SOLUTIONS OF PHYSICS PROBLEMS
12 GRADE

1

$d = 0{,}025\,m$

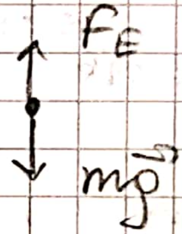
$\Delta V = 4000\,V$

$r = 1{,}25 \times 10^{-6}\,m$

$\rho = 1260\,kg/m^3$

$N - ?$

Gravitational force is balanced by an electrostatic force on oil drop



$F_E = qE$

$$mg = qE$$

Electric field between plates

$$E = \frac{\Delta V}{d}$$

$$\rho V g = \frac{\Delta V}{d} q$$

here mass in terms of ρ and V

Volume of oil drop is $V = \frac{4}{3}\pi r^3$

Charge from quantization rule

$$q = Ne$$

here N is intiger number

$$\rho \frac{4}{3}\pi r^3 g = \frac{\Delta V}{d} N e$$

$$4\pi r^3 \rho g d = 3\Delta V N e$$

$$N = \frac{4\pi r^3 \rho g d}{3\Delta V e}$$

Substituting numerical values

$$N = \frac{4\cdot 3{,}14\cdot(1{,}25\times10^{-6})^3\cdot 1260\cdot 10\cdot 0{,}025}{3\cdot 4000\cdot 1{,}6\times10^{-19}}$$

$$N = 4 \text{ electrons}$$

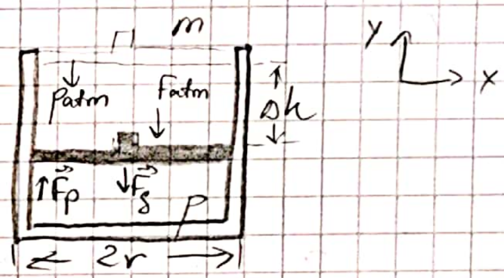
2) $r = 0{,}045\ m$

$n = 0{,}25\ mol$

$m = 0{,}5\ kg$

$\Delta T = -20\ K$

$\Delta h - ?$



Temperature of gas cools by $-20\ K$, while pressure and the number of moles of the gas stay constant.

Change in the enclosed cylindrical volume is a function of the change in height Δh of the piston.

$$\Delta V = \pi r^2 \Delta h$$

From Ideal Gas Law

$$p\Delta V = nR\Delta T \Rightarrow \Delta V = \frac{nR\Delta T}{p}$$

There are 3 forces acting on piston

- downward force F_{atm} due to atm. pressure
- downward force F_g of gravity due to mass of the piston
- upward force F_p due to the pressure p of the gas.

By 2nd Newton's law

$$F_p - F_g - F_{atm} = pA - mg - P_{atm}A = 0$$

from equation

$$p = p_{atm} + \frac{mg}{\pi r^2}$$

Change in height

$$\Delta h = \frac{\Delta V}{\pi r^2} = \frac{nR\Delta T}{\pi r^2 p} =$$

$$= \frac{nR\Delta T}{\pi r^2 \left(P_{atm} + \frac{mg}{\pi r^2}\right)} = \frac{nR\Delta T}{\pi r^2 P_{atm} + mg}$$

Substituting numerical values

$$\Delta h = \frac{0{,}25 \cdot 8{,}314 \cdot (-20)}{3{,}14 \cdot 0{,}045^2 \cdot 1{,}013 \times 10^5 + 0{,}5 \cdot 10}$$

$$\Delta h = -0{,}064\ m$$

Negative sign indicates that piston falls to lower height.

(3) $A = 0{,}45\,m$

$\omega = 5\,rad/s$

a) $v - ?$ if $x = \frac{2}{3}A$

b) A' if $v = 3v_i$

Velocity of the ball when position is $x = \frac{2}{3}A$ according to total energy of a simple harmonic oscillator

$$E_{tot.} = K.E + P.E$$

$$E_{tot.} = \frac{1}{2}mv^2 + \frac{1}{2}kx^2 = \frac{1}{2}kA^2$$

Solving for v

$$v = \pm\sqrt{\frac{k}{m}(A^2 - x^2)} = \pm\omega\sqrt{A^2 - x^2}$$

if $x = \frac{2}{3}A$, we get

$$v = \omega\sqrt{A^2 - \left(\frac{2}{3}A\right)^2} = \omega\sqrt{A^2 - \frac{4}{9}A^2} = \omega\sqrt{\frac{5}{9}A^2}$$

$$v = \frac{\omega A\sqrt{5}}{3} = \frac{5 \cdot 0{,}45\sqrt{5}}{3} = 1{,}677\,m/s$$

If ball's speed is tripled, new amplitude will be

$$v' = 3v = \omega\sqrt{A'^2 - \left(\frac{2A}{3}\right)^2}$$

$$\omega A\sqrt{5} = \omega\sqrt{A'^2 - \frac{4}{9}A^2}$$

$$5A^2 = A'^2 - \frac{4}{9}A^2$$

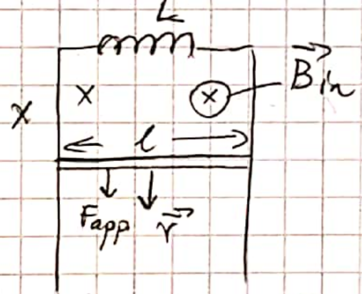
$$A'^2 = \frac{49}{9}A^2$$

$$A' = \frac{7}{3}A$$

$$A' = \frac{7}{3}\cdot 0{,}45 = \underline{1{,}05\ m}$$

(4) $m = 0{,}75$ kg
$l = 0{,}45$ m
$L = 5\times10^{-3}$ H
$v = 8$ m/s

$B - ?$



Conducting rod of length l sliding along two fixed parallel conducting rails. Rod is pulled downward with velocity $\vec{v}$ under influence of applied force Fapp. This force sets up induced current.

Magnetic flux through enclosed area is

$$\phi_B = BA = Blx$$

Using Faraday's law

$$\mathcal{E} = \frac{\Delta\phi_B}{\Delta t} = \frac{Blx}{\Delta t}$$

Self-induced emf in the coil

$$\mathcal{E}_i = L\frac{\Delta I}{\Delta t}$$

$$\mathcal{E} = \mathcal{E}_i$$

$$\frac{Blx}{\Delta t} = \frac{L\Delta I}{\Delta t}$$

$$Blx = L\Delta I \Rightarrow x = \frac{L\Delta I}{Bl} \quad (I)$$

Being at rest

$$F_g = F_{app}$$

$$mg = IBl \Rightarrow I = \frac{mg}{Bl} \quad (II)$$

Decrease in gravitational P.E = Increase of K.E plus energy stored in the inductor

$$mg\,x = \frac{1}{2}mv^2 + \frac{LI^2}{2} \quad (III)$$

Substituting the expression for x and I into (III) equation

$$mg\frac{LI}{Bl} = \frac{1}{2}mv^2 + \frac{L}{2}\left(\frac{mg}{Bl}\right)^2$$

$$mg\frac{L}{Bl}\frac{mg}{Bl} = \frac{1}{2}mv^2 + \frac{L}{2}\frac{m^2g^2}{B^2l^2} \quad \Big| \times 2$$

$$2L\left(\frac{mg}{Bl}\right)^2 = mv^2 + \frac{Lm^2g^2}{B^2l^2}$$

$$2L\frac{m^2g^2}{B^2l^2} - L\frac{m^2g^2}{B^2l^2} = mv^2$$

$$\frac{Lm^2g^2}{B^2l^2} = mv^2$$

$$B = \frac{g}{lv}\sqrt{Lm}$$

$$B = \frac{10}{0{,}45 \cdot 8}\sqrt{5 \times 10^{-3} \cdot 0{,}75} = \underline{0{,}1702\ T}$$

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