JNU-ENTRANCE EXAMINATION- 2004

M.Sc. PHYSICS

Maximum Marks: 100

PART-A

NOTE: Answer **all** questions. Each question carries 10 marks.

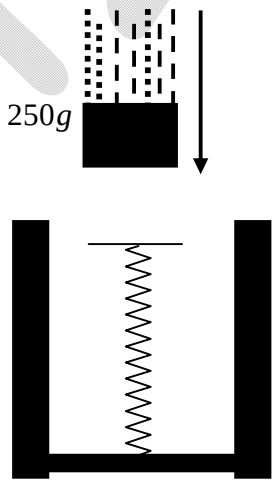
Q1. An inductor L and a capacitor C (which is initially charged) are connected in series to a supply of constant voltage V. The charge on the capacitor at time 't' is denoted as $q(t)$.

(a) Write down differential equation obeyed by $q(t)$.

(b) Solve this differential equation with the initial conditions.

$$q(0) = q_0, \left.\frac{dq}{dt}\right|_{t=0} = i_0$$

Q2. A 250 g block is dropped onto a relaxed vertical spring that has a spring constant of k = 2.5 N/cm (see figure). The block becomes attached to the spring and, compresses the spring 12 cm before momentarily stopping. While the spring is being compressed, what work is done on the block by (a) the gravitational force on it and (b) the spring force? What is the speed of the block just before it hits the spring? Assume that friction is negligible.



Q3. The atomic number Z of gold (Au) is 79 and the radius R of the Au nucleus is approximately 6.2×10^{-15} m. Assume the charge distribution inside the nucleus to be uniform.

(a) Using Gauss' law, derive general expressions for the electric field inside and outside the Au nucleus.

(b) Use the above values of Z and R to calculate the electric field at the surface of the nucleus.

(c) Sketch the variation of the electric field from the centre of the nucleus up to a distance thrice its radius.

Q4. Compute the temperature at which the root-mean-square speed is equal to the speed of escape from the earth for

(a) molecular hydrogen and (b) molecular oxygen.

The temperature high in the upper atmosphere of the earth is about 1000 K. Would you expect to find much hydrogen there? Much oxygen? Explain.

Q5. (a) Calculate approximately the probability that, at room temperature (300K), an electron at the top of the highest filled band in diamond (an insulator) will jump to the next higher vacant level at an energy gap E_g of 5.5 eV.

(b) How does the conductivity vary with temperature in a metal and in a semiconductor? Explain in brief.

PART-B

NOTE: Answer **all** questions. Each question carries 5 marks.

Q1. A sphere of radius R is centred at the origin of the coordinate system (x, y, z). A plane at $z = a$ ($a < R$) cuts off the cap from the sphere. Obtain the volume of the cap.

Q2. An electron of energy of about 200 eV is passed through a circular hole of radius 10^{-4} cm. Estimate the uncertainty introduced in its angle of emergence.

Q3. A particle moves in the xy-plane under a force field given by

$$\vec{F} = \left(2x + 4x^3y^3\right)\hat{i} + 3x^4y^2\,\hat{j}$$

Calculate the total work done to move the particle along straight lines from (0, 2) to (0, 0) and then from (0, 0) to (3, 0). Is the result different for the direct path from (0, 2) to (3, 0)?

Q4. A plane electromagnetic wave of intensity (flux) 6 W/m^2 strikes a small mirror having an area of 40 cm^2, held perpendicular to the approaching wave. What is the momentum the wave transfers to the mirror in one second?

Q5. Consider two materials separated by an infinite plane. The materials on the left and right sides of the plane have dielectric constants 1 and k, respectively. There is a uniform electric field $\vec{E}$ on the left, making an angle θ with the normal to the plane. Using appropriate boundary conditions, determine the field on the right side of the plane.

Q6. Using Maxwell's equations, determine the volume charge density ρ and the current density $\vec{J}$ corresponding to the electric and magnetic fields given by

$$\vec{E}(\vec{r},t) = -\frac{1}{4\pi\varepsilon_0}\frac{qe^{-\alpha t}}{r^3}\vec{r}, \qquad \vec{B}(\vec{r},t) = 0$$

where ε_0 is the permittivity of vacuum, q is a point charge, and α is a constant.

Q7. A piece of metal (specific heat of 3.9 cal/gm), weighing 1 kg and initially at 200ºC, is dropped into a reservoir of water at 20ºC. After equilibrium is established, what is the change in entropy of the metal? Also estimate the change in entropy of the water reservoir.

Q8. A double-slit arrangement, with a slit separation of 0.12 mm and a slit-to-screen separation of 55 cm, produces interference fringes for light of wavelength 546 nm. What is the distance on the screen between adjacent maxima near the centre of the interference pattern?

Q9. Take a 'thermal' neutron, i.e. which is in thermal equilibrium, at a temperature of 27ºC. What is its mean speed?

Q10. A black box with two terminals contains unknown sources of voltages and resistances connected in an unknown way. If a 10Ω resistance is connected across the terminals, a current of 1Å flows through it, and an 18Ω resistance is found to draw 0.6 A. What value of resistance will draw 0.1 A?