JEE Main 2021 Paper

Date: 16th March 2021 (Shift-1)

Subject: Physics

Section - A

1. A 25 m long antenna is mounted on an antenna tower. The height of the antenna tower is 75 m. The wavelength (in meter) of the signal transmitted by this antenna would be:

a. 200
b. 400
c. 100
d. 300

Answer: (c)

Sol.

Given that, height of peak of antenna : H = 25 m.

As, we know that

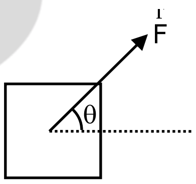
$\lambda = 4H$

$\therefore\ \lambda = 4 \times 25$

$\therefore\ \lambda = 100$ m

Hence option (c) is correct.

2. A block of mass m slides along a floor while a force of magnitude F is applied to it at an angle θ as shown in figure. The coefficient of kinetic friction is μ_K. Then, the block's acceleration 'a' is given by : (g is acceleration due to gravity)

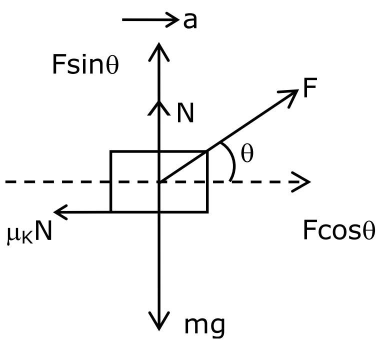


a. $\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$
b. $\frac{F}{m}\cos\theta - \mu_K\left(g + \frac{F}{m}\sin\theta\right)$
c. $\frac{F}{m}\cos\theta + \mu_K\left(g - \frac{F}{m}\sin\theta\right)$
d. $-\frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

Answer: (a)

Sol.

Drawing the FBD of the block.



$\Rightarrow$ N = mg – Fsinθ ...(1)

Also, Fcosθ – μ_KN = m·a ...(2)

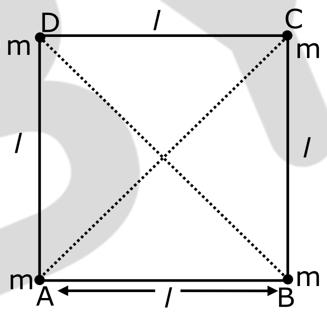
Substituting the value of N from eq. (1) in eq. (2)

$\Rightarrow$ Fcosθ – μ_K(mg–Fsinθ) = m·a

$\Rightarrow a = \frac{F}{m}\cos\theta - \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

Hence option (a) is correct.

3. Four equal masses, m each are placed at the corners of a square of length(l) as shown in the figure. The moment of inertia of the system about an axis passing through A and parallel to DB would be :

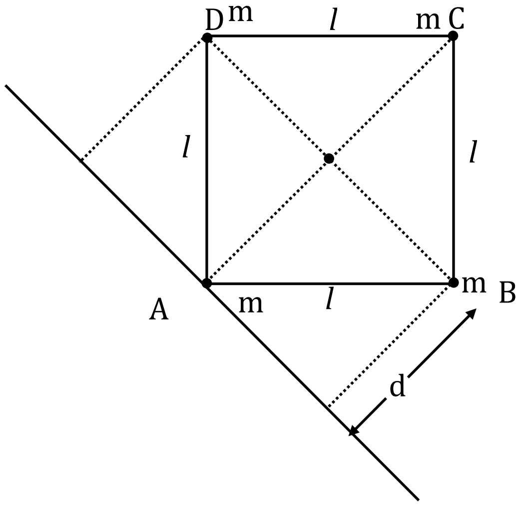


a. ml^2 b. 3ml^2

c. $\sqrt{3}$ml^2 d. 2 ml^2

Answer: (b)

Sol.



$AC = \sqrt{l^2 + l^2}$

$AC = l\sqrt{2}$

$d = \frac{l\sqrt{2}}{2}$

$\Rightarrow d = \frac{l}{\sqrt{2}}$

Moment of inertia about the axis passing through A :

$I = m(0)^2 + m(d)^2 + m(d)^2 + m(AC)^2$

$\Rightarrow I = 0 + m\left(\frac{l}{\sqrt{2}}\right)^2 + m\left(\frac{l}{\sqrt{2}}\right)^2 + m\left(l\sqrt{2}\right)^2$

$\Rightarrow I = \frac{ml^2}{2} + \frac{ml^2}{2} + 2ml^2$

$\Rightarrow I = 3ml^2$

Hence option (b) is correct.

4. The stopping potential in the context of photoelectric effect depends on the following property of incident electromagnetic radiation:

a. Amplitude
b. Phase
c. Frequency
d. Intensity

Answer: (c)

Sol.

According to Einstein's photoelectric equation, stopping potential depends on frequency as

$h\nu - h\nu_0 = eV$

$\Rightarrow V = \frac{h}{e}\nu - \frac{h}{e}\nu_0$

Hence stopping potential depends on frequency.

Hence option (c) is correct.

5. **One main scale division of a vernier callipers is 'a' cm and n^{th} division of the vernier scale coincide with $(n-1)^{th}$ division of the main scale. The least count of the callipers in mm is:**

a. $\left(\frac{n-1}{10n}\right)a$

b. $\frac{10a}{n}$

c. $\frac{10na}{(n-1)}$

d. $\frac{10\,a}{(n-1)}$

Answer: (b)

Sol.

MSD $\rightarrow$ Main scale division

VSD $\rightarrow$ Vernier scale division

LC $\rightarrow$ Least count

n VSD = (n–1) MSD

$1\ VSD = \left(\frac{n-1}{n}\right) MSD$

L·C=1 MSD – 1 VSD

$= 1\,MSD - \left(\frac{n-1}{n}\right) MSD$

$= 1\,MSD - 1\,MSD + \frac{MSD}{n}$

$= \frac{MSD}{n}$

$= \frac{a}{n} cm$

$= \frac{10\,a}{n} mm$

Hence option (b) is correct.

6. **A plane electromagnetic wave of frequency 500 MHz is travelling in vacuum along y-direction. At a particular point in space and time, $\vec{B} = 8.0 \times 10^{-8} \hat{z}\ T$. The value of electric field at this point is: (speed of light = 3×10^8 ms^{-1}) Assume $\hat{x}, \hat{y}, \hat{z}$ are unit vectors along x, y and z directions.**

a. $2.6\hat{x}\,\frac{V}{m}$

b. $-2.6\hat{y}\,\frac{V}{m}$

c. $24\hat{x}\,\frac{V}{m}$

d. $-24\hat{x}$ V/m

Answer: (d)

Sol.

$E_0 = B \cdot C$

$E_0 = (8\times10^{-8}) \times (3\times10^{8})$

$\Rightarrow |E_0| = 24$

Wave travels in the direction of $\vec{E} \times \vec{B}$

As $(-\hat{x}) \times \hat{z} = +\hat{y}$

$\therefore \hat{E} = -24\hat{x}$ V/m

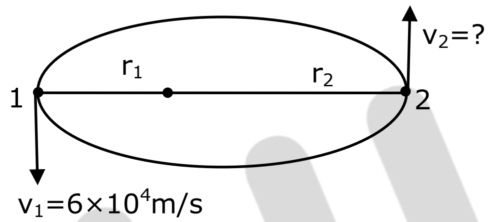
Hence option (d) is correct.

7. The maximum and minimum distances of a comet from the Sun are 1.6×10^{12} m and 8.0×10^{10} m respectively. If the speed of the comet at the nearest point is 6×10^4 ms^{-1}, the speed at the farthest point is :

a. 1.5×10^3 m/s
b. 4.5×10^3 m/s
c. 3.0×10^3 m/s
d. 6.0×10^3 m/s

Answer: (c)

Sol.



Let point 1 is nearest point,

and point 2 is farthest point.

Given, $r_1 = 8\times10^{10}$ m & $r_2 = 1.6\times10^{12}$ m

By angular momentum conservation

$L_1 = L_2$

$mr_1v_1 = mr_2v_2$

$\Rightarrow v_2 = \frac{r_1 v_1}{r_2}$

$\therefore v_2 = \frac{8\times10^{10}\times6\times10^4}{1.6\times10^{12}}$

$\therefore v_2 = 3.0\times10^3$ m/s

Hence option (c) is correct.

8. A block of 200 g mass moves with a uniform speed in a horizontal circular groove, with vertical side walls of radius 20 cm. If the block takes 40 s to complete one round, the normal force by the side walls of the groove is:

a. 6.28×10^{-3} N
b. 0.0314 N
c. 9.859×10^{-2} N
d. 9.859×10^{-4} N

Answer: (d)

Sol. Normal force will provide the necessary centripetal force.

$\Rightarrow N = m\omega^2 R$

Also; $\omega = \frac{2\pi}{T}$

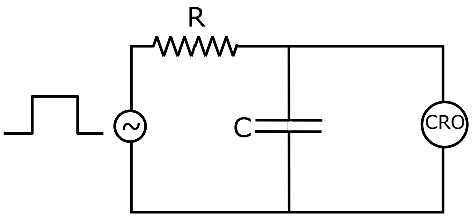
$N = (0.2)\left(\frac{4\pi^2}{T^2}\right)(0.2)$

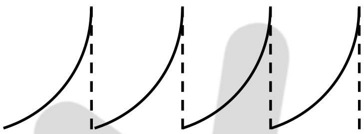
$\Rightarrow N = 0.2 \times \dfrac{4 \times (3.14)^2}{(40)^2} \times 0.2$

$\therefore$ N=9.859×10^{-4} N

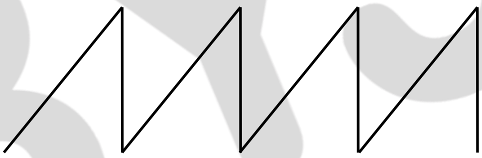
Hence option (d) is correct.

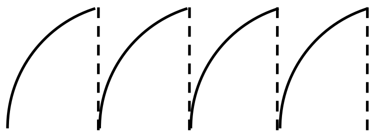
9. An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to:



a. 

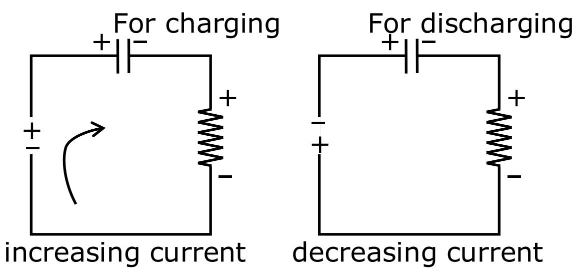
b. 

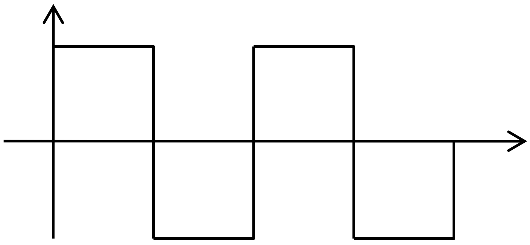
c. 

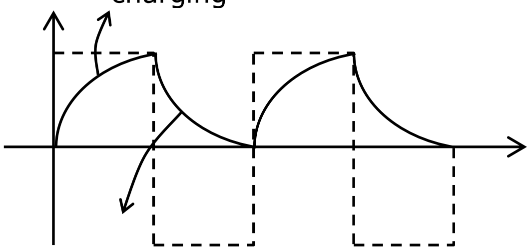
d. 

Answer: (b)

Sol. Assuming AC starts with positive voltage. When +ve voltage is across input then the capacitor starts charging, trying to reach saturation value, till then there is +ve voltage across input. When –ve voltage of AC appears across input, the capacitor starts discharging till then there is –ve voltage across input and this process of charging and discharging keeps on going alternatively.







Hence option (b) is correct.

10. In thermodynamics, heat and work are:

a. Intensive thermodynamics state variables

b. Extensive thermodynamics state variables

c. Path functions

d. Point functions

Answer: (c)

Sol.

Heat and work are path functions. Heat and work depends on the path taken to reach the final state from initial state. Intensive and extensive properties only applies to physical properties that are a function of state, heat is neither intensive nor extensive. Hence option (c) is correct.

11. A conducting wire of length '*l*', area of cross-section A and electric resistivity ρ is connected between the terminals of a battery. A potential difference V is developed between its ends, causing an electric current. If the length of the wire of the same material is doubled and the area of cross-section is halved, the resultant current would be:

a $\frac{1}{4}\frac{\rho l}{VA}$

b. $\frac{3}{4}\frac{VA}{\rho l}$

c. $4\frac{VA}{\rho l}$

d. $\frac{1}{4}\frac{VA}{\rho l}$

Answer: (d)

Sol.

We know that

$R = \rho \frac{l}{A}$

Now, new length : $l'=2l$

new area of cross section : A'=A/2

$\therefore$ New resistance : $R' = \rho \cdot \frac{2l}{A/2}$

$\Rightarrow R' = 4\frac{\rho l}{A}$

$\Rightarrow$ R'=4R

$\therefore$ Resultant current : $I = \frac{V}{4R}$

$\therefore I = \frac{1}{4}\frac{VA}{\rho l}$

Hence option (d) is correct.

12. The pressure acting on a submarine is 3×10^5 Pa at a certain depth. If the depth is doubled, the percentage increase in the pressure acting on the submarine would be :(Assume that atmospheric pressure is 1×10^5 Pa, density of water is 10^3 kg m^{-3}, acceleration due to gravity g = 10 ms^{-2})

a. $\frac{200}{3}\%$

b. $\frac{5}{200}\%$

c. $\frac{200}{5}\%$

d. $\frac{3}{200}\%$

Answer: (a)

Sol.

Pressure at depth h is

$P = P_0 + h\rho g = 3\times10^5$ Pa

$\Rightarrow h\rho g = 3\times10^5 - 1\times10^5$

$\Rightarrow h\rho g = 2\times10^5$

As h is doubled

$\therefore 2h\rho g = 4\times10^5$

$\therefore$ Increased pressure, $P' = P_0 + 4\times10^5$

$\therefore P' = 5\times10^5$ Pa

$\therefore$ % increase in pressure $= \frac{P' - P}{P} \times 100$

$= \frac{(5-3)\times10^5}{3\times10^5} \times 100$

$= \frac{200}{3}\%$

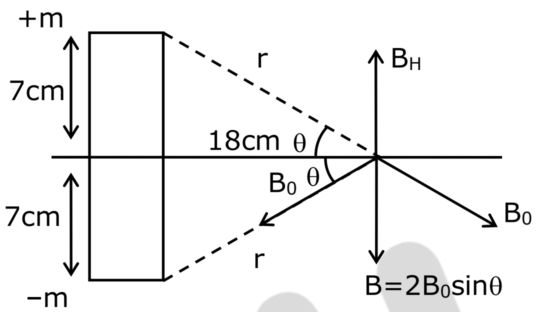
Hence option (a) is correct.

13. A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the center of the magnet. If B_H = 0.4 G, the magnetic moment of the magnet is (1 G = 10^{-4}T)

a. 28.80 J T^{-1}
b. 2.880 J T^{-1}
c. 2.880×10^3 J T^{-1}
d. 2.880×10^2 J T^{-1}

Answer: (b)

Sol.



M → magnetic moment of the magnet

m → **power of magnetic pole**

θ → angle made by B_0 with the horizontal

B_0 → **magnetic flux density**

$B=2B_0\sin\theta$

$$B = 2\frac{\mu_0}{4\pi}\frac{m}{r^2}\times\frac{7}{r}$$

$$\Rightarrow 0.4\times10^{-4} = 2\times10^{-7}\times\frac{m\times7}{(7^2+18^2)^{3/2}}\times10^4$$

$$\therefore\ m = \frac{4\times10^{-2}\times(373)^{3/2}}{14}$$

$$\therefore\ M = m\times14\,cm = m\times\frac{14}{100}$$

$$\therefore\ M = \frac{0.04\times(373)^{3/2}}{14}\times\frac{14}{100}$$

$\therefore$ M=2.880 J/T

Hence option (b) is correct.

14. The volume V of an enclosure contains a mixture of three gases, 16 g of oxygen, 28 g of nitrogen and 44 g of carbon dioxide at absolute temperature T. Consider R as universal gas constant. The pressure of the mixture of gases is:

a. $\frac{4RT}{V}$
b. $\frac{88RT}{V}$
c. $\frac{5}{2}\frac{RT}{V}$
d. $\frac{3RT}{V}$

Answer: (c)

Sol.

No. of moles of O_2 : $n_1=\frac{16}{32}=0.5$ mole

No. of moles of N_2 : $n_2=\frac{28}{28}=1$ mole

No. of moles of CO_2 : $n_3=\frac{44}{44}=1$ mole

Total no. of moles in container : $n=n_1+n_2+n_3$

$\therefore n=0.5+1+1=\frac{5}{2}$moles

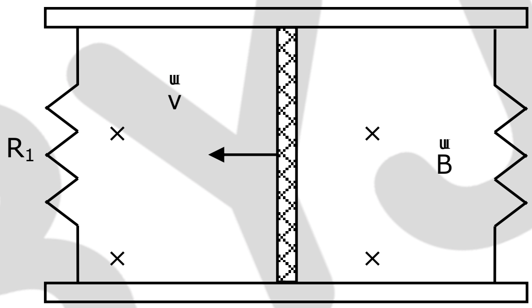
Now; PV=nRT

$$P=\frac{nRT}{V}$$

$$\therefore P=\frac{5}{2}\frac{RT}{V}$$

Hence option (c) is correct.

15. A conducting bar of length L is free to slide on two parallel conducting rails as shown in the figure



Two resistors R_1 and R_2 are connected across the ends of the rails. There is a uniform magnetic field $\vec{B}$ pointing into the page. An external agent pulls the bar to the left at a constant speed *v.* The correct statement about the directions of induced currents I_1 and I_2 flowing through R_1 and R_2 respectively is :

a. I_1 is in clockwise direction and I_2 is in anticlockwise direction

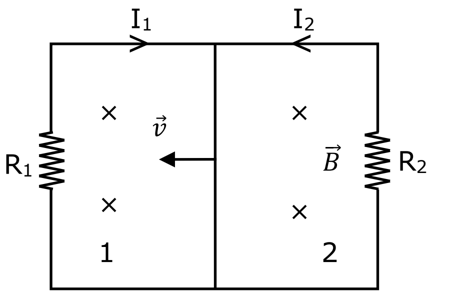
b. Both I_1 and I_2 are in clockwise direction

c. I_1 is in anticlockwise direction and I_2 is in clockwise direction

d. Both I_1 and I_2 are in anticlockwise direction

Answer: (a)

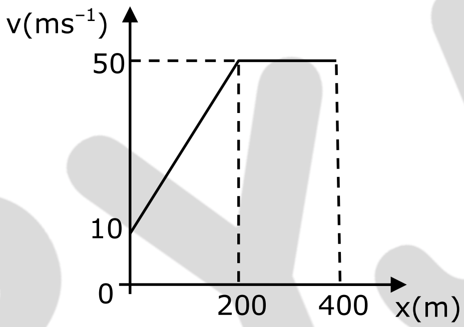
Sol.



When bar slides, area of loop 1 decreases and that of loop 2 increases. Magnetic flux decreases in 1 and increases in 2. Therefore induced emf and current resist this change. As a result B should increase in 1 and decrease in 2. So I_1 should be clockwise and I_2 anticlockwise.

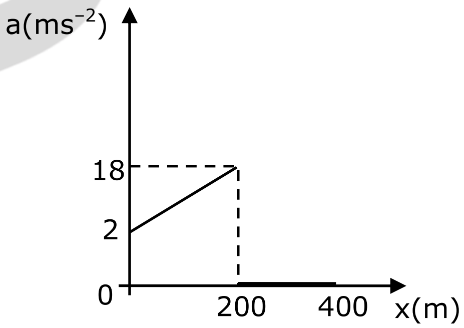
Hence option (a) is correct.

16. The velocity-displacement graph describing the motion of a bicycle is shown in the figure.

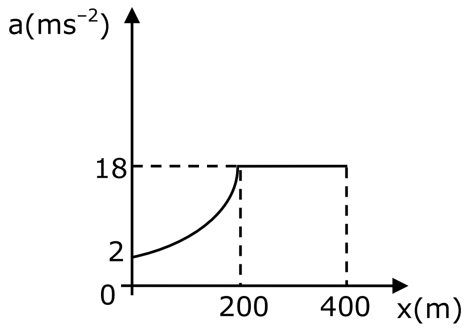


The acceleration-displacement graph of the bicycle's motion is best described by :

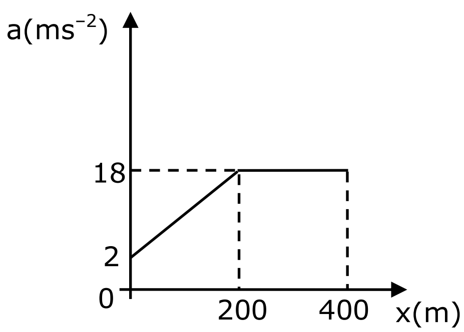
a.



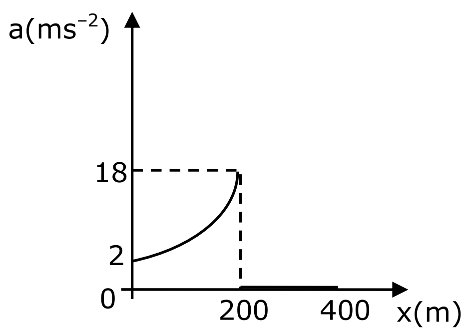
b.



c.



d.



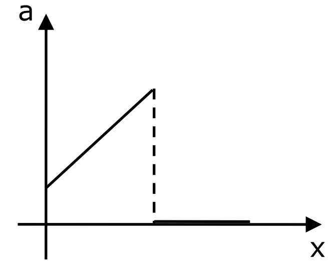
Answer: (a)

Sol.

We know that, $a = v\frac{dv}{dx}$

As slope is constant, so a $\propto$ v (from x=0 to 200 m) & Also, slope = 0, so a = 0 (from x=200 to 400 m)

Hence, the correct plot is

$\therefore$ 

Hence option (a) is correct.

17. For changing the capacitance of a given parallel plate capacitor, a dielectric material of dielectric constant K is used, which has the same area as the plates of the capacitor. The thickness of the dielectric slab is $\frac{3}{4}d$, where 'd' is the separation between the plates of parallel plate capacitor. The new capacitance (C') in terms of original capacitance (C_0) is given by the following relation:

a. $C' = \frac{4K}{K+3}C_0$

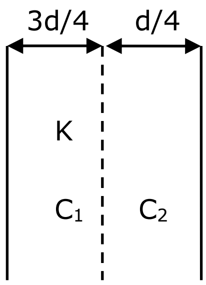
b. $C' = \frac{4}{3+K}C_0$

c. $C' = \frac{3+K}{4K}C_0$

d. $C' = \frac{4+K}{3}C_0$

Answer: (a)

Sol.



$$C_0 = \frac{\epsilon_0 A}{d}$$

C_1 and C_2 are in series and C' is new capacitance

$$\therefore \frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C'} = \frac{(3d/4)}{\epsilon_0 KA} + \frac{(d/4)}{\epsilon_0 A}$$
$$\frac{1}{C'} = \frac{d}{4\epsilon_0 A}\left(\frac{3+K}{K}\right)$$
$$\therefore C' = \frac{4K}{(K+3)}C_0$$

Hence option (a) is correct.

18. For an electromagnetic wave travelling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) fields is :

a. $U_e \neq U_m$

b. $U_e = U_m$

c. $U_e > U_m$

d. $U_e < U_m$

Answer: (b)

Sol.

In EMW, average energy density due to electric field (U_e) and magnetic field (U_m) is same.

Hence option (b) is correct.

19. Time period of a simple pendulum is T inside a lift when the lift is stationary. If the lift moves upwards with an acceleration g/2, the time period of pendulum will be:

a. $\sqrt{\frac{3}{2}}T$

b. $\frac{T}{\sqrt{3}}$

c. $\sqrt{\frac{2}{3}}T$

d. $\sqrt{3}T$

Answer: (c)

Sol.

When lift is stationary

$$T = 2\pi\sqrt{\frac{L}{g}}$$

A pseudo force will act downwards when lift is accelerating upwards.

$$\therefore\ g_{eff} = g + \frac{g}{2} = \frac{3g}{2}$$

$\therefore$ New time period

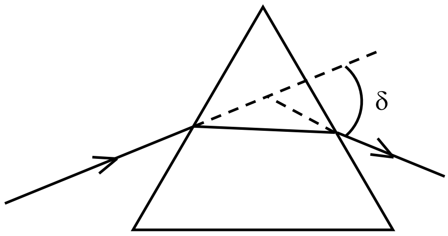
$$T' = 2\pi\sqrt{\frac{L}{g_{eff}}}$$

$$T' = 2\pi\sqrt{\frac{2L}{3g}}$$

$$\therefore \boxed{T' = \sqrt{\frac{2}{3}}T}$$

Hence option (c) is correct.

20. The angle of deviation through a prism is minimum when



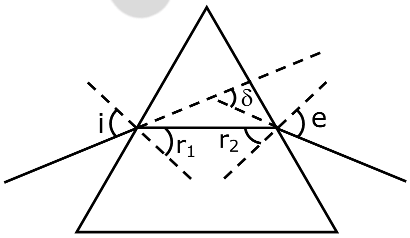
(A) Incident ray and emergent ray are symmetric to the prism
(B) The refracted ray inside the prism becomes parallel to its base
(C) Angle of incidence is equal to that of the angle of emergence
(D) When angle of emergence is double the angle of incidence

Choose the correct answer from the options given below:

a. Only statement (D) is true
b. Statements (A), (B) and (C) are true
c. Statements (B) and (C) are true
d. Only statement (A) and (B) are true

Answer: (b)

Sol.



Deviation is minimum in prism when, i = e, r_1=r_2 and ray inside prism is parallel to base of prism.
Hence option (b) is correct.

SECTION-B

1. A fringe width of 6 mm was produced for two slits separated by 1 mm apart. The screen is placed 10 m away. The wavelength of light used is 'x' nm. The value of 'x' to the nearest integer is ______.

Answer: (600)

Sol.

β = 6 mm, d =1 mm, D =10 m

λ = ?

$$\beta = \frac{\lambda D}{d}$$

$$6 \times 10^{-3} = \frac{\lambda \times 10}{1 \times 10^{-3}}$$

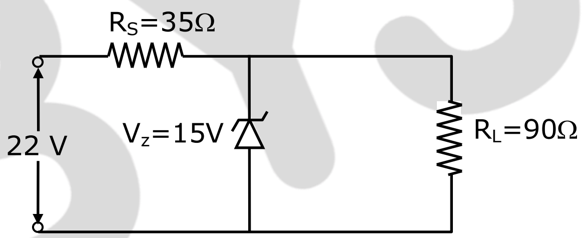
$$\therefore \lambda = \frac{6 \times 10^{-3} \times 1 \times 10^{-3}}{10}$$

$\lambda = 600 \times 10^{-9}$ m

$\therefore \lambda$ = 600 nm

$\therefore$ 600 is the required value.

2. The value of power dissipated across the zener diode (V_z = 15 V) connected in the circuit as shown in the figure is $x*10^{-1}$ watt.

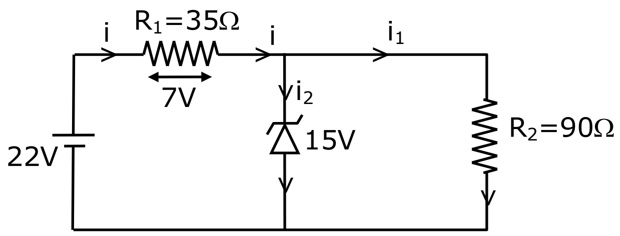


The value of x, to the nearest integer, is ______.

Answer: (5)

Sol.

Across R_1 potential difference is 22 V – 15 V = 7 V



$$i = \frac{7}{35} = \frac{1}{5} A$$

$$i_1 = \frac{15}{90} = \frac{1}{6} A$$

$i_2 = i - i_1$

$i_2 = \frac{1}{5} - \frac{1}{6}$

$i_2 = \frac{1}{30} A$

Power across diode ; P = V_2 i_2

$P = 15 \times \frac{1}{30}$

P = 0.5 W

∴ P = 5×10^{-1} W

∴ 5 is the required value.

3. The resistance $R = \frac{V}{I}$, where V = (50±2) V and I = (20±0.2) A. The percentage error in R is 'x' %. The value of 'x' to the nearest integer is ________.

Answer: (5)

Sol.

$R = \frac{V}{I}$

$\frac{\Delta R}{R} \times 100 = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$

% error in $R = \frac{2}{50} \times 100 + \frac{0.2}{20} \times 100$

% error in R = 4+1

∴ % error in R = 5%

∴ 5 is the required value.

4. A sinusoidal voltage of peak value 250 V is applied to a series LCR circuit, in which R = 8Ω, L=24 mH and C=60 μF. The value of power dissipated at resonant conditions is 'x' kW. The value of x to the nearest integer is ________.

Answer: (4)

Sol.

At resonance, power (P)

$P = \frac{(V_{rms})^2}{R}$

$\therefore P = \frac{\left(250/\sqrt{2}\right)^2}{8}$

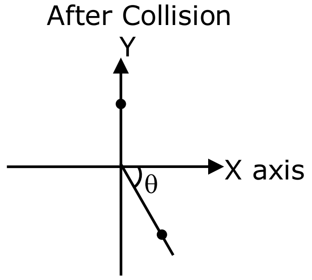
∴ P = 3906.25 W

∴ P ≅ 4 kW

∴ 4 is the required value.

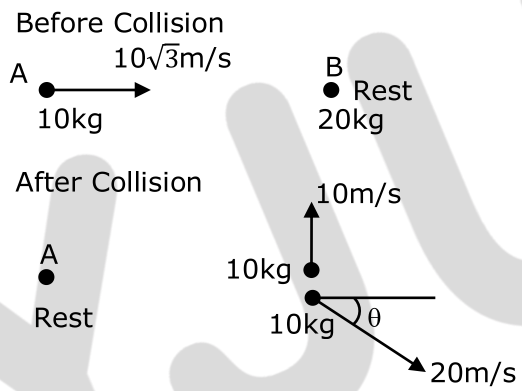
5. A ball of mass 10 kg moving with a velocity $10\sqrt{3}$ ms^{-1} along X-axis, hits another ball of mass 20 kg which is at rest. After collision, the first ball comes to rest and the second one disintegrates into two equal pieces. One of the

pieces starts moving along Y-axis at a speed of 10 m/s. The second piece starts moving at a speed of 20 m/s at an angle θ (degree) with respect to the X-axis. The configuration of pieces after collision is shown in the figure. The value of θ to the nearest integer is _______.



Answer: (30)

Sol.



Conserving momentum along x-axis

$\vec{p_i} = \vec{p_f}$

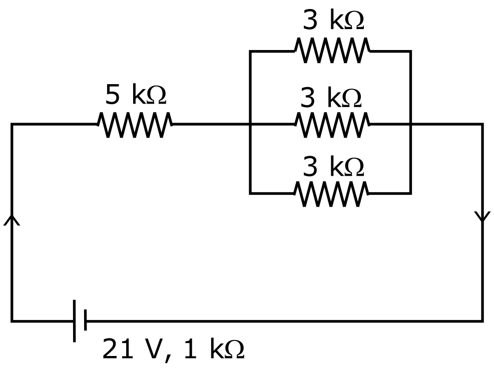
$10 \times 10\sqrt{3} = 10 \times 20 \cos\theta$

$\cos\theta = \frac{\sqrt{3}}{2}$

∴ θ = 30°

∴ 30 is the required value.

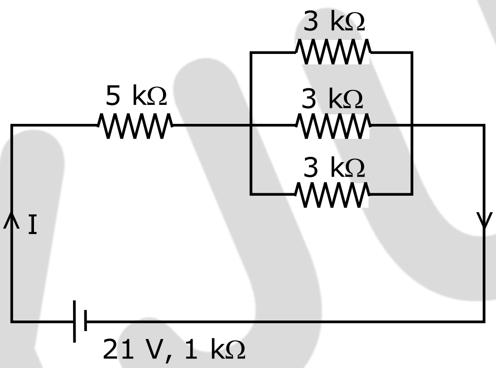
6. **In the figure given, the electric current flowing through the 5 kΩ resistor is 'x' mA.**

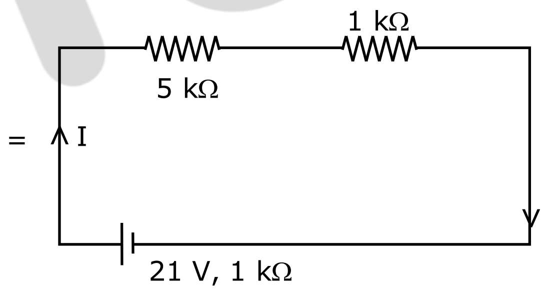


The value of x to the nearest integer is _______.

Answer: (3)

Sol.



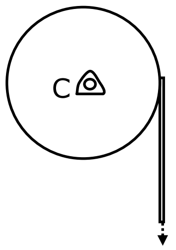


$$I = \frac{21}{5+1+1}$$

$\therefore$ I = 3 mA

$\therefore$ 3 is the required value.

7. **Consider a 20 kg uniform circular disk of radius 0.2 m. It is pin supported at its center and is at rest initially. The disk is acted upon by a constant force F=20 N through a massless string wrapped around its periphery as shown in the figure**



Suppose the disk makes n number of revolutions to attain an angular speed of 50 rad s^{-1}. The value of n, to the nearest integer is _______. [Given : In one complete revolution, the disk rotates by 6.28 rad]

Answer: (20)

Sol.

$\alpha = \frac{\tau}{I} = \frac{F.R.}{mR^2/2} = \frac{2F}{mR}$

$\alpha = \frac{2 \times 20}{20 \times (0.2)} = 10 \text{ rad/s}^2$

$\omega^2 = \omega_0^2 + 2\alpha\Delta\theta$

$(50)^2 = 0^2 + 2(10)\,\Delta\theta$

$\Rightarrow \Delta\theta = \frac{2500}{20}$

$\Delta\theta = 125$ rad

No. of revolution $= \frac{125}{2\pi} \approx 20$ revolutions.

$\therefore$ 20 is the required value.

8. The first three spectral lines of H-atom in the Balmer series are given $\lambda_1, \lambda_2, \lambda_3$ considering the Bohr atomic model, the wave lengths of first and third spectral lines $\left(\frac{\lambda_1}{\lambda_3}\right)$ are related by a factor of approximately 'x'×10^{-1}. The value of x, to the nearest integer, is _______.

Answer: (15)

Sol.

For 1st line

$\frac{1}{\lambda_1} = Rz^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$\frac{1}{\lambda_1} = Rz^2\frac{5}{36}$ ...(i)

For 3rd line

$$\frac{1}{\lambda_3} = Rz^2\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$$

$\frac{1}{\lambda_3} = Rz^2 \frac{21}{100}$ ...(ii)

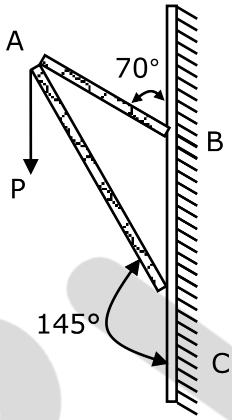
$\therefore \frac{(ii)}{(i)}$

$$\frac{\lambda_1}{\lambda_3} = \frac{21}{100} \times \frac{36}{5} = 1.512 = 15.12 \times 10^{-1}$$

$x \approx 15$

$\therefore$ 15 is the required value.

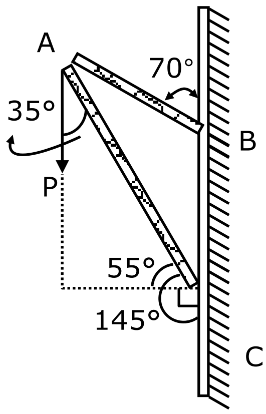
9. Consider a frame that is made up of two thin massless rods AB and AC as shown in the figure. A vertical force $\vec{P}$ of magnitude 100 N is applied at point A of the frame.



Suppose the force is $\vec{P}$ resolved parallel to the arms AB and AC of the frame. The magnitude of the resolved component along the arm AC is x N. The value of x, to the nearest integer, is ________. [Given: sin(35°)=0.573, cos(35°)=0.819, sin(110°)=0.939, cos(110°)=–0.342]

Answer: (82)

Sol.



Component along AC

= 100 cos 35°N

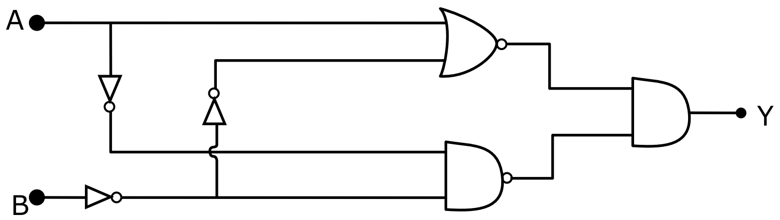
= 100 × 0.819 N

= 81.9 N

≈ 82 N

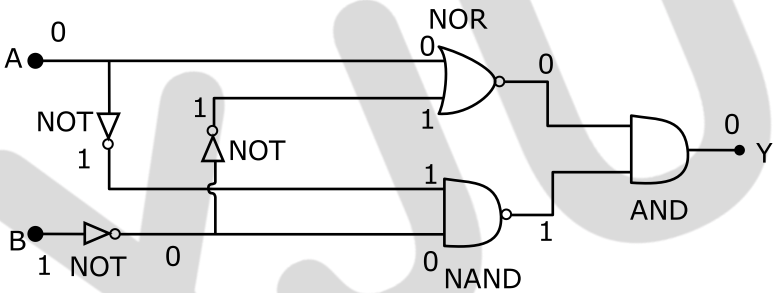
∴ 82 is the required value.

10. In the logic circuit shown in the figure, if input A and B are 0 to 1 respectively, the output at Y would be 'x'. The value of x is _______.



Answer: (0)

Sol.



∴ 0 is the required value.