JEE-MAIN-2021 (16TH March-First Shift)

PART – A (PHYSICS)

SECTION - A

(One Options Correct Type)

***Questions*: 1:-** 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) $4\frac{VA}{\rho\ell}$

(B) $\frac{1}{4}\frac{\rho\ell}{VA}$

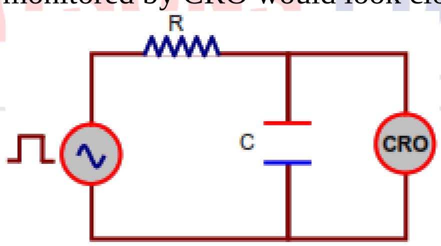
(C) $\frac{3}{4}\frac{VA}{\rho\ell}$

(D) $\boldsymbol{\frac{1}{4}\frac{VA}{\rho\ell}}$

***Ans*:-** $R = \frac{\rho\ell}{A} \Rightarrow I_1 = \frac{V}{R} = \frac{VA}{\rho\ell}$

When the length of the wire of the same material is doubled and the area of cross-section is halved $R' = \frac{\rho(2\ell)}{(A/2)} = \frac{4\rho\ell}{A} \Rightarrow I_2 = \frac{V}{R'} = \frac{VA}{4\rho\ell}$

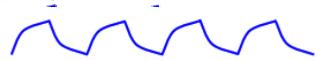
***Questions*: 2:-** An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to:



(A) 

(B) 

(C) 

(D) 

***Ans*:-** The capacitor will be repeatedly charged and discharged due to alternating source

During charging Process

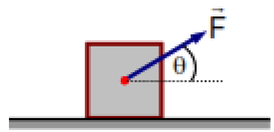
$Q = CV_o\left(1 - e^{-\frac{1}{RC}}\right) \Rightarrow$ Charge on the capacitor, and

$V_C = \frac{Q}{C} = V_o\left(1 - e^{-\frac{1}{RC}}\right) \Rightarrow$ Potential difference across capacitor

During discharging Process

$Q' = Q_o e^{-\frac{1}{RC}} + CV_o\left(1 - e^{-\frac{1}{RC}}\right) \Rightarrow$ Charge on the capacitor,

***Question*: 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 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) $-\frac{F}{m}\cos\theta + \mu_K\left(g - \frac{F}{m}\sin\theta\right)$

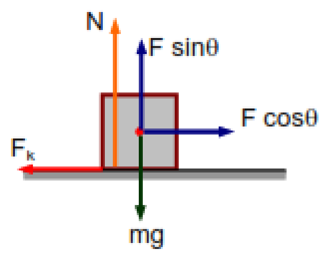
Ans:- N = mg – F sinθ ………(1)

According to Newton's second law we can write

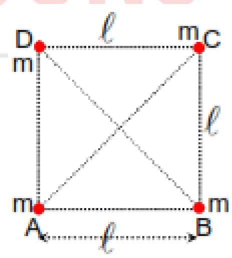
mg = F cosθ - μ_KN

$\Rightarrow$ ma = F cosθ – μ_K (mg – F sinθ)

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



***Question*: 4:-** 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) $2m\ell^2$

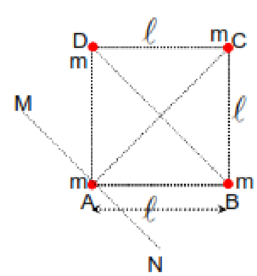
(B) $m\ell^2$

(C) $\sqrt{3}m\ell^2$

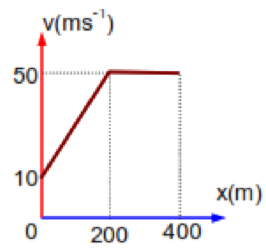
(D) $3m\ell^2$

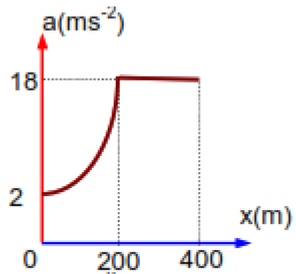
Ans:- $I_{MN} = m(0)^2 + m(\sqrt{2}\ell)^2 + m\left(\frac{\ell}{\sqrt{2}}\right)^2 \times 2$

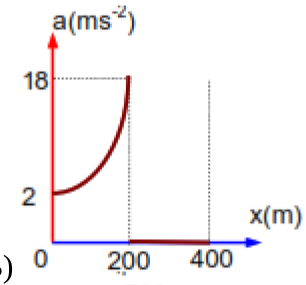
$\Rightarrow I_{MN} = 2m\ell^2 + m\ell^2 = 3m\ell^2$

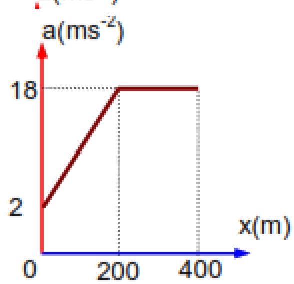


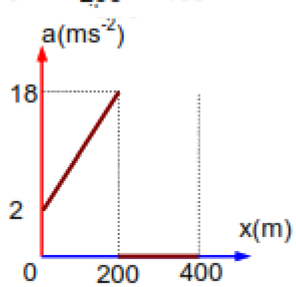
***Question*: 5:-** The velocity- displacement graph describing the motion of a bicycle is shown in the figure. The acceleration-displacement graph of the bicycle's motion is best described by:



(A) 

(B) 

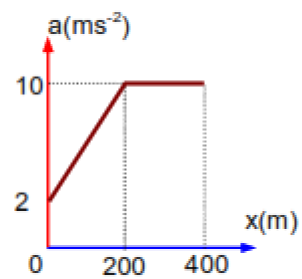
(C) 

(D) 

Ans:- $v = \begin{cases} 10 + \frac{x}{5} & \text{if } 0 \le x \le 200\text{m} \\ 50 & \text{if } 200\text{m} \le x \le 400\text{m} \end{cases}$

$\Rightarrow a = \frac{dv}{dt} = v\frac{dv}{dx} = \begin{cases} \frac{1}{5}\left(10 + \frac{x}{5}\right) & \text{if } 0 \le x \le 200\text{m} \\ 0 & \text{if } 200\text{m} \le x \le 400\text{m} \end{cases}$

$\Rightarrow a = \begin{cases} \left(2 + \frac{x}{25}\right) & \text{if } 0 \le x \le 200\text{m} \\ 0 & \text{if } 200\text{m} \le x \le 400\text{m} \end{cases}$



***Question*: 6:-** 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) $C' = \frac{4+K}{3}C_0$

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

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

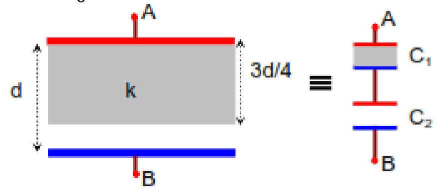
(D) $C' = \frac{4K}{K+3}C_0$

Ans:- $C_1 = \frac{\varepsilon_0 Ak}{3d/_4} = \frac{4\varepsilon_0 Ak}{3d} = \frac{4kC_0}{3}$

$C_2 = \frac{\varepsilon_0 A}{d/_4} = \frac{4\varepsilon_0 A}{d} = 4C_0$

Since capacitors C_1 and C_2 are in series, so

$\frac{1}{C'} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{3}{4kC_0} + \frac{1}{4C_0} \Rightarrow \frac{1}{C'} = \frac{3+k}{4kC_0} \Rightarrow C' = \frac{4k}{k+3}C_0$



***Question*: 7:-** A plane electromagnetic wave of frequency 500 MHz is traveling in vacuum along y-direction. At a particular point in space and time, $\hat{B}$ = 8.0 x 10^{-8} $\hat{z}$T. The value of electric field at this point is: (speed of light = 3 x 10^8 ms^{-1}) $\hat{x}$,$\hat{y}$,$\hat{z}$ are unit vectors along x, y and z directions.

(A) 24x V/m

(B) 2.6x V/m

(C) - 24x V/m

(D) – 2.6y V/m

Ans:- $c = \frac{E}{B} \Rightarrow E = cB = 24\ \text{V/m}$

As we know that direction of propagation of wave is $\hat{E} \times \hat{B} = \hat{c}$, so $\hat{E} = -\hat{x}$, hence

$\overline{E} = -24 \times \text{V/m}$

***Question*: 8:-** 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) $\sqrt{\frac{2}{3}}$ T

(B) $\sqrt{3}$ T

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

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

Ans:- $T = 2\pi\sqrt{\frac{\ell}{g_{eff}}}$

When lift is stationary, then $g_{eff} = g$, so $T = 2\pi\sqrt{\frac{\ell}{g}}$

When lift is moving up with acceleration g/2, then $g_{eff} = \frac{3g}{2}$, so $T = 2\pi\sqrt{\frac{2\ell}{3g}} = \sqrt{\frac{2}{3}}T$

***Question*: 9:-** The stopping potential in the context of photoelectric depends on the following property of incident electromagnetic radiation:

(A) Frequency

(B) Amplitude

(C) Intensity

(D) Phase

Ans:- The stopping potential in the context of photoelectric depends on frequency of incident electromagnetic radiation:

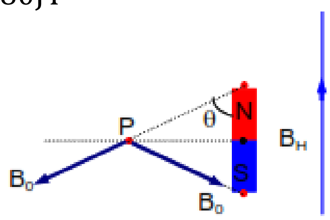
***Question*: 10:-** A bar magnet of length 14 cm is placed in the magnetic meridian with its north pole pointing towards the geographic north pole. A neutral point is obtained at a distance of 18 cm from the centre of the magnet. If $B_H = 0.4G$, the magnetic moment of the magnet is ($1G = 10^{-4}T$)

(A) $2.880 \times 10^3\ JT^{-1}$ **(B) $2.880\ JT^{-1}$**
(C) $2.880 \times 10^2\ JT^{-1}$ (D) $28.80\ JT^{-1}$

***Ans*:-** $B_H = 2B_0 \cos\theta = \frac{2\mu_0(m)}{4\pi(d^2+r^2)} \times \frac{r}{\sqrt{d^2+r^2}} = \frac{\mu_0 M}{4\pi(d^2+r^2)^{\frac{3}{2}}}$

$\Rightarrow M = \frac{4\pi(d^2+r^2)^{\frac{3}{2}} B_H}{\mu_0} = \frac{0.4\times10^{-4}\times(373\sqrt{373})\times10^{-6}}{10^{-7}}$

$\Rightarrow M = 2881.5 \times 10^{-3}\ JT^{-1} \approx 2.880 JT^{-1}$



***Question*: 11:-** A block of 200 g mass moves with a uniform speed in a horizontal circular groove, with vertical side walls of radius 20cm. 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**

***Ans*:-** $F = m\omega^2 R = m\left(\frac{2\pi}{T}\right)^2 R = \frac{0.2\times4\times\pi^2\times0.2}{40\times40} = 9.859\times10^{-4} N$

***Question*: 12:-** 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) $\frac{3RT}{V}$ **(B) $\frac{5}{2}\frac{RT}{V}$**
(C) $\frac{88RT}{V}$ (D) $\frac{4RT}{V}$

***Ans*:-** **Using Concept of Partial pressure, we can write**

$P = P_{O_2} + P_{N_2} + P_{CO_2} = \frac{n_1 RT}{V} + \frac{n_2 RT}{V} + \frac{n_3 RT}{V}$

$\Rightarrow P = \frac{RT}{V}\left(\frac{16}{32} + \frac{28}{28} + \frac{44}{44}\right) = \frac{5RT}{2V}$

***Question*: 13:-** The pressure acting on a submarine is 3×10^5 Pa at a certain depth. If the depth is doubled, the percentage in the pressure acting on the submarine would be:
(Assume that atmospheric pressure is 1×10^5 Pa density of water is $10^3\ kgm^{-3}$, $g = 10ms^{-1}$)

(A) $\frac{3}{200}$% (B) $\frac{5}{200}$%
(C) $\frac{200}{3}$% (D) $\frac{200}{5}$%

***Ans*:-** $P_1 = P_0 + \rho gh \Rightarrow h = \frac{P_1 - P_0}{\rho g}$, and $P_2 = P_0 + 2\rho gh = P_0 + 2\rho g\left(\frac{P_1-P_0}{\rho g}\right) = 2P_1 - P_0$

$\Rightarrow \Delta P = P_2 - P_1 = P_1 - P_0$

$\Rightarrow$ % increment in pressure $= \frac{P_1 - P_0}{P_1} \times 100 = \frac{200}{3}$%

***Question*: 14:-** 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:

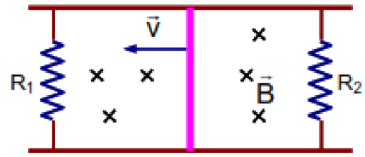
(A) 3.0×10^3 m/s (B) 1.5×10^3 m/s

(C) 4.5×10^3 m/s (D) 6.0×10^3 m/s

***Ans*:- According to conversation of angular momentum, we can write**

$$v_1 r_1 = v_2 r_2 \Rightarrow v_1 = \frac{v_2 r_2}{r_1} = \frac{8 \times 10^{10}}{1.6 \times 10^{12}} \times 6 \times 10^4 = 3 \times 10^3 \ m/s$$

***Question*: 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 $\bar{B}$ 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 anticlockwise direction and I_2 is in clockwise direction

(B) Both I_1 and I_2 are in anticlockwise direction

(C) Both I_1 and I_2 are in clockwise direction

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

***Ans*:-** Since magnetic flux linked with loop containing R_1 decreases with time, so

$\hat{B}_{ind} = +\hat{B}_{Source} = (-\hat{k})$, hence current I_1 in R_1 will be clockwise

Since magnetic flux linked with loop containing R_2 decreases with time, so

$\hat{B}_{ind} = -\hat{B}_{Source} = (+\hat{k})$, hence current I_2 in R_2 will be anti – clockwise

***Question*: 16:-** 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) $\frac{10na}{(n-1)}$ (B) $\frac{10a}{(n-1)}$

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

***Ans*:-** Least count of the callipar = 1 MSD – 1 VSD = $a - \frac{(n-1)a}{n} = \frac{a}{n} cm = \frac{10a}{n} mm$

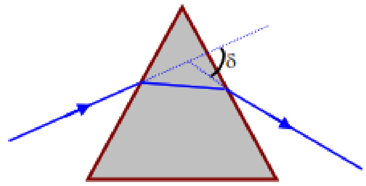
***Question*: 17:-** A 25 m long antenna is mounted on an antenna tower. The height of the antenna tower is 75m. The wavelength (in meter) of the signal transmitted by this antenna would be:

(A) 100 (B) 300

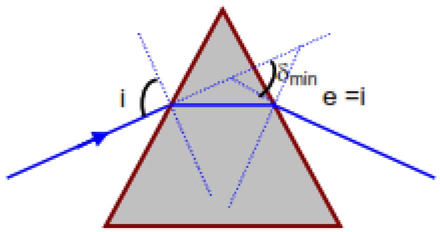
(C) 200 (D) 400

***Ans*:-** Height of Antenna $= \frac{\lambda}{4} \Rightarrow \lambda = 4h = 4 \times 25 = 100$ m

***Question*: 18:-** 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 if 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) Statements (B) and (C) are true   **(B) Statements (A), (B) and (C) are true**
(C) Only statement (D) is true   (D) Only statements (A) and (B) are true
Ans:- Basic Fact



***Question*: 19:-** For an electromagnetic wave traveling in free space, the relation between average energy densities due to electric (U_e) and magnetic (U_m) fields is:
(A) $U_e > U_m$ **(B) $U_e = U_m$**
(C) $U_e \neq U_m$ (D) $U_e < U_m$
Ans:- $U_e = U_m = \frac{1}{2}\varepsilon_0 E^2 = \frac{B^2}{2\mu_0}$ because $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = \frac{E}{B}$

***Question*: 20:-** In thermodynamics, heat and work are:
(A) Point functions   (B) Extensive thermodynamic state variables
(C) Path functions   (D) Intensive thermodynamic state variables
Ans:- In thermodynamics, heat and work are path function