FINAL JEE–MAIN EXAMINATION – MARCH, 2021

(Held On Tuesday 16th March, 2021) TIME : 9 : 00 AM to 12 : 00 NOON

PHYSICS | **TEST PAPER WITH ANSWER & SOLUTION**

SECTION-A

1. 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 : 80

(1) $\dfrac{10\,na}{(n-1)}$ (2) $\dfrac{10\,a}{(n-1)}$

(3) $\left(\dfrac{n-1}{10\,n}\right)a$ (4) $\dfrac{10\,a}{n}$

Official Ans. by NTA (4)

Sol. $(n-1)a = n(a')$

$$a' = \frac{(n-1)a}{n}$$

$\therefore$ L.C. = 1 MSD – 1 VSD

$= (a - a')\text{cm}$

$$= a - \frac{(n-1)a}{n}$$

$$= \frac{na - na + a}{n} = \frac{a}{n}\text{cm}$$

$$= \left(\frac{10a}{n}\right)\text{mm}$$

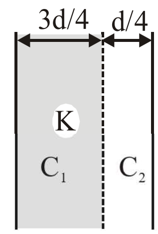
2. For changing the capacitance of a given parallel plate capacitor, a dielectric material of dielectric constant K is used, which has the same area as the plates of the capacitor. The thickness of the dielectric slab is $\frac{3}{4}d$, where 'd' is the separation between the plates of parallel plate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

(1) $C' = \dfrac{3+K}{4K}C_0$ (2) $C' = \dfrac{4+K}{3}C_0$

(3) $C' = \dfrac{4K}{K+3}C_0$ (4) $C' = \dfrac{4}{3+K}C_0$

Official Ans. by NTA (3)

Sol.



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

C' = C_1 and C_2 in series.

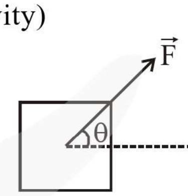
i.e. $\dfrac{1}{C'} = \dfrac{1}{C_1} + \dfrac{1}{C_2}$

$$\frac{1}{C'} = \frac{(3d/4)}{\epsilon_0 KA} + \frac{d/4}{\epsilon_0 A}$$

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

$$C' = \frac{4KC_0}{(3+K)}$$

3. 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)



(1) $-\dfrac{F}{m}\cos\theta - \mu_K\left(g - \dfrac{F}{m}\sin\theta\right)$

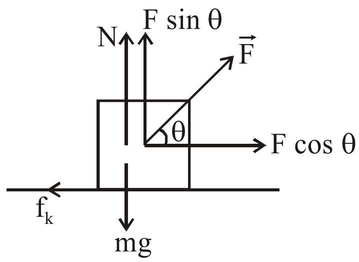
(2) $\dfrac{F}{m}\cos\theta - \mu_K\left(g - \dfrac{F}{m}\sin\theta\right)$

(3) $\dfrac{F}{m}\cos\theta - \mu_K\left(g + \dfrac{F}{m}\sin\theta\right)$

(4) $\dfrac{F}{m}\cos\theta + \mu_K\left(g - \dfrac{F}{m}\sin\theta\right)$

Official Ans. by NTA (2)

Sol.



$N = mg - F \sin\theta$

$F\cos\theta - \mu_k N = ma$

$F\cos\theta - \mu_k (mg - F\sin\theta) = ma$

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

4. 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}, g = 10 ms^{-2})

(1) $\frac{200}{3}\%$ (2) $\frac{200}{5}\%$

(3) $\frac{5}{200}\%$ (4) $\frac{3}{200}\%$

Official Ans. by NTA (1)

Sol. $P_1 = \rho gd + P_0 = 3 \times 10^5$ Pa

$\therefore \rho gd = 2 \times 10^5$ Pa

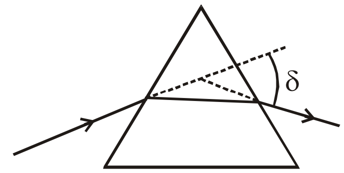
$P_2 = 2\rho gd + P_0$

$= 4 \times 10^5 + 10^5 = 5 \times 10^5$ Pa

$$\%\text{increase} = \frac{P_2 - P_1}{P_1} \times 100$$

$$= \frac{5\times10^5 - 3\times10^5}{3\times10^5} \times 100 = \frac{200}{3}\%$$

5. 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 :

(1) Statements (A), (B) and (C) are true

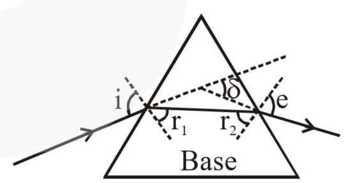
(2) Only statement (D) is true

(3) Only statements (A) and (B) are true

(4) Statements (B) and (C) are true

Official Ans. by NTA (1)

Sol. Deviation is minimum in a prism when : $i = e$, $r_1 = r_2$ and ray (2) is parallel to base of prism.



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})

$\hat{x}, \hat{y}, \hat{z}$ are unit vectors along x, y and z direction.

(1) $-24\hat{x}$ V/m (2) $2.6\hat{x}$ V/m

(3) $24\hat{x}$ V/m (4) $-2.6\hat{y}$ V/m

Official Ans. by NTA (1)

Sol. $f = 5 \times 10^8$ Hz

EM wave is travelling towards $+\hat{j}$

$\vec{B} = 8.0 \times 10^{-8} \hat{z} T$

$\vec{E} = \vec{B} \times \vec{C}$ = $(8 \times 10^{-8} \hat{z}) \times (3 \times 10^8 \hat{y})$

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

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 :

(1) 1.5×10^3 m/s (2) 6.0×10^3 m/s

(3) 3.0×10^3 m/s (4) 4.5×10^3 m/s

Official Ans. by NTA (3)

Sol. By angular momentum conservation :

$mv_1r_1 = mv_2r_2$

$$v_1 = \frac{48 \times 10^{14}}{1.6 \times 10^{12}} = 3000 \text{ m/sec}$$

$= 3 \times 10^3$ m/sec.

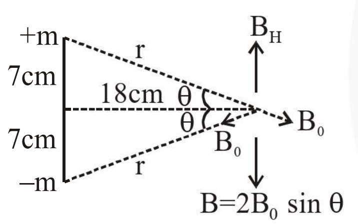
8. A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the center of the magnet. If $B_H = 0.4$ G, the magnetic moment of the magnet is ($1 \text{ G} = 10^{-4}$T)

(1) 2.880×10^3 J T^{-1} (2) 2.880×10^2 J T^{-1}

(3) 2.880 J T^{-1} (4) 28.80 J T^{-1}

Official Ans. by NTA (3)

Sol.



$$\text{i.e. } \frac{2\mu_0}{4\pi}\frac{m}{r^2} \times \frac{7}{r} = 0.4 \times 10^{-4}$$

$$\Rightarrow 2 \times 10^{-7} \times \frac{m \times 7}{(7^2 + 18^2)^{3/2}} \times 10^4$$

$= 0.4 \times 10^{-4}$

$$m = \frac{4 \times 10^{-2} \times (373)^{3/2}}{14}$$

$$M = m \times 14 \text{ cm} = m \times \frac{14}{100}$$

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

$= 4 \times 10^{-4} \times 7203.82 = 2.88$ J/T

9. 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 :

(1) $\frac{88RT}{V}$ (2) $\frac{3RT}{V}$

(3) $\frac{5}{2}\frac{RT}{V}$ (4) $\frac{4RT}{V}$

Official Ans. by NTA (3)

Sol. $PV = (n_1 + n_2 + n_3)RT$

$$P \times V = \left[\frac{16}{32} + \frac{28}{28} + \frac{44}{44}\right]RT$$

$$PV = \left[\frac{1}{2} + 1 + 1\right]RT$$

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

10. In thermodynamics, heat and work are :

(1) Path functions

(2) Intensive thermodynamic state variables

(3) Extensive thermodynamic state variables

(4) Point functions

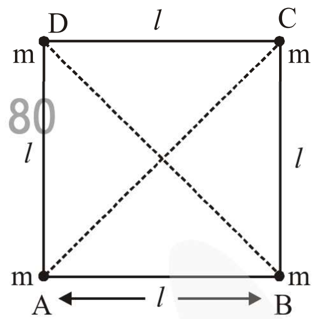
Official Ans. by NTA (1)

Sol. Heat and work are treated as path functions in thermodynamics.

$\Delta Q = \Delta U + \Delta W$

Since work done by gas depends on type of process i.e. path and ΔU depends just on initial and final states, so ΔQ i.e. heat, also has to depend on process is path.

11. 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 :



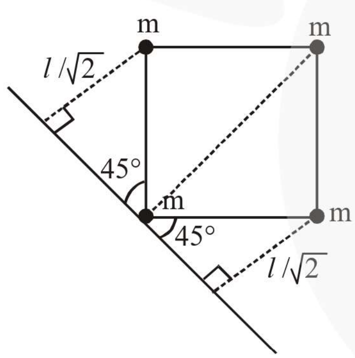
(1) ml^2 (2) $2\ ml^2$

(3) $3\ ml^2$ (4) $\sqrt{3}\,ml^2$

Official Ans. by NTA (3)

Sol. Moment of inertia of point mass

= mass × (Perpendicular distance from axis)^2



Moment of Inertia

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

$= 3\ ml^2$

12. 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.

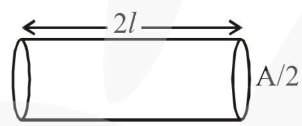
If the length of the wire of the same material is doubled and the area of cross-section is halved, the resultant current would be :

(1) $\frac{1}{4}\frac{VA}{\rho l}$ (2) $\frac{3}{4}\frac{VA}{\rho l}$

(3) $\frac{1}{4}\frac{\rho l}{VA}$ (4) $4\frac{VA}{\rho l}$

Official Ans. by NTA (1)

Sol. As per the question



$\text{Resistance} = \frac{\rho(2l)}{(A/2)} = \frac{4\rho l}{A}$

$\Rightarrow \text{Current} = \frac{V}{R} = \frac{VA}{4\rho l}$

13. 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 :

(1) $\sqrt{3}\,T$

(2) $\frac{T}{\sqrt{3}}$

(3) $\sqrt{\frac{3}{2}}\,T$

(4) $\sqrt{\frac{2}{3}}\,T$

Official Ans. by NTA (4)

Sol. When lift is stationary

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

When lift is moving upwards

$\Rightarrow$ Pseudo force acts downwards

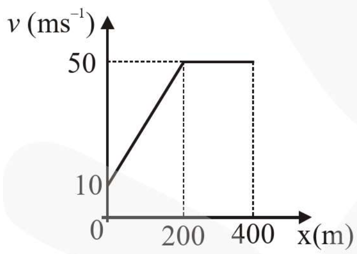
$$\Rightarrow g_{eff} = g + \frac{g}{2} = \frac{3g}{2}$$

$\Rightarrow$ New time period

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

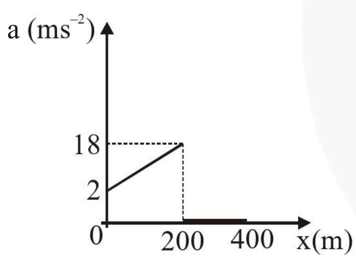
$$\boxed{T' = \sqrt{\frac{2}{3}}\,T}$$

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

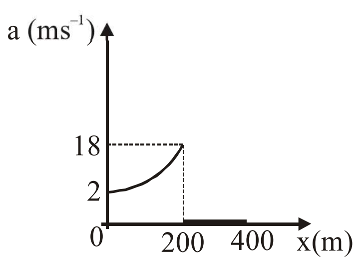


The acceleration-displacement graph of the bicycle's motion is best described by :

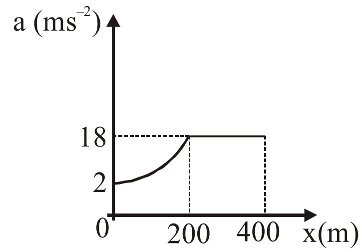
(1)



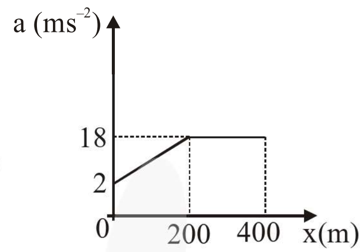
(2)



(3)



(4)



Official Ans. by NTA (1)

Official Ans. by ALLEN (1 or Bonus)

Sol. For $0 \le x \le 200$

$v = mx + C$

$$v = \frac{1}{5}x + 10$$

$$a = \frac{vdv}{dx} = \left(\frac{x}{5} + 10\right)\left(\frac{1}{5}\right)$$

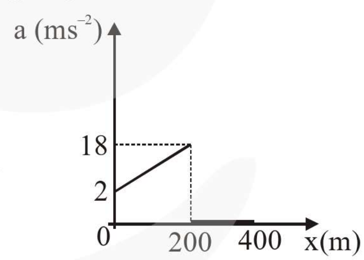
$$a = \frac{x}{25} + 2 \Rightarrow \text{Straight line till } x = 200$$

for $x > 200$

v = constant

$\Rightarrow a = 0$

$\Rightarrow$



Hence most approriate option will be (1), otherwise it would be BONUS.

15. 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 :

(1) 300 (2) 400

(3) 200 (4) 100

Official Ans. by NTA (4)

Sol. Length of Antena = 25m = $\frac{\lambda}{4}$

$$\Rightarrow \boxed{\lambda = 100\,m}$$

16. 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 :

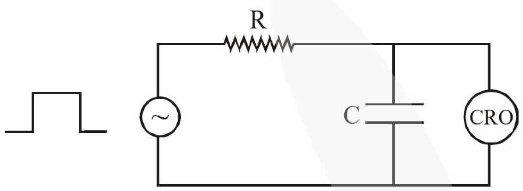
(1) $U_e = U_m$ (2) $U_e > U_m$

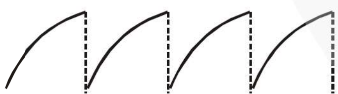
(3) $U_e < U_m$ (4) $U_e \neq U_m$

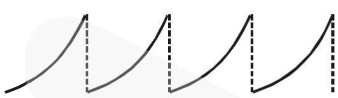
Official Ans. by NTA (1)

Sol. In EMW, Average energy density due to electric (U_e) and magnetic (U_m) fields is same.

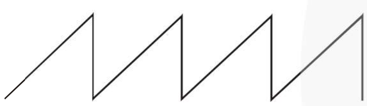
17. An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to :



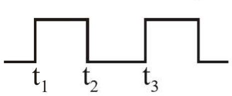
(1) 

(2) 

(3) 

(4) 

Official Ans. by NTA (3)

Sol. 

For $t_1 - t_2$ Charging graph

$t_2 - t_3$ Discharging graph

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

(1) Phase (2) Intensity

(3) Amplitude (4) Frequency

Official Ans. by NTA (4)

Sol. Stopping potential changes linearly with frequency of incident radiation.

19. 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 :

(1) 0.0314 N

(2) 9.859×10^{-2} N

(3) 6.28×10^{-3} N

(4) 9.859×10^{-4} N

Official Ans. by NTA (4)

Sol. $N = m\omega^2 R$

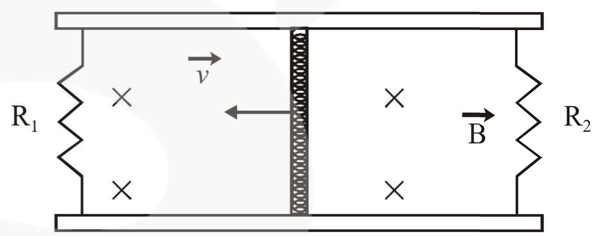
$$N = m\left[\frac{4\pi^2}{T^2}\right]R \qquad .....(1)$$

Given m = 0.2 kg, T = 40 S, R = 0.2 m

Put values in equation (1)

$N = 9.859 \times 10^{-4}$ N

20. 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 :

(1) Both I_1 and I_2 are in anticlockwise direction

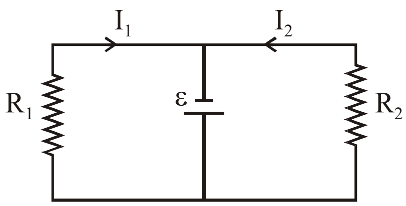
(2) Both I_1 and I_2 are in clockwise direction

(3) I_1 is in clockwise direction and I_2 is in anticlockwise direction

(4) I_1 is in anticlockwise direction and I_2 is in clockwise direction

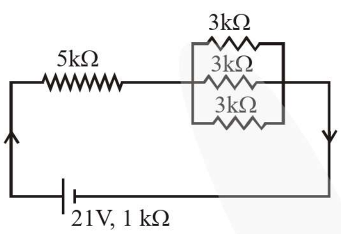
Official Ans. by NTA (3)

Sol.



SECTION-B

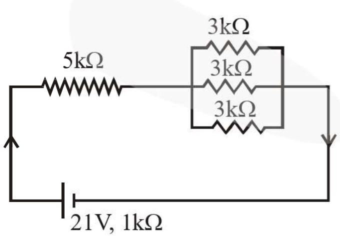
1. In the figure given, the electric current flowing through the 5 kΩ resistor is 'x' mA.



The value of x to the nearest integer is _______.

Official Ans. by NTA (3)

Sol.



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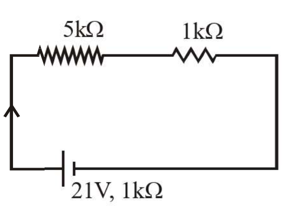


$$I = \frac{21}{5+1+1} = 3 \text{ mA}$$

2. 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 ______.

Official Ans. by NTA (600)

Sol. $\beta = \dfrac{\lambda D}{d}$

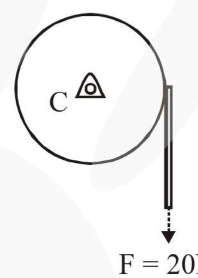
$$\lambda = \frac{\beta d}{D}$$

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

$\lambda = 6 \times 10^{-7}$ m $= 600 \times 10^{-9}$ m

$\lambda = 600$ nm

3. 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]

Official Ans. by NTA (20)

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

$$\alpha = \frac{2 \times 200}{20 \times (0.2)} = 10 \text{ rad/s}^2$$

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

$$(50)^2 = 0^2 + 2(10)\,\Delta\theta \Rightarrow \Delta\theta = \frac{2500}{20}$$

$\Delta\theta = 125$ rad

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

4. The first three spectral lines of H-atom in the Balmer series are given λ_1, λ_2, λ_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 ________.

Official Ans. by NTA (15)

Sol. For 1st line

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

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

For 3rd line

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

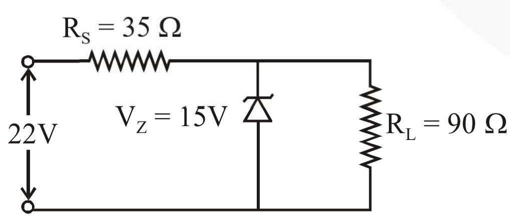
$$\frac{1}{\lambda_3} = Rz^2\,\frac{21}{100} \qquad .....(ii)$$

(ii) + (i)

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

$x \approx 15$

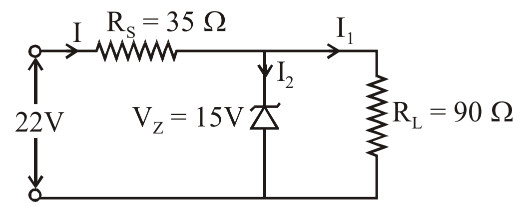
5. The value of power dissipated across the zener diode (V_z = 15 V) connected in the circuit as shown in the figure is x × 10^{-1} watt.



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

Official Ans. by NTA (5)

Sol.



Voltage across R_S = 22 – 15 = 7V

Current through $R_S = I = \frac{7}{35} = \frac{1}{5}$ A

Current through $90\Omega = I_2 = \frac{15}{90} = \frac{1}{6}$ A

Current through zener $= \frac{1}{5} - \frac{1}{6} = \frac{1}{30}$ A

Power through zener diode

P = VI

$P = 15 \times \frac{1}{30} = 0.5$ watt

$P = 5 \times 10^{-1}$ watt

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

Official Ans. by NTA (4)

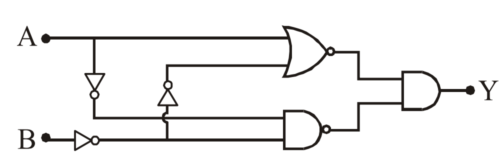
Sol. At resonance power (P)

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

$$P = \frac{(250/\sqrt{2})^2}{8} = 3906.25 \text{ W}$$

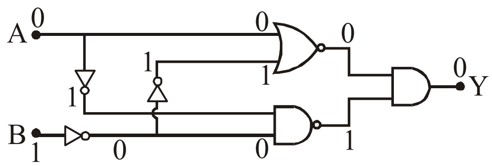
≈ 4 kW

7. 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 _______.



Official Ans. by NTA (0)

Sol.



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

Official Ans. by NTA (5)

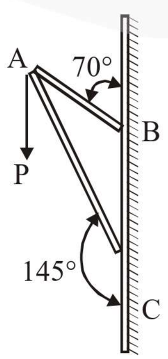
Sol. $\frac{\Delta R}{R} \times 100 = \frac{\Delta V}{V} \times 100 + \frac{\Delta I}{I} \times 100$

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

% error in R = 4 + 1

% error in R = 5%

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.

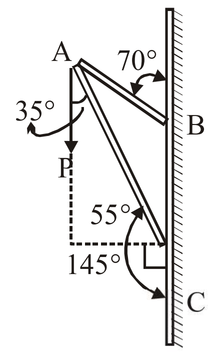


Suppose the force is $\vec{p}$ resolved parallel to the arms AB and AC of the frame. The magnitude of the resolved component along the arm AC is xN. The value of x, to the nearest integer, is ________.

[Given : sin(35°) = 0.573, cos(35°) = 0.819
sin(110°) = 0.939, cos(110°) = –0.342]

Official Ans. by NTA (82)

Sol.



Component along AC

= 100 cos 35°N

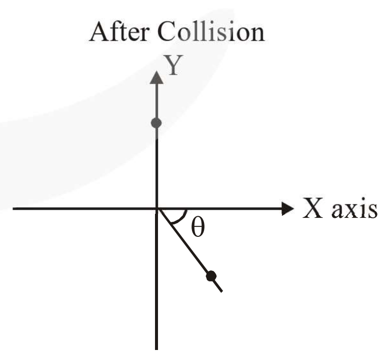
= 100 × 0.819 N

= 81.9 N

≈ 82 N

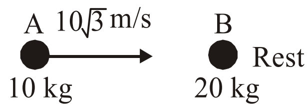
10. A ball of mass 10 kg moving with a velocity $10\sqrt{3}\, ms^{-1}$ along X-axis, hits another ball of mass 20 kg which is at rest. After collision, the first ball comes to rest and the second one disintegrates into two equal pieces. One of the pieces starts moving along Y-axis at a speed of 10 m/s.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

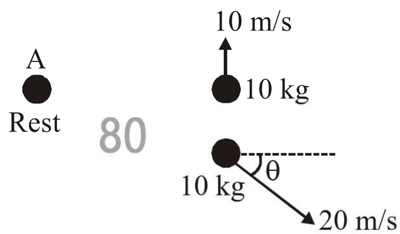


Official Ans. by NTA (30)

Sol. **Before Collision**



After Collision



From conservation of momentum along x axis;

$\vec{P}_i = \vec{P}_f$

$10 \times 10\sqrt{3} = 200 \cos\theta$

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

$\theta = 30°$