1.1 MEASUREMENT

1. If the wavelength of the green line of the visible spectrum is 546 nm, its value in metre is
   (*a*) 546×10^{-10}
   (*b*) 546×10^{-19}
   (*c*) 54.6×10^{-8}
   (*d*) 54.6×10^{9}.
2. The speed of light (c), Planck's constant (h) and gravitational constant (G) are taken as the fundamental units in a system. The dimensions of time in this system are
   (*a*) $h^{3/2}\, G^2\, C^{1/2}$
   (*b*) $G^{3/2}\, h^{1/3}\, C$
   (*c*) $C^2\, h\, G^{-2}$
   (*d*) $h^{1/2}\, G^{1/2}\, C^{-5/2}$.
3. Which one of the following has not been expressed in proper units?
   (*a*) momentum $\rightarrow$ kg m s^{-1}
   (*b*) power $\rightarrow$ kg m^2 s^{-3}
   (*c*) power $\rightarrow$ kg m^2 s^{-1}
   (*d*) pressure $\rightarrow$ kg m^{-2} s^{-2}.

4. What is the dimension of the physical quantity α in the equation, $P = \dfrac{\text{density}}{\alpha}$, where P is the pressure?
   (*a*) ML^2T^{-1} (*b*) ML^4T^{-2}
   (*c*) $L^{-2}T^2$ (*d*) $ML^{-2}T^2$.
5. A watt is equal to
   (*a*) 418 calorie per second
   (*b*) one joule per second
   (*c*) 4.18 joule per second
   (*d*) $\dfrac{1}{4.18}$ joule per second.
6. The intensity of the electric field has the unit
   (*a*) newton/coulomb
   (*b*) newton/ampere
   (*c*) ampere/newton
   (*d*) volt/sec.
7. Planck's constant has the dimensions of
   (*a*) power
   (*b*) electric charge
   (*c*) angular momentum
   (*d*) linear momentum.
8. If C and R denote the capacity and resistance respectively the dimensions of CR are
   (*a*) M^0L^2T
   (*b*) M^0L^0T
   (*c*) $M^0L^0T^0$
   (*d*) M^0LT^{-1}.
9. A student conducts an experiment and takes 100 readings. He repeats the experiment and takes 800 readings, by doing so the probability of error
   (*a*) becomes four times
   (*b*) is halved

(*c*) is reduced by $\frac{1}{8}$ factor

(*d*) remains unchanged.

10. The time dependence of a physical quantity L is given by $L = L_0 \exp(-\beta t^2)$, where β is a constant and t is the time. The constant β
(*a*) has the dimension of L
(*b*) has the dimension T^{-2}
(*c*) is dimensionless
(*d*) has the dimension of T^2.

11. Which of the following is the smallest one in magnitude?
(*a*) one metre
(*b*) one millimetre
(*c*) one fermi
(*d*) one angstron unit.

12. One torr is
(*a*) 1 m of Hg
(*b*) 1 atmosphere
(*c*) 1 mm of Hg
(*d*) 1 cm of Hg.

13. Joule degree^{-1} is the unit for
(*a*) solar constant
(*b*) Boltzmann's constant
(*c*) Stefan's constant
(*d*) Planck's constant.

14. The unit of thermal conductivity is
(*a*) $J^{-1} m^{-1} s^{-1} K^{-2}$
(*b*) $J\ m\ s\ K^{-1}$
(*c*) $J^2\ m\ s\ K^{-1}$
(*d*) $J\ m^{-1} s^{-1} K^{-1}$.

15. The unit of magnetic field is
(*a*) weber/m^2
(*b*) weber m
(*c*) m^2/weber
(*d*) weber^2/m^2.

16. The dimension for the universal gas constant is

(*a*) $ML^2T^{-2}\theta^{-1}$ (*b*) $M^2LT^{-2}\theta^{-1}$

(*c*) $MLT^{-1}\theta^{-2}$ (*d*) $ML^2T^{-1}\theta^{-3}$.

PROBLEMS AND SOLUTIONS

1. *Check the correctness of the equation $P = h\rho g$, where P is the pressure at a point h below the surface of a liquid of density, ρ and g is the acceleration due to gravity.*

Solution:

The dimensions of the quantity on the R.H.S. are $h = L$, $\rho = \frac{\text{Mass}}{\text{Volume}} = ML^{-3}$ and $g = LT^{-2}$. Thus the R.H.S. corresponds to $LML^{-3}LT^{-2} = ML^{-1}T^{-2}$

L.H.S. is

$$\boxed{\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{MLT^{-2}}{L^2} = ML^{-1}T^{-2}}$$ **Ans.**

Hence, the equation is dimensionally correct.

2. *The electrical conductivity of a metal is given by the equation*

$$\sigma = \frac{ne^2\tau}{2m}$$

where n is density of free electrons, e and m are respectively the charge and mass of the electron and τ is the relaxation time of the electron. Get the dimensions of electrical conductivity.

Solution:

$$\text{R.H.S.} = \frac{1}{L^3}\frac{(It)^2\,T}{M}$$

$$= M^{-1}L^{-3}A^2T^2\,T$$
$$= M^{-1}L^{-3}T^3A^2$$

This is the dimension of σ, electrical conductivity.

3. *Get the dimensional formula for coefficient of thermal conductivity.*

Solution:

Let us consider a copper rod of uniform cross-section say A sq. m. In the steady state, the quantity of heat conducted is proportional to

1. the area of cross-section
2. time of flow
3. temperature gradient

i.e.,
$$Q \propto At\,\frac{(\theta_1 - \theta_2)}{d}$$
$$Q = \lambda At\,\frac{(\theta_1 - \theta_2)}{d}$$

with λ as the coefficient of thermal conductivity.

Thus

$$\lambda = \frac{Q}{At\,\frac{(\theta_1 - \theta_2)}{d}} = \frac{\mathrm{J}}{\mathrm{m}^2\mathrm{s}\,\frac{\mathrm{K}}{\mathrm{m}}} \qquad ...(1)$$

or $\boxed{\frac{\mathrm{J\,m^{-1}K^{-1}}}{\mathrm{s}} = \mathrm{W\,m^{-1}\,K^{-1}}}$ **Ans.**

This is the unit of coefficient of thermal conductivity.

The dimensions: (Refer Eqn. 1)

$$\frac{MLT^{-2} \times L \times L^{-1}\theta^{-1}}{T} = \boxed{MLT^{-3}\theta^{-1}}$$ **Ans.**

This is the dimension of thermal conductivity.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*d*)	3. (*d*)	4. (*c*)
5. (*b*)	6. (*a*)	7. (*c*)	8. (*b*)
9. (*b*)	10. (*b*)	11. (*c*)	12. (*c*)
13. (*b*)	14. (*d*)	15. (*a*)	16. (*a*)

1.2 SIMPLE HARMONIC MOTION

1. A particle is vibrating in simple harmonic motion with an amplitude 0.04 m. At what displacement from the equilibrium position is its energy half potential and half kinetic?

   (*a*) 1 cm (*b*) 2 cm

   (*c*) $2\sqrt{2}$ cm (*d*) $\sqrt{2}$ cm.

2. Velocity of a particle executing simple harmonic motion is maximum at

   (*a*) mean position

   (*b*) extreme position

   (*c*) both (*a*) and (*b*)

   (*d*) none of these.

3. The number of waves that can be set up in a medium in one sec. is called

   (*a*) wavelength

   (*b*) wave amplitude

   (*c*) wave frequency

   (*d*) wave period.

4. The resultant motion of a particle under the action of two S.H.Ms of the same period and same amplitudes at right angles when the phase is $\frac{\pi}{2}$ is

   (*a*) ellipse

   (*b*) circle

   (*c*) straight line

   (*d*) none of these.

5. The total energy of a particle executing S.H.M. is
   (*a*) inversely proportional to the square of the amplitude
   (*b*) directly proportional to the amplitude
   (*c*) zero
   (*d*) directly proportional to the square of the amplitude.

6. A wheel of 0.5 m radius is considered. When it makes 30 revolutions per minute, the linear speed (in m/s) of a point on the circumfrance is
   (*a*) π (*b*) $\frac{\pi}{2}$
   (*c*) $30\,\pi$ (*d*) $\frac{\pi}{60}$.

7. A body executing S.H.M. will have
   (*a*) maximum velocity when its displacement is zero
   (*b*) no correlation between its displacement and velocity
   (*c*) zero velocity when its displacement is zero
   (*d*) all the above are true.

8. The period of a satellite in a circular orbit near a planet is independent of
   (*a*) the mass of the planet
   (*b*) the radius of the planet
   (*c*) the mass of the satellite
   (*d*) all are true.

9. A body of mass M is suspended from a rubber cord with force constant f. The maximum distance over which the body can be pulled down for the body's oscillations to remain harmonic is

(a) $\frac{2f}{Mg}$ (b) $\frac{f}{Mg}$

(c) $\frac{(\sqrt{Mg})^2}{f}$ (d) $\frac{f^2}{M}$.

10. Lissajous figures are obtained whenever a particle is subjected to two simple harmonic motions simultaneously

(a) along the same straight line

(b) at right angles to each other

(c) at any angle to each other

(d) at an angle of $\frac{3\pi}{4}$ to each other.

11. Lissajous figures are useful in comparing

(a) intensity (b) frequency

(c) loudness (d) quality.

12. If the length of a simple pendulum is increased by 2%, then the time period

(a) decreases by 2%

(b) increases by 1%

(c) decreases by 1%

(d) increases by 2%.

13. In the case of damped motion the forces acted upon the particles are

(a) restoring force

(b) frictional force

(c) the external periodic force

(d) both restoring force and frictional force.

14. Hooke's laws give us a relation between

(a) stress and strain

(b) Poisson's ratio

(c) potential energy and height

(d) velocity and mass.

15. The geometrical moment of inertia of a rectangular beam of breadth 2 cm and thickness 1 cm is

(*a*) $\frac{1}{10}$ (*b*) $\frac{1}{6}$

(*c*) $\frac{1}{12}$ (*d*) 12.

16. Relation between Young's modulus Y and bulk modulus k and the Poisson's ratio σ is
(*a*) $Y = 3k(1 + 2\sigma)$
(*b*) $k = Y(1 + 2\sigma)$
(*c*) $Y = 3k(1 - 2\sigma)$
(*d*) $k = 3Y(1 - 2\sigma)$.

17. Quartz and phosphor bronze are used for the suspension wires of galvanometers because they
(*a*) are highly plastic
(*b*) are highly elastic
(*c*) have negligible elastic after effect
(*d*) have high elastic after effect.

18. The relation for the twisting couple in an elastic material is

(*a*) $\frac{\pi n r^4 \theta}{2\,l}$ (*b*) $\frac{\pi n r^4}{l}$

(*c*) $\frac{l\theta}{\pi n r^4}$ (*d*) $\frac{\theta}{n}$.

19. Four wires of the same material are stretched by the same load. Their dimensions are given below. Which of them will elongates most?
(*a*) diameter 2×10^{-3} m and length 1.5 m
(*b*) diameter 1×10^{-3} m and length 2 m
(*c*) diameter 2×10^{-3} m and length 2 m
(*d*) diameter 0.8×10^{-3} m and length 4 m.

20. The work done in deforming unit volume of a body is
(*a*) stress × strain
(*b*) stress ∝ strain

(*c*) $\frac{1}{2}$ stress × strain

(*d*) stress/strain.

21. Shearing strain is possible only in
(*a*) solids
(*b*) liquids
(*c*) both solids and liquids
(*d*) gases.

22. Poisson's ratio is the ratio between
(*a*) rigidity modulus and Young's modulus
(*b*) Young's modulus and bulk modulus
(*c*) Young's modulus and modulus of rigidity
(*d*) lateral strain and modulus of rigidity.

23. The Young's modulus of rubber is
(*a*) zero
(*b*) 100 N/m^2
(*c*) less than that for steel
(*d*) greater than that for steel.

24. For all materials the frictional force is always
(*a*) perpendicular to the direction of motion
(*b*) along the direction of motion
(*c*) opposite to the direction of motion
(*d*) none of these.

25. If F and R are the limiting force and normal reaction, then coefficient of static friction is
(*a*) $\frac{F}{R}$ (*b*) $\frac{R}{F}$
(*c*) FR (*d*) F^2R.

26. For all materials the coefficient of friction is always
(*a*) less than one
(*b*) greater than one

(*b*) equal to one
(*d*) none of these.

27. Out of the following statements which one is not correct?
(*a*) the friction which comes into play when a body is sliding is known as dynamic friction
(*b*) the friction which comes into play when the body does not move though being pulled by a force is called static friction.
(*c*) the coefficient of static friction can be defined as equal to the tangent of the angle of friction.
(*d*) the work done to overcome friction results in the large amount of power loss.

28. When a body is moving along an inclined plane, the direction of frictional force is always
(*a*) perpendicular to the direction of motion
(*b*) along the direction of motion
(*c*) opposite to the direction of motion
(*d*) none of these.

29. The coefficient of friction is minimum for
(*a*) static friction
(*b*) dynamic friction
(*c*) rolling friction
(*d*) both (*a*) and (*b*).

30. A block of iron weighing 28 kg can be just pulled along a horizontal force of 12 kg. Find the coefficient of friction.
(*a*) $\frac{3}{7}$ (*b*) $\frac{7}{3}$
(*c*) 0.3 (*d*) 0.7.

PROBLEMS AND SOLUTIONS

1. *A body executes S.H.M. such that its velocity at the mean position is 1 m/s and acceleration at one of the extremities is 1.57 m/s^2. Calculate the period of vibration.*

Solution:

Velocity at any point is given by

$$v = \omega[(a^2 - y^2)]^{1/2}$$

At the mean position v = 1 m/s with $y = 0$

$$v = 1 = \omega\, a \qquad ...(1)$$

Acceleration at any point of a body executing S.H.M. is given by

$$\omega^2 y$$

At extremity, $y = a$. Hence, acceleration is

$$\omega^2 a = 1.57 \qquad ...(2)$$

Dividing Eqn. (2) by Eqn. (1),

$$\frac{1.57}{1} = \frac{\omega^2 a}{\omega\, a} = \omega$$

or $$T = \frac{2\pi}{\omega} = \frac{2\pi}{1.57} = 4$$

$$\boxed{T = 4 \text{ sec.}} \quad \textbf{Ans.}$$

2. *Two particles execute simple harmonic motions of the same amplitude and frequency almost along the same straight line. They pass one another, when going in opposite directions each time their displacement is half their amplitude. What is the phase difference between them?*

Solution:

Let the equations of motion of the two particles be

$$y = A \sin \omega t$$

and $$y = A \sin (\omega t + \phi),$$

where ϕ is the phase difference between the two motions. Setting $y = \frac{A}{2}$ in the first case we get $\frac{A}{2} = A \sin \omega t$ or $\sin \omega t = \frac{1}{2}$. Now setting $y = \frac{A}{2}$ in the second case $\frac{A}{2} = A \sin (\omega t + \phi)$ or $\sin (\omega t + \phi) = \frac{1}{2}$

i.e., $\sin \omega t \cos \phi + \cos \omega t \sin \phi = \frac{1}{2}$

or $\sin \omega t \cos \phi + \sqrt{1 - \sin^2 \omega t} \times \sin \phi = \frac{1}{2}$

$\sin \phi \sin \omega t = \frac{1}{2}$, we get

$$\frac{1}{2} \cos \phi + \left(\sqrt{1 - \frac{1}{4}}\right) \times \sin \phi = \frac{1}{2}$$

$$\frac{1}{2} \cos \phi + \sqrt{\frac{3}{4}} \sin \phi = \frac{1}{2}$$

$$\cos \phi + \sqrt{3} \sin \phi = 1$$

$$(1 - \cos \phi) = (\sqrt{3}) \sin \phi$$

Squaring

$$1 + \cos^2 \phi - 2 \cos \phi = 3 \sin^2 \phi$$

or $$1 + \cos^2 \phi - 2 \cos \phi = 3 (1 - \cos^2 \phi)$$

$$4 \cos^2 \phi - 2 \cos \phi = 2$$

or $$2 \cos^2 \phi - \cos \phi - 1 = 0$$

$$\cos \phi = \frac{1 \pm \sqrt{1 - 4 \times 2(-1)}}{2 \times 2} = \frac{1 \pm 3}{4}$$

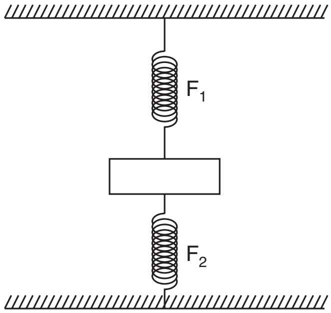
This gives $\cos \phi = -\frac{1}{2}$ or 1

When $\cos\phi = 1, \phi = 0$. This is not possible as particles are not in phase. Therefore

$\cos\phi = -\frac{1}{2}$ is possible or $\phi = 120°$

Thus the required phase difference between the particles = 120°. **Ans.**

3. *In the figure a combination of two springs of force constants F_1 and F_2 are given: Get the time period of oscillation.*



Solution:

In this arrangement, if the mass is displaced up or down by x, the restoring forces are

$$f_1 = -F_1x \text{ and } f_2 = -F_2x$$
$$f = -F_1x - F_2x$$

or $$m\frac{d^2x}{dt^2} + (F_1 + F_2)\,x = 0$$

So, the time period is

$$\boxed{T = 2\pi\left[\sqrt{\frac{m}{(F_1 + F_2)}}\right]}$$ **Ans.**

4. *The position of a particle moving along x-axis is given by $x = 10t^2 - 5t$, where x is in cm and t in sec. (a) What is its initial velocity? (b) Find the maximum distance the body moves to the left of the origin.*

Solution:

Displacement $x = 10t^2 - 5t$

Thus velocity $v = \dfrac{dx}{dt} = 20t - 5$

At $t = 0$; $v = 20 \times 0 - 5 = -5$ cm/s

This initial velocity of – 5 cm/s is directed to the left.

Now acceleration $\dfrac{dv}{dt} = -a = 20$ cm/s^2

Initially the particle is moving to the left and acceleration is to the right. Hence, the particle will come to rest momentarily at a distance s to the left of the origin such that,

$$v^2 = u^2 + 2as$$
$$0 = (-5)^2 + 2 \times 20 \times s$$
$$0 = 25 + 40\,s$$
$$s = -\frac{25}{40} = -0.63 \text{ cm}$$
$$\boxed{s = -0.63 \text{ cm}} \quad \textbf{Ans.}$$

Body moves a distance of 0.63 cm on the left.

5. *When a wave of frequency 300 Hz passes through a medium, the maximum displacement of a particle of the medium is 0.1 cm. Compute the maximum velocity of the particle.*

Solution:

Maximum velocity, $v = \omega a$

i.e., $v = \dfrac{2\pi}{T} a = 2\pi \nu a$

$$= 2\pi \times 300 \times 0.1$$
$$\boxed{v = 60\pi \text{ cm/s}} \quad \textbf{Ans.}$$

6. *Let a body of mass 5 gm execute S.H.M. about a point O with an amplitude of*

10 cm. Its maximum velocity is 1000 cm/s. Its velocity is 500 cm/sec at y cm. Find, y.

Solution:

Velocity will be maximum at $y = 0$. In other places it is $v = \omega\sqrt{a^2 - y^2}$

Thus $1000 = \omega\sqrt{a^2 - 0} = \omega a$

and $500 = \omega\sqrt{a^2 - y^2}$

$$\frac{2}{1} = \frac{a}{\sqrt{a^2 - y^2}}$$

$$4 = \frac{a^2}{a^2 - y^2}$$

$$4a^2 - 4y^2 = a^2$$

$$4y^2 = 3a^2;\ y^2 = \frac{3}{4}a^2$$

$$y = \frac{\sqrt{3}a}{2} = \frac{\sqrt{3} \times 10}{2} = 5(\sqrt{3})\text{ cm}$$

$$\boxed{y = 5(\sqrt{3})\text{ cm}}$$ **Ans.**

7. *A wire of uniform cross-section and 3 metre long weighing 21×10^{-3} kg elongates 2.4×10^{-3} m when stretched by a force of 5 kg.wt. The density of the metal is 8.8×10^3 kg/m^3. Determine (a) the value of Young's modulus of the material, (b) the energy stored in the wire. State the units in which each result is expressed.*

Solution:

$$\text{Work done} = \frac{1}{2}\text{ Stress} \times \text{Strain}$$

or Stress × Strain = 2 × Work done

Volume of the wire

$$= \frac{\text{Mass}}{\text{Density}} = \frac{21 \times 10^{-3}}{8.8 \times 10^{3}} = A \times 3$$

Hence, area of cross-section,

$$A = \frac{21 \times 10^{-3}}{8.8 \times 3 \times 10^{3}}$$

$$= 0.79 \times 10^{-6} \text{ m}^2$$

Young's modulus,

$$Y = \frac{F}{A} \times \frac{l}{x}$$

$$= \frac{5 \times 9.8 \times 3}{0.79 \times 10^{-6} \times 2.4 \times 10^{-3}}$$

$$\boxed{Y = 7.7 \times 10^{3} \text{ N/m}^2} \quad \textbf{Ans.}$$

Energy per m^3 of wire

$$= \frac{1}{2} \text{ Stress} \times \text{Strain}$$

$$= \frac{1}{2}\left[\frac{5 \times 9.8}{0.79 \times 10^{-6}}\right]\left(\frac{2.4 \times 10^{-3}}{3}\right)$$

$$= 10.3 \times 10^{3} \text{ J}$$

Hence, total energy

$$= 10.3 \times 10^{3} \times \text{Volume}$$

$$= \frac{10.3 \times 10^{3} \times 5}{8.8 \times 10^{3}} \text{ J}$$

$$\boxed{E = 5.85 \text{ J}} \quad \textbf{Ans.}$$

8. *On taking a solid ball of rubber from the surface to the bottom of a lake of depth 100 m, the volume of the ball is reduced by 0.2%. If the density of the lake water is 1×10^3 kg/m^3, find the bulk modulus of rubber ball taking $g = 9.8$ m/s^2.*

Solution:

Change in pressure of ball

$$= h\rho g$$

$$= 100 \times (1 \times 10^3 \times 9.8)$$
$$= 9.8 \times 10^5 \text{ N/m}^2$$

Volume of the strain

$$= \frac{v}{V} = 0.2\%$$

$$= \frac{0.2}{100} = 0.2 \times 10^{-2}$$

Thus bulk modulus,

$$k = \frac{9.8 \times 10^5}{0.2 \times 10^{-2}} = 4.4 \times 10^7$$

$$\boxed{k = 4.4 \times 10^7 \text{ N/m}^2} \quad \textbf{Ans.}$$

9. *A uniform disc is suspended by steel wire, allowed to oscillate torsionally with periodic time 4 sec. Find the time period if the length is doubled.*

Solution:

$$T_1 = 4 = 2\pi\sqrt{\frac{I}{C_1}} \quad \text{and}$$

$$T_2 = 2\pi\sqrt{\frac{I}{C_2}}$$

i.e., $$\frac{T_2}{T_1} = \sqrt{\frac{C_1}{C_2}}$$

$$= \sqrt{\frac{\pi n r^4}{2l} \times \frac{2(2l)}{\pi n r^4}} = \sqrt{2}$$

$$\frac{T_2}{T_1} = \sqrt{2} \quad \text{or} \quad T_2 = \sqrt{2}\,(T_1)$$

$$T_2 = 4 \times \sqrt{2} = 5.566 \text{ sec.}$$

$$\boxed{T_2 = 5.566 \text{ sec}} \quad \textbf{Ans.}$$

10. *Two pieces of iron wire have lengths L and 2L respectively with their diameters D and $\frac{D}{2}$ respectively. If the wires are stretched by same force, then find the relation between their elongations.*

Solution:

$$Y = \frac{F \times L}{\pi\left(\frac{D}{2}\right)^2 \times x_1}$$

$$= \frac{F \times 2L}{\pi\left(\frac{D}{2 \times 2}\right)^2 \times x_2}$$

i.e., $$\frac{4}{x_1} = \frac{2 \times 16}{x_2};\ \frac{x_2}{x_1} = 8$$

$$\boxed{x_2 = 8x_1} \quad \textbf{Ans.}$$

11. *The extension of a wire by the application of a load is 3×10^{-3} m. Find the extension in a wire of the same length and same material but half the radius for the same load.*

Solution:

$$Y = \frac{F}{A_1} \times \frac{L}{x_1} = \frac{FL}{A_2 x_2}$$

$$\frac{x_2}{x_1} = \frac{A_1}{A_2} = \frac{\pi r^2}{(\pi\, r/2)^2} = 4$$

$$x_2 = x_1 \times 4 = 4 \times 3 \times 10^{-13}$$

$$\boxed{x_2 = 12 \times 10^{-3}\ \text{m}} \quad \textbf{Ans.}$$

12. *A lady wearing high heel shoes balances on a single heel. The heel is circular with a diameter 0.8 cm. The pressure exerted by the heel on the horizontal floor is*

7.8×10^6 N/m^2. Calculate the mass of the lady.

Solution:

$$P = \frac{mg}{\pi r^2}$$

$$m = \frac{(P \times \pi r^2)}{g}$$

$$= \frac{7.8 \times 10^6 \times \pi \times (0.004^2)}{9.8}$$

$\boxed{m = 40 \text{ kg}}$ **Ans.**

13. *Compute the bulk modulus of water from the following data. Initial volume = 100 litre. Increase in pressure = 100 atmos. Final volume = 99.5 litre. (1 atmos = 1.013 × 10^5 Pa).*

Solution:

$$V_1 = 100 \text{ litre}, V_2 = 99.5 \text{ litre}$$

$$V_1 = 100 \times 10^{-3} = 10^{-1} \text{ m}^3$$

$$dV = V_1 \sim V_2 = 0.5 \text{ litre}$$

$$= 0.5 \times 10^{-3} \text{ m}^3 = 5 \times 10^{-4} \text{ m}^3$$

$$dP = 100 \text{ atoms}$$

$$= 100 \times 1.013 \times 10^5$$

$$= 1.013 \times 10^7 \text{ Pa}$$

$$B = \frac{dP \times V}{dV} = \frac{1.013 \times 10^7 \times 10^{-1}}{5 \times 10^{-4}}$$

$$= 2.026 \times 10^9 \text{ Pa}$$

$\boxed{2.026 \times 10^9 \text{ Pa}}$ **Ans.**

14. *A block of iron weighing 28 kg can be just pulled along a horizontal surface by a horizontal force of 12 kg. Find the coefficient of friction and angle of friction.*

Solution:

Coefficient of friction

$$\lambda = \frac{P}{W} = \frac{12}{28} = 0.4285$$

The angle of friction is given by

$$\tan\theta = \lambda = 0.4285$$
$$\theta = \tan^{-1}(0.4285)$$
$$\theta = 23.2°$$
$$\boxed{\theta = 23.2°} \quad \textbf{Ans.}$$

15. *A body starting from rest slides down an inclined plane whose angle of inclination 30°. What is its speed after sliding 25 metre, the coefficient of friction being 0.2?*

Solution:

The acceleration of a body on the inclined plane is given by

$$a = g(\sin\theta - \mu\cos\theta)$$
$$= 9.8\left[\frac{1}{2} - 0.2\frac{\sqrt{3}}{2}\right]$$
$$= 4.9\,(1 - 0.2 \times 1.732)$$
$$a = 4.9\,(1 - 0.3464) = 3.203 \text{ m/s}^2$$

Now, $v^2 = u^2 + 2as$ with $u = 0$ and $s = 25$ m

$$v^2 = 2 \times 3.203 \times 25 = 160.15$$
$$\boxed{v = 12.65 \text{ m/s}} \quad \textbf{Ans.}$$

16. *A body of weight 16 kg just slides down an inclined plane which is inclined at 30° to the horizontal. What force is necessary to just move it, if the plane is horizontal?*

Solution:

When the body just slides down an inclined plane,

$$W\sin\theta = F$$

Thus, the frictional force,

$$F = W \sin \theta = 16 \times \sin 30°$$

$$F = 16 \times \frac{1}{2} = 8 \text{ N}$$

Also $\mu = \tan \theta = \tan 30° = \dfrac{1}{\sqrt{3}} = 0.5773$

Now, when the plane is made horizontal

$\dfrac{P}{W} = \mu$, where P = Force required to just move the body along the horizontal plane.

$\therefore \quad P = \mu W = 0.577 \times 16 = 9.23$ kg.

$\therefore \quad \boxed{P = 9.23 \text{ kg}}$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*a*)	3. (*c*)	4. (*b*)
5. (*d*)	6. (*b*)	7. (*a*)	8. (*c*)
9. (*c*)	10. (*b*)	11. (*b*)	12. (*b*)
13. (*d*)	14. (*a*)	15. (*b*)	16. (*c*)
17. (*c*)	18. (*a*)	19. (*d*)	20. (*c*)
21. (*a*)	22. (*d*)	23. (*c*)	24. (*c*)
25. (*a*)	26. (*a*)	27. (*d*)	28. (*c*)
29. (*c*)	30. (*a*)		

1.3 MOMENT OF INERTIA, SURFACE TENSION AND VISCOSITY

1. Moment of inertia of a body depends on its
   (*a*) mass only
   (*b*) axis of rotation only
   (*c*) both (*a*) and (*b*)
   (*d*) none of these.

2. The mass of the electron is 9.1×10^{-31} kg. This electron revolves about a nucleus in a circular orbit of radius 0.05 nm at a speed of 2.2×10^{6} m/s. The linear momentum of the electron in this system is
(*a*) 1.1×10^{-24} kg m/s
(*b*) 4×10^{-24} kg m/s
(*c*) 4×10^{-24} kg
(*d*) 2×10^{-24} kg m/s.
3. If M and R are the mass and radius of a sphere, the M.I. about its diameter as the axis is
(*a*) $\frac{3}{5} MR^2$ (*b*) $\frac{2}{3} MR^2$
(*c*) MR^2 (*d*) $\frac{2}{5} MR^2$.
4. The work done by a torque in rotating a body about an axis is equal to the change in
(*a*) rotational K.E. of the body
(*b*) moment of the momentum of the body
(*c*) translational K.E. of the body
(*d*) all are true.
5. A proton is rotating along a circular path of radius 1 m under a centrifugal force of 4×10^{-12} N. If the mass of the proton be 1.6×10^{-27} kg, then the angular velocity of rotation is
(*a*) 5×10^{14} rad/s (*b*) 2.5×10^{6} rad/s
(*c*) 5×10^{2} rad/s (*d*) 5×10^{7} rad/s.
6. A hollow cylinder and a solid cylinder having the same mass and same diameter are released from rest simultaneously from the top of an inclined plane which will reach the bottom first
(*a*) the solid cylinder
(*b*) the hollow cylinder

(*c*) both will reach the same time
(*d*) none of these.

7. When a sphere of moment of inertia about its centre of gravity and mass m rolls from rest down an inclined plane without slipping. Its K.E. is calculated from

(*a*) $\frac{1}{2} I\omega^2$ (*b*) $I\omega + mv$

(*c*) $\frac{1}{2} mv^2$ (*d*) $\frac{1}{2} m\omega^2 + \frac{1}{2} mv^2$.

8. The radius of gyration of a sphere about its tangent is given by

(*a*) $\left(\frac{2}{5}\right) R$ (*b*) $\left(\frac{7}{5}\right) R$

(*c*) $\left(\sqrt{\frac{2}{5}}\right) R$ (*d*) $\left(\sqrt{\frac{7}{5}}\right) (R)$.

9. When a charge is given to a soap bubble, it shows
(*a*) decrease in size
(*b*) no change in size
(*c*) an increase in size
(*d*) sometimes an increase and sometimes a decrease in size.

10. Dettol can reach fine cavities formed in wounds to clean because the surface tension of dettol is
(*a*) surface tension of Dettol is greater than that of water
(*b*) surface tension of Dettol is equal to that of water
(*c*) Dettol is highly viscous
(*d*) Dettol is less viscous than that of water.

11. Air is pushed into a soap bubble of radius r so that its radius changes to $3r$. If the surface tension of the soap solution is S, the work done in the process is

(*a*) $8\pi r^2 S$ (*b*) $24\pi r^2 S$

(*c*) $64\pi r^2 S$ (*c*) $12\pi r^2 S$.

12. The excess of pressure inside a bubble is

(*a*) $p = \dfrac{r}{T}$ (*b*) $p = \dfrac{3T}{r}$

(*c*) $p = \dfrac{T}{r}$ (*d*) none of these

where T is the surface tension.

13. With rise of temperature which of the following forces can increase

(*a*) elastic force

(*b*) frictional force

(*c*) force due to surface tension

(*d*) viscous force.

14. What is surface tension of boiling water?

(*a*) zero

(*b*) 100 times that at 27°C

(*c*) infinity

(*d*) half of its value at room temperature.

15. To measure the surface tension of water by capillary rise method, the following formula is used

$$T = \frac{r\rho g\left(h + \dfrac{r}{3}\right)}{2}$$

The second term on the R.H.S. of this equation within brackets is a correction term for taking into account the

(*a*) exact value of angle of contact

(*b*) viscous property of water

(*c*) vapour pressure

(*d*) spherical shape of the surface.

16. Liquid drops always occupy minimum surface area on account of

(*a*) viscosity

(*b*) surface tension

(*c*) refractive index
(*d*) gravitational energy.

17. Small drops of mercury are practically spherical because of
(*a*) predominant *S.T.* force
(*b*) predominant gravitational force
(*c*) both (*a*) and (*b*)
(*d*) colour of mercury.

18. Small liquid drops assume spherical shape because
(*a*) gravitational force acts upon the drop
(*b*) atmospheric pressure exerts a force on a liquid drop
(*c*) volume of spherical drop is minimum
(*d*) liquid tends to have the minimum surface area due to surface tension.

19. A drop of water breaks into two droplets of equal size. In this process which of the following statements is correct.
(*a*) the sum of temperature of the two droplets together is equal to the original temperature
(*b*) the sum of surface areas of the droplets is equal to the surface area of the original drop
(*c*) the sum of masses of the droplets is equal to the original mass of the drop
(*d*) the sum of the radii of the two droplets is equal to the radius of the original drop.

20. When sugar is added to water, the surface tension of sugar solution is
(*a*) more than that of water
(*b*) same as that of water
(*c*) less than that of water
(*d*) sometimes more and sometimes less than that of water.

21. The excess of pressure due to surface tension in a spherical soap bubble of radius r is directly proportional to

(*a*) r^2 (*b*) r^{-1}

(*c*) $\frac{1}{r^2}$ (*d*) r.

22. The surface tension of water is 72 dyne/cm. This is equal to

(*a*) 17 N/m (*b*) 7×10^2 N/m

(*c*) 10^5 N/m (*d*) 72×10^{-3} N/m.

23. If A is the area of a layer of a fluid and $\frac{dV}{dx}$ is the velocity gradient, then the tangential viscous force F is

(*a*) $\frac{\eta}{A}\left(\frac{dV}{dx}\right)$ (*b*) $\eta A\ (dV/dx)$

(*c*) $\frac{\eta A}{(dV/dx)}$ (*d*) $\eta(dV/dx)$.

where η is the coefficient of viscosity.

24. In a human body the blood pressure is the greatest at

(*a*) brain (*b*) hands

(*c*) Abdomen (*d*) feet.

25. The value of Reynolds number signifies

(*a*) whether the flow is stream lined or turbulent

(*b*) high surface tension of the liquid

(*c*) whether the flow is vertical or horizontal

(*d*) all the above.

26. The unit of coefficient of viscosity is

(*a*) Nm^2 (*b*) Nm^2/s

(*c*) $\frac{1}{Nm^2}$ (*d*) Ns/m^2.

27. The dimensions of coefficient of viscosity are
(*a*) $ML^{-1}T^{-1}$ (*b*) MLT^{-1}
(*c*) M^2LT^2 (*d*) $ML^{-1}T^{-2}$.

28. Viscosity is a transport phenomenon explained using the concept of transfer of
(*a*) mass
(*b*) kinetic energy
(*c*) potential energy
(*d*) momentum.

29. Viscosity is closely similar to
(*a*) density (*b*) velocity
(*c*) friction (*d*) surface tension.

30. A drop of oil is placed on the surface of water. Which of the following statements is correct?
(*a*) it will spread as a thin layer
(*b*) it will remain on it as sphere
(*c*) it will partly be spherical and partly a thin film
(*d*) it will float as a distorted drop on the water surface.

31. The time taken by spherical object to reach the terminal velocity in a viscous liquid is
(*a*) $\frac{\eta r^2}{\rho}$ (*b*) $\frac{\eta r}{\rho}$
(*c*) $\frac{\rho r}{\eta}$ (*d*) $\frac{\rho r^2}{\eta}$.

32. A flask contains glycerine and another flask contains water. Both are stirred fast and kept on the table. Glycerine comes to rest earlier because
(*a*) the viscosity of glycerine is less than that of water

(*b*) the viscosity of glycerine is more than that of water

(*c*) the viscosity of water is around 70 units

(*d*) all are false.

33. If V_1 and V_2 be the volumes of the liquid flowing out of the same tube in the same interval of time and η_1 and η_2 their coefficients of viscosity respectively, then

(*a*) $\frac{\eta_1}{\eta_2} = \left(\frac{V_2}{V_1}\right)$ (*b*) $\frac{\eta_1}{\eta_2} = \left(\frac{V_1}{V_2}\right)$

(*c*) $\frac{\eta_1}{\eta_2} = V_1 \times V_2$ (*d*) $\frac{\eta_1}{\eta_2} = \left(\frac{V_1}{V_2}\right)^2$.

34. Water rises in a capillary tube while mercury in the same tube is depressed. This is because

(*a*) the angle of contact for mercury is 130°

(*b*) the angle of contact for water is 120°

(*c*) the angle of contact for mercury is 0°

(*d*) the angle of contact for water is 90°.

35. The total kinetic energy in pure rolling without sliding is

(*a*) $\frac{1}{2} I\omega^2$ (*b*) $\frac{1}{2} mv^2$

(*c*) $(I\omega)^2$ (*d*) $\frac{1}{2} \omega^2$.

PROBLEMS AND SOLUTIONS

1. *A solid sphere of mass 0.05 kg and diameter 2×10^{-2} m rolls without slipping with a uniform velocity of 0.05 m/sec along a straight line on a smooth horizontal table. Calculate its total energy.*

Solution:

$$\text{Total energy} = \frac{1}{2} I\omega^2 + \frac{1}{2} mv^2$$

With $$I = \left(\frac{2}{5}\right) MR^2 \text{ and } \omega^2 = \frac{v^2}{R^2}$$

$$\text{T.E.} = \frac{1}{2}\left(\frac{2}{5}\right) MR^2 \omega^2 + \frac{Mv^2}{2}$$

$$= \frac{1}{5} MR^2 \frac{v^2}{R^2} + \frac{Mv^2}{2}$$

$$= \frac{1}{5} Mv^2 + \frac{Mv^2}{2} = \frac{7}{10} Mv^2$$

$$= \frac{7}{10} \times (0.05)\,(0.05)^2 \text{ J}$$

$$\boxed{\text{T.E.} = 8.75 \times 10^{-5} \text{ J}}$$ **Ans.**

2. *A rigid horizontal smooth rod AB of mass 0.75 kg and length 40 cm rotates freely about a fixed vertical axis through its mid-point O. Two rings each of mass 1 kg initially at rest at a distance of 10 cm from O on either side of the rod. The rod is rotated with angular velocity of 30 rad / s. When the rings react to the ends of the rod, find the angular velocity of the rod.*

Solution:

$$I_1\omega_1 = I_2\omega_2$$

$$\left[\frac{ML^2}{12} + 2mr^2\right]\omega_1$$

$$= \left[\frac{ML^2}{12} + 2m\left(\frac{L}{2}\right)^2\right]\omega_2$$

$$= \left[\frac{0.75 \times (0.4^2)}{12} + 2 \times 1 \times (0.1)^2\right] 30$$

$$= \left[\frac{0.75 \times (0.4^2)}{12} + 2 \times 1 \times \frac{(0.4^2)}{4}\right] \omega_2$$

$\boxed{\omega_2 = 10 \text{ rad/s}}$ **Ans.**

3. *Two masses of 1 kg and 4 kg are moving with equal K.E. The ratio of their linear momentum may be obtained.*

Solution:

$$\frac{1}{2} m_1 v_1^{\ 2} = \frac{1}{2} m_2 v_2^{\ 2}$$

$$\frac{(m_1 v_1)^2}{m_1} = \frac{(m_2 v_2)^2}{m_2}$$

$$\frac{m_1 v_1}{m_2 v_2} = \left(\frac{m_1}{m_2}\right)^{1/2} = \left(\frac{1}{4}\right)^{1/2} = \frac{1}{2}$$

$\boxed{m_1 v_1 : m_2 v_2 = 1 : 2}$ **Ans.**

4. *What will be the total energy of an artificial satellite circling round the earth in an orbit of radius R?*

Solution:

$$\frac{mv^2}{R} = \frac{GMm}{R^2}$$

$$\frac{1}{2} mv^2 = \frac{1}{2} \frac{GMm}{R}$$

Again, potential energy at distance R from the centre of the earth is

$$\text{P.E.} = -2\frac{1}{2} \frac{GMm}{R} = -\frac{GMm}{R}$$

Therefore, total energy

$$\text{K.E.} + \text{P.E.} = \frac{1}{2} \frac{GMm}{R} - \frac{GMm}{R}$$

$\boxed{E = -\frac{GMm}{2R}}$ **Ans.**

5. *A particle performs uniform circular motion with an angular momentum I. If the frequency of particle's motion is doubled and its kinetic energy of rotation is halved, calculate the angular momentum.*

Solution:

Kinetic energy of rotation is $\frac{1}{2} I\omega^2$

Hence, $$E_1 = \frac{1}{2} I\omega_1^2$$

and $$E_2 = \frac{1}{2} I\omega_2^2 = \frac{2I\omega_1^2}{2}$$

$$\frac{E_2}{E_1} = \frac{I\,\omega_1^2}{(1/2\,I\,\omega_1^2)} = 2$$

$$\boxed{\frac{E_2}{E_1} = 2}$$ **Ans.**

6. *A flywheel is a uniform disc of mass 72 kg and radius 0.5 m. Calculate (a) M.I. (b) its kinetic energy when revolving at 70 r.p.m.*

Solution:

(*a*) M.I. of the flywheel

$$\text{M.I.} = \frac{MR^2}{2} = \frac{72 \times (0.5^2)}{2}$$

M.I = 9 kg m^2 **Ans.**

(*b*) K.E. of rotation = $\frac{1}{2} I\omega^2$

where $\omega = 2\pi\upsilon$ with $\upsilon = \frac{70}{60} = \frac{7}{6}$ sec^{-1}

Thus $$\frac{1}{2} I\omega^2 = \frac{9 \times (2\pi \times 7/6)^2}{2}$$

$$\boxed{= 242 \text{ joule}}$$ **Ans.**

7. *When a particle of mass m rotating in a plane circular path of radius r has an angular momentum I. Calculate centripetal force acting on it.*

Solution:

Centripetal force $= \dfrac{mv^2}{r}$

Angular momentum $= mv\,r = I$

$$mv = \frac{I}{r}$$

Thus centripetal force,

$$F = \frac{m^2v^2}{mr} = \frac{I^2}{r^2\,mr}$$

$$\boxed{F = \frac{I^2}{mr^3}} \quad \textbf{Ans.}$$

8. *What amount of energy will be liberated if 1000 droplets of water each 10^{-6} m in diameter coalesce to form one large spherical drop. S.T. of water = 72×10^{-3} N/m?*

Solution:

Radius of each droplet $r = 0.5 \times 10^{-6}$ m

Total volume of 1000 droplets

$$= 1000 \times \frac{4}{3}\pi\,(0.5 \times 10^{-6})^3$$

Hence, radius of the bigger drop R is given by

$$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi \times 1000\,(0.5 \times 10^{-6})^3$$

$$R = 10 \times 0.5 \times 10^{-6} = 5 \times 10^{-6}\text{ m}$$

Surface area of 1000 drops

$$= 1000 \times 4\pi\,(0.5 \times 10^{-6})^2$$

Surface area of the bigger drop

$$= 4\pi(5 \times 10^{-6})^2$$

Decrease in surface area

$$= 4\pi \times 10^{-12}\,(0.25 \times 1000 - 25)$$
$$= 4\pi \times 10^{-12}\,(250 - 25)$$
$$= 900\,\pi \times 10^{-12}\ \text{m}^2$$

Energy liberated

$$= 72 \times 10^{-3} \times 900 \times 3.14 \times 10^{-12}$$

$$\boxed{2.036 \times 10^{-12}\ \text{joule}}\quad \textbf{Ans.}$$

9. *An ice-berg floats in fresh water with a part of it outside the water surface. If the density of ice is 717 kg/m³ and that of water be 1000 kg/m³, compute the fraction of volume of ice-berg below water surface is formed.*

Solution:

Weight of the floating body = Weight of displaced liquid

i.e., $V_s d_s g = (KV_s)\, d_l g$

$$K = \frac{d_s}{d_l} = \frac{717}{1000} = 0.177$$

$$\boxed{K = 0.177}\quad \textbf{Ans.}$$

10. *A film of water is formed between two straight parallel wires each 10 cm long and at separation 0.5 cm. Calculate the work required to increase 1 mm distance between the wires. Surface tension of water is 72×10^{-3} N/m.*

Solution:

Initial surface area

$$= 2 \times \text{length} \times \text{separation}$$
$$= 2 \times 10 \times 0.5\ \text{cm} = 10 \times 10^{-4}\ \text{m}^2$$

Final surface area

$2 \times 10 \times (0.5 + 0.01)$

$$= 12\ \text{cm}^2 = 12 \times 10^{-4}\ \text{m}^2$$

The required work is $T \times \Delta A$

$$= 72 \times 10^{-3} \times 10^{-4} \times 2 \text{ J}$$

$$\boxed{W = 144 \times 10^{-7} \text{ J}} \quad \textbf{Ans.}$$

11. *Water rises to a height of 0.04 m in a capillary tube while mercury is depressed by 1.4 cm in the same tube. Compare the surface tensions of mercury and water if the density of mercury = 13600 kg/m³ and that of water be 1000 kg/m³. The angle of contact for mercury = 130°.*

Solution:

$$S = \frac{hr\rho g}{2\cos\theta}$$

$$S_1 = -\frac{1.4 \times r \times 13600 \times g}{2 \cos 130}$$

$$S_2 = \frac{4 \times r \times 1000 \times g}{2 \cos 0}$$

$$\frac{S_1}{S_2} = -\frac{1.4 \times 13600 \times 2}{2 \times 4 \times 1000 \times \cos 130}$$

$$= -\frac{1.4 \times 13.6}{4 \cos 130} = 7.4$$

$$\boxed{\frac{S_1}{S_2} = 7.4} \quad \textbf{Ans.}$$

12. *The capillary rise of water in a tube of radius r_1 is h_1. If the radius is doubled, find the relation between h_1 and h_2.*

Solution:

$$T = \frac{h_1 \rho g r_1}{2} = \frac{h_2 \rho g r_2}{2} \text{ with } r_2 = 2r_1$$

Thus $h_1 r_1 = h_2 2r_1$

$$\frac{h_1}{h_2} = \frac{2r_1}{r_1} = 2$$

$$\boxed{h_2 = \frac{h_1}{2} = 0.5\ h_1} \quad \textbf{Ans.}$$

13. *A U-tube is made up of two capillary tubes of bore 0.1 × 10^{-2} m and 0.2 × 10^{-2} m respectively. The tube is held vertically and partially filled with a liquid of surface tension 49 × 10^{-3} N/m and zero contact angle. Calculate the density of the liquid, if the difference in the levels of the meniscus is 1.25 × 10^{-2} m.*

Solution:

Let h_1 and h_2 be the heights of the liquid columns in two limbs, and r_1 and r_2, their respective radii. Then we have

$$T = \frac{h_1 r_1 \rho g}{2}$$

$$h_1 = \frac{2T}{r_1 \rho g}$$

Similarly $$h_2 = \frac{2T}{r_2 \rho g}$$

$$(h_1 - h_2) = \frac{2T}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

i.e., $$1.25 \times 10^{-2} = \frac{2 \times 49 \times 10^{-3}}{\rho \times 9.8} \times \left[\frac{1}{0.05 \times 10^{-2}} - \frac{1}{0.1 \times 10^{-2}}\right]$$

$$\Rightarrow \quad 1.25 \times 10^{-2} = \frac{98 \times 10^{-3}}{\rho \times 9.8}[2000 - 1000]$$

$$\Rightarrow \quad 1.25 \times 10^{-2} = \frac{9.8 \times 10^{-2} \times 1000}{\rho \times 9.8} = \frac{10}{\rho}$$

$$\rho = \frac{10}{1.25 \times 10^{-2}} = \frac{10^3}{1.25} = 800 \text{ kg/m}^3$$

$$\boxed{\rho = 800 \text{ kg/m}^3} \quad \textbf{Ans.}$$

14. *Compute the terminal velocity of a rain drop of radius 0.3 mm. Viscosity of air 1.83×10^{-5} Ns/m^2. Density of air is 1.3 kg/m^3 density of water = 10^3 kg/m^3 and g = 9.8 m/s^2.*

Solution:

Forces acting on the rain drops are

(1) Weight of the rain drop acting downwards

$$W = mg = V \times d \times g = \frac{4}{3}\pi r^3 dg$$

(2) Upward thrust = Weight of air displaced

$$= V\rho g = \frac{4}{3}\pi r^3 \rho g$$

(3) Viscous force acting upwards = $6\pi r\eta v$.

When the drop attains the terminal velocity, v

$$\frac{4}{3}\pi r^3 dg = \frac{4}{3}\pi r^3 \rho g + 6\pi r\eta v$$

$$\frac{4}{3} r^2 dg = \left(\frac{4}{3}\right) r^2 \rho g + 6\eta v$$

$$4r^2 dg = 4r^2 \rho g + 18\eta v$$

$$2r^2 dg - 2r^2 \rho g = 9\eta v$$

$$9\eta v = 2r^2 g(d - \rho)$$

$$v = \frac{2r^2 g\,(d - \rho)}{9\eta}$$

$$v = \frac{2\,(3 \times 10^{-4})^2\,(10^3 - 1.3)\,9.8}{9 \times 1.83 \times 10^{-5}}$$

$$\boxed{v = 10.696 \text{ m/s}} \quad \textbf{Ans.}$$

15. *A liquid is flowing in a tube of non-uniform bore. If the velocity of liquid is 8 cm/s when passing through the tube of radius 0.2 cm, then again passing through the tube of radius 0.4 cm, calculate the velocity of water in the second tube.*

Solution:

The equation of continuity is

$$A_1 v_1 = A_2 v_2$$

i.e.,
$$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$\frac{v_2}{v_1} = \left(\frac{r_2}{r_1}\right)^2$$

$$v_2 = v_1 \left(\frac{r_1}{r_2}\right)^2 = 8\left(\frac{0.2}{0.4}\right)^2$$

$$v_2 = 8 \times \left(\frac{1}{2}\right)^2 = 8 \times \frac{1}{4}$$

$$\boxed{v_2 = 2 \text{ cm/s}}$$ **Ans.**

16. *Water is flowing with a velocity of 2 m/s in a horizontal pipe with cross-sectional area decreasing from 2 × 10^{-2} m^2 to 0.01 m^2 at pressure 4 × 10^4 pascal. Calculate pressure at smaller cross-section.*

Solution:

The well known equation is

$$\frac{v_1}{v_2} = \frac{A_2}{A_1}$$

$$v_2 = v_1 \frac{A_1}{A_2} = \frac{2 \times 2 \times 10^{-2}}{0.01}$$

$$v_2 = 4 \text{ m/s}$$

Now
$$P_1 + \frac{\rho v_1^2}{2} = P_2 + \frac{\rho v_2^2}{2}$$

$$4 \times 10^4 + \frac{10^3 \times 4}{2} = P_2 + \frac{10^3 \times 16}{2}$$

$$4 \times 10^4 + 2 \times 10^3 = P_2 + 8 \times 10^3$$

$$P_2 = 40 \times 10^3 + 2 \times 10^3 - 8 \times 10^3$$

$$= 10^3(40 + 2 - 8)$$

$$= 34 \times 10^3 \text{ pascal}$$

$\boxed{34 \times 10^3 \text{ pascal}}$ **Ans.**

17. *Suppose the built-up fatty tissue on the wall of the artery decreased the radius by 10%. By how much would the pressure provided by the heart have to be increased to maintain constant blood flow?*

Solution:

$$\frac{r_1}{r_2} = \frac{100}{90} = \frac{10}{9}$$

Rate of flow, $V = \dfrac{\pi P a^4}{8\, l\eta}$ = constant

Hence, Pa^4 = constant

i.e., $P_1 a_1^4 = P_2 a_2^4$

$$\frac{P_2}{P_1} = \left(\frac{a_1}{a_2}\right)^4$$

i.e., $\dfrac{P_2}{P_1} - 1 = \dfrac{P_2 - P_1}{P_1} = \left(\dfrac{a_1}{a_2}\right)^4 - 1$

Percentage increase in pressure

$$\frac{(P_2 - P_1)}{P_1} \times 100 = \left[\left(\frac{a_1}{a_2}\right)^4 - 1\right] \times 100$$

$$= \left[\left(\frac{10}{9}\right)^2 - 1\right] \times 100 = 52\%$$

$\boxed{52\%}$ **Ans.**

18. *Calculate the pressure required to maintain the flow of water at the rate of 10 litre/s through a horizontal tube 10 cm in diameter and 1 km in length. Viscosity of water is 0.001 Ns/m².*

Solution:

$$(V/t) = \frac{\pi P r^4}{8 l \eta}$$

$$P = \frac{8\, l\eta\,(V/t)}{\pi r^4}$$

$$V/t = 10\ l/\text{s}$$

$$= 10^4\ \text{cm}^3/\text{sec} = 10^{-2}\ \text{m}^3/\text{s}$$

$$r = 5\ \text{cm} = 5 \times 10^{-2}\ \text{m}$$

$$l = 1\ \text{km} = 10^3\ \text{m},\ \eta = 0.001\ \text{Ns/m}^2$$

$$P = 8 \times 10^3 \times 0.0001/\pi\ (5 \times 10^{-2})^4$$

$$\boxed{P = 4.076 \times 10^3\ \text{N/m}^2} \quad \textbf{Ans.}$$

19. *A first graded motor oil has a viscosity 2 poise. How long would it take to pour 4 litre of oil into the engine through a funnel with neck 15 cm long and 2 cm diameter? (Assume the surface of the oil in the funnel is kept 6 cm above the top of the neck, and neglect any dray effect due to the upper part of the funnel. Density of oil is 18 m / cm³).*

Solution:

Rate of flow, $\dfrac{V}{t} = \dfrac{\pi P r^4}{8\, l\eta} = \dfrac{\pi h \rho g r^4}{8\, l\eta}$

i.e., $t = \dfrac{8 l\eta V}{\pi h d g r^4} = \dfrac{8 \times 15 \times 2 \times 4000}{3.14 \times 6 \times 1 \times 980}$

$$= 52\ \text{sec}$$

$$\boxed{t = 52\ \text{sec}} \quad \textbf{Ans.}$$

20. *A cylinderical vessel of radius 7 cm is completely filled with alcohol. If a capillary tube of length 16 cm and internal diameter 0.8 mm is connected horizontally at the bottom of this vessel, find how long it would take to empty half of the vessel. Density of alcohol = 800 kg/m^3, viscosity of alcohol = 0.0012 Ns/m^2.*

Solution:

Let x be the height of the liquid in the vessel $R = 7$ cm $= 7 \times 10^{-2}$ m; $l = 16 \times 10^{-2}$ m; $r = 0.4$ mm $= 4 \times 10^{-4}$ m; $d = 800$ kg/m^3 ; $\eta = 0.0012$ (in SI units)

Volume of the liquid flow, $V = \pi R^3 \times \dfrac{x}{2}$

$$V = \pi(7 \times 10^{-2})^3 \left(\frac{x}{2}\right)$$

Average height of the column (Average pressure head)

$$h = \frac{[x + (x/2)]}{2} = \frac{3x}{4}$$

$$\frac{V}{t} = \frac{\pi P r^4}{8\, l\eta} = \frac{\pi h \rho g r^4}{8\, l\eta}$$

$$t = \frac{8 l\eta V}{\pi\left(\dfrac{3x}{4}\right) d g r^4}$$

$$= \frac{8 \times 16 \times 10^{-2} \times 0.0012 \times \pi\,(7 \times 10^{-2})^2\,(x/2)}{\pi\,(3x/4) \times 800 \times 9.8 \times (4 \times 10^{-4})^4}$$

$= 2.5 \times 10^4$ sec

$\boxed{t = 2.5 \times 10^4 \text{ sec}}$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*d*)	3. (*d*)	4. (*a*)
5. (*d*)	6. (*a*)	7. (*a*)	8. (*d*)
9. (*c*)	10. (*d*)	11. (*c*)	12. (*d*)
13. (*d*)	14. (*a*)	15. (*d*)	16. (*b*)
17. (*a*)	18. (*d*)	19. (*c*)	20. (*d*)
21. (*b*)	22. (*d*)	23. (*b*)	24. (*c*)
25. (*a*)	26. (*d*)	27. (*a*)	28. (*d*)
29. (*c*)	30. (*a*)	31. (*d*)	32. (*b*)
33. (*a*)	34. (*a*)	35. (*a*).	

1.4 KINETIC THEORY OF GASES AND ACOUSTICS

1. If C_1 and C_2 are the root mean square velocities at densities ρ_1 and ρ_2, then

   (*a*) $\frac{C_1}{C_2} = (\rho_1\rho_2)^2$ (*b*) $\frac{C_1}{C_2} = \sqrt{\frac{\rho_2}{\rho_1}}$

   (*c*) $\frac{C_1}{C_2} = \frac{\rho_2}{\rho_1}$ (*d*) $C_1 = 2C_2$.

2. If E and V are the kinetic energy and volume respectively of the molecules, then the expression for pressure is

   (*a*) $P = \frac{2E}{3}\left(\frac{1}{V}\right)$ (*b*) $P = \frac{3}{2E}$

   (*c*) $P = \frac{E^2 \times V}{2}$ (*d*) $P = \frac{2V}{E^2}$.

3. The root mean square velocity of an ideal gas at constant pressure varies with density ρ as

   (*a*) ρ^2 (*b*) ρ

   (*c*) $\sqrt{\rho}$ (*d*) $\frac{1}{\sqrt{\rho}}$.

4. Gas at a pressure P_0 is contained in a vessel. If the masses of all the molecules are doubled and their speeds halved, the resulting pressure will be

(*a*) $\frac{P_0}{2}$ (*b*) $\frac{2}{P_0}$

(*c*) $2P_0$ (*d*) P_0^2.

5. The mass of oxygen molecule is 16 times the mass of hydrogen molecule. At room temperature the r.m.s. speed of oxygen molecule is v, then r.m.s speed of hydrogen molecule at the same temperature will be

(*a*) $\frac{v}{16}$ (*b*) v

(*c*) 16 v (*d*) 4 v.

6. The temperature of an ideal gas is increased from 120 K to 480 K. If at 120 K the root mean square velocity of the gas molecules is v, at 480 K it becomes.

(*a*) $4v$ (*b*) $2v$

(*c*) $\frac{v}{2}$ (*d*) $\frac{v}{4}$.

7. What will be the ratio of the average K.E. of molecules of a gas when temperature is raised from 27°C to 177°C?

(*a*) 3 : 2 (*b*) 4 : 3

(*c*) 2 : 3 (*d*) 1 : 7.

8. Consider a gas with density d and root mean ($\bar{c}$) square velocity of the molecules contained in a volume. If the system moves as a whole with a velocity v, then the pressure exerted by the gas is

(*a*) $\frac{1}{3}\, d\bar{c}^2$ (*b*) $\frac{1}{3}\, d(\bar{c} + v)^2$

(*c*) $\frac{1}{3}\, d(\bar{c} - v)^2$ (*d*) $\frac{3}{d\bar{c}^2}$.

9. A sample of an ideal gas is compressed isothermally to one half its original volume. What happens to the average speed of the molecules in the sample?
(*a*) it doubles
(*b*) it halves
(*c*) depends on the mass of the gas
(*d*) it does not change.

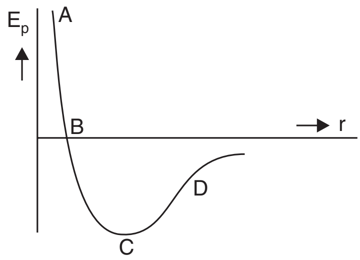
10. The mean free path λ of a gas molecule is related to the molecular density n as
(*a*) $\lambda \propto n$ (*b*) $\lambda \propto \frac{1}{n}$
(*c*) $\lambda \propto n^2$ (*d*) $\lambda \propto \frac{1}{n^2}$.

11. The r.m.s speed of the molecules of oxygen gas kept in a container at 0°C and at 1 atmosphere is
(*a*) 590 m/s
(*b*) 120 m/s
(*c*) 460 m/s
(*d*) 10 m/s.

12. At what temperature is the mean kinetic energy of a gas molecule one third its mean kinetic energy at 453 K?
(*a*) 151 K (*b*) 302 K
(*c*) 200 K (*d*) 183 K.

13. Average K.E. of a molecule is
(*a*) $\frac{k_B T}{2}$ (*b*) $k_B T$
(*c*) $\frac{3}{2} k_B T$ (*d*) $\frac{k_B T}{5}$.

14. The graph below shows the potential energy between two atoms in a diatomic molecule as a function of the distance r between the atoms.



The two molecules are

(*a*) attracted when *r* lies between *C* and *D* and repelled when *r* lies between *A* and *C*

(*b*) attracted when they reach *C*

(*c*) repelled when they reach *C*

(*d*) attracted when *r* lies between *A* and *C* and repelled when *r* lies between *C* and *D*.

15. The pressure exerted by a gas is proportional to the

(*a*) total K.E. of all the molecules of the gas

(*b*) mean square velocity of the gas molecules

(*c*) root mean square velocity of the gas molecules

(*d*) volume of the gas.

16. A gas at temperature 250 K is contained in a closed vessel. If the gas is heated through 1°C, the percentage increase in pressure is

(*a*) 1% (*b*) 0.8%

(*c*) 0.6% (*d*) 0.4%.

17. If masses of all molecules of a gas are halved and their speeds doubled, the ratio of initial and final pressure will be

(*a*) 2 : 1 (*b*) 1 : 4

(*c*) 4 : 1 (*d*) 1 : 2.

18. A sample of a diatomic ideal gas occupies 33.6 litres under standard condition. How many moles of gas are there in the sample?
(*a*) 0.75 (*b*) 1.5
(*c*) 2.5 (*d*) 3.5.

19. The temperature of a gas is due to
(*a*) the repulsive force between its molecules
(*b*) the potential energy of its molecules
(*c*) attractive force between its molecules
(*d*) the kinetic energy of its molecules.

20. At a given temperature which of the following gases possess maximum root mean square velocity
(*a*) air (*b*) nitrogen
(*c*) oxygen (*d*) hydrogen.

21. At what temperature will r.m.s velocity of hydrogen be double its velocity at S.T.P. when pressure remains constant.
(*a*) 992 K (*b*) 2005 K
(*c*) 1092 K (*d*) 10 K.

22. Four molecules have speeds 2 km/s, 3 km/s, 4 km/s and 5 km/s. The r.m.s. speed of these molecules in km/s is,
(*a*) $\sqrt{\frac{54}{4}}$ (*b*) $\sqrt{\frac{54}{2}}$
(*c*) 3.5 (*d*) $3\sqrt{2}$.

23. The frequency of the note produced by plucking a given string increases as
(*a*) the length of the string increases
(*b*) the tension in the string increases
(*c*) the tension in the string decreases
(*d*) the mass per unit length of the string increases.

24. Which of the following statements is wrong?
(*a*) speed of sound is very much smaller than that of light
(*b*) sound travels in the form of waves
(*c*) sound travels faster in vacuum than in air
(*d*) sound is a form of energy.

25. For a propagation of acoustical waves the medium must be
(*a*) plastic
(*b*) either elastic or plastic
(*c*) neither elastic nor plastic
(*d*) elastic.

26. It is possible to distinguish between longitudinal and transverse waves by studying the property of
(*a*) polarisation (*b*) reflection
(*c*) diffractions (*d*) holography.

27. The speed of sound in air is 332 m/s at N.T.P. The speed of sound in hydrogen at N.T.P. will be
(*a*) 600 m/s (*b*) 2222 m/s
(*c*) 1328 m/s (*d*) 13.3 m/s.

28. The velocity of sound in air is v and the root mean square velocity of the molecules is c. Then $\frac{v}{c}$ is
(*a*) $\left(\frac{\gamma}{3}\right)^{1/2}$ (*b*) $\frac{3}{\gamma}$
(*c*) $\gamma(\sqrt{3})$ (*d*) $\sqrt{\gamma}$.

29. A body is vibrating 3000 times in half a minute. If the velocity of sound in air is 350 m/s, the wavelength of the wave produced is

(*a*) 3.5 m (*b*) 35 m
(*c*) 350 m (*d*) 3500 m.

30. Transverse wave can travel
(*a*) both in gas and metal
(*b*) in a gas but not in metal
(*c*) neither in gas nor in metal
(*d*) not in gas but in metal.

31. If at same temperature and pressure the densities for two diatomic gases are respectively ρ_1 and ρ_2, then the ratio of velocity of sound in these gases will be (v_1/v_2)
(*a*) $\sqrt{\rho_1\rho_2}$ (*b*) $\sqrt{\dfrac{\rho_2}{\rho_1}}$
(*c*) $\sqrt{\dfrac{\rho_1}{\rho_2}}$ (*d*) $\rho_1 \, \rho_2$.

32. If amplitude of a particle executing S.H.M. is doubled which of the following quantity will be doubled?
(*a*) time period
(*b*) maximum velocity
(*c*) mass
(*d*) total energy.

33. Ultrasonic are used in SONAR with greater advantage because ultrasonics
(*a*) are electromagnetic waves
(*b*) have low frequency
(*c*) can be easily produced
(*d*) have short wavelengths.

34. A tuning fork vibrating with a sonometer having 20 cm long wire produces 5 beats per sec. The beat frequency does not change, if the length of the wire is changed to 21 cm. The frequency of the tuning fork must be
(*a*) 200 Hz (*b*) 205 Hz
(*c*) 215 Hz (*d*) 210 Hz.

35. Laplace correction in the expression for the velocity of sound given by Newton is needed because sound waves
(*a*) are longitudinal
(*b*) propagate isothermally
(*c*) propagate adiabatically
(*d*) are of long wavelengths.

36. The increase in velocity of sound in air for 1°C rise of temperature, if velocity of sound at 0°C is 332 m/s
(*a*) 0.3 m/s (*b*) 0.6 m/s
(*c*) 0.1 m/s (*d*) 10 m/s.

37. The speed of sound in a gas V and the root mean square speed of gas molecule is $V_{\text{r.m.s.}}$. If the ratio of the specific heats of the gas $\gamma = 1.5$, then $\dfrac{V}{V_{\text{rms}}}$ is
(*a*) 2 : 1 (*b*) 1 : 3
(*c*) $1 : \sqrt{3}$ (*d*) $1 : \sqrt{2}$.

38. We know the frequency of the note produced by plucking a string transversely increases as
(*a*) the length of the string increases
(*b*) the tension in the string increases
(*c*) the tension in the string decreases
(*d*) the mass per unit length of the string increases.

39. Ultrasonic probes can be used on different parts of human body for longer duration for diagonsis unlike X-rays, because
(*a*) the frequency of ultrasonic waves is much lower with that of X-rays
(*b*) the frequency of ultrasonic waves is much higher with that of X-rays
(*c*) they are also electromagnetic waves
(*d*) they are colourless radiation.

40. If the pressure amplitude of sound is tripled, then by what factor the intensity of sound wave increases

(*a*) $\sqrt{3}$ (*b*) 3

(*c*) 6 (*d*) 9.

41. Why does sound wave travel faster on a rainy day?

(*a*) air becomes drier

(*b*) the speed is independent of pressure

(*c*) density of moisture is less than that of dry air

(*d*) density of moisture is much greater than that of dry air.

42. In the case of closed pipe, the fundamental frequency υ_1 is given by

(*a*) $\upsilon_1 = \frac{V}{4l}$ (*b*) $\upsilon_1 = \frac{4l}{V}$

(*c*) $\upsilon_1 = \frac{h}{V}$ (*d*) $\upsilon_1 = \frac{V}{2l}$.

43. If the wavelength of a sound wave in a medium is reduced by 50%, then the percentage change in frequency is

(*a*) 25% (*b*) 50%

(*c*) 75% (*d*) 100%.

44. A tuning fork when sounded with a frequency 256 Hz gave 4 beats/sec. When a small bit of wax was attached to a prong of the fork of unknown frequency, 3 beats/sec were produced. The frequency of the unknown fork is

(*a*) 260 (*b*) 252

(*c*) 8 (*d*) 16.

45. Two tuning forks have frequencies 450 Hz and 454 Hz respectively. On sounding these forks together, the time interval between successive maximum intensities will be

(*a*) 1 sec (*b*) $\frac{1}{2}$ sec

(*c*) $\frac{1}{4}$ sec (*d*) 100 sec.

46. When stationary waves are produced, which physical characteristic, density or pressure will change at antinodes
(*a*) pressure
(*b*) density
(*c*) pressure as well as density
(*d*) no change of pressure or density.

47. Reverberation of sound in a hall results due to its continued
(*a*) reflection of sound
(*b*) diffraction of sound
(*c*) interference of sound
(*d*) absorption of sound.

48. In stationary sound wave produced in air
(*a*) all the air particles are stationary
(*b*) air particles do not execute periodic motion
(*c*) each particle executes simple harmonic vibration with the same amplitude
(*d*) amplitude of vibration is maximum at some points and minimum at some other places.

49. The walls of a hall built for music concert should
(*a*) amplify sound
(*b*) reflect sound
(*c*) transmit sound
(*d*) absorb sound.

50. The formula for standard time of reverberation is

(a) $t = \dfrac{0.21\,\Sigma\, aS}{V}$ (b) $t = \dfrac{0.165\, V}{\Sigma\, aS}$

(c) $t = \dfrac{0.165\,\Sigma\, aS}{2}$ (d) $t = \dfrac{V}{\Sigma aS}$.

51. A note emitted by a plucked string is more pleasing if it is plucked,
(a) near one end
(b) in the middle
(c) at a fixed point
(d) none of these.

52. In stationary waves, all points between two nodes are
(a) in the same phase
(b) out of phase
(c) in different phases
(d) none of these.

53. Ultrasonic waves have frequencies
(a) below 20 Hz
(b) above 20 Hz but below 20 kHz
(c) above 20 kHz
(d) below infrasonics.

54. The intensity of sound
(a) is directly proportional to square of frequency
(b) is inversely proportional to density of medium
(c) does not depend on speed of sound in the medium
(d) is inversely proportional to frequency of sound.

55. The intensity of sound
(a) and loudness have the same units
(b) cannot be measured

(*c*) depends on loudness
(*d*) is measured in W/m^2.

56. Sound waves are
(*a*) longitudinal waves
(*b*) transverse waves
(*c*) electromagnetic waves
(*d*) (*a*) and (*b*) above.

57. Transverse waves cannot be produced in
(*a*) solids
(*b*) liquids
(*c*) gases
(*d*) both (*b*) and (*c*).

58. Which of the following statements is correct?
(*a*) longitudinal waves can travel only in atmospheric air
(*b*) longitudinal waves can be propagated only in liquids
(*c*) transverse waves cannot be propagated through gases
(*d*) transverse waves can be produced in the three states of matter.

59. If v is the actual speed of sound and x is the speed of air, then the net speed of sound in the direction opposite to the direction of air is
(*a*) $v + x$ (*b*) $\frac{v}{x}$
(*c*) $x - v$ (*d*) $v - x$.

60. A labourer sets his watch on hearing a distant siren. His watch will record
(*a*) perfect time
(*b*) less than the actual time
(*c*) more than the actual time
(*d*) none of the above.

PROBLEMS AND SOLUTIONS

1. *At what temperature, pressure remaining constant, the r.m.s. velocity of a gas will double its value at 0°C?*

Solution:

Here $T_1 = 273$ K, $T_2 = ?$; $C = C_1$ and $C = C_2 = 2C_1$

Thus $2C_1 \propto \sqrt{T_2}$

$$C_1 \propto \sqrt{T_1}$$

$$2^2 = \frac{T_2}{T_1}$$

$$T_2 = 4 \times T_1 = 4 \times 273 = 1092 \text{ K}$$

$\boxed{T_2 = 1092 \text{ K}}$ **Ans.**

2. *A gas at 27°C in a cylinder has a volume of 4 litre and pressure 100 N/m². (a) Gas is compressed at constant temperature so that the pressure is 150 N/m². Calculate the change in volume (b) It is then heated at constant volume so that temperature becomes 127°C calculate the new pressure.*

Solution:

(*a*) $P_1 = 100$ N/m², $V_1 = 4$ litre
$P_2 = 150$ N/m²; $V_2 = ?$

Since the temperature remains constant,

$$P_1V_1 = P_2V_2;\ 100 \times 4 = 150 \times V_2$$

$$V_2 = \frac{400}{150} = 2.67 \text{ litre}$$

Change is volume

$$= V_1 - V_2 = 4 - 2.67 = 1.33$$

$\boxed{1.33 \text{ litre}}$ **Ans.**

(*b*) $P_1 = 150$ N/m^2, $T_1 = 273 + 27 = 300$ K

$P_2 = ?$, $T_2 = 273 + 127 = 400$ K

Since, the volume remains constant

$$\frac{P_1}{T_1} = \frac{P_2}{T_2}\ ; \quad \frac{150}{300} = \frac{P_2}{400}$$

$$P_2 = \frac{400 \times 150}{300} = 200 \text{ N/m}^2$$

$$\boxed{P_2 = 200 \text{ N/m}^2} \quad \textbf{Ans.}$$

3. *How much should the pressure of the gas be increased to decrease the volume by 10% at constant temperature?*

Solution:

Let $P_1 = P$, $V_1 = V$; $P_2 = P + \Delta P$

and $V_2 = \dfrac{9V}{10}$

Thus,

$$P_1V_1 = P_2V_2;$$

i.e., $$PV = (P + \Delta P)\,\frac{9V}{10}$$

i.e., $$PV = \frac{9PV}{10} + \frac{9V\Delta P}{10}$$

$$P = \frac{9P}{10} + \frac{9}{10}\,\Delta P$$

or $$\frac{9\Delta P}{10} = P - \frac{9P}{10} = \frac{P}{10}$$

or $$\frac{\Delta P}{P} = \frac{1}{9} \times 100$$

$$\boxed{11.11\%} \quad \textbf{Ans.}$$

4. *Calculate the molecular energy of one gram of hydrogen gas at 50°C given that the molecular weight of hydrogen is 2 × 10^{-3} kg and R = 8.3 J/mol-K.*

Solution:

2×10^{-3} kg of hydrogen contains N_A molecules. Hence, 10^{-3} kg will have $\frac{N_A}{2}$ molecules with $N_A = 6.1 \times 10^{26}$ called Avogadro's number.

We know

$$P = \frac{1}{3}\frac{mN_A \bar{c}^2}{V_m}$$

where V_m is molar volume

$$PV_m = \frac{1}{3} mN_A\bar{c}^2 = R_uT$$

$$m\bar{c}^2 = \frac{3R_uT}{N_A} = 3\,k_BT$$

$$\frac{1}{2}\,m\bar{c}^2 = \frac{3}{2}\,k_BT$$

Thus the required molecular energy is

$$\frac{3}{2}\,k_BT\left(\frac{N_A}{2}\right) = \frac{3}{4}\,R_u \times T$$

$$= \frac{3}{4} \times 8.3 \times 323$$

$$\boxed{E = 2010 \text{ J}} \textbf{ Ans.}$$

5. *6 gm of oxygen, 8 gm of nitrogen and 5 gm of carbondioxide are mixed in a vessel. The total volume is 3 litre at 27°C. R = 8.4 J mol^{-1} K^{-1}. The total pressure of the system is calculated as follows.*

Solution:

According to Dalton's law of partial pressure

$$P = P_1 + P_2 + P_3;\, P_1 = \frac{\mu_1 RT}{V},$$

$$P_2 = \frac{\mu_2 RT}{V} \text{ and } P_3 = \frac{\mu_3 RT}{V}$$

Thus $$P = \frac{RT}{V}(\mu_1 + \mu_2 + \mu_3)$$

$$= \frac{8.4 \times 300}{3 \times 10^{-3}}\left(\frac{6}{32} + \frac{8}{28} + \frac{5}{44}\right)$$

$$\boxed{P = 5 \times 10^5 \text{ N/m}^2} \textbf{ Ans.}$$

6. *Calculate the molecular velocity of a gas whose density is 1.4 kg/m³ at N.T.P.*
   Solution:

$$P = \frac{1}{3}\rho\bar{c}^2$$

$$P = 0.76 \times 13600 \times 9.8$$

$$= 1.013 \times 10^5 \text{ N/m}^2$$

$$\bar{c} = \sqrt{\frac{3 \times 1.013 \times 10^5}{1.4}}$$

$$= 4.659 \times 10^2 \text{ m/s}$$

$$\boxed{\bar{c} = 4.659 \times 10^2 \text{ m/s}} \textbf{ Ans.}$$

7. *The r.m.s. speed of oxygen molecule at temperature T is v. If the temperature is doubled and oxygen gas is dissociated, into atomic oxygen, the r.m.s. speed is calculated as given below:*
   Solution:

$$v_1 = \sqrt{\frac{3RT_1}{M_1}} \quad \text{and} \quad v_2 = \sqrt{\frac{3RT_2}{M_2}}$$

$$\frac{v_2}{v_1} = \sqrt{\frac{T_2}{M_2}\frac{(M_1)}{T_1}}$$

$$= \sqrt{\frac{2T_1M_1}{\left(\frac{M_1}{2}\right)T_1}} = \sqrt{4}$$

$$\boxed{v_2 = 2v_1} \textbf{ Ans.}$$

8. *At what temperature will oxygen molecules have the same root mean square velocity as hydrogen molecules at 60°C? Molecular mass of hydrogen and oxygen are 2 and 32 respectively.*

Solution:

The general formula is

$$P = \frac{1}{3}\rho\bar{c}^2 = \frac{1}{3}\frac{mN_A\bar{c}^2}{V_m}$$

$$PV_m = \frac{1}{3}M\,\bar{c}^2 = RT$$

where M is the molecular weight

$$\bar{c} = \sqrt{\frac{3RT}{M}}$$

Now, for hydrogen

$$\bar{c}_H = \sqrt{\frac{3RT_1}{M_H}}$$

For oxygen $\bar{c}_O = \sqrt{\frac{3RT_2}{M_O}}$

Let the r.m.s. velocity of hydrogen at $T_1\,K$ is equal to that of oxygen at $T_2\,K$, then

$$\sqrt{\frac{3RT_1}{M_H}} = \sqrt{\frac{3RT_2}{M_O}}$$

$$\frac{T_1}{M_H} = \frac{T_2}{M_O};$$

$$T_2 = \frac{M_O}{M_H} \times T_1 = \frac{32}{2} \times (60 + 273)$$

$\boxed{T_2 = 5328 \text{ K}}$ **Ans.**

9. *A wave is represented by the equation*

$$y = A\,sin\left(10\,\pi x + 15\,\pi t + \frac{\pi}{3}\right)$$

Calculate the velocity and wavelength of the wave.

Solution:

The standard wave equation is

$$y = A \sin(\omega t - kx + \phi)$$

For this given wave

$$\omega = 2\pi\upsilon = 15\,\pi,\ k = \frac{2\pi}{\lambda} = 10\pi$$

Now $$v = \frac{\omega}{k} = \frac{15\pi}{10\pi} = 1.5 \text{ m/s}$$

and $$\lambda = \frac{2\pi}{k} = \frac{2\pi}{10\pi} = 0.2 \text{ m/sec}$$

$$\boxed{v = 1.5 \text{ m/s}\ ;\ \lambda = 0.2 \text{ m}}$$ **Ans.**

10. *What is the relation between particle velocity, v and wave velocity c and the slope s of the wave?*

Solution:

One of the general equations is

$$y = a \sin(\omega t - kx)$$

$$v = \frac{dy}{dt} = a \cos(\omega t - kx)\,\omega$$

$$\text{slope } s = \frac{dy}{dx} = -\,a \cos(\omega t - kx)\,k$$

$$s = -\frac{kv}{\omega} = -\frac{2\pi}{\lambda}\left(\frac{v}{2\pi v}\right)$$

$$= -\frac{2\pi}{\lambda}\left[\frac{v}{2\pi(c/\lambda)}\right]$$

or $\boxed{v = -\,cs}$ **Ans.**

11. *A tuning fork vibrating with a sonometer wire of 20 cm length produces 5 beats per second. The beat frequency does not change if the length of the wire is changed*

to 21 cm. Compute the frequency of the tuning fork.

Solution:

When the length of the wire increases its frequency decreases. Let ν be the frequency and v the velocity of the wave.

$$\lambda = 2l_1, \text{ frequency is } \frac{v}{\lambda} = \frac{v}{2l_1}$$

Thus, $$\frac{v}{2l_1} - \nu = 5; \quad \frac{v}{2l_1} = \nu + 5 \qquad ...(1)$$

and $$\nu - \frac{v}{2l_2} = 5; \quad \frac{v}{2l_2} = \nu - 5 \qquad ...(2)$$

Dividing eqn. (1) by eqn. (2)

$$\frac{l_2}{l_1} = \frac{v+5}{v-5} = \frac{21}{20}$$

$$20\nu + 100 = 21\nu - 105$$

$$\boxed{\nu = 205} \textbf{ Ans.}$$

12. *The equations of two sound waves are given by*
$y_1 = 3 \sin 100\, \pi t$ and $y_2 = 4 \sin 150\, \pi t$
Get the ratio of the intensities of sound produced in the medium.

Solution:

Here $a_1 = 3, \nu_1 = \dfrac{100\,\pi}{2\pi} = 50$

Hence $I_1 \propto a_1^2 \nu_1^2$

or $I_1 \propto (3)^2\,(50)^2$

$I_2 \propto (4)^2\,(75)^2$

$$\frac{I_1}{I_2} = \frac{9}{16} \times \frac{(50^2)}{(75^2)}$$

$$= \frac{9}{(4^2)} \times \frac{50 \times 50}{75 \times 75}$$

$$\frac{I_1}{I_2} = \frac{9}{16} \times \frac{2 \times 2}{3 \times 3} = \frac{1}{4}$$

$$\boxed{I_1 : I_2 = 1 : 4} \quad \textbf{Ans.}$$

13. *The loudness changes from 30 dB to 60 dB. What is the ratio of intensities in the two cases?*

Solution:

The general equation is

$L = 10 \log (I_1/I_0)$ and $L_2 = 10 \log (I_2/I_0)$

$L_2 - L_1 = 10 \log (I_2/I_1) = 60 - 30$

$$\log (I_2/I_1) = \frac{60 - 30}{10} = 3$$

$$\boxed{\frac{I_2}{I_1} = 1000} \quad \textbf{Ans.}$$

14. *If the pressure amplitude of sound wave is doubled, then show that the percentage increase in its intensity will be 300%.*

Solution:

$$\frac{I'}{I} = 2^2 = 4$$

$$\frac{I' - I}{I} = (4 - 1) = 3$$

or $$\left[\frac{I' - I}{I}\right] \times 100 = 300\%$$

$$\boxed{300\ \%} \quad \textbf{Ans.}$$

15. *A progressive wave and a stationary wave have same frequency 200 Hz, same velocity 50 m/s. The amplitude of progressive wave is twice that of stationary wave. If the intensity of the progressive wave is 0.09 units, get the equation of the stationary wave.*

Solution:

Let λ, v and ν be the wavelength, velocity and frequency of the wave.

Now $$\lambda = \frac{v}{\nu} = \frac{50}{200} = 0.25 \text{ m}$$

$$I = a^2 = 0.09$$

$$a = 0.3 \text{ metre}$$

The equation of stationary wave is

$$y = 2\,a \cos \frac{2\pi x}{\lambda} \sin \frac{2\pi t}{T}$$

$$\boxed{y = 0.6 \cos 8\pi x \sin 400\,\pi\,t} \quad \textbf{Ans.}$$

16. *In a gas two waves of wavelength 1 m and 1.01 m superpose to produce 10 beats in 3 sec. Calculate the velocity of sound in the medium.*

Solution.

Number of beats = $\nu_1 - \nu_2$

$$\nu_1 - \nu_2 = \frac{v}{\lambda_1} - \frac{v}{\lambda_2}$$

$$\frac{10}{3} = v\left[\frac{1}{1} - \frac{1}{1.01}\right] = \frac{v \times 0.01}{1.01}$$

$$v = \frac{1.01 \times 10}{3 \times 0.01} = 336.7 \text{ m/s}$$

$$v = 336.7 \text{ m/s} \quad \textbf{Ans.}$$

17. *Sound of wavelength λ passes through a Quinke's tube and it produces of sound of maximum intensity I_0. Through what distance should the sliding tube be moved to give an intensity $(I_0/2)$?*

Solution:

$$I_0 = I + I + 2I \cos\theta = 4I \quad \text{...(1)}$$

Further,

$$\frac{I_0}{2} = I + I + 2I\cos\theta = 2I + 2I\cos\theta \quad \text{...(2)}$$

Dividing Eqn. (1) by Eq. (2), we get

$$2 = \frac{4I}{2I(1+\cos\theta)} = \frac{2}{(1+\cos\theta)}$$

$2\cos\theta + 2 = 2$

or $\quad \cos\theta = 0 \quad$ or $\quad \theta = \frac{\pi}{2}$

2π corresponds to a paths difference of λ, $\frac{\pi}{2}$ will corresponds to $\left(\frac{\lambda}{2\pi}\right)\left(\frac{\lambda}{2}\right)$.

Path difference $\frac{\lambda}{4}$

$$\boxed{p.d = \frac{\lambda}{4}} \quad \textbf{Ans.}$$

18. *A train moves towards a stationary observer with speed 34 m/s. The train sound a whistle and its frequency resistered is n_1. If the train speed is reduced to 17 m/s, the frequency resistered is n_2. If the speed of sound is 340 m/s, then find n_1/n_2.*

Solution:

$$n_1 = n_0\left[\frac{340}{340-34}\right] = \frac{10}{9}\,n_0$$

$$n_2 = n_0\left[\frac{340}{340-17}\right] = \frac{20}{19}\,n_0$$

$$\frac{n_1}{n_2} = \frac{10}{9\times 20} \times 19 = \frac{19}{18}$$

$$\boxed{\frac{n_1}{n_2} = \frac{19}{18}} \quad \textbf{Ans.}$$

19. *The earth is moving towards a stationary star at a speed of 30 km/sec. What is the wavelength of light emitted from the star?*

Solution:

Here earth (observer) is approaching the star and hence, the mutual distance is decreasing. So, the observer will notice an increase in frequency or decrease in wavelength. If v be the velocity of the observer and c, the velocity of light, then the change in wavelength is given by

$$d\lambda = \lambda - \lambda' = \frac{v}{c} \times \lambda$$

Substituting the given values, we have

$$d\lambda = \frac{30 \times 10^3}{3 \times 10^8} = 5875 \times 10^{-4}\ \text{Å}$$

Hence, the altered wavelengths

$$\lambda' = \lambda - d\lambda$$

$$= (5875 - 5875 \times 10^{-4}) \text{ in Å}$$

$$\boxed{\lambda' = 5874.4125\ \text{Å}}\ \textbf{Ans.}$$

20. *The speed of logitudinal wave is 75 times the speed of transverse in a metallic wire. Calculate the Young's modulus of the material of the wire $q = 1 \times 10^{11}\ N/m^2$.*

Solution:

The speed of longitudinal wave in a wire is given by

$$v_l = \sqrt{\frac{q}{\rho}}$$

The speed of transverse wave in a wire is

$$v_t = \sqrt{\frac{T}{m}}$$

with $m = \pi r^2 \rho$

$$\sqrt{\frac{q}{\rho}} = 75\sqrt{\frac{T}{m}} = 75\sqrt{\frac{T}{\pi r^2 \rho}}$$

$$q = \frac{75^2 \times T}{\pi r^2} \quad \text{or} \quad T = \frac{q\pi r^2}{75^2}$$

$$\text{Stress} = \frac{F}{A} = \frac{T}{\pi r^2}$$

$$= \frac{q\pi r^2}{\pi r^2 (75)^2} = \frac{(10)^{11}}{(75)^2}$$

$$\boxed{\text{Stress} = 1.8 \times 10^7 \text{ N/m}^2} \quad \textbf{Ans.}$$

21. *Two closed organ pipes, A and B have the same length. A is wider than B. They resonate in the fundamental mode. Get the frequency relalates.*

Solution:

Considering the end correction

$$\nu = \frac{v}{\lambda} = \frac{v}{4(l + 0.3d)}$$

Here, d is the diameter of the pipe. As λ is same, hence wider tube will resonate at a lower frequency

i.e., $\boxed{\nu_A < \nu_B}$ **Ans.**

22. *In an auditorium of volume of 1275 cubic metre it is found to have a reverberation time of 1.5 sec. What is the total absorbing power of all the surfaces in the auditorium? If the area of the surface absorbing the sound is 745 sq.m, calculate the average absorption coefficient.*

Solution:

$$T = \frac{0.158\, V}{\Sigma\, a_1 S_1} = \frac{0.158 \times 1275}{\Sigma\, a_1 S_1}$$

$$\Sigma\, a_1 S_1 = \frac{0.158 \times 1275}{T}$$

$$= \frac{0.158 \times 1275}{1.5} = 134.3$$

Average absorption coefficient

$$\bar{a} = \frac{\Sigma\, a_1 S_1}{S} = \frac{134.3}{745} = 0.1802$$

$$\boxed{\bar{a} = 0.1802} \quad \textbf{Ans.}$$

23. *Calculate the reverberation time in an auditorium having the dimension 12 × 30 × 6 metre with*

(*i*) *698 sq. m of plaster,* $a_1 = 0.03$

(*ii*) *560 sq. m of wood and floor,* $a_2 = 0.06$

(*iii*) *38 sq. m of glass,* $a_3 = 0.025$

(*iv*) *600 seats,* $a_4 = 0.3$ *and*

(*v*) *an audience of 500 persons with* $a_5 = 4.5$ *per person.*

Solution:

The total absorption in metric sabine is calculated as follows:

(*i*) Plaster = 698 × 0.03 = 20.94

(*ii*) Wood and floor = 560 × 0.06 = 33.6

(*iii*) Glass = 38 × 0.025 = 0.95

(*iv*) Seats = 600 × 0.3 = 180 × 0.093 = 16.74
[1 sq ft = 0.093 sqm]

(*v*) Audience 500 × (4.3 – 0.3) = 186

Total absorption,

$$\Sigma\, as = 20.94 + 33.6 + 0.95 + 16.74 + 186$$
$$= 258.23$$

$$T = \frac{0.158 \times V}{258.23}$$

$$= \frac{0.158 \times 12 \times 30 \times 6}{258.23} = 1.32 \text{ sec}$$

$$\boxed{T = 1.32 \text{ sec}} \quad \textbf{Ans.}$$

24. *The distance between the crystal and reflector in an ultrasonic interferometer is 4 cm. 100 loops are formed when the grating is obtained. If the velocity of*

ultrasonic waves in the given liquid is 1600 m/s, what is the frequency of the crystal?

Solution:

100 loops have a length 4 cm

Hence, loop length is $\frac{4}{100}$ which is $\frac{\lambda_u}{2}$

or $\frac{\lambda_u}{2} = \frac{4}{100}$ or $\lambda_u = 8 \times 10^{-2}$ cm

$$v = \nu\lambda_u;\ \nu = \frac{v}{\lambda_u} = \frac{1600 \times 100}{8 \times 10^{-2}}$$

$$= 2 \times 10^6 \text{ Hz}$$

$\boxed{\nu = 2 \text{ MHz}}$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*b*)	2. (*a*)	3. (*d*)	4. (*a*)
5. (*d*)	6. (*b*)	7. (*c*)	8. (*a*)
9. (*d*)	10. (*b*)	11. (*c*)	12. (*a*)
13. (*c*)	14. (*a*)	15. (*b*)	16. (*d*)
17. (*d*)	18. (*b*)	19. (*d*)	20. (*d*)
21. (*c*)	22. (*a*)	23. (*b*)	24. (*c*)
25. (*d*)	26. (*a*)	27. (*c*)	28. (*a*)
29. (*a*)	30. (*d*)	31. (*b*)	
32. (*b*), (*c*)	33. (*d*)	34. (*b*)	35. (*c*)
36. (*a*)	37. (*d*)	38. (*b*)	39. (*b*)
40. (*d*)	41. (*c*)	42. (*a*)	43. (*d*)
44. (*b*)	45. (*b*)	46. (*d*)	47. (*a*)
48. (*d*)	49. (*d*)	50. (*b*)	51. (*b*)
52. (*a*)	53. (*b*)	54. (*a*)	55 (*d*)
56. (*d*)	57. (*d*)	58. (*c*)	59. (*d*)
60. (*b*).			

CHAPTER 2

HEAT AND THERMODYNAMICS

1. SI unit of thermal conductivity is
   (*a*) J m^{-1} s^{-1} K^{-1}
   (*b*) J m s/K
   (*c*) J s m^{-1} K^2
   (*d*) J/s^2.
2. Temperature of human body is 98.4° F. The corresponding temperatures on the celsius scale and kelvin scale are
   (*a*) 0°C and 273K
   (*b*) 273 K and 17°C
   (*c*) 36.9°C and 309.9 K
   (*d*) 17.2°C and 120.2 K.
3. When 10 gm of water is heated from 10°C to 20°C, it requires an energy (in joule) of
   (*a*) 220　　(*b*) 41
   (*c*) 2000　　(*d*) 420.
4. A constant volume air thermometer works on the principle of
   (*a*) Boltzmann's law
   (*b*) Boyles law
   (*c*) Charle's law
   (*d*) Kelvin's law.
5. The temperature coefficient of resistance of a material of a wire is 0.00125/°C. Its resistance at 300 K is 1 ohm. At what temperature will the resistance of the wire be 2 ohm?
   (*a*) 400 K　　(*b*) 1100 K
   (*c*) 1013 K　　(*d*) 502 K.

6. The surface water in a lake is just going to freeze. What is the temperature at the bottom of the lake?
(*a*) 0°C (*b*) less than 0°C
(*c*) 4°C (*d*) – 4°C.

7. At every degree celsius rise of temperature, the volume of a given mass of a gas at constant pressure increases by
(*a*) $\frac{1}{273}$ of its value at 0°C
(*b*) $\frac{1}{373}$ of its value at 0°C
(*c*) $\frac{1}{173}$ of its volume at 0°C
(*d*) $\frac{1}{700}$ of its volume at 0°C.

8. In order to keep correct time, the balance wheel in modern watches is made of
(*a*) nichrome (*b*) steel
(*c*) platinum (*d*) invar.

9. Water evaporates under atmospheric pressure. Without changing the temperature the same water is placed under partial vacuum. Then the rate of evaporation
(*a*) will increase
(*b*) will decrease
(*c*) will remain unaffected
(*d*) will drop to zero.

10. Universal gas constant has the unit of
(*a*) newton/°C
(*b*) newton/K
(*c*) J/mol K
(*d*) watt/kelvin.

11. When water is heated from 0°C to 10°C, its volume
(*a*) decreases
(*b*) increases

(*c*) first decreases and then increases
(*d*) does not change.

12. Same mass of aluminium and lead are heated to 98°C and placed inside ice
(*a*) lead will melt more ice than aluminium
(*b*) aluminium will melt more ice than lead
(*c*) both will melt the same amount of ice
(*d*) none of these.

13. For a certain gas the ratio of specific heats is given to be $\gamma = 1.5$, then for this gas
(*a*) $C_v = \frac{3R}{J}$ (*b*) $C_v = \frac{5R}{J}$
(*c*) $C_p = \frac{5R}{J}$ (*d*) $C_p = \frac{3R}{J}$.

14. Which of the following has the largest heat capacity?
(*a*) 10 kg of silver
(*b*) 10 kg of water
(*c*) 10 kg of brass
(*d*) 10 kg of aluminium.

15. For a gas the ratio of specific heats γ = 1.5. For this gas
(*a*) $C_v = 3R$ (*b*) $C_p = 3R$
(*c*) $C_p = 5R$ (*d*) $C_v = 5R$.

16. 420 J of energy supplied to 10 gm of water will raise its temperature nearly by
(*a*) 4.2°C (*b*) 1°C
(*c*) 420°C (*d*) 10°C.

17. The amount of heat that is absorbed by unit mass of a substance during change of state is known as
(*a*) specific heat
(*b*) coefficient of linear expansion

(*c*) latent heat
(*d*) thermal capacity.

18. The heat capacity of a body depends on
(*a*) the mass of the body
(*b*) the colour of the body
(*c*) the heat given out
(*d*) the temperature rise.

19. If σ_T is the thermal conductivity of a metal and ρ the electrical resistivity and T the absolute temperature, then they are related as

(*a*) $\dfrac{\sigma_T}{\rho}$ = constant
(*b*) $\sigma_T \rho$ = constant
(*c*) $\dfrac{\sigma_T}{\rho_T}$ = constant
(*d*) $\dfrac{\sigma_T \rho}{T}$ = constant.

20. A wall has two layers A and B each made of different materials. Both the layers have the same thickness. The thermal conductivity of the material A is twice that of B. Under thermal equilibrium, the temperature difference across the wall is 36°. The temperature difference across the layer A is
(*a*) 6°C (*b*) 12°C
(*c*) 18°C (*d*) 24°C.

21. If the temperature of a black body becomes one half of its original temperature (in kelvin scale), the amount of radiation emitted by the body will reduce to

(*a*) $\dfrac{1}{4}$ (*b*) $\dfrac{1}{2}$
(*c*) $\dfrac{3}{4}$ (*d*) $\dfrac{1}{16}$

of the original value.

22. If the sun becomes twice as hot,
    (*a*) the output radiant energy will be sixteen times larger
    (*b*) it will radiate predominantly ultraviolet
    (*c*) it will radiate monochromatic radiation
    (*d*) it becomes dark.
23. Convection currents occur when water is heated because
    (*a*) warm water is heavier than cold water
    (*b*) heat pushes the water up
    (*c*) warm water is less dense than cold water
    (*d*) cold water is less dense than warm water.
24. For an ideal gas $PV = xT$ where x is a constant. Then x must be proportional to
    (*a*) mass of the gas molecule
    (*b*) number of gas molecules in the vessel
    (*c*) absolute temperature
    (*d*) colour of the gas.
25. The temperature gradient in a rod of length of 2 m is 60 °C/metre. If the temperature of hot end of rod is 40°C, the temperature at cold end is
    (*a*) – 20°C (*b*) 30°C
    (*c*) – 40°C (*d*) – 80°C.
26. The value of Stefan's constant is
    (*a*) 3.67×10^{-8} W/m^2 K^4
    (*b*) 5.67×10^{-8} W/m^2 K^4
    (*c*) 7.67×10^{-8} W/m^2 K^4
    (*d*) 1.22×10^{-8} W/m^2 K^4.
27. A glass rod is heated to a high temperature and then allowed to cool. If it cracks, a probable reason for this is the following property of glass.

(*a*) low heat capacity
(*b*) high thermal conductivity
(*c*) high specific heat
(*d*) low thermal conductivity.

28. Thermal radiations are in the region of
(*a*) infrared
(*b*) ultraviolet
(*c*) visible region
(*d*) microwaves.

29. Compared to the burn due to boiling water at 100°C, the burn due to steam 100°C is
(*a*) more dangerous
(*b*) equally dangerous
(*c*) less dangerous
(*d*) not dangerous at all.

30. A 50 watt heating coil is used for 2 minutes to heat a metal block of 500 gm and the specific heat capacity of the metal is 1 J/gm/°C. The temperature rise is
(*a*) 70°C (*b*) 12°C
(*c*) 62°C (*d*) – 20°C.

31. The gas equation PV^{γ} is a constant is true for
(*a*) isothermal change only
(*b*) adiabatic change only
(*c*) both isothermal and adiabatic changes.

32. The gas law $\frac{PV}{T}$ = constant is true for
(*a*) isothermal change only
(*b*) adiabatic changes only
(*c*) both isothermal and adiabatic changes.

33. The temperature of a gas is due to
(*a*) the potential energy of the molecules
(*b*) the attractive force between the molecules

(*c*) the repulsive forces between the molecules

(*d*) the kinetic energy of the molecules.

34. A monoatomic ideal gas initially at 17°C is suddenly compressed to one eighth of its original volume. The temperature after compression is

(*a*) 27°C (*b*) 111°C

(*c*) 1020°C (*d*) 736°C

Given $\gamma = 1.6$.

35. The water equivalent of a body is expressed in

(*a*) joule (*b*) erg

(*c*) calorie (*d*) kilogram.

36. If a substance is under going an adiabatic change, the correct relationship between V and temperature T is

(*a*) $T^{\gamma}V^{\gamma-1}$ = constant

(*b*) $TV^{\gamma-1}$ = constant

(*c*) $\dfrac{V^2}{T}$ = constant

(*d*) VT = constant.

37. During an isothermal compression, if the pressure of a given mass of a gas (of volume V) increases ten fold,

(*a*) volume will become 10 V and heat will be absorbed

(*b*) volume will become 10 V and heat will be given out

(*c*) volume will become $\dfrac{\text{V}}{10}$ and heat will be given out

(*d*) volume will become $\dfrac{\text{V}}{10}$ and heat will be absorbed.

38. Initial volume and pressure of a gas are V and P. If it is adiabatically expanded to volume $4V$, new pressure will be ($\gamma = 1.5$)

(*a*) $\frac{P}{4}$ (*b*) $\frac{P}{8}$

(*c*) $\frac{P}{16}$ (*d*) $2P$.

39. The work done in an adiabatic change in a particular gas, depends upon only

(*a*) change in volume

(*b*) change in temperature

(*c*) change of pressure

(*d*) change of entropy.

40. Which of the statements given below is correct in the case of a Carnot's engine?

(*a*) The efficiency of Carnot's engine is independent of the nature of working substance

(*b*) The efficiency of Carnot's engine cannot be 100%

(*c*) the efficiency of Carnot's engine depends upon the temperature of heat source and sink

(*d*) all of the above.

41. The efficiency of a Carnot engine is 66.7%. If an ideal gas having $\gamma = 1.5$ is used as working substance, the adiabatic expansion ratio is

(*a*) 22 (*b*) 9

(*c*) 19 (*d*) $\frac{1}{4}$.

42. In a closed vessel, the pressure increases by 0.4% when temperature increases by 1°C. The initial temperature is

(*a*) 250 K (*b*) 250°C

(*c*) 100 K (*d*) – 20°C.

43. A curve drawn between two points on P-V diagram represents
(*a*) the state of the system
(*b*) work done on or by the system
(*c*) work done in a cyclic process
(*d*) a thermodynamic process.

PROBLEMS AND SOLUTIONS

1. *At what temperature do the Kelvin and Fahrenheit scales coincide?*

Solution:

$$\frac{C}{5} = \frac{K-273}{5} = \frac{F-32}{9};$$

or $$\frac{x-273}{5} = \frac{x-32}{9}$$

$$9x - 9 \times 273 = 5x - 160$$
$$4x = 2457 - 160$$
$$4x = 2257$$
$$\boxed{x = 574.25} \quad \textbf{Ans.}$$

2. *Doctors use Fahrenheit scale to note the temperature of human body while Kelvin scale is used in solving many problems in Thermodynamics. If 98.4°F is the normal temperature of the human body, what is its value in Kelvin scale?*

Solution:

$$5(F-32) = 9C$$
$$C = \frac{5F-160}{9}$$
$$= \frac{5 \times 98.4 - 160}{9} = 36.9°\text{C}$$

or $36.9 + 273 = 309.9$ kelvin.

$$\boxed{309.9 \text{ K}} \quad \textbf{Ans.}$$

3. *A metallic rod with coefficient of linear expansion 10^{-3} K^{-1}, is heated from 0°C and 100°C; calculate the percentage increase in length.*

Solution:

$$\alpha = \frac{(l_2 - l_1)}{l_1 (T_2 - T_1)} = \frac{\Delta l}{l_1 \, \Delta T}$$

Hence percentage increase in length is given by

$$\frac{\Delta l \times 100}{l_1} = \alpha \Delta T = 10^{-3} \times 100 = 0.1$$

$$\boxed{0.1} \quad \textbf{Ans.}$$

4. *The temperatures inside and outside a refrigerator are 273 K and 303 K respectively. Assuming that refrigerator cycle is reversible, what is heat delivered to the surroundings for every joule of work done.*

Solution:

Refrigerator is a heat engine that works in backward direction.

$$\beta = \frac{T_2}{T_1 - T_2} = \frac{Q}{W}$$

$$Q = \frac{W\,T_2}{T_1 - T_2} = \frac{1 \times 273}{303 - 273}$$

$$\boxed{Q = 10 \text{ joule}} \quad \textbf{Ans.}$$

5. *A 10 kW drilling machine is used to drill a bore in a small aluminium block of mass 8 kg. How much is the rise in temperature in 2.5 minute assuming 50% of the power is used up in heating the machine itself or lost to the surroundings. Specific heat of aluminium is 0.91 J g^{-1} K^{-1}.*

Solution:

$P = 10$ kW $= 10^4$ watt, $m = 8$ kg, $\theta = ?$

$t = 2.5$ minute $= 150$, specific heat $c = 910$ J kg^{-1} K

Heat generated in 150 sec

$$= P \times t = 10^4 \times 150 = 1.5 \times 10^6 \text{ J}$$

Amount of heat used to heat the block is

$$Q = 50\% \text{ of } 1.5 \times 10^6$$
$$= 0.75 \times 10^6 \text{ J}$$

But $\quad Q = mc(T_2 - T_1)$

or $\quad (T_2 - T_1) = \theta = \dfrac{Q}{mc}$

$$\theta = \frac{0.75 \times 10^6}{8 \times 910} = 103°\text{C}$$

$$\boxed{\theta = 103°\text{C}}$$ **Ans.**

6. *The temperature of a furnace is 2000 K and the intensity is maximum in its radiation spectrum at 1200 nm. If the intensity in the spectrum of a star is maximum at 4800 Å, then calculate the surface temperature of the star.*

Solution:

$$\lambda_m T_1 = \lambda'_m T_2$$
$$1200 \times 2000 = 480 \times T_2$$
$$24 \times 10^5 = 480\, T_2$$

$$\boxed{T_2 = 5000 \text{ K}}$$ **Ans.**

7. *A body cools from 50°C to 40°C in five minutes when the surroundings are maintained at 20°C. What will be the temperature of the body after 10 more minutes?*

Solution:

In the first case mean difference between temperature of the body and that of the surroundings is $\frac{40+50}{2} - 20 = 25°$

Let θ be the temperature after 10 more minute. The mean difference in this case is

$$\frac{40+\theta}{2} - 20 = (0.5)\theta°\text{C}$$

Rate of cooling in the first case is

$$\frac{50-40}{5} = \frac{10}{5}$$

Rate of cooling in the second case is

$$\frac{40-\theta}{10}$$

But rate of cooling is proportional to the mean excess of temperature over the surrounding.

In the first case

$$\frac{10}{5} \propto 25$$

in the second case

$$\frac{40-\theta}{10} \propto \frac{\theta}{2}$$

$$\frac{\frac{10}{5}}{\frac{40-\theta}{10}} = \frac{25}{\theta/2}$$

$$\frac{10\times 10}{5(40-\theta)} = \frac{50}{\theta}$$

$$20\,\theta = 50(40-\theta)$$

$$70\,\theta = 2000$$

$$\theta = \frac{200}{7}$$

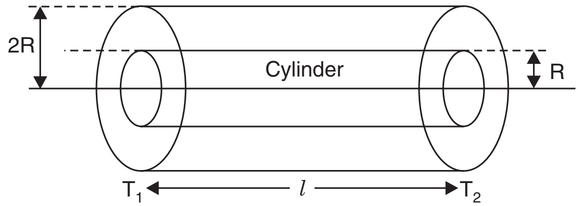
$$\boxed{\theta = 28.6°C} \quad \textbf{Ans.}$$

8. *A cylinder of radius R made of material of thermal conductivity σ_1 is surrounded by a cylindrical shell of inner radius R and outer radius 2R made of material of thermal conductivity σ_2. The two ends of the combined system are maintained at two different temperatures. There is no loss of heat across the cylindrical surface and the system is in a steady state. Calculate the effective thermal conductivity of the system.*

Solution:

Heat flowing per second through the cylinder of radius R

$$Q_1 = \sigma_1(\pi R^2)\left[\frac{T_1 - T_2}{l}\right]$$



Heat flowing per second through the cylinder of radius R

$$Q_2 = \sigma_1[\pi R^2]\left[\frac{T_1 - T_2}{l}\right]$$

Heat flowing per second through outer shell of radius $2R$

$$Q_2 = \sigma_2[\pi(2R)^2 - \pi(R^2)]\left\{\frac{T_1 - T_2}{l}\right\}$$

Thus

$Q = Q_1 + Q_2$

$$= \sigma_2 (3R^2\pi) \frac{(T_1 - T_2)}{l} + \sigma_1 \pi R^2 \frac{(T_1 - T_2)}{l}$$

$$= \pi R^2 \frac{(T_1 - T_2)}{l} [3\sigma_2 + \sigma_1] \quad ...(1)$$

Let σ be the equivalent thermal conductivity of the system. Then

$$Q = \sigma\pi (2R)^2 \frac{(T_1 - T_2)}{l} \quad ...(2)$$

Equating Eqns. (1) and (2),

$$\sigma_1 + 3\sigma_2 = 4\sigma$$

or $$\boxed{\sigma = \left[\frac{\sigma_1 + 3\sigma_2}{4}\right]}$$ **Ans.**

9. *A bottle half full of water at 0°C is sealed when the atmospheric pressure is 76 cm of mercury. What will be the pressure when the temperature rises to 100°C (The vapour pressure of water at 0°C may be neglected).*

Solution:

The total pressure at 100°C will be the sum of the pressure due to air and the saturated vapour pressure of water SVP of water at its boiling point 100°C is 76 cm and let P be the pressure due to air, such that

$$\frac{P}{76} = \frac{273 + 100}{273}$$

or $$P = 76 \left(\frac{373}{273}\right)$$

$$= 103.8 \text{ cm of mercury}$$

Thus the total pressure

$$P' = 76 + 103.8$$

$$\boxed{P' = 179.8 \text{ cm of mercury}} \quad \textbf{Ans.}$$

10. *A scooter tyre is filled with air at 1.5 atmosphere and temperature 27°C. The tyre suddenly bursts. Calculate the resulting temperature, γ for air is 1.4.*

Solution:

Initial pressure P_1 = 1.5 atmosphere

Initial temperature T_1 = 27°C

$= 27 + 273$

$= 300$ K

Final temperature T_2 = ?

Final pressure P_2 = ?

It is an adiabatic transformation.

Hence $$\frac{P_1^{\gamma-1}}{T_1^{\gamma}} = \frac{P_2^{\gamma-1}}{T_2^{\gamma}}$$

$$\left(\frac{T_2}{T_1}\right)^{\gamma} = \left(\frac{P_2}{P_1}\right)^{\gamma-1}$$

$$\gamma(\log T_2 - \log T_1) = (\gamma - 1)(\log P_2 - \log P_1)$$

$$\log T_2 - \log T_1 = (\gamma - 1)\frac{(\log P_2 - \log P_1)}{\gamma}$$

$$\log T_2 = \log T_1 - \frac{0.4}{1.4}(\log 1 - \log 1.5)$$

$$= \log 300 - \frac{0.4}{1.4}\log 1.5$$

$$\log T_2 = 2.4771 - 0.0503 = 2.4268$$

$$\boxed{T_2 = 267.2°\text{C} = 540.2 \text{ K}} \quad \textbf{Ans.}$$

11. *An air bubble of radius 1 cm is formed at the bottom of a lake 68 feet deep where the temperature is 4°C and rises to the top where the temperature is 27°C.*

Neglect surface tension effect. What will be the radius of the bubble in the following two cases?

(*a*) *it is continually at the same temperature as the surrounding water,*

(*b*) *there is no heat transfer between the bubble and water (1 atm = 76 cm of Hg = 34 feet of water)*

Solution:

(*a*) Let the atmospheric pressure be H cm of mercury.

The pressure at the bottom = $2H$ cm of mercury

Applying gas laws

$$\frac{2H \times \frac{4}{3} \times \pi \times 1^3}{277} = H \times \frac{4}{3} \pi r^3 \times \frac{1}{300}$$

$$\left(\because \frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}\right)$$

$$r^3 = \frac{600}{277}$$

$$r = \left(\frac{600}{277}\right)^{1/3} = 1.29 \text{ cm}$$

(*b*) For adiabatic change we have the relation

$$P_1 V_1^{\gamma} = P_2 V_2^{\gamma}$$

$$2H \times \left[\frac{4}{3} \pi 1^3\right]^{\gamma} = H\left[\frac{4}{3} \pi r^3\right]^{\gamma}$$

$$2 = [r^3]^{1.4};\ r^{4.2} = 2$$

$$\boxed{r = 2^{(1/4.2)} = 0.057 \text{ cm}} \quad \textbf{Ans.}$$

12. *A 5 kg of water at 373 K and normal pressure is converted into steam at the same pressure and temperature.*

Calculate the work done and the increase in the internal energy of water, given that the volumes of 1 kg of water and steam at 373 K are 1.0×10^{-3} m^3 and 1.671 m^3 respectively. Latent heat of steam is 2.3×10^6 J/kg.

Solution:

Latent heat = 2.3×10^6 J/kg

Mass of water = 5 kg

Therefore heat required to convert 5 kg of water into steam is

$$ML = 5 \times 2.3 \times 10^6 = 11.5 \times 10^6 \text{ J}$$

Volume of 1 kg of water at 373 K

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

Volume of 1 kg of steam at 373 K

$$= 1.671 \text{ m}^3$$

Change in volume when 1 kg of water changes into steam

$$= 1.671 - 1 \times 10^{-3} = 1.67 \text{ m}^3$$

Change in volume (dV) for 5 kg of water when it changes into steam

$$= 5 \times 1.67 \text{ m}^3$$

Hence work done

$$dW = p \times dV$$
$$= 1 \times 10^5 \times 5 \times 1.67$$
$$= 8.35 \times 10^5 \text{ Nm (or J)}$$

Change in internal energy

$$dU = dQ - dW$$
$$= 11.5 \times 10^6 - 8.35 \times 10^5$$

$\boxed{106.65 \times 10^5 \text{ J}}$ **Ans.**

13. *A reversible engine is working between 800 K and 400 K. Calculate the amount of heat the engine should absorb/sec from the source so that it develops power of 4200 watt.*

Solution:

$T_1 = 800$ K, $T_2 = 400$ K

Work done per sec W = power = 4200 watt

= 4200 J/s

Thus efficiency of the engine

$$\eta = 1 - \frac{T_2}{T_1} = \frac{W}{Q_1}$$

$$= 1 - \frac{400}{800} = \frac{4200}{Q_1}$$

i.e. $$\frac{1}{2} = \frac{4200}{Q_1} \quad \text{or} \quad Q_1 = 4200 \times 2$$

$$\boxed{Q_1 = 8400 \text{ J}} \quad \textbf{Ans.}$$

14. *Calculate the change in entropy when 10 kg of water at 283 K is frozen into ice at 268 K given that the specific heat of ice is 0.5 K cal/kg and latent heat of ice is 80 kcal/kg.*

Solution:

Mass of water = 10 kg, $T_1 = 283$ K

specific heat $S = 1$.

Therefore change in entropy when its temperature falls to 273 K.

$$ds = \int_{283}^{273} \frac{ms\,dT}{T}$$

$$= 10 \times 1 \times \log_e \frac{273}{283}$$

$$= -\,0.336 \text{ kcal/K.}$$

Change in entropy when this water freezes at 273 K.

$$d = \frac{mL}{T} = \frac{10 \times 80}{273} = -\,2.93$$

Change in entropy when the temperature of this ice falls to 268 K.

$$d = \int_{273}^{268} \frac{10 \times 0.5 \times dT}{T}$$

$$= 10 \times 0.5 \times 2.303 \log_{10} \frac{268}{273}$$

$$= -0.093$$

Total decrease in energy

$$= 0.336 + 2.93 + 0.093$$

$$\boxed{= 3.359 \text{ kcal/K.}} \quad \textbf{Ans.}$$

15. *Calculate under what pressure water will boil at 120°C, if the change in specific volume when 1 kg of water is converted into steam is 1.676×10^{-3} m^3.*

Solution:

Latent heat of steam 540 cal/kg

$$= 540 \times 4.2 \text{ J}$$

1 atmosphere = 10^5 N/m^2

$$dT = 120 - 100, T = 373 \text{ K}$$

$$dp = ?$$

$$\frac{dp}{dT} = \frac{L}{T(V_2 - V_1)}$$

$$dp = \frac{LdT}{T(V_2 - V_1)}$$

$$= \frac{540 \times 4.2 \times 20}{373 \times 1.676 \times 10^{-3}}$$

$$\boxed{\begin{array}{l} = 72.56 \times 10^3 \text{ N/m}^2 \\ \text{or} \quad 0.7256 \text{ atmosphere} \end{array}} \quad \textbf{Ans.}$$

Pressure required

$$= 1 + 0.7256 = 1.7256 \text{ atmosphere.}$$

16. *A 15 kW drilling machine is used to drill a bore in a small aluminium block of mass 10 kg. How much is the rise in temperature of the block in 2 min*

assuming 50% of the power is used up in heating the machine itself or lost to the surroundings (specific heat of aluminium is 900 J/kg-°C).

Solution:

$$P = 15 \times 10^3 = 15000 \text{ watt}$$

Work done in 2×60 sec $= P \times t$

i.e., $W = 15000 \times 120$ joule

Heat produced in the block is $mC\theta$

i.e., $mC\theta = \frac{W}{2}; \quad \theta = \frac{\mathrm{W}}{2\,c \times m}$

or $\theta = \frac{120 \times 15000}{2 \times 900 \times 10}$

$$\boxed{\theta = 100°\text{C}}$$ **Ans.**

17. *A 2.5 kilowatt electric water heater holds 30 gallons (1 gallon = 3.78 litre) of water. How long will it take to heat the water from 68°F to 149°F?*

Solution:

Rise in temperature is 149 – 68 = 81°F

We know

$$5(F - 32) = 9C$$
$$5(68 - 32) = 9C$$
$$180 = 9C$$
$$C = 20°\text{C}$$

and $5(149 - 32) = 9C$

$$585 = 9C$$
$$C = 65°\text{C}$$

Difference of temperatures 65 – 20 = 45°C

Mass of water

$= 30 \times 3.78 \times 1000 \times 1$

Heat required

$= 30 \times 3.78 \times 1000 \times 45$ (mst) cal

Energy required

$= 30 \times 3.78 \times 1000 \times 4.5$ J

$$\text{Time required} = \frac{30 \times 3.78 \times 1000 \times 4.5}{2500 \times 60}$$

$$\boxed{t = 142.9 \text{ minute}} \quad \textbf{Ans.}$$

18. *A solar engine uses a parabolic collector supplying the working fluid at 500°C. A second engine employs a flat plate collector supplying the working fluid at 80°C. The ratio of maximum work available in the two cases is to be calculated now. The ambient temperature is 27°C.*

Solution:

$$\eta_s = \frac{W_1}{Q_1} = \frac{(T_1 - T_2)}{T_1}$$

i.e.
$$\frac{W_1}{Q_1} = \frac{(500 + 273) - (27 + 273)}{(500 + 273)}$$

$$= \frac{473}{773}$$

$$\eta_s' = \frac{W_2}{Q_2}$$

$$= \frac{(273 + 80) - (273 + 27)}{(273 + 80)}$$

$$\eta_s' = \frac{53}{353}$$

Assuming same input in two engines

$$\frac{W_1}{W_2} = \frac{473}{773} \times \frac{353}{53}$$

$$\boxed{\frac{W_1}{W_2} = 4} \quad \textbf{Ans.}$$

ANSWERS TO OBJECTIVE QUESTIONS

1. (*a*)	2. (*c*)	3. (*d*)	4. (*c*)
5. (*b*)	6. (*c*)	7. (*a*)	8. (*c*)
9. (*a*)	10. (*c*)	11. (*c*)	12. (*b*)
13. (*d*)	14. (*b*)	15. (*b*)	16. (*d*)
17. (*c*)	18. (*a*)	19. (*d*)	20. (*b*)
21. (*d*)	22. (*a*)	23. (*c*)	24. (*b*)
25. (*d*)	26. (*b*)	27. (*d*)	28. (*a*)
29. (*a*)	30. (*b*)	31. (*b*)	32. (*c*)
33. (*d*)	34. (*d*)	35. (*d*)	36. (*b*)
37. (*d*)	38. (*b*)	39. (*b*)	40. (*d*)
41. (*b*)	42. (*a*)	43. (*d*).	

CHAPTER 3

RAY OPTICS, WAVE OPTICS AND SPECTRA

1. The ratio of the wavelength of the violet to yellow lines of mercury spectrum is 0.69. If the wavelength of the yellow line is 580 nm, the frequency of the violet line is approximately

   (*a*) 150 Hz (*b*) 300 Hz
   (*c*) 3×10^3 Hz (*d*) 7.5×10^{14} Hz.

2. In an experiment with a monochromatic sodium lamp, the angle of deviation at the minimum deviation position is half the angle of prism. If 60° is the angle of prism, the refractive index of the material of the prism is

   (*a*) 1.013 (*b*) 1.414
   (*c*) 2.122 (*d*) 0.707.

3. A specially designed transmitter sends radio waves of frequency 10^6 Hz travelling with $\frac{1}{3}$ of the velocity of light. The wavelength of such radio waves is

   (*a*) 100 m (*b*) 1500 m
   (*c*) 300 m (*d*) 3×10^8 m.

4. A medium in which the velocity of a wave depends on its frequency is called

   (*a*) dispersive medium
   (*b*) elastic medium

(*c*) viscous medium
(*d*) opaque medium.

5. Light rays from a sodium lamp are incident normally on one side of a glass prism of refractive index 1.5 and emerge out of the other surface. The angle of prism is 30°, the angle of deviation is
(*a*) 50° (*b*) 27.5°
(*c*) 18.5° (*d*) 7.5°.

6. 60° is the angle of prism. 50° and 46° are the angles of minimum deviation in a prism for two monochromatic radiations. If the refractive index is 1.63 in the first case, its value in the second case is
(*a*) $1.63 \times \left(\frac{\sin 53°}{\sin 55°}\right)$
(*b*) $1.63 \times \sin 55°$
(*c*) $1.63 \times \left(\frac{\sin 55°}{\sin 53°}\right)$
(*d*) $1.63 \times \sin 53°$.

7. If the velocity of light and permeability of free space are 3×10^8 m/s and $4\pi \times 10^{-7}$ H/m, the permittivity of free space is
(*a*) $\frac{10^9}{36\pi}$ F/m (*b*) $\frac{1}{36\pi}$ F/m
(*c*) 36π F/m (*d*) $\frac{10^{-9}}{36\pi}$ F/m.

8. If the refractive index of diamond with respect to a rarer medium is 2.42, the critical angle is
(*a*) 46.6° (*b*) 16.2°
(*c*) 60° (*d*) 24.4°.

9. Which one of the following phenomena support corpuscular nature of radiation?
(*a*) Compton effect
(*b*) Diffraction

(*c*) Polarization

(*d*) Scattering and Raman effect.

10. The refractive indices of a crown prism are 1.540, 1.528, 1.532 for the violet, red and the mean ray respectively, then the dispersive power of the prism is

(*a*) 1.5 (*b*) 0.0012

(*c*) 1.223 (*d*) 0.0225.

11. The value of Stefan's constant is

(*a*) 6.7×10^{8} W m^2 K^{-4}

(*b*) 5.7×10^{-8} J s^{-1} m^2 K^{-4}

(*c*) 8.7×10^{8} W m^2 K^{-4}

(*d*) 5.7×10^{-8} J s^{-1} m^2 K^{-1}.

12. Velocity of light in a transparent medium is $\frac{2}{3}$ of that in air. The refractive index of the medium is

(*a*) 0.67 (*b*) 1.1

(*c*) 1.5 (*d*) 0.12.

13. Snell's law of refraction is

(*a*) $\frac{1}{{}_1\mu_2} = \frac{\sin r}{\sin i}$

(*b*) ${}_1\mu_2 \sin i = \sin r$

(*c*) ${}_2\mu_1 = \sin i \sin r$

(*d*) ${}_1\mu_2 = \sin i$.

14. Stefan's law is used to determine

(*a*) earth's radius

(*b*) coefficient of conduction of a metal

(*c*) temperature of sun

(*d*) distance of the sun from the earth.

15. A prism of angle 16° has a dispersive power of 0.1 for two rays. If the refractive index of the mean ray is 1.6, the difference between the refractive indices of the two rays is

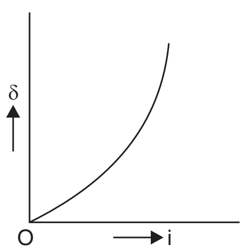
(*a*) 0.12 (*b*) 0.16

(*c*) 0.22 (*d*) 0.06.

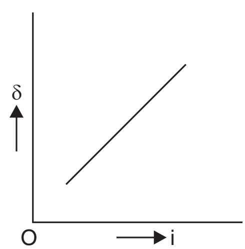
16. The source of energy for the sun to radiate is
(*a*) fission
(*b*) thermo-electric power
(*c*) fusion
(*d*) photoelectric effect.

17. At a distance 4 metre from a lamp the intensity of illumination is 6 lux. The illuminating power of lamp is
(*a*) 22 candela (*b*) 9 candela
(*c*) 28 candela (*d*) 96 candela.

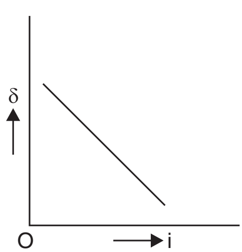
18. The correct graph between the angle of deviation and angle of incidence for a prism is



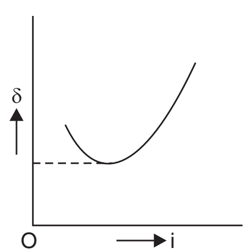
(A)



(B)



(C)



(D)

(*a*) *A* (*b*) *C*
(*c*) *D* (*d*) *B*.

19. To a fish under water, viewing obliquely a fisher-man standing on the bank of a lake, does appear as

(*a*) slightly shorter
(*b*) taller
(*c*) with no change in height
(*d*) with half the original height.

20. Two lamps of luminous intensity 4 and 16 units are 2 metre apart. At which point between the lamps illumination due to either one is the same
(*a*) 1.5 m (*b*) 1.2 m
(*c*) 0.889 m (*d*) 0.667 m.

21. Light travels through a glass plate of thickness t and having refractive index μ. If c is the velocity of light in vacuum, the time taken by light to travel this thickness of glass is
(*a*) $\frac{t}{\mu c}$ (*b*) $t\mu c$
(*c*) $\frac{\mu t}{c}$ (*d*) $\frac{tc}{\mu}$.

22. A light ray passes from air to crown glass through an organic liquid. The refractive index of this liquid with respect to glass is
(Given: μ of glass is 1.5 and the velocity of light in liquid is 0.8 times that in air)
(*a*) 0.8 (*b*) 1.6
(*c*) 2.2 (*d*) 1.2.

23. In the minimum deviation position
(*a*) angle of incidence is always twice the angle of refraction
(*b*) angle of incidence is equal to angle of refraction
(*c*) incident ray and emergent ray are symmetrical to refracting faces
(*d*) all the above are true.

24. The angles of deviation of two extreme colours are 37°C and 42°C respectively, then the angular dispersion is
(*a*) 10° (*b*) 5°
(*c*) 9° (*d*) 2°.

25. How much time will light take to transverse a glass slab of thickness 10 cm and refractive index 1.5?
(*a*) 3×10^{7} sec (*b*) 0.5×10^{-9} sec
(*c*) 1.5×10^{-9} sec (*d*) 3×10^{-8} s.

26. One lux (the unit of illumination) is
(*a*) one lumen/sec^2 (*b*) one lumen/sec
(*c*) 10 lumen/kelvin (*d*) one lumen/m^2.

27. Which of the following is true of SI units?
(*a*) it is comprehensive in the sense that its seven base units cover all disciplines of science and technology
(*b*) the system is coherent as the unit of a derived quantity can be obtained as the product of two or more fundamental units.
(*c*) it is internationally accepted
(*d*) all the above are true.

28. Two independent identical sodium lamps are not coherent sources because
(*a*) they produce waves of different wave lengths
(*b*) they produce waves of same amplitudes
(*c*) they produce waves of different frequencies
(*d*) they are producing waves of same wavelengths but not having a constant initial phase difference.

29. In a plane electromagnetic wave the electric field oscillates sinusoidally at a frequency of 2×10^{10} Hz and magnitude

51 V/m. The wavelength and amplitude of the oscillating magnetic field are

(*a*) 1.5×10^{-2} m, 17×10^{-8} tesla
(*b*) 1.5×10^{-3} m, 18×10^{-6} tesla
(*c*) 3×10^{-2} m, 6×10^{2} tesla
(*d*) 9×10^{6} m, 2×10^{-3} tesla.

30. Stationary waves are obtained when two progressive waves
(*a*) of unequal frequencies travelling in opposite directions along a straight line are superposed on another
(*b*) of equal frequencies and amplitudes travel in opposite directions along a straight line
(*c*) of equal frequencies and unequal amplitudes travelling in the same directions are superposed
(*d*) of unequal frequencies and equal amplitudes travelling in the same directions are superposed.

31. Acoustical waves easily undergo diffraction around normal obstacles while light waves do not because
(*a*) wavelength of light waves is large
(*b*) wavelength of sound waves is small
(*c*) wavelength of sound waves is large compared with that of light
(*d*) due to rectilinear propagation of light.

32. When a soap bubble is in air it exhibits different colours under sunlight. The absence of a particular colour in a region is due to
(*a*) constructive interference of light of that colour in that region
(*b*) destructive interference of light of that colour in that region
(*c*) double refraction
(*d*) straight line propagation of light.

33. Dermatologists advise patients with skin problems not to wear violet colour clothes, because
(*a*) violet rays have higher wavelength
(*b*) violet rays travel with the velocity of sound
(*c*) violet rays have higher frequencies
(*d*) they are not electromagnetic radiation.

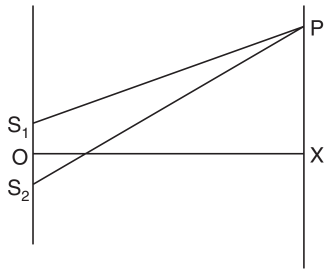
34. A double slit interference experiment is carried out in air and a fringe system is obtained. What change will you notice in the pattern if the whole arrangement is dipped in water?
(*a*) no change is noticed
(*b*) fringe width does not change
(*c*) fringe width decreases
(*d*) colours of fringes changes.

35. In Young's double slit experiment both the separation between the slits and the distance between the slits and the screen are halved; then the fringe width is
(*a*) halved (*b*) unchanged
(*c*) doubled (*d*) zero.

36. Which one of the following is not essential for sources of light in Young's double slit experiment to produce sustained interference?
(*a*) equal intensity
(*b*) equal frequency
(*c*) constant phase relationship
(*d*) same wavelengths.

37. The figure shows Young's double slit arrangements. S_1 and S_2 are the slits illuminated by light of wavelength λ. P is a point on the screen. If light waves leave S_1 and S_2 in phase and P corresponds to a fifth maximum then the

phase difference between the two waves is



(*a*) 10π (*b*) 9π

(*c*) 15π (*d*) 8π.

38. Two coherent sources of light will produce destructive interference when the phase difference between them is

(*a*) $\frac{\pi}{2}$ (*b*) 2π

(*c*) π (*d*) $\frac{\pi}{4}$.

39. The frequency range of microwaves in Hz is

(*a*) $5 \times 10^{14} - 6 \times 10^{14}$

(*b*) $2 \times 10^{15} - 2.5 \times 10^{16}$

(*c*) 1000 to 10000

(*d*) $3 \times 10^{8} - 1.5 \times 10^{12}$.

40. In an electromagnetic wave the angle between the planes of magnetic component and electric component is

(*a*) 0° (*b*) 90°

(*b*) 120° (*c*) 180°.

41. Laser is considered to be coherent because it consists of

(*a*) many wavelengths

(*b*) unco-ordinated wavelengths

(*c*) co-ordinated waves of exactly the same wavelength

(*d*) divergent beams.

42. The intensity ratio at a point of observation, of two coherent waves is 100 : 1. The ratio between their amplitudes is

(*a*) 10 : 1 (*b*) 1 : 10
(*c*) 100 : 20 (*d*) 1 : 1.

43. Light waves of wavelength λ_1 and λ_2 is made incident successively on the surface of a metal. Light wave of wavelength λ_1 produces photo-electric effect whereas λ_2 does not. Now interference fringes are produced with these sources; the fringe widths obtained are β_1 and β_2 respectively, then which of the following is correct

(*a*) $\beta_1 > \beta_2$ (*b*) $\beta_1 < \beta_2$
(*c*) $\beta_1 = \beta_2$ (*d*) $\beta_1 = \beta_2^2$.

44. Photons of wavelength 500 nm are incident on an atom in the ground state and scattered as 600 nm. The wavelength of the corresponding antistokes line is

(*a*) 700 nm (*b*) 500 nm
(*b*) 400 nm (*c*) 600 nm.

45. Two beams of equal intensities of wavelength 460 nm and 600 nm are scattered by a fine suspension. The ratio of intensities of the scattered radiation when viewed at right angles to the beam is approximately.

(*a*) 8 (*b*) 9
(*c*) 3 (*d*) 10.5.

46. Which one of the following statements is not correct?

(*a*) stimulated emission is a must in laser radiation
(*b*) lasers are widely used in holography
(*c*) Al_2O_3 is used in Ruby laser
(*d*) Lasers are highly non-coherent.

47. In optical pumping frequency of the incident photon to bring an atom from the ground state to the excited state is 10^{10} Hz, and it results in a laser output with the frequency 10^9 Hz; the energy lost is

(*a*) 10^2 J (*b*) 6.2×10^{-24} J

(*c*) 1.21×10^{-22} J (*d*) 5.94×10^{-24} J.

48. The wavelength of radiation emitted with maximum energy in a spectrum of black body is

(*a*) directly proportional to the absolute temperature of the body

(*b*) inversely proportional to the absolute temperature of the body

(*c*) directly proportional to the difference in the absolute temperature of the body and its surrounding

(*d*) inversely proportional to the difference between the absolute temperatures of the body and the surroundings.

49. According to Lloyd, reflection from the surface of a denser medium introduces an additional path difference equal to

(*a*) λ (*b*) 2λ

(*c*) $\frac{3\lambda}{4}$ (*d*) $\frac{2\lambda}{4}$.

50. Two coherent sources whose intensity ratio is 81 : 1 produce interference fringe. The ratio of the maximum intensity to minimum intensity in the fringe system is

(*a*) 20 : 10 (*b*) 28 : 14

(*c*) 25 : 16 (*d*) 1 : 2.

51. In thin films, the condition for constructive interference is

(*a*) $2\ \mu t \cos r = (2n - 1)\dfrac{\lambda}{2}$

(*b*)

$2\ \mu t \cos r = n\lambda$

(*c*) $2\ \mu t \cos r = 2n\lambda$

(*d*) $2\ \mu t \cos r = (\lambda + 1)$.

52. Electromagnetic theory was proposed by

(*a*) Newton (*b*) de Broglie

(*c*) Huygen (*d*) Maxwell.

53. Two beams of monochromatic light coming from two coherent sources produce an interference pattern on a screen. If a thin glass plate is introduced in the path of one of the two beams, then

(*a*) the fringe width will decrease

(*b*) the fringe width will increase

(*c*) the pattern of the fringes will disappear

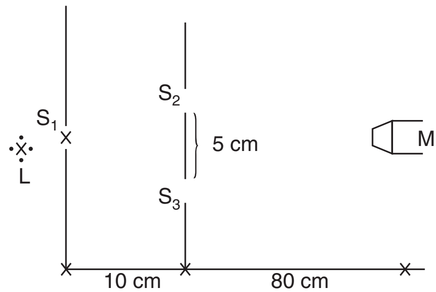
(*d*) all the fringes would be shifted laterally.

54. Newton's rings were observed in reflected light of wavelength λ. The diameter of the 10^{th} dark ring was 0.5 cm and the radius of curvature of the lens was 1 m, the wavelength of the light used is

(*a*) 6250 nm (*b*) 625 Å

(*c*) 500 nm (*d*) 6250 Å.

55. A student is asked to measure the wavelength of a monochromatic light. He sets up the apparatus as shown below. S_1, S_2, S_3 are narrow parallel slits. L is the given monochromatic source and M is a micrometer eye-piece. The student fails to observe interference fringes. You would advise him to



(a) increase the width of S_1

(b) decrease the distance between S_2 and S_3

(c) replace L with white light

(d) replace M with a telescope.

56. The diameter of the dark Newton's rings are

(a) proportional to square root of odd numbers

(b) proportional to the square of odd numbers

(c) inversely proportional to the natural numbers

(d) proportional to the square roots of natural numbers.

57. In Young's double slit experiment, the 6^{th} maximum with wavelength λ_1 is at a distance d_1 and that with λ_2 is at a distance d_2. Then $\dfrac{d_1}{d_2}$ is

(a) $\dfrac{\lambda_1}{\lambda_2}$ (b) $\dfrac{\lambda_2}{\lambda_1}$

(c) $(\lambda_1 - \lambda_2)$ (d) λ_2^2/λ_1^2.

58. In a given Newton's rings set-up, the 10^{th} dark ring is viewed first by a sodium light and then by a laser beam with their wavelengths in the ratio 9 : 10. If the radius of the 10^{th} dark ring in sodium

light is 0.50 cm, its radius in the laser light is $\left(\text{Given } \frac{\lambda_s}{\lambda_l} = 0.9\right)$

(*a*) $\sqrt{\frac{0.50}{90}}$ cm (*b*) $\sqrt{\frac{0.90}{0.50}}$ cm

(*c*) $\frac{5}{\sqrt{90}}$ cm (*d*) 0.45 cm.

59. In the Newton's rings experiment, if the radius of curvature of the plano-convex lens is reduced to 75%, of its original value the radius of the dark ring is

(*a*) reduced to $\frac{\sqrt{3}}{2}$ of its original value

(*b*) increased to $\frac{\sqrt{3}}{2}$ of its original value

(*c*) remains unaltered

(*d*) reduced to one fifth of its original value.

60. Which one of the following is not electromagnetic in nature?

(*a*) *X*-rays (*b*) γ-rays

(*c*) visible rays (*d*) cathode rays.

61. A spectrum produced by an incandescent solid, liquid, or gas is always

(*a*) a continuous spectrum

(*b*) a line spectrum

(*c*) an absorption spectrum

(*d*) a band spectrum.

62. In Newton's rings experiment, if the air film is replaced by benzene, then

(*a*) the rings widen

(*b*) the rings shrink

(*c*) the rings disappear

(*d*) central dark ring disappears.

63. In an Air-wedge experiment if α is the angle of the wedge and l is the length of the wedge, then the thickness of the filament d is equal to

(*a*) $l \tan \alpha$ (*b*) $\dfrac{l}{\tan \alpha}$

(*c*) $\dfrac{\cos \alpha}{l}$ (*d*) $l \cos \alpha$.

64. In a single slit diffraction experiment the width of the single slit is double the original width. The size of the central band is

(*a*) reduced to half of its original value
(*b*) reduced to one third of its original value
(*c*) remains the same
(*d*) increased to half of its original value.

65. Two students are separated by a 7m partition wall of a room 8 m high. They converse easily though they are unable to see each other. This is because

(*a*) diffraction of sound by macroscopic obstacles
(*b*) diffraction of light by macroscopic obstacles
(*c*) transverse nature of light
(*d*) sound velocity is greater than that of light.

66. Ultrasonic waves from a transducer of frequency 1 MHz travelling through a binary mixture of water and dimethyl sulphoxide were reflected back by forming a grating. The diffraction pattern on a screen produced by rays from a sodium lamp through the grating gave a value of 0.042 cm as the distance between a node and the subsequent antinode. The

velocity of ultrasonic waves in the binary system is

(*a*) 180 m (*b*) 3×10^5 m

(*c*) 7060 m (*d*) 1680 m.

67. Fraunhofer lines observed in the solar spectrum are due to

(*a*) photosphere

(*b*) Corona

(*c*) ozone layer

(*d*) layer of cooler gases between photosphore and chromosphere.

68. In a Newton's rings set-up, the radii of the n^{th} and $(n + 10)^{th}$ dark rings are respectively $\sqrt{6}$ mm and 6 mm. The value of n is

(*a*) 2 (*b*) 5

(*c*) 6 (*d*) 15.

69. The dispersive power of a grating $\frac{d\theta}{d\lambda}$ for n^{th} order is

(*a*) $\frac{nN}{\cos\theta}$ (*b*) $\frac{\cos\theta}{nN\lambda}$

(*c*) $\frac{\sin\theta}{nN\lambda}$ (*d*) $\sin\theta$.

70. The plane glass plate in Newton's rings arrangement is replaced by a plane mirror. Which one of the following statements is true?

(*a*) the radii of the fringes decrease

(*b*) the radii of the fringes increase

(*c*) the radii remain same

(*d*) no rings are observed.

71. The condition for observing Fraunhofer diffraction due to single slit is that the wavefront incident on the slit should be

(*a*) elliptical (*b*) plane

(*c*) cylinderical (*d*) spherical.

72. The first diffraction minimum due to a single slit diffraction is at $\theta = 30°$ for light of wavelength 500 nm. The width of the slit is

(*a*) 100 nm (*b*) 10 nm
(*c*) 150 nm (*d*) 1000 nm.

73. Diffraction of sound is easy to observe in day-to-day life. This is not so with light wave, because

(*a*) $\lambda_s << \lambda_L$
(*b*) $\lambda_s >> \lambda_L$
(*c*) $\lambda_s = \lambda_L$
(*d*) sound waves are longitudinal and light waves are transverse.

74. To explain the rectilinear propagation of light and to calculate the intensity at a point due to the wavefront, Fresnel divided the wavefront into a number of zones and suggested that

(*a*) areas of the zones are equal
(*b*) areas of the zones are unequal
(*c*) areas of the zones depends upon natural numbers
(*d*) areas of the zones are independent of the wavelength.

75. *X*-rays are widely used as a diagnostic tool in medicine because of its

(*a*) particle property
(*b*) cost of *X*-ray unit is low
(*c*) high penetrating power
(*d*) it is not electromagnetic waves.

76. Ultrasonics are preferred instead of *X*-rays in medicine because

(*a*) intensity of ultrasonic waves is much less compared with *X*-rays
(*b*) *X*-rays are harmful because of great intensity

(*c*) ultrasonic equipments are cheaper compared with *X*-ray units
(*d*) all the above are true.

77. The transverse nature of light is established by
(*a*) refraction of light
(*b*) straight line propagation of light
(*c*) speed of light
(*d*) polarization of light.

78. If the optic axis of the calcite crystal is parallel to the y-axis and the direction of light ray is along the x-axis, then the vibrations of the particles due to the polarization of light will be in the
(*a*) y-z plane
(*b*) x-z plane
(*c*) x-y plane
(*d*) none of them is correct.

79. Plane polarized light is passed through a polaroid. When the polaroid is given one full rotation about the direction of propagation of light, one of the following is observed
(*a*) the intensity of light gradually increases to a maximum and remains at maximum.
(*b*) the intensity reaches maximum and zero alternately for every rotation by 90°
(*c*) the intensity of light gradually decreases to zero and remains at zero
(*d*) there is no change in intensity.

80. The plane of polarization and the plane of vibration are
(*a*) right angles to each other
(*b*) parallel to each other
(*c*) inclined at an angle of 45°
(*d*) inclined at an angle of 60°.

81. Polaroid glass is used in sun glasses because
    (*a*) it is cheaper
    (*b*) it increases the light intensity to one and a half times on account of polarization
    (*c*) it reduces the light intensity to half its value on account of polarization
    (*d*) it produces irritation in the eye.

82. A ray of light is incident on the surface of a crystal at the polarizing angle. If the angle of refraction is 20° on entering the crystal, the angle of polarization is
    (*a*) 70° (*b*) 50°
    (*c*) 95° (*d*) 25°.

83. A ray of light strikes a piece of glass at an angle of incidence θ and the reflected beam is completely polarized. If the refractive index of glass is $\sqrt{3}$, the angle of incidence is
    (*a*) 20° (*b*) 30°
    (*c*) 50° (*d*) 60°.

84. The operation of Michelson interferometer with sodium lamp makes 200 fringes cross the field of view when the movable mirror is pushed through 0.0589 mm. The wavelength of sodium lamp is
    (*a*) 5461 nm (*b*) 589 nm
    (*c*) 579 Å (*d*) 577 nm.

85. Light travelling in water of refractive index 1.33 is incident on a plate of glass of refractive index 1.53. At what angle of incidence is the reflected light completely linearly polarized?
    (*a*) 49° (*b*) 39°
    (*c*) 59° (*d*) 29°.

86. When a ray of ordinary unpolarized light is passed through a uniaxial crystal (say

calcite), it is split up into two rays namely ordinary and extraordinary ray. Which of the following statements is correct?

(*a*) Ordinary ray is circularly polarised
(*b*) Extraordinary ray obeys the law of refraction
(*c*) The ordinary ray obeys the law of refraction
(*d*) Both the rays obey the laws of refraction.

87. Two polaroids are crossed to each other initially. Now one of them is rotated through 60°. What percentage of incident unpolarized light will pass through the system?

(*a*) 16% (*b*) zero
(*c*) 2% (*d*) 37.5%.

88. For water the polarizing angle is 53°4′ and the refractive index is 1.330. When the light reflected on its surface is completely polarized, what is the angle of refraction of the ray inside water?

(*a*) 53.2° (*b*) 60.3°
(*c*) 20.1° (*d*) 36.9°.

89. Choose the correct statement

(*a*) Brewster's angle is independent of the wavelength of light
(*b*) the angle is independent of the nature of the reflecting surface
(*c*) Brewster's angle is different for different wavelengths
(*d*) all are true.

90. In Nicol prism the extra ordinary ray travels from an optically rarer medium to a denser medium, then

(*a*) it undergoes total internal reflection
(*b*) it is transmitted completely through the prism

(*c*) it is partly reflected and partly refracted

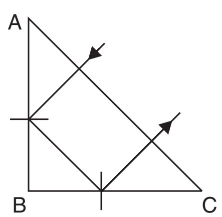
(*d*) it retraces the same path.

91. An eye-specialist prescribes a combination of convex lens of focal length 40 cm in contact with a concave lens of focal length 25 cm. The power of the combination in dioptre is

(*a*) + 6.67 (*b*) – 1.5

(*c*) + 2.5 (*d*) – 2.5.

92. A ray of light incident normally on the face *AB* of an isosceles right angled prism travels as shown in figure. The least value of the refractive index of the prism is



(*a*) $\sqrt{2}$ (*b*) $\sqrt{3}$

(*c*) 1.5 (*d*) 2.

93. In a Nicol prism which of the following statements is correct with respect to a monochromatic ray?

(*a*) extraordinary ray is polarized and ordinary ray is unpolarized

(*b*) ordinary ray is polarized and extraordinary ray is unpolarized

(*c*) both are polarized

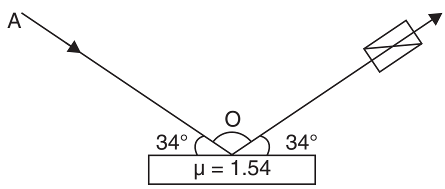
(*d*) all are false.

94. If light is polarized by reflection, then the angle between reflected and refracted ray is

(*a*) π (*b*) $\frac{\pi}{2}$

(*c*) 2π (*d*) $\frac{\pi}{4}$.

95. A beam of light AO is incident on a glass slab (μ = 1.54) in the direction shown in the figure. The reflected ray is passed through a Nicol prism. On rotating the Nicol prism one sees



(*a*) the intensity is reduces down to zero and remains zero

(*b*) the intensity reduces some what and rises again

(*c*) there is no change in intensity

(*d*) the intensity gradually reduces to zero and then again increases.

96. The electromagnetic wave used in telecommunication is of

(*a*) 1 MHz acoustical waves

(*b*) visible part of the electromagnetic spectrum

(*c*) γ-radiations

(*d*) microwave region.

97. Ozone layer is present

(*a*) 1 km above earth surface

(*b*) 1 km above the sea level

(*c*) ionosphere

(*d*) stratosphere.

98. A beam of light strikes a piece of glass at an angle of 60° and the reflected beam is completely polarized. The refractive index of glass is

(*a*) $\sqrt{2}$ (*b*) $\sqrt{3}$

(*c*) 2 (*d*) $\sqrt{6}$.

99. The amplitudes of electric field E and magnetic field B are related as

(*a*) $E = B$

(*b*) $\mu_0\varepsilon_0 E = B$

(*c*) $B = E\,(\sqrt{\mu_0\,\varepsilon_0}\,)$

(*d*) $E = B\,(\sqrt{\mu_0\,\varepsilon_0}\,)$.

100. Transmission of TV signals from the surface of the moon can be received on earth. But the signal from Delhi cannot be received beyond 100 km distance, the cause for this is

(*a*) there is no atmosphere on the moon

(*b*) there is atmosphere round the earth

(*c*) the curvature of the earth's surface not follow the curvature of the earth

(*d*) all are true.

101. The temperature of infrared radiation is calculated to be 3×10^9 K, the wavelength of the radiation is approximately

(*a*) 10^{12} m (*b*) 10^{-12} m

(*c*) 10 nm (*d*) 1 nm.

102. In Raman effect if the wavelength of the scattered photon is greater than the incident photon, then the energy of the scattered photon is

(*a*) less than the incident photon

(*b*) higher than the incident photon

(*c*) equal in magnitude

(*d*) all are true.

103. The difference in wavelengths of the two lines of sodium vapour lamp is approximately

(*a*) 20 nm (*b*) 66.6 nm

(*c*) 0.60 nm (*d*) 600 Å.

104. The ratio of the number of excited atoms (n^*) to that in the ground state (n) of an atom is given by

(*a*) $\dfrac{n^*}{n} = \exp(E/kT)$

(*b*) $\dfrac{n^*}{n} = \exp(-E/kT)$

(*c*) $\dfrac{n^*}{n} = \dfrac{E}{kT}$

(*d*) $\dfrac{n^*}{n} = \dfrac{kT}{E}$

where E is the energy difference between the ground state and the excited state k is Boltzmann's constant.

105. In Rayleigh scattering the scattered light has the same frequency as that of incident light while in Raman effect there is a frequency difference. This is

(*a*) true (*b*) false

106. With an exciting radiation a substance showed a Raman line at a wavelength of 300 nm. The frequency of Raman line is

(*a*) 10^{15} Hz (*b*) 10^{10} Hz

(*c*) 10^{-2} Hz (*d*) 1 MHz.

107. As the quantum number increases the difference of energy between consecutive energy levels

(*a*) increases (*b*) decreases

(*b*) remains constant(*d*) all are true.

108. Which of the double ionised lithium (Li^{++}) ion has the same energy as that of ground state energy of hydrogen atom

(*a*) $n = 4$ (*b*) $n = 2$

(*c*) $n = 3$ (*d*) $n = 1$.

109. Which of the following gives discrete emission spectrum?

(*a*) incandescent electric lamp
(*b*) mercury vapour lamp
(*c*) candle flame
(*d*) sunlight.

110. The scattering of light by colloidal particles is called
(*a*) Zeeman effect (*b*) Raman effect
(*c*) Stark effect (*d*) Tyndal effect.

111. In Ruby laser population inversion is achieved by
(*a*) aluminium oxide
(*b*) chromium flash lamp
(*c*) discharge tube
(*d*) chromium ions.

112. In Raman effect, an incident photon gives part of its energy to the atoms or molecules in a liquid and gets scattered. The scattered photon causes the spectral line of
(*a*) greater wavelength called antistoke's lines
(*b*) greater wavelength called Stoke's lines
(*c*) lesser wavelength called Stoke's lines
(*d*) all are true.

113. If a star moves away from the earth, the spectral line of the star
(*a*) shifts toward the red end of the spectrum
(*b*) shifts toward the violet end of the spectrum
(*c*) does not shift
(*d*) disappears.

114. Which of the following is untrue?
(*a*) stimulated emission is important in laser

(*b*) laser is used in the process called holography

(*c*) laser light is coherent, monochromatic, divergent and extremely intense

(*d*) they produce spectral lines.

115. The study of the wavelengths of Fraunhofer lines indicates the presence of hydrogen and helium in the sun. This statement is

(*a*) true (*b*) false.

116. No two electrons in the same atom can have the same values of the four quantum numbers n, l, m_1, m_s. This principle is called

(*a*) Bohr's correspondence principle

(*b*) Pauli's exclusion principle

(*c*) Bohr's assumptions of hydrogen atom

(*d*) None of these.

117. Zeeman effect is a magneto-optical phenomenon. This is

(*a*) true (*b*) false.

118. The splitting of spectral lines due to the application of an electric field is called

(*a*) Zeeman effect (*b*) magneto striction

(*c*) Stark effect

(*d*) thermo-electric effect.

119. The refractive indices for ordinary and extraordinary rays 1.54 and 1.55 respectively. The wavelength of light used is 589.6 nm. The thickness of the quarter wave plate is

(*a*) 1 Å (*b*) 2.2 nm

(*c*) 1.474×10^{-5} m (*d*) 1.68×10^{-8} m.

120. When low flying aircraft passes overhead we sometimes notice a slight shaking of the picture on our TV screen. This is due to

(*a*) diffraction of sound waves.
(*b*) interference of direct TV signal received by the antenna with weak signal produced by the passing of the aircraft
(*c*) polarization of radio waves
(*d*) interference of acoustical and optical waves.

121. For normal incidence of a ray of light
(*a*) $\angle i = 90°, \angle r = 0°$
(*b*) $\angle i = 0°, \angle r = 90°$
(*c*) $\angle i = 0°, \angle r = 0°$
(*d*) $\angle i = 90°, \angle r = 90°$.

122. The wavelength range of visible spectrum is
(*a*) 400 nm to 1000 nm
(*b*) 180 nm to 400 nm
(*c*) 400 nm to 650 nm
(*d*) 10 nm to 100 nm.

123. An air bubble in water in a glass shines well because of
(*a*) dispersion of light
(*b*) reflection of light
(*c*) refraction of light
(*d*) total internal reflection.

124. The solar spectrum is a
(*a*) band spectrum
(*b*) line spectrum
(*c*) continuous spectrum
(*d*) spectrum of dark and bright lens.

125. A girl is standing 7m from a plane mirror. The distance of the girl from her image in the mirror is
(*a*) 3.5 m (*b*) 7 m
(*c*) 10.5 m (*d*) 14 m.

126. Light wave can travel through vacuum but not sound waves because

(*a*) Light waves show particle nature
(*b*) They show wave nature
(*c*) They are longitudinal
(*d*) They are transverse.

127. One of the rays in the Nicol prism is eliminated by
(*a*) total internal refraction
(*b*) reflection
(*c*) absorption
(*d*) refraction.

128. The velocity of electromagnetic wave is
(*a*) $\mu_0\varepsilon_0$ (*b*) $\frac{1}{\mu_0\varepsilon_0}$
(*c*) $\sqrt{\mu_0\varepsilon_0}$ (*d*) $\frac{1}{\sqrt{\mu_0\varepsilon_0}}$.

129. The wavelength of *X*-rays varies from
(*a*) 0.01 nm to 10 nm
(*b*) 0.01 nm to 100 nm
(*c*) 0.01 nm to 1000 nm
(*d*) 0.01 nm to 10000 nm.

130. Velocity of light in a transparent medium is $\frac{2}{3}$ of the velocity of light in air. The refractive of the medium is
(*a*) 1.9 (*b*) 1.1
(*c*) 1.5 (*d*) 0.12.

131. Ionosphere is composed of
(*a*) ozone gas
(*b*) carbon dioxide
(*c*) hydrogen
(*d*) electron and positive ions.

132. Why does sound waves travel faster on a rainy day?
(*a*) air becomes more dry
(*b*) the speed is independent of pressure
(*c*) density of moisture is less than that of dry air

(*d*) density of moisture is much greater than that of dry air.

133. Time taken by sunlight to pass through a window of thickness 4 mm whose refractive index is $\frac{3}{2}$ is

(*a*) 2×10^{-4} sec (*b*) 2×10^{4} sec
(*c*) 2×10^{-11} sec (*d*) 2×10^{-20} sec.

134. A double slit interference experiment is carried out in air and later the entire arrangement is immersed in benzene. The fringe width

(*a*) decreases
(*b*) increases
(*c*) no change
(*d*) fringe system disappears.

135. The source of energy for the sun to radiate is due to

(*a*) fission
(*b*) fusion
(*c*) thermo-electric effect
(*d*) photoelectric effect.

136. The diameter of the dark Newton's rings are

(*a*) proportional to the square root of odd numbers
(*b*) proportional to the square of odd numbers
(*c*) inversely proportional to the natural numbers
(*d*) independent of these things.

137. Among the following the shorter wavelength is for

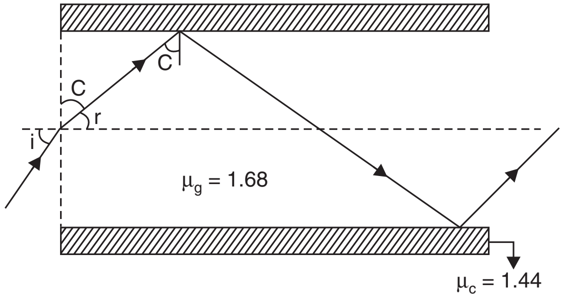
(*a*) *X*-rays (*b*) de Broglie
(*c*) γ-rays (*d*) sound wave.

138. The series limit of Balmer series is 364 nm. The wavelength of the first member of the series is

(*a*) 652.2 nm (*b*) 100 Å
(*c*) 2002 nm (*d*) 760 nm.

PROBLEMS AND SOLUTIONS

1. *The figure shows a cross-section of a 'light-pipe' made of a glass fibre of refractive index 1.68. The outer covering of the pipe is made up of a material of refractive index 1.44. What is the range of the angles of the incident rays with the axis of the pipe for which total internal reflections inside the pipe take place as shown in the figure?*



Solution:

$$ {}_1\mu_2 = \frac{1}{\sin C}; \quad \text{or} \quad \frac{\mu_2}{\mu_1} = \frac{1}{\sin C} $$

$$ \sin C = \frac{\mu_1}{\mu_2} = \frac{1.44}{1.68} = 0.8571 $$

$$ C = 59°, \quad r = 90° - 59° = 31° $$

Total internal reflection takes place if the angle of incidence is greater than $C = 59°$ *i.e.*, $r < 31°$

Now $\mu_2 = \dfrac{\sin i}{\sin r} = \dfrac{\sin i}{\sin 31°}$

or $\sin i = \mu_2 \times \sin 31° = 1.68 \times \sin 31°$

$i = 60°$

Thus all rays incident on the pipe between $i > 0°$ and $60°$ will suffer total internal reflection is the pipe.

2. *A crown glass prism of 12° is to be combined with a flint glass prism to form an achromatic combination. Find the angle of flint glass prism.*

		Crown	*Flint*
Refractive index	*Red*	*1.514*	*1.622*
	Blue	*1.523*	*1.638*

Solution:

For achromatic combination the dispersion produced by the two prisms must be equal and opposite

$$A = 12°; \quad \mu_b = 1.523;$$

$$n_r = 1.514$$

$$\mu_b' = 1.638, n_r' = 1.622$$

$$(n_b - n_r) A = (n_b' - n_r') A'$$

$$(1.523 - 1.514)\ 12 = (1.638 - 1.622) A'$$

$$A' = 6°\ 45'.$$

3. *A man with normal near point (25 cm) reads a book using a magnifying glass of focal length 5 cm.*
   (a) What are closest and farthest distances at which he can read the book when viewing through the magnifying glass?
   (b) What is the maximum and minimum angular magnification (magnifying points of the simple microscope)?

Solution:

(*a*) $u = ?$, $v = -25$ cm, $f = 5$ cm

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \quad \text{or} \quad \frac{1}{u} = \frac{1}{v} - \frac{1}{f}$$

$$= -\frac{1}{25} - \frac{1}{5} = \frac{-1-5}{25}$$

$$\frac{1}{u} = -\frac{6}{25}$$

$$\boxed{u = -4.2 \text{ cm}}$$ **Ans.**

This is the closest distance he can read the book. For farthest distances

$$u' = ? \quad v' = \infty, f = 5 \text{ cm}$$

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}; \quad \frac{1}{\infty} - \frac{1}{u'} = \frac{1}{f}$$

$$\boxed{u' = f = -5 \text{ cm}}$$ **Ans.**

This is the farthest distance.

(*b*) Maximum angular magnification $= \dfrac{D}{u}$

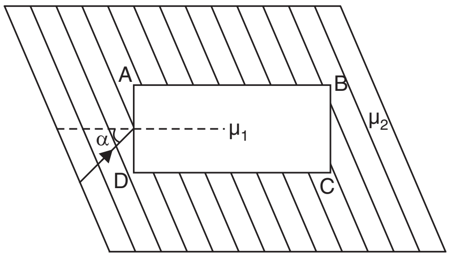
$$\boxed{= \frac{25}{25/6} = 6}$$ **Ans.**

minimum angular magnification

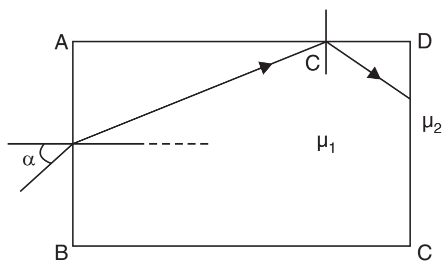
$$\boxed{= \frac{D}{u'} = \frac{25}{5} = 5}$$ **Ans.**

4. *A rectangular glass slab ABCD of refractive index* μ_1 *is immersed in water of refractive index* μ_2 *with* $\mu_1 > \mu_2$.
A ray of light is incident at the surface AB of the slab as shown in the figure. The maximum value of the angle of incidence α *such that the ray comes out only from the other surface CD is given by*

$$\alpha = sin^{-1}\left[\frac{\mu_1}{\mu_2} cos\left\{sin - \left(\frac{\mu_2}{\mu_1}\right)\right\}\right]$$



Solution:



The ray will come out from *CD* if it suffers total internal reflection at surface *AD* *i.e.*, it strikes the surface *AD* at critical angle *C*

Now $\mu_1 \sin C = \mu_2$

$\sin C = (\mu_2/\mu_1)$

Further, $\mu_2 \sin \alpha = \mu_1 \cos C$

$$\sin \alpha = \frac{\mu_1}{\mu_2} \cos \left\{\sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)\right\}$$

$$\alpha = \sin^{-1}\left[\frac{\mu_1}{\mu_2} \cos \left\{\sin^{-1}\left(\frac{\mu_2}{\mu_1}\right)\right\}\right]$$

5. The wavelength of light coming from a distant galaxy is found to be 0.5% more than that coming from a source on earth. Calculate the velocity of light source.

Solution:

In doppler effect in light, the wavelength displacement is

$$\Delta\lambda = \frac{v}{c}\lambda$$

where v is the velocity of light source. If the wavelength of light coming from source at earth is λ and λ' of the light coming from galaxy, then

$$\lambda' = \lambda(1 + 0.005) = 1.005\,\lambda$$

$$\frac{\lambda'}{\lambda} = 1.005$$

$$\frac{\Delta\lambda}{\lambda} = \frac{(\lambda' - \lambda)}{\lambda} = 0.005 \qquad ...(1)$$

Equation (1) becomes

$$0.005 = \frac{v}{c} \quad \text{or} \quad v = 0.005 \times c$$

$$v = 1.5 \times 10^6 \text{ m/s}$$

This is the velocity of galaxy. As the wavelength is increased, the galaxy is going away from the earth.

6. *A glass prism of refractive index 1.66 and angle of prism 72° is placed in a liquid of refractive index 1.33. Get the angle of minimum deviation.*

Solution:

$$\mu = {}_l\mu_g = \frac{\mu_g}{\mu_l} = \frac{1.66}{1.33} = 1.248$$

$$\mu = 1.248 = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\frac{A}{2}}$$

$$= \frac{\sin\left(\frac{A+D}{2}\right)}{\sin 36°}$$

$$\sin\left(\frac{A+D}{2}\right) = 1.248\ \lambda \sin 36°$$

$$= 0.733$$

$$\frac{A+D}{2} = 47.2°$$

$$36 + \frac{D}{2} = 47.2$$

$$\frac{D}{2} = 11.2$$

$$\boxed{D = 22.4°}$$ **Ans.**

7. *Two lamps of luminous intensity 4 and 16 cd are 2 metre apart. At which point between them the illuminations due to either one is the same.*

Solution:

$$\frac{I_1}{r_1^2} = \frac{I_2}{r_2^2}$$

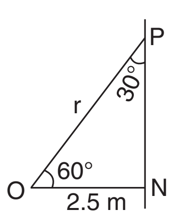
$$\frac{I_1}{x^2} = \frac{I_2}{(2-x)^2}; \quad \frac{4}{x^2} = \frac{16}{(2-x)^2}$$

or $$\frac{2}{x} = \frac{4}{(2-x)}; \quad 4x = 4 - 2x$$

$$6x = 4$$

$$\boxed{x = \frac{4}{6} = 0.667 \text{ m}}$$ **Ans.**

8. *A source of 100 cd is placed at a distance of 2.5 m from a wall. What is the illumination on the wall if it makes an angle 30° with the incident ray?*



Solution:

$$\cos 60° = \frac{2.5}{OP}$$

$$OP = \frac{2.5}{\cos 60°} = 5 \text{ m}$$

$$E = \frac{I \cos 60°}{r^2} = \frac{100 \times 0.5}{25}$$

$$\boxed{E = 2 \text{ lumen}}$$ **Ans.**

9. *A T.V. tower has a height of 100 m. How much population is covered by a T.V. broadcast if the average population density around the tower is 1000/km^2. Radius of earth is 6.37 × 10^6 m.*

Solution:

Distance up to which the broadcast covered is

$$d = \sqrt{2\,Rh}$$

$$= \sqrt{2 \times 6 \times 10^6 \times 100} = 3.5 \times 10^4 \text{ m.}$$

Area that can be covered,

$$\pi d^2 = 3.14 \times 3.5^2 \times 10^8 \text{ m}^2$$

Population density, $\rho = \dfrac{1000}{10^6} = 10^{-3} \text{ m}^2$

Population covered is

$$3.14 \times 3.5^2 \times 10^8 \times 10^{-3}$$

$$\boxed{P = 4 \times 10^6}$$ **Ans.**

10. *Two coherent sources whose intensity ratio is 81:1 produce interference fringes. Find the ratio of maximum intensity and minimum intensity.*

Solution:

$$I_{max} = (a_1 + a_2)^2 \text{ and } I_{min} = (a_1 - a_2)^2$$

$$\frac{I_{max}}{I_{min}} = \left[\frac{(a_1 + a_2)}{(a_1 - a_2)}\right]^2$$

$$\frac{I_1}{I_2} = \frac{{a_1}^2}{{a_2}^2} = \frac{81}{1} \quad \text{or} \quad \frac{a_1}{a_2} = 9;$$

i.e., $a_1 = 9a_2$

Thus

$$\frac{I_{max}}{I_{min}} = \left[\frac{9a_2 + a_2}{9a_2 - a_2}\right]^2$$

$$= \left(\frac{10}{8}\right)^2 = \frac{25}{16} = 1.56$$

$$\boxed{I_{max} = 1.56\, I_{min}}$$ **Ans.**

11. *Energy levels A, B and C of a certain atom corresponds to increasing energy value i.e., E_A, E_B and E_C. If λ_1, λ_2, λ_3 are the wavelengths corresponding to transition from C to A, C to B and B to A respectively, calculate the relation between λ_1, λ_2 and λ_3.*

Solution:

$$E_C - E_A = \frac{ch}{\lambda_1} \quad \text{and} \quad E_C - E_B = \frac{ch}{\lambda_2}$$

and $E_B - E_A = \dfrac{ch}{\lambda_3}$

$$(E_C - E_A) - (E_C - E_B) = ch\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

$$(E_B - E_A) = ch\left(\frac{\lambda_2 - \lambda_1}{\lambda_1\lambda_2}\right)$$

$$\boxed{\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_2 - \lambda_1}}$$ **Ans.**

12. *The angle of prism is thrice the angle of minimum deviation. Get the refractive index of the material of the prism if the angle of prism is 60°.*

Solution:

$$A = 60°, D = 20°$$

$$\frac{A+D}{2} = 40°$$

$$\mu = \frac{\sin\left(\frac{A+D}{2}\right)}{\sin\frac{A}{2}} = \frac{\sin 40°}{\sin 30°} = \frac{0.643}{0.5}$$

$$\boxed{\mu = 1.286} \quad \textbf{Ans.}$$

13. *A convex lens of total focal length f is placed in between a real object and a screen. The distance between the object and the screen is x. If the numerical value of magnification produced by the lens is m, obtain the equation for the focal length.*

Solution:

$$u + v = x \quad \text{and} \quad m = \frac{v}{u}$$

$$u + mu = x; \; u(m + 1) = x$$

Thus $\quad u = \dfrac{x}{(m+1)}$

and $\quad v = mu = \dfrac{mx}{(m+1)}$

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v} = \frac{u+v}{uv}$$

$$f = \frac{uv}{u+v} = \frac{mx^2}{(m+1)^2}\left(\frac{1}{x}\right)$$

$$\boxed{f = \frac{mx}{m+1}} \quad \textbf{Ans.}$$

14. *In Young's double slit experiment, the fringe width obtained is 0.6 cm when a source of light of wavelength 500 nm is used. If the distance between the screen and the slits is reduced to half, what will be the fringe width?*

Solution:

$$\beta = \frac{D}{d}\,\lambda$$

Since, λ and d are the same in both the cases

$$\beta \propto D$$

$$\frac{\beta_1}{\beta_2} = \frac{D_1}{D_2}; \quad \beta_2 = \frac{\beta_2 D_2}{D_1}$$

Let $D_1 = x$ and hence $D_2 = \dfrac{x}{2}$

$$\beta_1 = 0.6 \text{ cm}$$

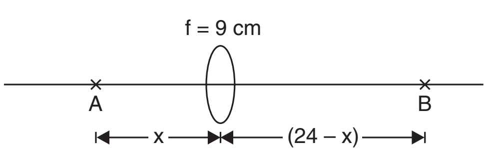
Thus $$\beta_2 = \frac{0.6 \times x}{2 \times x} = 0.3 \text{ cm}$$

$$\boxed{\beta_2 = 0.3 \text{ cm}}$$ **Ans.**

15. *The distance between two point sources of light is 24 cm. Find out where would you place a converging lens of focal length 9 cm, so that the images of both sources are formed at the same point.*

Solution:

Obviously, the problem indicates that the real image of one source coincides in position with the virtual image of the other point source.



Here sources B gives a real image at distance y to the left of the lens, also the source A gives a virtual image at distance y to the left of the lens.

Hence numerically,

$$\frac{1}{(24-x)} + \frac{1}{y} = \frac{1}{9} \quad ...(1)$$

Also $$\left(\frac{1}{x} - \frac{1}{y}\right) = \frac{1}{9} \quad ...(2)$$

Simplifying Eqns. (1) and (2), one gets

$$\frac{1}{(24-x)} + \frac{1}{x} = \frac{1}{9} + \frac{1}{9}$$

$$\frac{x + 24 - x}{x\,(24-x)} = \frac{2}{9}$$

$$\frac{12}{24x - x^2} = \frac{1}{9}$$

$$24x - x^2 = 108$$

$$x^2 - 24x + 108 = 0$$

$$x = \frac{24 \pm \sqrt{576 - 432}}{2}$$

$$\boxed{= 18 \text{ or } 6 \text{ cm}}$$ **Ans.**

Hence the lens should be placed between the two sources of light so that it is at distance 6 cm from one source and at 18 cm from the other.

16. *The central fringe of interference produced by light of wavelength 600 nm is shifted to a position of the 5th bright fringe by introducing a thin glass plate of refraction index 1.5. Get the thickness of the plate.*

Solution:

Shift $\quad x = \dfrac{D}{d}(\mu - 1)t = n\beta = \dfrac{n\,D\lambda}{d}$

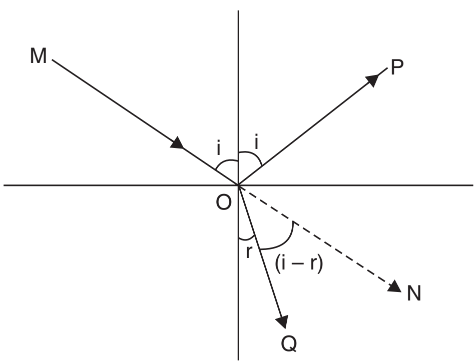
$(\mu - 1)\,t = n\lambda$

i.e., $\quad (1.5 - 1)\,t = 0.5\,t = 5 \times 600 \times 10^{-9}$

$$\boxed{t = 6 \times 10^{-4}\ \text{m}} \quad \textbf{Ans.}$$

17. *Ordinary light is incident on a glass slab at the polarizing angle. It suffers a deviation of 22°. Calculate the value of angle of refraction in glass.*

Solution:



$\angle NOQ = i - r = 22°$

with $\quad i + r = 90°$

$2r = 90° - 22° = 68°$

$$\boxed{r = 34°} \quad \textbf{Ans.}$$

18. *In a Newton's rings arrangement with air film observed with light of wavelength 6×10^{-5} cm, the difference of squares of diameters of successive rings are 0.125 cm^2. What will happen to this quantity if*

(*i*) *wavelength of light is changed 4.5×10^{-5} cm* (*ii*) *A liquid of refractive index 1.33 is introduced between the lens and the plate*

(*iii*) *The radius of curvature of the convex surface of the planoconvex lens is doubled.*

Solution:

If D_n and D_{n+p} are the diameters of the nth and $(n + p)$th rings, we have

$$(D_{n+p}^2 - D_n{}^2) = \frac{4p\,\lambda R}{\mu}$$

Here $p = 1$

Hence $(D_{n+1}^2 - D_n{}^2) = \dfrac{4\lambda R}{\mu}$ ...(1)

(*i*) When the wavelength of light is changed from λ to λ_1, we have

$$(D_{n+1}^2 - D_n^2)_{\lambda_1} = \frac{4\lambda_1 R}{\mu} \quad \text{...(2)}$$

Dividing (2) by (1), we get

$$\frac{(D_{n+1}^2 - D_n^2)_{\lambda_1}}{(D_{n+1}^2 - D_n^2)} = \frac{\lambda_1}{\lambda}$$

or $$(D_{n+1}^2 - D_n^2)_{\lambda_1} = \frac{\lambda_1 (D_{n+1}^2 - D_n{}^2)}{\lambda}$$

Here $\lambda_1 = 4.5 \times 10^{-5}$ cm, $\lambda = 6 \times 10^{-5}$ cm

and $\boxed{(D_{n+1}^2 - D_n{}^2) = 0.125 \text{ cm}^2}$ **Ans.**

(*ii*) When a liquid of refractive index μ_1 is introduced between the lens and the plate, we have

$$(D_{n+1}^2 - D_n{}^2)_{\mu_1} = \frac{4\lambda R}{\mu_1} \quad \text{...(3)}$$

Dividing (3) by (1),

$$\frac{(D_{n+1}^2 - D_n^2)_{\mu_1}}{(D_{n+1}^2 - D_n^2)} = \frac{\mu}{\mu_1}$$

$$(D_{n+1}^2 - D_n^2) = \frac{\mu}{\mu_1}\ (D_{n+1}^2 - D_n^2)$$

Here $\mu = 1,\ \mu_1 = 1.33$

and $(D_{n+1}^2 - D_n^2) = 0.125$

Hence $(D_{n+1}^2 - D_n^2)_{\mu_1} = \dfrac{\mu}{\mu_1}\ (D_{n+1}^2 - D_n^2)$

$$= \frac{1 \times 0.125}{1.33}$$

$$\boxed{\left(D_{n+1}^2 - D_n^2\right)_{\mu_1} = 0.094\ \text{cm}^2}$$ **Ans.**

(*iii*) When the radius of the convex surface is changed to R_1, we have

$$\left(D_{n+1}^2 - D_n^2\right)_{R_1} = \frac{4\,\lambda\, R_1}{\mu} \qquad ...(4)$$

Divide (4) by (1)

$$\frac{\left(D_{n+1}^2 - D_n^2\right)_{R_1}}{\left(D_{n+1}^2 - D_n^2\right)} = \frac{R_1}{R}$$

$$\left(D_{n+1}^2 - D_n^2\right)_{R_1} = \frac{R_1}{R} \times \left(D_{n+1}^2 - D_n^2\right)$$

$$\left(D_{n+1}^2 - D_n^2\right)_{2R} = \frac{2R}{R} \times 0.125$$

$$= 0.250\ \text{cm}^2$$

$$(D_{n+1}^2 - D_n^2)_{2R} = 0.250\ \text{cm}^2$$

19. *Monochromatic light of wavelength 590 nm is incident normally on a diffraction grating having N lines per cm. If the angle of diffraction for second order is 30° calculate the grating element.*

Solution:

$$\sin\theta = nN\lambda$$

$$N = \frac{\sin\theta}{n\lambda} = \frac{\sin 30^\circ}{2\times 590\times 10^{-9}}$$

$$= \frac{4.2\times 10^{-4}}{10^{-9}}\ \text{m}$$

$$N = 4.2 \times 10^{5}\ \text{metre}$$

$$(a + b) = \frac{1}{N} = 0.23 \times 10^{-5}\ \text{m}$$

$$\boxed{(a + b) = 0.23 \times 10^{-5}\ \text{m}}$$ **Ans.**

20. *Using sodium light (λ = 589.3 nm) interference fringe are formed from a thin air wedge. When received normally 10 fringes are observed in a distance of 1 cm. Calculate the angle of the wedge.*

Solution:

If θ is the angle of wedge, refractive index μ and β is the fringe width, then

$$\beta = \frac{\lambda}{2\mu\theta}$$

$$\theta = \frac{\lambda}{2\mu\beta}$$

$$\text{Fringe width, } \beta = \frac{1}{10} = 0.1\ \text{cm}$$

$$\theta = \frac{589.3\times 10^{-9}}{2\times 1\times 0.1}$$

$$\boxed{\theta = 2.946 \times 10^{-4}\ \text{radian}}$$ **Ans.**

21. *If the diameter of the nth dark ring in an arrangement giving Newton's rings changes from 0.30 cm to 0.25 cm as a liquid is introduced between the lens and the plate calculate the refractive index of the liquid.*

Solution:

$$(D_n^2)_{\text{liquid}} = \frac{4n\lambda R}{\mu}$$

In the absence of the liquid

$$(D_n^2)_{\text{air}} = 4n\lambda R$$

$$\frac{(D_n^2)_{\text{air}}}{(D_n^2)_{\text{liquid}}} = \mu = \left[\frac{0.30}{0.25}\right]^2$$

$$\boxed{\mu = 1.44} \quad \textbf{Ans.}$$

22. *At a certain temperature the critical angle of incidence of water for total internal reflection is 48° for a certain wavelength. What is the polarising angle and the angle of refraction of light incident on the water surface at an angle that gives maximum polarization of the reflected light.*

Solution:

The refractive index μ and the critical angle C are related by

$$\mu = \frac{1}{\sin C} = \frac{1}{\sin 48°}$$

or $\mu = 1.345$

For maximum polarization, the light, must be incident at polarizing angle from Brewster's law we have $\mu = \tan i_p$

Therefore polarizing angle,

$$i_p = \tan^{-1}(\mu) = \tan^{-1}(1.345)$$

$$i_p = 53°22'$$

If r is the angle of refraction we have

$$i_p + r = 90°$$

$$r = 90° - i_p$$

$$= 90° - 53°\ 22' = 36°38'$$

$$\boxed{r = 36°\ 38'} \quad \textbf{Ans.}$$

23. *Calculate the velocities of ordinary and extraordinary rays in calcite in a plane perpendicular to the optic axis. Given* $\mu_O = 1.658$ *and* $\mu_E = 1.486$.

Solution:

Velocity of ordinary ray, $v_o = \dfrac{c}{\mu_o}$

i.e., $v_o = \dfrac{3 \times 10^{10}}{1.658} = 1.809 \times 10^{10}$ cm/s

Velocity of extraordinary ray,

$$v_E = \frac{c}{\mu_E} = \frac{3 \times 10^{10}}{1.486} = 2.018 \times 10^{10} \text{ cm/s}$$

$$v_o = 1.81 \times 10^{10} \text{ m/s}$$

$\boxed{v_E = 2.02 \times 10^8 \text{ m/s}}$ **Ans.**

24. *Calculate the thickness of a quarter wave plate for sodium light of wavelength 589.3 nm. The refractive index of quartz for E-ray and O-ray are 1.5533 and 1.5442 respectively.*

Solution:

$$t = \frac{\lambda}{4(\mu_E - \mu_O)}$$

$$= \frac{589.3 \times 10^{-9} \times 100}{4(1.5533 - 1.5422)}$$

$\boxed{t = 1.62 \times 10^{-3} \text{ cm}}$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*d*)	2. (*b*)	3. (*a*)	4. (*a*)
5. (*c*)	6. (*a*)	7. (*d*)	8. (*d*)
9. (*a*)	10. (*d*)	11. (*b*)	12. (*c*)
13. (*a*)	14. (*c*)	15. (*d*)	16. (*c*)

17. (*d*)	18. (*c*)	19. (*b*)	20. (*d*)
21. (*d*)	22. (*a*)	23. (*c*)	24. (*b*)
25. (*b*)	26. (*d*)	27. (*d*)	28. (*d*)
29. (*a*)	30. (*b*)	31. (*c*)	32. (*b*)
33. (*c*)	34. (*c*)	35. (*b*)	36. (*a*)
37. (*a*)	38. (*d*)	39. (*d*)	40. (*b*)
41. (*c*)	42. (*a*)	43. (*a*)	44. (*c*)
45. (*c*)	46. (*d*)	47. (*d*)	48. (*b*)
49. (*d*)	50. (*c*)	51. (*a*)	52. (*d*)
53. (*d*)	54. (*d*)	55. (*b*)	56. (*d*)
57. (*a*)	58. (*c*)	59. (*a*)	60. (*d*)
61. (*a*)	62. (*b*)	63. (*a*)	64. (*a*)
65. (*a*)	66. (*d*)	67. (*d*)	68. (*a*)
69. (*a*)	70. (*d*)	71. (*b*)	72. (*d*)
73. (*b*)	74. (*a*)	75. (*c*)	76. (*d*)
77. (*d*)	78. (*c*)	79. (*b*)	80. (*a*)
81. (*c*)	82. (*a*)	83. (*d*)	84. (*b*)
85. (*a*)	86. (*c*)	87. (*d*)	88. (*d*)
89. (*c*)	90. (*b*)	91. (*b*)	92. (*a*)
93. (*c*)	94. (*b*)	95. (*d*)	96. (*d*)
97. (*c*)	98. (*b*)	99. (*d*)	100. (*c*)
101. (*b*)	102. (*a*)	103. (*c*)	104. (*b*)
105. (*a*)	106. (*a*)	107. (*b*)	108. (*b*)
109. (*b*)	110. (*d*)	111. (*d*)	112. (*b*)
113. (*a*)	114. (*c*)	115. (*a*)	116. (*b*)
117. (*a*)	118. (*c*)	119. (*c*)	120. (*b*)
121. (*c*)	122. (*c*)	123. (*d*)	124. (*a*)
125. (*d*)	126. (*d*)	127. (*a*)	128. (*d*)
129. (*b*)	130. (*c*)	131. (*d*)	132. (*c*)
133. (*c*)	134. (*a*)	135. (*b*)	136. (*a*)
137. (*c*)	138. (*a*).		

CHAPTER 4

MAGNETISM

1. If μ_r is the relative permeability of the medium, then the force of interaction between two magnetic poles m_1 and m_2 is

   (*a*) $10^{-7} \times \dfrac{\mu_r m_1 m_2}{d^2}$ newton

   (*b*) $4\pi \times 10^{-7} \times \dfrac{m_1 m_2}{d^2}$ newton

   (*c*) $\dfrac{\mu_r}{4\pi} \times \dfrac{m_1 m_2}{d^2}$ newton

   (*d*) $\mu_0 \dfrac{m_1 \times m_2}{d^2}$ newton.

2. The moment of a barmagnet of semi length 2 cm is 2×10^{-6} weber-metre; the pole strength is

   (*a*) 2×10^{-4} weber

   (*b*) 10^{-4} weber/metre

   (*c*) 0.5×10^{-4} weber

   (*d*) 0.75×10^{-4} weber.

3. The magnetic field due to a short magnet at a point d from its centre and making an angle θ with the axis of the magnet is

   (*a*) $\dfrac{\mu_0 m}{4\pi d^3}(1 + \cos^2 \theta)^{1/2}$

   (*b*) $\dfrac{m}{4\pi d^3} \cos^2 \theta$

(*c*) $\frac{\mu_0}{4\pi}(1 + \cos\theta)$

(*d*) $4\pi m\ (1 - \cos\theta)$.

4. Heating or rough handling will disturb the arrangement of molecular magnets and hence the strength is reduced. This statement is

(*a*) true (*b*) false.

5. When a magnet is broken, each piece becomes a complete magnet because

(*a*) the number of electrons in one piece are different from that of the other

(*b*) each piece becomes a complete magnet since molecular magnets cannot be broken

(*c*) the density of atoms in the pieces are different

(*d*) none of these.

6. If p is the magnetic moment of a bar magnet in a magnetic field, than maximum value of the torque is

(*a*) $pB \cos\theta$ (*b*) $p \cos\theta$

(*c*) 180° (*d*) pB.

7. The magnetic susceptibility of a material is 999. If this material is placed in a magnetic field of 1000 A/m, the value of the magnetic induction is

(*a*) π (*b*) 0.4π

(*c*) 4π (*d*) 9π.

8. Since the induced magnetic moments in a diamagnetic substance in a magnetic field oppose the applied field, the diamagnetic susceptibility is

(*a*) negative

(*b*) small positive value

(*c*) zero

(*d*) large positive value.

9. The magnetic field at any point on the axial line of a short magnet is
   (*a*) equal to the magnetic field at an equidistant point on its equatorial line
   (*b*) twice the magnetic field at an equidistant point on its equatorial line
   (*c*) zero
   (*d*) half the magnetic field at an equidistant point on its equatorial line.

10. B is the total intensity of the earth's magnetic field and θ is the angle of dip. Let B_H be the horizontal intensity and B_V the vertical intensity of the earth's magnetic field. Then
    (*a*) $\tan\theta = \dfrac{B_H}{B_V}$ and $B^2 = 1$
    (*b*) $\tan\theta = \dfrac{B_H}{B_V}$ and $B^2 = 0$
    (*c*) $\tan\theta = \dfrac{B_V}{B_H}$ and $B^2 = B_H^2 + B_V^2$
    (*d*) $\tan\theta = B_V B_H$ and $B^2 = 0$.

11. If m, e, r, v and ν be the mass, charge, radius, velocity and frequency of an electron in an orbit, then the magnetic moment of the current loop and the smallest magnitude of the magnetic moment with electron orbital motion are (where A is the area of the loop)
    (*a*) iA and $\dfrac{eh}{4\pi m}$
    (*b*) $\dfrac{i}{A}$ and $\dfrac{e}{4\pi m}$
    (*c*) $\dfrac{i}{A}$ and $\dfrac{h}{4\pi m}$
    (*d*) i^2A and $\dfrac{e^2h^2}{4\pi m}$.

12. For a diamagnetic substance the susceptibility is
(*a*) positive and very small
(*b*) positive and very large
(*c*) negative and very small
(*d*) zero.

13. A magnet of pole strength m and length l is broken into two pieces. The pole strength of each piece is
(*a*) m (*b*) $\frac{m}{2}$
(*c*) $2m$ (*d*) $\frac{m}{4}$.

14. Gauss theorem states that the surface integral of magnetic flux over a closed surface is zero. This is
(*a*) true (*b*) false.

15. All materials have
(*a*) paramagnetic property
(*b*) diamagnetic property
(*c*) ferromagnetic property
(*d*) ferrimagnetic property.

16. A magnetic material has a magnetization of 3200 A/m and flux density of $14\pi \times 10^{-4}$ weber/m^2. The magnetizing force is
(*a*) 10 A/m (*b*) 200 A/m
(*c*) 3000 A/m (*d*) 300 A/m.

17. If B is the intensity of the earth's magnetic field and θ is the angle of dip at a place, the vertical intensity B_V at the place is
(*a*) $B \cos \theta$ (*b*) $B \tan \theta$
(*c*) $B^2 \tan \theta$ (*d*) $B \sin \theta$.

18. If 3 units of the same type of poles are separated by a distance of 0.5 m, then the repulsive force between them is

(*a*) $4\pi \times 10^{-7}$ N (*b*) 36×10^{7} N
(*c*) 10^{7} N (*d*) 10^{-7} N.

19. The magnetic flux of 9.8×10^{-6} weber passing through a closed area has a magnetic induction 2×10^{-6} tesla. The area of the enclosed surface is
(*a*) 9 m^2 (*b*) 19 m^2
(*c*) 120 m^2 (*d*) 4.9 m^2.

20. The ratio of magnetic field due to a small bar magnet in the broad-on position to that in the end-on position is
(*a*) 0.25 (*b*) 1
(*c*) 2 (*d*) 0.50.

21. Which of the following materials has a very high positive susceptibility?
(*a*) diamagnetic material
(*b*) ferromagnetic material
(*c*) paramagnetic material
(*d*) anti ferromagnetic material.

22. The reduction factor of a tangent galvanometer is equal to the current required to produce a deflection of 45° in the galvanometer
(*a*) true (*b*) false.

23. The deflection at the centre of the tangent galvanometer is
(*a*) directly depending on the tangent of the deflection
(*b*) inversely depending on the tangent of the deflection
(*c*) directly depending on sin θ
(*d*) all the above are false.

24. In SI unit of magnetic moment is expressed in
(*a*) NT^{-1} (*b*) NT^{-2}
(*c*) A/m (*d*) JT^{-1}.

25. Which one of the following substances is a diamagnetic one?
(*a*) copper (*b*) iron
(*c*) $BaTiO_3$ (*d*) oxygen.

26. Steel is preferred to soft iron for making permanent magnet because
(*a*) coercivity of steel is zero
(*b*) coercivity of steel is low
(*c*) coercivity of steel is high
(*d*) none of these.

27. A magnet of moment m is freely suspended through its centre of gravity in a horizontal uniform field of flux density B. The work done in rotating the magnet through an angle θ is
(*a*) mB (*b*) $mB\ (1 - \cos\theta)$
(*c*) $-mB \cos\theta$ (*d*) mB^2.

28. If T_1 and I_1 are the period of oscillation and moment of inertia of the magnet of a magnetometer and T_2 and I_2 are the same quantities of the second magnet at the same place, then the ratio of their magnetic moment, say $\frac{m_1}{m_2}$, is
(*a*) $\left(\frac{T_2}{T_1}\right)\left(\frac{I_1}{I_2}\right)$ (*b*) $\left(\frac{T_2}{T_1}\right)^2\left(\frac{I_2}{I_1}\right)$
(*c*) $\frac{T_1^{\,2}}{T_2^{\,2}}$ (*d*) $\left(\frac{T_2}{T_1}\right)^2\left(\frac{I_1}{I_2}\right)$.

29. The magnetic moment per unit area is called magnetization. This is
(*a*) true (*b*) false.

30. Sure test of magnetism is
(*a*) attraction (*b*) repulsion
(*c*) both (*d*) none of these.

31. The radius of the coil in a T.G. is halved and the number of turns is also halved.

Then the magnetic field at the centre of the coil, for the same current will

(*a*) get halved

(*b*) get doubled

(*c*) becomes four times

(*d*) remain unchanged.

32. The unit of relative permeability of a medium is

(*a*) henry (*b*) no unit

(*c*) newton (*d*) metre/sec.

33. Substances having a net atomic or molecular magnetic dipole moment zero (because atoms of several electrons with their orbital and spin magnetic moments adding vectorially to zero) are called

(*a*) paramagnetic materials

(*b*) ferrites

(*c*) ferromagnetic materials

(*d*) diamagnetic materials.

34. Which of the following element is a diamagnetic one?

(*a*) mercury (*b*) iron

(*c*) $BaTiO_3$ (*d*) nickel.

35. Diamagnetism is independent of temperature. This is

(*a*) true (*b*) false.

36. In paramagnetism

(*a*) the susceptibility varies inversely with temperature

(*b*) the susceptibility varies directly with temperature

(*c*) independent of temperature the susceptibility

(*d*) all the above are not true.

37. Which of the following element is a paramagnetic material?

(*a*) gold (*b*) iron
(*c*) mercury (*d*) aluminium.

38. When magnetic specimen is subjected to a magnetizing field the magnetization M is proportional to
(*a*) H^2 (*b*) H
(*c*) $\sqrt{H}$ (*d*) $\frac{1}{H}$.

39. The relative permeability of iron is of the order of
(*a*) 10^{-4} (*b*) zero
(*c*) 1 (*d*) 10^4.

40. The period of oscillation of a magnet in a vibration magnetometer is 1.5 sec. The period of oscillation of another magnet similar in size, shape and mass but having $\frac{1}{4}$th of the magnetic moment of the first one at the same place is
(*a*) 8 sec (*b*) 2 sec
(*c*) 3 sec (*d*) 1 sec.

41. A hydrogen atom is paramagnetic and a hydrogen molecule is
(*a*) diamagnetic (*b*) paramagnetic
(*c*) ferromagnetic (*d*) none of these.

42. At Curie temperature
(*a*) ferromagnetism vanishes and the substance attains paramagnetic behaviour
(*b*) ferromagnetism becomes dominant
(*c*) ferromagnetic substance becomes diamagnetic
(*d*) all the above are true.

43. When iron undergoes a cycle of magnetization the hysteresis loop represents
(*a*) gain of energy
(*b*) zero loss of energy

(*c*) wastage of energy in the form of heat

(*d*) the fact that iron becomes paramagnetic.

44. Large magnetization for small magnetic field and low hysteresis loss are the characteristics of the case of the electromagnet

(*a*) true (*b*) false.

45. The earth's core is known to contain iron, yet geologists do not regard this as a source of earth's magnetism, because molten iron is not ferromagnetic. This is

(*a*) true (*b*) false.

46. The work required to turn a magnetic needle by 60° from equilibrium in a uniform magnetic field is *W*. The torque required to hold it in that position is

(*a*) $\frac{W}{2}$ (*b*) $W\sqrt{3}$

(*c*) $\frac{\sqrt{3}}{2}W$ (*d*) W.

47. The vertical component of earth's magnetic field is zero at

(*a*) magnetic equator

(*b*) magnetic poles

(*c*) geographic poles

(*d*) at 90° latitude.

48. In tan *A* position two short bar magnets of moments in the ratio 1 : 1.732 are placed at the same distance separately. If the deflection produced for the first magnet is 30°, the deflection for the second magnet is

(*a*) 20° (*b*) 30°

(*c*) 45° (*d*) 60°.

49. The magnetic field of earth has always a vertical component except at the

(*a*) magnetic equator
(*b*) 30° altitude
(*c*) magnetic poles
(*d*) 60° altitude.

50. The magnetic moment associated with a current loop is
(*a*) $\vec{m} = i\vec{A}$ (*b*) $\vec{m} = \frac{i}{\vec{A}}$
(*c*) $\vec{m} = \frac{\vec{A}}{i}$ (*d*) $\vec{m} = i^2\vec{A}$.

51. The magnetic elements of earth's magnetic field are
(*a*) dip and magnetic induction
(*b*) total flux and declination
(*c*) horizontal intensity
(*d*) horizontal intensity, declination and dip.

52. The magnetic needle in a tangent galvanometer is short. This is
(*a*) to have the interaction between aluminium needle and magnetic needle is small
(*b*) to have greater interaction between the two
(*c*) to bring the reading to zero
(*d*) to have both the poles in the same field due to the current in the coil.

53. If a toroid uses bismuth for its core, the field in the core will be
(*a*) slightly greater since bismuth is paramagnetic
(*b*) remains the same
(*c*) slightly less since bismuth is diamagnetic
(*d*) all the above are untrue.

54. The relative permeability of iron is 10^4. If this specimen is subjected to a field of

1000 A/m, the magnetic induction and susceptibility respectively are

(*a*) π Wb/m^2 and 99

(*b*) 3π Wb/m and 999

(*c*) 4πWb/m^2 and 9999

(*d*) $\frac{\pi}{2}$ Wb/m and 220.

55. The unit of pole strength is

(*a*) tesla (*b*) henry/metre

(*c*) amp m^2 (*d*) amp *m*.

56. If $\vec{A}$ is area vector and $\vec{B}$ is magnetic induction vector, then the magnetic flux ϕ is given by

(*a*) $\phi = \vec{B} . \vec{A} = BA \cos \alpha$

(*b*) $\phi = \dfrac{B}{A \cos \alpha}$

(*c*) $\phi = \dfrac{A \cos \alpha}{B}$

(*d*) $\phi = \dfrac{\vec{B} . \vec{A}}{|\vec{A}|}$.

where α is the angle between $\vec{B}$ and normal to area $\vec{A}$.

57. A cylindrical magnet of area of cross-section 1 sq. cm and volume 5×10^{-6} m^3 has a magnetic moment of 2×10^{-6} weber-m. The pole strength of the magnet is

(*a*) 0.04×10^{-4} weber

(*b*) 1.04×10^{-6} weber

(*c*) 0.4×10^{-4} weber

(*d*) 1000 weber.

58. The maximum value of angle of dip is at the

(*a*) equator

(*b*) north pole

(*c*) south pole
(*d*) both north and south poles.

59. The flux density describes the
(*a*) dimension of a magnet
(*b*) strength of the poles of a magnet
(*c*) distance between the two poles of a magnet
(*d*) none of the above.

60. A magnetic needle when kept in a non-uniform magnetic field experiences
(*a*) a force but not a torque
(*b*) a torque but not a force
(*c*) neither a force nor a torque
(*d*) both a force and a torque.

PROBLEMS AND SOLUTIONS

1. *A magnetic field 10^4 A/m produces a magnetic induction of 4π weber/m^2 in an iron rod. Compute the susceptibility.*
Solution:

$$\mu_r = \frac{B}{\mu_0 H} = 1 + \chi$$

$$\chi = \frac{B}{\mu_0 H} - 1 = \frac{4\pi}{4\pi \times 10^{-7} \times 10^4} - 1$$

$$\boxed{\chi = 999} \quad \textbf{Ans.}$$

2. *A tangent galvanometer has 5 turns and diameter 16 cm. When a current of 0.8 amp. is passed through it, the deflection is 45°. Calculate the horizontal intensity of earth's magnetic field.*
Solution:

$$B_H = \frac{i\,\mu_0 n}{2a \tan\theta} = \frac{0.8 \times 4\pi \times 10^{-7} \times 5}{2 \times 8 \times 10^{-2}}$$

$$B_H = 0.314 \times 10^{-4} \text{ tesla}$$

$$B_H = \mu_0 H;\ H = \frac{B_H}{\mu_0} = \frac{0.314 \times 10^{-4}}{4\pi \times 10^{-7}}$$

$$H = \frac{0.314 \times 10^{-4}}{4\pi} = \frac{3.14 \times 10^{-3}}{40\pi}$$

$$= 0.25 \times 10^{-4}$$

$$\boxed{H = 0.25 \times 10^{-4} \text{ A/m}} \qquad \textbf{Ans.}$$

3. *The magnetic moment due to orbital motion of the electron is 9.27×10^{-24} A/m^2. How?*

Solution:

$$\text{Bohr magneton} = \frac{eh}{4\pi m} = \mu_B$$

$$\mu_B = \frac{1.6 \times 10^{-19} \times 6.62 \times 10^{-34}}{4\pi \times 9.1 \times 10^{-31}}$$

$$\boxed{\mu_B = 9.27 \times 10^{-24}} \qquad \textbf{Ans.}$$

Unit calculation:

$$\frac{eh}{4\pi m} = \frac{\text{coulomb} \times \text{J} \times \text{s}}{\text{kg}} = \frac{\text{amp Js}^2}{\text{kg}}$$

But

W.D. = joule = F × d

= Mass × Acceleration × Distance

i.e., W.D. = kg (m/sec^2) × m

or $$\text{kg} = \frac{\text{J sec}^2}{\text{m}^2}$$

$$\frac{eh}{4\pi m} = \frac{\text{amp J s}^2}{\text{J sec}^2/\text{m}^2} = \text{amp m}^2$$

or $$\boxed{\mu_B = 9.27 \times 10^{-24} \text{ A m}^2} \qquad \textbf{Ans.}$$

4. *The magnetic moment of the magnet weighing 0.062 kg is 6×10^{-6} A m^2. Its density is 6200 kg/m^3. Calculate the intensity of magnetization.*

Solution:

$$\text{Volume} = \frac{W}{d} = \frac{0.062}{6200} = \frac{6200 \times 10^{-5}}{6200}$$

$$= 10^{-5} \text{ m}^3$$

$$M = \frac{M'}{V} = \frac{6 \times 10^{-6}}{10^{-5}}$$

where M' is magnetic moment

or $\boxed{M = 0.6 \text{ A/m}}$ **Ans.**

5. *The magnetic susceptibility of a material is 1000. If this material is placed in a magnetic field of strength 1000 A/m, what will be value of magnetic induction?*

Solution:

$$\chi = \frac{M}{H}\ ; M = \chi H = 1000 \times 1000 = 10^6$$

$$B = \mu_0 (H + M) = \mu_0(10^6 + 10^3)$$

$$B = 4\pi \times 10^{-7} \times 10^6 \left(1 + \frac{1}{10^3}\right) = 4\pi \times 10^{-1}$$

$\boxed{B = 0.4\pi \text{ Wb/m}^2}$ **Ans.**

6. *The period of oscillation of a magnet in a vibration magnetometer is 2.5 sec. The period of oscillation of another magnet similar in size, shape and mass but having $\frac{1}{4}$th of the magnetic moment of the first one at the same place is 3 sec. Calculate the period of the second magnet.*

Solution:

General equation,

$$T = 2\pi\sqrt{\frac{I}{HM}}$$

$$T_1 = 2\pi\sqrt{\frac{I}{M_1 H}} \text{ and } T_2 = 2\pi\sqrt{\frac{I}{M_2 H}}$$

$$\frac{T_1}{T_2} = \sqrt{\frac{M_2}{M_1}} = \sqrt{\frac{M_1}{4M_1}} = \frac{1}{2} = 0.5$$

$$T_2 = \frac{T_1}{0.5} = \frac{2.5}{0.5}$$

$$\boxed{T_2 = 5 \text{ sec}} \quad \textbf{Ans.}$$

7. *A metal bar of length 10 cm is placed in a magnetic flux of 0.45 × 10^{-4} weber. Show that the volume of the metal bar is 7.5 × 10^{-6} m^3. Given: the flux density is 0.6 weber/m^2.*

Solution:

$$B = \frac{\phi}{A} = \frac{0.45 \times 10^{-4}}{A}$$

or $$A = \frac{0.45 \times 10^{-4}}{B} = \frac{0.45 \times 10^{-4}}{0.6}$$

$$= \frac{4.5 \times 10^{-4}}{6}$$

$$\text{Volume} = A \times l = \frac{4.5 \times 10^{-4} \times 10^{-1}}{6}$$

$$= 7.5 \times 10^{-6} \text{ m}^3$$

$$\boxed{V = 7.5 \times 10^{-6} \text{ m}^3} \quad \textbf{Ans.}$$

8. *The period of a freely suspended cylindrical magnet is 4 sec. If it is broken transverse to its length into two equal parts and one part is suspended in the same way, find the time period.*

Solution:

$$T_1 = 2\pi\sqrt{\frac{I_1}{mB}} \qquad i.e., \quad T_1^2 \propto \frac{I_1}{m_1}$$

$$T_2^{\,2} \propto \frac{I_2}{m_2}$$

or $$\frac{T_1^{\,2}}{T_2^{\,2}} = \frac{I_1}{I_2}\left(\frac{m_2}{m_1}\right) \qquad \text{with } m_2 = \frac{m_1}{2}$$

$$\frac{T_1^2}{T_2^2} = \frac{I_1}{I_2}\left(\frac{1}{2}\right)$$

$$= \frac{Ml^2 \times 12}{12 \times 2\left(\frac{M}{2}\right)\left(\frac{l}{2}\right)^2} = \frac{8}{2} = 4$$

$$T_2^{\,2} = \frac{T_1^2}{4} = \frac{16}{4} = 4$$

$$\boxed{T_2 = 2 \text{ sec}} \quad \textbf{Ans.}$$

9. *The earth's field is claimed to be due to a dipole moment $m = 8 \times 10^{22}$ J T^{-1} located at its centre. Check the order of magnitude of this number.*

Solution:

B at the equatorial point is

$$B = \frac{\mu_0}{4\pi}\left(\frac{m}{r^3}\right) = \frac{4\pi \times 10^{-7} \times 8 \times 10^{22}}{(6.4 \times 10^6)^3}$$

$$\boxed{B = 0.3 \times 10^{-4} \text{ T}} \quad \textbf{Ans.}$$

This agrees approximately with the observed field of the earth at a point on the equator.

10. *Intersteller space has an extremely weak magnetic field of the order of 10^{-12} T. Can such field is of any consequence?*

Solution:

From the relation for the radius, $r = \dfrac{mv}{eB}$

we note that an extremely small field

bends the charged particle in a circle of large radius. The deflection can significantly affect the passage of charged particles like cosmic rays.

11. *One metre length of a steel wire is magnetized and then bent into a semicircle of radius r. Compute the ratio of magnetic moments of straight wire and the bent wire.*

Solution:

$$M_1 = l \times m = 1 \times m$$

Circumference of semicircle = πr

i.e., $r = \dfrac{1}{\pi}$ or $2r = \dfrac{2}{\pi}$

Diameter of the semicircle = $2r$

But $M_2 = 2r \times M_1 = \dfrac{2 \times m}{\pi}$

$$\frac{M_1}{M_2} = \frac{m}{2m/\pi} = \frac{\pi}{2}$$

$$\boxed{M_1 = \frac{\pi M_2}{2}}$$ **Ans.**

12. *A particle of mass m and charge q moves with a constant velocity V along the positive x-direction. It enters a region containing a uniform magnetic field B directed along the negative z-direction, extending from x = a to x = b. What is the minimum value of V required so that the particle can just enter the region x > b?*

Solution:

Lorentz force = Centripetal force

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

$$mv = eBr$$

$$dv = \frac{eB}{m} dr$$

Integrating,

$$V = \frac{eB}{m} \int_a^b dr = \frac{eB}{m} (b - a)$$

$$\boxed{V = \frac{e(b-a)B}{m}} \quad \textbf{Ans.}$$

13. *A bar magnet makes 12 vibrations per minute when it is suspended horizontally at a place. What will be its number of vibrations per minute when its pole strength is quadrupled by remagnetization?*

Solution:

$n_1 = 12$ vib./m, $m_1 = m$; $n_2 = ?$, $m_2 = 4m$

where m_1 and m_2 are the pole strength.

$$T = 2\pi\sqrt{\frac{I}{mB}}; \quad T^2 = \frac{4\pi I}{mB},$$

i.e., $m \propto \dfrac{1}{T^2}$ or $m \propto n^2$

(*I* is the intensity of magnetization)

i.e., $m_1 \propto n_1^2$

$m_2 \propto n_2^2$

$$\frac{m_1}{m_2} = \frac{m}{4m} = \frac{12^2}{n_2^2}$$

$$n_2^2 = 2^2 \times 12^2$$

$$\boxed{n_2 = 24 \text{ vib./m}} \quad \textbf{Ans.}$$

ANSWERS TO OBJECTIVE QUESTIONS

1. (*a*)	2. (*c*)	3. (*a*)	4. (*a*)
5. (*b*)	6. (*d*)	7. (*b*)	8. (*a*)

9. (*b*)	10. (*c*)	11. (*a*)	12. (*c*)
13. (*b*)	14. (*a*)	15. (*b*)	16. (*d*)
17. (*d*)	18. (*b*)	19. (*d*)	20. (*a*)
21. (*b*)	22. (*a*)	23. (*a*)	24. (*d*)
25. (*a*)	26. (*c*)	27. (*b*)	28. (*d*)
29. (*b*)	30. (*b*)	31. (*d*)	32. (*b*)
33. (*d*)	34. (*a*)	35. (*a*)	36. (*a*)
37. (*d*)	38. (*b*)	39. (*d*)	40. (*c*)
41. (*a*)	42. (*a*)	43. (*c*)	44. (*a*)
45. (*a*)	46. (*c*)	47. (*a*)	48. (*c*)
49. (*a*)	50. (*a*)	51. (*d*)	52. (*d*)
53. (*c*)	54. (*c*)	55. (*d*)	56. (*a*)
57. (*c*)	58. (*d*)	59. (*b*)	60. (*d*).

CHAPTER 5

ELECTROSTATICS

1. When the distance between two charged particles is halved the coulomb force between them becomes
   (*a*) one fourth of the initial force
   (*b*) four times the initial force
   (*c*) double the initial force
   (*d*) one-half of the initial force.
2. When a charged body is brought near an uncharged conductor on the insulating stand,
   (*a*) the nearer end of the conductor acquires the same charge while the farther end opposite charge
   (*b*) no charge is induced on the conductor
   (*c*) the nearer end of the conductor acquires opposite charge and the farther end the same charge
   (*d*) none of the above is correct.
3. The interaction between the charges q_1 and q_2 in a medium (other than air) separated by a distance r is given by

   $F \propto \dfrac{q_1 q_2}{r^2}$; or $F = \dfrac{A q_1 q_2}{r^2}$ where A is

   (*a*) $\dfrac{1}{4\pi\varepsilon}$ (*b*) $\dfrac{1}{4\pi\varepsilon_0}$

   (*c*) $\dfrac{4\pi}{\varepsilon}$ (*d*) $4\pi\varepsilon_0$.

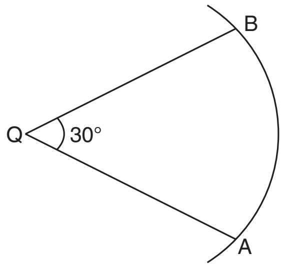
Here, ε is absolute permittivity of the medium and ε_0 is permittivity of free space.

4. If $\dfrac{A}{\varepsilon_r}$ is the force between two charges in a dielectric medium of dielectric constant ε_r, its value in a metallic medium is
   (*a*) A (*b*) $\varepsilon_r A$
   (*c*) less than A (*d*) zero.
5. Which one of the following statements is true?
   (*a*) electrostatic force obeys inverse square law while gravitational force does not
   (*b*) both gravitational force and electrostatic force are repulsive in nature
   (*c*) gravitational force is much weaker than electrostatic force
   (*d*) all the above are true.
6. Two equal charges are separated by a distance $(r/4)$. If the dipole moment is $2qr$, the magnitude of each charge is
   (*a*) $\dfrac{q}{r}$ (*b*) q^2
   (*c*) $8q$ (*d*) $2q$.
7. The unit of absolute permittivity ε is
   (*a*) farad/metre
   (*b*) coulomb/metre
   (*c*) ampere metre
   (*d*) ampere/metre.
8. In SI system the unit of ε_0 is
   (*a*) $\dfrac{\text{Nm}^2}{\text{C}^2}$ (*b*) $\dfrac{\text{C}}{\text{N}^2\text{m}^2}$
   (*c*) $\dfrac{\text{N}^2\text{m}}{\text{C}^2}$ (*d*) $\dfrac{\text{C}^2}{\text{Nm}^2}$.

9. The acceleration of a proton in a given field is
   (*a*) 1840 times that of the electron in the same field
   (*b*) 10 × 1840 times that of the electron in the same field
   (*c*) $\frac{1}{1840}$ times that of the electron in the same field
   (*d*) all the above are false.

10. If $\frac{dV}{dx}$ is the potential gradient, then the intensity of the electric field at a point is
   (*a*) $-\frac{dV}{dx}$ (*b*) $\frac{dV}{dx}$
   (*c*) $q\frac{dV}{dx}$ (*d*) $\frac{dx}{dV}$.

11. In an electric field due to a charge Q, a charge q moves from point A to B as shown in figure. The



work done is
   (*a*) $\frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$ (*b*) $\frac{1}{4\pi\varepsilon_0}\frac{q}{r^2}$
   (*c*) zero (*d*) $\frac{Qq}{r^2}$.

12. The work done in carrying a charge of 0.2 μC from a point A to B is 8 m J. The

difference of potential between A and B is

(*a*) 16 kV (*b*) 16 V

(*c*) 160 volt (*d*) 1.6 kV.

13. If electron volt is the energy acquired by an electron accelerated through a p.d. of 1 volt, then

(*a*) 1 eV = 5000 calorie

(*b*) 1 eV $= \frac{1}{1.6 \times 10^{-19}}$ joule

(*c*) 1 eV = 1.6×10^{-19} joule

(*d*) 1 eV = 1.6×10^{-19} calorie.

14. If two charges each of one coulomb are separated by a distance 1 metre, than the force between them is approximately

(*a*) 2.2 newton

(*b*) 8.85×10^{12} newton

(*c*) 1.6×10^{19} newton

(*d*) 9×10^{9} newton.

15. Coulomb is that charge which when placed in free space at a distance of 1 m form an equal and similar charge repels it with a force of

(*a*) $\frac{1}{8\pi\varepsilon_0^2}$ newton

(*b*) $8\pi\varepsilon_0$ newton

(*c*) $\frac{1}{4\pi\varepsilon_0}$ newton

(*d*) $\frac{1}{4\pi\varepsilon_0^2}$ newton.

16. If a current of 2 ampere is flowing through a conductor for one sec, then charge flowing through the section of the conductor is

(*a*) $\frac{1}{2}$ coulomb

(*b*) 2 coulomb

(*c*) 2^2 coulomb

(*d*) no charge flows.

17. The mathematical form of Gauss theorem is

(*a*) $\oint \vec{E} \cdot \vec{ds} = \varepsilon_0 \int dq$

(*b*) $\oint \varepsilon_0 \vec{E} \cdot \vec{ds} = \Sigma dq$

(*c*) $\oint \vec{E} \cdot \vec{ds} = q$

(*d*) $\oint E \cdot ds = \frac{q}{4\pi\varepsilon_0}$.

18. The bird perching on a high power line does not get electric shock. This is because

(*a*) the whole body of the bird sitting on the live wire is at the same potential and hence no current flows through the body

(*b*) the whole body of the bird sitting on the live wire is at zero potential and hence no current flows through the body

(*c*) because the air medium between the live wire and the earth contains large number of charge particles

(*d*) all the above are false.

19. The dimensions of ε_0 are

(*a*) $M^3L^{-2}T^2I^3A$

(*b*) $ML^{-2}T^{-2}$

(*c*) $M^0L^0T^{-2}I$

(*d*) $M^{-1}L^{-3}T^4A$.

20. Two charges kept in vacuum are acted upon by some force of attraction. If glass (ε_r = 8) is kept between them, the force now is

(*a*) increased to 6 times of the initial value

(*b*) reduced to $\frac{1}{6}$th of the initial value

(*c*) remains same as the initial one

(*d*) reduced to zero.

21. An atom is electrically neutral. Why then should an α-particle be deflected by the atom?

(*a*) the nucleus located at the centre of the atom is negatively charged and hence repels the α-particle

(*b*) the nucleus is positively charged and hence repels the uncharged α-particle

(*c*) the positively charged nucleus repels the positive charged α-particle and hence α-particle is deflected

(*d*) all the above are true.

22. A conducting surface is charged to a surface density σ. The outward pressure on the surface is

(*a*) $\frac{\sigma^2}{2\varepsilon_0}$ (*b*) $\frac{\sigma}{2\varepsilon_0}$

(*c*) $\frac{\varepsilon_0}{\sigma}$ (*d*) $\frac{\sigma}{\varepsilon_0}$.

23. The unit of electric field V/m can also be written

(*a*) newton/coulomb

(*b*) coulomb/newton

(*c*) amp/metre

(*d*) farad/metre.

24. The maximum resultant intensity at a point distance r from the centre of a dipole of moment μ is of magnitude

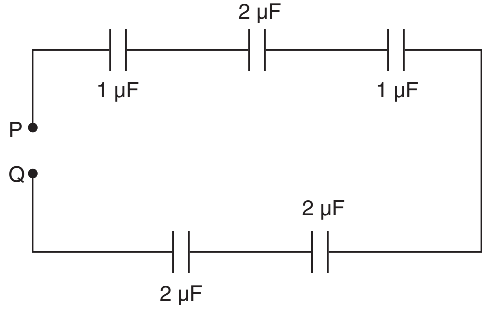
(a) $\dfrac{\mu}{2\pi\varepsilon_0 r^3}$ along the axial line

(b) $\dfrac{\mu}{4\pi\varepsilon_0 r^2}$ along the axial line

(c) $\dfrac{\mu}{2\pi\varepsilon_0 r^3}$ along the equatorial line of the dipole

(d) $\dfrac{\mu}{2\pi\varepsilon_0 r^2}$ along the axial line of the dipole.

25. What is the effective capacitance in the circuit given below?



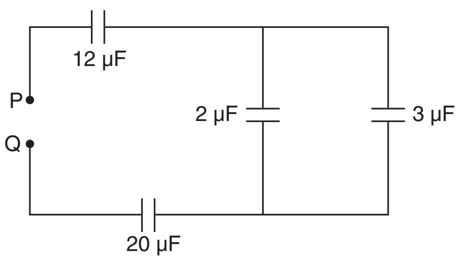
(a) 10.2 μF (b) 2.8 μF
(c) 1.4 μF (d) 14 μF.

26. The capacitance of a parallel plate condenser does not depend upon
(a) area of the plates
(b) medium between the plates
(c) distance between the plates
(d) nature of the material of the plates.

27. A parallel plate capacitor in charged and then isolated. What is the effect of increasing the plate separation?

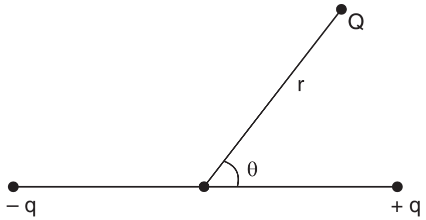
	Charge	*Potential*	*Capacitance*
(*a*)	remains the same	remains the same	decreases
(*b*)	increases	increases	decreases
(*c*)	remains the same	decreases	decreases
(*d*)	remains the same	increases	decreases

28. What is the effective capacitance in the circuit given below?



(*a*) zero (*b*) 10 μF
(*c*) 50 μF (*d*) 3 μF.

29. Potential at a point *Q* at a distance *r* from a short dipole of charge *q* and dipole moment μ is



(*a*) $\frac{p}{r^2}$ (*b*) $\frac{p \cos \theta}{r^2}$

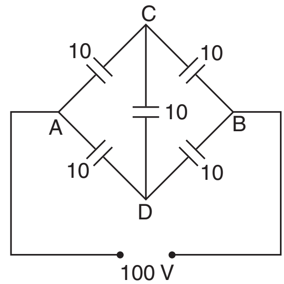
(*c*) $\frac{1}{4\pi\varepsilon_0} \quad \frac{p \cos \theta}{r^2}$ (*d*) $\frac{1}{4\pi\varepsilon_0} \quad \frac{p \sin \theta}{r^2}$

where *p* is the dipole moment.

30. A parallel plate condenser has a capacitance 50 μF in air and 100 μF in oil. The dielectric constant ε_r of oil is
(*a*) 0.45 (*b*) 0.55
(*c*) 2 (*d*) 0.5.

31. A parallel plate condenser of capacitance C_1 consists of two square plates of side 2.5 cm separated by a distance 3 mm. Another condenser with capacitance C_2 identical to that of the first one in all respects but with a dielectric of $\varepsilon_r = 4$ is considered. Thus $\dfrac{C_1}{C_2}$ is
(*a*) 0.8 (*b*) 0.1
(*c*) 1 (*d*) 0.25.

32. Five capacitors 10 μF capacity each is connected to a d.c. potential of 100 volt as shown in figure. The equivalent capacitance between *A* and *B* is



(*a*) 10 μF (*b*) 60 μF
(*c*) 20 μF (*d*) 30 μF.

33. The force experienced on an oil drop of charge 5 μC in an electric field of intensity 12×10^3 V/m is
(*a*) 10^{-2} N (*b*) 60×10^{-3} N
(*c*) 60×10^{-2} N (*d*) 10^{-6} N.

34. The capacitance of a capacitor that should be connected along with 2 capacitors,

having capacitance 4 μF and 8 μF all in series to produce an effective capacitance of $\frac{24}{11}$ μF.

(*a*) 12 μF (*b*) 120 μF

(*c*) 8 μF (*d*) 6 μF.

35. Separation between the plates of a parallel plate capacitor is d and the area of each plate is A. When a slab of material of dielectric constant ε_r and thickness t introduced between the plates, the capacitance becomes

(*a*) $\dfrac{A\varepsilon_0}{d+t\left[1-\dfrac{1}{\varepsilon_r}\right]}$ (*b*) $\dfrac{A\varepsilon_0}{d+t(1+\varepsilon_r)}$

(*c*) $\dfrac{A\varepsilon_0}{d-t\left[1-\dfrac{1}{\varepsilon_r}\right]}$ (*d*) $\dfrac{A\varepsilon_0}{(4\pi d-t)}$.

36. If a dielectric is placed between the plates, the capacitance

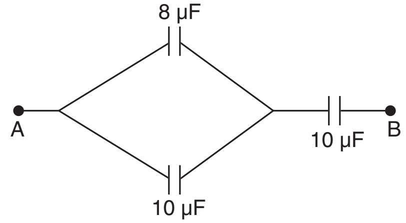
(*a*) decreases

(*b*) remains constant

(*c*) becomes zero

(*d*) increases.

37. The effective value of the capacitance of the capacitor shown in figure is



(*a*) 15 μF (*b*) 6.4×10^{-2} μF

(*c*) 6.4 μF (*d*) 2 μF.

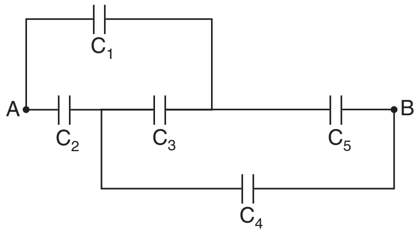
38. Asymmetric molecules have permanent dipole moment even in the absence of an external field. This is because
   (*a*) in such molecules the centres of charges coincide
   (*b*) in such molecules the centres of charges do not coincide
   (*c*) in some cases they coincide and in other cases they do not coincide
   (*d*) all the above statements are false.
39. Which one of the following is a polar molecule
   (*a*) H_2O (*b*) H_2
   (*c*) O_2 (*d*) CO_2.
40. Potential difference between two points under the field of an electric charge is the work done is moving a unit positive charge
   (*a*) from ∞ to the mid-point of the line joining the points
   (*b*) from the charge to ∞
   (*c*) from one point to the other
   (*d*) all the above are false.
41. The dipole moment of the water molecule is
   (*a*) 10^8 Debye unit
   (*b*) 8.84 Debye unit
   (*c*) Zero Debye unit
   (*d*) 1.84 Debye unit.
42. The dimensions of potential difference are
   (*a*) MLT^{-2} (*b*) MLT^{2}
   (*c*) ML^2 (*d*) $ML^2T^{-3}A^{-1}$.
43. Charge given to a conductor is
   (*a*) directly proportional to the voltage
   (*b*) inversely proportional to the voltage

(*c*) equal to the voltage
(*d*) none of these.

44. Capacitor is a device used
(*a*) to conduct charges
(*b*) to store charges
(*c*) to reduce the potential difference
(*d*) to reduce the current.

45. If V is the p.d. applied between the three condensers of capacities C_1, C_2 and C_3 connected in parallel then
(*a*) the p.d across the capacitors are V_1, V_2 and V_3 such that $V = V_1 + V_2 + V_3$
(*b*) the quantity of charge given to every condenser is the same
(*c*) the effective capacity is
$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$
(*d*) the p.d. across all the capacitors are equal.

46. Find the capacity of a system of identical capacitors between points A and B. Each capacitor has a capacitance 2 μF.



(*a*) 2 μF (*b*) 10 μF
(*c*) 6 μF (*d*) 8 μF.

47. If two identical point charges separated by 3 m experience a force of 10 newton, then the individual charge is
(*a*) 100 μC (*b*) 10 μC
(*c*) 1 μC (*d*) 0.1 μC.

48. If a hollow spherical conductor is filled with a liquid, its capacitance changes from 4 μF to 12 μF. The dielectric constant of the liquid is

(*a*) 2 (*b*) 4

(*c*) 8 (*d*) 3.

49. Which of the following statements is true?

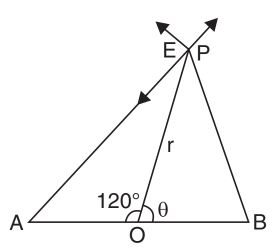
(*a*) When capacitors are connected in series, the effective capacitance will be greater than the smallest individual capacitance

(*b*) The capacitance of a parallel plate condenser can be increased by increasing the separation of the plates

(*c*) When the condensers are connected in parallel the effective capacity will be less than the individual capacitance

(*d*) all the above three statements are false.

50. The potential at a point due to an electric dipole is 1.8×10^5 volt. If *P* is at a distance of 50 cm from the centre *O* of the dipole and *OP* makes an angle 120° with the negative side of the axial line of dipole, what is the moment of the dipole?



(*a*) 0.2 cm (*b*) 10^{-3} cm

(*c*) 10^{-5} cm (*d*) zero.

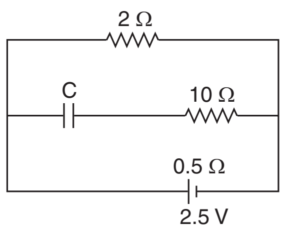
51. The charge of a dipole having a moment of 1 Debye and separated by 0.15 nm is approximately
(*a*) 1.6×10^{-19} coulomb
(*b*) 2.2×10^{-21} coulomb
(*c*) 22×10^{-21} coulomb
(*d*) 3.2×10^{-19} coulomb.

52. Calculate the electric field acting on a proton so that proton remains stationary in space
(*a*) 2.04×10^{-2} N/C
(*b*) 1.02×10^{-7} N/C
(*c*) 2.04×10^{2} N/C
(*d*) 1.02×10^{7} N/C.

53. A parallel plate condenser is formed with two circular plates of radius 0.25 m and another one with two square plates of side 0.25 m. The distance between the plates is 0.1 m in both the cases. The ratio of the capacitances of the circular plate capacitor is
(*a*) $1 : \pi$ (*b*) $1 : \pi^2$
(*c*) $\pi^2 : 1$ (*d*) $\pi : 1$.

54. If N identical capacitors each of capacity C are connected in series, then its equivalent capacitance is
(*a*) NC (*b*) $\frac{N}{C}$
(*c*) $\frac{C}{N}$ (*d*) NC^2.

55. A capacitor of capacitance 2 μF is connected as shown in figure. The internal resistance of the cell is 0.5 Ω. The amount of charge on the capacity plate is

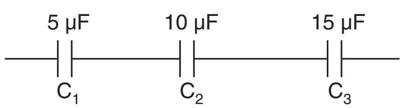


(a) zero (b) 2 μC

(c) 4 μC (d) 6 μC.

56. In the case of a parallel plate capacitor, when the distance between the two plates is reduced to one third and the area of the plate doubled, the capacitance
(a) remains the same
(b) is doubled
(c) increases to five times
(d) increases to six times.

57. If the potential difference across the combination shown in the figure is 33 volt, then the potential difference across C_2 is



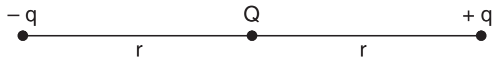
(a) 99 volt (b) 9 volt

(c) 2 volt (d) 100 volt.

58. An oil drop having 12 excess electrons is held stationary by a field of 2.56×10^4 V/m. Estimate the radius of the drop of density 1260 kg/m^3.
(a) 2.2×10^8 m
(b) 1000 m
(c) 1.1×10^2 m
(d) 9.8×10^{-7} m.

59. Three charges $-q$, Q and $+q$ are placed at equal distance on a straight line. If the total potential energy of the system of

three charges is zero, then the ratio $Q : q$ is



(*a*) 1 : 4 (*b*) 1 : 2
(*c*) 2 : 1 (*d*) 1 : 0.

60. A spherical liquid drop has a diameter of 2 cm and is given a charge of 1 μC (1) What is the potential at the surface of the drop? (2) If two such drops coalesce to form a single drop what is the potential at the surface of the drop so formed?
(*a*) 9×10^5 volt, 14.3×10^5 volt
(*b*) 22×10^2 volt, 2.2×10^5 volt
(*c*) 100 volt, 150 volt
(*d*) zero, 60 volt.

61. A substance has one coulomb of negative charge on it. How many electrons are in excess on it compared to its neutral state?
(*a*) 6.25×10^{18} (*b*) 6.25×10^{28}
(*c*) 10^{19} (*d*) 6.25×10^{-28}.

PROBLEMS AND SOLUTIONS

1. *Two fixed charges +4e and +e units are separated by a distance a. Where should be a third positive charge q be placed on the line joining the two charges so that it is in equilibrium?*

Solution:

Let the third point charge q be placed at a distance d from the charge $+4e$ for the charge q to be in equilibrium. Since q is in equilibrium, force on the charge q by the charge $4\,e$ = force on the charge q by the charge e

i.e., $$\left[\frac{1}{4\pi\varepsilon_0}\right]\left[\frac{4e\times q}{d^2}\right] = \left[\frac{1}{4\pi\varepsilon_0}\right]\left[\frac{eq}{(a-d)^2}\right]$$

$$\frac{4}{d^2} = \frac{1}{(a-d)^2}$$

or $$\frac{2}{d} = \frac{1}{(a-d)}$$

$$2a - 2d = d$$

$$3d = 2a$$

$$\boxed{d = \frac{2}{3}a}$$ **Ans.**

2. *The plates of parallel plate condenser are pulled apart with a velocity v. If at any instant their mutual distance of separation is d, then what is the rate of change of capacity dependence?*

Solution:

The general expression for capacitance

$$C = \frac{A\varepsilon_0}{d} = \frac{A\varepsilon_0}{vt}$$

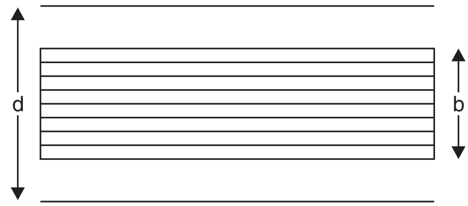
with $$v = \frac{d}{t}$$

$$\frac{dC}{dt} = -\frac{A\varepsilon_0}{vt^2} = -\frac{A\varepsilon_0 v^2}{vd^2} = -\frac{A\varepsilon_0 v}{d^2}$$

i.e., $$\boxed{\frac{dC}{dt} \propto \frac{1}{d^2}}$$ **Ans.**

3. *A slab of copper of thickness b is inserted in between the plates of a parallel plate capacitor as shown in figure. The separation between the plates is d. If $b = \frac{d}{2}$, find the ratio of the capacitance of the capacitor before and after inserting the slab.*

Solution:

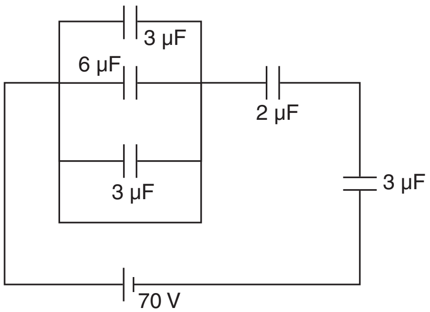


Assuming $\dfrac{A\varepsilon_0}{d} = C_0$,

$$C = \frac{A\varepsilon_0}{d\left(1-\dfrac{b}{d}\right)} = \frac{C_0}{\left(1-\dfrac{d}{2d}\right)} = 2C_0$$

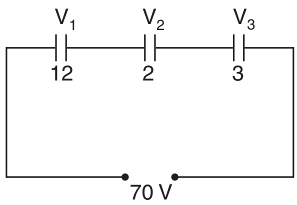
or $\boxed{\dfrac{C}{C_0} = 2}$ **Ans.**

4. *Calculate the p.d. across 2 μF in the following circuit*



Solution:

Equivalent circuit



$$V_1 + V_2 + V_3 = 70$$

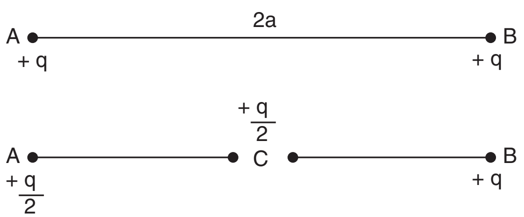
17 μF balances 70 volt

2 μF will balance $\frac{70 \times 2}{17}$ = 8.23 volt.

$\boxed{\text{8.23 volt.}}$ **Ans.**

5. *Two equally charged identical spheres A and B repel each other with a force of 2 × 10⁻⁵ newton. Another identical, uncharged sphere C touches A and then placed at the mid-point of the line joining A and B. What is the net electric force on C?*

Solution:



In the first case the force on B due to A is

$$\frac{1}{4\pi\varepsilon_0} \frac{q^2}{4a^2} = 2 \times 10^{-5} \text{ N}$$

In the second case

Force on C due to A

$$= \frac{1}{4\pi\varepsilon_0} \frac{q^2}{4a^2} \text{ towards right}$$

Force on C due to B

$$= \frac{1}{4\pi\varepsilon_0} \frac{q^2}{2a^2} \text{ towards left}$$

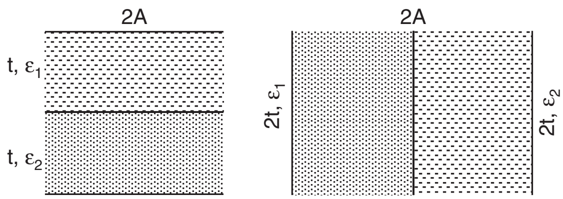
Therefore net force on C

$$= \frac{1}{4\pi\varepsilon_0} \left(\frac{q^2}{2a^2} - \frac{q^2}{4a^2} \right) \text{ towards left.}$$

Hence resultant force on C

$$\boxed{\begin{aligned} &= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{4a^2} \\ &= 2 \times 10^{-5} \text{ newton} \end{aligned}}$$ **Ans.**

6. *A capacitor is filled with two dielectrics of the same dimensions, but of dielectric constant 2 and 3 respectively in two different ways as in figure. What is the ratio of the capacitances in the two arrangements?*



Solution:

$$\frac{1}{C_1} = \frac{t}{2A\varepsilon_0\varepsilon_1} + \frac{t}{2A\varepsilon_0\varepsilon_2} = \frac{t}{2A\varepsilon_0}\left[\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2}\right]$$

or $$C_1 = \left[\frac{\varepsilon_1\varepsilon_2}{\varepsilon_1 + \varepsilon_2}\right]\left(\frac{2A\varepsilon_0}{t}\right) = \frac{12A\varepsilon_0}{5t}$$

Similarly

$$C_2 = \frac{A\varepsilon_0\varepsilon_1}{2t} + \frac{A\varepsilon_0\varepsilon_2}{2t}$$

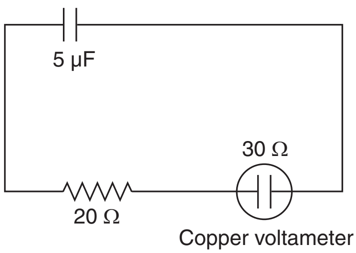
$$= \frac{A\varepsilon_0}{2t}(\varepsilon_1 + \varepsilon_2) = \frac{5A\varepsilon_0}{2t}$$

$$\frac{C_1}{C_2} = \left\{\frac{12\,A\varepsilon_0}{5t}\right\}\left\{\frac{2t}{5\,A\varepsilon_0}\right\} = \frac{24}{25}$$

$$\boxed{\frac{C_1}{C_2} = \frac{24}{25}}$$ **Ans.**

7. *A charged capacitor of 5 × 10^{-2} farad capacity is discharged through a resistor R of 20 Ω and a copper voltameter of internal resistance 30 Ω connected in series. If 4.62 × 10^{-6} kg copper is deposited, calculate the heat generated in the resistor R. Electrochemical equivalent of copper is 3.3 × 10^{-7} kg/C.*

Solution:



Let a charge q be flowing in a copper voltameter so that m kg of copper is deposited.

Faraday law gives

$$m = Zq$$

where Z is the electro-chemical equivalent of copper

$$q = \frac{m}{Z} = \frac{4.62 \times 10^{-6}}{3.3 \times 10^{-7}} = 14 \text{ coulomb}$$

Energy stored in the capacitor,

$$E = \frac{1}{2} CV^2 = \frac{1}{2}\frac{q}{V} V \frac{q}{C} = \frac{1}{2}\frac{q^2}{C}$$

$$= \frac{1}{2}\left[\frac{14^2}{5 \times 10^{-2}}\right] = 1960 \text{ J}$$

When the capacitor is discharged through a resistance R = 20 Ω and a voltameter of internal resistance 30 Ω in series, then 1960 J of energy will be produced in these resistances, in the form of heat.

Thus the heat produced in $R = 20\ \Omega$ is

$$\left[\frac{1960}{20+30}\right] = 784\ \text{J}$$

$$\boxed{E = 784\ \text{J}}\quad \textbf{Ans.}$$

8. *An electron of mass m_e initially at rest and moves through a certain distance in a uniform electric field in time t_1. A proton of mass m_p is also initially at rest, takes time t_2 to move through an equal distance in opposite direction in this uniform field.*

Find $\frac{t_2}{t_1}$.

Solution:

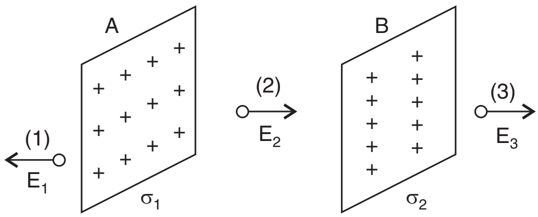
$$F_1 = m_e \frac{d}{t_1^2} \quad \text{and} \quad F_2 = m_p \frac{d}{t_2^2}$$

Also $\quad F_1 = eE = F_2$

Hence $\quad m_e \frac{d}{t_1^2} = m_p \frac{d}{t_2^2}$

$$\boxed{\frac{t_2}{t_1} = \sqrt{\frac{m_p}{m_e}}}\quad \textbf{Ans.}$$

9. *The parallel plates A and B have uniform surface densities σ_1 and σ_2 ($\sigma_1 > \sigma_2$). Obtain the values of the electric intensity in the regions (1), (2) and (3) by the principle of superposition.*



Solution:

Intensity in region (1) is

$$E_1 = \frac{\sigma_1}{2\varepsilon_0} + \frac{\sigma_2}{2\varepsilon_0} = \frac{1}{2\varepsilon_0}(\sigma_1 + \sigma_2)$$

towards left

In region (2)

$$E_2 = \frac{\sigma_1}{2\varepsilon_0} - \frac{\sigma_2}{2\varepsilon_0} = \frac{1}{2\varepsilon_0}(\sigma_1 - \sigma_2)$$

towards right

In region (3)

$$E_3 = \frac{\sigma_1}{2\varepsilon_0} + \frac{\sigma_2}{2\varepsilon_0} = \frac{1}{2\varepsilon_0}(\sigma_1 + \sigma_2)$$

towards right

Special case:

If $\sigma_1 = \sigma_2 = \sigma$ *i.e.,* we have two infinite plane sheets with equal and opposite uniform densities of charge. Then the field is non-zero only in between the two sheets and there it is constant. The electrical intensity between plates,

$$E = \frac{1}{2\varepsilon_0}[\sigma - (-\sigma)] = \frac{\sigma}{\varepsilon_0}$$

and this is independent of the distance between the sheets.

10. *If 125 drops charged to 200 volt each coalesce, what will be the potential of the bigger drop? What is the ratio of the energy of the bigger drop to the initial energy of all drops?*

Solution:

$$V = 9 \times 10^9 \times \frac{q}{r}$$

$$q = \frac{rV}{9 \times 10^9} = \frac{200\,r}{9 \times 10^9}$$

Therefore for bigger drop

$$Q = 125\ q = \frac{125 \times 200 \times r}{9 \times 10^9}$$

To find the radius R of the bigger drop,

$$\frac{4}{3}\pi R^3 = \frac{4}{3}\pi r^3 \times 125$$

$$R = 5\ r$$

Thus potential of the bigger drop

$$V = 9 \times 10^9 \times \frac{Q}{R}$$

$$= \frac{9 \times 10^9 \times 125 \times 200 \times r}{9 \times 10^9 \times 5 \times r}$$

$$\boxed{V = 5000 \text{ volt}} \quad \textbf{Ans.}$$

Energy of bigger drop

$$E_1 = \frac{1}{2}\ QV = \frac{125\, q \times 5000}{2}$$

Energy of 125 drops

$$E_2 = \frac{1}{2}\ QV \times 125$$

$$= \frac{1}{2}\ q \times 200 \times 125$$

$$\boxed{\frac{E_1}{E_2} = 25} \quad \textbf{Ans.}$$

11. *Two large sheets of charge with uniform charge densities 6.8 $\mu C/m^2$ are kept parallel to each other. Find the electric field (a) to the left of the sheets (b) between the sheets (c) to the right of the sheets.*

Solution:

Field due to positively charged sheet

$$E_1 = \frac{\sigma}{2\varepsilon_0} = \frac{\sigma_1}{2\varepsilon_0} = \frac{6.8 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}}$$

$$= 3.84 \times 10^5 \text{ N/C}$$

away from the sheet towards left.

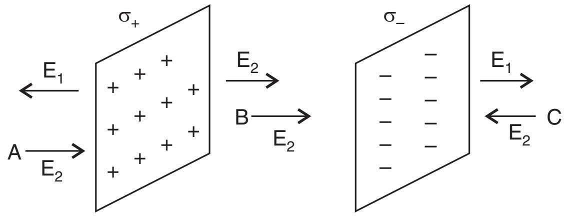
$$\boxed{E_1 = 3.84 \times 10^5 \text{ N/C}}$$

Field due to the negatively charged sheet

$$E_2 = \frac{\sigma_2}{2\varepsilon_0} = \frac{4.3 \times 10^{-6}}{2 \times 8.85 \times 10^{-12}}$$
$$= 2.43 \times 10^5 \text{ N/C}$$

$$\boxed{E_2 = 2.43 \times 10^5 \text{ N/C towards right.}}$$

Ans.



(*a*) Resultant field at *A, i.e.,* to the left of the sheets

$$E = E_1 - E_2$$
$$= (3.84 \times 10^5 - 2.43 \times 10^5)$$

towards left.

$$E = 1.41 \times 10^5 \text{ N/C towards left}$$
$$E = 1.41 \times 10^5 \text{ N/C.}$$

(*b*) Resultant field at *C*, *i.e.,* to the right of the sheets

$$E = E_1 - E_2 = 1.41 \times 10^5 \text{ N/C}$$

towards right.

$$E = 1.41 \times 10^5 \text{ N/C.}$$

(*c*) Resultant field at *B*, *i.e.,* between the sheets

$$E = E_1 + E_2$$
$$= (3.84 \times 10^5 + 2.43 \times 10^5)$$

towards right.

$$\boxed{E = 6.27 \times 10^5 \text{ N/C.}}$$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*b*)	2. (*c*)	3. (*a*)	4. (*d*)
5. (*c*)	6. (*c*)	7. (*a*)	8. (*d*)
9. (*c*)	10. (*a*)	11. (*c*)	12. (*d*)
13. (*c*)	14. (*d*)	15. (*c*)	16. (*b*)
17. (*b*)	18. (*a*)	19. (*d*)	20. (*b*)
21. (*c*)	22. (*a*)	23. (*a*)	24. (*a*)
25. (*c*)	26. (*d*)	27. (*c*)	28. (*d*)
29. (*c*)	30. (*c*)	31. (*d*)	32. (*a*)
33. (*b*)	34. (*a*)	35. (*c*)	36. (*d*)
37. (*c*)	38. (*b*)	39. (*a*)	40. (*c*)
41. (*d*)	42. (*d*)	43. (*a*)	44. (*b*)
45. (*d*)	46. (*a*)	47. (*a*)	48. (*d*)
49. (*d*)	50. (*c*)	51. (*c*)	52. (*b*)
53. (*d*)	54. (*c*)	55. (*c*)	56. (*d*)
57. (*b*)	58. (*d*)	59. (*a*)	60. (*a*)
61. (*a*).			

CHAPTER 6

CURRENT ELECTRICITY

1. If 1.5 coulomb of electricity flows through a conductor of uniform cross-section for a time of 0.5 second, then the current flowing through the conductor is
   (*a*) 2.5 A (*b*) 0.3 C
   (*c*) 3 A (*d*) 100 A/s.
2. How many electrons flowing per sec constitute a current of 1.6 ampere?
   (*a*) 1.6×10^8 (*b*) 1.6×10^{-19}
   (*c*) 10^{19} (*d*) 1000.
3. Ampere is
   (*a*) coulomb sec
   (*b*) volt/sec
   (*c*) coulomb/metre
   (*d*) coulomb/sec.
4. A coulomb is defined as the charge which when placed at a distance of 1 metre in air or vacuum from an equal and similar charge experiences a force of
   (*a*) $4\pi\,\varepsilon_0$ newton
   (*b*) $-\dfrac{4\pi}{\varepsilon_0}$ newton
   (*c*) $-\dfrac{1}{4\pi\varepsilon_0}$
   (*d*) $\dfrac{\varepsilon_0}{4\pi}$ number.
   Here ε_0 is permittivity of a free space.

5. The resistivity of a metal is
   (*a*) the resistance offered by one metre of a conductor
   (*b*) the resistance offered by a conductor of 10 metre with 2 m^2 as
   (*c*) the resistance offered by unit length of a conductor having unit area of cross-section
   (*d*) all are true.
6. If an electron moves along the circumference of a circle with a frequency ν, then the current flowing is
   (*a*) $\frac{\nu}{e}$ (*b*) $\frac{e}{\nu}$
   (*c*) $e^2\nu$ (*d*) $e\nu$.
7. Ohm's law is a basic law because
   (*a*) V does not depend on I linearly always
   (*b*) the relation between V and I depends on the sign of V for the same absolute value of I
   (*c*) at very low temperatures the resistance decreases rapidly
   (*d*) all the above are true.
8. If ρ, l and r are the resistivity, length and radius respectively of a copper wire and V and R are the p.d. and resistance, then the current in the circuit can be equated to
   (*a*) $\frac{Vr^2}{\rho l}$ (*b*) $\frac{l}{r^2}$
   (*c*) $\frac{\pi V r^2}{R\rho l}$ (*d*) $\frac{q^2}{4\pi\varepsilon_0}$.
9. A steady current flows through a metallic conductor of non-uniform cross-section. Which of the following quantities are constant along the conductor?
   (*a*) current
   (*b*) current density

(*c*) drift velocity

(*d*) potential gradient.

10. The e.m.f. of a cell is equal to the potential difference between its terminals when it is in the open circuit *i.e.*,

    (*a*) when a current of any value is drawn from the cell

    (*b*) when a current of 2 amp current is drawn from the cell

    (*c*) when no current is drawn from the cell

    (*d*) all the above are true.

11. If the temperature changes, Ohm's law does not hold good because the resistance R of a conductor changes with increase of temperature. This is

    (*a*) true (*b*) false.

12. Which type of the following sources of energy is required to maintain a p.d. in an electric circuit?

    (*a*) chemical reactions as in cells

    (*b*) rotating a coil in a magnetic field

    (*c*) by converting light energy due to electrical energy

    (*d*) all the above three sources.

13. The unit of electrical conductivity is

    (*a*) ohm metre

    (*b*) metre/ohm

    (*c*) ohm/metre

    (*d*) all the above are wrong.

14. The resistance R of a conductor depends on

    (*a*) the density of the metal

    (*b*) colour of the metal

    (*c*) molecular weight of the metal

    (*d*) all the above are false.

15. The microscopic relation for resistivity of a metal is

(*a*) $\rho = \dfrac{m}{ne^2}$ (*b*) $\rho = \dfrac{ne^2}{m}$

(*c*) $\rho = \dfrac{\tau}{m}$ (*d*) $\rho = \dfrac{m}{ne^2 \tau}$

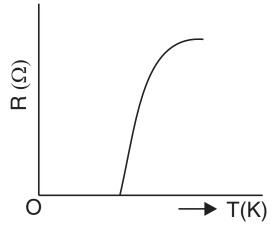
where τ is the relaxation time.

16. Dimensions of resistivity, are

(*a*) ML^3TA (*b*) $ML^2T^2A^2$

(*c*) ML^2AT (*d*) $ML^3T^{-3}A^{-2}$.

17. Actually the resistances of a superconductor does not fall sharply at a particular temperature, but in a small range of temperature as shown in figure. This is because of



(*a*) absence of impurities

(*b*) the crystal structure

(*c*) presence of impurities

(*d*) none of the above.

18. If R_1 and R_2 are the resistances of a given conductor at T_1K and T_2K, then the temperature coefficient of resistance of the metal α is

(*a*) $\dfrac{(R_2 - R_1)}{(T_2 - T_1)}$ (*b*) $\dfrac{R_2 / R_1}{R_1 (T_1 + T_2)}$

(*c*) $\dfrac{(R_2 - R_1)}{R_1 (T_2 - T_1)}$ (*d*) $\dfrac{R_1}{(R_2 - R_1)}$.

19. The resistance of a wire of uniform diameter d and length l is R. The resistance of another wire of the same material but of diameter $2d$ and length $4l$ will be
(*a*) $2R$ (*b*) R
(*c*) R^2 (*d*) $\frac{R}{2}$.

20. Work done in carrying a charge Q through a potential V is
(*a*) QV (*b*) $\frac{Q}{V}$
(*c*) $\frac{V}{Q}$ (*d*) $\frac{I}{V}$.

21. The low temperature coefficient of a material is the one in which the resistance
(*a*) increases slowly with decrease of temperature
(*b*) increases slowly with increase of temperature
(*c*) increases with increase of temperature
(*d*) increases with decrease of temperature.

22. Kirchhoff's laws are presented as
(*a*) $\Sigma I = 1, \Sigma IR = 0$
(*b*) $\Sigma IR = 0, \Sigma I = \Sigma E$
(*c*) $\Sigma I = 0, \Sigma IR = \Sigma E$
(*d*) $\Sigma R = 0, \Sigma I = 0$.

23. Faraday's first law is (where Z is the electro-chemical equivalent of the substance)
(*a*) $Z = \frac{q}{m}$ (*b*) $Z = \frac{4.2}{q}$
(*c*) $Z = \frac{q^2}{m}$ (*d*) $m = Zq$.
where q is the charge, m is the mass deposited.

24. The root mean square velocity of the electrons at 27°C in a metal is approximately
(*a*) 10^8 m/s (*b*) 10 m/s
(*c*) 10^5 m/s (*d*) 0.1 m/s.

25. The heat produced in a resistor is
(*a*) IRt (*b*) I^2Rt
(*c*) IR^2t (*d*) $\frac{I}{Rt}$.

26. One Faraday is
(*a*) 965 C/g mol
(*b*) 9650 C/g mol
(*c*) 2140 C/g mol
(*d*) 96500 C/g mol.

27. The force experienced by an electron of charge 1.6×10^{-19} coulomb is an electric field is 3.2×10^{-18} newton. The strength of the electric field is
(*a*) 200 V/m (*b*) 2 V/m
(*c*) 0.2 V/m (*d*) 20 V/m.

28. The critical temperature of the superconductor lead is
(*a*) 17.2 K (*b*) 7.1 K
(*c*) 22.21 K (*d*) 117.2 K.

29. The cause for the resistance in the conductor is due to
(*a*) vibration of electrons
(*b*) collisions of electrons on atoms
(*c*) magnitude of the charge of the electron
(*d*) none of these.

30. The current flowing through a conductor depends on
(*a*) quantity of charge carriers
(*b*) charge and voltage
(*c*) resistance and voltage
(*d*) resistance alone.

31. Resistance of an electric bulb varies
(*a*) inversely as its power
(*b*) directly as its power
(*c*) remains constant
(*d*) all are false.

32. The force on a charged particle moving inside a magnetic field is called magnetic Lorentz force. The magnitude and direction of the Lorentz force is
(*a*) $\overline{F} = \dfrac{q}{\vec{V}}$ (*b*) $\dfrac{q}{\vec{B}} = F$
(*c*) $\vec{F} = \dfrac{q}{\vec{V} \times \vec{B}}$ (*d*) $\vec{F} = q\ (\vec{V} \times \vec{B})$.

33. The material having negative temperature coefficient of resistance is
(*a*) copper (*b*) aluminium
(*c*) silicon (*d*) water.

34. A heater of 500 watt was used for 2 hours everyday in February 2004. The cost of a unit is Rs. 2. The bill for the month of February 2004 is
(*a*) Rs. 29 (*b*) Rs. 28
(*c*) Rs. 58 (*d*) Rs.116.

35. A current of 2 amp through a circular coil with 100 turns and diameter 20 cm produces a magnetic induction of 2×10^{-2} tesla at the centre. The number of turns required to produce a field of 4×10^{-2} tesla in the same coil is
(*a*) 50 turns (*b*) 100 turns
(*c*) 75 turns (*d*) 200 turns.

36. An electric filament bulb is labeled 250 V, 100 W. The resistance of the filament is
(*a*) 100 Ω (*b*) 625 Ω
(*c*) 525 Ω (*d*) 725 Ω.

37. A proton is moving perpendicular to a magnetic field

(*a*) gains momentum in opposite direction of motion

(*b*) the proton did not gain any momentum

(*c*) the magnetic field will not affect the motion of proton

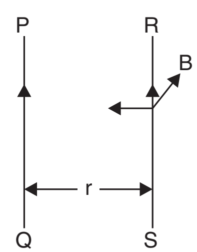
(*d*) the proton bends to an arc of circle.

38. If a charged particle say an electron is moving in a circular path of radius r subject to a magnetic field B in a perpendicular direction, then the centripetal and Lorentz force equaled by the are given by the relation

(*a*) $B = \frac{mv^2}{r}$ (*b*) $Be = \frac{m}{r}$

(*c*) $Ber = mv$ (*d*) $Bev = \frac{mv^2}{r}$.

39. PQ and RS are two conductors r metre apart carrying current I_1 and I_2 ampere respectively as in figure. The force experienced by the conductor RS per unit length is



(*a*) $\frac{I_1 I_2}{r}$ (*b*) $\frac{I_1 \times 1.6 \times 10^6}{I_2 r}$

(*c*) $\frac{2\pi}{\mu_0} \frac{2}{I_1}$ (*d*) $\frac{2 \times 10^{-7}\ I_1 I_2}{r}$.

40. The quantity of electricity passing, through unit area of copper for unit time is
(*a*) current density, $j = nev_d$
(*b*) current, $i = nev_d$
(*c*) charge, $q = ij$
(*d*) potential, $V = n^2e$.

40A. When 2 ampere current passes through a conductor of uniform cross-section of 10^{-3} m^2 for 1 sec with a drift velocity of 6×10^4 m/s, the number of free electrons/m^3 is
(*a*) 1.5×10^7 (*b*) 1.2×10^{18}
(*c*) 2×10^7 (*d*) 1000.

41. The probability of an electron colliding with an atom is higher if
(*a*) length and radius of the conductor are small
(*b*) length is small
(*c*) radius is large
(*d*) length of the conductor is higher and radius is smaller.

42. Constantan, nichrome and manganin are used for making standard resistance because their
(*a*) resistivity is low
(*b*) density is high
(*c*) resistivity is high
(*d*) temperature coefficient of resistance is high.

43. A proton is 1849 times heavier than electron. At 300 K, the average random velocity of the electron is
(*a*) 143 times that of the proton
(*b*) 123 times that of the proton
(*c*) 1849 times that of the proton
(*d*) 43 times that of the proton.

44. Two metallic wires of equal length of different materials say *x* and *y* have equal resistance. The ratio of the radii of the wires is 1 : 2 respectively. The ratio of the specific resistances of the materials of the wires is

(*a*) 1 : 4 (*b*) 1 : 1

(*c*) 2 : 4 (*d*) 1 : 0.5.

45. Though a number of charge carriers in a given volume remains the same and independent in a metal, the resistivity of a metal increases as the temperature increases because

(*a*) the mobility remains constant

(*b*) the mobility of the electron increases as temperature increases

(*c*) the mobility of the electron decreases as the temperature increases

(*d*) all the above are false.

46. Which device can convert all electrical energy into heat

(*a*) radiator (*b*) convertor

(*c*) generator (*d*) resistor.

47. How much of steady current can be drawn from an accumulator of capacity 80 AH?

(*a*) 4 ampere for 20 hours

(*b*) 50 ampere for 4 hours

(*c*) 2 ampere for 100 hours

(*d*) 2 ampere for 20 hours.

48. Why does the pointer of a dead beat galvanometer give a steady deflection?

(*a*) its magnetic field is very strong

(*b*) its pointer is light

(*c*) its frame is made of ebonite

(*d*) eddy currents are produced in the conducting from over which the coil is wound.

49. The current density in a conductor is directly proportional to the field strength. The corresponding constant of proportionality is

(*a*) ρ (*b*) ρ^2

(*c*) $\sqrt{\rho}$ (*d*) $\frac{1}{\rho}$.

where ρ is the resistivity of the conductor.

50. The resultant flow of a current in the absence of an electric field in a conductor is

(*a*) minimum

(*b*) zero

(*c*) maximum

(*d*) has a negative value.

51. The relation connecting the coefficient of thermal conductivity and electrical conductivity is known as

(*a*) Boltzmann's law

(*b*) Kirchhoff's law

(*c*) Ohm's law

(*d*) Wiedemann-Franz law.

52. The magnetic field at a point on the axial line distance x from the centre of a coil of radius a (carrying a current) varies as

(*a*) $B \propto (a^2 + x^2)^{3/2}$

(*b*) $B \propto \sqrt{a^2 - x^2}$

(*c*) $B \propto \frac{1}{(a^2 - x^2)^{3/2}}$

(*d*) $B \propto \sqrt{a^2 - x^2}$.

53. If a power of 50 watt is being supplied across a p.d. of 250 volt, current flowing is

(*a*) 0.1 A (*b*) 0.2 A

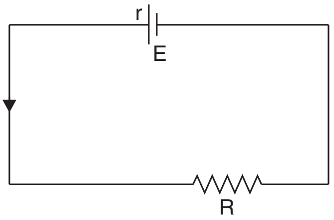
(*c*) 2 A (*d*) 5 A.

54. 1°C rise in temperature is observed in a conductor by passing a certain current.

If the current is doubled, then the rise of temperature is

(*a*) 4°C (*b*) 16°C
(*c*) 2°C (*d*) 12°C.

55. In the figure r is the internal resistance of the cell and R is the resistance in the circuit, then the terminal p.d. and the potential drop (voltage lost) are



(*a*) $\frac{(R+r)}{ER}$ and $\frac{Er^2}{R+r}$

(*b*) $\frac{(R+r)^2}{ER}$ and $\frac{E^2 r}{R+r}$

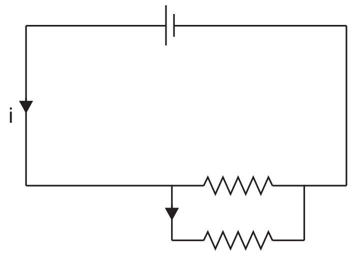
(*c*) $\frac{ER}{(R+r)}$ and $\frac{Er}{(R+r)}$

(*d*) $\frac{E-R}{(R+r)}$ and $\frac{E}{R}$.

56. When a Daniell cell of e.m.f. 1.08 volt is connected to an external resistor of 2 Ω, the p.d. falls to 0.9 volt. The internal resistance of the cell is

(*a*) 1 Ω (*b*) 0.5 Ω
(*c*) 0.6 Ω (*d*) 0.4 Ω.

57. Two wires of resistance 3 Ω and 6 Ω are connected in parallel with a battery of e.m.f. 6 volt and internal resistance 1 Ω. Calculate the current through each resistance following the figure given below:



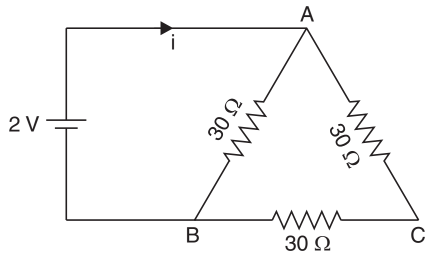
(*a*) 7.12 A, 0.1 A

(*b*) 6.2 A, 0.2 A

(*c*) 1.33 A, 0.67 A

(*d*) 1 A, 0.5A.

58. Find the value of the current in the circuit shown in figure



(*a*) 0.1 A (*b*) 1.2 A

(*c*) 4 A (*d*) 20 A.

59. Electron in hydrogen atom revolves around the nucleus with frequency 6×10^{14} Hz. The current is in the orbit is

(*a*) 9.6 A (*b*) 9.6×10^{2} A

(*c*) 9.6×10^{-5} A (*d*) 9.6×10^{5} A.

60. An electron is describing circular path in a magnetic field 10^{-4} tesla. The frequency of revolution of the electron is

(*a*) 2.8×10^{6} Hz

(*b*) 1.8×10^{-6} Hz

(*c*) 8.8×10^{2} Hz

(*d*) 1000 Hz.

61. A galvanometer can be converted into a voltmeter by connecting a
(*a*) high resistance in series
(*b*) low resistance in parallel
(*c*) low resistance in series
(*d*) high resistance in parallel.

62. The principle of a transformer is
(*a*) self induction
(*b*) joule heating
(*c*) mutual induction
(*d*) Ohm's law.

63. The frequency of the domestic power supply is of the order of
(*a*) 220 Hz (*b*) 50 Hz
(*c*) 100 Hz (*d*) 150 Hz.

64. A storage battery of e.m.f. 8 volt and internal resistance 0.5 Ω is being charged by a 120 volt d.c. supply using a series resistor of 15.5 Ω. The terminal voltage of the battery during charging is
(*a*) 1.52 V (*b*) 6.2 V
(*c*) 2 V (*d*) 11.5 V.

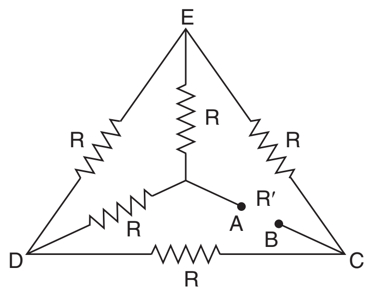
65. In a potentiometer set-up a cell of e.m.f. 1.25 volt gives a balance point at 0.35 m length of the wire. If the cell is replaced by another cell, and the balance point shifts to 0.63 m; what is the e.m.f. of the second cell?
(*a*) 1.25 V (*b*) 2.25 V
(*c*) 3.25 V (*d*) 4.25 V.

66. A battery of e.m.f. 2 volt and negligible internal resistance is connected to a 10 m long potentiometer wire of resistance 20 Ω. Find the length of the wire balancing a Daniell cell of e.m.f. 1.08 volt.

(*a*) 5.4 m (*b*) 6.4 m

(*c*) 7.5 m (*d*) 8.5 m.

67. If each of the resistance in the network is R, what is the resistance R' between the terminals A and B?



(*a*) $R' = \dfrac{R}{2}$ (*b*) $R' = R$

(*c*) $R' = 2R$ (*d*) $R' = \dfrac{2}{R}$.

68. A 500 watt heater is designed to operate on 220 volt line. By what percentage the heat output drop if the p.d. goes to 160 volt?

(*a*) 42% (*b*) 36%

(*c*) 17% (*d*) 28%.

69. A 100 watt bulb and 500 watt bulb are joined in parallel to the main supply voltage. Which bulb will draw more current?

(*a*) 500 watt bulb

(*b*) 100 watt bulb

(*c*) both will draw some current.

70. When a straight conductor (of length 2 metre) carrying a current of 5 A is placed in a uniform magnetic field of 0.8 tesla at an angle of 30° with the magnetic field, the force on the conductor is

(*a*) 8 N (*b*) 4 N
(*c*) 16 N (*d*) 160 N.

71. A galvanometer scale is divided into 100 equal divisions and a current of 2.5 mA required to produce a full scale division. The current required to produce a deflection of 40 division is
(*a*) 4 mA (*b*) 3 mA
(*c*) 2 mA (*d*) 1 mA.

72. The acceleration of an electron in an electric field of intensity 100 kV/m
(*a*) 100×10^2 m/s^2
(*b*) 0.01×10^{15} m/s^2
(*c*) 1.76×10^{16} m/s^2
(*d*) 11.21×10^{15} m/s^2.

73. Current is flowing through a conductor of resistance 10 Ω. Indicate in which of the following cases maximum heat will be generated
(*a*) 4.9 amp current for 3 minutes
(*b*) 3.9 amp current for 3 minutes
(*c*) 1.0 amp current for 4 minutes
(*d*) 1 amp current for 5 minutes.

74. The resistance of the shunt to be used to divert 60% of the total current is 200 Ω. The resistance of the galvanometer is approximately
(*a*) 733 Ω (*b*) 33 Ω
(*c*) 3.3 Ω (*d*) 133 Ω.

75. A superconductor at superconducting state
(*a*) requires larger power to carry even small current
(*b*) has no thermal losses but has high resistivity
(*c*) has no resistivity and no thermal losses associated with the passage of large current
(*d*) all the above are true.

76. The resistance of moving coil galvanometer is 150 Ω and its full scale deflection current is 0.5 mA. By connecting a series resistance of 950 Ω, the galvanometer can be converted into a voltmeter to read up to

(*a*) 0.55 V (*b*) 2 V
(*c*) 1.6 V (*d*) 6 V.

77. The dielectric constant of the three materials, water, mica and glass are respectively

(*a*) 80, 2 and 5.2
(*b*) 200, 100.2 and 7
(*c*) 800, 14.6 and 2
(*d*) 200, 8.6 and 15.2.

78. A 4 μF capacitor is charged by a 200 volt supply. It is disconnected and then connected to an uncharged 2 μF capacitor. The loss of energy on sharing is

(*a*) 36.8×10^{-3} J
(*b*) 2.1×10^{-2} J
(*c*) 26.7×10^{-3} J
(*d*) 100 J.

79. The heat developed in a resistor due to the flow of a current of 10 ampere for one minute is 18000 joule. The resistance of the resistor is

(*a*) 6 Ω (*b*) 12 Ω
(*c*) 5 Ω (*d*) 3 Ω.

80. The resistance of ebonite

(*a*) exponentially decreases as the temperature increases
(*b*) increases with increase of temperature
(*c*) does not change with temperature
(*d*) tends to infinity as temperature decreases.

81. If the resistance of a circuit having 12 volt source is increased by 4 Ω, the current drops by 0.5 A. The original resistance is

(*a*) 12 Ω (*b*) 6 Ω

(*c*) 8 Ω (*d*) 15 Ω.

82. The dielectric constant of a medium is the

(*a*) ratio of the electrostatic force between two point charges at certain distance apart in free space to the electrostatic force between same charges kept at the same distance apart in the medium.

(*b*) it is the ratio of the capacitance of a given capacitor with the material filling the entire space between the plates to the capacitance of the same capacitor in vacuum.

(*c*) ratio of the resistances in the medium to that in vacuum

(*d*) none of these.

83. Internal resistance of a cell depends upon

(*a*) the concentration of the electrolyte used in the cell

(*b*) distance between its electrodes

(*c*) the area of electrodes immersed in the electrolyte

(*d*) all the above are true.

84. When no resistance is connected across a cell, p.d. between its terminals is E. What will be the potential drop across its terminal if a resistance $R = r$ (where r is the internal resistance) is connected across?

(*a*) $2E$ (*b*) $\frac{E}{2}$

(*c*) $\frac{E}{4}$ (*d*) $\frac{E}{3}$.

85. Maganin wires are used in resistance boxes because
(*a*) its resistivity is low and temperature coefficient is high
(*b*) its temperature coefficient of resistance is very low but resistivity is high
(*c*) it is a semiconductor
(*d*) all the above are false.

86. Masses of three wires of the same material are in the ratio 1 : 2 : 3 and the lengths in the ratio 3 : 2 : 1. Electrical resistance of these wires will be in the ratio
(*a*) 27 : 6 : 1 (*b*) 1 : 27 : 6
(*c*) 1 : 2 : 3 (*d*) 27 : 54 : 2.

87. If a metallic rod has no p.d. applied across it, then the mean velocity of free electron is
(*a*) proportional to absolute temperature
(*b*) inversely proportional to T
(*c*) directly proportional to $\sqrt{T}$
(*d*) directly proportional to T^2.

88. A copper wire is subjected to a p.d. of V volt. If the p.d. is doubled
(*a*) the drift velocity is doubled
(*b*) the drift velocity remains the same
(*c*) the drift velocity is reduced to $\left(\frac{1}{4}\right)$th of the initial value
(*d*) the drift velocity is increased to 5 times the initial value.

89. A copper wire of length l and diameter d subjected to a p.d. of V volt. If both the length and diameter are halved keeping V constant, then the drift velocity is
(*a*) halved
(*b*) doubled

(*c*) tripled

(*d*) reduced to zero.

90. A current of 2 ampere is passing through a metal having an area of cross-section 4×10^{-6} m^2. If the drift velocity is 6.2×10^5 m/s, the number of free electrons/mm^3 is

(*a*) 717×10^6 (*b*) 2×10^{17}

(*c*) 5×10^{19} (*d*) 200×10^3

91. A steady current is passing through a linear conductor of non-uniform cross-section. The current density in the conductor is

(*a*) independent of the area of cross-section

(*b*) inversely proportional to the area of cross-section

(*c*) inversely proportional to the square of the area of cross-section

(*d*) all the above are false.

92. A copper wire of resistance R_0 is stretched the its length is increased to n times its original length. The new resistance is

(*a*) $\dfrac{R_0}{n^2}$ (*b*) $R_0 n$

(*c*) $\dfrac{R_0}{n}$ (*d*) $R_0 n^2$.

93. Null point of a potentiometer wire will shift beyond the potential wire if

(*a*) battery in the main circuit is low in e.m.f.

(*b*) battery in the main circuit is high in e.m.f.

(*c*) the length of the wire is small

(*d*) the length of the wire is high.

94. If a given piece of wire of length and cross sectional area A and resistance R, is

stretched uniformly to a length of $2l$. The new resistance is

(*a*) $2R$ (*b*) $3R$

(*c*) $4R$ (*d*) $6R$.

95. The potential gradient along the length of a uniform wire is 5 volt/m. There are two points on the wire at a distance of 20 cm and 40 cm from the initial end of the wire. The potential defference between these points is

(*a*) 0.5 V (*b*) 0.1 V

(*c*) 1 V (*d*) 2 V.

96. Two unequal resistances are connected in series across a battery. Which of the following statements is true?

(*a*) potential difference across each resistance is same

(*b*) potential difference across smaller resistance is lower

(*c*) potential difference across smaller resistance is higher

(*d*) potential difference can be higher or lower in any resistance.

97. The potential difference between the terminals of a cell is

(*a*) greater than its e.m.f. if the cell is being discharged

(*b*) greater than its e.m.f. if the cell is being charged

(*c*) less than its e.m.f. if the cell is being discharged

(*d*) less than its e.m.f. if the cell is being charged

(*e*) is equal to its e.m.f. if the cell is in open circuit.

98. An ammeter of resistance 0.16 Ω is shunted with resistance of 0.04 Ω. The reading is 8 amp. The current in the main circuit is

(*a*) 20 A (*b*) 2 A
(*c*) 10 A (*d*) 40 A.

99. Two resistors R_1 and R_2 may be connected either in series or in parallel across a battery of zero internal resistance. It is required that the joule heating for the parallel combinations be five times that for the series combination. If R_1 is 100 Ω, R_2 is
(*a*) 162 Ω or 18 Ω
(*b*) 268 Ω or 2 Ω
(*c*) 100 Ω or 10 Ω
(*d*) 262 Ω or 38 Ω.

100. Two resistances 400 Ω and 800 Ω are connected is series with a 6 volt battery. To measure the current in the circuit, an ammeter of 10 Ω resistance is used. The reading in the ammeter is
(*a*) 5.96 mA (*b*) 1.92 mA
(*c*) 2.6 mA (*d*) 4.96 mA.

PROBLEMS AND SOLUTIONS

1. *Let $\bar{c}$ be the root mean square velocity of free electron in copper at 27°C. If the cross-sectional area is 2 mm^2 and a current of 30 ampere is flowing, calculate $\bar{c}$. (Given concentration of electrons as $8.5 \times 10^{28}/m^3$ and mass of electron is 9.1×10^{-31} kg.)*

Solution:

$$\bar{c} = \sqrt{\frac{3k_BT}{m}}$$

$$= \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{9.1 \times 10^{-31}}}$$

$$\bar{c} = 1.1 \times 10^5 \text{ m/s}$$

$$j = nev_d$$

or $$v_d = \frac{j}{ne}$$

$$= \frac{15 \times 10^6}{1.6 \times 10^{-19} \times 8.5 \times 10^{28}}$$

$$= 1.1 \times 10^{-3}$$

$$= \frac{\bar{c}}{v_d} = \frac{1.1 \times 10^5}{1.1 \times 10^{-3}} = 10^8$$

$$\boxed{\bar{c} = 10^8 \times v_d}$$ **Ans.**

2. *The electrical conductivity of copper is 1.5 times that of aluminium and the area of cross-section of the copper wire is half that of aluminium wire. If the lengths are same in both the cases, calculate the resistance of copper in terms of that of aluminium.*

Solution:

$$\sigma_{cu} = \frac{l_{cu}}{a_{cu}\ R_{cu}} = \frac{l_{cu}}{(a_{al/2})\ R_{cu}} = \frac{2l_{cu}}{a_{al}\ R_{cu}}$$

with $l_{cu} = l_{al}$

Thus $$\sigma_{al} = \frac{l_{al}}{a_{al}\ R_{al}}$$

$$\frac{\sigma_{cu}}{\sigma_{al}} = \frac{2R_{al}}{R_{cu}}$$

$$\frac{1.5\ \sigma_{al}}{\sigma_{al}} = \frac{2R_{al}}{R_{cu}}$$

$$R_{cu} = \frac{2R_{al}}{1.5}$$

$$\boxed{R_{cu} = 1.3\ R_{al}}$$ **Ans.**

3. *A copper wire is stretched to make it 0.2% longer. The percentage change in resistance is 0.4%. How is this obtained?*

Solution:

$$R_1 = \frac{l_1\rho}{A_1} \quad \text{and} \quad R_2 = \frac{l_2\rho}{A_2}$$

$$\frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right)\left(\frac{A_1}{A_2}\right)$$

But $\quad A_1 l_1 = A_2 l_2 \quad \text{or} \quad \frac{A_1}{A_2} = \frac{l_2}{l_1}$

Hence $\quad \frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right)^2$

For 100 metre increase is 0.2

For l_1 metre increase will be

$$\frac{0.2\, l_1}{100} = 0.002\, l_1$$

Hence $l_1 + 0.002 l_1 = l_1(1 + 0.002)$

$$= 1.002 l_1$$

or $\quad l_2 = 1.002 l_1$

Thus $\quad \frac{R_2}{R_1} = \left(\frac{l_2}{l_1}\right)^2 = 1.002^2 = 1.004$

$$\frac{R_2}{R_1} - 1 = 1.004 - 1 = 0.004$$

$$\frac{(R_2 - R_1)}{R_1} = 0.004$$

$$\boxed{\left(\frac{R_2 - R_1}{R_1}\right) \times 100 = 0.4\%} \quad \textbf{Ans.}$$

4. *Two coils have combined resistance of 8 Ω when connected in parallel. Calculate the resistances. (The effective resistance when connected in series is 1.5 Ω).*

Solution:

$$R_1 + R_2 = 8$$

and $$\frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2} = \frac{8}{R_1 R_2}$$

Thus $$\frac{8}{R_1 R_2} = \frac{1}{1.5}$$

or $$R_1 R_2 = 12\ \Omega$$

Also $$(R_1 - R_2)^2 = (R_1 + R_2)^2 - 4\,R_1 R_2$$
$$= 8^2 - 4 \times 12 = 16$$

$$R_1 - R_2 = 4$$

and $R_1 + R_2 = 8$

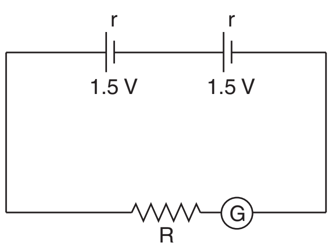
or $2R_1 = 12$, $R_1 = 6$

Hence $R_2 = 2$

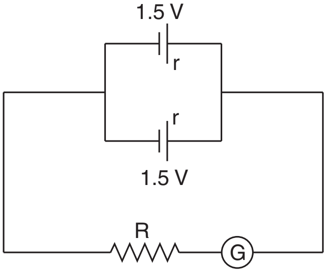
$$\boxed{R_1 = 6\ \Omega \text{ and } R_2 = 2\ \Omega}$$ **Ans.**

5. *A galvanometer together with an unknown resistance in series is connected across two identical cells each of 1.5 volt. When the cells are connected in series the galvanometer records a current of 1 ampere and when the cells are in parallel, the current is 0.6 ampere. What is the internal resistance of the cell?*

Solution:



(a)



(b)

In circuit (a)

$$i = \frac{1.5 + 1.5}{G + R + 2r} = 1$$

$(G + R + 2r) = 3\ \Omega$ ...(1)

In circuit (b), the total effective resistance of the cell is given by

$$\frac{1}{r_1} = \frac{1}{r} + \frac{1}{r} = \frac{2}{r}\ ; \quad \text{or} \quad r_1 = \frac{r}{2} = 0.5r$$

Effective e.m.f. = 1.5 volt

$$0.6 = \frac{1.5}{G + R + 0.5r}$$

$$G + R + 0.5r = \frac{1.5}{0.6} = 2.5\ \Omega \qquad \text{...(2)}$$

Eqn. (1 – 2) is

$$2r - 0.5r = 3 - 2.5 = 0.5$$

$$1.5r = 0.5$$

$$\boxed{r = 0.333\ \Omega} \qquad \textbf{Ans.}$$

6. *The number of electrons passing per minute through an electric bulb of 60 watt, 200 volt is approximately 10^{20}. Prove this.*

Solution:

$$I = \frac{P}{V} = \frac{6.0}{220} = \frac{3}{11} \text{ ampere}$$

$$Q = I \,.\, t = \frac{3 \times 60}{11} = \frac{180}{11} \text{ coulomb}$$

But $Q = ne; \; n = \dfrac{Q}{e} = \dfrac{180}{11 \times 1.6 \times 10^{-19}}$

$\boxed{n = 10^{20}}$ **Ans.**

7. *If the resistance of a circuit having 12 volt source is increased by 4 Ω, the current drops by 0.5 A. Calculate the original resistance.*

   Solution:

$$\frac{12}{R} = i \quad \text{and} \quad \frac{12}{R+4} = i - 0.5$$

i.e.,
$$\frac{12}{R+4} = \frac{12}{R} - 0.5$$

$$\frac{1}{R+4} = \frac{1}{R} - \frac{0.5}{12}$$

$$\frac{1}{R+4} - \frac{1}{R} = -\frac{1}{24}$$

$$\frac{R - R - 4}{R(R+4)} = -\frac{1}{24}$$

$$\frac{-4}{R^2 + 4R} = -\frac{1}{24}$$

$$R^2 + 4R - 96 = 0$$

$$R = \frac{-4 \pm \sqrt{16 + 384}}{2} = \frac{-4 + 20}{2} = 8$$

$\boxed{R = 8 \ \Omega}$ **Ans.**

8. *It is easier to start a car on a warm day than on a chilly day. Why?*

   Solution:

   The internal resistance of a battery with decrease of temperature. The starter has to draw a large current to start the car. Since, the internal resistance of the battery is greater on the chilly day, it cannot supply large current. So it is easier to start a car on a warm day than on a chilly day.

9. *Why do light of a car dim when the starter is operated?*

Solution: The starter draws a large current from the supply initially. This lowers the voltage of the supply from a moment. So, the light of a car becomes dim for a moment when the car is started.

10. *A 5°C rise in temperature is observed in a conductor by passing a current. When the current is doubled the rise in temperature will be approximately 20°C. Work out the details.*

Solution:

$$mST = I^2Rt$$

i.e., $$mS \times 5 = I^2Rt$$

$$mS \times x = 4I^2Rt$$

$$\frac{x}{5} = 4; \; x = 20$$

$$\boxed{x = 20°\text{C}} \quad \textbf{Ans.}$$

11. *If R_1 and R_2 are the filament resistances of 200 W and 100 W bulbs respectively. Find the relation between R_1 and R_2. (Both are designed to run at the same voltage).*

Solution:

$$P = \frac{V^2}{R} \; ; P_1 = \frac{V^2}{R_1} \text{ and } P_2 = \frac{V^2}{R_2}$$

$$\frac{P_1}{P_2} = \frac{R_2}{R_1} = \frac{200}{100} = 2$$

$$R_2 = 2R_1$$

$$\boxed{R_2 = 2R_1} \quad \textbf{Ans.}$$

12. *Two heating wires of equal lengths are first connected in series and then is parallel. Calculate the ratio of heat produced in the two cases.*

Solution:

$$H_1 = \frac{V^2}{R_1} \text{ in series and so } R_1 = R + R = 2R$$

$$H_2 = \frac{V^2}{R_2} \text{ in parallel and } \frac{1}{R_2} = \frac{1}{R} + \frac{1}{R} = \frac{2}{R}$$

or $\quad R_2 = \frac{R}{2} = 0.5R$

$$H_1 = \frac{V^2}{2R} \quad \text{and} \quad H_2 = \frac{V^2}{R_2} = \frac{V^2}{0.5R}$$

$$\frac{H_1}{H_2} = \frac{1 \times 0.5}{2} = 0.25 = \frac{1}{4}$$

$$\boxed{\frac{H_1}{H_2} = \frac{1}{4}} \quad \textbf{Ans.}$$

13. *When a high power, geyser is on, the light of bulbs in the house becomes dim. Why?*

Solution:

More current flows through the heater from the mains. Hence there is considerable potential drop along the wires coming from the mains. So lights become dim.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*c*)	3. (*d*)	4. (*c*)
5. (*c*)	6. (*d*)	7. (*d*)	8. (*c*)
9. (*a*)	10. (*c*)	11. (*a*)	12. (*d*)

13. (*d*)	14. (*d*)	15. (*d*)	16. (*c*)
17. (*c*)	18. (*c*)	19. (*b*)	20. (*a*)
21. (*b*)	22. (*c*)	23. (*d*)	24. (*c*)
25. (*b*)	26. (*d*)	27. (*d*)	28. (*b*)
29. (*b*)	30. (*c*)	31. (*a*)	32. (*c*)
33. (*c*)	34. (*c*)	35. (*d*)	36. (*b*)
37. (*d*)	38. (*d*)	39. (*a*)	40. (*c*)
40A. (*b*)	41. (*d*)	42. (*c*)	43. (*d*)
44. (*a*)	45. (*c*)	46. (*d*)	47. (*a*)
48. (*d*)	49. (*d*)	50. (*b*)	51. (*d*)
52. (*a*)	53. (*b*)	54. (*a*)	55. (*c*)
56. (*d*)	57. (*c*)	58. (*a*)	59. (*c*)
60. (*a*)	61. (*c*)	62. (*b*)	63. (*b*)
64. (*d*)	65. (*b*)	66. (*a*)	67. (*c*)
68. (*b*)	69. (*a*)	70. (*b*)	71. (*d*)
72. (*b*)	73. (*a*)	74. (*d*)	75. (*c*)
76. (*a*)	77. (*a*)	78. (*c*)	79. (*d*)
80. (*b*)	81. (*c*)	82. (*b*)	83. (*d*)
84. (*b*)	85. (*b*)	86. (*a*)	87. (*c*)
88. (*a*)	89. (*a*)	90. (*c*)	91. (*b*)
92. (*d*)	93. (*a*)	94. (*d*)	95. (*c*)
96. (*b*)	97. (*c*)	98. (*d*)	99. (*d*)
100. (*d*).			

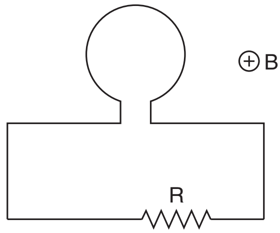
CHAPTER 7

ELECTROMAGNETIC INDUCTION

1. A coil having inductance of 0.14 henry and resistance 2 ohm is connected across 110 volt at 25 Hz. The current in the coil is approximately

   (*a*) 7.2 A (*b*) 8.2 A
   (*c*) 1 A (*d*) 4.4 A.

2. The magnetic flux in the loop shown is perpendicular to the coil and into the plane of the paper. This is given by $\phi = 6t^2 + 7t + 1$, where ϕ is in milli-weber and t in sec. The induced e.m.f. in 2 second is



   (*a*) 3.1 mV (*b*) 2 V
   (*c*) 31 mV (*d*) 21 mV.

3. The mechanical energy spent by the external agency is converted into electrical energy stored in the coil. This relates to

   (*a*) Ohm's law
   (*b*) Coulomb's law
   (*c*) Lenz's law
   (*d*) Newton's law of motion.

4. A magnetic field of induction 10 tesla acts along the axis of a coil of area 10m^2 with 20 turn. The magnetic flux linked with the coil is
(*a*) 1000 turn (*b*) 50 turn
(*c*) 500 turn (*d*) 2000 turn.

5. The dimensions of 'self inductance' and 'magnetic flux' are
(*a*) MLT^{-2} and $ML^2T^{-1}A^{-1}$ respectively
(*b*) $ML^2T^{-2}A^{-2}$ and $ML^2T^{-2}A^{-1}$ respectively
(*c*) $M^2L^{-1}T^{-1}$ and $M^2L^2T^{-2}$ respectively
(*d*) $MT^{-2}A^{-1}$ and M^2LT respectively.

6. An alternating e.m.f. is represented by the equation $e = 353.3 \sin (100\ \pi t)$. Find the amplitude and the frequency of the alternating voltage
(*a*) 172, 25 Hz
(*b*) 3533, 75 Hz
(*c*) 353.3, 50 Hz
(*d*) 120, 100 Hz.

7. A fan blade of length '*a*' rotates with frequency ν perpendicular to a magnetic field *B*. Find the p.d. between the centre and the end of the blade
(*a*) $B^2 a\nu$ (*b*) $Ba^2\nu$
(*c*) $\dfrac{\pi B}{a^2}$ (*d*) $B\pi a^2\nu$.

8. A coil rotates at a speed of $\dfrac{300}{2\pi}$ revolutions per minute. The angular velocity is
(*a*) 2 rad/s (*b*) 5 rad/s
(*c*) 10 rad/s (*d*) 50 rad/s

9. A car having, a vertical aerial 1.0 m high is moving with a uniform speed 80 km/hour in east-west direction. If the horizontal intensity at the place is

0.36×10^{-4} tesla, the induced e.m.f. between the ends of the aerial is

(*a*) 1.8×10^{-2} volt

(*b*) 8×10^{-2} volt

(*c*) 8.0×10^{-4} volt

(*d*) 2.8×10^{-2} volt.

10. A magnetic induction passing through a coil of 50 turns and of area 2 m^2 produces an e.m.f. of 100 volt. Then the rate of change of magnetic conduction is

(*a*) 100 weber/m^2s

(*b*) 50 weber/m^2s

(*c*) 1 weber/m^2s

(*d*) 2 weber/m^2s

11. If L_1 and L_2 are the self inductance of two coils then the mutual inductance between them is

(*a*) $M = K\,(L_1L_2)$ (*b*) $M = K\sqrt{\dfrac{L_1}{L_2}}$

(*c*) $M = K\sqrt{L_1L_2}$ (*d*) $M = K(L_1L_2)^2$.

where K is coefficient coupling between the coils.

12. Mutual inductance between a pair of coils is 5 henry. A circuit of 10 A flowing through one coil is cut off in 0.5 sec. The e.m.f. in the other coil is

(*a*) 5 V (*b*) 50 V

(*c*) 100 V (*d*) 150 V.

13. If i is the current passing through a solenoid, the magnetic flux linked with the whole solenoid is

(*a*) $\phi = \mu_0 n^2 lAi$ (*b*) $\phi = n^2 l \times i$

(*c*) $\phi = \mu_0 n \times i$ (*d*) $\sqrt{\mu_0 n \times i} = \phi$.

where n, l are the number of turns per unit length and l is the length and A area of cross-section of the solenoid.

14. The rate of change of current in primary coil that induces an e.m.f. of 150 volt in the secondary having a mutual conductance is
(*a*) 200 A/s (*b*) 100 A/s
(*c*) 50 A/s (*d*) 25 A/s.

15. *K* is coefficient coupling between the coils. If it is less than one, then the coupling between the coils is
(*a*) loose (*b*) medium
(*c*) zero (*d*) tight.

16. The efficiency of a transformer which draws a power of 20 watt is 60%. The power supplied by it is
(*a*) 5 W (*b*) 1.2 W
(*c*) 6 W (*d*) 12 W.

17. An e.m.f. of 5 volt is induced in a coil when the current changes at a rate of 100 A/s. The coefficient of self inductance of the coil is
(*a*) 200 mH (*b*) 20 mH
(*c*) 50 mH (*d*) 10 mH.

18. A transformer sets up 220 volt to 2200 volt. If the secondary coil of a transformer has 200 turns, the number of turns in the primary coil is
(*a*) 20 (*b*) 32
(*c*) 110 (*d*) 550.

19. Eddy current may be appreciable in many cases. It heats metals and so a wastage of electrical energy noticed. This is undesirable in transformers, induction coil and choke coil. This can be minimised by using
(*a*) laminated cores in transformers
(*b*) using bundles of soft iron rods in induction coils
(*c*) using glass surfaces
(*d*) all are false.

20. A circuit has a self inductance 1 H and carries a current of 2 amp. To prevent sparking when the circuit is broken, a capacitor which can withstand 400 volt is used. The capacitance of the capacitor connected across the switch must have a value of at least

(*a*) 12 μF (*b*) 25 μF
(*c*) 50 μF (*d*) 100 μF.

21. The inductance L, the resistance R and the impedance Z in an $L - R$ AC circuit are related by

(*a*) $R^2 = L^2\omega^2 + Z^2$
(*b*) $Z^2 = L^2 + R^2\omega^2$
(*c*) $L^2\omega^2 = Z^2 - R^2$
(*d*) $L^2\omega^2 = R^2 + Z^2$.

22. The resonance frequency of an LCR circuit is

(*a*) $\frac{1}{2\pi LC}$ (*b*) $2\pi\sqrt{LC}$
(*c*) $\frac{1}{LC}$ (*d*) $\frac{1}{2\pi\sqrt{LC}}$.

23. The instrument that is commonly used to study wavefront is

(*a*) voltmeter
(*b*) ammeter
(*c*) Bragg's spectrometer
(*d*) multimeter.

24. The instantaneous value of the current represented by $i = 6 \sin (314\ t)$ at $t = \frac{1}{200}$ sec

(*a*) 0 A (*b*) 6 A
(*c*) 12 A (*d*) 15 A.

25. The angular velocity of an alternating supply having a frequency of 50 Hz

(*a*) 2 rad/s (*b*) 314 rad/s
(*c*) 1000 rad/s (*d*) 20.2 rad/s.

26. In pure inductance, the average power dissipated is
(*a*) 1
(*b*) greater than 1
(*c*) less than 1
(*d*) zero.

27. When an iron core is inserted into a coil, its coefficient of self induction
(*a*) increases
(*b*) decreases
(*c*) remains the same
(*d*) becomes zero.

PROBLEMS AND SOLUTIONS

1. *A lamp is connected in series with a capacitor. Predict your observation of d.c. and a.c. connections. What happens in each case if the capacitance is decreased?*

Solution:

In a d.c. circuit a capacitor blocks the current in the circuit. Hence the lamp will not glow for any value of capacitance.

But the capacitor allows a.c. to pass through it; it offers only a reactance, $X_c = \frac{1}{2\pi\nu C}$. As the capacitance C is increased, its reactance decreases, the current increases and hence the bulb glows brighter.

2. *What will be the inductance in an a.c. circuit when the impedance of the coil is $\frac{0.5}{\pi}$ milli henry and frequency 50 Hz?*

Solution:

$$X_L = L\omega = 2\pi\nu L = \frac{2\pi \times 50 \times 0.5 \times 10^{-3}}{\pi}$$

$$\boxed{X_L = 0.05\ \Omega} \qquad \textbf{Ans.}$$

3. *The inductance and capacitance of the oscillatory circuit of a radio station are 10 mH and 0.25 μF respectively. Find the frequency and wavelength of the transmitted waves (neglect resistance effect).*

Solution:

$$\nu = \frac{1}{2\pi\sqrt{LC}}$$

$$= \frac{1}{2\pi\sqrt{10 \times 10^{-3} \times 0.25 \times 10^{-6}}}$$

$$\nu = 3184.5 \text{ Hz}$$

$$c = \nu\lambda; \quad \lambda = c/\nu = \frac{3 \times 10^8}{3184.5}$$

$$\boxed{\lambda = 9.42 \times 10^4 \text{ m}} \qquad \textbf{Ans.}$$

4. *If a magnetic induction of 0.6 T produces a flux of 0.6 weber through a single turn coil of area 2 m^2, find the angle between the direction of the magnetic induction and normal to the coil.*

Solution:

$$\frac{\phi}{AB} = \cos\theta; \ \frac{0.6}{0.6 \times 2} \ \cos\theta = 0.5$$

$$\boxed{\theta = 60°} \qquad \textbf{Ans.}$$

5. *A transformer with primary and secondary voltage of 2000 volt and 200 volt takes a current 0.5 amp from the mains. Calculate the resistance connected across the secondary.*

Solution:

$$\frac{V_p}{V_s} = \frac{I_s}{I_p}$$

$$\frac{2000}{200} = 10 = \frac{I_s}{0.5} \;;$$

$$I_s = 10 \times 0.5 = 5 \text{ A}$$

$$R_s = \frac{V_s}{I_s} = \frac{200}{5} = 40 \ \Omega$$

$$\boxed{R_s = 40 \ \Omega} \quad \textbf{Ans.}$$

6. *A 12 ohm resistance and an inductance of $\frac{0.05}{\pi}$ henry are connected in series. If at the end of the circuit they are connected to a 130 volt alternating voltage of frequency 50 Hz, the impedance is calculated as follows.*

Solution:

$$X = \sqrt{R^2 + (2\pi\upsilon L)^2}$$

$$= \sqrt{12^2 + (2 \times 3.14 \times 50)\,(0.05/\pi)^2}$$

$$\boxed{X = 13 \ \Omega} \quad \textbf{Ans.}$$

ANSWERS TO OBJECTIVE QUESTIONS

1. (*d*)	2. (*c*)	3. (*c*)	4. (*d*)
5. (*b*)	6. (*c*)	7. (*d*)	8. (*b*)
9. (*c*)	10. (*c*)	11. (*c*)	12. (*c*)
13. (*a*)	14. (*c*)	15. (*a*)	16. (*d*)
17. (*c*)	18. (*a*)	19. (*a*)	20. (*b*)
21. (*c*)	22. (*d*)	23. (*d*)	24. (*b*)
25. (*b*)	26. (*d*)	27. (*b*).	

CHAPTER 8

THERMAL AND CHEMICAL EFFECTS

1. Two bulbs have the following specifications:
   (*i*) 40 watt at 200 volt and 100 watt at 200 volt. Which bulb has higher resistance? Also find the ratio of the two resistances.
   (*a*) 40 watt bulb; $\frac{R_1}{R_2} = \frac{2}{5}$
   (*b*) 100 watt bulb; $\frac{R_1}{R_2} = 2$
   (*c*) 40 watt bulb; $\frac{R_1}{R_2} = \frac{5}{2}$
   (*d*) 100 watt bulb; $R_1 = R_2$.
2. Water boils in an electric kettle in 15 minute. Should the length of the heating element increased or decreased if water is to boil in 10 minute?
   (*a*) increased
   (*b*) decreased
   (*c*) No necessity to change the length.
3. The energy consumed in one hour at the rate of one kilowatt is one kilowatt-hour. One kilowatt-hour is
   (*a*) 3.6×10^6 J
   (*b*) 1.6×10^6 J
   (*c*) 4.8×10^2 J
   (*d*) 5×10^3 J.

4. The e c e of hydrogen, given that 1 ampere deposits 1.6 of silver in a voltameter in 25 minute is (Atomic weight of silver is 108)
   (*a*) 9.88×10^{-9} kg/C
   (*b*) 2 kg/C
   (*c*) 1.88×10^{-2} kg/C
   (*d*) 100 kg/C.
5. A small heating element made of nichrome resistor connected to 30 volt d.c. supply draws a current of 10 A. The electric power supplied to the heating element and the heat produced in 2 hrs are respectively
   (*a*) 30 watt, 1.16×10^2 J
   (*b*) 40 watt, 2.16×10^2 J
   (*c*) 60 watt, 2×10^3 J
   (*d*) 300 watt, 2.16×10^6 J.
6. The liberation or absorption of heat at the function of a thermocouple due to the passage of an electric current is
   (*a*) Peltier effect
   (*b*) Thomson effect
   (*c*) Joule's effect
   (*d*) Compton effect.
7. When a current passes through a wire whose different parts are maintained at different temperatures, the evolution or absorption of heat all along the length of the wire is known as
   (*a*) Joule's effect
   (*b*) Seeback effect
   (*c*) Peltier effect
   (*d*) Thomson effect.
8. Electrolysis by alternating current is not possible

(*a*) because of the slow change in the direction of current
(*b*) because of the fast change in the direction of current
(*c*) because of constant flow of current
(*d*) all the above are false.

9. Quantity of charge required to liberate 1 gm equivalent of the substance by electrolysis is
(*a*) 96500 C (*b*) 965 C
(*c*) 2100 C (*d*) 4.47 C.

10. If dV is the p.d. between two points of a conductor which have a small temperature difference, then Thomson coefficient σ is given by
(*a*) $\sigma = \dfrac{dT}{dV}$
(*b*) $\sigma = \dfrac{1}{T}\dfrac{dV}{dT}$
(*c*) $\sigma = \dfrac{d}{dT}\left(\dfrac{dT}{dV}\right)$
(*d*) $\sigma = \dfrac{dV}{dT}$.

11. The Faraday constant F is related with Avogadro's number as
(*a*) $F = \dfrac{N_A}{e}$ (*b*) $F = \dfrac{N_A}{e^2}$
(*c*) $F = N_A e^2$ (*d*) $F = N_A e$.

12. The rate at which thermo e.m.f. varies with temperature is known as
(*a*) Peltier effect
(*b*) Thomson effect
(*c*) Thermoelectric effect
(*d*) Joule's law.

13. In a thermocouple, one junction is kept at constant temperature and the other

junction is heated, the thermo e.m.f. increases and reaches maximum at a certain temperature. This temperature is known as

(*a*) absolute temperature
(*b*) Fermi temperature
(*c*) Debye temperature
(*d*) neutral temperature.

14. Heat produced in a resistor depends
(*a*) directly on time
(*b*) inversely on time
(*c*) inversely as current
(*d*) none of the above.

15. A 30 volt battery is charged from 120 volt d.c. supply, a resistor being connected in series with a battery to limit the charging current to 15 A. Find the rate at which energy is wasted as heat in the circuit.
(*a*) 700 J (*b*) 100 Ω kJ
(*c*) 1.350 kJ (*d*) 2.41×10^2 kJ.

16. Above neutral temperature, thermo e.m.f.
(*a*) changes sign
(*b*) increases with rise in temperature
(*c*) decreases with rise of temperature
(*d*) is constant.

17. What current should be passed through a silver voltameter for one hour to obtain 2.012×10^{-3} kg of silver (e c e of silver $= 1.118 \times 10^{-6}$ kg/C)?
(*a*) 0.5 A (*b*) 1 A
(*c*) 2 A (*d*) 3 A.

18. A copper voltameter is connected in series with a 100 Ω resistor. A steady current passing through the circuit deposits 0.1 gm of copper in 10 minute. Given:

e c e of copper = 3.3×10^{-7} kg/C. The heat liberated in the resistor is

(*a*) 308 J (*b*) 1402 J
(*c*) 1000 J (*d*) 1500 J.

19. Out of the three lamps with 100 watt, 80 watt and 60 watt, the lamp with higher resistance is
(*a*) 100 watt bulb
(*b*) 200 watt bulb
(*c*) 80 watt bulb
(*d*) 60 watt bulb.

20. Three equal resistors connected in series across a source of e.m.f. together dissipate 10 watt of power. If the resistors are connected in parallel across the same source of e.m.f. the energy dissipated is
(*a*) 90 watt (*b*) 75 watt
(*c*) 60 watt (*d*) 40 watt.

21. Which of the statements is true?
(*a*) both Peltier and Joule effects are irreversible
(*b*) both Peltier and Joule effects are reversible
(*c*) Joule effect is reversible but not Peltier effect
(*d*) Peltier effect is reversible but not Joule effect.

22. If 2.2 kilowatt power is transmitted through a 10 Ω line at 22000 volt, the power loss in the form of heat is
(*a*) 10 watt (*b*) 6 watt
(*c*) 1 watt (*d*) 0.1 watt.

23. A thermo-electric generator to generate thermo-electric power should have
(*a*) high thermo-electric power
(*b*) high electric conductivity
(*c*) low thermal conductivity
(*d*) all the above are true.

24. An apparatus in which the electrolysis is carried out is called
(*a*) Voltameter
(*b*) Voltmeter
(*c*) Electrometer
(*d*) Faraday meter.

25. In an *LCR* circuit the capacitor is changed form *C* to 4*C*. For the same resonant frequency the inductance should be changed from *L* to
(*a*) $4L$ (*b*) $\frac{L}{2}$
(*c*) $\frac{L}{4}$ (*d*) $8L$.

26. As the frequency of the a.c. voltage across an inductor approaches zero, the inductive reactance of the coil.
(*a*) approaches zero
(*b*) approaches infinity
(*c*) approaches unity
(*d*) none of the above.

27. As the frequency of the a.c. voltage across a capacitor approaches zero, the capacitive reactance of the capacitor
(*a*) approaches zero
(*b*) approaches infinity
(*c*) approaches unity
(*d*) none of the above.

PROBLEMS AND SOLUTIONS

1. *A small resistor is usually connected in parallel to the current carrying coil of an electromagnet. What purpose does it serve?*

Solution:

When the current in the coil of a large electromagnet is suddenly switched off, flux changes from a large value to zero value in a very short time. Consequently high voltage is induced across the open switch causing sparks damaging insulation. A small resistor in parallel provides a conducting path to the induced voltage thus avoiding sparks and other risks of high voltages.

2. *A virtual current of 2.5 amp flows in a coil when it is connected in a circuit having A.C. of frequency 50 Hz and power consumed in the coil is 250 watt. If the virtual p.d. across the coil is 200 volt, calculate the resistance and reactance of the coil.*

Solution:

$$\text{Impedence, } Z = \frac{\text{Virtual voltage}}{\text{Virtual current}}$$

$$= \frac{200}{2.5} = 80\ \Omega$$

Power consumed

$$= V \times I \cos\theta = V \times I \times \frac{R}{Z}$$

$$250 = 200 \times 2.5 \times \frac{R}{Z};\ R = \frac{250 \times Z}{200 \times 2.5}$$

$$R = \frac{80}{2} = 40\ \Omega$$

$$Z^2 = R^2 + X_L^{\,2}$$

where X_L is inductive reactance

$$6400 = 1600 + X_L^{\,2};$$

$$X_L^{\,2} = 6400 - 1600$$

$$X_L^{\,2} = 4800$$

$$X_L = 40 \times \sqrt{3}$$

$$\boxed{\begin{array}{l}\text{Resistance is } 40\ \Omega \\ \text{Reactance is } 40\sqrt{3}\ \Omega\end{array}}$$ **Ans.**

3. *Can you get the expression for the induced quantity of electricity?*

Solution:

$$e = -\frac{d\phi}{dt}$$

If R is the resistance of the circuit, the instantaneous induced current

$$I = -\frac{e}{R} = -\frac{1}{R}\frac{d\phi}{dt}$$

The charge that flows in a short time dt is

$$dq = Idt = -\frac{1}{R}\frac{d\phi}{dt}dt = -\frac{d\phi}{R}$$

Total charge flowing when the flux changes from ϕ_1 to $\phi_2 = \left(\frac{\phi_1 - \phi_2}{R}\right)$

$$\boxed{\begin{aligned} q &= \frac{\phi_1 - \phi_2}{R} \\ &= \frac{\text{Change of flux}}{\text{Resistance}} \end{aligned}}$$ **Ans.**

4. *A square shaped coil of side 10 cm and number of turns 500 is placed perpendicular to magnetic flux lines which are changing at a rate of 1.0 T/s. Calculate the e.m.f. induced in the coil.*

Solution:

$$\phi = BAn$$

$$e = \frac{d\phi}{dt} = An\frac{dB}{dt} = 500 \times 10^{-2} \times 1$$

$$\boxed{e = 5 \text{ volt}}$$ **Ans.**

5. *A coil has 200 turns and area 70 cm^2. The magnetic field perpendicular to the plane of the coil is 0.3 Wb/m^2 and the coil take*

1 sec to rotate through 180°. Calculate the value of the induced e.m.f.

Solution:

Change of flux, $d\phi = 2BAN$

$$e = \frac{2BAN}{dt} = \frac{d\phi}{dt}$$

$$e = \frac{2 \times 0.3 \times 200 \times 70 \times 10^{-4}}{0.1} = 8.4$$

$$\boxed{e = 8.4 \text{ volt}}$$ **Ans.**

6. *A transformer is used to light 100 W, 24 volt bulb from 240 volt a.c. main. The current in the main is 0.5 A. Calculate the efficiency of the transformer.*

Solution:

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

Input power $VI = 240 \times 0.5 = 120$ watt

$$\text{Efficiency} = \frac{100}{120} \times 100 = 83.3$$

$$\boxed{\text{Efficiency} = 83.3\%}$$ **Ans.**

7. *The thermo e.m.f. (E) of a copper-constantan thermocouple, and the temperature θ of the hot junction with cold junction at 0°C are found to satisfy the relation* $E = a\theta + \frac{1}{2} b\theta^2$ *where E is in volt and θ in °C, a = 41 μV/°C and b = 0.044 μV/°C², calculate the temperature of the hot junction when the thermo e.m.f. is 5.5 mV.*

Solution:

$$E = a\theta + \frac{1}{2} b\theta^2$$

$$5.5 \times 10^{-3} = 41 \times 10^{-6}\,\theta + \frac{1}{2}\,0.044 \times 10^{-6}$$

$$\frac{5.5 \times 10^{-3}}{10^{-6}} = \frac{41 \times 10^{-6}}{10^{-6}}\,\theta + \frac{0.022 \times 10^{-6}}{10^{-6}}\,\theta^2$$

$$5.5 \times 10^3 = 41\theta + 0.022\theta^2$$

$$0.022\theta^2 + 41\theta - 5.5 \times 10^3 = 0$$

$$\theta = \frac{-41 \pm \sqrt{41^2 + 4 \times 5.5 \times 0.022 \times 10^3}}{2 \times 0.022}$$

$\boxed{\theta = 125.6°C}$ **Ans.**

8. *Pure water and dry salt are both non-conductors of electricity, but the solution of salt water is conductor of electricity. Explain.*

   Solution:

   Due to absence of ionisation in pure water and dry salt, these are no free electrons in them. In salt solution NaCl ionises into Na^+ and Cl^- ions. Hence salt solution becomes conductor of electricity.

9. *Why are salts ionised on dissolving in water?*

   Solution:

   In a salt, the positive and negative ions are bound together by mutual force of attraction. When dissolved in water, the force between the ions is reduced to $\frac{1}{80}$th of the original value since the dielectric constant of water is 80. Dissociation of ions takes place and the salt is ionised.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*b*)	3. (*a*)	4. (*a*)
5. (*d*)	6. (*a*)	7. (*a*)	8. (*b*)
9. (*a*)	10. (*d*)	11. (*d*)	12. (*c*)
13. (*d*)	14. (*a*)	15. (*c*)	16. (*c*)
17. (*a*)	18. (*d*)	19. (*d*)	20. (*a*)
21. (*d*)	22. (*d*)	23. (*d*)	24. (*a*)
25. (*c*)	26. (*b*)	27. (*a*)	

CHAPTER 9

ATOMIC PHYSICS

9.1 CATHODE RAYS

1. The voltage required to produce lightning discharge near the earth is greater than that required between clouds at high altitudes, because
   (*a*) at high altitude cosmic ray intensity is very high and hence greater ionisation is possible
   (*b*) the presence of carbon tetrachloride at high altitude easily produces lightning
   (*c*) the presence of sodium chloride vapour is the cause of lightning
   (*d*) all the above are true.
2. When cathode rays are stopped by metals of high atomic number
   (*a*) protons are generated
   (*b*) γ-rays are produced
   (*c*) neutrons are generated
   (*d*) X-rays are produced.
3. A 2 keV electron enters a magnetic field of 5×10^{-4} tesla. If the radius of the electron path is 0.303, e/m of the electron is
   (*a*) 7.2×10^{10} C/kg
   (*b*) 6.2×10^{-9} C/kg
   (*c*) 1.74×10^{-11} C/kg
   (*d*) 3.74×10^{-10} C/kg.

4. Which of the following is true for cathode rays
   (*a*) they cannot be accelerated
   (*b*) they contain positively charged particles
   (*c*) they are deflected by magnetic and electric fields
   (*d*) they are electromagnetic radiation.
5. If M is the mass of the positive ion, then
   (*a*) $\frac{e}{M}$ is much higher than $\frac{e}{m}$ for electron
   (*b*) $\frac{e}{M}$ is half that of $\frac{e}{m}$ for electron
   (*c*) $\frac{e}{M}$ is much smaller than $\frac{e}{m}$ for electron
   (*d*) all the above are false.
6. Canal rays are
   (*a*) light rays
   (*b*) a stream of electrons
   (*c*) a stream of neutrons
   (*d*) a stream of positively charged particles.
7. The frequency of the charge circulating perpendicular to a uniform magnetic field does not depend on
   (*a*) the mass of the charge
   (*b*) the velocity of the particle
   (*c*) the magnetic field
   (*d*) the charge of the particle.
8. The specific charge (e/m) of the electron is approximately
   (*a*) 20×10^{2} C/kg
   (*b*) 40×10^{12} C/kg
   (*c*) 1.8×10^{11} C/kg
   (*d*) 100.2 C/kg.

9. Choose the correct statement
   (*a*) X-rays easily penetrate through matter because the wavelength is of the order of 6000 Å.
   (*b*) X-rays are easily deflected by electric field.
   (*c*) X-rays are electromagnetic radiation of wavelength of about 1 Å.
   (*d*) X-rays are similar to acoustical waves.
10. Cathode rays
    (*a*) produce ionisation of the gas through which they pass
    (*b*) travel with high velocities
    (*c*) produce fluorescence when they strike certain crystals
    (*d*) all the above are true.
11. An electron is accelerated through a p.d. of 500 volt. What is the energy acquired by the electron in electron volt?
    (*a*) 100 eV (*b*) 500 eV
    (*c*) 1000 eV (*d*) 10 eV.
12. Why frequent exposures of human body to X-rays are harmful?
    (*a*) The healthy blood cells are damaged due to the low frequency of X-ray radiation
    (*b*) The healthy blood cells are damaged due to high frequency of X-rays radiation
    (*c*) the penetrating power of X-rays is very low
    (*d*) all are true.
13. Doubly ionised helium atoms and hydrogen ions are accelerated from rest through the same potential drop. The ratio of the final velocities of helium atoms the help and hydrogen ions is

(*a*) $\frac{1}{\sqrt{2}}$ (*b*) $\frac{1}{4}$

(*c*) $\sqrt{3}$ (*d*) 4.

14. Specific charge of cathode rays means charge
(*a*) of a proton
(*b*) of a single electron
(*c*) per unit mass of electron
(*d*) of γ-ray.

15. The wavelength of X-rays is about
(*a*) 10^{10} times greater than that of ultrasonic waves
(*b*) 10^{10} times smaller than that of ultrasonic waves
(*c*) 10 times smaller than that of ultrasonic waves
(*d*) both have almost the same wavelength.

16. If v_g is the terminal velocity then by Stoke's formula the viscous force is given by
(*a*) $F = 2a\eta v_g$ (*b*) $F = 6\pi a\eta v_g$
(*c*) $F = \pi a\eta v_g$ (*d*) $F = 2\pi^2 a\eta v_g$.
where a is the radius of the drop and η the viscosity of air.

17. In a Millikan's oil drop experiment an oil drop having a charge e is held stationary with an external p.d. of 600 volt. If the radius of the drop is doubled without any change of charge, the p.d. required to keep the drop stationary is
(*a*) 600 volt
(*b*) 4800 volt
(*c*) 1600 volt
(*d*) 3200 volt.

18. The special feature of the value of e/m is that it is used
    (*a*) to determine the velocity of proton
    (*b*) to prove electrons do not have wave characteristic
    (*c*) to determine the mass of the electron
    (*d*) to estimate the rate of penetration of γ-ray.
19. E and B are respectively the strengths of electrical and magnetic fields respectively perpendicular to each other. The condition for no deflection for electron is
    (*a*) $Be^2v = Ee$ (*b*) $Bv = Ee$
    (*c*) $\frac{B}{e} = E$ (*d*) $Bev = Ee$.
20. A proton projected with kinetic energy E describes a circle of radius r in a uniform magnetic field. With what kinetic energy should an α-particle be projected in the same magnetic field so that it describes a circle of radius $2r$?
    (*a*) $2E$ (*b*) $3E$
    (*c*) $4E$ (*d*) $5E$.
21. The mass of a proton is about 2000 times that of electron. An electron and proton, with equal kinetic energies, enter perpendicularly a uniform electric field. Then
    (*a*) the path of proton will be more curved than that of electron
    (*b*) the path of a proton will be less curved than that of electron
    (*c*) the path of proton and electron will be equally curved
    (*d*) the paths of both will be straight.
22. In Millikan's oil drop experiment, when the force due to gravity and retarding

force become equal, the drop attains a constant velocity. The equation used here is

(*a*) $a^3(\rho - \sigma)g = 3\pi\eta av$

(*b*) $\frac{3}{4}\pi a^3(\rho - \sigma) = 8\pi\eta a$

(*c*) $\frac{4}{3}\pi a^3(\rho - a) = 8\pi\eta av$

(*d*) $\pi a^3(\sigma - \rho) = 3\pi\eta a$.

where ρ and σ are respectively the density of oil and air, a is the radius of the oil drop and v is the constant velocity of the oil drop.

23. The elementary particles having rest mass equal or greater than that of nucleons are

(*a*) mesons (*b*) leptons

(*c*) photons (*d*) baryons.

24. The ratio of specific charge of proton and α-particle is

(*a*) 2 : 4 (*b*) 2 : 1

(*c*) 1 : 4 (*d*) 4 : 1.

25. The value of $\frac{e}{m}$ obtained from Thomson's experiment for electron is 1.759×10^{11} C/kg. If mass of the electron is 1840 times smaller than that of a proton, than the mass of the proton is

(*a*) 1.27×10^{-27} kg

(*b*) 7×10^{11} kg

(*c*) 1840 kg

(*d*) 1.67×10^{-27} kg.

26. If an electron has no initial velocity in a direction different from that of an electric field, the path of the electron in the electric field will be

(*a*) straight line one
(*b*) circle
(*c*) parabola
(*d*) ellipse.

27. Positive rays
(*a*) cannot ionise gases
(*b*) have no effect on photographic plate
(*c*) cannot penetrate even through substances of small thickness
(*d*) can disintegrate metals or cause sputtering.

28. The volume of the electron cloud in an atom is largely dependent on the
(*a*) shape of the atom
(*b*) principal quantum number
(*c*) spin quantum number
(*d*) magnetic quantum number.

29. The constituent particles of a nucleus are
(*a*) electrons, protons and neutrons
(*b*) α-particles and β-particles
(*c*) protons and neutrons
(*d*) electrons and protons.

30. A cathode ray tube has a p.d of V volt between the cathode and the anode. The speed v attained by the cathode rays is directly proportional to
(*a*) V (*b*) V^2
(*c*) $\dfrac{1}{V^2}$ (*d*) $\sqrt{V}$.

31. In photoelectric emission electrons are emitted by heating the surface of the metal while in thermoionic emission, electrons are emitted under the influence of electromagnetic radiation. This is
(*a*) true (*b*) false.

32. The minimum frequency required for the electromagnetic radiation to produce photoelectric emission is called
    (*a*) Bohr's frequency
    (*b*) Pauli's frequency
    (*c*) Raman frequency
    (*d*) threshold frequency.
33. Electrons are emitted by a metal surface only if the light incident on it exceeds a certain minimum
    (*a*) wavelength (*b*) frequency.
34. The number of photoelectrons emitted and hence the photoelectric current is
    (*a*) directly proportional to the pressure of the surroundings
    (*b*) indirectly proportional to the intensity of the incident radiation
    (*c*) directly proportional to the intensity of the incident radiation
    (*d*) all are true.
35. Stopping potential of the photoelectron emitted in a photoelectric cell is 1.38 eV. If the cathode and the anode are kept at the same potential, the kinetic energy of the emitted electrons
    (*a*) have the same kinetic energy equal to 1.36 eV
    (*b*) have average kinetic energy equal to 0.68 eV
    (*c*) have maximum kinetic energy equal to 1.36 eV
    (*d*) have minimum kinetic energy equal to 1.36 eV.
36. If h, W, $h\nu_0$, m and v are Planck's constant, work function of the metal-mass of the electron threshold energy and velocity of the electron respectively, then Einstein's photoelectric equation is

(*a*) $h\nu_0 = W - \frac{1}{2} mv^2$

(*b*) $h\nu_0 = W$

(*c*) $h\nu_0 = W^2 - \frac{1}{2} mv^2$

(*d*) $h\nu_0 = W^2 + \frac{1}{2} mv^2$.

where ν_0 is the threshold frequency of the metal.

37. A radio transmitter operates at a frequency of 880 kHz and a power of 10 kW. The number of photons emitted per sec is

(*a*) 1.8×10^{31} (*b*) 1.8×10^{20}

(*c*) 7.8×10^{15} (*d*) 10^2.

38. The main advantage of solar cell is

(*a*) no external source of e.m.f. is required

(*b*) it is very cheap

(*c*) it is sturdy

(*d*) all are true.

39. The standard photoelectric equation is

$$h\nu = h\nu_0 + \frac{1}{2} mv^2 \text{ ; or } \qquad h\nu = h\nu_0 + eV_0$$

A graph is drawn between ν and V_0, the intercept on the y-axis is given by

(*a*) $h\nu_0$ (*b*) $(h\nu_0)^2$

(*c*) $\left(\frac{h\nu_0}{e}\right)^2$ (*d*) $\left(\frac{h\nu_0}{e}\right)$.

40. Photoelectric cells are used in

(*a*) sextants

(*b*) microscopes

(*c*) acoustical studies in halls

(*d*) reproduction of sound.

41. The wavelength of a photon having an energy 100 eV is

(*a*) 124.4 nm (*b*) 8 nm
(*c*) 427.5 nm (*d*) 12.4 nm.

42. In order to increase the kinetic energy of ejected photoelectrons, there should be an increase in the
(*a*) frequency of radiation
(*b*) intensity of radiation
(*c*) wavelength of radiation
(*d*) both wavelength and intensity of radiation.

43. The photoelectric work function of a metal is 2.061 eV. The threshold wavelength is
(*a*) 600 nm (*b*) 60 nm
(*c*) 250 nm (*d*) 160 nm.

44. Photon is a
(*a*) quantum of matter
(*b*) positively charged particle
(*c*) negatively charged particle
(*d*) quantum of light.

45. The mass of a photon is
(*a*) $h\nu$ (*b*) $\frac{h}{\nu}$
(*c*) zero (*d*) $\frac{h\nu}{c^2}$.

46. The photoelectric effect helps to convert
(*a*) light energy into sound energy
(*b*) sound energy into electrical energy
(*c*) electrical energy into light energy
(*d*) light energy into electrical energy.

47. Light of frequency 1.5 times the threshold frequency is incident on a photosensitive surface. If the frequency is halved, the photoelectric current is
(*a*) halved (*b*) doubled
(*c*) quadrupled (*d*) zero.

48. In photoelectric effect, the photoelectric current
    (*a*) increases when the frequency of the incident photon increases
    (*b*) decreases when the frequency of the incident photon increases
    (*c*) does not depend on the photon frequency
    (*d*) depends both on intensity and frequency of incident photon.
49. Photons which are having short wavelength and very high energy are
    (*a*) characteristic X-rays
    (*b*) hard X-rays
    (*c*) soft X-rays
    (*d*) secondary X-rays.

PROBLEMS AND SOLUTIONS

1. *Two ions of same charge and kinetic energy but having different masses m_1 and m_2 are projected into the same magnetic field. If r_1 and r_2 are the radii of the circular paths followed by the ions, find $\frac{r_1}{r_2}$.*

Solution:

$$\frac{1}{2} m_1 v_1^2 = Bev_1 r_1$$

$$\frac{1}{2} m_2 v_2^2 = Bev_2 r_2$$

$$\left(\frac{m_1}{m_2}\right)\left(\frac{v_1}{v_2}\right)^2 = \left(\frac{v_1}{v_2}\right)\left(\frac{r_1}{r_2}\right)$$

or $$\left(\frac{m_1}{m_2}\right)\frac{v_1}{v_2} = \frac{r_1}{r_2} \qquad \ldots(1)$$

Also $\frac{1}{2} m_1 v_1^2 = \frac{1}{2} m_2 v_2^2$

$$\left(\frac{v_1}{v_2}\right)^2 = \frac{m_2}{m_1} \quad \text{or} \quad \frac{v_1}{v_2} = \sqrt{\frac{m_2}{m_1}} \qquad ...(2)$$

Substituting this in Eqn. (1),

$$\left(\frac{m_1}{m_2}\right)\sqrt{\frac{m_2}{m_1}} = \frac{r_1}{r_2}$$

$$\boxed{\frac{r_1}{r_2} = \sqrt{\frac{m_1}{m_2}}} \quad \textbf{Ans.}$$

2. *Calculate the wavelength of a photon having an energy 100 eV.*

Solution:

$$h\nu = E$$
$$= 100 \times 1.6 \times 10^{-19}$$
$$= 1.6 \times 10^{-17}$$
$$\frac{hc}{\lambda} = 1.6 \times 10^{-17}$$
$$\lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-17}}$$
$$= 12.4 \text{ nm}$$

$$\boxed{\lambda = 12.4 \text{ nm}} \quad \textbf{Ans.}$$

3. *Can we assign a finite rest mass to a photon? If not, why?*

Solution:

We cannot assign a finite rest mass to the photons as they always move with the speed of light. If we were to assign a non-zero rest mass to them, their observed mass should be infinite. If m_0 is the rest mass of a particle, then the mass of the particle moving with a velocity v is given by

$$m = \frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

For a photon, $v = c$; so if m_0 is the rest mass of the photon its observed mass will be infinitely.

4. *Calculate the ratio of momentum of an electron and an α-particle which are accelerated from rest by a potential difference of 100 volt.*

Solution:

$$\frac{1}{2}m_e v^2 = eV$$

$$\frac{1}{2}\frac{(m_e v)^2}{m_e} = eV$$

or $$p_e^2 = 2eVm_e$$

and $$p_\alpha^2 = 2 \times 2eVm_\alpha$$

$$\frac{p_e^2}{p_\alpha^2} = \frac{m_e}{2m_\alpha}; \quad \frac{p_e}{p_\alpha} = \sqrt{\frac{m_e}{2m_\alpha}}$$

$$\boxed{\frac{p_e}{p_\alpha} = \left[\frac{m_e}{2m_\alpha}\right]^{1/2}} \quad \textbf{Ans.}$$

5. *What are 'Quarks'?*

Answer: Quarks are sub-nuclear particles of fractional charges. Protons and neutrons and other fundamental particles are supposed to be made up of three quarks. They are bound inside the protons and neutrons by very strong interacting forces. Quarks do not exist as free particles in nature. So, the observable charges are integral multiple of e, the electron charge.

6. *When neon ions are used in Bainbridge mass spectrograph it is found that lighter isotope Ne^{20} reaches the photograph plate at a distance 10 cm from the slit. Calculate the distance at which the heavier isotope Ne^{22} strikes the plate.*

Solution: In Bainbridge arrangement, ions are allowed to pass through a velocity filter (a crossed electric and magnetic field). Ions of same velocity pass through the filter undeviated. They are subjected to uniform magnetic field perpendicular their direction of velocity. So they take a semi-circular path on a photograph plate. From this impressions on the film, the radius (r) of the semicircular path can be determined. It can be shown that mass M of the ion is directly proportional to the radius r for ions of the same charge.

i.e., $M \propto r$

$$\frac{M_1}{M_2} = \frac{r_1}{r_2}$$

$$r_2 = r_1 \frac{M_2}{M_1} = 10 \times \frac{22}{20} = 11 \text{ cm}$$

$$\boxed{r_2 = 11 \text{ cm}}$$ **Ans.**

7. *Light of two different frequencies whose photons have energies 1 eV and 2.5 eV successively illuminate a metal surface of work function 0.5 eV. Get the ratio of the speeds of the electrons.*

Solution:

$$h\nu_1 = W + \frac{1}{2}mv_1^2$$

$$h\nu_2 = W + \frac{1}{2}mv_2^2$$

$$\frac{1}{2}mv_1^2 = 1 - 0.5 = 0.5 \text{ eV}$$

$$\frac{1}{2}mv_2^2 = 2.5 - 0.5 = 2 \text{ eV}$$

$$\left(\frac{v_1}{v_2}\right)^2 = \frac{0.5}{2} = 0.25$$

$$\frac{v_1}{v_2} = \frac{1}{2}$$

$$\boxed{v_1 : v_2 = 1 : 2}$$ **Ans.**

8. *Light of frequency 1.5 times the threshold frequency is incident on a photosensitive surface. If the frequency is halved what will be the photoelectric current?*

   Solution: If the incident radiation ($1.5\ \nu_0$) is halved, the frequency of radiation becomes $0.75\ \nu_0$ which is less than ν_0. So no photoelectron will be emitted.

9. *A drop of oil of radius 10^{-6} m carries a charge equal to that of an electron. If the density of the oil is 2×10^3 kg/m^3, calculate the electric field required to keep it stationary.*

   Solution:

   Mass = Volume × Density

$$= \frac{4}{3} \times 3.14 \times 10^{-18} \times 2 \times 10^3$$

$$= 8.373 \times 10^{-15} \text{ kg}$$

$$Ee = mg$$

$$E = \frac{mg}{e} = \frac{8.373 \times 10^{-15} \times 9.8}{1.6 \times 10^{-19}}$$

$$\boxed{E = 5.13 \times 10^5 \text{ V/m}}$$ **Ans.**

10. *Prove that the ratio of momentum of an electron and that of an α-particle which are accelerated from rest by a potential difference of 100 volt is* $\sqrt{\dfrac{m_e}{2m_\alpha}}$.

Solution:

$$\frac{1}{2}m_e v^2 = eV$$

$$\frac{1}{2}\frac{(m_e v)^2}{m_e} = eV$$

and $$\frac{\frac{1}{2}(m_\alpha v)^2}{m_\alpha} = 2\,eV$$

or $$p_e^2 = 2\,eVm_e$$

$$p_\alpha^2 = 2 \times 2\,eVm_\alpha$$

$$\frac{p_e^2}{p_\alpha^2} = \frac{m_e}{2m_\alpha}$$

$$\boxed{\frac{p_e}{p_\alpha} = \sqrt{\frac{m_e}{2m_\alpha}}}$$ **Ans.**

11. *In the determination of* $\dfrac{e}{m}$ *by Dunningston's method the frequency of the A.C. source is 20 MHz and* $\theta = 330°$. *The successive values of B for which the current is a maximum are* 1.6×10^{-4} *T and* 1.3×10^{-4} *T. Find the value of e/m.*

Solution:

If n is an integer, then $n \times 1.6 \times 10^{-4} = (n + 1) \times 1.3 \times 10^{-4}$. Solving this $n = 4.33$

Formula used:

$$\frac{e}{m} = \frac{\theta}{nTB_1} = \frac{\theta\nu}{TB_1}$$

$$360° = 2\pi \text{ radian}$$

$$330° = \frac{2\pi \times 330}{360} \text{ radian}$$

$$\frac{e}{m} = \frac{2\pi \times 330 \times 20 \times 10^{6}}{360 \times 4 \times 1.6 \times 10^{-4}}$$

$$\boxed{\frac{e}{m} = 1.8 \times 10^{11} \text{ C/kg}} \quad \textbf{Ans.}$$

12. *Calculate the potential difference through which an electron would have to pass to acquire a velocity of 0.995 c where, c is the velocity of light.*

Solution: We know from Einstein's theory of relativity that the mass of a particle increases with the increase in velocity. According to this theory, the mass m of a particle moving with a velocity v is given by

$$m = \frac{m_0}{[1-\beta^2]^{1/2}}$$

where m_0 is the rest mass of the particle

$$\beta = \frac{v}{c} = \frac{0.995c}{c} = 0.995$$

Mass of electron,

$$= \frac{m_0}{\sqrt{1-(0.995)^2}} = 10\, m_0$$

Hence, giving an electron a velocity of 0.995c is equivalent to increasing its mass by 9 m_0 or giving it an energy or m_0c^2. Therefore energy required to give a velocity of 0.995c to electron is 9 m_0c^2.

or $9 \times m_0 \times c^2 = 9 \times 9.1 \times 10^{-3} \times (3 \times 10^8)^2$ joule

$$= 7.37 \times 10^{-13} \text{ J}$$

$$= \frac{7.37 \times 10^{-13}}{1.6 \times 10^{-19}}$$

$= 4.6 \times 10^6$ eV

Energy, $E = eV = 4.6 \times 10^6 \times 1.6 \times 10^{-19}$ J

$$V = \frac{4.6 \times 10^6 \times 1.6 \times 10^{-19}}{1.6 \times 10^{-19}}$$

The electron has to be operated through 4.6×10^6 volt

i.e., $\boxed{\text{P.D. required, } V = 4.6 \times 10^6 \text{ volt}}$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*a*)	2. (*d*)	3. (*c*)	4. (*c*)
5. (*c*)	6. (*d*)	7. (*b*)	8. (*c*)
9. (*c*)	10. (*d*)	11. (*b*)	12. (*b*)
13. (*a*)	14. (*c*)	15. (*b*)	16. (*b*)
17. (*b*)	18. (*c*)	19. (*d*)	20. (*c*)
21. (*b*)	22. (*c*)	23. (*d*)	24. (*b*)
25. (*d*)	26. (*a*)	27. (*d*)	28. (*b*)
29. (*c*)	30. (*d*)	31. (*b*)	32. (*d*)
33. (*a*)	34. (*c*)	35. (*c*)	36. (*d*)
37. (*a*)	38. (*a*)	39. (*d*)	40. (*d*)
41. (*d*)	42. (*a*)	43. (*a*)	44. (*d*)
45. (*d*)	46. (*d*)	47. (*d*)	48. (*c*)
49. (*b*).			

9.2 ATOMIC STRUCTURE AND SPECTRA

1. Rutherford model of the atom failed to explain

(*a*) large angle of scattering of α-particles

(*b*) small angle scattering of α-particles

(*c*) radioactivity
(*d*) all the above are true.

2. The radius of the nucleus depends on mass number A as

(*a*) $R \propto \frac{1}{A}$ or $R = \frac{R_0}{A}$
(*b*) $R \propto A$ or $R = R_0 A$
(*c*) $R \propto A^{1/3}$ or $R = R_0 A^{1/3}$
(*d*) $R \propto \sqrt{A}$ or $R = R_0[\sqrt{A}]$.

3. In a hydrogen atom, the electron jumps from the state n to $(n - 1)$ where $n >> 1$. The frequency of the emitted radiation is proportional to

(*a*) $\frac{1}{n}$ (*b*) n
(*c*) n^{-6} (*d*) n^{-3}.

4. The energy of hydrogen atom in the ground state is –13.6 eV. The frequency due to transition from $n = 4$ to $n = 2$ is approximately

(*a*) 6×10^8 Hz (*b*) 1.2×10^2 Hz
(*c*) 2.8×10^{12} Hz (*d*) 6.2×10^{14} Hz.

5. Which one of the following particles can be added to the nucleus of an atom so that no change in properties is noticed

(*a*) proton (*b*) positron
(*c*) electron (*d*) neutron.

6. In a hydrogen like atom the energy required to excite the electron from 2nd to 3rd orbit is 47.2 eV. The atomic number of the atom is

(*a*) 1 (*b*) 5
(*c*) 2 (*d*) 3.

7. One nanometre is equal to

(*a*) 10^{-5} m (*b*) 10^{-10} m
(*c*) $[10^{-18}]^{1/2}$ m (*d*) $\frac{1}{200}$ m.

8. If the wave number of a spectral line of Brackett series of hydrogen is $\frac{9}{144}$ times the Rydberg constant, what is the state from which the transition has taken place.

(a) $n_2 = 4$ (b) $n_2 = 5$
(c) $n_2 = 7$ (d) $n_2 = 6$.

9. Compare the semi-major axis of $3p$, $4d$ sub-shells assuming semi-minor axes are the same

(a) $\frac{9}{8}$ (b) $\frac{8}{7}$
(c) $\frac{4}{3}$ (d) $\frac{1}{2}$.

10. If $n = 1.5$ and $h = 6.62 \times 10^{-34}$ Js, the angular momentum of the revolving electron in hydrogen atom as per Bohr's theory is

(a) $n\frac{h}{2\pi}$ (b) $n^2\frac{h}{2\pi}$
(c) $\frac{2\pi n}{h}$
(d) all the above are false.

11. Which of the following statements is correct?

(1) electron was discovered by Millikan
(2) electron is 2000 times heavier than a proton
(3) cathode rays are of electromagnetic radiation
(4) electron is a fundamental particle.

(a) (1) and (4) (b) (3)
(c) (2)
(d) all the four are correct.

12. The ratio of the orbital frequencies of the electron in the first and 4th orbit of hydrogen atom is

(*a*) 18 (*b*) 8
(*c*) 16 (*d*) 27.

13. The velocity of the electrons in the stationary orbits of hydrogen atom is
    (*a*) directly proportional to the square root of the principal quantum number
    (*b*) directly proportional to the square of the principal quantum number
    (*c*) independent of the principal quantum number
    (*d*) inversely proportional to the principal quantum number.
14. The fundamental particles that constitute the nucleus are called
    (*a*) α-particles
    (*b*) β-particles
    (*c*) cathode rays
    (*d*) nucleons.
15. The area covered by the electron orbit for the ground state of hydrogen atom is A. What will be the area covered by the electron orbit corresponding to the first excited state?
    (*a*) $2A$ (*b*) $6A$
    (*c*) $3A$ (*d*) $16A$.
16. Isobars are
    (*a*) atoms having the same number of neutrons
    (*b*) atoms that have the same mass number and different atomic number
    (*c*) atoms having the same atomic number but different mass number
    (*d*) all the above are false.
17. The fourth sub-shell of an atom can have a maximum of
    (*a*) 2 (*b*) 10
    (*c*) 6 (*d*) 14.

18. The total energy of the electron in the orbit of an atom is negative because
(*a*) kinetic energy of the electron is greater than the potential energy
(*b*) potential energy of the electron is greater than the kinetic energy
(*c*) potential energy is $\left(\frac{1}{3}\right)$rd of kinetic energy
(*d*) kinetic energy is $\left(\frac{1}{3}\right)$rd of potential energy.

19. The order of frequencies of the lines of the visible region of the mercury spectrum is approximately
(*a*) 60000×10^{14}/s
(*b*) 600×10^{14}/s
(*c*) 60×10^{14}/s
(*d*) 6×10^{14}/s.

20. If r_1 and r_3 are the radii of the first and third stationary orbits for electrons in hydrogen atom respectively, then $\frac{r_1}{r_3}$ is
(*a*) 0.25 (*b*) 0.45
(*c*) 0.11 (*d*) 1.1.

21. In Sommerfield atom model for the principal quantum number 4, ratio of the major axis to the minor axis of the various elliptical sub-shells are
(*a*) 1, 2, 3, 4 (*b*) 1, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$
(*c*) 4, 2, $\frac{4}{3}$, 1 (*d*) 1, 8, $\frac{3}{4}$, $\frac{1}{4}$.

22. If the radius of the first orbit in hydrogen atom is 0.05 nm, the radius of the first orbit in helium atom is
(*a*) 0.05 nm (*b*) 1 Å
(*c*) 0.8 nm (*d*) 0.025 nm.

23. The radius of the second orbit of hydrogen atom is 0.212 nm. The radius of the fourth orbit is
(*a*) 18.8 nm
(*b*) 16.2 nm
(*c*) 1.2 nm
(*d*) 0.848 nm.

24. One light year covers a distance of
(*a*) 10000 km
(*b*) 6.2×10^2 km
(*c*) 9×10^{12} km
(*d*) 7.2×10^{10} km.

25. The magnetic moment associated with the first orbit in hydrogen atom is
(*a*) $\frac{h}{4\pi me}$ (*b*) $\frac{4\pi m}{h}$
(*c*) $\frac{ehm}{4\pi}$ (*d*) $\frac{eh}{4\pi m}$.

26. The potential energy of an electron in an atom is
(*a*) twice its kinetic energy
(*b*) half its potential energy
(*c*) thrice its kinetic energy
(*d*) equal to its kinetic energy.

27. The number of spectral lines from a single atom of hydrogen is
(*a*) zero (*b*) one
(*c*) two (*d*) four.

28. If V is the velocity of the electron in a stationary orbit of radius, then the orbital frequency of the electron is
(*a*) $\frac{V}{r}$ (*b*) $\frac{V}{\pi r}$
(*c*) $\frac{V}{2\pi r}$ (*d*) $\frac{2\pi r}{V}$.

29. 4 electron volt is equivalent to
(*a*) 2.2×10^{-19} J (*b*) 6.4×10^{-19} J
(*c*) 3.2×10^{19} J (*d*) 6.8×10^{20} J.

30. 5460 Å unit is the wavelength of the green line of mercury spectrum; then in nanometre the value of wavelength is
(*a*) 5.46 (*b*) 546
(*c*) 54600 (*d*) 621.

31. In a hyrdogen–like atom the energy required to excite the electron from 2nd to the 3rd level is 47.2 eV. The atomic number of the atom (R_H = 1.096 × 10^7 sec^{-1}) is
(*a*) 1 (*b*) 5
(*c*) 2 (*d*) 3.

32. The first line in the Lyman series of hydrogen spectrum has a wavelength λ. The second line of Balmer series has a wavelength
(*a*) 4λ (*b*) $\frac{27}{5}\lambda$
(*c*) $\frac{6}{27}\lambda$ (*d*) 2λ.

33. The ratio of the energies of the hydrogen atom in its first to second excited state is
(*a*) 4 (*b*) $\frac{1}{4}$
(*c*) $\frac{3}{4}$ (*d*) $\frac{9}{4}$.

34. Volume of the electron cloud in an atom is largely dependent on the
(*a*) principal quantum number
(*b*) angular momentum quantam number
(*c*) spin quantam number
(*d*) magnetic quantam number.

35. The wave number of 2nd line of Lyman series is
(*a*) $2R_H$ (*b*) $\frac{12R_H}{5}$
(*c*) $\frac{3R_H}{4}$ (*d*) $\frac{8}{9}R_H$.

36. The length of the semi-major axis of an electron in an elliptical orbit is determined.

(*a*) soley by the principal quantum number

(*b*) soley by the azimuthal quantum number

(*c*) both by the principal quantum number and azimuthal quantum number

(*d*) all are true.

37. If n_ϕ and n for an electron in an elliptical orbit are 1 and 2 respectively, then the ratio of semi-major axis and semi-minor axis is

(*a*) 2 (*b*) 0.5

(*c*) 1 (*d*) 2.5.

38. Two elements are called isotones if their atoms have

(*a*) the same number of protons but different masses.

(*b*) The same number of neutrons but different masses

(*c*) the same number of electrons but different masses

(*d*) the same atomic mass.

39. An excited hydrogen atom emits a photon of wavelength λ during the transition to the ground state. The principal quantum number n of the excited state is

(*a*) $\left[\dfrac{\lambda R_H}{(\lambda R_H - 1)}\right]^{1/2}$ (*b*) $\left[\dfrac{\lambda R_H - 1}{\lambda R_H}\right]^{1/2}$

(*c*) λR_H (*d*) $\left[\dfrac{1}{R_H - 1}\right]^{1/3}$.

40. In the Bohr atom of hydrogen, the ratio of the kinetic energy to the total energy of the electron in quantum state n is

(*a*) 1 (*b*) – 1

(*c*) 2 (*d*) – 2.

41. Paschen series, Brackett series and Pfund series of the hydrogen spectrum lie

(*a*) partly in ultraviolet and partly infrared region

(*b*) partly in visible and partly infrared region

(*c*) partly in the visible and partly in the ultraviolet region

(*d*) wholly in the infrared region.

42. The speed of the electron in the orbit of hydrogen atom in the ground state according to de Broglie hypothesis is

(*a*) $v_n = \frac{n\lambda}{2\pi}$ (*b*) $v_n = \frac{2\pi}{\lambda}$

(*c*) $v_n = \frac{n\lambda}{\pi}$ (*d*) $v_n = \frac{n\lambda}{2}$.

43. The magnetic field at the centre of a hydrogen atom due to the motion of the electron in the first Bohr orbit is B. The magnetic field at the centre due to the motion of the electron in the second Bohr orbit is

(*a*) $\frac{B}{16}$ (*b*) $\frac{B}{32}$

(*c*) $\frac{B}{8}$ (*d*) $\frac{B}{4}$.

44. If the principal quantum number and azimuthal quantum number in the relativistic model of the atom are 3 and 1 respectively, then the magnitude of the semi-minor axis b in terms of the semi-major axis a is given by

(*a*) $b = \frac{2a}{3}$ (*b*) $\frac{a}{2}$

(*c*) $b = \frac{a}{4}$ (*d*) $\frac{a}{3}$.

45. Which of the following transition is ruled out in Sommer Feld model of the atoms

(*a*) $3_1 \to 2_2$ (*b*) $3_1 \to 2_1$

(*c*) $3_2 \to 2_1$ (*d*) $3_3 \to 2_2$.

46. One light year covers a distance of approximately

(*a*) 100000 km (*b*) 6.2×10^6 km

(*c*) 9×10^{12} km (*d*) 7.2×10^{10} km.

47. Light coming from a commercially lighted mercury fluorescence tube consists of

(*a*) emission lines of mercury

(*b*) emission lines of mercury with a few bonds

(*c*) emission lines of mercury with a continuous back ground

(*d*) emission lines of mercury and those of electrode material.

48. If the series limit wavelength of Lyman series for hydrogen atom is 91.2 nm, then the series limit wavelength for the Balmer series hydrogen atom is

(*a*) 912 nm

(*b*) 4×912 nm

(*c*) 2000 Å

(*d*) 4×91.2 nm.

49. Given: mass number of gold = 197, density of gold = 19700 k/m^3, Avogadro's number 6×10^{26}. The radius of the gold atom is approximately.

(*a*) 1.8×10^{-12} m

(*b*) 2.8×10^{-11} m

(*c*) 1.6×10^{-10} m

(*d*) 8.1×10^{10} m.

50. At the time of total solar eclipse, the spectrum of solar radiation will be
(*a*) large number of dark Fraunhoffer lines
(*b*) a smaller number of dark Fraunhoffer lines
(*c*) no lines at all
(*d*) all Fraunhoffer lines changed into brilliant colours.

51. When a magnetic field is applied to an atom, each spectral line splits. This is called
(*a*) photoelectric effect
(*b*) Zeeman effect
(*c*) Compton effect
(*d*) Thermoelectric effect.

52. The radius of electron's second orbit in hydrogen atom is R. The radius of the third orbit will be
(*a*) $\frac{R}{3}$ (*b*) 2.25 R
(*c*) 4.25 R (*d*) $\frac{R}{2}$.

53. If the principal quantum number and azimuthal quantum number in the relativistic model of the atom are 3 and 1 respectively, then the magnitude of the semi-minor axis b in terms of the semi major axis a is
(*a*) 2.5 (*b*) 0.5
(*c*) 1 (*d*) 2.

54. The maximum number of electrons in a sub-shell with orbital quantum number l is
(*a*) $(2l + 1)$ (*b*) $(2l - 1)$
(*c*) $2(2l + 1)$ (*d*) $2(2l - 1)$.

55. One Bohr magneton is approximately
(*a*) 10^{-23} A m^2 (*b*) 10^{10} A/m^2
(*c*) 10^{-10} A/m^2 (*d*) 10^2 Am^2.

56. The total energy of an electron in an atom is
(*a*) zero
(*b*) less than zero
(*c*) more than zero
(*d*) infinity.

PROBLEMS AND SOLUTIONS

1. *ΔE is the energy difference in electron volt in the energies of any two levels. Calculate wavelength of the photon emitted or absorbed.*

Solution:

$$\Delta E = h\nu$$

or $$\frac{hc}{\lambda} = \Delta E$$

$$\lambda = \frac{hc}{\Delta E} = \frac{3 \times 10^8 \times 6.62 \times 10^{-34}}{\Delta E \times 1.6 \times 10^{-19}}$$

$$\boxed{\lambda = \frac{1240}{\Delta E} \text{ nm}}$$ **Ans.**

2. *If the wave number of a spectral line of Brackett series of hydrogen is $\frac{9}{400}$ times the Rydberg constant, what is the state from which the transition takes place?*

Solution:

$$\frac{9}{400} R_H = R_H \left(\frac{1}{4^2} - \frac{1}{n_2^2} \right)$$

or $$\frac{9}{400} = \frac{1}{16} - \frac{1}{n_2^2}$$

$$\frac{1}{n_2^2} = \frac{1}{16} - \frac{9}{400} = \frac{400 - 9 \times 16}{16 \times 400}$$

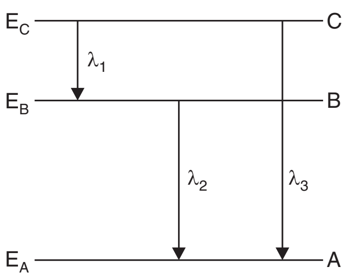
$$= \frac{256}{6400}$$

$$n_2^2 = \frac{6400}{256} = \frac{400}{16} = 25$$

$$\boxed{n_2 = 5}$$ **Ans.**

3. *Energy levels A, B, C of a certain atom corresponds to increasing values of energy. i.e., $E_A < E_B < E_C$. If λ_1, λ_2, λ_3 are the wavelength of radiations corresponding to C to B, B to A and C to A respectively. Find the value of λ_3.*

Solution:



$$E_C - E_B = h\nu_1 = \frac{hc}{\lambda_1} \quad ...(1)$$

$$E_C - E_A = h\nu_3 = \frac{hc}{\lambda_3} \quad ...(2)$$

$$E_B - E_A = h\nu_2 = \frac{hc}{\lambda_2} \quad ...(3)$$

$$E_C - E_A = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right)$$

Also, $E_C - E_A = hc \times \dfrac{1}{\lambda_3}$

$$\frac{hc}{\lambda_3} = hc\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right) = hc\frac{(\lambda_2 - \lambda_1)}{\lambda_1\lambda_2}$$

$$\boxed{\lambda_3 = \frac{\lambda_1 \lambda_2}{(\lambda_2 - \lambda_1)}} \quad \textbf{Ans.}$$

4. *The rest mass energy of an electron is 0.511 MeV. The electron is accelerated from rest to a velocity 0.5 c. Calculate the change in its energy.*

Solution:

$$E_1 = m_0c^2 = 0.511 \text{ MeV}$$

$$m = \frac{m_0}{\sqrt{1-(0.5\times c)^2/c^2}}$$

$$= \frac{m_0}{\sqrt{1-0.25}} = \frac{m_0}{\sqrt{0.75}}$$

$$E_2 = mc^2 = \frac{m_0 \times c^2}{0.87}$$

$$\frac{E_2}{E_1} = \frac{m_0c^2}{0.87\times m_0c^2} = \frac{1}{0.87}$$

$$E_2 = \frac{E_1}{0.87} = \frac{0.511}{0.87} = 0.079 \text{ MeV}$$

$$\boxed{E_2 = 0.079 \text{ MeV}} \quad \textbf{Ans.}$$

5. *The radius of the orbital electron in the hydrogen atom is 0.5Å. The speed of the electron is 2×10^6 m/s. Calculate current in the loop due to the motion of the electron.*

Solution:

The magnetic moment of the current loop is

$$M_L = iA = i\pi r^2$$

$$M_L = \frac{e}{T}\pi r^2$$

But $\frac{2\pi r}{T} = \nu$

$$\frac{1}{T} = \frac{\nu}{2\pi r}$$

$$M_L = i\pi r^2 = \frac{e\pi r^2 v}{2\pi r} = \frac{erv}{2}$$

$$i = \frac{ev}{2\pi r} = \frac{1.6 \times 10^{-19} \times 2 \times 10^6}{2\pi \times 0.5 \times 10^{-10}}$$

$$\boxed{i = 1 \text{ mA}}$$ **Ans.**

6. *Though hydrogen atom contains only one electron, its emission spectra consists of many lines. Explain.*

   Solution:

   Though hydrogen atom contains only one electron revolving round the nucleus, it can have many energy states. When atom absorbs energy from outside, the electron jumps from ground state to one of the higher energy states. Immediately it falls back to one of the lower energy states releasing a photon of definite frequency. In a light source (hydrogen lamp) there are millions of atoms and hence all possible transitions can take place. Hence we observe many lines in a hydrogen spectrum.

7. *The radius of a nucleus of mass number A is $R = R_0 A^{1/3}$ where $R_0 = 1.1 \times 10^{-5}$ m. Calculate the density of the nucleus.*

   Solution:

   Average mass of a nucleus is

   $$1 \text{ a.m.u.} = 1.66 \times 10^{-27} \times A = M$$

Radius of the nucleus, $r = R_0 A^{1/3}$

$$\rho = \frac{M}{V} = \frac{1.66 \times 10^{-27} \times A \times 3}{4\pi R_0^{\ 3} A}$$

$$\boxed{\rho = 2.98 \times 10^{17} \text{ kg/m}^3} \quad \textbf{Ans.}$$

8. *Half litre of water is added to one litre of milk to prepare tea. The Avogadro's number is 6 × 10^{26} k mol. The density of water is 1 gm/cc. Calculate number of water molecules of the water added molecular weight of water 18 and density 1000 kg/m^3.*

Solution:

$\frac{18}{1000}$ m^3 of water contains = 6 × 10^{26}

1 m^3 of water contains

$$= \frac{6 \times 10^{29}}{18} \text{ molecules}$$

$$= 3.33 \times 10^{28} \text{ molecules.}$$

1 cm^3 contains

$$= \frac{3.33 \times 10^{28}}{100 \times 100 \times 100}$$

$$= 3.33 \times 10^{22} \text{ molecules/cm}^3$$

i.e., one cc contains 3.33 × 10^{22}

500 cc contains

$$= 3.3 \times 500 \times 10^{22}$$

$$= 3.33 \times 5 \times 10^{24}$$

$$= 1.65 \times 10^{25} \text{ water molecules}$$

$$\boxed{1.65 \times 10^{25}} \quad \textbf{Ans.}$$

9. Get the unit of Bohr magneton

$$\mu_B = \frac{eh}{4\pi m} = \frac{\text{amp sec J sec}}{\text{kg}}$$

For joule

$$J = W \cdot D = F \times d$$

$$= \text{Mass} \times \text{Acceleration} \times \text{Distance}$$

$$J = \text{kg} \times \frac{\text{metre}}{\text{sec}^2} \times \text{metre} = \text{kg m}^2/\text{sec}^2$$

$$\mu_B = \left[\frac{\text{amp . J sec}^2}{\text{kg}}\right]$$

$$= \frac{\text{amp sec}^2}{\text{kg}} (\text{kg m}^2/\text{sec}^2)$$

$$= \text{amp m}^2$$

i.e., $\boxed{\text{unit of } \mu_B \text{ is amp m}^2}$ **Ans.**

10. *The energy of an excited hydrogen atom is – 3.4 eV. Calculate the angular momentum of the electron according to Bohr's theory.*

Solution:

The energy of the electron in the nth orbit of hydrogen atom,

$$E_n = -\frac{13.6}{n^2} \text{ eV} ; \quad -\frac{13.6}{n^2} = -3.4$$

or $n = 2$

Thus angular momentum,

$$L = \frac{nh}{2\pi} = \frac{2 \times 6.62 \times 10^{-34}}{2 \times 3.14}$$

$$\boxed{L = 2.11 \times 10^{-34} \text{ J s}}$$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*a*)	2. (*c*)	3. (*c*)	4. (*d*)
5. (*d*)	6. (*b*)	7. (*c*)	8. (*d*)
9. (*a*)	10. (*d*)	11. (*a*)	12. (*b*)
13. (*d*)	14. (*d*)	15. (*d*)	16. (*b*)

17. (*d*)	18. (*b*)	19. (*d*)	20. (*c*)
21. (*c*)	22. (*d*)	23. (*d*)	24. (*c*)
25. (*d*)	26. (*a*)	27. (*b*)	28. (*c*)
29. (*b*)	30. (*b*)	31. (*b*)	32. (*a*)
33. (*d*)	34. (*a*)	35. (*d*)	36. (*a*)
37. (*a*)	38. (*b*)	39. (*a*)	40. (*b*)
41. (*d*)	42. (*a*)	43. (*b*)	44. (*d*)
45. (*d*)	46. (*c*)	47. (*c*)	48. (*d*)
49. (*c*)	50. (*d*)	51. (*b*)	52. (*b*)
53. (*d*)	54. (*c*)	55. (*a*)	56. (*b*).

9.3 MATTER WAVES, X-RAYS AND X-RAY DIFFRACTION

1. The ratio of de Broglie wavelength for protons and electrons (their speed is 10^5 m/s) (m_e = 9.1 × 10^{-31} kg, m_p = 1.67 × 10^{-27} kg) is
   (*a*) 5.5 × 10^{-6} (*b*) 6.5 × 10^{-6}
   (*c*) 2 × 10^{-2} (*d*) 5.5 × 10^{-4}.
2. The de Broglie wavelength associated with a proton of kinetic energy 8 × 10^{-17} J and mass 1.67 × 10^{-27} kg (Planck's constant, h = 6.63 × 10^{-34} J s) is
   (*a*) 0.00128 nm
   (*b*) 0.00128 Å
   (*c*) 1.212 nm
   (*d*) 0.012 × 10^{-8} m.
3. Express the rest energy of an electron in *M* eV
   (*a*) 1.227 *M* eV
   (*b*) 500 *M* eV
   (*c*) 100 *M* eV
   (*d*) 0.51 *M* eV.
4. The de Broglie wavelength associated with the thermal neutron at 27°C is

(*a*) 1.45×10^{8} m
(*b*) 1.45×10^{-10} m
(*c*) 1.45×10^{-12} m
(*d*) 1.45×10^{-6} m.

5. When high speed electron hits a target of high atomic number, the efficiency of production of X-rays is
(*a*) 100%
(*b*) 50%
(*c*) even less than 1%
(*d*) 75%.

6. When X-rays pass through air they
(*a*) produce light track in the air
(*b*) ionise the gas
(*c*) produce fumes in air
(*d*) accelerate gas atoms.

7. Davisson and Germen were the first to demonstrate
(*a*) the straight line propagation of light
(*b*) the diffraction of electrons
(*c*) the effective mass of electron
(*d*) the particle nature property.

8. Which of the following has largest de Broglie wavelength λ, provided all have equal velocity.
(*a*) CO_2 molecule
(*b*) NH_3 molecule
(*c*) proton
(*d*) O_2 molecule.

9. Which of the following statements about X-rays is/are accepted fact(s)
(*a*) they are generated when fast moving electrons strike a metal target
(*b*) they can penetrate through a thin sheet of aluminium

(*c*) when they traverse a space across which there is a magnetic field and electric field perpendicular to one another they describe a circular path

(*d*) when they traverse a space across which there is a magnetic field and electric field parallel to one another they describe a circular path?

10. The wavelength associated with a moving particle

(*a*) depends upon the charge associated with it

(*b*) does not depend upon the charge associated with it

(*c*) depends upon the medium in which particle travels

(*d*) depends on the refractive index of the medium.

11. If particles are under thermal motion are at the associated temperature T, then the wavelength associated with them at temperature T is

(*a*) $\lambda = \dfrac{h}{\sqrt{3\, mk_B\, T}}$ (*b*) $\dfrac{\sqrt{3\, mk_B T}}{h}$

(*c*) $\lambda = \dfrac{h}{mk_B T}$ (*d*) $\lambda = mk_B T$.

12. An electron is accelerated by 144 volt; the wavelength of de Broglie associated with the electron in approximately

(*a*) 1 Å (*b*) 10 Å

(*c*) 0.1 Å (*d*) 100 Å.

13. The maximum frequency ν of continuous X-ray beam is related to the applied potential difference as

(*a*) $\nu \propto \sqrt{V}$ (*b*) $\nu \propto V^2$

(*c*) $\nu \propto \dfrac{1}{V}$ (*d*) $\nu \propto V$.

14. The mass of a neutron is 1.8×10^3 times greater than that of an electron at T kelvin. Their de Broglie wavelengths are related as

(a) $\lambda_e = \lambda_n \times \sqrt{1.8 \times 10^3}$

(b) $\lambda_e = \dfrac{\lambda_n}{\sqrt{1.8 \times 10^3}}$

(c) $\lambda_e = 2\lambda_n$

(d) $\lambda_e = 100\ \lambda_n$.

15. In an X-ray tube, the intensity of the emitted X-ray beam is increased by
(a) increasing the filament current
(b) decreasing the filament current
(c) increasing the target potential
(d) decreasing the target potential.

16. What determines the hardness of the X-rays obtained from the Coolidge tube?
(a) current in the filament
(b) presence of air in the tube
(c) nature of target
(d) potential difference between the cathode and the target.

17. The penetrating power of X-rays increases with the
(a) increase in intensity
(b) decrease in intensity
(c) decrease in velocity
(d) increase in frequency.

18. An X-ray tube operates at 50 kV. The minimum wavelength produced is
(a) 1 Å (b) 0.76 Å
(c) 0.0248 nm (d) 2.24 Å.

19. The resolving power of the given electron microscope is of the order of the wavelength of the ray used
(a) yes (b) no.

20. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation
    (*a*) the intensity increases
    (*b*) the minimum wavelength increases
    (*c*) the intensity remains unchanged
    (*d*) the minimum wavelength decreases.
21. For the structural analysis of the crystal, X-rays are used because
    (*a*) X-rays have wavelengths of the order of interatomic spacing
    (*b*) X-rays are highly penetrating radiation
    (*c*) wavelength of X-rays are of the order of nuclear size
    (*d*) the wavelength of X-rays is of the order of 546 nm.
22. If the momentum of an electron is doubled, the de Broglie wavelength is
    (*a*) halved
    (*b*) doubled
    (*c*) remains constant
    (*d*) none of these.
23. Which of the following statements is true for both X-rays and α-particles?
    (*a*) both cause ionisation of air when they pass through it
    (*b*) both can be deflected by electric and magnetic fields
    (*c*) both can be used to detect flaws on metal casting
    (*d*) both travel with the speed of light.
24. X-rays are
    (*a*) stream of electrons
    (*b*) stream of positive ions
    (*c*) electromagnetic radiations
    (*d*) stream of neutrons.

25. The bombarding electron with huge energy may penetrate into the atom and knock out tightly bound electrons from higher shells to the inner shells give rise to characteristic X-rays. This is

(*a*) true (*b*) false.

26. Four physical quantities are listed in column I. Their values are listed in column II in a random order

Column I	*Column II*
(*a*) thermal energy of air at room temperature	(*e*) 0.002 eV
(*b*) binding energy per nucleon of heavy nuclei	(*f*) 2 eV
(*c*) X-ray photon energy	(*g*) 1 keV
(*d*) photon energy of visible region	(*h*) 7 MeV

The correct matching of column I and column II is given by

(*a*) $a - e, b - g, c - f, d - h$

(*b*) $a - e, b - h, c - g, d - f$

(*c*) $a - f, b - c, c - g, d - h$

(*d*) $a - f, b - h, c - e, d - g$

27. As the wavelength of X-rays is smaller than that of visible light, the speed of X-rays in vacuum is

(*a*) same as that of light

(*b*) larger than that of visible light

(*c*) smaller than that of visible light

(*d*) twice that of visible light.

28. The ratio of speed of γ-rays and X-rays is

(*a*) < 1

(*b*) > 1

(*c*) 1

(*d*) depends on the ratio of their wavelengths.

29. X-rays which can penetrate through the longer distances in substances are called
(*a*) soft X-rays
(*b*) continuous X-rays
(*c*) hard X-rays
(*d*) none of the above.

30. X-rays cannot penetrate through
(*a*) wood (*b*) paper
(*c*) aluminium (*d*) lead.

31. The intensity of X-rays absorbed is I_a and the initial intensity is I_0. Then I_0 is given by
(*a*) $I_a = I_0 \, e^{-\mu x}$
(*b*) $I_a = \mu x$
(*c*) $I_a = \frac{I_0}{2}$
(*d*) $I = I_0 \, (1 - e^{-\mu x})$
where μ is the absorption coefficient.

32. If k_α radiations of a metal with $Z = 42$ has a wavelength 0.07 nm, the wavelength of an other element with $Z = 29$ is
(*a*) 0.1 Å (*b*) 0.15 nm
(*c*) 2 Å (*d*) 3.2 nm.

33. The wavelength λ of k_α line of an anticathode element of atomic number Z is
(*a*) Z^2 (*b*) $(Z - 1)^2$
(*c*) $\frac{1}{(Z-1)}$ (*d*) $\frac{1}{(Z-1)^2}$.

34. In a Bragg's spectrometer experiment, the glancing angle for the fourth order of spectrum of the X-rays was found to be 35°. What will be the glancing angle for the occurrence of the order of maximum?

(*a*) $\sin^{-1} 0.287$ (*b*) $\sin^{-1} 0.912$
(*c*) 4° (*d*) 8°.

35. X-ray region lies between
(*a*) short radio waves and visible region
(*b*) visible and ultraviolet region
(*c*) gamma ray and ultraviolet region
(*d*) short radio waves and long radio waves region.

36. A potential difference 42000 volt is used in an X-ray tube to accelerate electron. The minimum frequency of the X-radiator produced is
(*a*) 10^{19} Hz (*b*) 10^{3} Hz
(*c*) 10^{14} Hz (*d*) 10^{6} Hz.

37. The largest distance between the interatomic planes of a crystal is 1 nm; the upper limit for the wavelength of X-rays which can be studied with this crystal is
(*a*) 1 Å (*b*) 1 nm
(*c*) 3 nm (*d*) 2 nm.

38. The binding energy of the innermost electron in tungsten is 40 keV. To produce characteristic X-rays using tungesten target in X-ray tube the potential difference *V* between the cathode and anticathode should be
(*a*) $V < 40$ kV (*b*) $V \leq 40$ kV
(*c*) $V > 40$ kV (*d*) $V \geq 40$ kV.

39. If ν is the frequency of X-rays then $\sqrt{\nu} = k(Z - b)$ where k and b are constants. This relation is called
(*a*) Compton's law (*b*) Laue's law
(*c*) Mosley's law (*d*) Bragg's law

40. X-rays are
   (*a*) deflected by electric and magnetic fields
   (*b*) they are electromagnetic radiations of very short wavelength of about 1 Å
   (*c*) they travel in curved path with a velocity of 330 m/s
   (*d*) they do not affect photographic plates unlike ordinary light.
41. The frequency of X-rays
   (*a*) can be controlled by changing the p.d. between the cathode and target
   (*b*) cannot be controlled
   (*c*) can be controlled by increasing the production of number of electrons
   (*d*) can be controlled without cooling the target.
42. A narrow beam of X-rays of wavelength λ fall upon parallel diffracting planes at a glancing angle $\theta°$, then the angle of incidence is
   (*a*) $(\theta + 90)°$ (*b*) $(90 - \theta)°$
   (c) $(180 - \theta)°$ (*d*) 120°.
43. The distance between consecutive lattice planes, defined by Miller indices (110) in a cubic lattice of parameter 2.82 Å is
   (*a*) 2 Å (*b*) 1 Å
   (*c*) 0.5 Å (*d*) 1.5 Å.
44. The de Broglie wavelength associated with an electron accelerated by a potential 100 volt is approximately
   (*a*) 1.227×10^{-8} metre
   (*b*) 1.227 metre
   (*c*) 1.227×10^{-16} metre
   (*d*) 1.227×10^{-10} metre.

45. The short wavelength limit (or minimum wavelength) of continuous X-ray spectrum is

(*a*) $\lambda_{min} = \dfrac{(hc)^2}{eV}$ (*b*) $\dfrac{eV}{hc}$

(*c*) $\lambda_{min} = \dfrac{hc}{eV}$ (*d*) e^2V.

46. Continuous X-ray spectrum is due to deacceleration of high velocity electron

(*a*) yes (*b*) no.

47. Generation of X-rays is

(*a*) phenomenon of conservation of energy

(*b*) principal of conservation of momentum

(*c*) wave nature of matter

(*d*) phenomenon of conversion of K.E. into radiant energy.

48. Line spectrum is produced when electrons are dislodged from the innermost orbits of atom of the target material followed by electron jumps from outer orbits.

(*a*) yes (*b*) no.

49. Taking Δx as the error in determining its position and Δp the error in determining its momentum at the same instant, these quantities are Δx and Δp are approximately related as $\Delta x \, \Delta p \geq$

(*a*) $(2r\pi h)^2$ (*b*) $\dfrac{1}{2\pi h}$

(*c*) h (*d*) h^2

where h is Planck's constant.

50. The wavelength of the matter waves associated with a particle is given by

(*a*) $\frac{p}{h}$ (*b*) $\frac{h}{p}$

(*c*) $\frac{\sqrt{h}}{p}$ (*d*) $\frac{p}{\sqrt{h}}$

where p is momentum.

51. Which of the following has the highest frequency
(*a*) visible light
(*b*) ultraviolet rays
(*c*) infrared rays
(*d*) X-rays.

52. The quality of X-rays is determined by
(*a*) filament current
(*b*) filament voltage
(*c*) p.d. between the anode and the cathode
(*d*) none of the above.

53. Continuous X-rays are produced as a result of
(*a*) transition of electrons of target from lower to higher orbits
(*b*) transition of electrons of target from higher to lower orbits
(*c*) loss of kinetic energy of incident electrons
(*d*) loss of mass of incident electrons.

54. The kinetic energy of electrons which are converted into X-rays is
(*a*) 10% (*b*) 50%
(*c*) 100% (*d*) 2%.

55. The minimum frequency limit of the X-ray depends on
(*a*) nature of target material
(*b*) kinetic energy of incident electrons
(*c*) the degree of vacuum is Coolidge tube
(*d*) none of the above.

56. Hydrogen atom does not emit characteristics X-rays because
    (*a*) the electron is loosely bound
    (*b*) the electron is strongly bound
    (*c*) its energy levels are too close to each other
    (*d*) its atomic number is low.
57. The distance between various Bragg's planes in a crystal is
    (*a*) same (*b*) different
    (*c*) depends on type of crystal.
58. The frequency of any line in the characteristic X-rays is directly proportional to
    (*a*) atomic number of element
    (*b*) square of atomic number of element
    (*c*) square root of atomic number of element.
59. X-rays passing through a strong uniform magnetic field
    (*a*) get deflected along the direction of the field
    (*b*) get deflected opposite to the direction of the field
    (*c*) get deflected perpendicular to the direction of the field
    (*d*) do not get deflected at all.

PROBLEMS AND SOLUTIONS

1. *A bullet of mass 40 gm travels at 1000 m/s. The wavelength associated with it is*
   (a) 1.66×10^{-33} m (b) 1.26×10^{2} m
   (c) 17.2 m (d) 5.5×10^{-4}.
   Also point out the significance of the result with respect to diffraction.

Solution:

$$\lambda = \frac{6.62 \times 10^{-34}}{40 \times 10^{-3} \times 1000}$$

$$\boxed{= 1.66 \times 10^{-35} \text{ m}} \quad \textbf{Ans.}$$

Conclusion:

It is seen that the wavelength associated with the bullet extremely small. So it cannot be diffracted. Diffraction effects are noticeable for obstacles whose dimensions are of the order of the wavelength. Even for obstacles of the size of atom *i.e.* 10^{-10} m, the wavelength is small. Hence here the diffraction effects could not be detected.

2. *Compare the momentum of 10^5 eV X-rays (p_x) with that of 10^5 eV electron (p_e).*

Solution:

$$p_e = \sqrt{2\,mE} \quad \left\{\because \; E = \frac{1}{2}\frac{m^2v^2}{m}\,;\; p_e^2 = 2mE\right\}$$

$$p_x = \frac{E}{c} \qquad \left\{\because \; E = mc^2\,;\, mc = p_x = \frac{E}{c}\right\}$$

$$\frac{p_e}{p_x} = \frac{3 \times 10^8 \sqrt{2 \times 9.1 \times 10^{-31} \times E}}{E}$$

$$= \frac{3 \times 10^8 \sqrt{2 \times 9.1 \times 10^{-31}}}{\sqrt{10^5 \times 1.6 \times 10^{-19}}} = \frac{16}{5}$$

$$\boxed{\frac{p_e}{p_x} = \frac{16}{5}} \quad \textbf{Ans.}$$

3. *The maximum frequency ν of continuous X-rays is related to the applied potential difference. What is the type of relation?*

Solution:

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

and $\quad \frac{1}{2}(mv^2 - mv'^2) = h\nu.$

For ν to be maximum, $mv'^2 = 0$

or $\quad \frac{1}{2} mv^2 = Ve = h\nu_{\text{max}}$

$$h\nu_{\text{max}} = Ve$$

$$\nu_{\text{max}} = \frac{Ve}{h}$$

$$\boxed{\nu_{\text{max}} \propto V} \quad \textbf{Ans.}$$

4. *An α-particle and a proton have the same kinetic energy. If the mass of the proton is four times smaller than that of the α-particle, how do their wavelengths compare?*

Solution:

$$\frac{1}{2} m_1 v_1^2 = \frac{1}{2} 4\, m_1 v_2^2$$

$$\frac{v_1}{v_2} = 2$$

$$\lambda_p = \frac{h}{m_1 v_1} \quad \text{and} \quad \lambda_\alpha = \frac{h}{4 m_1 v_2}$$

$$\frac{\lambda_p}{\lambda_\alpha} = \frac{4 m_1 v_2}{m_1 v_1} = 4 \times \frac{v_2}{v_1} = 4 \times 1/2 = 2$$

$$\boxed{\lambda_p = 2\,\lambda_\alpha} \quad \textbf{Ans.}$$

5. *The velocity of ultrasonic waves in blood is 1576 m/s measured using a crystal of 1 MHz. The frequency of X-ray for comparison is 3 × 10^19 Hz. Compare the wavelength in the two cases. What are the conclusions arrived at?*

Solution:

Ultrasonic waves:

$$v = v_1\lambda_u$$

$$\lambda_u = \frac{1576}{10^6}\ \text{m} = \frac{157600}{10^6}\ \text{cm}$$

$$\lambda_u = 0.15\ \text{cm}$$

X-rays

$$v = c = \nu\lambda_x$$

$$\lambda_x = \frac{c}{\nu} = \frac{3\times 10^{10}}{3\times 10^{19}}\ \text{cm} = 10^{-9}\ \text{cm}$$

$$\lambda_x = 10^{-9}\ \text{cm}$$

$$\frac{\lambda_u}{\lambda_x} = \frac{0.15}{10^{-9}} = 10^{-9}$$

$$\boxed{\lambda_u = 10^9 \times \lambda_x} \quad \textbf{Ans.}$$

i.e., the wavelength of ultrasonic waves is 10^9 times greater than that of X-rays. *i.e.*, frequency or every associated with ultrasonic waves 10^9 times smaller than that of X-rays. Hence ultrasonic waves can be frequently used in medical diagonosis and also fairly for longer time.

6. *An electron microscope uses 1.25 keV electrons. Find its ultimate resolving power.*

Solution:

Energy $eV = 1.25$ keV

or $\quad V = 1.25 \times 10^3$ volt

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

$$\frac{m^2v^2}{2m} = eV$$

$$p^2 = 2\ meV$$

$$\lambda = \frac{h}{p}$$

$$= \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19} \times 1.25 \times 10^{3}}}$$

$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{18.2 \times 1.6 \times 1.25 \times 10^{-47}}}$$

$$\lambda = \frac{6.62 \times 10^{-34}}{2.13 \times 10^{-23}}$$

$$= 3.1 \times 10^{-11} = 0.31 \text{ Å}$$

$$\boxed{\lambda = 0.31 \text{ Å}}$$ **Ans.**

7. *Calculate the energy in electron volt of an electron wave $\lambda = 3 \times 10^{-2}$ m. Given $h = 6.62 \times 10^{-34}$ Js.*

Solution:

$$\lambda = \frac{h}{mv}$$

$$mv = \frac{h}{\lambda}$$

$$(mv)^2 = \left(\frac{h}{\lambda}\right)^2$$

$$\frac{1}{2}\frac{m^2v^2}{m} = \frac{h^2}{2\lambda^2} \times \frac{1}{m}$$

$$\frac{1}{2}mv^2 = E = \frac{h^2}{2m\lambda^2}$$

$$E = \frac{(6.62 \times 10^{-34})^2}{2 \times 9.1 \times 10^{-31} \times (3 \times 10^{-2})^2}$$

$$= 0.27 \times 10^{-33}$$

$$= \frac{0.27 \times 10^{-33}}{1.6 \times 10^{-19}}$$

$$\boxed{E = 1.68 \times 10^{-15} \text{ eV}}$$ **Ans.**

8. *What would be the wavelength of quantum of radiant energy emitted, if an electron is transmitted into radiation and converted into one quantum?*

Solution:

When the energy of electron is transmitted into radiations, we have the relation

$$E = mc^2 \text{ (mass energy relation)}$$

According to Planck, the energy E associated with one quantum $= h\nu$, where ν is the frequency of radiation.

$$h\nu = mc^2$$

or $$\frac{hc}{\lambda} = mc^2$$

$$\lambda = \frac{h}{mc} = \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^{8}}$$

$$= 0.0244 \text{ Å}$$

$$\boxed{\lambda = 0.00244 \text{ nm}}$$ **Ans.**

9. *An enclosure filled with helium is heated to 400 K. A beam of helium atoms emerges out of the enclosure. Calculate de Broglie wavelength corresponding to helium atoms. Mass of helium atom is 6.7×10^{-27} kg.*

Solution:

We know

$$\lambda = \frac{h}{mv}$$

$$mv = \frac{h}{\lambda}$$

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

$$\frac{1}{2}mv^2 = \frac{h^2}{2m\lambda^2} = E$$

$$\lambda^2 = \frac{h^2}{2mE}$$

$$\lambda^2 = \frac{h^2}{2mE} \quad \text{or} \quad \lambda = \frac{h}{\sqrt{2mE}}$$

$$\lambda = \frac{h}{\sqrt{2m\,\frac{3}{2}\,k_B T}} = \frac{h}{\sqrt{3\,m\,k_B T}}$$

$$\lambda = \frac{6.62\times 10^{-34}}{\sqrt{3\times(6.7\times 10^{-27})\times(1.38\times 10^{-23})\times 400}}$$

$$\boxed{\lambda = 0.63 \times 10^{-9} = 0.63 \text{ nm}} \quad \textbf{Ans.}$$

10. *An X-ray tube operates at 18 kV. Find the maximum speed of electron striking the target.*

Solution:

$$\frac{1}{2}\,m{v^2}_{\max} = eV$$

$$v_{\max} = \sqrt{\frac{2\,eV}{m}}$$

$$= \left[\frac{2\times 1.6\times 10^{-19}\times 18\times 10^3}{9.1\times 10^{-31}}\right]^{1/2}$$

$$\boxed{v_{\max} = 8 \times 10^7 \text{ m/s}} \quad \textbf{Ans.}$$

11. *An X-ray beam of wavelength 0.97 Å is obtained in the third order reflections at 60° from the crystal plane. Another beam is obtained in the first order reflection at 30° from the same crystal plane. Find the wavelength of the second X-ray beam.*

Solution:

$$2d \sin \theta = n\lambda$$

$$2d \sin 60° = 3 \times 0.97$$

$$2d \sin 30° = 1 \times \lambda'$$

$$\frac{\lambda'}{3 \times 0.97} = \frac{\sin 30°}{\sin 60°}$$

$$\lambda' = 3 \times 0.97 \left(\frac{1/2}{\sqrt{3}/2}\right)$$

$$\boxed{\lambda' = 1.68 \text{ Å}}$$ **Ans.**

12. *Calculate the cut-off wavelength when the potential difference applied to the X-ray tube is 25 kV.*

Solution:

The ratio is $\lambda_{min} = \frac{12400}{V} = \frac{12400}{25000}$

$$= 0.490 \text{ Å}$$

Corresponding maximum frequency is

$$\nu_{max} = \frac{c}{\lambda_{min}} = \frac{3 \times 10^8}{0.496 \times 10^{-10}}$$

$$\boxed{\nu_{max} = 6.05 \times 10^{18} \text{ Hz}}$$ **Ans.**

13. *Electrons are accelerated by 344 volt and are reflected from a crystal. The first reflection maximum occurs when glancing angle is 60°. Determine the spacing of diffracted planes.*

Solution:

$$\lambda = \frac{h}{mv}$$

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

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

$$m^2v^2 = 2mE \; ; \; mv = \sqrt{2mE}$$

$$\lambda = \frac{h}{\sqrt{2mE}} = \frac{h}{\sqrt{2meV}}$$

$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{31} \times 1.6 \times 10^{-19} \times 344}}$$

$$\lambda = 0.66 \text{ nm}$$

According to Bragg's law

$$2d \sin \theta = n\lambda = 1 \times 0.66 \times 10^{-10}$$

$$d = \frac{0.66 \times 10^{-10}}{2 \sin 60°}$$

$$= 0.38 \times 10^{-10} \text{ m}$$

$$\boxed{d = 0.38 \text{ Å}}$$ **Ans.**

14. *An X-ray machine uses an accelerating potential of 1000 volt. Calculate the shortest wavelength present in the X-ray produced.*

Solution:

We have

$$eV = h\upsilon_{max} = \frac{hc}{\lambda_{min}}$$

or $$\lambda_{min} = \frac{hc}{eV}$$

$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{50000 \times 1.6 \times 10^{-19}}$$

$$\boxed{\lambda_{min} = 0.248 \text{ Å}}$$ **Ans.**

ANSWERS TO OBJECTIVE QUESTIONS

1. (*d*)	2. (*a*)	3. (*b*)	4. (*d*)
5. (*c*)	6. (*b*)	7. (*b*)	8. (*c*)

9. (*a*), (*b*), (*c*)		10. (*b*)	11. (*a*)
12. (*a*)	13. (*d*)	14. (*a*)	15. (*a*)
16. (*d*)	17. (*d*)	18. (*c*)	19. (*a*)
20. (*d*)	21. (*a*)	22. (*a*)	23. (*b*)
24. (*c*)	25. (*a*)	26. (*b*)	27. (*a*)
28. (*c*)	29. (*c*)	30. (*d*)	31. (*a*)
32. (*b*)	33. (*d*)	34. (*a*)	35. (*c*)
36. (*a*)	37. (*d*)	38. (*c*)	39. (*c*)
40. (*b*)	41. (*a*)	42. (*b*)	43. (*a*)
44. (*d*)	45. (*c*)	46. (*a*)	47. (*d*)
48. (*a*)	49. (*c*)	50. (*b*)	51. (*d*)
52. (*c*)	53. (*c*)	54. (*d*)	55. (*b*)
56. (*d*)	57. (*b*)	58. (*c*)	59. (*d*).

CHAPTER 10

Radioactivity and Nuclear Reactions

1. Radioactivity involves the
   (*a*) spontaneous disintegration of an atom
   (*b*) spontaneous disintegration of the nucleus of an atom
   (*c*) spontaneous disintegration of protons present in the nucleus
   (*d*) spontaneous disintegration of electron present in the nucleus.
2. The ionisation power of α-particle is
   (*a*) 100 times smaller than that of β-particle
   (*b*) equal to that of β-rays
   (*c*) 100 times greater than that of β-rays
   (*d*) 1000 times less than that of β-rays.
3. The ratio of the radii of the nuclei $_{13}Al^{27}$ and $_{52}Te^{125}$ is approximately
   (*a*) 12 : 21 (*b*) 14 : 73
   (*c*) 40 : 177 (*d*) 6 : 10.
4. The radiations that cause ionisation of the gases and travel with 10% of the velocity of light in vacuum are
   (*a*) α-particles
   (*b*) β-particles
   (*c*) γ-rays
   (*d*) none of the above.
5. Which of the following do not cause any ionisation?

(*a*) α-particles (*b*) β-particles
(*c*) γ-rays (*d*) all the above.

6. β-rays are deflected by electric and magnetic fields. The statement is
(*a*) true (*b*) false.

7. γ-rays are
(*a*) acoustical waves
(*b*) cathode rays
(*c*) electromagnetic radiation
(*d*) none of these.

8. The half-life period of a radioactive element is the period in which the radioactive substance is disintegrated to its
(*a*) one-fourth by mass
(*b*) half by mass
(*c*) two-third by mass
(*d*) one-eighth by mass.

9. The rate of radioactive disintegration depends on
(*a*) the environmental factors
(*b*) on the number of atoms of the element present at any time
(*c*) the colour of the element
(*d*) none of the above.

10. The decay constant which is the reciprocal of the time duration for which the number of the atoms of radioactive substance falls to
(*a*) 17% of its original value
(*b*) 27% of its original value
(*c*) 37% of its original value
(*d*) 47% of its original value.

11. The half-life period of a radioactive element is

(*a*) $T = \frac{1.5}{\lambda}$ (*b*) $T = \frac{69.3}{\lambda}$

(*c*) 0.1λ (*d*) $T = \frac{0.693}{\lambda}$

where λ is the decay constant.

12. If the decay constant of a radioactive substance is λ, then its half-life and mean life are respectively are

(*a*) $\frac{\log_e 2}{\lambda}$ and $\frac{1}{\lambda}$

(*b*) $\frac{1}{\lambda}$ and $\frac{\log_e 2}{\lambda}$

(*c*) $\frac{\lambda}{\log_e 2}$ and $\frac{1}{\lambda}$

(*d*) λ and $\log_e 2$.

13. Which of the following nuclear equations is correct?

(*a*) ${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{92}U^{236} + \gamma$

(*b*) ${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{90}U^{236} + {}_1H^1$

(*c*) ${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{90}U^{236} + \beta$

(*d*) ${}_{92}U^{235} + {}_0n^1 \longrightarrow {}_{90}U^{236} + \alpha$.

14. 1.6×10^{-27} kg corresponds to an energy of

(*a*) 931 eV (*b*) 1900 MeV

(*c*) 100 J (*d*) 931 MeV.

15. The moderator in a reactor is to slow down the neutrons in order to prevent their non-fission capture in U^{238}

(*a*) false (*b*) true.

16. The half-life period of a radioactive element is

(*a*) 69.3% of the average life

(*b*) 6.93% of the average life

(*c*) 2.3% of the average life

(*d*) 10% of the average life.

17. The average life time of a radioactive element is
    (*a*) equal to the disintegration constant
    (*b*) twice to the disintegration constant value
    (*c*) half of the disintegration constant value
    (*d*) reciprocal of the disintegration constant.
18. The pairs of atoms which have the same atomic number and atomic mass number but have different radioactive properties are called isomers
    (*a*) true (*b*) false.
19. Energy equivalent to one atomic mass unit is
    (*a*) 9.31 eV (*b*) 931 eV
    (*c*) 93.1 MeV (*d*) 931 MeV.
20. In the study of radioactive element N number of β-particles are emitted during the time $t = 0$ to $t = 1$ sec and 1.37 N of β-particles during the time $t = 0$ to $t = 2$ sec. The mean life of the element is
    (*a*) 1 sec (*b*) 2 sec
    (*c*) 0.37 sec (*d*) 0.7 sec.
21. The emission of positron is quite common in α-particle induced artificial radioactivity. This is
    (*a*) true (*b*) false.
22. A neutron can penetrate relatively easily into the nucleus of other atoms because
    (*a*) the neutron is very heavy massive particle
    (*b*) the neutron experiences high coulomb repulsive force

(c) the neutron experiences no coulomb repulsive forces
(d) it has zero mass.

23. Radio isotopes
(a) have same atomic weights but different atomic number
(b) have same atomic number but different atomic weights
(c) but have same atomic weights and same atomic number
(d) have same density but different atomic number.

24. The conversion of one element into another by bombarding the nucleus is called
(a) natural radioactive
(b) chain reaction
(c) cosmic radiation
(d) artificial transmitation.

25. Which one of the following nuclear reactions is correct?
(a) ${}_7N^{14} + {}_2He^4 \longrightarrow {}_8Fe^{19} \longrightarrow {}_8O^{16} + {}_1H^1$
(b) ${}_7N^{14} + {}_1H^1 \longrightarrow {}_8Fe^{15} \longrightarrow {}_6O^{16} + {}_2H^1$
(c) ${}_7N^{14} + {}_2He^4 \longrightarrow {}_9Fe^{18} \longrightarrow {}_8O^{17} + {}_1H^1$
(d) all are the true.

26. The energy released in nuclear fusion is much more than that in nuclear fission.
(a) true (b) false.

27. The most important advantage of nuclear energy is
(a) less time is required to generate the energy
(b) a small nuclear fuel is sufficient to produce huge amount of energy
(c) less safety measures are sufficient
(d) many operational difficulties are not there.

28. Moderator is used to
    (*a*) accelerate the bombarding neutrons
    (*b*) slow down the bombarding neutrons
    (*c*) to eject more electrons
    (*d*) to arrest the nuclear reaction.
29. Most commonly used moderators are
    (*a*) benzene and copper
    (*b*) sodium chloride, and magnetic materials and silicon
    (*c*) heavy water, graphite and berryllium
    (*d*) silver oxide, dimethyl sulphoxide and air.

PROBLEMS AND SOLUTIONS

1. *The half-life of radon is 3.8 days. Find the percentage of atoms present after 10 days.*

Solution:

$$T = 3.8 \text{ day}$$

Decay constant, $\lambda = \dfrac{0.693}{T} = \dfrac{0.693}{3.8}$

The decay equation is

$$N = N_0 \exp(-\lambda t)$$
$$t = 10 \text{ days}$$

$$\frac{N}{N_0} = \exp\left(-\frac{0.693 \times 10}{3.8}\right)$$
$$= \exp(-1.82)$$

$$\boxed{\frac{N}{N_0} = 16\%} \quad \textbf{Ans.}$$

2. *A sample of radioactive material has mass m, decay constant λ and molecular weight M_A. Find the activity of the sample.*

Solution:

M_A corresponds to N_A (Avogadro's number)

m corresponds $\dfrac{N_A}{M_A} \times m = N$

The activity is defined as the number of disintegrations per unit time

$$= \frac{dN}{dt} = \lambda N$$

Thus, $\quad$ activity $= \dfrac{m N_A \lambda}{M_A}$

$$\boxed{\text{Activity} = \frac{m N_A \lambda}{M_A}} \quad \textbf{Ans.}$$

3. *The half-life of radium is 1500 years. In how many years will 1 gm of pure element is reduced to a centigram?*

Solution:

$$\frac{N_0}{N} = \frac{1}{0.01} = 100$$

i.e., $\quad \dfrac{N_0}{N_0 \exp(-\lambda t)} = 100$

$$\exp(\lambda t) = 100$$

Decay constant, $\quad \lambda = \dfrac{0.693}{T} = \dfrac{0.693}{1500}$

$$= 4.6 \times 10^{-4} \text{ per year}$$

$\exp(4.6 \times 10^{-4} \times t) = 100$

$$4.6 \times 10^{-4} \times t = \log_e 100$$

$$\boxed{t = 10000 \text{ years}} \quad \textbf{Ans.}$$

4. *Two radioactive materials X_1 and X_2 have decay constants 10λ and λ respectively. If initially they have the same number of nuclei, when will the ratio of the number of nuclei of X_1 to that of X_2 will be $\frac{1}{e}$.*

Solution:

$$N_1 = N_0 \exp(-10\,\lambda t)$$
$$N_2 = N_0 \exp(-\,\lambda t)$$
$$\frac{N_1}{N_2} = \frac{\exp(-10\,\lambda t)}{\exp(-\lambda t)} = \frac{1}{\exp(9\,\lambda t)}$$

Given: $\frac{N_1}{N_2} = \frac{1}{e}$

i.e., $\frac{1}{e} = \frac{1}{e^{9\,\lambda t}}$

or $9\,\lambda t = 1$

$$\boxed{t = \frac{1}{9\lambda}}$$ **Ans.**

5. *A count rate meter is used to measure the activity a radioactive sample. At a certain instant, the count rate was recorded as 4750 counts per minute. Five minutes later, the count rate recorded was 2700 counts per minute. Compute (i) the decay constant (ii) half-life of the sample.*

Solution:

Let N_0 be the number of atom originally present and N the number of atom present after $t = 5$ minutes

$$(i)\ \frac{\text{Original number of atoms present}}{\text{No. of atoms present after 5 min.}} = \frac{4750}{2700}$$

$$\frac{N_0}{N} = 1.76$$

$$\frac{N_0}{N_0 \exp(-5\lambda)} = 1.76$$

$$\exp(5\lambda) = 1.76$$

$$\lambda = \frac{2.303 \log_{10} 1.76}{5}$$

$$\lambda = 0.113/\text{minute}$$

(*ii*) Half-life, $T = \frac{0.693}{\lambda} = \frac{0.693}{0.113}$

$$\boxed{= 6.13 \text{ minute}} \quad \textbf{Ans.}$$

6. *A nuclear reaction is given by*

$${}_5B^{10} + {}_2He^4 \longrightarrow {}_7N^{14} \longrightarrow {}_6C^{13} + {}_1H^1$$

Explain the mechanism of this reaction and compute the energy release. Given that

${}_5B^{10}$ = *10.016125 a.m.u.;*

${}_2He^4$ = *4.003874 a.m.u.*

${}_6C^{13}$ = *13.00749 a.m.u.;*

${}_1H^1$ = *1.008146 a.m.u.*

Solution:

Mass of reactants

$$= {}_5\text{B}^{10} + {}_2\text{He}^4$$
$$= 10.016125 + 4.003874$$
$$= 14.019999 \text{ a.m.u.}$$

Mass of the products

$${}_6\text{C}^{13} + {}_1\text{H}^1 = 13.00749 + 1.008146$$
$$= 14.015636 \text{ a.m.u.}$$

Mass defect

$$= 14.015636 - 14.019999$$
$$= 0.004366 \text{ a.m.u.}$$

1 a.m.u. corresponds to 931 MeV; hence 0.004366 a.m.u. corresponds to

$$4.06 = 4.063 \text{ MeV.}$$

$$\boxed{4.063 \text{ MeV}} \quad \textbf{Ans.}$$

7. *Show that the mass of radium (mass number 226, half-life 1600 years) with an activity of one curie is almost 1 gm.*

Solution:

Let M be the mass of radium with an activity of one curie. Mass of one kg-atom of radium is 226 kg because atomic weight of radium is 226. We know that the number of atoms in one kg-atom is equal to Avogadro's number (6.02×10^{26}). Hence the number of atoms per kg of radium is $\dfrac{6.02 \times 10^{26}}{226}$.

Hence, the number of nuclei in M kg of radium is

$$\frac{6.02 \times 10^{26} \times M}{226} = 2.66 \times 10^{24} M$$

The general equation representing the rate of decay is

$$\frac{dN}{dt} \propto N; \quad i.e., \quad \frac{dN}{dt} = \lambda N$$

With
$$\lambda = \frac{0.693}{1600 \times 365 \times 24 \times 3600} = 1.37 \times 10^{-11}$$

But
$$\frac{dN}{dt} = 3.7 \times 10^{10} = 2.66 \times 10^{24} \times M \times 1.37 \times 10^{-11}$$

$$M = \frac{3.7 \times 10^{10}}{2.66 \times 1.37 \times 10^{-11}} = 10^{-3} \text{ kg}$$

or $\boxed{M = 1 \text{ gm}}$ **Ans.**

8. *Find the amount of energy produced in joule due to fission of one gm of uranium assuming that 0.1% of mass is transformed into energy.*

Solution:

Energy release per atom of uranium

$$\frac{0.1 \times 235}{100} = 0.235 \text{ a.m.u.}$$

$$E = 0.235 \times 931 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$
$$= 3.5 \times 10^{-11} \text{ J}$$

2.35 gm of uranium will have 6.02×10^{23} atoms 1 gm will have 2.56×10^{21}

The corresponding energy is

$2.56 \times 10^{21} \times 3.5 \times 10^{-11} = 8.97 \times 10^{10}$ J

$$\boxed{= 8.97 \times 10^{10} \text{ J}}$$ **Ans.**

9. *The usefulness of cadmium in a nuclear reactor depends on the high thermal absorption cross-section of the 113 isotope. The absorption cross-section σ of Cd^{113} is 21000 barns. If the density if cadmium is 8.7×10^3 kg/m^3; calculate the macroscopic cross-section of Cd^{113} and hence the thickness required to attenuate a neutron beam of 0.01% of its original intensity.*

Solution:

Macroscopic cross-section, $\alpha = \sigma N$ where N is the number of nuclei per m^3 in the absorber.

$\dfrac{M_A}{\rho}$ m^3 will have N_A nuclei.

1 m^3 will have $\dfrac{\rho N_A}{M_A} = N$

Now $\quad \alpha = \sigma N = \dfrac{\rho \sigma N_A}{M_A}$

$$\alpha = \frac{8.7 \times 10^3 \times 21000 \times 10^{-28} \times 6.02 \times 10^{26}}{113}$$
$$= 97332 \text{ m}$$

The general equation is

$$I = I_0 \exp(-\alpha x)$$

$$\exp(\alpha x) = \frac{I_0}{I} = 10000$$

$$\alpha x = \ln 10000 = 9.21$$

$$x = \frac{9.21}{97332} = 9.5 \times 10^{-5} \text{ m}$$

$$\boxed{x = 9.5 \times 10^{-5} \text{ m}} \quad \textbf{Ans.}$$

10. *Compute approximately how much of U^{235} has to undergo fission to produce energy equal to that produced by 100 tonnes of coal from the following data. Heat of combustion of coal = 32×10^6 J/kg. Energy released per fission of uranium atom is 200 MeV. Avogadro's number is 6.02×10^{26}.*

Solution:

Mass of coal $= 100 \times 1000 \times 1000$

$= 10^8$ gm $= 10^5$ kg

Heat obtained $= 32 \times 10^6 \times 10^5$

$= 32 \times 10^{11}$ J

Energy released by one atom of U^{235}

$= 200$ MeV

$= 200 \times 10^6 \times 1.6 \times 10^{-19}$ J

$= 3.2 \times 10^{-11}$ J

3.2×10^{-11} J of energy is released by one atom of U^{235}. Hence 32×10^{11} J of energy will be released

$$\frac{32 \times 10^{11}}{3.2 \times 10^{-11}} = 10^{23} \text{ atom}$$

Now 6.02×10^{26} atom will weigh 235 kg
Hence 10^{23} will weigh

$$\frac{235 \times 10^{23}}{6.02 \times 10^{26}} = 39 \text{ kg}$$

$$\boxed{39 \text{ kg}} \quad \textbf{Ans.}$$

11. *A railway engine develops an average power of 1800 during a 10 hour run from one station to another. If the engine is driven by an atomic power to an efficiency of 30%, how much U^{235} would be consumed on the run? Energy released per fission is 180 MeV.*

Solution:

Energy released per fission = 180 MeV

$$= 180 \times 10^6 \times 1.6 \times 10^{-19} \text{ J}$$

$$= 2.88 \times 10^{-11} \text{ J}$$

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

$$P = \frac{1800}{0.3} = 6000 \text{ kW}$$

Thus input nuclear energy

$$= P \times \text{time}$$

$$= 6000 \times 10^3 \times 3600$$

$$= 216 \times 10^8 \text{ J}$$

Therefore number of U^{235} atoms required for the run is

$$\frac{\text{Input nuclear energy}}{\text{Energy released per fission}}$$

$$= \frac{216 \times 10^8}{2.88 \times 10^{-11}} = 7.5 \times 10^{20}$$

atoms

6.02×10^{26} U^{235} atoms will weigh 235 kg

Hence 7.5×10^{20} atom will weigh

$$\frac{235 \times 7.5 \times 10^{20}}{6.02 \times 10^{26}} = \mathbf{2.92 \times 10^{-3}\ kg}$$

or $\boxed{\mathbf{2.92\ gm}}$ **Ans.**

It is now very clear that extremely small mass of nuclear fuel is sufficient to produce huge amount of energy which is most significant feature of radioactive substances.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*b*)	2. (*c*)	3. (*d*)	4. (*a*)
5. (*c*)	6. (*a*)	7. (*c*)	8. (*b*)
9. (*b*)	10. (*c*)	11. (*d*)	12. (*a*)
13. (*a*)	14. (*d*)	15. (*b*)	16. (*a*)
17. (*d*)	18. (*a*)	19. (*d*)	20. (*a*)
21. (*a*)	22. (*c*)	23. (*b*)	24. (*d*)
25. (*c*)	26. (*a*)	27. (*b*)	28. (*b*)
29. (*c*).			

CHAPTER 11

SOLID STATE PHYSICS AND MISCELLANEOUS TOPICS

11.1 BONDING IN SOLIDS AND CRYSTAL STRUCTURE

1. The atomic number of magnesium is 12. Which of the following is the electronic structure of magnesium?
   (*a*) $1s^2\,2s^2\,2p^6\,3s^0$
   (*b*) $1s^2\,2s^2\,2p^6\,3s^2$
   (*c*) $1s^2\,2s^3\,2p^6\,3s^2$
   (*d*) none of these.
2. The minimum energy required to remove the outer electron from the sodium atom to have a Na^+ ion is about
   (*a*) 50 eV (*b*) 5 eV
   (*c*) 0.5 eV (*d*) 0.05 eV.
3. Which of the following element is covalently bonded?
   (*a*) copper (*b*) zinc sulphide
   (*c*) silicon (*d*) lead.
4. If the energy required to break 1 kmol of H—Cl bonds is 420×10^3 kJ/kmol, then the energy required to break one bond is
   (*a*) 2.4 eV (*b*) 6.8 eV
   (*c*) 4.4 eV (*d*) 7 eV.
5. The number of molecules in the unit cell of KCl crystallizing in the sodium chloride structure is
   (*a*) 2 (*b*) 4
   (*c*) 8 (*d*) 16.

6. The number of molecules in the unit cell crystallizing in the sodium chloride structure is
   (*a*) 2 (*b*) 4
   (*c*) 8 (*d*) 1.
7. 6.4×10^{-19} joule is approximately
   (*a*) 4 electron volt
   (*b*) 6 electron volt
   (*c*) 8 electron volt
   (*d*) 1 electron.
8. The lattice constant of NaCl crystal is 5.6 Å. The distance between two adjacent cations is
   (*a*) $2.8 \times \sqrt{2}$ (*b*) $5.6 \times \sqrt{2}$
   (*c*) $\frac{5.6}{2}$ (*d*) $2 \times \sqrt{2.8}$.
9. Why are lithium and sodium similar chemically?
   (*a*) both have the same number of electrons
   (*b*) both are adjacent elements in the atomic table
   (*c*) both have one electron in the outer most incomplete shell
   (*d*) none of these.
10. One Debye unit is approximately
   (*a*) 3.5×10^{-20} C·m
   (*b*) 7.5×10^{-20} C·m
   (*c*) 5×10^{-31} C·m
   (*d*) 3.5×10^{-30} C·m.
11. Metallic elements have
   (*a*) low ionisation energy
   (*b*) high ionisation energy
   (*c*) zero ionisation energy
   (*d*) all the above are false.

12. The radii of Cs and Cl are r_1 and r_2 respectively. Which of the following gives the lattice constant of CsCl if it crystallizes in bcc structure?

(*a*) $\dfrac{2(r_1 + r_2)}{\sqrt{2}}$ (*b*) $\dfrac{2(r_1 + r_2)}{\sqrt{3}}$

(*c*) $\dfrac{(r_1 + r_2)}{\sqrt{3}}$ (*d*) $\dfrac{2(r_1 + r_2)}{3}$.

13. The number of atoms present in the unit cell of hcp structure is

(*a*) 12 (*b*) 1

(*c*) 6 (*d*) 7.

14. The number of calsium chloride molecules in the unit cell of calsium chloride is

(*a*) 2 (*b*) 4

(*c*) 1 (*d*) 3.

15. Classify the following unit cell into proper crystal system. a = 1.08 nm, b = 0.94 nm, c = 0.5 nm and α = 41°, β = 82° and γ = 95°

(*a*) orthorhombic

(*b*) monoclinic

(*c*) triclinic

(*d*) hexagonal.

16. The number of lattice points in a primitive cell are

(*a*) $\dfrac{3}{2}$ (*b*) $\dfrac{1}{2}$

(*c*) 1 (*d*) 2.

17. The number of atoms present in the unit cell of dcc structure is

(*a*) 2 (*b*) 4

(*c*) 8 (*d*) 16.

18. The packing factor of diamond cubic crystal structure is

(*a*) 62% (*b*) 86%

(*c*) 34% (*d*) 90%.

19. Magnesium crystallizes in hcp structure. If the lattice constant is 0.32 mm, the nearest neighbour distance in magnesium is

(*a*) 0.32 nm (*b*) 0.64 nm

(*c*) 0.16 nm (*d*) 1 nm.

20. If in a body centred cubic lattice, the distance of the nearest neighbours, $2r = \frac{a\sqrt{3}}{2}$, then the distance of the next neighbours is

(*a*) $\frac{a}{2}$ (*b*) $\frac{a}{3}$

(*c*) $2a$ (*d*) a.

21. The Miller indices of the plane parallel to y and z axes are

(*a*) (100) (*b*) (010)

(*c*) (001) (*d*) (111).

22. (3 2 6) are the Miller indices of the plane; the intercepts made by the plane on the three crystallographic axes are

(*a*) $(2a\ 3b\ c)$ (*b*) $(a\ b\ c)$

(*c*) $(a\ 2b\ 3c)$ (*d*) $(2a\ 2b\ 2c)$.

23. A plane intercepts at a, $\frac{b}{2}$, $3c$ in a cubic unit cell. The Miller indices of the plane are

(*a*) (1 3 2) (*b*) (2 6 1)

(*c*) (3 6 1) (*d*) (1 2 3).

24. If r is the radius of the atom, the number of atoms per unit area of the plane (0 1 0) of a simple cubic crystal is

(*a*) $\dfrac{1}{4r^2}$ (*b*) $4r^2$

(*c*) $\dfrac{1}{4r}$ (*d*) none of these.

25. Zinc has hcp structure. If the diagonal of the hexagon is 0.64 nm, the radius of the zinc atom is

(*a*) 0.2 nm (*b*) 0.52 m

(*c*) 0.16 nm (*d*) 2 nm.

26. If the lattice parameter of cubic crystal is 3 nm and the distance between two parallel planes is 1.732, the Miller indices of the plane are

(*a*) (2 2 3) (*b*) (1 1 1)

(*c*) (1 1 0) (*d*) (2 2 0).

ANSWERS TO OBJECTIVE QUESTIONS

1. (*d*)	2. (*b*)	3. (*c*)	4. (*c*)
5. (*b*)	6. (*d*)	7. (*a*)	8. (*a*)
9. (*c*)	10. (*d*)	11. (*a*)	12. (*b*)
13. (*c*)	14. (*c*)	15. (*a*)	16. (*c*)
17. (*c*)	18. (*c*)	19. (*a*)	20. (*d*)
21. (*a*)	22. (*a*)	23. (*c*)	24. (*a*)
25. (*c*)	26. (*b*).		

PROBLEMS AND SOLUTIONS

1. *Assume an overlap interaction between nearest neighbours of the type $\phi(x) = A \exp(-x/\alpha)$ where A and α are constants, calculate the equilibrium spacing x_0 in terms of A and α.*

Solution:

$$\phi(x) = A \exp(-x/\alpha)$$

At the equilibrium position,

$$x = x_0$$

Hence

$$[\phi(x)]_{x=x_0} = 0$$

Thus

$$A \exp(-x_0/\alpha) = 0$$

i.e.,
$$\ln A - \frac{x_0}{\alpha} = 0$$

$$\ln A = \frac{x_0}{\alpha};\ x_0 = \alpha \ln A$$

$$\boxed{x_0 = \alpha \ln A} \quad \textbf{Ans.}$$

2. *Suppose an atom A has an ionisation energy 5 eV, and an atom B has an electron affinity of 4 eV. Let the atoms A and B be 0.5 nm apart. What is the energy required to transfer an electron from A to B.*

Solution:

Coulomb energy of the system

$$= \frac{e^2}{4\pi\,\varepsilon_0\, r_0} \text{ joule}$$

$$= \frac{e}{4\pi\,\varepsilon_0 r_0} \text{ eV}$$

$$= \frac{1.6\times 10^{-19}}{4\pi\times 8.8\times 10^{-12}\times 0.5\times 10^{-9}}$$

$$= 2.9 \text{ eV}$$

The energy required to transfer an electron from A to B is equal to $I - E - C$

$$= 5 - 4 - 2.9 = -1.9 \text{ eV}$$

$$\boxed{= -1.9 \text{ eV}} \quad \textbf{Ans.}$$

3. *Assuming that the lattice points of lattice parameter 'a' in a bcc structure are occupied by spherical atom of radius r. Calculate the free volume per unit cell.*

Solution:

Volume of the unit cell = a^3

Volume of all the atoms in a unit cell

$$= 2\left[\frac{4\pi r^3}{3}\right]$$

For bcc structure,

$$a = \frac{4r}{\sqrt{3}};\ r = \frac{a\sqrt{3}}{4}$$

Now volume of all the atoms in a unit cell is

$$2 \times \left(\frac{4\pi}{3}\right)r^3 = \frac{8\pi}{3}\left[\frac{a\sqrt{3}}{4}\right]^3$$

$$= \frac{\pi a^3\sqrt{3}}{8}$$

Free volume is

$$\left[a^3 - \frac{\pi a^3\sqrt{3}}{8}\right]$$

$$= a^3\left[1 - \frac{\pi\sqrt{3}}{8}\right]$$

$$\boxed{= a^3\left[1 - \frac{\pi\sqrt{3}}{8}\right]}$$ **Ans.**

4. *The unit cell of aluminium is face centred with lattice constant a = 0.405 nm. How many units cells are there in an aluminium foil 0.005 nm thick and side 25 cm square.*

Solution:

$(0.405 \times 10^{-9})^3$ metre^3 has one unit cell.

Hence $(0.005 \times 10^{-2} \times 25 \times 10^{-2})^2$ metre^3 have 4.7×10^{22} cells.

5. *Obtain the Miller indices of a plane with intercepts at a, $\frac{b}{2}$, 3c in a simple unit cell. Draw a neat diagram showing the plane.*

Solution:

The coordinates of the given plane along the crystallographic axes are

$$\begin{array}{ccc} x & y & z \\ a & \frac{b}{2} & 3c \end{array}$$

Express these intercepts as multiples of unit cell dimensions along the axes

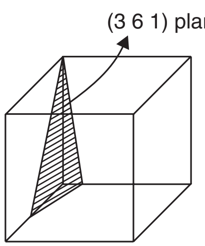
$$\begin{array}{ccc} \frac{a}{a} & \frac{b/2}{b} & \frac{3c}{c} \\ 1 & \frac{1}{2} & 3 \end{array}$$

Get the reciprocals

$$\begin{array}{ccc} \frac{1}{1} & 2 & \frac{1}{3} \end{array}$$

Reduce them into smallest numbers

$$\begin{array}{ccc} 3 & 6 & 1 \end{array}$$



6. *Calculate the lattice constant of potassium bromide, from the following data: Density of potassium bromide is 2700 kg/m^3 and belongs to fcc lattice. Molecular weight of potassium is 119.0 and Avogadro's number is 6.02 × 10^{26} (kg mol)$^{-1}$.*

Solution:

$\frac{119}{2700}$ m^3 will contain 6.02×10^{26} K Br molecules a^3 will have

$$\frac{2700 \times 6.02 \times 10^{26} \times a^3}{119} = 4$$

$$a^3 = \frac{4 \times 119}{2700 \times 6.02 \times 10^{26}}$$

$$= 0.029 \times 10^{-26}$$

$$\boxed{a = 6.63 \text{ Å}} \quad \textbf{Ans.}$$

7. *Magnesium has hcp structure. The nearest neighbour distance of this structure is 0.321 nm. Compute the height of the unit cell.*

Solution:

$$\frac{c}{a} = \sqrt{\frac{8}{3}}$$

$$c = a \times \sqrt{\frac{8}{3}}$$

with $a = 2r = 0.321$

$$c = 0.321 \times \sqrt{\frac{8}{3}} = 0.321 \times 1.63$$

$$\boxed{c = 0.524 \text{ nm}} \quad \textbf{Ans.}$$

8. *The unit cell of aluminium is face centred cubic with lattice constant a = 0.405 nm. How many unit cells are there in an aluminium foil 0.005 cm thick and side 25 cm square?*

Solution:

$(0.405 \times 10^{-9})^3$ has one unit cell.

Hence $[0.005 \times 10^{-2} \times (25 \times 10^{-2})^2]$ metre^3 will have 4.7×10^{22} cells

$$\boxed{= 4.7 \times 10^{22}} \quad \textbf{Ans.}$$

11.2 PHOTOELECTRIC EFFECT AND X-RAYS

1. When visible light falls on a negatively charged zinc plate, electrons are emitted
   (*a*) true (*b*) false.
2. Photoelectric emission depends upon both nature of the emitter and quality of light used
   (*a*) true (*b*) false.
3. The threshold frequency ν_0 and work function W_0 in photoelectric emission related by
   (*a*) $\lambda_0 = \dfrac{1241.2}{W_0}$ nm (*b*) $\lambda_0 = \dfrac{124.12}{W_0}$ nm
   (*c*) $\lambda_0 = \dfrac{1241.2}{2W_0}$ nm (*d*) none of these.
4. The minimum energy of the photoelectrons emitted is
   (*a*) directly proportional to the frequency of the incident light
   (*b*) inversely proportional to the frequency of the incident light
   (*c*) independent of frequency
   (*d*) none of these.
5. There exists a critical frequency for each emitter below which no photoelectric emission is possible. This frequency is called
   (*a*) orbital frequency
   (*b*) angular frequency
   (*c*) threshold frequency
   (*d*) acoustical frequency.
6. Photoemissive cell is used for
   (*a*) converting electrical energy into light energy

(*b*) converting light energy into electrical energy

(*c*) for the reproduction of sound from photofilms

(*d*) none of these.

7. For each radiation of frequency $\frac{\nu}{2}$ the energy of each quanta is

(*a*) $h\nu$ (*b*) $\frac{h\nu}{2}$

(*c*) $2h\nu$ (*d*) $\frac{2}{h\nu}$.

8. The Einstein's photoelectron equation is

$$\frac{1}{2}mv_{\max}^2 =$$

(*a*) $h\nu$ (*b*) $h\nu + W$

(*c*) $h\nu - W$ (*d*) $W - h\nu$.

9. Electromagnetic theory of light is

(*a*) quite capable of explaining the experimental results of photoelectricity

(*b*) quite incapable of explaining the experimental results of photoelectricity

(*c*) partly capable of explaining the experimental results

(*d*) all the above are wrong.

10. The emission of photoelectrons is instantaneous. This is

(*a*) true (*b*) false.

11. The phenomenon of photoelectricity can be explained only by

(*a*) classical theory

(*b*) quantum theory

(*c*) Stefan's law

(*d*) Lorentz theory.

12. Photocells are used for making
    (*a*) fuse wire
    (*b*) tube light
    (*c*) Burglar alarms
    (*d*) vacuum tubes.
13. Exposure metre is used
    (*a*) to amplify very weak signal
    (*b*) to calculate the correct time of exposure
    (*c*) for measuring the intensity of illumination of a light source
    (*d*) none of these.
14. The number of photoelectrons emitted by a surface is
    (*a*) inversely proportional to the intensity of the beam
    (*b*) independent of the intensity of the beam
    (*c*) directly proportional to the intensity of the beam
    (*d*) none of these.
15. The velocity of the emitted photons is independent of the intensity of light. This is
    (*a*) true (*b*) false.
16. The strength of the photoelectric current is
    (*a*) inversely proportional to the intensity of the incident beam
    (*b*) directly proportional to the intensity of the incident radiation
    (*c*) independent of the incident radiation
    (*d*) none of these.
17. The maximum velocity of the photoelectrons is approximately
    (*a*) $6 \times 10^5 \times \sqrt{V_0}$
    (*b*) $6 \times 10^2 \times \sqrt{V_0}$

(*c*) $1.5 \times 10^5 \times \sqrt{V_0}$

(*d*) $2.6 \times 10^3 \times \sqrt{V_0}$

where V_0 is the stopping potential.

18. When infrared light falls on one of the metals listed below electron are generated. Which is that metal?
(*a*) mercury (*b*) uranium
(*c*) gold (*d*) zinc.

19. The maximum energy of the photoelectrons emitted is
(*a*) directly proportional to the frequency of the incident light
(*b*) inversely proportional to the frequency of the incident light
(*c*) independent of the frequency
(*d*) none of these.

20. If the shortest wavelength emitted by an X-ray tube is 0.25 nm, the operating potential of the tube is approximately
(*a*) 50 kV (*b*) 5 kV
(*c*) 500 kV (*d*) 5000 kV.

21. The speed of X-rays is the same as that of visible light. Hence its wavelength is
(*a*) same as that of visible light
(*b*) larger than that of visible light
(*c*) smaller than that of visible light
(*d*) equal to that of visible light.

22. X-rays are produced whenever
(*a*) high speed cathode rays are stopped abruptly by a target
(*b*) low speed cathode rays are stopped abruptly by a target
(*c*) due to ionisation of gases
(*d*) due to the collision of material particles with glass.

23. In a Cooledge tube the source of electrons is
    (*a*) discharge of electricity
    (*b*) slow moving neutrons colliding with matter
    (*c*) heated filament
    (*d*) none of these.
24. X-rays are
    (*a*) ultrasonic waves of high wavelength
    (*b*) mechanical waves
    (*c*) electromagnetic waves
    (*d*) all the above are false.
25. The wavelength of X-rays is approximately
    (*a*) 1000 Å (*b*) 100 Å
    (*c*) 1 Å (*d*) 200 Å.
26. X-rays are not charged particles, and hence
    (*a*) they do not undergo diffraction
    (*b*) they are easily reflected by electric field or magnetic field
    (*c*) they are not deflected by magnetic or electric fields
    (*d*) they produce Laue spots.
27. The X-rays of wavelength greater than $2d$ can be diffracted from the crystal
    (*a*) yes (*b*) no
28. The short wavelength limit of X-rays depend upon
    (*a*) nature of the target
    (*b*) p.d. across the X-ray tube
    (*c*) size of the tube
    (*d*) nature of the target.
29. Because of which of the following properties of crystals, X-rays can be diffracted from the crystals?
    (*a*) random arrangement of atoms
    (*b*) colour of the crystals

(*c*) periodic array of atoms
(*d*) charge of the atom in the crystal.

30. Moseley's law is expressed by the relation $\sqrt{\nu}$ =
(*a*) $a(Z - b)$ (*b*) $(Z + b)$
(*c*) $a(Z + b)$ (*d*) $(a + Z)$
where Z is the atomic number, a and b are constants.

31. Moseley's work enhanced our understanding of
(*a*) crystal structure
(*b*) properties of X-rays
(*c*) uses of X-rays
(*d*) periodic table.

32. According to Compton theory, the wavelength increase $\Delta\lambda$ is
(*a*) independent of the incident wavelength
(*b*) dependent on the incident wavelength
(*c*) dependent on charge of the electron
(*d*) none of these.

33. As the wavelength of X-rays is smaller than that of visible light, the speed of X-rays in air is
(*a*) same as that of the visible light
(*b*) larger than that of visible light
(*c*) smaller than that of visible light
(*d*) none of these.

34. According to Moseley's law the frequency of the characteristics X-radiation is proportional to the square of
(*a*) atomic weight of the element
(*b*) atomic number of the element
(*c*) screening constant
(*d*) Rydberg constant.

35. If the angle between the direction of the incident X-ray and the diffracted one is 16°, the angle of incidence will be
(*a*) 32° (*b*) 24°
(*c*) 90° (*d*) 82°.

36. X-rays are
(*a*) negatively charged particles
(*b*) electromagnetic radiation
(*c*) positively charged particles
(*d*) a stream of newtons.

37. If 50 kV is the applied potential in an X-ray tube then the minimum wavelength of X-rays produced is
(*a*) 0.2 nm (*b*) 2 nm
(*c*) 0.02 nm (*d*) 2 Å.

38. When potential difference between the electrodes of an X-ray tube is increased, there takes place an increase in the
(*a*) intensity
(*b*) frequency
(*c*) wavelength
(*d*) speed of X-rays.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*b*)	2. (*a*)	3. (*a*)	4. (*a*)
5. (*c*)	6. (*b*)	7. (*b*)	8. (*c*)
9. (*b*)	10. (*a*)	11. (*b*)	12. (*c*)
13. (*b*)	14. (*c*)	15. (*a*)	16. (*b*)
17. (*b*)	18. (*d*)	19. (*a*)	20. (*a*)
21. (*c*)	22. (*a*)	23. (*c*)	24. (*c*)
25. (*c*)	26. (*c*)	27. (*a*)	28. (*b*)
29. (*c*)	30. (*a*)	31. (*d*)	32. (*a*)
33. (*a*)	34. (*b*)	35. (*d*)	36. (*b*)
37. (*c*)	38. (*b*).		

PROBLEMS AND SOLUTIONS

1. *Determine the region of the electromagnetic spectrum which librates photoelectrons from potassium. Electron exit work function of potassium is 2.24 V, Planck's constant= 6.6×10^{-34} J-s charge of electron 1.6×10^{-19} C, velocity of light is 3×10^{8} m/s.*

   Solution:

   The photoelectric equation is

   $$h\nu = \frac{1}{2} mv^2 + \phi e$$

   where ϕ is the electronic exit work function.

   When electrons are just liberated, $v = 0$ and the corresponding frequency is

   $$\nu = \frac{\phi e}{h} = \frac{2.24 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}}$$

   $$\nu = 5.43 \times 10^{14} \text{ Hz}$$

   But since

   $c = \nu\lambda$, the wavelength is

   $$\lambda = \frac{3 \times 10^{8}}{5.43 \times 10^{14}} = 5.520 \times 10^{-7} \text{ m}$$

   $$\lambda = 5.52 \times 10^{-7} \text{ m}$$

   Thus shorter wavelength than this can liberate electrons.

2. *The photoelectric work function for Na surface is 2 volt. Calculate the longest wavelength of light that will eject photo-electrons from Na surface.*

   Solution:

   Work function for Na surface, $W_0 = 2$ eV

   $$W_0 = h\nu_0 = \frac{hc}{\lambda_0}$$

$$\lambda_0 = \frac{hc}{W_0} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2 \times 1.6 \times 10^{-19}}$$

$$\boxed{\lambda_0 = 6000 \text{ Å}} \quad \textbf{Ans.}$$

3. *Light of wavelength 2000 Å falls on an aluminium surface. In aluminium 4.2 eV are required to remove an electron. What is the kinetic energy in electron volt of (a) the fastest, (b) the slowest emitted photoelectrons (c) what is stopping potential (d) what is the cut-off wavelength for aluminium?*

Solution:

(a) Energy corresponding to incident photon

$$h\nu = \frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{2000 \times 10^{-10}}$$

$$= 9.9 \times 10^{-19} \text{ J}$$

$$h\nu = \frac{9.9 \times 10^{-19}}{1.6 \times 10^{-19}}$$

$$h\nu = 6.2 \text{ eV}$$

The kinetic energy of the fastest electrons

$$E_k = h\nu - W = 6.2 - 4.2$$

$$E_k = 2 \text{ eV}.$$

(b) The kinetic energy of slowest electrons = zero

As the emitted electrons have all possible energies from 0 to certain maximum value E_k.

(c) If V_s is the stopping potential, then $E_k = eV_s$

$$V_s = \frac{E_k}{e} = \frac{2\, eV}{e} = 2 \text{ V}$$

(*d*) If λ_0 is the cut-off wavelength for aluminium,

then

$$W = \left(\frac{hc}{\lambda_0}\right) \quad \text{or} \quad \lambda_0 = \frac{hc}{W}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{4.2 \times 1.6 \times 10^{-19}}$$

$$= 3000 \times 10^{-10} \text{ m}$$

$$\boxed{W = 3000 \text{ Å}} \quad \textbf{Ans.}$$

4. *The energy required to remove an electron from sodium is 2.3 eV. Does sodium show a photoelectric effect for orange light with λ = 6800 Å?*

Solution:

The minimum energy required to remove the electron from the metal is known as its work function which is given by

$$W = h\nu_0$$

$$h\nu_0 = \frac{hc}{\lambda_0} = 2.3 \times 1.6 \times 10^{-19} \text{ J}$$

$$\lambda_0 = \frac{hc}{2.3 \times 1.6 \times 10^{-19}}$$

$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{2.3 \times 1.6 \times 10^{-19}}$$

$$= 5397 \text{ Å}$$

This is the threshold wavelength *i.e.,* maximum wavelength which can eject electrons from sodium. Hence sodium will not show photoelectric effect for orange light with 6800 Å.

5. *The cut-off potential for a photocell is V_0 volt, when the incident photon has energy E_0 electron volt. If the energy of the incident photon is 1.5 E_0 electron volt, find*

(*i*) *Work function of cathode material*

(*ii*) *The new cut-off potential.*

Solution:

Let K_{max} be the kinetic energy of the fastest photoelectrons when light of energy E_0 electron volt falls on the surface, then

$$K_{max} = \frac{1}{2} mv^2 = eV_0$$

Einstein photoelectric equation gives

$$eE_0 = W + \frac{1}{2} mv^2 = W + K_{max}$$

$$eE_0 = W + eV_0$$

Therefore, work function of cathode material

$$W = eE_0 - eV_0 \qquad ...(1)$$

If energy incident photon is $1.5 E_0 J$, then

$$W = 1.5\ eE_0 - eV_0' \qquad ...(2)$$

Comparing (1) and (2),

$$1.5\ eE_0 - eV_0' = eE_0 - eV_0$$

or $$eV_0' = 1.5\ eE_0 - eE_0 + eV_0$$

Therefore the new cut-off potential

$$\boxed{V_0' = 0.5E_0 + V_0} \quad \textbf{Ans.}$$

6. *Calculate the longest wavelength that can be analysed by a rock salt crystal of spacing d = 2.82 Å:*

(*i*) *in the first order*

(*ii*) *in the second order.*

Solution:

(*i*) According to Bragg's equation

$$2d \sin \theta = n\lambda$$

$$\lambda = \frac{2 \times 2.82 \times \sin 90°}{1} = 5.64 \text{ Å}$$

(*ii*) In the second order

$$\boxed{\lambda' = \frac{2.82 \times 2 \times \sin 90°}{2} = 2.82 \text{ Å}} \quad \textbf{Ans.}$$

7. *The wavelength of the incident photon in compton effect is 3×10^{-10} m. Find the wavelength of the photon scattered at an angle of 60°. $h = 6.62 \times 10^{-34}$ J-s, $m = 9.1 \times 10^{-31}$ kg, $c = 3 \times 10^8$ m/s.*

Solution:

The Compton shift

$$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

$$\Delta\lambda = \frac{6.62 \times 10^{-34}}{9.1 \times 10^{-31} \times 3 \times 10^8}(1 - \cos 60°)$$

$$= 0.012 \times 10^{-10} \text{ m}$$

The incident wavelength is

$$\lambda = 3 \times 10^{-10} \text{ m.}$$

Therefore the scattered wavelength will be

$$\lambda' = \lambda + \Delta\lambda$$

$$= 3 \times 10^{-10} + 0.012 \times 10^{-10} \text{ m}$$

$$\boxed{= 10^{-10} \times 3.012 = 3.012 \text{ Å}} \quad \textbf{Ans.}$$

8. *An X-ray tube operated at 40 kV emits a continuous X-ray spectrum with a short wavelength limit $\lambda_{min} = 0.310$ Å: Calculate Planck's constant.*

Solution:

$$h\nu = eV$$

$$\frac{h \cdot c}{\lambda_{\min}} = eV$$

$$\lambda_{\min} = \frac{hc}{eV}$$

or $$h = \frac{eV\lambda_{\min}}{c}$$

$$= \frac{1.6 \times 10^{-19} \times 40 \times 10^3 \times 0.310 \times 10^{-10}}{3 \times 10^{10}}$$

$$\boxed{h = 6.61 \times 10^{-24} \text{ J-s}} \quad \textbf{Ans.}$$

9. *If K_α radiation of M_o (Z = 42) has a wavelength of 0.71 Å. Calculate the wavelength of the corresponding radiation of Cu (Z = 29).*

Solution:

From Mosley's law we have $\nu = a(Z - b)^2$.
For K_α radiation, screen constant $b = 1$

and $\nu = \frac{c}{\lambda}$

i.e. $\frac{1}{\lambda} \propto (Z - 1)^2$

or $\lambda_{cu} \propto \frac{1}{(Z_{cu} - 1)^2}$

$$\Rightarrow \lambda_{cu} = \frac{c}{a} \times \frac{1}{(Z_{cu} - 1)^2}$$

Similarly $\lambda_{mo} \propto \frac{1}{(Z_{mo} - 1)^2}$

$$\Rightarrow \lambda_{mo} = \frac{c}{a} \times \frac{1}{(Z_{mo} - 1)^2}$$

$$\frac{\lambda_{cu}}{\lambda_{mo}} = \frac{(Z_{mo} - 1)^2}{(Z_{cu} - 1)^2} = \frac{41^2}{28^2}$$

$$\lambda_{cu} = \lambda_{mo} \times \frac{41^2}{28^2} = 0.71 \times \frac{41^2}{28^2}$$

$$\boxed{\lambda_{cu} = 1.52 \text{ Å}} \quad \textbf{Ans.}$$

10. *If the series limit of the Balmer series of hydrogen is 3636 Å, calculate the atomic number of the element which gives X-ray wavelengths down to 1 Å. Identify the element.*

Solution:

Limit of Balmer series is given by

$$\bar{\nu}_1 = \frac{1}{\lambda_1} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4}$$

Wavelength of K series

$$\bar{\nu}_2 = \frac{1}{\lambda_2} = R(Z-1)^2\left(\frac{1}{1^2} - \frac{1}{4^2}\right)$$

The maximum wave number occurs when $n = \infty$ also

$$\bar{\nu}_2 = \frac{1}{\lambda_2} = R(Z-1)^2$$

Then

$$\frac{1/\lambda_1}{1/\lambda_2} = \frac{R/4}{R(Z-1)^2}$$

$$\frac{\lambda_2}{\lambda_1} = \frac{1}{4(Z-1)^2}$$

$$(Z-1)^2 = \frac{\lambda_1}{4\lambda_2} = \frac{3636 \times 10^{-10}}{4 \times 10^{-10}}$$

$$(Z-1) = 30.2$$

$$Z = 31$$

The element is gallium.

11.3 THEORY OF RELATIVITY, WAVE NATURE OF MATTER AND X-RAYS

1. All motion is relative

   (*a*) yes (*b*) no

2. Maxwell's equation do not obey the Galilean relativity

   (*a*) true (*b*) false.

3. The speed of light is the same for any observer regardless of his state of motion

   (*a*) true (*b*) false.

4. Time is relative

   (*a*) true (*b*) false.

5. If m_0 denotes the rest mass of the body and m indicates the mass of the body when it is moving with a velocity v, then

(*a*) $m_0\,[1 - (v^2/c^2)]$ (*b*) $\dfrac{m_0}{(1-c^2)}$

(*c*) m_0c^2 (*d*) $\dfrac{m_0}{\sqrt{1-(v^2/c^2)}}$.

6. Mass energy equivalence is expressed by the relation

(*a*) $E = \dfrac{m}{c^2}$ (*b*) $E = \dfrac{1}{2}\dfrac{m}{c^2}$

(*c*) $E = mc^2$ (*d*) $E = m^2c^2$.

7. The wavelength of waves associated with particles is given by the relations

(*a*) hp (*b*) $\dfrac{p}{h}$

(*c*) $\dfrac{h}{p}$ (*d*) $\dfrac{h}{p^2}$.

where h is Planck's constant and p is momentum.

8. The relation between the p.d. that accelerates the electrons and de-Broglie wavelength is

(*a*) $\lambda \times \sqrt{V} = 12.26$ nm

(*b*) $\dfrac{\lambda}{\sqrt{V}} = 1.226$ nm

(*c*) $\lambda \times V = 12.26$ Å

(*d*) $\lambda\sqrt{V} = 1.226$ nm.

9. The wave property of large, massive objects is not observed because
(*a*) their acceleration is too small
(*b*) their momentum are too large
(*c*) their speeds are too small
(*d*) none of these.

10. The wavelength associated with a moving particle
(*a*) depends upon the charge associated with it
(*b*) does not depend upon the charge associated with it

(*c*) depends upon the medium in which the particle travels

(*d*) none of these.

11. A proton and an α-particle has the same kinetic energy. If the mass of the α-particle is four times that of a proton, how do their de Broglie wavelength compare?

(*a*) $\lambda_p = \frac{\lambda_a}{2}$ (*b*) $\frac{\lambda_a}{4}$

(*c*) $\lambda_p = \lambda_a$ (*d*) $\lambda_p = 2\lambda_a$.

12. If the momentum of an electron is doubled, the de Broglie wavelength is

(*a*) halved (*b*) doubled

(*c*) remains constant

(*d*) none of these.

13. If an electron is accelerated by a potential of 100 volt, then the wavelength associated with electron is

(*a*) 0.1225 Å (*b*) 1.1225 nm

(*c*) 12.25 nm (*d*) 0.01225 nm.

14. The principle of electron microscope is that the revolving power of the microscope is of the order of the wavelength of the ray used

(*a*) yes (*b*) no

15. Electron behaves as wave because they can be

(*a*) deflected by an electric field

(*b*) deflected by magnetic field

(*c*) diffracted by a crystal

(*d*) they ionise a gas.

16. The characteristic X-rays are emitted when

(*a*) electrons are accelerated to a fixed energy (*b*) the high velocity electrons are slowed down into the positive field of the nucleus

(*c*) the bombarding electrons knock out electrons from the inner shell of the target atom and one of outer electrons fall into the vacancy

(*d*) the valence electrons in the target atoms are removed as the result of the collision.

17. The continuous X-ray spectrum is due to

(*a*) a decrease in the K.E. of the incident electrons which approach the nuclei of the target atom

(*b*) jumping of electrons of all target atom from higher orbits

(*c*) jumping of electrons of the target atom from lower orbits

(*d*) annihilation of the mass of the incident electrons.

18. Hydrogen atoms do not emit X-rays because

(*a*) it has a single electron

(*b*) it is too small in size

(*c*) its energy levels are too far apart

(*d*) its energy levels are very close to each other.

19. The maximum frequency ν of continuous X-rays is related to the applied potential difference V as

(*a*) $\nu \propto \sqrt{V}$ (*b*) $\nu \propto V$

(*c*) $\nu \propto V^{3/2}$ (*d*) $\nu \propto V^2$.

20. A patient is asked to drink $BaSO_4$ for examining the stomach by X-rays, because X-rays are

(*a*) reflected by heavy atoms

(*b*) less absorbed by heavy atoms

(*c*) more absorbed by heavy atoms
(*d*) refracted by heavy atoms.

21. Moseley's law relates
(*a*) frequency and applied voltage
(*b*) frequency and square of atomic number
(*c*) wavelength and intensity of X-rays
(*d*) wavelength and angle of scattering.

22. Soft X-rays have
(*a*) high energy
(*b*) low energy
(*c*) high frequency
(*d*) refracted by heavy atom.

23. Bragg's law for second order diffraction is
(*a*) $d \sin \theta = \lambda$
(*b*) $2d \sin \theta = \lambda$
(*c*) $\dfrac{\sin \theta}{2d} = \lambda$
(*d*) $\sin \theta = 2d$.

24. A sodium chloride is observed to reflect X-rays at an angle of 30° in a crystal spectrometer. If the atomic specimen in a sodium chloride crystal is 2.8×10^{-10} m, the frequency of the *X*-rays is
(*a*) 1.1×10^{17} Hz
(*b*) 4.5×10^{12} Hz
(*c*) 2.2×10^{18} Hz
(*d*) 1.1×10^{18} Hz.

25. A surface ejects electrons when hit by green light, but none when hit by yellow light. Will electrons by ejected if the surface is hit by red light?
(*a*) yes
(*b*) no
(*c*) yes, if the red beam is quite intense
(*d*) yes; if the red beam fall upon the surface for a long time.

26. The energy E of a photon of frequency ν is $E = h\nu$, where h is Planck's constant. Also we know the momentum p of a photon is $p = \frac{h}{\lambda}$ where λ is the wavelength of the photon. From this we conclude that the wave velocity of light is equal to

    (a) 3×10^6 m/s (b) $\frac{E}{p}$

    (c) $E \times p$ (d) $\left(\frac{E}{p}\right)^2$.

27. Compare the momentum of a 10^5 eV X-ray photon p_x with that of a 10^5 eV electron momentum p_e

    (a) $\frac{p_e}{p_x} = \frac{16}{5}$ (b) $\frac{p_e}{p_x} = \frac{1}{2}$

    (c) $\frac{p_e}{p_x} = \frac{1}{5}$ (d) $\frac{p_e}{p_x} = 5$.

ANSWERS TO OBJECTIVE QUESTIONS

1. (a)	2. (a)	3. (a)	4. (d)
5. (c)	6. (c)	7. (d)	8. (b)
9. (b)	10. (d)	11. (a)	12. (b)
13. (a)	14. (c)	15. (c)	16. (a)
17. (d)	18. (b)	19. (c)	20. (b)
21. (b)	22. (a)	23. (d)	24. (b)
25. (b)	26. (a).		

PROBLEMS AND SOLUTIONS

1. *At what speed will the mass of a body be 1.25 times its rest mass?*

    Solution:

    Let the required speed be v and m be the mass of the body travelling with a speed v and rest mass m_0, then

$$\frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

$$1.25\ m_0 = \frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

$$1-\frac{v^2}{c^2} = \frac{1}{1.25^2}$$

$$\frac{v^2}{c^2} = 1-\frac{1}{1.25^2} = \frac{9}{25}$$

$$\frac{v}{c} = \frac{3}{5}$$

The required speed

$$v = \frac{3c}{5} = 0.6\ c.$$

2. *A particle of rest mass m_0 moves with a speed $\frac{c}{2}$. Calculate its mass, momentum, total energy and kinetic energy.*

Solution:

$$\text{Mass} = \frac{m_0}{\sqrt{1-(v^2/c^2)}}$$

$$= \frac{m_0}{[1-(c/2)^2/c^2]} = \frac{m_0}{\left[1-\frac{1}{4}\right]^{1/2}}$$

$$= \frac{2\,m_0}{\sqrt{3}}$$

$\boxed{\text{Mass} = 1.155\ m_0}$ **Ans.**

Momentum = $1.155\, m_0 \times \frac{c}{2} = 0.5775\ m_0 c$

Total energy = $1.155\ m_0 c^2$

K.E. = T.E. – Rest mass energy

$$= 1.155\ m_0c^2 - m_0c^2$$

$$\boxed{= 0.155\ m_0c^2} \quad \textbf{Ans.}$$

3. *An atomic particle has a rest mass of 2.5 × 10^{-25} kg. Find its total mass energy when (a) at rest, and (b) when it has a velocity of 0.90 the speed of light.*

Solution:

(a) Total energy $= m_0c^2$

$$= 2.5 \times 10^{-25} \times (9 \times 10^8)^2 \text{ J}$$

$$= \frac{2.5 \times 10^{-25} \times (9 \times 10^8)^2}{1.6 \times 10^{-19}}$$

$$= 14.06 \times 10^4 \text{ MeV}$$

(b) $v = 0.90\ c$

$$m = \frac{m_0}{\sqrt{1-(v^2/c^2)}} = \frac{2.5 \times 10^{-25}}{\sqrt{1-0.81}}$$

$$m = 5.735 \times 10^{-25} \text{ kg}$$

Total energy

$$= mc^2 = \frac{5.735 \times 10^{-25} \times (9 \times 10^8)^2}{1.6 \times 10^{-19}}$$

Total energy = 32.25×10^4 MeV.

4. *A wrist-watch keeps correct time on earth. If it is worn by the pilot of space ship, leaving the earth with a constant velocity of 10^9 cm / sec, how many seconds does it appear to lose in one day with respect to the observer on the earth.*

Solution:

Time dilation formula is

$$t = \frac{t_0}{\sqrt{1-(v^2/c^2)}}$$

$$t = 24 = \frac{t_0}{\sqrt{1-(10^7/3 \times 10^8)^2}}$$

$$= \frac{t_0}{\left[1 - \frac{1}{900}\right]^{1/2}}$$

$$t_0 = 24\left[1 - \frac{1}{900}\right]^{1/2} = 24\left[1 - \frac{1}{1800}\right]$$

$$t_0 = \left[24 - \frac{1}{75}\right]$$

Hence

$$\boxed{\text{loss in 24 hours} = \frac{1}{75} \text{ hour or 48 sec}}$$ **Ans.**

5. *If the energy associated with an atomic particle is of the order of $k_B T$ where k_B is Boltzmann's constant, calculate the wavelength of thermal neutrons.*

Solution:

$$\frac{1}{2} mv^2 = E = k_B T$$

$$v = \sqrt{\frac{2E}{m}}$$

$$\lambda = \frac{h}{mv} = \frac{h}{m}\sqrt{\frac{m}{2E}}$$

$$\lambda = \frac{h}{\sqrt{2mk_B T}}$$

$$= \frac{6.62 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 1.38 \times 10^{-23} \times 300}}$$

$$\boxed{\lambda = 0.177 \text{ nm}}$$ **Ans.**

6. *What is the energy of a neutron of mass 1.6×10^{-27} kg which has an associated de Broglie wavelength of 0.75×10^{-14} m?*

Solution:

de Broglie wavelength,

$$\lambda = \frac{h}{p};\, p = \frac{h}{\lambda} \qquad ...(1)$$

It may be anticipated that K.E. of the neutron will be much smaller than its rest mass (931 MeV), so that the classical relation between momentum p and kinetic energy K is applicable. Hence, setting, $p = \sqrt{2mK}$ in equation (1), we get

$$\sqrt{2mK} = \frac{h}{\lambda};$$

$$K = \frac{h^2}{\lambda^2}\left[\frac{1}{2m}\right]$$

$$= \frac{(6.62 \times 10^{-34})^2}{(0.75 \times 10^{-14})^2 \times 2 \times 1.67 \times 10^{-27}}$$

$$= 2.33 \times 10^{-12} \text{ joule}$$

$$= \frac{2.33 \times 10^{-12}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{\text{K.E.} = 14.5 \times 10^6 \text{ eV}} \quad \textbf{Ans.}$$

7. *Calculate the de Broglie wavelength in the following cases:*

   (a) an α*-particle accelerated by a p.d. of 25000 volt*

   (b) a proton moving with $\left(\frac{1}{20}\right)$ *the velocity of light*

Solution:

(a) The velocity of the α-particle is given by the relation $\frac{1}{2}mv_1^2 = 2$ eV

(because the charge of α-particle is 2 times that of electron)

$$v_1 = \sqrt{\frac{4\,eV}{m}}$$

Momentum of the α-particle is mv_1 and hence

$$mv_1 = \sqrt{\frac{4\,eVm^2}{m}} = \sqrt{4\,eVm}$$

$$p_1 = \sqrt{4 \times 1.6 \times 10^{-19} \times 25000 \times 4 \times 1.67 \times 10^{-27}}$$

$$p_1 = 1.027 \times 10^{-20}$$

$$\lambda_1 = \frac{h}{p_1} = \frac{6.62 \times 10^{-34}}{1.027 \times 10^{-20}}$$

$$\boxed{\lambda_1 = 6.39 \times 10^{-14} \text{ metre}} \quad \textbf{Ans.}$$

(*b*) Velocity of electron

$$v_2 = \frac{1}{20}c = \frac{3 \times 10^8}{20} \text{ m/s}$$

Mass of proton = 1.6×10^{-27} kg

Momentum of proton

$$= mv_2 = \frac{1.6 \times 100^{-27} \times 3 \times 10^8}{20}$$

$$= 2.4 \times 10^{-10}$$

$$\lambda_2 = \frac{h}{mv_2} = \frac{6.62 \times 10^{-34}}{2.4 \times 10^{-20}}$$

$$\boxed{\lambda_2 = 2.75 \times 10^{-14} \text{ m}} \quad \textbf{Ans.}$$

8. *An enclosure filled with helium is heated at 400 K. A beam of helium atoms emerges out of the enclosure. Calculate de Broglie wavelength corresponding to the atoms. Mass of the atom is 6.7×10^{-27} kg.*

Solution:

The de Broglie wavelength corresponds to helium atoms.

$$\lambda = \frac{h}{\sqrt{2mK}} = \frac{h}{\sqrt{2m \times \frac{3}{2} k_B T}}$$

$$\lambda = \frac{6.62 \times 10^{-34}}{\sqrt{3 \times 6.7 \times 10^{-27} \times 1.38 \times 10^{-23} \times 400}}$$

$\boxed{\lambda = 0.63 \text{ nm}}$ **Ans.**

9. *Compute the de Broglie wavelength of a proton whose kinetic energy is equal to the rest energy of an electron. Mass of a photon is 1836 times that of the electron.*

Solution:

According to Einstein's energy mass relation, we have rest mass of electron is

$$E = m_0 c^2$$
$$= 9.1 \times 10^{-31} \times (3 \times 10^8)^2$$
$$= 81.9 \times 10^{-15} \text{ J}$$

Mass of proton $= 1836 \times 9.1 \times 10^{-31}$

$$\frac{1}{2} mv^2 = 81.9 \times 10^{-15}$$

$$v = \left[\frac{2 \times 81.9 \times 10^{-15}}{1836 \times 9.1 \times 10^{-31}}\right]^{1/2}$$

$$\lambda = \frac{h}{mv}$$

$$= \left[\frac{6.62 \times 10^{-34}}{1836 \times 9.1 \times 10^{-31}}\right] \times \left(\frac{1836 \times 9.1 \times 10^{-31}}{2 \times 81.9 \times 10^{-15}}\right)^{1/2}$$

$$\lambda = 4 \times 10^{-4} \text{ Å}$$

$\boxed{\lambda = 0.0004 \text{ Å}}$ **Ans.**

11.4 UNCERTAINTY PRINCIPLE AND COMPTON EFFECT

1. If Δx and Δp are uncertainties in the measurement of position and momentum of a particle, then according to Heisenberg uncertainty principle
   (*a*) $(\Delta x)\,(\Delta p) \geq \hbar$
   (*b*) $(\Delta x)\,(\Delta p) < \hbar$
   (*c*) $(\Delta x)\,(\Delta p) > \hbar^2$
   (*d*) $(\Delta x)\,(\Delta p) < \hbar^2$.
2. Uncertainty principle is applicable to
   (*a*) large system only
   (*b*) small system only
   (*c*) subatomic particle only
   (*d*) both subatomic and large systems.
3. If the uncertainty in the location of a particle is equal to its de Broglie wavelength, minimum uncertainty in its velocity will be of the order of
   (*a*) its velocity
   (*b*) 10000 times its velocity
   (*c*) 100 times its velocity
   (*d*) 1000 times its velocity.
4. An electron has a speed of 100 m/s, accurate to 0.005%. The uncertainty in its position is
   (*a*) 0.147 m
   (*b*) 14.7 m
   (*c*) 1.47 nm
   (*d*) 0.0147 m.
5. If Δx is the error in determining the position of an electron and Δp in determining its momentum then $(\Delta x)\,(\Delta p)$ is equal to or greater than
   (*a*) $\dfrac{2\pi}{h}$ (*b*) $\dfrac{h}{2\pi}$
   (*c*) $(2\pi - h)$ (*d*) $(h - 2\pi)$.

6. According to uncertainty principle the exact location of the position of a particle and exact determination of its momentum
   (*a*) can be made simultaneously
   (*b*) can be done only under certain conditions
   (*c*) cannot be made simultaneously
   (*d*) are not possible.
7. The product of the uncertainty in the position of a body at some instant and the uncertainty in its momentum is at best equal to
   (*a*) $7\,\hbar$ (*b*) $\dfrac{\hbar}{7}$
   (*c*) $\hbar$ (*d*) $\hbar\, 2\pi$.
8. According to classical theory of scattering of X-rays, the scattered X-rays frequency is
   (*a*) greater than that of the incident X-rays
   (*b*) same as that of X-rays
   (*c*) less than that of the incident X-rays
   (*d*) not dependent on incident frequency.
9. The scattered spectrum (Compton experiment) shows in addition to the incident wavelength,
   (*a*) another one of longer wavelength
   (*b*) another one of smaller wavelength
   (*c*) no other line.
10. The wavelength of the scattered line in Compton effect
    (*a*) increases with the angle at which scattering is observed
    (*b*) decreases with the angle at which scattering is observed
    (*c*) remains the same
    (*d*) reduces to zero.

11. According to Compton theory, the wavelength $\Delta\lambda$ is
    (*a*) dependent of the incident wavelength
    (*b*) independent of the incident wavelength
    (*c*) none of the above.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*a*)	2. (*d*)	3. (*a*)	4. (*a*)
5. (*b*)	6. (*c*)	7. (*c*)	8. (*b*)
9. (*a*)	10. (*a*)	11. (*b*).	

PROBLEMS AND SOLUTIONS

1. *Show that if the uncertainty in the location of a particle is equal to the de Broglie wavelength the minimum uncertainty in its velocity is equal to its velocity.*

   Solution:

   Let Δx be the de Broglie wavelength of particle is $\dfrac{h}{mv}$.

   For uncertainty principle, minimum uncertainty product,

$$\Delta x \, \Delta p \approx h$$

$$\Delta p \sim \frac{h}{\Delta x} = \frac{h}{(h/mv)} = mv$$

$$\Delta p = mv$$

Also $\quad \Delta p = m \, \Delta v$

$\therefore \quad m\Delta v = mv$

$\Rightarrow \quad \Delta v = v$

Hence the minimum uncertainty in the velocity of the particle is equal to its velocity.

2. *Find the smallest possible uncertainty in the position of an electron moving with velocity 3×10^7 m/s. Given; $\hbar = 1.054 \times 10^{-34}$ J-s, $m_0 = 9.11 \times 10^{-31}$ kg.*

   Solution:

   The maximum uncertainty in the momentum is

$$\Delta p_x = p_x = mv = \frac{m_0 v}{\sqrt{1-(v^2/c^2)}}$$

   From the uncertainty relation $\Delta x \,.\, \Delta p_x \geq \hbar$, the maximum uncertainty in the position is given by

$$\Delta x = \frac{\hbar}{\Delta p_x} = \frac{\hbar}{m_0 v}\sqrt{1-(v^2/c^2)}$$

   But

$$\sqrt{1-(v^2/c^2)} = \sqrt{1-\left(\frac{3\times 10^7}{3\times 10^8}\right)^2} = \sqrt{\frac{99}{100}}$$

$$= 0.995$$

   Smallest possible uncertainty is

$$\Delta x = \frac{\hbar \times 0.995}{m_0 v} = \frac{1.054\times 10^{-34}\times 0.955}{9.11\times 10^{-31}\times 3\times 10^7}$$

$$\boxed{\Delta x = 0.0384 \text{ Å}}$$ **Ans.**

3. *The average period that elapses between the excitation of an atom and the time it emits radiation is 10^{-8} sec. Find the uncertainty in the energy emitted and the uncertainty in the frequency of the light emitted.*

   Solution:

   The maximum uncertainty in the interval of tune is $\Delta t = 10^{-8}$ sec

From the uncertainty relation $\Delta E \cdot \Delta t \geq \hbar$, the minimum uncertainty in the energy is given by

$$\text{then } \Delta E = \frac{\hbar}{\Delta t} = \frac{1.054 \times 10^{-34}}{10^{-8}}$$

$$= 1.054 \times 10^{-26} \text{ J}$$

$$h\nu = E$$

Thus the uncertainty in the frequency is given by

$$h\Delta\nu = \Delta E$$

$$\Delta\nu = \frac{\Delta E}{h} = \frac{1.054 \times 10^{-26}}{6.63 \times 10^{-34}}$$

$$\boxed{\Delta\nu = 1.59 \times 10^{7} \text{ Hz}} \quad \textbf{Ans.}$$

4. *The energy of an electron, at any instant, is equal to 40 eV with a possible error up to + 0.01 eV. Find the least error with which its position can be determined.*

Solution:

If Δp and Δx be the uncertainties in the determination of the momentum and position then, from uncertainty principle, we have

$$\Delta p \, \Delta x \geq 1 \qquad ...(1)$$

Now if p and E be the momentum and energy of the particle, then $p = mv$ and

$E = \frac{1}{2} mv^2$, so that

$$p = \sqrt{2mE} = (2\, mE)^{1/2}$$

$$\Delta p = \frac{1}{2} (2mE)^{-1/2} \times 2m \, \Delta E$$

$$= \left\{\frac{m}{2E}\right\}^{1/2} \Delta E$$

Substituting this in Eqn. (1), one gets

$$\left\{\frac{m}{2E}\right\}^{1/2} \Delta E \, \Delta x \geq h$$

Thus minimum $\Delta x = \dfrac{h}{\Delta E}\sqrt{\dfrac{2E}{m}}$

$$= \frac{6.62 \times 10^{-34}}{0.01}\left\{\frac{2 \times 40 \times 1.6 \times 10^{-19}}{9.1 \times 10^{-31}}\right\}^{1/2}$$

i.e., $\boxed{\text{Minimum } \Delta x = 1.56 \times 10^{-6} \text{ m}}$

Ans.

5. *An X-ray photon is found to have its wavelength doubled on being scattered through 90°. Find the wavelength and energy of the incident photon. Given:* $m_0 = 9 \times 10^{-28}$ *gm.*

Solution:

The Compton change in wavelength is given by

$$\Delta\lambda = \frac{h}{m_0 c}(1 - \cos\theta)$$

when $\theta = 90°$, $\Delta\lambda = \lambda' - \lambda = 2\lambda - \lambda = \lambda$

i.e., $\lambda = \dfrac{h}{m_0 c} = 0.024$

This is the wavelength of the incident photon. Its energy would be

$$E = h\nu = \frac{hc}{\lambda}$$

$$= \frac{hc}{h/m_0 c} = m_0 c^2$$

$$E = 9.1 \times 10^{-19} \times 3^2 \times 10^8$$

$\boxed{E = 8.1 \times 10^{-3} \text{ J}}$ **Ans.**

6. *An incident photon of wavelength 0.003 nm recoils at an angle of 60° after being scattered by a free electron. Find the energy of the recoiling electron.*

Solution:

Change in wavelength is

$$\frac{h}{m_0 c}(1 - \cos 60°) = 0.024\,(1 - 0.5)$$

$$= 0.024 \times 0.5$$

$$= 0.0121 \times 10^{-10}$$

$$= 1.21 \times 10^{-12} \text{ m}$$

Wavelength of the incident photon

$$= 0.003 \text{ nm} = 3 \times 10^{-12}$$

Wavelength of photon on scattering

$$= 3 \times 10^{-12} + 1.21 \times 10^{-12}$$

$$= 4.21 \times 10^{-12} \text{ metre}$$

$$\text{Energy} = h\upsilon = (hc/\lambda)$$

$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^{8}}{4.21 \times 10^{-12}}$$

$$E = 4.7 \times 10^{14} \text{ J.}$$

11.5 ELECTRICAL CONDUCTIVITY AND SUPERCONDUCTORS

1. If T is the absolute temperature, the random velocity of free electrons in a metal is
   (*a*) directly proportional to T
   (*b*) inversely proportional T
   (*c*) directly proportional to $\sqrt{T}$
   (*d*) independent of temperature.
2. If τ represents the average time between successive collisions (relaxation time), then the vectorial form of the drift velocity acquired by the electron in a field E is v_d and it is given by

(*a*) $v_d = -\dfrac{me}{\overline{E}t}$ (*b*) $v_d = \dfrac{me}{\overline{E}\tau}$

(*c*) $v_d = -\dfrac{eE\tau}{m}$ (*d*) $v_d = \dfrac{e\tau}{m}$.

3. If n is the number of free electrons in a conductor of uniform cross-section and v_d is the drift velocity then equation for the current density calculation is
   (*a*) ne (*b*) ne^2
   (*c*) $ne\, v_d$ (*d*) $\dfrac{ne}{v_d}$.
4. The microscopic expression for computing the resistivity is
   (*a*) $\rho = \dfrac{ne^2\tau}{m}$ (*b*) $\rho = \dfrac{m}{ne^2\tau}$
   (*c*) $\rho = \dfrac{ne\tau}{m}$ (*d*) $\rho = \dfrac{m^2}{ne\,\tau}$.
5. If I is the current passing through a conductor of uniform cross-section A, then the equation to compute the drift velocity is
   (*a*) $v_d = \dfrac{n\,Ae}{I}$ (*b*) $\dfrac{I}{nAe} = v_d$
   (*c*) $v_d = \dfrac{ne}{I}$ (*d*) $(n\,Ae)^2$.
6. The drift velocity for unit electrical field is called
   (*a*) collision time (*b*) random speed
   (*c*) mobility (*d*) conductivity.
7. The mobility of charge carriers depends on
   (*a*) the current through the conductor
   (*b*) density of the material
   (*c*) thermal conductivity of the metal
   (*d*) collision time of free electrons.

8. If J is the current density in a conductor under an electric field with σ as the electric conductivity, then $J = \sigma E$ is
   (*a*) Kirchhoff's law
   (*b*) Widemann-Franz law
   (*c*) Lorentz law
   (*d*) Ohm's law.
9. If n, e and σ are the usual parameters in a metal, then the mobility of charge carrier is
   (*a*) σne (*b*) $\frac{\sigma}{ne}$
   (*c*) $\frac{1}{ne}$ (*d*) $ne\mu$.
10. The residual resistivity will be high if
   (*a*) the metal is pure
   (*b*) the metal is impure
   (*c*) if it is a liquid metal
   (*d*) if the metal is a superconductor.
11. At room temperature the velocity of the random motion of the electron is of the order of
   (*a*) 10 m/sec (*b*) 10^{20} m/s
   (*c*) 10^5 m/sec (*d*) 0.1 m/s.
12. For constant value of n, A and e, the current flowing through a conductor is
   (*a*) proportional to drift velocity
   (*b*) inversely proportional to the drift velocity
   (*c*) directly proportional to the square of the drift velocity
   (*d*) directly proportional to the square root of drift velocity.
13. 10 Ω is the resistance of copper wire of length l and area of cross-section a. If the length is doubled and the area of cross-section is halved, the resistance of the new copper wire will be

(*a*) 5 ohm (*b*) 40 ohm
(*c*) 20 ohm (*d*) 10 ohm.

14. If 1 ampere current flows through a conductor for 1 sec, it is equivalent to the flow of how many electrons per sec?
(*a*) 1.6×10^{19} (*b*) 1 coulomb
(*c*) 6.25×10^{18} (*d*) 2.1×10^{17}.

15. The drift velocity of free electrons for ordinary field is of the order of
(*a*) 1 mm/s (*b*) 10^3 m/s
(*c*) 1 nm/s (*d*) 10^6 m/s.

16. Critical magnetic field
(*a*) does not depend on temperature
(*b*) increases if temperature increases
(*c*) increases if temperature decreases
(*d*) does not depend on superconducting transition temperature.

17. The transition temperature of most elemental superconductors fall in the range (low critical temperature range)
(*a*) 0–500 K (*b*) 0–5 K
(*c*) 0–10 K (*d*) 0–70 K.

18. Which of the following one is type-1 superconductor?
(*a*) niobium (*b*) tantalum
(*c*) lead (*d*) Nb_3Ge.

19. In a superconductor, critical magnetic field
(*a*) increases if temperature decreases
(*b*) does not depend on temperature
(*c*) increases if temperature increases
(*d*) remains constant.

20. A superconductor has
(*a*) a positive susceptibility
(*b*) a negative susceptibility
(*c*) becomes quite small as temperature approaches the transition temperature

(*d*) becomes quite large as temperature approaches the transition temperature.

21. In a superconductor the magnetic field required to destroy the conductivity at 0 K is
(*a*) maximum
(*b*) minimum
(*c*) 10 A/m
(*d*) all these are wrong.

22. The isotope effect coefficient
(*a*) is zero
(*b*) is generally in the range 0.2–0.6
(*c*) is generally in the range 0.5–1
(*d*) is generally greater than 1.

23. The width of the energy gap of a superconductor is maximum at
(*a*) T_cK (*b*) 0 K
(*c*) $\frac{T_c}{2}$ K (*d*) $\frac{T_c}{3}$ K.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*c*)	3. (*c*)	4. (*b*)
5. (*b*)	6. (*c*)	7. (*a*)	8. (*d*)
9. (*d*)	10. (*b*)	11. (*c*)	12. (*a*)
13. (*b*)	14. (*c*)	15. (*a*)	16. (*c*)
17. (*b*)	18. (*c*)	19. (*a*)	20. (*b*)
21. (*a*)	22. (*b*)	23. (*b*).	

PROBLEMS AND SOLUTIONS

1. *Calculate the average drift speed of conduction electron in a copper wire of cross-sectional area 10^{-7} m^2 and carrying a current of 1.5 ampere. The number of density of electrons in copper is*

8.5×10^{28} m^{-3}. Calculate the average drift velocity of electrons and compare it with the thermal velocity at 27°C.

Solution:

$$I = nAv_d$$

$$v_d = \frac{I}{nA}$$

$$= \frac{1.5}{8.5 \times 10^{28} \times 10^{-7} \times 1.6 \times 10^{-19}}$$

$$v_d = 1.1 \times 10^{-3} \text{ m/s}$$

Thermal velocity at 27°C is the r.m.s. velocity of electrons at that temperature. Thus the root mean square velocity,

$$\bar{c} = \sqrt{\frac{3\,k_B T}{m}}$$

$$= \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{9.1 \times 10^{-31}}}$$

$$\bar{c} = 1.17 \times 10^5 \text{ m/s} \quad \textbf{Ans.}$$

2. *Copper has density and electrical conductivity as 8.95×10^3 kg/m^3 and 6.4×10^7 Ω^{-1} m^{-1} respectively at the room temperature. Determine the relaxation time.*

Solution:

$\frac{M_A}{\rho}$ m^3 will contain N_A electrons

1 m^3 will have $\frac{N_A \rho}{M_A}$ electrons

i.e., $$n = \frac{N_A \rho}{m_A}$$

$$= \frac{6.02 \times 10^{26} \times 8.95 \times 10^3}{63.54}$$

$$n = 8.5 \times 10^{28}/\text{m}^3$$

Relaxation time,

$$\tau = \frac{\sigma m}{ne^2} = \frac{6.4 \times 10^7 \times 9.1 \times 10^{-31}}{8.5 \times 10^{28} \times (1.6 \times 10^{-19})^2}$$

$$\boxed{\tau = 2.67 \times 10^{-14} \text{ s}} \quad \textbf{Ans.}$$

3. *The number of free electrons per cubic metre is $8.5 \times 10^{28}/m^3$. How long does an electron take to drift from one end of the wire of length 3 m to its other end? The area of cross-section of the wire is 2×10^{-6} m^2 and it carries a current of 3 A. The charge of the electron is 1.6×10^{-19} coulomb.*

Solution:

$$I = nAev_d$$

$$v_d = \frac{I}{nAe}$$

$$= \frac{3}{8.5 \times 10^{28} \times 2 \times 10^{-6} \times 1.6 \times 10^{-19}}$$

$$v_d = 1.1 \times 10^{-4} \text{ m/s}$$

Let t be the time taken to drift from one end to the other,

$$t = \frac{\text{Distance}}{\text{Velocity}}$$

$$= \frac{3}{1.1 \times 10^{-4}} = 2.7 \times 10^4 \text{ s}$$

$$\boxed{t = 2.7 \times 10^4 \text{ sec}} \quad \textbf{Ans.}$$

4. *Compute the average kinetic energy of a gas molecule at 27°C. Express the result in electron volt. If the gas is hydrogen, what is the order of magnitude of the velocity of the molecule at 27°C.*

Solution:

The equation used is

$$E = \frac{1}{2}\, m\bar{c}^2 = \frac{3}{2}\, k_B T$$

$$E = \frac{3}{2}\, k_B T$$

$$= 1.5 \times 1.38 \times 10^{-23} \times 300$$

$$E = \frac{300 \times 1.5 \times 1.38 \times 10^{-23}}{1.6 \times 10^{-19}}$$

$$E = 0.039 \text{ eV}$$

Also $\bar{c} = \sqrt{\dfrac{3\, k_B T}{M_H}}$

$$= \sqrt{\frac{3 \times 1.38 \times 10^{-23} \times 300}{2 \times 1.008 \times 1.67 \times 10^{-27}}}$$

$\boxed{\bar{c} = 1920 \text{ m/s}}$ **Ans.**

5. *A uniform cross-section of silver has a resistivity of 1.54 × 10^{-8} Ω m at room temperature. For an electric field along the wire of 1 volt/cm, calculate (a) the drift velocity (b) the mobility and (c) the relaxation time of electrons assuming that there are 5.8 × 10^{28} free electrons/m^3.*

Solution:

(*a*) $\tau = \dfrac{m}{ne^2\, \rho}$

$$= \frac{9.11 \times 10^{-31}}{5.8 \times 10^{28} \times (1.6 \times 10^{-19})^2 \times 1.54 \times 10^{-8}}$$

$\boxed{\tau = 3.98 \times 10^{-14}}$ **Ans.**

(*b*) Drift velocity, is given by

$$v_d = \left[\frac{eE}{m}\right]\tau$$

$$= \frac{1.6 \times 10^{-19} \times 100 \times 3.98 \times 10^{-14}}{9.11 \times 10^{-31}}$$

$$\boxed{= 0.7 \text{ m/s}} \quad \textbf{Ans.}$$

(*c*) Relaxation for mobility is,

$$\mu = \frac{v_d}{E} = \frac{0.7}{100}$$

$$\boxed{\mu = 7 \times 10^{-3} \text{ m}^2/\text{V-sec}} \quad \textbf{Ans.}$$

6. *Critical temperature of sample with isotopic mass of 204.87 is 19.2 K. Find T_c when isotopic mass changes to 218.87.*

Solution:

The relation is given by

$$T_c\, m^{1/2} = \text{constant}$$

Thus
$$\frac{19.2 \times (204.87)^{1/2}}{T_c' \times (218.87)^{1/2}} = 1$$

$$\boxed{T_c' = 18.58 \text{ K}} \quad \textbf{Ans.}$$

7. *For a superconducting specimen, the critical fields are respectively 1.4 × 10^5^ and 4.2 × 10^5^ A/m for – 259°C and – 260°C. Determine the superconducting transition temperature and the critical field at 0 K.*

Solution:

$$T_1 = -259 + 273 = 14 \text{ K}$$

and
$$T_2 = -260 + 273 = 13 \text{ K}.$$

Formula used:

$$H_{c1} = H_0\left[1 - \left[\frac{T_1}{T_c}\right]^2\right]$$

$$H_{c2} = H_0 \left[1 - \left(\frac{T_2}{T_c}\right)^2\right]$$

$$\frac{H_{c1}}{H_{c2}} = \frac{T_c^2 - T_1^2}{T_c^2 - T_2^2}$$

$$\frac{1.4 \times 10^5}{4.2 \times 10^5} = \frac{T_c^2 - T_1^2}{T_c^2 - T_2^2}$$

$$\frac{1}{3} = \frac{T_c^2 - T_1^2}{T_c^2 - T_2^2}$$

$$3T_c^2 - 3(14)^2 = T_c^2 - 13^2$$

$$2T_c^2 = 3 \times 14 \times 14 - 13^2$$

$$T_c = 14.47 \text{ K}$$

Further $H_{c1} = H_0 \left[\frac{T_c^2 - T_1^2}{T_c^2}\right]$

$$H_0 = \frac{H_{c1}(T_c^2)}{T_c^2 - T_1^2}]$$

$$= \frac{1.4 \times 10^5 \times 14.47^2}{(14.47^2 - 14^2)}$$

$$\boxed{H_0 = 21.72 \text{ A/m}} \quad \textbf{Ans.}$$

8. *The transition temperature for Pb is 7.2 K. However at 5K it loses the superconducting property if subjected to a magnetic field of 3.3 × 10⁴ A/m. Find the maximum value of H which will allow the metal to retain its superconductivity at 0 K.*

Solution:

$$H_c(T) = H_c(0) \left[1 - \left\{\frac{T}{T_c}\right\}\right]^2$$

where $H_c(0)$ is the critical magnetic field at 0 K in the general formula.

Now $H_c(0) = \dfrac{H_c(T)}{\left[1 - \dfrac{T^2}{T_c^{\,2}}\right]} = \dfrac{3.3 \times 10^4}{\left\{1 - \dfrac{25}{7.2^2}\right\}}$

$$\boxed{H_c(0) = 6.37 \times 10^4 \text{ A/m}}$$ **Ans.**

11.6 MAGNETIC PROPERTIES OF MATERIALS AND SEMI-CONDUCTORS

1. The magnetic moment per unit volume is called
   (*a*) magnetic flux
   (*b*) intensity of magnetization
   (*c*) magnetic induction
   (*d*) magnetic field.
2. All materials have
   (*a*) paramagnetic property
   (*b*) diamagnetic property
   (*c*) ferrimagnetic property
   (*d*) ferromagnetic property.
3. Which quantity is measured in units of tesla metre/ampere
   (*a*) flux density
   (*b*) magnetic moment
   (*c*) magnetic susceptibility
   (*d*) permeability of free space.
4. A magnetic shielding to a magnetic instrument is provided by covering with
   (*a*) a soft iron of high permeability
   (*b*) a plastic material
   (*c*) a metal of high conductivity
   (*d*) none of the above.
5. The diamagnetic susceptibility is
   (*a*) positive always
   (*b*) negative always

(*c*) zero always
(*d*) depending on the material and can be positive, zero or negative.

6. In a magnetization curve (B-H) of a ferromagnetic materials
(*a*) susceptibility is constant throughout
(*b*) susceptibility is highest in the beginning and reduces to zero near full magnetization
(*c*) susceptibility is low in the beginning, assumes a maximum value in the middle and becomes almost zero near full magnetization
(*d*) susceptibility is maximum in the end of magnetization.

7. The ratio of intensity of the magnetizing field and the intensity of magnetization is called
(*a*) magnetic flux
(*b*) reciprocal of magnetic susceptibility
(*c*) simply magnetic susceptibility
(*d*) permeability.

8. For a paramagnetic substance, the dependence of the magnetic susceptibility χ on the absolute temperature (T) is given by
(*a*) $\chi \propto T$ (*b*) $\chi \propto \dfrac{1}{T}$
(*c*) χ = constant (*d*) $\chi \propto T^2$.

9. Curie temperature of a ferromagnetic material, nickel
(*a*) increases with addition of iron and cobalt
(*b*) increases with addition of iron and silicon
(*c*) decreases with addition of iron and silicon
(*d*) decreases with addition of cobalt and molybdenum.

10. Susceptibility of a ferromagnetic magnetic substance
(*a*) does not vary with temperature
(*b*) increases with temperature
(*c*) decreases with temperature
(*d*) first decreases and then increases.

11. In ferrimagnetism
(*a*) the number of atoms with opposite spins are unequal
(*b*) the number of atom with opposite spins are equal
(*c*) the number of atoms with opposite spins are zero
(*d*) there is zero magnetic moment.

12. Soft iron is used to manufacture electromagnets because of its
(*a*) high retentivity
(*b*) high coercivity
(*c*) large area of hysteresis curve
(*d*) all the above are wrong.

13. The magnetic moment of atomic neon is (μ_B -Bohr magneton)
(*a*) μ_B (*b*) $\frac{\mu_B}{2}$
(*c*) $\frac{3}{2}\mu_B$ (*d*) zero.

14. In an antiferromagnet, the susceptibility above the Neel temperature θ_N has the form
(*a*) $\frac{C}{T}$ (*b*) $\frac{C}{T-\theta_N}$
(*c*) $\frac{C}{T+\theta_N}$ (*d*) $\frac{C}{\theta_N}$.

15. Alnico is an alloy of
(*a*) aluminium, iron and cobalt
(*b*) aluminium, iron and nickel
(*c*) aluminium, cobalt and nickel
(*d*) none of these.

16. A good ferromagnetic material must have
    (*a*) high resistivity and permeability and low magnetostriction
    (*b*) low resistivity, high permeability, and high magnetostriction
    (*c*) low resistivity, low permeability and high magnetostriction
    (*d*) high resistivity, high magnetostriction and low permeability.
17. Permanent magnets are made of materials having
    (*a*) high resistance
    (*b*) high resistivity and high coercivity
    (*c*) low coercivity and resistivity
    (*d*) high resistivity and low coercivity.
18. Ferromagnetic materials owe their properties to
    (*a*) vacant inner shells
    (*b*) filled inner shells
    (*c*) vacant outer shells
    (*d*) partially filled inner shells.
19. Which of the following pair has the same unit
    (*a*) B and H (*b*) m and H
    (c) μ and M (*d*) H and M.
20. Which of the material is the best for making the core of an electromagnet
    (*a*) steel (*b*) iron
    (*c*) alnico (*d*) copper.
21. The examples of diamagnetic, paramagnetic and ferromagnetic materials are respectively
    (*a*) aluminium, copper, iron
    (*b*) aluminium, iron, copper
    (*c*) copper, aluminium, iron
    (*d*) iron, aluminium.

22. Soft iron at a temperature of 1500°C is
    (*a*) diamagnetic
    (*b*) ferromagnetic
    (*c*) paramagnetic
    (*d*) none of these.
23. An increase of temperature of a semiconductor decreases
    (*a*) the resistivity
    (*b*) the band gap
    (*c*) the conductivity
    (*d*) size of the semiconductor.
24. In an *n*-type semiconductor, the position of the Fermi level
    (*a*) is lower than the centre of the energy gap
    (*b*) is at the centre of the energy gap
    (*c*) is higher than that of the energy gap
    (*d*) can be anywhere depending on the doping concentrates.
25. At 0 K, germanium is a
    (*a*) conductor
    (*b*) insulator
    (*c*) superconductor
    (*d*) semiconductor.

25A. A *p*-type silicon crystal is electrically
    (*a*) positive
    (*b*) negative
    (*c*) neutral
    (*d*) either positive or negative.

26. A carbon microphone works on the principle that
    (*a*) carbon is a good conductor of electricity
    (*b*) its carbon granules are compressed and loosened by the sound waves

(*c*) carbon is a non-metal through which electricity passes in one direction.
(*d*) the circuit is completed without any source of electricity.

27. In a *p*-type silicon, which of the following statements is true.
(*a*) electrons are majority carriers and trivalent atoms are dopants
(*b*) electrons are minority carriers and pentavalent atoms are dopants
(*c*) holes are minority carriers and pentavalent atoms are dopants
(*d*) holes are majority and trivalent atoms are dopants.

28. The movement of charge carriers from a region of higher concentration to a region of lower concentration is called
(*a*) doping (*b*) tunneling
(*c*) diffusion (*d*) drifting.

29. The drift velocity of electrons is expected to be
(*a*) equal to that of holes
(*b*) less than that of holes
(*c*) greater than that of holes
(*d*) infinite.

30. When a *p*-*n* junction is reverse biased, the small reverse current through the barrier is due to the
(*a*) diffusion of charge carriers
(*b*) drifting of the charge carriers
(*c*) flow of free electron
(*d*) flow of holes.

31. A photodiode is made with a semiconductor of band gap of energy E_g. Light of energy $h\nu$ is falling on it. Current is obtained in the photodiode if the frequency of light satisfied the condition

(*a*) $\nu = E_g$ (*b*) $\nu > \frac{E_g}{h}$

(*c*) $\nu < \frac{E_g}{h}$ (*d*) $\nu > \frac{h}{E_g}$.

32. Hall effect occurs is
(*a*) metals only
(*b*) *n*-type semiconductors only
(*c*) intrinsic semiconductors only
(*d*) all of the above.

33. The smaller number of carriers and high mobility in semiconductors gives
(*a*) small hall angle
(*b*) large hall field
(*c*) small hall field
(*d*) all the above are wrong.

34. A transistor amplifier of voltage gain 10 produces an output voltage of 2 volt. The input signal of the amplifier is
(*a*) 0.001 volt (*b*) 20 volt
(*c*) 10 volt (*d*) 0.2 volt.

35. Which of the following statements is wrong about a junction transistor
(*a*) the doping of the collector is less than that of the emitter
(*b*) the electron hole recombination taking place at the base is very small
(*c*) the area of the base collector junction is larger than that of the base emitter junction
(*d*) the base is very thin and is heavily doped.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*b*)	2. (*b*)	3. (*d*)	4. (*a*)
5. (*b*)	6. (*c*)	7. (*b*)	8. (*b*)
9. (*a*)	10. (*c*)	11. (*a*)	12. (*a*)

13. (*d*)	14. (*c*)	15. (*b*)	16. (*a*)
17. (*b*)	18. (*d*)	19. (*d*)	20. (*b*)
21. (*c*)	22. (*a*)	23. (*a*)	24. (*c*)
25. (*c*)	25A. (*c*)	26. (*b*)	27. (*d*)
28. (*c*)	29. (*c*)	30. (*b*)	31. (*b*)
32. (*d*)	33. (*c*)	34. (*d*)	35. (*d*).

PROBLEMS AND SOLUTIONS

1. *A magnetic field of intensity 1600 A/m produces a magnetic flux of 4×10^{-4} weber in an iron bar of area of cross-section 4 cm^2. Calculate the magnetic permeability and susceptibility of the specimen.*

   Solution:

$$\mu = \frac{B}{H} \text{ and } B = \frac{\phi}{A} = \frac{4 \times 10^{-4}}{4 \times 100^2} = 1$$

Thus $$\mu = \frac{B}{H} = \frac{\phi}{AH}$$

$$= \frac{1}{1600} = 6.25 \times 10^{-4}$$

$$\mu = 6.25 \times 10^{-4} \text{ F/m}$$

If χ is the susceptibility, then

$$\chi = (\mu_r - 1) = \frac{\mu}{\mu_0} - 1$$

$$= \frac{6.25 \times 10^{-4}}{4\pi \times 10^{-7}} - 1$$

$$\boxed{\chi = 496.6}$$ **Ans.**

2. *A magnetic material has a magnetization of 2300 A/m and produces a flux density of 0.00314 Wb/m^2.*

   Calculate the magnetizing force and relative permeability of the material.

Solution:

$$B = \mu_0(H + M)$$

$$\frac{B}{\mu_0} - M = H$$

i.e., $$H = \frac{0.00314}{4\pi \times 10^{-7}} - 2300$$

$$= 198 \text{ A/m}$$

But $\mu_r \mu_0 H = B$

$$\mu_r = \frac{B}{H\mu_0} = \frac{0.00314}{198 \times 4\pi \times 10^{-7}}$$

$$\boxed{\mu_r = 12.56} \quad \textbf{Ans.}$$

3. *Iron crystallizes in body centred cubic form. The lattice parameter is 2.9×10^{-10} m. Iron has a transition temperature of 765°C. The number of effective atom in the unit cell is 2. Calculate the saturation magnetization, Weiss field constant and effective internal field intensity. Given:* $\gamma = \frac{1038}{0.68}$.

Solution:

$M_S = 2\ \mu_B n$ as iron has moments of two Bohr magneton per atom.

$$n = \frac{2}{a^3} = \frac{2}{(2.9 \times 10^{-10})^3}$$

$$= 8.2 \times 10^{28}/\text{m}^3$$

$$M_S = 2 \times 9.27 \times 10^{-27} \times 8.2 \times 10^{28}$$

$$\boxed{M_S = 15.03 \times 10^5 \text{ A/m}} \quad \textbf{Ans.}$$

Curie constant, $C = \dfrac{n\mu_0\mu_B^{\,2}}{k_B}$

$$= \frac{8.2 \times 10^{22} \times 4\pi \times 10^{-7} \times (9.27 \times 10^{-27})^2}{7 \times 1.38 \times 10^{-23}}$$

$$= 0.68$$

Effective field intensity $= \gamma M_S = \frac{\theta}{e} M_S$

$$= \frac{1038}{0.68} \times 15.03 \times 10^5$$

$$H_i = 2.29 \times 10^9 \text{ amp/m}$$

Internal magnetic flux density,

$$B_i = \mu_0 H_i$$
$$= 4\pi \times 10^{-7} \times 2.29 \times 10^9$$

$$\boxed{B_i = 2878.8 \text{ tesla}}$$ **Ans.**

4. *The magnetic susceptibility of silicon is – 0.4 × 10^{-5}. What is the flux density and the total magnetic moment per unit volume in a magnetic field of intensity 10^5 amp / m.*

Solution:

$$B = \mu_0(H + M)$$

$$= \mu_0 H \left(1 + \frac{M}{H}\right)$$

$$B = \mu_0 H (1 + \chi)$$

$$[\because \quad M = \chi H$$
$$= -0.4 \times 10^{-5} \times 10^5$$
$$= -0.4 \text{ amp/m}]$$

$$B = 4\pi \times 10^{-7} \times 10^5 (1 - 0.4 \times 10^{-5})$$

$$\boxed{B = 0.124 \text{ weber/m}^2}$$ **Ans.**

5. *The ions in the molecule of magnetite are Fe^{+2}, Fe^{+3}, and O_4^{-2}, the subscripts, giving the number of ions per molecule. In the conventional unit cell, which is cubic with a = 0.837 nm, there are eight molecules.*

The Fe^{+3} magnetic moments cancel and the magnetization is produced by the Fe^{2+} ions only. If the saturation magnetisation of magnetite is 5.2×10^5 A/m, calculate the moment per Fe^{2+} ion in Bohr magneton.

Solution:

There are eight magnetic molecules per unit cell. There is one Fe^{+2} ion per molecule. Number of Fe^{+2} ion per m^3 is

$$N = \frac{8}{a^3} = \frac{8}{0.837 \times 10^{-27}}$$

$$= 1.36 \times 10^{28}/\text{m}^3$$

Also $M_S = N(n\mu_B)$

$$n = \frac{M_S}{N \times \mu_B}$$

$$= \frac{5.2 \times 10^5}{1.36 \times 10^{28} \times 9.27 \times 10^{-24}}$$

$$n = 4$$

The moment per Fe^{+2} is $4\ \mu_B$

$\boxed{4\ \mu_B}$ **Ans.**

6. *A circular loop conductor having a diameter of 50 cm carries a current of 100 mA. The loop is placed in a magnetic field having a uniform flux density of 0.05 weber/m² with its axis inclined at 60° to the direction of the field. Calculate the values of magnetic dipole moment and torque experienced by the current loop.*

Solution:

The magnetic dipole moment,

$$\mu_m = IA = 0.1 \times 0.1963$$

$$= 0.0196 \text{ amp m}^2$$

Torque $= I\,B \cos\theta$

$= 100 \times 10^{-3} \times (0.05) \cos 60°$

$= 0.0025$ newton metre

7. *Find the concentration of atoms in germanium crystal from the following data:*

Solution:

Atomic weight of Ge = 72.6

Avogadro's number = 6.02×10^{26}/kg mol

Density of Ge = 5.32×10^3 kg/m^3

$\frac{72.6}{5.32 \times 10^3}$ m^3 will have

6.02×10^{26} Ge atoms

1 m^3 will have $\frac{5.32 \times 10^3 \times 6.02 \times 10^{26}}{72.6}$

$$\boxed{N = 4.41 \times 10^{28}/\text{m}^3} \quad \textbf{Ans.}$$

8. *The resistivity of pure silicon is 2300 Ωm and the mobilities of electrons and holes in it are 0.135 and 0.048 m²/V-s respectively. Find the electron and hole concentrations, and the resistivity of a specimen of silicon doped with 10^{19} atoms of phosphorus/m³.*

Solution:

$$\rho_i = \frac{1}{n_i e(\mu_e + \mu_p)}$$

$$n_i = \frac{1}{e\rho_i\,(\mu_e + \mu_p)}$$

$$= \frac{1}{2300 \times 1.6 \times 10^{-19}\,(0.048 + 0.135)}$$

$$n_i = 1.48 \times 10^{16}/\text{m}^3$$

If n_e is the electron from donor level, then

$$n_e\, n_p = n_i^2$$
$$N_d n_p = n_i^2$$
$$n_p = \frac{n_i^2}{N_d} = \frac{1.48^2 \times 10^{32}}{10^{19}}$$
$$= 2.2 \times 10^{13}$$

The conductivity of doped semiconductor is

$$\sigma_d = e(n_e\mu_e + n_p\mu_p)$$

As $\quad n_e >> n_p$

$$\sigma_d = e\mu_e n_e$$
$$\rho_d = \frac{1}{e\,\mu_e n_e}$$
$$= \frac{1.0}{1.6 \times 10^{-19} \times 0.135 \times 10^{19}}$$
$$\boxed{\rho_d = 4.63\ \Omega\ \text{m}} \quad \textbf{Ans.}$$

9. *If the effective mass of an electron is equal to twice the effective mass of the hole, determine the position of the Fermi level is an intrinsic semiconductor from the centre of the forbidden gap at 300 K. Given: $m_e^* = 2\, m_p^*$, $k_BT = 0.026$ eV.*

Solution:

$$E_F = \frac{E_g}{2} + \frac{3}{4}\, k_BT \ln\left[\frac{m_p{}^*}{m_e{}^*}\right]$$
$$E_F = \frac{E_g}{2} - \frac{3}{4} \times 0.026 \times \ln\left[\frac{m_e{}^*}{m_p{}^*}\right]$$

or
$$E_F = \frac{E_g}{2} - \frac{3}{4} \times 0.026 \times \ln\left[\frac{2\, m_p{}^*}{m_p{}^*}\right]$$
$$E_F = \frac{E_g}{2} - 0.0135$$

i.e., the Fermi level is below the centre of the forbidden gap by 0.014 eV.

10. *A specimen of silicon doped semiconductor having the Hall coefficient of 3.55 × 10^{-4} m^3/C. Calculate the voltage between the contacts when a current of 15 mA is flowing: Magnetic field applied is B_z = 0.48 weber/m^2. Other data are:*
Hall coefficient, R_H = 3.55 × 10^{-4} m/C
Current, I_x = 15 mA = 0.015 amp
Area = 15 mm × 1 mm = 15 × 10^{-6} m^2.

Solution:

Current density,

$$J_x = \frac{I_x}{A} = \frac{0.015 \times 1}{15 \times 10^{-6}} = 1000 \text{ A/m}^2$$

Hall coefficient is given by the relation

$$R_H = \frac{E_y}{B_z J_x}$$

$$3.55 \times 10^{-4} = \frac{E_y}{0.48 \times 1000}$$

$$\boxed{E_y = 0.002556 \text{ volt}} \quad \textbf{Ans.}$$

11. *A high-purity sample of germanium has intrinsic behaviour at 300 K. If λ^{-1} threshold value for continuous absorption is 5.5 × 10^5 m^{-1}, estimate the temperature rise that will result in a 20% increase in the conductivity.*

Solution:

The band gap is given by

$$E_g = h\nu = \frac{hc}{\lambda} = hc\lambda^{-1} \text{ joule}$$

$$E_g = \frac{6.62 \times 10^{-34} \times 3 \times 10^8 \times 5.5 \times 10^5}{1.6 \times 10^{-19}}$$

$E_g = 0.683$ eV

The conductivity

$$\sigma \propto n \propto \exp(-E_g/2\,k_B T)$$

We want 20% increase in the conductivity

$$\frac{(\sigma_2 - \sigma_1)}{\sigma_1} = \frac{20}{100} = 0.2$$

i.e., $$\frac{\sigma_2}{\sigma_1} = 1 + 0.2 = 1.2$$

$$\frac{\sigma_2}{\sigma_1} = \frac{\exp(-E_g/2k_BT_1)}{\exp(-E_g/2k_BT_2)}$$

$$1.2 = \exp\left\{-\frac{E_g}{2k_B}\left(\frac{1}{T_2} - \frac{1}{T_1}\right)\right\}$$

$$\ln 1.2 = \left\{\left(-\frac{E_g}{2\,k_B}\right)\left[\frac{1}{T_2} - \frac{1}{T_1}\right]\right\}$$

$$\frac{1}{T_2} - \frac{1}{T_1} = -\frac{2k_B}{E_g} \times \ln 1.2$$

$$\frac{1}{T_2} = \frac{1}{T_1} - \frac{2k_B}{T} \times \ln 1.2$$

$$= \frac{1}{300} - \frac{2 \times 1.38 \times 10^{-23}}{0.683 \times 1.6 \times 10^{-19}}$$

$$\boxed{T_2 = 304.5 \text{ K}}$$ **Ans.**

11.7 DIELECTRICS, LASERS AND FIBRE OPTICS

1. Newton/coulomb is equivalent
   (*a*) volt (*b*) ampere/m
   (*c*) volt/metre (*d*) tesla.

2. The number of electrons equivalent to one coulomb of charge is
   (*a*) 1.6×10^{-19} (*b*) 6.24×10^{18}
   (*c*) 1.6×10^{19} (*d*) 7.2×10^{11}.
3. At optical frequencies, the dielectric constant is
   (*a*) linearly proportional to the refractive index
   (*b*) linearly proportional to the square of the refractive index
   (*c*) inversely proportional to the refractive index
   (*d*) inversely proportional to the square of the refractive index.
4. A particle of mass m and charge Q moves through a p.d. of V volt. The velocity acquired by it is
   (*a*) $\sqrt{\frac{m}{Q}}$ (*b*) $\sqrt{\frac{2QV}{m}}$
   (*c*) $\sqrt{\frac{m}{2QV}}$ (*d*) $\frac{2QV}{m}$.
5. The unit of dipole moment/unit volume is
   (*a*) coulomb/m^2 (*b*) coulomb/m^3
   (*c*) m^2/coulomb (*d*) ampere/m^3.
6. When a monoatomic gas atom is placed in a uniform electric field E, the displacement of the nucleus is proportional to
   (*a*) $\frac{1}{E}$ (*b*) E
   (*c*) independent of E (*d*) $\sqrt{E}$.
7. The capacitance of a parallel plate condenser does not depend on
   (*a*) area of the plates
   (*b*) nature of the metals of the plate

(*c*) medium between the plates

(*d*) distance between the plates.

8. A charged particle of mass M and charge Q is placed in an electric field E. The velocity of the charge at time t is

(*a*) $\dfrac{Q\,Et}{m}$ (*b*) $\dfrac{m}{QEt}$

(*c*) $\dfrac{Q\,Em}{t}$ (*d*) $\sqrt{\dfrac{m}{QEt}}$.

9. The electronic polarizability, at moderate temperature, is

(*a*) linearly depending on temperature

(*b*) independent of temperature

(*c*) inversely proportional to temperature

(*d*) inversely depending on square of temperature.

10. If some insulating material is filled between the plates of a parallel plate condenser, its capacity will

(*a*) decrease (*b*) be infinite

(*c*) gets zero value (*d*) increase.

11. The polarization P in a solid is related to the electric field E and the electric flux density D by the relation

(*a*) $E = \varepsilon_0 D + P$ (*b*) $D = E + \varepsilon_0 P$

(*c*) $D = E\varepsilon_0 + P$ (*d*) $D = \varepsilon_0 (E + P)$.

12. In a ferroelectric material, as the applied field is gradually reduced to zero, the polarization still left is known as

(*a*) remanent polarization

(*b*) coercive polarization

(*c*) zero polarization

(*d*) positive polarization.

13. Two conducting spheres of radii r_1 and r_2 are equally charged. The ratio of their potentials is

(*a*) $\left(\frac{r_1}{r_2}\right)^2$ (*b*) $\left(\frac{r_2}{r_1}\right)^2$

(*c*) $\left(\frac{r_1}{r_2}\right)^3$ (*d*) $\frac{r_2}{r_1}$.

14. The electronic polarizability α_e of a monoatomic gas atom is

(*a*) $4\pi\varepsilon_0$ (*b*) $4\pi\varepsilon_0 R$

(*c*) $4\pi\varepsilon_0 R^3$ (*d*) $4\pi\varepsilon_0 R^2$.

15. At frequencies around 5×10^{14} Hz, the ionic polarization is

(*a*) zero (*b*) unity

(*c*) infinity (*d*) negative.

16. Spontaneous emission

(*a*) is proportional to the number of atoms per unit volume of excited state

(*b*) is proportional to the number of atoms per unit volume of the ground state

(*c*) takes place when pumping is done

(*d*) results in photons of the same phase.

17. The rate of stimulated radiation

(*a*) does not depend on the number of atoms in excited state

(*b*) is responsible for producing population inversion

(*c*) depends on the number of atoms in the ground state

(*d*) depends on the intensity of external radiation.

18. The lasant

(*a*) in He–Ne laser is helium

(*b*) in ruby laser is Cr^{3+} ion

(*c*) in CO_2 laser is helium

(*d*) in CO_2 laser is nitrogen.

19. Electric discharge is the pumping mechanism in
(*a*) ruby laser
(*b*) semiconductor diode laser
(*c*) CO_2 laser
(*d*) Nd–YAG laser.

20. The unit of energy density of radiation is
(*a*) Jm^3/Hz (*b*) m^3 Hz/Js
(*c*) J/m^3 (*d*) JHz.

21. The unit of Einstein coefficient of stimulated absorption is
(*a*) J/m^3 Hz (*b*) J/m^3
(*c*) m^3J/s (*d*) m^3/Js.

22. Einstein coefficient of stimulated emission
(*a*) does not depend on energy density of incident radiation
(*b*) is inversely proportional to rate of stimulated emission
(*c*) is directly proportional to the number of atoms per unit volume in excited state
(*d*) depends on pair of energy levels involved.

23. Which of the following statements is correct?
(*a*) semiconductor diode laser is a three-level laser
(*b*) Nd-YAG is a four-level laser
(*c*) CO_2 laser is a three-level laser
(*d*) CO_2 laser is a two-level laser.

24. If n_0, n_1 and n_2 are refractive indices of air, core and cladding materials of optical fibre respectively, then the critical angle of core with respect to cladding is

(*a*) $\sin\left[\frac{n_1}{n_2}\right]$ (*b*) $\sin^{-1}\left[\frac{n_2}{n_1}\right]$

(*c*) $\sin^{-1}\left[\frac{n_2}{n_1}\right]$ (*d*) $\frac{n_1}{n_2}$.

25. Assume that light enters from air into an optical fibre and if n_0, n_1 and n_2 are the refractive indices of air, core and cladding materials of the optical fibre respectively, then

(*a*) $n_0 > n_1 > n_2$ (*b*) $n_0 < n_1 < n_2$

(*c*) $n_0 < n_1 > n_2$ (*d*) $n_0 < n_2 < n_1$.

26. Critical angle for a pair of media

(*a*) depends on wavelength of light used

(*b*) does not depend on second medium

(*c*) does not depend on first medium

(*d*) is a constant.

27. Addition of GeO_2 with silica

(*a*) increases the refractive index of silica

(*b*) decreases the refractive index of silica

(*c*) does not change the refractive index of silica

(*d*) is not permitted in optical fibres.

28. The velocity of electromagnetic waves in a medium of dielectric constant 4 is (velocity of light in air is 3×10^8 m/sec)

(*a*) 3×10^{16} m/s

(*b*) 0.75×10^9 m/s

(*c*) 1.5×10^8 m/s

(*d*) 2×10^{10} m/s.

ANSWERS TO OBJECTIVE QUESTIONS

1. (*c*)	2. (*b*)	3. (*b*)	4. (*b*)
5. (*a*)	6. (*b*)	7. (*b*)	8. (*a*)
9. (*b*)	10. (*d*)	11. (*c*)	12. (*a*)
13. (*d*)	14. (*c*)	15. (*a*)	16. (*a*)

17. (*d*)	18. (*b*)	19. (*c*)	20. (*c*)
21. (*d*)	22. (*d*)	23. (*b*)	24. (*b*)
25. (*c*)	26. (*a*)	27. (*a*)	28. (*c*).

PROBLEMS AND SOLUTIONS

1. *An electron starts from rest from a point on one conductor and reaches a second parallel conductor, with a velocity 10^7 m/s. Calculate the p.d. between the conductors.*

Solution:

When the electron moves from one conductor to the other, the kinetic energy $= \frac{1}{2} mv^2$. It is equal to the work done due to the p.d. between the conductors, $W = qV$

i.e., $\frac{1}{2} mv^2 = qV$

$$v = \sqrt{\frac{2qV}{m}}$$

or $$V = \sqrt{\frac{vm}{2q}} = \left(\frac{10^7 \times 9.1 \times 10^{-31}}{2 \times 1.6 \times 10^{-19}}\right)^{1/2}$$

i.e., $\boxed{V = 284.4 \text{ V}}$ **Ans.**

2. *A conductor has a negative charge of 8×10^{-17} coulomb. Determine the number of excess electrons in the conductor. Charge of the electron is 1.6×10^{-19} coulomb.*

Solution:

$$q = ne$$

i.e., $$n = \frac{q}{e} = \frac{8 \times 10^{-17}}{1.6 \times 10^{-19}} = \frac{800}{1.6} = 500$$

$\boxed{n = 500}$ **Ans.**

3. *If NaCl crystal is subjected to an electric field of 1000 volt/m and the resultant polarization is 4.3 × 10^−8^ c-m^2^, calculate the relative permittivity of NaCl.*

Solution:

$$P = \varepsilon_0(\varepsilon_r - 1)\, E$$

$$\varepsilon_r = 1 + \frac{P}{E\varepsilon_0}$$

$$= 1 + \frac{4.3 \times 10^{-8}}{1000 \times 8.85 \times 10^{-12}}$$

$$= 5.86$$

i.e., $\boxed{\varepsilon_r = 5.86}$ **Ans.**

4. *The number of atoms in a volume of one cubic metre of hydrogen gas is 9.8 × 10^26^. The radius of the hydrogen atom is 0.53 Å. Calculate the polarizability and relative permittivity.*

Solution:

$$\alpha_e = 4\pi\, \varepsilon_0 R^3$$

$$= 4\pi \times 8.8 \times 10^{-12} \times (0.53 \times 10^{-10})^3$$

$$= 1.66 \times 10^{-41} \text{ F m}^2$$

$$\varepsilon_r = 1 + \chi = 1 + \frac{P_e}{\varepsilon_0 E}$$

$$= 1 + \frac{N\alpha_e E}{\varepsilon_0 E} = 1 + \frac{N\alpha_e}{\varepsilon_0}$$

$$\varepsilon_r = 1 + \frac{N}{\varepsilon_0}(4\pi\varepsilon_0 R^3)$$

$$\varepsilon_r = 1 + 4\pi \times 9.8 \times 10^{26} \times (0.53 \times 10^{-10})^3$$

$\boxed{\varepsilon_r = 1.0018}$ **Ans.**

5. *If all the molecular dipoles in a 1 cm radius water drop are pointed in the same direction, calculate the intensity of*

polarization. Dipole moment of the water molecule is 6×10^{-30} c-m.

Solution:

$\frac{18}{1000}$ m^3 will contain 6×10^{26} water molecules

$\frac{4}{3} \times 10^{-6}$ m^3 will contain 1.4×10^{23} molecules

$$P = N\mu = 1.4 \times 10^{23} \times 6 \times 10^{-30}$$

$$P = 8.4 \times 10^{-10} \text{ c/m}^2$$

$$\boxed{P = 8.4 \times 10^{-10} \text{ c/m}^2}$$ **Ans.**

6. *A relative population of $\frac{1}{e}$ is often considered in two energy states at room temperature of 300 K. Determine the wavelength of the radiation emitted at that temperature.*

Solution:

We know that

$$\frac{N_2}{N_1} = e^{-[(E_2 - E_1)/k_B T]}$$

Given $$\frac{N_2}{N_1} = \frac{1}{e}$$

$$= \frac{1}{\exp[+(E_2 - E_1)/k_B T]}$$

So $$\frac{E_2 - E_1}{k_B T} = \ln\frac{1}{e} = 1$$

$$(E_2 - E_1) = k_B T = h\nu = \frac{hc}{\lambda}$$

$$\lambda = \frac{ch}{k_B T} = \frac{3 \times 10^8 \times 6.62 \times 10^{-34}}{1.38 \times 10^{-23} \times 300}$$

$$\lambda = 0.048 \times 10^{-3} \text{ m}$$

$$\boxed{\lambda = 48 \ \mu\text{m}}$$ **Ans.**

7. *The output of a laser has a pulse width of 30 m sec and average output power of 0.6 watt. If the wavelength of the laser light is 640 nm; (i) how much energy is deposited per pulse and (ii) how many photons does each pulse contain?*

Solution:

(*i*) Energy = Power × Time

$$= 0.6 \times 30 \times 10^{-3}$$

$$\boxed{= 0.018 \text{ J}} \quad \textbf{Ans.}$$

(*ii*) Number of photons in each pulse

$$= \frac{\text{Energy}}{h\nu} = \frac{\text{Energy} \times \lambda}{hc}$$

$$= \frac{0.018 \times 640 \times 10^{-9}}{6.62 \times 10^{-34} \times 3 \times 10^{8}}$$

$$\boxed{= 5.8 \times 10^{16}} \quad \textbf{Ans.}$$

8. *A laser has a power of 50 mW. It has an aperature of 5 × 10^{–3} m and wavelength 700 nm. A beam is focused with the lens of focal length 0.2 m. Calculate the area spread and intensity of the image.*

Solution:

Angular spread,

$$d\theta = \frac{\lambda}{d} = \frac{700 \times 10^{-9}}{5 \times 10^{-3}}$$

$$d\theta = 1.4 \times 10^{4} \quad \text{radian}$$

Area spread $= (d\theta \times f)^2$

$$= (1.4 \times 10^{-4} \times 0.2)^2$$

$$= 0.4 \times 10^{-8}$$

$$\boxed{A_{sp} = 0.48 \times 10^{-8} \text{ m}^2} \quad \textbf{Ans.}$$

9. *An optical fibre has a numerical aperature of 0.2 and a cladding of refractive index 1.55. Find the acceptance*

angle for the fibre in air and critical angle of core cladding interface.

Solution:

Numerical aperature N.A. = $n \sin \theta_0$

Here N.A. = 0.2, n = 1 (air)

$$\text{Acceptance angle } \theta = \sin^{-1}\left(\frac{0.2}{1}\right) = 11°30'$$

Also, $\quad \text{N.A.} = \sqrt{n_1^2 - n_2^2}$.

Here $\quad n_2 = 1.55$

$$0.2 = \sqrt{n_1^2 - 1.55^2}$$

$$n_1^2 = 0.04 + 1.55^2 = 2.44$$

$$n_1 = 1.563$$

If θ_c is the critical angle,

$$\sin \theta_c = \frac{n_2}{n_1} = \frac{1.55}{1.563}$$

$$\boxed{\theta_c = \sin^{-1}\left[\frac{1.55}{1.563}\right] = 82°36'} \quad \textbf{Ans.}$$

10. *Velocity of light in the core of a step index fibre is 2 × 10⁸ m/s, and critical angle at the case cladding surface is 80°. Find the numerical aperature and acceptance angle for the fibre in air. Velocity of high in vacuum is 3 × 10⁸ m/s.*

Solution:

Refractive index of case

$$= n_1 = \frac{c}{v} = \frac{3}{2}\left(\frac{10^8}{10^8}\right) = 1.5$$

If θ_c is the critical angle, $\sin \theta_c = \dfrac{n_2}{n_1}$

$$n_2 = n_1 \sin \theta_c = 1.5 \times \sin 80°$$

$$n_2 = 1.4772$$

$$\text{N.A.} = \sqrt{n_1^2 - n_2^2}$$

$$= \sqrt{1.5^2 - 1.4772^2} = 0.264$$

Acceptance angle,

$$\theta_0 = \sin^{-1}(\text{N.A.}) = \sin^{-1}[0.264]$$

i.e., $\boxed{\theta_0 = 15° \; 18'}$ **Ans.**

11. *A telephone transmission network works at 12 MHz. For each telephone, a band of 8 kHz is allowed. Calculate the number of connections that can be made.*

Solution:

Number of connections

$$= \frac{\text{Transmission frequency}}{\text{Bandwidth}}$$

$$\boxed{= \frac{12 \times 10^6}{8 \times 10^3} = 1500}$$ **Ans.**

12. *A microwave telephone operating a system is working of a central frequency of 10 GHz. If 10% of this is available as the bandwidth and 8 kHz is allotted for each phone, find the number telephone channels that can be simultaneously granted.*

Solution:

Available frequency bandwidth

$$= 10 \times 10^9 \times \frac{10}{100} = 10^9$$

Bandwidth for each telephone

$$= 8 \times 10^3 \text{ Hz}$$

Therefore number of channels

$$\boxed{= \frac{10^9}{8 \times 10^3} = 1.25 \times 10^5}$$ **Ans.**

A.1 SALIENT FEATURES OF SI UNITS

1. It is a coherent system of units, *i.e.*, product or quotient of any two base quantities results in a unit resultant quantity. For example, unit length divided by unit time gives unit velocity.
2. It is a rationalized system of units. It clearly distinguishes between the units of mass and weight (force) which are expressed in kilogram and newton respectively.
3. All the units of the system can be derived from the base and supplementary units.
4. The decimal relationship between units of same quantity makes it possible to express any small or large quantity as power of 10.
5. For any quantity there is one and only one SI unit. For example, joule is the unit of energy of all forms such as mechanical, heat, chemical, electrical and nuclear. However, kWh also continues as unit of electrical energy.

Advantages of SI units

1. Units of many different quantities are related through a series of simple and basic relationship.
2. Being an absolute system, it avoids the use of factor '*g*'. *i.e.*, acceleration due to gravity in several expressions in Science

and Technology which had been a nuisance in all numerical examples.

3. Being an absolute system, it ensures all the advantages of the rationalized MKSA system in the fields of electricity, magnetism, electrical engineering and electronics.
4. Joule is the sole unit of energy of all forms and watt is the sole unit of power; hence a lot of labour is saved in calculations.
5. It is coherent system of units and involves only decimal coefficient. Hence it is very convenient and a quick system for calculations.
6. In electricity, all the practical units like volt, ohm, ampere, henry, farad, coulomb, joule and watt are accepted in industries and laboratories all over the world for well over a century and have become absolute in their own right in SI system, without the need for any more practical units.

Disadvantages

1. The non SI time units 'minute' and hour will still continue to be used until the clocks and watches are all changed to kilo second and mega second.
2. SI units for energy, power and pressure (*i.e.,* joule, watt and pascal) too small to be expressed in many areas, and, therefore, in such cases, the larger units such mJ, kW, kPa will have to be used.

A.3 SOME GENERAL KNOWLEDGE QUESTIONS WITH ANSWERS

Q. 1. *Diamond is a good thermal conductor. But it is an excellent electrical insulator. Explain.*

Ans. Diamond crystal is a three-dimensional network of carbon atoms. All carbon atoms in the network are strongly bonded by – carbon covalent bonds. Therefore diamond crystal has a highly symmetric cubic structure. The carbon atoms in diamond are precisely aligned. Thus diamond is an ideal crystals. Atoms in the crystal lattices in solids vibrate. These vibrations, called the atomic vibrations facilitate thermal conduction (transport of heat) in solids. An ideal crystal, the lattices are so precisely aligned that they do not interact with each other.

Therefore an ideal crystal conducts better than a non-ideal crystal resulting in ideal crystal having good thermal conductivity, which is a measure of heat conduction. Diamond being an ideal crystal is thus a good thermal conductor.

Mobile electrons facilitate electrical conductor-flow of current in solids. There are no free mobile electrons in diamond crystal to facilitate electric conduction. Thus diamond is an excellent electrical insulator.

Q. 2. *For sprain you are advised to give hot water fomentation while for fracture pouring cold water in the affected area. Why?*

Ans. In the case of sprain, more blood must flow to the affected area to release the twisted muscle. Hot water fomentation will increase the temperature and decrease the pressure in that area. So blood from places of higher pressure will flow to this area.

In treating the fracture, we require less blood in the fractured area in order to go for a surgery or other treatment. Hence pouring cold water on the fractured area is preferred.

Q. 3. *Women having some kind of skin problems are advised not to wear violet/red sarees. Explain*

Ans. Violet rays (or ultraviolet rays) from the sun has high energy. Absorption of such radiation easily reacts with the thin skin and aggravates the skin problems or brings new problems to the skin. Red is heat radiation unlike green radiations with wavelength of the order of 5460 Å.

Q. 4. *Explain anomalous expansions of water.*

Ans. In majority of liquids, the increase in temperature produces an increase in volume of the liquids but water in a notable exception *i.e.,* the expansion of water is so markedly irregular that even ordinary laboratory methods can detect the anomaly. In the case of water, from 0°C to 4°C, instead of expanding, actually contracts, from 4°C upwards it expands, but far from uniformly. It is also noted the density curve with temperature is not uniform even beyond 4°C. The anomalous behaviour of water has been explained on the assumption that three types of water molecules, H_2O, $(H_2O)_2$ and $(H_2O)_3$ which have different specific volumes and are mixed in different proportions at different temperatures, so that the maximum density at 4°C is probably due to greater proportions of the higher types. The result is water at 4°C sinks to the bottom of a tank or lake during winter, while ice floats on the top. This prevents the freezing of a tank at the bottom and thus enables aquatic life to survive during the winter. See the beauty of Nature for a safe and better living of beings.

Q. 5. *Discuss the benefits of vegetarian food.*

Ans. The natural diet for human beings is vegetarian food. This is mainly based on the grounds of natural constitution, instinct, ethics, morality, ecology, health etc. Fresh fruits, vegetables, greens, grains, pulses and dry fruits can be easily obtained and kept under hygienic conditions by rich and poor and they generally do not carry diseases. They are easily digestible, economical, tasty, ethically good and supply all the nutrients if consumed in the proper proportion.

The emperor of the animal kingdom (elephant) is a vegetarian. It consumes large quantity leaves, coconuts and plantains, and then at least 10 litres of water two or three times in a day. Watery and fibre (extracted) content stool every time unlike that of lion. This vegetarian animal can be tamed easily for any heavy work.

Vegetarianism is our tradition. Structurally and functionally human system is meant for vegetarian food. Vegetarianism promotes peace and gives a feeling of mental purity. Vegetarianism sharpens the intellect, helps us to overcome passion and is especially for older people.

Q. 6. *Doctors advise to consume a cup of ice-cream just after the extraction of a tooth. Why?*

Ans. First clean the mouth with one or two cups of cold water. Then consume the ice-cream keeping it for few minutes in the mouth. Thus the temperature of the organs in the mouth will come down. Thus a high pressure exists mouth in the various parts of the mouth. This causes the blood to flow to the outside organs and hence bleeding stops. After 20 to 30 minutes normal flow starts.

Q. 7. *Write a note on transcendental meditation introducing scientific findings.*

Ans. A recent study on drugs reveals that for stress relief, a lot of drugs are coming to the market. Men and women consume these drugs trusting that they would be safe.

On the contrary, there is no such thing as a safe drug. Many drugs strain the functions of liver and kidney if swallowed and followed for longes period. A natural release can be secured through Transcendental Meditation (TM). You can very easily develops it as habit like the habit of taking pills. In fact, it would replace the latter habit. T.M. is not a form of prayer and works physiologically.

The natural and complete reduction of mental activity during TM seems to be the key to its effectiveness in triggering a state of deep rest coupled with heightened awareness. When one practises TM twice daily, it is of great interest to note that the beneficial psychological and physiological effect have been found to be increase as the practice is continued. TM has a double effect one is stress relief and the other, rendering clarity and creativity to one who practises it. What happens to the brain and mind during TM? They are correlated with the deep rest (inactivity) that is produced by this technique. TM produces a metabolic rate lower than the lowest rate established in deep sleep. The third law of thermodynamics in physics is analogous to the deep order to the brain and creative intelligence through rest. The condition of zero entropy coincides with absolute zero temperature. Similarly, disorderliness decreases when activity decreases. Perfect orderliness is obtain at absolute zero activity.

According to students reports, the academic work has not only become easier but also has become more enjoyable. Their experience and knowledge of science education becomes increasingly more rewarding and successful. A clear thinking is provided by TM. The very complex and integrated function of the brain called motivation, is enhanced by TM. This capacity is most certainly not available through any other known means.

Q. 8. *Quote one commonly known bio-molecule. Give some of its important properties.*

Ans. H_2O is a well known Bio molecule. H_2O is a polar molecule with bond angle 105° and a permanent dipole moment of 1.8 Debye unit. The dielectric constant of water is high (about 80); hence it is a good solvent. The density of water is maximum at 4°C. Pumbing 6×10^{25} molecules (2 litre) every day with prescribed intervals into your stomach will make the job of many vital organs of our body easier.

A.4 INTEGRAL TABLES

Some Important Differentials

1. $d(x + y - z) = dx + dy - dz$
2. $d\left(\frac{x}{y}\right) = \frac{ydx - xdy}{y^2}$
3. $d(xy) = xdy + ydx$
4. $d(x^n) = nx^{n-1}\, dx$
5. $d(x^y) = yx^{y-1}dx + x^y\,(\log_e x)\, dy$
6. $d(e^x) = e^x\, dx$
7. $d(e^{ax}) = ae^{ax}\, dx$
8. $d(a^x) = a^x\,(\log_e a)\, dx$
9. $d \sinh x = \cosh x dx$
10. $d \cosh x = \sinh x dx$
11. $d \tanh x = \text{sech}^2\, x dx$

Infinite Integrals

1. $\int (ax+b)^n\, dx = \frac{(ax+b)^{n+1}}{a(n+1)},\ n \neq -1$
2. $\int \frac{dx}{ax+b} = \frac{1}{a} \log (ax+b)$
3. $\int \frac{dx}{x(ax+b)} = \frac{1}{b} \log \frac{x}{ax+b}$
4. $\int \sqrt{(ax+b)}\, dx = \frac{2}{3a}\,(ax+b)^{3/2}$
5. $\int \frac{dx}{\sqrt{(ax+b)}}\, dx = \frac{2\sqrt{(ax+b)}}{a}$

EXPONENTIAL AND LOGARITHMIC INTEGRALS

1. $\int e^{ax}\, dx = \frac{1}{a} e^{ax}$

2. $\int b^{ax}\, dx = \frac{b^{ax}}{a \log b}$

3. $\int x^n e^{ax}\, dx = \frac{1}{a} x^n e^{ax} - \frac{n}{a} \int x^{n-1} e^{ax}\, dx$, n positive

4. $\int e^{ax} \sin bx\, dx = \frac{e^{ax}}{a^2 + b^2} (a \sin bx - b \cos bx)$

5. $\int \log ax\, dx = x \log ax - x$

6. $\int x^n \log ax\, dx = x^{n+1} \left[\frac{\log ax}{n+1} - \frac{1}{(n+1)^2} \right]$, $n \neq -1$

7. $\int \frac{dx}{x \log ax} = \log(\log ax)$

DEFINITE INTEGRALS

1. $\int_0^\infty \frac{a\,dx}{a^2 + x^2} = \frac{\pi}{2}$, if $a > 0$; 0, if $a = 0$; $-\frac{\pi}{2}$, if $a < 0$

2. $\int_0^\infty \frac{\sin^2 x}{x^2}\, dx = \frac{\pi}{2}$

3. $\int_0^\infty \frac{\sin^2 ax}{a}\, dx = \frac{\pi}{2}$, if $a > 0$

4. $\int_0^\pi \sin^2 ax\, dx = \int_0^\pi \cos^2 ax\, dx = \frac{\pi}{2}$

5. $\int_0^{\pi} \sin ax \cos bx \, dx$

$$= \frac{2a}{a^2 - b^2}, \quad \text{if } a - b \text{ is odd}$$
$$= 0 \qquad \text{if } a - b \text{ is even}$$

6. $\int_0^{\infty} \frac{\sin ax \sin bx}{x^2} \, dx = \frac{1}{2} \pi a$, if $a < b$

7. $\int_0^{\infty} \cos (x^2) \, dx = \int_0^{\infty} \sin(x^2) \, dx = \frac{1}{2} \sqrt{\frac{\pi}{2}}$

8. $\int_0^{\infty} e^{-a^2 x^2} \, dx = \sqrt{\frac{\pi}{2a}}$ if $a > 0$

9. $\int_0^{\infty} x^n e^{-ax} \, dx = \frac{n!}{a^{n+1}}$ if n is a positive integer

10. $\int x^{2n} e^{-ax^2} \, dx = \frac{1.3.5 \ldots (2n-1)}{2^{n+1} a^n} \sqrt{\frac{\pi}{a}}$

$$\int_0^{\infty} \sqrt{x} \, e^{-ax} \, dx = \frac{1}{2a} \sqrt{\frac{\pi}{a}}$$

11. $\int_0^{\infty} \frac{e^{-ax}}{\sqrt{x}} \, dx = \sqrt{\frac{\pi}{a}}$

12. $\int_0^{\infty} e^{(-x^2 - a^2)/x^2} \, dx = \frac{e^{-2a} \sqrt{\pi}}{2}$, if $a > 0$

13. $\int_0^{\infty} e^{-ax} \cos bx \, dx = \frac{a}{a^2 + b^2}$, if $a > 0$

14. $\int_0^{\infty} e^{-ax} \sin bx \, dx = \frac{a}{a^2 + b^2}$, if $a > 0$

15. $\int_0^{1} \frac{\log x}{1 - x} \, dx = -\frac{\pi^2}{6}$

16. $\int_0^{1} \frac{\log x}{1 + x} \, dx = -\frac{\pi^2}{12}$

17. $\int_0^1 \frac{\log x}{1-x^2}\, dx = -\frac{\pi^2}{8}$

18. $\int_0^1 \frac{\log x}{\sqrt{1-x^2}}\, dx = -\frac{\pi^2}{2} \log 2$

19. $\int_0^1 \log\left[\frac{1+x}{1-x}\right] \frac{dx}{x} = \frac{\pi^2}{4}$

20. $\int \log\left[\frac{e^x+1}{e^x-1}\right] dx = \frac{\pi^2}{4}$

21. $\int \frac{dx}{\log(1/x)} = \sqrt{\pi}$

22. $\int_0^{\pi} x \log \sin x\, dx = -\frac{\pi^2}{2} \log_e 2$

23. $\int_0^1 [\log(1/x)]^{1/2}\, dx = \frac{\sqrt{\pi}}{2}$.