NEET
SOLVED PAPER 2018

1. The volume \( V \) of a monoatomic gas varies with its temperature \( T \), as shown in the graph. The ratio of work done by the gas, to the heat absorbed by it, when it undergoes a change from state \( A \) to state \( B \), is

- (a) \( \frac{1}{3} \)
- (b) \( \frac{2}{3} \)
- (c) \( \frac{2}{5} \)
- (d) \( \frac{2}{7} \)

2. The fundamental frequency in an open organ pipe is equal to the third harmonic of a closed organ pipe. If the length of the closed organ pipe is 20 cm, the length of the open organ pipe is

- (a) 12.5 cm
- (b) 8 cm
- (c) 13.3 cm
- (d) 16 cm

3. At what temperature will the rms speed of oxygen molecules become just sufficient for escaping from the Earth’s atmosphere?

- Given: mass of oxygen molecule, \( m = 2.76 \times 10^{-28} \) kg,
- Boltzmann’s constant \( k_B = 1.38 \times 10^{-23} \) J K\(^{-1}\)

- (a) \( 5.016 \times 10^4 \) K
- (b) \( 8.326 \times 10^4 \) K
- (c) \( 2.508 \times 10^4 \) K
- (d) \( 1.254 \times 10^4 \) K

4. The efficiency of an ideal heat engine working between the freezing point and boiling point of water, is

- (a) 6.25%
- (b) 20%
- (c) 26.8%
- (d) 12.5%

5. A carbon resistor of \( (47 \pm 4.7) \) k\( \Omega \) is to be marked with rings of different colours for its identification. The colour code sequence will be

- (a) Yellow - Green - Violet - Gold
- (b) Yellow - Violet - Orange - Silver
- (c) Violet - Yellow - Orange - Silver
- (d) Green - Orange - Violet - Gold

6. A set of \( n \) equal resistors, of value ‘\( R \)’ each, are connected in series to a battery of emf ‘\( E \)’ and internal resistance ‘\( R \)’. The current drawn is \( I \). Now, the ‘\( n \)’ resistors are connected in parallel to the same battery. Then, the current drawn from battery becomes \( 10I \). The value of ‘\( n \)’ is

- (a) 20
- (b) 11
- (c) 10
- (d) 9

7. A battery consists of a variable number ‘\( n \)’ of identical cells (having internal resistance ‘\( r \)’ each) which are connected in series. The terminals of the battery are short-circuited and the current \( I \) is measured. Which of the graphs shows the correct relationship between \( I \) and \( n \)?
8. Unpolarised light is incident from air on a plane surface of a material of refractive index \( \mu \). At a particular angle of incidence \( \theta \), it is found that the reflected and refracted rays are perpendicular to each other. Which of the following options is correct for this situation?

(a) \( i = \sin^{-1}\left(\frac{1}{\mu}\right) \)

(b) Reflected light is polarised with its electric vector perpendicular to the plane of incidence

(c) Reflected light is polarised with its electric vector parallel to the plane of incidence

(d) \( i = \tan^{-1}\left(\frac{1}{\mu}\right) \)

9. In Young’s double slit experiment, the separation \( d \) between the slits is 2 mm, the wavelength \( \lambda \) of the light used is 5896 Å and distance \( D \) between the screen and slits is 100 cm. It is found that the angular width of the fringes is 0.20°. To increase the fringe angular width to 0.21° (with same \( \lambda \) and \( D \)) the separation between the slits needs to be changed to

(a) 2.1 mm

(b) 1.9 mm

(c) 1.8 mm

(d) 1.7 mm

10. An astronomical refracting telescope will have large angular magnification and high angular resolution, when it has an objective lens of

(a) large focal length and large diameter

(b) large focal length and small diameter

(c) small focal length and large diameter

(d) small focal length and small diameter

11. The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom, is

(a) 2 : −1

(b) 1 : −1

(c) 1 : 1

(d) 1 : −2

12. An electron of mass \( m \) with a velocity \( v = v_0 \hat{a} \) \((v_0 > 0)\) enters an electric field \( \mathbf{E} = -E_0 \hat{a} \) \((E_0 = \text{constant} > 0)\) at \( t = 0 \). If \( \lambda_0 \) is its de-Broglie wavelength initially, then its de-Broglie wavelength at time \( t \) is

(a) \( \lambda_0 \)

(b) \( \lambda_0 \left(1 + \frac{eE_0 t}{mv_0}\right) \)

(c) \( \lambda_0 \left(1 + \frac{eE_0 t}{mv_0}\right)^2 \)

(d) \( \lambda_0 \)

13. For a radioactive material, half-life is 10 minutes. If initially there are 600 number of nuclei, the time taken (in minutes) for the disintegration of 450 nuclei is

(a) 30

(b) 10

(c) 20

(d) 15

14. When the light of frequency \( 2\nu_0 \) (where, \( \nu_0 \) is threshold frequency), is incident on a metal plate, the maximum velocity of electrons emitted is \( v_1 \). When the frequency of the incident radiation is increased to \( 5\nu_0 \), the maximum velocity of electrons emitted from the same plate is \( v_2 \). The ratio of \( v_1 \) to \( v_2 \) is

(a) 4 : 1

(b) 1 : 4

(c) 1 : 2

(d) 2 : 1

15. In the circuit shown in the figure, the input voltage \( V_i \) is 20 V, \( V_{BE} = 0 \) and \( V_{CE} = 0 \). The values of \( I_B, I_C \) and \( \beta \) are given by

\[ R_B = 4 \, \text{k\Omega} \]

\[ V_i = 20 \, \text{V} \]

\[ 500 \, \text{k\Omega} \]

\[ R_C = 4 \, \text{k\Omega} \]

\[ 20 \, \text{V} \]

\[ C \]

\[ E \]

\[ B \]

\[ R_B \]

\[ I_B = 20 \mu A, I_C = 5 mA, \beta = 250 \]

\[ I_B = 25 \mu A, I_C = 5 mA, \beta = 200 \]

\[ I_B = 40 \mu A, I_C = 10 mA, \beta = 250 \]

\[ I_B = 40 \mu A, I_C = 5 mA, \beta = 125 \]

16. In a \( p-n \) junction diode, change in temperature due to heating

(a) does not affect resistance of \( p-n \) junction

(b) affects only forward resistance

(c) affects only reverse resistance

(d) affects the overall \( V-I \) characteristics of \( p-n \) junction
17. In the combination of the following gates the output $Y$ can be written in terms of inputs $A$ and $B$ as

(a) $\overline{A} \cdot \overline{B} + A \cdot B$
(b) $A \cdot \overline{B} + A \cdot B$
(c) $A \cdot B$
(d) $A + B$

18. An EM wave is propagating in a medium with a velocity $v = vi$. The instantaneous oscillating electric field of this EM wave is along $+y$-axis. Then, the direction of oscillating magnetic field of EM wave will be along

(a) $-y$-direction
(b) $+z$-direction
(c) $-z$-direction
(d) $-x$-direction

19. The refractive index of the material of a prism is $\sqrt{2}$ and the angle of the prism is $30^\circ$. One of the two refracting surfaces of the prism is made a mirror inwards, by silver coating. A beam of monochromatic light entering the prism from the other face will retrace its path (after reflection from the silvered surface) if its angle of incidence on the prism is

(a) $30^\circ$
(b) $45^\circ$
(c) $60^\circ$
(d) zero

20. An object is placed at a distance of 40 cm from a concave mirror of focal length 15 cm. If the object is displaced through a distance of 20 cm towards the mirror, the displacement of the image will be

(a) 30 cm towards the mirror
(b) 36 cm away from the mirror
(c) 30 cm away from the mirror
(d) 36 cm towards the mirror

21. The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance

(a) 1.389 H
(b) 138.88 H
(c) 0.138 H
(d) 13.89 H

22. An electron falls from rest through a vertical distance $h$ in a uniform and vertically upward directed electric field $E$. The direction of electric field is now reversed, keeping its magnitude the same. A proton is allowed to fall from rest in it through the same vertical distance $h$. The time of fall of the electron, in comparison to the time of fall of the proton is

(a) 10 times greater
(b) 5 times greater
(c) smaller
(d) equal

23. The electrostatic force between the metal plates of an isolated parallel plate capacitor $C$ having a charge $Q$ and area $A$, is

(a) proportional to the square root of the distance between the plates
(b) linearly proportional to the distance between the plates
(c) independent of the distance between the plates
(d) inversely proportional to the distance between the plates

24. A tuning fork is used to produce resonance in a glass tube. The length of the air column in this tube can be adjusted by a variable piston. At room temperature of $27^\circ C$, two successive resonances are produced at 20 cm and 73 cm of column length. If the frequency of the tuning fork is 320 Hz, the velocity of sound in air at $27^\circ C$ is

(a) 350 m/s
(b) 339 m/s
(c) 330 m/s
(d) 300 m/s

25. A pendulum is hung from the roof of a sufficiently high building and is moving freely to and fro like a simple harmonic oscillator. The acceleration of the bob of the pendulum is $20 m/s^2$ at a distance of 5 m from the mean position. The time period of oscillation is

(a) 2 s
(b) $\pi$ s
(c) $2\pi$ s
(d) 1 s

26. A metallic rod of mass per unit length 0.5 kg m$^{-1}$ is lying horizontally on a smooth inclined plane which makes an angle of $30^\circ$ with the horizontal. The rod is not allowed to slide down by flowing a current through it when a magnetic field of induction 0.25 T is acting on it in the vertical direction. The current flowing in the rod to keep it stationary is

(a) 14.76 A
(b) 5.98 A
(c) 7.14 A
(d) 11.32 A
27. A thin diamagnetic rod is placed vertically between the poles of an electromagnet. When the current in the electromagnet is switched on, then the diamagnetic rod is pushed up, out of the horizontal magnetic field. Hence, the rod gains gravitational potential energy. The work required to do this comes from (a) the lattice structure of the material of the rod (b) the magnetic field (c) the current source (d) the induced electric field due to the changing magnetic field.

28. An inductor 20 mH, a capacitor 100 µF and a resistor 50 Ω are connected in series across a source of emf, \( V = 10 \sin 314 t \). The power loss in the circuit is (a) 2.74 W (b) 0.43 W (c) 0.79 W (d) 1.13 W.

29. Current sensitivity of a moving coil galvanometer is 5 div/mA and its voltage sensitivity (angular deflection per unit voltage applied) is 20 div/V. The resistance of the galvanometer is (a) 250 Ω (b) 25 Ω (c) 40 Ω (d) 500 Ω.

30. A body initially at rest and sliding along a frictionless track from a height \( h \) (as shown in the figure) just completes a vertical circle of diameter \( AB = D \). The height \( h \) is equal to (a) \( \frac{7}{5} D \) (b) \( D \) (c) \( \frac{3}{2} D \) (d) \( \frac{5}{4} D \).

31. Three objects, \( A \) (a solid sphere), \( B \) (a thin circular disk) and \( C \) (a circular ring), each have the same mass \( M \) and radius \( R \). They all spin with the same angular speed \( \omega \) about their own symmetry axes. The amounts of work (W) required to bring them to rest, would satisfy the relation (a) \( W_A > W_B > W_C \) (b) \( W_A > W_B > W_C \) (c) \( W_C > W_B > W_A \) (d) \( W_A > W_C > W_B \).

32. A moving block having mass \( m \), collides with another stationary block having mass \( 4m \). The lighter block comes to rest after collision. When the initial velocity of the lighter block is \( v \), then the value of coefficient of restitution \( e \) will be (a) 0.8 (b) 0.25 (c) 0.5 (d) 0.4.

33. Which one of the following statements is incorrect? (a) Frictional force opposes the relative motion (b) Limiting value of static friction is directly proportional to normal reaction (c) Rolling friction is smaller than sliding friction (d) Coefficient of sliding friction has dimensions of length.

34. A toy car with charge \( q \) moves on a frictionless horizontal plane surface under the influence of a uniform electric field \( E \). Due to the force \( qE \), its velocity increases from 0 to 6 m/s in one second duration. At that instant, the direction of the field is reversed. The car continues to move for two more seconds under the influence of this field. The average velocity and the average speed of the toy car between 0 to 3 seconds are respectively (a) 1 m/s, 3.5 m/s (b) 1 m/s, 3 m/s (c) 2 m/s, 4 m/s (d) 1.5 m/s, 3 m/s.

35. A block of mass \( m \) is placed on a smooth inclined wedge \( ABC \) of inclination \( \theta \) as shown in the figure. The wedge is given an acceleration \( a \) towards the right. The relation between \( a \) and \( \theta \) for the block to remain stationary on the wedge is (a) \( a = g \cos \theta \) (b) \( a = \frac{g}{\sin \theta} \) (c) \( a = \frac{g}{\cos \theta} \) (d) \( a = g \tan \theta \).

36. The moment of the force, \( \mathbf{F} = 4\mathbf{i} + 5\mathbf{j} - 6\mathbf{k} \) at \( (2, 0, -3) \), about the point \( (2, -2, -2) \), is given by (a) \( -7\mathbf{i} - 8\mathbf{j} - 4\mathbf{k} \) (b) \( -4\mathbf{i} - \mathbf{j} - 8\mathbf{k} \) (c) \( -8\mathbf{i} - 4\mathbf{j} - 7\mathbf{k} \) (d) \( -7\mathbf{i} - 4\mathbf{j} - 8\mathbf{k} \).
37. A student measured the diameter of a small steel ball using a screw gauge of least count 0.001 cm. The main scale reading is 5 mm and zero of circular scale division coincides with 25 divisions above the reference level. If screw gauge has a zero error of −0.004 cm, the correct diameter of the ball is
(a) 0.053 cm   (b) 0.525 cm
(c) 0.521 cm   (d) 0.529 cm

38. A solid sphere is rotating freely about its symmetry axis in free space. The radius of the sphere is increased keeping its mass same. Which of the following physical quantities would remain constant for the sphere?
(a) Rotational kinetic energy
(b) Moment of inertia
(c) Angular velocity
(d) Angular momentum

39. The kinetic energies of a planet in an elliptical orbit about the Sun, at positions A, B and C are \( K_A, K_B \) and \( K_C \), respectively. \( AC \) is the major axis and \( SB \) is perpendicular to \( AC \) at the position of the Sun \( S \) as shown in the figure. Then
(a) \( K_B < K_A < K_C \)  
(b) \( K_A > K_B > K_C \)
(c) \( K_A < K_B < K_C \)  
(d) \( K_B > K_A > K_C \)

40. If the mass of the Sun were ten times smaller and the universal gravitational constant were ten times larger in magnitude, which of the following is not correct?
(a) Time period of a simple pendulum on the Earth would decrease
(b) Walking on the ground would become more difficult
(c) Raindrops will fall faster
(d) ‘g’ on the Earth will not change

41. A solid sphere is in rolling motion. In rolling motion, a body possesses translational kinetic energy \( (K_t) \) as well as rotational kinetic energy \( (K_r) \) simultaneously. The ratio \( K_t : (K_t + K_r) \) for the sphere is
(a) 10 : 7  
(b) 5 : 7  
(c) 7 : 10  
(d) 2 : 5

42. A small sphere of radius \( r \) falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity, is proportional to
(a) \( r^5 \)  
(b) \( r^2 \)  
(c) \( r^3 \)  
(d) \( r^4 \)

43. The power radiated by a black body is \( P \) and it radiates maximum energy at wavelength, \( \lambda_o \). If the temperature of the black body is now changed, so that it radiates maximum energy at wavelength \( \frac{3}{4} \lambda_o \), the power radiated by it becomes \( nP \). The value of \( n \) is
(a) \( \frac{256}{81} \)  
(b) \( \frac{4}{3} \)  
(c) \( \frac{3}{4} \)  
(d) \( \frac{81}{256} \)

44. Two wires are made of the same material and have the same volume. The first wire has cross-sectional area \( A \) and the second wire has cross-sectional area \( 3A \). If the length of the first wire is increased by \( \Delta \) on applying a force \( F \), how much force is needed to stretch the second wire by the same amount?
(a) \( 4F \)  
(b) \( 6F \)  
(c) \( 9F \)  
(d) \( F \)

45. A sample of 0.1 g of water at 100°C and normal pressure \( (1.013 \times 10^5 \text{ Nm}^{-2}) \) requires 54 cal of heat energy to convert to steam at 100°C. If the volume of the steam produced is 167.1 cc, the change in internal energy of the sample, is
(a) 42.2 J  
(b) 208.7 J  
(c) 104.3 J  
(d) 84.5 J

Answers

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1. (c) According to the given graph, 
Volume ($V$) $\propto$ Temperature ($T$) 
or $\frac{V}{T}$ = constant  
Thus, the process is isobaric.

\[ L = \frac{2}{3} L' \]

Given, 
\[ L' = 20 \text{ cm} \]
\[ \Rightarrow L = \frac{2}{3} \times 20 \text{ cm} = \frac{40}{3} \text{ cm} = 13.3 \text{ cm} \]

3. (b) Key Concept The minimum velocity with which the body must be projected vertically upwards, so that it could escape from the Earth’s atmosphere, is its escape velocity ($v_e$).

\[ v_e = \sqrt{\frac{2gR}{T}} \]

Substituting the value of \( g \) (9.8 m s\(^{-2}\)) and radius of Earth \((R = 6.4 \times 10^6 \text{ m})\), we get
\[ v_e = \sqrt{2 \times 9.8 \times 6.4 \times 10^6} \approx 11.2 \text{ km s}^{-1} = 11200 \text{ m s}^{-1} \]

Let the temperature of molecule be $T$ when it attains $v_e$.

According to the question,
\[ v_{rms} = v_e \]
where, $v_{rms}$ is the rms speed of the oxygen molecule.
\[ \Rightarrow \frac{3k_B}{m_{O_2}} = 11.2 \times 10^3 \]

or
\[ T = \frac{(11.2 \times 10^3)^2 (m_{O_2})}{(3k_B)} \]

Substituting the given values, i.e.,
\[ R_g = 1.38 \times 10^{-23} \text{ JK}^{-1} \text{ mol}^{-1} \] and
\[ m_{O_2} = 2.76 \times 10^{-26} \text{ kg} \]

We get,
\[ T = \frac{(11.2 \times 10^3)^2 (2.76 \times 10^{-26})}{(3 \times 1.38 \times 10^{-23})} = 8.3626 \times 10^4 \text{ K} \]

4. (c) Efficiency of an ideal heat engine is given as
\[ \eta = 1 - \frac{T_s}{T_i} \]
where, $T_i$ is the temperature of the source and $T_s$ is the temperature of the sink.

Here,
\[ T_i = 100 + 273 = 373 \text{ K} \]
\[ T_s = 0 + 273 = 273 \text{ K} \]
\[ \Rightarrow \eta = 1 - \frac{273}{373} = \frac{373 - 273}{373} = \frac{100}{373} = 0.268 \]
\[ \therefore \eta \% = 0.268 \times 100 = 26.8 \% \]
5. (b) Given, \( R = (47 \pm 4.7) \text{k}\Omega \)
\[ = 47 \times 10^3 \pm 10\% \Omega \]
As per the colour code for carbon resistors, the colour assigned to numbers.
4 – Yellow
7 – Violet
3 – Orange
For \( \pm 10\% \) accuracy, the colour is silver. Hence, the bands of colours on carbon resistor in sequence are yellow, violet, orange and silver.

**Note** To remember the colour code sequence for carbon resistor, the following sentence should be kept in memory. B B Roy of Great Britain has a Very Good Wife.

6. (c) When \( n \) equal resistors of resistance \( R \) are connected in series, then the current drawn is given as
\[ I = \frac{E}{nR + r} \]
where,
\( nR = \text{equivalent resistance of } n \text{ resistors in series} \)
and \( r = \text{internal resistance of battery} \).
Given, \( r = R \)
\[ \Rightarrow \quad I = \frac{E}{nR + R} = \frac{E}{R(n + 1)} \quad \ldots \text{(i)} \]
Similarly, when \( n \) equal resistors are connected in parallel, then the current drawn is given as
\[ I' = \frac{E}{nR + r} \]
where, \( \frac{R}{n} = \text{equivalent resistance of } n \text{ resistors in parallel} \).
Given, \( I' = 10I \)
\[ \Rightarrow \quad 10I = \frac{E}{\frac{R}{n} + R} = \frac{nE}{R(n + 1)} \quad \ldots \text{(ii)} \]
Substituting the value of \( I \) from Eq. (i) in Eq. (ii), we get
\[ 10\left( \frac{E}{R(n + 1)} \right) = \frac{nE}{R(n + 1)} \]
\[ \Rightarrow \quad n = 10 \]

7. (c) If \( n \) identical cells are connected in series, then Equivalent emf of the combination,
\[ E_{\text{eq}} = nE \]
Equivalent internal resistance,
\[ r_{\text{eq}} = nr \]
\[ \because \] Current,
\[ I = \frac{E_{\text{eq}}}{r_{\text{eq}}} = \frac{nE}{nr} \]

8. (b) The figure shown below represents the course of path an unpolarised light follows when it is incident from air on plane surface of material of refractive index \( \mu \).

When the beam of unpolarised light is reflected from a medium (refractive index \( = \mu \)) and if reflected and refracted light are perpendicular to each other. Then, the reflected light is completely plane polarised at a certain angle of incidence. This means, the reflected light has electric vector perpendicular to incidence plane.

9. (b) In a YDSE, angular width of a fringe is given as
\[ \theta = \frac{\lambda}{d} \]
where, \( \lambda \) is the wavelength of the light source and \( d \) is the distance between the two slits.
\[ \Rightarrow \quad \theta = \frac{1}{d} \]
or
\[ \frac{\theta_1}{\theta_2} = \frac{d_2}{d_1} \quad \ldots \text{(i)} \]
Here, \( \theta_1 = 0.20^\circ \), \( \theta_2 = 0.21^\circ \),
\[ d_2 = 2 \text{ mm} \]
Substituting the given values in Eq. (i), we get
\[ d_2 = 2 \times \frac{0.20}{0.21} = 0.40 \]
\[ \therefore d_2 = 1.90 \text{ mm} \]

10. (c) Angular magnification of an astronomical refracting telescope is given as
\[ M = \frac{\text{f}_0}{\text{f}_e} \]
where, \( \text{f}_0 \) and \( \text{f}_e \) are the focal length of objective and eye-piece, respectively.
From the given relation, it is clear that for large magnification either \( \text{f}_0 \) has to be large or \( \text{f}_e \) has to be small.
Angular resolution of an astronomical refracting telescope is given as
\[ R = \frac{a}{1.22\lambda} \]
where, \( a \) is the diameter of the objective.
Thus, to have large resolution, the diameter of the objective should be large.
Hence, from the above objective lens should have large focal length \( (\text{f}_0) \) and large diameter \( (a) \).

11. (b) Kinetic energy of an electron in a Bohr orbit of a hydrogen atom is given as
\[ \text{KE}_n = \frac{\text{Rhc}}{n^2} \quad \ldots (i) \]
Total energy of an electron in a Bohr orbit of a hydrogen atom is given as
\[ \text{TE}_n = -\frac{\text{Rhc}}{n^2} \quad \ldots (ii) \]
Dividing Eq. (i) by Eq. (ii), we get
\[ \frac{\text{KE}_n}{\text{TE}_n} = \left( \frac{\text{Rhc}}{\text{Rhc}} \right) \]
\[ \therefore \text{KE}_n: \text{TE}_n = 1: -1 \]

12. (c) According to the question,
\[ \mathbf{v} = v_0 \hat{i}, \quad \mathbf{E} = -E_0 \hat{i} \]
Thus, magnitude of force on the electron due to the electric field, \( |\mathbf{F}| = q| \mathbf{E}| \)
\[ \therefore \mathbf{F} = eE_0 \]
From Newton’s second law of motion,
\[ F = ma \]
\[ \therefore \quad \mathbf{F} = ma = eE_0 \]
\[ \Rightarrow \quad a = \frac{eE_0}{m} \quad \ldots (i) \]
or\[ a = (-e)(-E_0 \hat{i}) = \frac{eE_0 \hat{i}}{m} \]
From first equation of motion,
\[ v = u + at \]
Here, \( u \) (initial velocity) = \( v_0 \)
\[ \Rightarrow \quad v = v_0 + \frac{eE_0 \hat{i}}{m} t \quad \ldots (ii) \]
(from Eq. (i))
Initial de-Broglie wavelength of the electron is given as
\[ \lambda_0 = \frac{h}{mv} \Rightarrow h = \lambda_0 mv_0 \quad \ldots (iii) \]
After time \( t \), de-Broglie wavelength is given as
\[ \lambda = \frac{h}{mv} \]
Substituting the value of \( v \) from Eq. (ii), we get
\[ \lambda = \frac{\left( v_0 + \frac{eE_0 \hat{i}}{m} t \right)}{mv} = \frac{h}{mv} \left[ 1 + \frac{eE_0 \hat{i} t}{mv_0} \right] \]
\[ \Rightarrow \quad \lambda = \frac{\lambda_0}{1 + \frac{eE_0 \hat{i} t}{mv_0}} \]
13. (c) Key Concept After \( n \) half-life, the number of nuclei left undecayed is given as
\[ N = N_0 \left( \frac{1}{2} \right)^n \]
where, \( n = \frac{t}{t_{1/2}} \)
Here, initially number of nuclei, \( N_0 = 600 \)
After disintegration, number of nuclei, \( N’ = 450 \)
15. (d) Given, \( V_{BE} = 0 \) V, \( V_{CE} = 0 \) V and \( V_i = 20 \) V

Applying Kirchhoff’s law to the base-emitter loop, we get

\[ V_i = I_B R_B + V_{BE} \]

Substituting the values, we get

\[ 20 = I_B \times (500 \times 10^3) + 0 \]

\[ \Rightarrow \quad I_B = \frac{20}{500 \times 10^3} = 0.04 \times 10^{-3} \]

\[ = 40 \times 10^{-6} = 40 \mu A \] \( \cdots (i) \)

Similarly, \( V_{CC} = I_C R_C + V_{CE} \)

Substituting the given values, we get

\[ 20 = I_C \times (4 \times 10^3) + 0 \]

\[ \Rightarrow \quad I_C = \frac{20}{4 \times 10^3} = 5 \times 10^{-3} = 5 mA \] \( \cdots (ii) \)

Current gain is given as

\[ \beta = \frac{I_C}{I_B} \]

Substituting the value of \( I_B \) and \( I_C \) from Eqs. (i) and (ii), we get

\[ \Rightarrow \quad \beta = \frac{5 \times 10^{-3}}{40 \times 10^{-6}} = 0.125 \times 10^3 \]

\[ = 125 \]

16. (d) Due to increase in temperature because of heating, thermal collision between the electron and holes increases. Thus, net electron-hole pairs increase.

This leads to increase in the current in diode and overall resistance of the diode changes.

This in turn changes both the forward biasing and the reverse biasing.

Thus, the overall I-V characteristics of p-n junction diode gets affected.
17. (b) According to the question, the figure of combination of gates in terms of inputs and outputs can be given as

Thus,

\[ Y = A \cdot \vec{B} + \vec{A} \cdot \vec{B} \]

18. (b) Here, velocity of EM wave, \( v = \frac{v}{c} \)

Instantaneous oscillating electric field,

\[ E = \vec{E}_j \]

As we already know that, during the propagation of EM waves through a medium oscillating electric and magnetic field vectors are mutually perpendicular to each other and to the direction of propagation of each other and to the direction of propagation of the wave (\( \vec{E} \times \vec{B} \)),

i.e.

\[ \vec{E} \times \vec{B} = v \]

\[ (\vec{E}_j) \times \vec{B} = \vec{v} \]

As we know that from vector algebra,

\[ \vec{j} \times \vec{k} = \vec{i} \]

Comparing Eqs. (i) and (ii), we get

\[ \vec{B} = B \vec{k}, \]

where \( B \) (say) be the magnitude of magnetic field.

Thus, we can say that the direction of oscillating magnetic field of the EM wave will be along \( +z \) direction.

19. (b) According to the question, the figure of mentioned prism is given as

(since, there is no refraction at the face AC)

Given,

RefRACTIVE Index of the material of prism, \( \mu = \sqrt{2} \)

Angle of prism, \( A = 30^\circ \)

If the ray \( OR \) has to retrace its path after reflection (as per the given condition), then the ray has to fall normally on the surface \( AC \).

This means

\[ \angle ARO = \angle ORC = 90^\circ \]

In \( \triangle AOR \),

\[ \angle AOR + \angle ARO + \angle OAR = 180^\circ \]

\[ \Rightarrow \angle AOR + 90^\circ + 30^\circ = 180^\circ \]

\[ \Rightarrow \angle AOR = 180^\circ - 120^\circ = 60^\circ \] \( \ldots \)(i)

As we know,

\[ \angle AOR + \angle r_1 = 90^\circ \]

\[ \Rightarrow \angle r_1 = 90^\circ - 60^\circ = 30^\circ \] \( \text{[from Eq. (i)]} \)

Applying Snell’s law at the face \( AB \), we get

\[ \mu = \frac{\sin i}{\sin r_1} \]

Substituting the given values, we get

\[ \sqrt{2} = \frac{\sin i}{\sin 30^\circ} \]

\[ \Rightarrow \sin i = \sin 30^\circ \times \sqrt{2} \]

\[ = \frac{1}{2} \times \sqrt{2} \]

\[ = \frac{1}{\sqrt{2}} \]

or

\[ i = \sin^{-1} \left( \frac{1}{\sqrt{2}} \right) \]

\[ = 45^\circ \]

The angle of incidence of the ray on the prism is \( 45^\circ \).

20. (b) **Key Concept** The net displacement of the images is equal to the difference between the image distance in both the cases.

**Case 1** When the object distance, \( u_1 = -40 \text{ cm} \)

Focal length of mirror, \( f = -15 \text{ cm} \)

Using the mirror formula, we get

\[ \frac{1}{f} = \frac{1}{v_1} + \frac{1}{u_1} \]

Substituting the given values, we get

\[ -\frac{1}{15} = \frac{1}{v_1} + \frac{1}{-40} \]

\[ \Rightarrow \frac{1}{v_1} = \frac{1}{40} - \frac{1}{15} = \frac{3 - 8}{120} = -\frac{5}{120} \]

\[ \Rightarrow \quad v_1 = \frac{120}{5} = -24 \text{ cm} \]
Case 2 When the object distance, $u_2 = 20$ cm

Using the mirror formula, we get

$$\frac{1}{f} = \frac{1}{v_2} + \frac{1}{u_2}$$

Substituting the given values, we get

$$\frac{1}{15} = \frac{1}{v_2} + \left(\frac{1}{20}\right)$$

$$\Rightarrow \frac{1}{v_2} = \frac{1}{20} - \frac{1}{15} = \frac{3 - 4}{60} = \frac{-1}{60}$$

$$\Rightarrow v_2 = -60 \text{ cm}$$

:. The displacement of the image is

$$v = v_2 - v_1$$

$$= -60 - (-24) = -60 + 24$$

or

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

$$= 36 \text{ cm}, \text{ away from the mirror}$$

21. (d) Given, magnetic potential energy stored in an inductor,

$$U = 25 \text{ mJ} = 25 \times 10^{-3} \text{ J}$$

Current in an inductor, $I_0 = 60 \text{ mA} = 60 \times 10^{-3} \text{ A}$

As, the expression for energy stored in an inductor is given as

$$U = \frac{1}{2} LI_0^2$$

where, $L$ is the inductance of the inductor.

Substituting the given values in above equation., we get

$$(25 \times 10^{-3}) = \frac{1}{2} \times L \times (60 \times 10^{-3})^2$$

$$\Rightarrow L = 2 \times 25 \times 10^{-3} \times 500$$

$$= 3600 \times 10^{-6}$$

or

$$L = 13.89 \text{ H}$$

22. (c) Force on a charged particle in the presence of an electric field is given as

$$F = qE$$  \hspace{1cm} ...(i)$$

where, $q$ is the charge on the charged particle and $E$ is the electric field.

From Newton’s second law of motion, force on a particle with mass $m$ is given as

$$F = ma$$  \hspace{1cm} ...(ii)$$

where, $a$ is the acceleration.

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From Eqs. (i) and (ii), we get

$$F = ma = qE$$

$$\Rightarrow a = \frac{qE}{m} \hspace{1cm} ...(iii)$$

Now, consider that a particle falls from rest through a vertical distance $h$. Therefore, $u = 0$ and the second equation of motion becomes

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

or

$$h = 0 \times t + \frac{1}{2}at^2$$

$$= \frac{1}{2} \times \frac{qE}{m}t^2 \hspace{1cm} \text{[from Eq. (iii)]}$$

$$\Rightarrow t^2 = \frac{2hm}{qE}$$

or

$$t = \sqrt{\frac{2hm}{qE}}$$

Since, the particles given in the question is electron and proton; and the quantity $\frac{q_e}{q_p} = \frac{e}{e}$ (here, $q_e = q_p = e$) for both of them is constant. Thus, we can write

$$t = k \sqrt{m}$$

where,

$$k = \frac{\sqrt{q_e}}{q_p}$$

or

$$t \propto \sqrt{m}$$

As, mass of proton $(m_p) >>$ mass of electron $(m_e)$.

Thus, the time of fall of an electrons would be smaller than the time of fall of a protons.

23. (c) As we know that, the total work done in transferring a charge to a parallel plate capacitor is given as

$$W = \frac{Q^2}{2C} \hspace{1cm} ...(i)$$

where, $C$ is the capacitance of the capacitor.

We can also write a relation for work done as,

$$W = F \cdot d \hspace{1cm} ...(ii)$$

where, $F$ is the electrostatic force between the plates of capacitor and $d$ is the distance between the plates.

From Eqs. (i) and (ii), we get

$$W = \frac{Q^2}{2C} = Fd$$

$$\Rightarrow F = \frac{Q^2}{2Cd} \hspace{1cm} ...(iii)$$
As, the capacitance of a parallel plate is given as 
\[ C = \frac{\varepsilon_0 A}{d} \]
Substituting the value of \( C \) in Eq. (iii), we get
\[ F = \frac{Q d}{2\varepsilon_0 A} = \frac{Q^2}{2\varepsilon_0 A} \]
This means, electrostatic force is independent of the distance between the plates.

24. (b) For first resonance, \( l_1 = \frac{\lambda}{4} \)
For second resonance, \( l_2 = \frac{3\lambda}{4} \)
\[ \therefore (l_2 - l_1) = \frac{3\lambda}{4} - \frac{\lambda}{4} \]
or \[ \lambda = 2(l_2 - l_1) \quad \ldots \text{(i)} \]
As, velocity of sound wave is given as,
\[ v = v_\lambda \]
where, \( v \) is the frequency.
\[ \Rightarrow v = v[2(l_2 - l_1)] \quad \text{[from Eq. (i)]} \]
Here, \( v = 320 \text{ Hz}, \ l_2 = 0.73 \text{ m}, \ l_1 = 0.20 \text{ m} \)
\[ \Rightarrow v = 2\times (0.73 - 0.20) \]
\[ = 2\times 0.53 \text{ m/s} \]
\[ = 339.2 \text{ m/s} \]

25. (b) The acceleration of particle/body executing SHM at any instant (at position \( x \)) is given as
\[ a = -\omega^2 x \]
where, \( \omega \) is the angular frequency of the body.
\[ \Rightarrow |a| = \omega^2 |x| \quad \ldots \text{(i)} \]
Here, \( x = 5 \text{ m}, \ |a| = 20 \text{ m/s}^2 \)
Substituting the given values in Eq. (i), we get
\[ 20 = \omega^2 \times 5 \]
\[ \Rightarrow \omega^2 = \frac{20}{5} = 4 \]
or \[ \omega = 2 \text{ rad/s} \]
As, we know that
\[ \text{Time period,} \quad T = \frac{2\pi}{\omega} \quad \ldots \text{(ii)} \]
\[ \therefore \text{Substituting the value of} \ \omega \ \text{in Eq. (ii), we get} \]
\[ T = \frac{2\pi}{2} = \pi \text{ s} \]

26. (d) **Key Concept** Firstly, make a free body diagram of the system and indicate the magnitude and direction of all the forces acting on the body. Then, choose any two mutually perpendicular axes say \( X \) and \( Y \) in the plane of forces in case of coplanar forces.

As, the system is in equilibrium,
\[ \Sigma F_x = 0 \]
or \[ mg \sin \theta = F \cos \theta \quad \ldots \text{(i)} \]
where, \( F \) is the magnitude of force experienced by the rod when placed in a magnetic field and current \( I \) is flowing through it.
But the force experienced by the given rod in a uniform magnetic field is
\[ F = ILB \]
\[ \therefore \text{Eq. (i) becomes,} \]
\[ mg \sin \theta = ILB \cos \theta \]
\[ \Rightarrow \]
\[ I = \frac{mg \sin \theta}{LB} = \frac{mg}{LB} \tan \theta \]
\[ I = \left( \frac{m}{L} \right) \frac{g \tan \theta}{B} \]
\[ \ldots \text{(ii)} \]
According to the question,
\[ \frac{m}{L} = 0.5 \text{ kg/m}, \ g = 9.8 \text{ m/s}^2, \ \theta = 30^\circ, \]
\[ B = 0.25 \text{ T} \]
Substituting the given values in Eq. (ii), we get
\[ I = \frac{0.5 \times 9.8}{0.25} \times \tan 30^\circ \]
\[ = 0.5 \times 9.8 \times \frac{1}{\sqrt{3}} \]
\[ = 11.32 \text{ A} \]

27. (c) As the source of current is switched on, a magnetic field sets up in between the poles of the electromagnet.
As we know that a diamagnetic substance when placed in a magnetic field acquires a feeble magnetism opposite to the direction of magnetic field.
Also, in the presence of the field (non-uniform), these substances are attracted towards the weaker field, i.e. they move from stronger to weaker magnetic field.
Due to these reasons, the rod is repelled by the field produced to the current source. Hence, it is pushed up, out of horizontal field and gains gravitational potential energy.
28. (c) Here, inductance, \( L = 20 \times 10^{-3} \text{ H} \)

Capacitance, \( C = 100 \mu \text{F} = 100 \times 10^{-6} \text{ F} \)

Resistance, \( R = 50 \Omega \)

eMF, \( V = 10 \sin 314t \) \( \text{(i)} \)

\( \vdash \): The general equation of eMF is given as \( V = V_0 \sin \omega t \) \( \text{(ii)} \)

Comparing Eqs. (i) and (ii), we get \( V_0 = 10 \text{ V}, \omega = \frac{314}{1} \text{ rad/s} \)

The power loss associated with the given AC circuit is given as \( P = \frac{V}{R} \text{rms} \times \frac{I}{R} \text{rms} \cos \phi \)

\( \therefore \) Impedance, \( Z = \sqrt{R^2 + (X_L - X_C)^2} \)

\( \therefore \) Substituting the given values in the above equation, we get

\[
Z = \sqrt{50^2 + (20^2 - 10^2)} = 50 \Omega
\]

Thus, power loss in the circuit is 0.79 W.

29. (a) Current sensitivity of a moving coil galvanometer is the deflection \( \theta \) per unit current \( I \) flowing through it, i.e.

\( I_S = \frac{\theta}{I} = \frac{NAB}{k} \) \( \text{(i)} \)

where, \( N \) = number of turns in the coil,
\( A \) = Area of each turn of coil,
\( B \) = magnetic field
\( k \) = restoring torque per unit twist of the fibre strip.

Similarly, voltage sensitivity is the deflection per unit voltage, i.e.

\( V_S = \frac{\theta}{V} = \frac{NAB}{Z} \text{ or } V = \frac{NAB}{Z} \text{ V} \text{rms} \)

Here, \( R_g \) is the resistance of the galvanometer.

From Eqs. (i) and (ii), we get

\( R_g = \frac{I_S}{V_S} \text{ (iii)} \)

Here, \( I_s = 5 \text{ div/mA} = 5 \times 10^{-3} \text{ div/A} \)

and \( V_s = 20 \text{ div/V} \)

Substituting the given values in Eq. (iii), we get \( R_g = \frac{5 \times 10^3}{20} = 250 \Omega \)

\( \vdash \): The resistance of the galvanometer is 250 \( \Omega \).

30. (d) Key Concept

If a body is moving on a frictionless surface, then its total mechanical energy remains conserved.

According to the conservation of mechanical energy,

\( (\text{TE})_{\text{initial}} = (\text{TE})_{\text{final}} \)

\( \Rightarrow \) \( (\text{KE})_i + (\text{PE})_i = (\text{KE})_f + (\text{PE})_f \)

\( 0 + mgh = \frac{1}{2}mv^2 + 0 \)

\( \Rightarrow \)

\( gh = \frac{v^2}{2} \)

or

\( h = \frac{v^2}{2g} \) \( \text{(i)} \)

In order to complete the vertical circle, the velocity of the body at point \( A \) should be

\( v_A = v_{\text{min}} = \sqrt{2gh} \)

where, \( R \) is the radius of the body.

Here,

\( R = \frac{AB}{2} = \frac{D}{2} \)

\( \Rightarrow \) \( v_{\text{min}} = v_A = \sqrt{\frac{5gD}{2}} \)

Substituting the value of \( v_A \) in Eq. (i), we get

\[
h = \frac{\left( \frac{5gD}{2} \right)^2}{2g} = \frac{5gD^2}{2 \times 2g} = \frac{5D}{4}
\]
31. (c) Work done required to bring an object to rest is given as
\[
W = \frac{1}{2} I \omega^2
\]
where, \( I \) is the moment of inertia and \( \omega \) is the angular velocity.
Since, here all the objects spin with the same \( \omega \), this means,
\[
W \propto I
\]
As, \( I_A \) (for a solid sphere) = \( \frac{2}{5} MR^2 \)
\( I_B \) (for a thin circular disk) = \( \frac{1}{2} MR^2 \)
\( I_C \) (for a circular ring) = \( MR^2 \)
\[
∴ \frac{W_A}{W_B} = \frac{2}{5} \frac{1}{2} = \frac{2}{5} \]
\[
\frac{W_A}{W_B} = \frac{2}{5} \frac{1}{2} = \frac{4}{5} \]
\[
⇒ W_A < W_B < W_C
\]
32. (b) Since, the collision mentioned is an elastic head-on collision. Thus, according to the law of conservation of linear momentum, we get
\[
m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2
\]
where, \( m_1 \) and \( m_2 \) are the masses of the two blocks, respectively and \( u_1 \) and \( u_2 \) are their initial velocities and \( v_1 \) and \( v_2 \) are their final velocities, respectively.
Here,
\[
m_1 = m, m_2 = 4m
\]
\[
u_1 = v, u_2 = 0 \text{ and } v_1 = 0
\]
\[
\Rightarrow \quad mv = 4mv
\]
or
\[
\frac{v_2}{v} = \frac{4}{1}
\]
As, the coefficient of restitution is given as,
\[
e = \frac{\text{relative velocity of separation after collision}}{\text{relative velocity of approach}}
\]
\[
e = \frac{v_2 - u_1}{u_2 - u_1}
\]
\[
\frac{v}{v} = \frac{u}{0 - v}
\]
\[
\Rightarrow \quad e = \frac{1}{4}
\]
\[
∴ \quad e = 0.25
\]
33. (d) The opposing force that comes into play when one body is actually sliding over the surface of the other body is called sliding friction.
The coefficient of sliding is given as
\[
\mu_s = \frac{N}{F_{sliding}}
\]
where, \( N \) is the normal reaction and \( F_{sliding} \) is the sliding force.
As, the dimensions of \( N \) and \( F_{sliding} \) are same.
Thus, \( \mu_s \) is a dimensionless quantity.
Hence, statement(d) is incorrect.
34. (b) According to the question,
For the time duration \( 0 < t < 1 \text{s} \),
the velocity increase from 0 to 6 ms\(^{-1}\).
As the direction of field has been reversed for, \( 1 < t < 2 \text{s} \), the velocity firstly decreases from 6 ms\(^{-1}\) to 0.
Then, for \( 2 < t < 3 \text{s} \); as the field strength is same; the magnitude of acceleration would be same, but velocity increases from 0 to −6 ms\(^{-1}\).
Acceleration of the car
\[
|a| = \frac{|v - \dot{v}|}{t} = \frac{6 - 0}{1} = 6 \text{ms}^{-2}
\]
The displacement of the particle is given as
\[
s = ut + \frac{1}{2}at^2
\]
For \( t = 0 \text{ to } t = 1 \text{s} \),
\[
u = 0, \quad a = + 6 \text{m/s}^2
\]
\[
⇒ \quad s_1 = 0 + \frac{1}{2} \times 6 \times (0)^2 = 3 \text{m}
\]
For \( t = 1 \text{s} \text{ to } t = 2 \text{s} \),
\[
u = 6 \text{ms}^{-1}, \quad a = - 6 \text{ms}^{-2}
\]
\[
⇒ \quad s_2 = 6 \times 1 - \frac{1}{2} \times 6 \times (0)^2
\]
\[
= 6 - 3 = 3 \text{m}
\]
For \( t = 2 \text{s} \text{ to } t = 3 \text{s} \),
\[
u = 0, \quad a = - 6 \text{ms}^{-1}
\]
\[
⇒ \quad s_3 = 0 - \frac{1}{2} \times 6 \times (0)^2 = -3 \text{m}
\]
Net displacement, \[ s = s_1 + s_2 + s_3 \]
\[ = 3 \text{ m} + 3 \text{ m} - 3 \text{ m} = 3 \text{ m} \]

Hence, average velocity \[ = \frac{\text{Net displacement}}{\text{Total time}} \]
\[ = \frac{3}{3} = 1 \text{ m s}^{-1} \]

Total distance travelled, \[ d = 9 \text{ m} \]

Hence, average speed \[ = \frac{\text{Total distance}}{\text{Total time}} \]
\[ = \frac{9}{3} = 3 \text{ m s}^{-1} \]

**Alternative Method**

Given condition can be represented through graph also as shown below.

\[ \therefore \text{Displacement in three seconds} \]
\[ = \text{Area under the graph} \]
\[ = \text{Area of } \Delta OA'O' + \text{Area of } \Delta AOB' - \text{Area of } \Delta BCD \]
\[ = \frac{1}{2} \times 1 \times 6 + \frac{1}{2} \times 1 \times 6 - \frac{2}{2} \times 6 \times 1 \]
\[ = 3 \text{ m} \]
\[ \therefore \text{Average velocity} = \frac{3}{3} = 1 \text{ m s}^{-1} \]

Total distance travelled, \[ d = 9 \text{ m} \]
\[ \therefore \text{Average speed} = \frac{9}{3} = 3 \text{ m s}^{-1} \]

35. (d) According to the question, the FBD of the given condition will be

Since, the wedge is accelerating towards right with \( a \), thus a pseudo force acts in the left direction in order to keep the block stationary. As, the system is in equilibrium.

\[ \therefore \Sigma F_x = 0 \]
or \[ \Sigma F_y = 0 \]
\[ \Rightarrow R \sin \theta = ma \]
or \[ mg \sin \theta = ma \]
\[ \Rightarrow \tan \theta = \frac{a}{g} \]

or \[ a = g \tan \theta \]

\[ \therefore \text{The relation between } a \text{ and } g \text{ for the block to remain stationary on the wedge is } a = g \tan \theta. \]

36. (d) **Key Concept**

Moment of force is defined as the cross product of the force and the force arm.

Given,
\[ \mathbf{F} = 4\hat{i} + 5\hat{j} - 6\hat{k} \]
\[ r_1 = 2\hat{i} + 0\hat{j} - 3\hat{k} \]
\[ r_2 = 2\hat{i} - 2\hat{j} - 2\hat{k} \]

\[ \text{Moment of force} = \mathbf{r} \times \mathbf{F} \]
\[ = (r_1 - r_2) \times \mathbf{F} \]
\[ = [-2\hat{i} - 2\hat{j} - 3\hat{k}] \times [4\hat{i} + 5\hat{j} - 6\hat{k}] \]
\[ = [0\hat{i} + 2\hat{j} - 1\hat{k}] \times [4\hat{i} + 5\hat{j} - 6\hat{k}] \]
\[ = \hat{i}[0 \times 2 - (-1 \times 4)] - \hat{j}[0 \times (-1 \times 1) - (-1 \times 4)] + \hat{k}[0 \times 5 - 2 \times 4] \]
\[ = -7\hat{i} - 4\hat{j} - 8\hat{k} \]

37. (d) Given, least count of screw gauge,
\[ LC = 0.001 \text{ cm} \]

Main scale reading, \[ MSR = 5 \text{ mm} = 0.5 \text{ cm} \]

Number of coinciding divisions on the circular scale, i.e. Vernier scale reading, \[ VSR = 25 \]

Here, zero error \[ = -0.004 \text{ cm} \]

Final reading obtained from the screw gauge is given as \[ MSR + VSR \times LC - \text{ zero error} \]

Final reading from the screw gauge
\[ = 0.5 + 25 \times 0.001 - (-0.004) \]
\[ = 0.5 + 0.025 + 0.004 \]
\[ = 0.5 + 0.029 = 0.529 \text{ cm} \]

Thus, the diameter of the ball is 0.529 cm.
38. (d) Moment of inertia of a rotating solid sphere about its symmetrical (diametric) axis is given as,
\[ I = \frac{2}{5} mR^2 \]
Rotational kinetic energy of solid sphere is
\[ K_r = \frac{1}{2} I \omega^2 \]
where, \( I = \frac{2}{5} mR^2 \)
Angular velocity, \( \omega = V_{cm} \frac{R}{L} \)
As, we know that external torque,
\[ \tau_{ext} = \frac{dL}{dt} \]
where, \( L \) is the angular momentum.
Since, in the given condition, \( \tau_{ext} = 0 \)
\[ \Rightarrow \frac{dL}{dt} = 0 \]
or \( L = \text{constant} \)
Hence, when the radius of the sphere is increased keeping its mass same, only the angular momentum remains constant. But other quantities like moment of inertia, rotational kinetic energy and angular velocity changes.

39. (b) According to the question,
\[ \begin{align*}
A & \quad B \\
\omega & \quad C
\end{align*} \]
The figure above shows an ellipse traced by a planet around the Sun, S. The closed point A is known as perihelion (perigee) and the farthest point C is known as aphelion (apogee).
Since, as per the result the Kepler’s second law of area, that the planet will move slowly \( (v_{\text{min}}) \) only when it is farthest from the Sun and more rapidly \( (v_{\text{max}}) \) when it is nearest to the Sun.
Thus, \( v_A = v_{\text{max}}, v_C = v_{\text{min}} \)
Therefore, we can write
\[ v_A > v_B > v_C \] ...
(i)
Kinetic energy of the planet at any point is given as, \( K = \frac{1}{2} m v^2 \)
Thus, at A, \( K_A = \frac{1}{2} m v_A^2 \)
At B, \( K_B = \frac{1}{2} m v_B^2 \)
At C, \( K_C = \frac{1}{2} m v_C^2 \)
From Eq. (i), we can write
\[ K_A > K_B > K_C \]

40. (d) Let the original mass of Sun was \( M_s \) and gravitational constant \( G' \).
According to the question,
New mass of Sun, \( M'_s = \frac{M_s}{10} \)
New gravitational constant, \( G' = 10G \)
As, the acceleration due to gravity is given as
\[ g = \frac{GM_E}{R^2} \] ...
(i)
where, \( M_E \) is the mass of Earth and \( R \) is the radius of the Earth.
Now, new acceleration due to gravity,
\[ g' = \frac{G'M_s}{R^2} = 10 \frac{G M_s}{R^2} \] ...
(ii)
\[ \therefore g' = 10g \] [from Eqs. (i) and (ii)]
This means the acceleration due to gravity has been increased. Hence, force of gravity acting on a body placed on or surface of the Earth increases. Due to this, rain drops will fall faster, walking on ground would become more difficult.
As, time period of the simple pendulum is
\[ T = 2\pi \sqrt{\frac{l}{g}} \]
Or
\[ T \propto \sqrt{\frac{1}{g}} \]
Thus, time period of the pendulum also decreases with the increase in \( g \).

41. (b) Translational kinetic energy of a rolling body is
\[ K_i = \frac{1}{2} m v^2_{CM} \] ...
(i)
Total kinetic energy of a rolling body
\[ = K_i + K_r = \text{Rotational KE} + \text{Translational KE} \]
\[ = \frac{1}{2} I \omega^2 + \frac{1}{2} m v^2_{CM} \] ...
(ii)
For a solid sphere, moment of inertia about its diametric axis, \( I = \frac{2}{5} MR^2 \)

Substituting the value of \( I \) in Eq. (ii), we get

\[
K_j + K_r = \frac{1}{2} \left( \frac{2}{5} MR^2 \right) \left( \omega^2 + \frac{1}{2} mv_{CM}^2 \right)
\]

\[
= \frac{1}{2} \left( \frac{2}{5} MR^2 \right) \left( \frac{v_{CM}^2}{R^2} \right) + \frac{1}{2} mv_{CM}^2 \quad \text{[} v_{CM} = R\omega \text{]}
\]

\[
= \frac{1}{5} mv_{CM}^2 + \frac{1}{2} mv_{CM}^2
\]

\[
= \left( \frac{1}{5} + \frac{1}{2} \right) mv_{CM}^2
\]

\[
= \frac{7}{10} mv_{CM}^2
\]

... (iii)

\[
\therefore \quad \text{Ratio, } \frac{K_j}{K_j + K_r} = \frac{\frac{1}{2} mv_{CM}^2}{\frac{7}{10} mv_{CM}^2}
\]

\[
\Rightarrow \quad K_j = \frac{5}{7} (K_j + K_r)
\]

... (iii)

Alternate Method

Suppose, moment of inertia,

\( I = xMR^2 \) \hspace{1cm} \text{(i)}

For solid sphere, moment of inertia,

\( I = \frac{2}{5} MR^2 \) \hspace{1cm} \text{(ii)}

Thus, from Eqs. (i) and (ii), we get

\( x = \frac{2}{5} \)

Since, the ratio of translational energy to the total energy can be written as

\[
\frac{K_j}{K_j + K_r} = \frac{\frac{1}{2} mv_{CM}^2}{\frac{7}{10} mv_{CM}^2}
\]

... (iii)

where, \( k \) is called the radius of gyration.

As,

\( K = \frac{T}{m} \)

or

\( K^2 = \frac{l}{m} \)

From Eq. (i), we get

\[
K^2 = \frac{xMR^2}{m} = xR^2
\]

Substituting the value of \( K^2 \) in Eq. (iii), we get

\[
\frac{K_j}{K_j + K_r} = \frac{\frac{1}{2} mv_{CM}^2}{\frac{1 + xR^2}{R^2}} = \frac{1}{1 + \frac{1}{4}}
\]

Here,

\[
x = \frac{2}{5}
\]

\[
\Rightarrow \quad \frac{K_j}{K_j + K_r} = \frac{\frac{1}{2}}{1 + \frac{2}{5}} = \frac{5}{7}
\]

42. (a) Key Concept  The rate of heat generation is equal to the rate of work done by the viscous force which in turn is equal to its power.

Rate of heat produced, \( \frac{dQ}{dt} = F \times v_T \)

where, \( F \) is the viscous force and \( v_T \) is the terminal velocity.

As,

\[
F = 6 \pi \eta v_T
\]

\[
\Rightarrow \quad \frac{dQ}{dt} = 6 \pi \eta v_T \times v_T
\]

\[
= 6 \pi \eta v_T^2
\]

... (i)

From the relation for terminal velocity,

\[
v_T = \frac{2 r^2 (\rho - \sigma)}{9 \eta} g, \text{ we get}
\]

\[
v_T \propto r^2
\]

... (ii)

From Eq. (ii), we can rewrite Eq. (i) as

\[
\frac{dQ}{dt} \propto (v_T)^2
\]

or

\[
\frac{dQ}{dt} \propto r^5
\]

43. (a) According to Wien's law,

\[
\lambda_{\text{max}} \propto \frac{1}{T}
\]

i.e.

\[
\lambda_{\text{max}} T = \text{constant}
\]

where, \( \lambda_{\text{max}} \) is the maximum wavelength of the radiation emitted at temperature \( T \).

\[
\therefore \quad \lambda_{\text{max}} T_1 = \lambda_{\text{max}} T_2
\]

or

\[
\frac{T_1}{T_2} = \frac{\lambda_{\text{max}}}{\lambda_{\text{max}}}
\]

... (i)

Here, \( \lambda_{\text{max}_1} = \lambda_0 \) and \( \lambda_{\text{max}_2} = \frac{3}{4} \lambda_0 \)

Substituting the above values in Eq. (i), we get

\[
\frac{T_1}{T_2} = \frac{\frac{3}{4} \lambda_0}{\lambda_0} = \frac{3}{4}
\]

or

\[
\frac{T_1}{T_2} = \frac{3}{4}
\]

... (ii)
As we know that, from Stefan’s law, the power radiated by a body at temperature $T$ is given as

$$P = \sigma A e T^4$$

i.e. $P \propto T^4$

($\because$ the quantity $\sigma A e$ is constant for a body)

$$\Rightarrow \frac{P_1}{P_2} = \left(\frac{T_1}{T_2}\right)^4$$

From Eq. (i), we get

$$\frac{P_1}{P_2} = \left(\frac{3}{4}\right)^4 = \frac{81}{256}$$

Given, $P_1 = P$ and $P_2 = nP$

$$\Rightarrow \frac{P_1}{P_2} = \frac{P}{nP} = \frac{81}{256}$$

or $n = \frac{256}{81}$

44. (c) According to the question,

**For wire 1**

Area of cross-section = $A_1$

Force applied = $F_1$

Increase in length = $\Delta l$

From the relation of Young’s modulus of elasticity,

$$Y = \frac{F_1}{A_1 \Delta l}$$

Substituting the values for wire 1 in the above relation, we get

$$\Rightarrow Y_1 = \frac{F_1}{A_1 \Delta l} \quad \ldots (i)$$

**For wire 2**

Area of cross-section = $A_2$

Force applied = $F_2$

Increase in length = $\Delta l$

Similarly,

$$Y_2 = \frac{F_2}{A_2 \Delta l} \quad \ldots (ii)$$

$\therefore$ Volume, $V = Al$

or $l = \frac{V}{A}$

Substituting the value of $l$ in Eqs. (i) and (ii), we get

$$Y_1 = \frac{F_1 V}{A_1 \Delta l} \quad \text{and} \quad Y_2 = \frac{F_2 V}{A_2 \Delta l}$$

As it is given that the wires are made up of same material, i.e. $Y_1 = Y_2$

$$\Rightarrow \frac{F_1 V}{A_1 \Delta l} = \frac{F_2 V}{A_2 \Delta l}$$

$$\Rightarrow \frac{F_1}{F_2} = \frac{A_2}{A_1} = \frac{A^2}{9A^2} \quad \ldots \quad (\because A_1 = A \text{ and } A_2 = 3A)$$

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

or $F_2 = 9F_1 = 9F$ (given, $F_1 = F$)

45. (b) According to the question,

Heat spent during the conversion of sample of water at 100°C to steam is,

$$\Delta Q = 54 \text{ cal} \times 54 \times 4.18 \text{ J} = 225.72 \text{ J}$$

Normal pressure, $p = 1.013 \times 10^5 \text{ Nm}^{-2}$

Net work done during the conversion would be given as

$$\Delta W = p \Delta V$$

$$= p \left[V_{steam} - V_{water}\right]$$

Here, $V_{steam} = 1671 \text{ cc} = 167.1 \times 10^{-6} \text{ m}^3$

$V_{water} = 0.1 \text{ g} = 0.1 \text{ cc} = 0.1 \times 10^{-6} \text{ m}^3$

$\therefore \Delta W = 1.013 \times 10^5 \times [(167.1 - 0.1) \times 10^{-6}]$

$= 1.013 \times 167 \times 10^{-1}$

$= 16.917 \text{ J}$

Now, by the first law of thermodynamics,

$$\Delta Q = \Delta U + \Delta W$$

where, $\Delta U$ is the change in internal energy of the sample.

$$\Rightarrow \Delta U = \Delta Q - \Delta W$$

Substituting the values in the above equation, we get

$$\Delta U = 225.72 - 16.917 = 208.7 \text{ J}$$