10. Two point charges of \( +2, -2, +2, -2 \) are arranged symmetrically on the circumference of a circle as shown in the figure. If \( V \) and \( E \) are potential and field at the centre of the circle, they choose correct statements.

\[ \text{I) } E = 0, \ V = 0 \]
\[ \text{II) } E \neq 0, \ V = 0 \]
\[ \text{III) } E = 0, \ V \
eq 0 \]
\[ \text{IV) } E \neq 0, \ V \neq 0 \]

Solution:

For \( V \),

\[ V = \sum \left( \frac{kq_1r_1}{r_1} \right) - \sum \left( \frac{kq_2r_2}{r_2} \right) = 0 \]

For \( E \),

As all vectors are cancelled out, then

\[ \theta \neq 0 \quad E = 0 \]
Q. 1: A body of mass 2 kg is moving under the influence of constant power delivery 4 J watt which is initially kept at rest. The distance travelled by body in initial 6 sec will be-

- a) \(2\sqrt{3}\) m
- b) \(3\sqrt{3}\) m
- c) \(5\sqrt{3}\) m

Solution:

\[ P = \int F \, dt \]

\[ W = Pt \]

\[ \text{work} \equiv W = 1 \times t - c.i.

By using work energy theorem

\[ \Delta KE = W \]

\[ KE_{\text{final}} - KE_{\text{in}} = t \]

\[ \frac{1}{2} mv^2 = t \]

\[ v^2 = t \]

\[ v = \sqrt{t} \]

\[ \frac{ds}{dt} = \sqrt{t} \]

\[ ds = \int \sqrt{t} \, dt \]

\[ s = \frac{2}{3} \times 12 \]

\[ s = \frac{2}{3} \times 8\sqrt{6} \]

\[ s = 4\sqrt{6} \, m \]
Q.2 For a parallel plate capacitor length of plate is \( l \) and width of plate is \( b \). This capacitor is charged to some potential difference and filled with dielectric of constant \( k=4 \). Now length of plate is increased by \( l \), amount keeping dielectric medium as per previous dimensions. If energy stored in capacitors becomes doubled then find \( l \), in terms of \( l \).

\[ a) \quad l_1 = l \]
\[ b) \quad l_1 = 2l \]
\[ c) \quad l_1 = 4l \]
\[ d) \quad l_1 = 8l \]

\[ \text{Solution:} \quad \text{Before} \quad \Rightarrow \quad C_{\text{in}} = \frac{4\varepsilon_0 \cdot b \cdot l}{d} \]
\[ V_{\text{in}} = \frac{1}{2} \frac{Q^2}{C_{\text{in}}} \]

\[ \text{After} \quad \Rightarrow \quad C_{\text{final}} = \frac{\varepsilon_0}{d} (4b^2 + 4l^2) \]
\[ V_{\text{final}} = \frac{1}{2} \frac{Q^2}{C_{\text{final}}} \]

Now
\[ \frac{Q^2}{2C_{\text{final}}} = \frac{Q^2}{2C_{\text{in}}} \]
\[ \text{by solving} \]
\[ l_1 = 4l \]
Problem 3: An ideal gas (diatomic) is taken through an adiabatic process to change its density by 32 times. Then find increase in pressure.

a) 4 \times \text{time} \\
b) 16 \times \text{time} \\
c) 64 \times \text{time}

Solution:

For adiabatic process,

\[ pV^n = \text{constant} \]

\[ \Rightarrow \text{For ideal gas} \quad \frac{p}{V} = \text{constant} \]

\[ \Rightarrow \text{then relation would be} \]

\[ \frac{p}{V^n} = \text{constant} \]

\[ \Rightarrow \frac{P_1}{V_1^n} = \frac{P_2}{V_2^n} \Rightarrow \text{now} \quad P_2 = 32P_1 \]

\[ \frac{P_1}{V_1^n} = \frac{P_2}{(32^n) V_1^n} \Rightarrow P_2 = (32^n) P_1 \]

For diatomic

\[ P_2 = (32) \times 5 P_1 \]

\[ P_2 = 2^7 P_1 = 128 P_1 \]
Q: \[ y = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \] 
and \( z = \frac{1}{\mu_0 c} \), which of the following option is correct?

a) dimensions of \( y \) and \( z \) are the same
b) dimensions of \( y \) and \( z \) are different
c) dimension of \( y \) and \( z \) are the same

SOL: for \( y = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \) then \( y = LT^{-1} \) \( \mu \) speed of light

\( y = \frac{E}{B} = c \) then \( c = LT^{-1} \) \( \mu \) speed of light

\( z = \frac{1}{\mu_0 c} = \frac{1}{\mu_0} \) then \( z = T^{-1} \) time constant
2.5 Two metallic rods of length $d_1$ and $d_2$ and coefficient of linear expansion $\alpha_1$ and $\alpha_2$ are connected in series, find effective coefficient of linear expansion of combination.

a) \[ \frac{\alpha_1 + \alpha_2}{2} \]

b) \[ \frac{d_1 \alpha_1 + d_2 \alpha_2}{d_1 + d_2} \]

c) \[ \frac{d_1 \alpha_1 - d_2 \alpha_2}{d_1 + d_2} \]

d) \[ \frac{d_1 \alpha_2 + d_2 \alpha_1}{d_1 + d_2} \]

Sol:

then change in length with $\Delta t$ temp rise

\[ \Delta d = \Delta d_1 + \Delta d_2 \]
\[ = d_1 \alpha_1 \Delta t + d_2 \alpha_2 \Delta t \]

now for effective expansion coefficient $\alpha_{\text{eff}}$

\[ \Delta d = (d_1 + d_2) \alpha_{\text{eff}} \Delta t \]

then for same temp rise $\Delta d$ must be same

\[ (d_1 + d_2) \alpha_{\text{eff}} \Delta t = d_1 \alpha_1 \Delta t + d_2 \alpha_2 \Delta t \]

\[ \alpha_{\text{eff}} = \frac{d_1 \alpha_1 + d_2 \alpha_2}{d_1 + d_2} \]
Q6: For a particle performing straight line
motion, velocity-time graph is given as
shown in figure, what will be displacement
of particle in 6 sec of motion.
a) 300 \( \sqrt{3} \) (meter) b) 11 (meter)
c) 51.5 (meter) d) 431.3 (meter)

\[ v(t) \]

\[ \begin{array}{c}
\text{4} \\
\text{0} \\
\text{2} \\
\end{array} \]

Sodi: Area under v-t graph shows displacement.

\[
S = \left[ \frac{1}{2} \times \left( 2 + \frac{13}{3} \right) \times 4 \right] - \left[ \frac{1}{2} \times 2 \times \left( 6 - \frac{13}{3} \right) \right]
\]

\[
S = \frac{38}{3} - \frac{5}{2} = 11 \text{ m}
\]

Use concept of similar triangle to find time
at which velocity becomes zero again.
Q. 7: A ball is released from rest at a height of \( h \) from surface of liquid which is filled inside a very long vertical container as shown in figure. If velocity of ball remain constant after entering in liquid then find \( h \). If density of liquid = \( \sigma \), density of ball = \( \rho \), viscosity of liquid = \( \eta \) and radius of ball is \( R \).

\[
\begin{align*}
\text{a)} & \quad \frac{2}{50} \frac{s^4 (1 - \sigma^2)}{\eta^2} \\
\text{b)} & \quad \frac{2}{81} \frac{s^4 (1 - \sigma^2)}{\eta^2} \\
\text{c)} & \quad \frac{2}{81} \frac{s^4 (1 - \sigma^2)}{\eta^2} \\
\text{d)} & \quad \frac{2}{50} \frac{s^4 (1 - \sigma^2)}{\eta^2}
\end{align*}
\]

Sol.:- As velocity of ball doesn’t change after it hit liquid surface, the it must be equal to terminal velocity then

\[
v = \frac{2}{9} \frac{(1 - \sigma^2) s^2 g}{\eta^2} \quad \text{now after travelling } h \text{,}
\]

\[
\sqrt{2g h} = \frac{2}{9} \frac{(1 - \sigma^2) s^2 g}{\eta^2} \implies h = \frac{2}{81} \frac{s^4 (1 - \sigma^2)}{\eta^4} \]
Q.6: For a thin prism, angle of prism is given as 2° and its refractive index is 1.5. Then maximum deviation of any light ray incident on prism will be.

a) 1°  

b) 2°  

c) 3°  

d) 1/2°

so, for thin prism, the minimum deviation is given as

\[ \delta_{\text{min}} = (n-1) A \]

\[ \Rightarrow \delta_{\text{min}} = (1.5-1) 2° \]

\[ = 1° \]
Two bodies A and B of equal masses are weighs equally when body A is placed near to equator of earth and body B is placed at a height $h$ above pole of earth, consider rotation of earth and $\omega =$ angular speed of earth, $g =$ acceleration due to gravity near to earth's surface, and $R =$ radius of earth.

Find $h$ in terms of $r$, $g$, $\omega$.

\[ h = \frac{R^2 \omega^2}{2g} \]

\[ h = \frac{R \omega^2}{2g} \]

\[ h = \frac{g^2 \omega^2}{2g} \]

\[ h = \frac{R^2 \omega^2}{g} \]

\[ \text{Substitute for body A:} \]

\[ V_A = mg - mR\omega^2 \]

\[ \text{Now for body B:} \]

\[ V_B = mg \left(1 - \frac{h}{R}\right) \]

\[ g' = g \left(1 - \frac{h}{R}\right) \]

\[ V_A = V_B \]

\[ m(g - R\omega^2) = mg \left(1 - \frac{h}{R}\right) \]

\[ \frac{g + R\omega^2}{R} = \frac{g'}{R} \]

\[ h = \frac{R^2 \omega^2}{g} \]
Q9: For the given capacitor circuit, find charge on 5μF capacitor.

\[
\begin{align*}
\text{a)} & \quad \frac{120}{11} \, \mu C \\
\text{b)} & \quad \frac{140}{11} \, \mu C \\
\text{c)} & \quad \frac{160}{11} \, \mu C \\
\text{d)} & \quad \frac{160}{11} \, \mu C
\end{align*}
\]

soln: By using Kirchhoff's Law for given circuit

Let \( q_1 \) and \( q_2 \) are in \( \mu C \) unit.

For Loop 1 2 5 6

\[ 6 - \frac{q_1}{2} - \frac{q_1 + q_2}{5} = 0 \]  \quad (1)

For Loop 3 4 5 6

\[ 6 - \frac{q_2}{4} - \frac{q_1 + q_2}{5} = 0 \]  \quad (2)

By solving (1) \( \quad (2) \)

\[ q_1 = \frac{60}{11} \, \mu C \quad \text{and} \quad q_2 = \frac{120}{11} \, \mu C \]

Then charge on 5μF \( \Rightarrow q_1 + q_2 = \frac{180}{11} \, \mu C \)
A car is moving with constant velocity towards a fixed wall and blows horn at a frequency of 440Hz. If an observer seating in car, observe frequency of 480Hz of reflected sound, then find speed of car if speed of sound is 350 m/s. (In km/h)

a) 62.70  c) 23.33
b) 54.70  d) 55.55

**Solution:**

From given condition

\[ v_{source} = v_{0} \]
\[ v_{observe} = v_{0} \]

Then

\[ f_{apparent} = f_{0} \left( \frac{v_{0} + v_{observe}}{v_{0} - v_{source}} \right) = 480 \left( \frac{350 + v_{0}}{350 - v_{0}} \right) \]

\[ 480 = 440 \left( \frac{350 + v_{0}}{350 - v_{0}} \right) \Rightarrow v_{0} = \frac{350}{23} \text{ m/s} \]

Then for km/h

\[ v_{0} = \frac{350}{25} \times \frac{3600}{1000} = 54.78 \text{ km/h} \]
A light gets incident on two different metal surfaces with energy $4\text{ eV}$ and $2.5\text{ eV}$ having work functions as $\phi_1\text{ eV}$ and $\phi_2\text{ eV}$ respectively. Now, if the maximum velocity of photons emitted is $v_1\text{ m/s}$ and $v_2\text{ m/s}$ respectively for a given metal surface, then find $\frac{v_1}{v_2}$.

\begin{align*}
\text{a) } & \sqrt{\frac{3 - \phi_1}{2.5 + \phi_2}} \\
\text{b) } & \sqrt{\frac{3 + \phi_1}{2.5 - \phi_2}} \\
\text{c) } & \sqrt{\frac{4 - \phi_1}{2.5 + \phi_2}} \\
\text{d) } & \sqrt{\frac{4 - \phi_1}{2.5 - \phi_2}}
\end{align*}

Solve:- By using energy conservation.

$$kE_{\text{max}} = E - \phi$$

for 1st emission

$$\frac{1}{2}mv_1^2 = 4 - \phi_1$$

$$v_1 = \sqrt{\frac{2(4 - \phi_1)}{m}}$$

for 2nd emission

$$\frac{1}{2}mv_2^2 = 2.5 - \phi_2$$

$$v_2 = \sqrt{\frac{2}{m}(2.5 - \phi_2)}$$

Then

$$\frac{v_1}{v_2} = \sqrt{\frac{4 - \phi_1}{2.5 - \phi_2}}$$
A ring oscillates in two different manners with time period $T_1$ and $T_2$ respectively as shown in figure. For $T_1$ time period, axis of rotation is passing from circumference and for $T_2$ time period, axis of rotation is perpendicular to plane of ring and passing from perimeter. Find $\frac{T_1}{T_2} =$ 

\[ \begin{array}{c}
\text{Ti time period} \\
\includegraphics[width=0.3\textwidth]{ti.png}
\end{array} \quad \begin{array}{c}
\text{T2 time period} \\
\includegraphics[width=0.3\textwidth]{t2.png}
\end{array} \]

a) $\sqrt{\frac{3}{2}}$

b) $\sqrt{\frac{3}{8}}$

d) $\sqrt{\frac{2}{3}}$

d) $\sqrt{\frac{2}{3}}$

so $T_1 \propto \sqrt{I_1}$

then $\frac{T_1}{T_2} = \sqrt{\frac{I_1}{I_2}}$

Now $I_1 = \frac{MR^2}{2} + ml^2 = \frac{3}{2}ml^2$

$I_2 = ml^2 + mr^2 = 2ml^2$

Hence $\frac{T_1}{T_2} = \sqrt{\frac{3}{4}}$
4.14 A rod of length \( l \) and resistance \( R \) is sliding on rails of U-shaped wire as shown in figure. There exists an uniform magnetic field \( B \), which is perpendicular to the plane of arrangement, and it is moving uniformly on smooth rail with a velocity \( \nu \). Find current across the rod.

\[ \vec{B} \times \vec{v} \]

\[ I = \frac{B \nu}{R} \]

\[ E = BL \nu \] (PD across rod)

Then apply Ohm's law for rod

\[ E = IR \]

\[ I = \frac{E}{R} = \frac{BL \nu}{R} \]
For a current carrying solenoid, turn density is given as 10 turns/cm. If iron core is fitted inside solenoid having relative permeability of 1000. Now a current of 0.5 A is flowing from wire of solenoid then find magnetic moment of solenoid if its volume is $10^{-3}m^3$.

a) 250 A·m²
b) 500 A·m²
c) 750 A·m²
d) 1000 A·m²

\[ M = N \, \ell \, A \times \frac{1}{d} \left( \mu_r - 1 \right) \]

\[ M = \frac{N \, \ell \, \nu}{d} = \frac{N \, \ell \, \nu}{d} \left( \mu_r - 1 \right) \]

\[ M = 10 \times 0.5 \times 10^{-3} \left( \mu_r - 1 \right) \]

\[ M = 5 \times 10^{-3} \left( 1000 - 1 \right) \]

\[ M = 499.5 \text{ A·m}^2 \]
A rocket has varying mass due to fuel exhaustion, \[
\frac{dm}{dt} = -b \frac{v^2}{m}
\]
Assume rocket to move in free space and \(v\) is instantaneous velocity then find acceleration of rocket if gases are leaving rocket at a rate of \(c\) units with respect to rocket (If mass of rocket at this instant is \(m\)).

\begin{align*}
a) \quad & \frac{bu^2}{mu} \\
\text{b) } \quad & \frac{bu^2}{2mu} \\
\text{c) } \quad & \frac{bu^2}{2m} \\
\text{d) } \quad & \frac{bu^2}{m}
\end{align*}

Solution: By applying variable-mass system concept

\[
F = v_2 \frac{dm}{dt}
\]
where \(v_2\) = relative velocity of leaving gas

\[
F = u \times (-b \frac{v^2}{m}) = ma
\]

\[
a = \frac{bu \frac{v^2}{m}}{m}
\]
A radioactive nucleus A converts in nucleus B and C with half life 10 sec and 100 sec respectively. Then what will be half life of A for both emissions? (Approx.)

a) 8 sec  

b) 9 sec  

c) 10 sec  

d) 9.5 sec

Sol.:

\[ -\frac{dN}{dt} = \lambda_1 N + \lambda_2 N \]

\[ -\frac{dN}{dt} = (\lambda_1 + \lambda_2)N = \lambda_{eq} N \]

Now \( \lambda_{eq} = \lambda_1 + \lambda_2 \)

\[ \frac{\ln 2}{T} = \frac{\ln 2}{10} + \frac{\ln 2}{100} \]

\[ \frac{1}{T} = \frac{1}{10} + \frac{1}{100} = \frac{1}{10} \left(1 + \frac{1}{10}\right) \]

\[ \frac{1}{T} = \frac{11}{100} \]

\[ T = \frac{100}{11} \text{ sec} \approx 9 \text{ sec} \]
A uniform rod of mass 0.5 kg and length 1 m is suspended from one end and free to rotate in vertical plane by horizontal arms as shown in figure. A point mass 0.1 kg is moving with 30 m/s hit the free end of rod normally, and stick to rod then find angular speed of (rod+point mass) just after collision.

a) 10 rad/s
b) 20 rad/s
c) 5 rad/s
d) 15 rad/s

Solution: By using conservation of angular momentum about hinge point

\[ L_{in} = L_{final} \]

\[ (0.1 \times 0.5 \times 1) = \left( \frac{0.5 \times 1^2}{3} + 0.1 \times 1^2 \right) \omega \]

\[ \omega = \frac{(0.3 + 0.1)}{0.1} \Rightarrow \omega = \frac{0.5}{0.1} = 50 \]

\[ \omega = 20 \text{ rad/s} \]