IIT-JEE-2003

PHYSICS

Mains

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1. N -divisions on the main scale of a vernier calipers coincide with $N+1$ divisions on the vernier scale. If each division on the main scale is of a units, determine the least count of the instrument.

2. Characteristic x-rays of frequency $4.2\times10^{18}\,\text{Hz}$ are produced when transitions from L shell to K shell take place in a certain target material. Use Mosley's law to determine the atomic number of the target material. Given Rydberg constant

$R=1.1\times10^{7}\,\text{m}^{-1}$.

3. In a resonance tube experiment to determine the speed of sound in air, a pipe of diameter $5\,\text{cm}$ is used. The air column in pipe resonates with a tuning fork of frequency $480\,\text{Hz}$ when the minimum length of the air column is $16\,\text{cm}$. Find the speed of sound in air at room temperature.

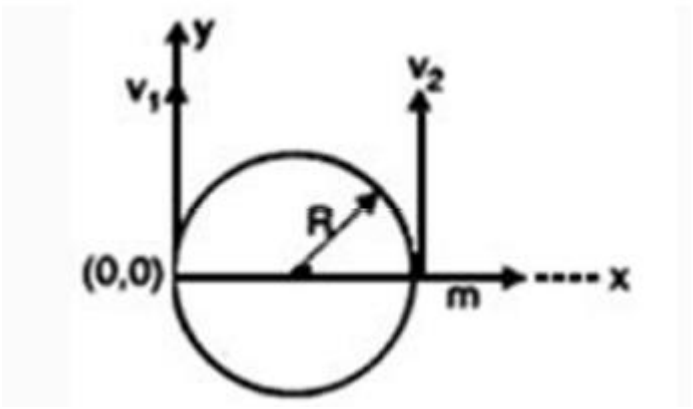
4. An insulated box containing a monoatomic gas of molar mass M moving with a speed v_0 is suddenly stopped. Find the increment in gas temperature as a result of stopping the box.

5. A soap bubble is being blown at the end of a very narrow tube of radius b. Air (density r) moves with a velocity v inside the tube and comes to rest inside the bubble. The surface tension of the soap solution is T. After some time the bubble, having grown to a radius r, separates from the tube. Find the value of r. Assume that $r >> b$ so that you can consider the air to be falling normally on the bubble's surface.

6. Show by diagram, how can we use a rheostat as the potential divider.

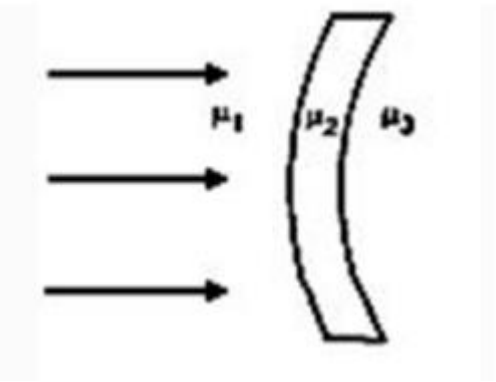
7. A radioactive element decays by b emission. A detector records n beta particles in 2 beta particles in 2 seconds it records $0.75n$ beta particles. Find mean life correct to nearest whole number. Given In $\frac{1}{2}2\frac{1}{2} = 0.6931$, In $\frac{1}{2}3\frac{1}{2} = 1.0986$.

8. 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 positive 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.

9. In the figure, light is incident on the thin lens as shown. The radius of curvature



for both the surface is R. Determine the focal length of this system.

10. In a photoelectric experiment setup, photons of energy $5\ \text{eV}$ falls on the cathode having work function $3\ \text{eV}$. (a) If the saturation current is $i_A = 4\text{mA}$ for intensity $10^{-5}\ \text{W/m}^2$, then plot a graph between anode potential and current. (b) Also draw a graph for intensity of incident radiation $2\times10^{-5}\ \text{W/m}^2$.

11. Eight point charges are placed at the corners of a cube of edge a as shown in

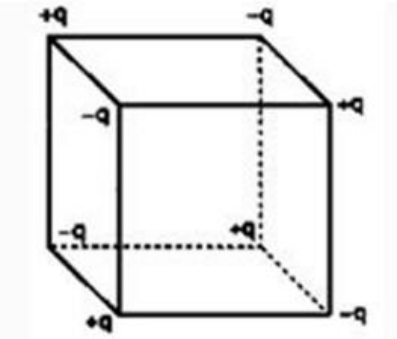


figure. Find the work done in disassembling this system of charges.

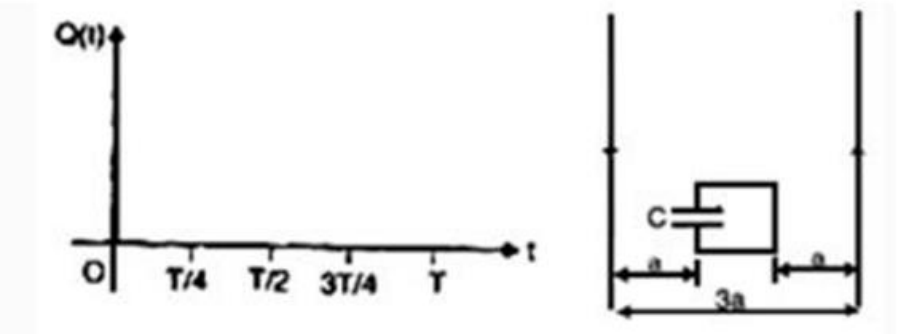
12. There is a crater of depth $R/100$ on the surface of the moon (radius R). A projectile is fired vertically upward from the crater with a velocity, which is equal to the escape velocity v from the surface of the moon. Find the maximum height attained by the projectile.

13. A positive point charge q is fixed at origin. A dipole with a dipole moment vector p is placed along the x-axis far away from the origin with vector p pointing along positive x-axis. Find :

(a) the kinetic energy of the dipole when it reaches a distance d from the origin, and

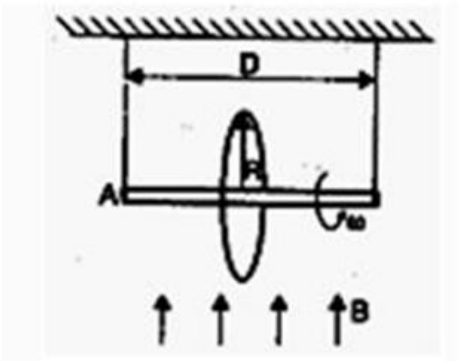
(b) the force experienced by the charge q at this moment.

14. Two infinitely long parallel wires carrying currents $I = I_0 \sin \omega t$ in opposite directions are placed a distance $3a$ apart. A square loop of side a of negligible resistance with a capacitor of capacitance C is placed in the plane of wires as



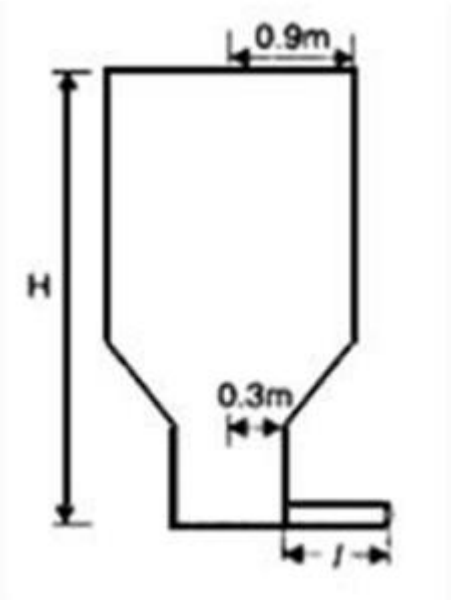
shown. Find the maximum current in the square loop. Also sketch the grap showing the variation of charge on the upper plate of the capacitor as a function loop as positive.

15. A ring of radius R having uniformly distributed charge Q is mounted on a rod suspended by two identical strings. The tension in strings in equilibrium is T_0.



Now a vertical magnetic field is switched on and ring is rotated at constant angular velocity w. Find the maximum w with which the ring can be rotated if the strings can withstand a maximum tension of $3T_0/2$.

16. A liquid of density $900\,\text{kg/m}^3$ is filled in a cylindrical tank of upper radius $0.9\,\text{m}$ lower radius $0.3\,\text{m}$. A capillary tube of length / is attached at the bottom of the tank as shown in the figure. The capillary has outer radius $0.002\,\text{m}$ and inner

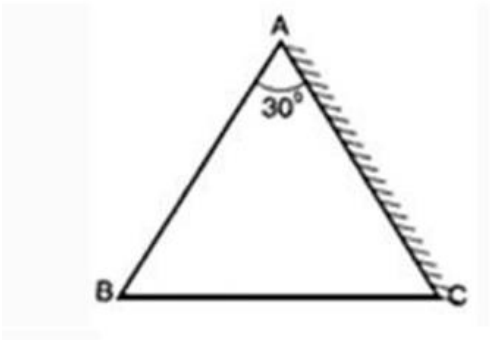


radius a. When pressure P is applied at the top of the tank volume flow rate of the liquid is $8\times10^{-6}\,\mathrm{m^3/s}$ and if capillary tube is detached, the liquid comes out from the tank with a velocity $10\,\mathrm{m/s}$. Determine the coefficient of viscosity of the liquid.

$\left[\text{Given}: pa^2 = 10^{-6}\,\mathrm{m^3}\ \text{and}\ a^2/I = 2\times10^{-6}\,\mathrm{m}\right]$

17. A string of mass per unit length m is clamped at both ends such that one end of the string is at $x=0$ and the other is at $x=I$. When string vibrates in fundamental mode amplitude of the mid point of the string is a, and tension in the string is T. Find the total oscillation energy stored in the string.

18. A prism of refracting angle $30°$ is coated with thin film of transparent material of refractive index 2.2 on face AC of the prism. A light of wavelength $6600\,A$ is incident of face AB such that angle of incidence is $60°$, find



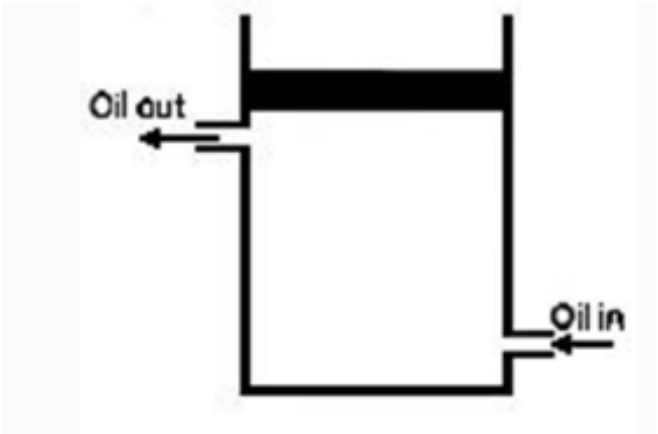
(a) the angle of emergence, and

(b) the minimum value of thickness of the coated film on the face AC for which the light emerging from the face has maximum intensity.

19. Two point masses m_1 and m_2 are connected by a spring of natural length I_0. The spring is compressed such that the two point masses touch each other and then they are fastened by a string. Then the system is moved with a velocity v_0 along positive x-axis. When the system reaches the origin the string breaks $(t=0)$. Then position of the point mass m_1 is given by $x_1 = v_0 t - A(1-\cos wt)$ where A and w are constants.

Find the position of the second block as a function of time. Also find the relation between A and I_0.

20. The top of an insulated cylindrical container is covered by a disc having emissivity 0.6 and conductivity $0.167\,W/Km$ and thickness $1cm$. The temperature is maintained by circulating oil as shown : (a) Find the radiation loss to the surroundings in J/m^2s if temperature of the upper surface of disc is $127°C$, and temperature of surroundings is $27°C$. (b) Also find the temperature of the circulating oil. Neglect the heat loss due to convection.



$\left[\text{Given } \sigma = 17/3\times10^{-8}\,Wm^{-2}K^{-4}\right]$