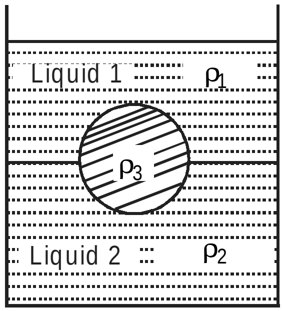
PHYSICS

71. A Jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 , respectively, A solid ball, made of a material of density ρ_3 , is dropped in the jar. It comes to equilibrium in the position shown in the figure.



which of the following is true for ρ_1, ρ_2 and ρ_3 ?

(1) $\rho_1 < \rho_3 < \rho_2$

(2) $\rho_3 < \rho_1 < \rho_2$

(3) $\rho_1 < \rho_3 < \rho_2$

(4) $\rho_1 < \rho_2 < \rho_3$

Sol. (1)

From the figure it is clean that

(a) Liquid 1 is lighter than Liquid 2

(b) The ball is lighter than Liquid 1

(c) The ball is lighter than Liquid 2

$\therefore \rho_1 < \rho_3 < \rho_2$

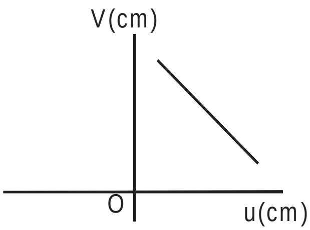
72. A working transistor with its three legs marked P, Q and R is tested using a multimeter. No conduction is found between P and Q. By connecting the common (negative) terminal of the multimeter to R and the other (positive) terminal to P or Q. some resistance is seen on the multimeter. Which of the following is true for the transistor ?

(1) It is an npn transistor with R as collector
(2) It is an npn transistor with R as base
(3) It is an pnp transistor with R as collector
(4) It is an npn transistor with R as emitter

Sol.

R has to be the base because it conducts current when connected with both the other terminals. But the ckt will conduct only if the junction is forward biased. If negative terminal of multimeter is connected to R, R must be n-type.
Hence the transistor is p-n-p.
No correct option is available.

73. A student measures the focal length of a convex lens by putting an object pin at a distance ‘u’ from the lens and measuring the distance ‘v’ of the image pin. The graph between ‘u’ and ‘v’ plotted by the student should look like

(1)


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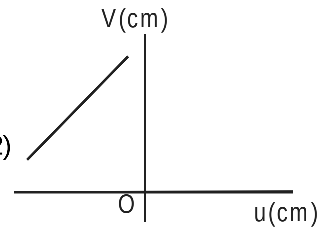

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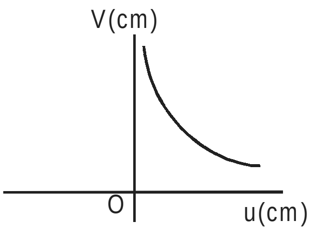

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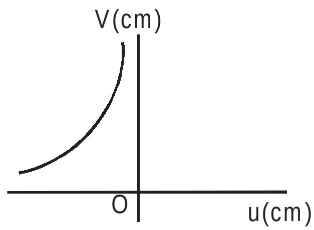
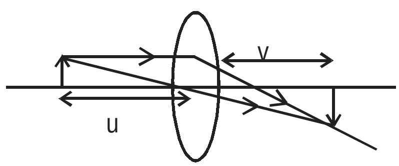


Sol. (4)


Lens formula:

$\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$ = constant

Also, v and u are of opposite signs.
Hence correct answer is (4)

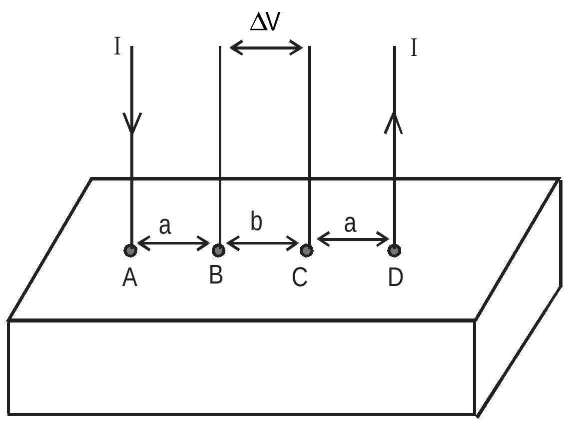
Directions: Questions No. 74 and 75 are based on the following paragraph.
Consider a block of conducting material of resistivity 'p' shown in the figure. Current 'I' enters at 'A' and leaves from 'D'. We apply superposition principle to find voltage 'ΔV' developed between 'B' and 'C'. The calculation is done in the following steps:

(i) Take current 'I' entering from 'A' and assume it to spread over a hemispherical surface in the block.

(ii) Calculate field E(r) at distance 'r' from A by using Ohm's law $E = \rho j,$ where j is the current per unit area at 'r'.

(iii) From the 'r' dependence of E(r), obtain the potential V(r) at r.

(iv) Repeat (i), (ii) and (iii) for current 'I' leaving 'D' and superpose result for 'A' and 'D'.



74. ΔV measured between B and C is

(1) $\frac{\rho I}{2\pi(a-b)}$ (2) $\frac{\rho I}{\pi a}-\frac{\rho I}{\pi(a+b)}$

(3) $\frac{\rho I}{a}-\frac{\rho I}{(a+b)}$ (4) $\frac{\rho I}{2\pi a}-\frac{\rho I}{2\pi(a+b)}$

Sol. (2)

$E(r)=\frac{\rho I}{2\pi r^2}$ for current entering at A.

$E(r)=\frac{-\rho I}{2\pi r^2}$ for current leaving at D.

$$\Delta V = V_B - V_C = \int_a^{a+b}\frac{\rho I}{2\pi r^2}dr - \int_{a+b}^{a}\frac{\rho I}{2\pi r^2}dr$$

$$= -2\int_{a+b}^{a}\frac{\rho I}{2\pi r^2}dr = \frac{\rho I}{\pi}\left[\frac{1}{a}-\frac{1}{a+b}\right]$$

$$= \frac{\rho I}{\pi a}-\frac{\rho I}{\pi(a+b)}$$

75. For current, entering at A, the electric field at a distance 'r' from A is

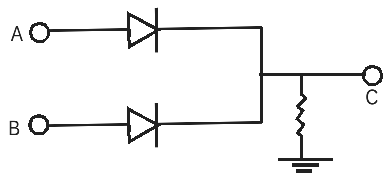
(1) $\frac{\rho I}{4\pi r^2}$ (2) $\frac{\rho I}{8\pi r^2}$ (3) $\frac{\rho I}{r^2}$ (4) $\frac{\rho I}{2\pi r^2}$

Sol. (4)

$(E(r)=\frac{\rho I}{2\pi r^2}$

$\therefore$ Loss of energy during collision = 0.67

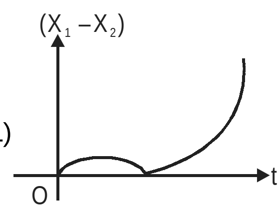
76. In the circuit below, A and B represent two inputs and C represents the output.

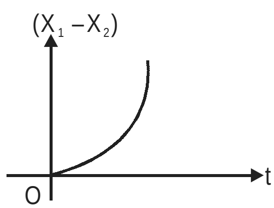


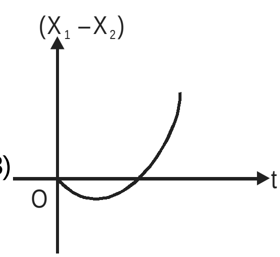
The circuit represents
(1) OR gate
(2) NOR gate
(3) AND gate
(4) NAND gate

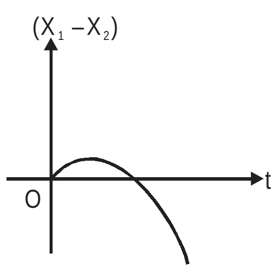
Sol. (1)
If output is measured across the resistor shown . There will be current through the rerister if any or both A and B are 1. There will be output in this case. These will be no current through the resistor, if both A and B are 0. Output will be 0 is this case.
Hence the circuit is OR.

77. A body is at rest at x = 0, At t = 0, it starts moving in the positive x-direction with a constant acceleration. At the same instant another body passes through x = 0 moving in the posisitive x-direction with a constant speed. The position of the first body is given by $x_1(t)$ after time 't' and that of the second body by $x_2(t)$ after the same time interval. Which of the following graphs correctly describes $(x_1 – x_2)$ as a function of time 't' ?

(1)


(2)


(3)


(4)


Sol. (3)

$x_1 = \frac{1}{2}at^2$ $x_2 = ut$

$x_1 - x_2 = \frac{1}{2}at^2 - ut$

This will be zero at two values of t = 0, $\frac{2u}{a}$ $\frac{d}{dt}(x_1 - x_2)$ = at – u. Thus for $t = \frac{u}{a}$, $(x_1 - x_2)$ is either maximum or minimum. $\frac{d^2}{dt^2}$ $(x_1 - x_2)$ = a which is + ve which corresponds to minima.

78. This question contains Statement-I and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.
Statement-I
Energy is released when heavy nuclei undergo fission or light nuclei undergo fusion.
and
Statement-2:
For heavy nuclei, binding energy per nucleon increases with increasing Z while for light nuclei it decreases with increasing Z.
(1) Statement-1 is true, Statement-2 is false
(2) Statement-1 is false, Statement-2 is true
(3) Statement-1 is true, Statement-2 is true; Statement-2 os a correct explanation for Statement-1
(4) Statement-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1.

Sol. (1)

79. This question contains Statement-1 and Statement-2. Of the four choices given after the statements, choose the one that best describes the two statements.

Statement-1:

For a mass M kept at the centre of a cube of side 'a', the flux of gravitational field passing throug its sides is 4π G M.

and

Statement-2:

If the direction of a field due to a point source is radial and its dependence on the distance 'r' from the source is given as $\frac{1}{r^2}$, its flux through a closed surface depends only on the strength of the source enclosed by the surface and not on the size or shape of the surface.

(1) Statement-1 is true, Statement-2 is false

(2) Statement-1 is false, Statement-2 is true

(3) Statement-1 is true, Statement-2 is true; Statement-2 os a correct explanation for Statement-1

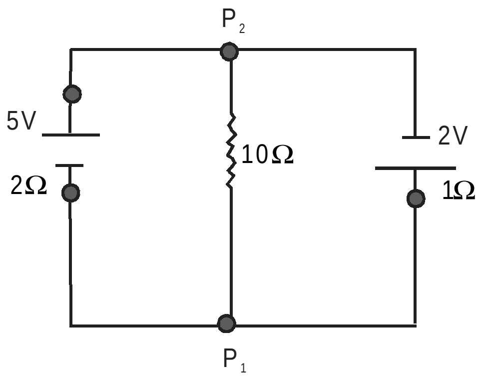
(4) Statement-1 is true, Statement-2 is true; Statement-2 is not a correct explanation for Statement-1.

Sol. (3)

$$\varnothing = \phi \vec{I}\,\overrightarrow{ds} = \phi \frac{GM}{r^2}.ds = \frac{GM}{r^2}\phi\, ds$$

$$= \frac{GM}{r^2}.\,4\pi r^2 = 4\pi\, GM$$

80. A 5 V battery with internal resistance 2 Ω and a 2 V battery with internal resistance 1 Ω are connected to a 10 Ω resistor as shown in the figure



The current in the 10 Ω resistor is

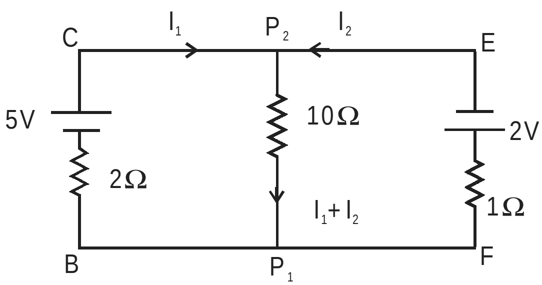
(1) $0\cdot27$ A P_1 to P_2

(2) $0\cdot27$ A P_2 to P_1

(1) $0\cdot03$ A P_1 to P_2

(1) $0\cdot03$ A P_2 to P_1

Sol. (4)



Applying kirchoff's loop law

loop P_1 BC P_2 P_1 $2I_1 - 5 + 10\ (I_1 + I_2) = 0$

loop P_1 FE P_2 P_1 $I_1 + 2 + 10\ (I_1 + I_2) = 0$

on solving $I_1 = 2.344$ Amp $I_2 = -2.312$ amp

and $I_1 + I_2 = 0.3$ amp

81. An experiment is performed to find the refractive index of glass using a travelling microscope. In this experiment distance are measured by

(1) a screw gauge provided on the microscope
(2) a vernier scale provided on the microscope
(3) a standard laboratory scale
(4) a meter scale provided on the microscope

Sol. (2)

82. A horizontal overhead powerline is at a height of 4 m from the ground and carries a current of 100 A from east to west. The magnetic field directly below it on the ground is

$\left(\mu_0 = 4\pi\times10^{-7}\ \text{T m A}^{-1}\right)$

(1) 2.5×10^{-7} T northward
(2) 2.5×10^{-7} T southward
(3) 5×10^{-6} T northward
(1) 6×10^{-6} T southward

Sol.(4)

$B = \frac{\mu_0 I}{2\pi r}$ and its direction is given by right hand rule

83. The speed of sound in oxygen (O_2) at a certain temperature is 460 ms^{-1}. The speed of sound in helium (He) at the same temperature will be (assume both gases to be ideal)

(1) 330 ms^{-1}
(2) 460 ms^{-1}
(1) 500 ms^{-1}
(1) 650 ms^{-1}

Sol.

We know $V = \sqrt{\frac{\gamma RT}{M}}$

where r = Cp/Cv, T = Tempreture &
M = molecular weight

$$\frac{V_{O_2}}{V_{He}} = \sqrt{\left(\frac{\gamma_{O_2}}{M_{O_2}} \times \frac{M_{He}}{\gamma_{He}}\right)} = \sqrt{\frac{7/5\times4}{32\times5/3}}$$

$$= \sqrt{\frac{84}{800}}$$

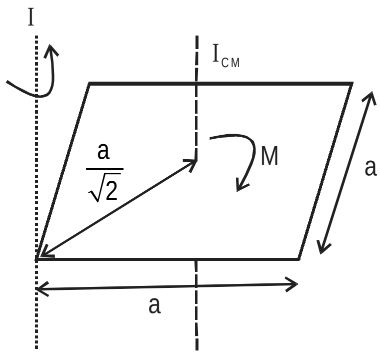
$\Rightarrow V_{He}$ 1419 m/s

No correct option is available.

84. Consider a uniform square plate of side 'a' and mass 'm'. The moment of inertia of this plate about an axis perpendicular to its plane and passing through one of its corners is

(1) $\frac{2}{3}ma^2$ (2) $\frac{5}{6}ma^2$ (3) $\frac{1}{10}ma^2$ (4) $\frac{7}{12}ma^2$

Sol. (1)



$\because \ I_{cm} = \frac{1}{12}m\left[a^2 + a^2\right] = \frac{1}{6}ma^2$

$\therefore \ I = I_{cm} + M\left(\frac{a}{\sqrt{2}}\right)^2$

$= \frac{1}{6}Ma^2 + \frac{1}{2}Ma^2$

$= \frac{2}{3}Ma^2$

85. A body of mass m = 3.513 kg is moving along the x-axis with a speed of 5.00 ms^{-1}. The magnitude of its momentum is recorded as

(1) 17.57 kg ms^{-1}
(2) 17.6 kg ms^{-1}
(1) 17.565 kg ms^{-1}
(1) 17.56 kg ms^{-1}

Sol.(2)

Momentum P = mv
= (3.513) (5.00)
= 17.565 kg m/s
$\because$ least significant eligit is 3
$\therefore$ Answer should be given in three significant eligit only. So 17.565 can be written as 17.6kg. ms^{-1}

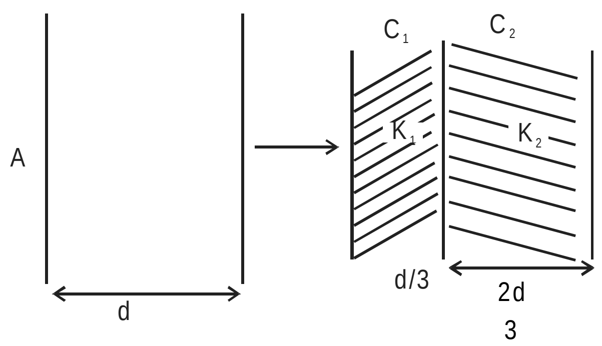
86. The dimension of magnetic filed in M, L, T and C (Coulomb) is given as
(1) $M\,T^{-2}\,C^{-1}$
(2) $M\,L\,T^{-1}\,C^{-1}$
(3) $M\,T^{2}\,C^{-2}$
(4) $M\,T^{-1}\,C^{-1}$

Sol. (4)

By $F = qvB\sin\theta$
$[MLT^{-2}] = [c]\,[LT^{-2}]\,[B]$
$\Rightarrow\ [B] = [MLT^{-1}\,c^{-1}]$

87. A parallel plate capacitor with air between the plates has a capacitance of 9 pF. The separation between its plate is 'd'. The space between the plates is now filled with two dielectrics. One of the dielectrics has dielectric constant $\kappa_1 = 3$ and thickness $\frac{d}{3}$ while the other one has dielectric constant $\kappa_2 = 6$ and thickness $\frac{2d}{3}$. Caoacutance of the capacitor is now
(1) 20.25 pF
(2) 1.8 pE
(3) 45 pE
(4) 40.5 pF

Sol. (4)



After inserting the chaelectric, these are two capacitor which are in series connection ray

$$C_1 \frac{a\varepsilon_0 \cdot k_1}{d/3} = \frac{9A\varepsilon_0}{d}$$

$$\& \; C_2 \frac{A\varepsilon_0 \cdot k_2}{2d/3} = \frac{9A\varepsilon_0}{d}$$

$$\text{By } \frac{1}{c_1} = \frac{1}{c_1} + \frac{1}{c_2}$$

$$\Rightarrow \; c^1 = \frac{9}{2}\frac{A\varepsilon_0}{d} = \frac{9}{2} \times \mu f$$

$$= 40.5 \; \mu f$$

88. An athlete in the olympic games covers a distance of 100 m in 10s. His kinetic energy can be estimated to in the range

(1) 2,000 J — 5,000 J
(2) 200 J — 500 J
(3) 2×10^5 J — 3×10^5 J
(4) 20,000 J — 50,000 J

Sol. (1)

Athlete covers 100 m in 10 second

$\therefore \; S = vt$

100 = 40 × 10

$\Rightarrow$ v = 10 m/s

we can assume the mass of athelete as 60 kg

$\therefore \; K \cdot E = 1/2 \; MV^2$

= 1/2 × 60 × 10 × 10

= 3000 J

89. Relative permittivity and permeability of a material are ε_r and μ_r, respectively. Which of the following values of these quantities are allowed for a diamagnetic material?

(1) $\varepsilon_r = 1 \cdot 5, \mu_r = 1 \cdot 5$

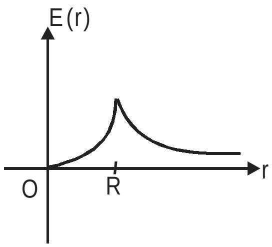
(2) $\varepsilon_r = 0 \cdot 5, \mu_r = 1 \cdot 5$

(3) $\varepsilon_r = 1 \cdot 5, \mu_r = 0 \cdot 5$

(4) $\varepsilon_r = 0 \cdot 5, \mu_r = 0 \cdot 5$

Sol. (3)

90. A thin spherical shell of radius R has charge Ω spread uniformly over its surface. Which of the following graphs most closely represents the electric field E(r) produced by the shell in the range $0 \le r < \infty$, where r is the distance from the centre of the shell ?

(1)


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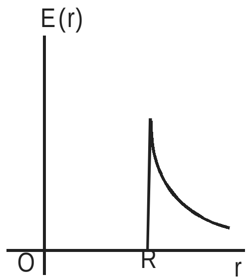
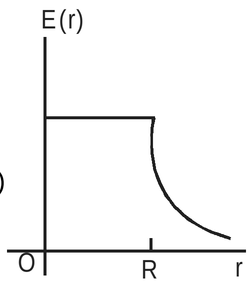
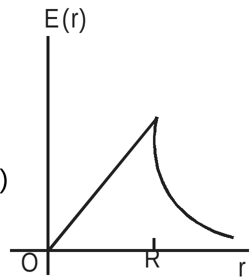


(3)


(4)


Sol. (2)

Inside a conducting shell, E = 0

At the surface of shell, $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{R^2}$

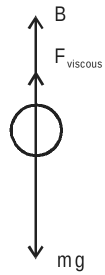
At the points outside the shell, $E = \frac{1}{4\pi\epsilon_0} \cdot \frac{Q}{r^2}$

91. A spherical solid ball of bolume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_2 $(\rho_2 < \rho_1)$. Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed v, i.e., $F_{viscous} = kv^2$ (k > 0). The terminal speed of the ball is

(1) $\frac{V g(\rho_1 - \rho_2)}{k}$ (2) $\sqrt{\frac{V g(\rho_1 - \rho_2)}{k}}$

(3) $\frac{V g \rho_1}{k}$ (4) $\sqrt{\frac{V g \rho_1}{k}}$

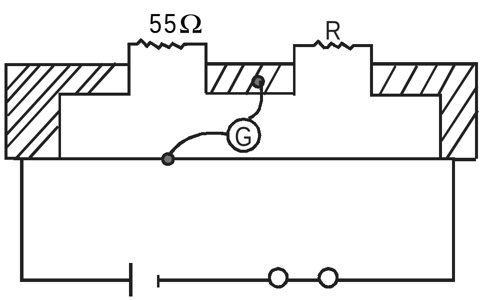
Sol. (2) For the terminal velocity, $mg = B + F_{viscous}$



$\Rightarrow \; V\rho_1 g = V\rho_2 g + kv_{ter}^2$

$\Rightarrow v_{ter} = \sqrt{\frac{V(\rho_1 - \rho_2)g}{k}}$

92. Shown in the figure below is a meter-bridge set up with null deflection in the galvanometer.



The value of the unknown resistor R is

(1) 55 Ω (2) 13.75 Ω (3) 220 Ω (4) 110 Ω

Sol. (3)

For balanced wheatstone bridge arrangement

$\frac{55}{20} = \frac{R}{(100-20)} \qquad \Rightarrow \; R = 220\,\Omega$

93. While measuring the speed of sound by performing a reasonance column experiment,a student gets the first resonance condition at a column length of 18 cm during winter. Repeating the same experimetn during summer, she measures the column length to be x cm for the second resonance. Then

(1) 36 > x > 18
(2) 18 > x
(3) x > 54
(4) 54 > x > 36

Sol. (3)

For first resonance,

$$f = \frac{v}{4l_1}$$

$$= \frac{v}{4 \times 18};$$

v is speed of sound in winter
for second resonance,

$$f = \frac{3v'}{4 \times x}$$; v' speed of sound in summer

$$\therefore \frac{v}{4 \times 18} = \frac{3v'}{4 \times x}$$

$$\Rightarrow x = 54\frac{v'}{v}$$

$v' > v$ (During summer temperature is higher)
$\therefore$ x > 54

94. A wave travelling along the x-axis is described by the equation y(x, t) = 0.005 cos(αx – βt). If the wavelength and the time period of the wave are 0.08 m and 2.0 s, respectively, then α and β in appropriate units are

(1) $\alpha = 12.50\pi, \beta = \frac{\pi}{2.0}$
(2) $\alpha = 25.00\pi, \beta = \pi$
(3) $\alpha = \frac{0.08}{\pi}, \beta = \frac{2.0}{\pi}$
(4) $\alpha = \frac{0.04}{\pi}, \beta = \frac{1.0}{\pi}$

Sol. (2)

$$\alpha = \frac{2\pi}{\lambda} = \frac{2\pi}{0.08} = 25\pi$$

$$\beta = \frac{2\pi}{T} = \frac{2\pi}{2} = \pi$$

95. A block of mass 0.50 kg is moving with a speed of 2.00 ms^{-1} on a smooth surface. It strikes another mass of 1.00 kg and then they move together as a single body. The energy loss during the collision is

(1) 0.34 J (2) 0.16 J (3) 1.00 J (4) 0.67 J

Sol. (4)

By conservation of momentum

$$m_1u = (m_1 + m_2)v$$

$$0.5 \times 2 = (0.5 + 1)v$$

$$v = \frac{1}{1.5} = \frac{2}{3}\ m/s$$

Energy lost $\Delta E = k_I - k_F$

$$\Delta E = \frac{1}{2}m_1u^2 - \frac{1}{2}(m_1 + m_2)v^2$$

$$\Delta E = \frac{1}{2}\left(0.5 \times 4 - 1.5 \times \frac{4}{9}\right)$$

$$\Delta E = \frac{1}{2}\left(2 - \frac{2}{3}\right) = \frac{2}{3}\ J$$

$$\Delta E = 0.67\ J$$

96. Suppose an electron is attracted towards the origin by a force $\frac{k}{r}$ where 'k' is a constant and 'r' is the distance of the electron from the origin. By applying Bohr model to this system, the radius of the n^{th} orbital of the electron is found to be $'r_n'$ and the kinetic energy of the electron to be $'T_n'$. Then which of the following is true?

(1) $T_n \propto \frac{1}{n}, r_n \propto n^2$ (2) $T_n \propto \frac{1}{n^2}, r_n \propto n^2$

(3) T_n independent of n, $r_n \propto n$ (4) $T_n \propto \frac{1}{n}, r_n \propto n$

Sol. (3)

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

$$v = \sqrt{\frac{k}{m}} \qquad \text{... (i)}$$

Using Bohrs quantisation principle

$$mvr = \frac{nh}{2\pi}$$

$$m\sqrt{\frac{k}{m}}r = \frac{nh}{2\pi}$$

$$r \propto n$$

$$T = \frac{1}{2}mv^2 = \frac{1}{2}m\left(\frac{k}{m}\right) \text{ from (i)}$$

$$T = \frac{k}{2} \text{ independent of n}$$

97. Two full turns of the circular scale of a screw gauge cover a distance of 1 mm on its main scale. The total number of divisions on the circular scale is 50. Further, it is found that the screw guage has a zero error of –0.03 mm. While measuring the diameter of a thin wire, a student notes the main scale reading of 3 mm and the number of circular scale divisions in line with the main scale as 35. The diameter of the wire is

(1) 3.38 mm (2) 3.32 mm (3) 3.73 mm (4) 3.67 mm

Sol. (1)

Pitch = 0.5 mm

$$LC = \frac{0.5}{50} = 0.01\,\text{mm}$$

error = –0.03 mm

Reading = MSR + CSR × LC – error

$$= 3 + 35 \times 0.01 - (-0.03)$$

$$= (3 + 35 + 0.03)\text{ mm} = 3.38\text{ mm}$$

98. An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure P_1 and temperature T_1. The other chamber has volume V_2 and temperature T_2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be

(1) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$ (2) $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$

(3) $\frac{P_1V_1T_1+P_2V_2T_2}{P_1V_1+P_2V_2}$ (4) $\frac{P_1V_1T_2+P_2V_2T_1}{P_1V_1+P_2V_2}$

Sol. (2)

Moles in chamber 1, $n_1 = \frac{P_1V_1}{RT_1}$

Moles in chamber 2, $n_2 = \frac{P_2V_2}{RT_2}$

Wall are insulating hence $\Delta Q = 0$ and given W = 0
From Ist law of thermodynamics $\Delta U = 0$

$$n_1CvT_1 + n_2CvT_2 = (n_1+n_2)CvT$$

$$T = \frac{n_1T_1+n_2T_2}{n_1+n_2}$$

Substituting values of n_1 and n_2

$$T = \frac{(P_1V_1+P_2V_2)T_1T_2}{P_1V_1T_2+P_2V_2T_1}$$

99. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoids has 300 turns and the other 400 turns, their mutual inductance is

$(\mu_0 = 4\pi\times10^{-7}\ \text{T m A}^{-1})$

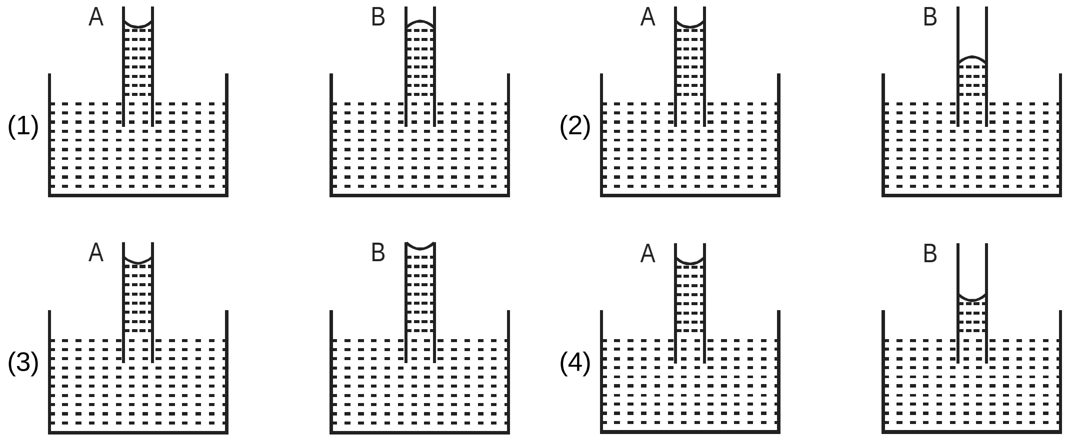
(1) $2.4\pi\times10^{-4}$ H (2) $2.4\pi\times10^{-5}$ H (3) $4.8\pi\times10^{-4}$ H (4) $4.8\pi\times10^{-5}$ H

Sol. (1)

$$M = \frac{\mu_0N_1N_2A}{l} = \frac{(4\pi\times10^{-7})\times300\times400\times10\times10^{-4}}{20\times10^{-2}}$$

$$M = 24\pi\times10^{-5} = 2.4\pi\times10^{-4}\ \text{H}$$

100. A capillary tube (A) is dipped in water. Another identical tube (B) is dipped in a soap-water solution. Which of the following shows the relative nature of the liquid columns in the two tubes?



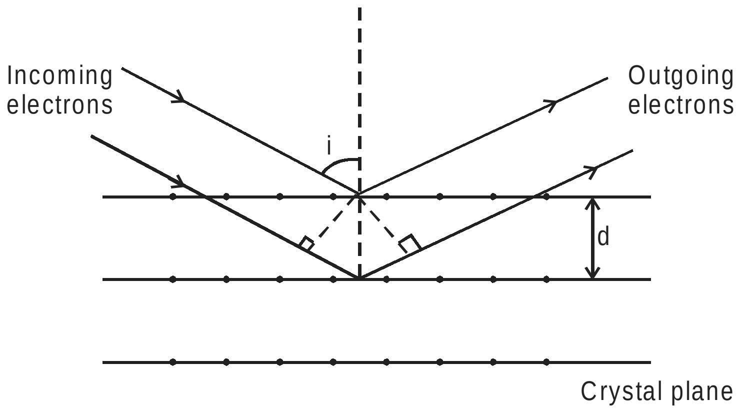
Sol. (4)

We know, $h \propto \frac{l}{\rho}$

In case of soap solution T decreases and increases.
Hence, correct option is (4).

Directions for questions 101 to 103: Answer the questions based on the following paragraph

Wave property of electrons implies that they will show diffraction effects. Davisson and Germer demonstrated this by diffracting electrons from crystals. The law governing the diffraction from a crystal is obtained by requiring that electron waves reflected from the planes of atoms in a crystal interfere constructively (see figure)



101. Electrons accelerated by potential V are diffracted from a crystal. If d = 1 Å and $i = 30°$, V should be about $\left(h = 6.6\times10^{-34}\ \text{Js},\ m_e = 9.1\times10^{-31}\ \text{kg},\ e = 1.6\times10^{-19}\,\text{C}\right)$

(1) 1000 V (2) 2000 V (3) 50 V (4) 500 V

Sol. (3)

Path difference from diagram is 2dcosi.

$2d\cos i = n\lambda \quad (n = 1)$

$$\frac{nh}{\rho} = \frac{h}{\sqrt{2meV}}$$

$$V = \frac{h^2}{2me\times4d^2\cos^2 i} = \frac{6.6\times6.6\times10^{-68}\times4}{2\times9.1\times10^{-31}\times1.6\times10^{-19}\times4\times10^{-20}\times3}$$

$$= \frac{6.6\times6.6}{2\times9.1\times1.6\times3}\times100 = \frac{66\times66}{2\times3\times91\times1.6}\times100$$

$$= \frac{11\times66}{9.1\times1.6}\times100 \cong 0.5\times100\ \text{V} = 50\ \text{V}$$

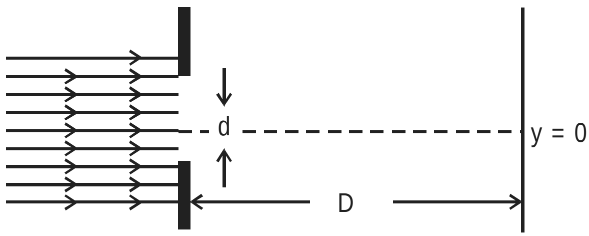
102. If a strong diffraction peak is observed when electrons are incident at an angle 'i' from the normal to the crystal planes with distance 'd' between them (see figure), de Broglie wavelength λ_{dB} of electrons can be calculated by the relationship (n is an integer)

(1) $d\cos i = n\lambda_{dB}$ (2) $d\sin i = n\lambda_{dB}$ (3) $2d\cos i = n\lambda_{dB}$ (4) $2d\sin i = n\lambda_{dB}$

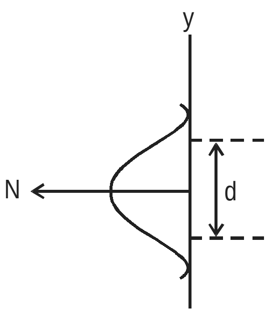
Sol. (3)

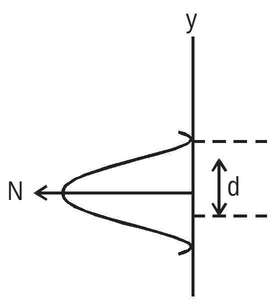
$2d\cos i = n\lambda_{dB}$ (for particles, λ corresponds to de-Broglie waveelength).

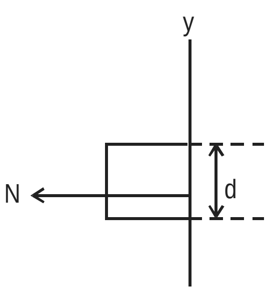
103. In an experiment, electrons are made to pass through a narrow slit of width 'd' comparable to their de Broglie wavelength. They are detected on a screen at a distance 'D' from the slit (see figure)

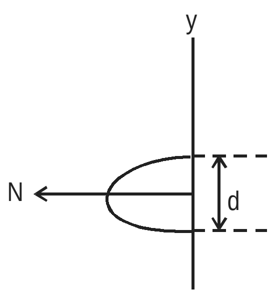


Which of the following graphs can be expected to represent the number of electrons 'N' detected as a function of the detector position 'y' (y = 0 corresponds to the middle of the slit)?

(1) 

(2) 

(3) 

(4) 

Sol. (1)

$d\sin\theta = n\lambda$

$\lambda \simeq d$

$\Rightarrow \sin\theta \simeq n$ (possible for n = 1 only)

104. A planet in a distant solar system is 10 times more massive than the earth and its radius is 10 times smaller. Given that the escape velocity from the earth is 11 km s^{-1}, the escape velocity from the surface of the planet would be

(1) $0.11\,km\ s^{-1}$ (2) $1.1\,km\ s^{-1}$ (3) $11\,km\ s^{-1}$ (4) $110\ km\ s^{-1}$

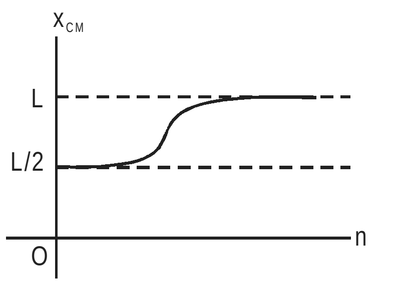
Sol. (4)

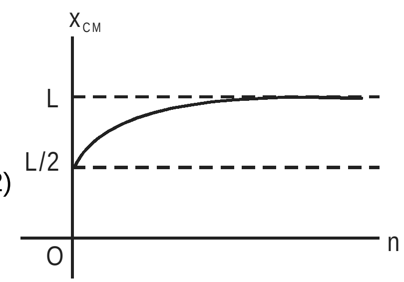
$$V_{es} = \sqrt{\frac{2GM_e}{R_e}} = 11\ km/s$$

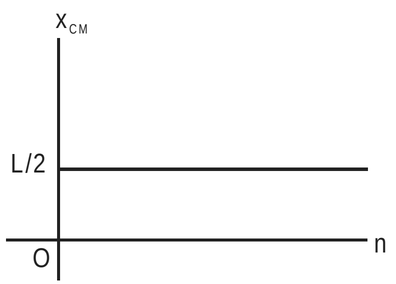
$$V'_{es} = \sqrt{\frac{2GM}{R}}\ ;\ M = 10Me,\ R = \frac{R_e}{10}$$

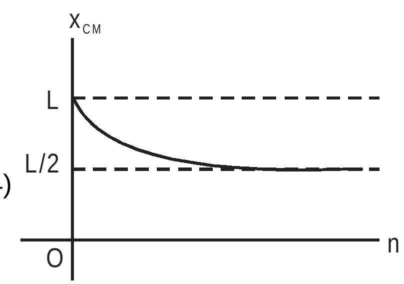
$$= \sqrt{\frac{2GM_e}{R_e} \times 100} = 10 \times 11\,km/s = 110\ km/s$$

105. A thin rod of length 'L' is lying along the x-axis with its ends at x = 0 and x = L. Its linear density (mass/length) varies with x as $k\left(\frac{x}{L}\right)^n$, where n can be zero or any positive number. If the position x_{CM} of the centre of the mass of the rod is plotted against 'n', which of the following graphs best approximates the dependence of x_{CM} on n?

(1)


(2)


(3)


(4)


Sol. (2)

$$\lambda = k\left(\frac{x}{L}\right)^n$$

$$x_{CM} = \frac{\int x\, dm}{\int dm} = \frac{\int_0^L x\,\lambda\, dx}{\int_0^L \lambda\, dx}$$

$$= \frac{\int_0^L \frac{k}{L^n}\, x^{n+1}\, dx}{\int_0^L \frac{k}{L^n}\, dx} = \left.\frac{(n+1)_x\,(n+2)}{(n+2)_x\,(n+1)}\right]_0^L$$

$$= \left(\frac{n+1}{n+2}\right)L$$

$$x_{CM} = L - \frac{L}{n+2}$$