PHYSICS

SECTION 1 (Maximum Marks : 28)

- This section contains **SEVEN** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four options is (are) correct
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
- For each question, marks will be awarded in one of the following categories :

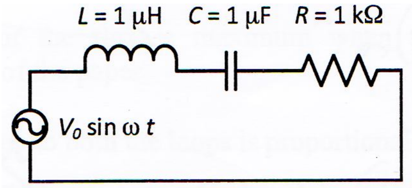
  Full Marks : +4 If only the bubble(s) corresponding to all the correct option(s) is(are) darkened

  Partial Marks : +1 For darkening a bubble corresponding **to each correct option,** provided NO incorrect option is darkened

  Zero Marks : 0 If none of the bubbles is darkened

  Negative Marks : –2 In all other cases
- For example, if (A), (C) and (D) are all the correct options for a question, darkening all these three will get +4 marks; darkening only (A) and (D) will get +2 marks; and darkening (A) and (B) will get –2 marks, as a wrong option is also darkened.

1. In the circuit shown, L = 1 μH, $C = 1\mu F$ and $R = 1\,k\Omega$. They are connected in series with an a.c. source $V = V_0 \sin\omega t$ as shown. Which of the following options is/are correct?



(A) At $\omega \sim 0$ the current flowing through the circuit becomes nearly zero

(B) The frequency at which the current will be in phase with the voltage is independent of R

(C) The current will be in phase with the voltage of $\omega = 10^4\ \text{rad.s}^{-1}$

(D) At $\omega >> 10^6\ \text{rad.s}^{-1}$, the circuit behaves like a capacitor

Ans. **(A, B)**

Sol. $$I = \frac{V}{\sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}}$$

As $\omega \to 0,\ I \approx 0$ So, option (A) is correct.

when current is in phase with voltage.

$$X_L = X_C$$

$$\omega_0 L = \frac{1}{\omega_0 C}$$

$\omega_0 = \frac{1}{\sqrt{LC}}$ Which is independent from R. So (B) is correct.

Now, $\omega_0 = \frac{1}{\sqrt{10^{-6} \times 10^{-6}}} = 10^6\ \text{rad/s}$ $\therefore$ (C) is false

when $\omega >> \omega_0$ then $X_L >> X_C$

In this case capacitor offer no resistance for the flow of current. So (D) is false.

2. For an isosceles prism of angle A and refractive index μ, it is found that the angle of minimum deviation $\delta_m = A$. Which of the following options is/are correct ?

(A) For the angle of incidence $i_1 = A$, the ray inside the prism is parallel to the base of the prism

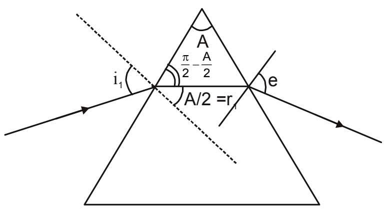
(B) At minimum deviation, the incident angle i_1 and the refracting angle r_1 at the first refracting surface are related by $r_1 = (i_1/2)$

(C) For this prism, the emergent ray at the second surface will be tangential to the surface when the angle of incidence at the first surface is $i_1 = \sin^{-1}\left[\sin A\sqrt{4\cos^2\frac{A}{2} - 1} - \cos A\right]$

(D) For this prism, the refractive index μ and the angle of prism A are related as $A = \frac{1}{2}\cos^{-1}\left(\frac{\mu}{2}\right)$.

Ans. **(A,B,C)**

Sol.



At minimum deviation

$i_1 = e$

$r_1 = r_2$

$r_1 + r_2 = A$

$r_1 + r_2 = \frac{A}{2}$

$\delta_{min} = A$

For minimum deviation

$$\mu = \frac{\sin\left(\frac{A+\delta_m}{2}\right)}{\sin\frac{A}{2}} = \frac{\sin A}{\sin\frac{A}{2}} = 2\cos\frac{A}{2}$$

$$\therefore\ A = 2\cos^{-1}\left(\frac{\mu}{2}\right) \qquad \text{...(i)}$$

so, option (D) is incorrect.

From Snell's law at 1st interface,

$1\ .\ \sin i_1 = \mu\ \sin r_1$

from eqn. (i)

$$\Rightarrow\ \sin i_1 = 2\cos\frac{A}{2}\cdot\sin\frac{A}{2}$$

$$\Rightarrow\ i_1 = A$$

Option (A) is correct.

From geometry,

$$r_1 = \frac{A}{2} = \frac{i_1}{2}$$

Option (B) is correct.

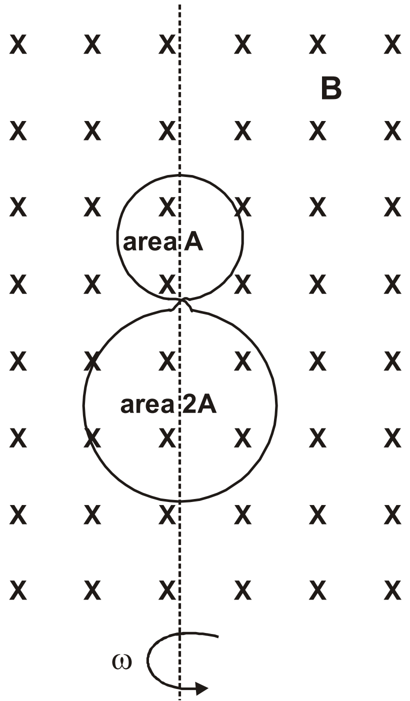
For grazing emergence,

$$i_1 = \sin^{-1}\left[\sqrt{\mu^2-1}\ \sin\ A - \cos A\right]$$

$$i_1 = \sin^{-1}\left[\sqrt{4\cos^2\frac{A}{2}-1}\cdot\sin\ A - \cos A\right]$$

So, option (C) is correct.

3. A circular insulated copper wire loop is twisted to form two loops of area A and 2A as shown in the figure. At the point of crossing the wires remain electrically insulated from each other. The entire loop lies in the plane (of the paper). A uniform magnetic field $\vec{B}$ points into the plane of the paper. At t = 0, the loop starts rotating about the common diameter as axis with a constant angular velocity ω in the magnetic field. Which of the following options is/are correct?



(A) The emf induced in the loop is proportional to the sum of the areas of the two loops

(B) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper

(C) The net emf induced due to both the loops is proportional to $\cos\omega t$

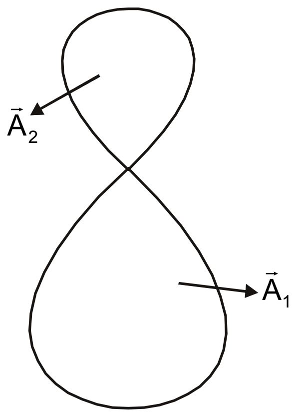
(D) The amplitude of the maximum net emf induced due to both the loops is equal to the amplitude of maximum emf induced in the smaller loop alone

Ans. (B, D)

Sol. At any time t the loop will rotate by angle $\theta = \omega t$

The area vector of loops will be opposite to each other.

Flux linked to the loop at time t



$$\phi = B(2A)\cos(\omega t) - BA\cos(\omega t) = BA\cos(\omega t)$$

So, $\varepsilon_{ind} = -\frac{d\phi}{dt}(BA\omega)\sin(\omega t) \propto \sin(\omega t)$

$\frac{d\phi}{dt}$ will be maximum when $\sin(\omega t) = 1$

i.e. loop will rotate by 90°.

So option (B) is correct.

Now, $(\varepsilon_{ind})_{max} = BA\omega$

Now, ε_{ind} is smaller loop

$$\varepsilon_{ind} = -\frac{d\phi}{dt} = +BA\frac{d}{dt}(\cos\omega t) = -BA\omega\sin(\omega t)$$

so, $(\varepsilon_{ind})_{max} = BA\omega$ in smaller loop

So option (D) is correct.

4. A flat plate is moving normal to its plane through a gas under the action of a constant force F. The gas is kept at a very low pressure. The speed of the plate v is much less than the average speed u of the gas molecules. Which of the following options is/are true?

(A) At a later time the external force F balances the resistive force

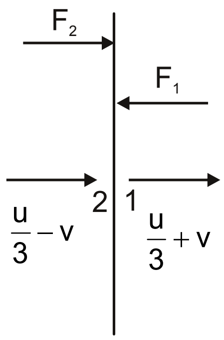
(B) The plate will continue to move with constant non-zero acceleration, at all times

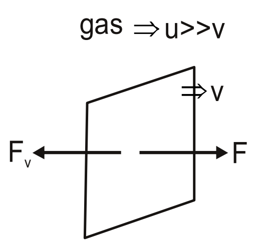
(C) The resistive force experienced by the plate is proportional to v

(D) The pressure difference between the leading and trailing faces of the plate is proportional to uv

Ans. **(A, C, D)**

Sol. The resistive force on the plate is resultant of force exerted by gas on left surface and right surface of the plate.





The resistive force on the plate by gas is given by

$F_{resistive} = F_1 - F_2 = \rho A\left(\frac{u}{3}+v\right)^2 - \rho A\left(\frac{u}{3}-v\right)^2 = \left(4\rho A\frac{u}{3}\right)v$ ($\frac{u}{3}$ is taken due to equipartition of energy)

so, $F_{resistive} \propto v$

So, option (C) is correct.

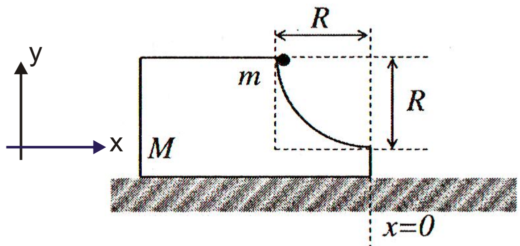
Pressure difference between the leading and traling faces of plate = $\Delta P = \frac{F_{resistive}}{A} = \left(4\rho\frac{u}{3}\right)v$

So, option (D) is correct.

The speed of plate will first increase then resistive force will also increase and finally external force F balances the resistive force.

So, option (A) is correct.

5. A block of mass M has a circular cut with a frictionless surface as shown. The block rests on the horizontal frictionless surface of a fixed table. Initially the right edge of the block is at x = 0, in a co-ordinate system fixed to the table. A point mass m is released from rest at the topmost point of the path as shown and it slides down. When the mass loses contact with the block, its position is x and the velocity is v. At that instant, which of the following options is/are correct?



(A)The velocity of the point mass m is : $v = \sqrt{\frac{2gR}{1+\frac{m}{M}}}$

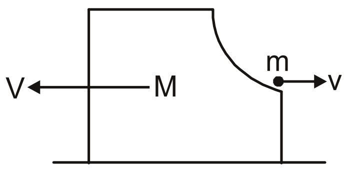
(B) The x component of displacement of the center of mass of the block M is : $-\frac{mR}{M+m}$

(C) The position of the point mass is : $x = -\sqrt{2}\frac{mR}{M+m}$

(D) The velocity of the block M is : $V = -\frac{m}{M}\sqrt{2gR}$

Ans. (A, B)

Sol.



Using COLM along X-axis :

mv = MV ...(i)

Using COME :

$$mgR = \frac{1}{2}MV^2 + \frac{1}{2}mv^2$$

$$mgR = \frac{1}{2}MV^2 + \frac{1}{2}m\frac{M^2V^2}{m^2}$$

$$2\ mgR = \frac{MV^2(M+m)}{m}$$

$$V = \sqrt{\frac{2m^2gR}{(M+m)M}}$$

using (i)

$$v = \frac{M}{m}\sqrt{\frac{2m^2gR}{(M+m)M}}$$

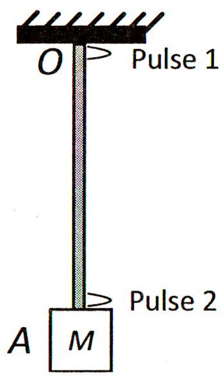
$$v = \sqrt{\frac{2gR}{\left(1+\frac{m}{M}\right)}}$$

Displacement of COM of M block along X-axis $= \frac{m(-R)}{(M+m)}$

Position of point mass at moment when it leaves the contact,

$$x = -R + \frac{MR}{M+m} = \frac{-mR}{(M+m)}$$

6. A block M hangs vertically at the bottom end of a uniform rope of constant mass per unit length. The top end of the rope is attached to a fixed rigid support at O. A transverse wave pulse (Pulse 1) of wavelength λ_0 is produced at point O on the rope. The pulse takes time T_{OA} to reach point A .If the wave pulse of wavelength λ_0 is produced at point A (Pulse 2) without disturbing the position of M it takes time T_{AO} to reach point O. Which of the following options is/are correct?



(A) The time $T_{AO} = T_{OA}$

(B) The wavelength of Pulse 1 becomes longer when it reaches point A

(C) The velocity of any pulse along the rope is independent of its frequency and wavelength

(D) The velocities of the two pulses (Pulse 1 and Pulse 2) are the same at the midpoint of rope

Ans. **(A, C)**

Sol. Let μ be mass per unit length of rope and L is length of rope.

As the pluse move down, tension decreases hence wavelength will also decrease becaue

$$v = \nu\lambda \text{ \& } v = \sqrt{\frac{T}{\mu}}$$

$\therefore\ \lambda \propto \sqrt{T}$ So, (B) is worng.

For pulse produced at O (i.e. for pulse 1) at a distance x from O.

$$\sqrt{\frac{\{M+(L-x)\mu\}g}{\mu}} = \frac{dx}{dt} \qquad \left(\because\ v = \frac{dx}{dt} = \sqrt{\frac{T}{\mu}}\right)$$

$$\int_0^{t_{OA}} dt = \sqrt{\mu}\int_0^L \frac{dx}{\sqrt{\{M+(L-x)\mu\}g}}$$

$$t_{OA} = -\sqrt{\mu}\,\frac{2}{3}\left[\left(\{M+(L-x)\mu\}g\right)^{3/2}\right]_0^L = \frac{-2\sqrt{\mu}}{3}\left[(Mg)^{3/2} - \{(M+\mu L)g\}^{3/2}\right]$$

$$t_{OA} = \frac{2}{3}\sqrt{\mu}\left[\{(M+\mu L)g\}^{3/2} - (Mg)^{3/2}\right]$$

For the pulse produced at A (i.e. pulse 2) at a distance y from A

$$\frac{dy}{dt} = \sqrt{\frac{(M+y\mu)g}{\mu}}$$

$$\sqrt{\mu}\int_0^2 \frac{dy}{\sqrt{(M+y\mu)g}} = \int_0^{t_{AO}} dt$$

$$\frac{2}{3}\sqrt{\mu}\left[\{(M+\mu y)g\}^{3/2}\right]_r^L = t_{AO}$$

$$t_{AO} = \frac{2}{3}\sqrt{\mu}\left[\{(M+\mu L)g\}^{3/2} - \{Mg\}^{3/2}\right]$$

clearly $t_{OA} = t_{AO}$

Speed of pulse 1 and pluse 2 both will be same at mid point of rope.

Also speed of pulse in rope is independent of the frequency and wavelength both. It depends on tension and mass for unit length only.

Direction of motion is opposite for both pulse. Hence velocity will be different.

7. A human body has a surface area of approximately $1\,m^2$. The normal body temperature is 10 K above the surrounding room temperature T_0. Take the room temperature to be $T_0 = 300K$. For $T_0 = 300K$, the value of $\sigma T_0^4 = 460\,Wm^{-2}$ (where σ is the Stefan-Boltzmann constant). Which of the following options is/are correct?

(A) If the body temperature rises significantly then the peak in the spectrum of electromagnetic radiation emitted by the body would shift to longer wavelengths

(B) If the surrounding temperature reduces by a small amount $\Delta T_0 << T_0$, then to maintain the same body temperature the same (living) human being needs to radiate $\Delta W = 4\sigma T_0^3 \Delta T_0$ more energy per unit time

(C) The amount of energy radiated by the body in 1 second is close to 60 Joules

(D) Reducing the exposed surface area of the body (e.g. by curling up) allows humans to maintain the same body temperature while reducing the energy lost by radiation

Ans. (D)

Sol. For electromagnetic radiation by a body, According to Wien's displacement law,

$$\lambda T = \text{constant} = b$$

$$\Rightarrow \lambda = \frac{b}{T}$$

As T increases, λ decreases, so the peak of electromagnetic radiation shifts towards left.

Hence, (A) is incorrect

(B) is incorrect because energy radiated by body depends on surface area and body temperature which are constant always.

(C(is incorrect because rediated energy is $E_1 = eA\sigma T^4$

$\therefore$ (D)is correct because surface area decreases.

SECTION 2 (Maximum Marks : 15)

- This section contains **FIVE** questions
- The answer to each question is a **SINGLE DIGIT INTEGER** ranging from 0 to 9, both inclusive
- For each question, darken the bubble corresponding to the correct integer in the ORS
- For each question, marks will be awarded in one of the following categories :

Full Marks : +3 If only the bubble corresponding to the correct answer is darkened

Zero Marks : 0 In all other cases

8. An electron in a hydrogen atom undergoes a transition from an orbit with quantum number n_i to another with quantum number n_f. V_i and V_f are respectively the initial and final potential energies of the electron. If $\frac{V_i}{V_f} = 6.25$, then the smallest possible n_f is

Ans. (5)

Sol. for hydrogen atom $V = \frac{-27.2}{n^2} ev$

$$\frac{V_i}{V_f} = 6.25$$

$$\Rightarrow \frac{\frac{-27.2}{n_i^2}}{\frac{-27.2}{n_f^2}} = \frac{25}{4}$$

$$\Rightarrow \left(\frac{n_f}{n_i}\right)^2 = \frac{25}{4}$$

$$\Rightarrow \frac{n_f}{n_i} = \frac{5}{2}$$

$$\Rightarrow n_f = \left(\frac{5}{2}\right)n_i$$

$$\Rightarrow (n_f)_{min} = 5$$

9. A drop of liquid of radius $R = 10^{-2}$ m having surface tension $S = \frac{0.1}{4\pi} Nm^{-1}$ divides itself into K identical drops. In this process the total change in the surface energy $\Delta U = 10^{-3} J$. If $K = 10^{\alpha}$ then the value of α is

Ans. (6)

Sol $A_i = 4\pi R^2$

$\frac{4}{3}\pi R^3 = K\frac{4}{3}\pi r^3$

$\Rightarrow r^3 = \frac{R^3}{K}$

$\Rightarrow r = \frac{R}{K^{1/3}}$

$A_f = K4\pi\left(\frac{R}{K^{1/3}}\right)^2 = K^{1/3}\,4\pi R^2$

$\Delta A = 4\pi R^2\left(K^{1/3}-1\right)$

$\Delta U = S\Delta A = 4\pi R^2 S\left(K^{1/3}-1\right)$

$= 4\pi\left(10^{-2}\right)^2\left(\frac{0.1}{4\pi}\right)\left(K^{1/3}-1\right)$

$= 10^{-5}\left(K^{1/3}-1\right)$

$\Rightarrow\ 10^{-5}\left(K^{1/3}-1\right) = 10^{-3}$ [As $\Delta u = 10^{-3} J$] $\Rightarrow\ K^{1/3}-1 = 100$

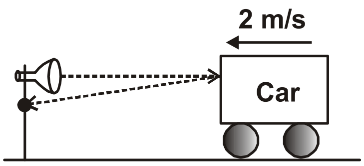
$\Rightarrow\ K^{1/3} = 101$

$\Rightarrow\ K \approx 10^6 \Rightarrow \alpha = 6$

10. A stationary source emits sound of frequency f_0 = 492 Hz. The sound is reflected by a large car approaching the source with a speed of 2 ms^{-1}. The reflected signal is received by the source and superposed with the original. What will be the beat frequency of the resulting signal in Hz ? (Given that the speed of sound in air is 330 ms^{-1} and the car reflects the sound at the frequency it has received).

Ans. **(6)**

Sol.



Initially car is an observer

so, frequency received by car is $f_1 = \frac{v+v_0}{v}\times f_0$

$= \frac{330+2}{330}\times 492$ Hz

$= \frac{332\times 492}{330}$Hz

for reflected sound car is a source, $f_2 = \frac{v}{v - v_s} \times f_1$

$$= \frac{330}{330-2} \times \frac{332 \times 492}{330} \text{Hz} = 498\,\text{Hz}$$

Source will receive 498 Hz frequency

so,

Beat frequency $= (498 - 492)\text{Hz}$

= 6 Hz

11. ^{131}I is a isotope of Iodine that β decays to an isotope of Xenon with a half-life of 8 days. A small amount of a serum labelled with ^{131}I is injected into the blood of a person. The activity of the amount of ^{131}I injected was 2.4×10^5 Becquerel (Bq). It is known that the injected serum will get distributed uniformly in the blood stream in less than half an hour. After 11.5 hours, 2.5 ml of blood is drawn from the person's body, and gives an activity of 115 Bq. The total volume of blood in the person's body, in litres is approximately (you may use $e^x \approx 1 + x$ for $|x| << 1$ and ln 2 ≈ 0.7).

Ans. **(5)**

Sol Total volume of blood = V

Volume taken out = 2.5 ml

Fraction of volume take out $= \frac{2.5}{V}$

Initially, $\frac{dN}{dt} = \lambda N_0 = 2.4 \times 10^5$ ....(i)

After 11.5 hrs,

$$\frac{dN}{dt} = \lambda N = \lambda\left(N_0 \times \frac{2.5}{V}\right)e^{-\lambda t} = 115 \quad \text{....(ii)}$$

From (i) & (ii)

$$\frac{\lambda N_0}{\lambda N_0 \left(\frac{2.5}{V}\right) e^{-\lambda t}} = \frac{2.4 \times 10^5}{115}$$

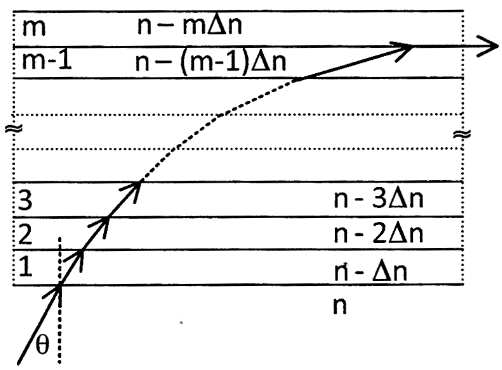
$$V = \frac{2.5 \times e^{-\lambda t} \times 2.4 \times 10^5}{115}$$

$$\Rightarrow V = \frac{2.5 \times e^{-\left(\frac{\ell n 2}{8 \times 24} \times 11.5\right)} \times 2.4 \times 10^5}{115}$$

$= 4998.6$ ml

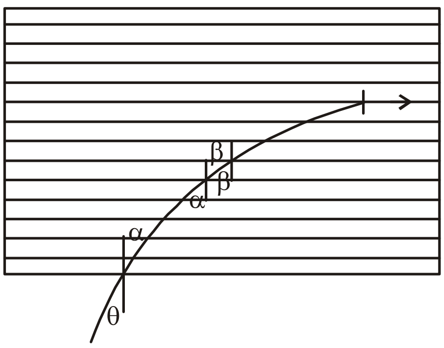
$= 4.9986$ lit $\simeq 5$ lit

12. A monochromatic light is travelling in a medium of refractive index n = 1.6. It enters a stack of glass layers from the bottom side at an angle $\theta = 30°$. The interfaces of the glass layers are parallel to each other. The refractive indices of different glass layers are monotonically decreasing as $n_m = n - m\Delta n$, where n_m is the refractive index of the m^{th} slab and $\Delta n = 0.1$ (see the figure). The ray is refracted out parallel to the interface between the $(m-1)^{th}$ and m^{th} slabs from the right side of the stack. What is the value of m ?



Ans. (8)

Sol. Refracted angle becomes incident angle for all surface



$n \sin\theta = (n - m\Delta n) \sin 90°$

$1.6 \times \frac{1}{2} = (1.6 - 0.1\,m)\,1$

0.8 = 1.6 – 0.1 m

m = 8

SECTION 3 (Maximum Marks : 18)

- This section contains **SIX** questions of matching type
- This section contains **TWO** tables (each haivng 3 columns and 4 rows)
- Based on each table, there are **THREE** questions
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct
- For each question, darken the bubble corresponding to the correct option in the ORS
- For each question, marks will be awarded in one of the following categories :

Full Marks : +3 If only the bubble corresponding to the correct option is darkened

Zero Marks : 0 If none of the bubbles is darkened

Negative Marks : –1 In all other cases

Answer Q.13, Q.14 and Q.15 by appropriately matching the information given in the three columns of the following table.

A charged particle (electron or proton) is introduced at the origin (x = 0, y = 0, z = 0) with a given initial velocity $\vec{v}$. A uniform electric field $\vec{E}$ and a uniform magnetic field $\vec{B}$ exist everywhere. The velocity $\vec{v}$, electric field $\vec{E}$ and magnetic field $\vec{B}$ are given in columns 1, 2 and 3, respectively. The quantities E_0, B_0, are positive in magnitude.

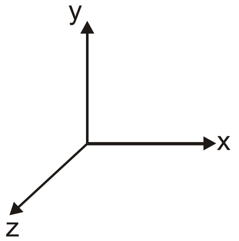
	Column 1		Column 2		Column 3
(I)	Electron with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(i)	$\vec{E} = E_0\hat{z}$	(P)	$\vec{B} = -B_0\hat{x}$
(II)	Electron with $\vec{v} = \frac{E_0}{B_0}\hat{y}$	(ii)	$\vec{E} = -E_0\hat{y}$	(Q)	$\vec{B} = B_0\hat{x}$
(III)	Proton with $\vec{v} = 0$	(iii)	$\vec{E} = -E_0\hat{x}$	(R)	$\vec{B} = B_0\hat{y}$
(IV)	Proton with $\vec{v} = 2\frac{E_0}{B_0}\hat{x}$	(iv)	$\vec{E} = E_0\hat{x}$	(S)	$\vec{B} = B_0\hat{z}$

13. In which case would the particle move in a straight line along the negative direction of y-axis (i.e. move along $-\hat{y}$)?

(A) (IV) (ii) (S) (B) (II) (iii) (Q) (C) (III) (ii) (R) (D) (III) (ii) (P)

Ans. (C)

Sol.



(A) $\vec{v} = 2\frac{E_0}{B_0}\hat{x},\ \vec{E} = -E_0\,\hat{y},\ \vec{B} = B_0\,\hat{z}$

velocity is along x - axis and cross fields
are there

$F_E = -qE_0\hat{y} = -eE_0\hat{y}$

Magnetic force

$F_B = q\left(\vec{v}\times\vec{B}\right) = q\frac{2E_0}{B_0}\times B_0\left(-\hat{y}\right)$

$= 2q_0E_0\ \left(-\hat{y}\right) = -2eE_0\hat{y}$

velocity is along x-axis and net force is along –ve y-axis, therefore path can not be a straight line

(B) $\vec{v} = \frac{E_0}{B_0}\hat{y}\ ,\ \vec{E} = -E_0\hat{x},\ \vec{B} = B_0\,\hat{x}$

Electric force,

$\vec{F}_E = -qE_0\hat{x} = eE_0\hat{x}$

Magnetic force,

$= q\left[\frac{E_0}{B_0}\hat{y}\times B_0\,\hat{x}\right]$

$= qE_0\left(-\hat{z}\right) = eE_0\hat{z}$

Under given condition particle wil not move on straight line.

(C) $\vec{v} = 0, \vec{E} = -E_0\,\hat{y}, \vec{B} = B_0\hat{y}$

Initially charge is at rest magnetic force = 0

Charge will be accelerated along y- axis due to electric field. Magnetic Field is along y-axis, therefore magnetic force on particle will be zero. Hence it moves in a straight line.

(D) $\vec{v} = 0, \vec{E} = -E_0\hat{y}, \vec{B} = -B_0\,\hat{x}$

Initially particle accelerate along – ve y-axis, but B is along –ve x-axis. Straight line is not posible.

14. In which case will the particle move in a straight line with constant velocity ?

(A) (II) (iii) (S) (B) (III) (iii) (P) (C) (IV) (i) (S) (D) (III) (ii) (R)

Ans. **(A)**

Sol. For constant velocity,

$\vec{F}_E + \vec{F}_B = 0$

(A) $\vec{v} = \frac{E_0}{B_0}\hat{y}\ \ \vec{E} = -E_0\,\hat{x},\ \vec{B} = B_0\,\hat{z}$

Electric force,

$\vec{F}_E = -qE_0\hat{x} = eE\hat{x},\ \ \vec{F}_B = q\left(\vec{v}\times\vec{B}\right)$

$= q\left[\frac{E_0}{B_0}\hat{y} \times B_0\hat{z}\right]$

$= -eE_0\hat{x}$ therefore, it will move with constant velocity.

(B) $\vec{v} = 0, \vec{E} = -E_0\,\hat{x}, \vec{B} = -B_0\hat{x}$

Particle will accelerated along –ve x-axis

(C) $\vec{v} = \frac{2E_0}{B_0}\hat{x}, \vec{E} = E_0\hat{z}, B = B_0\hat{z}$

Electric force,

$F_e = qE_0\hat{z}$ $i = \frac{V_0}{R}e^{-\frac{t}{RC}}$

$F_B = q\left(\frac{2E_0}{B_0}\hat{x} \times B_0\hat{z}\right) = -2eE_0\hat{y}$

Straight line with constant velocity is not possible.

(D) $\vec{v} = 0, \vec{E} = -E_0\hat{y}, \vec{B} = B_0\hat{y}$

Electric force,

$\vec{F}_e = eE_0\hat{y}$

Magnetic force,

$\vec{F}_B = q(\vec{v} \times \vec{B})$

$\vec{F}_B = 0, (\because \vec{v} \,||\, \vec{B})$

Straight line with constant velocity not possible.

15. In which case will the particle describe a helical path with axis along the positive z direction ?

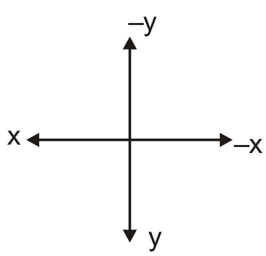
(A) (II) (ii) (R) (B) (III) (iii) (P) (C) (IV) (i) (S) (D) (IV) (ii) (R)

Ans. (C)

Sol. (A) $\vec{v} = \frac{E_0}{B_0}\hat{y},\ \vec{E} = -E_0\hat{y}, \vec{B} = B_0\hat{y}$

$\vec{F}_B = 0, \vec{F}_E$ is along +ve x-axis

Particle will move in straight line along y-axis.



(B) $\vec{v} = 0,\ \vec{E} = -E_0\hat{x}, \vec{B} = -B_0\hat{x}$

particle will move along –ve x-axis

(C) $\vec{v} = 2\frac{E_0}{B_0}\hat{x};\ \vec{E} = E_0\hat{z};\ \vec{B} = B_0\hat{z}$

Due to magnetic force path will be circular in x – y plane and due to electric field it will translate along Z-axis therefore path will be helical.

(D) $\vec{v} = 2\frac{E_0}{B_0}\hat{x}, \vec{E} = -E_0\hat{y},\ \vec{B} = B_0\hat{y}$

Electric force,

$\vec{F}_e = -eE_0\hat{y}$

Magnetic force,

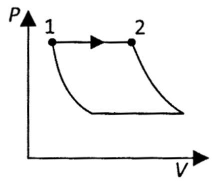
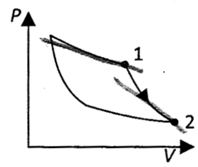
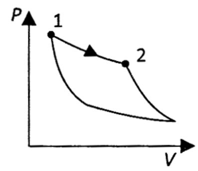
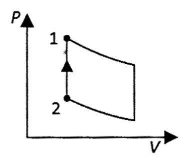
$\vec{F}_m = q(\vec{v}\times\vec{B}) = 2e\frac{E_0}{B_0}B_0\hat{z}$

$= 2eE_0\hat{z}$

Helical path along – ve y-axis.

Answer Q.16, Q.17 and Q.18 by appropriately matching the information given in the three columns of the following table.

An ideal gas is undergoing a cyclic thermodynamic process in different ways as shown in the corresponding P – V diagrams in column 3 of the table. Consider only the path from state 1 to state 2. W denotes the corresponding work done on the system. The equations and plots in the table have standard notations as used in thermodynamic processes. Here γ is the ratio of heat capacities at constant pressure and constant volume. The number of moles in the gas is n.

	Column I		**Column 2**		**Column 3**
(I)	$W_{1\to2} = \frac{1}{\gamma-1}(P_2V_2 - P_1V_1)$	(i)	Isothermal	(P)	
(II)	$W_{1\to2} = -PV_2 + PV_1$	(ii)	Isochoric	(Q)	
(III)	$W_{1\to2} = 0$	(iii)	Isobaric	(R)	
(IV)	$W_{1\to2} = -nRT\ \ln\left(\frac{V_2}{V_1}\right)$	(iv)	Adiabatic	(S)	

16. Which one of the following options correctly represents a thermodynamic process that is used as a correction in the determination of the speed of sound in an ideal gas ?

(A) (IV) (ii) (R) (B) (I) (ii) (Q) (C) (I) (iv) (Q) (D) (III) (iv) (R)

Ans. (C)

Sol. For correction in speed of sound, process is adiabatic.

$$V_{sound} = \sqrt{\frac{\gamma P}{\rho}}$$

$W_{adiabatic} = -\Delta U = -nC_v\Delta T$; $\Delta Q = \Delta U + \Delta W$

$$= -n\frac{R}{\gamma-1}(T_2 - T_1) = \frac{nRT_1 - nRT_2}{\gamma-1} = \frac{P_1V_1 - P_2V_2}{\gamma-1}$$

So work done on the system is $\frac{P_2V_2 - P_1V_1}{\gamma-1}$.

17. Which of the following options is the only correct representation of a process in which $\Delta U = \Delta Q - P\Delta V$?

(A) (II) (iii) (S) (B) (II) (iii) (P) (C) (III) (iii) (P) (D) (II) (iv) (R)

Ans. (B)

Sol. $\Delta U = \Delta Q - P\Delta V$ (this is isobaric process)

(A) S is isochoric but process is isobaric
so option (A) is incorrect.

(B) $W_{system} = P(V_1 - V_2)$
(B) is correct option.

(C) Work is not zero in isobaric process.

(D) W_{system} is for isobaric process and hence option (D) is incorrect.

18. Which one of the following options is the correct combination ?

(A) (II) (iv) (P) (B) (III) (ii) (S) (C) (II) (iv) (R) (D) (IV) (ii) (S)

Ans. (B)

Sol. (A) Process is isobaric.
$\therefore$ (A) is incorrect.

(B) Process is isochoric
$\therefore$ V = constant, $W_{1\to 2} = 0$
$\therefore$ (B) is correct.

(C) Process is adiabatic therefore $W_{1\to 2} = -PV_2 + PV_1$ is wrong.
$\therefore$ (C) is incorrect.

(D) Process is isochoric
$\therefore$ (D) is incorrect.