# PHYSICS

## SECTION 1 (Maximum Marks : 21)

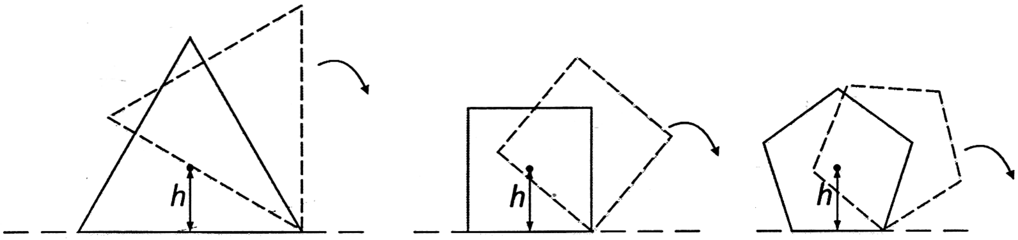
- This section contains **SEVEN** questions
- Each question has **FOUR** options (A), (B), (C) and (D), **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following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

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

Full Marks : 0 If none of the bubbles is darkened.

Negative Marks : –1 In all other cases.

**1.** Consider regular polygons with number of sides $n = 3, 4, 5$ ........... as shown in the figure. The center of mass of all the polygons is at height h from the ground. They roll on a horizontal surface about the leading vertex without slipping and sliding as depicted. The maximum increase in height of the locus of the center of mass for each polygon is $\Delta$. Then $\Delta$ depends on n and h as




(A) $\Delta = h\sin^2\left(\frac{\pi}{n}\right)$ (B) $\Delta = h\sin\left(\frac{2\pi}{n}\right)$

(C) $\Delta = h\tan^2\left(\frac{\pi}{2n}\right)$ (D) $\Delta = h\left(\frac{1}{\cos\left(\frac{\pi}{n}\right)} - 1\right)$

**Ans.** **(D)**

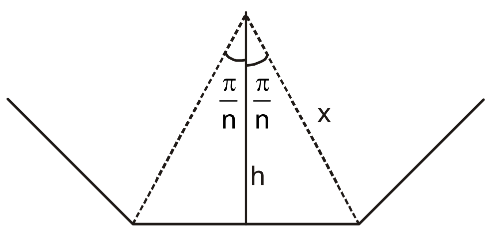
**Sol.** Consider a n – sided regular polygon

From figure

$$x\cos\frac{\pi}{n} = h$$

$$x = \frac{h}{\cos\frac{\pi}{n}}$$

$$\Delta = \frac{h}{\cos\frac{\pi}{n}} - h$$



$$\Delta = h\left(\frac{1}{\cos\frac{\pi}{n}} - 1\right)$$

Hence option (D) is correct

**2.** Consider an expanding sphere of instantaneous radius R whose total mass remains constant. The expansion is such that the instantaneous density $\rho$ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho}\frac{d\rho}{dt}\right)$ is constant. The velocity v of any point on the surface of the expanding sphere is proportional to

(A) R (B) $\frac{1}{R}$ (C) $R^3$ (D) $R^{2/3}$

**Ans.** **(A)**

**Sol.** $M = \frac{4}{3}\pi R^3 \rho$

$$\frac{dM}{dt} = \frac{4}{3}\pi\left[\rho\frac{d}{dt}R^3 + R^3\frac{d\rho}{dt}\right]$$

$$0 = \left[3R^2\rho\frac{dR}{dt} + R^3\frac{d\rho}{dt}\right]$$

$$\left(\frac{dR}{dt}\right) = -\frac{R}{3\rho}\frac{d\rho}{dt}$$

$v_{point}\ \alpha\ R$

Hence option (A) is correct

**3.** A photoelectric material having work-function $\phi_0$ is illuminated with light of wavelength $\lambda$ $\left(\lambda < \frac{hc}{\phi_0}\right)$. The fastest photoelectron has a de Broglie wavelength $\lambda_d$. A change in wavelength of the incident light by $\Delta\lambda$ results in a change $\Delta\lambda_d$ in $\lambda_d$. Then the ratio $\Delta\lambda_d / \Delta\lambda$ is proportional to

(A) $\lambda_d^2 / \lambda^2$ (B) $\lambda_d / \lambda$ (C) $\lambda_d^3 / \lambda$ (D) $\lambda_d^3 / \lambda^2$

**Ans.** **(D)**

**Sol.** Kinetic energy of electron emitted is given by

$$K = \frac{hc}{\lambda} - \phi_0 \qquad .....(i)$$

Linear momentum and kinetic energy are related as

$$K = \frac{P^2}{2m}$$

so, $K = \dfrac{(h/\lambda_d)^2}{2m}$ ....(ii)

from (i) & (ii)

$$\frac{hc}{\lambda} - \phi_0 = \frac{h^2}{2m} \times \frac{1}{\lambda_d^2}$$

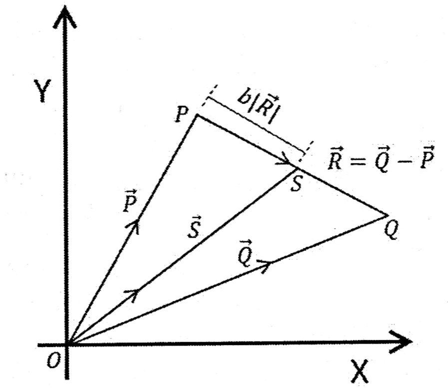
on differentiating both sides wrt. '$\lambda$'

$$-\frac{hc}{\lambda^2} = \frac{-h^2}{2m} \times \frac{2}{\lambda_d^3} \frac{d\lambda_d}{d\lambda}$$

on approximating for calculating error

$$\frac{\Delta\lambda_d}{\Delta\lambda} = \frac{mc}{h} \frac{\lambda_d^3}{\lambda^2}$$

**4.** Three vectors $\vec{P}, \vec{Q}$ and $\vec{R}$ are shown in the figure. Let S be any point on the vector $\vec{R}$. The distance between the points P and S is $b|\vec{R}|$. The general relation among vectors $\vec{P}, \vec{Q}$ and $\vec{S}$ is




(A) $\vec{S} = (1-b^2)\vec{P} + b\vec{Q}$

(B) $\vec{S} = (b-1)\vec{P} + b\vec{Q}$

(C) $\vec{S} = (1-b)\vec{P} + b\vec{Q}$

(D) $\vec{S} = (1-b)\vec{P} + b^2\vec{Q}$

**Ans.** **(C)**

**Sol.** $\vec{S} = \vec{P} + b|\vec{R}|\hat{R}$

$= \vec{P} + b\vec{R}$

$= \vec{P} + b(\vec{Q} - \vec{P})$

$= (1-b)\vec{P} + b\vec{Q}$

$\therefore$ (C)

**5.** A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T = 0.01$ seconds and he measures the depth of the well to be L = 20 meters. Take the acceleration due to gravity $g = 10\ ms^{-2}$ and the velocity of sound is $300\,ms^{-1}$. Then the fractional error in the measurement, $\delta L / L$, is closest to

(A) 1% (B) 5% (C) 3% (D) 0.2%

**Ans.** **(A)**

**Sol.** $\sqrt{\frac{2L}{g}} + \frac{L}{v} = T$ ....(i)

$\sqrt{\frac{2}{g}}\frac{1}{2\sqrt{L}}\,dL + \frac{dL}{v} = dT$ ....(ii)

from (ii)

$$dL\left(\frac{1}{v} + \frac{1}{\sqrt{2gL}}\right) = dT$$

$$dL = \frac{0.01}{\frac{1}{300} + \frac{1}{20}} = \frac{0.01 \times 20 \times 300}{320} = \frac{6}{32} = \frac{3}{16}$$

$$\frac{dL}{L} \times 100\% = \frac{3}{16 \times 20} \times 100\% = \frac{15}{16}\% \approx 1\%$$

**6.** A rocket is launched to the surface of the Earth, away from the Sun, along the line joining the Sun and the Earth. The Sun is $3 \times 10^5$ times heavier than the Earth and is at a distance $2.5 \times 10^4$ times larger than the radius of the Earth. The escape velocity from Earth's gravitational field is $v_e = 11.2\ km\ s^{-1}$. The minimum intial velocity ($v_s$) required for the rocket to be able to leave the Sun-Earth system is closest to (Ignore the rotation and revolution of the Earth and the presence of any other planet)

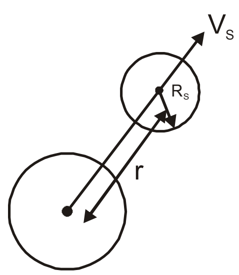
(A) $v_s = 72\ km\ s^{-1}$ (B) $v_s = 22\ km\ s^{-1}$ (C) $v_s = 42\ km\ s^{-1}$ (D) $v_s = 62\ km\ s^{-1}$

**Ans.** **(C)**

**Sol.** $r = 2.5 \times 10^4 R_e$

$m_s = 3 \times 10^5 m_e$

Let $V_s$ velocity is provided to escape the satellite from Earth- Sun System




$$\frac{1}{2}mV_S^2 = \frac{Gm_e m}{R_e} + \frac{Gm_S m}{r + R_e}$$

$$\frac{1}{2}V_S^2 = G\left(\frac{m_e}{R_e} + \frac{m_S}{r + R_e}\right)$$

$$= G\left(\frac{m_e}{R_e} + \frac{m_e \times 3 \times 10^5}{2.5 \times 10^4 R_e + R_e}\right)$$

$$= G\left(\frac{m_e}{R_e} + \frac{3 \times 10^5 m_e}{2.5 \times 10^4 R_e}\right) = \frac{Gm_e}{R_e}\left(1 + \frac{3 \times 10^5}{2.5 \times 10^4}\right) = G\frac{m_e}{R_e}\left(1 + \frac{30}{2.5}\right) = \frac{Gm_e}{R_e}(1+12)$$

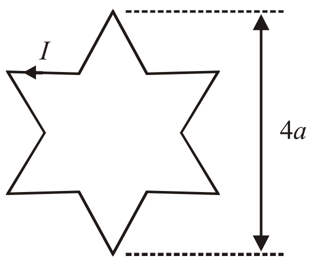
$$\frac{1}{2}V_S^2 = \frac{Gm_e}{R_e} \times 13$$

$$V_S = \sqrt{\frac{2Gm_e}{R_e} \times 13} \qquad \left(\text{given } V_e = \sqrt{\frac{2Gm_e}{R_e}} = 11.2\,\text{Km/s}\right)$$

$$= 11.2 \times \sqrt{13} = 40.38 = 42\text{Km / sec}$$

$\therefore$ (C)

**7.** A symmetric star shaped conducting wire loop is carrying a steady state current $I$ as shown in the figure. The distance between the diametrically opposite vertices of the star is 4a. The magnitude of the manetic field at the center of the loop is




(A) $\frac{\mu_0 I}{4\pi a} 6\left[\sqrt{3} - 1\right]$ (B) $\frac{\mu_0 I}{4\pi a} 6\left[\sqrt{3} + 1\right]$

(C) $\frac{\mu_0 I}{4\pi a} 3\left[\sqrt{3} - 1\right]$ (D) $\frac{\mu_0 I}{4\pi a} 3\left[2 - \sqrt{3}\right]$

**Ans.** **(A)**

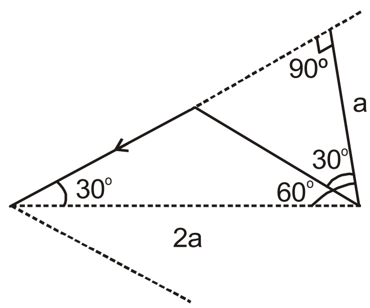
**Sol.** For v-shaped section of star loop as shown in the figure

$$B = \frac{\mu_0}{4\pi}\frac{I}{a}\left(-\sin 30^\circ + \sin 60^\circ\right) \times 2$$

$$B = \frac{\mu_0}{4\pi}\frac{I}{a}\left(\sqrt{3} - 1\right)$$

$\therefore$ For complete star loop

$$B_{net} = 6B = \frac{\mu_0}{4\pi}\frac{I}{a} 6\left(\sqrt{3} - 1\right)$$



# SECTION 2 (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(s) is (are) correct.
- For each question, darken the bubble(s) corresponding to all the correct options(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 the correct option(s) is(are) darkened.

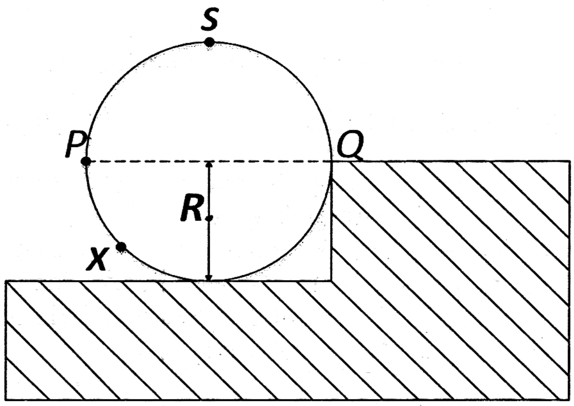
  Partial Marks : +1 For darkening a bubble corresponding **to each correct option,** provided NO incorrect option is darkened

  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 result in +4marks; darkening only (A) and (D) will result in +2 marks; and darkening (A) and (B) will result in –2 marks, as a wrong option is also darkened.

**8.** A wheel of radius R and M is placed at the bottom of a fixed step of height R as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque $\tau$ about an axis normal to the plane of the paper passing through the point Q. Which of the following options is/are correct ?




(A) If the force is applied normal to the circumference at point P then $\tau$ is zero

(B) If the force is applied tangentially at point S then $\tau \neq 0$ but the wheel never climbs the step

(C) If the force is applied at point P tangentially then $\tau$ decreases continuously as the wheel climbs

(D) If the force is applied normal to the cirumference at point X then $\tau$ is constant

**Ans. (A,C)**

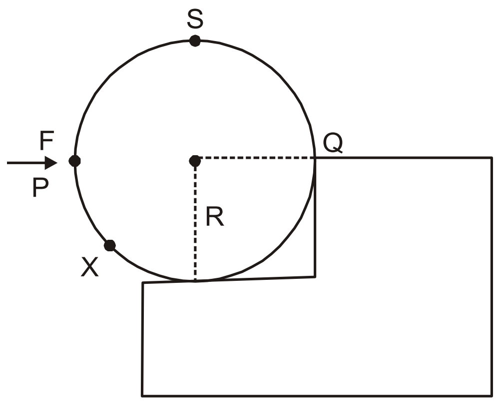
**Sol.** If F is applied normal to the circumference at P then $\vec{F}$ is along $\overrightarrow{PQ}$

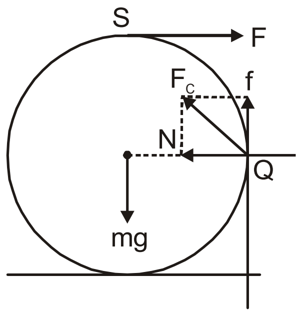
So, $\tau_Q = 0$

So, (A) is correct

If F is applied at S tangentially

Then ,




As wheel is moving slowly

So $a_{cm} = 0$

So $F = N$ & $f = Mg$

to climb up the step

$$(\tau_F)_Q \geq (\tau_{Mg})_Q$$

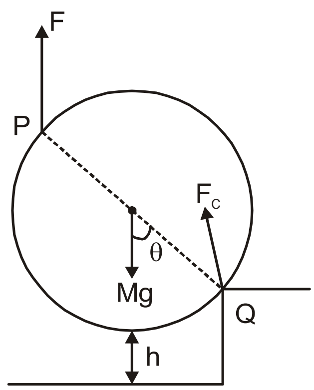
Now,

$$(\tau_F)_Q = FR$$

So, $F \geq Mg$

So wheel will climb the step

So (B) is incorrect




If F is applied at P tangentially

Then,

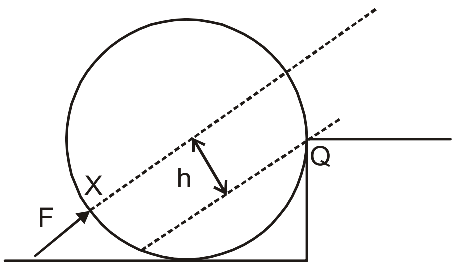
When wheel will be at height h above the floor then

$\tau_Q = F(2R\sin\theta)$

As wheel will start climbing then $\theta$ will decrease

So, $\tau$ will decrease continuously

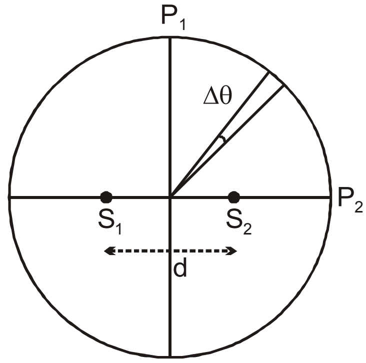
So, (C) is correct




If F is applied normally at X then $\tau_Q = Fh$

when the wheel start climbing h will increase so $\tau_Q$ will increase

**9.** Two coherent monochromatic point sources $S_1$ and $S_2$ of wavelength $\lambda = 600 \text{nm}$ are placed symmetrically on either side of the center of the circle as shown. The sources are separated by a distance d = 1.8 mm. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta\theta$. Which of the following options is/are correct?




(A) The angular separation between two consecutive bright spots decreases as we move from $P_1$ to $P_2$ along the first quadrant

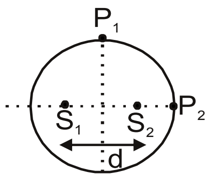
(B) A dark spot will be formed at the point $P_2$

(C) The total number of fringes poduced between $P_1$ and $P_2$ in the first quadrant is close to 3000

(D) At $P_2$ the order of the fringe will be maximum

**Ans. (C,D)**

**Sol.**




$\Delta x \text{ at } P_2 = d = 1.8 \text{ mm}$

$\Delta x = n\lambda$ for maxima.

1.8 mm = $n\lambda$ = n × 600 mm

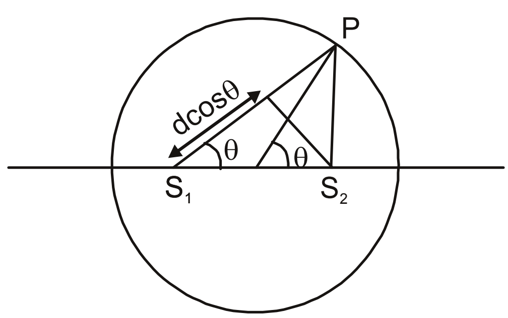
n = 3000

option (D) is correct.

$\Delta x \text{ at } P_1 = 0$

in between $P_1$ & $P_2$, 2999 maximas are formed

Option (C) is correct.




Path difference at any point P

x = dcos $\theta$

dx = d sin $\theta$ d $\theta$

$dx = \lambda$ for consecutive maxima

$\lambda = d\sin\theta \, d\theta$

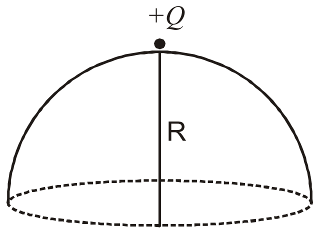
$d\theta = \dfrac{\lambda}{d\sin\theta}$

$\theta \uparrow \sin\theta \uparrow d\theta \downarrow$

as move from $P_2$ to $P_1$ $d\theta \downarrow$

so as we move $P_1$ to $P_2$ $d\theta \uparrow$

**10.** A point charge +Q is placed just outside an imaginary hemispherical surface of radius R as shown in the figure. Which of the following statements is/are correct?




(A) The electric flux passing through the curved surface of the hemisphere is $-\dfrac{Q}{2\varepsilon_0}\left(1-\dfrac{1}{\sqrt{2}}\right)$

(B) The component of the electric field normal to the flat surface is constant over the surface

(C) Total flux through the curved and the flat surfaces is $\dfrac{Q}{\varepsilon_0}$

(D) The circumference of the flat surface is an equipotential

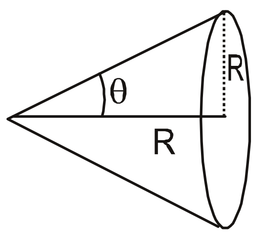
**Ans.** **(A,D)**

**Sol.** Net flux through curved + flat surface = 0 [no charge inside]

$\phi_1 + \phi_2 = 0$

Solid angle $\Omega = 2\pi(1-\cos\theta)$

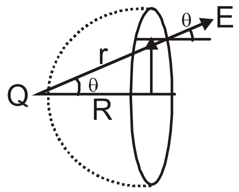
$\theta = 45°$




$\phi_2 = \dfrac{Q}{\varepsilon_0}\dfrac{\Omega}{4\pi} = \dfrac{Q}{\varepsilon_0} \times \dfrac{2\pi(1-\cos\theta)}{4\pi}$

$\phi_2 = \dfrac{Q}{2\varepsilon_0}\left(1-\dfrac{1}{\sqrt{2}}\right)$

So, $\phi_1 = -\dfrac{Q}{2\varepsilon_0}\left(1-\dfrac{1}{\sqrt{2}}\right)$

(B) 


$$E = \frac{KQ}{r^2}$$

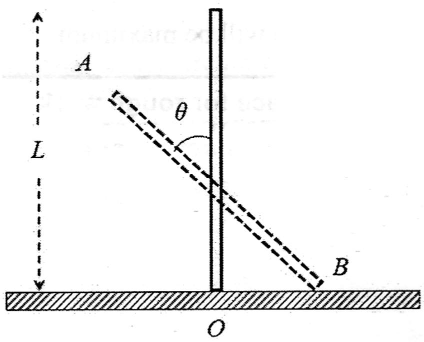
Component of E.F. $\perp$ to flat surface.

$$E_{\perp} = E\cos\theta = \frac{KQ}{r^2}\cos\theta = \frac{KQ}{r^2} \times \frac{R}{r} = \frac{KQR}{r^3}$$

not const.

(D) Circumference is equidistant from the point charge and symmetrical so, it is equipotential.

**11.** A rigid uniform bar AB of length L is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is $\theta$. Which of the following statements about its motion is/are correct?




(A) Instantaneous torque about the point in contact with the floor is proportional to $\sin\theta$

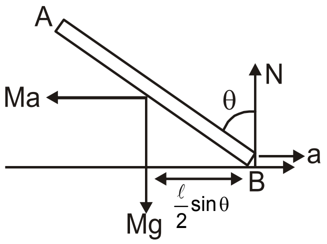
(B) The trajectory of the point A is a parabola

(C) The midpoint of the bar will fall vertically downward

(D) When the bar makes an angle $\theta$ with the vertical, the displacement of its midpoint from the intial position is proportional to $(1 - \cos\theta)$

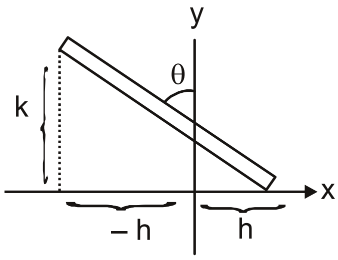
**Ans. (C,D)**

**Sol.**




Torque about B = $Mg\times\frac{\ell}{2}\sin\theta + Ma\frac{\ell}{2}\cos\theta$

option (A) is incorrect.




$2h = \ell\sin\theta$

$k = \ell\cos\theta$

$(2h)^2 + k^2 = \ell^2$

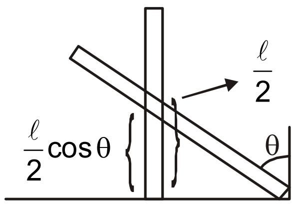
$\Rightarrow 4x^2 + y^2 = \ell^2$

$\Rightarrow$ ellipse

Option (B) is incorrect.

No force acts horizontally, so the centre of mass will fall vertically downward.

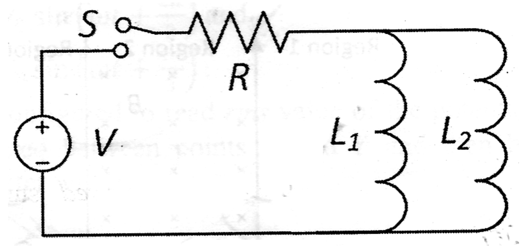
Option (C) is correct.




displacement = $\frac{\ell}{2}-\frac{\ell}{2}\cos\theta \propto (1-\cos\theta)$

Option (D) is correct.

**12.** A source of constant voltage V is connected to a resistance R and two ideal inductors $L_1$ and $L_2$ through a switch S as shown. There is no mutual inductance between the two inductors. The switch S is initially open. At t = 0, the switch is closed and current begins to flow. Which of the following options is/are correct ?




(A) After a long time, the current through $L_1$ will be $\frac{V}{R}\frac{L_2}{L_1+L_2}$

(B) After a long time, the current through $L_2$ will be $\frac{V}{R}\frac{L_1}{L_1+L_2}$

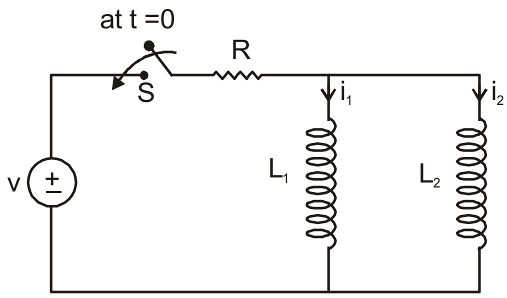
(C) The ratio of the currents through $L_1$ and $L_2$ is fixed at all times (t > 0)

(D) At t = 0, the current through the resistance R is $\frac{V}{R}$

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

**Sol.** $i = \frac{V}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$

$L_{eq} = \left(\frac{L_1L_2}{L_1+L_2}\right)$




$i_1 = \left(\frac{L_2}{L_1+L_2}\right)i$

at $t \to \infty$, $i = \frac{V}{R}$

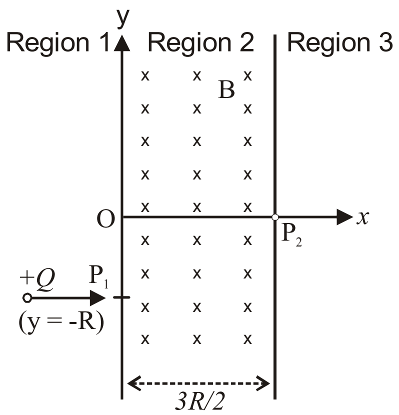
$i_1 = \frac{V}{R}\left(\frac{L_2}{L_1+L_2}\right)$

similarly $i_2 = \frac{V}{R}\left(\frac{L_1}{L_1+L_2}\right)$

$\frac{i_1}{i_2} = \frac{L_2}{L_1} = \text{constant}$

so correct answer is A, B, C

**13.** A uniform magnetic field B exists in the region between x = 0 and $x = \frac{3R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge +Q and momentum p directed along x-axis enters region 2 from region 1 at point $P_1(y = -R)$. Which of the following options(s) is/are correct?




(A) When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point $P_1$ and the farthest point from y-axis is $p/\sqrt{2}$.

(B) For $B = \frac{8}{13}\frac{p}{QR}$, the particle will enter region 3 through the point $P_2$ on x-axis

(C) For $B > \frac{2}{3}\frac{p}{QR}$, the particle will re-enter region 1

(D) For a fixed B, particles of same charge Q and same velocity v, the distance between the point $P_1$ and the point of re-entry into region 1 is inversely proportional to the mass of the particle

**Ans. (B,C)**

**Sol.**

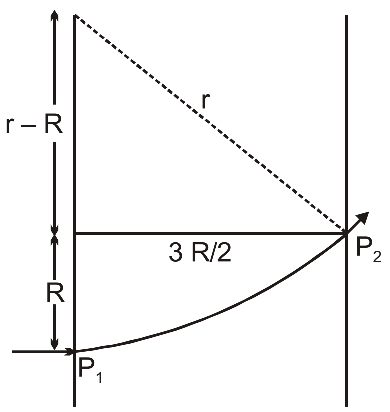
For particle to exit at $P_2$

$$(r-R)^2 + \left(\frac{3R}{2}\right)^2 = r^2$$

$$r = \frac{13R}{8}$$

$$B = \frac{mv}{Qr} = \frac{p}{Q(13R/8)}$$

$$B = \frac{8p}{13QR}$$




So, (B) is correct

for particle to re-enter region (1)

$r < \frac{3R}{2}$

$\frac{p}{QB} < \frac{3R}{2} \qquad \Rightarrow B > \frac{2p}{3QR}$

$\therefore$ (C) is correct

**14.** The instantaneous voltages at three terminals marked X, Y and Z are given by

$$V_X = V_0 \sin\omega t,$$
$$V_Y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) \text{and}$$
$$V_Z = V_0 \sin\left(\omega t + \frac{4\pi}{3}\right)$$

An ideal voltmeter is configured to read rms value of the potential difference between its terminals. It is connected between points X and Y and then between Y and Z. The reading (s) of the voltmeter will be

(A) $V_{YZ}^{rms} = V_0\sqrt{\frac{1}{2}}$

(B) $V_{XY}^{rms} = V_0\sqrt{\frac{3}{2}}$

(C) independent of the choice of the two terminals

(D) $V_{XY}^{rms} = V_0$

**Ans. (B,C)**

$V_{XY} = V_X - V_Y$

$= \left(v_0 \sin\omega t - v_0 \sin\left(\omega t + 2\pi/3\right)\right)$

$= 2v_0 \cos\left(\omega t + \pi/3\right) \sin\left(-\frac{2\pi}{3}\right)$

$= \frac{-\sqrt{3}}{2} 2v_0 \cos\left(\omega t + \frac{\pi}{3}\right)$

$V_{XY}^{rms} = \frac{\sqrt{3}}{\sqrt{2}} v_0$

hence (B) is correct

$V_{YZ} = V_Y - V_Z$

$= v_0 \sin\left(\omega t + \frac{2\pi}{3}\right) - v_0 \sin\left(\omega t + \frac{4\pi}{3}\right) = 2v_0 \cos\left(\omega t + \pi\right) \sin\left(-2\pi/3\right) \; = -\frac{\sqrt{3}}{2} \times 2v_0 \cos\left(\omega t + \pi\right)$

$v_{YZ}^{rms} = \frac{\sqrt{3}}{\sqrt{2}} v_0$

$v_{XZ}^{rms} = \frac{\sqrt{3}}{\sqrt{2}} v_0$

So (C) is correct

## SECTION – 3 (Maximum Marks : 12)

- This section contains **TWO** paragraphs
- Based on each paragraph, there will be **TWO** questions
- Each question has **FOUR** option (A), (B), (C) and (D). **ONLY ONE** of these four option is correct.
- For each question, darken the bubble corresponding to all 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 In all other cases.

### Paragraph-1

Consider a simple RC circuit as shown in Figure 1.

Process 1 : In the circuit the switch S is closed at t = 0 and the capacitor is fully charged to voltage $V_0$ (i.e., charging continues for time T >> RC). In the process some dissipation ($E_D$) occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is $E_C$.

Process 2 : In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time T >> RC.

Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time T >> RC.

The process is repeated one more time by raising the voltage to $V_0$ and the capacitor is charged to the same final voltage $V_0$ as in Process 1.

These two processes are depicted in Figure 2.

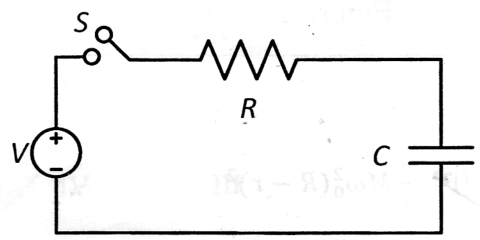


Figure 1

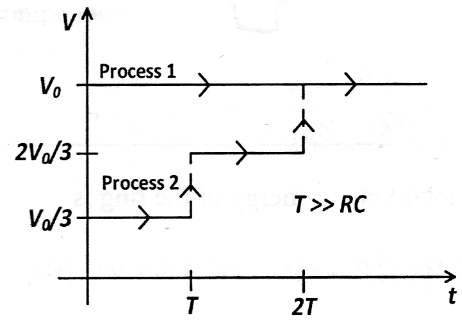


Figure 2

**15.** In process 1, the energy stored in the capacitor $E_C$ and heat dissipated across resistance $E_D$ are related by:

(A) $E_C = E_D \ln 2$ (B) $E_C = E_D$ (C) $E_C = 2E_D$ (D) $E_C = \frac{1}{2}E_D$

**Ans.** **(B)**

**Sol.** Since, T >> RC

Final charge on capacitor will be $CV_0 \Rightarrow E_C = \frac{1}{2}CV_0^2$

At any time t = t,

Charge on the capacitor will be $q = CV(1 - e^{-\frac{t}{RC}})$; $i = \frac{dq}{dt}$

$i = \frac{V_0}{R} e^{-\frac{t}{RC}}$

Total energy dissipation $E_D = \int_0^{\infty} i^2 R dt$

$\Rightarrow E_D = \int_0^{\infty} \frac{V_0^2}{R^2} \times R \times e^{-\frac{2t}{RC}} dt = \frac{V_0^2}{R^2}\left(-\frac{RC}{2}\right) R \times \left(e^{-\frac{2t}{RC}}\right)_0^{\infty}$

$E_D = \frac{1}{2} C V_0^2$

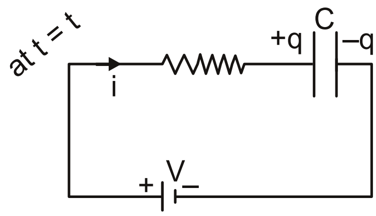
$\Rightarrow E_D = E_C$

**16.** In Proces 2, total energy dissipated across the resistance $E_D$ is :

(A) $E_D = \frac{1}{3}\left(\frac{1}{2} C V_0^2\right)$ (B) $E_D = 3\left(\frac{1}{2} C V_0^2\right)$ (C) $E_D = 3 C V_0^2$ (D) $E_D = \frac{1}{2} C V_0^2$

**Ans.** **(A)**

**Sol.** Let at t = 0 charge on the capacitor is $q_1$ and at t = t charge becomes q = q




Applying KVL

$-iR - \frac{q}{C} + V = 0$ ; $\left(i = \frac{dq}{dt}\right)$

$\Rightarrow \int_{q_1}^{q} \frac{dq}{CV - q} = \frac{1}{RC} \int_0^t dt$

$\ln\left(\frac{CV - q}{CV - q_1}\right) = -\frac{t}{RC}$

$q = CV - (CV - q_1) e^{-\frac{t}{RC}}$

$\Rightarrow$ Current $i = \frac{dq}{dt} = \frac{(CV - q_1)}{RC} e^{-\frac{t}{RC}}$

Total energy dissipation across resistor is $U = \int i^2 R dt$

For time t = 0 to t = T (T >>RC)

$$U_1 = \frac{1}{9}\left(\frac{1}{2}CV_0^2\right)$$

For time t = T to t = 2T (T >>RC)

$$U_2 = \frac{1}{9}\left(\frac{1}{2}CV_0^2\right)$$

For time t = 2T to t = 3T

$$U_3 = \frac{1}{9}\left(\frac{1}{2}CV_0^2\right)$$

$\Rightarrow$ Total energy dissipated $E_D = U_1 + U_2 + U_3 = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

## Paragraph-2

One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in Figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is r. The finger rotates with an angular velocity $\omega_0$. The rotating ring rolls without slipping on the outside of a smaller circle described by the point where the ring and the finger is in contact (Figure 2). The coefficient of friction between the ring and the finger is $\mu$ and the acceleration due to gravity is g.

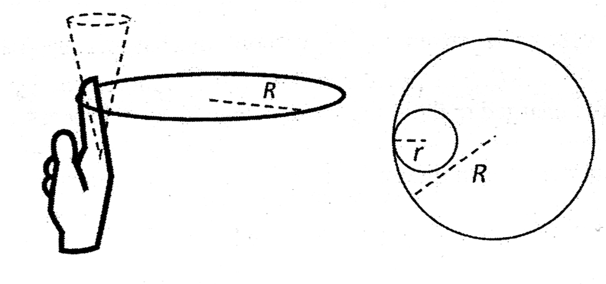



Figure 1 Figure 2

**17.** The total kinetic energy of the ring is

(A) $M\omega_0^2(R-r)^2$ (B) $\frac{1}{2}M\omega_0^2(R-r)^2$ (C) $M\omega_0^2R^2$ (D) $\frac{3}{2}M\omega_0^2(R-r)^2$

**Ans. (A)**

**18.** The minimum value of $\omega_0$ below which the ring will drop down is

(A) $\sqrt{\frac{g}{2\mu(R-r)}}$ (B) $\sqrt{\frac{3g}{2\mu(R-r)}}$ (C) $\sqrt{\frac{g}{\mu(R-r)}}$ (D) $\sqrt{\frac{2g}{\mu(R-r)}}$

**Ans. (C)**