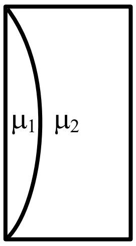
PHYSICS

SECTION-A

1. Curved surfaces of a plano-convex lens of refractive index μ_1 and a plano-concave lens of refractive index μ_2 have equal radius of curvature as shown in figure. Find the ratio of radius of curvature to the focal length of the combined lenses.

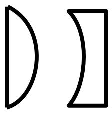


(1) $\frac{1}{\mu_2 - \mu_1}$ (2) $\mu_1 - \mu_2$

(3) $\frac{1}{\mu_1 - \mu_2}$ (4) $\mu_2 - \mu_1$

Official Ans. by NTA (2)

Sol.



$$\frac{1}{f_1} = (\mu_1 - 1)\left(\frac{1}{R}\right)$$

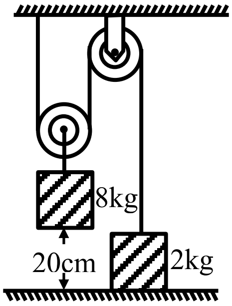
$$\frac{1}{f_2} = (\mu_2 - 1)\left(-\frac{1}{R}\right)$$

$$\frac{1}{f_1} + \frac{1}{f_2} = \frac{1}{f_{eq}} = \frac{(\mu_1 - 1) - (\mu_2 - 1)}{R}$$

$$\frac{1}{f_{eq}} = \frac{(\mu_1 - \mu_2)}{R}$$

$$\frac{R}{f_{eq}} = (\mu_1 - \mu_2)$$

2. The boxes of masses 2 kg and 8 kg are connected by a massless string passing over smooth pulleys. Calculate the time taken by box of mass 8 kg to strike the ground starting from rest. (use $g = 10\ m/s^2$)

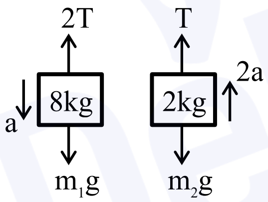


(1) 0.34 s (2) 0.2 s

(3) 0.25 s (4) 0.4 s

Official Ans. by NTA (4)

Sol.



$(m_1g - 2T) = m_1a$ – (1)

$T - m_2g = m_2(2a)$

$2T - 2m_2g = 4m_2 a$ – (2)

$m_1g - 2m_2g = (m_1 + 4m_2)\ a$

$$a = \frac{(8-4)g}{(8+8)} = \frac{4}{16}g = \frac{g}{4}$$

$$a = \frac{10}{4}\ m/s^2$$

$$S = \frac{1}{2}at^2$$

$$\frac{0.2 \times 2 \times 4}{10} = t^2$$

$t = 0.4$ sec

3. For a transistor α and β are given as $\alpha = \frac{I_C}{I_E}$ and $\beta = \frac{I_C}{I_B}$. Then the correct relation between α and β will be :

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

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

Official Ans. by NTA (2)

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

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

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

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

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

4. Water drops are falling from a nozzle of a shower onto the floor, from a height of 9.8 m. The drops fall at a regular interval of time. When the first drop strikes the floor, at that instant, the third drop begins to fall. Locate the position of second drop from the floor when the first drop strikes the floor.

(1) 4.18 m

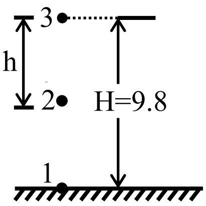
(2) 2.94 m

(3) 2.45 m

(4) 7.35 m

Official Ans. by NTA (4)

Sol.



$$H = \frac{1}{2}gt^2$$

$$\frac{9.8 \times 2}{9.8} = t^2$$

$$t = \sqrt{2} \text{ sec}$$

Δt: time interval between drops

$$h = \frac{1}{2}g(\sqrt{2} - \Delta t)^2$$

$$0 = \frac{1}{2}g(\sqrt{2} - 2\Delta t)^2$$

$$\Delta t = \frac{1}{\sqrt{2}}$$

$$h = \frac{1}{2}g\left(\sqrt{2} - \frac{1}{\sqrt{2}}\right)^2 = \frac{1}{2} \times 9.8 \times \frac{1}{2} = \frac{9.8}{4} = 2.45\text{m}$$

$$H - h = 9.8 - 2.45$$

$$= 7.35 \text{ m}$$

5. Two discs have moments of intertia I_1 and I_2 about their respective axes perpendicular to the plane and passing through the centre. They are rotating with angular speeds, ω_1 and ω_2 respectively and are brought into contact face to face with their axes of rotation coaxial. The loss in kinetic energy of the system in the process is given by :

(1) $\frac{I_1 I_2}{(I_1 + I_2)}(\omega_1 - \omega_2)^2$ (2) $\frac{(I_1 - I_2)^2 \omega_1 \omega_2}{2(I_1 + I_2)}$

(3) $\frac{I_1 I_2}{2(I_1 + I_2)}(\omega_1 - \omega_2)^2$ (4) $\frac{(\omega_1 - \omega_2)^2}{2(I_1 + I_2)}$

Official Ans. by NTA (3)

Sol. From conservation of angular momentum we get

$I_1\omega_1 + I_2\omega_2 = (I_1 + I_2)\omega$

$$\omega = \frac{I_1\omega_1 + I_2\omega_2}{I_1 + I_2}$$

$$k_i = \frac{1}{2}I_1\omega_1^2 + \frac{1}{2}I_2\omega_2^2$$

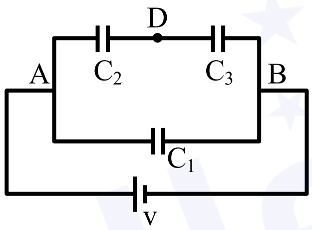
$$k_f = \frac{1}{2}(I_1 + I_2)\omega^2$$

$$k_i - k_f = \frac{1}{2}\left[I_1\omega_1^2 + I_2\omega_2^2 - \frac{(I_1\omega_1 + I_2\omega_2)^2}{I_1 + I_2}\right]$$

Solving above we get

$$k_i - k_f = \frac{1}{2}\left(\frac{I_1 I_2}{I_1 + I_2}\right)(\omega_1 - \omega_2)^2$$

6. Three capacitors C_1 = 2μF, C_2 = 6 μF and C_3 = 12 μF are connected as shown in figure. Find the ratio of the charges on capacitors C_1, C_2 and C_3 respectively :

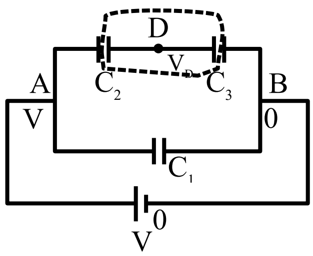


(1) 2 : 1 : 1 (2) 2 : 3 : 3

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

Official Ans. by NTA (3)

Sol.



$(V_D - V) C_2 + (V_D - 0) C_3 = 0$

$(V_D - V) 6 + (V_D - 0) 12 = 0$

$V_D - V + 2V_D = 0$

$$V_D = \frac{V}{3}$$

$$q_2 = (V - V_D) C_2 = \left(V - \frac{V}{3}\right)(6\ \mu F)$$

$q_2 = (4V)\ \mu F$

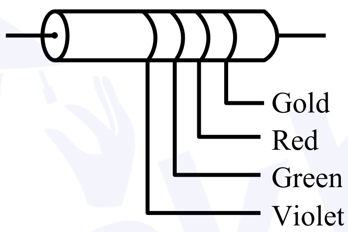
$$q_3 = (V_D - 0) C_3 = \frac{V}{3} \times 12\mu F = 4V\mu F$$

$q_1 = (V - 0) C_1 = V(2\mu F)$

$q_1 : q_2 : q_3 = 2 : 4 : 4$

$q_1 : q_2 : q_3 = 1 : 2 : 2$

7. The colour coding on a carbon resistor is shown in the given figure. The resistance value of the given resistor is :



(1) (5700 ± 285) Ω

(2) (7500 ± 750) Ω

(3) (5700 ± 375) Ω

(4) (7500 ± 375) Ω

Official Ans. by NTA (4)

Sol. $R = 75 \times 10^2 \pm 5\%$ of 7500

$R = (7500 \pm 375)\Omega$

8. An antenna is mounted on a 400 m tall building. What will be the wavelength of signal of signal that can be radiated effectively by the transmission tower upto a range of 44 km?

(1) 37.8 m

(2) 605 m

(3) 75.6 m

(4) 302 m

Official Ans. by NTA (2)

Sol. h : height of antenna
λ : wavelength of signal
$h < \lambda$
$\lambda > h$
$\lambda > 400$ m

9. If the rms speed of oxygen molecules at 0°C is 160 m/s, find the rms speed of hydrogen molecules at 0°C.

(1) 640 m/s (2) 40 m/s
(3) 80 m/s (4) 332 m/s

Official Ans. by NTA (1)

Sol. $V_{rms} = \sqrt{\frac{3KT}{M}}$

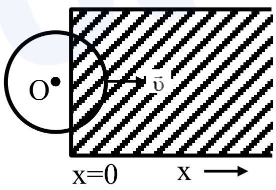
$$\frac{(V_{rms})_{O_2}}{(V_{rms})_{H_2}} = \sqrt{\frac{M_{H_2}}{M_{O_2}}} = \sqrt{\frac{2}{32}}$$

$$(V_{rms})_{H_2} = 4 \times (V_{rms})_{O_2}$$

$= 4 \times 160$

$= 640$ m/s

10. A constant magnetic field of 1 T is applied in the x > 0 region. A metallic circular ring of radius 1m is moving with a constant velocity of 1 m/s along the x-axis. At t = 0s, the centre of O of the ring is at x = – 1m. What will be the value of the induced emf in the ring at t = 1s? (Assume the velocity of the ring does not change.)



(1) 1 V (2) 2π V
(3) 2 V (4) 0 V

Official Ans. by NTA (3)

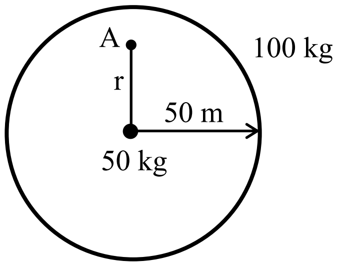
Sol. emf = BLV
= 1.(2R) .1
= 2 V

11. A mass of 50 kg is placed at the centre of a uniform spherical shell of mass 100 kg and radius 50 m. If the gravitational potential at a point, 25 m from the centre is V kg/m. The value of V is :

(1) – 60 G (2) + 2 G
(3) – 20 G (4) – 4 G

Official Ans. by NTA (4)

Sol.



$$V_A = \left[-\frac{GM_1}{r} - \frac{GM_2}{R}\right]$$

$$= \left[-\frac{50}{25}G - \frac{100}{50}G\right]$$

$= -4G$

12. For full scale deflection of total 50 divisions, 50 mV voltage is required in galvanometer. The resistance of galvanometer if its current sensitivity is 2 div/mA will be :

(1) 1 Ω (2) 5 Ω (3) 4 Ω (4) 2 Ω

Official Ans. by NTA (4)

Sol. $I_{max} =$

$$\mathbf{R} = \frac{V}{I} = \frac{50mV}{25mA} = 2\Omega$$

13. A monochromatic neon lamp with wavelength of 670.5 nm illuminates a photo-sensitive material which has a stopping voltage of 0.48 V. What will be the stopping voltage if the source light is changed with another source of wavelength of 474.6 nm?

(1) 0.96 V (2) 1.25 V (3) 0.24 V (4) 1.5 V

Official Ans. by NTA (2)

Sol. $kE_{max} = \frac{hc}{\lambda_i} + \phi$

or $eV_o = \frac{hc}{\lambda_i} + \phi$

when $\lambda_i = 670.5$ nm ; $V_o = 0.48$

when $\lambda_i = 474.6$ nm ; $V_o = ?$

So, $e(0.48) = \frac{1240}{670.5} + \phi$ ...(1)

$e(V_o) = \frac{1240}{474.6} + \phi$ ...(2)

(2) – (1)

$$e(V_o - 0.48) = 1240\left(\frac{1}{474.6} - \frac{1}{670.5}\right)eV$$

$$V_o = 0.48 + 1240\left(\frac{670.5 - 474.6}{474.6 \times 670.5}\right) \text{Volts}$$

$V_o = 0.48 + 0.76$

$V_o = 1.24$ V $\simeq$ 1.25 V

14. Match List-I with List-II.

List-I	List-II
(a) R_H (Rydberg constant)	(i) kg m^{-1} s^{-1}
(b) h(Planck's constant)	(ii) kg m^2 s^{-1}
(c) μ_B (Magnetic field energy density)	(iii) m^{-1}
(d) η(coefficient of viscocity)	(iv) kg m^{-1} s^{-2}

Choose the most appropriate answer from the options given below :

(1) (a)–(ii), (b)–(iii), (c)–(iv), (d)–(i)

(2) (a)–(iii), (b)–(ii), (c)–(iv), (d)–(i)

(3) (a)–(iv), (b)–(ii), (c)–(i), (d)–(iii)

(4) (a)–(iii), (b)–(ii), (c)–(i), (d)–(iv)

Official Ans. by NTA (2)

Sol. SI unit of Rydberg const. = m^{-1}

SI unit of Plank's const. = kg m^2s^{-1}

SI unit of Magnetic field energy density= kg $m^{-1}s^{-2}$

SI unit of coeff. of viscosity = kg $m^{-1}s^{-1}$

15. If force (F), length (L) and time (T) are taken as the fundamental quantities. Then what will be the dimension of density :

(1)$[FL^{-4}T^2]$ (2) $[FL^{-3}T^2]$

(3) $[FL^{-5}T^2]$ (4) $[FL^{-3}T^3]$

Official Ans. by NTA (1)

Sol. Density = $[F^aL^bT^c]$

$[ML^{-3}] = [M^aL^aT^{-2a}L^bT^c]$

$[M^1L^{-3}] = [M^aL^{a+b}T^{-2a+c}]$

$a = 1$; $a + b = -3$; $-2a + c = 0$

$1 + b = -3$ $c = 2a$

$b = -4$ $c = 2$

So, density = $[F^1L^{-4}T^2]$

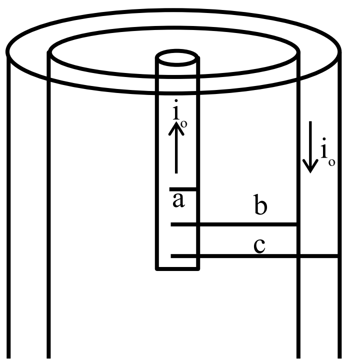
16. A coaxial cable consists of an inner wire of radius 'a' surrounded by an outer shell of inner and outer radii 'b' and 'c' respectively. The inner wire carries an electric current i_0, which is distributed uniformly across cross-sectional area. The outer shell carries an equal current in opposite direction and distributed uniformly. What will be the ratio of the magnetic field at a distance x from the axis when (i) x < a and (ii) a < x < b ?

(1) $\frac{x^2}{a^2}$ (2) $\frac{a^2}{x^2}$

(3) $\frac{x^2}{b^2 - a^2}$ (4) $\frac{b^2 - a^2}{x^2}$

Official Ans. by NTA (1)

Sol.



when x < a

$$B_1(2\pi x) = \mu_o\left(\frac{i_o}{\pi a^2}\right)\pi x^2$$

$$B(2\pi x) = \frac{\mu_o i_o x^2}{a^2}$$

$$B_1 = \frac{\mu_o i_o x}{2\pi a^2} \quad ...(1)$$

when a < x < b

$B_2(2\pi x) = \mu_o i_o$

$$B_2 = \frac{\mu_o i_o}{2\pi x} \quad ...(2)$$

$$\frac{B_1}{B_2} = \frac{\mu_o i_o \frac{x}{2\pi a^2}}{\frac{\mu_o i_o}{2\pi x}} = \frac{x^2}{a^2}$$

17. The height of victoria falls is 63 m. What is the difference in temperature of water at the top and at the bottom of fall ?

[Given 1 cal = 4.2 J and specific heat of water = 1 cal g^{-1} $^oC^{-1}$]

(1) 0.147º C (2) 14.76º C

(3) 1.476º (4) 0.014º C

Official Ans. by NTA (1)

Sol. Change in P.E. = Heat energy

mgh = mSΔT

$$\Delta T = \frac{gh}{S}$$

$$= \frac{10 \times 63}{4200 J / kgC}$$

= 0.147°C

18. A player kicks a football with an initial speed of 25 ms^{-1} at an angle of 45º from the ground. What are the maximum height and the time taken by the football to reach at the highest point during motion ? (Take g = 10 ms^{-2})

(1) h_{max} = 10 m T = 2.5 s

(2) h_{max} = 15.625 m T = 3.54 s

(3) h_{max} = 15.625 m T = 1.77 s

(4) h_{max} = 3.54 m T = 0.125 s

Official Ans. by NTA (3)

Sol. $$H = \frac{U^2 \sin^2\theta}{2g}$$

$$= \frac{(25)^2.(\sin 45)^2}{2 \times 10}$$

= 15.625 m

$$T = \frac{U \sin\theta}{g}$$

$$= \frac{25 \times \sin 45°}{10}$$

= 2.5 × 0.7

= 1.77 s

19. The light waves from two coherent sources have same intensity $I_1 = I_2 = I_0$. In interference pattern the intensity of light at minima is zero.What will be the intensity of light at maxima ?

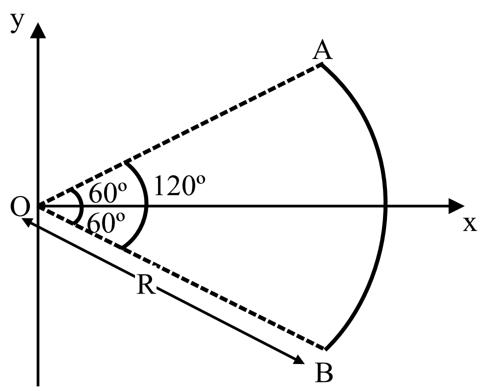
(1) I_0 (2) 2 I_0 (3) 5 I_0 (4) 4 I_0

Official Ans. by NTA (4)

Sol. $I_{max} = \left(\sqrt{I_1} + \sqrt{I_2}\right)^2$

$= 4I_o$

20. Figure shows a rod AB, which is bent in a 120º circular arc of radius R. A charge (–Q) is uniformly distributed over rod AB. What is the electric field $\vec{E}$ at the centre of curvature O ?



(1) $\frac{3\sqrt{3}Q}{8\pi\varepsilon_0 R^2}(\hat{i})$ (2) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(\hat{i})$

(3) $\frac{3\sqrt{3}Q}{16\pi^2\varepsilon_0 R^2}(\hat{i})$ (4) $\frac{3\sqrt{3}Q}{8\pi^2\varepsilon_0 R^2}(-\hat{i})$

Official Ans. by NTA (2)

Sol. $\varepsilon = \frac{2k\lambda}{R}\sin\left(\frac{\theta}{2}\right)(-\hat{i})$

$\lambda = \left(\frac{-Q}{R\theta}\right) = \left(\frac{-Q}{R.\frac{2\pi}{3}}\right)$

$\lambda = \frac{-3Q}{2\pi R}$

$\varepsilon = \frac{2k}{R}.\frac{-3Q}{2\pi R}.\sin(60°)(-\hat{i})$

$\varepsilon = \frac{3\sqrt{3}Q}{8\pi^2 \epsilon_o R^2}(+\hat{i})$

SECTION-B

1. A heat engine operates between a cold reservoir at temperature T_2 = 400 K and a hot reservoir at temperature T_1. It takes 300 J of heat from the hot reservoir and delivers 240 J of heat to the cold reservoir in a cycle. The minimum temperature of the hot reservoir has to be ________K.

Official Ans. by NTA (500)

Sol. Q_{in} = 300 J ; Q_{out} = 240 J

Work done = $Q_{in} - Q_{out}$ = 300 – 240 = 60 J

Efficiency = $\frac{W}{Q_{in}} = \frac{60}{300} = \frac{1}{5}$

efficiency = $1 - \frac{T_2}{T_1}$

$\frac{1}{5} = 1 - \frac{400}{T_1} \Rightarrow \frac{400}{T_1} = \frac{4}{5}$

T_1 = 500 k

2. Two simple harmonic motion, are represented by the equations $y_1 = 10 \sin\left(3\pi t + \frac{\pi}{3}\right)$

$y_2 = 5 (\sin 3\pi t + \sqrt{3} \cos 3\pi t)$

Ratio of amplitude of y_1 to y_2 = x : 1. The value of x is ________.

Official Ans. by NTA (1)

Sol. $y_1 = 10 \sin\left(3\pi t + \frac{\pi}{3}\right) \Rightarrow$ Amplitude= 10

$y_2 = 5 (\sin 3\pi t + \sqrt{3} \cos 3\pi t)$

$y_2 = 10\left(\frac{1}{2}\sin 3\pi t + \frac{\sqrt{3}}{2}\cos 3\pi t\right)$

$y_2 = 10\left(\cos\frac{\pi}{3}\sin 3\pi t + \sin\frac{\pi}{3}\cos 3\pi t\right)$

$y_2 = 10 \sin\left(3\pi t + \frac{\pi}{3}\right) \Rightarrow$ Amplitude = 10

So ratio of amplitudes = $\frac{10}{10} = 1$

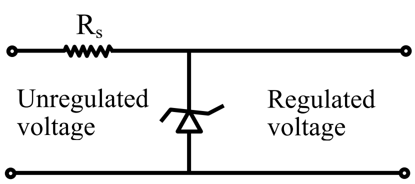
3. X different wavelengths may be observed in the spectrum from a hydrogen sample if the atoms are exited to states with principal quantum number n = 6 ? The value of X is _______.

Official Ans. by NTA (15)

Sol. No. of different wavelengths = $\frac{n(n-1)}{2}$

$= \frac{6\times(6-1)}{2} = \frac{6\times 5}{2} = 15$

4. A zener diode of power rating 2W is to be used as a voltage regulator. If the zener diode has a breakdown of 10 V and it has to regulate voltage fluctuated between 6 V and 14 V, the value of R_s for safe operation should be _______ Ω.



Official Ans. by NTA (20)

Sol. When unregulated voltage is 14 V voltage across zener diode must be 10 V So potential difference across resistor $\Delta V_{Rs} = 4V$

and $P_{zener} = 2W$

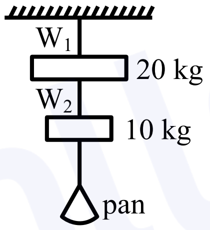
$VI = 2$

$I = \frac{2}{10} = 0.2\ A$

$\Delta V_{Rs} = I\ R_s$

$4 \times 0.2\ R_s \Rightarrow R_s = \frac{40}{2} = 20\Omega$

5. Wires W_1 and W_2 are made of same material having the breaking stress of $1.25 \times 10^9\ N/m^2$. W_1 and W_2 have cross-sectional area of $8 \times 10^{-7}\ m^2$ and $4 \times 10^{-7}\ m^2$, respectively. Masses of 20 kg and 10 kg hang from them as shown in the figure. The maximum mass that can be placed in the pan without breaking the wires is ____ kg. (Use $g = 10\ m/s^2$)



Official Ans. by NTA (40)

Sol. $B.S_1 = \frac{T_{1max}}{8\times10^{-7}} \Rightarrow T_{1\ max} = 8 \times 1.25 \times 100$

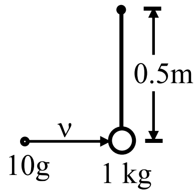
$= 1000\ N$

$B.S_2 = \frac{T_{2max}}{4\times10^{-7}} \Rightarrow T_{2max} = 4\times1.25\times100$

$= 500\ N$

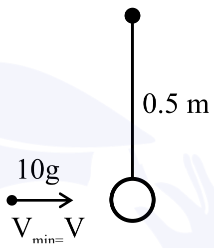
$m = \frac{500-100}{10} = 40\ kg$

6. A bullet of 10 g, moving with velocity v, collides head-on with the stationary bob of a pendulum and recoils with velocity 100 m/s. The length of the pendulum is 0.5 m and mass of the bob is 1 kg. The minimum value of v = _____ m/s so that the pendulum describes a circle. (Assume the string to be inextensible and $g = 10\ m/s^2$)



Official Ans. by NTA (400)

Sol.



$V' = \sqrt{5gR} = \sqrt{5\times10\times0.5}$

$V' = 5\ m/s$

$m_1V = m_2 \times 5 - m_1 \times 100$

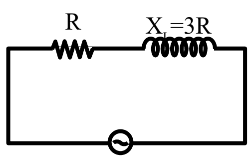
$\frac{10}{1000}\times V = 5 - \frac{10}{1000}\times100$

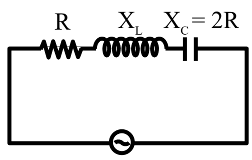
$V = 400\ m/s$

7. An ac circuit has an inductor and a resistor of resistance R in series, such that $X_L = 3R$. Now, a capacitor is added in series such that $X_C = 2R$. The ratio of new power factor with the old power factor of the circuit is $\sqrt{5}:x$. The value of x is _____.

Official Ans. by NTA (1)

Sol.



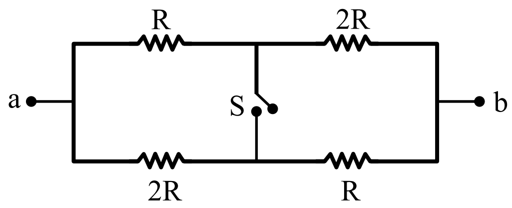


$\cos\phi = \frac{R}{\sqrt{R^2+3R^2}}$ $\quad\quad \cos\phi' = \frac{R}{\sqrt{R^2+R^2}}$

$= \frac{1}{\sqrt{10}}$ $\quad\quad = \frac{1}{\sqrt{2}}$

$$\frac{\cos\phi'}{\cos\phi} = \frac{\sqrt{10}}{\sqrt{2}} = \frac{\sqrt{5}}{1} \qquad \therefore x = 1$$

8. The ratio of the equivalent resistance of the network (shown in figure) between the points a and b when switch is open and switch is closed is x : 8. The value of x is _______.



Official Ans. by NTA (9)

Sol. $R_{eq\ open} = \frac{3R}{2}$

$R_{eq\ closed} = 2 \times \frac{R \times 2R}{3R} = \frac{4R}{3}$

$\frac{R_{eq\ open}}{R_{eq\ closed}} = \frac{3R}{2} \times \frac{3}{4R} = \frac{9}{8}$

$\therefore$ x = 9

9. A plane electromagnetic wave with frequency of 30 MHz travels in free space. At particular point in space and time, electric field is 6 V/m. The magnetic field at this point will be x × 10^{-8} T. The value of x is _____.

Official Ans. by NTA (2)

Sol. $|B| = \frac{|E|}{C} = \frac{6}{3 \times 10^8}$

$= 2 \times 10^{-8}$ T

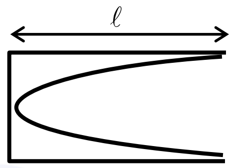
$\therefore$ x = 2

10. A tuning fork is vibrating at 250 Hz. The length of the shortest closed organ pipe that will resonate with the tuning fork will be _____ cm.

(Take speed of sound in air as 340 ms^{-1})

Official Ans. by NTA (34)

Sol.



$\frac{\lambda}{4} = \ell \Rightarrow \lambda = 4\ell$

$f = \frac{V}{\lambda} = \frac{V}{4\ell}$

$\Rightarrow 250 = \frac{340}{4\ell}$

$\Rightarrow \ell = \frac{34}{4 \times 25} = 0.34m$

$\ell = 34cm$ s