Chapter: 01

Physical Quantities and Measurement

Exercise MCQs

1. **The number of base unit is SI is:**

   Ⓐ 3 Ⓑ 6 Ⓒ 7 Ⓓ 9

2. **Which one of the following unit is not a derived unit?**

   Ⓐ Pascal Ⓑ Kilogram Ⓒ Newton Ⓓ Watt

3. **Amount of a substance in terms of numbers is measured in:**

   Ⓐ Gram Ⓑ Kilogram Ⓒ Newton Ⓓ Mole

4. **An interval of 200μs is equivalent to:**

   Ⓐ 0.2 s Ⓑ 0.02 s Ⓒ 2×10^{-4} s Ⓓ 2×10^{-6} s

5. **Which one of the following is the smallest quantity?**

   Ⓐ 0.01g Ⓑ 2mg Ⓒ 3mg Ⓓ 5000ng

6. **Which instrument is most suitable to measure the internal diameter of a test tube?**

   Ⓐ Metre Rule Ⓑ Vernier Calipers Ⓒ Measuring Tap Ⓓ Screw Gauge

7. **A student claimed the diameter of a wire as 1.032cm using Vernier Calipers. Unto what extent do you agree with it?**

   Ⓐ 1cm Ⓑ 1.0cm Ⓒ 1.03cm Ⓓ 11.032cm

8. **A measuring cylinder is used to measure.**

   Ⓐ Mass Ⓑ Area Ⓒ Volume Ⓓ Level of a liquid

9. **A student noted the thickness of a glass sheet using a screw gauge. On the main scale, it reads 3 divisions while the 8th division on the circular scale coincides with the index line. Its thickness is.**

   Ⓐ 3.8cm Ⓑ 3.08mm Ⓒ 3.8mm Ⓓ 3.08cm

10. Significant figures in an expression are:

Ⓐ All the digits

Ⓑ All the accurately known digits

Ⓒ All the accurately known digits and the first doubtful digit

Ⓓ All the accurately known and the doubtful digits

Answer Key:

1	Ⓒ	**6**	Ⓑ
2	Ⓑ	**7**	Ⓒ
3	Ⓓ	**8**	Ⓒ
4	Ⓒ	**9**	Ⓑ
5	Ⓓ	**10**	Ⓒ

Short Questions

1. What is the difference between base quantities and derived quantities? Give three examples in each case.

Ans: The difference between base quantities and derived quantities is:

Base Quantities	Derived Quantities
Base quantities are the quantities on the basis of which other quantities are derived. **Example:** Length, mass, time, electric current, temperature, intensity of light, and amount of substance.	The quantities that are expressed in terms of base quantities are called derived quantities. **Example:** Volume, speed, force, work, energy, power, and electric charge.

2. Pick out the base units in the following:
Joule, Newton, Kilogram, Hertz, Mole, Ampere, Metre, Kelvin, Coulomb, and Watt.

Ans: **Base Units:**

Kilogram, mole, ampere, metre and kelvin and the base units.

3. Estimate your age in seconds.

Ans: My age is 17 years old. So,

1 year = 365 days

1 day = 24 hours

1 hour = 60 minutes

1 minute = 60 seconds

Total seconds in one year = $365 \times 24 \times 60 \times 60$ = 31536000 seconds

Total seconds in 17 years = 17×31536000

My age is seconds = 536112000 seconds.

4. Find the base quantities involved in each of the following derived quantities.

Speed Volume Force Work

Ans: **Speed:** Derived from "Length and time".

Volume: Derived from "Length".

Force: Derived from "Mass, length and time".

Work: Derived from "Mass, length and time".

5. What role Si units have played in the development of science?

Ans: Si units have brought consistency and uniformity in calculation and results. SI units are very helpful to exchange scientific and technical information at the international level.

6. What is meant by Vernier constant?

Ans: The least count of Vernier calipers is known as Vernier constant.

Vernier Constant: It is ratio between smallest readings on main scale to the total divisionon Vernier scale.

OR

The difference between one small division on the main scale and one Vernier scale division.

Formula:

$$\text{Vernier constant} = \frac{\text{Smallest reading on main scale}}{\text{Total No.of divisions on vernier scale}}$$

7. Why is the use of zero error necessary in a measuring instrument?

Ans: Zero error is necessary in measuring instrument to obtain an extreme correct value.

8. What do you understand by the zero error of a measuring instrument?

Ans: When zero of Vernier scale does not coincide with zero of main scale, then instrumenthas "zero error".

9. What is a stopwatch? What is the least count of a mechanical stopwatch you haveused in the laboratories?

Ans: Stopwatch:

"Stopwatch is a device used to measure the time interval of an event".

Least count:

Mechanical stopwatches have least count up to 0.1 second.

10. What is meant by significant figures of a measurement?

Ans: Significant figures:

"All the accurately known digits and the first doubtful digit in anexpression are called significant figures".

Significant figures reflect the precision of a measure value of a physical quantity.

11. Why do we need to measure extremely small interval of times?

Ans: We need to measure extremely small interval of times to calculate the time intervals of natural and artificial events. As in nature and also in physics, there are so many phenomenon's which vary with respect to the small intervals of time.

12. How is precision related the significant figures in a measured quantity?

Ans: An improvement in the quality of measurement by using better instrument increases the significant figures in the measured results. The significant figures are all accurately known digits and the one estimated digit.

Important Conversion

- 1MW = 10^6 W
- 1kg = 10^3 g
- 1 Milligram = 10^{-3} g
- 1 Micro gram = 10^{-6} g
- 1 Nano gram = 10^{-9} g
- 1 Pico gram = 10^{-12} g

- 1 day = 24 hours
- 1 hour = 60 minutes
- 1 minute = 60 seconds
- 1 day = 24 ×60 ×60
- 1 day = 86400 seconds

Important Formulas

- Least count of Screw Gauge = $\dfrac{\text{Pitch}}{\text{No. of division on circular scale}}$
- Least count of Vernier Caliper = $\dfrac{\text{Smallest reading within main scale}}{\text{Number of divisions within vernier scale}}$
- Least count of Vernier caliper = 0.1 mm or 0.01 cm
- Least count of Screw Gauge = 0.01 mm or 0.001 cm
- Area = Length × Width

Numerical

1. Express the following quantities using prefixes.

(a) 5000 g (b) 2000000 W (c) 52×10^{-10} kg (d) 225×10^{-8} S

Ans: Solution:

(a) 5000 g

$5000\ g = 5 \times 10^3\ g$ $(\because\ 10^3\ g = 1\ kg)$

$5000\ g = 5\ kg$

(b) 2000000 W

$2000000\ W = 2 \times 10^6\ W$ $(\because\ 10^6\ W = 1\ MW)$

$2000000\ W = 2\ MW$

(c) 52×10^{-10} kg

$52 \times 10^{-10}\ kg = 52 \times 10^{-10} \times 10^3\ g$ $(\because\ 1\ kg = 10^3\ g)$

$52 \times 10^{-10}\ kg = 52 \times 10^{-7}\ g$

$52 \times 10^{-10}\ kg = 5.2 \times 10^1 \times 10^{-7}\ g$

$52 \times 10^{-10}\ kg = 5.2 \times 10^{-6}\ g$ $(\because\ 10^{-6}\ g = 1\ \mu g)$

$52 \times 10^{-10}\ kg = 5.2\ \mu g$

(d) 225×10^{-8} s

$225 \times 10^{-8}\ s = 2.25 \times 10^2 \times 10^{-8}\ s$

52×10^{-10} kg $= 2.25 \times 10^{-6}$ s $(\therefore\ 10^{-6}\,s = 1\ \mu s)$

52×10^{-10} kg $= 2.25\ \mu s$

2. How do their prefixes micro, nano and pico relate to each other?

Ans: Solution:

As

micro $= 10^{-6}$, nano $= 10^{-9}$, pico $= 10^{-12}$

So,

1000 nano $=$ 1000×10^{-9}

1000 nano $=$ $10^{3} \times 10^{-9}$

1000 nano $=$ 10^{-6}

1000 nano = 1 micro

As,

1000 pico $=$ 1000×10^{-12}

1000 pico $=$ $10^{3} \times 10^{-12}$

1000 pico $=$ 10^{-9}

1000 pico = 1 nano

3. You hair grow at the rate of 1 mm per day. Find their growth rate in nms^{-1}.

Ans: Solution:

Length of hair $= 1mm = 1 \times 10^{-3}$ m

Time $= 24$ hours $= 86400$ seconds

To Find:

Growth rate per day = ?

Formula:

$$\text{Growth rate per day} = \frac{\text{Lenth of hair}}{\text{Time}}$$

Solution:

Putting the values, we have

$$\text{Growth rate per day} = \frac{1 \times 10^{-3}\ \text{m}}{876400\ \text{sec}}$$

Growth rate per day = 1.157×10^{-8} ms^{-1}

Growth rate per day = 11.57×10^{-9} ms^{-1}

Growth rate per day = 11.57 nms^{-1} ($\therefore$ 1 n = 10^{-9})

Result:

The growth rate per day of human hair is 11.57 nms^{-1}.

4. Rewrite the following in standard form.

(a) 1168×10^{-27} (b) 32×10^{5} (c) 725×10^{-5} kg (d) 0.02×10^{-8}

Ans: Solution:

(a) 1168×10^{-27}

$1168 \times 10^{-27} = 1.168 \times 10^{3} \times 10^{-27}$

$1168 \times 10^{-27} = 1.168 \times 10^{3-27}$

$1168 \times 10^{-27} = 1.168 \times 10^{-24}$

(b) 32×10^{5}

$32 \times 10^{5} = 3.2 \times 10^{1} \times 10^{5}$

$32 \times 10^{5} = 3.2 \times 10^{1+5}$

$32 \times 10^{5} = 3.2 \times 10^{6}$

(c) 725×10^{-5} kg

725×10^{-5} kg $= 7.25 \times 10^{2} \times 10^{-5}$ kg

725×10^{-5} kg $= 7.25 \times 10^{2-5}$ kg

725×10^{-5} kg $= 7.25 \times 10^{-3}$ kg ($\therefore$ 1 kg = 10^{3} g)

725×10^{-5} kg $= 7.25 \times 10^{-3} \times 10^{3}$ g

725×10^{-5} kg $= 7.25 \times 10^{-3+3}$ g ($\therefore$ $10^{-3+3} = 10^{0} = 1$)

725×10^{-5} kg $= 7.25$ g

5. Write the following quantities in standard form.

(a) 6400 km (b) 380000 km (c) 300000000 ms^{-1} (d) No. of second in a day

Ans: Solution:

(a) 6400 km

6400 km = 6.4×10^{3} km

(b) 380000 km

380000 km = 3.8×10^{5} km

(c) 380000 km

$300000000\ ms^{-1} = 3 \times 10^8\ ms^{-1}$

(d) No. of second in a day

No. of second in a day = $24 \times 60 \times 60$ s

No. of second in a day = 86400 s

No. of second in a day = 8.64×10^4 s

6. One closing the jaws of Vernier caliper, zero the Vernier scale is on the right to its main scale such that 4th division of its Vernier scale coincides with one of the main scale division. Find its zero error and zero correction.

Ans: Solution:

Vernier division coinciding with main scale = 4th division

Least count = 0.01 cm

Vernier scale reading = 4×0.01

Vernier scale reading = 0.04 cm

Since zero of Vernier scale is on the right side of zero of the main scale, so, instrument has measured more than actual reading. It is positive zero error and correction should be negative.

Zero error = +0.04 cm

Zero correction = −0.04 cm

7. A screw gauge has 50 divisions on its circular scale. The pitch of the screw gauge is 0.5mm. What is the least count?

Ans: Given data:

Number of divisions on circular scale = 50 divisions

Pitch of screw gauge = 0.5 mm

To Find:

Least count = ?

Solutions:

$$\text{Least Count} = \frac{\text{Pitch}}{\text{No. of division on circular scale}}$$

$$\text{Least Count} = \frac{0.5\ \text{mm}}{50}$$

Least Count = 0.01 mm $\quad (\because\ 1\ \text{cm} = 10\ \text{mm})$

Least Count = 0.001 cm

8. Which of the following quantities have three significant figures?

(a) 3.0066 m (b) 0.00309 kg (c) 5.05×10^{-27} kg (d) 301.0 s

Ans: Solution:

(a)	**3.0066 m**	has 5 significant digits.
(b)	**0.00309 kg**	has 3 significant digits.
(c)	**5.05×10^{-27} g**	has 3 significant digits.
(d)	**301.0 s**	has 4 significant digits.

So, values in part (b) and (c) have three significant figures.

9. What are the significant figures in the following measurements?

(a) 1.009 m (b) 0.00450 kg (c) 1.66×10^{-27} kg (d) 2001 s

Ans: Solution:

(a)	**1.009 m**	has 4 significant digits.
(b)	**0.00450 kg**	has 3 significant digits.
(c)	**1.66×10^{-27} kg**	has 3 significant digits.
(d)	**2001 s**	has 4 significant digits.

10. A chocolate wrapper is 6.7cm long and 5.4 cm wide. Calculate its area up to reasonable number of significant figures.

Ans: Given data:

Length of wrapper = 6.7 cm

Width of wrapper = 5.4 cm

Required:

Area of wrapper = ?

Solutions:

Area = Length × Width

Area = 6.7 cm × 5.4 cm

Area = 36.18 cm^2

According to the principle of reasonable numbers of significant figures.

Area = 36 cm^2 (after rounding)

Chapter: 02

Kinematics

Exercise MCQs

1. **A body has translatory motion if it moves along a:**

   Ⓐ straight line Ⓑ circle Ⓒ line without rotation Ⓓ curved path

2. **The motion of a body about an axis is called:**

   Ⓐ Circular Motion Ⓑ Rotatory Motion
   Ⓒ Vibratory Motion Ⓓ Random Motion

3. **Which of the following is a vector quantity?**

   Ⓐ Speed Ⓑ Distance Ⓒ Displacement Ⓓ Power

4. **If an object is moving with constant speed then its distance time graph will be a straight line:**

   Ⓐ along time axis Ⓑ along distance axis
   Ⓒ parallel to time axis Ⓓ inclined to time axis

5. **A straight line parallel to time axis on a distance time graph tells that the object is:**

   Ⓐ moving with constant speed Ⓑ at rest
   Ⓒ moving with variable speed Ⓓ in motion

6. **By dividing displacement of a moving body with time, we obtain:**

   Ⓐ Speed Ⓑ Acceleration Ⓒ Velocity Ⓓ Deceleration

7. **A ball is thrown vertically upward. Its velocity at the highest point is:**

   Ⓐ $-10\ ms^{-1}$ Ⓑ zero Ⓒ $10\ ms^{-2}$ Ⓓ none of these

8. **A change in position is called:**

   Ⓐ speed Ⓑ velocity Ⓒ displacement Ⓓ distance

9. **A train is moving at a speed of $36kmh^{-1}$. Its speed expressed to ms^{-1} is:**

   Ⓐ $10ms^{-1}$ Ⓑ $20ms^{-1}$ Ⓒ $25ms^{-1}$ Ⓓ $30ms^{-1}$

10. A car starts from rest. It acquires a speed of 25ms^{-1} after 20s. The distance moved by the car during this time is:

Ⓐ 31.25m Ⓑ 250m Ⓒ 500m Ⓓ 5000m

Answer Key:

1	Ⓐ	**6**	Ⓒ
2	Ⓑ	**7**	Ⓑ
3	Ⓒ	**8**	Ⓓ
4	Ⓒ	**9**	Ⓐ
5	Ⓐ	**10**	Ⓒ

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Short Questions

Q1: Explain translatory motion and give examples of various types of translatory motion.

Ans: Translatory motion:

The motion, in which a body moves along a line (straight or curved) without any rotation, is called translator motion.

Example:

Motion of Ferris wheel

Types of translatory motion:

(a) Circular motion (b) Linear motion (c) Random motion

(a) Circular motion:

The motion of an object in a circular path is known as circular motion.

Example:

A car is moving along a circular track.

(b) Linear motion:

The straight line motion of a body is known as its linear motion.

Example:

Rocket flying straight in the air is linear motion.

(c) Random motion:

The disordered or irregular motion of an object is called random motion.

Example:

The motion of insects and birds is random motion.

Q2: Define the terms speed, velocity, and acceleration.

Ans: **Speed (V):**

The rate of change of position with time is called speed. Its unit is ms^{-1}.

Velocity ($\vec{V}$):

The rate of change of displacement is called velocity and its unit is ms^{-1}.

Acceleration ($\vec{a}$):

The rate of change of velocity is called acceleration and its unit is ms^{-2}.

Q3: Differentiate between the following:

(a) Rest and motion.
(b) Circular motion and rotatory motion.
(c) Distance and displacement.
(d) Speed and velocity.
(e) Linear and random motion.
(f) Scalars and vectors.

Ans: Difference between Rest and Motion is:

Rest	Motion
"A condition in which a body does not change its position with respect to its surroundings". **Example:** ➢ A book lying on the table. ➢ A bench fixed in a park.	"A condition in which a body changes its position with respect to its surroundings". **Example:** ➢ A flying bird. ➢ A boy playing football.

Difference Circular Motion and Rotatory Motion is:

Circular Motion	Rotatory Motion
➢ The motion of an object or body in a circular path is called circular motion. ➢ In circular motions, the point about which a body goes around is	➢ The motion of a body around an axis passing through it is called rotatory motion. ➢ In rotatory motion, the line around which a body moves about

outside the body. **Examples:** ➢ The moon circling the earth. ➢ A satellite circling round the earth.	is passing through the body itself. **Examples:** ➢ A rotating fan. ➢ A spinning top.

Difference Distance and Displacement:

Distance	Displacement
➢ Total length of a path between two points is called distance. ➢ Distance is a scalar quantity.	➢ The shortest distance between two points is called displacement. ➢ Displacement is a vector quantity.

Difference Speed and Velocity:

Speed	Velocity
➢ Distance covered by a body in unit time is called speed. ➢ Distance is a scalar quantity. **Formula:** $V = \frac{s}{t}$	➢ The shortest distance between two points is called displacement. ➢ Displacement is a vector quantity. **Formula:** $V = \frac{d}{t}$

Difference Linear and Random Motion:

Linear Motion	Random Motion
The motion of a body along a straight line is called linear motion. **Example:** Freely falling object.	The irregular or zigzag motion of a body is called random motion. **Example:** Random motion of gas molecules.

Difference Scalars and vectors:

Scalars	Vectors
A scalar quantity is a quantity which can be completely specified by a magnitude only. **Example:** Work, power, speed and distance, etc.	Vectors are quantities, which are completely specified by both magnitude and direction. **Example:** Velocity, force, torque and displacement

	etc.

Q4: Can a body moving at a constant speed have acceleration?

Ans: **Yes,** a body moving at constant speed has acceleration if it changes its direction or moves in a circular path.

Q5: How do riders in a Ferries wheel possess translatory motion but not rotatory motion?

Ans: In rotatory motion, the line, about which a body moves, it's passing through the body itself. Here, riders in the Ferris wheel have circular motion (a type of translatory motion) because the line about which wheel riders go around lies outside the body.

Q6: What would be the shape of a speed-time graph of a body moving with variable speed?

Ans: The shape of the velocity-time graph is zigzag i.e. not a straight line, when the body is moving at variable speed.

Q7: Sketch a distance-time graph for a body starting from rest. How will you determine the speed of a body from this graph?

Ans: The shape of the graph is as shown in Fig.

$$\text{The slope of this graph gives} = \frac{\Delta S}{t}$$

$$\text{The slope of this graph gives} = \frac{\text{change in distance}}{\text{time}}$$

$$\text{The slope of this graph gives} = \frac{d}{t}$$

i.e. slope of this graph = speed

Q8: Which of the following can be obtained from speed-time graph of a body?

(a) Initial speed **(b) Final speed**

(c) Distance covered in time t **(d) Acceleration of motion**

Ans: All the above quantities can be obtained from the speed-time graph of a moving body.

Q9: How can vector quantities be represented graphically?

Ans: Vectors are graphically represented by a straight line with an arrowhead. The length of a line shows the magnitude and arrowhead tells about direction.

Q10: How are vector quantities important to us in our daily life?

Ans: Vectors quantities are important to us in our daily life because they provide complete information about quantity i.e. magnitude and direction.

Q11: Why vector quantities cannot be added and subtracted like scalar quantities?

Ans: Scalar quantities are the quantities which can be described completely by magnitude while vector quantities need direction and magnitude for their complete description. The quantities having direction cannot be added and subtracted like scalar quantities.

Q12: Derive equations of motion for uniformly accelerated rectilinear motion?

Ans: Equations of motion for uniformly accelerated rectilinear motion is:

(a) $\mathbf{v_f = v_i + at}$

$$\text{Slope of AB} = a, = \frac{BC}{AC} = \frac{BC - CD}{OD}$$

As $BD = v_f \quad , \quad CD = v_i \quad , \quad OD = t$

$$a = \frac{v_f - v_i}{t}$$

$$v_f = v_i + at$$

(b) $\mathbf{S = v_i t + \frac{1}{2} at^2}$

From figure,

$$\text{Area of OACD} = OA \times OD$$

$$\text{Area of OACD} = v_i \times t$$

$$\text{Area of triangle ABC} = \frac{1}{2} \times \text{height} \times \text{base}$$

$$\text{Area of triangle ABC} = \frac{1}{2}(AC)(BC)$$

$$\text{Area of triangle ABC} = \frac{1}{2} at^2$$

Total area OABD = Area of rectangle OACD + Area of triangle ABC

$$\text{Total area} = v_i t + \frac{1}{2} at^2$$

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

(c) $\mathbf{2aS = v_f^2 - v_i^2}$

$$\text{Total area of OABD} = \left(\frac{\text{OA} + \text{BD}}{2}\right) \times \text{OD}$$

$$S = \left(\frac{OA + BD}{2}\right) \times OD$$

$$2S = (OA + BD) \times OD$$

Multiplying by $\left(\frac{BC}{OD}\right)$ on both sides

$$2S \times \left(\frac{BC}{OD}\right) = [(OA + BD) \times OD] \left(\frac{BC}{OD}\right)$$

$$2S \times \left(\frac{BC}{OD}\right) = (OA + BD) \times BC$$

$$2S \times a = (v_f + v_i)(v_f - v_i)$$

$$2aS = v_f^2 - v_i^2$$

Important Formulas

- $v_f = v_i + at$
- $2aS = v_f^2 - v_i^2$
- $S = v_i t + \frac{1}{2}at^2$
- $S = v_{av} \times t$

Important Values

- $1km = 1000m$
- $1hour = 3600second$
- $1kmh^{-1} = \frac{1000m}{3600second}$

  $1kmh^{-1} = \frac{10}{36} ms^{-1}$
- $1kmh^{-1} = 0.277\ ms^{-1}$
- $1m = \frac{11}{1000} km = \frac{1}{10^3} km$
- $1m = 10^{-3}km = 0.001km$
- $1m = \frac{1}{3600} h$
- $\frac{1m}{second} = \frac{0.001km}{\frac{1}{3600} h}$
- $1ms^{-1} = 0.001 \times 3600\ kmh^{-1}$
- $1ms^{-1} = 3.6\ kmh^{-1}$

Units: (S.I)

- Distance = S = metre (m)
- Displacement = d = metre (m)
- Speed = v = ms^{-1}
- Velocity = v = ms^{-1}
- Acceleration = a = ms^{-2}
- Time = t

Numerical

1. A train moves with a uniform velocity of 36kmh^{-1} for 10s. Find the distance travelled by it.

Ans: Given data:

$$V = 36\ \text{kmh}^{-1} = \frac{36 \times 1000}{3600}$$

$$V = \frac{36000}{3600}$$

$$V = 10\text{ms}^{-1}$$

$$t = 10\text{s}$$

To Find:

$$S = ?$$

Solution:

$$S = v_i \times t$$

$$S = 10 \times 10$$

$$\mathbf{S = 100m}$$

2. A train starts from rest. It moves through 1km in 100s with uniform acceleration. What will be its speed at the end of the100s?

Ans: Given data:

$$V_i = 0\text{ms}^{-1}$$

$$S = 1\text{km} = 1000\text{m}$$

$$t = 100\text{s}$$

To Find:

$$V_f = ?$$

Solution:

By using 2nd equation of motion.

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

$$1000 = 0 \times t + \frac{1}{2}(a)(100)^2$$

$$1000 = \frac{1}{2}(a)(10000)$$

$$2000 = (a)(10000)$$

$$\frac{2000}{10000} = a$$

$$0.2\ ms^{-2} = a$$

Now, we can find the final velocity:

$$v_f = v_i + at$$

Using the values:

$$v_f = 0 + (0.2)\ (100)$$

$$v_f = 20ms^{-1}$$

The speed of the train is $20ms^{-1}$.

3. A car has a velocity of $10ms^{-1}$. It accelerates at $0.2ms^{-2}$ for half a minute. Find the distance travelled during this time and the final velocity of the car.

Ans: Given data:

$$V_i = 10ms^{-1}$$

$$a = 0.2\ ms^{-2}$$

$$t = \frac{1}{2}\text{minute} = 30\text{sec}$$

To Find:

$$S = ?$$

$$V_f = ?$$

Solution:

(i) By using 2nd equation of motion.

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

$$S = 10 \times 30 + \frac{1}{2}(0.2)(30)^2$$

$$S = 300 + \frac{1}{2}(0.2)(900)$$

$$S = 300 + (0.1)(900)$$

$$S = 300 + 90$$

$$\mathbf{S = 390m}$$

(ii) Using 1st equation of motion.

$$v_f = v_i + at$$

Using the values

$$v_f = 10 + (0.2)\ (30)$$

$$v_f = 10 + 6$$

$$\mathbf{v_f = 16ms^{-1}}$$

4. A tennis ball is hit vertically upward with a velocity of $30ms^{-1}$. It takes 3sec to reach the highest point. Calculate the maximum height reached by the ball. How long it will take to return to the ground?

Ans: Given data:

$$v_i = 30ms^{-1}$$
$$v_f = 0ms^{-1}$$
$$g = -10ms^{-2}$$
$$t = 3sec$$

To Find:

$$S = h = ?$$

Solution:

$$H = v_i t + \frac{1}{2} gt^2$$
$$h = 30 \times 3 + \frac{1}{2}(-10)(3)^2$$
$$h = 30 \times 3 + (-5)(9)$$
$$h = 90 - 45$$
$$h = 45$$

The time taken by the ball to come to the ground:

Data can be written in this case as,

Initial velocity $= v_i = 0ms^{-1}$

Gravitational Acceleration $= g = 10ms^{-2}$

Time $= t = ?$

Distance $=$ height $= h = 45m$

As we know from second equation of motion.

$$H = v_i t + \frac{1}{2} at^2$$

By putting values, we get

$$45m = (0)\,(t) + \frac{1}{2}(10)(t)^2$$
$$45m = (5)\,t^2$$
$$\frac{45}{5} = t^2$$
$$9 = t^2$$

Or $t^2 = 9$

By taking under root on both sides:

$$\sqrt{t^2} = (3)^2$$

$$t = 3s$$

Total time taken by the ball is

$$3 + 3 = 6s$$

5. A car moves with a uniform velocity of 40ms^{-1} for 5s. It comes to rest in the next 10s with uniform deceleration. Find (i) the deceleration (ii) the total distance travelled by the car.

Ans: Given data:

Part (I)

$$\text{Time} = t = 10sec$$

$$\text{Initial velocity} = v_i = 40ms^{-1}$$

$$\text{Final velocity} = v_f = 0ms^{-1}$$

To Find:

$$\text{Deceleration} = a = ?$$

$$\text{Total distance covered} = S = ?$$

Solution:

$$v_f = v_i + at$$

$$0 = 40 + a\,(10)$$

$$-40 = 10a$$

$$A = -4ms^{-2}$$

Part (II)

To find the total distance (s)

$$S = v \times t$$

Using the values, we have

$$S = 40 \times 10$$

$$\mathbf{S = 400m}$$

The total distance covered by a car is 400m.

6. A train starts from rest with an acceleration of 0.5ms^{-2}. Find its speed in kmh^{-1} when it has moved through 100m.

Ans: Given data:

$$v_i = 0ms^{-1}$$

$$a = 0.5ms^{-2}$$

$$S = 100m$$

To Find:

$$v_f = ?$$

Solution:

Using 3rd equation of motion

$$2aS = v_f^2 - v_i^2$$

$$2\ (0.5)\ (100) = v_f^2 - 0^2$$

$$v_f^2 = 100$$

By taking square root on both sides

$$v_f = 10ms^{-1}$$

Conversion of ms^{-1} into Kmh^{-1}

$$v_f = \frac{10 \times 3600}{1000} kmh^{-1}$$

$$v_f = 36kmh^{-1}$$

7. A train starting from rest accelerates uniformly and attains a velocity of 48 kmh^{-1} in 2 minutes. It travels at this speed for 5 minutes. Finally, it moves with uniform retardation and is stopped after 3 minutes. Find the total distance traveled by the train.

Ans: Given data:

$$V_i = 0ms^{-1}$$

$$V_f = 48kmh^{-1} = \frac{48 \times 100}{36000} ms^{-1}$$

$$V_f = 13.3ms^{-1}$$

$$t_1 = 2min = 2 \times 60 = 120sec$$

Required:

Total distance $= S = ?$

Solution:

$$v_f = v_i + at$$

$$13.3 = 0 + a\ (120)$$

$$a = 0.1ms^{-2}$$

(i) Distance $= S_1 = ?$

$$S_1 = v_i t + \frac{1}{2} at^2$$

By putting values, we get

$$S_1 = 0 \times 120 + \frac{1}{2}(0.1)(120)^2$$

$$S_1 = 0 + \frac{1}{2}(0.1)(14400)$$

$$\mathbf{S_1 = 720m}$$

(ii) Motion with constant velocity

$$v = 13.33ms^{-1}$$

$$t_2 = 5min = 5 \times 60 = 300sec$$

$$S_2 = v \times t_2$$

$$S_2 = 13.33 \times 300$$

$$\mathbf{S_2 = 3999m}$$

(iii) Motion with negative acceleration

$$V_i = 13.33ms^{-1}$$

$$V_f = 0ms^{-1}$$

$$t_3 = 3min = 3 \times 60 = 180sec$$

$$S_3 = v_{av} \times t_3$$

$$S_3 = \frac{v_i - v_f}{2} \times t_3$$

$$S_3 = \frac{13.33 - 0}{2} \times 180$$

$$\mathbf{S_3 = 1199.7m}$$

Total distance $= 720m + 3999m + 1199.7m$

Total distance $= 5918.7m$

8. A cricket ball is hit vertically upwards and returns to the ground in 6s later. Calculate

(i) The maximum height reached by the ball

(ii) The initial velocity of the ball.

Ans: Given data:

Time taken by the ball to return to ground $= 6s$

Time to reach maximum height $= t = \frac{6}{2}$

$t = 3s$

$$v_f = 0ms^{-1}$$

To find:

i. $v_i = ?$

ii. $S = h = ?$

Solution:

i. By using the 1st equation of motion.

$$v_f = v_i + at$$

$$v_i = v_f - at$$

$$v_i = v_f - gt$$

$$v_i = 0 - (-10)(3)$$

$$\mathbf{v_i = 30ms^{-1}}$$

ii. By using the 3rd equation of motion.

$$2aS = v_f^2 - v_i^2$$

$$2(-10)h = (0)^2 - (300)^2$$

$$-20h = -900$$

$$H = \frac{-900}{-20}$$

$$\mathbf{h = 45m}$$

9. When brakes are applied, the speed of a train decreases from 96 kmh^{-1} to 48 kmh^{-1} in 800m. How much further will the train move before coming to rest?

Ans: Given data:

$$V_i = 96kmh^{-1} = \frac{96 \times 1000}{3600} ms^{-1} = 26.67ms^{-1}$$

$$V_f = 48kmh^{-1} = \frac{48 \times 1000}{3600} ms^{-1} = 13.33ms^{-1}$$

$$S_1 = 800m$$

To find:

$$S_2 = ?$$

Using 3rd equation of motion

Solution:

The motion of train consists of two steps:

$$2aS_1 = v_f^2 - v_i^2$$

$$a = \frac{v_f^2 - v_i^2}{2S_1}$$

$$a = \frac{(13.33)^2 - (26.67)^2}{2\,(800)}$$

$$a = -0.33 ms^{-2}$$

Distance covered $= ?$

Using 3rd equation of motion

$$2aS_2 = v_f^2 - v_i^2$$

$$S_2 = \frac{v_f^2 - v_i^2}{2a}$$

$$S_2 = \frac{(13.33)^2 - (26.67)^2}{2\,(-0.33)}$$

$$\mathbf{S_2 = 266.6m}$$

10. In the above problem, find the time taken by the train to stop after the application of brakes.

Ans: Given data:

$$V_i = 26.67\ ms^{-1}$$

$$V_f = 0\ ms^{-1}$$

$$a = -0.33 ms^{-2}$$

To find:

$$t = ?$$

Using 1st equation of motion,

Solution:

$$v_f = v_i + at$$

$$at = v_i - v_f$$

$$t = \frac{vi - vf}{a}$$

$$t = \frac{0 - 26.67}{-0.33}$$

$$\mathbf{t = 80.1S}$$

Chapter: 03

Dynamics

Exercise MCQs

1. Newton's first law of motion is valid only in the absence of:

Ⓐ Force Ⓑ Net force Ⓒ Friction Ⓓ Momentum

2. Inertia depends upon:

Ⓐ Force Ⓑ Net force Ⓒ Mass Ⓓ Velocity

3. A boy jumps out of a moving bus. There is a danger for him to fall:

Ⓐ Towards the moving bus Ⓑ Away from the bus
Ⓒ in the direction of motion Ⓓ opposite to the direction of motion

4. A string is stretched by two equal and opposite forces 10N each. The tension in the string is:

Ⓐ Zero Ⓑ 5N Ⓒ 10N Ⓓ 20N

5. The mass of a body:

Ⓐ decrease when accelerated Ⓑ increases when accelerated
Ⓒ decreases when moving with high velocity Ⓓ none of the above

6. Two bodies of masses m_1 and m_2 attached to the ends of an inextensible string passing over a frictionless pulling such that both move vertically. The acceleration of the bodies is:

Ⓐ $\frac{m_1 \times m_2}{m_1 \times m_2} g$ Ⓑ $\frac{m_1 - m_2}{m_1 + m_2} g$ Ⓒ $\frac{m_1 + m_2}{m_1 - m_2} g$ Ⓓ $\frac{2m_1 m_2}{m_1 + m_2} g$

7. Which of the following is the unit of momentum?

Ⓐ Nm Ⓑ $kgms^{-2}$ Ⓒ Ns Ⓓ Ns^{-1}

8. When a horse pulls a cart, the action is on her:

Ⓐ Cart Ⓑ Earth Ⓒ Horse Ⓓ Earth and cart

9. Which of the following materials lowers friction when pushed between metal plates?

Ⓐ water Ⓑ fine marble powder Ⓒ Air Ⓓ Oil

Answer Key:

1	Ⓑ	**6**	Ⓑ
2	Ⓒ	**7**	Ⓒ
3	Ⓒ	**8**	Ⓓ
4	Ⓒ	**9**	Ⓓ
5	Ⓓ		

Short Questions

1. Define the following terms:

(a) Inertia (b) Momentum (c) Force (d) Force of friction

(e) Centripetal force

Ans:

(a) Inertia:

The inertia of a body is its property due to which is resists any change in its state of rest or motion.

(b) Momentum:

The momentum of a body is the quantity of motion possessed by the body. The momentum of a body is equal to the product of its mass and velocity.

Formula:

$$P = mv$$

Unit:

Ns or $kgms^{-1}$

(c) Force:

A force is a push or pull. It moves or tends to move, stops or tends to stop the motion of a body. The force can also change the direction of motion of a body.

Unit:

Its SI unit is $kgms^{-2}$.

(d) Force of friction:

The force that opposes the motion of moving objects is called friction.

(e) Centripetal force:

The force which keeps the body to move in a circular path is called the centripetal force.

Formula:

$$P_c = \frac{mv^2}{r}$$

2. What is the law of inertia?

Ans: Law of inertia:

Newton's first law of motion deals with the inertial property of matter, so Newton's first law of motion is also known as law of inertia.

Statement:

"A body continues its state of rest or of uniform motion in a straight line provided no net force acts on it".

3. What is the difference between?

(a) Mass and weight.

(b) Action and reaction.

(c) Sliding friction and rolling friction.

Ans: Difference between Mass and weigh is:

Mass (m)	Weight (w)
➢ The mass of a body is the quantity of matter that it possesses. ➢ Mass is a scalar quantity.	➢ The weight of the body is equal to the force with which Earth attracts it. ➢ Weight is a vector quantity.

Difference Action and reaction is:

Action	Reaction

It is a force that is exerted by the body on other body. **Examples:** Let the force of **A** on the other body **B** is called action force.	It is also a force which is exerted by the other body on the first one. **Examples:** Let the force of B on the first body A is called reaction force.

Difference sliding friction and Rolling friction is:

Sliding Friction	Rolling Friction
A force between the sliding objects which opposes the relative motion between them is called sliding friction.	Rolling friction is the force of friction between a rolling body and the surface over which it rolls.

4. Why is it dangerous to travel on the roof of a bus?

Ans: If a person travels on the roof of a bus, it would be dangerous because when a bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

5. How can you relate a force with the change of momentum of a body?

Ans: When a force acts on a body, it produces acceleration in the body and will be equal to the rate of change of momentum of the body.

Suppose a force 'F' acts on a body of mass 'm' moving with initial velocity 'v_i' which produces an acceleration a in it. This changes the velocity of the body to 'v_f' after time t. If P_i, and P_f be the initial momentum and final momentum of the body's final velocities, then,

Momentum of the body having velocity $v_i = P_i = mv_i$

Momentum of the body having velocity $v_f = P_f = mv_f$

Change in momentum = final momentum − initial momentum

Change in momentum $= P_f - P_i = mv_f - mv_i = m(v_f - v_i)$

$$\text{Rate of change in momentum} = \frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

$$\text{Rate of change in momentum} = m\frac{v_f - v_i}{t}$$

Since $\frac{v_f - v_i}{t}$ is the rate of change of velocity equal to acceleration produced by the force F.

So,

$$\frac{P_f - P_i}{t} = ma$$

According to Newton's second law of motion,

$$F = ma$$

So,

$$\frac{P_f - P_i}{t} = \frac{mv_f - mv_i}{t}$$

So, equation (I) can be written as,

Rate of change in momentum = ma

According to second law of motion,

$$F = ma$$

So,

$$\frac{P_f - P_i}{t} = F$$

Rate of change of momentum of a body is equal to the applied force on it and the direction of change of in momentum is in the direction of the force.

6. Why does a passenger move outward when a bus takes a turn?

Ans: When a bus takes a sharp turn, passengers fall in the outward direction. It is due to inertia that they want to continue their motion in a straight line and thus fall outwards.

7. What will be the tension in a rope that is pulled from its ends by two opposite forces 100N each?

Ans: When two forces of 100N, each are applied on a string, then the resultant tension is 100N.

8. A horse pulls that cart. If the action and reaction are equal and opposite then how does the cart move?

Ans: The horse applies action by feet on the road; the reaction is given by the road on the horse, due to which the horse moves. The cart, which is tied to the horse, also moves. Since, action and reaction never act on the same body, so the cart moves.

9. Action and reaction are always equal and opposite. Then how does a body move?

Ans: According to Newton's third law of motion, action and reaction are always equal and opposite in direction. But action and reaction forces always act on different bodies, so they do not cancel the effect of each other, and under the condition of forces the body moves irrespective of this, that action and reaction are equal but opposite in direction.

10. What is the law of conservation of momentum?

Ans: **Law of conservation of momentum:**

"The momentum of an isolated system of two or more than two interacting bodies remains constant."

Examples:

Firing a bullet, release of air from a balloon.

11. When a gun is fired, it recoils. Why?

Ans: As the gun is fired, the bullet shoots out of the gun and acquires some momentum. To conserve the momentum of the system, the gun recoils.

12. Why is the law of conservation of momentum important?

Ans: By using the law of conservation of momentum, it is possible to calculate the force, velocity, and acceleration of a body. Most elementary particles are discovered by the use of this law.

13. Describe two situations in which force of friction is needed?

Ans: There are many conditions in which friction is desirable; two of them are given below:

- Friction is needed when we write.
- Friction enables us to walk on the ground.

14. Describe ways to reduce friction.

Ans: Method of reducing friction:

- Using grease or any other lubricant.
- Using smoother surfaces.
- Using rollers, wheels, or ball bearings.
- Objects like cars and planes are modeled with streamlined shapes.

15. How does oiling the moving parts of a machine lower friction?

Ans: Oiling the moving parts of a machine lowers friction because the oil fills up all the rough spot (cold welds) and make the surface smooth.

16. Why roiling friction is less than sliding friction?

Ans: "Rolling friction is much less than sliding friction because in the case of rolling friction contact area (cold welds points) of the two surfaces is very small as compared to sliding friction."

17. What you know about the following.

(a) Tension in a string **(b) Limiting force of friction**

(c) Braking force **(d) Skidding of vehicles**

(e) Seatbelts **(f) Banking of roads**

(g) Cream separator

Ans:

(a) Tension in a string:

The force acting along a string causes tension in the string.

(b) Limiting force of friction:

The frictional force that exists between the surfaces of two stationary bodies in contact with each other.

(c) Braking force:

It is a measure of the braking power of a vehicle.

(d) Skidding of vehicles:

The act of sliding or slipping of a vehicle over a surface, often sideways without revolving.

(e) Seatbelts:

A belt or strap in an automobile, or airplanes to hold you in your seat in case of an accident or sudden stop.

(f) Banking of roads:

The phenomenon of raising the outer edge of the curved road above the inner edge to provide the necessary centripetal force to the vehicle to take a safer turn on the curve road is called banking of roads.

(g) Cream separator:

A device which is used to separate cream from milk.

18. What would happen if all friction suddenly disappears?

Ans: If there was no friction then we could not walk, we would keep slipping. Nothing would steady on the ground and nothing would exist in the way they do now.

19. What would happen if all friction suddenly disappears?

Ans: The spinner of a washing machine is made to spin at a very high speed. Because when it spins at high speed, the water from wet clothes is forced out through these holes due to lack of centripetal force.

Important Formulas

- $F = ma$
- $F = \frac{\Delta P}{t}$
- $F_c = \frac{mv^2}{r}$

If both masses are suspended vertically

- $T = \left(\frac{2m_1 m_2}{m_1 + m_2}\right) g$
- $a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g$
- Unit of tension = Newton
- Unit of acceleration $= ms^{-2}$

- $W = mg$
- $F_s = \mu_s R = \mu_s mg$

If one mass is horizontal and other is suspended vertically.

- $T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g$
- $a = \left(\frac{m_1 g}{m_1 + m_2}\right)$

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Numerical

1. A force of 20N moves a body with an acceleration of $2ms^{-2}$, what is its mass?

Ans: Given data:

$F = 20N$

$a = 2ms^{-2}$

To Find:

$m = ?$

Solution:

By using Newton's second law of motion,

$F = ma$

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

$$m = \frac{20}{2}$$

m = 10kg

2. The weight of a body is 147. What is its mass? (Take the value of g as $10ms^{-2}$).

Ans: Given data:

$$w = 147N$$

$$g = 10ms^{-2}$$

To Find:

$$m = ?$$

Solution:

We know that,

$$w = mg$$

$$m = \frac{w}{g}$$

$$m = \frac{147}{10}$$

m = 14.7kg

3. How much force is needed to prevent a body of mass 10kg from falling?

Ans: Given data:

$$m = 10kg$$

$$g = 10ms^{-2}$$

To Find:

$$F = ?$$

Solution:

We know that,

$$F = ma$$

$$F = (10)(10)$$

F = 100N

4. Find the acceleration produced by a force of 100N in a mass of 50kg.

Ans: Given data:

$$F = 100N$$

$$m = 50kg$$

To Find:

$a = ?$

Solution:

Using Newton's second law of motion,

$$F = ma$$

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

$$a = \frac{100}{50}$$

$$\mathbf{a = 2ms^{-2}}$$

5. A body has a weight 20N. How much force is required to move it vertically upwards with an acceleration of $2ms^{-2}$?

Ans: Given data:

$w = 20N$

$a = 2ms^{-2}$

To Find:

$F = ?$

Solution:

As we know that,

$$w = mg$$

$$m = \frac{w}{g}$$

$$m = \frac{20}{2}$$

$$m = 2kg$$

Using Newton's 2nd law of motion,

$$F = ma$$

$$F = (2)(2)$$

$$\mathbf{F = 4N}$$

6. Two masses 52kg and 48 kg are attached to the ends of a string that passes over a frictionless pulley. Find the tension in the string and acceleration in the bodies, when both masses are moving vertically.

Ans: Given data:

$m_1 = 52kg$

$m_2 = 48kg$

$g = 10ms^{-2}$

To Find:

$T = ?$

$a = ?$

Solution:

As we know that,

$$T = \left(\frac{2m_1 m_2}{m_1 + m_2}\right) g$$

$$T = \left(\frac{2 \times 52 \times 48}{52 + 48}\right) 10$$

$$T = 499.2N$$

$T = 500N$ (approximately)

Now for acceleration,

$$a = \left(\frac{m_1 - m_2}{m_1 + m_2}\right) g$$

$$a = \left(\frac{52 - 48}{52 + 48}\right) \times 10$$

$$a = \frac{4 \times 10}{100}$$

$$a = \frac{40}{100}$$

$a = 0.4ms^{-2}$

7. Two masses 26kg and 24kg are attached to the ends of the string which passes over a frictionless pulley. 26kg is lying over a smooth horizontal table. 24N mass is moving vertically downward. Find the tension in the string and the acceleration in the bodies.

Ans: Given data:

$m_1 = 24kg$

$m_2 = 26kg$

$g = 10ms^{-2}$

To Find:

$T = ?$

$a = ?$

Solution:

As we know that,

$$T = \left(\frac{m_1 m_2}{m_1 + m_2}\right) g$$

$$T = \left(\frac{24 \times 26}{24 + 26}\right) \times 10$$

$$T = \frac{6240}{50}$$

$$\mathbf{T = 125N}$$

Now for acceleration,

$$a = \left(\frac{24 \times 10}{24 + 26}\right)$$

$$a = \frac{240}{50}$$

$$a = \frac{240}{50}$$

$$\mathbf{a = 4.8ms^{-2}}$$

8. How much time is required to change 22Ns momentum by a force of 20N?

Ans: Given data:

Change in momentum = $\Delta P = 22Ns$

$F = 20N$

To Find:

$t = ?$

Solution:

As we know that rate of change of momentum is equal to force acting on it,

$$F = \frac{\Delta P}{t}$$

$$t = \frac{\Delta P}{F}$$

$$t = \frac{22}{20}$$

$$\mathbf{t = 1.1s}$$

9. How much is the force of friction between a wooden block of mass 5kg and the horizontal marble floor? The coefficient of friction between wood and marble is 0.6.

Ans: Given data:

$m = 5kg$

$\mu_s = 0.6$

$g = 10ms^{-2}$

To Find:

Force of friction = F = ?

Solution:

By using formula,

$$F = \mu_s R$$

$$F = \mu_s mg \qquad (\therefore F = mg)$$

$$F = (0.6)(5)(10)$$

$$\mathbf{F = 30N}$$

10. How much centripetal force is needed to make a body of mass 0.5kg to move in a circle of radius 50cm with a speed $3ms^{-1}$?

Ans: Given data:

$m = 0.5kg$

$r = 50cm = \frac{50}{100} m = 0.5m$

$v = 3ms^{-1}$

To Find:

$F_c = ?$

Solution:

By using formula,

$$F_c = \frac{m v^2}{r}$$

$$F_c = \frac{(0.5)(3)^2}{(0.5)}$$

$$F_c = \frac{(0.5)(9)}{(0.5)}$$

$$\mathbf{F_c = 9N}$$

Chapter: 04

Turning Effect of Forces

Exercise MCQs

1. Two equal but unlike parallel forces having different lines of action produce:

Ⓐ a torque Ⓑ a couple Ⓒ equilibrium Ⓓ neutral equilibrium

2. The number of forces that can be added by head to tail:

Ⓐ 2 Ⓑ 3 Ⓒ 4 Ⓓ any number

3. The Number of perpendicular components of a force is:

Ⓐ 1 Ⓑ 2 Ⓒ 3 Ⓓ 4

4. A force of 10N is making an angle of 30o with the horizontal. It's horizontal the component will be:

Ⓐ 4N Ⓑ 5N Ⓒ 7N Ⓓ 8.7N

5. A couple is formed by:

Ⓐ two forces perpendicular to each other
Ⓑ two like parallel forces
Ⓒ two equal and opposite forces in the same line
Ⓓ two equal and opposite forces not in the same line

6. A body is in equilibrium when its:

Ⓐ acceleration is uniform Ⓑ speed is uniform
Ⓒ speed and acceleration are uniform Ⓓ acceleration is zero

7. A body is a neutral equilibrium when its centre of gravity:

Ⓐ is at its highest position Ⓑ is at the lowest position
Ⓒ keeps its height if displaced Ⓓ is situated at its bottom

8. Racing cars are made stable by:

Ⓐ increasing their speed Ⓑ decreasing their mass
Ⓒ lowering their centre of gravity Ⓓ decreasing their width

Answer Key:

1	B	5	D
2	D	6	B
3	B	7	C
4	D	8	C

Short Questions

1. Define the following.

(a) Resultant vector **(b) Torque**

(c) Centre of mass **(d) Centre of gravity**

Ans:

(a) Resultant vector:

A resultant vector is a single vector that has the same effect as the combined effect of all the vectors to be added.

(b) Torque (τ):

The tuning effect of a force is called torque or moment of the force.

Formula:

$$\tau = r \times f$$

Unit:

Newton metre (Nm)

(c) Centre of mass:

Centre of mass of a system is such a point where an applied force causes the system to move without rotation.

(d) Centre of gravity:

The centre of gravity of a body is defined as the point where the whole weight of the body appears to act vertically downward.

2. How head to head-to-tail rule help to find the resultant forces?

Ans: Head-to-tail rule:

The vectors are added graphically such that the tail of the 2nd vector coincides with the head of the 1st vector and so on. The resultant of all vectors is obtained by coinciding the tail of 1st vector to the head of the last vector.

The resultant of two forces can be found by using the method for adding vectors

when the vectors are geometric representations.

3. When a body is said to be in equilibrium?

Ans: A body is said to be in equilibrium if it satisfies both conditions of equilibrium.

- A body is in equilibrium if the net force acting on it is zero.

$$\Sigma F = 0, \quad \text{or} \quad \Sigma F_y = 0, \quad \Sigma F_x = 0$$

- A body is said to be in equilibrium if the resultant torque acting on it is zero.

$$\Sigma \tau = 0$$

4. How can a force be resolved into its rectangular components?

Ans: The decomposition or division of a vector into its components is called the resolution of a vector.

OR

The splitting of a single vector into two mutually perpendicular components is called the resolution of that force.

The process of splitting up vectors (forces) into their component forces is called resolution of force. If a force is formed from two mutually perpendicular components then such components are called **perpendicular components.**

Determination of Rectangular components of a vector:

Suppose a vector **F** acts on a body by making an angle θ with the x-axis which is represented by the vector **OA** as shown in the figure. Draw perpendicular **BA** from the **A** on x-axis as **AB.** According to head to tail rule, **OA** is the resultant vector of **OB** and **BA.**

So,

$$\mathbf{CA = OB + BA} \quad \text{----------} \quad (1)$$

Since the angle between **BA** and **OB** is 90°, hence these are called the perpendicular components of the vector **OA** representing F.

Horizontal or x-component

The component **OB** along x-axis is represented by F_x, and is called the X-component or horizontal component of the vector **F.**

Vertical or y-component:

The component **BA** is represented by F_y and is called the y-component or vertical component of the vector **F.**

So equation (1) can be represented by,

$$F = F_x + F_y$$

Magnitude of Rectangular components:

The magnitude of the perpendicular components F_x, and F_y of forces F_x, and F_y can be found by using the trigonometric ratios. In right angled triangle **OAB**,

$$\cos\theta = \frac{OB}{OA} \quad \text{OR} \quad OB = OA\cos\theta$$

But $OB = F_x$ OR $OA = F$

Hence, $F_x = F\cos\theta$

Similarly,

$$\sin\theta = \frac{BA}{OA} \quad \text{OR} \quad BA = OA\sin\theta$$

But $BA = F_y$ OR $OA = F$

Hence, $F_y = F\sin\theta$

These two components are the two sides of the right-angled triangle whereas hypotenuse represents the magnitude of the actual vector.

5. Differentiate the following.

(a) Like and unlike parallel forces.

(b) Torque and couple.

(c) Stable and neutral equilibrium.

Ans: Difference between Like Parallel Forces and Unlike Parallel Forces is:

Like Parallel Forces	Unlike Parallel Forces
If two parallel forces act in the same direction then they are called like parallel forces.	If two parallel forces act in opposite direction they are called unlike parallel forces.

Difference Torque and couple is:

Torque	Couple
➢ The turning effect of a force is called torque. ➢ Torque is produced under the action of only one force.	➢ A couple is formed by two unlike parallel forces of the same magnitude but not along the same line. ➢ A couple is produced under the action of two unlike parallel forces.

Difference Stable and neutral equilibrium:

Stable Equilibrium	Neutral Equilibrium
In stable equilibrium centre of mass of a body lies at the lowest position.	In neutral equilibrium, the centre of gravity lies at the same height.

6. Explain the first condition for equilibrium.

Ans: First condition for equilibrium:

"A body is said to satisfy the first condition for equilibrium if the resultant of all the forces acting on it is zero".

$$\Sigma F = 0$$

i.e. $\Sigma F_x = 0$

$\Sigma F_y = 0$

7. What is the second condition for equilibrium?

Ans: Second condition for equilibrium:

"A body satisfies the second condition for equilibrium when the resultant torque acting on it is zero".

Mathematically:

$$\Sigma \tau = 0.$$

8. Why there is a need for the second condition for equilibrium if a body satisfies the first condition for equilibrium?

Ans: Reason: Two equal and opposite forces having different lines of action form a couple, which produces angular acceleration. Although, the first condition for equilibrium is satisfied but still in this case, the object needs to satisfy the second condition to ensure an equilibrium state.

9. Give an example of a moving body which is in equilibrium.

Ans: A paratrooper coming down with terminal velocity (constant velocity) is in equilibrium as all the forces acting on it is equal to zero, which satisfies the first condition for equilibrium.

10. Why a body cannot be in equilibrium due to single force acting on it?

Ans: Single force acting on a body is not balanced and produces acceleration. Therefore under the influence of a single force, a body cannot be in equilibrium.

11. Think of a body which is at rest but not in equilibrium.

Ans: A body thrown upward is at rest just for a while at the highest point. But the force of gravity still acts on it to produce acceleration. Thus, the body is at rest but not in equilibrium.

12. Why the height of vehicles is kept as low as possible?

Ans: Vehicles are made heavy at the bottom and their height is kept to be minimum. This lowers their centre of gravity and helps to increase their stability. As to make them stable, their centre of mass must be kept as low as possible.

13. Explain what is meant by stable, unstable, and neutral equilibrium. Give one example in each case.

Ans: **Stable equilibrium:**

Equilibrium is considered stable if, after a slight tilt, it returns to its previous positions.

Example:

A book lying on a table

Unstable equilibrium:

If a body does not return to its previous position when set free after a slight tilt, then the equilibrium is unstable.

Example:

A pencil standing on its point

Neutral equilibrium:

If a body remains in its new position when disturbed from its previous position, it is said to be in neutral equilibrium.

Example:

Rolling Ball

Important Formulas

- Magnitude $= F = \sqrt{F_x^2 + F_y^2}$
- Direction $= \theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$
- Torque $= \tau = r \times F$
- Conditions of equilibrium

i. $\Sigma F = 0$ i.e. $\Sigma F_x = 0,\ \Sigma F_y = 0$

ii. $\Sigma \tau = 0$ i.e. $\tau_1 = \tau_2$

- $F_x = F \cos\theta$
- $F_y = F \sin\theta$

Numerical

1. Find the resultant of the following forces:

(a) 10N along x-axis (b) 6N along y-axis (c) 4N along the negative x-axis

Ans: Given data:

F_1 = 10N along x-axis

F_2 = 6N along y-axis

F_3 = 4N along x-axis

Solution:

Scale 2N = 1cm

10N = 5cm

6N = 3cm

4N = 2cm

2. Find the rectangular components of a force of 50N making an angle of 30° with the x-axis.

Ans: Given data:

Force = F = 50N

Angle = θ = 30°

Required:

Horizontal component of force = F_x = ?

Vertical component of force = F_y = ?

Solution:

As we know that,

$$F_x = F \cos \theta$$

By putting the values, we have

$$F_x = 50 \times \cos 30^o$$

$$F_x = 50 \times 0.866$$

$$F_x = 43.3 \text{ N}$$

As we know that,

$$F_y = F \sin \theta$$

$$F_y = 50 \times \sin 30^o$$

$$F_y = 50 \times 0.5$$

$$F_y = 25 \text{ N}$$

Result:

Horizontal component of force = F_x = 43.3 N

Vertical component of force = F_y = 25 N

3. Find the magnitude and direction of a force if its x-component is 12N and y-component is 5N?

Ans: Given data:

$F_x = 12\ N$

$F_y = 5\ N$

To Find:

$F = ?$

$\theta = ?$

Solution:

We know that,

$$F = \sqrt{F_X^2 + F_y^2}$$

$$F = \sqrt{(12)^2 + (5)^2}$$

$$F = \sqrt{144 + 25}$$

$$F = \sqrt{169}$$

$$\mathbf{F = 13\ N}$$

Now,

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

$$\theta = \tan^{-1}\left(\frac{5}{12}\right)$$

$$\theta = \tan^{-1}(0.41)$$

$$\mathbf{\theta = 22.6^o \text{ with x-axis}}$$

4. A force of 100N is applied perpendicularly on a spanner at a distance of 10cm from a nut. Find the torque produced by the force.

Ans: Given data:

$F = 100N$

$r = 10cm = \frac{10}{100} m = 0.1m$

To Find:

$\tau = ?$

Solution:

$\tau = r \times F$

$$\tau = 0.1 \times 100$$

$$\boldsymbol{\tau = 10Nm}$$

5. A force is acting on a body making an angle of 30° with the horizontal. The horizontal component of the force is 20N. Find the force.

Ans: Given data:

$$\theta = 30^o$$

$$F_x = 20\ N$$

To Find:

$$F = ?$$

Solution:

As we know that,

$$F_x = F\cos\theta$$

$$20 = F\cos 30^o$$

$$F = \frac{20}{\cos 30^o}$$

$$F = \frac{20}{0.866}$$

$$F = 23.09\ N$$

$$\boldsymbol{F = 23.1\ N}$$

6. The steering of a car has a radius 16cm. Find the torque produced by a couple of 50N.

Ans: Given data:

$$F = 50N$$

$$r = 16cm = \frac{16}{100}m = 0.16m$$

Perpendicular distance between forces = $r = 0.16 + 0.16$

$$r = 0.32m$$

To Find:

$$\tau = ?$$

Solution:

$$\tau = \text{Force} \times \text{Perpendicular distance between forces}$$

$$\tau = 50 \times 0.32$$

$$\boldsymbol{\tau = 16Nm}$$

7. A picture frame is hanging by two vertical strings. The tensions in the springs are 3.8N and 4.4N. Find the weight of the picture frame.

Ans: Given data:

$T_1 = 3.8N$

$T_2 = 4.4N$

To Find:

Weight = W = ?

Solution:

As picture frame is in equilibrium

$\Sigma Fx = 0, \qquad \Sigma Fy = 0$

Therefore

$T - W = 0$

$(T_1 + T_2) - W = 0$

$T_1 + T_2 = W$

$3.8 + 4.4 = W$

$8.2\ N = W$

Or **W = 8.2N**

8. Two blocks of masses 5kg and 3kg are suspended by the two strings as shown in the figure. Find the tension in each string.

Ans: Given data:

Mass of upper block = 5kg

Mass of below block = 3kg

Mass of upper block = $w_1 = m_1g = 5 \times 10 = 50N$

Mass of below block = $w_2 = m_2g = 3 \times 10 = 30N$

Required:

Tension in upper string = T_1 = ?

Tension in lower string = T_2 = ?

Solution:

From second condition of equilibrium, we have

$\Sigma F_y = 0$

OR Tension in the lower string = weight of the lower block

$T_2 = w_2$

$T_2 = 30\ N$

Tension in the upper string = weight of lower block + weight of the lower block

$T_1 = w_1 + w_2$

$T_1 = 50 + 30$

$T_1 = 80\,N$

Result:

Tension in upper string $= T_1 = 80\,N$

Tension in lower string $= T_2 = 30\,N$

9. A nut has been tightened by a force of 200N using 10cm long spanner. What length of a spanner is required to loosen the same nut with 150N force?

Ans: Given data:

$F_1 = 200N$

$F_2 = 150N$

$L_1 = 10cm = 0.1m$

To Find:

$L_2 = ?$

Solution:

$$\tau_1 = \tau_2$$

$$F_1 \times L_1 = F_2 \times L_2$$

$$L_2 = \frac{F_1 \times L_1}{F_2}$$

$$L_2 = \frac{200 \times 0.1}{150}$$

$$L_2 = 0.133m$$

$$L_2 = 0.133 \times 100cm$$

$$\mathbf{L_2 = 13.3cm}$$

10. A block of mass 10kg is suspended at a distance of 20cm from the centre of a uniform bar 1m long. What force is required to balance it at its centre of gravity by applying the force at the other end of the bar?

Ans: Given data:

Mass of block $= m = 10kg$

Weight of block $= w = mg$

Weight of block $= w = 10 \times 10$

Weight of block $= w = 100N$

Weight of block $= L = 1m$

Distance of block from center of nod $= 20cm$

Distance of block from center of nod $= \frac{20}{100}\,m = 0.20m$

Distance of force from center = 50cm

$$\text{Distance of force from center} = \frac{50}{100}\ \text{m} = 0.50\text{m}$$

To Find:

$$F = ?$$

Solution:

Now using condition of equilibrium,

$$F \times L_2 = w \times L_1$$

$$F \times L_2 = w \times L_1$$

$$F \times 0.5 = 100 \times 0.2$$

$$F = \frac{100 \times 0.2}{0.5}$$

$$\mathbf{F = 40N}$$

Chapter: 05

Gravitation

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Exercise MCQs

1. **Earth's gravitational force of attraction vanishes at:**

   Ⓐ 6400km Ⓑ infinity Ⓒ 42300km Ⓓ 1000km

2. **Value of g increases with the:**

   Ⓐ increases in the mass of the body Ⓑ increase in altitude
   Ⓒ decrease in altitude Ⓓ none of the above

3. **The value of g at a height one Earth's radius above the surface of the Earth is:**

   Ⓐ $2g$ Ⓑ $\frac{1}{2}g$ Ⓒ $\frac{1}{3}g$ Ⓓ $\frac{1}{4}g$

4. **The value of g on moon's surface is $1.6ms^{-2}$. What will be the weight of a 100 kg body on the surface of the moon?**

   Ⓐ 100N Ⓑ 160N Ⓒ 1000N Ⓓ 1600N

5. **The altitude of geostationary orbits in which communication satellites are launched above the surface of the Earth is:**

   Ⓐ 850km Ⓑ 1000km Ⓒ 6400km Ⓓ 42,300km

6. **The orbital speed of a or orbit satellite is:**

   Ⓐ Zero Ⓑ $8ms^{-1}$ Ⓒ $800ms^{-1}$ Ⓓ $8000ms^{-1}$

Answer Key:

1	Ⓑ	4	Ⓑ
2	Ⓒ	5	Ⓓ
3	Ⓓ	6	Ⓓ

Short Questions

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1. What is meant by the force of gravitation?

Ans: Force of gravitation:

"The force due to which everybody of the universe attracts every other body is called force of gravitation".

Formula:

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

2. What is a field force?

Ans: Field force:

The force which is acting on the body by another body whether the body is in contact with other body or not. It is a non-contact force. The gravitational pull of the Earth acting on the body whether the body is in contact with the Earth or not.

3. Do you attract the Earth or the Earth attracts you? Which one is attracting with a larger force? You or the Earth.

Ans: Yes, Earth attracts us and in reaction we attract Earth as well. Both of these forces are equal in magnitude.

4. How can you say that gravitational force is a field force?

Ans: As gravitational force is a non-contact force. For example, the velocity of a body, thrown up, goes on decreasing while on return its velocity goes on increasing. This is due to the gravitational pull of the Earth's action on the body whether the body is in contact with the Earth or not. So, gravitational force is a field force.

5. Why earlier scientists could not goes about the gravitational force?

Ans: The earlier scientists could not guess about the gravitational force because they were not known about the concept of gravity. Concept of gravity was put forth by ISSAC NEWTON in 1665.

6. Explain, what is meant by gravitational field strength.

Ans: Gravitational field strength:

In the gravitational field of the earth, the gravitational force per unit mass is called the gravitational field strength of the earth.

Value:

At any place, its value is $10 Nkg^{-1}$

7. Explain the law of gravitation.

Ans: Law of gravitation:

The force of attraction between two objects is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

Formula:

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

The law of gravitation depends upon masses of objects and the distance between them.

- The greater the masses of objects, the greater will be force of gravitation.
- The greater the distance between objects, less will be the force of gravitation.

8. Why law of gravitation is important to us?

Ans: It is important to us because it helps us to understand why.

- Binds all terrestrial objects to earth.
- Keeps the atmosphere close to the earth.
- Keeps the moon revolving around the earth.
- The gravitational pull of the sun on the planet keeps them revolving around the sun.

9. How the mass of the earth can be determined?

Ans: The mass of the earth can be calculated with the help of the law of gravitation.

$$M_e = \frac{R^2 g}{G}$$

After calculation,

$$M_e = 6 \times 10^{24}\ kg$$

10. Why does the value of g vary from place to place?

Ans:

$$g_h = \frac{G\, M_e}{(R + h)^2}$$

The value of g is inversely proportional to the square of the radius of the earth. But it does not remain constant and decreases with altitude, that's why the value of g varies from place to place.

11. Can you determine the mass of our moon? If yes, then what do you need to know?

Ans: **Yes,** we can calculate the mass of our moon by using a formula.

$$M_m = \frac{R^2\, gm}{G}$$

Need to know:

- Value of radius of moon.
- Gravitational acceleration on the moon.
- Gravitational constant on moon.

12. Explain how the value of g varies with altitude.

Ans: The value of gravitational acceleration is determined by the following formula:

$$g_h = \frac{G\, M_e}{(R+h)^2}$$

So, g is inversely proportional to $(R+h)^2$. It means that with increasing altitude, the value of g decreases.

13. How Newton's law of gravitation help in understanding the motion of satellites?

Ans: A satellite requires centripetal force that keeps it to move around the earth. The gravitational force of attraction between the satellite and the earth provides the necessary centripetal force. This centripetal force is introduced by the Newton. So, in this way Newton's law of gravitation helps in understanding the motion of satellites.

14. What are artificial satellites?

Ans: **Artificial satellites:**

Scientists have sent many objects into space. Some of these objects revolve around the earth. These are called artificial satellites.

Example:

Geostationary satellites

15. Why communication satellites are stationed at geostationary orbits?

Ans: The satellites in the geometry orbits and remain all the time in front of the target part of the earth so that the direction of receiver is dish do not to be changed.

16. On what factors the orbital speed of a satellite depends?

Ans: The orbital speed of the satellite depends only on the height of satellites from the surface of the earth because both the gravitational acceleration of the earth and the radius of the earth are constants. It is clear from the given formula:

$$v_o = \sqrt{g_h (R + h)}$$

Important Formulas

- $g = \frac{G M_e}{R^2}$ or $M_e = \frac{g R^2}{G}$
- $g_h = \frac{G M_e}{(R+h)^2}$
- $F = \frac{G m_1 m_2}{r^2}$
- $v_o = \sqrt{g_h (R + h)}$

Important Values

- Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$
- Mass of earth = M_e = $6 \times 10^{24} kg$
- Radius of earth = R_e = $6.4 \times 10^6 m$
- Orbital speed = v_o = $29000 kmh^{-1}$ ($8 kms^{-1}$)

Numerical

1. Find the gravitational force of attraction between two spheres each of mass 1000kg. The distance between the centers of the spheres is 0.5m.

Ans: Given data:

$m_1 = 1000kg$
$m_2 = 1000kg$
$r = 0.5m$
$G = 6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

$F = ?$

Solution:

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

By putting the values, we have

$$F = \frac{6.67 \times 10^{-11} \times 1000 \times 1000}{(0.5)^2}$$

$$F = \frac{6.67 \times 10^{-5}}{0.25}$$

$$F = 26.68 \times 10^{-5}$$

$$F = 2.67 \times 10^{-4}\text{N}$$

Result:

Gravitational force of attraction between two spheres $= F = 2.67 \times 10^{-4}$N

2. The gravitational force between two identical lead spheres kept at 1m apart is 0.006673N. Find their masses.

Ans: Given data:

$F = 0.006673\text{N}$

$r = 1\text{m}$

$G = 6.67 \times 10^{-11}\text{Nm}^2\text{kg}^{-2}$

To Find:

Mass of each lead spheres $= m = m_1 = m_2 = ?$

Solution:

From law of gravitation, we have

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

As $m = m_1 = m_2$

$$F = \frac{G\, m \times m}{r^2}$$

$$F = \frac{G\, m^2}{r^2}$$

$$m^2 = \frac{F\, r^2}{G}$$

$$m^2 = \frac{0.006673 \times (1)^2}{6.67 \times 10^{-11}}$$

$$m^2 = 0.001000 \times 10^{11}$$

$$m^2 = 1.00 \times 10^{8}$$

$$m = 1.00 \times 10^{4}\text{kg}$$

Result:

Mass of each lead spheres = $m = m_1 = m_2 = 1.00 \times 10^4 kg$

3. Find the acceleration due to gravity on the surface of Mars. The mass of Mars is $6.42 \times 10^{23} kg$ and its radius is 3370km.

Ans: Given data:

$$M = 6.42 \times 10^{23}\ kg$$

$$R = 3370km = 3370 \times 10^3 m = 3.37 \times 10^6 m$$

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

To Find:

Gravitational acceleration = g = ?

Solution:

As we know that,

$$g = \frac{G\,M}{R^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6.42 \times 10^{23}}{(3.37 \times 10^6)^2}$$

$$g = \frac{42.8214 \times 10^{12}}{11.3569 \times 10^{12}}$$

$$g = 3.77\ ms^{-2}$$

Result:

Gravitational acceleration = $g = 3.77\ ms^{-2}$

4. The acceleration due to gravity on the surface of the moon is $1.62 ms^{-2}$. The radius of the moon is 1740km find the mass of the moon.

Ans: Given data:

$$g_m = 1.62\ ms^{-2}$$

$$R = 1740km = 1740 \times 10^3 m = 1.74 \times 10^6 m$$

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

To Find:

Mass of the moon = M = ?

Solution:

As we know that,

$$g = \frac{G\,M}{R^2}$$

$$M = \frac{R^2 g}{G}$$

By putting the values, we have

$$M = \frac{(1.74 \times 10^6)^2 \times 1.62}{6.67 \times 10^{-11}}$$

$$M = \frac{3.0276 \times 10^{12} \times 1.62}{6.67 \times 10^{-11}}$$

$$M = \frac{4.90 \times 10^{12}}{6.67 \times 10^{-11}}$$

$$M = 0.735 \times 10^{23}$$

$$M = 7.35 \times 10^{22}\ \text{kg}$$

Result:

Mass of the moon = M = 7.35×10^{22} kg

5. Calculate the value of g at a height of 3600km above the surface of the earth.

Ans: Given data:

Height above the surface of Earth = h = 3600km

Height above the surface of Earth $= 3600 \times 10^3 m = 3.6 \times 10^6 m$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2 kg^{-2}$

Mass of Earth = M = 6×10^{24} kg

To Find:

Gravitational acceleration = g = ?

Solution:

As we know that,

$$g = \frac{G\,M}{(R+h)^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(6.4 \times 10^6 + 3.6 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{(10 \times 10^6)^2}$$

$$g = \frac{40.02 \times 10^{13}}{1 \times 10^{14}}$$

$$g = 40.02 \times 10^{-1}$$

$$g = 4.002\ ms^{-2}$$

$$g = 4.0ms^{-2}$$

Result:

Gravitational acceleration = g = $4.0ms^{-2}$

6. Find the value of g due to earth at a geostationary satellite. The radius of the geostationary orbit is 48700km.

Ans: Given data:

Radius of geostationary satellite = R = 48700km

Radius of geostationary satellite $= 48700 \times 10^3 m$

Radius of geostationary satellite $= 4.87 \times 10^7 m$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

Mass of Earth = M = 6×10^{24} kg

To Find:

Gravitational acceleration = g_h = ?

Solution:

As we know that,

$$g = \frac{G\,Me}{R^2}$$

By putting the values, we have

$$g = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{(4.87 \times 10^7)^2}$$

$$g = \frac{40.02 \times 10^{13}}{23.72 \times 10^{14}}$$

$$g = 1.68 \times 10^{-1}$$

$$g = 0.168\ ms^{-2}$$

$$g = 0.17ms^{-2}$$

Result:

Gravitational acceleration = g_h = $0.17ms^{-2}$

7. The value of g is $4ms^{-2}$ at a distance of 10000km from the centre of the earth. Find the mass of the earth.

Ans: Given data:

Radius from the center of Earth = R = 1000km

Radius from the center of Earth $= 1000 \times 10^3 m = 1 \times 10^7 m$

Gravitational acceleration = g = $4.0 ms^{-2}$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2 kg^{-2}$

To Find:

Mass of Earth = M = ?

Solution:

As we know that,

$$g = \frac{G M}{R^2}$$

$$M = \frac{R^2 g}{G}$$

By putting the values, we have

$$M = \frac{(1 \times 10^7)^2 \times 4}{6.67 \times 10^{-11}}$$

$$M = \frac{4 \times 10^{14}}{6.67 \times 10^{-11}}$$

$$M = 0.599 \times 10^{25}$$

$$M = 5.99 \times 10^{24}$$

$$M = 6 \times 10^{24} kg$$

Result:

Mass of the Earth = M = 6×10^{24} kg

8. At what altitude the value of g would become one-fourth than on the surface of the earth?

Ans: Given data:

Gravitational acceleration = g = $10\ m^{-2}$

Gravitational acceleration at height = $g_h = \frac{g}{4} = \frac{10}{4} = 0.25\ ms^{-2}$

Radius of earth = $R_e = 6.4 \times 10^6 m$

Mass of Earth = $M_e = 6 \times 10^{24} kg$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

h = ?

Solution:

As we know that,

$$g_h = \frac{G M_e}{(R+h)^2}$$

$$(R + h)^2 = \frac{G M_e}{g_h}$$

$$(6.4 \times 10^6 + h)^2 = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{0.25}$$

$$(6.4 \times 10^6 + h)^2 = \frac{40.02 \times 10^{13}}{0.25}$$

By taking square root on both sides, we have

$$6.4 \times 10^6 + h = \sqrt{\frac{40.02 \times 10^{13}}{0.25}}$$

$$h = \sqrt{\frac{40.02 \times 10^{13}}{0.25}} - 6.4 \times 10^6$$

$$h = \sqrt{17.79 \times 10^{13}} - 6.4 \times 10^6$$

$$h = \sqrt{177.9 \times 10^{12}} - 6.4 \times 10^6$$

$$h = 13.3 \times 10^6 - 6.4 \times 10^6$$

$$h = 6.9 \times 10^6 \text{ m}$$ (Approximately equal to the radius of Earth)

Result:

$h = 6.9 \times 10^6$ m (Approximately equal to the radius of Earth)

9. A polar satellite is launched at 850km above earth. Find its orbital speed.

Ans: Given data:

Height of satellite = h = 850 km = 850×10^3m = 0.85×10^6m

Radius of earth = $R_e = 6.4 \times 10^6$m

Mass of Earth = $M_e = 6 \times 10^{24}$ kg

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

Orbital Speed of Satellite = v_o = ?

Solution:

As we know that,

$$v_o = \sqrt{g_h\,(R + h)} \qquad \therefore g_h = \frac{G\,M_e}{(R+h)^2}$$

$$v_o = \sqrt{\left(\frac{G\,M_e}{(R+h)^2}\right)(R + h)}$$

$$v_o = \sqrt{\frac{G\,M_e}{(R+h)}}$$

$$v_o = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^{6} + 0.85 \times 10^{6}}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{24-11}}{7.25 \times 10^{6}}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{13}}{7.25 \times 10^{6}}}$$

$$v_o = \sqrt{5.52 \times 10^{13-6}}$$

$$v_o = \sqrt{5.52 \times 10^{7}}$$

$$v_o = \sqrt{55.2 \times 10^{6}}$$

$$v_o = 7.4296 \times 10^{3}$$

$$v_o = 7429.6\ ms^{-1}$$

Result:

Orbital Speed of Satellite = $v_o = 7429.6\ ms^{-1}$

10. A communication, satellite is launched at 42000km above the earth. Find its orbital speed.

Ans: Given data:

Height of satellite = h = 42000 km

Height of satellite = $42000 \times 10^3 m = 4.2 \times 10^7 m$

Radius of earth = $R_e = 6.4 \times 10^6 m$

Mass of Earth = $M_e = 6 \times 10^{24}\ kg$

Gravitational constant = G = $6.67 \times 10^{-11} Nm^2kg^{-2}$

To Find:

Orbital Speed of Satellite = v_o = ?

Solution:

As we know that,

$$v_o = \sqrt{g_h (R + h)} \qquad \therefore g_h = \frac{G M_e}{(R+h)^2}$$

$$v_o = \sqrt{\left(\frac{G M_e}{(R+h)^2}\right)(R + h)}$$

$$v_o = \sqrt{\frac{G M_e}{(R+h)}}$$

$$v_o = \sqrt{\frac{6.67 \times 10^{-11} \times 6 \times 10^{24}}{6.4 \times 10^6 + 4.2 \times 10^7}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{24-11}}{4.84 \times 10^7}}$$

$$v_o = \sqrt{\frac{40.02 \times 10^{13}}{4.84 \times 10^7}}$$

$$v_o = \sqrt{8.26 \times 10^{13-7}}$$

$$v_o = \sqrt{8.26 \times 10^6}$$

$$v_o = 2.87 \times 10^3$$

$$v_o = 2870\ ms^{-1}$$

Result:

Orbital Speed of Satellite = v_o = 2870 ms^{-1}

Chapter: 06

Work and Energy

Exercise MCQs

1. **The work done will be zero when the angle between the force and the distance is:**

   (A) 45° (B) 60° (C) 90° (D) 180°

2. **If the direction of motion of the force is perpendicular to the direction of motion of body, then work done will be:**

   (A) maximum (B) minimum (C) Zero (D) None

3. **If the velocity of a body becomes double, then its kinetic energy will:**

   (A) remain the same (B) become double
   (C) become four times (D) become half

4. **The work done in lifting a brick of mass 2 kg through a height of 5 m above ground will be?**

   (A) 2.5J (B) 10 J (C) 50J (D) 100J

5. **The kinetic energy of a body of mass 2 kg is 25 J. It is speed is?**

   (A) $5ms^{-1}$ (B) $1.5ms^{-1}$ (C) $12.5ms^{-1}$ (D) $50ms^{-1}$

6. **Which one of the following converts light energy into electrical energy?**

   (A) electric bulb (B) electric generator (C) photocell (D) electric cell

7. **When a body is lifted through a height h, the work done on it appears in the form of its:**

   (A) kinetic energy (B) potential energy
   (C) elastic potential energy (D) geothermal energy

8. **The energy stored in coal is:**

   (A) heat energy (B) kinetic energy (C) chemical energy (D) nuclear energy

9. The energy stored in a dam is:

Ⓐ electric energy Ⓑ potential energy Ⓒ kinetic energy Ⓓ thermal energy

10. In Einstein's mass-energy equation, c is the:

Ⓐ speed of sound
Ⓑ speed of light
Ⓒ speed of electron
Ⓓ speed of earth

11. The rate of doing work is called:

Ⓐ energy Ⓑ torque Ⓒ power Ⓓ momentum

Answer Key:

1	Ⓒ	7	Ⓑ
2	Ⓒ	8	Ⓒ
3	Ⓒ	9	Ⓑ
4	Ⓓ	10	Ⓑ
5	Ⓐ	11	Ⓒ
6	Ⓒ		

Short Questions

1. Define work. What is its SI unit?

Ans: Work:

Work is said to be done when force acting on a body displaces it in the direction of the force.

Formula:

$$\text{Work} = \text{Force} \times \text{distance}$$

$$W = F \times S$$

SI unit of work:

SI unit of work is joule (J) or Nm

Joule:

The amount of work done will be one joule if a force of one Newton displaces a body through a distance of one meter in the direction of the force.

2. Why do we need energy?

Ans: We need energy to do different types of work in our daily life. When we say that body has energy, we mean that it has the ability to do work.

OR

- Energy is used by us to perform many activities of life.
- Energy is necessary for running and walking for humans.

3. When does a force do work? Explain.

Ans: Work is done when the force acting on a body displaces it in the direction of applied force.

4. Define energy, and give two types of mechanical energy.

Ans: Energy:

A body possesses energy if it is capable to do work.

Types of mechanical energy:

Mechanical energy has two following types:

(i) Kinetic energy (ii) Potential energy

Kinetic energy:

The energy possessed by a body due to its motion is called its kinetic energy.

Formula:

$$K.E = \frac{1}{2}mv^2$$

Potential energy:

The ability of a body to do work due to its position is known as its potential energy.

Formula:

$$P.E = mgh$$

5. Define potential energy and derive its relation.

Ans: Potential energy:

Energy possessed by a body due to its position is called potential energy.

$$P.E = mgh$$

Derivation:

$$P.E = work$$

$$P.E = F.d$$

$$P.E = (mg)(h)$$

$$P.E = mgh$$

6. Define K.E and derive its relation.

Ans: "The energy possessed by a body due to its motion is called kinetic energy".

Example:

- Moving air is called wind. We can use wind energy for doing various things. It drives windmills and pushes sailing boats.
- Moving water in a river can carry wooden logs through large distances and can also be used to drive turbines for generating electricity.

Mathematical Derivation:

Let a body of mass m is moving with velocity v. An opposing force F acting through a distance S brings it to rest. The body possesses kinetic energy and is capable to do work against opposing force F until add of its kinetic energy used up.

K.E of the body = Work done by it due to motion

$$K.E = FS$$

$$v_i = v$$

$$v_f = 0$$

As $F = ma$

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

Since motion is opposed, hence, is a negative.

Using 3rd equation of motion:

$$2aS = v_f^2 - v_i^2$$

$$2\left(-\frac{F}{m}\right)S = (0)^2 - (v)^2$$

$$2(-FS) = -mv^2$$

$$-FS = -\frac{1}{2}mv^2$$

$$FS = \frac{1}{2}mv^2$$

As we know that K.E is equal to the work done,

So $K.E = \frac{1}{2}mv^2$

The above equation gives the K .E possessed by a body of mass m moving with velocity v.

7. Why fossils fuels are called non-renewable form of energy?

Ans: The fossil fuels take millions of years for their formation. So, these are known as nonrenewable resources.

8. How is energy converted from one form to another? Explain.

Ans: With the help of different devices and through chemical reactions energy is converted from one form to another.

Example:

Solar cells are used to convert light energy into electrical energy.

9. Which form of energy is most preferred and why?

Ans: Solar energy is the most preferred energy because sunlight does not pollute the environment in any way.

Solar energy reaching Earth is a thousand times more than the energy consumption of mankind.

10. Name a device that converts mechanical energy into electrical energy.

Ans: A generator is a device that converts mechanical energy into electrical energy.

11. Name the five devices that convert electrical energy into mechanical energy.

Ans: Name of five devices:

(i) Washing machine
(ii) Electric motor
(iii) Electric grinder
(iv) Electric spinner
(v) Juicer

12. What is meant by the efficiency of a system?

Ans: Efficiency:

The efficiency of a system is the ratio of required form of energy obtained from a system as output to the total energy given to it as input.

Formula:

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

Input is the energy given to machine to work while output is work done by machine.

13. What is meant by the term power?

Ans: **Power:**

Power is defined as the rate of doing work.

Formula:

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

i.e. $$P = \frac{W}{t}$$

Unit:

The SI unit of power is watt (W).

14. How can you find the efficiency of a system?

Ans: The efficiency of a system can be determined by following the formula.

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$$

$$\%\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

15. Define Watt.

Ans: **Watt:**

The power of a body is one watt if it does work at the rate of 1 joule per second ($1Js^{-1}$).

$$1 \text{ watt} = \frac{1J}{1 \text{ sec}}$$

Important Formulas

- $\%\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$
- $\text{Efficiency} = \frac{\text{Output}}{\text{Input}}$
- $W = F \times S$
- $K.E = \frac{1}{2}mv^2$
- $P.E = mgh$
- $E = mc^2$
- $P = F.V$ or $P = \frac{W}{t}$

Important Values

- Speed of light = $e = 3 \times 10^8\ ms^{-1}$
- Density of water = $1000\ kgm^{-3}$
- Mass of 1 liter water = 1kg
- 1hp = 746 watt
- $1MJ = 10^6 J$

Units:

- Work = Joule
- Power = Watt
- Energy = Joule
- (1 joule = Newton meter)
  (Watt = Joule/sec)

Numerical

1. A man has pulled a cart through 35m applying a force of 300N. Find the work done by the man.

Ans: Given data:

S = 35m

F = 300N

To Find:

Work = W = ?

Solution:

$W = F \times S$

$W = 300 \times 35$

$W = 10500\ J$

Result:

Work done by the man = W = 10500 J

2. A block weighing 20N is lifted 6m vertically upward. Calculate the potential energy stored in it.

Ans: Given data:

Weight = S = 20N

$h = 6m$

To Find:

$P.E = ?$

Solution:

$$P.E = \text{Work done}$$
$$P.E = F.d = mgh = w.h$$
$$P.E = w.h$$
$$P.E = 20 \times 6$$
$$P.E = 120\ J$$

Result:

Potential energy $= P.E = 120\ J$

3. A car weighing 12kN has the speed of $20ms^{-1}$. Find its kinetic energy.

Ans: Given data:

$$\text{Weight} = w = 12kN = 12 \times 1000N = 12000N$$
$$v = 20ms^{-1}$$

To Find:

$K.E = ?$

Solution:

$$K.E = \frac{1}{2}mv^2 \quad \text{----------(i)}$$

Now, $w = mg$

$$m = \frac{w}{g} = \frac{12000}{10} = 1200kg$$
$$K.E = \frac{1}{2} \times 1200 \times (20)^2$$
$$K.E = \frac{1}{2} \times 1200 \times 400$$
$$K.E = 240000\ J \qquad \therefore\ 1000\ J = 1Kj$$
$$K.E = 240kJ$$

Result:

Kinetic energy $= K.E = 240kJ$

4. A 500g stone is thrown up with a velocity of $15ms^{-1}$. Find its.

(a) P.E at its maximum height.

(b) K.E when it hits the ground.

Ans: Given data:

$$m = 500g = \frac{500}{1000} = 0.5kg$$

$$v = 15ms^{-1}$$

To Find:

$$P.E = ?$$

$$K.E = ?$$

Solution:

$$K.E = \frac{1}{2}mv^2$$

$$K.E = \frac{1}{2} \times 0.5 \times (15)^2$$

$$K.E = \frac{1}{2} \times 1200 \times 225$$

$$\mathbf{K.E = 56.25\ J}$$

As we know that;

Potential energy at maximum height = Kinetic energy while throwing

$$K.E = P.E$$

So **P .E will also be = 56.25J**

Because energy is converted one form to another but it remains the same.

5. On reaching the top of a slope 6m high from its bottom, a cyclist has a speed of 1.5ms^{-1}. Find the K.E and P.E of the cyclist. The mass of the cyclist and his bicycle is 40kg.

Ans: Given data:

$$h = 6m$$

$$g = 1.5ms^{-1}$$

$$m = 40kg$$

To Find:

$$K.E = ?$$

$$P.E = ?$$

Solution:

$$K.E = \frac{1}{2}mv^2$$

$$K.E = \frac{1}{2} \times 40 \times (1.5)^2$$

$$K.E = \frac{1}{2} \times 40 \times 2.25$$

$$\mathbf{K.E = 45\ J}$$

$$P.E = mgh$$

$$P.E = 40 \times 10 \times 6$$

$$\mathbf{P.E = 2400J}$$

6. A motorboat moves at a steady speed of $4ms^{-1}$, water resistance acting on it is 4000N. Calculate the power of its engine.

Ans: Given data:

$$v = 4ms^{-1}$$

$$F = 4000N$$

To Find:

$$P = ?$$

Solution:

$$P = F.v$$

$$P = 4000 \times 4$$

$$P = 16000\ watt$$

$$P = 16 \times 1000$$

$$P = 16 \times 10^3$$

$$\mathbf{P = 16kW}$$

7. A man pulls a block with a force of 300N through 50m in 60s. Find the power used by him to pull the block.

Ans: Given data:

$$F = 300N$$

$$S = 50m$$

$$t = 60s$$

To Find:

$$P = ?$$

Solution:

$$P = \frac{W}{t} \qquad \therefore W = F \times S$$

$$P = \frac{F \times S}{t}$$

$$P = \frac{300 \times 50}{60}$$

$$\mathbf{P = 250watt}$$

8. A 50kg man moved 25 steps up in 20 seconds. Find his power, if each step is 16cm high.

Ans: Given data:

$$m = 50kg$$

$$t = 20s$$

$$\text{Height of each step} = 16cm = \frac{16}{100} = 0.16m$$

$$\text{Height of 25 step} = 0.16 \times 25 = 4m$$

To Find:

$$P = ?$$

Solution:

$$P = \frac{W}{t} \qquad \because W = mgh$$

$$P = \frac{mgh}{t}$$

$$P = \frac{50 \times 10 \times 4}{20}$$

$$\mathbf{P = 100watt}$$

9. Calculate the power of a pump which can lift 200kg of water through a height of 6m in 10 seconds.

Ans: Given data:

$$m = 200kg$$

$$h = 6m$$

$$t = 10s$$

To Find:

$$P = ?$$

Solution:

$$P = \frac{W}{t} \qquad \therefore W = mgh$$

$$P = \frac{mgh}{t}$$

$$P = \frac{200 \times 10 \times 6}{10}$$

$$\mathbf{P = 1200watt}$$

10. An electric motor of 1hp is used to run water pump. The water pump takes 10 minutes to fill an overhead tank. The tank has a capacity of 800 liters and height of 15m. Find the actual work done of motor to fill the tank. Also find efficiency of the system.
(Density of water = 1000kgm^{-1})
Mass of 1 litre of water = 1kg).

Ans: Given data:

$v = 800$ liters

$t = 10$ min $= 10 \times 60 = 600$ sec

$P = 1hP$ $\quad \therefore$ 1hp = 746 watt

$P = 746$ watt

$h = 15m$

To Find:

$W = ?$

Efficiency $= ?$

Solution:

$$P = \frac{W}{t}$$

$$W = P \times t$$

$$W = 746 \times 600$$

$$\mathbf{Input = W = 447600J}$$

We know that;

1 litre of water = 1kg of water

So,

$800\text{litres} = 800\text{kg}$

$m = 800\text{kg}$

Now,

$$W = mgh$$

$$W = 800 \times 10 \times 15$$

$$W = 120000J$$

Here

$$\text{Work input} = 447600\text{J}$$

$$\text{Work input} = 120000\text{J}$$

$$\%\text{Efficiency} = \frac{\text{Output}}{\text{Input}} \times 100$$

$$\%\text{Efficiency} = \frac{120000}{447600} \times 100$$

$$\%\textbf{Efficiency} = \textbf{26.8\%}$$

Chapter: 07

Properties of Matter

Exercise MCQs

1. In which of the following state molecules do not leave their position?

Ⓐ Solid Ⓑ Liquid Ⓒ Gas Ⓓ Plasma

2. Which of the substance is the highest one?

Ⓐ copper Ⓑ mercury Ⓒ aluminium Ⓓ lead

3. SI unit of pressure is Pascal, which is equal to:

Ⓐ 10^4 Nm^{-2} Ⓑ 1 Nm^{-2} Ⓒ 10^2 Nm^{-2} Ⓓ 10^3 Nm^{-2}

4. What should be the approximate length of a glass tube to construct a water barometer?

Ⓐ 0.5m Ⓑ 1m Ⓒ 2.5m Ⓓ 11m

5. According to Archimedes, up thrust is equal to:

Ⓐ weight of displaced liquid Ⓑ volume of displaced liquid
Ⓒ mass of displaced liquid Ⓓ none of these

6. The density of a substance can be found with the help of:

Ⓐ Pascal's law Ⓑ Hooke's law
Ⓒ Archimedes principle Ⓓ Principle of floatation

7. According to Hooke's law:

Ⓐ stress× strain = constant Ⓑ stress / strain = constant
Ⓒ strain / stress = constant Ⓓ stress = strain

Answer Key

1	Ⓐ	5	Ⓓ
2	Ⓒ	6	Ⓒ
3	Ⓑ	7	Ⓑ
4	Ⓓ		

Short Questions

1. How kinetic molecular model of matter is helpful in differentiating various states of matter?

Ans: Kinetic molecular model is used to explain three states of matter solid, liquid, and gas.

Solid:

In solids molecules are very close to one another, they possess greater attractive forces.

Liquids:

The distance between molecules is greater as compared to solids.

Gases:

In gases distance between molecules is too much.

2. What is meant by density? What is its SI unit?

Ans: Density:

Density of a substance is defined as the mass per unit volume.

Formula:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$d = \frac{m}{v}$$

Unit:

The SI unit of density is kilogram per cubic metre (kgm^{-3}).

3. Does there exist a fourth state of matter? What is that?

Ans: Yes, there exists a fourth state of matter that is called **plasma.**

At very high temperature, the matter assumes the state of ions and electrons this is called plasma.

4. Can we use a hydrometer to measure the density of milk?

Ans: A Hydrometer is a device which is used to measure the density of the fluid.as the hydrometer is a glass tube with a scale marked on its stem and heavy weight in the bottom. It is partially immersed in the milk that is also a fluid, the density of which is to be measured; hence we can use a hydrometer to measure the density of milk.

5. Show that the atmosphere exerts pressure.

Ans: **Experiment:**

Boil an empty tin, half-filled with water, cap the tin. Let it cool under tap water. The tin will get crumpled as the water cool down. As the steam condenses, the pressure inside the metal tin decreases, the external atmospheric pressure that is higher, crushes the tin.

6. Define the term pressure.

Ans: **Pressure:**

The force acting normally on a unit area at the surface of a body is called pressure.

Formula:

$$\text{Formula} = \frac{\text{Force}}{\text{Area}}$$

$$P = \frac{F}{A}$$

Units:

In SI, the unit of pressure is Newton per square metre (Nm^{-2}) or Pascal (Pa).

Physical quantity:

It is a scalar quantity.

7. It is easy to remove air from a balloon but it is very difficult to remove air from a glass bottle. Why?

Ans: It is very difficult to remove air from a glass bottle because air pressure in the bottle is less than atmospheric pressure but it is easy to remove air from a balloon due to lower external pressure.

8. Why water is not suitable to be used in a barometer?

Ans: Mercury is 13.6 times denser than water. Atmospheric pressure can hold vertical column of water about 13.6 times the height of mercury column at a place. Thus, at a sea level, the vertical height of water column would be $0.76 \times 13.6 = 10.4m$. Thus, a glass tube more than 10m long is required to make a water barometer.

9. What is a barometer?

Ans: **Barometer:**

The instrument that measures atmospheric pressure is called barometer. One of the simple barometers is mercury barometer. It consists of a glass tube 1m long closed at one end.

10. What makes a sucker pressed on a smooth wall sticks to it?

Ans: Air pressure makes the sucker pressed on a smooth wall stick to it.

11. What does it mean when the atmospheric pressure at a place falls suddenly?

Ans: A sudden fall in atmospheric pressure often followed by a storm, rain, and typhoon occurs in a few hours' time that cause internal energy of air to decrease, and coldness is produced.

12. Why does the atmospheric pressure vary with height?

Ans: The density of air is not uniform in the atmosphere. It decreases continuously as we go up. Hence atmospheric pressure is also decreased.

13. What changes are expected in weather if the barometer reading shows a sudden increase?

Ans: If the barometer reading shows a sudden increase or a rapid increase in atmospheric pressure, means that it will soon be followed by a decrease in the atmospheric pressure indicating poor weather ahead.

14. Explain the working of a hydraulic press.

Ans: The hydraulic press works on the principle of Pascal's law and consists of two cylinders fitted with pistons of different cross-sectional area.

15. State Pascal's law.

Ans: Pascal's law:

Pressure applied at any point of a liquid enclosed in a container is transmitted without loss to all other parts of the liquid.

16. What is meant by elasticity?

Ans: Elasticity:

Elasticity is the property of matter by virtue of which matter resists any force which tries to change its length, shape or volume.

17. What is up thrust? Explain the principle of floatation.

Ans: Up thrust:

The fluids (liquids) exert force in the upward direction when some object is immersed into them. This is called upward thrust.

Principle of floatation:

The weight of the fluid displaced is equal to the weight of the floating object inside the liquid. Then object will into sink and keep floating. It is called the principle of floatation.

18. State Archimedes principle.

Ans: Archimedes principle:

When an object is whole or partially immersed in a liquid, an upthrust force acts on it equal to the weight of the liquid displaced. This is known as Archimedes principle.

19. Explain how a submarine moves up the water surface and down into the water.

Ans: If the submarine is not filled with seawater then, its weight is less than the upward thrust. So that floats on the surface of seawater. But when, it is filled with water, then its weight becomes larger as compared with the upward thrust of water then it sinks into the water.

20. What is Hooke's law? What is meant by elastic limit?

Ans: Hooke's law:

The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body is called Hooke's law.

$$\text{Stress} \propto \text{strain}$$

Elastic limit:

An elastic limit can be defined as a limit within which a body recovers its original length, volume, or shape after the deforming force is removed.

21. Why does a piece of stone sink in water but a ship with a huge weight floats?

Ans: Ships and boats float on water. It is because the weight of an equal volume of water is greater than the weight of ships and boats. Ships have less density and large volume. A stone sinks in water. It is because the weight of an equal volume of water is smaller than the weight of a stone. Stone has high density and small volume.

22. Take a rubber band. Construct a balance of your own using a rubber band. Check its accuracy by weighing various objects.

Ans: Take a rubber band, hang it with a hook. Then pointer is attached at the lower end of it with a scale in front of pointer. Different known weights are suspended one by

one at lower end of this rubber band. The pointer position on the scale is marked for each different known weight suspended. It is called the calibration of scale for weight measurement. This makes a balance for weight measurement.

Important Formulas

- $A = \pi r^2$
- Volume = $l \times w \times h$
- Area = length × width
- Young's Modulus: $Y = \frac{F L_O}{A \Delta L}$
- $\frac{\text{Volume of ice}}{\text{Volume of water}} = \frac{\text{Density of water}}{\text{Density of ice}}$
- $\rho = \frac{m}{v}$
- $\rho_{obj} = \frac{w_1}{w_1 - w_2} \times \rho_{water}$
- Pascal's law: $P_1 = P_2$

$$\frac{F_1}{A} = \frac{F_2}{a}$$

$$P = \frac{F}{A} = \frac{mg}{A}$$

Important Values and Some Units

Values:

- Density of ice = $920 kgm^{-3}$
- Density of water = $1000 kgm^{-3}$
- Density of A1 = $2727 kgm^{-3}$
- 1m = 100cm
- $1m^4 = 10^4 cm^2$
- $1m^3 = 10^6 cm^2$
- $1m = 10^3 mm \Rightarrow 1m^2 - 10^6 mm^2$

Units:

- Area = m^2
- Density = kgm^{-3}
- Young's Modulus = Y = Nm^{-2}
- Volume = m^3
- Pressure = Pa = Nm^{-2}
- Stress = Nm^{-2}

Numerical

1. A wooden block measuring 40cm × 10cm × 5cm has a mass 850g. Find the density of wood?

Ans: Given data:

$$\text{Volume} = V = 40\text{cm} \times 10\text{cm} \times 5\text{cm}$$

$$\text{Volume} = V = 2000\text{cm}^3$$

$$F = 300\text{N}$$

To Find:

$$\text{Work} = W = ?$$

Solution:

$$W = F \times S$$

$$W = 300 \times 35$$

$$W = 10500\ \text{J}$$

Result:

Work done by the man = W = 10500 J

2. How much would be the volume of ice formed by freezing 1 liter of water?

Ans: Given data:

$$\text{Density of ice} = 920\text{kgm}^{-3}$$

$$\text{Density of water} = 1000\text{kgm}^{-3}$$

$$\text{Volume of water} = \rho_2 = 1000\text{kgm}^{-3}$$

$$\text{Volume of water} = V_2 = 1\ \text{litre}$$

To Find:

$$\text{Volume of ice} = V_1 = ?$$

Solution:

$$\frac{\text{Volume of ice}}{\text{Volume of water}} = \frac{\text{Density of water}}{\text{Density of ice}}$$

Or $$\frac{V_1}{V_2} = \frac{\rho_2}{\rho_1}$$

Or $$v_1 = \frac{\rho_2}{\rho_1} \times v_2$$

Putting the values, we have

$$V_{ice} = \frac{1000}{920} \times 1$$

$$\text{Volume of ice} = 1.09 \text{ liter}$$

Result:

Thus, the volume of following of ice is 1.09 liter.

3. Calculate the volume of the following objects:

(a) An iron sphere of mass 5kg, the density of iron is 8200kgm^{-3}

(b) 200g of lead shot having density 11300kgm^{-3}

(c) A gold bar of mass 0.2kg and ρ = 19300 kgm^{-3}

Ans: Given data:

(a) Mass of iron = m = 5kg

Density of iron = ρ = 8200kgm^{-3}

To Find:

Volume of iron = V = ?

Solution:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{V}$$

$$8200 = \frac{5}{V}$$

$$V = \frac{5}{8200}$$

$$V = 6.1 \times 10^{-4} m^3$$

Volume of iron sphere = V = $6.1 \times 10^{-4} m^3$

(b) Mass of lead = m = 200g = $\frac{200}{1000}$kg = 0.2kg

Density of lead = ρ = 11300kgm^{-3}

To Find:

Volume of lead = V = ?

Solution:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{V}$$

$$11300 = \frac{0.2}{V}$$

$$v = \frac{5}{11300}$$

$$v = 1.77 \times 10^{-5} m^3$$

Volume of iron sphere $= v = 1.77 \times 10^{-5} m^3$

(c) Mass of gold bar $= m = 200g = \frac{200}{1000} kg = 0.2kg$

Density of gold bar $= \rho = 19300 kgm^{-3}$

To Find:

Volume of gold bar $= V = ?$

Solution:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{V}$$

$$19300 = \frac{0.2}{V}$$

$$v = \frac{5}{19300}$$

$$v = 1.04 \times 10^{-5} m^3$$

Volume of gold bar $= v = 1.04 \times 10^{-5} m^3$

4. The density of air is 1.3 kgm^{-3}. Find the mass of air in a room measuring $8m \times 5m \times 4m$.

Ans: Given data:

Density of air $= \rho = 1.3 kgm^{-3}$

Volume $= V = 8m \times 5m \times 4m$

Volume $= V = 160 m^3$

To Find:

Mass of air $= m = ?$

Solution:

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{V}$$

$$1.3 = \frac{m}{160}$$

$$m = 1.3 \times 160$$

$$\mathbf{m = 208kg}$$

Result:

Mass of air = m = 208kg

5. A student presses her palm by her thumb with a force of 75N. How much would be the pressure under his thumb having contact area 1.5cm²?

Ans: Given data:

$$\text{Force} = F = 75N$$

$$\text{Area} = A = 1.5cm^2 = \frac{1.5}{(100)^2} = 1.5 \times 10^{-4}\ m^2$$

To Find:

$$\text{Pressure} = P = ?$$

Solution:

$$P = \frac{F}{A}$$

$$P = \frac{75}{1.5 \times 10^{-4}}$$

$$P = 5 \times 10^5\ Nm^{-2}$$

6. The head of a pin is a square of side 10mm. Find the pressure on it due to the force of 20N.

Ans: Given data:

$$\text{Side of square} = L = 10mm$$

$$\text{Area of square} = A = L \times L = 10 \times 10 = 100mm^2$$

$$\text{Area of square} = A = 1 \times 10^{-4}\ m^2$$

$$\text{Force} = F = 20N$$

To Find:

$$\text{Pressure} = P = ?$$

Solution:

$$P = \frac{F}{A}$$

$$P = \frac{20}{1 \times 10^{-4}}$$

$$P = 20 \times 10^4\ Nm^2$$

$$\mathbf{P = 2 \times 10^5\ Nm^{-2}}$$

7. A uniform rectangular block of wood 20cm × 7.5cm ×7.5cm and of mass 1000g stands on a horizontal surface with its longest edge vertical. Find

(i) The pressure exerted by the block on the surface

(ii) Density of the wood.

Ans: Given data:

$$\text{Area of block} = A = 7.5 \times 7.5 = 56.25\text{cm}^2$$

$$\text{Area of block} = A = 56.25 \times 10^{-4}\ \text{m}^2$$

$$\text{Mass of block} = m = 1000\text{g} = 1\text{kg}$$

$$\text{Volume} = V = 20\text{cm} \times 7.5\text{cm} \times 7.5\ \text{cm} = 1125\text{cm}^3$$

$$\text{Volume} = V = 1125 \times 10^{-6}\ \text{m}^3$$

$$g = 9.8\text{ms}^{-2}$$

To Find:

$$\text{Pressure} = P = ?$$

$$\text{Density} = \rho = ?$$

Solution:

(i) $$P = \frac{F}{A} = \frac{mg}{A}$$

$$P = \frac{1 \times 10}{56.25 \times 10^{-4}}$$

$$\mathbf{P = 1778\ Nm^{-2}}$$

(ii) $$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{m}{V}$$

$$\text{Density} = \rho = \frac{1}{1125 \times 10^{-6}}$$

$$\rho = \frac{10^6}{1125}$$

$$\boldsymbol{\rho = 889\text{kgm}^{-3}}$$

8. A cube of glass of 5cm side and mass 306g has a cavity inside it. If the density of glass is 2.55gcm^{-3}. Find the volume of the cavity.

Ans: Given data:

$$\text{Original volume of glass} = V = 5\text{cm} \times 5\text{cm} \times 5\text{cm} = 125\text{cm}^3$$

$$V = 125 \times 10^{-6}\ \text{m}^3 = 1.25 \times 10^{-4}\ \text{m}^3$$

$$\text{Mass of cube} = 306\text{g} = 0.306\text{kg} = 3.06 \times 10^{-1}\text{kg}$$

To Find:

$$\text{Volume of cavity} = V = ?$$

Solution:

$$\text{Volume of cavity} = \frac{\text{Mass}}{\text{Density}}$$

$$\text{Volume of cavity} = \frac{3.06 \times 10^{-1}}{2.55 \times 10^{3}}$$

$$\text{Volume of cavity} = 1.20 \times 10^{-4}\ m^3$$

$$\text{Volume of cavity} = \text{Volume without cavity} - \text{Volume with cavity}$$

$$\text{Volume of cavity} = 1.25 \times 10^{-4} - 1.20 \times 10^{-4}$$

$$\text{Volume of cavity} = 0.05 \times 10^{-4}\ m^3$$

$$\text{Volume of cavity} = 5 \times 10^{-6}\ m^3 \quad \text{or} \quad 5\ cm^3$$

9. An object has a weight 18N in the air. Its weight is found to be 11.4N, when immersed in water. Calculate its density. Can you guess the material of the object?

Ans: Given data:

Weight of object in air $= w_1 = 18N$

Weight of object in water $= w_2 = 11.4N$

Density of air $= \rho_w = 1000 kgm^{-3}$

Gravitational acceleration $= g = 10 ms^{-2}$

Weight of equal volume of water $= w = 18N - 11.4N = 6.6N$

To Find:

Density of material $= D_m = ?$

Density of material $= ?$

Solution:

As we know that;

$$\frac{D}{\rho} = \frac{m_1}{w}$$

By putting the value, we have

$$\frac{D}{1000} = \frac{18}{6.6}$$

$$D = \frac{18}{6.6} \times 1000$$

$$D = \frac{18000}{6.6}$$

$$D = 2727 Kgm^{-3}$$

Result:

Density of material = D_m = 2727Kgm^{-3}

As we know that density of aluminum is approximately equal to the density found in the numerical. So, the material is aluminum.

10. A solid block of wood of density 0.6gcm^{-3} weighs 3.06N in air. Determine

(a) Volume of the block

(b) The volume of the block immersed when placed freely in a liquid of density 0.9gcm^{-3}?

Ans: Given data:

Density of wood = 0.6gcm^3

Weight of wood in air = w_1 = 3.06N

Weight of wood in air = w_1 = mg

$$m = \frac{3.06}{10}$$

$$m = 0.306kg$$

$$m = 306g$$

To Find:

Volume of block = V_1 = ?

Volume when immersed in liquid = V_2 = ?

Solution:

Density of liquid = ρ = 10.9gcm^{-3}

(a) $$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$0.6 = \frac{306}{V_1}$$

$$V_1 = \frac{306}{0.6}$$

$$V_1 = 510cm^3$$

Volume of block = V_1 = 510cm^3

(b) $$\text{Density} = \frac{\text{Mass}}{\text{Volume}}$$

$$0.9 = \frac{306}{V_2}$$

$$V_2 = \frac{306}{0.9}$$

Volume in water $= V_2 = 340cm^3$

11. The diameter of the piston of a hydraulic press is 30cm. How much force is required to lift a car weighing 20000N on its piston if the diameter of the piston of the pump is 3cm?

Ans: Given data:

Weight on small piston $= W = F_1 = 20000N$

Diameter of large piston $= D = 30cm$

Radius of large piston $R = \frac{D}{2} = \frac{30}{2} = 15cm = 0.15m$

Area of large piston $= A = \pi R^2$

Area of large piston $= A = 3.14 \times (0.15)^2$

Diameter of small piston $= d = 3cm$

Radius of small piston $= r = \frac{\beta}{2} = 1.5cm = 0.015m$

Area of small piston $= a = \pi r^2 = 3.14 \times (0.015)^2$

Area of small piston $= a = 0.000706m$

To Find:

Force on small piston $= F_2 = ?$

Solution:

$$P = P$$

$$\frac{F_1}{A} = \frac{F_2}{a}$$

$$\frac{20000}{\pi R^2} = \frac{F_2}{\pi r^2}$$

$$\frac{20000}{0.0706} = \frac{F_2}{(0.000706)}$$

$$\mathbf{F_2 = 200N}$$

12. A steel wire of cross–sectional area $2 \times 10^{-5}m^2$ is stretched through 2mm by a force of 4000N. Find the Young's modulus of the wire. The length of the wire is 2m.

Ans: Given data:

Cross-sectional area of wire $= A = 2 \times 10^{-5}m$

Length of wire $= L_o = 2m$

Force $= F = 4000N$

Increase in length $= \Delta L = 2mm = 2 \times 10^{-3}m$

To Find:

Young's modulus $= Y = ?$

Solution:

$$Y = \frac{FL_o}{A\Delta L}$$

$$Y = \frac{4000 \times 2}{2 \times 10^{-5} \times 2 \times 10^{-3}}$$

$$Y = \frac{4000}{2 \times 10^{-8}}$$

$$Y = \frac{4 \times 10^{3} \times 10^{6}}{2}$$

$$\mathbf{Y = 2 \times 10^{11} Nm^{-2}}$$

Chapter: 08

Thermal properties of matter

Exercise MCQs

1. Water freezes at:

Ⓐ 0^oF Ⓑ 32^oF Ⓒ $-273K$ Ⓓ $0K$

2. Normal human body temperature is:

Ⓐ 0^oC Ⓑ 37^oC Ⓒ 37^oF Ⓓ 98.6^oC

3. Mercury is used as thermometric material because it has:

Ⓐ uniform thermal expansion Ⓑ low freezing point
Ⓒ small heat capacity Ⓓ all the above properties

4. Which of the following material has large specific heat?

Ⓐ copper Ⓑ ice Ⓒ water Ⓓ mercury

5. Which of the following materials has a large value of temperature coefficient of linear expansion?

Ⓐ aluminium Ⓑ gold Ⓒ brass Ⓓ steel

6. What will be value of Q for a solid for which a has value of $2 \times 10^{-5}K^{-1}$?

Ⓐ $2 \times 10^{-5}K^{-1}$ Ⓑ $6 \times 10^{-5}K^{-1}$ Ⓒ $8 \times 10^{-15}K^{-1}$ Ⓓ $8 \times 10^{-5}K^{-1}$

7. A large water reservoir keeps the temperature of nearby land moderate due to:

Ⓐ low temperature of water Ⓑ specific heat of water
Ⓒ less absorption of heat Ⓓ large specific heat of water

8. Which of the following affects evaporation?

Ⓐ temperature Ⓑ wind
Ⓒ the surface area of the liquid Ⓓ all of the above

Answer Key:

1	B	5	A
2	B	6	B
3	D	7	D
4	C	8	D

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Short Questions

1. Why does heat flow from a hot body to a cold body?

Ans: Heat flows from a hot body to a cold body to attain the condition of thermal equilibrium.

2. What is meant by the internal energy of a body?

Ans: Internal energy of a body:

The sum of kinetic energy and potential energy associated with the atoms, molecules, and particles of a body is called its internal energy.

3. Define the terms heat and temperature.

Ans: Heat:

Heat is the form of energy that is transferred from one body to another in thermal contact with each other as a result of the difference in temperature between them.

Temperature:

"The temperature of a body is the degree of hotness or coldness of a body".

4. How does heating affect the motion of molecules of a gas?

Ans: By heating the gas, its molecules get high kinetic energy and start to collide more randomly and the motion of gas molecules is increased by heating. So, the pressure and volume of gas molecules increase by heating.

5. Explain the volumetric thermal expansion.

Ans: Volumetric thermal expansion:

It is usually expressed as a fractional change in volume per unit temperature change.

$$V = V_o (1 + \beta \Delta T)$$

6. What is a thermometer? Why mercury is preferred as a thermometric substance?

Ans: Thermometer:

A thermometer is a device which is used to measure the temperature of a body. Mercury is preferred as a thermometric substance due to the following properties.

Mercury as a thermometric substance:

- It is easily visible.
- It has uniform thermal expansion.
- It has a low freezing point and high boiling point.
- It has a small specific heat capacity.

7. Define specific heat. How would you find the specific heat of a solid?

Ans: Specific heat:

"The specific heat of a substance is the amount of heat required to raise the temperature of 1kg mass of that substance through 1K".

The specific heat of any substance can be found out by using the following formula:

$$c = \Delta Q \; m\Delta T$$

c is the specific heat capacity

ΔQ is the amount of heat absorbed by the body

m is the mass of the body

ΔT is the change in temperature

8. Define latent heat of vaporization.

Ans: Latent heat of vaporization:

"The quantity of heat that changes the unit mass of a liquid completely into the gas at its boiling point without any change in its temperature is called its latent heat of vaporization denoted by H_v".

Formula:

$$H_v = \frac{\Delta Q_v}{m}$$

Unit:

$$Jkg^{-1}$$

9. Define and explain the latent heat of fusion.

Ans: **Latent heat of fusion:**

The latent heat of fusion is the amount of thermal energy, which must be absorbed for 1 mole of substance to change its state from solid to liquid without change in temperature, is called the latent heat of fusion.

Formula:

$$H_f = \frac{\Delta Q_f}{m}$$

Unit:

Its SI unit is Jkg^{-1}.

10. What is meant by evaporation? On what factors the evaporation of a liquid depends? Explain how cooling is produced by evaporation.

Ans: **Evaporation:**

Evaporation is escaping out of fast-moving water molecules from the surface of a liquid without heating.

Factors:

(i) Temperature ii) Surface area

(iii) Wind iv) Nature of liquid

Cooling by evaporation:

During evaporation molecules having greater kinetic energy escape out from the surface of a liquid, while the molecules having lower kinetic energies are left behind. In this way, evaporation produces cooling by lowering the average kinetic energy and the temperature of molecules of a liquid.

Important Formulas

- $T_k = T^oC + 273$
- $^oF = 1.8^oC + 32$
- $V = V_o(1 + \beta\Delta T)$
- $L = L_o(1 + \alpha\Delta T)$
- $P = \frac{Q}{t}$
- $Q = mc\Delta T$
- $Q_f = mH_f$
- $Q_v = mH_v$
- $\Delta T = T - T_o$

Important Units

- Co-efficient of linear thermal expansion = α = K^{-1}
- Co-efficient of volume expansion = β = K^{-1}
- Specific heat capacity = c = $Jkg^{-1}K^{-1}$
- Latent heat of fusion = Hf = Jkg^{-1}
- Latent heat of vaporization = Hv = Jkg^{-1}
- Specific heat of water = c = $4200Jkg^{-1}K^{-1}$

Numerical

1. Temperature of water in a beaker is 50°C. What is its value in Fahrenheit scale?

Ans: Given data:

$$T^oC = 50^oC$$

To Find:

$$^oF = ?$$

Solution:

$$^oF = 1.8^oC + 32^o$$
$$^oF = 1.8^o \times 50^o + 32^o$$
$$^oF = 90^o + 32^o$$
$$^oF = 122^oF$$

2. Normal human body temperature is 98.6°F. Convert it into Celsius scale and Kelvin scale.

Ans: Given data:

$$T^oF = 98.6^oF$$

To Find:

$$T^oF = ?$$
$$T_k = ?$$

Solution:

$$T_k = 1.8T^0C + 32^0$$
$$98.6^o - 32^0 = 1.8T^0C$$
$$66.6^0 = 1.8T^0C$$
$$T^0C = \frac{66.6}{1.8}$$
$$T^0C = 37^0C$$

Now

$$T_k = T^0C + 273$$
$$T_k = 37 + 273$$
$$\mathbf{T_k = 310K}$$

3. Calculate the increase in the length of an aluminum bar 2m long when heated form 0^o to 20^oC. If thermal coefficient of linear expansion of aluminium is $2.5 \times 10^{-5}K^{-1}$.

Ans: Given data:

Original length $= L_o = 2m$
$T_o = 0^oC = 0 + 273 = 273K$
$T^oC = 20^oC = 20 + 273 = 293K$
$T^0C = T - T_0$
$\Delta T = 293 - 273$
$\Delta T = 20K$
Co-efficient of linear expansion $= \propto = 2.5 \times 10^{-5}K^{-1}$

To Find:

Increase in length $= \Delta L = ?$

Solution:

$L = L_o(1 + \alpha\Delta T)$
$L = 2 \times (1 + 2.5 \times 10^{-5} \times 20)$
$L = 2 \times (1 + 0.0005)$
$L = 2.001m$
Increase in length $= \Delta L = L - L_o$
Increase in length $= \Delta L = 2.001 - 2$
Increase in length $= \Delta L = 0.001m$ $\quad \therefore 1m = 100cm$
Increase in length $= \Delta L = 0.001 \times 100$

Increase in length = ΔL = 0. 1cm

4. A balloon contains 1.2m³ air at 15°C. Find its volume at 40°C. Thermal coefficient of volume expansion of air is $3.67 \times 10^{-3} K^{-1}$.

Ans: Given data:

Initial volume of air in balloon $= V_o = 1.2m^3$

Initial temperature $= T_o = 15^oC = (15 + 273)K = 288K$

Final temperature $= T = 40^oC = (40 + 273)K = 313K$

$\Delta T = T - T_0$

$\Delta T = 313 - 288$

$\Delta T = 25K$

Coefficient of volume expansion $= \beta = 3.67 \times 10^{-3} K^{-1}$

To Find:

Final volume of gas = V = ?

Solution:

As we know that;

$V = V_o (1 + \beta \Delta T)$

$V = 1.2 \times (1 + 3.67 \times 10^{-3} \times 25)$

$V = 1.2 \times (1 + 0.09175)$

$V = 1.2 \times (1.0917)$

$V = 1.3m^3$

5. How much heat is required to increase the temperature of 0.5kg of water from 100°C to 65°C?

Ans: Given data:

$m = 0.5kg$

$T_o = 10^oC = (10 + 273)K = 283K$

$T = 65^oC = (65 + 273)K = 338K$

$\Delta T = T - T_0$

$\Delta T = 338 - 283$

$\Delta T = 55K$

Specific heat capacity of water = c = $4200 Jg^{-1}K^{-1}$

To Find:

Heat = Q = ?

Solution:

As we know that;

$$Q = mc\Delta T$$

$$Q = 4200 \times 0.5 \times 25$$

$$\mathbf{Q = 115500J}$$

Required heat is 115500J

6. An electric heater supplies heat at the rate of 1000 joule per second. How much time is required to raise the temperature of 200g of water from 20°C to 90°C?

Ans: Given data:

$$\text{Power} = P = 1000\text{J/sec}$$

$$\text{Mass} = m = 200\text{g} = \frac{200}{1000} = 0.2\text{kg}$$

$$T_o = 20^oC = (20 + 273)K = 293K$$

$$T = 90^oC = (90 + 273)K = 363K$$

$$\Delta T = T - T_0$$

$$\Delta T = 363 - 293$$

$$\Delta T = 70K$$

Specific heat capacity of water = c = $4200Jg^{-1}K^{-1}$

To Find:

Time = t = ?

Solution:

As we know that;

$$Q = mc\Delta T$$

$$Q = 0.2 \times 4200 \times 70$$

$$Q = 58800J$$

$$P = \frac{Q}{t}$$

$$1000 = \frac{48800}{t}$$

$$t = \frac{48800}{1000}$$

$$\mathbf{t = 58.8sec}$$

7. How much ice will melt by 50000J of heat? Latent heat of fusion of ice = 336000Jkg^{-1}?

Ans: Given data:

$$Q_f = 50{,}000J$$

$$\text{Latent heat of fusion of ice} = H_f = 336000Jkg^{-1}$$

To Find:

$$\text{Mass} = m = ?$$

Solution:

As we know that;

$$Q_f = mH_f$$

$$m = \frac{Q_f}{H_f}$$

$$m = \frac{50000}{336000}$$

$$m = 0.15kg$$

$$m = 0.15 \times 1000g$$

$$\mathbf{m = 150g}$$

8. Find the quantity of heat needed to melt 100g of ice at – 10^{o}C at it no water at 10^{o}C. (Note: Specific heat of ice is 2100Jkg^{-1}K^{-1}. The specific heat of water is 4200Jkg^{-1}K^{-1}. Latent heat of fusion of ice is 336000Jkg^{-1}).

Ans: Given data:

$$\text{Mass of ice} = 100g = 0.1kg$$

$$\text{Change in temperature of ice} = \Delta T = T - T_0$$

$$\text{Change in temperature of ice} = \Delta T = 0^oC - (-10^oC)$$

$$\text{Change in temperature of ice} = \Delta T = 10^oC$$

$$\text{Change in temperature of water} = \Delta T = 10^oC - 0^oC$$

$$\text{Change in temperature of water} = \Delta T = 10^oC$$

$$\text{Specific heat of ice} = 2100Jg^{-1}K^{-1}$$

$$\text{Specific heat of water} = 4200Jkg^{-1}K^{-1}$$

$$\text{Specific heat of fusion of ice} = 336000Jkg^{-1}$$

To Find:

$$\text{Heat} = Q = ?$$

Solution:

(i) Heat gained by ice from -10^oC to 0^oC =

$$Q_1 = mc\Delta T$$

$$Q_1 = 0.1 \times 2100 \times 10$$

$$\mathbf{Q_1 = 2100\ J}$$

(ii) Heat gained by ice to melt $= Q_2 = mt$

$$Q_2 = 0.1 \times 3360000$$

$$\mathbf{Q_2 = 33600J}$$

(iii) Heat required to raise temperature from 0^oC to 10^oC =

$$Q_3 = mc\Delta T$$

$$Q_3 = 0.1 \times 4200 \times 10$$

$$\mathbf{Q_3 = 4200\ J}$$

Total heat required $= Q = Q_1 + Q_2 + Q_3$

$$Q = 2100 + 33600 + 4200$$

$$\mathbf{Q = 39900J}$$

9. How much heat is required to change 100g of water at 100^oC into steam? The latent heat of the vaporization of water is $2.26 \times 10^6 Jkg^{-1}$.

Ans: Given data:

Mass of water $= 100g$

$$M = \frac{100}{1000} = 0.1kg$$

$T = 100^oC$

Latent heat of vaporization of water $= H_v = 2.26 \times 10^6\ Jkg^{-1}$

To Find:

$Q_v = ?$

Solution:

As we know that;

$$Q_v = mH_v$$

$$Q_v = 0.1 \times 2.26 \times 10^6$$

$$\mathbf{Q_v = 2.26 \times 10^5\ g}$$

10. Find the temperature of water after passing 5g of steam at 100°C through 500g of water at 10°C. (Note: Specific heat of water is 4200Jkg^{-1}K^{-1}, Latent heat of vaporization of water Is 2.26×10^6Jkg^{-1}).

Ans: Given data:

$$\text{Mass of water} = m_1 = 500g = 0.5kg$$
$$\text{Mass of steam} = m_2 = 5g = 0.005kg$$
$$\text{Temperature of water} = T_1 = 10^oC$$
$$\text{Temperature of steam} = T_2 = 100^oC$$
$$\text{Latent heat of vaporization of water} = H_v = 2.26 \times 10^6 \ Jkg^{-1}$$
$$\text{Specific heat of water} = c = 4200Jkg^{-1}K^{-1}$$

To Find:

$$\text{Final temperature of water} = T = ?$$

Solution:

As we know that;

$$Q = m_1H_v$$
$$Q = 0.005 \times 2.26 \times 10^6$$
$$Q = 1.13 \times 10^4 \quad \text{---------- (i)}$$

And $$Q = m_2c\Delta T$$
$$Q = 0.005 \times 4200 \times (T - 10)$$
$$Q = 2100 \times (T - 10) \quad \text{---------- (ii)}$$

Comparing equation (i) and (ii), we get

$$1.13 \times 10^4 = 2100 \times (T - 10)$$
$$\frac{1.13 \times 10^4}{2100} = (T - 10)$$
$$5.4 = (T - 10)$$
$$T = 10 + 5.4$$
$$T = 15.4^oC$$

Result:

Final temperature of water = T = 15.4°C

Chapter: 09

Transfer of Heat

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Exercise MCQs

1. In solids, heat is transferred by:

Ⓐ radiation Ⓑ conduction Ⓒ convection Ⓓ absorption

2. What happens to the thermal conductivity of a wall if its thickness is doubled?

Ⓐ becomes double
Ⓑ remains the same
Ⓒ becomes half
Ⓓ becomes one-fourth

3. Metals are good conductor of heat due to the:

Ⓐ free electrons
Ⓑ big size of their molecules
Ⓒ small size of their molecules
Ⓓ rapid vibrations of their atoms

4. In gases, heat is mainly transferred by:

Ⓐ molecular collision Ⓑ Conduction Ⓒ convection Ⓓ radiation

5. Convection of heat is the process of heat transfer due to the molecules:

Ⓐ random motion
Ⓑ downward movement
Ⓒ upward movement
Ⓓ free movement

6. False ceiling is done to:

Ⓐ lower the height of the ceiling
Ⓑ keep the roof clean
Ⓒ cool the room
Ⓓ insulate the ceiling

7. Rooms are heated using gas heaters by:

Ⓐ conduction only
Ⓑ convection and radiation
Ⓒ radiation only
Ⓓ convection only

8. Land breeze blows from:

Ⓐ sea to land during night
Ⓑ sea to land during the day
Ⓒ land to sea during night
Ⓓ land to sea during the day

9. Which of the following is a good radiator of heat?

Ⓐ a shining silvered surface
Ⓑ a dull black surface
Ⓒ a white surface
Ⓓ a green coloured surface

10. Styrofoam is a :

Ⓐ Conductor Ⓑ Semiconductor Ⓒ Bad conductor Ⓓ None of them

11. Unit of thermal conductivity is :

Ⓐ $Wm^{-1}K^{-1}$ Ⓑ $Wm^{-1}K^{-2}$ Ⓒ $Wm^{-2}K^{-1}$ Ⓓ $Wm^{2}K^{-1}$

Answer Key:

1	Ⓑ	7	Ⓑ
2	Ⓒ	8	Ⓒ
3	Ⓐ	9	Ⓑ
4	Ⓑ	10	Ⓒ
5	Ⓒ	11	Ⓐ
6	Ⓓ		

Short Questions

1. Why metals are good conductors of heat?

Ans: Metals are good conductors of heat because they possess freely moving electrons.

2. Explain why.

(a) A metal feels colder to touch than wood kept in a cold place!

(b) Land breeze blows from land towards sea!

(c) Double-walled glass vessel is used in thermos flask!

(d) Deserts soon get hot during the day and soon get cold after sunset!?

Ans:

(a) A metal feels colder to touch than wood because it is a good conductor due to free electrons. So it cools down more rapidly as compared to wood. Wood is an example of an insulator.

(b) At night, the land cools faster than the sea. Therefore, air above the sea is warmer, rises up and colder air from the land begins to move towards the sea.

(c) A double-walled glass vessel is used in a thermos flask because a double-walled glass vessel has air between two glass walls that provide insulation.

(d) Deserts soon get hot during the day and soon get cold after sunset because the sand in the deserts has a very low value of specific heat. It cools down and warms up fastly.

3. Why transfer of heat in fluids take place by convection?

Ans: Transfer of heat in fluids takes place by convection because fluids are not good conductors of heat. As, molecules of fluids are able to move freely, hence heat transfer takes place by convection.

4. Why conduction of heat does not take place in gases?

Ans: Conduction of heat does not take place in gases because gases are bad conductors of heat.

5. What measures do you suggest to conserve energy in houses?

Ans: Measures to conserve energy:

- Hot water tanks are insulated by plastic or foam lagging.
- The bottoms of cooking pots are made black to increase the absorption of heat from the fire.
- Solar energy is used by solar panels in houses. The solar energy is converted into electric energy.
- Switch off the electric appliances when these are not used by humans.
- Energy in houses can be conserved by using energy savers instead of bulbs.

6. What is meant by convection current?

Ans: Convection current:

Hot air rises up creating a gap which is filled by colder air, this air also gets warm and rises up. That is how convection currents are produced.

7. How does heat reach us from the sun?

Ans: Heat reaches us from the sun through the radiation process.

8. Suggest a simple activity to show the convection of heat in gases not given in the book.

Ans: An example of convection in daily life is when we use a fireplace of heat in our home, as the fire heats up the air in front of it, the hot air rises up as it is less dense and then, in turn, pushes the cool air down so that it is heated and then rises, this motion is called convection currents and in the reaction fireplace air effective to heat us.

9. How various surfaces can be compared by a Leslie cube?

Ans: The rate at which various surfaces absorb heat is different from one another. So, on the basis of their ability to absorb heat through different surfaces can be compared to Leslie's cube.

10. Explain the impact of the greenhouse effect on global warming.

Ans: During the recent years, the percentage of carbon dioxide has been increased considerably. This has caused an increase in the average temperature of the earth by trapping more heat due to the greenhouse effect. This phenomenon is known as global warming. This is serious implications for global climate.

11. What is the greenhouse effect?

Ans: **Greenhouse effect:**

Greenhouse effect is the result of infrared light not being able to transmit it back through the atmosphere into space after it has been radiated to the earth from the sun.

Important Formulas

- $\frac{Q}{t} = \frac{kA\Delta T}{t}$ or $Q = \frac{tkA\Delta T}{L}$
- Rate of flow of heat $= \frac{Q}{t}$
- Rate of flow of heat $= k = Wm^{-1}K^{-1}$

Numerical

1. The concrete roof of a house of thickness 20cm has an area 200m². The temperature inside the house is 15°C and outside is 35°C. Find the rate at which thermal energy will be conducted through the roof. The value of k for concrete is $0.65Wm^{-1}K^{-1}$.

Ans: Given data:

Thickness of the roof $= V = 20cm = 0.2m$

Area of the roof $= A = 200m^2$

Temperature outside the house $= T_1 = 35^0\ C$

Temperature outside the house = (35 + 273)K = 308K

Temperature inside the house = T_2 = 15^0 C

Temperature inside the house = (15 + 273)K = 288K

Coefficient of thermal conductivity = k = 0.65 $Wm^{-1}K^{-1}$

Required:

Rate of conduction of energy through the roof = W = ?

Solution:

As we know that,

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{kA\,(T_1 - T_2)}{L}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{0.65 \times 200 \times (308 - 288)}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{130 \times 20}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = \frac{2600}{0.2}$$

$$\text{Rate of flow of heat} = \frac{Q}{t} = 13000 Js^{-1}$$

Result:

Rate of conduction of energy through the roof = $\frac{Q}{t}$ = 13000Js^{-1}

2. How much heat is lost in an hour through a glass window measuring 2.0m by 2.5m when the inside temperature is 25^oC and that of the outside is 5^oC. The thickness of glass is 0.8cm and the value of k for glass is 0.8Wm-$1K^{-1}$?

Ans: Given data:

Area of the window = A = 2.0m × 2.5m = $5.0m^2$

Temperature inside the window = T_1 = 25^0 C

Temperature inside the window = (25 + 273)K = 298K

Temperature outside the window = T_2 = 5^0 C

Temperature outside the window = (5 + 273)K = 278K

Coefficient of thermal conductivity = k = 0.8 $Wm^{-1}K^{-1}$

Required:

Heat lost through the glass = Q = ?

Solution:

As we know that,

$$Q = \frac{kA\,(T_1 - T_2)t}{L}$$

$$Q = \frac{0.8 \times 5 \times (298 - 278) \times 3600}{0.008}$$

$$Q = \frac{4 \times 20 \times 3600}{0.008}$$

$$Q = \frac{288000}{0.008}$$

$$Q = 36000000\text{J}$$

$$Q = 3.6 \times 10^7\text{J}$$

Result:

Heat lost through the glass = Q = 3.6×10^7J