Assertion:** If an object is moving with uniform acceleration, the velocity of the object changes by an equal amount in every equal time period.

Reason: Uniform acceleration means that the velocity of an object is not changing with time.

Ans. (c)

15. **Assertion:** The average speed of an object for a given interval of time can be equal to the average velocity of that object in the same interval of time.

Reason: The total distance covered by an object in a given interval of time can be equal to the total displacement in the same interval of time.

Ans. (a)

Source-based/Case-based/Passage-based/ Integrated Assessment Questions

Answer questions on the basis of your understanding of the following passages and the related studied concepts. (any four)

16. In February, 2018, the highways ministry of the Government of India approved the increase of the speed limit of cars for national highways from 80 km/h to 100 km/h. The speed limit for expressways was raised to 120 km/h. The state and local authorities will decide the speed limits for state and local roads, especially in urban areas. The speed limits were raised owing to the improvement in road infrastructure in the country. The limit for two-wheelers is 80 km/h for both national highways and expressways, while the limit for trucks and buses is 80 km/h for national highways and 90 km/h for expressways.

I. (a) A car travelling at 75% of the speed limit on the Mumbai–Pune expressway has to stop at a toll booth ahead. If the car can decelerate at a maximum rate of 2 m/s^2, what is the minimum time before reaching the toll booth that the car can start its uniform deceleration?

Ans. 12.5 s

(b) After paying the toll, if the car accelerates uniformly at the same maximum rate, what speed (in km/h) will it reach in 10 seconds?

Ans. 72 km/h

(c) Why do roads have speed limits? State one reason.

Ans. Roads have speed limits mainly to keep the time required for the vehicle to stop after braking under control. Other reasons include to minimize the impact on collision, to control effects of air pollution, and to maintain fuel efficiency.

(d) Are the speed limits in urban areas likely to be higher than the speed limits of national highways and expressways or lower? Why?

Ans. Urban roads have lower speed limits because the traffic is heavier. This means that the time available to apply brakes and stop the car is much lower.

II. (a) An object at rest is imparted motion to move in a straight line. It is then obstructed by an opposite force, then

(i) the object may necessarily change direction.
(ii) the object is sure to slow down.
(iii) the object will necessarily continue to move in the same direction with same speed.
(iv) none of the above.

Ans. (ii) the object is sure to slow down.

(b) If a body starts from rest and travels 120 m in 8 seconds, then acceleration is

(i) 10 m/s^2 (ii) 0.23 m/s^2
(iii) 0.03 m/s^2 (iv) 5 m/s^2

Ans. (iv) 5 m/s^2

(c) A car is travelling at a speed of 72 km/h on an expressway. Brakes are applied so as to produce a uniform acceleration of $-0.5\ m/s^2$. Find how far the car will go before it is brought to rest.

(i) 425 m (ii) 1600 m
(iii) 800 m (iv) 400 m

Ans. (iv) 400 m

(d) If a car at rest accelerated uniformly attains a speed of 72 km/h in 10 s, then it covers a distance of

(i) 50 m (ii) 200 m
(iii) 250 m (iv) 500 m

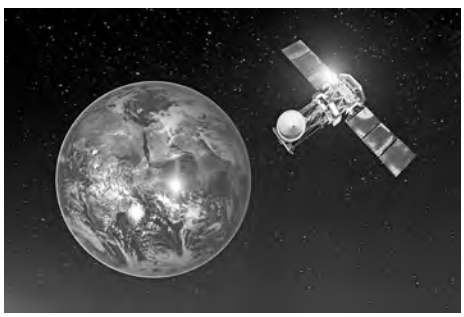
Ans. (ii) 200 m

(e) On a national highway, the speed of a car increases from 90 km/h to 108 km/h in 5 seconds. What would be the acceleration of the car?

(i) 5 m/s^2 (ii) 1 m/s^2
(iii) 2 m/s^2 (iv) 0.2 m/s^2

Ans. (ii) 1 m/s^2

17. Indian scientists developed the GSAT communication satellites that are used for digital audio, data and video broadcasting. As of mid-2019, ISRO has 15 of these geostationary satellites in operation, including 5 in the INSAT series. Apart from telecommunications, these satellites have also proven useful in weather forecasting, disaster warning and search and rescue operations. Being geostationary, these satellites revolve in an orbit about 35,872 kilometres from the earth's equator (where the earth's radius is about 6,378 kilometres) and cover one revolution in the about the same period as that of one earth rotation. These communication satellites are the pride of India's advanced space programme, among the most developed in the world and a huge jump from 1981 when the country's first experimental communication satellite APPLE was launched.



I. (a) Assuming that a geostationary satellite moves in uniform circular motion around earth, what is the radius of this circular orbit?

Ans. 42,250 km

(b) What is the orbital speed of the satellite (in km)?

Ans. 3.07 km/s

(c) Consider three GSATs (1, 2 and 3), each moving in an orbit of the same radius. If the mass of GSAT 1 is 50 kg, that of GSAT 2 is 65 kg and that of GSAT 3 is 80 kg, which of the three will have the greatest orbital speed?

Ans. All three will have the same speed.

(d) What is the relative speed of a GSAT for an observer on the surface of earth?

Ans. Zero

II. (a) The force that keeps the objects in a circular path is called

(i) centripetal force. (ii) centrifugal force.
(iii) force of gravity. (iv) reaction forces.

Ans. (i) centripetal force.

(b) GSAT stands for

(i) Geometrical Satellites.
(ii) Geographical Satellites.
(iii) Geostationary Satellites.
(iv) None of these.

Ans. (iii) Geostationary Satellites.

(c) Which one of the following devices acts on the principle of circular motion?

(i) Centrifuge machine
(ii) Screw Gauge
(iii) Skinfold calipers
(iv) Vernier calipers

Ans. (i) Centrifuge machine

(d) Which was the first communication satellite of India?

(i) SRMSAT (ii) SARAL
(iii) ASAT (iv) APPLE

Ans. (iv) APPLE

(e) Which of the following is India's first pico-satellite?

(i) GSAT-4 (ii) INSAT
(iii) StudSat (iv) ANUSAT

Ans. (iii) StudSat

Very Short Answer Type Questions

18. An athlete completes a race of 1600 m in 3 min 20 s. What is his average speed?

Ans. Average speed $= \frac{\text{Total distance}}{\text{Total time}} = \frac{1600\text{ m}}{3\text{ min }20\text{ s}}$

$= \frac{1600\text{ m}}{200\text{ s}} = 8\text{ m/s}$

19. A particle is moving along a circle of radius 5 m. What is its displacement when it completes 2.5 revolutions?

Ans. After 2.5 revolutions, the displacement of the particle is equal to the diameter of the circle.

Therefore,

displacement = 2 × radius = 2 × 5 m = 10 m

20. Starting from rest, a car acquires a speed of 144 km/h in 8 s. What is its average acceleration?

Ans. Average acceleration

$= \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$

$= \frac{144\text{ km/h} - 0}{8\text{ s}} = \frac{40\text{ m/s}}{8\text{ s}}$

$= 5\text{ m/s}^2$

Short Answer Type-I Questions

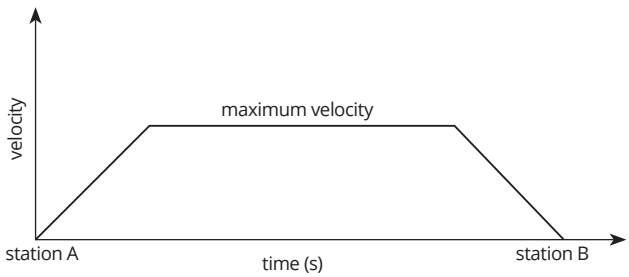
21. Give an example to show that the state of rest and motion depends on who the observer is.

Ans. Consider three people. Person A and Person B are sitting in a moving car. Person C is standing stationary by the side of the road. To Person B, Person A will appear to be at rest. To Person C, Person A will appear to be moving at the speed

of the car. Thus, the state of rest and motion depend on who the observer is.

22. A train starts from rest from station A. It accelerates for some time, acquires a maximum velocity and travels some distance at this velocity. As the train approaches station B, it begins to slow down and comes to rest finally at station B. Draw a velocity–time graph for the train's motion between stations A and B. How will you find the total distance of the railway line between A and B through this graph?

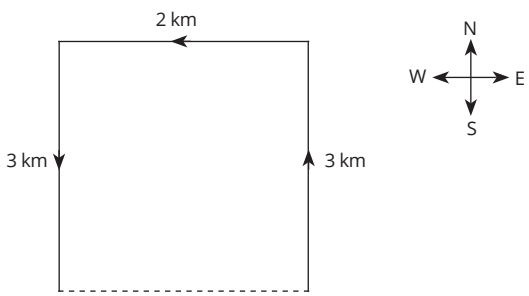
Ans. The figure below shows the velocity – time graph for the train.



The total distance of the railway line between A and B can be obtained by calculating the area under the velocity–time graph.

23. A person moves a distance of 3 km towards north, then 2 km towards west and finally 3 km towards the south. If the total time taken for this entire process is 2 hours, what is the person's average speed? Is his average velocity equal to his average speed?

Ans. The figure below shows the motion of the person.



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

$$= \frac{3\text{ km} + 2\text{ km} + 3\text{ km}}{2\text{ h}} = 4\text{ km/h}$$

$$\text{Average velocity} = \frac{\text{Total displacement}}{\text{Total time}} = \frac{2\text{ km}}{2\text{ h}}$$

$$= 1\text{ km/h}$$

Therefore, the average velocity is not equal to the average speed.

24. A satellite revolves around the earth in a circular orbit of radius 6400 km and completes one revolution in 84 minutes. Calculate its linear speed in m/s.

Ans. Distance covered by the satellite in one revolution = $2\pi \times$ radius = $2 \times 3.14 \times 6400$ km = 40192 km = 4.02×10^7 m

Time taken to complete one revolution = 84 min = 5040 s

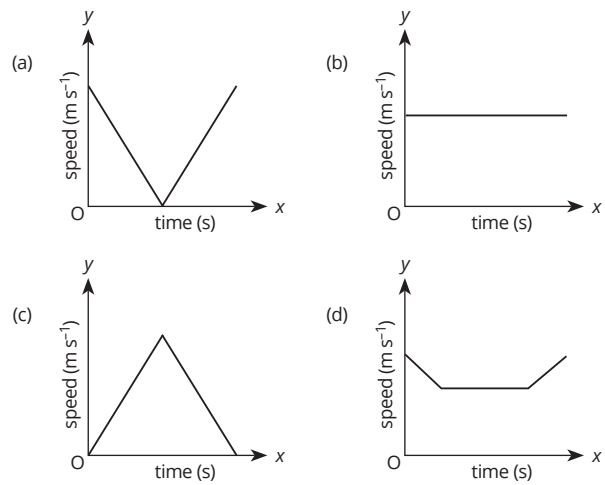
Therefore, speed of the satellite

$$= \frac{\text{Distance covered}}{\text{Time}}$$

$$= \frac{4.02 \times 10^7 \text{m}}{5040\text{ s}} = 7.98 \times 10^3 \text{ m/s}$$

Short Answer Type-II Questions

25. Four speed–time graphs are shown below:



Which graph represents the following case? Justify your choice.

(i) A ball thrown vertically upwards and returning to the hand of the thrower.

(ii) An object decelerating to a constant speed and then accelerating.

(iii) Uniform motion of a car.

Ans. (i) Graph (a) as the speed of the ball goes to zero at the highest point and then increases as it comes down.

(ii) Graph (d) as the graph shows an initial decrease in speed, followed by the speed remaining constant for some time, and then increasing.

(iii) Graph (b) as the graph shows a constant speed.

26. A bullet hits a 4 cm thick wall at a velocity of 20 m/s and decelerates at the rate of 4000 m/s^2. Will the bullet cross to the other side of the wall or remain embedded in it?

Ans. Initial velocity, u = 20 m/s;

acceleration, $a = -4000$ m/s^2

If the bullet comes to a stop inside the wall, its final velocity, $v = 0$

Using $v^2 = u^2 + 2as$, we have

$$s = \frac{v^2 - u^2}{2a} = -\frac{-(20\ \text{m/s})^2}{2 \times (4000\ \text{m/s}^2)}$$

$$= \frac{400}{8000}\ \text{m} = 0.05\ \text{m} = 5\ \text{cm}$$

Therefore, for the bullet to get embedded in the wall, the wall's thickness will have to be 5 cm.

The actual thickness of the wall is only 4 cm.

Therefore, the bullet will cross to the other side of the wall.

Long Answer Type Questions

27. A ball thrown upwards reaches a point P of its path at the end of 4 seconds and the highest point Q at the end of 12 seconds. After how many seconds from the start will it reach the point P again?

Ans. When a projectile is thrown vertically upwards, the time taken for it to travel between two fixed points during the upward journey is the same as the time taken for it to travel between the same two fixed points during the downward journey.

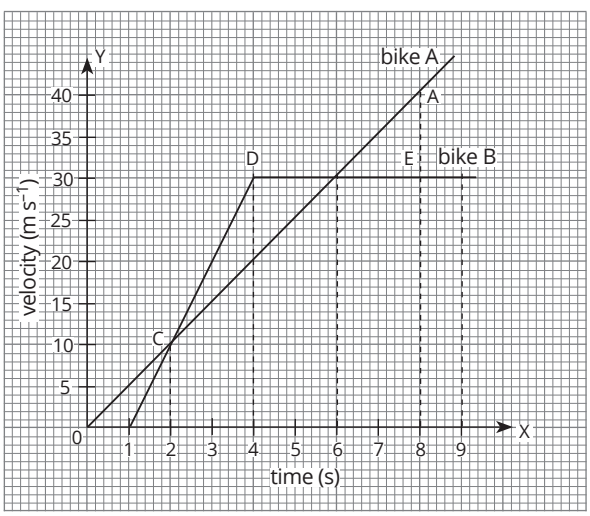
The time taken for the ball to travel between points P and Q during the upward journey = 12 s – 4 s = 8 s

Therefore, the time taken for the ball to travel from Q to P during the downward journey = 8 s

The ball reaches the maximum height Q, 12 seconds after starting its upward journey.

Therefore, it will reach point P in its downward journey 12 + 8 = 20 seconds from the start.

28. The velocity–time graphs of bikes A and B, which start from the same place and move along a straight road in the same direction, are shown below.



Calculate:

(a) the acceleration of bike A between 0 and 8 s.

(b) the acceleration of bike B between 2 and 4 s.

(c) the points of time at which both the bikes have the same velocity.

(d) which of the two bikes is ahead after 8 s and by how much.

Ans. (a) Acceleration of bike A between 0 and 8 s = slope of the velocity – time graph = $\frac{40\ \text{m/s} - 0\ \text{m/s}}{8\ \text{s} - 0\ \text{s}} = 5\ \text{m/s}^2$

(b) Acceleration of bike B between 2 and 4 s = slope of the velocity – time graph between C and D = $\frac{30\ \text{m/s} - 10\ \text{m/s}}{4\ \text{s} - 2\ \text{s}} = 10\ \text{m/s}^2$

(c) The two velocity – time graphs meet at $t = 2$ s and $t = 6$ s. Therefore, both the bikes have the same velocity at 2 s and 6 s.

(d) Distance covered by bike A after 8 s = area under its velocity – time graph = $\frac{1}{2} \times 40\ \text{m/s} \times 8\ \text{s} = 160\ \text{m}$

Distance covered by bike B after 8 s = area under its velocity – time graph = $(\frac{1}{2} \times 30\ \text{m/s} \times 3\ \text{s}) + (30\ \text{m/s} \times 4\ \text{s}) = 45\ \text{m} + 120\ \text{m} = 165\ \text{m}$

Therefore, bike B is ahead of bike A by 5 m.

Let's Compete

(Page 27)

Multiple-Choice Questions

1. The numerical ratio of displacement to distance for a moving object is

(a) always less than 1.

(b) always equal to 1.

(c) always greater than 1.

(d) equal to or less than 1.

Ans. Since displacement is always equal to or less than distance, the numerical ratio of displacement to distance is equal to or less than 1. Therefore, the correct answer is (d).

2. The speed of a moving object is determined to be 0.06 m/s. This speed is equal to

(a) 2.16 km/h.

(b) 1.08 km/h.

(c) 0.216 km/h.

(d) 0.0216 km/h.

Ans. $0.06\ \text{m/s} = \frac{0.06/1000}{1/3600}\ \text{km/h} = 0.216\ \text{km/h}$

Therefore, the correct answer is (c).

3. Which of the following can sometimes be zero for a moving body?

(i) Average velocity

(ii) Distance travelled

(iii) Average speed

(iv) Displacement

(a) only (i) (b) (i) and (ii)

(c) (i) and (iv) (d) only (iv)

Ans. We have seen that the displacement of a moving body can be zero if its final position is the same as its initial position. Also, if displacement is zero, the average velocity is zero. Therefore, the correct answer is (c).

4. A freely falling object travels 4.9 m in the 1st second, 14.7 m in the 2nd second, 24.5 m in the 3rd second and so on. This data shows that the motion of a freely falling object is a case of

(a) uniform motion.

(b) uniform acceleration.

(c) no acceleration.

(d) uniform velocity.

Ans. Using $s = ut + \frac{1}{2} gt^2$, where the initial velocity is zero for a freely falling object, we can see that the object falls under a constant acceleration of 9.8 m/s^2. Therefore, the correct answer is (b).

5. A car driver driving at a speed of 90 km/h applies brakes and brings the car to rest in 20 s. The acceleration of the car is

(a) 1 m/s^2. (b) –1.5 m/s^2.

(c) –1.25 m/s^2. (d) 2.5 m/s^2.

Ans. Initial velocity, u = 90 km/h = 25 m/s; time, t = 20 s; final velocity, v = 0

$$a = \frac{v-u}{t} = \frac{0-25 \text{ m/s}}{20 \text{ s}}$$

$$= -1.25 \text{ m/s}^2$$

Therefore, the correct answer is (c).

6. A car accelerates uniformly from 18 km/h to 36 km/h within a distance of 15 m. The uniform acceleration of the car is

(a) 2.5 m/s^2. (b) 5 m/s^2.

(c) 1.5 m/s^2. (d) 3 m/s^2.

Ans. Initial velocity, u = 18 km/h = 5 m/s; final velocity, v = 36 km/h = 10 m/s; distance, s = 15 m

Using $v^2 = u^2 + 2as$, we have

$$(10 \text{ m/s})^2 = (5 \text{ m/s})^2 + 2 \times a \times 15 \text{ m}$$

or $a = 2.5 \text{ m/s}^2$

Therefore, the correct answer is (a).

7. A motorbike is running at a velocity of 72 km/h. On applying brakes, it is brought to rest in 2 s. What is the distance covered by the motorbike before coming to rest? Assume that the acceleration produced by the brakes is uniform throughout.

(a) 40 m (b) 20 m

(c) 10 m (d) 5 m

Ans. Initial velocity, u = 72 km/h = 20 m/s; final velocity, v = 0; time, t = 2 s

$$a = \frac{v-u}{t} = \frac{0-20 \text{ m/s}}{2 \text{ s}} = -10 \text{ m/s}^2$$

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

$$= (20 \text{ m/s} \times 2 \text{ s}) + (\frac{1}{2} \times -10 \text{ m/s}^2 \times 4 \text{ s}^2)$$

$$= 20 \text{ m}$$

Therefore, the correct answer is (b).

8. Suppose a boy is enjoying a ride on a merry-go-round, which is moving with a constant speed of 10 m/s. it implies that the boy is

(a) at rest.

(b) moving with no acceleration.

(c) in accelerated motion.

(d) moving with uniform velocity.

Ans. Since the merry-go-round is moving in a circular motion, it is undergoing accelerated motion because of change in direction of velocity. The boy sitting on the merry-go-round is also undergoing the same motion. Therefore, the correct answer is (c).

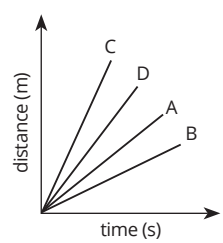
9. A car of mass 1000 kg is moving with a velocity of 10 m/s. If the velocity–time graph for this car is a horizontal line parallel to the time axis, then the velocity of the car at the end of 25 s will be

(a) 25 m/s. (b) 40 m/s.

(c) 10 m/s. (d) 250 m/s.

Ans. Since the velocity – time graph for the car is parallel to the time axis, its velocity does not change with time. Therefore, the correct answer is (c).

10. Four cars A, B, C and D are moving on a leveled, straight road. Their distance–time graphs are shown in the figure. Which of the following is the correct statement regarding the motion of these cars?



(a) Car A is faster than car D.

(b) Car B is the slowest.

(c) Car D is faster than car C.

(d) Car C is the slowest.

Ans. The greater the slope of the distance–time graph, the higher is the speed of the car. The only option correct among the four is option (b).

Value-based Questions

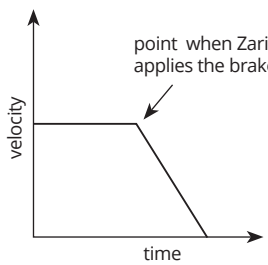
(Optional) (Page 28)

1. Zarina is driving her car at a certain constant speed when she sees an injured dog some distance away beside the road. She immediately applies the car's brakes to bring it to a stop and saves the dog.

(a) Draw a velocity–time graph to describe the motion of the car.

(b) What qualities of Zarina would you appreciate?

Ans. (a) The velocity–time graph is given below.



(b) Her compassion for animals and driving at a safe speed that allows her to stop the car on time.

2. The top speed limit on the Mumbai–Pune Expressway is 80 km/h. Madhukar covers the 100 km stretch of the beautiful road in 1 hour.

(a) What was the average speed of Madhukar's car?

(b) What mistake did Madhukar make?

Ans. (a) Average speed = $\frac{\text{Total distance}}{\text{Total time}} = \frac{100\text{ km}}{1\text{ h}}$

$= 100$ km/h

(b) Exceeding the speed limit can be dangerous for oneself and other travellers on the road

3. A top fuel dragster is a racing car designed and built to run a quarter mile long straight track as fast as possible. At launch, the mass of a top fuel dragster is 1050 kg. At the end of its quarter mile run, a dragster is brought to rest using brake parachutes. At the end of its run, the mass of the dragster is 910 kg, the rest having been burnt as fuel. A top fuel dragster racer experiences extremes of acceleration and high speeds in the time frame of 5 seconds.

A top fuel dragster starting from rest covers a distance of 300 m in 4.4 seconds. The top speed of a top fuel dragster is 530 km/h, which is achieved towards the end of the run. It is brought to rest at the end of its run by using brake parachutes.

(a) Assuming constant acceleration, what is the acceleration of the dragster?

(b) What is the average speed of a top fuel dragster?

(c) If a dragster experiences a deceleration of 60 m/s^2, what is the length of the track used by it to stop after brakes are deployed?

(d) In how much time does a dragster come to a stop after the brake chutes are deployed? Assume that the deceleration is 60 m/s^2.

(e) Name three important qualities that one would need to inculcate to become a top fuel dragster racer.

Ans. (a) Initial velocity, $u = 0$; distance, $s = 300$ m; time, $t = 4.4$ s

Using $s = ut + \frac{1}{2}at^2$, we have

$$300\text{ m} = 0 + \frac{1}{2} \times a \times (4.4\text{ s})^2$$

or $$a = 2 \times \frac{300}{19.36}\text{ m/s}^2 \quad 31\text{ m/s}^2$$

(b) Average speed = $\frac{\text{Total distance}}{\text{Time}} = \frac{300\text{ m}}{4.4\text{ s}}$

$= 68.18$ m/s

(c) Initial speed, u = Maximum speed = 530 km/h = 147.22 m/s; final velocity, $v = 0$; acceleration, $a = -60$ m/s^2

Using $v^2 = u^2 + 2as$, we have

$$s = \frac{v^2 - u^2}{2a} = \frac{0 - (147.22\text{ m/s})^2}{2 \times -60\text{ m/s}^2}$$

$= 180.6$ m

(d) Using $v = u + at$, we have

$$t = \frac{v - u}{a} = \frac{0 - 147.22\text{ m/s}}{-60\text{ m/s}^2}$$

$= 2.45$ s

(e) Discipline, skill, and fearlessness

9

Force and Laws of Motion

Checkpoint (Page 31)

1. Which of these is a vector quantity?

(a) Speed (b) Velocity

(c) Time (d) Distance

Ans. The correct answer is (b) Velocity.

2. Asif applies force F_1 on a book kept on a table making the book move. He also applies force F_2 on a wall in his bedroom, but it does not move. Which of these statements is not true for this case?

(a) F_1 can be greater than F_2

(b) F_1 can be equal to F_2

(c) F_1 can be less than F_2

(d) F_1 has to be greater than F_2

Ans. From the given information, we cannot say with certainty if F_1 is greater than, equal to, or less than F_2. It can be any of these. Therefore, the statement that is not true is (d).

3. The cheetah is the fastest land animal, with a top speed of 60 miles per hour. The force responsible for its superfast speed is

(a) frictional force. (b) muscular force.

(c) gravitational force. (d) electrostatic force.

Ans. The correct answer is (b) muscular force.

4. If an object does not change its position with respect to its surroundings, it is said to be in a state of

(a) equilibrium. (b) uniform motion.

(c) rest. (d) weightlessness.

Ans. The correct answer is (c) rest.

5. State whether true or false: When we press an inflated balloon using both our palms, if there is no motion of the balloon, it implies that there is no force acting on it.

Ans. The statement is false. Force does not have to result in motion in every case. Also, in case of the inflated balloon, even a compression of the balloon would indicate that force is acting on it, even if the balloon does not move.

6. If a car moving at 25 km/h uniformly increases its speed to reach 50 km/h in 2 minutes, what is the acceleration experienced by the car over this period in m/s^2?

Ans. Initial velocity, u = 25 km/h = 6.94 m/s

Final velocity, v = 50 km/h = 13.89 m/s

Time, t = 2 min = 120 s

$$\text{Acceleration, } a = \frac{v-u}{t}$$

$$= \frac{13.89 \text{ m/s} - 6.94 \text{ m/s}}{120 \text{ s}}$$

$$= 0.058 \text{ m/s}^2$$

7. Is there a difference between the mass of an object and its weight? Which of these is a scalar quantity? Which one of the two is a constant for a given object?

Ans. Yes, mass is the measure of amount of matter in an object, while weight is the gravitational force acting on an object. Mass is a scalar quantity and is also constant for a given object.

8. Give one example each of a situation where you would pull or push to change the state of motion of an object.

Ans. Pull: A rope is pulled to draw a bucket filled with water from a well, changing the state of motion of the bucket from rest to motion.

Push: A football lying at rest on the ground is made to move when a player pushes it through a kick.

9. Riddhima is trying to push a block of wood kept on the ground towards the left. The opposing force exerted by the ground on the block, which

resists the force exerted by her is known as .....

Ans. The opposing force is frictional force.

10. A train was moving with velocity of 45 km/h at 8:00 am. It is found moving at a velocity of 55 km/h at 10:00 am. If you had to calculate the change in velocity of the train, is this information enough or do you need anything else?

Ans. Since velocity is a vector quantity, we also need to know the direction of the velocity at 8:00 am and 10:00 am to calculate the change in the train's velocity.

Milestone 1

(Page 34)

Multiple-Choice Questions

1. Which of these is an example of force?

(a) Listening to a song on the FM channel

(b) Tasting a plate of cooked vegetables

(c) Pulling a pan off the stove

(d) Watching television

Ans. The correct answer is (c).

2. The study of causes of motion or changes in motion is called

(a) mechanics. (b) electronics.

(c) dynamics. (d) mechatronics.

Ans. The correct answer is (a).

3. If the resultant of all the forces acting on an object is zero, then the forces are

(a) balanced. (b) unbalanced.

(c) frictional. (d) none of these

Ans. The correct answer is (a).

4. The SI unit of force is

(a) kilogram. (b) newton.

(c) metre. (d) newton-second.

Ans. The correct answer is (b).

5. Which of these is equivalent to the SI unit of force?

(a) kg m/s (b) kg m/s^2

(c) kg/m (d) kg/m^2

Ans. We know that 1 N is the force required to cause a mass of 1 kg to accelerate at 1 m/s^2. Therefore, 1 N = 1 kg × 1 m/s^2 = 1 kg m/s^2.

The correct answer is (b).

Very Short Answer Type Questions

6. State the various effects of force.

Ans. Force can have one or more of the following effects:

(a) It can cause motion in a stationary object.

(b) It can cause a moving object to come to a stop.

(c) It can change the velocity of a moving object.

(d) It can change the direction of motion of an object.

(e) It can change the shape or size of an object.

7. Do two bodies always have to be in contact to exert forces on each other?

Ans. No, there are certain forces like gravitational force and magnetic force that can be exerted even when two objects are not in contact with each other.

8. If you drop a ball from a height, its velocity increases as it comes down. What force is responsible for this increase?

Ans. The force responsible for the increase in velocity of a falling ball is earth's gravitational force.

Short Answer Type-I Questions

9. When the two ends of a spring balance are pulled by two equal forces *F*, what is the force indicated on the spring balance?

Ans. The force indicated on the spring balance is *F*.

10. If the motor of a toy car on horizontal ground exerts a force of 2 N for the car to move forward, and the ground exerts a frictional force of 1 N, how much minimum force would a child have to exert on the car to keep it from moving forward?

Ans. The net force acting on the car is 1 N in the forward direction, which is the resultant of the 2 N acting in the forward direction and the 1 N frictional force acting on it in the reverse direction. Therefore, a child will have to exert at least 1 N force in the reverse direction to keep the car from moving.

Short Answer Type-II Questions

11. The train you are traveling in crosses point A at 25 km/h, point B at 35 km/h and point C at 45 km/h. What can you infer about the nature of forces acting on the train?

Ans. The given velocity data for the train shows that its velocity is increasing as it moves from A to B to C. Therefore, there is positive acceleration acting on the train. This implies that there is net force acting on the train in the forward direction.

12. What forces are acting on the scooter being driven by this boy?

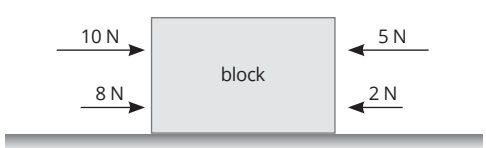
Ans. The figure below shows the forces acting on the scooter:

Long Answer Type Questions

13. A football is resting at the centre of the field at the beginning of a match. The referee blows his whistle and a player kicks the ball. Draw a diagram of the ball showing the forces acting on it at the moment when it is kicked.

Ans. The figure below shows the forces acting on the football:

14. What is the resultant force acting on the block shown in the figure? If the block is kept on a frictionless surface, what would be the change in its motion if all these forces act on it simultaneously?



Ans. The forces in the vertical direction are balanced, so we consider only the four forces shown in the horizontal direction. If left to right is taken as positive, the resultant force on the block is given by,

$$F = (10\ \text{N} + 8\ \text{N}) - (5\ \text{N} + 2\ \text{N})$$
$$= 11\ \text{N}$$

If the block is kept on a frictionless surface and all these forces act on it simultaneously, the block will show accelerated motion from left to right.

Milestone 2

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Multiple-Choice Questions

1. When a bus starts suddenly, the passengers standing within it lean backwards. This is an example of

(a) Newton's first law of motion.

(b) Newton's second law of motion.

(c) Newton's law of gravitation.

(d) None of these

Ans. The passengers lean backwards because of inertia due to rest. Therefore, this is an example of the law of inertia. The correct answer is (a).

2. The unit of momentum is

(a) N s (b) kg m/s^2

(c) N/s (d) kg m/s

Ans. We know that momentum is the product of mass (kg) and velocity (m/s). Therefore, the correct answer is (d).

3. The relationship between force (F), mass (m) and acceleration (a) is given by

(a) $F = \frac{m}{a}$ (b) $F = m \times a$

(c) $F = \frac{a}{m}$ (d) $F = m a^2$

Ans. The correct answer is (b).

4. Two balls A and B of masses m and $2m$ are in motion with velocities $2v$ and v, respectively. Their momenta are in the ratio

(a) 1 : 2 (b) 2 : 1

(c) 1 : 1 (d) 4 : 1

Ans. Momentum of ball A, $p_1 = m \times 2v = 2mv$

Momentum of ball B, $p_2 = 2m \times v = 2mv$

$$\frac{p_1}{p_2} = \frac{2mv}{2mv} = 1 : 1$$

Therefore, the correct answer is (c)

5. The mass and speed of four objects are given below:

Object	Mass (kg)	Speed (m/s)
A	1	10
B	2	9
C	3	6
D	4	5

The object with the largest magnitude of momentum is

(a) A (b) B

(c) C (d) D

Ans. p_A = 10 kg m/s, p_B = 18 kg m/s, p_C = 18 kg m/s, p_D = 20 kg m/s

Therefore, the correct answer is (d).

Very Short Answer Type Questions

6. If thrown with the same speed, which will have more momentum, a cricket ball or a tennis ball? Why?

Ans. Momentum is the product of mass and velocity (or speed). In the given case, the speeds of both the balls are the same. Since the mass of a standard cricket ball is greater than the mass of a standard tennis ball, the momentum of the cricket ball will also be more than that of the tennis ball.

7. Many restaurants show this trick to impress guests – the waiter quickly pulls off the tablecloth on a table covered with plates and spoons; the cloth comes off but the crockery remains on the table without falling down. How is this explained through physics?

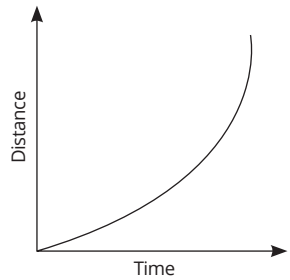
Ans. This can be explained through Newton's first law of motion. The crockery remains on the table because of inertia of rest.

8. Under identical conditions, the same force can accelerate a lighter block of wood more easily than a heavier block. Which law of motion given by Newton explains this phenomenon?

Ans. Newton's second law of motion says that, for the same amount of force, the acceleration is greater when the mass is lower, which explains the given phenomenon.

9. If an object starts from rest under the action of a constant force, what will its distance–time graph look like?

Ans. If an object is moving under a constant force, it means it is experiencing a uniform acceleration. The distance-time graph would look like the figure given below:



Short Answer Type-I Questions

10. A car weighing 2500 kg and moving with a velocity of 10 m/s is stopped in 5 s on applying brakes. What is the retardation experienced by the car and the retarding force?

Ans. Mass of the car, m = 2500 kg

Initial velocity, u = 10 m/s

Final velocity, v = 0

Time, t = 5 s

Acceleration experienced by the car,

$$a = \frac{v-u}{t} = \frac{0-10 \text{ m/s}}{5 \text{ s}} = -2 \text{ m/s}^2$$

Therefore, the retardation experienced = 2 m/s^2

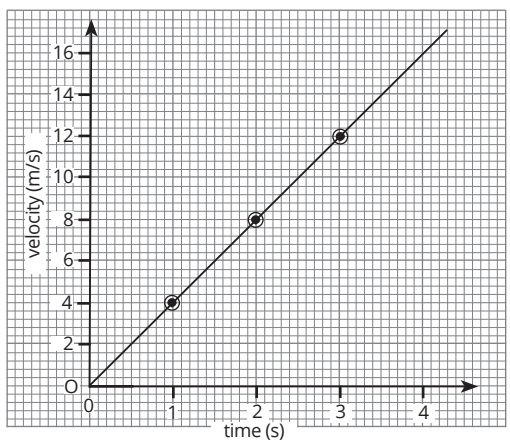
The retarding force, $F = m \times$ retardation

= 2500 kg × 2 m/s^2 = 5000 N

11. The table below gives the velocity and time data for an object of mass 200 g moving in a fixed direction. What is the force acting on it?

Time (s)	0	1	2	3
Velocity (m/s)	0	4	8	12

Ans. The velocity-time graph for the given data is given below:



This shows uniform acceleration acting on the object. This acceleration can be calculated by:

$$a = \frac{8 \text{ m/s} - 4 \text{ m/s}}{2 \text{ s} - 1 \text{ s}} = 4 \text{ m/s}^2$$

Therefore, the force acting on the object,
$F = 200\ g \times 4\ m/s^2 = 0.2\ kg \times 4\ m/s^2 = 0.8\ N$

12. A man throws a ball weighing 500 g vertically upwards with a speed of 10 m/s.

(a) What will be its initial momentum?

(b) What would be its momentum at the highest point of its flight?

Ans. (a) The initial momentum = mass × initial velocity
$= 0.5\ kg \times 10\ m/s$
$= 5\ kg\ m/s$

(b) The velocity of the ball at its highest point is 0. Therefore, momentum at the highest point is 0.

13. A car weighing 1000 kg is accelerated to 20 m/s from start in 5 s. Calculate the rate of change of momentum of the car.

Ans. Acceleration experienced by the car,

$$a = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$
$$= \frac{20\ m/s - 0}{5\ s}$$
$$= 4\ m/s^2$$

Force acting on the car = mass × acceleration
$= 1000\ kg \times 4\ m/s^2$
$= 4000\ N$

Since the rate of change of momentum of an object is the same as the force acting on it, the answer is 4000 N.

Alternate method: Initial momentum of the car, $p_1 = 1000\ kg \times 0 = 0$

Final momentum of the car, $p_2 = 1000\ kg \times 20\ m/s = 20000\ kg\ m/s$

Rate of change of momentum $= \frac{p_2 - p_1}{\text{time}}$

$= \frac{20000\ kg\ m/s - 0}{5\ s} = 4000\ kg\ m/s^2$

Short Answer Type-II Questions

14. Give reasons:

(a) A stuntman is made to fall on a thick bed of foam while jumping from a height rather than on the ground.

(b) A truck driver prefers to hit something soft (say a haystack) rather than a wall if his vehicle goes out of control while driving.

Ans. (a) When the stuntman falls on a soft surface, he takes longer to come to a stop. The rate of change of momentum is lower than it would be if he were to fall on hard ground. Thus, the resultant force he experiences is also lower.

(b) The rate of change of momentum, again, is lower when the truck hits a soft surface. The resultant force experienced by the truck and the damage caused by it is lower than it would be if the truck hit a solid wall.

15. A force of 4 N acts on an object of mass 2 kg for 4 seconds. If the object is initially at rest, find

(a) its velocity when the force stops acting.

(b) the distance covered in 10 seconds after the force starts acting.

Ans. Force, $F = 4\ N$

Mass, $m = 2\ kg$

Time, $t = 4\ s$

Initial velocity, $u = 0$

Acceleration experienced by the object,

$$a = \frac{F}{m} = \frac{4\ N}{2\ kg} = 2\ m/s^2$$

(a) Final velocity, $v = u + at = 0 + 2\ m/s^2 \times 4\ s = 8\ m/s$

(b) The force acts for 4 seconds and then there is no acceleration experienced by the object for the next 6 seconds

Distance covered in the first 4 seconds,

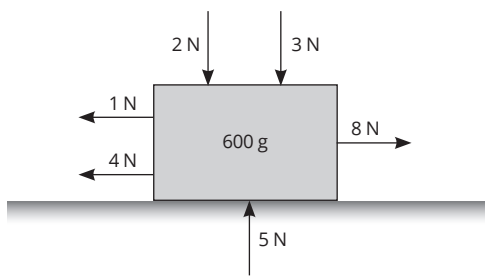
$$s_1 = ut + \frac{1}{2}at^2 = 0 + \frac{1}{2} \times 2\ m/s^2 \times (4\ s)^2$$
$$= 16\ m$$

Distance covered in the next 6 seconds,

s_2 = velocity × time = 8 m/s × 6 s = 48 m

Therefore, total distance covered in 10 s = 16 m + 48 m = 64 m

16. All the forces acting on an object of mass 600 g are shown in the figure below. What is the acceleration of the object and in which direction?



Ans. The forces in the vertical direction are balanced. In the horizontal direction, the net force acting on the object is (8 N – 1 N – 4 N) = 3 N towards the right.

Therefore, acceleration of the object is towards the right and its value is, $a = \frac{\text{Force}}{\text{mass}} = \frac{3\ N}{0.6\ kg}$
$= 5\ m/s^2$

Long Answer Type Questions

17. Two balls, A and B, of the same mass are moving with velocities v and $3v$, respectively. Give the ratio of their (a) inertia, (b) momentum, and (c) the force

needed to stop them in the same time.

Ans. (a) Mass is a measure of the inertia of an object

Therefore, ratio of inertia = ratio of mass = 1 : 1 (since the two balls are of the same mass)

(b) If the mass of each ball is m, $p_A = m \times v$ and $p_B = m \times 3v$

Therefore, ratio of momentum

$$= \frac{p_A}{p_B} = \frac{mv}{3mv} = 1 : 3$$

(c) If the time in which the two balls are stopped is t

Force needed to stop ball A, $F_A = \frac{mv - 0}{t} = \frac{mv}{t}$

Force needed to stop ball B, $F_B = \frac{3mv - 0}{t} = \frac{3mv}{t}$

Therefore, ratio of the two forces $= \frac{F_A}{F_B} = \frac{mv/t}{3mv/t}$

$= 1 : 3$

18. A certain amount of force produces an acceleration of 8 m/s^2 on an object of mass 750 g. What would be the mass of another object on which the same force produces an acceleration of 12 m/s^2? What acceleration would this force produce if the two objects are tied together?

Ans. Force acting on object 1,

F = mass × acceleration

= 0.75 kg × 8 m/s^2

= 6 N

Mass of object 2, $m_2 = \frac{F}{\text{acceleration}} = \frac{6\text{ N}}{12\text{ m/s}^2}$

= 0.5 kg = 500 g

Mass of the combined object,

$m = m_1 + m_2$

= 0.75 kg + 0.5 kg = 1.25 kg

Acceleration $= \frac{6\text{ N}}{1.25\text{ kg}} = 4.8\text{ m/s}^2$

19. A vehicle of mass 1500 kg moving with a velocity of 10 m/s is brought to rest in 4 seconds after covering a distance of 25 m.

(a) Find the acceleration.

(b) Calculate the unbalanced force acting on the vehicle.

(c) The actual force applied by the brakes may be slightly less than that calculated in (b). Why?

Ans. (a) Acceleration, $a = \frac{\text{final velocity} - \text{initial velocity}}{\text{time}}$

$= \frac{0 - 10\text{ m/s}}{4\text{ s}} = -2.5\text{ m/s}^2$

(b) The unbalanced force on the vehicle,

F = mass × acceleration

= 1500 kg × –2.5 m/s^2

= –3750 N

(c) The actual force applied by the brakes may be slightly less than the figure in (b) because of frictional force which assists the brakes in bringing the vehicle to a stop.

Milestone 3

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Multiple-Choice Questions

1. Action and reaction forces act on

(a) the same body in opposite directions.

(b) the same body in the same direction.

(c) different bodies in opposite directions.

(d) different bodies in the same direction.

Ans. The correct answer is (c).

2. The principle of conservation of momentum states that the momentum of a system

(a) cannot be changed.

(b) cannot remain constant.

(c) can be changed only if internal forces act.

(d) can be changed only if external forces act.

Ans. The correct answer is (d).

3. A labourer is carrying a load of bricks that presses his head with a force of 100 N. If this force is taken as action, the reaction force is exerted by

(a) the head on the bricks.

(b) the earth on the bricks.

(c) the earth on the labourer.

(d) the bricks on the earth.

Ans. The action force is exerted by the bricks on the head. So, the reaction force is exerted by the head on the bricks. Therefore, the correct answer is (a).

4. The principle of conservation of momentum is deduced from

(a) Newton's first law of motion.

(b) Newton's second law of motion.

(c) Newton's third law of motion.

(d) It is an independent law not connected to any of Newton's laws.

Ans. The correct answer is (c).

5. The recoil velocity of a gun is

(a) equal to the velocity of the bullet.

(b) much greater than velocity of the bullet.

(c) much lower than velocity of the bullet.

(d) cannot say

Ans. The recoil of a gun immediately after the bullet is shot is based on the principle of conservation of momentum. The momentum of the bullet moving forward is equal to that of the gun moving backward. We know that momentum is the product of mass and velocity. Since the mass of a bullet is much lower than that of the gun, for their momenta to be equal, the velocity of the gun will have to be much lower than the velocity of the bullet. Therefore, the correct answer is (c).

Very Short Answer Type Questions

6. Rowing is an Olympic sport in which a single athlete or a team propels a boat in water using oars. How does Newton's third law of motion play a very important role in the sport?

Ans. The rower (the player) rows the water in the backward direction, which is the action force. An equal and opposite reaction force is exerted by the water on the boat, which makes the boat move forward. The stronger the force with which the rowers push the water backwards, the stronger will the force from the water be and the faster the boat will move forward.

7. Give an example to show that it is not necessary that if two forces are equal and opposite, they have to form an action–reaction pair.

Ans. Consider a door that person A is trying to push open from one side. There is another person B who is pushing the door shut from the other side. The door remains stationary because the forces exerted by both A and B are equal and opposite. These two push forces do not form an action and reaction pair despite being equal and opposite in nature.

8. A small animal does not sustain serious injury even if it falls to the ground from considerable height. How can this be explained in terms of change in momentum and Newton's third law of motion?

Ans. When an animal falls to the ground, it exerts a force on the ground. In keeping with Newton's third law of motion, the ground exerts an equal and opposite force on the animal. This force is equal to the rate of change of momentum of the animal. Since the mass of a small animal is very low, the change in momentum needed to bring its fall to a stop (final velocity = 0) is very low. Therefore, the force experienced by it is very small, which is not enough to cause serious injury.

Short Answer Type-I Questions

9. When a ball is thrown upwards, its momentum first decreases and then increases. Is the principle of conservation of linear momentum violated in this process? Explain.

Ans. The principle of conservation of linear momentum holds when there are no external forces acting on the system. In the given case, there are external forces like earth's gravitational pull and air drag that act on the ball. Therefore, the principle cannot be expected to hold true here.

10. A ball X of mass 1 kg travelling at 5 m/s has a head-on collision with an identical ball Y at rest. Ball X stops and ball Y moves off. Calculate the velocity of ball Y after the collision.

Ans. Momentum of ball X before the collision,

$$p_{X_1} = 1 \text{ kg} \times 5 \text{ m/s} = 5 \text{ kg m/s}$$

Momentum of ball Y before the collision,

$$p_{Y_1} = 1 \text{ kg} \times 0 = 0$$

Momentum of ball X after the collision,

$$p_{X_2} = 1 \text{ kg} \times 0 = 0$$

According to the principle of conservation of linear momentum,

$$p_{X_1} + p_{Y_1} = p_{X_2} + p_{Y_2}$$

or $5 \text{ kg m/s} + 0 = 0 + p_{Y_2}$

or $p_{Y_2} = 5 \text{ kg m/s}$

Therefore, the velocity of ball Y after collision

$$= \frac{5 \text{ kg m/s}}{1 \text{ kg}} = 5 \text{ m/s}$$

11. A book is lying on a table. Name the forces acting on the book. How are they balanced according to Newton's third law of motion?

Ans. The forces acting on the book are the gravitational pull of the earth, which acts in the downward direction, and the normal force exerted by the surface of the table, which acts in the upward direction. This satisfies Newton's third law of motion because the weight of the book or the force of gravitation acts on the table. The normal force is an equal and opposite reaction force exerted by the table on the book. This balances the forces acting on the book in the vertical

direction, keeping it from flying off or falling down.

12. Tony Stark is inside his Iron Man suit and standing on a frictionless surface. His combined weight with his suit is 150 kg. He suddenly jumps out of his suit at 2 m/s. If his own mass is 85 kg, at what velocity will his Iron Man suit move when he jumps forward?

Ans. Combined mass of Tony Stark and suit, M = 150 kg

Tony Stark's mass, m_T = 85 kg

Therefore, the suit's mass, m_S = 150 kg – 85 kg = 65 kg

The initial velocity for Tony Stark and his suit is zero.

According to the principle of conservation of linear momentum,

$$150 \text{ kg} \times 0 = 85 \text{ kg} \times 2 \text{ m/s} + 65 \text{ kg} \times v$$

where v is the velocity of the suit after Tony Stark jumps out

or $v = -85 \times 2/65 \text{ m/s} = -2.62 \text{ m/s}$

Therefore, the suit's velocity is 2.62 m/s in the backward direction.

Short Answer Type-II Questions

13. A man wearing a bullet-proof vest stands still on roller skates. The total mass is 100 kg. A bullet of mass 25 g is fired at 500 m/s. It is stopped by the vest and falls to the ground. What is the velocity of the man immediately after being hit?

Ans. If v is the velocity of the man after being hit, by the principle of conservation of linear momentum, we have

$$100 \text{ kg} \times 0 + 0.025 \text{ kg} \times 500 \text{ m/s} = 100 \text{ kg} \times v + 0.025 \text{ kg} \times 0$$

or $v = 0.125 \text{ m/s}$

14. Object A of mass m_1 is moving in a certain direction at a velocity of v_1, and object B of mass m_2 is moving in the same direction with velocity v_2. Objects A and B collide and stick together, with the velocity of the combined mass being $\frac{v_1+v_2}{2}$.

If v_1 is not equal to v_2, what is the relationship between m_1 and m_2?

Ans. We have $m_1v_1 + m_2v_2 = (m_1 + m_2)(v_1 + v_2)/2$

or $2m_1v_1 + 2m_2v_2 = m_1v_1 + m_1v_2 + m_2v_1 + m_2v_2$

or $m_1v_1 + m_2v_2 = m_1v_2 + m_2v_1$

or $m_1 (v_1 - v_2) = m_2 (v_1 - v_2)$

Therefore, if v_1 is not equal to v_2, $m_1 = m_2$

15. An iron ball of mass 5 kg falls from a height of 20 m. What is the momentum transferred by the iron ball while hitting the ground?

Ans. Velocity of the ball as it hits the ground (v) is given by,

$$v^2 = u^2 + 2gs = 0 + (2 \times 9.8 \text{ m/s}^2 \times 20 \text{ m}) = 392 \text{ m}^2/\text{s}^2$$

or $v = 19.8 \text{ m/s}$

Therefore, momentum transferred by the ball to the ground = 5 kg × 19.8 m/s = 99 kg m/s

Long Answer Type Questions

16. The head of a golf club of mass 250 g is used to hit a stationary golf ball of mass 50 g. The club is traveling at a velocity of 40 m/s when it touches the ball. It remains in contact with the ball for 0.5 milliseconds, after which the ball starts to move away at 40 m/s. What is the velocity of the club after it hits the ball? What is the average force on the club due to the golf ball?

Ans. When the club hits the ball, it exerts a force for 0.5 milliseconds, which causes the ball to accelerate to reach the velocity of 40 m/s from rest.

If the acceleration experienced by the ball is a, using $v = u + at$, we have

$$40 \text{ m/s} = 0 + a \times 0.5 \times 10^{-3} \text{ s}$$

or $a = 80000 \text{ m/s}^2$

Therefore, force experienced by the ball

$$= 0.05 \text{ kg} \times 80000 \text{ m/s}^2 = 4000 \text{ N}$$

This force is equal to the rate of change of momentum of the club

Therefore, 0.25 kg × (40 m/s – x m/s) = 4000 N × 0.5 × 10^{-3} s, where x is the velocity of the club after it hits the ball

This gives us, x = 32 m/s

17. A block of mass 10 kg starts from rest and moves in a straight line under the effect of a constant force of 10 N. After 10 s, it collides head-on with another block of mass 50 kg that was moving in the opposite direction at 2 m/s. If both the blocks stick together after the collision, what is the velocity of this combined entity?

Ans. The acceleration experienced by block 1 for 10 s = 10 N/10 kg = 1 m/s^2

The velocity of block 1 immediately before collision, v = 0 + 1 m/s^2 × 10 s = 10 m/s

If v' is the velocity of the combined entity, we have

$$(10 \text{ kg} \times 10 \text{ m/s}) + (50 \text{ kg} \times -2 \text{ m/s}) = (10 \text{ kg} + 50 \text{ kg}) \times v' \text{ m/s}$$

or $v' = 0$

18. On the basis of Newton's third law of motion, explain the following phenomena: (a) It becomes difficult to balance our body when we accidentally slip on a banana peel. (b) An athlete pushes the earth backwards with his hand and feet just before the start of the race. (c) As water starts coming out from the curved nozzles of a lawn sprinkler, the sprinkler starts rotating in the opposite direction.

Ans. (a) When we walk normally on the ground, we push the ground backward. According to Newton's third law of motion, the ground pushes us forward. This reaction force keeps us balanced. When we slip on a banana peel, we are unable to push the ground backward due to the slippery nature of the peel. As a result, there is no reaction force acting on the foot, and we find it difficult to balance our body.

(b) An athlete pushes the earth backward because the equal and opposite force from the earth in the forward direction helps the athlete with an initial spurt in the race.

(c) As water rushes out in the forward direction, it exerts an equal and opposite force in the backward direction on the sprinkler. This makes the sprinkler rotate in a direction opposite to that of the flow of water.

Higher Order Thinking Skills (HOTS) Questions

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1. If an object of mass 500 g is moving with constant speed on a frictionless surface, how much force does one require to keep it moving with the same speed?

Ans. In the given scenario, according to Newton's first law of motion, no external force is required to keep the object moving with constant speed.

2. If the mass of an object is doubled and the push force acting on it is halved, what is the resultant change in its acceleration?

Ans. Initial force, $F = m \times a$

or $$a = \frac{F}{m}$$

Acceleration after the changes, $a' = \frac{F/2}{2\ \text{m}} = \frac{1}{4}(F/m)$

Therefore, the resultant acceleration becomes one-fourth of the original value.

3. Why does a cricketer move his arms backwards in the direction of the ball when taking a catch? Explain using the concepts studied in this chapter.

Ans. The cricketer does this to reduce the rate of change of momentum and, thus, the force his hand has to experience when catching the ball.

4. Why is it advised to always wear a seat belt when sitting in a moving car?

Ans. If the car stops or reduces its speed suddenly, because of inertia of motion, we will get thrown forward with a jerk if we are not wearing a seat belt.

5. Can the momentum of an object change even if its mass and speed remain constant? Give an example.

Ans. Yes, momentum of an object can change even if the mass and speed remain constant. This is because momentum is the product of mass and velocity. Even if the magnitude of the velocity isn't changing, its direction could be changing. This would result in change in momentum also. An example is a stone tied to a thread being moved in a circular motion.

6. Action and reaction forces are equal in magnitude and work in opposite directions. Even then they do not cancel each other. Why so?

Ans. This is because action and reaction forces act on different objects.

7. If you throw a plastic ball and an iron ball of same size at a wall and they hit it with equal velocities, the wall receives a greater amount of momentum from which ball?

Ans. The wall receives the greater amount of momentum from the ball that has greater mass. In this case, it is the iron ball.

8. In a game of tug of war, both teams are pulling the rope with immense force, but the rope isn't moving. What can you say about the forces acting on the rope?

Ans. The forces acting on the rope are balanced in all directions.

9. You would often see members of your family jerk wet clothes before spreading them on the clothesline to dry. Why do they do this?

Ans. When we jerk wet clothes, the water present in them gets separated and removed due to its inertia of rest. As a result, the wet clothes dry up quickly.

10. You have two identical balls made of the same wooden material with you. One is at rest while the other is rolling on the ground at 1 m/s. Which ball has greater inertia?

Ans. The inertia of an object depends on the mass of the object and not the velocity. Thus, the inertia of both the balls is equal.

Self-Assessment

(Page 44)

Multiple-Choice Questions

1. The principle of conservation of momentum is deduced from

(a) Newton's first law of motion.

(b) Newton's second law of motion.

(c) Newton's third law of motion.

(d) None of the above

Ans. The correct answer is (c).

2. The action–reaction forces act on

(a) bodies at rest only.

(b) bodies in uniform motion only.

(c) bodies in uniformly accelerated motion.

(d) two bodies irrespective of their position and state of motion.

Ans. The correct answer is (d).

3. A body of mass 1 kg is moving with a uniform speed of 1 m/s in a circular path of radius 1 m. The external force acting on the body is

(a) 1 N

(b) 2.4 N

(c) 3.1 N

(d) 0

Ans. The centripetal acceleration experienced by the body is given by, $a = \frac{v^2}{r} = \frac{1\,\text{m/s}^2}{2\,\text{m}} = 1\ \text{m/s}^2$

Therefore, the force acting on the body $= 1\ \text{kg} \times 1\ \text{m/s}^2 = 1\ \text{N}$

The correct answer is (a).

4. In the above question, the direction of acceleration is

(a) away from the centre.

(b) along the tangent to the circle.

(c) towards the centre and along the radius of the circle.

(d) variable.

Ans. The correct answer is (c).

5. A ball set rolling on the ground stops after some time. This is due to

(a) unbalanced force of friction.

(b) unbalanced force of air resistance.

(c) both (a) and (b).

(d) neither (a) nor (b).

Ans. The correct answer is (c).

Assertion–Reason Type Questions

For question numbers 6 to 15, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of the assertion.

(b) Both A and R are true but R is not the correct explanation of the assertion.

(c) A is true but R is false.

(d) A is false but R is true.

6. **Assertion:** If an object is in motion, there must be some external force acting on it.

Reason: Force changes the state of rest or uniform motion of an object.

Ans. (d)

7. **Assertion:** Even if an external force acts on a stationary object, it is not necessary that the object will begin moving.

Reason: Force tries to change the state of rest or uniform motion of an object.

Ans. (b)

8. **Assertion:** Balanced forces do not cause a change in an object's motion.

Reason: Balanced forces can cause a change in an object's shape.

Ans. (b)

9. **Assertion:** In real-life, a ball rolling on the ground comes to rest on its own after slowing down for some time.

Reason: A frictional force is exerted by the ground on all objects in contact with it.

Ans. (a)

10. **Assertion:** When the branches of a tree are shaken, fruits on the branch fall down because of inertia.

Reason: Inertia of motion is the tendency of an object to resist any change in its state of motion.

Ans. (b)

11. **Assertion:** The greater is the mass of an object, the more acceleration is produced in it for the same magnitude of force.

Reason: Force is directly proportional to mass and acceleration.

Ans. (d)

12. **Assertion:** A plastic ball thrown at you at high velocity may not hurt you, but an iron ball of the same size thrown at the same velocity could.

Reason: The momentum of an object is proportional to the net force it applies on another object.

Ans. (c)

13. **Assertion:** Long jump athletes are made to fall on a sand bed to minimise the force experienced by them.

Reason: Prolonging the time in which change in momentum takes place can reduce the resulting force.

Ans. (a)

14. **Assertion:** Newton's third law of motion can be restated as every action has an equal and opposite reaction.

Reason: The acceleration due to gravity experienced by an object on the surface of earth is equal and opposite to the acceleration experienced by the earth because of that object.

Ans. (c)

15. **Assertion:** A man pushes a wall but might not be able to move it.

Reason: Action and reaction forces cancel each other, according to Newton's third law of motion.

Ans. (c)

Source-based/Case-based/Passage-based/ Integrated Assessment Questions

Answer questions on the basis of your understanding of the following passages and the related studied concepts. (any four)

16. As per the data from the Ministry of Road Transport and Highways, 75% vehicle users in India do not wear seat belts, resulting in 15 deaths, on average, every day in the country. In comparison, the compliance rate in the US is 85%, and in Europe, it is 98%. Road accidents are, in fact, the leading cause of deaths in India, with over 1.5 lakh individuals losing their lives in road accidents in 2016. At least 4% of these could have been prevented with better compliance of the seat belts rule. Studies have found that there is a particular lack of awareness about the importance of seat belts for rear passengers, who are as much at risk as the passengers sitting in the front row of a vehicle.

I. (a) Why do authorities stress upon wearing seat belts in moving vehicles?

Ans. Because if the moving vehicle comes to an abrupt stop in an accident or when the brakes are applied, the passenger will be thrown forward at a high speed if he/she is not wearing a seat belt.

(b) Which type of inertia is involved when a passenger not wearing a seat belt gets injured?

Ans. Inertia of motion

(c) Consider a man sitting in the second row of a car moving at 72 km/h. The car strikes another vehicle and comes to an abrupt stop in 0.1 seconds. If the man weighs 100 kg, what is the rate of change in momentum experienced by him?

Ans. –20,000 kgm/s^2

(d) What is the acceleration experienced in the above situation by the man?

Ans. –200 m/s^2

II. (a) The seat belts are provided in the cars so that if the brakes of the car are applied suddenly, the persons sitting on the front seats are not thrown forward and can be saved from getting injured. Which of the following laws is applicable in a situation when a person falls in forward direction on the sudden stopping of the car?

(i) Newton's first law of motion
(ii) Newton's second law of motion
(iii) Newton's third law of motion
(iv) Newton's law of gravitation

Ans. (i) Newton's first law of motion

(b) The inertia of an object tends to cause an object

(i) to decrease its speed.
(ii) to increase its speed.
(iii) to resist a change in its state of motion.
(iv) none of the above.

Ans. (iii) to resist a change in its state of motion.

(c) The inertia of a moving body depends on

(i) mass of the object.
(ii) speed of the object.
(iii) momentum of the object.
(iv) none of the above.

Ans. (i) mass of the object.

(d) In the game of cricket, a fielder pulls her hands backwards after catching the cricket ball. This enables the fielder to

(i) increase the momentum.
(ii) reduce the force exerted by cricket ball.
(iii) exert larger force on cricket ball.
(iv) catch the ball firmly.

Ans. (ii) reduce the force exerted by cricket ball.

(e) When a train suddenly stops, the passengers fall forward. This is due to

(i) inertia of direction.
(ii) inertia of motion.
(iii) gravitational pull by earth.
(iv) none of the above.

Ans. (ii) inertia of motion.

17. Curling is a sport in which players slide stones on a sheet of ice towards a target area segmented into four concentric circles. Two teams of four players each take turns to slide heavy, polished granite stones (weighing between 17.24 and 19.96 kg), also known as rocks, across the ice curling sheet towards the house, which is a circular target marked on the ice. Points are scored according to the stones that are the closest to the house. As the stones are highly polished and being slid on ice, the friction is almost negligible. This requires little physical effort but a lot of care when sliding the stones on the ice surface. Players typically exert an average force of 10 N on the stones. Curling is a Winter Olympics sport and very popular in cold climates.

I. (a) In a match, Kevin Martin, one of the star players of curling, exerts average force on a stone with the lowest allowed mass for 2 s. What is the average acceleration of the stone if it is at rest initially?

Ans. 0.58 m/s^2

(b) Which of Newton's laws of motion helped you obtain the answer in (a)?

Ans. Second law

(c) What is the velocity of the stone when Jones lets it go?

Ans. 1.16 m/s

(d) Considering negligible friction from ice or air, what should be the velocity of the stone 40 m from the point it is let go by Jones?

Ans. 1.16 m/s

II. (a) What is the curling stone made of?

(i) Granite (ii) Steel
(iii) Cement (iv) All of these

Ans. (i) Granite

(b) Suppose a 20 kg curling rock is sliding with a constant velocity of 4 m/s on the frictionless ice surface. The force required to keep the rock moving with the same velocity is

(i) 10 N (ii) 20 N
(iii) 40 N (iv) 0 N

Ans. (iv) 0 N

(c) What is the unit for measuring the momentum of a moving body?

(i) m/s (ii) kg·m/s
(iii) $kg \cdot m/s^2$ (iv) $N\,m^2kg^2$

Ans. (ii) kg·m/s

(d) A curling rock of mass 18 kg exerts a force of 10 N on the ground. The force exerted by ground on the curling rock will be

(i) 180 N (ii) 90 N
(iii) 10 N (iv) 1.8 N

Ans. (iii) 10 N

(e) The direction of force of friction is

(i) perpendicular to the motion of the body.
(ii) along the direction of motion of body.
(iii) opposite to the direction of motion of body.
(iv) none of the above.

Ans. (iii) opposite to the direction of motion of body.

Very Short Answer Type Questions

18. A bull is charging towards you with a certain velocity. What other quantity would you need to know to be able to calculate its momentum?

Ans. We would need to know the bull's mass to calculate its momentum.

19. A sprinter is advised to reduce her speed slowly after completing the race. Why?

Ans. If the sprinter stops suddenly, the rate of change of momentum would be very high. This would make her experience a large amount of force. If she reduces her speed slowly, the rate of change of momentum is much lower, and the corresponding force acting on her body is low also.

20. What is the total momentum of a gun and the bullet inside it just before firing?

Ans. The total momentum of a gun and the bullet inside it, just before firing, is 0.

21. Do action and reaction forces take place simultaneously, or one after the other?

Ans. Action and reaction forces take place simultaneously.

22. When we stop pedaling a bicycle, it slows down and comes to a stop. Identify the force(s) involved in this.

Ans. The frictional force of the road acting on the cycle makes it slow down and stop.

23. Reema is wearing a T-shirt of mass 100 grams. How much force is she exerting on the dress?

Ans. The force exerted by Reema on the T-shirt = Weight of the T-shirt = 0.1 kg × 9.8 m/s^2 = 0.98 N in the upward direction.

Short Answer Type-I Questions

24. The earth attracts an apple with a force of 1 N. If this is the action force, how much is the reaction force? What exerts this reaction force? On which body does this reaction force act?

Ans. The reaction force is also 1 N. The reaction force is exerted by the apple. The reaction force acts on the earth.

25. Which would require a greater force – accelerating an object of mass 2 kg at 5 m/s^2 or an object of mass 10 kg at 1 m/s^2?

Ans. Since the product of mass and acceleration in both cases is equal, both would require equal force.

26. Can non-living objects exert a force? If yes, give two examples.

Ans. Yes, they can. The earth exerts a gravitational force on us. A magnet exerts an attractive force on a piece of iron.

27. Why do we get hurt more by falling on a concrete structure than on a bed of sand?

Ans. When we fall on a concrete structure, our speed comes to zero immediately. This high change in momentum makes us experience a massive amount of force. When we fall on sand, our speed falls down gradually. The rate of change of momentum is much lower, which exerts a much lower force on our body.

Short Answer Type-II Questions

28. How can Newton's first law of motion be mathematically stated from the mathematical expression for the second law of motion?

Ans. According to Newton's second law of motion,

Force, $F = m \times a$

If no external force acts on a body, $F = 0$

or $m \times a = 0$

Since mass of a body cannot be zero, it means $a = 0$

In other words, a body at rest will continue to be in a state of rest if no external force acts on it.

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

Therefore, if $a = 0$, $v - u = 0$

or $v = u$

This means that if no external force acts on a body, its velocity remains unchanged. The body will continue to be in its state of rest or uniform motion along a straight line if no external force acts on it.

29. Two friends on roller skates are standing 5 m apart facing each other. One of them throws a ball of 2 kg towards the other, who catches it. How will this activity affect the position of the two? Explain your answer.

Ans. When friend 1 throws the ball towards the friend 2, in keeping with the principle of conservation of linear momentum, friend 1 will get pushed in the opposite direction slightly. When friend 2 catches the ball, he will get pushed in the same direction that the ball was travelling in slightly.

30. State the action and the reaction in the following:

(a) A person diving into the swimming pool

(b) A bird flying

(c) A cricket ball dropping into the gloves of a fielder

Ans. (a) Action: Person's force on the water; reaction: water's force on the person

(b) Action: Bird's wings' force on the wind; reaction: the wind's force on the bird

(c) Action: Cricket ball's force on the hands of the fielder; reaction: the hands' force on the ball

31. When a horizontal force P acts on a cart of mass 20 kg, it moves with a uniform velocity on a horizontal floor. When a force of 1.2 P acts on the same cart, it moves with an acceleration of 0.05 m/s^2. What is the value of P?

Ans. When P acts on the cart, the velocity is uniform, i.e. there is no acceleration. Therefore, an opposing force equal in magnitude to P is also acting on the cart.

When a force of 1.2P acts on the cart, the net force that causes the acceleration is $1.2P - P = 0.2P$

Therefore, $0.2P = 20 \text{ kg} \times 0.05 \text{ m/s}^2$

or $P = 5$ N

32. A truck starting from rest moves down a hill with a constant acceleration. If it covers a distance of 500 m in 10 s, what is the acceleration experienced by it. What is the force acting on it if its mass is 6000 kg?

Ans. Using $s = ut + \frac{1}{2}at^2$,

we have $500 \text{ m} = 0 + \frac{1}{2} \times a \times (10 \text{ s})^2$

or $a = 10 \text{ m/s}^2$

Therefore, force acting on the truck = 6000 kg × 10 m/s^2 = 60000 N

33. A 50 kg shell is moving with a velocity of 36 km/h. It explodes into two pieces, one of which, weighing 30 kg, stops immediately. Calculate the velocity of the other piece.

Ans. If the velocity of the other piece is v km/h, we have

50 kg × 36 km/h = (30 kg × 0) + (20 kg × v km/h)

or v = 90 km/h

[Note that we haven't converted speed into SI units here. We can manage it without conversion here because it gets cancelled on both sides and does not affect the calculation.]

Long Answer Type Questions

34. (a) With the help of the Newton's third law of motion prove that the total momentum of two bodies is conserved during collision, provided no external force acts on them.

(b) A car A of mass 1200 kg travelling at 20 m/s collides with another car B of mass 800 kg travelling at 10 m/s in the same direction. After collision, the velocity of car A becomes 15 m/s. Calculate the velocity of car B after the collision.

Ans. (a) Let us consider two bodies A and B with masses m_1 and m_2, respectively. Let their velocities be u_1 and u_2.

Initial momentum of this two-body system = $m_1u_1 + m_2u_2$

Body A collides with body B, and after collision, their velocities become v_1 and v_2, respectively

Final momentum of the system = $m_1v_1 + m_2v_2$

Body A exerts a force of action F_{AB} on body B

Body B exerts a force of reaction F_{BA} on body A

If the collision lasts for t seconds, we have

$$F_{AB} = m_1 (v_1 - u_1)/t$$
$$F_{BA} = m_2 (v_2 - u_2)/t$$

According to Newton's third law of motion,

$$F_{AB} = -F_{BA}$$

or $m_1(v_1 - u_1)/t = -m_2 (v_2 - u_2)/t$

or $m_1v_1 + m_2v_2 = m_1u_1 + m_2u_2$

Therefore, momentum of the system after the collision = momentum of the system before the collision

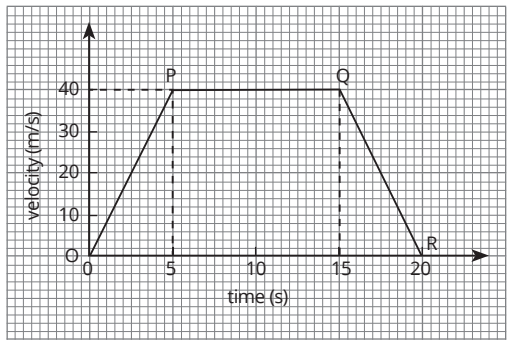
(b) If v is the velocity of car B after the collision, we have

(1200 kg × 20 m/s) + (800 kg × 10 m/s)

= (1200 kg × 15 m/s) + (800 kg × v)

or v = 17.5 m/s

35. For a mass of 5 kg, the velocity–time graph is given here. Find the force experienced by the mass in regions OP, PQ and QR.



Ans. The acceleration experienced by the mass is given by the slope of the graph in each region.

For region OP:

$$\text{acceleration} = \frac{40 \text{ m/s} - 0}{5 \text{ s} - 0} = 8 \text{ m/s}^2$$

Therefore, force = 5 kg × 8 m/s^2 = 40 N

For region PQ:

$$\text{acceleration} = \frac{40 \text{ m/s} - 40 \text{ m/s}}{15 \text{ s} - 5 \text{ s}} = 0$$

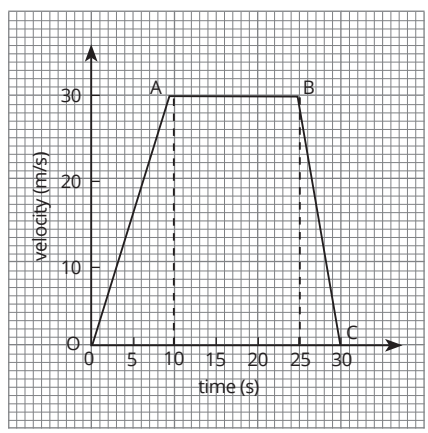
Therefore, force = 0

For region QR:

$$\text{acceleration} = \frac{0 - 40 \text{ m/s}}{20 \text{ s} - 15 \text{ s}}$$
$$= -8 \text{ m/s}^2$$

Therefore, force = 5 kg × –8 m/s^2 = –40 N

36. The velocity–time graph of a car of mass 1200 kg is given. From the graph, answer the following questions:



(a) When is the maximum force acting on the car? Why?

(b) What is the retarding force?

(c) For how long is there no force acting on the car?

Ans. (a) The maximum force acts on the car when the acceleration is positive between O and A.

Its value = 1200 kg × $\frac{30 \text{ m/s} - 0}{10 \text{ s} - 0}$ = 3600 N

(b) The retarding force = 1200 kg × $\frac{0 - 30 \text{ m/s}}{30 \text{ s} - 25 \text{ s}}$

= –7200 N

(c) There is no force acting on the car for 15 seconds between A and B.

Let's Compete

(Page 47)

Multiple-Choice Questions

1. In a tug of war, if the rope does not move in any direction, the net force is

(a) zero. (b) low.

(c) high. (d) cannot say.

Ans. The correct answer is (a).

2. The physical quantity that makes it easier to accelerate a small car than a large car is measured in the unit of

(a) m/s. (b) kg.

(c) kg m/s. (d) kg m/s^2.

Ans. This physical quantity is inertia or mass. Therefore, the correct answer is (b).

3. A gun fires a bullet with a speed of 400 m/s. What is the recoil velocity of the gun if its mass is 200 times the mass of the bullet?

(a) 4 m/s

(b) 2 m/s

(c) 8 m/s

(d) We need more information.

Ans. If the recoil velocity is v m/s and the mass of the bullet is m kg, we have

$m \times 0 + 200\ m \times 0 = m \times 400 \text{ m/s} + 200\ m \times v$

or $v = -2$ m/s

Therefore, the correct answer is (b).

4. The inertia of an object tends to cause the object

(a) to increase its speed.

(b) to decrease its speed.

(c) to resist any change in its state of rest or motion.

(d) to decelerate due to friction.

Ans. The correct answer is (c).

5. A water tank filled up to 2/3rd of its height is moving with a uniform speed. On sudden application of the brake, the water in the tank would

(a) move backward. (b) move forward.

(c) be unaffected. (d) rise upwards.

Ans. The water will display inertia due to motion. Therefore, the correct answer is (b).

6. Two identical bullets are fired one by a light rifle and another by a heavy rifle with the same force. Which rifle will exert more force on the shoulder of the shooter more?

(a) The light rifle

(b) The heavy rifle

(c) Both will exert same force

(d) It cannot be determined from the given information

Ans. The rifle that has the greater recoil hurts the shooter more. Since the force with which the bullet is fired is the same in both cases, the recoil is greater for the rifle with the lower mass. Therefore, the correct answer is (a).

7. A truck of mass M is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, how does the truck's acceleration change?

(a) Decreases to 1/4th of original

(b) Decreases to half of original

(c) Increases to twice the original

(d) Does not change

Ans. Initial acceleration, $a = \frac{F}{M}$

Final acceleration, $a' = \frac{\left(\frac{F}{2}\right)}{2M} = \frac{1}{4} \times \frac{F}{M} = \frac{1}{4} \times a$

Therefore, the correct answer is (a).

8. A spring balance A is suspended vertically from a rigid support. Another spring balance B is suspended from the hook of spring balance A. Now, a weight of 1 kg is suspended from the hook of spring balance B. The readings of spring balances A and B would be

(a) $\frac{1}{2}$ kg each. (b) 2 kg each.

(c) 1 kg each. (d) None of these

Ans. The correct answer is (c).

9. Which of these is the essential condition for the validity of the law of conservation of momentum?

(a) The system should be isolated.

(b) The system should have no more than two bodies interacting with each other.

(c) At least one of the bodies in the system should be stationary.

(d) None of these. The law is valid under all conditions.

Ans. The correct answer is (a).

10. If the time taken to bring a ball to rest from a certain velocity v is reduced to half, what will be

the change in the value of the rate of change of momentum?

(a) It will get halved.

(b) It will remain the same.

(c) It will get doubled.

(d) It will become four times.

Ans. Rate of change of momentum is inversely proportional to time. If the time is halved, the rate of change of momentum becomes twice its previous value. Therefore, the correct answer is (c).

Value-based Questions

(Optional) (Page 48)

1. James is trying to push a heavy table along a rough surface, but he is not able to do it. His friend Monika sees him and helps in pushing the table, which both of them are able to move now.

(a) Why was James not able to push the table alone?

(b) What is the force opposing the movement of the table?

(c) What values do we learn from Monika?

Ans. (a) The force exerted by James was not enough to overcome the opposing force.

(b) Frictional force

(c) We should help our friends in need.

2. Nikhat saw an elderly person in the metro train riding without holding anything for support. She advised the elderly person to hold the seat handle or the pole for safety.

(a) What was the reason behind Nikhat's advice to the elderly person?

(b) What values do we learn from Nikhat?

Ans. (a) The person could fall when the train stopped suddenly because of inertia of motion.

(b) We should use our knowledge to help other people.

10

Gravitation

Checkpoint (Page 51)

1. A particular force F produces an acceleration of magnitude a on a mass m. If the mass is reduced to half its original value, what is the force required to produce an acceleration of $2a$?

(a) $\frac{F}{4}$ (b) $\frac{F}{2}$

(c) F (d) $2F$

Ans. $F = ma$

When mass becomes half and acceleration needed is $2a$, the product = $\frac{m}{2} \times 2a = ma = F$

Therefore, the correct answer is (c).

2. If multiple forces act on an object, which continues to move with constant velocity on a straight path, the forces can be said to be

(a) balanced. (b) unbalanced.

(c) reactive. (d) conserved.

Ans. Constant velocity is an indication of zero acceleration. This means there is no net force acting on the object. All forces acting on the object are balanced. Therefore, the correct answer is (a).

3. Which of these is the most accurate explanation for how we are able to drink liquids through straws?

(a) Gravitational force is lower in the small area of the straw compared to the surroundings, causing the liquid to rise easily.

(b) We suck the air out of the straw, which causes the atmospheric pressure to force the liquid into this empty space.

(c) We exert a strong force on the liquid, which causes it to rise up by overcoming the force of gravity.

(d) Our breath exerts electrostatic force, which causes certain liquids to move upwards.

Ans. The correct answer is (b).

4. Which of these properties is constant for a given object?

(a) Mass (b) Volume

(c) Weight (d) Area

Ans. The correct answer is (a).

5. State whether true or false: If the earth attracts an object kept on the ground with a force of 100 N, the object also attracts the earth with a force of equal magnitude.

Ans. The statement is true because of Newton's third law of motion.

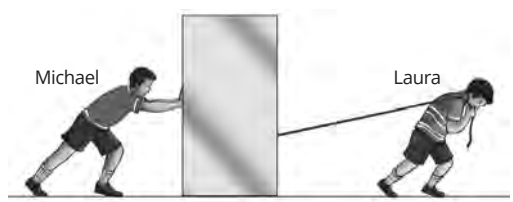
6. Which of the three Newton's laws of motions defines force and inertia?

Ans. Newton's first law of motion defines force and inertia.

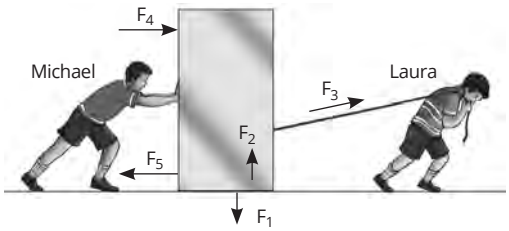
7. If an object is moving in uniform circular motion, what is the direction of its velocity and acceleration?

Ans. The velocity is directed towards the tangent at a given position of the object in its path. The acceleration is directed towards the centre along the radius.

8. Michael and Laura are two friends trying to move a large block of wood towards the right. Mark the forces acting on the block of wood.



Ans. F_1: Weight, F_2: Normal force, F_3: Pull, F_4: Push, F_5: Friction



9. A motorcycle is moving with a velocity of 90 km/h and it takes 5 seconds to stop after its brakes are applied. If the motorcycle's mass, along with the rider, is 200 kg, what force is exerted by the brakes?

Ans. Initial velocity, u = 90 km/h = 25 m/s

Final velocity, v = 0

Time, t = 5 s

$$\text{acceleration, } a = \frac{v-u}{t}$$

$$= \frac{0-25 \text{ m/s}}{5 \text{ s}}$$

$$= -5 \text{ m/s}^2$$

$$\text{Force} = \text{total mass} \times a$$

$$= 200 \text{ kg} \times -5 \text{ m/s}^2$$

$$= -1000 \text{ N}$$

10. The weight of air in a column of the height of atmosphere and area of about 100 cm^2 is as large as 1000 kg. Why are our bodies not crushed by this large amount of atmospheric pressure?

Ans. The pressure inside our body is equal to the atmospheric pressure and cancels the pressure from outside.

Milestone 1

(Page 53)

Multiple-Choice Questions

1. If the distance between two objects is increased, the gravitational force of attraction between them will

(a) increase.

(b) decrease.

(c) not change.

(d) increase or decrease depending on the nature of the two objects.

Ans. Gravitation force, $F = \frac{Gm_1m_2}{r^2}$

or $F \propto 1/r^2$, i.e. gravitational force between two objects is inversely proportional to the square of the distance between the two objects

If r is increased, F decreases. Therefore, the correct answer is (b).

2. Two objects are kept at a distance of d from each other. The gravitational force between them is proportional to

(a) d (b) d^2

(c) $\frac{1}{d}$ (d) $\frac{1}{d^2}$

Ans. As seen above, $F \propto \frac{1}{d^2}$, if d is the distance between the two objects.

Therefore, the correct answer is (d).

3. The force of gravitation between two objects of mass 1 kg kept at a distance of 1 m from each other is

(a) 6.67 N (b) 6.67×10^{-9} N

(c) 6.67×10^{-7} N (d) 6.67×10^{-11} N

Ans.

$$F = \frac{Gm_1m_2}{r^2}$$

$$= G\frac{(1 \text{ kg})(1 \text{ kg})}{(1 \text{ m})^2}$$

$$= G$$

$$= 6.67 \times 10^{-11} \text{ N}$$

Therefore, the correct answer is (d).

4. The force of gravitation between two objects is F when they are placed at a specific distance on earth's surface. The force between them if they are placed at the same distance on the surface of moon will be

(a) $\frac{F}{6}$ (b) $\frac{F}{2}$

(c) F (d) $6F$

Ans. Since the values of G, mass or distance do not change between the earth and the moon, the force of gravitation between two objects will be the same on the moon as it is on earth. Therefore, the correct answer is (c).

Very Short Answer Type Questions

5. Though gravitational force is the weakest force in nature, yet it is responsible for holding our solar system. How?

Ans. Gravitational force is weak between small-sized objects but it becomes very strong between large-sized objects like planets and satellites.

6. Mass is a scalar quantity, while force is a vector. Is G, the universal gravitational constant, a scalar or a vector quantity?

Ans. G is a scalar quantity as its value does not depend on direction.

7. What is the direction of the force of gravitation between two particles?

Ans. The force of gravitation between two particles is directed along the line joining the centres of the two particles.

Short Answer Type-I Questions

8. If the distance between two objects is increased by a multiple of four, then by how many times should the mass of one of the objects be changed to maintain the same gravitational force?

Ans. Suppose we have two objects of mass $m1$ and $m2$ with distance between them r.

$$\text{Force, } F = \frac{Gm_1m_2}{r^2}$$

Now, the new distance becomes $4r$. If we are changing the mass of m_1 to m_1' we have

$$F' = \frac{Gm_1'm_2}{4r^2}$$

$$= \frac{Gm_1'm_2}{16r^2}$$

$$F/F' = \frac{\frac{Gm_1m_2}{r^2}}{\frac{Gm_1'm_2}{16r^2}}$$

or $$F/F' = \frac{16m_1}{m_1'}$$

If $F' = F$, $m_1' = 16m_1$

Therefore, the mass of one of the objects has to be increased 16 times for the force to be maintained at the same value.

9. Consider two objects A and B. What will happen to the value of G involved in calculating the gravitational force between the two objects, if

(a) sizes of the two objects are doubled?

(b) both the objects are immersed in water?

(c) both the objects are placed in vacuum?

Ans. G is a universal constant. Its value does not depend on properties of the objects involved, the medium, or the location in the universe. Therefore, its value will remain unchanged in all three cases.

Short Answer Type-II Questions

10. The mass of the planet Jupiter is 1.9×10^{27} kg and that of the sun is 1.99×10^{30} kg. The mean distance of Jupiter from the sun is 7.8×10^{11} m. Calculate the gravitational force that the sun exerts on Jupiter.

Ans. $F = \dfrac{(G \times \text{mass of Jupiter} \times \text{mass of Sun})}{(\text{mean distance between Jupiter and Sun})^2}$

$$= \frac{\left(6.67\times10^{-11}\ \text{N m}^2/\text{kg}^2 \times 1.9\times10^{27}\ \text{kg} \times 1.99\times10^{30}\ \text{kg}\right)}{\left(7.8\times10^{11}\ \text{m}\right)^2}$$

$= 4.15 \times 10^{23}$ N

11. A mass of 40 kg is attracted by a mass of 25 kg lying at a distance of 2 m from it with a force of 1.67×10^{-8} N. Find the value of G using this data.

Ans. $$F = \frac{Gm_1m_2}{r^2}$$

or $$G = \frac{Fr^2}{m_1m_2}$$

$$= \frac{\left(1.67\times10^{-8}\ \text{N}\right)\times\left(2\ \text{m}\right)^2}{40\ \text{kg}\times25\ \text{kg}}$$

$= 6.68 \times 10^{-11}\ \text{Nm}^2/\text{kg}^2$

Long Answer Type Questions

12. Two particles of mass 200 g each are placed at a separation of 10 cm. Assume that the only forces acting on them are due to their gravitational attraction. Find the acceleration of each when they are allowed to move.

Ans. Force acting on each particle, $F = \dfrac{Gm^2}{r^2}$ (since both particles are of equal masses)

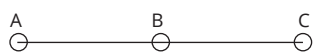
Therefore, acceleration acting on each = $\dfrac{F}{m}$

$$= \frac{Gm}{r^2} = \frac{6.67\times10^{-11}\ \text{N m}^2/\text{kg}^2 \times 0.2\ \text{kg}}{\left(0.1\ \text{m}\right)^2}$$

$= 1.33 \times 10^{-9}\ \text{m/s}^2$

13. Three balls A, B and C are kept in a straight line. The separation between A and C is 1 m, and B is placed at the mid-point between them. The masses of A, B and C are 100 g, 200 g and 300 g, respectively. Find the net gravitational force on each of the three balls.

Ans. Distance between A and C, $r_{AC} = 1$ m; distance between A and B, $r_{AB} = 0.5$ m; distance between B and C, $r_{BC} = 0.5$ m; $m_A = 0.1$ kg; $m_B = 0.2$ kg; $m_C = 0.3$ kg



Force on A because of B (towards the right)
= Force on B because of A (towards the left)

$$= \frac{Gm_Am_B}{\left(r_{AB}\right)^2}$$

$$= \frac{6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2 \times 0.1\,\text{kg} \times 0.2\ \text{kg}}{\left(0.5\ \text{m}\right)^2}$$

$= 5.34 \times 10^{-12}$ N

Force on A because of C (towards the right)
= Force on C because of A (towards the left)

$$= \frac{Gm_A m_C}{(r_{AC})^2}$$

$$= \frac{6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2 \times 0.1\ \text{kg} \times 0.3\ \text{kg}}{(1\ \text{m})^2}$$

$= 2 \times 10^{-12}$ N

Force on B because of C (towards the right)
= Force on C because of B (towards the left)

$$= \frac{Gm_B m_C}{(r_{BC})^2}$$

$$= \frac{6.67 \times 10^{-11}\ \text{N m}^2/\text{kg}^2 \times 0.2\ \text{kg} \times 0.3\ \text{kg}}{(0.5\ \text{m})^2}$$

$= 16 \times 10^{-12}$ N

Net force on A = 5.34×10^{-12} N + 2×10^{-12} N
= 7.34×10^{-12} N towards the right

Net force on B = 16×10^{-12} N – 5.34×10^{-12} N
= 10.66×10^{-12} N towards the right

Net force on C = 2×10^{-12} N + 16×10^{-12} N
= 18×10^{-12} N towards the left

14. A particle of mass m_1 is kept at $x = 0$ and another of mass m_2 at $x = r$. When a third particle is kept at $x = \frac{r}{4}$, it experiences no net gravitational force due to the two particles. Find $\frac{m_2}{m_1}$.

Ans. If m is the mass of the third particle, force on the third particle due to $m_1 = \frac{Gmm_1}{(r/4)^2}$

Force on the third particle due to $m_2 = \frac{Gmm_2}{(3r/4)^2}$

The two forces are equal.

Therefore,

$$\frac{Gmm_1}{(r/4)^2} = \frac{Gmm_2}{(3r/4)^2}$$

or $$\frac{m_2}{m_1} = \frac{(3r/4)^2}{(r/4)^2} = 9 : 1$$

Milestone 2

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Multiple-Choice Questions

1. The force that is needed to make an object travel in a circular path is called

(a) electrostatic force. (b) gravitational force.
(c) centripetal force. (d) centrifugal force.

Ans. The correct answer is (c).

2. The gravitational force exerted by a stone on the earth produces

(a) no acceleration.
(b) large acceleration.
(c) exactly the same acceleration as produced in the stone itself.
(d) very small acceleration.

Ans. The force exerted by a stone on the earth is of the same magnitude and opposite direction as the force exerted by the earth on the stone. However, because of the huge mass of the earth, the acceleration is very small. Therefore, the correct answer is (d).

3. Every planet revolves around the sun in a/an

(a) circular orbit.
(b) square orbit.
(c) elliptical orbit.
(d) irregular orbit.

Ans. The correct answer is (c).

4. An object is thrown vertically upwards. Acceleration of the object

(a) increases as it goes up.
(b) decreases as it goes up.
(c) remains the same as it goes up.
(d) becomes zero as it goes up.

Ans. The correct answer is (c).

5. When an object is thrown upwards, its final velocity becomes

(a) maximum.
(b) negative.
(c) zero.
(d) negative or stays positive depending upon the initial velocity.

Ans. The correct answer is (c). The final velocity becomes zero at the object's maximum height.

6. The acceleration due to gravity is 9.8 m/s^2

(a) much above the earth's surface.
(b) near the earth's surface.
(c) deep inside the earth.
(d) at the centre of the earth.

Ans. The correct answer is (b).

7. A particle is taken to a height R above the earth's surface, where R is the radius of the earth. The acceleration due to gravity there is

(a) 2.45 m/s^2 (b) 4.9 m/s^2
(c) 9.8 m/s^2 (d) 19.6 m/s^2

Ans. $g \propto \frac{1}{r^2}$

So if r becomes $2R$ from R, the value of g decreases 4 times

Therefore, the correct answer is (a).

Very Short Answer Type Questions

8. List two factors on which acceleration due to gravity depends.

Ans. The mass of the earth and the distance between the object and the centre of the earth.

9. Is there any change in the velocity of a freely falling object? Discuss.

Ans. Yes, because of the constant acceleration due to gravity, the velocity of a freely falling object continues to increase as it falls towards the earth's surface.

10. Explain how Newton's third law of motion is applicable to gravitational force.

Ans. Newton's third law of motion says that for every action force, there is an equal and opposite reaction force. In case of gravitational force between two objects, the force that one object exerts is equal to the force the other object exerts on the first one. Moreover, these two are in opposite direction.

11. For a heavenly body that has both mass and radius twice those of earth's, what is the value of acceleration due to gravity at its surface?

Ans.
$$g' = \frac{G2M_e}{(2R_e)^2}$$
$$= \frac{1}{2} \times \frac{GM_e}{R_e^2}$$
$$= \frac{1}{2} \times 9.8 \text{ m/s}^2$$
$$= 4.9 \text{ m/s}^2$$

Short Answer Type-I Questions

12. The acceleration due to gravity on the moon is 1.67 m/s^2. If the radius of the moon is 1.74 × 10^6 m, calculate the mass of the moon.

Ans.
$$g_{moon} = \frac{GM_{moon}}{(R_{moon})^2}$$
or
$$M_{moon} = \frac{g_{moon} \times (R_{moon})^2}{G}$$
$$= \frac{1.67 \text{ m/s}^2 \times (1.74 \times 10^6 \text{ m})^2}{(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2)}$$
or
$$M_{moon} = 7.6 \times 10^{22} \text{ kg}$$

13. The value of acceleration due to gravity is lower on the top of mountains than it is on plains. Give reasons.

Ans. Acceleration due to gravity is inversely proportional to the distance from the earth's centre. Since this distance is slightly higher on top of mountains than it is on sea level, the acceleration due to gravity is lower there.

14. Even though according to our understanding of acceleration due to gravity, a coin and a feather dropped from a height should reach the ground at the same time, it does not generally happen in real life. Why?

Ans. In real life, a feather experiences greater air drag because of its spread out structure as compared to a coin. Because of this upward acting force, the net gravitational force experienced by a feather is lower than the coin. Thus, a coin has greater downward acceleration and will reach the ground earlier than a feather even if both are dropped from the same height.

Short Answer Type-II Questions

15. A particle is dropped from a tower 180 m high. How long does it take to reach the ground? What is the velocity when it touches the ground? (Take g = 10 m/s^2)

Ans. u = 0, s = 180 m, g = 10 m/s^2
$$v^2 = u^2 + 2gs,$$
$$v^2 = 0 + 2 \times 10 \text{ m/s}^2 \times 180 \text{ m}$$
or $v = 60$ m/s
$$v = u + gt$$
or $60 \text{ m/s} = 0 + 10 \text{ m/s}^2 \times t$
or $t = 6$ s

16. A man is standing on the top of a 60 m high tower. He throws a ball vertically upwards with a velocity of 20 m/s. After what time will the ball pass him while going downwards towards the ground? How long after its release will the ball reach the ground?

Ans. When thrown vertically upwards, the ball will take the same time to reach its maximum height as it will take to reach his level on its downward journey while coming down from its maximum height.

At maximum height, v = 0, u = 20 m/s
$$v = u - gt$$
or $0 = 20 \text{ m/s} - 9.8 \text{ m/s}^2 \times t$
or $t = 2.04$ s

The ball takes 2.04 s to reach the maximum height.

Therefore, it takes 2 × 2.04 s = 4.08 s to reach the man's level again on its way down.

The velocity of the ball at this point = 20 m/s

To reach the ground from this point, it covers a distance of 60 m

$$v^2 = u^2 + 2gs$$
$$= (20\ \text{m/s})^2 + 2 \times 9.8\ \text{m/s}^2 \times 60\ \text{m}$$
$$= 1576\ \text{m}^2/\text{s}^2$$

or $v = 39.7$ m/s

$$v = u + gt$$

or $$t = \frac{(v-u)}{g}$$

$$= \frac{(39.7\ \text{m/s} - 20\ \text{m/s})}{9.8\ \text{m/s}^2}$$

$$= 2\ \text{s}$$

Therefore, the total time taken by the ball to reach the ground = 4.08 s + 2 s = 6.08 s

17. If the density of two planets is the same, but their radii are in the ratio 1 : 2, prove that the ratio of accelerations due to gravity on their surfaces is also 1 : 2.

Ans. Let the density of the two planets be d_1 and d_2; masses be m_1 and m_2; radii be r_1 and r_2, such that $r_2 = 2r_1$ or $\frac{r_2}{r_1} = 2$

We know that density = mass/volume

$$d_1 = m_1/4/3\pi r_1^3$$
$$d_2 = m_2/4/3\pi r_2^3$$
$$d_1 = d_2$$

or $m_1/4/3\pi r_1^3 = m_2/4/3\pi r_2^3$

or $$\frac{m_1}{m_2} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{r_1}{2r_1}\right)^3 = \frac{1}{8}$$

If g_1 and g_2 are the accelerations due to gravity for the two planets

$$\frac{g_1}{g_2} = \frac{(Gm_1/r_1^2)}{(Gm_2/r_2^2)}$$

$$= \frac{m_1}{m_2} \times \left(\frac{r_2}{r_1}\right)^2$$

$$= \frac{1}{8} \times 4 = \frac{1}{2} = 1 : 2$$

Long Answer Type Questions

18. An object is thrown vertically upwards and rises to a height of 4.9 m. Calculate

(a) the velocity with which the object was thrown upwards, and

(b) the time taken by the object to reach the highest point.

Take $g = 9.8\ \text{m/s}^2$.

Ans. Maximum height reached by the object, $s = 4.9$ m

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

or $0 = u^2 - 2 \times 9.8\ \text{m/s}^2 \times 4.9\ \text{m}$

or $u^2 = 2 \times 9.8\ \text{m/s}^2 \times 4.9\ \text{m}$

or $u = 9.8$ m/s

(b) $v = u - gt$

or $0 = 9.8\ \text{m/s} - 9.8\ \text{m/s}^2 \times t$

or $t = 1$ s

19. A stone is dropped from the edge of a roof.

(a) How long does it take to fall through 4.9 m?

(b) How fast does it move towards the end of that fall?

(c) How fast will it move at the end of 7.9 m?

(d) What is its acceleration after 1 s and after 2 s?

Ans. (a) and (b) $u = 0$, $s = 4.9$ m

$$v^2 = u^2 + 2gs$$

or $v^2 = 0 + 2 \times 9.8\ \text{m/s}^2 \times 4.9\ \text{m}$

or $v = 9.8$ m/s

$$t = \frac{(v-u)}{g}$$

$$= \frac{(9.8\ \text{m/s} - 0)}{9.8\ \text{m/s}^2} = 1\ \text{s}$$

(c) $u = 0$, $s = 7.9$ m

$v^2 = 0 + 2 \times 9.8\ \text{m/s}^2 \times 7.9\ \text{m}$

or $v = 12.4$ m/s

(d) The acceleration is constant at 9.8 m/s^2 after 1 s and 2 s.

Milestone 3

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Multiple-Choice Questions

1. The ratio of mass of the earth to the mass of moon is approximately

(a) 10 : 1 (b) 1 : 1

(c) 100 : 1 (d) 1000 : 1

Ans. The correct answer is (c).

2. Which of these is a measure of the force on any object due to attraction of the earth?

(a) Mass (b) Weight

(c) Gravitation (d) Inertia

Ans. The correct answer is (b).

3. The weight of an object of mass 1 kg on earth's surface will be

(a) 1 N (b) 9.8 N

(c) 0 N (d) 100 N

Ans. Weight = mass × g = 1 kg × 9.8 m/s^2 = 9.8 N. Therefore, the correct answer is (b).

4. The weight of an object on earth's surface is 120 N. The weight of the same object on moon's surface will be

(a) 120 N (b) 20 N

(c) 0 N (d) 240 N

Ans. The value of acceleration due to gravity on moon is 1/6th that on earth, i.e., $g_m = \frac{g}{6}$

Mass of the object on earth's surface = $\frac{\text{Weight}}{g}$

$= \frac{120}{g}$ kg

Weight on moon = $\frac{120}{g}$ kg × $\frac{g}{6}$ m/s^2 = 20 N

Therefore, the correct answer is (b).

5. Mass of an object can be measured with the help of a

(a) spring balance. (b) weighing machine.

(c) beam balance. (d) none of these.

Ans. The correct answer is (c).

6. The weight of an object on earth's surface is W. At a height of R_e from earth's surface, where R_e is earth's radius, its weight will be

(a) $\frac{W}{4}$ (b) $\frac{W}{2}$

(c) W (d) $2W$

Ans. The value of g at the given height = $\frac{GM_e}{(R_e + R_e)^2}$

$= \frac{1}{4} \times \frac{GM_e}{R_e^2} = \frac{g}{4}$

Since weight is directly proportional to g, the weight of the object at the given height will be $\frac{W}{4}$.

Therefore, the correct answer is (a).

Very Short Answer Type Questions

7. Is it more or less difficult to lift heavy weights on the moon as compared to the earth? Why?

Ans. It is less difficult to lift heavy weights on the moon because the gravitational force that one has to work against is only about 1/6th of what the force would be on earth.

8. Can the weight of an object on earth be taken as a measure of its mass? Why or why not?

Ans. Yes, the weight of an object on earth can be taken as a measure of its mass because weight is the product of mass and acceleration due to gravity and the value of acceleration due to gravity is relatively constant all over the earth's surface.

9. Can a spring balance measure both mass and weight?

Ans. A spring balance measures only weight.

Short Answer Type-I Questions

10. If a man has a mass of 70 kg on earth's surface, what will be his mass and weight on the moon's surface?

Ans. The person's mass on moon's surface will be 70 kg. The person's weight will be 70 kg × (9.8/6 m/s^2) = 114.33 N.

11. What is the weight of an object whose mass is 20 kg? (Take g = 10 m/s^2)

Ans. Weight = mass × g = 20 kg × 10 m/s^2 = 200 N

12. A stone resting on the ground has a gravitational force of 20 N acting on it. What is the weight of the stone? What is its mass? (Take g = 10 m/s^2)

Ans. The weight of the stone is the same as the gravitational force acting on it. So, weight = 20 N

$$\text{Mass} = \frac{\text{Weight}}{g}$$

$$= \frac{20 \text{ N}}{10 \text{ m/s}^2} = 2 \text{ kg}$$

Short Answer Type-II Questions

13. An object weighs 490 N on a planet whose acceleration due to gravity is half that of earth's. Calculate

(a) the mass of the object.

(b) the weight of the object on the earth.

Ans. (a) Mass = $\frac{\text{Weight}}{g'} = \frac{490 \text{ N}}{\left(\frac{9.8}{2} \text{ m/s}^2\right)}$ = 100 kg

(b) Weight on earth = 100 kg × 9.8 m/s^2 = 980 N

14. Consider a heavenly body that has a mass twice that of the earth and a radius thrice that of the earth. What will be the weight of an object on this heavenly body if its weight on earth is 450 N?

Ans. If g' is the acceleration due to gravity on this heavenly body, $g' = \frac{G(2M_e)}{(3R_e)^2} = \frac{2}{9} \times \frac{GM_e}{R_e^2} = \frac{2}{9} \times g$

Therefore, weight of an object on this heavenly body = $\frac{2}{9}$ × 450 N = 100 N

Long Answer Type Questions

15. Show that if an object is taken to a height H above the earth's surface, its weight decreases by the factor $\frac{R^2}{(R+H)^2}$, where R is the radius of the earth.

Ans. Weight of an object on earth, W = mg, where m is the mass of the object and g is the acceleration due to gravity on earth.

The value of g is given by,

$$g = \frac{GM}{R^2}$$

where M is the mass of the earth

If g' is the acceleration due to gravity at height H from the earth's surface, $g' = \frac{GM}{(R+H)^2}$

Weight of the object at height H,

$$W' = m \times \frac{GM}{(R+H)^2}$$

$$\frac{W'}{W} = \frac{\left(m \times GM/(R+H)^2\right)}{\left(m \times GM/R^2\right)}$$

$$= \frac{R^2}{(R+H)^2}$$

or $$W' = \frac{W \times R^2}{(R+H)^2}$$

This shows that the weight at height H is less than the weight on earth's surface by a factor of $\frac{R^2}{(R+H)^2}$

16. (a) A bar of metal has a mass 200 g and a certain weight at the poles. Mass remains the same but weight decreases when measured at the equator. Why?

(b) Give two main differences between mass and weight.

(c) What will happen if there is no acceleration due to gravity?

Ans. (a) This is because the value of acceleration due to gravity is slightly lower at the earth's equator than it is at the poles. Since weight is directly proportional to acceleration due to gravity, the weight also decreases slightly when one moves from the poles to the equator.

(b) Mass is a measure of the matter contained in an object while weight is a measure of the earth's gravitational force acting on an object. Mass is a scalar quantity while weight is a vector quantity.

(c) If there would be no acceleration due to gravity then the objects would not be attracted to the earth and everything would be floating in the air.

Milestone 4

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Multiple-Choice Questions

1. Pressure is defined as

(a) acceleration per unit area.

(b) area per unit mass.

(c) thrust per unit area.

(d) area per unit thrust.

Ans. The correct answer is (c).

2. The pressure acting on an object and area of contact are

(a) directly proportional.

(b) inversely proportional.

(c) not related to each other.

(d) related but not proportional.

Ans. The correct answer is (b).

3. A cuboidal wooden block has length of 10 cm, breadth of 5 cm and height of 2 cm. It is placed on a tabletop in three different ways, turn by turn. Which of the following statements is the most accurate in relation to the pressure exerted by the block on the tabletop?

(a) The pressure exerted is maximum when the length and the breadth of the block form the base.

(b) The pressure exerted is maximum when the length and height of the block form the base.

(c) The pressure exerted is maximum when the breadth and height of the block form the base.

(d) The pressure exerted is least when the length and height of the block form the base.

Ans. Since the weight of the block is the same in all three cases, the pressure will depend on the area on which this weight acts. Since pressure is inversely proportional to area, the lower the area, the higher is the pressure. The lowest area is possible when breadth and the height form the base. Therefore, the correct answer is (c).

4. Pressure exerted by a liquid on a container (in which it is enclosed) acts on

(a) the base of the container.

(b) the walls of the container.

(c) both the base and the walls of the container.

(d) none of these

Ans. The pressure of a liquid (or gas) acts in all directions equally. Therefore, the correct answer is (c).

5. Fluid pressure acts ..... to any surface in the fluid no matter how the surface is oriented.

(a) normal (b) parallel
(c) diagonal (d) at 60°

Ans. The correct answer is (a).

Very Short Answer Type Questions

6. Why does an army tank weighing about a hundred tonnes rest upon a continuous and broad steel chain?

Ans. A broad steel chain increases the area of contact of the heavy tank and the ground. This reduces the pressure acting on the ground and keeps the ground from getting damaged.

7. If an elephant steps on a man's chest, his ribs would crack. Then how does a circus performer manage to save himself from such an accident during his performance with an elephant?

Ans. A circus performer uses a plank between his chest and the elephant's foot. This spreads the force of the elephant's weight over a wider surface and reduces the pressure experienced by the performer.

8. One day, while swimming below the surface of the sea, you let out a small bubble of air from your mouth. What happens to the bubble as it rises towards the surface?

Ans. As the bubble rises, the pressure of the surrounding water decreases. As the surrounding pressure decreases, the bubble keeps on expanding.

Short Answer Type-I Questions

9. A jug of height 15 cm is filled to the surface with water. Find the pressure at the bottom of the jar in kPa. Ignore atmospheric pressure and take g as 10 m/s^2. Density of water = 1000 kg/m^3.

Ans. Pressure at the bottom of the jar

$= h \times \text{density} \times g$

$= 0.15 \text{ m} \times 1000 \text{ kg/m}^3 \times 10 \text{ m/s}^2$

$= 1500 \text{ Pa}$

$= 1.5 \text{ kPa}$

10. Naina weighs 36 kg. If the area of either of her foot is 150 cm^2, what is the pressure exerted by Naina on the ground? (Take g = 10 m/s^2)

Ans. When Naina is standing on both her feet, the force of her weight is divided equally between the two feet.

$$\text{Total pressure} = \frac{\text{Weight}}{\text{Total area}}$$

$$= \frac{\left(36 \text{ kg} \times 10 \text{ m/s}^2\right)}{\left(2 \times 0.015 \text{ m}^2\right)}$$

$= 1.2 \times 10^4$ Pa

11. The units of both force and thrust are newton, so can all forces acting on an object be called thrust? Explain.

Ans. No, all forces acting on an object cannot be called thrust. Only when a force acts normal to a surface can it be called thrust.

Short Answer Type-II Questions

12. A cubical iron block of side 5 cm exerts a pressure of 4000 Pa when placed on a table top. What is the mass of the block? (Take g = 10 m/s^2)

Ans. The area on which the weight of the block acts = 5 cm × 5 cm = 25 cm^2 = 0.0025 m^2

Weight = Pressure × area

$= 4000 \text{ Pa} \times 0.0025 \text{ m}^2$

$= 10 \text{ N}$

$$\text{Mass} = \frac{10 \text{ N}}{10 \text{ m/s}^2} = 1 \text{ kg}$$

13. A cubical box 20 cm on a side is completely immersed in a fluid. At the top of the box, the pressure is 105 kPa and at the bottom the pressure is 106.8 kPa. What is the density of the fluid?

Ans. The difference in the pressure at the two heights is because of the difference in pressure of the liquid itself because of the height difference

Pressure due to 20 cm column of the liquid

$= 106.8 \text{ kPa} - 105 \text{ kPa}$

$= 1.8 \text{ kPa}$

$= 1800 \text{ Pa}$

or $0.2 \text{ m} \times \text{density} \times 9.8 \text{ m/s}^2 = 1800 \text{ Pa}$

or density = 918.4 kg/m^3

14. The Titanic was found in 1985 lying on the bottom of the North Atlantic ocean at a depth of 2.5 miles. What is the pressure at this depth? (Given 1 mile = 1609 m, 1 atm = 1.01 × 10^5 Pa and density of ocean water = 1025 kg/m^3)

Ans. Pressure at the given depth = 1.01×10^5 Pa + (2.5 × 1609 m × 1025 kg/m^3 × 9.8 m/s^2) = 4.05×10^7 Pa

Long Answer Type Question

15. Find the pressure exerted on the skin of a balloon with a force of 2.1 N using (a) your finger and (b) a needle. Assume the area of your finger tip is 10^{-4} m^2 and the area of a needle tip is 2.5×10^{-7} m^2. (c) Find the maximum force necessary to burst the balloon with the needle, given that the balloon bursts with a pressure of 3×10^5 N/m^2.

Ans. (a) Pressure because of finger

$$= \frac{2.1 \text{ N}}{10^{-4} \text{ m}^2}$$

$= 2.1 \times 10^4$ Pa

(b) Pressure because of needle

$$= \frac{2.1\ \text{N}}{2.5\times10^{-7}\ \text{m}^2}$$

$$= 8.4 \times 10^6\ \text{Pa}$$

(c) Maximum force = $3 \times 10^5\ \text{N/m}^2 \times 2.5 \times 10^{-7}\ \text{m}^2$

$$= 0.075\ \text{N}$$

Milestone 5

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Multiple-Choice Questions

1. If the density of aluminium is 2700 kg/m^3, its value in CGS system is

(a) 2700 g/cm^3 (b) 270 g/cm^3

(c) 27 g/cm^3 (d) 2.7 g/cm^3

Ans. 2700 kg/m^3 = 2700 kg × 1000 g/1 × 10^6 cm^3 = 2700 × 1000/10^6 g/cm^3 = 2.7 g/cm^3

Therefore, the correct answer is (d).

2. If the density of a liquid increases, the buoyant force will

(a) increase.

(b) remain the same.

(c) decrease.

(d) increase then decrease.

Ans. The correct answer is (a).

3. An object weighs 10 N in air. When immersed in a liquid, it weighs only 8 N. The weight of liquid displaced by the object is

(a) 2 N (b) 8 N

(c) 10 N (d) 12 N

Ans. Apparent loss in weight = Weight of the liquid displaced. Therefore, the correct answer is (a).

4. Four balls A, B, C and D displace 12 mL, 24 mL, 5 mL and 18 mL of a liquid, respectively, when immersed completely. The ball that will undergo the maximum apparent loss in weight will be

(a) A (b) B

(c) C (d) D

Ans. The greater the weight of the liquid displaced, the greater is the apparent loss in weight. Since the liquid is the same in all four cases here, the greater the volume, the greater is the weight. Therefore, the correct answer is (b).

5. When an object is weighed in a liquid, the loss in its weight depends upon

(a) volume of the object.

(b) mass of the object.

(c) shape of the object.

(d) centre of gravity of the object.

Ans. The loss in weight depends upon the volume of liquid displaced. The volume of liquid changes with the volume of the object. Therefore, the correct answer is (a).

6. An object floats with 1/3rd of its volume outside water and 3/4th of its volume outside another liquid. If the density of water is 1000 kg/m^3, the density of the other liquid is

(a) $\frac{9}{4} \times 10^3$ kg/m^3 (b) $\frac{4}{9} \times 10^3$ kg/m^3

(c) $\frac{8}{3} \times 10^3$ kg/m^3 (d) $\frac{7}{4} \times 10^3$ kg/m^3

Ans. The weight of water of volume equal to 2/3 of the volume of the object = the weight of the liquid of volume equal to 1/4 of the volume of the object

2/3 V × 1000 kg/m^3 = 1/4 V × density of the liquid

or density of the liquid = 8/3 × 1000 kg/m^3

Therefore, the correct answer is (c).

7. An empty tin container with its mouth closed has an average density equal to that of liquid A. The container is taken 2 m below the surface of liquid A and is then left there. What happens next?

(a) The container will bounce back to the surface.

(b) The container will remain where it is left.

(c) The container will sink further.

(d) Nothing can be said with the given data.

Ans. The correct answer is (a).

Very Short Answer Type Questions

8. State the principle on which the working of a hydrometer and a lactometer is based.

Ans. Both the hydrometer and the lactometer are based on the Archimedes' principle.

9. The relative density of glycerine is 1.3. State its density in SI and CGS units.

Ans. Relative density = density of substance/density of water

or density of substance = 1000 kg/m^3 × 1.3 = 1300 kg/m^3 = 1.3 g/cm^3

10. Two equal weights of unequal volume are balanced in air. If they are completely immersed in water, do they remain balanced? Why?

Ans. No, they will not remain balanced as they will displace water of different weights. The object with greater volume will appear to be lighter inside the water.

11. A piece of cork of mass 10 g is floating on the surface of water. If a spring balance is attached to the cork, what would be the reading on the balance?

Ans. Since there is no net force acting on the cork in the vertical direction, the reading of the spring balance will be 0.

12. An object weighs 10.5 N in air and 9 N when fully immersed in water. How much is the buoyant force on the object?

Ans. Buoyant force = 10.5 N – 9 N

= 1.5 N

Short Answer Type-I Questions

13. It is easier to lift a heavy stone under water than in air. Explain.

Ans. This is because under water there is an apparent loss in weight of the stone that is equal to the weight of the volume of water displaced by the stone.

14. Why does an egg shell sink in fresh water but float in a strong solution of salt?

Ans. The greater the density of the liquid, the higher the buoyant force exerted by it. A strong solution of salt has a density much higher than fresh water, so the buoyant force acting in the upward direction is greater in a salt solution and, hence the egg shell floats in it.

15. An object of mass 40 g has a volume of 80 cm^3. Will the object float in water? Why?

Ans. Volume of water displaced = 80 cm^3

Weight of water displaced = 80 cm^3 × 1 g/cm^3

= 80 g

Since the upward buoyant force acting on the object (80 × g) is greater than the weight of the object (40 × g), it will float in water.

16. A raft of wood (density 600 kg/m^3) of mass 120 kg floats in water. How much weight can be put on the raft to make it just sink?

Ans. Volume of the raft = $\frac{\text{mass}}{\text{density}}$

= 120 kg/600 kg/m^3

= 0.2 m^3

Volume of the water displaced by the raft = 0.2 m^3

Weight of the water displaced by the raft

= 0.2 m^3 × 1000 kg/m^3

= 200 kg

Extra mass that can be put on the raft to make it just sink = 200 kg – 120 kg = 80 kg

Weight that can be put on the raft to make it just sink = 80 kg × 9.8 m/s^2 = 784 N

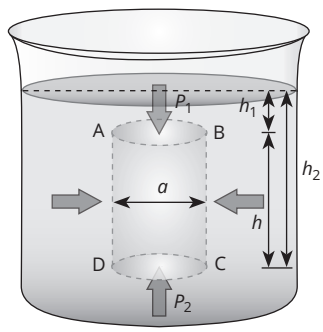
17. Rajiv and Faisal are friends who notice two objects that have undergone the same loss in weight when immersed in water completely. Rajiv tells Faisal that the two objects will have equal weights in air too. Faisal says that this is not necessary. Which of the two friends is right, and why?

Ans. The loss in weight when immersed in water depends upon the volumes of the objects. Therefore, if the two objects are balanced in water, this is because of their equal volume. We cannot say anything about their weights in the air. Faisal is correct.

Short Answer Type-II Questions

18. Derive mathematically that the magnitude of buoyant force acting on an object is equivalent to the liquid displaced by the immersed part of the object.

Ans. Consider a cylindrical object ABCD of height h and cross-sectional area a completely immersed in a liquid of density ρ. let the upper surface AB of the object be at a depth h_1 below the free surface of the liquid and the lower surface CD be at a depth h_2 below the free surface of the liquid.



At depth h_1, the downward pressure on AB,

$$P_1 = h_1 \times \rho \times g$$

At depth h_2, the upward pressure on CD,

$$P_2 = h_2 \times \rho \times g$$

Net upward pressure in the upward direction,

$$P = (h_2 - h_1) \times \rho \times g$$

$$= h \times \rho \times g$$

Force = Pressure × area

Therefore, buoyant force = hρg × a = $ah\rho g$ = $V\rho g$, where V is the volume of the liquid displaced by the object

Now, V × ρ = mass (m) and mass × g = weight (W)

Therefore, buoyant force = W

Thus, buoyant force is equal to the weight of the liquid displaced by the object.

19. Joseph buys 4 bottles of milk every morning, each bottle containing 1 litre. The weight of an empty bottle is 400 g. If the relative density of milk is 1.03, what total weight does Joseph carry home each morning?

Ans. 1 litre = 0.001 m^3,

density of milk = 1.03 × 1000 kg/m^3

Therefore, mass of 1 litre of milk

= 0.001 m^3 × 1.03 × 1000 kg/m^3

= 1.03 kg

Mass of 1 bottle along with the milk in it

= 1.03 kg + 0.4 kg = 1.43 kg

Mass of 4 bottles = 4 × 1.43 kg = 5.72 kg, which is the total weight carried by Joseph every morning.

20. You have four liquids – water, mercury, glycerine and olive oil. The densities of the four are, respectively, 1000 kg/m^3, 13600 kg/m^3, 1300 kg/m^3 and 900 kg/m^3. Theoretically, if you had to stack them in a glass cylinder one over the other, what would be the order in which you will do it, starting from bottom to top? What is the theory behind this?

Ans. The order from bottom to top will be mercury-glycerine-water-olive oil. The theory behind this is that a substance of lower density floats over another substance of higher density.

Long Answer Type Questions

21. An object weighs 700 gf in air and 500 gf when immersed completely in water. Find

(a) the loss of weight of the object, and

(b) the buoyant force acting on the object.

Ans. (a) The loss of weight of the object

= Actual weight – apparent weight in water

= 700 gf – 500 gf = 200 gf

(b) The buoyant force acting on the object = the apparent loss of weight of the object = 200 gf

22. For the principle of floatation, let W be the weight of an object and T be the buoyant force or upthrust. What will happen in the following situations when the object is immersed in water?

(a) $T > W$ (b) $W > T$

(c) $T = W$

Ans. (a) The object will float partially above the surface of the water.

(b) The object will sink in the water.

(c) The object will float just below the surface of the water.

Higher Order Thinking Skills (HOTS) Questions

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1. Two objects with masses m and $2m$ are separated by a distance r. They exert a gravitational force of F on each other. What happens to F if the all the air in the space between the two objects is removed and they are placed in complete vacuum?

Ans. The gravitational force between two objects does not depend on the medium or the lack of medium between them. As we have seen in the case of calculating gravitational force between heavenly bodies, the absence of air has no bearing on the calculations. Thus, the gravitational force between these two objects will still be F.

2. If the masses of two objects are doubled and the separation between them is halved, what is the effect on the gravitational force between them?

Ans. Original force, $F = \frac{Gm_1m_2}{r^2}$

Force after the changes, $F' = \frac{G(2m_1)(2m_2)}{(r/2)^2}$

$= \frac{16\ Gm_1m_2}{r^2} = 16\ F$

Therefore, the gravitational force increases 16 times.

3. If earth had twice the radius as it does now, but had the same mass, what would happen to the value of g?

Ans. $g \propto \frac{1}{R_e^2}$

If R_e is doubled, g becomes $1/4^{th}$ of its original value.

4. If the force of the earth on the moon vanishes suddenly, what will be the path of the moon (assuming that no other celestial body affects it)? Give reasons.

Ans. The earth's gravitational force is the main force acting on the moon that makes it move in a circular orbit around the earth. If this force were to vanish, in the absence of any other force, the moon will move in a straight line with the velocity it has at the time the force vanishes. This is in keeping with Newton's first law of motion.

5. The acceleration due to gravity for falling objects is taken to be a constant. How is this justified in view of the fact that the distance of a falling object from the earth's surface keeps changing?

Ans. The effect of the changing distance of an object is not taken into account because it is negligible when compared to the earth's radius (more than 6300 km).

6. Suppose the scientists at ISRO have found a new planet that has twice the mass and twice the radius as that of earth. What would be the value of acceleration due to gravity at its surface?

Ans.

$$g' = \frac{G2M_e}{(2R_e)^2}$$

$$= \frac{1}{2} \times \frac{GM_e}{R_e^2}$$

$$= \frac{1}{2} \times g = \frac{1}{2} \times 9.8 \text{ m/s}^2$$

$$= 4.9 \text{ m/s}^2$$

7. What is the source of the centripetal force required by a planet to revolve around the sun? On what factors does this force depend?

Ans. The source of the centripetal force is the gravitational attraction force of the sun on the planet. The force depends on the masses of the sun and the planet and the distance between their centres.

8. A ball thrown upwards with a velocity u is free to move under gravity alone. Show that it may go to a maximum height $h = u^2/2g$ before falling back.

Ans. For the vertically upward motion, the acceleration of the object is $-g$.

We know that final velocity, $v^2 = u^2 + 2as$

If the maximum height is h where the velocity of the ball becomes 0, we have

$$0 = u^2 + 2 \times (-g) \times h$$

or $$h = u^2/2g$$

9. We know that density = mass/volume. Calculate the average density of the earth in terms of g, G and R, assuming that earth is a perfect sphere.

Ans.

$$M = \text{volume} \times \text{density} = \frac{4}{3}\pi R^3 \rho$$

$$g = \frac{GM}{R^2}$$

$$= \frac{G\left(\frac{4}{3}\pi R^3 \rho\right)}{R^2}$$

$$= \frac{4}{3}\pi GR\rho$$

or $$\rho = \frac{3g}{4 \neq GR}$$

10. When an object floating in water is pressed down a little, which of these two will increase – weight or upthrust?

Ans. When an object floating in water is pressed down a little, it will displace more water. This will increase the upthrust.

11. State whether upthrust will increase or decrease if:

(a) the volume of the solid in the liquid increases.

(b) the density of the liquid in which the solid is immersed decreases.

Ans. (a) If the volume of the solid in the liquid increases, it means more liquid is being displaced. Therefore, the upthrust will increase.

(b) If the density of the liquid decreases, the upthrust also decreases.

Self-Assessment

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Multiple-Choice Questions

1. The gravitational force of attraction between any two objects does not depend upon

(a) masses of the objects.

(b) distance between the objects.

(c) size and shape of the objects.

(d) all the three above

Ans. The correct answer is (c).

2. Two bodies of masses 1 quintal each are separated by 1 metre. The force of attraction between them is

(a) 6.67×10^5 N (b) 6.67×10^{-5} N

(c) 6.67×10^9 N (d) 6.67×10^{-9} N

Ans. 1 quintal = 1000 kg

$$\text{Force} = \frac{\left(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \times 1000 \text{ kg} \times 1000 \text{ kg}\right)}{(1 \text{ m})^2}$$

$= 6.67 \times 10^{-5}$ N

Therefore, the correct answer is (b).

3. The earth attracts a body of mass 2 kg on its surface with a force of

(a) 9.8 N

(b) 19.6 N

(c) 6.67×10^{-11} N

(d) $2 \times 6.67 \times 10^{-11}$ N

Ans. Earth's mass = 6×10^{24} kg and radius is 6371 km

$$\text{Force} = \frac{\left(6.67 \times 10^{-11} \text{ N m}^2/\text{kg}^2 \times 6 \times 10^{24} \text{kg} \times 2 \text{ kg}\right)}{(6371000 \text{ m})^2}$$

= 19.7 N, which is close to option (b).

4. A stone dropped from a building takes 4 s to reach the ground. The building's height and the stone's velocity on hitting the ground are

(a) 78.4 m, zero

(b) 78.4 m, 39.2 m/s

(c) 80.4 m, 39.2 m/s

(d) 80.4 m, 19.6 m/s

Ans.

$$v = 0 + 9.8 \text{ m/s}^2 \times 4 \text{ s}$$

$$= 39.2 \text{ m/s}$$

$$h = 0 \times 4 + \frac{1}{2} \times 9.8 \text{ m/s}^2 \times (4 \text{ s})^2$$

$$= 78.4 \text{ m}$$

The correct answer is (b).

5. Acceleration due to gravity on the surface of earth is g. If g' is acceleration due to gravity at a height h above the surface of the earth, then

(a) $g' = g$ (b) $g' > g$

(c) $g' < g$ (d) $g' = 0$

Ans. The greater the distance from the surface of the earth, the lower is the value of acceleration due to gravity. Therefore, the correct answer is (c).

6. The relative densities of four liquids A, B, C and D are 1.24, 1.0, 0.76 and 11.3, respectively. If an object is floated in each of these liquids one by one, in which liquid will it float with its maximum volume submerged under the surface of the liquid?

(a) A (b) B

(c) C (d) D

Ans. The lower the density of the liquid, the greater is the submerged part of the solid being floated in it. Since the lowest density in this group is of liquid C, the correct answer is (c).

7. An object of weight W_1 displaces an amount of water W_2 when immersed in a container filled with the liquid. If the object floats,

(a) $W_1 > W_2$

(b) $W_1 = W_2$

(c) $W_1 < W_2$

(d) any of (a), (b) and (c) are possible

Ans. For the object to float, its weight has to be equal to the buoyant force, which is the weight of the water displaced by it. Therefore, the correct answer is (b).

Assertion–Reason Type Questions

For question numbers 8 to 17, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of the assertion.

(b) Both A and R are true but R is not the correct explanation of the assertion.

(c) A is true but R is false.

(d) A is false but R is true.

8. **Assertion:** If the distance between the centres of two bodies is doubled, the gravitational force acting between them becomes one-fourth.
Reason: Gravitational force is inversely proportional to the square of the distance between the centres of the two bodies.

Ans. (a)

9. **Assertion:** The value of the Universal Gravitational Constant on moon is one-sixth of its value on earth.
Reason: G is a scalar quantity.

Ans. (d)

10. **Assertion:** Acceleration due to gravity experienced by an object is independent of the mass of the object.
Reason: Acceleration due to gravity is a constant.

Ans. (c)

11. **Assertion:** The magnitude of the acceleration due to gravity is the lowest at the equator.
Reason: The radius of the earth is the greatest at the equator.

Ans. (a)

12. **Assertion:** In real-life, a large sheet of cloth and a piece of rock with the same mass take different times to reach the ground when released from the height of 50 m.
Reason: Gravitational force is not the only force acting on objects when they are dropped from a height.

Ans. (a)

13. **Assertion:** A blunt knife is not as effective in cutting vegetables as a sharp-edged knife is.
Reason: The same magnitude of force when applied over a smaller area results in a large amount of pressure.

Ans. (a)

14. **Assertion:** For the same combination of a solid object and a fluid, the object will experience greater buoyant force in lower temperature conditions.
Reason: Generally, the density of a fluid increases with decrease in temperature.

Ans. (d)

15. **Assertion:** An object immersed in a liquid weighs more than it would outside the liquid.
Reason: When an object is immersed in a liquid, an upward buoyant force acts on it.

Ans. (d)

16. **Assertion:** An object with volume 25 cm^3 and mass 50 g will float on the surface of water.
Reason: An object with density lower than the density of water will float on the surface of water.

Ans. (d)

17. **Assertion:** When ice is placed in water, about nine-tenths of the ice stays below the water surface.

Reason: The relative density of ice is 1.9.

Ans. (c)

Source-based/Case-based/Passage-based/ Integrated Assessment Questions

Answer questions on the basis of your understanding of the following passages and the related studied concepts. (any four)

18. As drones have become more advanced and affordable, the sport of drone cricket ball catching has become popular in some parts of the world. In the sport, a drone carries a cricket ball to a specific height and drops it vertically. The drone's height is increased progressively until there is only one player who can catch the ball. The first Drone Catch World Cup was organised in England, at the famous Wormsley Cricket Ground, in July 2019. The goal was to beat the world record for the highest cricket ball catch created by Australian wicket keeper Alyssa Healy earlier in 2019. She had caught a ball dropped from 82.5 m. At the world cup, the new world record was created by UK's Sam Norman, who caught a ball released from 89.9 m. The prize included a hand-crafted bat from Gray-Nicolls, the bat-makers for top players like Alistair Cook.

I. (a) If Norman caught the ball at a height of 1.7 m from the ground, what was the velocity of the ball when it was caught by him for the world record? [Assume no air resistance and g = 10 m/s^2]

Ans. 42 m/s

(b) What would have been the velocity of the ball if it would have been a tennis ball instead of a cricket ball?

Ans. 42 m/s

(c) What would the velocity be if it was a cricket ball but the ground was on a planet with acceleration due to gravity half of that of earth?

Ans. 29.7 m/s

(d) What is the shape and slope of the velocity–time graph for the ball in (a)?

Ans. Straight inclined line, slope = 10 m/s^2

II. (a) A cricket ball is thrown vertically upwards with a velocity of u, the greatest height h to which it will rise before falling back is given by

(i) u/g (ii) $u^2/2g$

(iii) u^2/g (iv) $u/2g$

Ans. (ii) $u^2/2g$

(b) A cricket ball is dropped vertically using a drone and it reaches the ground after 2.5 seconds. What is the height of drone at the moment when it is dropped (Take g = 9.8 m/s^2)?

(i) 30.6 m (ii) 10.2 m

(iii) 9.8 m (iv) 24 m

Ans. (i) 30.6 m

(c) A cricket ball is thrown vertically upwards. It reaches a maximum height of 5 m. What was the initial speed of the ball (Take g = 10 m/s^2)?

(i) 5 m/s (ii) 10 m/s

(iii) 20 m/s (iv) 9.8 m/s

Ans. (ii) 10 m/s

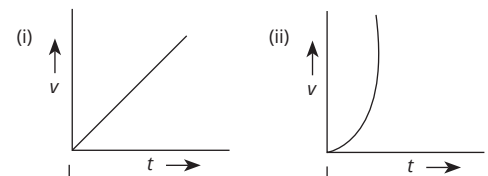
(d) If Norman caught the ball at a height of 1.7 m from the ground, what would the velocity be if it was a cricket ball but the ground was of the moon with acceleration due to gravity one-sixth that of earth (Take g_m = 1.6 m/s^2)?

(i) 10 m/s (ii) 8.4 m/s

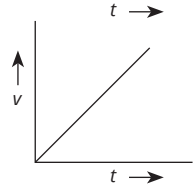
(iii) 16.8 m/s (iv) 0 m/s

Ans. (iii) 16.8 m/s

(e) An object is dropped from rest. Its v–t graph is



Ans. (i)



19. Deepsea Challenger is a deep-diving submersible designed in Australia in 2012 with the specific purpose of reaching the bottom of Challenger Deep, the deepest-known point on Earth. Located in the Pacific Ocean, Challenger Deep is at the southern end of the Mariana Trench and has a depth of about 10,900 km. To construct Deepsea Challenger, the lead engineer, Ron Allum, created several new materials, including a specialized foam of specific density 0.7.

This foam comprises about 70% of the submarine's volume and gives it the strength to withstand the substantial compressive forces at the bottom of the ocean. The first solo dive to Challenger Deep was carried out by the famous film director James Cameron on 26 March 2012, when he reached the location in Deepsea Challenger.

I. (a) If the density of ocean water is 3% higher than that of water, what is the pressure experienced by any submarine at Challenger Deep?

Ans. 3.2×10^9 Pa

(b) As the Deepsea Challenger went lower in the ocean, did the water surrounding it get colder or warmer? Why?

Ans. Colder. Cold water has higher density and so sinks below water that is warmer.

(c) If the strongest submarines used by naval forces can withstand a maximum pressure of 2.06×10^7 Pa, what is the maximum depth they can reach in ocean water?

Ans. 2.04 km

(d) If a solid block made of the foam designed by Ron Allum is placed on the surface of fresh water, what percentage of the block will be below the surface of water?

Ans. 70%

II. (a) What is the depth of the Challenger Deep?

(i) About 10,900 km
(ii) About 32,000 km
(iii) About 11,900 km
(iv) About 15,900 km

Ans. (i) About 10,900 km

(b) The specific density of the material used to construct the Deepsea Challenger was

(i) 1.7 (ii) 2.7
(iii) 0.7 (iv) 1.2

Ans. (iii) 0.7

(c) A metal in which even iron can float is

(i) manganese. (ii) mercury.
(iii) sodium. (iv) magnesium.

Ans. (ii) mercury.

(d) The relative densities of four liquids A, B, C and D are 1.26, 1.0, 0.84 and 13.6 respectively. An object is floated in all these liquids one by one. In which liquid will the object float with its maximum volume submerged under the liquid?

(i) A (ii) B
(iii) C (iv) D

Ans. (iii) C

(e) The Mariana Trench is located in

(i) the western Pacific Ocean.
(ii) the eastern Pacific Ocean.
(iii) the Bay of Bengal.
(iv) the Atlantic Ocean.

Ans. (i) the western Pacific Ocean.

Very Short Answer Type Questions

20. An object of weight 150 N is floating in a liquid. What is the magnitude of buoyant force acting on it?

Ans. The buoyant force = weight of the object = 150 N

21. Can gravitational force be repulsive in nature?

Ans. No, gravitational force is always attractive in nature.

22. When a spring balance holding a mass is allowed to fall freely, what reading will it show?

Ans. It will show a zero reading.

23. The density of an object is 700 kg/m^3. Will it sink or float when dipped in a container of water, if density of water is 1000 kg/m^3?

Ans. Since the density of the object is less than the density of water, the object will float.

Short Answer Type-I Questions

24. You buy a box full of apples of weight *W* at a town near the equator. You take this bag to a snow-covered town near the North Pole. Will the box's weight as shown in a balance be less than *W* or greater than *W*? Why?

Ans. Since the value of acceleration due to gravity is slightly lower at the poles than it is at the equator, for the same mass, the *W* noted at the equator will appear to be greater than *W* at North Pole.

25. Why do we neglect gravitational forces exerted on a falling stone by nearby trees while calculating its acceleration?

Ans. Gravitational force is directly proportional to the mass of the two objects involved. Since the mass of the earth is much greater compared to that of any other object on the earth's surface, the effect of the gravitational force due to other objects is negligible compared to the gravitational force due to earth.

26. The gravitational force between two objects is 100 N. How should the distance between the two objects be changed so that the force between them becomes 50 N?

Ans. Given, $100\ \text{N} = \dfrac{Gm_1m_2}{r^2}$ ...(i)

If for distance r', the force becomes 50 N, we have

$$50\ \text{N} = \frac{Gm_1m_2}{r'^2} \quad \text{...(ii)}$$

Dividing (i) by (ii),

$$2 = \frac{\left(1/r^2\right)}{\left(1/r'^2\right)} = \frac{r'^2}{r^2}$$

or $r' = r \times \sqrt{2}$

Therefore, the distance has to be increased by $\sqrt{2}$ times.

27. An iron cube of side 10 cm is kept on a horizontal table. If the density of iron is 8000 kg/m^3, find the pressure on the portion of the table where the cube is kept. (Take g = 10 m/s^2)

Ans. $$\text{Pressure} = \frac{\text{Weight}}{\text{area}}$$

$$= \frac{\left(\text{volume} \times \text{density} \times g\right)}{\text{area}}$$

$$= \frac{\left(1000 \times 10^{-6}\ \text{m}^3 \times 8000\ \text{kg/m}^3 \times 10\ \text{m/s}^2\right)}{\left(100 \times 10^{-4}\ \text{m}^2\right)}$$

= 8000 Pa

Short Answer Type-II Questions

28. A cube of side 5 cm immersed in water experiences a buoyant force of F. if each side of the cube is reduced to 4 cm and then immersed in water, what is the buoyant force experienced by the cube in terms of F?

Ans. We know that the buoyant force on a cubical object

= Weight of water immersed by the cube

= volume × density of water × g

= l^3 × density of water × g,

where l is the side of the cube

$$F'/F = \frac{\left(l'^3 \times \text{density of water} \times g\right)}{\left(l^3 \times \text{density of water} \times g\right)}$$

$$= \left(\frac{l'}{l}\right)^3$$

$$= \left(\frac{4\ \text{cm}}{5\ \text{cm}}\right)^3 = \frac{64}{125}$$

or $F' = 0.512\ F$

29. A firecracker is fired. It rises to a height of 1000 m. Find the (a) velocity with which it was released, and (b) time taken by it to reach the highest point.

Ans. (a) v = 0. Using $v^2 = u^2 - 2gh$

$$u^2 = 2 \times 9.8\ \text{m/s}^2 \times 1000\ \text{m}$$

or u = 140 m/s

(b) $v = u - gt$

or $$t = \frac{140\ \text{m/s}}{9.8\ \text{m/s}^2}$$

= 14.3 s

30. Suppose an astronaut lands on the moon and drops an object from a height of 7.35 m from the surface. How much time will the object take to reach the moon's surface?

Ans. The value of g on moon's surface is 9.8/6 m/s^2 = 1.63 m/s^2

$$v^2 = u^2 + 2 \times g \times h$$

$$= 0 + 2 \times 1.63\ \text{m/s}^2 \times 7.35\ \text{m}$$

or v = 4.9 m/s

$$v = u + gt$$

or $$t = \frac{v}{g}$$

$$= \frac{4.9\ \text{m/s}}{1.63\ \text{m/s}^2} = 3\ \text{s}$$

31. As one moves to a place 3,200 km above the earth's surface, the acceleration due to gravity reduces to 4/9 of its value on earth. Calculate the radius of earth from this data.

Ans. $$\frac{GM_e}{\left(R_e + 3.2 \times 10^6\ \text{m}\right)^2} = \frac{4}{9} \times \frac{GM_e}{R_e^2}$$

or $$\frac{1}{\left(R_e + 3.2 \times 10^6\ \text{m}\right)} = \frac{2}{3} \times \frac{1}{R_e}$$

or $3R_e = 2R_e + 6.4 \times 10^6$ m

or $R_e = 6.4 \times 10^6$ m = 6,400 km

Long Answer Type Questions

32. Ball A is dropped from a height of 40 m and simultaneously another ball B is thrown upwards from the ground with a speed of 40 m/s. When and where do they meet?

Ans. Suppose that the two balls meet at a height h above the ground.

For ball A:

$$(40 - h) = 0 + \frac{1}{2}gt^2 = \frac{1}{2}gt^2$$

For ball B:

$$h = 40 \times t - \frac{1}{2}gt^2$$

or $\frac{1}{2}gt^2 = 40t - h$

Therefore,

$40 - h = 40t - h$

or $t = 1\ s$

$40 - h = \frac{1}{2} \times 9.8\ m/s^2 \times (1\ s)^2$

or $h = 40 - 4.9 = 35.1\ m$

The balls meet 1 s after they are released at a height 35.1 m above the ground.

33. A stone is dropped from a cliff at 2:30:30 pm. (hour: minute: second). Another stone is dropped from the same point at 2:30:31 pm. Find the separation between the stones at

(a) 2:30:31 pm

(b) 2:30:35 pm

Ans. (a) The separation at 2:30:31 is the distance travelled by the first stone in 1 s

$\Delta s = 0 + \frac{1}{2} \times 9.8\ m/s^2 \times (1\ s)^2$

$= 4.9\ m$

(b) The separation at 2:30:35 is the difference in distance travelled by first stone in 5 s and the second stone in 4 s.

$\Delta s = 0 + \frac{1}{2} \times 9.8\ m/s^2 \times (5\ s)^2$

$- [0 + \frac{1}{2} \times 9.8\ m/s^2 \times (4\ s)^2]$

$= 4.9\ m/s^2 \times (25\ s^2 - 16\ s^2) = 44.1\ m$

34. An elephant weighing 40,000 N stands on one foot of area 1000 cm^2, while a girl weighing 400 N stands on one stiletto heel of area 1 cm^2.

(a) Which of the two, the elephant or the girl, exerts a larger force on the ground and by how much?

(b) Which of the two exerts a larger pressure on the ground?

(c) What is the ratio of pressure exerted by the girl to the pressure exerted by the elephant?

Ans. (a) The elephant exerts the larger force by 40000 N – 400 N = 39600 N

(b) Pressure due to elephant $= \frac{40000\ N}{0.1\ m^2}$

$= 4 \times 10^5\ Pa$

Pressure due to the girl $= \frac{400}{10^{-4}\ m^2} = 4 \times 10^6\ Pa$

The girl exerts a larger pressure.

(c) Ratio $= \frac{4 \times 10^6\ Pa}{4 \times 10^5\ Pa} = 10 : 1$

Let's Compete

(Page 75)

Multiple-Choice Questions

1. The force of attraction between two unit point masses separated by a unit distance is called

(a) gravitational potential.

(b) acceleration due to gravity.

(c) gravitational field strength.

(d) universal gravitational constant.

Ans. $F = \frac{G(1\ kg)(1\ kg)}{(1\ m^2)} = G$

Therefore, the correct answer is (d).

2. The gravitational force between two objects is *F*. If the mass of one object is halved and the other is reduced to one-third without changing the distance between them, the gravitational force between them becomes

(a) $\frac{F}{6}$ (b) $\frac{F}{4}$

(c) $2F$ (d) $6F$

Ans. $F = \frac{Gm_1m_2}{r^2}$

$F' = \frac{G(m_1/2)(m_2/3)}{r^2}$

$= \frac{1}{6} \times \frac{Gm_1m_2}{r^2} = \frac{F}{6}$

Therefore, the correct answer is (a).

3. When an object is thrown up, the force of gravity is

(a) in the upward direction.

(b) in the downward direction.

(c) zero.

(d) in the horizontal direction.

Ans. The correct answer is (b).

4. The acceleration due to gravity near the moon's surface is

(a) approximately equal to that near the earth's surface.

(b) approximately six time that near the earth's surface.

(c) approximately one-sixth of that near the earth's surface.

(d) slightly greater than that near the earth's surface.

Ans. The correct answer is (c).

5. The force acting on a human being due to the earth has a magnitude F_e and that acting on the earth due to the human being is F_h. Then,

(a) $F_e = F_h$ (b) $F_e < F_h$

(c) $F_e > F_h$ (d) $F_h = 0$

Ans. The correct answer is (a) because of Newton's third law of motion.

6. If a stone dropped from the edge of a roof passes a window 2 m high in 0.1 s, the distance between the roof and the top of the window is

(a) 4.85 m (b) 9.7 m

(c) 14.5 m (d) 19.4 m

Ans. Let the distance between the roof and the top of the window be x m

If t_1 is the time taken for the stone to reach the top of the window from the roof,

$$x = 0 + \frac{1}{2}gt_1^2$$

$$= \frac{1}{2}gt_1^2 \quad \text{...(i)}$$

If t_2 is the time taken for the stone to reach the bottom of the window from the roof,

$$x + 2 = 0 + \frac{1}{2}gt_2^2$$

$$= \frac{1}{2}g(t_1 + 0.1)^2 \quad \text{...(ii)}$$

Subtracting (i) from (ii),

$$2 = \frac{1}{2}g(t_1^2 + 0.01 + 0.2t_1 - t_1^2)$$

or $$\frac{4}{g} = 0.01 + 0.2t_1$$

or $$t_1 = \frac{1}{0.2}\left(\frac{4}{g} - 0.01\right)$$

$$= 1.99 \text{ s}$$

$$x = \frac{1}{2} \times 9.8 \text{ m/s}^2 \times (1.99 \text{ s})^2$$

$$= 19.4 \text{ m}$$

Therefore, the correct answer is (d).

7. According to Kepler's third law, with usual notation:

(a) T^2/R^2 = constant (b) R^2/T^3 = constant

(c) T^2/R^3 = constant (d) T^2R^3 = constant

Ans. The correct answer is (c).

8. Two stretched membranes of areas 2 cm^2 and 3 cm^2 are placed in a liquid at the same depth. The ratio of the pressures on them is

(a) 1 : 1 (b) 2 : 3

(c) 3 : 2 (d) 22 : 32

Ans. Since the pressure is same at equal depth, the correct answer is (a).

9. A body weighs 40 g in air. If its volume is 10 cm^3, in water it will weigh

(a) 30 g (b) 40 g

(c) 50 g (d) Insufficient data

Ans. Buoyant force on the body

= volume × density of water × g

= 10×10^{-6} $m^3 \times 1000$ kg/$m^3 \times 9.8$ m/s^2

= 9.8×10^{-2} N

Apparent loss in weight

$$= \frac{9.8 \times 10^{-2} \text{ N}}{9.8 \text{ m/s}^2} = 0.01 \text{ kg} = 10 \text{ g}$$

Therefore, the body's weight in water

= 40 g – 10 g = 30 g

The correct answer is (a).

10. A tank with length 10 m, breadth 8 m and depth 6 m is filled with water up to the top. If g = 10 m/s^2 and density of water = 1000 kg/m^3, the thrust on the bottom of the tank is

(a) (6 × 1000 × 10 × 80) N

(b) (3 × 1000 × 10 × 48) N

(c) (3 × 1000 × 10 × 60) N

(d) (3 × 100 × 10 × 80) N

Ans. Thrust at the bottom

= $h\rho g$ × area = 6 m × 1000 kg/m^3 × 10 m/s^2 × 80 m^2

= (6 × 1000 × 10 × 80) N

Therefore, the correct answer is (a).

Value-based Questions

(Optional) (Page 76)

1. Take a piece of thread and tie a small stone to one end of this thread. Hold the other end of the thread in your hand and whirl it around. Note the motion of the stone. Answer the following questions based on this activity.

(a) Which force is whirling the stone? What/who is providing this force?

(b) What happens when the thread breaks off suddenly or if it is let go?

(c) What values related to motivation do you learn from this activity?

Ans. (a) Centripetal force provided by our hand.

(b) Centripetal force is not available anymore, so inertia of direction takes the stone along the tangent at that instant.

(c) To remain on the right path, motivation has to be continuous.

2. The phenomenon of free fall involves an object falling down towards the earth due to earth's gravitational pull. The acceleration produced in

the object in free fall is called acceleration due to gravity, denoted by g. The value of g does not depend on the mass or the nature of the object.

(a) Convert the value of g (9.8 m/s^2) to km/h^2.

(b) Is the value of g the same on moon as it is on earth?

(c) What values of life do you learn from the concept of free fall?

Ans. (a) $9.8\ \text{m/s}^2 = 9.8\ \text{m/s}^2 \times \left(\frac{1\ \text{km}}{1000\ \text{m}}\right) \times \frac{(3600\ \text{s} \times 3600\ \text{s})}{1\ \text{h}^2}$

$= 1.27 \times 10^5\ \text{km/h}^2$

(b) No, it is 1/6$^{\text{th}}$ of the value on earth.

(c) Without checks and balances, each of us can face a free fall situation. In the absence of control or discipline, irrespective of the nature of the individual, he or she can face a downfall.

3. Whenever an object is thrown up with a certain velocity, the upward motion is opposed by the gravitational pull of the earth and also the resistance of air. Therefore, velocity of the object goes on decreasing, till it reaches a point where the velocity becomes zero. From this height, the object begins to fall downwards under the action of gravity.

(a) At the highest point, what is the acceleration experienced by the object?

(b) What is the maximum height attained by an object thrown upwards with a velocity of 19.6 m/s?

(c) What values do you learn from this concept?

Ans. (a) 9.8 m/s^2 in the downward direction

(b) Maximum height = $\frac{u^2}{2g}$

$$= \frac{(19.6\ \text{m/s})^2}{(2 \times 9.8\ \text{m/s}^2)} = 19.6\ \text{m}$$

(c) Just as an object has to work against gravity to rise upwards, every individual has to work against obstacles to rise in life. Consistent and right efforts can help surmount all impediments.

4. Asif planned to go to Kashmir during winter vacations to enjoy the snow. When his friend Raghav came to know of Asif's plan, he gave his long flat skis, which his aunt had brought him from abroad, to Asif for the duration of the vacation.

(a) Why do skiers need flat skis to slide over snow?

(b) What values do we learn from Raghav?

Ans. (a) Larger the area of cross-section, lower is the pressure on the snow. Flat skis prevent skiers from going deep into the snow while walking.

(b) Friendship is more important than material possessions.

5. Naveen and Paul are friends. Paul wanted to celebrate his birthday at home. He bought balloons filled with hydrogen gas and Naveen helped Paul in decorating his room with the balloons and cards.

(a) Why do balloons filled with hydrogen rise up in the air?

(b) What qualities can we learn from Naveen?

Ans. (a) Hydrogen is less dense than air, so it floats in air.

(b) We should always be ready to help our friends.

6. Reena and Prabhjot were holidaying with friends in Goa. When Reena wanted to go into the sea water for a swim, Prabhjot recalled something she had studied in her science class and advised Reena to take a rubber tube along with her for safety.

(a) How does a rubber tube make swimming in water safer?

(b) What qualities can we learn from Prabhjot?

Ans. (a) The air in the tube is less dense than water and helps in floating.

(b) We should learn to apply knowledge from classroom to the real world.

11

Work and Energy

Checkpoint (Page 81)

1. A bullet is fired into a wall with a velocity of 50 m/s. If the bullet stops at a distance of 10 cm inside the wall, the retardation provided by the wall is

(a) 1,250 m/s^2 (b) 12.5 km/h^2

(c) 12.5 km/s^2 (d) 12,500 m/h^2

Ans. u = 50 m/s; v = 0; s = 10 cm = 0.1 m

Using $v^2 = u^2 - 2as$,

$0 = (50 \text{ m/s})^2 - (2 \times a \times 0.1 \text{ m})$

or $a = \frac{2500}{0.2}$ m/s^2

$= 12500$ m/s^2

$= 12.5$ km/s^2

Therefore, the correct answer is (c).

2. The blades of a regular ceiling fan are moving at constant speed. Which of these statements is true about the fan?

(a) It is in circular motion only.

(b) It is in periodic motion only.

(c) It is in both circular and periodic motion.

(d) It is in neither circular nor periodic motion.

Ans. The correct answer is (c).

3. The displacement of an object starting from rest in uniform motion is given by the equation $s = (0 \times 5) - 4.9 \times 25$. What is the likely value of the object's acceleration based on this equation?

(a) 5 m/s^2 (b) 4.9 m/s^2

(c) – 4.9 m/s^2 (d) – 9.8 m/s^2

Ans. The given equation is $s = (0 \times 5) - 4.9 \times 25$

Since the object starts from rest, u = 0

Comparing the above equation with

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

we can see that

$t = 5$ s

Therefore, $\frac{1}{2} \times a = -4.9$

or $a = -4.9 \times 2$

$= -9.8$ m/s^2

Therefore, the correct answer is (d).

4. Classify the following properties based on whether they are scalar or vector in nature:

(a) Mass (e) Time

(b) Acceleration (f) Weight

(c) Momentum (g) Displacement

(d) Density (h) Speed

Ans. (a) Mass - Scalar

(b) Acceleration - Vector

(c) Momentum - Vector

(d) Density - Scalar

(e) Time - Scalar

(f) Weight - Vector

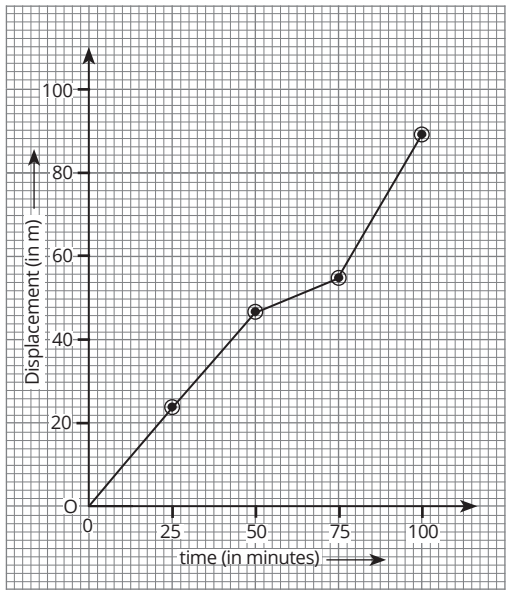
(g) Displacement - Vector

(h) Speed - Scalar

5. The following table gives the pattern of displacement of an object that starts moving from rest at 10:00 am in a straight line. What can you say about the nature of the object's velocity?

Time	10:00 am	10:25 am	10:50 am	11:15 am	11:40 am
Displacement (*m*)	0	22	47	55	89

Ans. Note that the time increases uniformly in intervals of 25 minutes. The displacement-time graph for the data is shown below:



Since the slope is not constant, the velocity is variable.

6. A car with mass 1000 kg has to be stopped with a negative acceleration of 2 m/s^2. What should be the force between the car and the road to achieve this?

Ans. If there is no other force except the opposing force applied by the road to stop the car, the force needed is mass × acceleration
= 1000 kg × – 2 m/s^2 = – 2000 N

7. A force acts for 0.1 s on a body of mass 1.2 kg initially at rest. The force then ceases to act and the body moves through 2 m in the next one second. Find the magnitude of the force.

Ans. Let v be the velocity of the body after the force ceases to act. Since there is no acceleration acting on the body after the force ceases to act, distance covered = v × time

or $$v = \frac{2\text{ m}}{1\text{ s}} = 2\text{ m/s}$$

When the force acts on the body for 0.1 s, let the acceleration be a. The initial velocity of the body is 0.

Therefore, 2 m/s = 0 + a × 0.1

or $a = 20\text{ m/s}^2$

Thus, force = 1.2 kg × 20 m/s^2 = 24 N

8. Two mountaineering teams start from Everest base camp located at 5,380 m above sea level. Team A takes a shorter route of 7.3 km to reach the peak of Mount Everest (altitude 8,848 m). Team B takes a longer, but safer, route that is 8.1 km long. What is the displacement of each team from the base camp to the peak of the mountain?

Ans. Since displacement depends only on the initial and final points and not on the path taken to travel between the two points, the displacement for both the teams is 8848 m – 5380 m = 3468 m.

9. What is the velocity acquired by a mass just before hitting the ground when dropped from a height of 100 m? (Take g = 10 m/s^2)

Ans. u = 0, s = 100 m

$$v^2 = u^2 + 2gs$$

or $$v^2 = 0 + 2 \times 10\text{ m/s}^2 \times 100\text{ m}$$

$$= 2000\text{ m}^2/\text{s}^2$$

or $$v = 44.7\text{ m/s}$$

10. Two balls A and B of masses 3 m and 2 m, respectively, are in motion. What is the ratio of their velocities if their momenta are in the ratio 2 : 1?

Ans. Let the velocity of A be v_A and that of B be v_B

Given, $$\frac{3m \times v_A}{2m \times v_B} = \frac{2}{1}$$

or $$\frac{v_A}{v_B} = 2 \times \frac{2}{3} = 4 : 3$$

Milestone 1

(Page 85)

Multiple-Choice Questions

1. A porter holds a load of 500 N for 10 seconds. The work done by him is

(a) 50 J (b) 5000 J
(c) 500 J (d) zero

Ans. Since there is no displacement involved, the work done is 0. Therefore, the correct answer is (d).

2. The amount of 1 J is equivalent to

(a) 1 newton second.
(b) 1 newton metre square.
(c) 1 newton metre.
(d) 1 newton gram.

Ans. Work = Force × displacement

Thus, 1 J = 1 N × 1 m

Therefore, the correct answer is (c).

3. Work done in lifting an object is calculated by

(a) mass of the object × vertical distance moved
(b) force acting on the object × vertical distance moved.
(c) weight of the object × vertical distance moved
(d) none of these.

Ans. The correct answer is (c).

4. The work done on an object of mass 10 g moving in a circular path of radius 10 cm is

(a) 10 J (b) 50 J

(c) 100 J (d) 0 J

Ans. When an object moves in a circular path, the centripetal force acting on it is at right angle to the displacement of the body. Work = force × displacement × cos θ. Therefore, the correct answer is (d).

5. In case of negative work, the angle between force and displacement is possibly which of the following?

(a) 0° (b) 45°

(c) 90° (d) 135°

Ans. Among the given angles, the cosine value of 135° is negative. Therefore, the correct answer is (d).

Very Short Answer Type Questions

6. State the essential conditions needed for work to be done.

Ans. (i) A force should act on an object.

(ii) The object must be displaced in the direction of the force.

7. A stone is tied to a string and whirled in a circle. Is the work done by the weight of the stone for a small displacement zero, positive or negative?

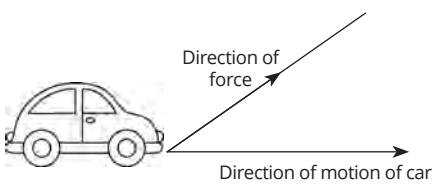
Ans. Displacement when a circle is completed by the stone is zero, and so work is zero. Therefore, the work done by the weight of the stone for small displacement, i.e. when displacement is greater than zero, is positive.

8. A child standing erect pulls a toy car with a string attached to it. With the help of a simple diagram, show

(a) the direction in which the car moves.

(b) the direction in which the force is applied.

Ans.



Short Answer Type-I Questions

9. A man weighing 70 kg carries a weight of 10 kg to the top of a tower 100 m high. What is the work done by the man in kilojoules? (g = 10 m/s^2)

Ans. The total weight carried by the man

= (70 kg + 10 kg) × 10 m/s^2

= 800 N

Work done = 800 N × 100 m

= 80000 J

= 80 kJ

10. A person pulls a block on a horizontal surface by applying a force of 5 N at an angle of 30° with the horizontal. Find the work done by this force in displacing the block through 2 m.

Ans. Work done = 5 N × 2 m × cos 30°

$= 10 \times \frac{\sqrt{3}}{2}$ J

$= 5\sqrt{3}$ J

11. An object is displaced by 5 m after a force of 10 N acts on it. If the angle between the force and the displacement is not known, what are the maximum and minimum possible values for work done?

Ans. Maximum possible value of work is when the force and displacement are in the same direction. This value is 10 N × 5 m × cos 0° = 50 J

Minimum possible value is when they are in exactly opposite directions.

This value is 10 N × 5 m × cos 180° = –50 J

Short Answer Type-II Questions

12. State with reasons if the work done in the following cases is positive or negative:

(a) Work done in pulling a string

(b) Work done in dropping a stone down

(c) Work done in throwing a ball up

(d) Work done in moving on a circular track

(e) Work done by a man in lifting a bucket out of a well with the help of a rope tied to the bucket

(f) Work done by the gravitational force when the bucket is lifted out in the above case

(g) Work done by friction on an object sliding down an inclined plane

(h) Work done by the resistive force of air on a vibrating pendulum to bring it to rest

Ans. (a) Positive, as the force and displacement are in the same direction

(b) Work done by gravity is positive as the force and displacement are downward.

(c) Work done by gravity is negative as the force is downward while displacement is upward.

(d) Work done is zero as the displacement is zero.

(e) Work done by the man is positive as force applied by him is upward as is the displacement of the bucket.

(f) Work done by the gravitational force is negative as the force acts downward while the displacement takes place upward.

(g) Work done by friction is negative as it always works opposite to the direction of displacement.

(h) Work done by the resistive force is negative as it acts in a direction opposite to the direction of displacement of the pendulum to bring it to rest.

13. A car of mass 1000 kg travelling at 30 m/s stops after a distance of 50 m, decelerating uniformly. What is the force exerted by it on the brakes? What is the work done by the brakes?

Ans. u = 30 m/s, v = 0, s = 50 m

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

or $$0 = (30 \text{ m/s})^2 + 2 \times a \times 50 \text{ m}$$

or $$a = \frac{-900}{100} \text{ m/s}^2$$

$$= -9 \text{ m/s}^2$$

Force exerted by the brakes on the car

$$= 1000 \text{ kg} \times -9 \text{ m/s}^2$$

$$= -9000 \text{ N}$$

Therefore, according to Newton's third law of motion, force exerted by the car on the brakes = 9000 N

Word done by the brakes = –9000 N × 50 m

= –450000 J

14. A car weighing 500 kg moving against a resistance of 500 N accelerates from rest to 20 m/s in 100 m. If g = 10 m/s^2, calculate the work done by the engine of the car.

Ans. u = 0, v = 20 m/s, s = 100 m

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

or $$(20 \text{ m/s})^2 = 0 + 2 \times a \times 100 \text{ m}$$

or $$a = 2 \text{ m/s}^2$$

Total force applied by the engine

$$= 500 \text{ N} + 500 \text{ kg} \times 2 \text{ m/s}^2$$

$$= 1500 \text{ N}$$

Work done by the engine

$$= 1500 \text{ N} \times 100 \text{ m}$$

$$= 150000 \text{ J}$$

Long Answer Type Question

15. Two farmers raise a sack of wheat of 100 kg to a height of 1 m and keep holding it at the same height for a few minutes. (g = 10 m/s^2)

(a) How much work is done by each farmer in lifting the sack, if each of them does equal work?

(b) How much work is done by the farmers in just holding the sack?

(c) Why do farmers get tired while holding the sack?

(d) What will be the velocity with which the sack will hit the ground if it is dropped from this height?

Ans. (a) Total work done in lifting the sack

$$= 100 \text{ kg} \times 10 \text{ m/s}^2 \times 1 \text{ m}$$

$$= 1000 \text{ N}$$

Work done by each farmer

$$= \frac{1000}{2} \text{ N}$$

$$= 500 \text{ N}$$

(b) No work is done in just holding the sack as there is no displacement involved.

(c) The farmers get tired because of application of muscular force against gravity.

(d) $$v^2 = 0 + 2 \times 10 \text{ m/s}^2 \times 1 \text{ m}$$

$$= 20 \text{ m}^2/\text{s}^2$$

or $$v = 4.47 \text{ m/s}$$

Milestone 2

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Multiple-Choice Questions

1. The amount of energy possessed by an object is equivalent to

(a) the force applied on it.

(b) its mass.

(c) the amount of work it can do.

(d) its weight.

Ans. The correct answer is (c).

2. If both mass and velocity of an object are doubled, the kinetic energy becomes

(a) four times. (b) six times.

(c) eight times. (d) ten times.

Ans. $$\text{KE} = \frac{1}{2} mv^2$$

or $$\text{KE} \propto m$$

and $$\text{KE} \propto v^2$$

Therefore, when mass is doubled, KE gets doubled and when velocity is doubled, KE becomes four times.

Therefore, the correct answer is (c).

3. A compressed spring can do work due to stored

(a) kinetic energy.

(b) elastic potential energy.

(c) gravitational potential energy.

(d) none of these

Ans. The correct answer is (b).

4. The extreme position of a simple pendulum has

(a) only kinetic energy.

(b) more kinetic and less potential energy.

(c) more potential energy and less kinetic energy.

(d) only potential energy.

Ans. At its extreme position, the simple pendulum has zero velocity and is raised by a certain height from its equilibrium position. Therefore, the correct answer is (d).

5. Two objects of unequal masses are dropped from the same height. They have equal

(a) potential energy. (b) kinetic energy.

(c) acceleration. (d) momentum.

Ans. Potential energy, kinetic energy, and momentum depend on the mass of the object. Therefore, the correct answer is (c).

6. Which one of the following energy changes involves frictional force?

(a) kinetic energy to heat energy

(b) potential energy to sound energy

(c) chemical energy to heat energy

(d) chemical energy to kinetic energy

Ans. The correct answer is (a).

Very Short Answer Type Questions

7. When the speed of a particle is doubled, how does the ratio of its kinetic energy to its momentum change?

Ans. Let the original speed be v.

$$\text{Ratio of KE to momentum} = \frac{\frac{1}{2}mv^2}{mv} = \frac{v}{2}$$

The new speed is $2v$.

$$\text{Ratio of KE to momentum} = \frac{\frac{1}{2}m(2v)^2}{m2v}$$

$$= \frac{\frac{1}{2}\times 4mv^2}{2mv}$$

$$= v$$

$$= 2\frac{v}{2}$$

Therefore, the ratio gets doubled.

8. What energy transformation takes place in a dynamo?

Ans. In a dynamo, mechanical energy gets transformed into electrical energy.

9. A photoelectric cell converts what energy into electrical energy?

Ans. A photoelectric cell converts light energy into electrical energy.

10. If negative work is done by external forces on a system, what is its effect on the energy of the system?

Ans. If negative work is done by external forces on a system, the system's overall energy decreases.

Short Answer Type-I Questions

11. A wheat bag has a mass of 200 kg. To what height should it be raised so that its potential energy may be 9800 J?

Ans. $$\text{PE} = mgh$$

or $$h = \frac{\text{PE}}{mg}$$

$$= \frac{9800\ \text{J}}{200\ \text{kg} \times 9.8\ \text{m/s}^2} = 5\ \text{m}$$

12. How fast should a man of 50 kg run so that his kinetic energy is 625 J?

Ans. $$\text{KE} = \frac{1}{2}mv^2$$

or $$v = \sqrt{\frac{2KE}{m}}$$

$$= \sqrt{\frac{2\times 625\ \text{J}}{50\ \text{kg}}}$$

$$= \sqrt{25} = 5\ \text{m/s}$$

13. A light and a heavy object have the same momentum. Which one of the two has a higher kinetic energy?

Ans. Let the mass and velocity of the lighter object be m_1 and v_1, and mass and velocity of the heavier object be m_2 and v_2, such that $m_2 > m_1$

Since their momenta are equal, $m_1v_1 = m_2v_2$

This implies that $v_1 > v_2$ and $m_1/m_2 = v_2/v_1$

$$\frac{\text{KE}_1}{\text{KE}_2} = \frac{\frac{1}{2}m_1v_1^2}{\frac{1}{2}m_2v_2^2}$$

$$= \frac{m_1}{m_2} \times \left(\frac{v_1}{v_2}\right)^2$$

$$= \frac{v_2}{v_1} \times \left(\frac{v_1}{v_2}\right)^2$$

$$= \frac{v_1}{v_2}$$

Since $v_1 > v_2$, $\text{KE}_1 > \text{KE}_2$

Short Answer Type-II Questions

14. What kind of energy transformation takes place in the following man-made objects?

(a) Solar cell

(b) Electric heater

(c) Magnetic compass

(d) Telephone
(e) Electric cell
(f) Matchstick

Ans. (a) Heat to electrical,
(b) Electrical to heat,
(c) Magnetic to mechanical,
(d) Sound to electrical,
(e) Chemical to electrical,
(f) Chemical to light

15. A boy of mass 50 kg climbs 30 steps of a staircase, each measuring 20 cm in height. Calculate the potential energy gained by the boy. (Take g = 10 m/s^2)

Ans. Total height climbed by the boy
= 30 × 20 cm
= 600 cm
= 6 m
PE = mgh
= 50 kg × 10 m/s^2 × 6 m
= 3000 J

16. A man drops a 10 kg rock from the top of a 5 m ladder. What is the rock's speed just before it hits the ground? What is its kinetic energy when it reaches the ground? (Take g = 10 m/s^2)

Ans. u = 0, s = 5 m
Using $v^2 = u^2 + 2gs$,
v^2 = 0 + 2 × 10 m/s^2 × 5 m
or v = 10 m/s
KE on reaching the ground
$= \frac{1}{2} mv^2$
$= \frac{1}{2}$ × 10 kg × (10 m/s)^2
= 500 J

17. At sea level, a nitrogen molecule in air has an average translational kinetic energy of 6.2 × 10^{-21} J. Its mass is 4.7 × 10^{-26} kg. If the molecule shoots up straight without resistance, what is the height in km it will rise to?

Ans. The molecule's kinetic energy at sea level will get converted into potential energy and will decide the maximum height it can climb to.
Therefore, mgh = initial kinetic energy
or $h = \frac{6.2 \times 10^{-21} \text{J}}{4.7 \times 10^{-26} \text{ kg} \times 9.8 \text{ m/s}^2}$
= 1.35 × 10^4 m
= 13.5 km

18. A girl having mass of 35 kg sits on a trolley of mass 5 kg. The trolley is given an initial velocity of 4 m/s by applying a force. The trolley comes to rest after travelling a certain distance.
(a) How much work is done on the trolley?
(b) How much work is done by the girl?

Ans. (a) The work done on the trolley results in its initial velocity. Therefore, its kinetic energy gives a measure of the work done on the trolley.
$\text{KE} = \frac{1}{2} mv^2$
$= \frac{1}{2}$ × (35 kg + 5 kg) × (4 m/s)^2
= 320 J
(b) There is no work done by the girl sitting in the trolley.

Long Answer Type Questions

19. An object of mass 10 kg is dropped from a height of 20 m. Calculate the potential energy and kinetic energy of the object at various heights as mentioned in the data below. Use this to show that the law of conservation of energy is held. (Take g = 10 m/s^2)

Height at which the object is located
20 m
15 m
10 m
5 m
Just above the ground

Ans. At height 20 m:
Potential energy = mgh
= 10 kg × 10 m/s^2 × 20 m
= 2000 J
Kinetic energy = 0 as velocity is zero
Total mechanical energy
= 2000 J + 0
= 2000 J
At height 15 m:
v^2 = 0 + 2 × 10 m/s^2 × 5 m
or v = 10 m/s
PE = 10 kg × 10 m/s^2 × 15 m
= 1500 J
$\text{KE} = \frac{1}{2}$ × 10 kg × (10 m/s^2)^2
= 500 J
Total mechanical energy = 1500 J + 500 J = 2000 J
At height 10 m:
v^2 = 0 + 2 × 10 m/s^2 × 10 m

or $v = 10\sqrt{2}$ m/s

$PE = 10 \text{ kg} \times 10 \text{ m/s}^2 \times 10 \text{ m}$

$= 1000 \text{ J}$

$KE = \frac{1}{2} \times 10 \text{ kg} \times (10\sqrt{2} \text{ m/s})^2$

$= 1000 \text{ J}$

Total mechanical energy = 1000 J + 1000 J = 2000 J

At height 5 m:

$v^2 = 0 + 2 \times 10 \text{ m/s}^2 \times 15 \text{ m}$

or $v = 10\sqrt{3}$ m/s

$PE = 10 \text{ kg} \times 10 \text{ m/s}^2 \times 5 \text{ m} = 500 \text{ J}$

$KE = \frac{1}{2} \times 10 \text{ kg} \times (10\sqrt{3} \text{ m/s})^2$

$= 1500 \text{ J}$

Total mechanical energy = 500 J × 1500 J = 2000 J

Thus, the total mechanical energy of the object remains 2000 J and the law of conservation of energy is held.

20. Derive the formula for kinetic energy using Newton's second law of motion.

Ans. Newton's second law of motion says that Force = mass × acceleration

or $F = m \times a$ ...(i)

Consider an object that has a force acting on it so that its velocity increases to v starting from rest in time t and the object travels by distance s

Thus, $v^2 = 0 + 2as$

or $s = \frac{v^2}{2a}$ ...(ii)

Work done by the force on the object,

$W = F \times s$

From (i) and (ii)

$W = ma \times \frac{v^2}{2a} = \frac{1}{2} mv^2$

Work done on the object gets stored in the object as kinetic energy.

Therefore, KE of the object = $\frac{1}{2} mv^2$

21. A truck of mass 5000 kg travelling at 40 m/s is brought to rest by applying brakes. The truck comes to rest after travelling 20 m after the application of brakes. What is the initial kinetic energy of the truck?

Ans. We just need to know the initial velocity of the truck to find its initial KE.

$KE = \frac{1}{2} \times 5000 \text{ kg} \times (40 \text{ m/s})^2$

$= 4 \times 10^6 \text{ J}$

Milestone 3

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Multiple-Choice Questions

1. Labourer A completes 500 J of work in 10 minutes, while labourer B completes 600 J of work in 20 minutes. What can be said about the powers of the two labourers?

(a) Labourer A has more power than labourer B

(b) Labourer B has more power than labourer A

(c) Both have the same power

(d) Data is insufficient to comment

Ans. Power of labourer A = $\frac{500 \text{ J}}{600 \text{ s}} = \frac{5}{6}$ W

Power of labourer B = $\frac{600 \text{ J}}{1200 \text{ s}} = \frac{1}{2}$ W

Since $\frac{5}{6}$ W > $\frac{1}{2}$ W, the correct answer is (a).

2. How much energy does a 100 W electric bulb transfer in 1 minute?

(a) 100 J (b) 600 J

(c) 3600 J (d) 6000 J

Ans. Energy = Power × time = 100 W × 60 s = 6000 J

Therefore, the correct answer is (d).

3. If a 300 N force is applied to a skier to drag her up a hill at a speed of 1.5 m/s, the power delivered by the rope pulling her is

(a) 300 W (b) 400 W

(c) 450 W (d) 550 W

Ans. Power = Force × speed

= 300 N × 1.5 m/s

= 450 W

Therefore, the correct answer is (c).

4. 1 kWh is equivalent to

(a) 3.6×10^4 J

(b) 3.6×10^5 J

(c) 3.6×10^6 J

(d) 3.6×10^7 J

Ans. 1 kWh = 1000 J/s × 1 h

= 1000 J/s × 3600 s

= 3.6×10^6 J

Therefore, the correct answer is (c).

Very Short Answer Type Questions

5. Two railway trains, A and B, of the same weight run at 60 km/h and 80 km/h, respectively. If the friction of the rails and the resistance due to air are the same for both the trains, do both trains

have the same power? If not, which of the two trains has more?

Ans. If all other conditions are same, the train doing more work has more power. The kinetic energy of train B is higher than that of train A, so train B is doing more work. Hence, the power of train B is greater.

6. Name the two factors on which power depends.

Ans. Power depends on energy output and time.

7. If Ranbir's office consumes 3250 units of energy in a particular month, how much energy in joules has the office used up in this period?

Ans. $1 \text{ unit} = 1 \text{ kWh}$

$= 3.6 \times 10^6 \text{ J}$

$3250 \text{ units} = 3250 \times 3.6 \times 10^6 \text{ J}$

$= 1.2 \times 10^{10} \text{ J}$

Short Answer Type-I Questions

8. The work done by the heart is 1 J per beat. Calculate the power of the heart if it beats 72 times in a minute.

Ans. Work done in a minute

$= 72 \text{ beats} \times 1 \text{ J/beat}$

$= 72 \text{ J}$

Therefore,

$$\text{power} = \frac{\text{Work done}}{\text{time}}$$

$$= \frac{72 \text{ J}}{60 \text{ s}}$$

$$= 1.2 \text{ W}$$

9. A man exerts a force of 200 N in pulling a cart at a constant speed of 16 m/s. Calculate the power spent by the man.

Ans. Power = Force × speed = 200 N × 16 m/s = 3200 W

10. Derive the relationship between the SI unit of electrical energy and the commercial unit of energy. Why is there a need for a commercial unit of energy when we have an SI unit?

Ans. The SI unit of energy is joule and the commercial unit is kilowatt-hour

$1\text{kWh} = 1\text{kW} \times 1 \text{ h}$

$= 1000 \text{ W} \times 3600 \text{ s}$

$= 1000 \text{ J/s} \times 3600 \text{ s}$

$= 3.6 \times 10^6 \text{ J}$

A commercial unit is needed because joule is too small a unit to express the large quantity of energy that gets used in houses and factories.

11. A boy X can run with a speed of 8 m/s against the frictional force of 10 N and another boy Y can move with a speed of 3 m/s against the frictional force of 20 N. Find the ratio of powers of X and Y.

Ans.
$$\frac{P_X}{P_Y} = \frac{10 \text{ N} \times 8 \text{ m/s}}{20 \text{ N} \times 3 \text{ m/s}}$$

$$= \frac{80}{60} = 4 : 3$$

Short Answer Type-II Questions

12. Superman pulls Wonder Woman out of a ditch 10 m deep in 5 seconds. Batman pulls the Joker out of a vat of oil from a depth of 5 m in the same time. If the Joker weighs 70 kg, for Superman and Batman to have the same power, what should Wonder Woman's weigh in kg?

Ans. For Superman and Batman to have the same power, the energy each spends in pulling Wonder Woman and Joker out, respectively, has to be the same per second.

Energy spent in pulling Joker out

$= 70 \text{ kg} \times 9.8 \text{ m/s}^2 \times 5 \text{ m}$

Energy spent in pulling Wonder Woman out

$= m \times 9.8 \text{ m/s}^2 \times 10 \text{ m}$

Power of Superman = Power of Batman

$$\text{or} \quad \frac{70 \text{ kg} \times 9.8 \text{ m/s}^2 \times 5 \text{ m}}{5 \text{ s}} = \frac{m \times 9.8 \text{ m/s}^2 \times 10 \text{ m}}{5 \text{ s}}$$

$$\text{or} \quad m = 35 \text{ kg}$$

13. A pump of power 760 W lifts water stored in a water tank to a height of 19 m. What is the mass of water it can lift in 25 s? (Take $g = 10 \text{ m/s}^2$)

Ans.
$$760 \text{ W} = \frac{m \times 10 \text{ m/s}^2 \times 19 \text{ m}}{25 \text{ s}}$$

$$\text{or} \quad m = 100 \text{ kg}$$

14. Priyank and Baseer are asked to take 4 chairs each from the ground floor to a room at the second floor. Priyank takes 30 minutes to do this work, while Baseer takes 60 minutes for the same. What is the ratio of work done by Priyank to that by Baseer? What is the ratio of their powers?

Ans.
$$\frac{\text{Work done by Priyank}}{\text{Work done by Baseer}}$$

$$= \frac{\text{Mass of 4 chairs} \times g \times \text{height of second floor}}{\text{Mass of 4 chairs} \times g \times \text{height of second floor}}$$

$= 1 : 1$

$$\frac{\text{Priyank's power}}{\text{Baseer's power}} = \frac{\dfrac{\text{Work done by Priyank}}{(30 \times 60 \text{ s})}}{\dfrac{\text{Work done by Baseer}}{(60 \times 60 \text{ s})}}$$

$$= \frac{60}{30} = 2 : 1$$

15. How is the electricity bill of a household calculated? If a 100 W electric bulb is lighted for 20 hours, how much electrical energy will be consumed? Also, find the cost, if 1 unit costs ₹ 4.

Ans. Our household electricity bill shows the total electrical energy consumed in our household in a month in terms of units of electricity. The bill also shows the cost of one unit. The bill is calculated by multiplying the number of units consumed with the cost of one unit.

Electrical energy consumed

= 100 W × 20 h

= 2000 Wh

= 2 kWh

= 2 units

Cost = ₹4/unit × 2 units = ₹8

Long Answer Type Questions

16. From a 20 m high fall in a reservoir, nearly 25 metric tonnes of water fall per second. Calculate the equivalent power if 40% of this energy is lost and the rest converted into electrical energy.

Ans. Total potential energy contained in the water that falls per second

= 25 metric tonnes × 9.8 m/s^2 × 20 m

= 25000 kg × 9.8 m/s^2 × 20 m

= 4.9 × 10^6 J

Only 60% of this potential energy is converted into electrical energy

$$\text{Power} = \frac{0.6 \times 4.9 \times 10^6 \text{ J}}{1 \text{ s}}$$

= 2.94 × 10^6 W

= 3 MW

17. In a house, following appliances are working: 4 tube lights of 40 W each for 8 hours daily, 2 fans of 60 W each for 10 hours daily and one TV set of 200 W for 8 hours daily.

(a) Calculate the total energy consumption per day.

(b) What will be the units recorded in the house's electrical meter for a month of 30 days?

(c) Find the electricity bill for the same month, if the cost per unit is ₹ 5.

Ans. (a) Total energy consumption

= (4 × 40 W × 8 h) + (2 × 60 W × 10 h) + (1 × 200 W × 8 h)

= 1280 Wh + 1200 Wh + 1600 Wh

= 4080 Wh

= 4.08 kWh

(b) Units recorded in the meter in a 30-day month

= 4.08 kWh × 30

= 122.4 kWh

(c) Electricity bill for the month

= 122.4 kWh × ₹5/kWh

= ₹612

Higher Order Thinking Skills (HOTS) Questions

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1. What brings a greater change in the kinetic energy of an object – doubling the velocity or doubling the mass?

Ans. KE is directly proportional to mass but directly proportional to the square of velocity. Thus, doubling the mass will double the KE while doubling the velocity will increase the KE 4 times. So, doubling the velocity brings a greater change in the kinetic energy.

2. The moon goes around the earth in an orbit. What is the energy it spends in one complete revolution?

Ans. The displacement after one complete revolution is 0. Therefore, the work done is zero and, hence, the energy spent by the moon is also 0.

3. Why does a man carrying a heavy load at rest feel tired after some time, even though he has not done any work?

Ans. The man feels tired because he has to continuously apply a force equal to the weight of the heavy load to keep the load from falling down due to earth's gravitational pull.

4. Daniel and Mohit are having an argument. Daniel says that any object with zero momentum has zero mechanical energy. Mohit says that if an object's momentum is zero, we can only say that its kinetic energy is zero, while it can still have mechanical energy. Who among the two friends is correct? Why?

Ans. Momentum = $m \times v$. Since mass cannot be zero, this means the velocity has to be zero.

If velocity is 0, kinetic energy of the object ($1/2mv^2$) is also zero. However, since mechanical energy is the sum of kinetic energy and potential energy, and potential energy does not depend upon the velocity of the object, we cannot say anything about the potential energy or the mechanical energy of the object. Therefore, Mohit is correct.

5. If Daniel and Mohit's friend Reema joins them in the discussion in the previous question and says that if the mechanical energy of an object is zero, we can say with certainty that its momentum is also zero, would she be correct?

Ans. If mechanical energy is zero, then, in general, both KE and PE are zero. If KE is zero, the velocity is zero, and, hence the momentum is zero. So Reema is correct.

6. Shyam went to a waterfall. He observed that the temperature at the foot of the waterfall is slightly different than that of the top. Was Shyam's observation correct? Justify your answer using the concept of transformation of energy.

Ans. We know that when water falls from a height, its potential energy gets converted into kinetic energy and the overall mechanical energy remains conserved. But in real-life conditions, some of this mechanical energy gets wasted in the form of heat (and sound and other forms of energy). This heat energy, which gets converted from mechanical energy, raises the temperature of the water at the foot of the waterfall slightly. Shyam's observation is correct.

7. An object falls from a height, bounces from the ground and goes upward again with loss of a part of its energy.
   (a) How will its potential energy change?
   (b) What are the various energy conversions taking place?
   (c) What will be its ultimate energy?

Ans. (a) and (b) When an object falls from a height (say h), its potential energy is gradually transformed into kinetic energy. At the time of reaching the ground, whole energy of the object is kinetic in nature. A part of it is lost to the ground, and with the remaining energy, the object bounces back up. Since some of the energy is lost, the object can only reach a height h', where $h' < h$. At h', the entire energy of the object is again potential energy. The same process gets repeated again and again and the object's mechanical energy decreases during each collision of the object with the ground.

(c). Finally, the mechanical energy of the object is zero and it is transformed into heat energy.

8. Can either the kinetic energy or the gravitational potential energy of an object be negative? Give reason.

Ans. Kinetic energy cannot be negative as mass can never be negative and velocity is present in the formula in squared form. Potential energy can be negative if we consider negative vertical displacement, e.g. an object taken down from sea level to depth h.

Self-Assessment

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Multiple-Choice Questions

1. No work is done by a man pushing a wall because
   (a) no force is applied.
   (b) no energy is applied.
   (c) no displacement takes place.
   (d) no energy is produced.

Ans. The correct answer is (c).

2. Which of these angles between force and displacement results in minimum work?
   (a) 0° (b) 30°
   (c) 60° (d) 90°

Ans. Work = Force × displacement × cos θ. The correct answer is (d) as the cosine of this value is the lowest among the four options.

3. If 20 J of work is done in moving an object from one place to another, the energy of the object is
   (a) zero (b) 20 J
   (c) 10 J (d) 40 J

Ans. Energy of an object is the work done on it. Therefore, the correct answer is (b).

4. An object is falling from a height h. When it has fallen a height of $\frac{h}{2}$, it will possess
   (a) only potential energy.
   (b) only kinetic energy.
   (c) half potential and half kinetic energy.
   (d) more kinetic energy and less potential energy.

Ans. Initial PE = mgh; PE at $\frac{h}{2} = \frac{mgh}{2}$, which is half of the initial PE. The remaining PE has been converted into KE. Therefore, the correct answer is (c).

5. A car moving on a road accelerates and acquires a velocity three times its initial velocity. During this process, the potential energy of the car
   (a) becomes three times that of the initial potential energy.
   (b) becomes nine times that of the initial potential energy.
   (c) becomes 1/3rd of the initial potential energy.
   (d) does not change.

Ans. Potential energy of an object does not vary with

its velocity. Therefore, the correct answer is (d).

6. An object of mass 2 kg is thrown vertically upwards with a velocity of 3 m/s. The maximum gravitational potential energy of the object possible is

(a) 4.5 J (b) 6 J

(c) 9 J (d) 18 J

Ans. The maximum potential energy possible is equal to the initial kinetic energy of the object.

$$KE = \frac{1}{2} \times 2 \text{ kg} \times (3 \text{ m/s})^2 = 9 \text{ J}$$

The correct answer is (c).

7. In which of the following cases is the potential energy of a spring minimum?

(a) When it is compressed.

(b) When it is stretched.

(c) When it is at its natural length.

(d) When it is at its natural length, but kept at a height *h* above the ground.

Ans. The correct answer is (c).

Assertion–Reason Type Questions

For question numbers 8 to 17, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given in the following column.

(a) Both A and R are true and R is the correct explanation of the assertion.

(b) Both A and R are true but R is not the correct explanation of the assertion.

(c) A is true but R is false.

(d) A is false but R is true.

8. **Assertion:** The total work done by gravity when a book is raised from height A to height B and then brought back to height A is zero.

Reason: Work is a scalar quantity.

Ans. (b)

9. **Assertion:** A porter carrying a heavy suitcase on his head and walking in a straight line on the ground is said to be doing no work.

Reason: The work done by a force *F* for displacements is given by $F \times s \times \cos\theta$ where θ is the angle between the directions of the force and *s* the displacement.

Ans. (a)

10. **Assertion:** Work done by friction when a child comes down a slide in the park is negative.

Reason: Work is positive when the angle between force and displacement is between 90° and 180°.

Ans. (c)

11. **Assertion:** The work done by the centripetal force when a stone is tied to a string and rotated in a circle is zero.

Reason: In the case of a stone being rotated on a string, the centripetal force acts perpendicular to the displacement.

Ans. (a)

12. **Assertion:** An object cannot undergo displacement unless a force acts on it.

Reason: The absence of force only implies that there is no acceleration.

Ans. (d)

13. **Assertion:** The work done by the weight of a ball when it is thrown upward is negative.

Reason: If we take the upward direction as positive, the work done by the ball's weight can also be considered positive.

Ans. (c)

14. **Assertion:** A spring possesses potential energy when compressed and kinetic energy when stretched.

Reason: The kinetic energy of an object is its capacity to do work by virtue of its motion.

Ans. (d)

15. **Assertion:** If two objects have the same momentum, they also have the same kinetic energies.

Reason: Both momentum and kinetic energy depend only on the mass and velocity of an object.

Ans. (d)

16. **Assertion:** When an object falls freely from a height towards the ground, all its potential energy gradually gets converted into mechanical energy.

Reason: In real-life, potential energy and kinetic energy can be converted into each other infinite times without any loss of energy.

Ans. (b)

17. **Assertion:** If machine A does more work than machine B, we can say that machine A has more power than machine B.

Reason: The work done by two machines in a certain time is used to compare the power of the two machines.

Ans. (d)

Source-based/Case-based/Passage-based/ Integrated Assessment Questions

Answer questions on the basis of your understanding of the following passages and the related studied concepts. (any four)

18. Skydiving is a popular adventure sport that involves jumping from a high point towards the earth's

surface, with the speed during descent controlled by the use of a parachute. But how about diving from a great height without a parachute? Sounds crazy, right? In July 2016, Luke Aikins, an American professional skydiver and stuntman (43 years old and weighing a healthy 80 kg) became the first person on record to skydive intentionally without a parachute or a wingsuit and survive. He jumped from an aircraft at a height of about 25,000 ft (7,620 m) and after about two minutes of free fall, landed successfully on a 100-by-100-foot net placed a little above the ground. His speed by the time he reached the net was 120 mile/h (54 m/s). The net, made of a special material and equipped with compressed air cylinders, was meant to slow him down gently after impact. Moment after this death-defying feat, Aikins was up and around meeting the crowd assembled in the California desert to encourage him.

I. (a) What was the work done by air resistance on Aikins? [For ease of calculation, increase his jumping height to the nearest thousand (in m) and take acceleration due to gravity as 10 m/s^2]

Ans. 6.3×10^6 J

(b) What was the average air resistance acting on Aikins during the jump?

Ans. 785.42 N

(c) What was the difference between the average air resistance acting on Aikins and his weight?

Ans. 14.58 N

(d) If there was no air resistance, at what velocity would Aikins hit the net?

Ans. 400 m/s

II. (a) Which of the following equipment is/are used in skydiving?

(i) Parachute (ii) Helmet
(iii) Altimeter (iv) All of these

Ans. (iv) All of these

(b) When an object falls freely towards the earth, then its total energy

(i) decreases. (ii) increases.
(iii) remains constant. (iv) none of these.

Ans. (iii) remains constant.

(c) An object is falling freely from a height h. After it has fallen a height $h/2$, it will possess

(i) only P.E.
(ii) only K.E.
(iii) half P.E. and half K.E.
(iv) less P.E. and more K.E.

Ans. (iii) half P.E. and half K.E.

(d) If an object of mass 80 kg falls from a height of 7620 m. What would be the kinetic energy of the object when it reaches the ground (Take g = 10 m/s^2)?

(i) 7620 J (ii) 6096 kJ
(iii) 696 kJ (iv) 762 kJ

Ans. (ii) 6096 kJ

(e) A ball is dropped from a tower reaches ground in 5 s. What is the height of tower (Take g = 10 m/s^2)?

(i) 25 m (ii) 100 m
(iii) 125 m (iv) 150 m

Ans. (iii) 125 m

19. Pole vaulting is an athletics event and an Olympic sport in which the athlete uses a long flexible pole as an aid to jump over a bar. Basic physics plays an important role in pole vault. The pole vaulter is supposed to run as fast as he or she can and then use the conversion of kinetic energy into potential energy to reach the maximum height possible. The faster the vaulter can run while carrying the pole, the higher they can vault. Top vaulters can cover a distance of 100 m in 10 seconds and clear a bar of 6 m above the ground. But the kinetic energy is not converted directly into the athlete's potential energy. It is first transferred to the pole itself, which bends almost to 90° before the athlete makes the jump.

I. (a) What two forms of potential energy are involved in the pole-vaulting process?

Ans. Gravitational potential energy, elastic potential energy of the pole

(b) Assuming an average weight of 80 kg for a pole vaulter, what are the maximum kinetic and gravitational potential energies possessed by the vaulter for the values given above?

Ans. 4,000 J, 4704 J

(c) Where is the additional gravitational potential energy coming from in (b) above?

Ans. Contributed by the pole's elastic gravitational energy

(d) In high altitude conditions, athletes can run a little faster than usual because of low density of the air. If a pole vaulter can run 2% faster at a higher altitude, what is the height reached in the above scenario (assuming the same contribution from the pole's elastic potential energy)?

Ans. 6.2 m

II. (a) Which of the following is not an example of gravitational potential energy?

(i) A brick on the top of a roof
(ii) Ripe fruit before it falls
(iii) A stretched spring
(iv) A book lying on the table

Ans. (iii) A stretched spring

(b) If a pole vaulter clears the maximum height of 5 m, what is the speed with which he should run carrying the pole (Take g = 10 m/s^2)?

(i) 5 m/s (ii) 10 m/s
(iii) 15 m/s (iv) 2.5 m/s

Ans. (ii) 10 m/s

(c) The work done of an object does not depend on the

(i) displacement.
(ii) angle between force and displacement.
(iii) force applied.
(iv) initial velocity of the object.

Ans. (iv) initial velocity of the object.

(d) When the angle between the direction of force and the direction of motion is 0°, the work done by a force will be

(i) maximum.
(ii) minimum.
(iii) first minimum then maximum.
(iv) none of the above.

Ans. (i) maximum.

(e) A 60 kg athlete runs up a flight of stairs 3 m high in 2 seconds. What is his average power?

(i) 441 W (ii) 882 W
(iii) 1 horse power (iv) 1764 W

Ans. (ii) 882 W

Very Short Answer Type Questions

20. Does the kinetic energy of an object depend upon the direction of the object's motion?

Ans. No, it does not because v^2 has the same value irrespective of velocity being positive or negative.

21. A woman pulls a bucket of water of mass 5 kg from a well that is 100 m deep in 10 s. Calculate the power used by her. (Take g = 10 m/s^2)

Ans. Power = work done on the bucket/time

= potential energy of the bucket/time

= (5 kg × 10 m/s^2 × 100 m)/10s

= 500 W

22. Where does a pendulum have maximum (a) potential energy and (b) kinetic energy?

Ans. A pendulum has maximum potential energy at the two ends of its trajectory and maximum kinetic energy at the midpoint (or lowest point) of its trajectory.

23. How will you find the value of one electrical unit consumed by a household in terms of joules?

Ans. 1 electrical unit = 1 kWh

= 1 kW × 1 h

= 1000 W × 3600 s

= 1000 J/s × 3600 s

= 3.6 × 10^6 J

Short Answer Type-I Questions

24. Why does a nail become warmer when hammered into a wooden plank?

Ans. Some of the kinetic energy of the hammer, as it strikes the nail, gets lost in the form of heat energy. This heat energy raises the temperature of the nail.

25. Two masses m and 2m are dropped from heights 2h and h, respectively. On reaching the ground, which one will have more kinetic energy? Why?

Ans. Since the initial potential energy of both the masses is the same (2mgh), the kinetic energy of both on reaching the ground would be the same.

26. An object of mass 2 kg slides up a plane of inclination 30° to the ground. What is the work done by the force of gravity in moving the object through 1 m?

Ans. If the inclined plane makes an angle of 30° with the ground, it makes an angle of 120° with the direction of earth's gravitational pull (acting vertically downward).

Work done by force of gravity

= force × displacement × cos θ

= 2 kg × 9.8 m/s^2 × 1 m × cos 120° = – 9.8 J

27. A man, whose mass is 70 kg, climbs to one hill station B from another hill station A. Hill station B is located at a height of 1800 m above sea level. What is the work done by the man in climbing to B, if the height of A above sea level is 1200 m? (Take g = 10 m/s^2)

Ans. The work done by the man

= $m \times g \times$ difference in height between A and B

= 70 kg × 10 m/s^2 × (1800 m – 1200 m)

= 4.2 × 10^5 J

28. An adult sparrow and an adult crow are flying with the same kinetic energy. Which of the two is moving faster and why?

Ans. Since the mass of an adult sparrow is lower than the mass of an adult crow, if the kinetic energy is equal for both of them, the velocity of the sparrow must be greater.

Let mass of sparrow be m_s and mass of crow be m_c, such that $m_c > m_s$

$$\frac{1}{2} m_s v_s^2 = \frac{1}{2} m_c v_c^2$$

or $$\frac{m_c}{m_s} = \left(\frac{v_s}{v_c}\right)^2$$

Since the ratio on the left hand side is greater than 1 , the ratio on the right hand side is also greater than 1. Therefore, the sparrow is moving faster.

Short Answer Type-II Questions

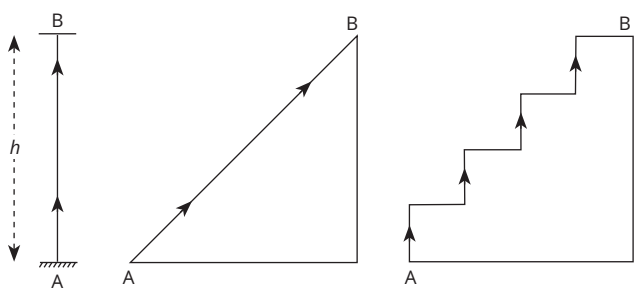
29. A ball is thrown vertically upwards with a kinetic energy 1 J. If it goes up to a maximum height of 1 m, find the mass of the ball.

Ans. Initial KE = final PE

or 1 J = m × 9.8 m/s^2 × 1 m

or m = 0.102 kg = 102 g

30. An object of mass m is moved to a height h by taking three different paths as shown in the figure. What is the work done against gravity in each of the cases?



(a) (b) (c)

Ans. The work done in each case is the potential energy of the object at position B. The potential energy depends upon the displacement or height from ground and not the path taken to get to the height.

Therefore, the work done in each case = mgh.

31. Mohana and Shabnam weigh 60 kg and 40 kg, respectively. They climb a staircase, each carrying a load of 20 kg on their head. The staircase has 10 steps, each of height 50 cm. If Mohana takes 20 s to climb and Shabnam takes 10 s to climb, then (a) who possesses greater power, and (b) what is the ratio of their powers?

Ans. Mohana's power = $\frac{\text{Work done}}{\text{time}}$

$$= \frac{(60 \text{ kg} + 20 \text{ kg}) \times g \times (10 \times 50 \text{ cm})}{20 \text{ s}}$$

= 20g W

Shabnam's power

$$= \frac{(40 \text{ kg} + 20 \text{ kg}) \times g \times (10 \times 50 \text{ cm})}{10 \text{ s}}$$

= 30g W

Therefore, Shabnam possesses greater power.

Ratio of their powers = 2 : 3

Long Answer Type Questions

32. A ball dropped from a height of 10 m loses 40% of its energy after impact on the ground. How much height will it gain after one impact?

Ans. If the mass of the ball is m,

its initial PE = mg × 10 m = 10 mg J

It retains only 60% of this energy before bouncing back. So, kinetic energy before bouncing back

= 0.6 × 10mg J = 6mg J

This is the PE when it reaches maximum height again. If this height is h',

$mg \times h' = 6mg$

or h' = 6 m

33. An object A of mass 3 kg and another object of mass 10 kg are dropped simultaneously from a height of 14.9 m. At the point when they are 10 m above the ground, calculate

(a) their momenta,

(b) their potential energies, and

(c) their kinetic energies.

Ans. Initial PE of mass A = 3 kg × 9.8 m/s^2 × 14.9 m

= 438.06 J

Initial PE of mass B = 10 kg × 9.8 m/s^2 × 14.9 m

= 1460.2 J

PE of A at 10 m height = 3 kg × 9.8 m/s^2 × 10 m

= 294 J

PE of B at 10 m height = 10 kg × 9.8 m/s^2 × 10 m

= 980 J

KE of A at 10 m height = 438.06 J – 294 J

= 144.06 J

KE of B at 10 m height = 1460.2 J – 980 J

= 480.2 J

Velocity of A at 10 m height

$$= \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 144.06\ J}{3\ kg}}$$

= 9.8 m/s

Velocity of B at 10 m height

$$= \sqrt{\frac{2 \times 480.2\ J}{10\ kg}}$$

= 9.8 m/s

Momentum of A at 10 m height

= 3 kg × 9.8 m/s

= 29.4 kg m/s

Momentum of B at 10 m height

= 10 kg × 9.8 m/s

= 98 kg m/s

34. An 80 kg box is pushed across the floor through a certain distance so as to attain kinetic energy of 160 J. If the pushing force is 375 N, the force of friction between the box and the floor is 25 N and the box is starting from rest, calculate

(a) its final velocity,

(b) net force acting on the box,

(c) acceleration of the box,

(d) the distance up to which the box has been pushed, and

(e) the total work done during the process.

Ans. (a) KE = 160 J, m = 80 kg

$$v = \sqrt{\frac{2KE}{m}}$$

$$= \sqrt{\frac{2 \times 160\ J}{80\ kg}}$$

= 2 m/s

(b) Net force on the box = 375 N – 25 N = 350 N

(c) Acceleration of the box

$$= \frac{\text{net force}}{\text{mass}}$$

$$= \frac{350\ N}{80\ kg}$$

= 4.375 m/s^2

(d) Work done on the box = the box's KE

or Net force × distance pushed = KE

or distance pushed = KE/Net force

$$= \frac{160\ J}{350\ N} = 0.46\ m$$

(e) The total work done is the same as the KE gained by the box = 160 J

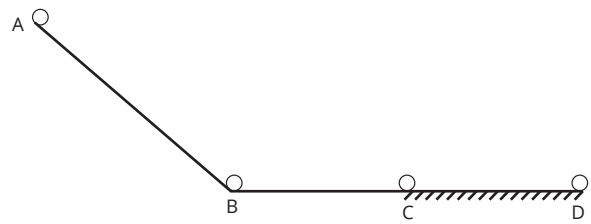
35. The figure given below shows the movement of an ice skater from point A to D, through B and C. The ice surface is frictionless from point A to point C, while heavy friction is present due to unpacked ice from point C to point D. Comment on the various changes in:

(a) kinetic energy

(b) potential energy

(c) total mechanical energy

(d) work done



Ans. (a) As the ice skater moves from A to B, his KE goes on increasing and becomes maximum at B. From B to C, KE remains unchanged. From C to D, the KE goes on decreasing and is zero at D.

(b) The PE of the ice skater is the maximum at A. It gradually falls from A to B. At B, PE = 0 and it remains 0 from B to D.

(c) From A to C, the total mechanical energy remains constant. From C to D, the total mechanical energy decreases gradually and is zero at D.

(d) From A to B, work is done by the force of gravity and work is positive. From B to C, no work is being done as gravity and displacement are perpendicular to each other. From C to D, negative work is being done by the force of friction.

36. Complete the following table for an object of mass 10 kg falling freely from a height of 10 m above the ground. Take g = 10 m/s^2 and make use of the law of conservation of energy.

Height above the ground, h (m)	10	8	6	4	2	0
Potential energy, PE (J)	1000					
Kinetic energy, KE (J)	0					
Total mechanical energy, E (J)	1000					

Ans. The total mechanical energy remains constant throughout. The PE at each point can be calculated using mgh, where h is the height at that point.

Thus,

PE at 8 m = 10 kg × 10 m/s^2 × 8 m = 800 J

PE at 6 m = 10 kg × 10 m/s^2 × 6 m = 600 J

PE at 4 m = 10 kg × 10 m/s^2 × 4 m = 400 J

PE at 2 m = 10 kg × 10 m/s^2 × 2 m = 200 J

PE at 0 m = 10 kg × 10 m/s^2 × 0 = 0 J

Now, KE can be obtained by subtracting PE from total mechanical energy at each point.

Thus,

KE at 8 m = 1000 J – 800 J = 200 J

KE at 6 m = 1000 J – 600 J = 400 J

KE at 4 m = 1000 J – 400 J = 600 J

KE at 2 m = 1000 J – 200 J = 800 J

KE at 0 m = 1000 J – 0 J = 1000 J

Height above the ground, h (m)	10	8	6	4	2	0
Potential energy, PE (J)	1000	800	600	400	200	0
Kinetic energy, KE (J)	0	200	400	600	800	1000
Total mechanical energy, E (J)	1000	1000	1000	1000	1000	1000

Let's Compete

(Page 98)

Multiple-Choice Questions

1. An electric lamp consumes 2 units of electricity in 50 hours. Its power is

(a) 100 W (b) 25 W

(c) 40 W (d) 20 W

Ans. $$\text{Power} = \frac{2 \text{ units}}{50 \text{ h}}$$

$$= \frac{2 \text{ kWh}}{50 \text{ h}}$$

$$= \frac{2000 \text{ Wh}}{50 \text{ h}} = 40 \text{ W}$$

The correct answer is (c).

2. 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.

Ans. The correct answer is (d).

3. When an object is thrown up, work done on the object by gravity is

(a) zero. (b) negative.

(c) positive. (d) none of these

Ans. The correct answer is (b).

4. The weight of a person on Planet A is half that on the earth. If he can jump up to 0.4 m height on the surface of the earth, how high can he jump on Planet A?

(a) 0.2 m (b) 0.24 m

(c) 0.4 m (d) 0.8 m

Ans. The person's maximum possible potential energy remains the same on earth and on Planet A

Maximum possible PE on earth = mg × 0.4 m

Maximum possible PE on planet A

$= (mg)/2 \times h$

$0.4\ mg = (mg)/2 \times h$

or $h = 0.8$ m

The correct answer is (d).

5. Which one of the following is not a unit of energy?

(a) watt (b) joule

(c) newton metre (d) kilowatt hour

Ans. The correct answer is (a).

6. A stone tied to the string is whirled in a vertical circle. Then

(a) the potential energy of the stone is maximum at the topmost position.

(b) the potential energy of the stone is maximum at the lowest position.

(c) the kinetic energy of the stone is maximum at the lowest position.

(d) both (a) and (c)

Ans. The correct answer is (d).

7. The kinetic energy acquired by a mass m in travelling a certain distance s, starting from rest, under the action of a constant force is directly proportional to

(a) m (b) $\sqrt{m}$

(c) $\frac{1}{\sqrt{m}}$ (d) None of these

Ans. Let the force acting on the mass be F and acceleration be a

$$v = 0 + 2as = 2s \times F/m$$

$$KE = \frac{1}{2} mv^2$$

$$= \frac{1}{2} \times m \times (2Fs/m)^2$$

$$= 2(Fs)^2/m$$

Thus, $KE \propto \frac{1}{m}$

Therefore, the correct answer is (d).

8. A 4 kg mass and a 1 kg mass are moving with equal kinetic energies. The ratio of their momenta is

(a) 1 : 2 (b) 1 : 1

(c) 2 : 1 (d) 4 : 1

Ans. $\frac{1}{2} \times 4 \text{ kg} \times v_1^2 = \frac{1}{2} \times 1 \text{ kg} \times v_2^2$

or $4v_1^2 = v_2^2$

or $2v_1 = v_2$

Ratio of momenta $= \frac{4 \text{ kg} \times v_1}{1 \text{ kg} \times v_2}$

$$= \frac{4v_1}{2v_1} = 2:1$$

The correct answer is (c).

9. A bullet of mass 20 g moving with a velocity of 500 m/s strikes a tree and comes out from the other side with a velocity of 400 m/s. The work done by the bullet in passing through the tree is

(a) 500 J (b) 900 J

(c) 1000 J (d) 1800 J

Ans. Work done by the bullet

= loss in KE

$$= \frac{1}{2} m (v_2^2 - v_1^2)$$

$$= \frac{1}{2} \times 0.02 \text{ kg} \times [(500 \text{ m/s})^2 - (400 \text{ m/s})^2]$$

= 900 J

The correct answer is (b).

10. A bullet of mass 20 g is found to pass two points 30 m apart in 4 s. Assuming the speed to be constant, the bullet's kinetic energy is

(a) 0.2625 J (b) 0.3285 J

(c) 0.4935 J (d) 0.5625 J

Ans. The speed of the bullet $= \frac{30 \text{ m}}{4 \text{ s}} = 7.5 \text{ m/s}$

$$KE = \frac{1}{2} \times 0.02 \text{ kg} \times (7.5 \text{ m/s})^2$$

= 0.5625 J

The correct answer is (d).

Value-based Questions

(Optional) (Page 99)

1. Iqbal heard of a recent hurricane that caused a lot of damage to life and property in a coastal region. He got together with his school friends to organize a drive to collect old clothes and other donations for the affected people.

(a) If the winds of a typical full-blown hurricane generate 1.3×10^{17} J/day in energy, what is its power in watts?

(b) What values do we learn from Iqbal and his friends?

(c) Global warming makes the effects of hurricanes worse by raising the temperature of oceans. Identify three ways in which we can contribute to controlling global warming.

Ans. (a) $\text{Power} = 1.3 \times 10^{17} \text{ J/day} \times \frac{1 \text{ day}}{24 \times 3600 \text{ s}}$

$= 1.5 \times 10^{12}$ J/s

$= 1.5 \times 10^{12}$ W

(b) We should always help those less fortunate than us, and all of us can find ways to do this.

(c) i. Drive less or carpool, ii. Reduce waste, use recycled products, iii. Turn off lights and other electrical appliances when they are not in use.

2. Rohan's mother told her that she worships the sun every morning because sun is the ultimate source of energy. Rohan asked his teacher what her mother meant by this statement.

(a) Identify any two processes by which sun's energy reaches us.

(b) What values do we learn from Rohan?

Ans. (a) i. Sun's energy is used in photosynthesis by plants to produce food, which provides us with nutrition and energy, ii. Sun's heat energy causes wind to move, which is then used to turn turbines and produce electricity.

(b) We should try to understand the logic behind any statement instead of blindly following it.

3. In a game of tug of war, Amina's team is slowly giving way to Ruby's team.

(a) What work is being done and by whom?

(b) What values are learnt from the game of tug of war?

Ans. (a) Ruby's team is doing the work, which is moving the rope and Amina's team towards themselves.

(b) Team spirit, sportsmanship, leadership.

12

Sound

Checkpoint (Page 102)

1. Which of the following statements are correct?

(i) Sound is produced by vibrations.

(ii) Sound can travel in solids, liquids and gases.

(iii) Sound travels at a constant speed through all media.

(iv) The speed of sound is greater than that of light.

(a) (i) and (ii) (b) (i), (ii) and (iii)

(c) (i) and (iii) (d) (i), (ii), (iii) and (iv)

Ans. The correct answer is (a).

2. What is the thin membrane stretched tightly at the end of our ear canal known as?

(a) Earflap (b) Eardrum

(c) Earlobe (d) Eartube

Ans. The correct answer is (b).

3. The number of oscillations per second is known as frequency. Which famous physicist is the unit of frequency named after?

(a) Isaac Newton (b) Blaise Pascal

(c) Enrico Fermi (d) Heinrich Hertz

Ans. The correct answer is (d).

4. Loudness depends on which of these properties of sound?

(a) Amplitude (b) Frequency

(c) Time period (d) None of these

Ans. The correct answer is (a).

5. Which of these is expected to be the best absorber of sound?

(a) Iron (b) Wood

(c) Wool (d) Cemented wall

Ans. The correct answer is (c).

6. In terms of frequency, what is the audible range for the human ear?

Ans. The audible range is 20 Hz to 20,000 Hz.

7. Why is it said that sound cannot travel in space?

Ans. It is said that sound cannot travel in space because there is no atmosphere in space, and sound doesn't travel in a vacuum

8. A pendulum oscillates 50 times in 5 seconds. Find its time period and frequency.

Ans. 50 oscillations in 5 seconds. Therefore,

1 oscillation in $\frac{5}{50}$ = 0.1 s. This is the time period.

$$\text{Frequency} = \frac{1}{t} = \frac{1}{0.1\,\text{s}} = 10\ \text{Hz}$$

9. What is the unit that loudness of sound is measured in?

Ans. Loudness of sound is measured in decibel (dB).

10. Why are we able to see a lightning before we hear the sound of the thunderstorm even though both take place at the same time?

Ans. We are able to see lightning before we hear the sound of a thunderstorm because light travels faster than sound and reaches us quicker.

Milestone 1

(Page 108)

Multiple-Choice Questions

1. What is the resultant effect of wind on the speed of sound?

(a) It is always positive.

(b) It is always negative.

(c) It can be positive or negative.

(d) It has no effect on the speed of sound.

Ans. We have seen that the wind can aid the speed of sound or hamper it depending on whether it is flowing in the same direction or not. Therefore, the correct answer is (c).

2. The distance between a crest and an adjacent trough is

(a) λ (b) $\frac{\lambda}{2}$

(c) 2λ (d) none of these

Ans. The correct answer is (b).

3. Clapping of our hands produces

(a) transverse waves.

(b) light waves.

(c) longitudinal waves.

(d) magnetic waves.

Ans. The correct answer is (c).

4. The frequency of a source is 20 kHz. The time periods of the sound waves produced by it in water and air will

(a) be the same as that of the source.

(b) depend upon the velocity of the waves in these media.

(b) depend upon the wavelength of the waves in these media.

(d) depend upon the density of the media.

Ans. Time period is the reciprocal of frequency and does not depend on the speed or the wavelength of the wave. Therefore, the correct answer is (a).

5. The time period of a sound wave travelling in a medium is T. At a given instance ($t = 0$) a particular region in the medium has minimum density. The density of this region will be minimum again at

(a) $t = T$ (b) $t = \frac{T}{2}$

(c) $t = \frac{T}{3}$ (d) $t = \frac{T}{4}$

Ans. The definition of time period is that it is the time between two consecutive crests (or two consecutive troughs) or two consecutive minimum density points. Therefore, the correct answer is (a).

Very Short Answer Type Questions

6. If all sound is produced by vibrations, what part of our body vibrates to produce speech?

Ans. The tissues in our larynx or voice box vibrate to produce speech.

7. If you place some small beads on a drum and beat this drum with a drumstick, what will you observe? Explain.

Ans. The beads will jump up and down. This happens because the vibrations created by beating the drum propagate in the outer direction from the point of contact of the drumstick and drum. When the vibration or wave reaches the point where a bead is placed, the bead jumps up.

8. A tuning fork has a number 384 marked on it. What does this number signify?

Ans. The number signified the frequency of the tuning fork. If the number marked is 384, it means the fork will vibrate 384 times in one second.

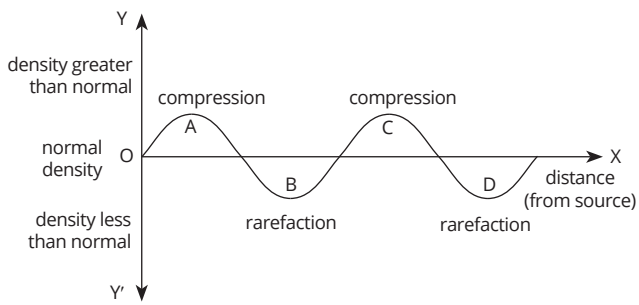
Short Answer Type-I Questions

9. Describe an experiment to show that waves do not carry matter while travelling.

Ans. If we drop a stone in a pond, we see circular water waves spreading out in all directions on the water surface. If we place a small leaf on the water surface, the leaf moves up and down about its original position but does not move away from or towards the source of disturbance along with the waves. This shows that a wave does not carry matter while travelling.

10. Draw a density–distance graph for a longitudinal wave and indicate the position of compression and rarefaction.

Ans.



11. A boat at anchor is rocked by waves whose crests are 100 m apart and whose velocity is 25 m/s. What is the time interval in which consecutive crests reach the boat?

Ans. Wavelength = 100 m, velocity of wave = 25 m/s

$$\text{Frequency} = \frac{\text{velocity}}{\text{wavelength}}$$

$$= \frac{25\ \text{m/s}}{100\ \text{m}}$$

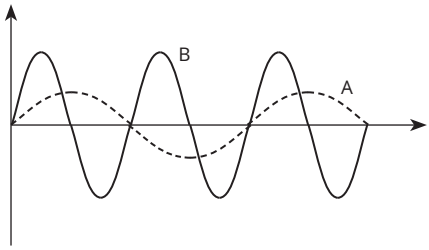
$$= 0.25\ \text{Hz}$$

$$\text{Time period} = \frac{1}{0.25}\ \text{Hz} = 4\ \text{s}$$

Thus, consecutive crests reach the boat in 4 seconds.

12. Draw the sketches of two waves A and B such that wave A has twice the wavelength and half the amplitude of wave B.

Ans. The two waves are shown below:



Short Answer Type-II Questions

13. Derive the relationship between wave velocity, frequency and wavelength.

Ans. If the time period of a wave is T s,

Number of waves produced in T s = 1

Number of waves produced in 1 s = $\frac{1}{T}$

But the number of waves produced in 1 second is equal to the frequency (ν) of the wave.

Therefore, $\nu = \frac{1}{T}$

$$\text{Wave velocity} = \frac{\text{Distance travelled by a wave}}{\text{Time taken}}$$

By definition, wavelength (λ) is the distance travelled by the wave in time T.

Therefore, $v = \frac{\lambda}{T}$

or $v = \frac{1}{T} \times \lambda$

or $v = \nu \times \lambda$

Thus, wave velocity = frequency × wavelength

14. A wave pulse on a string moves a distance of 8 m in 0.05 s.

(a) Find the velocity of the pulse.

(b) What would be the wavelength of the wave on the same string if its frequency is 200 Hz?

Ans. (a) Wave velocity = $\frac{8 \text{ m}}{0.05 \text{ s}}$ = 160 m/s

(b) Wavelength = $\frac{\text{wave velocity}}{\text{frequency}}$

$$= \frac{160 \text{ m/s}}{200 \text{ Hz}} = 0.8 \text{ m}$$

15. Find the wavelength of sound waves in air produced by a 20 kHz source, if the speed of sound in air is 340 m/s. If the same source is put in a water tank, what would be the wavelength of the sound waves in water? Speed of sound in water = 1480 m/s.

Ans. Wavelength in air = $\frac{340 \text{ m/s}}{20000 \text{ Hz}}$ = 0.017 m

Wavelength in water = $\frac{1480 \text{ m/s}}{20000 \text{ Hz}}$ = 0.074 m

16. If a thunder is heard by a man 5 seconds after lightning is seen, how far is the lightning from the man? (Speed of sound in air = 344 m/s)

Ans. Let the distance of the lightning from the man be x m. The speed of light in air is 3×10^8 m/s

Therefore, $\frac{x}{344 \text{ m/s}} - \frac{x}{3 \times 10^8 \text{ m/s}} = 5$ s

or $x = 5 \text{ s} \times 344 \text{ m/s} = 1720 \text{ m}$

[we take $\frac{x}{3 \times 10^8 \text{ m/s}}$ as zero because its value is much smaller when compared to $\frac{x}{344}$]

Long Answer Type Questions

17. A teacher wants to give a practical demonstration to explain the propagation of longitudinal and transverse waves to her class. She asks a few of her students to stand at equal intervals in a row holding hands.

Explain how the students will have to move in each of the two cases for this demonstration.

Ans. Transverse waves: If the first student jumps up and down, he/she will pull the hand of the student next to him/her, causing this student to start moving up and down. Now the first student will stop, but the jumping motion of the second student will cause the third student to start jumping. This goes on till the last student has jumped and there is nobody more to pass this disturbance along to.

Longitudinal waves: In the second case, instead of jumping up and down, imagine that the first student bumps into the second student, passing on extra energy to the second student. The first student then gets back to his/her original position, but the second student bumps into the third student. This goes on till the disturbance reaches the last student. In this case, the students are moving in the horizontal direction and the disturbance is moving in the horizontal direction also.

18. A vibrating object having a constant vibrational frequency sends sound waves of wavelength 0.16 m in medium A and of wavelength 0.20 m in medium B. If the speed of sound in medium A is

352 m/s, find the speed of sound in medium B. What is the frequency?

Ans. Frequency of the waves

$$= \frac{352 \text{ m/s}}{0.16 \text{ m}}$$

$$= 2200 \text{ Hz}$$

$$= 2.2 \text{ khz}$$

Since the frequency of the wave does not change with medium,

Speed of sound in medium B

$$= 2200 \text{ Hz} \times 0.2 \text{ m}$$

$$= 440 \text{ m/s}$$

Milestone 2

(Page 114)

Multiple-Choice Questions

1. The quality of a musical note depends on

(a) frequency. (b) waveform.

(c) intensity. (d) loudness.

Ans. The correct answer is (b).

2. A key of a mechanical piano is first struck gently and then struck again much harder. In the second case,

(a) sound will be louder but pitch will remain unaffected.

(b) sound will be louder and pitch will be higher.

(c) sound will be louder and pitch will be lower.

(d) both loudness and pitch will remain unaffected.

Ans. The force with which you strike the piano key has an effect on the amplitude of the wave generated, not on the frequency. The frequency remains the same for a particular key. Therefore, the correct answer is (a).

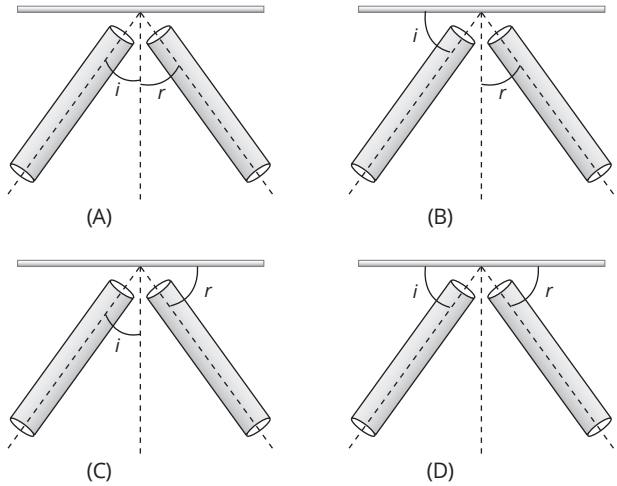
3. If we strike a drum softly, its skin vibrates with

(a) small amplitude. (b) medium amplitude.

(c) large amplitude. (d) any amplitude.

Ans. The correct answer is (a).

4. Four students A, B, C and D were conducting an experiment to verify the laws of reflection of sound. Each of them measured the angle of incidence and angle of reflection in a different manner as shown in the figures below. Which of them has made the correct measurement of the two angles?



(a) A (b) B

(c) C (d) D

Ans. The correct answer is (a).

5. The unit of amplitude in case of a pressure–distance graph for a longitudinal wave is

(a) m (b) kg/m^3

(c) Pa (d) m/s^2

Ans. In a pressure-distance graph, the amplitude of the wave is measured along the pressure-axis. Therefore, the unit of amplitude is the same as the unit of pressure. The correct answer is (c).

Very Short Answer Type Questions

6. Why is there a lower chance of an echo being heard in a small hall?

Ans. For an echo to be heard distinctly, the minimum distance between the sound source and the reflector should be 17.2 m. Since the length of a small hall might be less than this minimum required distance, the chance of an echo being heard is low.

7. Why is a sound board placed behind a speaker in an auditorium?

Ans. This is done to minimise the effect of reflected sound waves interfering with the words of the speaker.

8. Why is soft furnishing avoided in concert halls?

Ans. This is because soft furnishing leads to multiple reflections of sound, which can adversely affect the quality of the sound reaching the audience.

9. Why does sound become faint with distance?

Ans. Sound becomes faint with distance because as distance from the sound source increases, the area covered by the sound waves also increases. The same amount of energy is spread over a

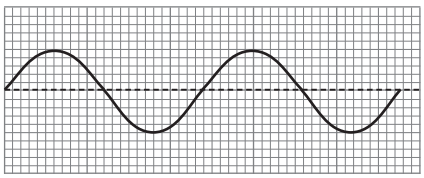
greater area, so the intensity and loudness of the sound keeps getting weaker.

Short Answer Type-I Questions

10. The figure below shows the trace of a sound wave produced by a tuning fork. On the same graph,

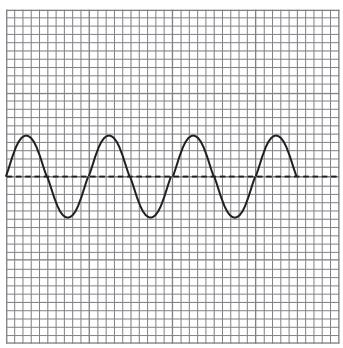
(a) draw a trace of a sound wave that has a higher frequency.

(b) draw a trace of a sound wave that has a larger amplitude.

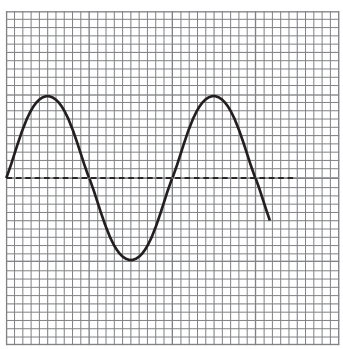


Ans. The two traces are shown below:

(a)



(b)



11. An echo heard at the same location in winter might not be heard in summer. Why?

Ans. We know that the speed of sound increases with temperature and also that to hear an echo, the reflected sound must reach our ears at least 0.1 s after the original sound dies off. In summer, because of the higher speed of sound, the reflected sound is likely to reach our ears earlier than 0.1 s, while in winter, there will be a longer gap between the original sound dying off and the reflected sound reaching our ears. Thus, an echo heard at the same location in winter might not be heard in summer.

12. State one feature of reflection of sound that is similar to reflection of light and one feature that is dissimilar.

Ans. Similar: Angle of incidence = angle of reflection

Dissimilar: Sound does not require a smooth and shining surface to get reflected, unlike light.

Short Answer Type-II Questions

13. A man is standing at a distance of 85 m from a high wall. He hears the echo of the high wall, produced by a clap of his hands. If the velocity of sound is 340 m/s, what would be the time interval between his original clap and hearing of the echo?

Ans. The original sound travels 85 m to the wall and then 85 m back to be heard as an echo.

Therefore, time = $\frac{2 \times 85 \text{ m}}{340 \text{ m/s}}$ = 0.5 s

14. A man hears sound of thunder 4 seconds after lightning is seen. How far is the lightning from the man? (Speed of sound in air = 340 m/s)

Ans. Let the distance of the lightning from the man be x m

Therefore, $\frac{x}{(340 \text{ m/s})} - \frac{x}{(3 \times 10^8 \text{ m/s})}$ = 4 s

or x = 340 m/s × 4 s

= 1360 m

[$\frac{x}{3 \times 10^8 \text{ m/s}}$ is taken as 0 because its value is much lower than $\frac{x}{340}$]

Long Answer Type Questions

15. An observer standing between two cliffs hears two successive echoes at 5 s and 6 s. Calculate the distance between the cliffs. (Speed of sound in air = 340 m/s)

Ans. Let the distance between the first cliff and the man be d_1 and the distance between the second cliff and the man be d_2.

$2d_1$ = 340 m/s × 5 s

or d_1 = 850 m

$2d_2$ = 340 m/s × 6 s

Or d_2 = 1020 m

Therefore, total distance between the two cliffs

= $d_1 + d_2$

= 850 m + 1020 m

= 1870 m

16. A man is standing between two parallel cliffs. He produces a sharp sound and receives the first echo after 3 seconds. If the speed of sound in air is 340 m/s and the distance between the two cliffs

is 1360 m, how long after the first echo reaches the man will the echo from the second cliff reach him?

Ans. Let the distance between the first cliff and the man be d. Then the distance between the second cliff and the man is 1360 – d.

$$2d = 340 \text{ m/s} \times 3 \text{ s}$$

or $$d = 510 \text{ m}$$

$$2(1360 \text{ m} - 510 \text{ m}) = 340 \text{ m/s} \times t$$

or $$t = 5 \text{ s}$$

Therefore, the man hears the second echo (5 s – 3 s) = 2 seconds after the first echo.

Milestone 3

(Page 120)

Multiple-Choice Questions

1. Sound whose frequency is below 20 Hz is called

(a) ultrasound. (b) audible sound.

(c) infrasound. (d) none of these

Ans. The correct answer is (c).

2. Which of these is not a bone of the middle ear?

(a) Hammer (b) Anvil

(c) Stirrup (d) Ulna

Ans. The correct answer is (d).

3. Which of these creatures can hear infrasound?

(a) Dog (b) Bat

(c) Rhinoceros (d) Human being

Ans. The correct answer is (c).

4. Wavelength of ultrasonic waves is of the order of

(a) 5×10^{-3} m (b) 5 m

(c) 5×10^{3} m (d) 5×10^{5} m

Ans. The correct answer is (a). This can be calculated using the speed of sound and the frequency of ultrasonic waves.

5. The frequencies of four sound waves are given below. Which one of these can be used to measure the depth of sea by the echo method?

(a) 100 kHz (b) 10 kHz

(c) 100 Hz (d) 10 Hz

Ans. Ultrasound is used to measure depth of the sea. The only ultrasound frequency among the given four is 100 kHz. Therefore, the correct answer is (a).

6. A fishing boat receives an echo from a shoal of fish 0.4 s after the original sound wave was sent out. If the speed of sound in water is 1500 m/s, the depth of the shoal is

(a) 150 m (b) 300 m

(c) 600 m (d) 1500 m

Ans.

$$2d = 1500 \text{ m/s} \times 0.4 \text{ s}$$

or $$d = 300 \text{ m}$$

The correct answer is (b).

7. Which of these parts of the human ear has sensory hair cells that change sound vibrations into nerve impulses?

(a) Pinna

(b) Stirrup

(c) Tympanic membrane

(d) Cochlea

Ans. The correct answer is (d).

Very Short Answer Type Questions

8. What is the main function of the bones of the middle ear?

Ans. The main function of the bones of the middle ear is to amplify the vibrations in the ear.

9. Is it possible for any human being to hear outside the audible range of 20 Hz to 20,000 Hz? Give an example.

Ans. Yes, children under the age of 5 can hear sounds up to 25 KHz.

10. If all vibrations produce sound, why are we not able to hear any sound when we vibrate our hands to and fro?

Ans. We can't hear the sound of vibrations from our hands as the frequency of vibrations is much lower than the minimum value that can be heard by us.

Short Answer Type-I Questions

11. State the properties of ultrasonic waves that make them suitable for use in detection of cracks in metal blocks, in sonar and as a cleaning agent.

Ans. Ultrasonic waves are used for the given purposes because of their high frequency and low wavelength, which makes it possible for them to penetrate deep inside an object or over a long distance in water. Another benefit of the high frequency when used for sonar is that the waves cannot be confused with engine noises or other sounds made by the ship because ultrasonic waves cannot be heard by humans.

12. Describe one medical use of ultrasonic waves.

Ans. Ultrasonic waves are used in ultrasonography, which is the technique of obtaining images of the internal organs of the body. The scanner produces ultrasonic waves that travel through the tissues of the body and get reflected if there are stones or tumours inside. The reflected waves are fed into

the computer and converted into electrical signals, generating three-dimensional images of the organ on the monitor.

13. Using sonar, sound pulses are emitted at the surface. The pulses, after being reflected from the bottom, are detected. If the time interval from the emission to the detection of the sound pulses is 2 seconds, find the depth of the water. (take velocity of sound through water, v, to be 1500 m/s.)

Ans. $2 \times d = v \times t$

or $2d = 1500 \text{ m/s} \times 2 \text{ s}$

or $d = 1500 \text{ m}$

Short Answer Type-II Questions

14. Two children are at opposite ends of an iron pipe. One strikes an end of the pipe with a stone. Find the ratio of times taken by the sound waves in air and in iron to reach the other child. Take speed of sound in air at this temperature as 344 m/s and in iron as 1530 m/s.

Ans. Sound through air and sound through iron has to cover the same distance to reach the other child. Let this distance be d. If t_1 is the time taken for sound to travel through air and t_2 is the time taken for sound to travel through iron,

$$\frac{t_1}{t_2} = \frac{\left(\frac{\text{d}}{344} \text{ m/s}\right)}{\left(\frac{\text{d}}{1530} \text{ m/s}\right)}$$

$$= 4.45 : 1$$

15. Radio waves sent from the earth towards the surface of moon are received back on the earth after reflection in 2.5 seconds. If the velocity of radio waves is 3×10^8 m/s, calculate the distance of moon from earth.

Ans. $2d = 3 \times 10^8 \text{ m/s} \times 2.5 \text{ s}$

or $d = 3.75 \times 10^8 \text{ m}$

Long Answer Type Question

16. The helmet of a construction worker slipped and fell on hard ground, when he was 78.4 m above the ground. The sound of the helmet striking the ground was heard by the worker 4.23 s after it slipped. Find the speed of sound in air.

Ans. Let the time taken by the helmet to reach the ground after slipping be t_1 and the time for the sound to reach the construction worker be t_2

$$t_1 + t_2 = 4.23 \text{ s}$$

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

$$78.4 \text{ m} = 0 + \frac{1}{2} \times 9.8 \text{ m/s}^2 \times t_1^2$$

or $t_1 = 4 \text{ s}$

Therefore, $t_2 = 4.23 \text{ s} - 4 \text{ s}$

$= 0.23 \text{ s}$

$$\text{Speed of sound} = \frac{78.4 \text{ m}}{0.23 \text{ s}}$$

$= 340.9 \text{ m/s}$

Higher Order Thinking Skills (HOTS) Questions

(Page 121)

1. Space is filled with large explosions that release the energy equal to thousands of bombs. Why is this not considered a major risk for an astronaut's hearing?

Ans. This is because sound cannot travel in vacuum. In the absence of a medium for it to travel, the sound from these explosions cannot reach the astronaut's ears.

2. Why is it that the vibratory motion of a simple pendulum does not produce any sound?

Ans. The frequency of oscillation of a pendulum is very low, lower than the lowest frequency in the human audible range.

3. A sound wave of frequency 512 Hz moves with a speed of 340 m/s in air. What will be the speed of a sound wave with frequency 256 Hz?

Ans. The speed will be the same (340 m/s). Speed of a wave depends on the medium, and the medium is the same for both the sound waves here.

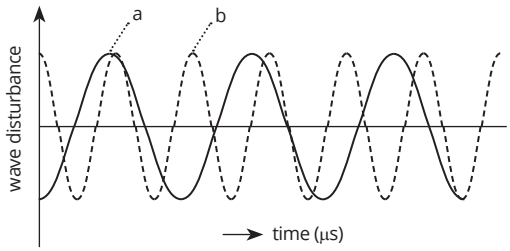
4. When trains used to travel much slower than they do today, people would try to figure out if a train was coming by placing their ears next to the railway track. What was the science behind this unsafe practice?

Ans. Sound travels faster in solids than in air, so the sound from an incoming train would be heard first through the railway track before it reached the person through air.

5. A piece from a glacier falls off into the ocean, creating a large wave. Is this wave a transverse wave or a longitudinal wave? How can you say?

Ans. It is a transverse wave as the wave particles move normal to the direction of the movement of the wave. The waves on the surface of water are transverse waves.

6. One of the two graphs shown in the figure belongs to a male person and the other to a female person. Which one of these two is likely to belong to a man? Justify your answer.



Ans. The pitch and hence the frequency of female voice is generally higher than that of a male voice. In the given two graphs, we can see that the frequency of *a* is less than that of *b*, so *a* is likely to be the male voice and *b* the female voice.

7. Hari and Shivam were playing identical guitars whose strings were adjusted to give notes of the same pitch. Which of the two, the quality and the frequency, is same for the two notes? Give reason for your answer.

Ans. As the pitch is the same for the two guitars, the frequency of notes is the same. We cannot say anything about the quality of the notes from the given information.

8. Why is a bell provided with a big outer case?

Ans. The outer case causes multiple reflections and increases the amplitude of the sound waves. This makes the sound louder.

9. Moths of certain families are able to escape capture from a bat. Why?

Ans. Moths of certain families have very sensitive hearing organs. They can hear the high frequency squeaks of a bat, figure out if a bat is flying nearby, and seek cover.

10. Name the characteristics of sound that help to distinguish between.

(a) a male and a female voice,

(b) voice of a woman and a girl child, and

(c) voice of two friends singing a song together.

Ans. (a) Pitch
(b) Pitch
(c) Quality

Self-Assessment

(Page 113)

Multiple-Choice Questions

1. Which of the following is not based on reflection of sound?

(a) Megaphone (b) Sound board
(c) Microphone (d) Stethoscope

Ans. The correct answer is (c).

2. If an echo is heard 0.6 s after a person bursts a cracker at a distance of 102 m from a high building, the speed that sound is travelling with is

(a) 330 m/s (b) 340 m/s
(c) 350 m/s (d) 360 m/s

Ans. $$v = \frac{2 \times 102 \text{ m}}{0.6 \text{ s}} = 340 \text{ m/s}$$

The correct answer is (b).

3. Which one of the following does not consist of transverse waves?

(a) Light emitted by a tube light

(b) TV signals from a satellite

(c) Ripples on the surface of a pond

(d) Musical notes of an orchestra

Ans. The correct answer is (d).

Assertion–Reason Type Questions

For question numbers 4 to 13, two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of the assertion.

(b) Both A and R are true but R is not the correct explanation of the assertion.

(c) A is true but R is false.

(d) A is false but R is true.

4. **Assertion:** A person will have to talk six times louder on the moon than he would on the earth to make himself heard to a person standing close to him.

Reason: There is no atmosphere on the moon.

Ans. (d)

5. **Assertion:** Sound travels faster in solids than it does in liquids and gases.

Reason: Molecules in solids can pass on disturbances faster as they are placed closer together.

Ans. (a)

6. **Assertion:** When sound travels, it is the disturbance from the source of the sound that travels from one part of the medium to another.

Reason: When a disturbance travels, there is both transfer of energy and transfer of matter in the medium through which the disturbance travels.

Ans. (c)

7. **Assertion:** The wavelength of a sound wave is inversely proportional to its frequency.

Reason: The time period of a sound wave is the reciprocal of its frequency.

Ans. (b)

8. **Assertion:** Two sounds with different pitch can have the same amplitude.

Reason: The pitch of a sound is a characteristic of the frequency of the sound.

Ans. (a)

9. **Assertion:** Intensity and loudness of sound are the same.

Reason: The higher the amplitude of a sound wave, the higher are its intensity and loudness.

Ans. (d)

10. **Assertion:** Sound travels faster in air in summer.

Reason: Humidity reduces the density of air.

Ans. (b)

11. **Assertion:** A sound that gets reflected and reaches us 0.01 seconds after the original sound reaches us will not be perceived as an echo by our ears.

Reason: The persistence of hearing for human ears is 1 second.

Ans. (c)

12. **Assertion:** Sound travels faster in solids than it does in liquids.

Reason: Solids have greater density than liquids do.

Ans. (b)

13. **Assertion:** Ultrasonic waves carry more energy than sound waves in the audible range.

Reason: Ultrasonic waves have higher frequency than sound waves in the audible range.

Ans. (a)

Source-based/Case-based/Passage-based/ Integrated Assessment Questions

Answer questions on the basis of your understanding of the following passages and the related studied concepts. (any four)

14. While sonars are generally spoken of in relation to ultrasound, in real-life, the frequencies of sonars can range from infrasonic to over 1 megahertz. Waves of different frequencies are used depending on the range to be covered and the resolution (clarity) required. In fact, the earliest modern usage of sonar, believed to have been prompted by the Titanic disaster of 1912, involved sound waves of frequencies in the range of 500 Hz. The two world wars necessitated rapid developments in the field of underwater echolocation. Even during World War II, the frequencies used were in the range of 14.5 to 17.5 KHz.

I. (a) Generally speaking, longer range of sonar will be possible with higher frequencies or lower frequencies? Why?

Ans. Lower frequencies have longer range because the energy lost is lower for lower frequencies.

(b) An American WW II ship emits a sound wave in the Atlantic Ocean. There's a German U-boat at a depth of 250 m vertically below the ship. If the speed of sound in ocean water is 1450 m/s, how much time would the wave reflected from the U-boat take to return to the ship?

Ans. 0.345 seconds

(c) If the same situation occurred in fresh water, will the wave take more time to return to the ship or less time? Why?

Ans. Less time, as speed travels faster in freshwater because of lower density.

(d) In ocean water, what would be the difference in the time taken to return to the ship between a 14.5 KHz wave and a 17.5 KHz wave?

Ans. No difference

II. (a) In SONAR, we use

(i) ultrasonic waves.
(ii) infrasonic waves.
(iii) radio waves.
(iv) none of the above.

Ans. (i) ultrasonic waves.

(b) Which waves are generated by SONAR device fixed to a fishing ship?

(i) Water waves (ii) Radio waves
(iii) Sound waves (iv) Infrared waves

Ans. (iii) Sound waves

(c) Infrasound can be heard by

(i) dog. (ii) bat.
(iii) rhinoceros. (iv) human beings.

Ans. (iii) rhinoceros.

(d) Bats search their prey at night by the method of

(i) echo destination.
(ii) echolocation.
(iii) echo displacement.
(iv) echo dictation.

Ans. (ii) echolocation.

(e) An eco-sounder in a fishing boat receives an echo from a shoal of fish 0.4 s after it was

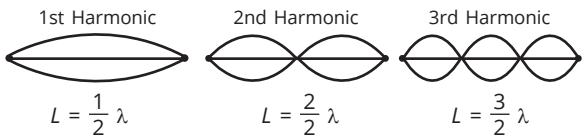
sent. What will be the depth of the shoal if speed of sound in water is 1500 m/s?

(i) 100 m (ii) 200 m

(iii) 300 m (iv) 400 m

Ans. (iii) 300 m

15. In general, the natural frequency at which any string vibrates depends upon the length of the string, the linear density of the string, and the tension in the string. A guitar string can naturally vibrate at different frequencies, which are known as the harmonics of the string. Each of these harmonics is associated with a standing wave pattern. The image below depicts the standing wave patterns associated with the lowest three harmonics or frequencies of a guitar string. *L* stands for the length of the string, and its relationship with the wavelength varies depending on the harmonic.



I. (a) What length of guitar string is required to produce a fundamental frequency (1st harmonic) of 256 Hz if the speed of waves in the string is given to be 405 m/s?

Ans. Wavelength (λ) = Wave velocity (*v*)/Frequency (ν)

(b) If the velocity of the waves in a guitar string is known, how do you find the wavelength for a wave of a specified frequency?

Ans. 0.791 m

(c) How many first harmonic waves are produced by this string in a second?

(i) 256 (ii) 128

(iii) 512 (iv) 0

Ans. (i) 256

(d) What is the frequency of the second harmonic for this guitar string?

(i) 64 Hz (ii) 128 Hz

(iii) 256 Hz (iv) 512 Hz

Ans. (iv) 512 Hz

II. (a) In which of the following instruments, sound is produced by the vibrations of stretched strings when plucked?

(i) Guitar (ii) Flute

(iii) Tabla (iv) Cymbals

Ans. (i) Guitar

(b) In which of the following instruments, sound is produced by the vibrations of stretched skin when struck?

(i) Guitar (ii) Flute

(iii) Drum (iv) Sitar

Ans. (iii) Drum

(c) Which of the following vibrates when a musical note is produced by the cymbals in an orchestra?

(i) Metal plates

(ii) Stretched skin

(iii) Stretched string

(iv) Air columns

Ans. (i) Metal plates

(d) When we change a feeble sound to a loud sound, we increase its

(i) frequency. (ii) amplitude.

(iii) velocity. (iv) wavelength.

Ans. (ii) amplitude.

(e) We can distinguish between the musical sounds produced by different singers on the basis of which characteristic of sound?

(i) Loudness (ii) Pitch

(iii) Timbre (iv) Frequency

Ans. (ii) Pitch

Very Short Answer Type Questions

16. Which has shorter wavelength, infrasonic or ultrasonic waves?

Ans. Ultrasonic waves have higher frequency than infrasonic waves, so their wavelength is shorter.

17. What is the relationship between the time period, wavelength and velocity of wave?

Ans. $\text{Velocity} = \text{wavelength} \times \frac{1}{\text{time period}}$

18. When one end of a metal pipe of length 2 m is struck a blow, what does a listener hear at the other end of the pipe, and why?

Ans. The listener hears two sounds, one travelling through the air and the other travelling through the metal pipe. The sound through metal reaches the listener before sound through air does.

19. Name two factors that can alter the speed of sound in a medium.

Ans. Temperature and density are two factors that can affect the speed of sound in a medium.

20. When sound is produced by a vibrating object, which form of energy is transformed into sound energy?

Ans. When sound is produced by a vibrating object, mechanical energy is transformed into sound energy.

21. A human heart beats 75 times a minute. Calculate its frequency.

Ans. The heart beats 75 times in 60 s. Therefore, it beats 1 time in $\frac{60}{75}$ s, which is the time period.

$$\text{Frequency} = \frac{1}{T} = \frac{1}{\left(\frac{60}{75}\right)} = \frac{75}{60}\ \text{Hz}$$

$$= 1.25\ \text{Hz}$$

22. A sound wave causes the density of air at a place to oscillate 1200 times in 2 minutes. Find the time period and frequency of the wave.

Ans. Oscillation takes place 1200 times in 120 s.

Therefore, it takes 1 time in $\frac{120}{1200\ \text{s}}$.

Thus, time period = $\frac{120}{1200\ \text{s}} = 0.1\ \text{s}$

$$\text{Frequency} = \frac{1}{T} = \frac{1}{0.1\,\text{s}}$$

$$= 10\ \text{Hz}$$

23. The frequency of a tuning fork is 440 Hz and the speed of sound in air is 352 m/s. How far has the sound travelled while the tuning fork completes 30 vibrations?

Ans. The sound travels one wavelength in one vibration

$$\text{Wavelength} = \frac{352\ \text{m/s}}{440\ \text{Hz}}$$

$$= 0.8\ \text{m}$$

In 30 vibrations, distance travelled

$$= 30 \times 0.8\ \text{m}$$

$$= 24\ \text{m}$$

24. A sonar device installed on a coastguard ship picks up a return signal from an enemy submarine after 8 s. How far is the enemy submarine from the ship? (Assume speed of sound in sea water to be 1540 m/s)

Ans. $2d = 1540\ \text{m/s} \times 8\ \text{s}$

or $d = 6160\ \text{m}$

25. A bat in search of prey hears the echo of its squeak after 0.1 s. How far is the prey from the bat, if the squeak got reflected from it? (Speed of sound = 340 m/s)

Ans. $2d = 340\ \text{m/s} \times 0.1\ \text{s}$

or $d = 17\ \text{m}$

26. An FM radio station broadcasts songs at 93.5 MHz. If the speed of radio waves is 3×10^8 m/s, what is the wavelength of the radio waves emitted by the radio station?

Ans. $$\text{Wavelength} = \frac{3\times10^8\ \text{m/s}}{93.5\times10^6\ \text{Hz}}\ \text{Hz}$$

$$= 3.2\ \text{m}$$

Short Answer Type-I Questions

27. Why is the velocity of sound higher in steel than in water or air?

Ans. The molecules inside iron are more closely packed together than they are in water or in air. Since the propagation of a wave through a medium takes place through the transfer of disturbance from one particle to the adjacent one, the closer the adjacent molecules are, the faster this transfer of disturbance will be. Thus, velocity of sound is higher in steel than in water or air.

28. 50 waves pass through a point in 0.1 second. If the distance between one crest and the adjacent trough is 0.34 m, calculate the

(a) frequency,

(b) wavelength, and

(c) wave velocity.

Ans. (a) 50 waves pass through a point in 0.1 s

Therefore, one wave pass in $\frac{0.1}{50\ \text{s}}$

$$\text{Frequency} = \frac{1}{\left(\frac{0.1}{50\ \text{s}}\right)}$$

$$= 500\ \text{Hz}$$

(b) The distance between one crest and the adjacent trough = 0.34 m

Then, wavelength = the distance between two adjacent crests = $2 \times 0.34\ \text{m} = 0.68\ \text{m}$

(c) Wave velocity = frequency × wavelength
$= 500\ \text{Hz} \times 0.68\ \text{m} = 340\ \text{m/s}$

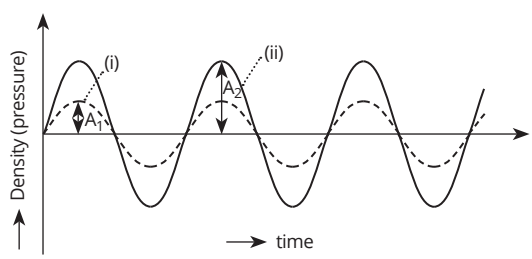
Short Answer Type-II Questions

29. Draw graphs to show difference between.

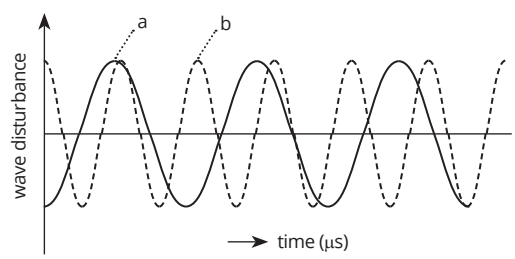
(a) a loud sound and a soft sound of the same pitch, and

(b) a low-pitched sound and a high-pitched sound of the same amplitude

Ans. (a)



(b)



30. How is the pressure variation in a sound wave amplified in the human ear?

Ans. The eardrum is attached to three bones in the middle ear called the hammer, the anvil, and the stirrup. The pressure variation in a sound wave causes the eardrum to vibrate, and the eardrum passes these vibrations on to the three bones. These three bones increase the strength of vibration or amplify the pressure variation of the sound wave before passing them on to the inner ear.

31. Two buildings are 3.3 km apart. A gun is fired from one building. The time difference between seeing the flash of gun and hearing its sound is 10 s. Find the speed of sound in air.

Ans. Let speed of sound v.

$$\frac{3300\ m}{v} - \frac{3300\ m}{3\times10^8\ \text{m/s}} = 10\ \text{s}$$

or $$\frac{3300\ m}{v} = 10\ \text{s}$$

or $$v = 330\ \text{m/s}$$

Long Answer Type Questions

32. A reporter from a TV channel watches the flashes of two tanks firing at each other at the same time on a straight road ahead of him. He hears the sounds of the two shots 2 seconds and 3.5 seconds after seeing the flashes. He assumes the speed of sound in air to be 340 m/s, and is quickly able to report the distance between the two tanks. What distance did he report (assuming he got his calculations right)?

Ans. Let the distance of the first tank from the reporter be d_1 and that of the second tank be d_2.

$$\frac{d_1}{340\ \text{m/s}} = 2\ \text{s}$$

or $$d_1 = 680\ \text{m}$$

$$\frac{d_2}{340\ \text{m/s}} = 3.5\ \text{s}$$

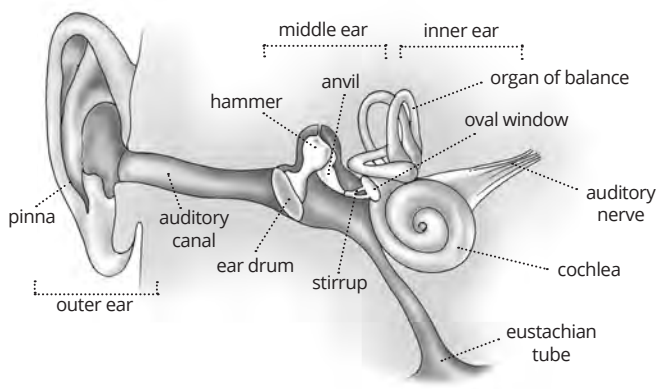
or $$d_2 = 1190\ \text{m}$$

The distance between the two tanks

$$= d_2 - d_1$$
$$= 1190\ \text{m} - 680\ \text{m}$$
$$= 510\ \text{m}$$

33. Explain the structure of the human ear with the help of a simple diagram.

Ans.



Structure of ear

34. (a) Can transverse waves travel in gases?

(b) Can longitudinal waves travel in solids, liquids as well as gases?

(c) At any instant, a compression is formed at a point. After how much time will
(i) a rarefaction, and
(ii) a compression be formed at the same point?

Ans. (a) No, transverse waves cannot travel in gases. Light and electromagnetic waves, even though they are transverse in nature, can do so because of certain special properties.

(b) Yes, longitudinal waves (like sound) can travel in solids, liquids, as well as gases.

(c) (i) A rarefaction will be formed after half the time-period of the wave. (ii) A compression will be formed after a time equal to the time period of the wave.

Let's Compete

(Page 124)

Multiple-Choice Questions

1. The technique of obtaining images of the heart by using ultrasound is called

(a) ultrasonography. (b) echocardiography.
(c) sonar. (d) ultrascanning.

Ans. The correct answer is (b).

2. For the formation of a distinct echo, the distance between the sound source and the reflecting surface must be at least about

(a) 10 m (b) 17 m
(c) 34 m (d) 100 m

Ans. The correct answer is (b).

3. An aircraft moving at supersonic speed produces

(a) magnetic waves.

(b) electromagnetic waves.

(c) shock waves.

(d) none of these

Ans. The correct answer is (c).

4. In 2004, NASA's X-43A unmanned aircraft hit a speed of Mach 9.6. What is this speed approximately equal to in km/h?

(a) 3300 km/h (b) 5500 km/h

(c) 8500 km/h (d) 11880 km/h

Ans. Speed = Mach × speed of sound in air = 9.6 × 340 m/s = 3264 m/s = 11750.4 km/h. This is close to option (d). Therefore, the correct answer is (d).

5. A longitudinal wave is produced on a toy slinky. The wave travels at a speed of 30 cm/s and the frequency of the wave is 20 Hz. The minimum distance between consecutive compressions of the slinky is

(a) 1 cm (b) 1.5 cm

(c) 3 cm (d) 5 cm

Ans. Wavelength = $\frac{30 \text{ cm/s}}{20 \text{ Hz}} = \frac{0.3 \text{ m/s}}{20 \text{ Hz}}$ = 0.015 m

= 1.5 cm

Therefore, the correct answer is (b).

6. A sound wave consists of

(a) a number of compression pulses one after the other.

(b) a number of rarefaction pulses one after the other.

(c) compression and rarefaction pulses one after the other.

(d) a compression and a rarefaction pulse separated by a distance equal to one wavelength.

Ans. The correct answer is (c).

7. Which one of the following statements is correct?

(a) A pulse is of long duration.

(b) A pulse is a sudden disturbance of short duration.

(c) A pulse is produced by clapping of hands once.

(d) Mass is transported from one place to the other by a pulse.

Ans. The correct answer is (b).

8. A sound wave of wavelength 90 cm in glass is refracted into air. If the speed of sound in glass is 5400 m/s, the wavelength of the wave in air (speed of sound in air = 330 m/s) is

(a) 55 cm (b) 5.5 cm

(c) 55 m (d) 5.5 m

Ans. Frequency of the wave = $\frac{5400 \text{ m/s}}{0.9 \text{ m}}$ = 6000 Hz

Wavelength in air = $\frac{330 \text{ m/s}}{6000 \text{ Hz}}$ = 0.055 m = 5.5 cm

The correct answer is (b).

9. Mechanical waves can be

(a) longitudinal only.

(b) transverse only.

(c) both longitudinal and transverse.

(d) neither longitudinal nor transverse.

Ans. The correct answer is (c).

10. Chandigarh radio station broadcasts at 1200 kHz. At what metre Chandigarh station would be tuned in your transistor? (Hint. Find out the speed of radio waves)

(a) 200 m (b) 225 m

(c) 250 m (d) 275 m

Ans. Wavelength = $\frac{\text{speed}}{\text{frequency}}$

= $\frac{3 \times 10^8 \text{ m/s}}{1200000 \text{ Hz}}$

= 250 m

Therefore, the correct answer is (c).

Value-based Questions

(Optional) (Page 125)

1. Shahrukh and Anushka study in the same school in Class IV and Class IX, respectively, and live in the same tall multi-storey building. Shahrukh got hold of some crackers during his Diwali vacations and decided to burst them on his own. Standing behind his building one evening, he exploded the first cracker and heard another similar loud sound immediately afterwards. He got scared, but Anushka, who was passing by, reassured him that this was just an echo and explained the phenomenon to him. Anushka also advised Shahrukh that it is unsafe to burst crackers without the presence of an adult.

(a) What is an echo? How is it formed?

(b) On noting the time, they found that the echo is heard 1.2 s after the cracker explodes. How far from the building was Shahrukh standing if the speed of sound in air is 340 m/s?

(c) What can we learn from Anushka from the way she behaved with her young friend?

Ans. (a) An echo is heard when one or more sounds caused by the reflection of sound waves from a surface travel back to the source of the sound.

(b) $2d$ = 340 m/s × 1.2 s

or $d = 204$ m

(c) Being considerate, respecting younger children, explaining things instead of ordering or scolding them

2. Roshan and his friend Tavleen were out on a drive in Roshan's car. As they neared a hospital, they could see another car moving in front of them at a very slow speed. Roshan was about to blow the horn, when Tavleen stopped him and pointed at the hospital sign.

(a) Why is it inadvisable to blow the horn near a hospital?

(b) What can we learn from Tavleen from this incident?

Ans. (a) The high decibel sound from a horn can be particularly discomforting for the sick as they need proper rest to get better.

(b) Develop civic sense; never hesitate to point out if someone is breaking rules or being inconsiderate

3. Joseph's young nephew had just started taking *tabla* lessons and was eager to show the entire family what he had learnt. But when he sat down with the *tabla* drums in front of everyone, he was disheartened to find that the sound from them was very flat. Joseph informed him that the membrane of the drums needs to be tightened for a high pitch sound to be produced by the instrument, and taught the boy how to do it.

(a) How does the tightening of the membrane result in high-pitched sound?

(b) What do we learn from Joseph's behaviour?

Ans. (a) The tighter the membrane is, higher is the frequency of the vibration produced.

(b) Apply your knowledge to help others; be considerate towards children