

FINAL JEE-MAIN EXAMINATION – APRIL, 2024

(Held On Thursday 04th April, 2024)

TIME : 3 : 00 PM to 6 : 00 PM

PHYSICS

TEST PAPER WITH SOLUTION

SECTION-A

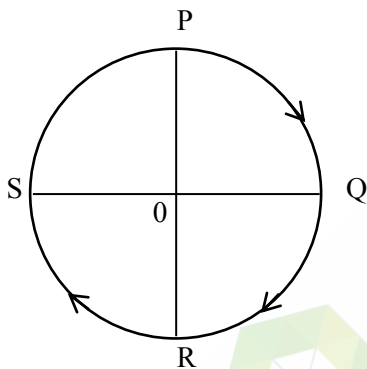
31. The translational degrees of freedom (f_t) and rotational degrees of freedom (f_r) of CH_4 molecule are :

- (1) $f_t = 2$ and $f_r = 2$ (2) $f_t = 3$ and $f_r = 3$
 (3) $f_t = 3$ and $f_r = 2$ (4) $f_t = 2$ and $f_r = 3$

Ans. (2)

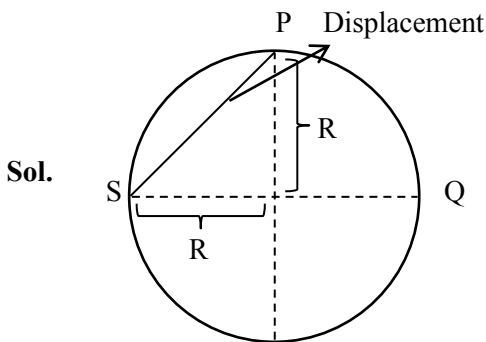
Sol. Since CH_4 is polyatomic Non-Linear
 D.O.F of CH_4
 T. DOF = 3
 R DOF = 3

32. A cyclist starts from the point P of a circular ground of radius 2 km and travels along its circumference to the point S. The displacement of a cyclist is :



- (1) 6 km (2) $\sqrt{8}$ km
 (3) 4 km (4) 8 km

Ans. (2)



Sol.

\therefore Displacement = $R\sqrt{2} = 2\sqrt{2} = \sqrt{8}$ km

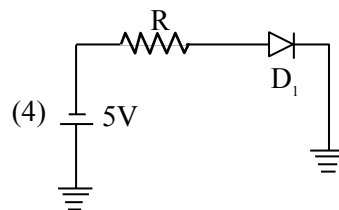
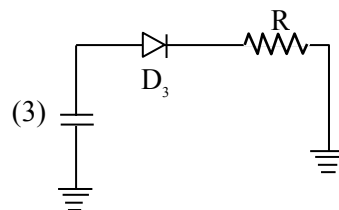
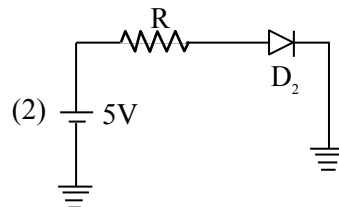
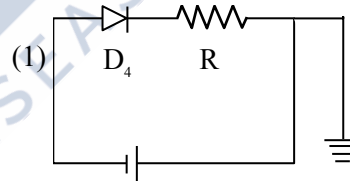
33. The magnetic moment of a bar magnet is 0.5 Am^2 . It is suspended in a uniform magnetic field of $8 \times 10^{-2} \text{ T}$. The work done in rotating it from its most stable to most unstable position is :

- (1) $16 \times 10^{-2} \text{ J}$ (2) $8 \times 10^{-2} \text{ J}$
 (3) $4 \times 10^{-2} \text{ J}$ (4) Zero

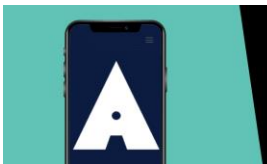
Ans. (2)

Sol. At stable equilibrium
 $U = -mB \cos 0^\circ = -mB$
 At unstable equilibrium
 $U = -mB \cos 180^\circ = +mB$
 $W = \Delta U$
 $W.D. = 2 mB$
 $= 2 (0.5) 8 \times 10^{-2} = 8 \times 10^{-2} \text{ J}$

34. Which of the diode circuit shows correct biasing used for the measurement of dynamic resistance of p-n junction diode :



Ans. (2)



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Sol. Diode should be in forward biased to calculate dynamic resistance

Hence correct answer would be 2.

35. Arrange the following in the ascending order of wavelength :

- (A) Gamma rays (λ_1) (B) x-ray (λ_2)
(C) Infrared waves (λ_3) (D) Microwaves (λ_4)

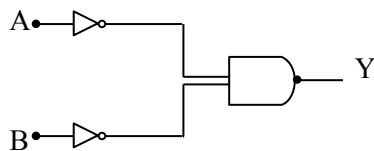
Choose the most appropriate answer from the options given below :

- (1) $\lambda_4 < \lambda_3 < \lambda_1 < \lambda_2$ (2) $\lambda_4 < \lambda_3 < \lambda_2 < \lambda_1$
(3) $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$ (4) $\lambda_2 < \lambda_1 < \lambda_4 < \lambda_3$

Ans. (3)

Sol. $\lambda_1 < \lambda_2 < \lambda_3 < \lambda_4$

36. Identify the logic gate given in the circuit :



- (1) NAND - gate (2) OR - gate
(3) AND gate (4) NOR gate

Ans. (2)

Sol. $Y = \overline{\overline{A} \cdot \overline{B}}$

By De-Morgan Law

$$Y = \overline{\overline{A} \cdot \overline{B}}$$

$$Y = A + B$$

Hence OR gate

37. The width of one of the two slits in a Young's double slit experiment is 4 times that of the other slit. The ratio of the maximum of the minimum intensity in the interference pattern is :

- (1) 9 : 1 (2) 16 : 1
(3) 1 : 1 (4) 4 : 1

Ans. (1)

Sol. Since, Intensity \propto width of slit (ω)

so, $I_1 = I$, $I_2 = 4I$

$$I_{\min} = (\sqrt{I_1} - \sqrt{I_2})^2 = I$$

$$I_{\max} = (\sqrt{I_1} + \sqrt{I_2})^2 = 9I$$

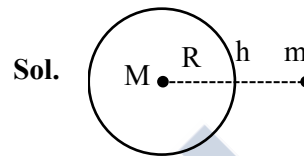
$$\frac{I_{\max}}{I_{\min}} = \frac{9I}{I} = \frac{9}{1}$$

38. Correct formula for height of a satellite from earth's surface is :

$$(1) \left(\frac{T^2 R^2 g}{4\pi} \right)^{1/2} - R \quad (2) \left(\frac{T^2 R^2 g}{4\pi^2} \right)^{1/3} - R$$

$$(3) \left(\frac{T^2 R^2}{4\pi^2 g} \right)^{1/3} - R \quad (4) \left(\frac{T^2 R^2}{4\pi^2} \right)^{-1/3} + R$$

Ans. (2)



Sol.

$$\Rightarrow \frac{GMm}{(R+h)^2} = \frac{mv^2}{(R+h)}$$

$$\Rightarrow \frac{GM}{(R+h)} = v^2 \dots (1)$$

$$\Rightarrow v = (R+h)\omega$$

$$\Rightarrow v = (R+h) \frac{2\pi}{T} \dots (2)$$

$$\Rightarrow \frac{GM}{R^2} = g$$

$$\Rightarrow GM = gR^2 \dots (3)$$

Put value from (2) & (3) in eq. (1)

$$\Rightarrow \frac{gR^2}{(R+h)} = (R+h)^2 \left(\frac{2\pi}{T} \right)^2$$

$$\Rightarrow \frac{T^2 R^2 g}{(2\pi)^2} = (R+h)^3$$

$$\Rightarrow \left[\frac{T^2 R^2 g}{(2\pi)^2} \right]^{1/3} - R = h$$



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39. Match List I with List II

	List-I		List-II
A.	Purely capacitive circuit	I.	
B.	Purely inductive circuit	II.	
C.	LCR series at resonance	III.	
D.	LCR series circuit	IV.	

Choose the correct answer from the options given below :

- (1) A-I, B-IV, C-III, D-II
- (2) A-IV, B-I, C-III, D-II
- (3) A-IV, B-I, C-II, D-III
- (4) A-I, B-IV, C-II, D-III

Ans. (4)

Sol. A – V lags by 90° from I hence option (I) is correct.

B – V lead by 90° from I hence option (IV) is correct

C – In LCR resonance $X_L = X_C$. Hence circuit is purely resistive so option (II) is correct

D – In LCR series V is at some angle from I hence (III) is correct

Hence option (4) is correct.

40. Given below are two statements :

Statement I : The contact angle between a solid and a liquid is a property of the material of the solid and liquid as well.

Statement II : The rise of a liquid in a capillary tube does not depend on the inner radius of the tube.

In the light of the above statements, choose the correct answer from the options given below :

- (1) Both Statement I and Statement II are false
- (2) Statement I is false but Statement II is true.
- (3) Statement I is true but Statement II is false.
- (4) Both Statement I and Statement II are true.

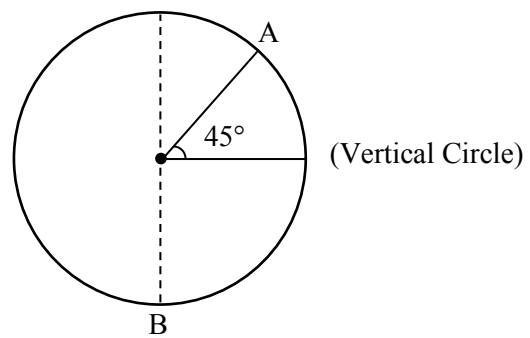
Ans. (3)

Sol. Statement I is correct as we know contact angle depends on cohesive and adhesive forces.

Statement II is incorrect because height of liquid is given by $h = \frac{2T \cos \theta_c}{\rho g r}$ where r is radius of

Tube (assuming length of capillary is sufficient) Hence option (3) is correct.

41. A body of m kg slides from rest along the curve of vertical circle from point A to B in friction less path. The velocity of the body at B is :



(given, $R = 14 \text{ m}$, $g = 10 \text{ m/s}^2$ and $\sqrt{2} = 1.4$)

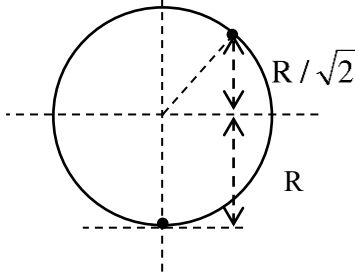
- (1) 19.8 m/s
- (2) 21.9 m/s
- (3) 16.7 m/s
- (4) 10.6 m/s

Ans. (2)

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Sol.



Apply W.E.T. from A to B

$$\Rightarrow W_{mg} = K_B - K_A$$

$$\Rightarrow mg \times \left(\frac{R}{\sqrt{2}} + R \right) = \frac{1}{2} m v_B^2 - 0 \quad \{v_A = 0 \text{ rest}\}$$

$$\Rightarrow mgR \frac{(\sqrt{2} + 1)}{\sqrt{2}} = \frac{1}{2} m v_B^2$$

$$\Rightarrow \sqrt{gR \frac{2(\sqrt{2} + 1)}{\sqrt{2}}} = v_B$$

$$\Rightarrow \sqrt{\frac{10 \times 14 \times 2(2.4)}{1.4}} = v_B$$

$$\Rightarrow 21.9 = v_B$$

Hence option (2) is correct

42. An electric bulb rated 50 W – 200 V is connected across a 100 V supply. The power dissipation of the bulb is :

- (1) 12.5 W (2) 25 W
(3) 50 W (4) 100 W

Ans. (1)

Sol. Rated power & voltage gives resistance

$$R = \frac{V^2}{P} = \frac{(200)^2}{50} = \frac{40000}{50}$$

$$R = 800$$

$$P = \frac{(V_{\text{applied}})^2}{R} = \frac{(100)^2}{800}$$

$$P = 12.5 \text{ watt}$$

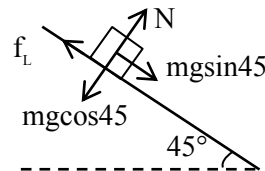
Hence option 1 is correct.

43. A 2 kg brick begins to slide over a surface which is inclined at an angle of 45° with respect to horizontal axis. The co-efficient of static friction between their surfaces is :

- (1) 1 (2) $\frac{1}{\sqrt{3}}$
(3) 0.5 (4) 1.7

Ans. (1)

Sol.



$$mg \sin 45 = f_L$$

$$mg \cos 45 = N$$

$$f_L = \mu_s N$$

$$\mu_s = \tan 45 = 1$$

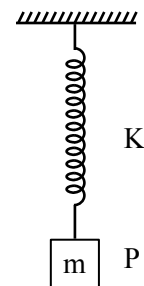
or

$$\tan \theta = \mu_s \quad (\theta \text{ is angle of repose})$$

$$\tan 45 = \mu_s = 1$$

correct option (1)

44. In simple harmonic motion, the total mechanical energy of given system is E. If mass of oscillating particle P is doubled then the new energy of the system for same amplitude is :



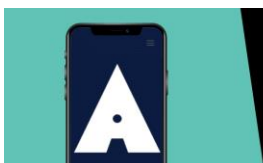
(1) $\frac{E}{\sqrt{2}}$ (2) E

(3) $E\sqrt{2}$ (4) 2E

Ans. (2)

Sol. T.E. = $\frac{1}{2} kA^2$

since A is same T.E. will be same
correct option (2)



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45. Given below are two statements : one is labelled as **Assertion A** and the other is labelled as **Reason R**.
Assertion A : Number of photons increases with increase in frequency of light.

Reason R : Maximum kinetic energy of emitted electrons increases with the frequency of incident radiation.

In the light of the above statements, choose the **most appropriate** answer from the options given below :

- (1) Both **A** and **R** are correct and **R** is **NOT** the correct explanation of **A**.
- (2) **A** is correct but **R** is not correct.
- (3) Both **A** and **R** are correct and **R** is the correct explanation of **A**.
- (4) **A** is not correct but **R** is correct.

Ans. (4)

Sol. Intensity of light $I = \frac{nh\nu}{A}$

Here n is no. of photons per unit time.

$n = \frac{IA}{h\nu}$ so on increasing frequency ν , n decreases taking intensity constant.

$K_{\max} = h\nu - \phi$

So on increasing ν , kinetic energy increases.

46. According to Bohr's theory, the moment of momentum of an electron revolving in 4th orbit of hydrogen atom is :

- (1) $8 \frac{h}{\pi}$
- (2) $\frac{h}{\pi}$
- (3) $2 \frac{h}{\pi}$
- (4) $\frac{h}{2\pi}$

Ans. (3)

Sol. Moment of momentum is $\vec{r} \times \vec{P}$

$\vec{L} = \vec{r} \times m\vec{v}$

$L = mvr = \frac{nh}{2\pi} = \frac{4h}{2\pi} = \frac{2h}{\pi}$

47. A sample of gas at temperature T is adiabatically expanded to double its volume. Adiabatic constant for the gas is $\gamma = 3/2$. The work done by the gas in the process is : ($\mu = 1$ mole)

- (1) $RT[\sqrt{2} - 2]$
- (2) $RT[1 - 2\sqrt{2}]$
- (3) $RT[2\sqrt{2} - 1]$
- (4) $RT[2 - \sqrt{2}]$

Ans. (4)

Sol. $W = \frac{nR\Delta T}{1 - \gamma}$

$TV^{\gamma-1} = \text{const} \Rightarrow T = T_f(2V)^{\gamma-1}$

$T_f = T\left(\frac{1}{2}\right)^{1/2} = \frac{T}{\sqrt{2}}$

$W = \frac{R\left(\frac{T}{\sqrt{2}} - T\right)}{1 - \frac{3}{2}} = 2RT \frac{(\sqrt{2} - 1)}{\sqrt{2}}$

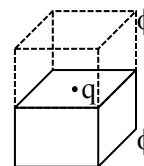
$= RT(2 - \sqrt{2})$

48. A charge q is placed at the center of one of the surface of a cube. The flux linked with the cube is :-

- (1) $\frac{q}{4\epsilon_0}$
- (2) $\frac{q}{2\epsilon_0}$
- (3) $\frac{q}{8\epsilon_0}$
- (4) Zero

Ans. (2)

Sol. From



$2\phi = \frac{q}{\epsilon_0}$

$\phi = \frac{q}{2\epsilon_0}$

49. Applying the principle of homogeneity of dimensions, determine which one is correct.
where T is time period, G is gravitational constant, M is mass, r is radius of orbit.

$$(1) T^2 = \frac{4\pi^2 r}{GM^2} \quad (2) T^2 = 4\pi^2 r^3$$

$$(3) T^2 = \frac{4\pi^2 r^3}{GM} \quad (4) T^2 = \frac{4\pi^2 r^2}{GM}$$

Ans. (3)

Sol. According to principle of homogeneity dimension of LHS should be equal to dimensions of RHS so option (3) is correct.

$$T^2 = \frac{4\pi^2 r^3}{GM}$$

$$[T^2] = \frac{[L^3]}{[M^{-1}L^3T^{-2}][M]}$$

(Dimension of G is $[M^{-1}L^3T^{-2}]$)

$$[T^2] = \frac{[L^3]}{[L^3T^{-2}]} = [T^2]$$

50. A 90 kg body placed at 2R distance from surface of earth experiences gravitational pull of:
(R = Radius of earth, $g = 10 \text{ ms}^{-2}$)
- (1) 300 N (2) 225 N
(3) 120 N (4) 100 N

Ans. (4)

Sol. Value of $g = g_s \left(1 + \frac{h}{R}\right)^{-2}$

$$= g_s (1+2)^{-2} = \frac{g_s}{9}$$

Here g_s = gravitational acceleration at surface

$$\text{Force} = mg = 90 \times \frac{g_s}{9} = 100 \text{ N}$$

SECTION-B

51. The displacement of a particle executing SHM is given by $x = 10 \sin\left(\omega t + \frac{\pi}{3}\right)$ m. The time period of motion is 3.14 s. The velocity of the particle at $t = 0$ is _____ m/s.

Ans. (10)

Sol. Given,

$$T = 3.14 = \frac{2\pi}{\omega}$$

$$\omega = 2 \text{ rad/s}$$

$$x = 10 \sin\left(\omega t + \frac{\pi}{3}\right)$$

$$v = \frac{dx}{dt} = 10\omega \cos\left(\omega t + \frac{\pi}{3}\right)$$

at $t = 0$

$$v = 10\omega \cos\left(\frac{\pi}{3}\right) = 10 \times 2 \times \frac{1}{2} \text{ [using } \omega = 2 \text{ rad/s]}$$

$$v = 10 \text{ m/s}$$

52. A bus moving along a straight highway with speed of 72 km/h is brought to halt within 4s after applying the brakes. The distance travelled by the bus during this time (Assume the retardation is uniform) is _____ m.

Ans. (40)

Sol. Initial velocity = $u = 72 \text{ km/h} = 20 \text{ m/s}$

$$v = u + at$$

$$\Rightarrow 0 = 20 + a \times 4$$

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

$$v^2 - u^2 = 2as$$

$$\Rightarrow 0^2 - 20^2 = 2(-5)s$$

$$s = 40 \text{ m}$$

53. A parallel plate capacitor of capacitance 12.5 pF is charged by a battery connected between its plates to potential difference of 12.0 V. The battery is now disconnected and a dielectric slab ($\epsilon_r = 6$) is inserted between the plates. The change in its potential energy after inserting the dielectric slab is _____ $\times 10^{-12}$ J.

Ans. (750)



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Sol. Before inserting dielectric capacitance is given $C_0 = 12.5 \text{ pF}$ and charge on the capacitor $Q = C_0 V$
After inserting dielectric capacitance will become $\epsilon_r C_0$.

Change in potential energy of the capacitor = $E_i - E_f$

$$= \frac{Q^2}{2C_i} - \frac{Q^2}{2C_f} = \frac{Q^2}{2C_0} \left[1 - \frac{1}{\epsilon_r} \right]$$

$$= \frac{(C_0 V)^2}{2C_0} \left[1 - \frac{1}{\epsilon_r} \right] = \frac{1}{2} C_0 V^2 \left[1 - \frac{1}{\epsilon_r} \right]$$

Using $C_0 = 12.5 \text{ pF}$, $V = 12 \text{ V}$, $\epsilon_r = 6$

$$= \frac{1}{2} (12.5) \times 12^2 \left[1 - \frac{1}{6} \right] = \frac{1}{2} (12.5) \times 12^2 \times \frac{5}{6}$$

$$= 750 \text{ pJ} = 750 \times 10^{-12} \text{ J}$$

54. In a system two particles of masses $m_1 = 3\text{kg}$ and $m_2 = 2\text{kg}$ are placed at certain distance from each other. The particle of mass m_1 is moved towards the center of mass of the system through a distance 2cm . In order to keep the center of mass of the system at the original position, the particle of mass m_2 should move towards the center of mass by the distance ____ cm.

Ans. (3)

Sol. $m_1 = 3\text{kg}$ $m_2 = 2\text{kg}$

$$\Delta X_{\text{C.O.M.}} = \frac{m_1 \Delta x_1 + m_2 \Delta x_2}{m_1 + m_2}$$

$$\Rightarrow 0 = \frac{3 \times 2 + 2(-x)}{3 + 2}$$

$$\Rightarrow x = 3 \text{ cm}$$

55. The disintegration energy Q for the nuclear fission of $^{235}\text{U} \rightarrow ^{140}\text{Ce} + ^{94}\text{Zr} + n$ is ____ MeV.

Given atomic masses of

$^{235}\text{U} : 235.0439\text{u}$, $^{140}\text{Ce} : 139.9054\text{u}$,

$^{94}\text{Zr} : 93.9063\text{u}$, $n : 1.0086\text{u}$,

Value of $c^2 = 931 \text{ MeV/u}$.

Ans. (208)

Sol. $^{235}\text{U} \rightarrow ^{140}\text{Ce} + ^{94}\text{Zr} + n$

Disintegration energy

$$Q = (m_R - m_P) \cdot c^2$$

$$m_R = 235.0439 \text{ u}$$

$$m_P = 139.9054\text{u} + 93.9063\text{u} + 1.0086 \text{ u}$$

$$= 234.8203\text{u}$$

$$Q = (235.0439\text{u} - 234.8203\text{u})c^2$$

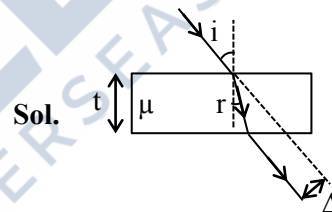
$$= 0.2236 \text{ c}^2$$

$$= 0.2236 \times 931$$

$$Q = 208.1716$$

56. A light ray is incident on a glass slab of thickness $4\sqrt{3} \text{ cm}$ and refractive index $\sqrt{2}$. The angle of incidence is equal to the critical angle for the glass slab with air. The lateral displacement of ray after passing through glass slab is ____ cm.
(Given $\sin 15^\circ = 0.25$)

Ans. (2)



$$i = \theta_c$$

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

$$\Rightarrow i = 45^\circ$$

and according to snell's law

$$1 \sin 45^\circ = \sqrt{2} \sin r$$

$$\Rightarrow r = 30^\circ$$

$$\text{Lateral displacement } \Delta = \frac{t \sin(i - r)}{\cos r}$$

$$\Rightarrow \Delta = \frac{4\sqrt{3} \times \sin 15^\circ}{\cos 30^\circ}$$

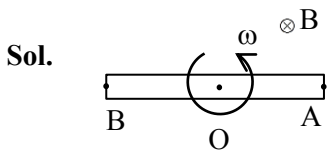
$$\Rightarrow \Delta = 2\text{cm}$$

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57. A rod of length 60 cm rotates with a uniform angular velocity 20 rad s^{-1} about its perpendicular bisector, in a uniform magnetic field 0.5 T. The direction of magnetic field is parallel to the axis of rotation. The potential difference between the two ends of the rod is ____ V.

Ans. (0)



$$\therefore V_0 - V_A = \frac{B\omega l^2}{2}$$

$$V_0 - V_B = \frac{B\omega l^2}{2}$$

$$\therefore V_A = V_B \therefore V_A - V_B = 0$$

58. Two wires A and B are made up of the same material and have the same mass. Wire A has radius of 2.0 mm and wire B has radius of 4.0 mm. The resistance of wire B is 2Ω . The resistance of wire A is ____ Ω .

Ans. (32)

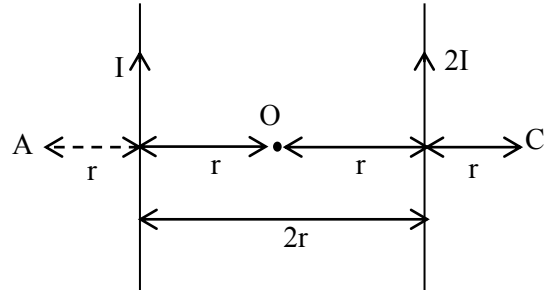
Sol. $\therefore R = \frac{\rho l}{A} = \frac{\rho V}{A^2}$

$$\therefore \frac{R_A}{R_B} = \frac{A_B^2}{A_A^2} = \frac{l_B^4}{l_A^4}$$

$$\Rightarrow \frac{R_A}{2} = \left[\frac{4 \times 10^{-3}}{2 \times 10^{-3}} \right]^4$$

$$\Rightarrow R_A = 32 \Omega.$$

59. Two parallel long current carrying wire separated by a distance $2r$ are shown in the figure. The ratio of magnetic field at A to the magnetic field produced at C is $\frac{x}{7}$. The value of x is ____.



Ans. (5)

Sol. $B_A = \frac{\mu_0 i}{2\pi r} + \frac{\mu_0 (2i)}{2\pi(3r)} = \frac{5\mu_0 i}{6\pi r}$

$$B_C = \frac{\mu_0 (2i)}{2\pi r} + \frac{\mu_0 i}{2\pi(3r)} = \frac{7\mu_0 i}{6\pi r}$$

$$\therefore \frac{B_A}{B_C} = \frac{5}{7}$$

$$\therefore x = 5$$

60. Mercury is filled in a tube of radius 2 cm up to a height of 30 cm. The force exerted by mercury on the bottom of the tube is ____ N.

(Given, atmospheric pressure = 10^5 Nm^{-2} , density of mercury = $1.36 \times 10^4 \text{ kg m}^{-3}$, $g = 10 \text{ ms}^{-2}$, $\pi = \frac{22}{7}$)

Ans. (177)

Sol. $F = P_0 A + \rho_m g h A$

$$= 10^5 \times \frac{22}{7} \times (2 \times 10^{-2})^2$$

$$+ 1.36 \times 10^4 \times 10 \times (30 \times 10^{-2}) \left(\frac{22}{7} \times (2 \times 10^{-2})^2 \right)$$

$$F = 51.29 + 125.71 = 177 \text{ N}$$



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