Integrated Syllabus

USEFUL FOR ALL BOARDS

IIT FOUNDATION & OLYMPIAD

EXPLORER

CLASS - IX

Solutions

BRAIN MAPPING ACADEMY

PHYSICS

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CONTENTS

1. Measurement 01
2. Motion in one Dimension 07
3. Newton's Laws of Motion 17
4. Work, Power & Energy 26
5. Turning Forces & Equilibrium 35
6. Gravitation 43
7. Fluid Pressure 52
8. Heat 61
9. Wave Motion & Sound 70
10. Magnetism 79

Chapter 1

Measurement

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (B) $T_1 = T_2$

$l_1 : l_2 = 1 : 9$

$$\frac{g_1}{g_2} = \frac{l_1}{l_2} \times \frac{T_2^2}{T_1^2}$$

$$\frac{g_1}{g_2} = \frac{1}{9}$$

2. (C) $l = 2$ m; $T = 2$ s; $g_P = ?$

$$g_P = 4\pi^2 \frac{l}{T^2} = 4\pi^2 \times \frac{2}{2^2} = 2\pi^2 \text{ m s}^{-2}$$

3. (B) $d_{steel} = \frac{\text{mass}}{\text{volume}}$

$$= \frac{7.9 \text{ kg}}{0.2 \times 0.1 \times 0.05} \text{ m}^3 = \frac{7.9}{0.001}$$

$= 7900 \text{ kg m}^{-3}$

4. (A) P = 0.5 mm; d = 8.3 mm

PSR = P × reading

8 mm = 0.5 mm × R

since 8.3 mm is (8 mm + 0.3 mm), 0.3 mm is less than pitch.

$$R = \frac{8}{0.5} = 16$$

5. (A) Given 25 VSD = 23 MSD

$$1 \text{ VSD} = \frac{23}{25} \text{ MSD}$$

$$\text{VSD} = \frac{23}{25} \times 1 \text{ mm}$$

LC = 1 MSD – 1 VSD

$$\text{L.C} = 1 \text{mm} - \frac{23}{25} \text{mm}$$

$$= \left(\frac{25-23}{25}\right) \text{mm} = \left(\frac{2}{25}\right) \text{mm}$$

= 0.08 mm (or) 0.008 cm or 80 μm.

6. (B) SI unit of volume = m^3

SI unit of area = m^2

$$\frac{\text{volume unit}}{\text{Area unit}} = \frac{m^3}{m^2}$$

i.e., unit of length

7. (B) Height of a room is not a derived quantity as it measures fundamental quantity length.

8. (D) The volume of a single liquid drop can be measured using a burette.

9. (D) Relative density has no units.

10. (D) $\text{Speed} = \frac{\text{distance}}{\text{Time}} = \frac{m}{s}$

If units of length and time are doubled then speed = $\frac{2m}{2s}$. Unit of speed remains same.

11. (D) The significant figures in 10.02 are 4. As zero before and after decimal has to be included when a number exists after the or before zero's.

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12. (C) $LC = \frac{1\ MSD}{No.\ of\ VSD}$

$= \frac{0.1\ cm}{20} = 0.05\ mm$ or $0.005\ cm$

13. (A) The time taken by bob to go from one extreme to other extreme is equal to other extreme is equal to half revolution i.e., 0.75 s i.e., half of time period.

$\therefore \frac{T}{2} = 0.75\ s$, $T = 1.5\ s$

14. (C) The number of significant figures of 0.0632 m is 3 as zero at the beginning of a number are not significant.

15. (B) MSR is between 4 mm and 5 mm.

$\therefore$ MSR = 4.5 mm

16. (A) As the zero of the circular scale is below the index line of main scale the error is positive.

17. (C) Correction = + [[n – coinciding division of C.S] × L.C]

18. (D) Given N = 200

$d = PSR + (CSR \times LC)$

$= 5 + (34 \times 0.005\ mm)$

$= 5 + 0.170 = 5.17\ mm$

$r = 2.585\ mm = 0.2585\ cm$

19. (A) $P = \frac{6\ mm}{6} = 1\ mm$

20. (B) N = 100

$P = \frac{2.5\ mm}{5} = 0.5\ mm$

$LC = \frac{0.5\ mm}{100} = 0.005\ mm$

MULTIPLE ANSWERS QUESTIONS

1. (A,B,D) If the zeroeth divisions of the vernier and main scales of a standard vernier callipers coincide then the measured length is equal to the actual length.

The least count of vernier scale is 0.9 mm.

The internal jaws are used for measuring the internal diameter of a hollow cylinder.

The length of a one vernier scale division is less than that of one main scale division.

2.(A,B,C) It is a derived quantity.

The unit of density in SI system is kilogram per metre^3.

The density of a substance can be measured if the mass of the substance for a certain volume is known.

3.(A,B,C) The derived quantities are gravitational constant, frequency, electric charge.

4.(A,B,C) The unit for power is J s^{-1}, g m^2 s^{-3}, kg cm^2 s^{-3}.

5.(A,C,D) The symbol named after scientist should have capital letter, they can be written in full and they should be written only in the agreed symbols be used while using the symbol for a unit of a physical quantity. They cannot take plural forms.

ASSERTION AND REASONING

1. (A) kilogram is a standard unit of mass is true as kilogram is well defined and invariant.

2. (E) Time period of a simple pendulum is directly proportional to square root of length of simple pendulum. Time period of a simple pendulum is the reciprocal of number of oscillations made by it in one second.

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3. (A) A screw gauge of pitch 1 mm advances 3/4 mm for three fourth rotation of head. Pitch of the screw is the distance moved by the screw for one complete rotation of head.

4. (C) $1\ mm^2 = 10^{-6}\ m^2$. The numerical value of a physical quantity is more for a smaller unit.

5. (A) The SI unit of volume is m^3 because volume is a derived quantity of length.

6. (A) A vernier calipers has a positive error of 0.5 mm then the correction is –0.5 mm. As in case of positive zero error, measured length is greater than the actual length.

7. (A) The SI unit of weight is newton because weight is the force of gravity with which a body is attracted towards the earth.

8. (A) As 1 century makes 100 years and 1 decade makes 10 years. 10 decades make a century.

9. (C) The least count of vernier calipers is 0.1 mm because LC = 1MSD – 1 VSD.

10. (D) The watches having hour hand, minute hand and seconds hand have least count as 1 ms is false. Least count is the measurement that can be measured accurately by an instrument is true.

PARAGRAPH QUESTIONS

(i) (C) n = 7

1 MSD = 1 mm (as 1 cm = 10 divisions)

Pitch of a screw = 1 mm or 0.1 cm

(ii) (C) $LC = \frac{P}{\text{No. of CSD}}$

$= \frac{1\ mm}{100} = 0.01\ mm$

10^{-2} mm or 10^{-3} cm

(iii) (D) Observed diameter

$= (2 \times 1\ mm) + (78 \times 0.01)\ mm$

$= (2 + 0.78)\ mm$

$= 2.78\ mm$ (or) $0.278\ cm$

(iv) (C) Correct diameter = observed diameter – correction

$= 2.78\ mm - (7) \times 0.01\ mm$

$= 2.78 - 0.07 = 2.71\ mm$

NUMERICAL PROBLEMS

1. Given: $m_1 = m_2$, $r_1 : r_2 = 3 : 4$

$$\frac{\rho_1}{\rho_2} = \frac{V_2}{V_1} = \frac{\frac{4}{3}\pi r_2^3}{\frac{4}{3}\pi r_1^3} = \left(\frac{4}{3}\right)^3 = 64 : 27$$

2. Given, PSR = 4 mm

HSR = 50

LC = 0.01 mm

zero error = –0.45 mm

∴ Diameter of the lead shot

= PSR + (HSR + LC) + correction

$= [4 + (50 \times 0.01) + 0.45]\ mm = 4.95\ mm$

3. R.D = 13.6

$$R.D = \frac{\text{Density of mercury}}{\text{Density of water}}$$

$$13.6 = \frac{m_{Hg}}{V_{Hg}} \times \frac{V_{water}}{m_{water}}$$

$$13.6 = \frac{m_{Hg}}{V_{Hg}} \times \frac{10V_{Hg}}{m_{water}}$$

$$\therefore \frac{m_{Hg}}{m_{water}} = 13.6 : 10$$

$$= 34 : 25$$

4. Given
Screw advances 0.4 mm for 4/5 rotation

$$\text{pitch} = 5 \times \frac{0.4}{4} = 0.5\,\text{mm}$$

Pitch = 0.5 mm

Given N = 50 divisions.

$$\text{L.C} = \frac{\text{pitch}}{N} = \frac{0.5\text{ mm}}{50} = 0.01\text{ mm}$$

5. Given 1 MSD = 1 mm

correct LC = 0.01 cm

LC taken = 0.01 mm

Length of copper rod taken by student = 6.506 cm

6.506 = 6.5 cm (as 0.006 cm cannot be measured)

6. Time taken to move from mean position to an extreme end is one fourth of time period.

$$\therefore \frac{T}{4} = 0.5 \Rightarrow T = 2\text{ s}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

$$2 = 2\pi\sqrt{\frac{l}{9.8}} \Rightarrow l = \frac{9.8}{\pi^2} = 0.991\text{m}$$

7. L.C. = 0.0005 mm

$$P = \frac{0.1\text{ mm}}{2} = 0.05\text{mm}$$

$$\text{L.C.} = \frac{P}{N}$$

$$\therefore N = \frac{P}{\text{L.C}} = \frac{0.05}{0.0005} = 100$$

8. 20 VSD = 17 MSD

1 cm = 20 equal divisions (MSD)

$$\therefore \quad 1\text{ MSD} = \frac{1}{20}\text{ cm} = 0.5\text{ mm}$$

L.C = 1 MSD – 1 VSD

$$0.05 - \frac{17}{20} \times 0.05 = 0.0075\text{cm}$$

9. $R.D_A = 10 \Rightarrow d_A = 10\text{ g cm}^{-3} = \frac{m_1}{V_1}$

$R.D_B = 20 \Rightarrow d_B = 20\text{ g cm}^{-3} = \frac{m_2}{V_2}$

Let the mass of each metal be m and their respective volumes by V_1 and V_2.

$$\therefore \quad \rho_{1^{st}} = \frac{2m}{V_1 + V_2} = \frac{2m}{\frac{m}{10} + \frac{m}{20}} = \frac{40}{3}$$

$$\rho_{2^{nd}\text{alloy}} = \frac{m_1 + m_2}{2V} = \frac{10V + 20V}{2V} = 15$$

On preparation of cubes out of two alloys density remains same.

$$\frac{\rho_{1^{st}}\text{cube}}{\rho_{2^{nd}}\text{cube}} = \frac{\rho_{1^{st}}\text{alloy}}{\rho_{2^{nd}}\text{alloy}} = \frac{40}{3 \times 15} = \frac{8}{9}$$

10. 1 year = 365 days.

From 2005 to 2008 = 4 years and 2008 is a leap year i.e., 366 days.

$\therefore$ No. of days from year 2005 to 2008
= (365 × 4) + 1 = 1461 days

CONCEPTUAL QUESTIONS

1. The student took the string and wrapped around the cross section of the rod. This length of string on placing on the metre scale found its length. The found length is circumference of rod = πd

Divide this length by π we get diameter of the rod.

2. $A = s^2$; $TSA = 6\,s^2 = 6A$

$$6\,u_2^2 = A\,u_1^2; \quad u_2 = \sqrt{\frac{A}{6}}\,u_1$$

3. N VSD = (N – 1) MSD

$$1\text{ VSD} = \frac{(N-1)\text{MSD}}{N}$$

LC = 1 MSD – 1 VSD

$$= 1\text{MSD} - \frac{(N-1)\text{MSD}}{N} = \frac{\text{MSD}}{N}$$

If $N = (N - 3)$ MSD

$$LC = 1MSD - \frac{(N-3)MSD}{N} = \frac{3MSD}{N}$$

If N is equal to fewer number of main scale divisions, the least count value will be greater, i.e. the smallest measurement measured by it increases.

4. If the zeroth division of vernier scale coincides with 2nd division on the main scale, the Vernier suffers positive error such that the measured length is (2×0.1) mm i.e. 0.2 mm greater than actual length. Hence the accuracy of observed readings done with this instrument decreases.

5. Number of nanoseconds in a second

$$= \frac{1s}{10^{-9}s} = 10^9$$

Number of seconds in a year

$= 365 \times 24 \times 60 \times 60 = 3.1536 \times 10^7$.

Therefore, number of nanoseconds in a second is more than the number of second in a year.

6. The angle (in radian) substended by an arc of a circle at its centre is defined as the ratio of the length of the arc to its radius i.e.,

$$\theta(\text{in radian}) = \frac{\text{length of arc}}{\text{radius}}$$

no dimension

Hence, the measure of an angle is independent of the unit of length used to measure the angle.

PREVIOUS CONTEST QUESTIONS

1. (A) Volume = $(\text{side})^3$

$= (1.2 \times 10^{-2})\ m^3$

$= 1.728 \times 10^{-6}\ m^3$

2. (B) $L.C. = \frac{P}{N} = \frac{0.5\,mm}{50} = 0.01\,mm$

MSR = 2, CSR = 25

dia = $(MSR \times P) + (CSR) \times LC$

$= (2 \times 0.5)$ mm $+ (25 \times 0.01)$ mm

= 1.25 mm

3. (B) Given $(N + 1)V = NS$

$LC = 1\ MSD - 1\ VSD$

$$= S - \frac{NS}{(N+1)} = \frac{S}{(N+1)}$$

$= (N + 1)^{-1}$ main scale divisions

4. (B) A light year is a unit of distance

5. (C) On stretching volume, density and mass remains same.

$V^1 = \pi(r^1)^2 \times l^1$

$V^1 = \pi\frac{r^2}{4}l^1$ and $V = \pi r^2 l$

$\Rightarrow\ l^1 = 4l = 4 \times 50$ cm

= 200 cm

Hence, $\frac{\text{mass}}{\text{unit length}} = \frac{20g}{200cm}$

$= 0.1\ g\ cm^{-1}$

6. (D) Thickness of the page on which you are writing is the order of 0.1 mm.

7. (A) 1 horse power is equal to 746 watt.

8. (C) Fermi = 10^{-5} Å = 10^{-12} mm

Fermi is smallest

9. (D) Light year is a unit of distance not time.

10. (C) Parallactic second is a unit of distance.

BRAIN NURTURES

1. From the fig.,

Distance between zero's of two jaws

= 9 divisions

= 9 × 1 mm

= 9 mm or 0.9 cm

Diameter of a lead shot

= (length due to jaw J_2 – length due to jaw J_1 + distance between zero's of two jaws.)

= (6.2 cm + 4 × 0.01 cm) – (3.6 cm + 3 × 0.01 cm) + 0.9 cm

= 6.24 cm – 3.63 cm + 0.9 cm = 3.51 cm

2. 1 inch = 16 parts

$\therefore$ 1 part = $\frac{1}{16}$ inch

5th part coincides with x block

i.e., $\left(2+\frac{5}{16}\right)$ inch.

y coincides with 10th part after 3 inches.

i.e., $\left(4+\frac{10}{6}\right)$ inch = $\frac{74}{16}$ inch (or) $\frac{37}{8}$

Difference is (y – x)

$= \frac{37}{8} - \frac{37}{16} = \frac{37}{16}$ inches

1 inch = 2.54 cm

$\therefore \frac{37}{16}$ inches = $\frac{37}{16} \times 2.54$ cm

= 5.87 cm

3. $LC = \frac{1MSD}{\text{No. of VSD}} = \frac{1 \text{ mm}}{10} = 0.1$ mm

From the figure 8th division on vernier scale coincides with on main scale.

Then distance between zero of main scale and vernier scale

= VCD × LC = 8 × 0.1 mm

= 0.8 mm

4. The figure below shows that

Length of a rod = MSR + (VCD × LC)

= 24 mm

Correct length of rod = 25.4 mm

The measured length is greater than actual length, error is positive.

Zero error value = (25.4 – 24) mm

= 1.4 mm

5. From fig., it is observed that

Screw gauge has negative zero error of

= (100 – 92) × LC

$= -8 \times \frac{1\text{mm}}{100} = -0.08$ mm

Diameter of lead shot

= (6 + (33 × 0.01)] + correction (in mm)

= [6 + 0.33 + 0.08] mm = 6.41 mm

Volume of lead shot $= \frac{4}{3}\pi\frac{d^3}{8}$ mm^3

$= \frac{4}{3} \times \frac{22}{7} \times \frac{6.41}{8} \times 6.41 \times 6.41$

= 140.56 mm^3

6. Given: 1 solar day = 100 decidays

1 deci day = 10 centidays

1 centi day = 10 milliday

$\Rightarrow$ 1 milli day = 10^{-1} centiday

= $10^{-1} \times 10^{-1}$ deciday

= $10^{-2} \times 10^{-1}$ solarday

= 10^{-3} solar day

For seconds pendulum,

1 oscillation = 2 second

? = 1 milli day

i.e., $10^{-3} \times 86400$ s

$\frac{86.4\text{s} \times 10\text{s}}{2}$ = 43.2 Oscillations

7. We know, size of the atom = 10^{-11} m;

size of the earth = 10^7 m

Thus, we are scaling up atom by a factor of $\frac{10^7}{10^{-11}}$ i.e., 10^8.

Actual size of the nucleus = 10^{-4} m

Scaling up by a factor 10^8,

the apparent size of the nucleus

= $10^{-4} \times 10^{18} = 10^4$ m

The apparent size of the nucleus (when scaled up) is that of the height of Mount Everest.

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Chapter 2

Motion in One Dimension

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (B) At the maximum height of a body thrown vertically up acceleration is not zero but velocity is zero.

2. (B) Given $h_{max} = \frac{u^2}{2g}$ is to be same on earth and moon, $\frac{u_m^2}{2g_m} = \frac{u_e^2}{2g_e}$ but $g_{earth} = 6g_m$

$$\therefore \frac{u_m^2}{2g_m} = \frac{u_e^2}{2(6g_m)}$$

$$u_e = \sqrt{6}\, u_m \Rightarrow u_e > u_m$$

3. (D) $t_d = 4$ s

$$h = \frac{1}{2} g t_d^2 = \frac{1}{2} \times 9.8 \times 4^2$$

$$= 4.9 \times 16 = 78.4 \text{ m}$$

4. (C) $u = 10 \text{ m s}^{-1}$; $h = 20$ m

$u_1 = 20 \text{ m s}^{-1}$; $h_1 = ?$

$$\frac{h}{h_1} = \frac{u^2}{u_1^2} \; ; \quad \frac{20}{h_1} = \frac{10^2}{20^2}$$

$$h_1 = \frac{20 \times 400}{100} = 80 \text{ m}$$

5. (A) $h = -ut + \frac{1}{2} gt^2$

$$300 = -10u + \frac{1}{2} \times 9.8 \times 100$$

$$-10u = 300 - 490 = -190$$

$$u = \frac{190}{10} = 19 \text{ m s}^{-1}$$

6. (B) The graph of distance versus time indicates that the velocity of the particle is constant throughout

7. (B) $S = \frac{v^2 - u^2}{2a}$

$$v = 54 \times \frac{5}{18} = 15 \text{ m s}^{-1}$$

$$a = \frac{v - u}{t} = \frac{-15 + 5}{5} = -2 \text{ m s}^{-2}$$

$$S = \frac{-15^2 + 5^2}{-2 \times 2} = \frac{-20 \times 10}{-4} = 50 \text{ m}$$

8. (A) $a = \frac{v^2 - u^2}{2s} = \frac{5^2 - 15^2}{2 \times 10}$

$$= \frac{-20 \times 10}{20} = -10 \text{ m s}^{-2}$$

9. (D) $\text{Average speed} = \frac{\text{total distance}}{\text{total time taken}}$

$$= \frac{(10 \times t) + (40 \times t)}{2t}$$

$$= \frac{50t}{2t} = 25 \text{ m s}^{-1}$$

10. (B) $t = 2$ s

$$h_1 = \frac{1}{2} g t^2$$

$$h_1 = \frac{1}{2} \times 10 \times 4 = 20 \text{ m}$$

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After falling through 20 m, g becomes zero remaining distance to be travelled (d = 200 – 20 = 180 m) and v = gt = 10 × 2 = 20 m s^{-1}

$\therefore t = \frac{d}{v} = \frac{180}{20} = 9$ s

11. (C) Given initial velocity = u m s^{-1}

$h = \frac{u^2}{2g}$; $T = \frac{u}{g}$

option (A) : At $\frac{h}{2}$

$v^2 = u^2 - 2g\frac{h}{2}$

$= u^2 - 2g\left(\frac{u^2}{2g \times 2}\right) = \frac{u^2}{2}$

$V = \frac{u}{\sqrt{2}}$

Option B, at a time T velocity is zero (as it is time at which maximum height is reached)

Option C, At time (2T) i.e it again reaches ground with same velocity u (in opposite direction)

12. (C) Initial velocity = u

Maximum height reached = h

$h \alpha u^2$

Let velocity be u_1 to reach 2h

$\frac{h}{2h} = \frac{u^2}{u_1^2}$; $u_1^2 = 2u^2$; $u_1 = \sqrt{2}u$

13. (B) $P \leftrightarrow Q$

average speed = $\frac{2d}{\frac{d}{20} + \frac{d}{30}}$

$= \frac{2 \times 600}{50} = 24 \text{ km h}^{-1}$

14. (C) $h^1 = \frac{1}{2} \times g \times \frac{T^2}{9}$ and $T = \sqrt{\frac{2h}{g}}$

$\therefore h^1 = \frac{1}{\cancel{2}} \cancel{g} \times \frac{\cancel{2}h}{\cancel{g} \times 9}$

$h^1 = \frac{h}{9}$

From ground, the position of ball is $\left(h - \frac{h}{9}\right)m = \frac{8h}{9}m$

15. (A) Let initial velocity be u

$h_{max} = \frac{u^2}{2g}$; $\frac{h_{max}}{2} = \frac{u^2 - 10^2}{+2g}$

$\frac{u^2}{4g} = \frac{u^2 - 10^2}{2g}$

$u^2 = 2u^2 - 200$

$u^2 = 200$

$u = 10\sqrt{2}$ m s^{-1}

$\therefore h_{max} = \frac{(10\sqrt{2})^2}{2 \times 10} = 10$ m

16. (B) $t = \frac{u}{g}$

But $u = \sqrt{2gh}$

$\therefore t = \frac{\sqrt{2gh}}{g} = \sqrt{\frac{2h}{g}}$ (or) $h = \frac{1}{2}gt^2$

17. (C) $h = -ut + \frac{1}{2}gt^2$

$= -4.9 \times 2 + \frac{1}{2} \times 9.8 \times 2^2$

$= 9.8$ m

18. (A) $\frac{u^2}{8g} \times 2(+g) = (20)^2 - u^2$

$+\frac{u^2}{4} + u^2 = 400$

$5u^2 = 1600$

$u = \sqrt{\frac{1600}{5}}$ m s^{-1}

$h_{max} = \frac{u^2}{2g} = \frac{1600}{5 \times 2 \times 10} = 16$ m

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19. (B) $T_d = 5$ s, $H = \frac{1}{2} \times g \times 25 = 12.5g$

$t_1 = 3$ s ; $h = \frac{1}{2} \times g \times 9 = 4.5g$

$(H - h) = 8g$

$= \frac{1}{2} \times g \times t^2 \Rightarrow t = \sqrt{16} = 4$ s

20. (B) $u = 0$

$h_1 = \frac{1}{2}(g)$; $h_2 = \frac{4}{2}g$; $h_3 = \frac{9g}{2}$

∴ Ratio of distances travelled in first, second and thirds seconds

$= h_1 : (h_2 - h_1) : (h_3 - h_2)$

$= \frac{g}{2} : \left(\frac{4g}{2} - \frac{g}{2}\right) : \left(\frac{9g}{2} - \frac{4g}{2}\right)$

$= 1 : 3 : 5$

MULTIPLE ANSWERS QUESTIONS

1.(A,C,D) $t_P : t_Q = \sqrt{2} : 1$; $u_P = u_Q = 0$

$\frac{v_P}{v_Q} = \frac{t_P}{t_Q} = \frac{\sqrt{2}}{1} \Rightarrow v_P = \sqrt{2} V_Q$

∴ Final velocity of car P > final velocity of Q

$v_P : v_Q = 2 : \sqrt{2}$

$\frac{s_P}{s_Q} = \frac{t_P^2}{t_Q^2} = \frac{(\sqrt{2})^2}{(1)^2} = \frac{2}{1}$

2.(A,C) A person seated in a train is at rest with reference to train, a car moving in the opposite to the train.

3.(A,B) The direction of motion of a body is decided by the velocity and acceleration of the body.

4.(B,C,D) If a train covers equal displacements in equal intervals of time, this implies body moves with uniform velocity. If a body moves with uniform velocity, the motion and speed of the body are also uniform.

5.(A, C) $\frac{d_A}{d_B} = \frac{t_A^2}{t_B^2} = n \Rightarrow \frac{t_A}{t_B} = \sqrt{n}$

if $n = 1$; $t_A = t_B$

if $n > 1$; $t_A > t_B$

6. (A, B) A body having zero speed is always under rest and also has zero acceleration.

7. (A,B,D) The v – t values given in table represent uniform speed, uniform motion and uniform velocity.

8.(C, D) $u = 0$

$t = 2$ s $y = \frac{4}{2} a = 2a$

$t = 4$ s $(X + Y) = \frac{16a}{2} = 8a$

$X + Y = 4Y$ (or) $X = 3Y$

9. (A, B) $s_1 = \frac{a}{2}$

$s_2 = \frac{4a}{2} = 2a$; $s_3 = \frac{9a}{2}$

$s_1 : (s_2 - s_1) : (s_3 - s_2) = \frac{a}{2} : \frac{3a}{2} : \frac{5a}{2}$

$= 1 : 3 : 5$

10. (A, D) $V = 6 - 0.02t$

compare with $v = u + at$

$\Rightarrow u = 6$ m s^{-1} ; $a = -0.02$ m s^{-2}

ASSERTION AND REASONING

1. (A) If the magnitude of displacement is zero, then it is not a vector quantity as it needs both magnitude (=0) and direction.

2. (A) The direction of acceleration is opposite in direction to the displacement of the body.

$a = \frac{v - u}{t}$ and $v = \frac{\text{displacement}}{\text{time}}$

3. (C) Time of flight is the time for which a body remains in the air.

$T_f = \frac{2u}{g}$ i.e. $T_f \alpha u$

4. (D) $h_{max} = \frac{u^2}{2g} \Rightarrow h_{max} \alpha u^2$

5. (B) $T = T_a + T_d$ became it is time taken by body to reach maximum height and return $\left(T_a = T_d = \frac{u}{g}\right)$ back to ground again.

6. (E) g is independent of mass of body. Gravitational force acting between two bodies equal and opposite.

7. (A) $H_{max} = \frac{u^2}{2g}\sin^2\theta$

If $\theta = 90^0$

then $H_{max} = \frac{u^2}{2g}$

8. (C) Two bodies of different masses are dropped from same height reach the ground at same instant of time, as g is independent of mass of the body. Time of flight depends on g is initial velocity of the body.

9. (A) Distance covered by a moving body is always greater than zero. As displacement may be negative or zero even after travelling some distance.

10. (E) A stone dropped from a certain height moves with uniform acceleration. Hence, time of descent is directly proportional to the initial velocity of the body.

PARAGRAPH QUESTIONS

(i) (C) For the dance step depicted by CD:

Path length = 5.5 m;
displacement = – 5.5 m;
time taken, t = 2 s

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

$$= \frac{-5.5}{2} = 2.75 \text{ m s}^{-1}$$

(ii) (D) For the dance step depicted by AB:

Path length = 0;
displacement = 0;
time taken, t = 1 s

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

$$= \frac{0}{1} = 0$$

(iii) (D) Here, displacement = – 4 m;

time taken, t = 4.5 s

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

$$= \frac{-4}{4.5} = -0.89 \text{ m s}^{-1}$$

NUMERICAL PROBLEMS

1. l = 4 cm

(a) The angle between the positions of 3.15 pm to 3.30 is 90°.

$\therefore$ displacement $= \sqrt{l^2 + l^2}$

$= \sqrt{2l^2} = \sqrt{2}l$

$= 4\sqrt{2}$ cm

Time = 15 min

$$\text{Average velocity} = \frac{\text{displacement}}{\text{total time taken}}$$

$$= \frac{4\sqrt{2}\text{ cm}}{15 \times 60\text{ s}} = \frac{\sqrt{2}}{225}\text{cm s}^{-1}$$

(b) The angle between the positions of 4.15pm to 4.45 pm is 180°

$\therefore$ displacement = 2 l

= 2×4 cm = 8 cm

Time = 30 min.

Average velocity

$$= \frac{\text{displacement}}{\text{total time taken}}$$

$$= \frac{8\text{ cm}}{30 \times 60\text{ s}} = \frac{1}{225}\text{ cm s}^{-1}$$

2. $S_n = (4+6n)$ ...(1)

$S_n = u + \frac{a}{2}(2n-1) = \left(u - \frac{a}{2}\right) + an$ ...(2)

Comparing (1) and (2)

$u - \frac{a}{2} = 4$

and $an = 6n$

$\Rightarrow a = 6\,m\ s^{-2}$

and $u - \frac{6}{2} = 4 \Rightarrow u = 7\,m\ s^{-1}$

3. Distance travelled $= (12+5)m = 17$ m

Displacement $= \left(\sqrt{12^2+5^2}\right)m = 13$ m

$= \frac{\text{Average speed}}{\text{Average velocity}} = \frac{\text{Distance}}{\text{Displacement}}$ (for given time)

$= \frac{17}{13}$

4. Distance = 10 + 12 + 5 = 27 m

Displacement = straight path from A to E

$= \sqrt{5^2+12^2} = 13\,m$

Average speed

$= \frac{\text{distance}}{\text{time}} = \frac{27}{0.5} = 54\,m\ s^{-1}$

Average velocity

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

$= \frac{13}{0.5} = 26\,m\ s^{-1}$

5. Given v = 0, u = initial velocity

retardation = a, s = 16 m

$\therefore \quad a = \frac{-u^2}{2s}$

$u_1 = 2u;\ a_1 = a\ ;\ s_1 = ?$

$s_1 = \frac{-4u^2}{2a}$

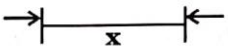
From (1)

$s_1 = \frac{-4u^2}{2(-u^2)}\ (2s)$

$s_1 = 4 \times 16 = 64$ m

% change $= \frac{s_1 - s}{s} \times 100$

$= \frac{4s - s}{s} \times 100 = 300\%$

6. 

$u = 2\ m\ s^{-1}$

Body 1	Body 2
$u = 2\ m\ s^{-1}$	$u = 2\ m\ s^{-1}$
$a_1 = 3\ m\ s^{-1}$	$a_2 = 2\ m\ s^{-2}$
$t = 4$ s	

If body 1 moves s distance then body 2 moves (x – s) distance for t = 4 s

$\therefore \quad s = (2)(4) + \frac{1}{2}(3)(4)^2$

$= 8 + 24 = 32$ m

$(s - x) = 2(4) + \frac{1}{2}(2)(4)^2$

$= 8 + 16 = 24$ m

$\therefore$ Total distance (x) = s + (s – x)

= 32 + 24 = 56 m

7. Let h_1 = height of stone A

h_2 = height of stone B

Distance travelled in last second

$S_A = 44.1$ m

$S_B = 63.7$ m

$S_n = u + \frac{g}{2}(2n-1)$

For body A,

$44.1 = \frac{9.8}{2}(2n-1)$

For body B,

$$63.7 = \frac{9.8}{2}(2n^1 - 1)$$

$$(2n - 1) = \frac{44.1}{4.9}$$

$$2n^1 - 1 = \frac{63.7}{4.9}$$

$2n - 1 = 9 \Rightarrow n = 5$ s

$2n^1 - 1 = 13 \Rightarrow n^1 = 7$ s

$$\therefore \quad h_1 = \frac{1}{2} g(5)^2$$

$$h_2 = \frac{1}{2} g(7)^2$$

Ratio of h_1 and $h_2 = 25 : 49$

8. $20 = un - \frac{1}{2} gn^2$ ..... (1)

$t_a = t_d = u/g$

While falling down distance travelled in last n second.

$$D = S_{\text{for n sec}} - S_{\text{first n sec}}$$

$$= \frac{1}{2}\frac{u^2}{g} - \frac{g}{2}(t_d - n)^2$$

$$= \frac{1}{2}\frac{u^2}{g} - \frac{g}{2}\left(\frac{u}{g} - n\right)^2$$

$$= \frac{u^2}{2g} - \frac{g}{2}\left[\frac{u^2}{g^2} + n^2 - \frac{2un}{g}\right]$$

$$= \frac{u^2}{2g} - \frac{u^2}{2g} - \frac{n^2 g}{2} + un = 20\,\text{m}$$

9. $u = 0$

S for $(n - 3)$ seconds $= \frac{1}{2} g(n - 3)^2$

S for $(n-3)$ second $= \frac{1}{2} g(2(n-3)-1)$

$$\text{Ratio} = \frac{(n-3)^2}{(2(n-3)-1)} = \frac{4}{3}$$

$3(n - 3)^2 = 4(2n - 7)$

$3n^2 - 18n + 27 - 8n + 28 = 0$

$3n^2 - 26n + 55 = 0$

$$n = \frac{26 \pm \sqrt{26^2 - 4(3)(55)}}{2(3)} = 5 \text{ s}$$

$$h = \frac{1}{2} gn^2 = \frac{10}{2} \times 25 = 125\,\text{m}$$

10. $S_3 = 2 S_5$

$$u - \frac{g}{2}(2(3) - 1) = 2\left[u - \frac{g}{2}[2(5) - 1]\right]$$

$$u - \frac{5g}{2} = 2u - \frac{18g}{2}$$

$$\frac{13g}{2} = u$$

$u = 65 \text{ m s}^{-1}$

11. $u = 0$; $S_n = S_3$

$$\frac{g}{2}(2n - 1) = \frac{1}{2} g(9)$$

$2n - 1 = 9$

$n = 5$ s

$$h = \frac{1}{2} gt^2$$

$4.5 \times 25 = 125.5$ m

12. $-h = ut - \frac{1}{2} gt^2$

$$-40 = 10t - \frac{1}{2} \times 10 \times t^2$$

$t^2 - 2t - 8 = 0$

$t^2 - 4t + 2t - 8 = 0$

$t(t - 4) + 2(t - 4) = 0$

$t = 4$ s

13. $S_1 = \frac{1}{2} \times g \times 1 = 5\,\text{m}$

$$t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 125}{10}} = 5 \text{ s}$$

$$S_5 = \frac{g}{2}(2(5) - 1)$$

$$= 9 \times 5 = 45\,\text{m}$$

$S_1 : S_5 = 1 : 9$

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14. Figure (i) represents a velocity – time graph when the body starts from rest, and its velocity increases at a uniform rate.

The slope of the graph AC, i.e., $\frac{AB}{BC}$ gives the acceleration of body.

$$\therefore \text{Acceleration} = \frac{\text{Change in velocity}}{\text{Total time}}$$

$$= \frac{(16-0)\text{ m s}^{-1}}{5\text{ s}} = 3.2\text{ m s}^{-2}$$

The area of triangle ABC, gives the displacement.

Thus, displacement in 5 s

$$\frac{1}{2} \times AB \times BC = \frac{1}{2} \times 16\text{ m s}^{-1} \times 5\text{ s}$$

$$= 40\text{ m}$$

Figure (ii) represents velocity – time graph, where the body is initially not at rest.

The slope of graph AC, i.e., $\left(\frac{AB}{BC}\right)$ gives the acceleration.

$\therefore$ Acceleration

$$= \frac{AB}{BC} = \frac{(25-5)\text{ m s}^{-1}}{4\text{ s}} = \frac{20}{4}\text{ m s}^{-2}$$

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

The distance covered by the body in specified direction is area of trapezium ECAD.

$$\therefore \quad \text{Displacement} = \frac{1}{2}(CE+AD) \times ED$$

$$= \frac{1}{2}(5+25)\text{ m s}^{-1} \times 4\text{ s} = 60\text{ m}$$

15. Slope of the graph $\left(\frac{\overline{BC}}{DC}\right)$ at any point gives the instantaneous velocity at that point. For example, velocity at A is

$$\frac{\overline{BC}}{DC} = \frac{(8-2)\text{ m}}{(3-1)\text{ s}} = \frac{6\text{ m}}{2\text{ s}} = 3\text{ m s}^{-1}$$

CONCEPTUAL QUESTIONS

1. Yes, distance travelled will be equal to magnitude of displacement for a moving body only when the particle moves in a straight path.

2. No, A body if it has uniform velocity will also move with uniform speed.

3. Yes, If a body moves with uniform speed and the direction of the body changes continuously, then the moving body has non-uniform velocity. For **eg:** A body moving in a uniform circular motion moves with uniform speed but with non-uniform velocity.

4. Yes, A body moving with acceleration can have zero velocity.

   Eg: For a body projected vertically up at maximum weight v = 0, a = –g.

5. Yes, A body moving in a uniform circular motion moves with uniform speed but with non-uniform velocity. i.e., has acceleration.

6. No, If a body is projected vertically up with velocity of 8 km s^{-1} i.e. greater than orbital velocity, then the body orbits around the earth. If it is above 11.2 km s^{-1}, the body escapes the gravitational pull of the earth.

7. Yes, For a body projected velocity up the acceleration is vertically downwards while velocity is in vertically upwards direction i.e. they are opposite to each other.

8. Average velocity $= \frac{\text{total distance}}{\text{total time taken}}$

$$\frac{d}{\frac{d}{v_0} + \frac{d}{(v_1+v_2)2}} = \frac{d}{\frac{d(v_1+v_2)+2v_0 d}{2v_0(v_1+v_2)}}$$

$$= \frac{2v_0(v_1+v_2)}{2v_0+(v_1+v_2)}$$

PREVIOUS CONTEST QUESTIONS

1. (A) $t \alpha \sqrt{h}$

$$\frac{t_a}{t_b} = \sqrt{\frac{a}{b}} = \sqrt{a} : \sqrt{b}$$

2. (C) After 2 s or any difference in seconds separation will be 30 cm only as both bodies covers same distance for same time interval under gravity.

3. (C) $h_1 = \frac{1}{2}g\left(\frac{t}{2}\right)^2$ and $h = \frac{1}{2}gt^2$

$h_1 = \frac{1}{2}g\frac{t^2}{4} = \frac{h}{4}$ from the top or $\frac{3h}{4}$ from the ground

4. (C) $h_1 = \frac{1}{2}g3^2 = 9g/2$

$t_2 = 2\,s$;

$h_2 = \frac{1}{2}g(2)^2 = 2g$

$h_1 - h_2 = \frac{9g}{2} - 2g = \frac{5g}{2}$

$= 5 \times 4.9 = 24.5$ m

5. (C) $t = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2 \times 500}{10}} = 10$ s

Time taken for sound to travel t_1

$= \frac{500}{330} = 1.5$ s

$\therefore$ Total time taken

$= t + t_1 = (10 + 1.5) = 11.5$ s

6. (B) $X = \frac{1}{2}a(3)^2$

$X + Y = \frac{1}{2}a(6)^2$

$X + Y = 18\,a = \frac{18 \times 2}{9}$

$X + Y = 4X$

$Y = 3X$

7. (B) $-h = ut - \frac{1}{2}gt^2$

$-h = \frac{4u^2}{g} - \frac{1}{2}g\left(\frac{16u^2}{g^2}\right)$

$-h = \frac{4u^2}{g} - \frac{8u^2}{g} = \frac{-4u^2}{g}$

$h = \frac{4u^2}{g}$

8. (B) $t = \frac{2u}{g} = \frac{2 \times 4.9}{9.8} = 1$ s

9. (B) $t_a = \frac{u}{g} = 10$ s

$t_d = 10$ s

10. (B) $h \alpha u^2$

$\frac{h_1}{h_2} = \frac{u_1^2}{u_2^2}$

$\frac{50}{h_2} = \frac{u_1^2}{4u_1^2} \Rightarrow h_2 = 200\,m$

11. (C) After 2 s or any difference in seconds separation will be 30 cm only as both bodies covers same distance for same time interval under gravity.

12. (A) $h = \frac{1}{2}gt^2 = \frac{1}{2} \times g \times 2^2 = 2g$

$h_3 = \frac{g}{2}(2(3) - 1) = \frac{5g}{2}$

13. (B) S_1, S_2, S_3

$\frac{1}{2}g(1)^2 : \left(\frac{1}{2}g(2)^2 - \frac{1}{2}g(1)^2\right) : \left(\frac{1}{2}g(3)^2 - \frac{1}{2}g(2)^2\right)$

$= \frac{g}{2} : \frac{3g}{2} : \frac{5g}{2} = 1 : 3 : 5$

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14. (B) A gun is fired at a target. At the moment of firing, the target is released and allowed to fall freely under gravity. Then the bullet hits the target.

15. (A) $h = \frac{v^2}{2g}$

$h_{max} = \frac{4v^2}{2g} = 4h$

Distance has to fall further

$= 4h - h = 3h$

BRAIN NURTURES

1. Particle X and Y both move with uniform speed. But slope of X is greater than slope of Y because, X has more inclination than Y and $\tan\theta$ values increases with increase in value of θ.

2. From the graph we can understand that velocity becomes zero at t = 3 s, when a body is projected with initial velocity v.

This t = 3 s = $\frac{v}{g}$ (time of ascent)

$\Rightarrow v = 3g$

Maximum height reached

$= \frac{v^2}{2g} = \frac{(3g)^2}{2g} = 4.5g = 45$ m

3. Let the radius of circular path travelled by body bar.

Distance travelled from P to Q

$= \frac{2\pi r \times 90°}{360°} = \frac{\pi r}{2}$

Distance travelled from Q to R

$= \frac{2\pi r \times 210}{360} = \frac{7\pi r}{6}$

Distance travelled from R to P

$= \frac{2\pi r \times 60}{360} = \frac{\pi r}{3}$

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

$= \frac{2\pi r}{\frac{\pi r}{2(v)} + \frac{7\pi r}{6(2v)} + \frac{\pi r}{3(3v)}}$

$= \frac{2\pi r}{\pi r\left[\frac{18+21+4}{36v}\right]}$

$= \frac{2 \times 36v}{43} = \frac{72v}{43}$

4. $u = 50$ m s^{-1}

for t = 1 s

$h_1 = ut - \frac{1}{2}gt^2$

$h_1 = 50 - 5 \times 1$

$h_1 = 45$ m

h_2 = distance travelled in last 3 secend

$t_a = \frac{u}{g} = \frac{50}{10} = 5$ s.

Distance in last 3 sec (h_2)

= Distance travelled for 5 s
– Distance travelled for 2 s

$= \left(\frac{u^2}{2g}\right) - \left(2u - \frac{1}{2}g(2)^2\right)$

($\therefore$ Distance travelled for 5 s is maximum height)

$= \left(\frac{50 \times 50}{20}\right) - (2(50 - (5 \times 4))$

$= 125 - 80$

$= 45$ m

$\therefore \quad h_1 = h_2$

5. Let the depth of the well be h.

Time taken by stone to reach water is

$t_1 = \sqrt{\frac{2h}{g}} = \sqrt{\frac{2h}{9.8}} = \frac{\sqrt{10h}}{7}$

Time taken by sound to travel back to the person is

$$t_2 = \frac{h}{V_{sound}} = \frac{h}{352.8}$$

Given $t_1 + t_2 = \frac{25}{8}$

$$\frac{\sqrt{10h}}{7} + \frac{h}{352.8} = \frac{25}{8}$$

$$\frac{50.4\sqrt{10h} + h}{44.1} = \frac{25}{8}$$

$$50.4\sqrt{10h} + h = 25 \times 44.1$$

Let $\sqrt{h} = a$

$$(50.4)\left(\sqrt{10h}\right)a + a^2 = 25 \times 44.1$$

on solving we get a = 32

so $h = 32^2 = 1024$ m

6. Let heights of distances AB, BC, CD be respectively

then $t_1 = \sqrt{\frac{2h}{g}}$ ..... (1)

$$t_1 + t_2 = \sqrt{\frac{2(2h)}{g}} \quad ..... (2)$$

$$(t_1 + t_2 + t_3) = \sqrt{\frac{2(3h)}{g}} \quad ..... (3)$$

From equation (1)

$$t_1 + t_2 = \sqrt{2}\,t_1$$

$$\therefore \quad t_2 = t_1\left(\sqrt{2} - 1\right) \quad ..... (4)$$

From equation (1) and (2)

$$t_1 + t_1\left(\sqrt{2} - 1\right) + t_3 = \sqrt{3}\,t_1$$

$$t_3 = \sqrt{3}\,t_1 - t_1 - t_1\left(\sqrt{2} - 1\right)$$

$$t_3 = \sqrt{3}t_1 - t_1 - \sqrt{2}\,t_1 + t_1$$

$$t_3 = t_1\left(\sqrt{3} - \sqrt{2}\right) \quad ..... (5)$$

From (1), (4) and (5)

$t_1 : t_2 : t_3$

$$= t_1 : t_1\left(\sqrt{2} - 1\right) : t_1\left(\sqrt{3} - \sqrt{2}\right)$$

$$= 1 : \left(\sqrt{2} - 1\right) : \left(\sqrt{3} - \sqrt{2}\right)$$

7. $$-h = \frac{\sqrt{gh}}{2}t - \frac{1}{2}gt^2$$

$$gt^2 - \sqrt{gh}\,t - 2h = 0$$

Solving equation, we get

$$t = \frac{+\sqrt{gh} \pm \sqrt{gh - 4(g)(-2h)}}{2g}$$

$$= \frac{\sqrt{g}h \pm 3\sqrt{g}h}{2g} = 2\sqrt{\frac{h}{g}}$$

❖ ❖ ❖

Chapter 3

Newton's Laws of Motion

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (A) China wares are wrapped in straw or paper before packing to increase time of impulse. This is the application of concept of impulse.

2. (A) In a game of tug of wars, a condition of equilibrium exists. Both the teams pull the rope with a force of 10^4 N. The tension in the rope is equal and opposite to the force with which both teams pull the rope i.e., 10^4 N.

3. (B) A spring balance is graduated on sea level. If a body is weighed with at consecutively increasing heights from earth's surface, the weight indicated by the balance will go on decreasing continuously. This is because value of g decreases with height.

4. (B) A truck and a car are moving with equal velocity, $a = \frac{v^2 - u^2}{2s}$ and $m \alpha \frac{1}{a}$, therefore $m \alpha s$. This implies car will cover less distance before stopping.

5. (B) A man is walking from east to west on a level rough surface. The force on the man is directed from east to west.

6. (B) A ball freely falling from a certain height, the moves with constant acceleration net force is not zero. Apparent weight of a floating body is zero.

7. (B) A car and a lorry are moving with same momentum, if same breaking force is applied, then lorry comes to rest in shorter distance as it has greater mass so moves with less velocity.

8. (D) Inertia is the property of a body by virtue of which the body is unable to change by itself the state of rest or of uniform linear motion.

9. (A) While dusting a carpet, we give a sudden jerk or beat with a stick because inertia of rest keeps the dust in its position and the dust is removed by movement of carpet away.

10. (C) The impulse of a body is equal to the product of force applied on it and the time of application of the force.

11. (D) Two bodies A and B, moving in the same direction collide and after collision, move with the common velocity in the direction of A. Both exert equal but opposite force on each other. The change in momentum of A and B are equal but opposite in direction.

12. (C) $\Delta p = m(v - u) = 3(10 - 4)$

$= 18 \text{ kg m s}^{-1}$

13. (D) While opening a tap with two fingers, the forces applied are equal in magnitude, parallel to each other and opposite in direction.

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14. (D) When a body is stationary, then the net forces acting on its balances each other.

15. (C) Inertia of a body has direct dependence on mass.

16. (A) Initial momentum = 0

Final momentum = $(0.02\times 100) + 8\times v$

According to law of conservation of momentum,

$$(0.02\times100)+8v=0$$

$$8v=-2$$

$$v=-\frac{1}{4}ms^{-1} \text{ or } 25 \text{ cm } s^{-1}$$

17. (C) $F=\frac{m(v-u)}{t}$

$$100=\frac{2\times(v-u)}{10}$$

$$(v-u)=500 \text{ m } s^{-1}$$

18. (A) $F=m\left(\frac{v^2-u^2}{2s}\right)$

$$5\times10^4=3\times10^7\left(\frac{v^2-o^2}{2\times3}\right)$$

$$v^2=10^{5-7}$$

$$v=\sqrt{10^{-2}}=0.1 \text{ m } s^{-1}$$

19. (A) $F=\frac{m(v-u)}{t}$

$$t=\frac{p}{F}=\frac{0.4}{2}=0.2 \text{ s}$$

20. (B) $F=2m\times a^1$

Given $F=m\times a$

$=m\times 4$

$$m\times4=2m\times a^1$$

$$a^1=2 \text{ m } s^{-2}$$

MULTIPLE ANSWERS QUESTIONS

1. (A,B,C) The accelerated motion of a body can occur due to change in its speed only, due to change in direction of motion only and due to change in both speed and direction of motion.

2. (A,B,D) These act on two different bodies, these are equal in magnitude but opposite in direction, these are necessary to explain reactions in third law are correct for action and reaction forces.

3. (A,B) It is a measure of quantity of motion contained by the body, change in momentum is the measurement of impulse are correct regarding linear momentum of a body.

4. (A,B) Impulse is the product of force and time for which the force acts and SI unit of impulse is N s.

5. (A,B,C,D) When the mass of a body is doubled then the momentum of a body is also doubled, provided the body maintains the same velocity. We feel pain in the hand on hitting the wall, this is a consequence of Newton's third law of motion. A table cloth can be pulled from a table without dislodging the dishes, this is due to inertia of rest and Momentum is a vector quantity.

ASSERTION AND REASONING

1. (D) Inertia is the property by virtue of which the body is unable to change by itself not only the state of rest, but also the state of constant motion, i.e, motion with fixed linear velocity change of state occurs when acted upon by an unbalanced external force.

2. (C) According to Newton's second law,

$$\text{acceleration} = \frac{\text{Force}}{\text{Mass}}$$

i.e, if net external force on the body is zero F = 0. Then there is zero acceleration of a body.

3. (C) According to definition of momentum, p = mv if p = constant,

$mv = \text{constant or } v \propto \frac{1}{m}$.

As velocity is inversely proportional to mass, therefore lighter body posses greater velocity.

4. (A) As the fuel in rocket undergoes combustion, the gases so produced leave the body of the rocket with large velocity and give upthrust to the rocket. If we assume that the fuel is burnt at a constant rate, then the rate of change of momentum of the rocket will be constant. As more and more fuel gets burnt, the mass of the rocket goes on decreasing and it leads to increase of the velocity of rocket more and more rapidly.

5. (A) According to Newton's second law,

$F = ma \Rightarrow a = F/m$

For constant F, acceleration is inversely proportional to mass i.e. acceleration produced by a force depends only upon the mass of the body and for larger mass, acceleration will be less.

6. (D) According to third law of motion it is impossible to have a single force out of mutual interaction between two bodies, whether they are moving or at rest. While, Newton's third law is applicable for all types of forces.

PARAGRAPH QUESTIONS

(i) (B) $50 = (20 + 30)\,a$

$a = 1 \text{ m s}^{-2}$

(ii) (A) $F - T = 30\,a$

$50 - T = 30$

$T = 20 \text{ N}$

(iii) (D) Acceleration of either 20 kg or 30 kg block is 1 m s^{-2}

NUMERICAL PROBLEMS

1. Here, M = 8 g

F = 64 dyne (at an $\angle 60°$ with the horizontal)

Therefore, component of the force along the horizontal,

$F_x = F \cos 60° = 64 \times \frac{1}{2} = 32 \text{ dyne}$

If a is acceleration along the horizontal, then

$F_x = Ma$ (or)

$a = \frac{F_x}{M} = \frac{32}{8} = 4 \text{ cm s}^{-2}$

2. Here, $F = 10 \text{ N}, t = 3\ \mu\text{s} = 3\times10^{-6}\text{s};$

$M = 5 \text{ g} = 5\times10^{-3} \text{ kg}$

Now, impulse $= Ft = 10 \times 3 \times 10^{-6}$

$= 3 \times 10^{-5} \text{ N s}$

Also, impulse = change in momentum

$= Mv_2 - Mv_1$

$= M(v_2 - v_1)$

$\therefore (v_2 - v_1) = \frac{\text{impulse}}{M} = \frac{3\times10^{-5}}{5\times10^{-3}}$

$= 6 \times 10^{-3} \text{ m s}^{-1}$

3. Here, initial velocity of the nail = velocity of the hammer, $u = 20 \text{ m s}^{-1}$;

final velocity of the nail, v = 0; distance covered, S = 10 cm = 0.1 m

Suppose that the impact lasts for a time t and as a result, an acceleration a is produced.

(i) Now, $v^2 - u^2 = 2as$

$(0)^2 - (10)^2 = 2a \times 0.1$

$$a = -\frac{100}{2\times 0.1} = 500 \text{ m s}^{-2}$$

(ii) Also, $v = u + at$

$0 = 10 + (-500) \times t$

$$t = \frac{10}{500} = 0.02 \text{ s}$$

(iii) Now, impulse = Ft = (Ma) t

Here, mass of the hammer, M = 1 kg

Therefore, impulse = $1 \times (-500) \times 0.02 = -10$ N s

4. When the lift is stationary:

The reaction is equal to weight of the block i.e.,

$R = Mg = 98$ N

$$\therefore \quad M = \frac{98}{g} = \frac{98}{9.8} = 10 \text{ kg}$$

When the lift is moving:

Let R' be reaction, when the lift is moving with acceleration $a = 2 \text{ m s}^{-2}$ in downward direction.

Then, $R' = M(g - a)$

$= 10 \times (9.8-2) = 78$ N

5. Let the force acting on the two bodies be 'F' N.

m_1 = '3 m' kg , m_2 = '4 m' kg,

$a_1 = 6 \text{ m s}^{-2}, a_2 = ?$

$F = m_1 \times a_1 = 3 \text{ m} \times 6 = 18 \text{ m}$

$F_2 = m_2 \times a_2 = 4 \text{ m} \times a_2 = 4 \text{ m } a_2$

$$\frac{F}{F} = \frac{18 \text{ m}}{4 \text{ m } a_2} \Rightarrow 4 a_2 = 18$$

$\Rightarrow a_2 = 4.5 \text{ m s}^{-2}$

Therefore, acceleration produced in the second body by application of same force is 4.5 m s^{-2}.

6. Mass of the bullet = m

$= 5 \text{ g} = 5 \times 10^{-3}$ kg

Initial velocity of the bullet = u

$= 120 \text{ m s}^{-1}$

Final velocity of the bullet = v

$= 0 \text{ m s}^{-1}$

Time taken by the bullet to come to rest

$= t = 0.01$ s

Force exerted on the bullet = F= ?

We know, that

$F = ma$

$$\Rightarrow F = m\left(\frac{v-u}{t}\right) \quad .....(1)$$

$$\left[\because a = \frac{v-u}{t}\right]$$

Substituting the above values in (1), we get,

$$F = 5 \times 10^{-3}\left(\frac{0-120}{0.01}\right)$$

$= (5 \times 10^{-3}) \times (-12000)$

$= -5 \times 12 = -60$ N

As 'F' is negative, it indicates that the retarding force is 60 N.

Therefore, the force exerted on the bullet by the target to stop it is 60 N.

7. Let the acceleration of two spheres be 'a' units.

Given that two spheres are made of same material.

$\Rightarrow$ densities of two spheres is same and let it be 'd'.

F_1 = 'F' units F_2 = ?

Mass = volume × density

$$\Rightarrow m = V \times d = \left(\frac{4}{3}\pi r^3 \times d\right)$$

(since volume of sphere = $\frac{4}{3}\pi r^3$)

$F = \frac{4}{3}\pi r^3 d \times a \Rightarrow F \propto r^3$

$\Rightarrow F = kr^3$

(since 'd' and 'a' are same for both the spheres)

$\Rightarrow F_1 = kr_1^3 \Rightarrow F = kr^3$

$\Rightarrow F_2 = kr_2^3 \Rightarrow F_2 = k(2r)^3\ k \times 8r^3$

$$\frac{F_2}{F} = \frac{k \times 8r^3}{kr^3} = 8 \Rightarrow F_2 = 8\,F$$

8. F = 20 N, m = 10 kg, t = 8 s
u, v = 2u

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

$$20 = 10\left(\frac{2u-u}{8}\right)$$

$u = 16\ m\ s^{-1}$

9. Impulse $= m(v-u)$
$= 5(0-2)$
$= 10$ N s

10. $u = 54 \times \frac{5}{1s} = 15\ m\ s^{-1}$

Average force to stop an automobile,

$$F = m\frac{(v^2-u^2)}{2s}$$

$$= 2000\frac{(0^2-15^2)}{2\times(25)} = -9000\ N$$

Retarding force = 9000 N

11. $F = m_1a_1 = m_2a_2$

$$\frac{m_1}{m_2} = \frac{4}{6} = \frac{2}{3}$$

$F = (m_1 + m_2)\,a$

$$m_2 \times 4 = \left(\frac{2}{3}m_2 + m_2\right)a$$

$$m_2 \times 4 = \frac{5}{3}m_2 a$$

$$a = \frac{12}{5} = 2.4\ m\ s^{-2}$$

12. Retarding force,
F = – (mass of car + mass of driver)

$$\left(\frac{v^2-u^2}{2s}\right)$$

$$= -(1140+60)\left[\frac{0^2-10^2}{2\times150}\right]$$

$$= -1200\left(\frac{-100}{300}\right) = 400\,N$$

13. Average resistance offered by the wall

$$= \frac{m_2^{\ 2}}{(m_1+m_2)}\frac{(v^2)}{2s}N$$

14. At point P, $u = 0.5\ m\ s^{-1}$
Total energy at point
P = total energy at point R

$$mgh_P + \frac{1}{2}mu^2 = \frac{1}{2}mv^2 + mg\,h_R$$

$$10\times4 + \frac{1}{2}\times5^2 = \frac{1}{2}\times v^2 + (10\times1.65)$$

$$\frac{1}{2}v^2 = (40+12.5)(16.5)$$

$v^2 = 36 \times 2$

$v = \sqrt{36\times2}\ m\ s^{-1}$

$v = 6\sqrt{2}\ m\ s^{-1}$

15. Given, $\frac{v_n}{v_x} = \frac{1}{57}$

$m_xv_x + m_nv_n = 0$

$m_xv_x = -m_nv_n$

$$\frac{v_n}{v_x} = \frac{m_x}{m_n}$$

$$\frac{1}{57} = \frac{m_x}{(232 - m_x)}$$

$$232 - m_x = 57\, m_x$$

$$58\, m_x = 232$$

$$m_x = \frac{232}{58} = 4$$

∴ Mass of a particle x is 4.

CONCEPTUAL QUESTIONS

1. When a person falls on a cemented floor, the person is abruptly stopped within a short time making the impulsive force very high, which injures the person. But when a person falls on a heap of sand, the sand yields under the weight of the person, and the person takes more time to come to rest. This reduces the impact of impulsive force.

2. Let us verify the above statement by solving the problem.

Case I:

Let mass of first body = m_1

Let acceleration of first body = a_1

Let force acting on first body = F_1

Case II:

Mass of second body = m_2

Acceleration of second body = a_2

Let force acting on second body = F_2

Given that equal forces are acting on a body

$\Rightarrow$ $F_1 = F_2$ ..... (1)

$m_1a_1 = m_2a_2$ (since F = ma)

$$\Rightarrow \frac{a_1}{a_2} = \frac{m_2}{m_1} \Rightarrow a \propto \frac{1}{m}$$

Thus, when equal forces act on two different bodies, the acceleration is inversely proportional to the mass of the body.

For a given force, smaller bodies produce higher acceleration and bigger bodies produce lower acceleration.

3. Let the constant acceleration be 'a' units.

As the body is starting from rest, initial velocity of the body = u = 0

Case I:

S_1 = 'x'

P_1 = 'k' (given)

Case II:

then $S_2 = 2x$

then P_2 = ?

Mass is same in both the cases we

$v^2 - u^2 = 2aS$

$\Rightarrow$ $v^2 - 0^2 = 2aS$

$\Rightarrow$ $v^2 = 2aS$

$\Rightarrow$ $v = \sqrt{2aS}$

Substituting (2) in (1), we get

$P = m \times v = m \times \sqrt{2aS}$

$\Rightarrow$ $P \propto \sqrt{S}$

(since 'm' and 'a' are constant)

$$\therefore \frac{P_1}{P_2} = \frac{\sqrt{S_1}}{\sqrt{S_2}} = \frac{\sqrt{x}}{\sqrt{2x}} = \frac{1}{\sqrt{2}}$$

$\Rightarrow$ $P_2 = \sqrt{2}\, P_1 = \sqrt{2}k$

Therefore, momentum at double the initial distance (x) is $\sqrt{2}$ times the initial momentum.

4. To pull the cart, a horse pushes the ground in backward direction with its feet. The reaction from the ground

makes the cart to move forward. In an empty space, the horse cannot push in backward direction and get a forward reaction. That is why, a horse cannot pull a cart and run in the empty space.

5. By running some steps before taking the jump, the athlete adds momentum to the effort, he can put in. It helps the athlete to make a longer jump.

6. Being light, the momentum of the table tennis ball is very small as compared to that of a cricket ball. In order to catch i.e. stop the two balls in the given same time, the rate of change of momentum. Hence, the force required in case of the table tennis ball is very small.

7. When a scooter or a car moves on a rough road, it receives an impulse due to the jerky road. The shockers used in the vehicle helps in increasing the time of impact, their by decreasing the force of impact as impulse is product of force of time of impact.

8. The particle is stationary under the action of forces F_1, F_2 and F_3. It implies that the force F_1 is equal and opposite to the resultant of the forces F_2 and F_3. Therefore, if force F_1 is removed, the particle will move under the action of force F_1. Hence, the acceleration of the particle, $a = -\frac{F_1}{m}$.

PREVIOUS CONTEST QUESTIONS

1. (C) Initial momentum = 0

Final momentum = $m_g v_g + m_b v_b$

$(0.05 \times 30) + (m_g \times 1) = 0$

$m_g = 1.5$ kg

2. (A) Impulse = Force × time

$25 = F \times 0.05$

$$F = \frac{25}{0.05} = 500\text{N}$$

3. (B) $u = 108 \times \frac{5}{18} = 30 \text{ m s}^{-1}$

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

$$= 120\frac{(0-30)}{0.1} = 360 \text{ N}$$

4. (C) $w = mg = 10m$ N

When lift is moving downwards apparent weight

$W = m(g - a)$

$= m(10 - 5) = 5m$ N

% change in weight

$$= \frac{w^1 - w}{w} \times 100$$

$$= \frac{5m - 10m}{10m} \times 100$$

$$= -\frac{1}{2} \times 100 = -50\%$$

5. (D) $F = \frac{m(v-u)}{t}$

$$100 = \frac{2(v-u)}{10}$$

$\Rightarrow (v - u) = 500 \text{ m s}^{-1}$

Change in momentum = $m(v - u)$

$= 2 \times (500)$

$= 1000$ N – S

6. (C) Physical independence of force is a consequence of Newton's first law of motion.

7. (C) Conservation of linear momentum is equivalent to Newton's third law of motion.

8. (A) $F = \frac{\Delta P}{t}$

$2 = \frac{0.4}{t}$ (or) $t = 0.2$ s

9. (D) Apparent weight W^1

$= 4.8$ kg wt

$= 4.8g$ N

When lift moves upwards,

$4.8\ g = 4(g + a)$

$1.2g = g + a$

$a = 0.2g = 0.2 \times 9.8$

$= 1.96\ m\ s^{-2}$

When lift moves with $1.96\ m\ s^{-2}$ upwards

10. (A) Impulse

$= F \times t$ = change in momentum

$= 0.06(4-(-4))$

$= 0.48$ kg m s^{-1}

BRAIN NURTURES

1. Because during the upward and the downward journey; due to inertia, the ball also moves along horizontal with the velocity of the train. Hence, it covers the same horizontal distance as the train does and the ball returns to the thrower.

2. Impulse at $t = 0$; Before $t = 0$, the particle is at rest and after $t = 0$, it moves with a constant velocity of $0.75\ m\ s^{-1}$ i.e.

$u = 0$ and

$v = 0.75\ m\ s^{-1}$

Also, mass of the particle, $M = 4$ kg

Therefore, impulse = total change in momentum

$= M(v - u) = 4(0.75 - 0) = 3$ kg m s^{-1}

Impulse at $t = 4$ s; Before $t = 4$ s, the particle is moving with constant velocity of $0.75\ m\ s^{-1}$ and after $t = 4$ s, it is at rest i.e., $v = 0.75\ m\ s^{-1}$ and $v = 0$

Therefore, impulse

$= M(v - u)$

$= 4(0 - 0.75) = 3$ kg m s^{-1}

3. When the spring is released, then m_1 pulls m_2 with a certain force, and as a reaction, m_2 pulls m_1 with the same force (F_1) but in the opposite direction.

$\Rightarrow F_2 = -F_1$ ..... (1)

Given,

m_1 = 'm_1' kg, m_2 = 'm_2' kg

$F_1 = F_1$ N, $F_2 = F_2$ N

$a_1 = a\ m\ s^{-2}$, $a_2 = ?$

$F_1 = m_1 a_1 = m_1 a$ ..... (2)

$F_1 = m_1 a_1$ ..... (3)

Substituting values from (2) and (3) in (1), we have,

$m_2 a_2 = -m_1 a$

$\Rightarrow a_2 = \left(-\frac{m_1 a}{m_2}\right) m\ s^{-2}$

$\therefore$ Acceleration of the second body

$= \left(-\frac{m_1 a}{m_2}\right) m\ s^{-2}$

Negative sign indicates that the second body moves in the direction opposite to that of the first body.

4. To hold the firing gun in position, we have to exert certain amount of the force on the gun. This force can be obtained by finding the rate of change of momentum of the bullet.

$\therefore$ force F = Rate of change of momentum of the bullet.

= No. of bullets fired per second × change in momentum of each bullet .....(1)

No. of bullets fired per second = x

Mass of each bullet = 'm' kg

Initially a bullet is at rest

$\Rightarrow$ Initial velocity of bullet = u = 0 m s^{-1}

Final velocity of bullets = v = 'y' m s^{-1}

Change in momentum of bullets

= mv – mu

= (my) – 0 = my

Substituting the above value in (1), we have

F = (x × my) N = (mxy) n

Therefore, force necessary to hold the gun in position is (mxy)N.

5. Force acting on a sphere = F = 'F' = N

Acceleration of the sphere = a = 'a' m s^{-2}

Density of sphere = d = ?

Volume of the sphere = v = 'V' m^3

We know that, density (d)

$$= \frac{\text{mass}(m)}{\text{volume}(V)} \quad ..... (1)$$

How to get mass from the given data F and a?

We know that,

$$F = ma \Rightarrow m = \frac{F}{a} \quad ..... (2)$$

Substituting (2) in (1), we get,

$$\text{Density (d)} = \frac{F}{a} \times \frac{1}{V} = \frac{F}{aV} \text{ kg m}^{-3}$$

Therefore, density of sphere is

$$\left(\frac{F}{aV}\right) \text{kg m}^{-3}.$$

6. Mass of the first body = m_1 = m

Mass of the second body = m_2 = m

Ratio of the forces acting on them

$$F_1 : F_2 = ?$$

We know that, F = ma

How to get acceleration (a)?

Slope of velocity–time graph gives acceleration.

$\Rightarrow$ slope = a = tan θ ..... (a)

$\therefore$ F = ma = m (tan θ) ..... (1)

[since from (a)]

Applying (1) to both the cases, we get

$$F_1 = m_1(\tan\theta_1)$$

$$\Rightarrow F_1 = m(\tan 30°)$$

$$\Rightarrow F_1 = m \times \frac{1}{\sqrt{3}} = \frac{m}{\sqrt{3}} \quad ..... (2)$$

$$F_2 = m_2(\tan\theta_2)$$

$$\Rightarrow F_2 = \frac{m}{2}(\tan 60°)$$

$$\Rightarrow F_2 = \frac{m}{2} \times \sqrt{3} = \frac{m\sqrt{3}}{2} \quad ..... (3)$$

Dividing (2) by (3), we have

$$\frac{F_1}{F_2} = \frac{m/\sqrt{3}}{m\sqrt{3}/2}$$

$$= \frac{m}{\sqrt{3}} \times \frac{2}{m\sqrt{3}} = \frac{2}{3}$$

$$\Rightarrow F_1 : F_2 = 2 : 3$$

Therefore, the ratio of the forces acting on the two bodies is 2 : 3.

❖ ❖ ❖

Chapter 4

Work, Power and Energy

SOLUTIONS

BASIC PRACTICE

FILL IN THE BLANKS

4. $m = 20$ kg ; $h = ?$

$PE = mgh$; $h = \frac{784}{20 \times 9.8} = 4$ m

TRUE OR FALSE

22. $\Delta PE = mg(h_2 - h_1)$

Given $h_2 = 25$ cm $= 0.25$ m

$h_1 = 0$

$\therefore \Delta PE = 20 \times 9.8 \times 25 \times 10^{-2}$

$= 196 \times 0.25 = 49$ J

But given $\Delta PE = 98$ J

$\therefore$ Statement is false.

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. (A) Power $= \frac{\text{work done}}{\text{time taken}}$

Given $T_{Rahul} < T_{Rohan}$ (For same amount of work)

$\therefore$ Power is inversely proportional to time.

Hence, Rahul has more power than Rohan.

2. (D) $m = 60$ kg

Length of staircase = 20 m

Height of staircase = 10 m

Workdone = mgh = mg (length + height of stair case)

$= 60 \times 10 \times (20 + 10)$

$= 600 \times 30 = 18$ kJ

3. (D) When a ball is projected upwards;

(a) velocity decreases

(b) height increases

(c) retardation of the ball remains constant.

Hence, KE decreases whereas PE increases.

4. (C) Let $KE = \frac{1}{2}mv^2$

Given, $m^1 = 2m$ and $v^1 = 2v$

$\therefore KE^1 = \frac{1}{2}m^1(v^1)^2$

$= \frac{1}{2} \times 2m \times (2v)^2$

$= \frac{1}{2} \times 8mv^2 = 8$ KE

$\therefore$ KE of the body becomes 8 times.

5. (D) Let $KE = \frac{p^2}{2m}$

Given $p^1 = 2p$

$\therefore KE^1 = \frac{(p^1)^2}{2m} = \frac{(2p)^2}{2m}$

$= \frac{4p^2}{2m} = 4KE$

$\therefore$ KE is increased by four times.

6. (A) Let $KE = \frac{1}{2}mv^2$

Given $m^1 = \frac{1}{2}m$

$V^1 = 2V$

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$\therefore KE^1 = \frac{1}{2}m^1(V^1)^2$

$= \frac{1}{2} \times \frac{1}{2} m \times (2V)^2$

$= \frac{1}{2}(2)mv^2 = 2\ KE$

$\therefore$ KE is doubled

7. (C) Given: $m_1 = 2$ kg
$m_2 = 4$ kg ; $h_1 = 60$ ft ; $h_2 = 30$ ft
According to law of conservation of energy,

$\Delta KE = \Delta PE$

$\therefore \frac{KE_1}{KE_2} = \frac{m_1 g(h_1 - h_2)}{m_2 g(h_1 - h_2)}$

$\frac{KE_1}{KE_2} = \frac{2}{4} = 1:2$

8. (B) Let $W = F \times S$
Given, $F^1 = 2F$

$S^1 = 2S$

$\therefore W^1 = F^1S^1 = (2F)(2S) = 4W$

$\therefore$ Work should become four times

9. (B) When the force retards the motion of a body, the work done is negative.

10. (A) When a force acts on body its KE increases.

11. (C) $E_b = \frac{1}{2}mv^2$

$E_g = \frac{1}{2}mV^2$

Since KE $\propto V^2$ and $v >> V$

$E_b > E_g$

12. (B) Given: $F \propto x \Rightarrow F = kx$

$W = Fx = k(x)(x)$

$= kx^2 = W \propto x^2$

13. (B) Let mass of light body and heavy body be m_1 and m_2 respectively.

Now, $KE = \frac{P^2}{2m}$

Since P is same, $KE \propto \frac{1}{m}$

So, lighter body has more KE.

14. (B) $p = \frac{mgh}{t}$

$= \frac{100 \times 10 \times 20}{10}$

$= 2$ kW or 2×10^3 W

15. (D) Workdone in holding a suitcase while waiting for a bus i.e. stationary position. Hence, no displacement and no work is done.

FURTHER PRACTICE

MULTIPLE ANSWERS QUESTIONS

1. (A,B,D) Let $KE = \frac{1}{2}mV^2$

(A) If $V = 2V$

then $KE^1 = \frac{1}{2}m(V^1)^2$

$= \frac{4}{2}mV^2 = 4\ KE$

(B) $KE = \frac{1}{2}mV^2$

$\therefore KE \propto V^2$

(C) $\therefore$ KE depends on mass of a body.

(D) Work done $= F \times S$

$= ma \times S$

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

$= \frac{1}{2}mv^2 - \frac{1}{2}mv^2 = \Delta KE$

2.(A,B,C,D) Energy is capacity to do work. Therefore 1 J of work done uses up 1 J of energy.

Power $= \frac{\text{workdone}}{\text{time}}$

$\therefore 1\ W = \frac{1J}{1s}$

i.e., ability to do 1 J of work per second.

PE = mgh

= 40 × 10 × 8 = 3200 J

∴ 3200 J energy is needed

SI unit of power is watt

3.(A, B, D) The energy used by a man to climbing a staircase (mgh)

(A) weight of his body

(B) height of the staircase

(C) mass of his body choices

4.(A, C) Given W = 600 N

L = 100 N; S = 5 M

Workdone = F × d

= (600 + 100)5

= 700 × 5 = 3500 J

or 3.5×10^{10} ergs

5. (A,C,D) Work is done when the force is applied as a body such that it causes displacement:

Shopping in the supermarket

Climbing a tree to pluck

In all these cases displacement is caused.

ASSERTION AND REASONING

1. (A) KE with any reference must be positive as in its expression velocity appears as a square i.e., with power 2 and mass is never negative.

2. (A) $KE = \frac{p^2}{2m}$

Given $p^1 = 2p$

∴ $KE^1 = 4\,KE$

$$\% \text{ increase} = \frac{KE^1 - KE}{KE} \times 100$$

$$= \frac{4KE - KE}{KE} \times 100 = 300\ \%$$

3. (B) $KE = \frac{P^2}{2m}$

Given P is same for two bodies.

$$\therefore KE \propto \frac{1}{m}$$

⇒ Lighter body possess more KE. KE of a body varies as the square of its velocity is correct.

4. (A) The PE stored in a spring is positive, when it is compressed. PE is negative, when it is stretched. This is because when spring is compressed work done is positive and when stretched work done is negative.

5. (E) A man carrying a bucket of water and walking on a rough level round with a uniform velocity does work while carrying the bucket because here work done is equal to $\frac{1}{2}$.

6. (A) The fuel consumed by a crane is equal to the power of the crane.

$$\therefore \frac{Power_P}{Power_Q} = \frac{\frac{m \times g \times h}{t_1}}{\frac{mgh}{t_2}} = \frac{t_2}{t_1} = \frac{2}{1}$$

∴ Power P = 2 Power Q

So, crane P consumes more fuel than crane Q.

PARAGRAPH QUESTIONS

(i) (A) W = M g h

= 2,000 × 9.8 × 30

= 5.88×10^5 J

From the principle of conservation of energy, both the cranes will consume fuel equivalent to 5.88×10^5 J i.e., two cranes consume same amount of fuel.

(ii) (B) Power supplied by first crane,

$$P_1 = \frac{W}{t_1} = \frac{5.88 \times 10^5}{60} = 9,800 \text{ W}$$

(iii) (A) Power supplied by second crane,

$$P_2 = \frac{W}{t_2} = \frac{5.88 \times 10^5}{120} = 4900 \text{ W}$$

NUMERICAL PROBLEMS

1. $W = F \times s = mgh$

$= 30 \times 10 \times 50 = 15000$

Work done $= 15 \times 10^3$ joule

2. Displacement s = 8 m

angle $\theta = 60^0$

Force F = 3 N

Work done $W = F \times s \cos\theta$

$= 3 \times 8 \times \cos 60^0$

$= 3 \times 8 \times 1/2$

$= 24 \times 1/2 = 12$

$\therefore$ The work done by the child to pull the toy car is 12 J

3. Power (P) = 4.9 kilo watt

= 4.9 × 1000 watt

= 4900 watts

Depth of a well (h) = 50 meter

Acceleration due to gravity

$g = 9.8 \text{ m s}^{-2}$

t = 1 hour

= 60 × 60 = 3600 s

$$P = \frac{\text{workdone}}{\text{time}} = \frac{mgh}{t}$$

$$4900 = \frac{m \times 9.8 \times 50}{3600}$$

$$3600 \times 4900 = m \times 9.8 \times 50$$

$$m = \frac{3600 \times 4900}{9.8 \times 50} = 36000 \text{ kg}$$

$\therefore$ Volume of water pumped per hour

= 36000 litre

= 36.0 litre. ($\therefore$ 1 litre = 1 kg)

= 36 kilolitre

4. Given,

Mass of a body (m) = 4 kg

Velocity of the body (v) = ?

Kinetic energy (K.E) = 0.02 J

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

$$\frac{1}{2} \times 2 \times v^2 = 0.02 \text{ joule}$$

$$v = \sqrt{0.02}\ ;\ v = 0.141 \text{ m s}^{-1}$$

5. Percentage increase in K.E,

$$(E) = \left[\frac{E_2 - E_1}{E_1}\right] \times 100 = \left[\frac{E_2}{E_1} - 1\right] \times 100$$

But $E \propto p^2 \Rightarrow \frac{E_2}{E_1} = \frac{p_2^2}{p_1^2}$

$$\therefore \% \text{ increase in K.E.} = \left[\frac{p_2^2}{p_1^2} - 1\right] \times 100$$

Let $p_1 = 100$, then

$p_2 = 100 + 50 = 150$ % increase in

$$K.E. = \left[\frac{(150)^2}{(100)^2} - 1\right] \times 100 = \left[\frac{225}{100} - 1\right] \times 100$$

= 125%

Therefore, the percentage increase in its kinetic energy is 125%.

6. % increase in momentum

$$\frac{\text{Change in momentum}}{\text{Initial momentum}} \times 100$$

$$= \frac{p_2 - p_1}{p_1} \times 100 = \left[\frac{p_2}{p_1} - 1\right] \times 100$$

$$p = \sqrt{2mE}$$

$$\Rightarrow p \propto \sqrt{E} \Rightarrow \frac{p_2}{p_1} = \frac{\sqrt{E_2}}{\sqrt{E_1}}$$

∴ Percentage increase in momentum

$$= \left[\frac{\sqrt{E_2}}{\sqrt{E_1}} - 1\right] \times 100$$

Let $E_1 = 100$, then

$E_2 = 100 + 300 = 400$

Percentage increase in momentum

$$= \left[\frac{\sqrt{400}}{\sqrt{100}} - 1\right] \times 100 = \left|\sqrt{4} - 1\right| \times 100$$

$= (2 - 1) \times 100 = 100\%$

Therefore, percentage increase in momentum is 100%.

7. Initial mass of the body = $m_1 = m$

Final mass of the body = $m_2 = 4m$

Initial velocity of the body = $v_1 = v$

Final velocity of the body = $v_2 = ?$

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

Applying the above formula in both the cases, we get

$$K.E_1 = \frac{1}{2} m_1 v_1^2 \quad ..... \quad (I)$$

$$K.E_2 = \frac{1}{2} m_2 v_2^2 \quad ..... \quad (II)$$

$K.E_1 = K.E_2$

(∴ K.E is same for both bodies)

$$\Rightarrow \frac{1}{2} mv^2 = \frac{1}{2} \times 4m \times v_2^2$$

$$v^2 = 4 \; ; \; v_2^2 \Rightarrow v_2 = \frac{1}{2} v$$

Therefore, the velocity of a body should be halved, if its mass is increased by four times for the same K.E. of the body.

8. P.E = mgh

$9800 = 100 \times 9.8 \times h$

$$h = \frac{9800}{100 \times 9.8}$$

h = 10 m.

∴ The bag of wheat should be raised to a height of 10 m.

9. Mass of body A, $m_1 = m$

Mass of body B, $m_2 = m$

Height $h_1 = h$

Height $h_2 = 2h$

Acceleration due to gravity, $g_1 = g$

Acceleration due to gravity, $g_2 = g$

$$\frac{\text{Potential Energy}(P.E_1)}{\text{Potential Energy}(P.E_2)} = ?$$

P.E. = mgh

$\Rightarrow$ P.E $\propto$ h

(∴ 'm' and 'g' are constants)

$$\Rightarrow \frac{P.E_1}{P.E_2} = \frac{h_1}{h_2}$$

$$\Rightarrow \frac{P.E_1}{P.E_2} = \frac{h}{2h} \Rightarrow \frac{P.E_1}{P.E_2} = \frac{1}{2}$$

Therefore, the ratio of potential energy is of the two bodies is 1 : 2.

10. Given:

Mass of the body, m =10 kg

Initial velocity, $u = 19.6 \text{ m s}^{-1}$

Potential energy (P.E.) at highest point= ?

For this, first we have to find maximum height, h = ?

The maximum height reached by a body is given by $h = \frac{u^2}{2g}$.

$$\Rightarrow h = \frac{(19.6)^2}{2 \times 10} = \frac{384.16}{20} = 19.208 \text{ m}$$

Therefore, potential energy at maximum height is, P.E. = mgh

$\Rightarrow$ P.E. = 10 × 10 × 19.208 = 1920.8 J

11. Mass of the body, m = 10 kg

When the body is released from a certain height, the total potential energy gets converted into kinetic energy when it reaches the ground.

Given, kinetic energy (K.E.) = 1920.8 J

Velocity of the body (v) = ?

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

$$\Rightarrow \quad 1920.8 = \frac{1}{2} \times 10 \times v^2$$

$$\Rightarrow \quad v^2 = \frac{192.8}{5} = 384.16$$

$$\Rightarrow \quad v = 19.6 \text{ m s}^{-1}$$

Therefore, the velocity of the body when it reaches the ground is 19.6 m s^{-1}.

12. Density of water

$= 10^3$ kg m^{-3} : 1000 liters = 1 m^3

Volume of water = 40,000 liters

$$= \frac{40,000}{1000} = 40 \text{ m}^3$$

Mass of water, m= density × volume

= 1000 × 40

= 40,000 kg.

PE = mgh

$= 40,000 \times 9.8 \times 35 = 1.37 \times 10^7$ J

13. Mass of the body, m_E = 'm' kg

Mass of the body m_O = 'm' kg

Height, h_E = 'h' m

Height, $h_O = h_2$ = '4h' m

Weight of the body, W_E = 600 N

Weight of the body, W_O = ?

Therefore, the weight of the body on other plane,

$$W_O = mg_O \quad \text{..... (1)}$$

Given, their potential energies are same

$$\Rightarrow \quad (P.E.)_E = (P.E.)_O$$

$$\Rightarrow \quad mg_E h_E = mg_O h_O$$

$$\Rightarrow \quad mg_E h_E = mg_O 4h_E \text{ (since } h_O = 4h_E)$$

$$\Rightarrow \quad g_O = \frac{g_E}{4} \quad \text{..... (2)}$$

Substituting (2) in (1), we get

$$W_O = mg_O = \frac{mg_E}{4} = \frac{W_E}{4}$$

(since $W_E = mg_E$)

Substituting the value of W_E in the above equation, we get

$$W_O = \frac{600}{4} = 150 \text{ N}$$

Therefore, the weight of the body on the other planet is 150 N

CONCEPTUAL QUESTIONS

1. Mass of the first body (m_1) = m

Mass of second body (m_2) = 2m

Velocity of the first body (v_1) = v

Velocity of second body $(v_2) = \frac{v_1}{2} = \frac{v}{2}$

$$KE_1 = \frac{1}{2}mv^2 \quad \text{..... (I)}$$

$$KE_2 = \frac{1}{2}2m(v/2)^2 = \frac{1}{2}mv^2 \times \frac{1}{2} \quad \text{..... (II)}$$

Dividing (II) by (I), we get

$$\frac{KE_2}{KE_1} = \frac{1}{2} \text{ i.e., } 1 : 2$$

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

Applying the above formula in both the cases, we get

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{1}{2}(nm)$$

$$v_2^2 \Rightarrow v_2^2 = \frac{v^2}{n}$$

∴ To keep the kinetic energy constant, the velocity of the body should be changed to $\frac{v}{\sqrt{n}}$.

$$\text{change in velocity} = \frac{V}{\sqrt{n}} - V$$

$$V\left[\frac{1-\sqrt{n}}{\sqrt{n}}\right]$$

3. $K.E = \frac{p^2}{2m}$ and $KE \propto \frac{1}{m}$

$$\Rightarrow \frac{(K.E)_1}{(K.E)_2} = \frac{m_2}{m_1} \text{ (or) } \frac{E_1}{E_2} = \frac{m_2}{m_1}$$

Therefore, the ratio of their kinetic energy is $m_2 : m_1$.

4. Momentum (p) = Kinetic energy (K.E.)
Velocity (v) = ?

$$P = mv, KE = \frac{1}{2}mv^2$$

But, given p = KE

$$\Rightarrow \quad mv = \frac{1}{2}mv^2 \Rightarrow v = 2 \text{ m s}^{-1}.$$

Therefore, we can conclude that any body moving with 2 m s^{-1}, has same momentum and K.E.

5. The maximum height reached by a body is given by $h = \frac{u^2}{2g}$ and P.E = mgh

$$\Rightarrow \quad h_1 = \frac{u_1^2}{2g} \Rightarrow h_1 = \frac{u^2}{2g}$$

$$\Rightarrow \quad h_2 = \frac{u_2^2}{2g_2} \Rightarrow h_2 = \frac{(3u)^2}{2g} = \frac{9u^2}{2g}$$

$$\therefore \quad P.E_1 = m_1g_1h_1 \text{ and } P.E_2 = m_2g_2h_2$$

$$\Rightarrow \quad m \times g \times \frac{u^2}{2g} = \frac{mu^2}{2} \quad .... (1)$$

$$m \times g \times \frac{9u^2}{2g} = \frac{9mu^2}{2} \quad .... (2)$$

Dividing (1) by (2) we get,

$$\frac{P.E_1}{P.E_2} = \frac{\frac{mu^2}{2}}{\frac{9mu^2}{2}} = \frac{1}{9}$$

$$\therefore \quad P.E_1 : P.E_2 = 1:9$$

$\therefore$ The ratio of their potential energies is 1 : 9.

6. Let T be K.E. of a vehicle. If the vehicle comes to rest in a distance S on applying a retarding force, F, then work done by the retarding force has to be just equal to the kinetic energy of the vehicle i.e.,

$$FS = T \quad \text{or} \quad S = \frac{T}{F}$$

Since for both the vehicles, the values of T and F are same, they will come to rest in the same distance and hence in the same time.

PREVIOUS CONTEST QUESTIONS

1. (C) $KE \alpha V^2$ and $v^2 = \frac{2KE}{m} = 2 \times \frac{490}{2}$
$= 490 \text{ m s}^{-1}$

$$\frac{KE}{\frac{1}{2}KE} = \frac{v^2}{v_1^2}$$

$$v_1 = \frac{v}{\sqrt{2}}$$

$$v_1^2 - v^2 = -2gh$$

$$\frac{v^2}{2} - v^2 = -2gh$$

$$h = \frac{v^2}{4g} = \frac{490}{4 \times 9.8} = 12.5\text{m}$$

2. (A) $P = F \times V$
$= 600 \times 20$
$= 12 \times 10^3$ W or 12 kW

3. (C) $KE = \frac{p^2}{2m}$

$$\frac{KE_1}{KE_2} = \frac{p_1^2}{p_2^2} \times \frac{m_2}{m_1}$$

$$\frac{8}{1} = \frac{p_1^2}{p_2^2} \times \frac{m}{2m}$$

$$\frac{p_1}{p_2} = \sqrt{\frac{16}{1}} = \frac{4}{1}$$

4. (B) $\frac{KE_1}{KE_2} = \frac{p_1^2}{p_2^2} \times \frac{m_2}{m_1}$

$$\frac{p_1^2}{p_2^2} = \frac{m_1}{m_2} \quad (\therefore KE_1 = KE_2)$$

$$p_1 : p_2 = 1 : 2$$

5. (D) PE at height of 10 m = mgh
$= 0.1 \times 10 \times 10 = 10$ J

KE before it strikes growing = PE at 10 m = 10 J

6. (C) KE α p^2

$$\frac{KE_1}{KE_2} = \frac{p_1^2}{p_2^2}$$

$$\frac{KE_1}{2KE} = \frac{p_1^2}{p_2^2}$$

$$\frac{p_1}{p_2} = \frac{1}{\sqrt{2}} \Rightarrow p_2 = \sqrt{2}p_1$$

7. (C) KE α v^2

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

$$KE_1 = \frac{1}{2}mv_1^2 = \frac{1}{2}m(3v)^2 = 9KE$$

8. (A) $KE = \frac{p^2}{2m}$

If KE = constant

$p \alpha \sqrt{m}$

Heavier ball has more mass hence has greater momentum than lighter ball.

9. (C) Workdone $W = F \times 1\ S = 6\left(\frac{t^2}{4}\right)$

at $t = 2$ s

$$W = 6\left(\frac{2^2}{4}\right) = 6J$$

10. (A) Power $= \frac{\text{work}}{\text{time}} = \frac{F \times s}{t} = F \times v$

BRAIN NURTURES

1. When the force acts at angle of 30°

$$w = 5 \times \cos 30^0 \times 2$$

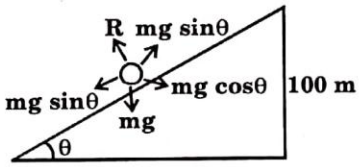
$$= 10 \times \sqrt{3}/2$$

$$= 8.66\ J$$

$$\therefore F = \frac{W}{s\cos\theta} = \frac{8.66}{2m \times \cos 45°}$$

$$= 6.12\ N$$

2. F = mg sin θ (in the direction of motion)



$$W = mg \sin\theta \times h$$

$$= 160 \times 9.8 \times \frac{1}{10} \times 50 = 7840\ J.$$

3. Mass of first car $m_1 = m$

Mass of second car $(m_2) = 2m$

velocity of the car $(v_1) = y$

velocity of second car $(v_2) = \frac{v_1}{2} = \frac{v}{2}$

$$KE_1 = \frac{1}{2}m_1v_1^2 \quad \text{..... (I)}$$

$$KE_2 = \frac{1}{2}2m\left(\frac{v}{2}\right)^2 = \frac{1}{2}mv^2 \times \frac{1}{2} \quad \text{..... (II)}$$

Dividing (II) by (I) we get

∴ The ratio of K.E of the second car to first car is 1 : 2.

4. $K.E. = \frac{p^2}{2m}$

$$(K.E.)_1 = \frac{p_1^2}{2m_1} \quad \text{..... (I)}$$

$$(K.E.)_2 = \frac{p_2^2}{2m_2} \Rightarrow KE_2 = \frac{(2p_1)^2}{2m_1} = \frac{4p_1^2}{2m_1} \quad \text{... (II)}$$

$$\frac{(K.E.)_2}{(K.E.)_1} = \frac{4p_1^2/2m_1}{p_1^2/2m_1} \Rightarrow \frac{(K.E.)_2}{(K.E.)_1}$$

$$\Rightarrow (K.E.)_2 = 4(K.E.)_1$$

Therefore, the final kinetic energy becomes 4 times the initial kinetic energy.

Percentage change

$$= \frac{(4KE_1 - KE_1) \times 100}{KE_1} = 300\ \%$$

5. $p = \sqrt{2mK.E}$

$p_1 = \sqrt{2m\ E}$

$p_2 = \sqrt{2\times m\times 2E} \Rightarrow p_2 = \sqrt{2}p_1$

$\Rightarrow \frac{p_2}{p_1} = \frac{\sqrt{2}\times\sqrt{2mE}}{\sqrt{2mE}} = \sqrt{2}$

$\therefore\ p_2 = \sqrt{2}p_1$

Change in momentum

$= p_2 - p_1$

$= \sqrt{2}p_1 - p_1 = (\sqrt{2}-1)p_1$

6. $p = \sqrt{2mKE}$

$p_1 = \sqrt{2\times 2m\times 2E}$

$p_1 = 2\sqrt{2mE}$

$p_2 = \sqrt{2mE} = 2\ p_1$

$\therefore\ p_1 : p_2 = 2 : 1$

Therefore, the ratio of their momenta is 2 : 1.

7. $K.E. = \frac{p^2}{2m}$

$E_1 = \frac{(4p)^2}{2(2m)}$

$E_2 = \frac{p^2}{2m} = 8\ E_1$

$\therefore\ K.E_1 : K.E_2 = 8 : 1$

8. Given, mass of a car, m = 1650 kg

Initial velocity of the car,

$v_1 = 65\ km\ h^{-1} = 65 \times \frac{5}{18}\ m\ s^{-1}$

$\left(\therefore 1\ kmph = \frac{5}{18} m\ s^{-1}\right)$

Final velocity of the car,

$v_2 = 20\ km/h = 20 \times \frac{5}{18}\ m\ s^{-1}$

Initial KE $= \frac{1}{2}mv_1^2$

Final KE $= \frac{1}{2}mv_2^2$

Change in K.E. = Final K.E – Initial K.E

$= \frac{1}{2}mv_2^2 - \frac{1}{2}mv_1^2 = \frac{1}{2}m\left(v_2^2 - v_1^2\right)$

$= \frac{1}{2}\times 1650\left[\left(20\times\frac{5}{18}\right)^2 - \left(65\times\frac{5}{18}\right)^2\right]$

$= 825\ [(30.8) - 325.8] = 825\ (-295)$

$= 243375$

Therefore, the kinetic energy is decreased by 243375 J.

9. Mass of the ball (m) = 800 g = 0.8 kg.

Height (h) = 20 cm = 0.2 m

Gravitational force (g) = 9.8 m s^{-2}

P.E = mgh

$= 0.8 \times 9.8 \times 0.2$

$= 1.568$ J.

10. Given, mass of the ball, m = 20 kg

Potential energy, when the ball reaches the highest point and the maximum height it reaches = ?

Kinetic energy = $\frac{1}{2}$ mv^2 and potential energy = mgh

K.E. = $\frac{1}{2}$ $(20)\ (6)^2 = \frac{1}{2} \times 20 \times 36$ J

$= 360$ J

At the highest point, the kinetic energy becomes zero, thus the entire K.E. of 360 J is converted into P.E. So the P.E. at the highest point is 360 J.

$\Rightarrow$ P.E = 360 J $\Rightarrow 360 = 20\times 9.8\times h$

$\Rightarrow h = \frac{360}{20\times 9.8} = 1.84$ m

$\therefore$ The maximum height the ball reaches is 1.84 m.

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Chapter 5

Turning Forces and Equilibrium

SOLUTIONS

BASIC PRACTICE

FILL IN THE BLANKS

3. The resultant of two like parallel forces = difference of the two forces

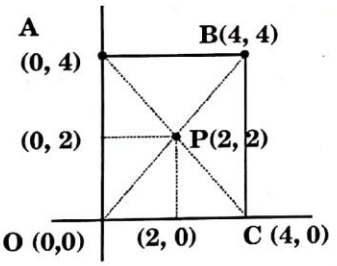
$= 12 - 7$

$= 5$ N

6. $\dfrac{\text{SI unit of torque}}{\text{CGS unit of Torque}} = \dfrac{\text{Nm}}{\text{dyne cm}}$

$= \dfrac{10^5 \text{ dyne} \times 10^2 \text{ cm}}{\text{dyne cm}} = 10^7 : 1$

7.



CG of square is at p (2, 2)

9. Turning force of

A to B = $F_A d_A : F_B d_B$

$I_A : I_B = 4 : 9$ (since $d_A = d_B$)

$\therefore$ Turning force of object B is greater

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. (A) Based on principle on moments, in the given options the figure in option (A) gives the direction in which the forces are acting. The correct order of forces for support A and support B is upwards which balances the force due to weight of the uniform rod acting downwards.

2. (A) The figure given in option (A) gives the correct forces acting on the rod due to support A and spring balance which is acting vertically upwards to balance the weight due to rod.

3. (B) Weight of rod acts vertically down. The force of floor and rough wall act on either ends of the rod. The force of rod on rough wall acts vertically upwards. Hence, the forces can be illustrated as in option (B).

4. (B) When a body is at rest, it is obeying principle of moments. Because for a body to be at rest (under equilibrium) the algebraic sum of moments acting on it is zero.

5. (D) Simple balance is an instrument that makes use of principle of moments during operation.

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6. (D) An object will not turn when all the forces are acting at its centre of gravity, as force is not away from the fixed point.

7. (D) When a uniform object is being supported at its centre of gravity, the total weight acts this point. Hence CG = weight due to presence of weight mass and force of gravity are non-zero. But a moment of force at this point is zero as object does not turn.

8. (C) An object is said to be equilibrium when there is no resultant force acting on the object, the total clockwise moments about any point is equal to the total anti-clockwise moments about the same point.

9. (D) Moment of force F about point W. = Force × distance between W & T.

$= F\ N \times (90 - 10)\ cm = 80F\ N\ cm.$

10. (B) To make wind mill stand still,

Algebraic sum of moments = 0

$(-3 \times 2) + (-2 \times 3) + (-1 \times 4) + (F \times 4) = 0$

$4F = 16 \Rightarrow F = 4N$

11. (B) For books to arrange in descending order of stability, is 2, 3, 1, 4. Because is book shelf 2 has more number of books arranged in its lower most shelf for greater stability. Next to that, book shelf 3 has more books. On comparing book shelves 1 and 4 shelf 1 is more stable as its second rack has more books compared to third rack.

12. (C) Force required to lift the beam vertically up

$F = m\,g\,\sin\theta\, l/2$

$F = 2 \times 10 \times \frac{1}{2} \times 1$

$F = 10\ N$

13. (A) As the beamis at equilibrium, sum of clockwise moments = sum of anticlockwise moments.

$\therefore$ $F \times 2 = 4 \times 1$ (3 N is a parallel force no moment is created)

$\Rightarrow F = \frac{4}{2} = 2\ N$

14. (C) As the beam is horizontal is at equilibrium,

Sum of clockwise moments = sum of anticlock wise moments.

$5 \times 40 = F \times 10 + 3 \times 30$

$10F = 200 - 90$

$F = \frac{11\cancel{0}}{1\cancel{0}} = 11\ N$

$G = F - 6\ N = 5\ N$

15. (D) Clock wise moment about the point of balancing

$= F \times (60 - 50) + 3 \times (80 - 50)$

$= 10\ F + 30 \times 3$

$= (10F + 90)\ N\ cm.$

Anti clockwise moments about the point of balancing

$= 5 \times (50 - 10) = 200\ N\ cm$

According to principle of moment

$10F + 90 = 200.$

or $10F = 200 - 90$

$F = \frac{110}{10} = 11\ N$

MULTIPLE ANSWERS QUESTIONS

1.(A,B,C,D) Cycling, swimming, badminton and Hockey are the sports that uses the turning effect of forces.

2. (A,C,D) See-saw, Swing and Toy horse are the playground equipment make use of the turning effect of forces.

3. (A.B,D) A sleeping cat, a flask resting on a table and winding a clock are the objects is/are in equilibrium.

4.(A,B,C) Opening the lid of cool drink bottle, opening the lid of a tin and opening the door are the applications of torque.

5.(A,B,D) The properties of moment of a couple are:

(i) It tends to produce pure rotation, It is different about any point in the plane of lines of action of the forces.

(ii) The resultant of set of two or more couples is equal to the sum of the moments of the individual couples.

ASSERTION AND REASONING

1. (B) The centre of mass of a body may lie where there is no mass.

Centre of mass of a body is a point, where the whole mass of the body is supposed to be concentrated.

2. (D) The position of centre of mass of a body depends upon the shape and size of the body.

Centre of mass of a body lies always at the centre of the body.

3. (C) It is harder to open and shut the door if we apply force near the hinge.

Torque is maximum when applied away from the hinge of the door.

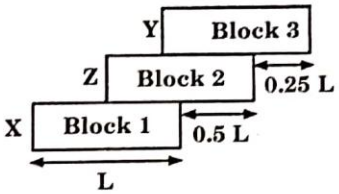
4. (A) A sphere cannot roll on a smooth inclined surface. Becuase for a smooth inclined surface force of friction is equal to zero.

5. (C) To unscrew a rusted nut, we need a wrench with longer arm. Wrench with longer arm increases the torque of the arm.

6. (A) The centre of mass of uniform triangular lamina is centroid. Because centroid is centre of symmetry of mass of the triangular.

PARAGRAPH QUESTIONS

(i) (B)



The maximum horizontal distance betwen side 'X' of block1 and side 'Y' of block 3 before any of the block topples = 1 L + 0.25 L + 0.5 L = 1.75 L.

(ii) (C) The maximum horizontal distance betwen side 'X' of block1 and side 'Z' of block 2 before any of the block topples = 1 L + 0.25 L = 1.25 L.

NUMERICAL PROBLEMS

1. T = F × ⊥ distance
= 8 × 125 dyne cm
= 1000 dyne cm

2. T = force × ⊥ distance
= 1875 dyne × 20 cm
= 37500 dyne cm

3. T = Force × ⊥ distance
2100 = force × 60 cm

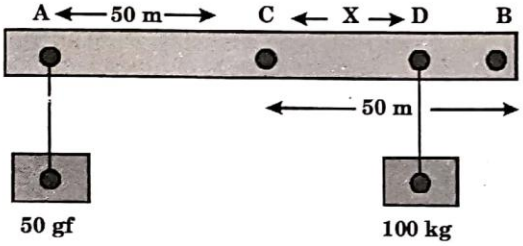
$$\text{force} = \frac{2100}{60} = 35\,\text{dyne}$$

4. F = 8 N
T = 4 N m
T = force × distance
4 = 8 × distance
distance = 0.5 m

∴ Distance of point of application of the force from the point p is 0.5 m

5. Let AB be the uniform metre rule, such that C is its midpoint. The metre rule is pivoted at C, such that AC = 50 cm and CB = 50 cm. 50 gf weight is suspended near A.

Let D be the point of suspension of 100 gf weight at a distance of x from C, so that the rule is horizontal.



Left hand side moment,

LHM = 50 × 50 = 2500 gf cm ... (1)

Right hand side moment,

RHM = x × 100 = 100 × gf cm ...(2)

To keep the rule horizontal,

LHM = RHM

2500 = 100x ⇒ x = 25 cm.

∴ 100 gf is to be suspended at a distance of 25 cm from mid point (or) 75 cm from the end of the rule.

6. Let mass of each coin is 'm'.

Then the weight of each coin = mg.

The distance of 5 coins on right sides is x, from the mid point.

Let hand side moment by 4 coins at mark 4 is.

LHM = 4 mg × 4 ..... (1)

Right hand side moment by 5 coins at mark x is,

RHM = x × 5 mg

According to the law of moments,

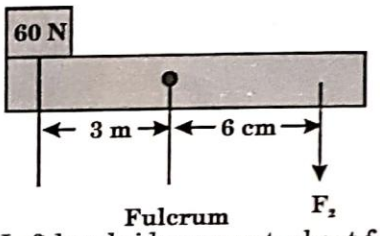
LHM = RHM.

4 mg × 4 = x × 5 mg

$$\Rightarrow \quad x = \frac{16}{5} = 3.2$$

5 coins should be located at 3.2, on right side.

7. $F_1 = 60$ N, $l_1 = 3$ m, $l_2 = 6$ cm, $F_2 = ?$



Left hand side moment, about fulcrum = 60 × 3 = 180 N m.

Right hand side movement, about fulcrum = $6 \times 10^{-2} \times x$ Nm.

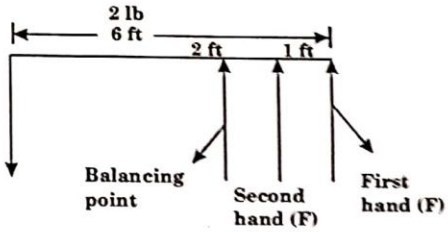
According to principle of moment, L.H.M = R.H.M

$$180 = 6 \times 10^{-2} \times x$$

$$x = \frac{180}{6 \times 10^{-2}} = 3000 \text{ N}$$

Therefore, a force of 3000 N is required to lift the load.

8. At the balancing condition, clockwise moment produced by weight of the scale, should be equal to anti clockwise moment produced by 100N.



Anti clockwise moment produced by 100 N weight is

= F × distance from the balancing point.

= 100 × x

Clockwise moment produce by weight of the scale = W × (5 – x) = 100 (5 – x)

At the balancing condition.

Clock wise moment

= Anti-clockwise moment.

$100x = 100(5 - x)$

$$x = \frac{100(5-x)}{100} \Rightarrow x = 5 - x$$

$$2x = 5x = \frac{5}{2} = 2.5 \text{ m}$$

10 m length rod will balance at 2.5 m from the extreme.

9. Let the metre scale is balanced at X cm mark on the scale.

At the balancing condition, Anticlock wise moment must be equal to clock wise moment.

Clockwise moment, about the balancing point is

= moment by 80 gf

= 80 gf × (80 – X) cm

= 6400 gf cm – 80 X gf cm ..... (1)

Anticlock wise moment about the balancing point is

= moment by 10gf + moment by 50 gf

= 10 gf × (X – 10) + 50 gf × (X – 50)

= 10 X gf cm – 100 gfcm

+ 50 Xgfcm – 2500 gfcm ..... (2)

At the balancing condition, Clock wise at equilibrium = Anti clock wise moments.

$6400 - 80X = 100X - 100 + 50X - 2500$

$6400 + 2600 = 140X \Rightarrow 140X = 8000$

$$\Rightarrow X = \frac{8000}{140} = 64.28 \text{ cm}$$

Scale is balanced at 64.28 cm from the beginning.

10. Force (F) = 1600 dyne

Perpendicular distance = 40 cm

∴ Moment of force

= F × Perpendicular distance

= 1600 × 40

= 64,000 dyne-cm.

11. F = 525 N

$\tau = 420$ N – m

Moment of force

= Force × Perpendicular distance

∴ 420 N-m = 525 N × Perpendicular distance.

∴ Perpendicular distance

$$= \frac{420}{525} = 0.8 \text{ m}$$

0.8 m is the shortest distance between the point of application of force and the turning point.

12. With repeat to A,

$1000 \times (2.5 - x) = 4F \times (2.5)1000$

with repeat to B,

$1000 \times x = F \times 2.5$

$$\frac{1000 \times (2.5 - x)}{1000 \times (x)} = \frac{(4F \times 2.5)}{F \times 2.5}$$

$$\frac{(2.5 - x)}{x} = 4$$

$4x = 2.5 - x$

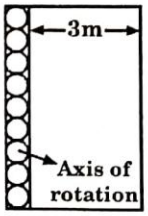
$5x = 2.5$

$x = 0.5$ m

CONCEPTUAL QUESTIONS

1. The force F should be applied in horizontal direction, which will produce clock wise moment and will pull the body on the pavement (XY).

2. The least force which can open the door



By applying for F_1 = 100 N of force at the middle of the door i.e., d_1 = 1.5 m from the fixed point we can open the door.

The couple required to open $C_1 = F_1 d_1$ required force is minimum where F_2 force is applied at the end. i.e., d_2 = 3 m.

$F_2 = ?\ C_2 = d_2 F_2$

In both the cases couple is same.

$$C_1 = C_2; \qquad F_1 d_1 = F_2 d_2$$

$$100 \times 1.5 = F_2 \times 3 \Rightarrow \frac{100 \times 1.5}{3} = F_2$$

F_2 = 50 N.

3. Let M_1 and M_2 be the moment of forces of 1st and 2nd levers, respectively.

Lever - I	**Lever - II**
F_1 = 10 N	F_2 = 8 N
l_1 = 3 m	l_2 = 4 m
M_1 = ?	M_2 = ?
Moment of force,	Moment of force,
$M_1 = F_1 \times l_1$	$M_2 = F_2 \times l_1$
= 10 × 3	= 30 N m
= 8 × 4	= 32 N m

From the above observation, it is clear that $M_2 > M_1$

i.e., Moment of force produced by the 2nd lever is more than the first lever.

4. Let the length of the handle be 1 cm

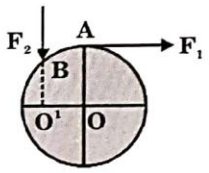
Applying principle of lever,

Effort × Effort arm = load × load arm

$$F \times h = l \times \left(\frac{2F}{3}\right)$$

$$l = \frac{F \times h}{2F/3} = \frac{3h}{2} \text{ cm}$$

5. Force F_1 applied at A, produces clockwise moment of the wheel. It can be stopped by applying the force F_2 at B, in a direction such that it produces anti-clockwise moment. Therefore, forces should be applied in the downward direction as shown in the figure.



Moment of force by F_1 about O

$= F_1 \times OA.$

Moment of force by F_2 about O

$= F_2 \times OO^1.$

When the wheel is in equilibrium position,

$$F_1 \times OA = F_2 \times OO^1$$

$$\frac{F_2}{F_1} = \frac{OA}{OO^1} \qquad \text{..... (1)}$$

Since $OA > OO^1$ then $F_2 > F_1$

F_2 is greater force than F_1.

The ratio of forces $\frac{F_2}{F_1} = \frac{x}{3x} = 1:3$

6. (i) If the resulting torque on a body is zero the body is under rotational equilibrium. Hence no effect of the torques acting on the body.

(ii) If the resulting torque on a body is non-zero the body can either move in clockwise or anti clockwise direction. If algebraic sum of torque i.e., $\Sigma\tau$ = positive body moves in anticlock wise direction.

If algebraic sum of torque i.e., $\Sigma\tau$ = negative .

If algebraic sum of clockwise direction.

PREVIOUS CONTEST QUESTIONS

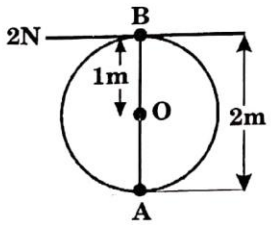
1. (B) The unit of torque is N m.
2. (A) If F is force and r is radius, then torque = $\vec{F}\times\vec{r}$
3. (C) A bicycle tyre in motion has linear and rotatory motion.
4. (B) Since the metre rule is uniform, the CM will be at the middle i.e. 50 cm. Then, mass of ruler $(w)\times(55-50)=25(100-55)$

$$w=\frac{25\times45}{5}=225\text{ g}$$

5. (A) The principle involved in the construction of beam balance is principle of moments.
6. (B) A couple always tends to produce rotatory motion.

BRAIN NURTURES

1.



Applied force F = 2N.

(i) Moment of force about O is

$\tau_1 = F\times OB = 2\times1 = 2$ N m

(ii) Moment of force about A is

$\tau_2 = F\times AB = 2\times2 = 4$ N m

2. $F_1 = 4$ N, $F_2 = 4$ N, $F_2 = 6$ N

(i) Moment by F_1 is = $F_1 \times 3$ m

$= 4 \times 3$ m .....(1)

= 12 N m

Moment by F_2 is = $F_2 \times 1$ m

$= 4 \times 1 = 4$ N m

Moment by F_3 about O is

$= F_3 \times 1$ m = 6 N × 1 m = 6 N m

Least moment from the above data is by F_2

(ii) Greatest moment from the above data is by F_1

Clock wise moment is taken as negative and Anti-clockwise moment is taken as positive.

(iii) Force F_3 has positive moment.

(iv) F_1 and F_2 have negative moment.

3. Two forces $F_1 = 5$ N and $F_2 = 5$ N are acting

About X: $d_1 = 1$ m, $d_2 = 1$ m

Net moment = Moment by F_1 – Moment by F_2 about X

$= F_1 d_1 - F_2 d_2$

$= (5 \times 1) - (5 \times) = 0$ N m,

About Y: $d_1 = 2$m, $d_2 = 0$ m.

Net moment about Y = Moment by F_1 – Moment by $F_2 = F_1 d_1 - F_2 d_2$

$= (5 \times 2) - (5 \times 0)$

$= 10 - 0 = 10$ N m.

4. The metre scale is uniform, so, its weight acts at 50 cm mark. Metre scale is balanced at 40 cm mark with weights 25 gf and 10 gf at 5 cm and 75 cm mark. Under the equilibrium condition, anti-clock wise moments is equal to clockwise moments.

Clock wise moments produced about the balancing point is

= moment by weight of the scale + moment by 10 gf

= 10Wcm + 10 gf × 35 cm

= 10Wcm + 350 gf cm .....(1)

The unit of torque is N m

Anti clock wise moments produced about, the balancing point = moment produced by 25 gf = 25 gf × 35 cm

= 25 gf × 35 cm = 875 gf cm .....(2)

Under the equilibrium condition, eq.(1) is equal to eq. (2).

L.H.M = R.H.M.

10 W cm+350 gf×cm = 875 gf× cm

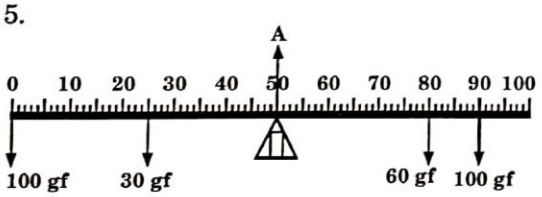
10 W cm = (875 – 350) gf × cm

10 W cm = 525 gf cm

$$\Rightarrow \quad W = \frac{525 \text{ gf}}{10} = 52.5 \text{ gf}$$

Weight of the scale is 52.5 gf.

5.



A.C.M = (100 × 50) + (30 × 25)

= 5000 + 750 = 5700

C.W.M = (60 × 30) + (100 × 40)

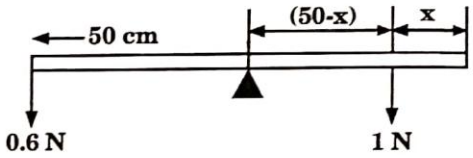
= 1800 + 4000 = 5800

Total moment about A is

= C.W.M – A.C.W

Result = 5800 – 5750 = 50 gf cm.

6.



To find the distance we have to find clockwise moment and anti clock wise moment.

Clock wise moment = force × distance from the balancing point

= 0.6 N × 50

Under balancing Condition

ACM – Anti clockwise moments

CWM – Clockwise moments

0.6 × 50 = 1 × (50 – x)

30 = (50 – x)

x = 50 – 30 = 20 cm.

❖ ❖ ❖

Chapter 6

Gravitation

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (B) $\frac{1}{4}g = \frac{g}{\left(1+\frac{h}{R}\right)^2}$

$1+\frac{h}{R} = 2 \Rightarrow \frac{h}{R} = 1$

$h = R$

2. (D) $R^1 = \frac{R}{2}$

M = constant

$W^1 \propto g^1$

$g^1 = g\left(\frac{R}{R^1}\right)^2$

$g^1 = g(4)$

$\frac{g^1 - g}{g} \times 100 = \frac{4g - g}{g} \times 100 = 300\%$

3. (D) $W_{earth} = 72\ N = mg$

$h = \frac{R}{2}$

$g_h = \frac{g}{\left(1+\frac{h}{R}\right)^2} = \frac{g}{\left(1+\frac{1}{2}\right)^2} = \frac{g}{9}(4)$

$W_{height} = mg_h$

$= m \times g\left(\frac{4}{9}\right) = 72 \times \frac{4}{9} = 32\ N$

4. (B) As value of g is minimum at equator for same value of mass. Weight of 1 kg sugar is measured less at equator.

5. (A) In the figure shown, at point P_1 the kinetic energy of the planet is maximum as it has the least value of radius vector with greater forces of gravitational attraction.

6. (C) Mass of a body remains same at any place in the universe. Hence the mass of a body M on earth is same as on the moon's surface.

7. (C) As we go from equator to poles the value of g increases. This is because the value of latitude causes the decrease in the g value and also $R_{equatorial} > R_{poles}$

8. (A) $W_{earth} = 700\ N = mg_{earth}$

$g_{planet} = \frac{GM_{planet}}{R^2_{planet}} = \frac{G\left(\frac{1}{7}M_{earth}\right)}{\left(\frac{1}{2}R_{earth}\right)^2}$

$= \frac{4}{7}\frac{GM_{earth}}{(R_{earth})^2} = \frac{4}{7}g_{earth}$

$W_{planet} = mg_{planet}$

$= m \times \frac{4}{7} \times g_{earth}\ N$

$= \frac{4}{7} \times 700\ N = 400\ N$

9. (D) The value of g is maximum at poles and minimum at equator.

10. (D) $T_1 \Rightarrow g$

$T_2 \Rightarrow$ at a height R

$g_R = g\Big/\left(1+\frac{h}{R}\right)^2 = \frac{g}{4}$

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$$\frac{T_1}{T_2} = \sqrt{\frac{g_R}{g}} = \sqrt{\frac{g}{4g}} = \frac{1}{2}$$

11. (A) Let acceleration due to gravity at a place be g_d. If g is accèleration due to gravity at the surface then,

$$g_d = g\left(1 - \frac{d}{R}\right)$$

$$0.99\cancel{g} = \cancel{g}\left(1 - \frac{d}{R}\right)$$

$$\frac{d}{R} = (0.01)$$

d = 0.01 × 6400 = 64 km below the surface of earth

12. (B) $V_e^1 = 10\,V_e$

$$V_e = \sqrt{2gR} = \sqrt{\frac{2GM}{R}}$$

$$100 = \frac{R}{R_1}; \quad R_1 = \frac{R}{100} = 64\,\text{km}$$

13. (D) Given $M_p = 2\,M_e$

$(R_p) = 2\,R_e$

$T_{earth} = 2\,s$

$$T = 2\pi\sqrt{\frac{l(R^2)}{GM}}$$

$$\frac{T_{planet}}{T_{earth}} = \sqrt{\frac{Rp^2}{M_p} \times \frac{M_e}{R_e^2}} = \sqrt{\frac{\cancel{4} \times 1}{\cancel{2}}} = \sqrt{2}$$

$$T_{planet} = \sqrt{2}\ T_{earth}$$

$$= \sqrt{2} \times 2 = 2\sqrt{2}\ s$$

14. (C) $$h = \frac{\left(\frac{3}{4}\sqrt{2gR}\right)^2}{2g} = \frac{9(2gR)}{16 \times 2g} = \frac{9}{16}R$$

15. (B) The gravitational force with which the earth attracts the moon is equal to the force with which the moon attracts the earth.

16. (B) The value of g at a place increases with increase in the latitude of the place.

17. (D) $d_{neptune} = 10^{13}$ m ; $d_{Saturn} = 10^{12}$ m

$T^2 \alpha R^3$ (Kepler's 3rd law)

$$\left(\frac{T_{neptune}}{T_{saturn}}\right)^2 = \left(\frac{d_{neptune}}{d_{saturn}}\right)^3$$

$$\left(\frac{10^{13}}{10^{12}}\right)^3$$

$$\frac{T_{neptune}}{T_{saturn}} = \sqrt{\frac{1000}{1}}$$

$$\frac{T_{neptune}}{T_{saturn}} = 10\sqrt{10} : 1$$

18. (B) $V_e = 11\ km\ s^{-1}$; $V_e = \sqrt{\frac{2GM}{R}}$

$M_e = 2M$; $R_e = 2R$

$$V_e^1 = \sqrt{\frac{2GM_e}{R_e^1}} = \sqrt{\frac{2GM(\cancel{2})}{\cancel{2}R}} = V_e$$

19. (A) If x is the distance of that point from 2 kg, then

$$x = \frac{r}{\sqrt{\frac{m_1}{m_2} + 1}} = \frac{9}{\sqrt{\frac{8}{2} + 1}} = 3\,m$$

It means distance of that point from 8 kg is 6 m.

20. (A) On the earth, $h = \frac{1}{2}gt^2$ where

$$g = \frac{GM}{R^2}$$

On that planet $h' = \frac{1}{2}g't^2$ where

$$g' = \frac{G2M}{(2R)^2} = \frac{g}{2} \text{ then } h' = \frac{1}{2}.\frac{g}{2}.t^2 = \frac{h}{2}.$$

MULTIPLE ANSWER QUESTIONS

1. (A,B,D) The acceleration due to gravity 'g' decreases if we go down from the surface of the earth towards its centre As g is proportional to $(d)^{-1}$, we go up from the surface of earth $g \propto (R+h)^{-2}$ and the rotational velocity of the earth is increased $g \propto \omega$.

2. (A,C,D) $R_A:R_B = 2:5$, $D_A: D_B = 1:6$

$g_A : g_B =$

$$\frac{\frac{GM_A}{R_A^2}}{\frac{GM_B}{R_B^2}} = \frac{4}{3}\pi\frac{R^3{}_A D_A}{R_A^2} \times \frac{R_B^2}{\frac{4}{3}\pi R_B^3 d_B} = \frac{R_A d_A}{R_B d_B}$$

$$\frac{g_A}{g_B} = \frac{2}{5} \times \frac{1}{6} = \frac{1}{15}$$

$W_B = m g_B = 15\ m g_A = 15\ W_A$

For the same volume of planets, mass of planet A is 1/6 the mass of planet B.

Planet B have greater volume than planet A.

3. (A,B,C) If a body is projected with speed less than escape velocity the body:
can reach a certain height and may fall down following a straight line path.
can reach a certain height and may fall down following a parabolic path.
may orbit the earth in a circular orbit.

4. (B,C,D) A planet rotating around the sun in an elliptical orbit has:
(i) Its kinetic energy varying due to non uniform speed of the planet.
(ii) Its angular momentum is constant as areal velocity is constant.
(iii) Its areal velocity is constant.
(iv) Its time period is proportional to r^3 according to Kepler's law of periods.

5. (B,D) The escape velocity from a planet of mass (M), radius (R) and acceleration due to gravity (g) is given by:

$$= \sqrt{2gR} = \sqrt{\frac{2GM(R)}{R^2}} = \sqrt{\frac{2GM}{R}}$$

ASSERTION AND REASONING

1. (A) According to Kepler's third law of motion, the square of time period of a planet about the sun is proportional to the cube of the semi major of the ellipse or mean distance of the planet from sun. i.e. $T^2 \propto a^3$, where a is smaller, shorter is the time period. Hence, smaller the orbit, less is the period of revolution.

2. (E) The universal gravitational constant G is totally different from g. The constant G is scalar and possess the dimensions.

$$\left[M^{-1}L^3T^{-2}\right]\left(G = \frac{FR^2}{Mm}\right)$$

While G is a vector and has got the dimensions.

$$\left[M^0LT^{-2}\right]\left(g = \frac{GM}{R^2}\right).$$

It is not a universal constant.

3. (C) Acceleration due to gravity is given by $g = \frac{GM}{R^2}$.

Thus it does not depend on mass of body on which it is acting. Also it is not a constant quantity changes with change in value of both M and R (distance between two bodies). Even for earth it is a constant only near the earth's surface.

4. (C) The value of g at any place is given by the relation,

$g' = g - \omega^2 R_e \cos^2\lambda$

When λ is angle of latitude and ω is the angular velocity of earth.

If $\omega = 0$, $\therefore$ $g' = g$, there is no rotation.

5. (B) Acceleration due to gravity,

$g^1 = g - R_e\omega^2 \cos^2\lambda$

At equator, $\lambda = 0°$ $\therefore \cos 0° = 1$

$\therefore g_e = g - R_e\omega^2$

At poles, $\lambda = 90°$ $\therefore \cos 90° = 0$

$\therefore g_p = g$

Thus,

$g_p - g_e = g - g + R_e\omega^2 = R_e\omega^2$

Also, the value of g is maximum at poles and minimum equator.

6. (C) According to Kepler's law of planetary motion, a planet revolves around the sun in such a way that its areal velocity is constant. i.e., it move faster when it is closer the sun and vice versa.

7. (B) The value of escape velocity on the surface of moon is small (only 2.5 km s^{-1}). The molecules of the atmosphere gases, on the moon have thermal velocity greater than escape velocity. Due to which all the molecules of gases have escaped and there is no atmosphere.

8. (E) As, escape velocity = $\sqrt{\frac{2GM}{R}}$, so it value depends on mass of planet and radius of planet. The two different planets have same escape velocity, when these quantities (mass and radius) of planets are equal.

9. (A) According to Newton's law of gravitation, $F = \frac{Gm_1m_2}{r^2}$.

When m_1, m_2 and r all are doubled,

$$F = \frac{G(2m_1)(2m_2)}{(2r^2)} = \frac{Gm_1m_2}{r^2}$$

i.e., F remains the same.

10. (E) The radius and mass of Jupiter's larger than that of earth.

Therefore, the escape velocity $\left(= \frac{\sqrt{2Gm}}{R}\right)$ is more at the surface of Jupiter than at earth's surface.

PARAGRAPH QUESTIONS

(i) (A) As the planet revolves round the sun from position P to Q, the radius vector decreases, hence velocity of the planet increases as mvr = constant.

(ii) (B) V_1 is velocity at position P_1 and V_2 is velocity at position Q. $V_1 < V_2$ as velocity of planet increases from P to Q.

(iii) (C) According to Kepler's law of areas, a planet sweeps equal areas in equal intervals of time. Since time periods to change positions from P to X and Q to Y are equal, the areas A_1 and A_2 swept in this time interval are equal i.e. $A_1 : A_2 = 1$

NUMERICAL PROBLEMS

1. $g_p = \frac{1}{4}g_e$

$w_e = mg_e$

$w_p = mg_p = m\left(\frac{1}{4}g_e\right)$

$w_p = \frac{1}{4}w_e$

% change in weight = $\frac{w_p - w_e}{w_e} \times 100$

$= \frac{\frac{1}{4}w_e - w_e}{w_e} \times 100 = \frac{-3}{4} \times 100 = -75\%$

2. $F_{gravitation} = \frac{6.67 \times 10^{-11} \times 10^5 \times 10^5}{(10)^2}$

$= 6.67 \times 10^{1-2}$

$= 6.67 \times 10^{-3}$ N

3. Here G = 6.67 × 10-11 N m^2 kg^{-2}

$M_1 = M_2 = 1.67 \times 10^{-27}$ kg ;

r = 1 Å = 10^{-10} m

Now, $F = G\frac{M_1M_2}{r^2}$

$= \frac{6.67 \times 10^{-11} \times 1.67 \times 10^{-27} \times 1.67 \times 10^{-27}}{(10^{-10})^2}$

$= 1.86 \times 10^{-44}$ N

4. Given $F = \frac{Gm^2}{a^2}$

(a) Final mass of one object is
m + 0.25 m = 1.25 m
Then

$$F' = \frac{G(1.25\ m)^2}{a^2} = 1.5625F$$

(b) Final distance between the masses is = a + 0.5a = 1.5 a
Then,

$$F' = \frac{G \times m^2}{(1.5a)^2} = \frac{Gm^2}{2.25(a)^2} = \frac{4}{9}F$$

5. Given $M_{planet} = \frac{1}{4} M_{earth}$ and

$R_{planet} = \frac{4}{3} R_{earth}$,

(a) $W = 160\ N = mg_{earth}$

$$g_{planet} = \frac{G\left(\frac{1}{4}M_{earth}\right)}{\left(\frac{1}{3}R_{earth}\right)^2}$$

$$= \frac{9}{4}\frac{GM_{earth}}{R^2_{earth}} = \frac{9}{4}g_{earth}$$

$$W_{planet} = m\ g_{planet}$$

$$= m\left(\frac{9}{4}g_{earth}\right)$$

$$= \frac{9}{4} \times 160 = 360N$$

(b) Given $M_{planet} = \frac{5}{2} M_{earth}$ and

$R_{planet} = \frac{4}{5} R_{earth}$,

$W = 160\ N = mg_{earth}$

$$g_{planet} = \frac{G\left(\frac{5}{2}M_{earth}\right)}{\left(\frac{4}{5}R_{earth}\right)^2}$$

$$= \frac{125}{32}\frac{GM_{earth}}{R^2_{earth}} = \frac{125}{32}g_{earth}$$

$$W_{planet} = m\ g_{planet}$$

$$= m\left(\frac{125}{32}g_{earth}\right)$$

$$= \frac{125}{32} \times 160 = 625N$$

6. Given $M_{earth} = 81\ m_{moon}$

Let p be a null point

Let x m be distance from moon to the null point.

Distance of null point from earth is $(3.8 \times 10^8 - x)$ m

Force due to earth on null point

= Force due to moon on null point

$$\frac{Gm_{earth}(1)}{(3.8 \times 10^8 - x)^2} = \frac{Gm_{moon}(1)}{x^2}$$

$$\frac{81m_{moon}}{(3.8 \times 10^8 - x)^2} = \frac{m_{moon}}{x^2}$$

$$\frac{9}{3.8 \times 10^8 - x} = \frac{1}{x}$$

$$9x = 3.8 \times 10^8 - x$$

$$x = 3.8 \times 10^7\ m$$

The net is zero at 3.8×10^7 m from moon.

7. Let null point be x m from 10^4 kg mass. Distance of null point from 10^6 kg mass is $(1.21 \times 10^3 - x)$ m

$$\therefore \frac{10^4}{x^2} = \frac{10^6}{(1.21 \times 10^3 - x)^2}$$

Taking square root

$$\frac{1}{x} = \frac{10}{(1.21 \times 10^3 - x)}$$

$$10x = 1.21 \times 10^3 - x$$

$$11x = 1.21 \times 10^3$$

$$x = \frac{1.21 \times 10^3}{11} = 110\ m$$

8. $\frac{2g}{5} = g\left(1 - \frac{d}{R}\right)$

$\frac{d}{R} = 1 - \frac{2}{5}$; $d = \frac{3}{5}R$

9. $g_h = \frac{gR^2}{(R+h)^2}$

(a) $\frac{g}{2} = \frac{gR^2}{(R+h)^2}$

$(R + h)^2 = 2R^2$

$(R + h) = \sqrt{2}R$

$h = R(\sqrt{2} - 1)$

(b) $\frac{4g}{9} = \frac{gR^2}{(R+h)^2}$

$4(R + h)^2 = 9R^2$

$2(R + h) = 3R$; $h = R/2$

(c) $\frac{g}{100} = \frac{gR^2}{(R+h)^2}$

$(R + h)^2 = 100R^2$

$(R + h) = 10R$

$h = 9R$

10. $W_d = 100$ N at a distance $\frac{R}{4}$ from centre of earth.

$\therefore \quad d = R - \frac{R}{4} = \frac{3R}{4}$

$\therefore \quad g_d = g\left(1 - \frac{d}{R}\right)$; $g_d = g/4$

Now mass $= \frac{W_d}{g_d} = \frac{400}{g}$

At height 9R,

$g_h = \frac{g(R^2)}{100R^2} = \frac{g}{100}$

$\therefore \quad w_h = mg_h = \frac{400}{g} \times \frac{g}{100} = 4$ N

11. $m_1 = m_2 = 50$ kg, $r = 1$ m,

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

Force of gravitation

$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11} \times 50 \times 50}{(1)^2}$

$= 1.67 \times 10^{-7}$ N

Force of gravity $F' = \frac{GMm}{r^2}$,

Here $r = R$ (the radius of earth)

and $m_1 = m_2 = m$

$F' = \frac{6.67 \times 10^{-11} \times 6 \times 10^{24} \times 50}{(6.4 \times 10^6)^2}$

$= 0.48 \times 10^3$ N

F' is much greater than F so the persons will not move towards each other but each of them moves towards the earth.

12. According to Newton's law of gravitation,

$F = \frac{GM_1M_2}{R^2}$; $F' = \frac{GM_1M_2}{(R+d)^2}$

$\therefore \frac{F'}{F} = \frac{R^2}{(R+d)^2}$; $\therefore F' = \frac{R^2F}{(R+d)^2}$

13. Let u be the speed of the man, while talking the jump and h, the height of the jump.

From the relation : $v^2 - u^2 = 2as$,

we have $0^2 - u^2 = 2 \times (-g) \times h$, or

$h = \frac{u^2}{2g}$.

If h_A and h_B are the heights of jump on the planets A and B respectively, then

$\frac{h_B}{h_A} = \frac{u^2}{2g_B} \times \frac{2g_A}{u^2} = \frac{8g_B}{g_B} = 8$

or $h_A = 8 \times 1.5 = 12$ m

CONCEPTUAL QUESTIONS

1. Given $F = K\frac{\sqrt{m_1m_2}}{d^3}$

If m_1, m_2 are doubled,

new masses are $2m_1$, $2m_2$

F = Constant

Let new distance of separation be d^1 then,

$$K\frac{\sqrt{m_1m_2}}{d^3} = K\frac{\sqrt{(2m_1)(2m_2)}}{d^{13}}$$

$$(d)^3 = 2d^3 ; d^1 = \sqrt[3]{2d}$$

New distance of separation is $\sqrt[3]{2}$ time initial value.

2. Weight = mass × g at the given place

For a given mass of body if g value increases weight measure increases.

So, for the given mass to be profitable to sell the given weight is at poles.

3. Common balance gives the mass of an object spring balance gives the weight of an object.

Since mass being same throughout universe common balance does not change i.e reading X remains same. Spring balance i.e reading Y reads less since $g_m = \frac{1}{6} g_e$

4. Earth is moving around the sun to overcome the gravitational pull of sun.

5. Let M and R be the mass and radius of the earth.

Then, the weight of a body of mass m,

$$W = \frac{GMm}{R^2}$$

If the earth becomes of diameter i.e. of radius two times its present value (mass unchanged), the weight of the body of mass m will become.

$$W^1 = \frac{GMm}{(2R)^2} = \frac{1}{4}\times\frac{GMm}{R^2} = \frac{1}{4}W$$

i.e., weight of the body will become one fourth of the present value.

6. If g is acceleration due to gravity on the surface of earth, then weight of the body on the surface of earth,

$$W = Mg$$

Since, $g = 9.8 \text{ m s}^{-2}$,

We have $W = M \times 9.8 \text{ N}$

Therefore, weight of the body per unit mass $= \frac{M\times 9.8}{M} = 9.8 \text{ N kg}^{-1}$

PREVIOUS CONTEST QUESTIONS

1. (A) $\frac{g_e}{g_m} = \frac{\frac{4}{3}G\pi R\rho_e}{\frac{4}{3}G\pi R\rho_m} = \frac{R}{r}.\frac{\rho_e}{\rho_m}$

2. (A) Value of g is maximum at poles.

3. (B) $g_m = \frac{GM_m}{R^2_m} = \frac{G\left(\frac{1}{80}\right)M_e}{\left(\frac{R_e}{4}\right)^2} = \frac{16}{80}\times g_e$

$\frac{16}{80}\times 9.8 = 1.96 \text{ m s}^{-2}$

4. (D) $\frac{R^1 - R}{R}\times 100 = -1$

$R^1 = 0.99R$

$g^1 = \frac{G(M)}{(99R)^2} = \frac{g}{(0.99)^2}$

Percentage change in $g = \frac{g^1 - g}{g}\times 100$

$= \left(\frac{1}{(0.99)^2 - 1}\right)\times 100 = 2\%$

5. (A) $g^1 = g/\left(1+\frac{h}{R}\right)^2$

$0.99 = \frac{1}{\left(1+\frac{h}{R}\right)^2}$

$0.995 = \frac{R}{R+h}$

$0.995\ h = 0.0050\ R$

$h = 32.2 \text{ km}$

6. (A) $g = 980 \text{ cm s}^{-2}$

$g_h = g\left(1-\frac{2h}{R}\right) = 980\left(1-\frac{2(64)}{6400}\right)$

$= 960.40 \text{ cm s}^{-2}$

7. (B) $g = G\left[\frac{4}{3}\pi R_e\right]\rho$

$$\rho = \frac{\left(\frac{g}{G}\right)}{\frac{4}{3}\pi R_e}$$

8. (B) The acceleration due to gravity on the surface of earth varies directly with latitude.

9. (B) $g = \frac{GM}{R^2}$

If $R^1 = \frac{R}{2}, M^1 = M$

$$g^1 = \frac{GM}{\left(\frac{R}{2}\right)^2} = 4\frac{GM}{R^2} = 4g$$

10. (A) As the value of g decreases continuously as we, move consecutively from earth's surface. The weight indicated by a spring balance of a body at consecutively increasing height from earth's surface also decreases.

11. (D) Given $g = \frac{GM}{R^2}$

$$1 - 1.5 = \frac{R^1 - R}{R} \times 100$$

$R^1 = -0.015\,R + R = 0.985\,R$

$$g^1 = \frac{GM}{R_1^2} = \frac{GM}{(0.985)^2 R^2} = \frac{g}{(0.985)^2}$$

percentage change in

$$g = \frac{g^1 - g}{g} \times 100$$

$$= \frac{\left(\frac{g}{(0.985)^2} - g\right)}{g} \times 100$$

$$= \frac{0.029775}{0.970225} \times 100 = 4\%$$

12. (B) $g_m = \frac{GM}{R^2}$

$$1.4 = \frac{(6.667 \times 10^{-11})(7.34 \times 10^{22})}{R^2}$$

$$R = \sqrt{\frac{6.667 \times 10^{-11}(7.34 \times 10^{22})}{1.4}}$$

$$= \sqrt{34.95 \times 10^{11}} = 1.87 \times 10^6\,m$$

13. (B) $g_m = \frac{GM_m}{R_m^2} = \frac{G\left(\frac{1}{80}M_e\right)}{\left(\frac{1}{4}R_e\right)^2}$

$$= \frac{16}{80}\frac{GM_e}{R_e^2} = \frac{g}{5}$$

14. (A) The gravitational force that earth exerts on the moon is equal to the gravitational force the moon exerts on earth.

15. (D) $W_e = mg_e = 60$ kg

$$w_m = mg_m = \frac{mg_e}{6} = \frac{60}{6} = 10\,kg$$

BRAIN NURTURES

1. Given $\frac{R^{13}}{R^3} = 8$; $\frac{M'_{earth}}{M_{earth}} = 2$

M_{earth} is doubled R_{moon} - earth is doubled

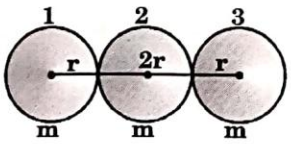
$$\frac{T^1}{T} = \frac{2\pi\sqrt{\frac{R'^3}{GM'}}}{2\pi\sqrt{\frac{R^3}{GM}}}$$

$$T^1 = 28 \times \sqrt{\frac{8}{2}} = 28 \times 2 = 56 \text{ days.}$$

2. We know $= g = \frac{GM}{R^2}$

$$= \frac{G\left(\frac{4}{3}\pi R^3 \rho\right)}{R^2} \quad (\therefore M = \rho \times V)$$

$$g = G\frac{4}{3}\pi R\rho;\ \rho = \frac{3g}{4G\pi R}.$$

3. 

Net force on sphere 1 = $\overline{F_{12}} + \overline{F_{13}}$

$$= \frac{Gm^2}{(2r)^2} + \frac{Gm^2}{(4r)^2} = \frac{5Gm^2}{16r^2}$$

Net force on sphere 2 = $\overline{F_{21}} + \overline{F_{23}}$

$$= \frac{-Gm^2}{(2r)^2} + \frac{Gm^2}{(2r)^2} = \frac{5Gm^2}{16\,r^2} = 0$$

Net force on sphere 3 = $\overline{F_{31}} + \overline{F_{32}}$ =

$$\frac{Gm^2}{(4r)^2} + \frac{Gm^2}{(2r)^2} = \frac{5\,Gm^2}{16\,r^2}.$$

4. (a) $F = \dfrac{G\left(\dfrac{m}{4}\right)\left(\dfrac{3m}{4}\right)}{d^2} = \dfrac{3}{16}\dfrac{Gm^2}{d^2}$

(b) $F = \dfrac{G\left(\dfrac{m}{7}\right)\left(\dfrac{5m}{7}\right)}{d^2} = \dfrac{5}{49}\dfrac{Gm^2}{d^2}$

(c) $F = \dfrac{G\left(\dfrac{m}{2}\right)\left(\dfrac{5m}{2}\right)}{d^2} = \dfrac{1}{4}\dfrac{Gm^2}{d^2}$

(d) $F = \dfrac{G\left(\dfrac{m}{5}\right)\left(\dfrac{4m}{5}\right)}{d^2} = \dfrac{4}{25}\dfrac{Gm^2}{d^2}$

Hence in case (c) gravitational force is maximum.

5. Suppose that the tennis ball bounces with a velocity u. It will go up, till its velocity becomes zero. If h is the height upto which it rises on the hill, then

$$(0)^2 - u^2 = 2(-g')h,$$

where g' is acceleration due to gravity on the hill.

$$\therefore h = \frac{u^2}{2g'}$$

Since the acceleration due to gravity on the hill (g') is less than that on the surface of earth (effect of height), it follows that tennis ball will bounce higher on hills than in plains.

6. Acceleration due to gravity on the moon is one sixth of that on the surface of earth. Maximum height reached by a body is inversely proportional to acceleration due to gravity i.e. $h_{max} \propto (g)^{-1}$.

Hence, for smaller value of g on earth one can jump to a greater maximum height.

7. Let M and m be the masses of the earth and the apple respectively. If r is the distance between them, then force of attraction between the earth and the apple,

$$F = G\frac{Mm}{r^2}$$

When this force acts on the apple, the acceleration produced in the motion of the apple,

$$a_{apple} = \frac{F}{m} = \frac{Gm}{r^2}$$

On the other hand, when this force acts on the earth, the acceleration produced in the motion of earth,

$$a_{earth} = \frac{F}{M} = \frac{Gm}{r^2}$$

Since $m << M$, $a_{apple} >> a_{earth}$.

For this reason, it is apple, which falls towards the earth.

8. As the spacecraft moves away from the surface of the earth towards moon, there will be no change in the mass of the spacecraft. However, its weight will keep on changing as described below:

1. Its weight will decrease in the be ginning.
2. It will become zero at some point, where the force of attraction on the spacecraft due to the earth and that due to the moon become just equal and opposite.
3. It will again start increasing as the spacecraft further moves towards the moon.

Chapter 7

Fluid Pressure

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (A) Increase in pressure of the fluid in the syringe (ΔP)

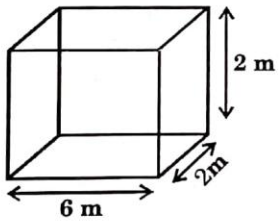
$$= \frac{\text{Force applied}}{\text{Area of cross section of syringe}}$$

Area of cross section = πr^2

$= \pi \times (0.9)^2 \text{ cm}^2 = \pi \times (0.9)^2 \times 10^{-4}$

$$\therefore \Delta P = \frac{3.8}{\pi (0.9)^2 \times 10^{-4}} = 14.927 \text{ kPa.}$$

2. (A)



Thrust = Total weight acting normally = mg

But mass = volume × density

$\therefore$ Thrust = volume of tank × density of water × g

$= (6 \times 2 \times 2) \times (10^3) \times (9.8)$

$= 23.52 \times 10^4$ N.

3. Total pressure acting on side of

$$A_1 = \frac{F}{A_1} + h\rho g$$

$$= \frac{F}{6 \times 10^{-4}} + (2 \times 0.75 \times 9.8 \times 10^3) \text{pa}$$

pressure acting on side

$$A_2 = \frac{2700 \times 9.8}{90 \times 10^{-4}} \text{ pa}$$

According to Pascal's law

Pressure acting on side of

A_1 = pressure acting on side A_2

$$= \frac{F}{6 \times 10^{-4}} + (2 \times 0.75 \times 9.8 \times 10^3)$$

$$= \frac{270\cancel{0} \times 9.8}{9\cancel{0} \times 10^{-4}}$$

$$\frac{F}{6 \times 10^{-4}} = 294 \times 10^4 - 14.7 \times 10^3$$

$F = 6 \times 10^{-4} (292.53 \times 10^4)$

$F = 1755.18$ N

4. (B) The size of an air bubble rising up in water increases.

5. (D) $V\rho_{solid} = V_{immersed}\, \rho_{liquid}$

$V \times 800 = V_{immersed}\, 1000$

$V_{immersed} = v(0.8)$

$V_{outside} = 0.2\, v$

Percentage of solid outside

Water $= 0.2 \times 100$

$= 20\%$

6. (B) As we move upwards, the atmospheric pressure decreases.

7. (B) $$\text{R.D} = \frac{\text{Density of solid}}{\text{Density of liquid}} = \frac{4}{5}$$

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$$R.D_2 = \frac{\text{Density of liquid}}{\text{Density of water}} = \frac{10}{9}$$

$$R.D_{solid} = \frac{\text{Density of solid}}{\text{Density w.r.t liquid}} \times \frac{\text{density of liquid}}{\text{density w.r.t water}}$$

$$= R.D_1 R.D_2 = \frac{4}{5} \times \frac{10}{9} = \frac{8}{9}$$

8. (B) $v\rho_{wood}\, g = v_{imm}\, \rho_{water} g$

$\cancel{v}\rho_{wood} = \cancel{0.42v} \times 1000$

$\rho_{wood} = 420\, kg\, m^{-3}$

or $0.42\ g\ cm^{-3}$

9. (D) When a body is weighed in a liquid the loss in its weight is equal to the upthrust of liquid on the body.

10. (B) R.D. metal

$$= \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}}$$

$$= \frac{210}{(210-180)} = 7$$

11. (C) When a body of density ρ and volume V is floating in a liquid of density σ then its apparent weight is zero.

12. (B) $R.D. = \frac{\text{Density of liquid}}{\text{Density of water}} = 2$

$\Rightarrow$ Density of liquid = $2\ g\ cm^{-3}$

Density of mixture (D)

$$= \frac{\text{Total mass}}{\text{Total volume}} = \frac{2m}{V_1 + V_2}$$

But $\frac{m}{V_1} = 2\ g\ cm^{-3}$; $\frac{m}{V_2} = 1\ g\ cm^{-3}$

$$D = \frac{2}{\frac{1}{2}+1};\ D = \frac{4}{3}\ g\ cm^{-3}$$

13. (D) Pressure at a point inside a liquid does not depends on the shape of the containing vessel.

14. (A) $P \alpha$ depth

$\therefore$ Ratio of pressure of two stretched membranes is 1 : 1

15. (A) A dam for water reservoir is built thicker at the bottom than at the top because pressure of water is very large at the bottom due to its large depth.

16. (C) $P = \frac{\text{weight}}{\text{area}} = \frac{v\rho_w g + v\rho_{oil} g}{\text{Area}}$

$$= \frac{(A \times 2.5 \times 1 \times g + A \times 1.5 \times 0.85 \times g)}{A} \times (10^{+2} cm)$$

$$= 2.5 \times g\,(1.85) = 4.625 \times 10^{+2} g$$

$= 462.5\ g\ dyne\ cm^{-2}$

17. (C) $P_A \times P_B$

$$\frac{10^7}{100} = \frac{2000 \times 10^3 \times 10^3}{A}$$

$$A = \frac{2 \times 10^9 \times 100}{10^7};\ A = 2 \times 10^4\ cm^2$$

18. (C) Two pieces of metal when immersed in a liquid have equal upthrust on them; then both pieces must have equal volumes.

19. (A) An iron ball is weighed in air and then in water by a spring balance its weight in air is more than in water.

20. (A) Loss in weight in water = 10×1

= 10 g

mass of body in water

= mass in air – loss in weight in water

= 40 g – log = 30 g

MULTIPLE ANSWERS QUESTIONS

1.(B,C) Weight of body = upthrust

$$\cancel{v}\rho_b \cancel{g} = \left(1 - \frac{p}{q}\right) \cancel{v}\rho_w \cancel{g}$$

$$\therefore \frac{\rho_b}{\rho_w} = 1 - \frac{p}{q}$$

i.e., R.D. of body = $\left(1 - \frac{p}{q}\right)$ or $\left(\frac{q-p}{q}\right)$

2. (A,B) The upper surface of a stationary liquid is always horizontal and pressure of a given liquid is directly proportional to the depth of the liquid are the correct statements.

3. (A,B,C) At sea level, the mercury inside the tube stands upto 76 cm. The pressure exerted inside a liquid is same at all points along the horizontal plane. The vertical height of the liquid column is independent of the shape and size of the tube. The height of barometric liquid column depends on nature of liquid used.

4. (A,B,C) The upthrust of a floating body is in upwards direction and is equal to the weight of the liquid displaced, The upthrust is directly proportional to the density of the liquid in which the solid is immersed. The upthrust is directly proportional to the volume of the fluid displaced by a solid are the correct statements.

5. (A,B,D) The pressure at a point in a fluid is directly proportional to the depth of the point from the surface, The pressure at a point is independent of acceleration due to gravity. The pressure at a point is proportional to the density of the fluid are the wrong statements.

ASSERTION AND REASONING

1. (A) P = hdg and is independent of shape and width of the container. Hence pressure at the bottom of two tanks of different areas of cross sections are equal provided they contain same liquid to same height.

2. (C) A balloon filled with hydrogen stops rising after it has attains a certain height in the sky. This is because as height increases, density of air decreases resulting in decrease of buoyant force.

3. (A) A wooden cube when placed in two liquids of different densities the volume of immersed part of cube in each liquid can be:

First liquid:

$$V_1 = \frac{V_{cube} \times d_{cube}}{d_1}$$

Second liquid:

$$V_2 = \frac{V_{cube} \times d_{cube}}{d_2}$$

Since $V_{cube} \times d_{cube}$ is constant volume of immersed part depends on density of liquid.

4. (A) For floating a body, the apparent weight of the body is zero. i.e., entire weight of the block is supported by the buoyant force due to water. Thus the loss in weight in water is just equal to the weight of the block and there is no net downward force.

5. (A) The free surface of a liquid (ideal) at rest, under gravity taken in a container is always horizontal. As at fluid at rest has no shear stress acts and the force acting have to be normal to the surface.

6. (B) Pascal's law is the working principle of hydraulic H. As an increase in pressure at any point inside a liquid at rest is transmitted equally and undiminshed in all directions. Pressure is thrust acting per unit normal area.

7. (A) The blood pressure of the humans acting at the feet is greater than at the brain, as h value is more at feet than at brain and $p \alpha h$ (depth).

8. (D) Pressure is a scalar quantity. Pressure is $\frac{\text{Thrust}}{\text{Area}}$ (force) hence, depends on force which is a vector quantity.

9. (A) A floating body must displace liquid whose weight is equal to actual weight of the body because up thrust is equal to its actual weight.

10. (A) A piece of ice floats in water. The level of water remains unchanged when the ice melts completely because the loss in weight of ice in the liquid is equal to the weight of the liquid displaced by immersed part of the body.

PARAGRAPH QUESTIONS

(i) (B) R. D. of the block

$$= \frac{\text{weight of body}}{\text{weight of equal vol. of water}}$$

$$= \frac{\text{weight of body}}{\text{thrust from water}}$$

$$= \frac{W_{air}}{W_{air} - W_{water}} = \frac{22}{22-17} = \frac{22}{5}$$

$= 4.4$

(ii) (A) R.D. of other liquid

$$= \frac{\text{Thrust of liquid}}{\text{Thrust of water}} = \frac{W_{air} - W_L}{W_{air} - W_{water}}$$

$$= \frac{22-18}{22-17} = \frac{4}{5} = 0.8.$$

(iii) (A) Volume of the block $= \frac{\text{Thrust}}{d_w \times g}$

$$= \frac{W_{air} - W_{water}}{10^3 \times 10} = \frac{5N}{10^3 \times 10}$$

$= 5 \times 10^{-4}\ m^3$ or $500\ cm^3$.

NUMERICAL PROBLEMS

1. Given:

mass = 5 kg
height = 6 cm
radius = 4 cm

Pressure on bottom surface

$$= \frac{\text{Thrust}}{\text{area of bottom surface}} = \frac{mg}{\pi r^2}$$

$$= \frac{5 \times 10}{\left(\frac{22}{7} \times (0.04)^2\right)} = 0.9744 \times 10^4 \text{ Pa.}$$

2. Given,

For mercury	for liquid
$h_1 = 74$ cm	$h_2 = ?$
$d_1 = 13.6\ g\ cm^{-3}$	$d_2 = 5.44\ g\ cm^{-3}$

Since pressure at a place is same

$P_1 = P_2$

$\therefore\ h_1 d_1 g = h_2 d_2 g\ (\because P = hdg)$

$74 \times 13.6 = h_2 \times 5.44$

$h_2 = 185$ cm.

3. According to pascal's law, pressure acting on press plunger = pressure acting on pump plunger.

$$= \frac{800 \times g}{40 \times 10^{-4}\ m^2}$$

$$\Rightarrow \therefore F = \frac{800 \times 9.8 \times 0.02}{40 \times 10^{-4}}$$

$= 39200$ N

4. $d_l = 1.2\ g\ cm^{-3}$

Let S be the side of cube.

Height of the vertical side

Inside the liquid $= \left(S - \frac{1}{4}\right)$ cm

Upthrust = weight of the body

$$S^2\left(S - \frac{1}{4}\right) \times d_l \times g = S^3 \times d_{cube} \times g$$

$$\therefore\ d_{cube} = \frac{\left(S - \frac{1}{4}\right) d_l}{S}\ g\ cm^{-3}$$

When a weight of 67.5 g is placed on the top;

$(S^3 \times d_{cube} \times g) + 67.5 = S^3 \times d_l \times g$

$S^3 \times d_{cube} \times g + 67.5 = S^3 \times 1.2 \times g$

$$\frac{S^3 \times \left(S - \frac{1}{4}\right) 1.2}{S} \times g + 67.5 = S^3 \times 1.2 \times g$$

$$1.2\ \cancel{S^3 g} - 3S^2 g + 67.5\ S + 1.2\ \cancel{S^3 g} = 0$$

$$S^2 = +\frac{(67.5)\ \cancel{S}}{0.3\ g}$$

$$S = \frac{225}{9.8} = 22.9 \text{ cm}$$

$$\therefore\ d_{cube} = \frac{(22.9 - 0.25)\ 1.2}{22.9}$$

$= 1.19\ g\ cm^{-3}$

Specific gravity of wooden cube = 1.19

5. Let volume of bubble on the surface of water be V

Volume of bubble inside = $\frac{V}{4}$

Pressure P at surface = 76 cm of Hg

Let depth of bubble inside = h cm

∴ Pressure of bubble inside water

$$= \left(76 + \frac{h}{13.6}\right) \text{cm of Hg}$$

Given, P_1 = 76 cm of Hg, V1 = V

$$P_2 = \left(76 + \frac{h}{13.6}\right) \text{cm of Hg},$$

$$V_2 = \frac{V}{4}$$

According to Boyle's law,

$$P_1V_1 = P_2V_2$$

$$(76)\,V = \left(76 + \frac{h}{13.6}\right)\left(\frac{V}{4}\right)$$

$$76 = \frac{76}{4} + \frac{h}{13.6 \times 4}$$

$$\frac{h}{13.6 \times 4} = 57$$

h = 3100.8 cm.

6. $d_{ball} = \frac{1}{7} d_{liquid}$

To completely submerge ping pong ball under water, let 'F' be the force required.

$$\therefore \quad V \times d_{ball} \times g + F = V \times d_{liquid} \times g$$

$$F = (V \times d_{liquid} \times g - V \times d_{ball} \times g)$$

$$= V_g\,(d_{liquid} - \tfrac{1}{7} d_{liquid})$$

$$= \frac{6}{7} Vg\, d_{liquid}$$

7. W_{air} = 60 g

W_{water} = 56.5 g

Mass of ornament in air = 60 g

Mass of ornament in water = 56.5 g

Apparrent loss in weight of ornament

= 60 – 56.5 = 3.5 g

Volume of water displaced

$$= \frac{W}{d} = \frac{3.5}{1} = 35 \text{ cm}^3$$

Let mass of metal gold be (60 – x) g and mass of metal copper is (x) g, V = 3.5 cm³.

$$\therefore \quad V_{gold} = \frac{x}{10};\ V_{copper} = \frac{(60-x)}{20}$$

Total volume = $V_{gold} + V_{copper}$

$$63.5 = \frac{x}{10} + \frac{(60-x)}{20}$$

$$3.5 \times = 2x + (60 - x)$$

$$70 = x + 60$$

$$x = 10 \text{ g}$$

Mass of copper is 10 g.

8. Let m be the mass of the car

$$\frac{m}{400 \times 10^{-4}} = \frac{25}{5 \times 10^{-4}} + 8 \times 0.9 \times 10^3 \times 9.8$$

$$\frac{m}{400 \times 10^{-4}} = \frac{25 \times 10^{-1}}{5 \times 10^{-4}}$$

M = 492 kg

9. **Case (i):**

Let V be the volume

m_1, m_2 be the masses.

Specific gravity of the mixture = 4

∴ Density (D) = 4 g cm^{-3}

$$D = \frac{m_1 + m_2}{2V} = \frac{\frac{m_1}{V} + \frac{m_2}{V}}{2}$$

$$= \frac{D_1 + D_2}{2} = 4 \quad \text{.... (1)}$$

Case (ii):

Let m be the mass.

V_1, V_2 be the volume

Specific gravity of the mixture = 3

$\therefore$ Density (D) = 3 g cm^{-3}

$$D = \frac{2m}{V_1 + V_2} = \frac{2}{\frac{V_1}{m} + \frac{V_2}{m}}$$

$$= \frac{2}{(1/D_1) + (1/D_2)}$$

$$= \frac{2\,D_1\,D_2}{D_1 + D_2} = 3 \quad .... (2)$$

Substitute (1) in (2)

$\therefore \frac{D_1D_2}{4} = 3$

$D_1D_2 = 12$

$D_1(8 - D_1) = 12$

$8D_1 - D_1^2 = 12$

$D_1^2 - 8D_1 + 12 = 0$

$D_1^2 - 2D_1 - 6D_1 + 12 = 0$

$(D_1 - 2)(D_1 - 6) = 0$

$D_1 = 2$ or 6 and $D_2 = 6$ or 2

$\therefore$ If density of one liquid is 2 g cm^{-3} then density of other liquid is 6 g cm^{-3}.

10. (a) Given, volume of room

= 3 m × 4 m × 5 m

= 60 m^3

Density of air at NTP

= 1.3 kg m^{-3}

Mass of air in the room

= volume × density

= 60 m^3 × 1.3 kg m^{-3}

= 78 kg.

(b) Given, base area of tank(A) = 1.5 m^2

Height of the tank = 1 m

Density of water(D) = 10^3 k gm^{-3}

Force executed by water

= pressure × area

= h d g × A

= 1 × 10^3 × 10 × 1.5

= 1.5 × 10^4 N

11. $P_1 = 3\times10^5$ N m^{-2}, $P_2 = 5\times10^5$ N m^{-2},

$P_A = 0.7\times10^5$ N m^{-2},

$P_A = 10^5$ N m^{-2}, $\frac{h_1}{h_2} = ?$

We know,

$P = P_A + hdg \Rightarrow$

$P_1 = P_A + h_1\,dg, P_2 = P_A + h_2\,dg$

$\therefore \quad 3\times10^5 = h_1dg \Rightarrow h_2dg = 2\times10^5$ ...(1)

$5\times10^5 = 10^5 + h_2dg \Rightarrow h_2dg = 4\times10^5$ ....(2)

On $\frac{(1)}{(2)}$, $\frac{h_1dg}{h_2dg} = \frac{2\times10^5}{4\times10^5} = \frac{2}{4} = \frac{1}{2}$

$\Rightarrow \frac{h_1}{h_2} = \frac{1}{2}$

12. R = 2, h = 5 cm, a = 5 cm^2,

loss of weight = $\frac{\text{weight}}{2} = \frac{mg}{2}$

$d_2 = ?$

We know, loss of weight = $\frac{\text{weight}}{2}$

$\therefore V \times d_1 \times g = \frac{V\times d\times g}{2} \Rightarrow d_L = \frac{d}{2}$

But density of cylinder d

= R.d× 1 g cm^{-3} = 2 g cm^{-3}

$\therefore \quad d_L = \frac{2}{2} = 1$ g cm^{-3}

13. d = 1.5 g cm^{-3}, FB_1 = 4 N

$d_{L1} = d$, $FB_2 = ?$, $d_{L2} = 3d$

We know,

$FB \propto d_1$

$\Rightarrow \frac{FB_1}{FB_2} = \frac{d_{L1}}{d_{L2}}$

$\Rightarrow FB_2 = \frac{FB_1 \times d_{L2}}{d_{L1}} = \frac{4\times3d}{d} = 12N$

14. T.S.A of cube = S.A of sphere, $r_s : s_c = ?$

$FB_s : FB_c = X : Y$

We know,

$$\frac{FB_s}{FB_c}=\frac{V_s}{V_c}=\frac{\frac{4}{3}\pi r_S^3}{S_c^3}=\frac{\frac{4}{3}\pi r_S^3\times r_s}{6S_c^2\times\frac{S_c}{6}}$$

$$\frac{FB_s}{FB_c}=\frac{\text{S.A. of sphere}\times r_s}{\text{T.S.A of cube}\times S_{C/6}}$$

($\therefore$ S.A. of sphere $= 4\pi rs^2$, T.S.A. of cube $6S_c^2$)

$$\Rightarrow \frac{X}{Y}=\frac{r_s}{\frac{S_c}{6}}$$

($\therefore$ T.S.A of cube = S.A of sphere)

$$\Rightarrow \frac{r_s}{S_c}=\frac{X}{6Y}$$

15. $d = 1.5\ g\ cm^{-3}$, $d_L = 1\ g\ cm^{-3}$,

We know

weight = mg = v × d × g

$\Rightarrow$ weight $\propto$ d ....(1)

$FB = v\times d_L\times g \Rightarrow FB \propto d_L$ ....(2)

Given,

$d > d_L \Rightarrow$ weight > FB $\therefore$ cylinder will not move up.

CONCEPTUAL QUESTIONS

1. Darjeeling is at higher altitude than Puri. As the altitude increases, the atmospheric pressure decreases hence the value of barometric height reads less at Darjeeling.

2. If M g ice is floating in a liquid of density σ_L, then for its equilibrium.

weight of ice = thrust, i.e., $Mg = V_D\sigma_L g$

So the volume of liquid displaced by the floating ice,

$$V_D = (M/\sigma_L) \quad .... (1)$$

Now if M g ice melts completely, water formed will have mass M g (as mass is conserved). Now if σ_W is the density of water, the volume of water formed will be

$$V_F = (M/\sigma_W) \quad .... (2)$$

Here the liquid is water, i.e., $\sigma_L = \sigma_W$; so water displaced by floating ice is equal to water formed by melting of whole ice and hence the level of water will remain unchanged.

3. Sleepers used in railways provide greater base area there by reduces the pressure on the tracks hence prevents their wear and tear.

4. At higher altitude the atmospheric pressure reduces and there causes a great difference in the blood pressure between external atmosphere and our blood pressure due to this it becomes difficult to stop bleeding from a cut in the body.

5. The sports boot for soccer and hockey have studs on their soles to increase the base area. So that the weight of the players acts over a small area.

6. The loss in weight of the steel ball in water is equal to the loss in weight of the hollow steel ball in water. The loss in weight of the balls in water is equal to the upthrust of either balls, dependent completely upon its submerged volume and not on whether there was air in the ball.

7. The difference in the upward and downward force acting on the submerged block is the same at any depth.

8. Float a block of iron on a beaker of mercury.

9. Float a block of iron on the mercury and then repeat in water.

PREVIOUS CONTEST QUESTIONS

1. (A) R.D. of body

$$= \frac{\text{weight in air}}{\text{Apparent loss in weight}}$$

$$= \frac{60}{(60-40)} = \frac{60}{20} = 3$$

2. (C) Volume of capacity

= volume displaced – actual volume

$$40 - \frac{261}{9} = \frac{99}{9} = 11 \text{ cc}$$

3. (D) Pressure at a point inside the liquid (P) = hdg

Hence, it depends on the depth of the point below the surface of the liquid the acceleration due to gravity at that point and on the nature of the liquid but not on the shape of the containing liquid.

4. (D) Pressure at any point in the liquid (P) = hdg

i.e., $P \alpha h$

(depth of point below the surface)

α d (density of liquid)

α g (acceleration due to gravity)

5. (C) P = h d g

$P = (250 \times 1 \times g) + (250 \times 0.85 \times g)$

$P = 1.85 \times 250 \times g$

$P = 462.5 \text{ g dyne cm}^{-2}$.

6. (B) Force = pressure× area

= hdg× A

$= 1\times 10^3 \times 10 \times 1.5 = 1.5000$ N

7. (A) Buoyant force

= weight in air – weight in liquid

= 5 N – 2 N = 3 N

8. (D) Apparent weight of a floating body = 0

9. (C) Apparent weight of floating body is weight of body minus weight in liquid.

10. (A) If the ice cube initially contains the lead piece then as $\rho_{Pb} > \sigma_W$, it will sink when ice melts and so the water displaced by it will be equal to its own volume,

i.e., $V_2 = (m/\rho_{Pb})$ [as $\rho = m/V$]

So finally total volume occupied by water formed by melting of ice and lead piece.

$$V_1 + V_2 = \frac{M}{\sigma_W} + \frac{m}{\rho_{Pb}}$$

Now as $\rho_{Pb} > \sigma_W$, this volume will be lesser than initial by water displaced by the floating system (Eqn. 1); so the level of water is beaker will go down as the ice melts if the ice contains a sinking impurity.

BRAIN NURTURES

1. Let volume of liquids be v_1 and v_2 respectively.

$m_1 : m_2 = 3 : 5$

$$\text{Density of mixture} = \frac{\text{total mass}}{\text{total volume}}$$

$$= \frac{(m_1 + m_2)}{(v_1 + v_2)}$$

$$= \frac{(3+5)m}{\frac{m_1}{d_1} + \frac{m_2}{d_2}} = \frac{8\cancel{m}}{\frac{(3d_2 + 5d_1)\cancel{m}}{d_1 d_2}}$$

$$= \frac{8d_1 d_2}{(3d_2 + 5d_1)}$$

2. On connecting a small tube at the bottom of two tanks.

Let (h – 30) be the height of the column A then, (h + 20)

$(30 + h) \times 800 = 1600 (-h + 20)$

$3 + h = -2h + 40$

$3h = 10$

$h = \frac{10}{3}$ cm

$\therefore$ Height in tank A = 30 + h

$= 30 + \frac{10}{3}$

$= \frac{100}{3}$ cm

Height in tank B = (20 – h)

$= 20 - \frac{10}{3} = \frac{50}{3}$ cm

Let h be the height from the bottom of the tank. On connecting a horizontal tube B, no liquid flows between the tanks.

$(30 - h) \times 800 = 1600 \times (20 - h)$

$30 - h = +40 - 2h$

$h = +40 - 30$

h = 10 cm from the bottom of the tank.

3. Density of body $= \frac{\text{mass}}{\text{volume}}$

$= \frac{716}{448} = 1.598 \text{ g cm}^{-3}$

Density of liquid = 1.3 g cm^{-3}

The density of the body is greater than density of liquid.

Hence, the body sinks in the liquid.

4. The oil exerts same pressure on CCl_4 as the pressure exerted by water on CCl_4.

Let 'h' be the height of water column

$[(h - 12) \times 1.6 \times g] + [12 \times 0.6 \times g]$

$= [h \times 1 \times g]$

$1.6 h - (12 \times 1.6) = 7.2 = h$

$0.6 h = -7.2 + 19.2$

$h = \frac{12}{0.6} = 20$ cm

5. Pressure exerted by pump piston

$(A) = \frac{W}{\pi (r_a)^2}$

$= \frac{50}{\pi \times (16 \times 10^{-4})}$

If m_2 kgwt is maximum weight to be lifted then according to pascal's law,

$P_A = P_B$

$\frac{50}{\pi(16 \times 10^{-4})} = \frac{m_2}{\pi(625 \times 10^{-4})}$

$\frac{50 \times 625}{16} = m_2$

$m_2 = 1953.125$ kg

Mechanical advantage

$= \frac{\text{load}}{\text{effort}} = \frac{1953.125}{50} = 63$

6. According to the laws of flotation by immersing a block of wood over different base areas. It is shown that a floating object displaces a weight of liquid equal to its own weight, depending on the volume of the object and not on the base area submerged.

7. Both the parts of homogeneous object will sink because both are dense than water. The smaller part has the same density as the larger part.

8. Yes, a piece of paraffin pressed to the bottom of the beaker rises when released.

❖ ❖ ❖

Chapter 8

Heat

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (B) $\frac{C}{100} = \frac{F-32}{180}$

Given C = 120 °C

$\therefore \frac{120}{100} = \frac{F-32}{180}$

F – 32 = 216

F = 216 + 32 = 248 °F.

2. (A) Given,

Temperature of a room is 77 °F

$\frac{C}{100} = \frac{F-32}{180}$

$\frac{C}{100} = \frac{(77-32)}{180}$

$C = \frac{45}{180} \times 100 = 25°C.$

3. (B) Given,

Temperature of liquid hydrogen = 20 K

$\frac{F-32}{180} = \frac{K-273}{100}$

$\frac{F-32}{180} = \frac{(20-273)}{100}$

$F - 32 = \frac{(-253)}{100} \times 180$

F – 32 = (–455.4)

F = – 455.4 + 32

F = – 423.4 °F .

4. (A) On heating metal plate having two holes at certain distance of separation between them, the holes expands. Due to expansion of holes, radius of holes increases resulting in increase in distance between the centres of holes.

5. (C) Iron or steel is used in reinforcement in concrete because both have nearly equal coefficient of expansions. So, on changes in temperature they expand uniformly.

6. (A) Crucibles are made of mixture of quartz and silica since the linear coefficient of expansion is zero for that mixture. Hence they does not expand when heated.

7. (C) It is hotter at the same distance over the top of a fire than it is on the sides as convection takes the heat in upwards.

8. (C) Ventilators are placed on the top of room as the warm air rises up due to convection. If warm air is rised up and taken out by ventilators fresh air remains in the room.

9. (B) Size of 1 degree depends on length of 1 degree.

Length of 1 degree

$= \frac{\text{Total length}}{\text{Number of divisions}}$

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If no. of divisions are more, length of 1 degree is less. (provided for same amount of total length an all scales). In three scales, Celsius, Fahrenheit and Kelvin, Fahrenheit has more no. of divisions i.e., 180. Hence size of 1 degree is smallest on Fahrenheit scale.

10. (C) Two thermometers are used to record the temperature of a room. If the bulb of one is wrapped in wet hanky evaporation of water molecules on hanky leads to cooling. Hence temperature recorded by thermometer wrapped with wet hanky is less compared to dry bulb thermometer.

11. (A) When a metal rod is heated it expands because of increase in the size of its atoms.

12. (C) When a strip made of iron (α_1) and copper $\alpha_2 (> \alpha_1)$ is heated copper expand more. Due to this, copper bends with iron on concave side.

13. (D) Increase in length of cylinder = 2%.

$$\left(100 \times \frac{\Delta l}{l}\right) = (\alpha \Delta t \times 100)$$

% increase in area

$$\left(\frac{\Delta A}{A} \times 100\right) = (\beta \Delta t \times 100)$$

$$= 2(\alpha \Delta t \times 100)$$

$$= 2 \times 2\% = 4\%$$

14. (B) There are two spheres of same material and radius. One is solid sphere, second one is hollow sphere.

15. (D) Water is filled in a glass beaker at room temperature and the beaker is heated. Initially the level of water falls due to expansion of glass beaker, then on further heating level of water rises due to expansion of water.

MULTIPLE ANSWERS QUESTIONS

1. (A,C) Two rods are of same material and same mass.

$\therefore \alpha_1 = \alpha_2$

Given $l_1 \neq l_2$

On heating

if $\Delta\theta$ is same,

let $l_1 > l_2$

$\Delta l_1 = l_1 \times \alpha_1 \times \Delta\theta$

$\Rightarrow \Delta l_1 \, \alpha \, l_1$

$\therefore$ longer rod expands more.

If Q is same, longer rod expands more.

2. (A,B,D) When hot water is poured in a thick walled glass tumbler suddenly it develops cracks because of unequal expansions of the surfaces, For the use of hot liquids thin walled glass containers are preferred. Bimetallic strip works on the principle of unequal expansion.

3. (A,B,C) The apparent expansion of liquid depends on the expansion of material of the container. The real expansion of the liquid depends on the density of the liquid. The expansion of liquid with respect to the container is called the apparent expansion.

4. (A,B,C) C = 50°C

$$F = \left(50 \times \frac{9}{5}\right) + 32$$

F = 122 °F

A clinical thermometer has a maximum range of 110 °F while boiling water is at 212 °F. So, cannot be sterilised.

Unequal expansions causes cracks in the walls of the buildings .

Graphite is a good conductor of heat

5.(A,B,C,D) Woolen clothes keep the warm in winter because they trap air within the layers. Air being a bad conductor of heat prevents loss of body heat.

Shinning surfaces are good reflectors of heat.

Heat radiations travel with speed of light.

$$\gamma = \frac{\Delta V}{V(\Delta t)} = \frac{\text{litre}}{\text{litre(kelvin)}}$$

$\therefore$ SI unit of γ is K^{-1}.

ASSERTION AND REASONING

1. (A) When a hot substance is mixed with a cold substance, then the temperature of hot substance gradually decreases. Because hot body is at higher temperature.

2. (D) The melting point of ice and boiling poing of water are taken as LFP and UFP only on celsius and fahrenheit scale

3. (A) A brass disc is just fitted in a hole is a steel plate.The system must be cooled to loosen the disc from the hole because the coefficient of linear expansion for brass is greater than the coefficient of linear expansion for steel.

4. (C) The centigrade and farhenheit thermometers reads same temperature at –40 °C because

$$C = \frac{5}{9}(F - 32)$$

5. (C) Air trapped between two blankets provides warmthness as air is a bad conductor of heat. Thickness increase is not responsible for warmthness.

PARAGRAPH QUESTIONS

(i) (C) The ratio of linear expansions of rod P to that of rod Q is 1 : 1

As both the rods are made of same material and their initial length, rise in temperatures.

(ii) (A) As rod P is less thick than Q, for same length and same amount of heat supply rod P expands more.

NUMERICAL PROBLEMS

1. Let the reading on celsius scale be x.

$\therefore$ Reading on Fahrenheit.

F = 5x

$$\frac{C}{5} = \left(\frac{F-32}{9}\right)$$

$$\frac{x}{5} = \frac{(5x-32)}{9}$$

9x = 25x – 160

160 = 16 x

Reading on x = 10 °C

(i) Celsius scale = 10 °C

(ii) Fahrenheit scale = 5(1) = 50 °C

2. Given Fundamental interval of

$X = UFP_1 - LFP_1 = 70°$

Fundamental interval of

$Y = UFP_2 - LPF_2 = 140$

LFP of X = 10°

LFP of Y = 0°

Reading on Y = 90°

$$\frac{X - LFP_1}{UFP_1 - LFP_1} = \frac{Y - LFP_2}{UFP_2 - LFP_2}$$

$$\frac{X - 10}{70} = \frac{90 - 0}{140}$$

$$X - 10 = \frac{90 \times 70}{140}$$

$$X = 45 + 10 = 55°$$

3. Let the reading on celsius scale be x.

Given, reading on celsium scale (x) $= \frac{1}{2}$ (absolute reading – K)

$$C = K - 273$$

$$\frac{1}{2}K = K - 273$$

$$273 = \frac{1}{2}K$$

$$K = 246\ K$$

$$c = x = \frac{1}{2}K = \frac{546}{2} = 273\ °C$$

4. $\Delta C = 75 - 15 = 60\ °C$

(a) $\frac{60}{100} = \frac{F - 32}{180}$

$\Delta F = 140\ °F$

(b) $\Delta K = \Delta C = 60K$

5. Let θ_0 be the lower fixed point of the faulty thermometer and 'n' be the number of divisions between its lower and the upper fixed points. If a temperature C on celsius scale corresponds to temperature θ on the scale of faulty thermometer, then

$$\frac{C - \theta}{100} = \frac{\theta - \theta_0}{n}$$

Here, $\theta_0 = 10°$, $n = 90 - 10 = 80$ and $\theta = 66°$

Therefore, the equation becomes

$$\frac{C - 0}{100} = \frac{66 - 10}{90 - 10}$$

$$C = \frac{56}{80} \times 100$$

$$C = 70°$$

6. For brass rod: $\alpha = 1.9 \times 10^{-5}\ °C^{-1}$

$l_1 = 40$ cm; $\Delta T = 280 - 40 = 240°C$

The length of the brass rod at 280 °C is given by $l_2 = l_1(1 + \alpha\Delta T)$

$= 40 \times (1 + 1.9 \times 10^{-5} \times 240)$

$= 40.1824$ cm

For copper rod: $\alpha' = 1.7 \times 10^{-5}\ °C^{-1}$

$l_1' = 50$ cm; $\Delta T' = 280 - 40 = 240°C$

The length of the steel rod at 280 °C is given by:

$l_2' = l_1'(1 + \alpha'\Delta T)$

$= 50 \times (1 + 1.7 \times 10^{-5} \times 240)$

$= 50.2040$ cm

Therefore, the length of the combined rod at 280 °C,

$l_2 + l_2' = 40.1824 + 50.2040$

$= 90.3864$ cm

As the length of the combined rod at 40 °C is 50 + 40 i.e., 90 cm, the change in length of the combined rod at 280 °C $= 90.3864 - 90 = 0.3864$ cm

7. Here, $l_1 = 5$ m; $\Delta T = 40 - 20 = 20$ °C;

$\alpha = 1.2 \times 10^{-5}\ °C^{-1}$

If l_2 is length of the beam at 40 °C, then

$l_2 = l_1(1 + \alpha\Delta T)$

$= 5 \times (1 + 1.2 \times 10^{-5} \times 20)$

$= 5 \times (1 + 2.4 + 10^{-4}) = 5.0012$ m

Therefore, increase in length of the beam,

$$\Delta l = l_2 - l_1 = 5.0012 - 5$$
$$= 0.0012 \text{ m} = 1.2 \text{ mm}$$

8. Let α_1 and α_2 be the coefficients of linear expansion of steel and copper respectively. Suppose that the steel rod is of length l_1 and copper rod of length l_2; so that at all temperatures, the steel rod is 5 cm longer than the copper rod i.e.

$$l_1 - l_2 = 5 \text{ cm} \quad \text{..... (1)}$$

It will happen so, if on increase of temperature say by θ°C, the increase in length of the two rods is same i.e.

$$\Delta l_1 = \Delta l_2$$
$$l_1\alpha_1\theta = l_2\alpha_2\theta$$
$$l_2 = \frac{\alpha_1}{\alpha_2} l_1$$

Here, $\alpha_1 = 1.1 \times 10^{-5}$ °C^{-1},
$\alpha_2 = 1.7 \times 10^{-5}$ °C^{-1}

$$\therefore \quad l_2 = \frac{1.1 \times 10^{-5}}{1.7 \times 10^{-5}} l_1 = \frac{11}{17} l_1$$

In the equation, (1) substituting for l_2, we have

$$l_1 - \frac{11}{17} l_1 = 5$$
$$l_1 = \frac{85}{6} = 14.17 \text{ cm}$$

Also, $l_2 = l_1 - 5 = 14.17 - 5 = 9.17$ cm.

9. Here, $S = \pi \times 35^2 = 3{,}848.45$ cm^2;

$$\Delta S = 14.5 \text{ cm}^2; \ \theta_1 = 20°\text{C};$$
$$\beta = 2\alpha = 2 \times 1.7 \times 10^{-5}$$
$$= 3.4 \times 10^{-5} \text{ °C}^{-1}$$

Now, $\Delta S = S\beta\Delta T$ or $\Delta T = \frac{\Delta S}{S\beta}$

$$\therefore \ \Delta T = \frac{14.5}{3{,}848.45 \times 3.4 \times 10^{-5}}$$
$$= 110.82 \text{ °C}$$

If θ_2 is the temperature to which the copper sheet was heated, then

$$\theta_2 = \theta_1 + \Delta T = 20 + 110.82 = 130.82 \text{ °C}$$

10. $$\frac{l_{20}}{l_{25}} = \frac{l_0(1 + \alpha\, 20)}{l_0(1 + \alpha\, 95)}$$

$$\frac{50}{50.06} = \frac{1 + \alpha\, 20}{1 + \alpha\, 95}$$

$$50 + (50\alpha)(95)$$
$$= 50.06 + \alpha(20)(50.06)$$
$$\alpha[4750 - 1001.2] = 0.06$$
$$\alpha(3748.8) = 0.06$$
$$\alpha 16.005 \times 10^{-6}\,{}^0\text{C}^{-1}$$
$$50 = l_0(1 + 16.005 \times 10^{-6} \times 20)$$
$$l_0 = 49.98 \text{ cm}$$

11. Let temperature at which the lengths of brass rod (l_b) and a steel rod (l_s) are equal

$$l_b = l_s$$
$$l_0(1 + \alpha b\Delta\theta) = l_0^1(1 + \alpha_s\Delta\theta)$$
$$120(1 + 12 \times 10^{-6} \times \theta)$$
$$= 120.2(1 + 17 \times 10^{-6} \times \theta)$$
$$120 + 120 \times 12 \times 10^{-6} \times \theta$$
$$= 120.2 + 120.2 \times 17 \times 10^{-6}\theta$$

solving we get,

$$\theta = 57.415 \text{ °C}$$

12. $\Delta\theta = 500 - 0 = 500\ °C$

$$d_{500} = \frac{d_0}{1.027}$$

$$d_{500} = d_0(1 - 3\alpha\Delta\theta)$$

$$\frac{d_0}{1.027} = d_0(1 - 3\alpha(500))$$

$$\frac{1}{1.027} = 1 - 1500\alpha$$

$$1500\alpha = 1 - \frac{1}{1.027} = \frac{0.027}{1.027}$$

$$\alpha = 1.8 \times 10^{-5}\ °C^{-1}$$

13. $\Delta A = 14.5\ cm^2$

$\alpha = 1.7 \times 10^{-5}\ ^0C^{-1}$

$\Delta A = A_0(2\alpha\theta)$

$$14.5 = \pi \times (35)^2 (2 \times 1.7 \times 10^{-5}\theta)$$

$$\frac{14.5}{\pi \times (35)^2} = (3.4 \times 10^{-5}\theta)$$

$$\theta = 110.8\ ^0C$$

14. Here, $\gamma = 1.82 \times 10^{-4}\ °C^{-1}$;

$\rho = 13.6\ g\ cm^{-3}$

$\Delta T = 50 - 0 = 50\ °C$

Now, $\rho' = \rho(1 - \gamma\Delta T)$

$= 13.6\ (1 - 1.82 \times 10^{-4} \times 50)$

$= 13.48\ g\ cm^{-3}$.

15. Here, $\gamma = 5.4 \times 10^{-4}\ °C$, $\Delta T = 80\ °C$

Let there be m grams of mercury and its initial volume be V. Suppose that the volume of the mercury becomes V^1 after a rise of temperature of 80 °C. Then,

$V^1 = V(1 + \gamma\Delta T)$

$V = (1 + 5.4 \times 10^{-4} \times 80)$

$V^1 = 1.0432\ V$

Initial density of the mercury, $\rho = \frac{m}{V}$

Final density of the mercury,

$$\rho^1 = \frac{m}{V^1} = \frac{m}{1.0432V} = \frac{\rho}{1.0432}$$

$$= 0.9586\rho$$

Therefore, fractional change in the value of density of mercury,

$$\frac{\rho - \rho^1}{\rho} = \frac{\rho - 0.9586\rho}{\rho} = 0.0414$$

CONCEPTUAL QUESTIONS

1. There will be no change in mass. The volume will undergo largest percentage increase; while the radius, minimum. It is because, volume of the spherical ball depends on cube of its radius. (i.e. $V \propto r^3$)

2. The melting point of ice and the boiling point of water change with change in the value of pressure. Further, melting point of ice and the boiling point of water also change, if some impurities and dissolved in water.

3. The double walls used in the cold storages helps in trapping certain amount of air. Air being a bad conductor of heat prevents the loss of heat.

4. Glass tumblers are made of thin glass: The large forces involved during expansion often cause thick glass tumblers to crack when boiling water is poured into it. Glass is a poor conductor of heat. When the water is first added, the inside of the tumbler is at a higher temperature than the outside glass. As a result, the inside glass expands more than the outside, and it cracks.

5. To keep tea hot for a long time, teapots are kept shining as shining surfaces are bad radiation.

6. In a barometer the atmospheric pressure is measured as P = hdg, where 'h' is the height of mercury column, 'd' is density of mercury and 'g' is acceleration due to gravity.

Atmospheric pressure does not change with temperature.

i.e. $P_1 = P_2 \Rightarrow h_1 d_1 g = h_2 d_2 g$

$$\Rightarrow h_1 d_1 = h_2 d_2 \Rightarrow \frac{h_2}{h_1} = \frac{d_1}{d_2}$$

As the temperature increases, density of mercury decreases (i.e., $d_2 < d_1$)

$$\therefore \frac{h_2}{h_1} = \frac{d_1}{d_2} > 1 \qquad \therefore \frac{h_2}{h_1} > 1$$

The barometer shows increase in reading.

PREVIOUS CONTEST QUESTIONS

1. (D) Given, F = 2C

$$\frac{C}{100} = \frac{F-32}{180}$$

$$\frac{C}{100} = \frac{2C-32}{180}$$

$C \times 9 = 5(2C - 32)$

$9C = 10C - 10$

$C = 160\ °C.$

2. (D) When a metal sphere is heated, the maximum percentage increase occurs in its volume (as volume is proportional to cube of radius).

3. (D) Two Cu rods have same length, same area of cross section. If same heat is supplied, both rods expand equally as their initial length, α and $\Delta\theta$ are same.

4. (A) A brass disc is fitted tightly in a hole in a steel plate. To loosen it, the disc from hole should be cooled, the disc contracts and can be removed.

5. (B) Bimetallic strip contains two metals. Hence they are used in

(i) metal thermometers to control temperatures.

(ii) in relays to open or close electric circuits by temperature control.

(iii) in thermostats in regulating heating or cooling of rooms.

Bimetals cannot generate electricity.

6. (A) A bimetallic strip, when heated bends towards the metal with lower thermal expansion coefficient.

7. (D) Given,

$\Delta l_1 = \Delta l_2$

$l_1 \alpha_A t = l_2 \alpha_B t$

$l_1 \alpha A = l_2 \alpha B$

Now,

$$\frac{l_1}{l_1 + l_2} = \frac{l_1}{l_1 + \left(l_1 \frac{\alpha A}{\alpha B}\right)} = \frac{1}{1 + \frac{\alpha A}{\alpha B}}$$

$$= \frac{\alpha B}{\alpha A + \alpha B}.$$

8. (A) When a liquid is heated, its volume increases and mass of liquid being same density decreases.

9. (B) The surface water in a lake is going to freeze (i.e., 0°C), then the temperature of water at the bottom is 277 K.

10. (B) On heating a liquid of coefficient of cubical expansion α in a container having coefficient of linear expansion on '$\alpha/3$', the level of liquid in the container will fall.

11. (B) By increasing the temperature of a liquid, volume of liquid increases and density decreases.

12. (C) Sun's heat reaches the earth by the process of radiation.

BRAIN NURTURES

1. Given, Boiling point of turpentine on fahrenheit scale $(F_1) = 2C_1$

Boiling point of tar on celsius scale $C_2 = 140 + C_1$

$$\frac{(F_1 - 32)}{9} = \frac{C_1}{5}$$

$$\frac{2C_1 - 32}{9} = \frac{C_1}{5}$$

$$10C_1 - 160 = 9C_1$$

$$C_1 = 160\ °C$$

Boiling point of tar $C_2 = 140 + C_1$

$= 140 + 160$

$= 300°C$

$C_2 = K - 273$

$K = C_2 + 273$

$= 300 + 273$

$= 573\ K$

Hence, boiling point of tar on kelvin scale is 573 K.

2. Reading on celsius scale (C) = 65 °C

$$\frac{C}{5} = \frac{(F - 32)}{9}$$

$$\frac{65}{5} = \frac{F - 32}{9}$$

$$13 = \frac{F - 32}{9}$$

$$F = 149\ °F$$

Reading as Fahrenheit scale = 154 °F

Error = 154 – 149 = 5 °F

3. Let the temperature of hot liquid be x and distance between two fixed points by y.

Rise in liquid level $= \frac{4}{5}y$

Reading on celsius scale

$$= \frac{4}{5}\frac{y}{y} \times 100 = 80\ °C$$

Reading on Fahrenheit scale

$$= \left(\frac{4}{5}\frac{y}{y} \times 180°\right) + 32 = 176\ °F$$

4. The radius of iron rim to be put on the cart wheel is always a little smaller than the radius of the wheel. When the iron rim is heated red hot, its size becomes greater than that of wheel and it easily slips on the wheel. When the rim is allowed to cool, it returns to its original size and fits firmly on the wheel.

5. The size of the hole will increase. To understand it, think of the piece of metal removed from the hole, rather than of the hole itself. This piece would expand on heating. This piece will fit into the hole only, if the hole has also increased in size. Another way to analyse the situation is that if we draw a circle on the metal sheet, the radius of the circle will increase.

6. Distance between LFP and UFP

(x) = 20 cm

Distance between LFP and liquid

(y) = 16 cm

$$\frac{y}{x} = \frac{16\ cm}{20\ cm} \quad .....(1)$$

$$\frac{y}{x} = \frac{C}{100} \quad .....(2)$$

from (1) and (2)

$$\frac{16}{20} = \frac{C}{100}$$

$$C = 80\ °C$$

7. The different forms of heat loss are minimized in a thermos flask, due to the following reasons.

Conduction loss: Since there is a vacuum, heat cannot be conducted by means of conduction. Further there is a cork and glass wool which are bad conductors of heat.

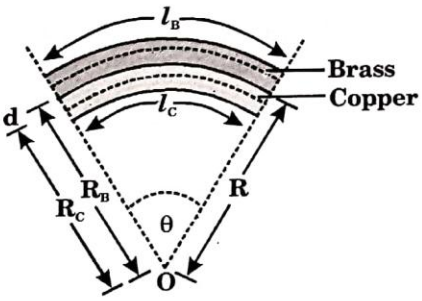
Convection loss: Since there is a vacuum, loss due to convection is avoided.

Radiation loss: Since the glass is shinning, radiation loss is minimized.

8. Let there be two identical strips of copper and brass of equal thickness d and length l_0, When the bimetallic strip is heated through temperature ΔT, the copper strip increases to length l_C and the brass strip to length l_B. Since $\alpha_B > \alpha_C$, the increase in the length of the brass strip is more than that of the copper strip. As a result, the bimetallic strip bends into a circular arc.

Let R, R_B and R_C be the mean radii of curvature of the bimetallic strip, brass strip and copper strip respectively.

Then, $R_B - R_C = d$, the thickness of copper or brass strip.



Now, $l_C = l_0(1 + \alpha_C \Delta T)$ and $l_B = l_0(1 + \alpha_B \Delta T)$

$$\therefore\ l_B - l_C = l_0(1 + \alpha_B \Delta T) - l_0(1 + \alpha_C \Delta T)$$

$$l_B - l_C = l_0(\alpha_B - \alpha_C)\,\Delta T \qquad \text{..... (1)}$$

Let θ be the angle subtended by the bimetallic strip at its centre of curvature O. Then and $l_B = \theta R_B$

$$\therefore\ l_B - l_C = \theta R_B - \theta R_C = \theta(R_B - R_C)$$

Since, $R_B - R_C = d$, we have

$$l_B - l_C = \theta d \qquad \text{..... (2)}$$

From the equations (1) and (2), we have

$$\theta d = l_0(\alpha_B - \alpha_C)\Delta T \qquad \text{..... (3)}$$

The mean radius of curvature of the bimetallic strip is approximately given by

$$\theta = \frac{l_0}{R} \qquad \text{..... (4)}$$

From the equations (3) and (4), we have

$$\frac{l_0}{R} d = l_0(\alpha_B - \alpha_C)\Delta T$$

$$R = \frac{d}{(\alpha_B - \alpha_C)\Delta T}.$$

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Chapter 9

Wave Motion and Sound

SOLUTIONS

BASIC PRACTICE

FILL IN THE BLANKS

3. Distance between 1st crest and 7th crest $= 6\lambda$

Distance between 7th crest and 7th through $= \lambda/2$

$\therefore$ Distance between 1st crest and 7th through

$$= 6\lambda + \frac{\lambda}{2}$$

$$= \frac{13\lambda}{2} = \frac{13\times 20}{2} = 130\,\text{cm}$$

4. $n = \dfrac{330}{1.1} = 300\,\text{Hz}$

6. $\lambda = \left(\dfrac{330}{20}\text{m} - \dfrac{330}{20\times 10^3}\text{m}\right)$

$= (16.5\text{ m} - 16.5\text{ mm})$

7. $v = 250\times 1 = 250\,\text{m s}^{-1}$;

$t = \dfrac{100}{250}\text{ s} = 0.45$

Distance travelled by wave in the time taken to produce 100 waves $= v \times \text{time}$

$= 250 \times 0.4$

$= 100$ m

11. $\dfrac{v_0}{v_T} = \sqrt{\dfrac{273}{t+273}}$

$$\left(\frac{v_0}{2v_0}\right)^2 = \frac{273}{t+273}$$

$t + 273 = 4\times 273$

$t = 819\ °C$

FURTHER PRACTICE

MULTIPLE CHOICE QUESTIONS

1. (D) $V = \nu\lambda$

$= 10^3\text{ Hz} \times 0.25\text{ m}$

$= 250\text{ m s}^{-1}$

Time taken to travel 2.2 km

$$= \frac{\text{Distance}}{\text{velocity}} = \frac{2200\text{ m}}{250\text{ m s}^{-1}}$$

$$= 8.8\text{ s} = 8\frac{4}{5}\text{ s}$$

2. (C) Distance between 2nd crest and 6th trough

$$= 4\lambda + \frac{\lambda}{2} = \frac{9\lambda}{2}$$

$\dfrac{9\lambda}{2} = 24$ cm

$\lambda = \dfrac{24\times 2}{9}\text{ cm} = \dfrac{48}{9}\text{ cm}$

$V = 20\text{ m s}^{-1}$

$\nu = \dfrac{V}{\lambda} = \dfrac{20}{48}\times 9\times 100\text{ Hz}$

$= 375$ Hz

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3. (A) A wave covers 2.5 oscillations while producing 3 crests and 2 troughs.

Given 2.5 oscillations complete in 2 ms

2.5 oscillations complete in 1 sec.

$$\frac{2.5\times 1s}{2\times 10^{-3}s} = 1.25\times 10^{3}\ Hz$$

$$= 1250\ Hz$$

4. (C) The audible wave length range of human beings in (16.5 mm–16.5 m)

Hence 1 m is the correct option.

5. (C) $$\frac{V_{27}}{V_{127}} = \sqrt{\frac{(27+273)}{(127+273)}}$$

$$\frac{30}{V_{127}} = \sqrt{\frac{300}{400}}$$

$$V_{127} = 34.64\ m\,s^{-1}$$

(or)

$$20\sqrt{3}\ m\,s^{-1}$$

6. (B) When the pressure of a gas is changed, then the ratio of the pressure to the density remains unaffected as $\frac{P}{\rho} = \frac{RT}{M}$.

7. (B) If wind blows in a direction opposite to the sound propagation, then the velocity of the sound decreases.

8. (C) The persistence of sound in a closed enclosure, due to continuous reflections at the walls, even after the source has stopped producing sound is known as reverberation.

9. (B) The person sitting in Hyderabad will hear him first as he receives in the form of electromagnetic waves electromagnetic waves travels with speed of light. ($3 \times 10^{8}\ m\,s^{-1}$). The sound heard by a person sitting in the auditorium hears sound waves directly which may travel with $330\ m\,s^{-1}$ (approx).

10. (D) Given, $\nu = 1000$ Hz

$$V = \frac{d}{t} = \frac{600}{2} = 300\ m\,s^{-1}$$

$$\lambda = \frac{V}{\nu} = \frac{300}{1000} = 0.3\ m$$

Distance between XY = 600 m

$\therefore$ No. of wavelengths

$$= \frac{\text{Distance between XY}}{\lambda}$$

$$= \frac{600}{0.3} = 2000$$

11. (C) Human ears can sense sound waves travelling in air having wave length of 1 m.

12. (B) $\nu = 440$ Hz

$V = 340\ m\,s^{-1}$

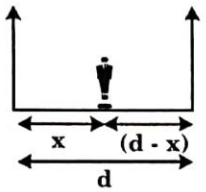
$$\lambda = \frac{V}{\nu} = \frac{340}{440} = 0.77\,m$$

13. (C) Elastic waves in solid are either transverse or longitudinal.

14. (A) Changes in air temperature have no effect on the speed of sound is the wrong statement as $V \alpha \sqrt{T}$.

15. (C) In an orchestra, the musical sounds of different instruments are distinguished from one another by quality of sound.

16. (B)



If x is the distance of 1st cliff to hear first echo then;

$$V = \frac{2x}{2} \Rightarrow x = V = 330m$$

If (d – x) is the distance to hear 2nd echo from 2nd cliff then,

$$V = \frac{2(d-x)}{4} \Rightarrow (d-x) = 660 \text{ m}$$

Distance between two cliffs

$$(d) = x + (d - x)$$
$$= 330 + 660$$
$$= 990 \text{ m}$$

MULTIPLE ANSWERS QUESTIONS

1. (A, B) A mechanical wave will be transverse or longitudinal depending on the nature of medium and the mode of excitation.

2. (A,C,D) Transverse mechanical wave can travel in iron rod or water or stretched string i.e., in solid or on the surface of liquids.

3. (A, B) The velocity of sound is affected by change in temperature or in medium.

4. (A, D) Bells are made of metal and not of wood because metals are more elastic than wood or wood dampness vibrations faster.

5. (A,B,C) Light waves or Heat waves or X–rays can travel through vacuum.

ASSERTION AND REASONING

1. (A) Ultrasonic waves are longitudinal waves of frequency greater than 20,000 Hz. This implies that a human being cannot hear beyond 20,000 Hz. i.e., the maximum frequency of audible sound is 20,000 Hz.

2. (A) A sound wave travels slowly when moisture is present in air. Because on presence of moisture in air the density of air increases hence velocity of sound decreases as it is inversely proportional to density. Hence on a rainy day sound travels slower than on a dry day.

3. (C) Two persons on the surface of moon cannot talk to each other. Because sound needs a material medium for its propagation.

4. (A) In a longitudinal wave, the particles of the medium vibrate to and fro parallel to the direction of propagation of the wave. When a piston is moved back and forth the waves in a cylinder containing a liquid produces a series of compressions and rarefactions resulting in a longitudinal wave.

5. (A) The longitudinal waves are called pressure waves because propagation of longitudinal waves through a medium involves changes in pressure and volume of air, when compression and rarefaction are formed.

PARAGRAPH QUESTIONS

(i) (C) Given, Distance between points and D = 12 m

Distance between points A and D

$$= AC + CD = \frac{3\lambda}{2}$$

$$\frac{3\lambda}{2} = 12$$

$$\lambda = 8 \text{ m}$$

(ii) (A) Time taken by wave to propagate between points A and C = (2–0.4) s

1.6 s is the time period of the wave

(iii) (D) Velocity of the wave

$$= \frac{\text{wavelength}}{\text{timeperiod}} = \frac{8}{1.6} = 5\,\text{m s}^{-1}$$

NUMERICAL PROBLEMS

1. (i) Speed of sound

$$v = \frac{2d}{t} = \frac{2\times 66}{0.4} = 330\,\text{m s}^{-1}$$

(ii) Distance of man from cliff

$$y = d = \frac{v\times t}{2} = 330\times\frac{1.2}{2} = 198\,\text{m}.$$

2. Given velocity, V_1 (in air) = 344 m s^{-1}, V_2 (an iron) = 5130 m s^{-1}

Let l (m) be the length of the pipe and t_1 and t_2 are time taken by sound in air and in iron respectively to reach the other end of the pipe $t = \frac{l}{v}$

$$\therefore \quad t_1 = \frac{l}{v_1} = \frac{l}{344}\,\text{s} \quad \text{and}$$

$$t_2 = \frac{l}{v_2} = \frac{l}{5130}\,\text{s}$$

Ratio

$$\frac{t_1(\text{in air})}{t_2(\text{in iron})} = \left(\frac{l}{344}\right)\Big/\left(\frac{l}{5130}\right)$$

$$= \frac{5130}{344} = 14.9 \approx 15:1$$

3. $V = \sqrt{\frac{\gamma p}{d}}$ and $\frac{p}{d} = \frac{RT}{M}$

$$V = \sqrt{\frac{\gamma RT}{M}}$$

For nitrogen, $V_{N_2} = \sqrt{\frac{\gamma RT_{N_2}}{M_{N_2}}}$

For Oxygen, $V_{O_2} = \sqrt{\frac{\gamma RT_{O_2}}{M_{O_2}}}$

Given $V_{N_2} = \frac{1}{2}V_{O_2}$

$$\therefore \quad \frac{V_{O_2}}{V_{N_2}} = \sqrt{\frac{T_{O_2}}{M_{O_2}}\times\frac{M_{N_2}}{T_{N_2}}}$$

$$2 = \sqrt{\frac{298}{16}\times\frac{14}{T_{N_2}}}$$

$$(T_{N_2})4 = \frac{298(14)}{(16)}$$

$$T_{N_2} = \frac{1043}{16} = 65.18\,\text{K}$$

4. Let t_a be time taken in air and t_i be the time taken in iron by the sound and $\Delta t = t_a - t_1 = 0.55$ velocity of sound in air = 320 m s^{-1} velocity of sound in iron = 4320 m s^{-1}.

If λ is the length of iron pipe, then

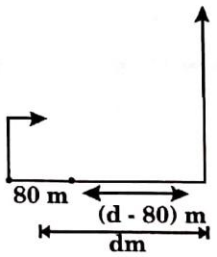
$$\Delta t = t_a - t_1 = \frac{L}{V_s} - \frac{L}{V_i}$$

$$0.5 = \frac{L}{320} - \frac{L}{4320}$$

$$\lambda = \frac{0.5\times 320\times 4320}{(4320-320)}$$

$$\lambda = 172.8\,\text{m}$$

5. Let distance from wall to the first fired place be 'd' m.



Then the time after which echo heard is 2s.

$\therefore \quad V = \frac{2d}{t} = \frac{2d}{2}$

$V = d$ .... (1)

He walked 80 m then the distance of person from wall to the second fired place is (d – 80) m and time taken for echo to be heard at this point is 1 s.

$V = \frac{2(d-80)}{1}$

$V = 2(d-80)$ .... (2)

From (1) and (2)

$d = 2d - 160$

$d = 160$ m

The distance from wall to the second fired place is $(d - 80) = 160 - 80 = 80$ m.

6. Let initial temperature of sound be T. increased temperature

$T^1 = T + 0.44\,T$

$T^1 = 1.44\,T$

$V \alpha \sqrt{T}$

$\frac{V_1}{V^1} = \sqrt{\frac{T}{T^1}}$

$\frac{V}{V^1} = \sqrt{\frac{T}{1.44T}}$

$V = \frac{V^1}{1.2}$

$V^1 = 1.2V$

Percentage change in velocity

$= \frac{V^1 - V}{V} \times 100$

$\frac{1.2V - V}{V} \times 100$

7. Let time taken to traverse 2 m distance by rods P and Q able t_p and t_Q respectively.

Velocity of sound in solids = $\sqrt{\frac{Y}{d}}$

Given $Y_P = 2\,Y_Q$

$dP_Q = 18\,d_P$

$\therefore \quad \frac{V_P}{V_Q} = \sqrt{\frac{Y_P}{Y_Q} \times \frac{d_Q}{d_P}}$

$= \sqrt{\frac{1}{2} \times \frac{18}{1}} = \sqrt{9} = 3$

$V_P = 3V_Q$

$V \alpha \frac{1}{t}$ (for same distance)

$\therefore$ Time taken by rod P is less than that of Q and by 3 times.

8. Given density of hydrogen = 1

density of nitrogen = 14

Let the volume of the mixture be x

Volume of hydrogen in the mixture

$= \frac{2x}{3}$

Volume of hydrogen in the mixture

$= \frac{2x}{3} \times 1 = \frac{2x}{3}$

Mass of oxygen in the mixture = $\frac{x}{3} \times 14$

Total mass of the mixture = $\frac{16x}{3}$

Density of mixture = $\frac{\text{total mass}}{\text{total valume}}$

$= \frac{16x}{3(x)} = \frac{16}{3}$

$V \alpha \frac{1}{\sqrt{d}}$

$\therefore \quad \frac{v_1}{v_2} = \sqrt{\frac{d_2}{d_1}}$

$$\frac{1400}{v_2}=\sqrt{\frac{16}{3\times1}}$$

$$V_2=\frac{1400\sqrt{3}}{4}=350\sqrt{3}\,ms^{-1}$$

9. The time taken for a particle to oscillate from one extreme to other extreme is equal to half the time period i.e., $\frac{T}{2}$.

$\therefore \quad \frac{T}{2}=4s$ (given)

$T = 8$ s

$$\omega=\frac{2\pi}{1}=\frac{2\pi}{8}=0.25\pi$$

10. We know that for longitudinal waves in solids,

$$v=\sqrt{\frac{Y}{\rho}}, \text{ so } v=\sqrt{\frac{8\times10^{10}}{2.65\times10^3}}$$

$= 5.5 \times 10^3$ m/s

so 10^{-2} m

But as $v = f\lambda$, i.e, $f=(v/\lambda)$

so $f\,[5.5 \times 10^3/10^{-2}] = 5.5 \times 10^5$ Hz

$= 550$ kHz.

11. In terms of density and pressure.

$$\frac{v_H}{v_{air}}=\sqrt{\frac{P_H}{\rho_H}\times\frac{\rho_{air}}{P_{air}}}=\sqrt{\frac{\rho_{air}}{\rho_H}}$$

$$[\text{as } P_{air}=P_H] \text{ or } v_H=v_{air}\times\sqrt{\frac{\rho_{air}}{\rho_H}}$$

$$=332\times\sqrt{\frac{16}{1}}=1328\ ms^{-1}$$

12. In terms of temperature and molecular weight,

$$\frac{v_{Ne}}{v_W}=\sqrt{\frac{\gamma_{Ne}}{M_{Ne}}\times\frac{M_W}{\gamma_W}} \qquad [\text{as } T_N=T_W]$$

Now as neon is monatomic ($\gamma = 5/3$) while water vapours poly atomic

($\gamma = 4/3$) ; so

$$\frac{v_{Ne}}{v_W}=\sqrt{\frac{(5/3)\times1.8\times10^{-2}}{(4/3)\times2.02\times10^{-2}}}$$

$$=\sqrt{\frac{5}{4}\times\frac{1.8}{2.02}}=1.055$$

13. $v_l = 4\,v_{air}$

$$\frac{v_l}{v_{air}}=\frac{\lambda_l}{\lambda_{air}}$$

$\therefore \quad \lambda_l = 4\lambda_{air}$

change in wave length $= \lambda_l - \lambda_{air} = 3\lambda_{air}$

14. Let v_1 and v_2 be the speeds of sound in neon and water vapour respectively. Suppose that M_1 and M_2 are that molecular weights of neon and water vapour respectively. If γ is their ratio of the specific heats, then

$$\text{Let } \frac{v_1}{v_2}=\sqrt{\frac{\lambda RT}{M_1}}\times\sqrt{\frac{M_2}{\lambda RT}}=\sqrt{\frac{M_2}{M_1}}$$

Here, $M_1 = 2.02 \times 10^{-2}$ kg mole^{-1};

$M_2 = 1.8 \times 10^{-2}$ kg mole^{-1};

$$\therefore \quad \frac{v_1}{v_2}=\sqrt{\frac{1.8\times10^{-2}}{2.02\times10^{-2}}}=0.944$$

15. Here, $\upsilon = 220$ kHz $= 220 \times 10^3$

$= 2.2 \times 10^5$ Hz;

speed of sound in air, $v_a = 352$ m s^{-1}

speed of sound in water, $v_w = 1.496$ m s^{-1}

(a) The reflected sound: After reflection, the ultrasonic sound continues to travel in air. If λ_a is wavelength in air, then

$$\lambda_a = \frac{v_a}{v} = \frac{352}{2.2\times10^5} = 1.6 \times 10^{-3} \text{ m.}$$

(b) The transmitted sound: The transmitted ultrasonic sound travels in water. If λ_w is wavelength of ultrasonic sound in water, then

$$\lambda_w = \frac{v_w}{v} = \frac{1,496}{2.2\times10^5} = 6.8 \times 10^{-3} \text{ m.}$$

CONCEPTUAL QUESTIONS

1. Ordinarily, the velocity of the wind at a certain altitude above the ground is greater than at its surface. For this reason the wave surfaces which in immobile air have the form of spheres with their centre at the point of the sound sources change of the wind the sound is deflected towards the ground and the man hears it.

2. Speed of sound in air, V = 344 m s^{-1}, Lowest frequency N_1 = 20 Hz, Highest frequency,

N_2 = 20 kHz = 2×10^4 Hz

Corresponding wavelengths,

λ_1 and λ_2 = ? (to the calculated)

From relation, $V = N\lambda$

We have $\lambda = \frac{V}{N}$,

Longest wavelength, $\lambda_1 = \frac{V}{N_1}$

Putting values, we get

$$\lambda_1 = \frac{344}{20} = 17.2 \text{ m}$$

Longest wavelength = 17.2 m,

Shortest wavelength, $\lambda_2 = \frac{V}{N_2}$

Putting values, we get

$$\lambda_2 = \frac{344}{2\times10^4} = 17.2\times10^{-3} \text{ m}$$

3. Person Q hears the sound twice:

(i) due to travelling of sound in air from P to Q

(ii) due to echo

t = 2 S

$$\frac{2x}{t} = V$$

$$x = \frac{V\times t}{2} = \frac{340\times2}{2}$$

x = 340 m

Distance between P and Q

= x + 680

= 340 + 680

= 1020 m

4. Following are the points that distinguish a sound wave from a radio wave :

(a) Sound waves cannot travel through free space while radio waves can.

(b) The speed of sound in air is 332 m s^{-1} while of radio waves 3×10^8 m s^{-1}.

(c) With rise in temperature the velocity of sound increases while that of radio waves does not change.

(d) Sound waves can never be polarised (excluding the transverse mode in solids) while radio waves can always be polarised.

5. (a) To transmit a transverse mechanical wave the medium must be elastic so as to provide a restoring force when acted on by shearing stress. But liquids and gases flow when acted on by shearing stress. But liquids and gases flow when acted on by shearing stress, i.e, they cannot sustain shear stress to provide restoring force and so cannot transmit transverse mechanical

waves.

(b) Longitudinal waves are pressure waves, i.e, they are transmitted as compression and rarefaction in a medium. Now as the string is non-stretchable so it can neither be compressed.

PREVIOUS CONTEST QUESTIONS

1. (C) A vibrating body produces sound, which depends on frequency.

2. (D) When a bomb explodes on the moon, the sound does not propagate on moon. This is because there is no medium for propagation of sound and hence cannot reach the earth.

3. (A) On increasing the stretching force on a wire in a guitar, the frequency also increases.

4. (A) When sound wave of a sound propagates in different medium, the frequency of sound does not change. Hence the frequency of a source of 20 kHz remain same when produced in water or in air.

5. (B) The velocity of sound in any gas depends upon density and elasticity of gas.

6. (D) When a longitudinal wave is propagated through a material medium, energy and momentum are propagated.

7. (C) Velocity of sound in maximum in a gas of least molecular mass

$$\left(v \alpha \frac{1}{\sqrt{m}}\right) \quad M_H = 2$$

$$M_{He} = 4$$

$$M_{N_2} = 28$$

$$M_{O_2} = 32$$

$\therefore$ Velocity of sound is maximum in H_2

8. (C) $v = \nu\lambda = \frac{54}{60} H_z \times 10\,m = 9\ m\ s^{-1}$

9. (D) In air, sound waves are always longitudinal and light waves are transverse.

10. (A) $\lambda = 5\,cm = 0.05\,m$

$\gamma = 2H_2$

$v = \gamma\lambda = 2 \times 0.05\,m\,s^{-1}$

$= 0.1\ m\ s^{-1}$

or

$10\ cm\ s^{-1}$

BRAIN NURTURES

1. The situation is shown in figure.

Given the velocity of motorist

= 36 km / hour

= 10 m/sec.

So he travels a distance of 10 m in one second. He will hear the first echo after the sound had travelled 330 m through the last path, i.e., reflected at point B.

From figure,

$$AB = \sqrt{(AF^2 + BF^2)} = \sqrt{(5^2 + x^2)}$$

$$\therefore \quad AB + BC = 2\sqrt{(5^2 + x^2)}$$

But $AB + BC = 330$

$$\therefore \quad 2\sqrt{(5^2 + x^2)} = 330\,m$$

Solving we get x = 164.9 m

2. Distance of the object is $l = \frac{c}{\pi} = 120\,m$ and the maximum distance is

$$L = \frac{cT}{2} \cong 90\,km$$

3. At a given temperature, the velocity of sound in a gas is independent of pressure. Since the pressure is increased at constant temperature, the

velocity of sound in the tube will remain 330 m s^{-1}.

4. It is because, the speed of sound in air is independent of the frequency of sound waves.

5. Both the sound of the explosion and the sound produced by a humming bee travel with the same speed. Generally, the amplitude of the sound of the explosion is extremely large. Due to this, the compressions and rarefactions result in appreciable change in temperature of the air. Since the velocity of sound increases with the amplitude of sound waves, the speed of the sound of explosion is usually greater than that produced by the humming bee.

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Chapter 10

Magnetism

SOLUTIONS

MULTIPLE CHOICE QUESTIONS

1. (C) The north pole of earth's magnet is near geographic south.

2. (A) The magnetic lines of force due to a bar magnet are curved lines.

3. (D) Magnetic field lines are closed curves but electric field lines are not is the correct statement.

4. (A) $M = 10\ A\ m^2 = m \times 2l$

$M' = m \times d$ and $2l = \frac{\pi d}{2}$

$\therefore\ d = \frac{2(2l)}{\pi}$

$M' = \frac{m \times (2\,l) \times 2}{\pi} = \frac{2M}{\pi}$

Decrease in magnetic moment

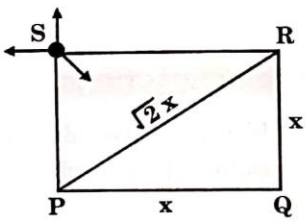
$= M - M' = M - \frac{2M}{\pi}$

$= 10\left[\frac{\pi - 2}{\pi}\right] A\ m^2$

5. (A) $B = \frac{\mu_0 m}{4\pi r^2} = \frac{10^{-7} \times 1500}{(0.5)^2} = 6 \times 10^{-4}\,T$

6. (B) $B_{equi} = \frac{\mu_0}{4\pi}\frac{\mu}{r^3} = \frac{10^{-7} \times 5.4}{(0.3)^3} = 2 \times 10^{-5}\,T$

7. (D) $m = 16\ A\ m$



Let pole strength of pole placed on Q be m_1 A – m

At S, resultant magnetic field = 0.

$$\Rightarrow \sqrt{\left(\frac{\mu_0 m}{4\pi x^2}\right)^2 + \frac{\mu_0 m}{4\pi (x)^2} - \frac{\mu_0\ m_1}{4\pi\,(\sqrt{2}x)^2}}$$

$$= \sqrt{2}\,\frac{\mu_0 m}{4\pi x^2} = \frac{\mu_0 m_1}{4\pi(2)x^2} = 0$$

$m_1 = 2\sqrt{2}\ m = 2\sqrt{2} \times 1$

$m_1 = 32\sqrt{2}\ A$

The pole must be north pole.

8. (C) Final magnetic moment

$= m \times$ gap between its ends

$= \frac{\mu}{2\,l} \times 2\ cm$

$= \frac{0.4}{10} \times 2 = 0.08\ A\ m^2$

9. (C) $F = \frac{k\ m_1\ m_2}{d^2}$

Given $m_1 = 2m_2^1$

$m_2 = 2m_2^1$

$d^1 = 2d$

$F' = \frac{k(2m_1)\,(2m_2)}{(2d)^2} = \frac{km_1\ m_2}{d^2} = F$

$\therefore$ Force between them remains unchanged.

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10. (B) Magnetic lines of force are closed curves, that never, intersect and pass through vacuum.

11. (D) Two short magnets placed along the same axis with their like poles facing each other will repel each other with a force which varies inversely as fourth power of distance.

12. (B) Earth's magnetic field always has a horizontal component except at magnetic pole.

13. (D) The angle of dip at a place on the earth gives the direction of the earth's magnetic field.

14. (A) The angle of dip at the magnetic equator is zero.

15. (B) The magnetic field of earth is due to motion and distribution of some material in and outside the earth.

MULTIPLE ANSWERS QUESTIONS

1.(B, C, D) The figures given in option B,C and D depict non uniform magnetic field.

2.(A,B,D) Magnetic lines of force appear to converge or diverge at poles, Magnetic lines of force never intersect each other. A magnet attracts certain other substances through the phenomenon of magnetic induction.

3.(A,B,C,D) At a neutral point, there cannot be any lines of force. Magnetic lines of force exist inside every magnetised material. Soft iron pieces are used as magnetic keepers. The magnetic moment of a magnet decreases on bending it into a semicircle.

4. (A, C) Magnetic moment and Magnetic induction are vector quantities.

5. (B, D) A magnet is placed in earth's magnetic field with south pole of the magnet pointing north. At the neutral point the fields of the magnet and the earth are equal and in opposite direction or the net magnetic field is zero.

ASSERTION AND REASONING

1. (A) Since no electric lines of forces exist inside a charged body, the electric lines of force only travel from positive to negative and are discontinuous. Secondly, magnetic lines of force travel from north to south pole and inside magnet they are from south pole to north pole hence, continuous.

2. (A) At neutral point, a compass needle point out in any arbitrary direction. Hence magnetic field of earth is balanced by field due to magnets at the neutral points.

3. (A) There are two neutral points on a horizontal board when a magnet is held vertically on the board because at the neutral point the net magnetic field due to the magnetic and magnetic field of the earth is zero.

4. (C) Poles of a magnet can never be separated because since each molecule of a magnetic material magnet in itself.

5. (A) To protect any instrument from external magnetic field, it is put inside an iron body because Iron is a magnetic substance.

PARAGRAPH QUESTIONS

1. (i) (C) If $\theta = 60°$ the dotted lines are radius of the circle then, distance between ends of two wires r.

$$M' = m \times r \quad \text{But } 2l = 4 \times \frac{\pi}{3}$$

$$= m \times \frac{3}{\pi}(2l) = \frac{3M}{\pi}$$

(ii) (D) At $\theta = 240°$

$$2l = 4 \times \frac{4}{3}\pi \Rightarrow r = (2l)\frac{3}{4\pi}$$

$$\therefore \quad M' = m \times (2l)\frac{3}{4\pi} = \frac{3M}{4\pi}$$

(iii) (B) If the value of θ increases r value decreases. Hence magnetic moment value decreases.

NUMERICAL PROBLEMS

1. On the axial line $B_a = \frac{\mu_0}{4\pi}\frac{2M}{d^3}$

So, $\frac{512}{125} = \left(\frac{x+15}{x}\right)^3$ where 'x' is distance to first point from the magnet on simplifying we get x = 25 cm.

2. $M = 0.2 \times 0.314 \text{ A m}^2 = 0.0628 \text{ Am}^2$

When bent in the form of a semicircle

New magnetic length = 2r

$$\pi r = 2l$$

$$r = \frac{2l}{\pi}$$

$$\text{Magnetic moment} = m \times 2 \times \frac{2l}{\pi}$$

$$= M \times \frac{2}{\pi}$$

$$= 0.0399 \text{ A m}^2$$

$$= 0.04 \text{ A m}^2$$

3. Given, $F = \frac{G\, m_1\, m_2}{d^2}$

$$4F = \frac{Gm_1m_2}{d^{12}}$$

$$(d^1)^2 = \frac{Gm_1m_2}{4F} = \frac{d^2}{4}$$

$$d^1 = \frac{d}{2}$$

$$\% \text{ Change in distance} = \frac{d' - d}{d} \times 100$$

$$= \frac{\frac{d}{2} - d}{d} \times 100$$

$$= \frac{-d}{2d} \times 100 = -50\%$$

4. $B = \frac{\mu_0\, 2M}{4\pi d^3}$

(a) At (d/4) distance,

$$B' = \frac{\mu_0\, 2M}{4\pi\,(d/4)^3}$$

$$= \frac{\mu_0\, 2M}{4\pi d^3} \times 64 = 64\, B$$

(b) At (4d/5) distance

$$B' = \frac{\mu_0 2M}{4\pi\left(\frac{4d}{5}\right)^3} = \frac{\mu_0\, 2M}{4\,\pi\,(d^3)}\left(\frac{125}{64}\right)$$

$$= \frac{125}{64}B$$

5. Distance of null point from pole shorter

$$= \frac{d}{\sqrt{\frac{m_2}{m_1}} + 1} = \frac{d}{\sqrt{\frac{9m}{m}} + 1} = \frac{d}{3+1} = \frac{d}{4}$$

$\therefore$ Distance of null point from larger pole

$$= d - \frac{d}{4} = \frac{3d}{4}.$$

6. Given $m_1 = m_2 = 16$ A m

d = 2 m

$$F = \frac{\mu_0}{4\pi}\frac{m_1m_2}{d^2} = \frac{10^{-7} \times 16 \times 16}{2^2}$$

$$= 64 \times 10^{-7} \text{ N}$$

7. $r = \sqrt{13}\,d\,;\,2l = 2d$

$$B_{eq} = \frac{\mu_0}{4\pi} \times \frac{\mu}{(r^2 + l^2)^{3/2}}$$

$$= \frac{\mu_0}{4\pi} \times \frac{M}{\left((\sqrt{13}d)^2 + (2d)^2\right)^{3/2}}$$

$$= \frac{\mu_0}{4\pi} \times \frac{M}{(17d^2)^{3/2}} = \frac{\mu_0 M}{4\pi(d^3)(17)^{3/2}}$$

8. Magnetic induction due to S-pole at point q.

$$\frac{\mu_0 m}{4\pi r^2} \text{ (attractive)}$$

Magnetic induction due to N-pole (B_2)

$$= \frac{\mu_0 m}{4\pi(2)^2 r^2} \text{ (repulsions)}$$

Resultant magnetic induction at point q

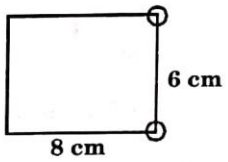
$$= B_1 - B_2$$

$$= \frac{\mu_0 m}{4\pi r^2} - \frac{\mu_0 m}{4\pi(4r^2)}$$

$$= \frac{\mu_0 m\,(4-1)}{4\pi\left(\frac{4r^2}{1}\right)}$$

$$= \left(\frac{3}{4}\right)\frac{\mu_0 M}{4\pi r^2}$$

9.



$$F = \frac{\mu_0}{4\pi} \times \frac{(m)(m)}{(6)^2 \times 10^{-4}}$$

$$F = \frac{\mu_0}{4\pi} \frac{m^2}{(36 \times 10^{-4})}$$

Distance between diagonal points

$$d' = \sqrt{8^2 + 6^2} = \sqrt{64 + 36} = 10 \text{ cm}$$

$$F \propto \frac{1}{d}$$

$$\therefore \quad \frac{F'}{F} = \frac{36 \times \cancel{10^{-4}}}{100 \times \cancel{10^{-4}}}$$

$$F' = \frac{9}{25} F \text{ or } \frac{18}{50} F$$

10. $F = \frac{\mu_0}{4\pi} \frac{(m)(5m)}{a^2}$

Distance between A and C i.e.,

$$AC = \sqrt{a^2 + (4a)^2} = \sqrt{17}a$$

$$F' = \frac{\mu_0}{4\pi} \frac{(m)(5m)}{(\sqrt{17}a)^2} = \frac{\mu_0 (m)(5m)}{4\pi(17)(a^2)}$$

$$F' = \frac{F}{17}$$

11. $M = \frac{30}{\pi} A\,m^2 = m \times r$

$\frac{1}{6}^{th}$ of circumference of a circle

$$= \frac{1}{6}(2\pi r)$$

Angle subtended by $\frac{1}{6}^{th}$ of a circle (θ)

$$= \frac{1}{6}(360°) = 60° \text{ or } \frac{\pi}{3}$$

$\therefore$ New magnetic moment M^1

$$= m \times 2l$$

$$= m \times r\theta$$

$$= (m \times r) \times \frac{\pi}{3}$$

$$= \frac{30}{\pi} \times \frac{\pi}{3} = 10 \text{ A m}^2$$

12. $B_{axial} = \frac{\mu_0}{4\pi} \frac{2Mr}{(r^2 - l^2)^2}$

$$B_{20} : B_{30} = 128 : 27$$

$$\frac{20}{(20^2 - l^2)^2} \times \frac{(30^2 - l^2)^2}{30} = \frac{128}{127}$$

$$2(30^2 - l^2)^2 (27) = 3 (20^2 - l^2)^2 128$$

$$\sqrt{54}\ (900 - l^2) = \sqrt{384}\ (400 - l^2)$$

$$900\sqrt{54} - \sqrt{54}\ l^2 = \sqrt{384} \times 400 - \sqrt{384}\ l^2$$

$$l^2 (12.2474) = 1224.75$$

$$l^2 = 100;\ l = \sqrt{100} - 10 \text{ cm}$$

$\therefore$ Magnetic length = $2l$ = 20 cm

CONCEPTUAL QUESTIONS

1. If on bringing different ends of the two bars close to each other, they produce repulsion in some case, then both the iron bars are magnetised. Otherwise, one bar is magnetised and the other is simply iron bar. To findout which one is magnetised, call one bar as A and B. Place bar B on table. Bring one end of bar close to the one end of bar B. The bar A will experience attraction. Now, move the bar A to the middle of bar B. If A experiences no force, then A is iron bar and B is magnetised. On the other hand, if bar A experiences force, then A is magnetised and B is iron bar.

2. It is misleading to call magnetic field lines as magnetic lines of force. To elaborate, consider the expression for magnetic Lorentz force :

$$\overline{F_m} = q\left(\vec{v} \times \vec{B}\right)$$

The magnetic force $\overline{F_m}$ is perpendicular to magnetic field $\vec{B}$ i.e. magnetic force is not along the direction of the magnetic field. Hence, the magnetic lines of force should be called only as the magnetic field lines.

3. The temperature inside the earth is so high that it is impossible for the iron core to remain as a magnet and act as a source of magnetic field. The magnetic field due to the earth is considered to be due to the circulating electric currents induced in the iron in molten state and other conducting material inside the earth.

4. Declination at a place is angle between the geographic and magnetic meridians. By knowing the declination, the ship can be steered in the required direction, so as to reach the destination.

5. It will stand vertical with its north pole downwards and south pole upwards.

6. The magnetic compass needle can point in any direction on the geomagnetic north or south pole. It is because, the horizontal component of the earth's field is zero at these points. (The earth's field is vertical).

PREVIOUS CONTEST PROBLEMS

1. (B) Given, Magnetic moment
$M = m \times 2\,l = 80$ units
On cutting it into two equal halves, length, becomes halved

$$\text{i.e., } 2\,l' = \left(\frac{2l}{2}\right)$$

$$\therefore M' = m \times 2\,l' = m \times \left(\frac{2l}{2}\right)$$

$$= \left(\frac{M}{2}\right) = \frac{80}{2} = 40 \text{ units}$$

2. (D) All magnetic materials lose their magnetic properties when strongly heated.

3. (C) Tesla is the unit of magnetic induction

4. (C) If r be the dsitance of a point on the axis of a bar magnet from its centre, the magnetic field at this point is proportional to $(1/r^3)$.

5. (A) The magnetic induction at magnetic poles is along vertical.

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6. (A) A dip needle in a plane perpendicular to magnetic meridian will be vertical.

7. (D) Isogonic lines on a magnetic map will have the same angle of declination.

8. (D) The magnetic field lines due to a bar magnet are correctly shown in figure given in option D.

BRAIN NURTURES

1. Let pole strength be 'm' and magnetic moment of straight wire be 'M'.

So, $M = ml$ ..... (1)

Final magnetic moment ..... (2)

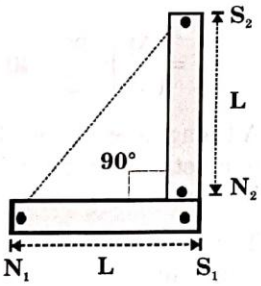
We know that $l = r\theta$ ..... (3)

From the Δ^{le} OQP ; $\sin\frac{\theta}{2} = \frac{x}{r}$

So $x = r\sin\frac{\theta}{2} = \left(\frac{l}{\theta}\right)\sin\left(\frac{\theta}{2}\right)$

Then $M^1 = m\left(\frac{2l}{\theta}\right)\sin\frac{\theta}{2} = 2\left(\frac{M}{\theta}\right)\sin\frac{\theta}{2}$.

2. When the magnets $N_1 S_2$, each of pole strength m and length L, are placed at right angles to each other, the system behaves as a magnet, whose pole strength is m and length is N_1S_2.



Now,

$N_1S_2 = \sqrt{N_1S_1^2 + N_2S_2^2}$

$\sqrt{L^2 + L^2} = \sqrt{2}L$

Therefore, magnetic moment of the system,

M = pole strength $\times N_1S_2 = m \times \sqrt{2}L$.

3. A compass needle is free to rotate in horizontal plane, while a dip needle can freely rotate in vertical plane. The earth has only vertical component of its magnetic field at the magnetic poles. The vertical component of earth's field will exert torque on the magnetic needle so as to align it along its direction. As the compass needle can not rotate in vertical plane, it will rest horizontally, when placed on the magnetic north pole of the earth. On the other hand, the dip needle will come to rest along the vertical.

4. $B_3 - B_1 = \frac{-\mu_0 M(2)}{4\pi d^3} + \frac{\mu_0 4M}{4\pi d^3} = \frac{2\mu_0 M}{4\pi d^3}$

$B_2 = \frac{2\mu_0 M}{4\pi d^3}$

Magentic moment at P

$$= \sqrt{(B_1 - B_3)^2 + B_2^2}$$

$$= \sqrt{\left(\frac{\mu_0 2M}{4\pi d^3}\right)^2 + \left(\frac{\mu_0 2M}{4\pi d^3}\right)^2}$$

$$= \sqrt{8\left(\frac{\mu_0 M}{4\pi d^3}\right)^2} = \sqrt{8}\,\frac{\mu_0 M}{4\pi d^3}$$

If poles of a magnet of higher magnetic moment are reversed:

Magnetic moment at

$$P = \sqrt{(B_1 + B_3)^2 + B_2^2}$$

$$= \sqrt{\left(\frac{2\mu_0 2M}{4\pi d^3}\right)^2 + \left(\frac{\mu_0 2M}{4\pi d^3}\right)^2}$$

$$= \sqrt{40}\,\frac{\mu_0 M}{4\pi d^3}$$

5. $\sqrt{(B_1 - B_3)^2 + B_2^2}$

$$= \sqrt{\left[\frac{\mu_0 M}{4\pi d^3} - \frac{\mu_0 2M}{4\pi d^3}\right]^2 + \left[\frac{\mu_0 2M}{4\pi d^3}\right]^2}$$

$$= \sqrt{\left(\frac{\mu_0 M}{4\pi d^3}\right)^2 + 4\left(\frac{\mu_0 M}{4\pi d^3}\right)^2} = \sqrt{5}\,\frac{\mu_0 M}{4\pi d^3}$$