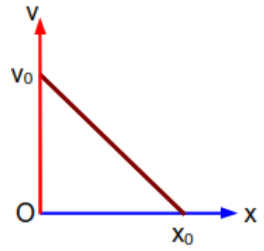
JEE-MAIN-2021 (18th March-Second Shift)

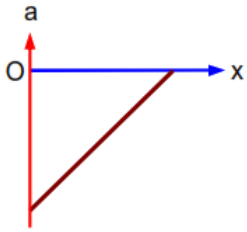
PART – A (PHYSICS)

SECTION - A

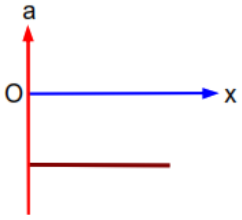
***Questions*: 1:-** The velocity –displacement graph of a particle is shown in the figure. The acceleration – displacement graph of the same particle is represented by:



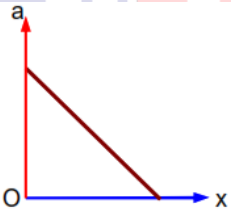
(A)



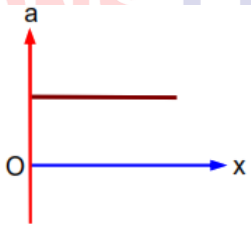
(B)



(C)



(D)

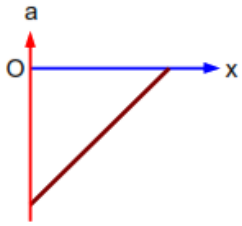


***Ans*:-A**

Equation of curve is

$$\frac{v}{v_0}+\frac{x}{x_0}=1 \Rightarrow v=-\left(\frac{v_0}{x_0}\right)x+v_0$$

$$\Rightarrow a=\frac{dv}{dt}=-\left(\frac{v_0}{x_0}\right)(v)=-\left(\frac{v_0}{x_0}\right)\left(-\left(\frac{v_0}{x_0}\right)x+v_0\right) \Rightarrow a=\left(\frac{v_0}{x_0}\right)^2 x-\frac{v_0^2}{x_0}$$



Concept involved: Graph of kinematics
Topic: Kinematics
Difficulty level: Moderate
Note: IIT-Jee-2005
Point of Error: Writing Equation of straight line and differentiation

***Questions*: 2:-** 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 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:

***Ans*:- A**

Basic Fact

Concept involved: Electric and magnetic field lines
Topic: Magnetics and Magnetic Material
Difficulty level: Moderate
Point of Error: Fact

***Questions*: 3:-** The speed of electrons in a scanning electron microscope is1 x 10^7m/s. If 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

(A) 1837 (B) $\sqrt{1837}$
(C) $\frac{1}{\sqrt{1837}}$ (D) 1/1837

***Ans*:- A**

As we know that resolving power (R) of a microscope is given as

$$R = \frac{2\mu \sin\theta}{1.22\lambda} \ldots\ldots\ldots (1)$$

According to de-Broglie's hypothesis, we can write

$$\lambda = \frac{h}{mv} \ldots\ldots\ldots\ldots (2)$$

With the help of equations (1) and (2) , we can write

$$R = \frac{2\mu mv \sin\theta}{1.22h} \Rightarrow \frac{R_p}{R_e} = \frac{m_p}{m_e} = 1837 \Rightarrow R_p = 1837 R_e$$

Concept involved: Resolving Power of Microscope
Topic: Optics
Difficulty level: Moderate
Point of Error: Formula

***Questions*: 4:-** A proton and an α-particle , having kinetic energy K_ρ and Kα 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_ρ : Kα is

(A)1:8 (B) 8:1
(C) 1:4 (D) 4:1

***Ans*:- D**

As we know that radius of trajectory is given as

$$R = \frac{mv}{qB} = \frac{\sqrt{2mK}}{qB} \Rightarrow K = \frac{R^2 q^2 B^2}{2m}$$

$$\Rightarrow \frac{K_p}{K_\alpha} = \frac{R_p^2 q_p^2 B^2}{2m_p} \times \frac{2m_\alpha}{R_\alpha^2 q_\alpha^2 B^2} = \left(\frac{m_\alpha}{m_p}\right) \times \left(\frac{R_p}{R_\alpha}\right)^2 \times \left(\frac{q_p}{q_\alpha}\right)^2$$

$$\Rightarrow \frac{K_p}{K_\alpha} = (4) \times (2)^2 \times \left(\frac{1}{2}\right)^2 = 4:1$$

Concept involved: Motion of charged particle in magnetic Field
Topic: Magnetics
Difficulty level: Easy

***Questions*: 5:-** The time taken for the magnetic energy to reach 25% of its maximum value , when solenoid of resistance R, inductance L is connected to a battery , is:

(A) $\frac{L}{R}\ell n(2)$ (B) $\frac{L}{R}\ell n(10)$

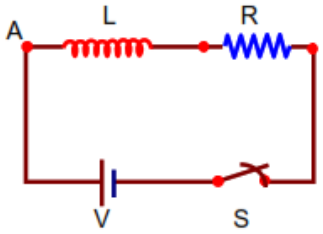
(C) Infinite (D) $\frac{L}{R}\ell n(5)$

***Ans*:-A**

As we know that the current in L-R - circuit is given as

$$I = \frac{V}{R}\left(1 - e^{-\frac{t}{\tau}}\right), \text{ where } \tau = \frac{L}{R}$$

$$E = \frac{LI^2}{2} = \frac{LV^2}{2R^2}\left(1 - e^{-\frac{t}{\tau}}\right)^2 \Rightarrow \text{Energy stored in inductor}$$



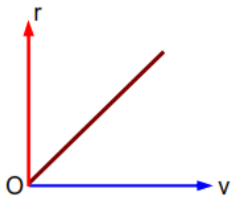
According to Question, we can write

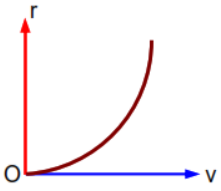
$$\frac{1}{4}\left(\frac{LV^2}{2R^2}\right) = \frac{LV^2}{2R^2}\left(1 - e^{-\frac{t}{\tau}}\right)^2 \Rightarrow \frac{1}{4} = \left(1 - e^{-\frac{t}{\tau}}\right)^2 \Rightarrow \frac{1}{2} = 1 - e^{-\frac{t}{\tau}} \Rightarrow e^{-\frac{t}{\tau}} = \frac{1}{2}$$

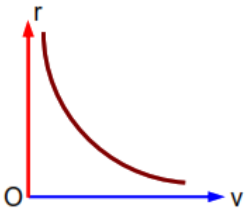
$$\Rightarrow \frac{t}{\tau} = \ell n(2) \Rightarrow t = \tau \ell n(2) = \frac{L}{R}\ell n(2)$$

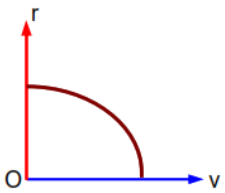
Concept involved: Energy stored in inductor in L-R - circuit
Topic: EMI
Difficulty level: Moderate
Point of Error: Formula

***Questions*: 6:-** A particle of mass m moves in a circular orbit under the central potential field, $V(r) = \frac{C}{r}$, where C is a constant. The correct radius – velocity graph of the particle's motion is;

(A) 

(B) 

(C) 

(D) 

***Ans*:- C**

$$U = mV(r) = -\frac{Cm}{r}$$

$$F = -\frac{dU}{dr} = \frac{Cm}{r^2} \Rightarrow \text{The force which provides required centripetal force}$$

$$\Rightarrow \frac{mv^2}{r} = \frac{Cm}{r^2} \Rightarrow r = \frac{C}{v^2}$$

Concept involved: Dynamics of circular motion
Topic: Work ,power and Energy
Difficulty level: Moderate

***Questions*: 7:-** 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):

(A) $-\gamma \frac{dV}{V}$ (B) $\frac{dV}{V}$

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

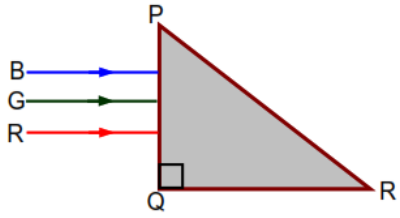
***Ans*:- A**

As we know that for adiabatic expansion

$$PV^{\gamma} = C \Rightarrow V^{\gamma}\frac{dP}{dV} + P\left(\gamma V^{\gamma-1}\right) = 0 \Rightarrow \frac{dP}{dV} = -\gamma\frac{P}{V} \Rightarrow \frac{dP}{P} = -\gamma\frac{dV}{V}$$

Concept involved: Adiabatic Process
Topic: Heat and Thermodynamics
Difficulty level: Easy

***Questions*: 8:-** Three rays of light, red (R) , green(G) and blue (B) are incident on the face PQ of a right angled prism PQR as shown in the figure. The refractive indices of material of the prism for red, green and blue wavelength are 1.27, 1.42 and 1.49 respectively. The colour of ray(s) emerging out of the face PR is



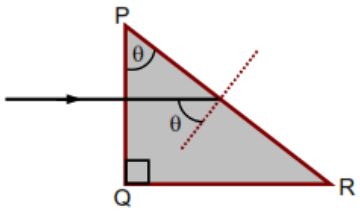
(A) red (B) blue and green
(C) green (D) blue

***Ans*:-** A

For light ray to come out from face PR of prism

$$\theta_C > i = \theta \Rightarrow \sin\theta_C > \sin\theta \Rightarrow \frac{1}{\mu} > \sin\theta$$

$$\Rightarrow \mu < \frac{1}{\sin\theta}$$



Note: If we assume $\theta = 45^0 \Rightarrow \mu < 1.414$, then red colour light ray will come out from face PR of prism

Concept involved: Total internal refraction
Topic: Optics
Difficulty level: Moderate
Note: IIT-Jee-1989

***Questions*: 9:-** 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;

(A) $\frac{2L}{M}$ (B) $\frac{L}{2M}$

(C) $\frac{4L}{M}$ (D) $\frac{L}{M}$

***Ans*:-** B

A= Area swept $\Rightarrow \frac{dA}{dt} = \frac{1}{2}r^2\frac{d\theta}{dt} = \frac{1}{2}\left(\frac{Mr^2\omega}{M}\right) = \frac{L}{2M}$

Concept involved: Kepler's Second Law
Topic: Gravitation
Difficulty level: Easy

***Questions*: 10:-** The decay of a proton to neutron is :
(A) possible only inside the nucleus
(B) not possible but neutron to proton conversion is possible
(C) not possible as proton mass is less than the neutron mass
(D) always possible as it is associated only with β^+ decay

***Ans*:-** A

Basic Fact

Concept involved: β^+ decay
Topic: Modern Physics
Difficulty level: Easy

***Questions*: 11:-** The function of time representing a simple harmonic motion with time period of π/ω is :

(A) $\sin(\omega t) + \cos(\omega t)$ (B) $\sin^2(\omega t)$

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

***Ans*:-** B, C

(A) $\sin(\omega t)+\cos(\omega t)=\sqrt{2}\sin\left(\omega t+\frac{\pi}{4}\right)\Rightarrow T=\frac{2\pi}{\omega}$

(B) $\sin^2(\omega t)=\frac{1}{2}-\frac{1}{2}\cos(2\omega t)\Rightarrow T=\frac{2\pi}{2\omega}=\frac{\pi}{\omega}$

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

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

Time period of $\cos(\omega t)=\frac{2\pi}{\omega}$

Time period of $\cos(2\omega t)=\frac{2\pi}{2\omega}$

Time period of $\cos(3\omega t)=\frac{2\pi}{3\omega}$

Time period of combined function $=\frac{2\pi}{\omega}$

Concept involved: Basic equation of SHM
Topic: SHM
Difficulty level: Easy

***Questions*: 12:-** 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 :

$\left[Take\ \ g=10\,ms^{-2},the\ \ radius\ of\ \ earth,\ R=6400\times10^3\ m,\ Take\ \pi=3.14\right]$

(A) 1200 minutes (B) does not change
(C) 60 minutes (D) 84 minutes

***Ans*:-** D

$g_e=g-\omega^2R\Rightarrow0=g-\omega^2R\Rightarrow\omega=\sqrt{\frac{g}{R}}$

$\Rightarrow T=\frac{2\pi}{\omega}=2\pi\sqrt{\frac{R}{g}}=2\times3.14\times\sqrt{\frac{6400\times10^3}{10}}$

$\Rightarrow T=2\times3.14\times80\times10\,s=83.733\,\text{min}\simeq84\,\text{min}$

Concept involved: Variation of g[Circular motion of earth]
Topic: Laws of motion
Difficulty level: Moderate

***Questions*: 13:-** 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:

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

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

***Ans*:-** B

As we know that for a transistor

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

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

Concept involved: Transistor
Topic: Semiconductor and devices
Difficulty level: Easy

***Questions*: 14:-** 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:

(A) $S_1 - S_2$ (B) $\frac{S_1}{S_2}$

(C) $S_1 \times S_2$ (D) $S_1 + S_2$

***Ans*:-** D

$S = S_1 + S_2$

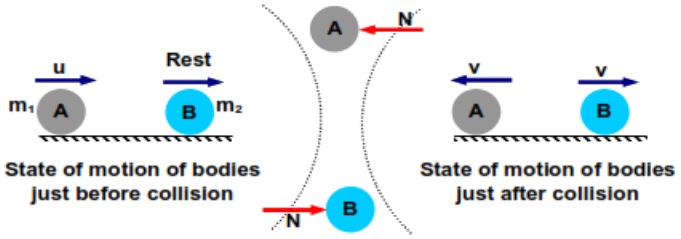
Concept involved: Entropy
Topic: Heat and thermodynamics
Difficulty level: Moderate

***Questions*: 15:-** An object of mass m1 collides with another object of mass m_2 , which is at rest. After collision the objects move with equal speeds in the opposite direction. The ratio of the masses m_2: m_1 is:

(A) 1:1 (B) 3:1

(C) 1:2 (D) 2:1

***Ans*:-** B



With the help of Conservation of linear momentum, we can write

$$m_1 u = (m_2 - m_1)v \ldots\ldots\ldots(1)$$

With the help of definition of e, we can write

$$e = \frac{v_s}{v_a} = \frac{2v}{u} \Rightarrow u = \frac{2v}{e} \ldots\ldots\ldots(2)$$

Putting the value of e in equation (1) , we have

$$m_1 \frac{2v}{e} = (m_2 - m_1)v \Rightarrow 2m_1 = em_2 - em_1 \Rightarrow \frac{m_2}{m_1} = \frac{2+e}{e} = 1 + \frac{2}{e} > 2$$

From options, only possible answer is B
Concept involved: Collision
Topic: Centre of mass and collision
Difficulty level: Difficult

***Questions*: 16:-**

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 :

(A) 1/2 (B) $\frac{\sqrt{3}}{2}$

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

***Ans*:-** C

$$z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{(6)^2 + (4-10)^2} = 6\sqrt{2}\,\Omega$$

$$\text{Power factor} = \cos\phi = \frac{R}{z} = \frac{6}{6\sqrt{2}} = \frac{1}{\sqrt{2}}$$

Concept involved: Power Factor of LCR-circuit
Topic: Alternating Current
Difficulty level: Easy

***Questions*: 17:-** Consider a uniform wire of mass M and length L . It is bent into a semi-circle. Its moment of inertia about a line perpendicular to the plane of the wire passing through centre is :

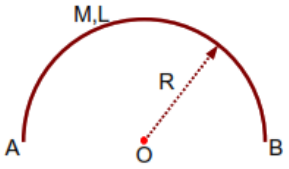
(A) $\frac{ML^2}{\pi^2}$ (B) $\frac{2ML^2}{5\pi^2}$

(C) $\frac{ML^2}{2\pi^2}$ (D) $\frac{ML^2}{4\pi^2}$

***Ans*:-** A

$$\pi R = L \Rightarrow R = \frac{L}{\pi}$$

$$I_O = MR^2 = M\left(\frac{L}{\pi}\right)^2 = \frac{ML^2}{\pi^2}$$



Concept involved: Moment of Inertia
Topic: Rotation
Difficulty level: Moderate

***Questions*: 18:-** A plane electromagnetic wave propagating along y-direction, can have the following pair of electric field($\vec{E}$) and magnetic field ($\vec{B}$) components:

(A) E_x, B_y or E_y, B_x

(B) E_y, B_x or E_x, B_y

(C) E_y, B_y or E_z, B_z

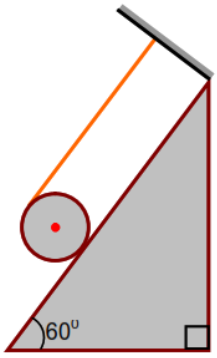
(D) E_x, B_z or E_z, B_x

***Ans*:-** D

As we know that direction of propagation of electromagnetic wave is perpendicular to plane containing mutually perpendicular electric field and magnetic field , so option D will be correct answer.

Concept involved: Propagation of EMW
Topic: EMW
Difficulty level: Easy

***Questions*: 19:-** 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]



(A) 0

(B) 7mg/2

(C) 5mg

(D) mg/5

***Ans*:-** D

As we know that for rolling without slipping on inclined plane, the minimum value of coefficient of static friction will be

$$\mu_{\min} = \frac{I\tan\theta}{I + mR^2}$$

$$\Rightarrow \mu_{\min} = \frac{\frac{mR^2}{2}\tan\theta}{\frac{mR^2}{2} + mR^2} = \frac{\tan\theta}{3} = \frac{\tan 60^0}{3} = \frac{\sqrt{3}}{3} = \frac{1.732}{3} = 0.5773$$

Since given coefficient of static friction is less than $\mu_{\min}$, so body will perform rolling with slipping and kinetic friction will act

$$F_K = \mu N = \mu mg\cos\theta = (0.4)\times mg\cos 60^0 = \frac{mg}{5}$$

Concept involved: Rolling motion on inclined plane
Topic: Rotation
Difficulty level: Difficult

***Questions*: 20:-** Consider a sample of oxygen behaving like an ideal gas. At 300K, 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 JK^{-1} mol^{-1})

(A) $\sqrt{\frac{8\pi}{3}}$ (B) $\sqrt{\frac{8}{3}}$

(C) $\sqrt{\frac{3}{3}}$ (D) $\sqrt{\frac{3\pi}{8}}$

***Ans*:-** D

As we know that

$$v_{rms} = \sqrt{\frac{3RT}{M}} \text{ and } v_{av} = \sqrt{\frac{8RT}{\pi M}}$$

$$\Rightarrow \frac{v_{rms}}{v_{av}} = \frac{\sqrt{\frac{3RT}{M}}}{\sqrt{\frac{8RT}{\pi M}}} = \sqrt{\frac{3\pi}{8}}$$

Concept involved: Kinetic theory of gases
Topic: Heat and thermodynamics
Difficulty level: Easy