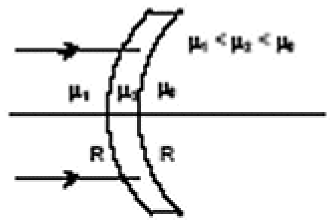
Physics

1. If n^{th} division of main scale coincides with $(n+1)^{th}$ divisions of vernier scale. Given one main scale division is equal to 'a' units. Find the least count of the vernier.

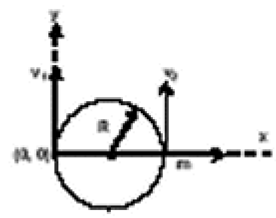
2. Find the focal length of the lens shown in the figure. The radii of curvature of both the surfaces are equal to R.



3. Frequency of a photon emitted due to transition of electron of a certain element from L to K shell is found to be 4.2×10^{18} Hz. Using Moseley's law, find the atomic number of the element, given that the Rydberg's constant $R = 1.1 \times 10^{7}\ m^{-1}$.

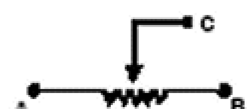
4. An insulated container containing mono atomic gas of molar mass m is moving with a velocity v_0. If the container is suddenly stopped, find the change in temperature.

5. A particle of mass m, moving in a circular path of radius R with a constant speed v_2 is located at point (2R, 0) at time t = 0 and a man starts moving with a velocity v_1 along the +ve y-axis from origin at time t = 0. Calculate the linear momentum of the particle w.r.t. the man as a function of time.

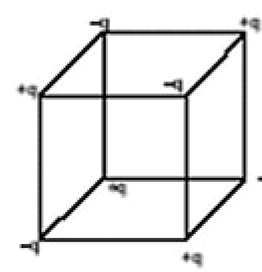


6. A tuning fork of frequency 480 Hz resonates with a tube closed at one end of length 16 cm and diameter 5 cm in fundamental mode. Calculate velocity of sound in air.

7. How a battery is to be connected so that the shown rheostat will behave like a potential divider? Also indicate the points about which output can be taken.



8. Charges +q and −q are located at the corners of a cube of side a as shown in the figure. Find the work done to separate the charges to infinite distance.



9. A radioactive sample emits n β-particles in 2 sec. In next 2 sec it emits 0.75 n β-particle, what is the mean life of the sample?

10. In a photoelectric experiment set up, photons of energy 5 eV falls on the cathode having work function 3 eV. (a) If the saturation current is $i_A = 4\mu A$ for intensity 10^{-5} W/m^2, then plot a graph between anode potential and current. (b) Also draw a graph for intensity of incident radiation $2 \times 10^{-5}\ W/m^2$.

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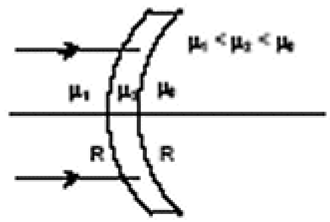

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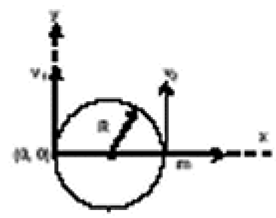

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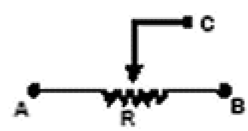

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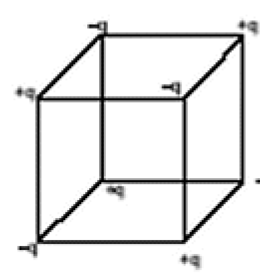

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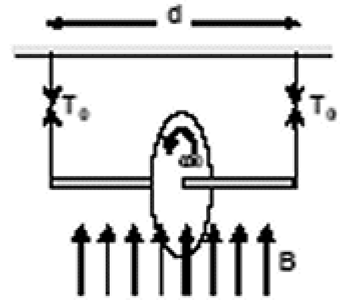
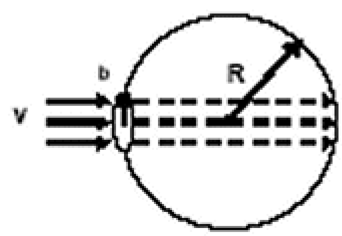
17. A wheel of radius R having charge Q, uniformly distributed on the rim of the wheel is free to rotate about a light horizontal rod. The rod is suspended by light inextensible strings and a magnetic field B is applied as shown in the figure. The initial tensions in the strings are T_0. If the breaking tension of the strings are $\frac{3T_0}{2}$, find the maximum angular velocity ω_0 with which the wheel can be rotated.

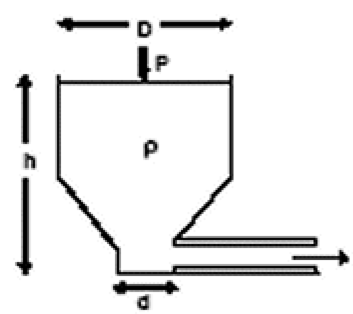


18. A string tied between x = 0 and x = ℓ vibrates in fundamental mode. The amplitude A, tension T and mass per unit length μ is given. Find the total energy of the string.

19. A bubble having surface tension T and radius R is formed on a ring of radius b (b << R). Air is blown inside the tube with velocity v as shown. The air molecule collides perpendicularly with the wall of the bubble and stops. Calculate the radius at which the bubble separates from the ring.



20. Shown in the figure is a container whose top and bottom diameters are D and d respectively. At the bottom of the container, there is a capillary tube of outer radius b and inner radius a. The volume flow rate in the capillary is Q. If the capillary is removed the liquid comes out with a velocity of v_0. The density of the liquid is given as ρ. Calculate the coefficient of viscosity η.



SOLUTIONS

1. (n + 1) division of vernier scale = n division of main scale

$\therefore$ one Vernier division = $\frac{n}{n+1}$ main scale division

Least count = 1 M.S.D. – 1 V.D. = $\frac{1}{n+1}$ M.S. D. = $\frac{a}{n+1}$

2.

For an object placed at infinity the image after first refraction will be formed at v_1

$$\frac{\mu_2}{v_1} - \frac{\mu_1}{-\infty} = \frac{\mu_2 - \mu_1}{+R} \quad \ldots \text{(i)}$$

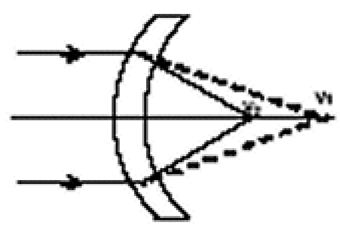
The image after second refraction will be found at v_2

$$\frac{\mu_3}{v_2} - \frac{\mu_2}{v_1} = \frac{\mu_3 - \mu_2}{+R} \quad \ldots \text{(ii)}$$

adding (i) and (ii)

$$\frac{\mu_3}{v_2} = \frac{\mu_3 - \mu_1}{R} \Rightarrow v_2 = \frac{\mu_3 R}{\mu_3 - \mu_1}$$

Therefore focal length will be $\frac{\mu_3 R}{\mu_3 - \mu_1}$



3. $(Z-1)^2 Rhc \left[\frac{1}{1} - \frac{1}{4}\right] = h\nu$

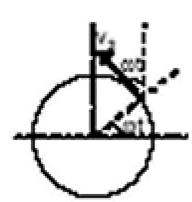
$(Z-1)^2 = \frac{\nu 4}{3RC} \qquad \Rightarrow Z = 42$

4. Loss in K.E. of the gas $\Delta E = \frac{1}{2}(nm)v_0^2$,
where n = number of moles.
If its temperature change by ΔT.

Then $n\frac{3}{2}R\Delta T = \frac{1}{2}(nm)v_0^2$

$\Rightarrow \Delta T = \frac{mv_0^2}{3R}$.

5.



$\omega = \frac{v_2}{R}$

$\overline{v}_2 = (-v_2 \sin\omega t\hat{i} + v_2 \cos\omega t\hat{j})$

$\overline{v}_1 = v_1\hat{j}$

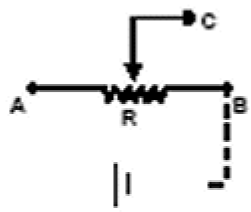
$\overline{v}_{BM} = \overline{v}_2 - \overline{v}_1 = -v_2 \sin\omega t\hat{i} + (v_2 \cos\omega t - v_1)\hat{j}$

6. $(\ell + 0.6r) = \frac{\lambda}{4} = \frac{v}{4f}$

$v = 4f(\ell + 0.6\,r) = 336$ m/s.

7.

Battery should be connected across A and B. Out put can be taken across the terminals A and C or B and C.

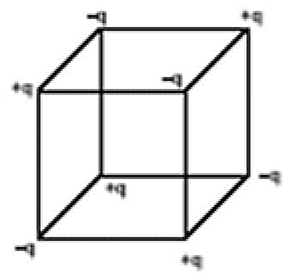


8.

$W_{external} = \Delta PE =$

$$\frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}\left[-\frac{3}{1}+\frac{3}{\sqrt{2}}-\frac{1}{\sqrt{3}}\right]\times\frac{8}{2}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q^2}{a}\cdot\frac{4}{\sqrt{6}}[3\sqrt{3}-3\sqrt{6}-\sqrt{2}]$$



9.

Let N be the number of active nuclei at time t = 0.

Hence $n = N_0(1 - e^{-2\lambda})$

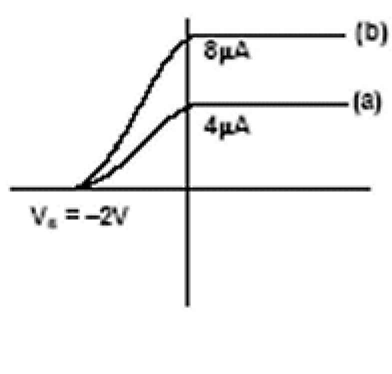
$1.75\,n = N_0(1 - e^{-4\lambda})$

$\Rightarrow \frac{1}{1.75} = \frac{1-e^{-2\lambda}}{1-e^{-4\lambda}}$

$\Rightarrow e^{-4\lambda} - 1.75\,e^{-2\lambda} + 0.75 = 0$

$\Rightarrow \frac{1}{\lambda} = \frac{2}{\ln(4/3)}$ sec.

10.



11. (a) $\frac{dQ}{dt} = \sigma s A[(T_\ell)^4 - (T_a)^4]$.

Rate of heat loss per unit area = 595 watt / m^2.

(b) Let T_0 be the temperature of the hot oil

$\Rightarrow \frac{KA(T_0 - T_\ell)}{t} = 595\,A$

$\Rightarrow T_0 \approx 420$ K

$x_{cm} = \frac{m_1x_1 + m_2x_2}{m_1 + m_2} = v_0t$

$\Rightarrow x_2 = v_0t + \frac{m_1}{m_2}A(1-\cos\omega t)$

(b) $a_1 = \frac{d^2x_1}{dt^2} = -A\omega^2\cos\omega t$

The separation $(x_2 - x_1)$ between the two blocks will be equal to ℓ_0 when the acceleration will be equal to zero.

$x_2 - x_1 = \frac{m_1}{m_2}A(1-\cos\omega t) + A(1-\cos\omega t)$

for $a_1 = 0$

$x_2 - x_1 = \ell_0 = \left(\frac{m_1}{m_2}+1\right)A$

Alternate (b)

In center of mass reference frame, maximum separation of the blocks = $2\ell_0$ (using conservation of energy). If x_1 and x_2 be the separation of the blocks from center of mass at the moment of maximum separation

$x_1 + x_2 = 2\ell_0$ and $m_1x_1 = m_2x_2$

$\Rightarrow x_1 = 2\ell_0 \Big/ \left(1+\frac{m_1}{m_2}\right)$ but $x_1 = 2A$

$\Rightarrow \ell_0 = A\left(1+\frac{m_1}{m_2}\right)$

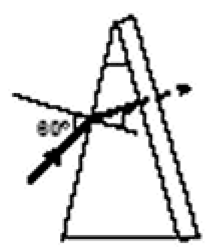
13.

(a) $\mu_{air}\sin 60° = \mu_p \sin r$

$\Rightarrow \frac{\sqrt{3}}{2} = \sqrt{3}\sin r$

$\Rightarrow r = 30°$

The refracted ray inside the prism hits the other face at 90°; hence deviation produced by this face is zero and hence angle of emergence is zero.



(b) Multiple reflection occurs between the surfaces of the film

for minimum thickness

$\Delta x = 2\mu t = \lambda$, where t = thickness

$\Rightarrow t = \frac{\lambda}{2\mu} = 125$ nm

14. For escape velocity from the surface of moon

$\Rightarrow v_e = \sqrt{\frac{2GM}{R}}$ where M is the mass of the moon.

P.E. inside the crater of moon will be $= -\frac{GMm}{R} + \int_R^{99R/100} \frac{GMmx}{R^3}dx$

199 GMm

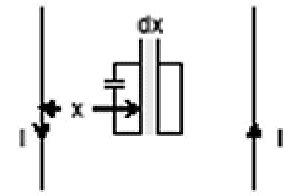
$$-\frac{199\,GMm}{20000R} + \frac{1}{2}mv_e^2 = -\frac{GMm}{R+h} + 0$$

$\Rightarrow h \approx 100R$

15.

(a) Flux through the square loop

$$= \int_a^{2a} \frac{\mu_0}{4\pi} 2I\left[\frac{1}{x} + \frac{1}{3a-x}\right] a\,dx = \frac{\mu_0}{4\pi} Ia4\ln 2$$



Induced emf $e = -\frac{d\phi}{dt} = -\frac{\mu_0}{\pi} aI_0\omega \ln 2 \cos\omega t$

Charge on the capacitor

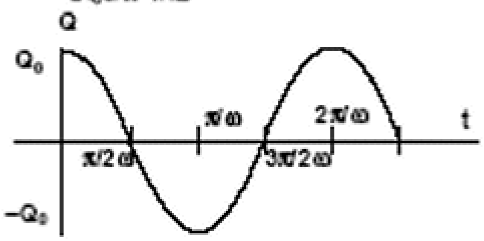
$$Q = Ce = -C\frac{\mu_0}{\pi} aI_0\omega \ln 2 \cos\omega t = -Q_0\cos\omega t \text{ (say)}$$

Current in the loop $= \frac{dQ}{dt}$

$$= \frac{\mu_0}{\pi} CI_0\omega^2 a \ln 2 \sin\omega t$$

$$I_{max} = \frac{\mu_0}{\pi} CI_0 a\omega^2 \ln 2$$

(b)



16. (a) $K.E._{final} = -\Delta P.E. = \vec{P}.\vec{E} = \frac{P}{4\pi\varepsilon_0}\frac{Q^2}{d^2}$

(b) $F = Q\vec{E}$

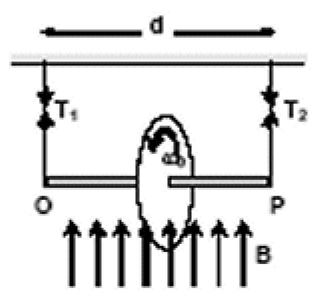
$$= \frac{QP}{2\pi\varepsilon_0 d^3} \text{ along positive x-axis.}$$

17.

$2T_0 = mg$ . . . (1)

For moment of forces about P

$$q\frac{\omega_{max}}{2\pi} \times \pi R^2 \times B + mg\frac{d}{2} = \left(\frac{3T_0}{2}\right)d$$



$$\Rightarrow \omega_{max} = \frac{T_0 d}{qBR^2}$$

18.

where $k = \pi/\ell$ and $\omega = \frac{\pi}{\ell}\sqrt{\frac{T}{\mu}}$

$\frac{dy}{dt} = -A\omega \sin kx \sin \omega t \Rightarrow v_{max}(x) = A\omega \sin kx$

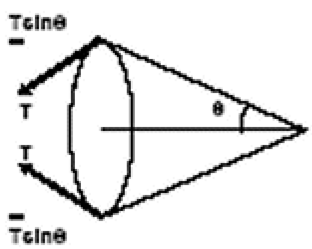
$E = \int_0^{\ell} \frac{1}{2}\mu dx A^2\omega^2 \sin^2 kx = \frac{A^2\pi^2 T}{4\ell}$.

19.

$2\pi b \times 2T\sin\theta = \rho A v^2$

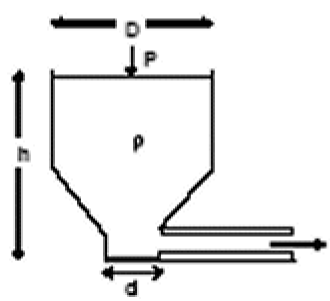
$\Rightarrow 4\pi b T \times \frac{b}{R} = \rho\pi b^2 v^2$

$\Rightarrow R = \frac{4T}{\rho v^2}$



20. When the tube is not there.

$P + h\rho g + \frac{1}{2}\rho v_1^2 = \frac{1}{2}\rho v_0^2$



$\frac{\pi D^2}{4} v_1 = \frac{\pi b^2}{4} v_0$

By Poiseuille's equation the rate of flow of liquid in the capillary tube

$Q = \frac{\pi \Delta P a^4}{8\eta\ell}$

where $\Delta P = P + \rho g h = \frac{1}{2}\rho v_0^2 \left[1 - \frac{b^2}{D^2}\right]$

$Q = \frac{1}{2}\rho v_0^2 \left[1 - \frac{b^2}{D^2}\right] \frac{\pi a^4}{8\eta\ell}$

$\eta = \frac{\pi a^4 \rho v_0^2}{16 Q\ell}\left[1 - \frac{b^2}{D^2}\right]$