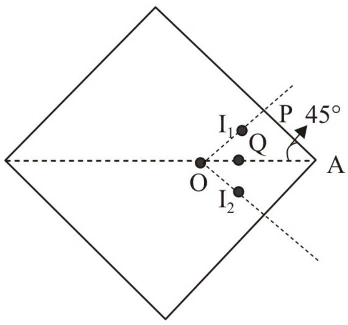
VMC Vidyamandir Classes SINCE 1986
IIT JEE | MEDICAL | FOUNDATION

JEE Advanced 2020
Physics Paper - 2_Solutions

1.(3) Assuming image formation by near normal incident rays $d_{app} = \frac{d_{real}}{\mu}$

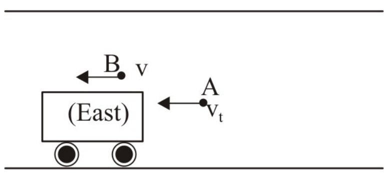


Separation between I_1 and I_2

$$= 2I_1Q = 2 \times OI_1 \times \sin 45° = 2 \times (OP - I_1P)\sin 45° = 2 \times \left(12\sin 45° - \frac{12\sin 45°}{4/3}\right)\sin 45° = 2 \times \frac{12}{\sqrt{2}}\left(1 - \frac{3}{4}\right)\sin 45°$$

$$= 12 \times \frac{1}{4} = 3cm$$

2.(9) In frame of train



$$(S_0 - S_T)V = SV_T$$

$$V = \frac{4S_T}{3S_T} \times V_T = \frac{4}{3}V_T$$

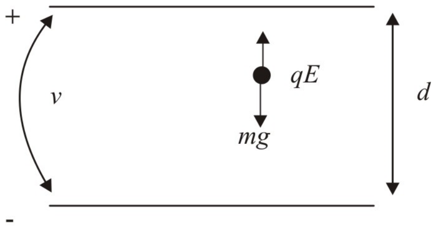
Applying Bermulli's between points A and B

$$P_0 + \frac{1}{2}\rho V_T^2 = P + \frac{1}{2}\rho V^2$$

$$P_0 - P = \frac{1}{2}\rho\left(V^2 - V_T^2\right) = \frac{1}{2}\rho\left(\frac{16}{9}V_T^2 - V_T^2\right)$$

$$= \frac{1}{2}\rho \times \frac{7V_T^2}{9} \Rightarrow N = 9$$

3.(6)



$$E=\frac{v}{d}$$

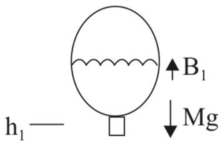
As oil droplet is in equilibrium

$$qE=mg \Rightarrow q\frac{v}{d}=mg \Rightarrow q=\frac{mgd}{v}=N\ e$$

(where N is the number of excess electron in oil drop)

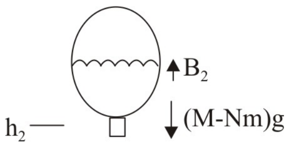
$$N=\frac{mgd}{ev}=\frac{\rho\times\frac{4}{3}\pi r^3\times g\times d}{ev}=\frac{900\times\frac{4}{3}\times\pi\times\left(8\times10^{-7}\right)^3\times10\times0.01}{1.6\times10^{-19}\times200}=6$$

4.(4)



$$Mg=\rho_1\times v\times g$$

$$Mg=\rho_0 e^{-h_1/h_0}\times v\times g \quad .....(i)$$



$$(M-Nm)=\rho_2 vg$$

$$(M-Nm)g=\rho_0 e^{-h_2/h_0}vg \,.........(ii)$$

$$\frac{M}{M-Nm}=\frac{e^{-h_1/h_0}}{e^{-h_2/h_0}}$$

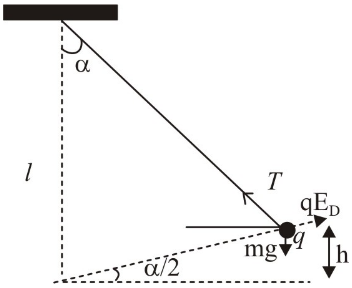
$$N=\frac{M-Me^{-(h_2-h_1)/h_0}}{m}=480\left(1-e^{-(50/6000)}\right)$$

$$e^{-x}=1-x\left(if\ x<<1\right)$$

$$1-e^{-x}=x$$

$$N=\frac{480\times50}{6000}=4$$

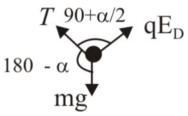
5.(2)



Workdone W = Final potential energy of the system

$$\Rightarrow W = q(v) + mgh$$

$$\Rightarrow W = \frac{qkp}{\left(2l\sin\frac{\alpha}{2}\right)^2} + mgh \text{ ....(i)}$$



Also , q is in equilibrium

$$\frac{qE_0}{\sin(180-\alpha)} = \frac{mg}{\sin\left(90+\frac{\alpha}{2}\right)}$$

$$q \times \frac{2kp}{(2l\sin\alpha/2)^3} = \frac{mg\sin\alpha}{\cos\alpha/2}$$

$$\frac{q \times kp}{(2l\sin\alpha/2)^2} = \frac{2l\sin\alpha/2}{2} \times \frac{mg\sin\alpha}{\cos\alpha/2} = l\sin\frac{\alpha}{2} \times mg \times 2l\sin\frac{\alpha}{2}$$

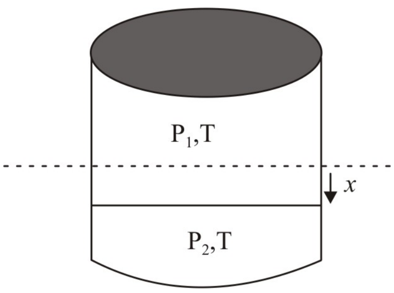
$$= 2mgl^2\sin^2\frac{\alpha}{2} = 2mgl^2 \times \frac{h}{2l} = mgh$$

Substituting back in (i)

$$w = mgh + mgh = 2mgh$$

$$w = 2$$

6.(6)



If we assume final temperature of both chambers to be same and equal to 300 K (neglecting work done by gravity on piston)

$$P_1 = \frac{nR(300)}{A(4+x)} \text{ and } P_2 = \frac{nR(300)}{A(4-x)}$$

Also $P_2A - P_1A = mg$

$$\frac{nR300}{A}\left[\frac{1}{4-x} - \frac{1}{4+x}\right] = 83$$

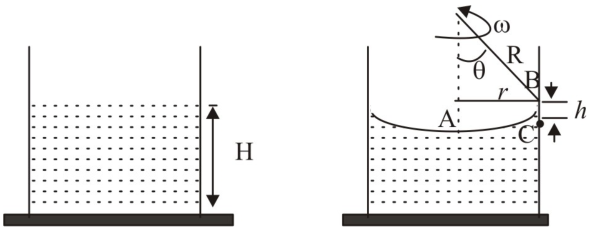
$$3\left[\frac{2x}{16-x^2}\right] = 1$$

$$x^2 + 6x - 16 = 0$$

$$x = \frac{-6+\sqrt{36+64}}{2} = \frac{-6+10}{2} = 2\,m$$

Note: Work done by gravitational force on piston goes into increasing the internal energy of the system. As $\Delta U = nC_v\Delta T$, the value of C_v is required for analysis, which is not given. So, this question may be given as bonus.

7.(AD)



From geometry, $r = R\sin\theta$ …….(i)

$h = R - R\cos\theta$

$R\cos\theta = R - h$ …….(ii)

From (i) and (ii)

$$r^2 + (R-h)^2 = R^2$$

$$r^2 + R^2 + h^2 - 2Rh = R^2$$

$$r^2 + h^2 = 2Rh$$

$$R = \frac{r^2+h^2}{2h}$$

As $h << r$

$$R = \frac{r^2}{2h}$$

$$R = \frac{2gh}{\omega^2(2h)} \quad \left\{As\, h = \frac{\omega^2 r^2}{2g}\right\}$$

$$R = \frac{g}{\omega^2} \text{ ……….(iv)}$$

To calculate apparent depth, we will use formula

$$\frac{\mu_2}{v}-\frac{\mu_1}{u}=\frac{\mu_2-\mu_1}{R}$$

Where $\mu_2=1,\ \mu_1=\frac{4}{3}$

$u=-H, v=apparent\,depth$

$$\frac{1}{v}-\frac{4}{3(-H)}=\frac{1-\frac{4}{3}}{R}$$

$$\frac{1}{v}+\frac{4}{3H}=\frac{-1}{3R}$$

$$\frac{1}{v}=\frac{-1}{3R}-\frac{-4}{3H}$$

$$or\ -\frac{1}{v}=\frac{1}{3R}+\frac{4}{3H}$$

$$-\frac{1}{v}=\frac{\omega^2}{3g}+\frac{4}{3H}$$

$$-\frac{1}{v}=\frac{\left(\omega^2 H+4g\right)}{3gH}$$

$$-v=\frac{3gH}{4g+H\omega^2}=\frac{3gH}{4g\left(1+\frac{H\omega^2}{4g}\right)}$$

Apparent depth $=\frac{3H}{4}\left(1+\frac{H\omega^2}{4g}\right)^{-1}$

8.(AD) At point y,

$$mg\sin 30=\frac{mu^2}{R}$$

$$g\left(\frac{1}{2}\right)=\frac{u^2}{R}$$

$$u^2=\frac{Rg}{2}$$

Also by conservation of energy between bottom and topmost point,

Loss of K.E. = Gain in GPE

$$\frac{1}{2}m\left[v_0^2-u^2\right]=mgh$$

$$v_0^2-u^2=2gh$$

$$v_0^2 - 2gh = u^2 = \frac{Rg}{2}$$

The centripetal force required at points x and z will be maximum as velocity a those points will be maximum

9.(ACD) Angular momentum will remain conserved about the pivot.

$$(L)_i = (L)_f$$

$$mvx = \frac{ml^2\omega}{3} + m(\omega x)x$$

$$3mvx = \omega L^2 + 3(\omega x)^2$$

$$\omega = \frac{3vx}{l^2 + 3x^2}$$

For ω to be maximum,

$$\frac{d\omega}{dx} = \frac{(l^2 + 3x^2)(3v) - 3vx(6x)}{(l^2 + 3x^2)^2} = 0$$

$$l^2 + 3x^2 = 6x^2 \Rightarrow x = \frac{l}{\sqrt{3}}$$

$$x_m = \frac{L}{\sqrt{3}}$$

$$\omega_m = \frac{3v\left(\frac{L}{\sqrt{3}}\right)}{\left(L^2 + \frac{3L^2}{3}\right)} = \frac{3vL}{2\sqrt{3}L^2} = \frac{\sqrt{3}v}{2L}$$

10.(AC) Cut off wavelength will change.

Cut off wavelength is inversely proportional to voltage.

Cut off wavelength will reduce to half, as voltage is doubled.

Intensity will decrease, as filament current is decreased

Characteristic wavelength remains the same as it depends only on target metal.

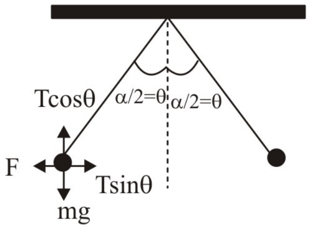
11.(BC) Electrostatic force in vaccum

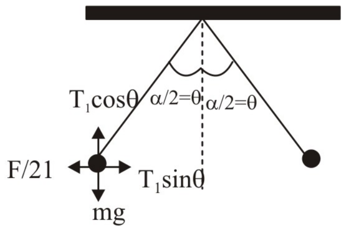
$$F = \left(\frac{1}{4\pi\varepsilon_0}\right)\frac{q^2}{r^2}$$

In dielectric liquid of dielectric constant K,

$$F = \left(\frac{1}{4\pi\varepsilon_0 K}\right)\frac{q^2}{r^2}$$

Electric force between the sphere decreases.





$T\cos\theta = mg$

$T\sin\theta = F$

$\tan\theta = \dfrac{F}{mg}$ …..(i)

$T_1\sin\theta = \dfrac{F}{21}$

$T_1\cos\theta + Buoyant\ \ force = mg$

$T_1\cos\theta = mg - B.F$

$\tan\theta = \dfrac{F}{21(\rho_s - \rho_L)vg}$ ……….(ii)

From (i) and (ii)

$$\frac{F}{mg} = \frac{F}{21(\rho_S - \rho_L)vg}$$

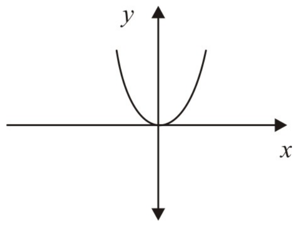
$$\rho_s vg = 21(\rho_s - 800)vg$$

$$\rho_s = 840$$

12.(ABCD) Given at $t = 0$

$u = 1m/s$

Equation of trajectory $\Rightarrow y = \dfrac{x^2}{2}$



$y = \dfrac{x^2}{2}$ ………(i)

$$\frac{dy}{dt} = \frac{2x}{2}\left(\frac{dx}{dt}\right)$$

$v_y = xv_x$

At $x = 0, t = 0$, $v_y = 0$

$v_x = 1m/s$ particles velocity points in x-direction

On double differentiation of equation (i)

$$\frac{dv_y}{dt}=x\frac{dv_x}{dt}+v_x\frac{dx}{dt}$$

$$a_y=xa_x+v_x^2$$

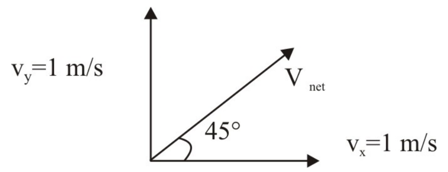
If $a_x=1m/s^2$ and particle is at origin

At $x=0, a_y=v_x^2=1m/s^2$

If $a_x=0, a_y$ will always be equal to $v_x^2\ \left(=1m/s^2\right)$

At $t=1s$, *with* $a_x=0$

$$v_x=1m/s,\ v_y=v_y+a_yt=0+1\times1=1m/s$$



Velocity will make 45° with x axis.

13.(1.05) $P_1=P_0, V_1=\frac{4}{3}\pi R^3,\ V_2=\frac{4}{3}\pi(R-a)^3$

$$P_1V_1^{\gamma}=P_2V_2^{\gamma}\Rightarrow P_2=P_1\left(\frac{V_1}{V_2}\right)^{\gamma}$$

$$P_2=P_0\left[\frac{R^3}{(R-a)^3}\right]^{\frac{41}{30}}=P_0\left(\frac{R}{R-a}\right)^{41/10}$$

$$W=\frac{P_1V_1-P_2V_2}{\gamma-1}=\frac{P_0\frac{4}{3}\pi R^3-P_0\left(\frac{R}{R-a}\right)^{41/10}\frac{4}{3}\pi(R-a)^3}{\left(\frac{41}{30}-1\right)}$$

$$=\frac{P_0\frac{4}{3}\pi R^3\left(1-\left(\frac{R}{R-a}\right)^{41/10}\frac{(R-a)^3}{R^3}\right)}{11/30}$$

$$=\frac{30}{11}P_0\frac{4}{3}\pi R^3\left(1-\left(\frac{R-a}{R}\right)^{3-41/10}\right)$$

$$=\frac{30}{11}P_0\frac{4}{3}\pi R^3\left[1-\left(\frac{R-a}{R}\right)^{-11/10}\right]=\frac{30}{11}P_0\frac{4}{3}\pi R^3\left(1-\left(1-\frac{a}{R}\right)^{-11/10}\right)$$

$$=\frac{30}{11}P_0\frac{4}{3}\pi R^3\left[1-\left(1+\frac{11}{10}\frac{Q}{R}+\frac{1}{2}\frac{11}{10}\left(\frac{11}{10}+1\right)\frac{a^2}{R^2}\right)\right]$$

$$= \frac{40}{11} P_0 \pi R^3 \left(-\frac{11}{10} \frac{a}{R} \right) \left[1 + \frac{1}{2} \times \frac{21}{10} \frac{a}{R} \right] = -P_0 4\pi R^2 a \left[1 + \frac{21}{20} \frac{a}{R} \right]$$

$$\omega_{liquid} = P_0 4\pi R^2 a$$

$$\omega_{gas} + \omega_{liq} = -P_0 4\pi R^2 a \left(1 + \frac{21}{20} \frac{a}{R} \right) + P_0 4\pi R^2 a$$

$$= -P_0 4\pi R^2 a \left(\frac{21}{20} \frac{a}{R} \right) = -4\pi P_0 R a^2 \left(\frac{21}{20} \right)$$

So, total work done in the process $= 4\pi P_0 R a^2 \left(\frac{21}{20} \right)$

$$\therefore x = \frac{21}{20} = 1.05$$

14.(0.27) $R_3' = 300 + 300(0.0004)(100) = 312\Omega$

The voltmeter is ideal, so no current flows through it

$$v_p - v_s = \frac{50}{312 + 60} \times 60 = \frac{500}{62} \quad \text{.........(i)}$$

$$v_p - v_T = \frac{50}{500 + 100} \times 100 = \frac{500}{60} \quad \text{............(ii)}$$

(ii) – (i) given

$$v_S - v_T = 500 \left(\frac{1}{60} - \frac{1}{62} \right) = 500 \times \frac{2}{60 \times 62} = \frac{25}{93} = 0.2688$$

15.(1.30) $U = \frac{1}{2} C V^2$

$$\frac{\Delta U}{U} = \frac{\Delta C}{C} + \frac{2\Delta V}{V}$$

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

$$\frac{1}{C} = \frac{1}{2000} + \frac{1}{3000} \Rightarrow C = 1200\,pF$$

$$\frac{\Delta C}{C^2} = \frac{\Delta C_1}{C_1^2} + \frac{\Delta C_2}{C_2^2}$$

$$\frac{\Delta C}{C^2} = \left[\frac{10}{(2000)^2} + \frac{15}{(3000)^2} \right] 1200 = \left(\frac{10}{4} \times 10^{-6} + \frac{5}{3} \times 10^{-6} \right) 1200$$

$$= \frac{50}{12} \times 10^{-6} \times 1200 = 5 \times 10^{-3}$$

$$\frac{\Delta V}{V} = \frac{0.02}{5.00} = 4 \times 10^{-3}$$

$$\frac{\Delta U}{U}=5\times10^{-3}+2\left(4\times10^{-3}\right)=13\times10^{-3}$$

Percentage error $=\frac{\Delta U}{U}\times100=1.3$

16.(0.24) $v=a^3\Rightarrow\frac{\Delta V}{V}=\frac{3\Delta a}{a}$

$$B=\frac{\Delta P}{\left(-\frac{\Delta V}{V}\right)}\Rightarrow-\frac{\Delta V}{V}=\frac{\Delta P}{B}$$

$$-\frac{\Delta a}{a}=\frac{1}{3}\frac{\Delta P}{B}$$

$$-\Delta a=\frac{\rho gh}{3B}a=\frac{1000\times10\times5000}{3\left(70\times10^9\right)}(1)=\frac{5}{21}\times10^{-3}m=\frac{5}{21}mm$$

17.(55) Flux through coil 1

$\phi_1=L_1I_1+MI_2$

(Due to opposite direction of current in coil 1 and 2, flux is additive)\

$$\varepsilon_1=L_1\frac{dI_1}{dt}+M\frac{dI_2}{dt}$$

$P_1=I_1\varepsilon_1$

Flux through coil 2

$\phi_2=L_2I_2+MI_1$

$$\varepsilon_2=L_2\frac{dI_2}{dt}+M\frac{dI_1}{dt}$$

$P_2=I_2\varepsilon_2$

Work done by cell against induced emf in inductors

$$=\int\left(P_1dt+P_2dt\right)=\int L_1I_1dI_1+MI_1dI_2+L_2I_2dI_2+MI_1dI_2$$

$$=L_1\int I_1dI_1+L_2\int I_2dI_2+M\int d\left(I_1I_2\right)=\frac{1}{2}L_1I_{1s}^2+\frac{1}{2}L_2I_{2s}^2+MI_{1s}I_{2s}$$

Where $I_{1s}\ and\ I_{2s}$ are steady state currents

$$I_{1s}=\frac{V_1}{R_1}=\frac{5}{5}=1A;\ I_{2s}=\frac{V_2}{R_2}=\frac{20}{10}=2A$$

$$work=\frac{1}{2}\times10\times\left(1^2\right)+\frac{1}{2}\times20\left(2^2\right)+5(1)(2)=55\,mJ$$

18.(8.33) $-\frac{dT}{dt}=k\Delta T;$ given $K=0.001\ s^{-1}$

Rate of heat loss

$$\frac{-dq}{dt} = ms\left(-\frac{dT}{dt}\right) = msk\Delta T$$

At steady state,

$$P_{loss} = P_{gained}$$

$$msk\Delta T = IA$$

$$\Delta T = \frac{IA}{msk} = \frac{700(0.05)}{1(4200)(0.001)} = \frac{35}{4.2} = 8.33$$