FINAL JEE–MAIN EXAMINATION – MARCH, 2021
Held On Thursday 18th March, 2021
TIME: 3:00 PM to 06:00 PM

SECTION-A

1. Which of the following statements are correct?

(A) Electric monopoles do not exist whereas magnetic monopoles exist.

(B) Magnetic field lines due to a solenoid at its ends and outside cannot be completely straight and confined.

(C) Magnetic field lines are completely confined within a toroid.

(D) Magnetic field lines inside a bar magnet are not parallel.

(E) $\chi = -1$ is the condition for a perfect diamagnetic material, where χ is its magnetic susceptibility.

Choose the correct answer from the options given below :

(1) (C) and (E) only
(2) (B) and (D) only
(3) (A) and (B) only
(4) (B) and (C) only

Official Ans. by NTA (1)

Sol. Statement (C) is correct because, the magnetic field outside the toroid is zero and they form closed loops inside the toroid itself.

Statement (E) is correct because we know that super conductors are materials inside which the net magnetic field is always zero and they are perfect diamagnetic.

$\mu_r = 1 + \chi$

$\chi = -1$

$\mu_r = 0$

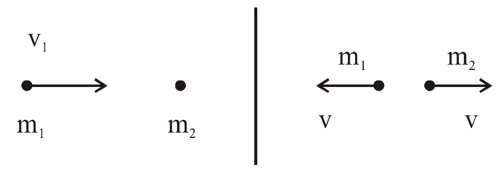
For superconductors.

2. An object of mass m_1 collides with another object of mass m_2, which is at rest. After the collision the objects move with equal speeds in opposite direction. The ratio of the masses $m_2 : m_1$ is :

(1) 3 : 1 (2) 2 : 1
(3) 1 : 2 (4) 1 : 1

Official Ans. by NTA (1)

Sol.



$$m_1v_1 = -m_1v + m_2v$$

$$v_1 = -v + \frac{m_2}{m_1}v$$

$$\frac{(v_1 + v)}{v} = \frac{m_2}{m_1}$$

$$e = \frac{2v}{v_1} = 1$$

$$v = \frac{v_1}{2}$$

$$\frac{v_1 + v_1/2}{v_1/2} = \frac{m_2}{m_1}$$

$$3 = \frac{m_2}{m_1}$$

3. For an adiabatic expansion of an ideal gas, the fractional change in its pressure is equal to (where γ is the ratio of specific heats):

(1) $-\gamma\frac{dV}{V}$ (2) $-\gamma\frac{V}{dV}$

(3) $-\frac{1}{\gamma}\frac{dV}{V}$ (4) $\frac{dV}{V}$

Official Ans. by NTA (1)

Sol. PV^{γ} = constant

Differentiating

$$\frac{dP}{dV} = -\frac{\gamma P}{V}$$

$$\frac{dP}{P} = -\frac{\gamma dV}{V}$$

4. A proton and an α-particle, having kinetic energies K_p and K_α, respectively, enter into a magnetic field at right angles.

The ratio of the radii of trajectory of proton to that of α-particle is 2 : 1. The ratio of $K_p : K_\alpha$ is :

(1) 1 : 8 (2) 8 : 1

(3) 1 : 4 (4) 4 : 1

Official Ans. by NTA (4)

Sol. $r = \frac{mv}{qB} = \frac{p}{qB}$ $\frac{m_\alpha}{m_p} = 4$

$$\frac{r_p}{r_\alpha} = \frac{p_p}{q_p}\frac{q_\alpha}{p_\alpha} = \frac{2}{1}$$

$$\frac{p_p}{p_\alpha} = \frac{2q_p}{q_\alpha} = 2\left(\frac{1}{2}\right)$$

$$\frac{p_p}{p_\alpha} = 1$$

$$\frac{K_p}{K_\alpha} = \frac{p_p^2}{p_\alpha^p}\frac{m_\alpha}{m_p} = (1)\ (4)$$

5. A plane electromagnetic wave propagating along y-direction can have the following pair of electric field $(\vec{E})$ and magnetic field $(\vec{B})$ components.

(1) E_y, B_y or E_z, B_z

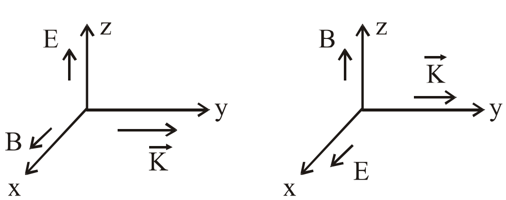
(2) E_y, B_x or E_x, B_y

(3) E_x, B_z or E_z, B_x

(4) E_x, B_y or E_y, B_x

Official Ans. by NTA (3)

Sol.



6. Consider a uniform wire of mass M and length L. It is bent into a semicircle. Its moment of inertia about a line perpendicular to the plane of the wire passing through the centre is :

(1) $\frac{1}{4}\frac{ML^2}{\pi^2}$ (2) $\frac{2}{5}\frac{ML^2}{\pi^2}$

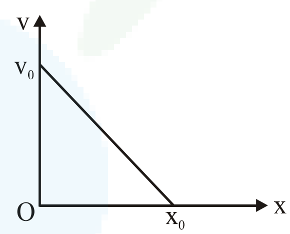
(3) $\frac{ML^2}{\pi^2}$ (4) $\frac{1}{2}\frac{ML^2}{\pi^2}$

Official Ans. by NTA (3)

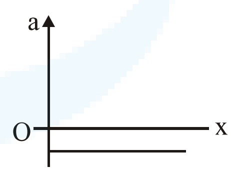
Sol. $\pi r = L \Rightarrow r = \frac{L}{\pi}$

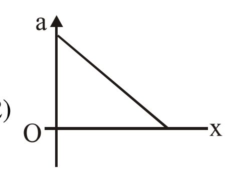
$$I = Mr^2 = \frac{ML^2}{\pi^2}$$

7. The velocity-displacement graph of a particle is shown in the figure.



The acceleration-displacement graph of the same particle is represented by :

(1)


(2)


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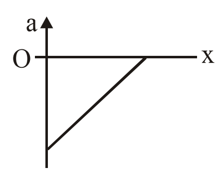

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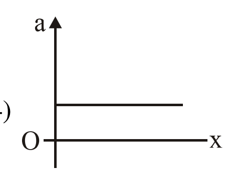


Official Ans. by NTA (3)

Sol. $v = -\left(\frac{v_0}{x_0}\right)x + v_0$

$$a = \frac{vdv}{dx}$$

$$a = \left[-\left(\frac{v_0}{x_0}\right)x + v_0\right]\left[-\frac{v_0}{x_0}\right]$$

$$a = \left(\frac{v_0}{x_0}\right)^2 x - \frac{v_0^2}{x_0}$$

8. The correct relation between α (ratio of collector current to emitter current) and β (ratio of collector current to base current) of a transistor is :

(1) $\beta = \frac{\alpha}{1+\alpha}$

(2) $\alpha = \frac{\beta}{1-\alpha}$

(3) $\beta = \frac{1}{1-\alpha}$

(4) $\alpha = \frac{\beta}{1+\beta}$

Official Ans. by NTA (4)

Sol. $\alpha = \frac{I_C}{I_E}, \beta = \frac{I_C}{I_B}$

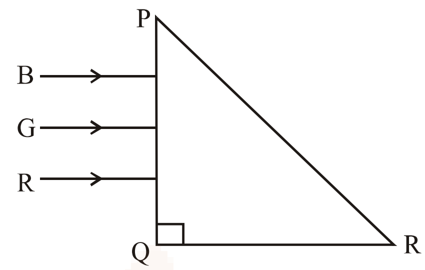
$I_E = I_B + I_C$

$$\alpha = \frac{I_C}{I_B + I_C} = \frac{1}{\frac{I_B}{I_C} + 1}$$

$$\alpha = \frac{1}{\frac{1}{\beta} + 1}$$

$$\alpha = \frac{\beta}{1+\beta}$$

9. Three rays of light, namely red (R), green (G) and blue (B) are incident on the face PQ of a right angled prism PQR as shown in figure.



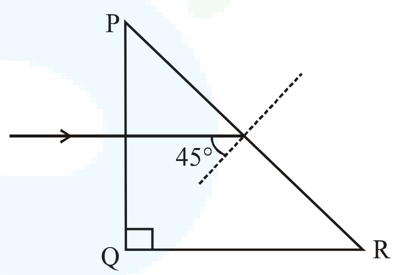
The refractive indices of the material of the prism for red, green and blue wavelength are 1.27, 1.42 and 1.49 respectively. The colour of the ray(s) emerging out of the face PR is :

(1) green (2) red

(3) blue and green (4) blue

Official Ans. by NTA (2)

Sol.



Assuming that the right angled prism is an isoceles prism, so the other angles will be 45° each.

$\Rightarrow$ Each incident ray will make an angle of 45° with the normal at face PR.

$\Rightarrow$ The wavelength corresponding to which the incidence angle is less than the critical angle, will pass through PR.

$\Rightarrow$ θ_C = critical angle

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

$\Rightarrow$ If $\theta_C \geq 45°$

the light ray will pass

$$\Rightarrow (\theta_C)_{Red} = \sin^{-1}\left(\frac{1}{1.27}\right) = 51.94°$$

Red will pass.

$$\Rightarrow (\theta_C)_{Green} = \sin^{-1}\left(\frac{1}{1.42}\right) = 44.76°$$

Green will not pass

$$\Rightarrow (\theta_C)_{Blue} = \sin^{-1}\left(\frac{1}{1.49}\right) = 42.15°$$

Blue will not pass

$\Rightarrow$ So only red will pass through PR.

10. If the angular velocity of earth's spin is increased such that the bodies at the equator start floating, the duration of the day would be approximately :

(Take : $g = 10\ ms^{-2}$, the radius of earth, $R = 6400 \times 10^3$ m, Take $\pi = 3.14$)

(1) 60 minutes

(2) does not change

(3) 1200 minutes

(4) 84 minutes

Official Ans. by NTA (4)

Sol. For objects to float

$mg = m\omega^2R$

ω = angular velocity of earth.

R = Radius of earth

$$\omega = \sqrt{\frac{g}{R}} \quad \text{... (1)}$$

Duration of day = T

$$T = \frac{2\pi}{\omega} \quad \text{... (2)}$$

$$\Rightarrow T = 2\pi\sqrt{\frac{R}{g}}$$

$$= 2\pi\sqrt{\frac{6400 \times 10^3}{10}}$$

$$\Rightarrow \frac{T}{60} = 83.775 \text{ minutes}$$

$\simeq$ 84 minutes

11. The decay of a proton to neutron is :

(1) not possible as proton mass is less than the neutron mass

(2) possible only inside the nucleus

(3) not possible but neutron to proton conversion is possible

(4) always possible as it is associated only with β^+ decay

Official Ans. by NTA (2)

Sol. It is possible only inside the nucleus and not otherwise.

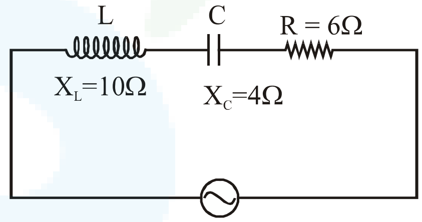
12. In a series LCR circuit, the inductive reactance (X_L) is 10 Ω and the capacitive reactance (X_C) is 4 Ω. The resistance (R) in the circuit is 6 Ω. The power factor of the circuit is :

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

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

Official Ans. by NTA (3)

Sol.

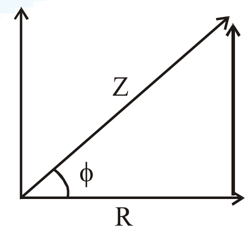


We know that power factor is $\cos\phi$,

$$\cos\phi = \frac{R}{Z} \quad \text{... (1)}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \text{... (2)}$$

($\omega L - 1/\omega C$)



$$\Rightarrow Z = \sqrt{6^2 + (10-4)^2}$$

$$\Rightarrow Z = 6\sqrt{2} \mid \cos\phi = \frac{6}{6\sqrt{2}}$$

$$\cos\phi = \frac{1}{\sqrt{2}}$$

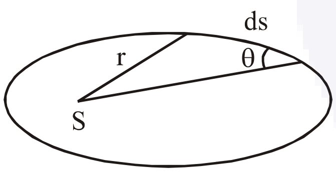
13. The angular momentum of a planet of mass M moving around the sun in an elliptical orbit is $\vec{L}$. The magnitude of the areal velocity of the planet is :

(1) $\frac{4L}{M}$ (2) $\frac{L}{M}$

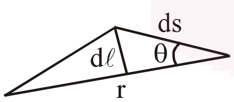
(3) $\frac{2L}{M}$ (4) $\frac{L}{2M}$

Official Ans. by NTA (4)

Sol.



For small displacement ds of the planet its area can be written as



$$dA = \frac{1}{2} r d\ell$$

$$= \frac{1}{2} r ds \sin\theta$$

$$\text{A.vel} = \frac{dA}{dt} = \frac{1}{2} r \sin\theta \frac{ds}{dt} = \frac{Vr\sin\theta}{2}$$

$$\frac{dA}{dt} = \frac{1}{2}\frac{mVr\sin\theta}{m} = \frac{L}{2m}$$

14. The function of time representing a simple harmonic motion with a period of $\frac{\pi}{\omega}$ is :

(1) $\sin(\omega t) + \cos(\omega t)$

(2) $\cos(\omega t) + \cos(2\omega t) + \cos(3\omega t)$

(3) $\sin^2(\omega t)$

(4) $3\cos\left(\frac{\pi}{4} - 2\omega t\right)$

Official Ans. by NTA (4)

Sol. Time period $T = \frac{2\pi}{\omega'}$

$$\frac{\pi}{\omega} = \frac{2\pi}{\omega'}$$

$\omega' = 2\omega \rightarrow$ Angular frequency of SHM

Option (3)

$$\sin^2 \omega t = \frac{1}{2}\left(2\sin^2 \omega t\right) = \frac{1}{2}\left(1 - \cos 2\omega t\right)$$

Angular frequency of $\left(\frac{1}{2} - \frac{1}{2}\cos 2\omega t\right)$ is 2ω

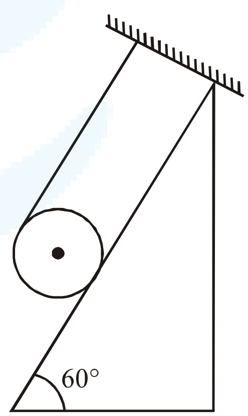
Option (4)

Angular frequency of SHM

$3\cos\left(\frac{\pi}{4} - 2\omega t\right)$ is 2ω.

So option (3) & (4) both have angular frequency 2ω but option (4) is direct answer.

15. A solid cylinder of mass m is wrapped with an inextensible light string and, is placed on a rough inclined plane as shown in the figure. The frictional force acting between the cylinder and the inclined plane is :



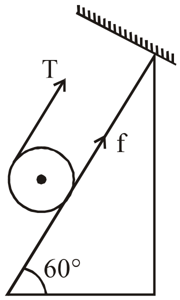
[The coefficient of static friction, μ_s, is 0.4]

(1) $\frac{7}{2}mg$ (2) 5 mg

(3) $\frac{mg}{5}$ (4) 0

Official Ans. by NTA (3)

Sol.



Let's take solid cylinder is in equilibrium

T + f = mg sin60 ....(i)

TR – fR = 0 ....(ii)

Solving we get

$$T = f_{req} = \frac{mg\sin\theta}{2}$$

But limiting friction < required friction

$$\mu mg\cos 60° < \frac{mg\sin 60°}{2}$$

∴ Hence cylinder will not remain in equilibrium

Hence f = kinetic

$= \mu_k N$

$= \mu_k mg\cos 60°$

$$= \frac{mg}{5}$$

16. The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance R, inductance L is connected to a battery, is :

(1) $\frac{L}{R}\ell n5$ (2) infinite

(3) $\frac{L}{R}\ell n2$ (4) $\frac{L}{R}\ell n10$

Official Ans. by NTA (3)

Sol. Magnetic energy = $\frac{1}{2}Li^2 = 25\%$

$$ME \Rightarrow 25\% \Rightarrow i = \frac{i_0}{2}$$

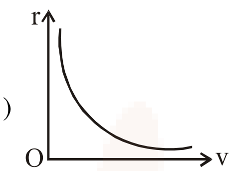
$$i = i_0(1 - R^{-Rt/L}) \text{ for charging}$$

$$t = \frac{L}{R}\ell n2$$

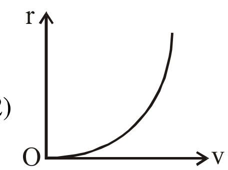
17. A particle of mass m moves in a circular orbit under the central potential field, $U(r) = \frac{-C}{r}$, where C is a positive constant.

The correct radius – velocity graph of the particle's motion is :

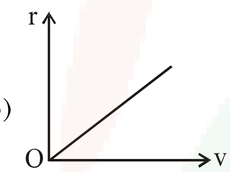
(1)



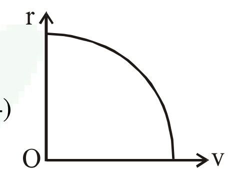
(2)



(3)



(4)



Official Ans. by NTA (1)

Sol. $U = -\frac{C}{r}$

$$F = -\frac{dU}{dr} = -\frac{C}{r^2}$$

$$|F| = \frac{mv^2}{r}$$

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

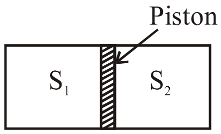
$$v^2 \propto \frac{1}{r}$$

18. An ideal gas in a cylinder is separated by a piston in such a way that the entropy of one part is S_1 and that of the other part is S_2. Given that $S_1 > S_2$. If the piston is removed then the total entropy of the system will be :

(1) $S_1 \times S_2$ (2) $S_1 - S_2$

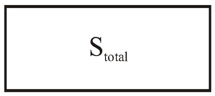
(3) $\frac{S_1}{S_2}$ (4) $S_1 + S_2$

Official Ans. by NTA (4)

Sol. 

; $S_1 > S_2$

After piston is removed



; $S_{total} = S_1 + S_2$

19. Consider a sample of oxygen behaving like an ideal gas. At 300 K, the ratio of root mean square (rms) velocity to the average velocity of gas molecule would be :
(Molecular weight of oxygen is 32 g/mol; R = 8.3 J K^{-1} mol^{-1})

(1) $\sqrt{\frac{3}{3}}$ (2) $\sqrt{\frac{8}{3}}$

(3) $\sqrt{\frac{3\pi}{8}}$ (4) $\sqrt{\frac{8\pi}{3}}$

Official Ans. by NTA (3)

Sol. $v_{rms} = \sqrt{\frac{3RT}{M}}$

$v_{avg} = \sqrt{\frac{8}{\pi}\frac{RT}{M}}$

$\frac{v_{rms}}{v_{avg}} = \sqrt{\frac{3\pi}{8}}$

20. The speed of electrons in a scanning electron microscope is 1×10^7 ms^{-1}. If the protons having the same speed are used instead of electrons, then the resolving power of scanning proton microscope will be changed by a factor of:

(1) 1837 (2) $\frac{1}{1837}$

(3) $\sqrt{1837}$ (4) $\frac{1}{\sqrt{1837}}$

Official Ans. by NTA (1)

Sol. Resolving power (RP) $\propto \frac{1}{\lambda}$

$\lambda = \frac{h}{P} = \frac{h}{mv}$

So (RP) $\propto \frac{mv}{h}$

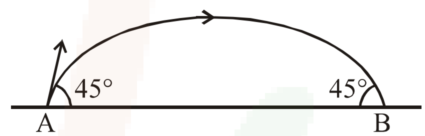
RP $\propto$ P

RP $\propto$ mv

RP $\propto$ m

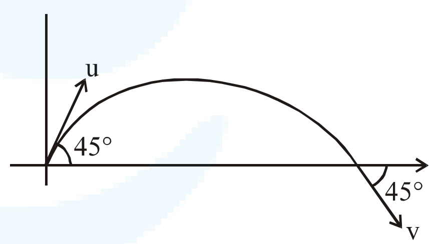
SECTION-B

1. The projectile motion of a particle of mass 5 g is shown in the figure.



The initial velocity of the particle is $5\sqrt{2}$ ms^{-1} and the air resistance is assumed to be negligible. The magnitude of the change in momentum between the points A and B is $x \times 10^{-2}$ $kgms^{-1}$. The value of x, to the nearest integer, is _______.

Official Ans. by NTA (5)

Sol. 

$|\vec{u}| = |\vec{v}|$ ... (1)

$\vec{u} = u\cos 45\hat{i} + u\sin 45\hat{j}$ ... (2)

$\vec{v} = v\cos 45\hat{i} - v\sin 45\hat{j}$ ... (3)

$|\overline{\Delta P}| = |m(\vec{v} - \vec{u})|$ ... (4)

ΔP = 2mu sin 45°

$= 2 \times 5 \times 10^{-3} \times 5\sqrt{2} \times \frac{1}{\sqrt{2}}$

$= 50 \times 10^{-3}$

$= 5 \times 10^{-2}$

2. A ball of mass 4 kg, moving with a velocity of 10 ms^{-1}, collides with a spring of length 8 m and force constant 100 Nm^{-1}. The length of the compressed spring is x m. The value of x, to the nearest integer, is_____.

Official Ans. by NTA (6)

Sol. Let's say the compression in the spring by : y. So, by work energy theorem we have

$$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{2}ky^2$$

$$\Rightarrow y = \sqrt{\frac{m}{k}} \cdot v$$

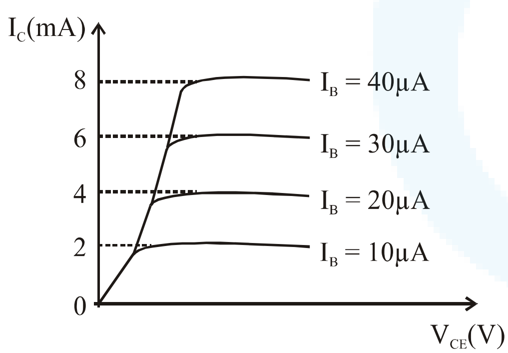
$$\Rightarrow y = \sqrt{\frac{4}{100}} \times 10$$

$\Rightarrow$ y = 2m

$\Rightarrow$ final length of spring

= 8 – 2 = 6m

3. The typical output characteristics curve for a transistor working in the common-emitter configuration is shown in the figure.



The estimated current gain from the figure is

Official Ans. by NTA (200)

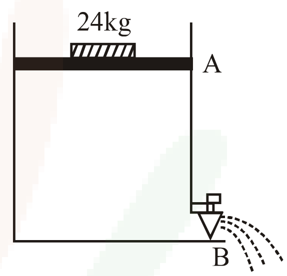
Sol. $\beta = \frac{\Delta I_C}{\Delta I_B} = \frac{2 \times 10^{-3}}{10 \times 10^{-6}}$

$$\beta = \frac{1}{5} \times 10^3$$

β = 2 × 10^2

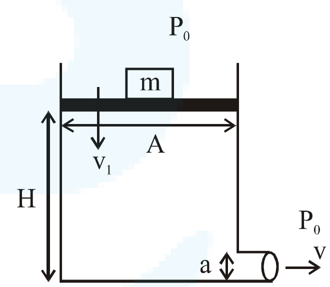
β = 200

4. Consider a water tank as shown in the figure. It's cross-sectional area is 0.4 m^2. The tank has an opening B near the bottom whose cross-section area is 1 cm^2. A load of 24 kg is applied on the water at the top when the height of the water level is 40 cm above the bottom, the velocity of water coming out the opening B is v ms^{-1}. The value of v, to the nearest integer, is___. [Take value of g to be 10 ms^{-2}]



Official Ans. by NTA (3)

Sol.



m = 24 kg

A = 0.4 m^2

a = 1 cm^2

H = 40cm

Using Bernoulli's equation

$$\Rightarrow \left(P_0 + \frac{mg}{A}\right) + \rho gH + \frac{1}{2}\rho v_1^2 \;(\to 0)$$

$$= P_0 + 0 + \frac{1}{2}\rho v^2 \qquad \text{... (1)}$$

$\Rightarrow$ Neglecting v_1

$$\Rightarrow \; v = \sqrt{2gH + \frac{2mg}{A\rho}}$$

$$\Rightarrow \; v = \sqrt{8 + 1.2}$$

$\Rightarrow$ v = 3.033 m/s

$$\Rightarrow \; v \simeq 3 m/s$$

5. A TV transmission tower antenna is at a height of 20 m. Suppose that the receiving antenna is at.

(i) ground level

(ii) a height of 5 m.

The increase in antenna range in case (ii) relative to case (i) is n%.

The value of n, to the nearest integer, is .

Official Ans. by NTA (50)

Sol. Range = $\sqrt{2Rh}$

Range (i) = $\sqrt{2Rh}$

Range (ii) = $\sqrt{2Rh} + \sqrt{2Rh'}$

where h = 20 m & h' = 5m

$$\text{Ans} = \frac{\sqrt{2Rh'}}{\sqrt{2Rh}} \times 100\% = \frac{\sqrt{5}}{\sqrt{20}} \times 100\% = 50\%$$

6. The radius of a sphere is measured to be (7.50 ± 0.85) cm. Suppose the percentage error in its volume is x. The value of x, to the nearest x, is_______.

Official Ans. by NTA (34)

Sol. $\because\; v = \frac{4}{3}\pi r^3$

taking log & then differentiate

$$\frac{dV}{V} = 3\frac{dr}{r}$$

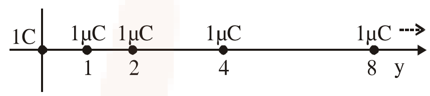
$$= \frac{3 \times 0.85}{7.5} \times 100\% = 34\ \%$$

7. An infinite number of point charges, each carrying 1 μC charge, are placed along the y-axis at y = 1 m, 2 m, 4 m, 8 m................. The total force on a 1 C point charge, placed at the origin, is x × 10^3 N. The value of x, to the nearest integer, is________.

[Take $\frac{1}{4\pi \in_0}$ = 9 × 10^9 Nm^2/C^2]

Official Ans. by NTA (12)

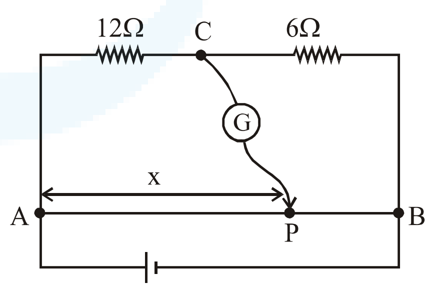
Sol.



$$F = k(1C)(1\mu C)\left[1 + \frac{1}{2^2} + \frac{1}{4^2} + \frac{1}{8^2} + \ldots\right]$$

$$= 9 \times 10^3 \left[\frac{1}{1 - \frac{1}{4}}\right] = 12 \times 10^3 N$$

8. Consider a 72 cm long wire AB as shown in the figure. The galvanometer jockey is placed at P on AB at a distance x cm from A. The galvanometer shows zero deflection.



The value of x, to the nearest integer, is

Official Ans. by NTA (48)

Sol. In Balanced conditions

$$\frac{12}{6} = \frac{x}{72 - x}$$

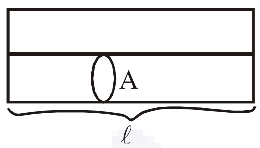
x = 48 cm

9. Two wires of same length and thickness having specific resistances 6Ω cm and 3Ω cm respectively are connected in parallel. The effective resistivity is ρ Ω cm. The value of ρ, to the nearest integer, is_____.

Official Ans. by NTA (4)

Sol. ∵ in parallel

$$R_{net} = \frac{R_1R_2}{R_1 + R_2}$$



$$\frac{\rho\ell}{2A} = \frac{\rho_1\frac{\ell}{A}\times\rho_2\frac{\ell}{A}}{\rho_1\frac{\ell}{A}+\rho_2\frac{\ell}{A}}$$

$$\frac{\rho}{2} = \frac{6\times3}{6+3} = 2$$

$\rho = 4$

10. A galaxy is moving away from the earth at a speed of 286 kms^{-1}. The shift in the wavelength of a red line at 630 nm is $x \times 10^{-10}$ m. The value of x, to the nearest integer, is_____.

[Take the value of speed of light c, as 3×10^8 ms^{-1}]

Official Ans. by NTA (6)

Sol. $\frac{\Delta\lambda}{\lambda}c = v$

$$\Delta\lambda = \frac{v}{c}\times\lambda = \frac{286}{3\times10^5}\times630\times10^{-9} = 6 \times 10^{-10}$$