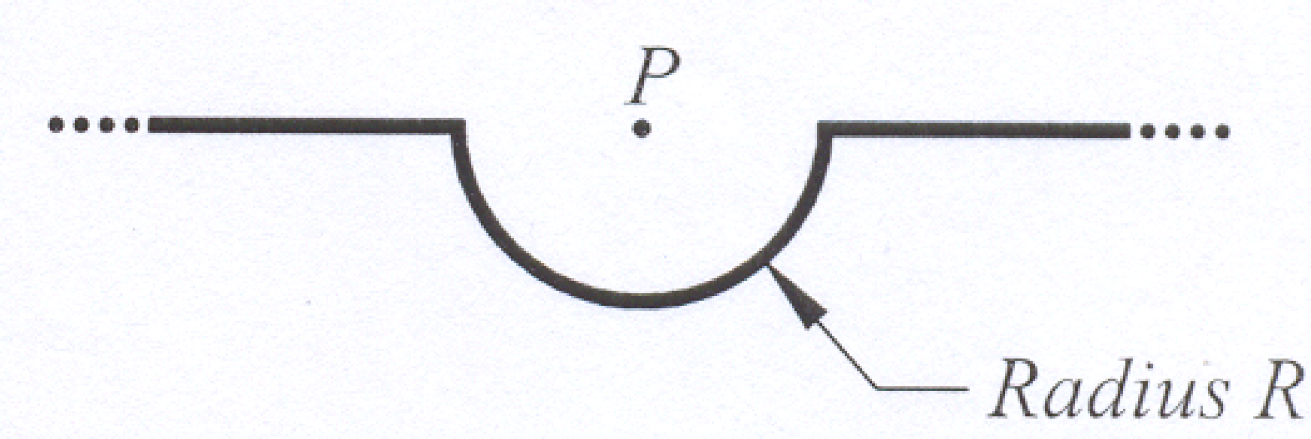
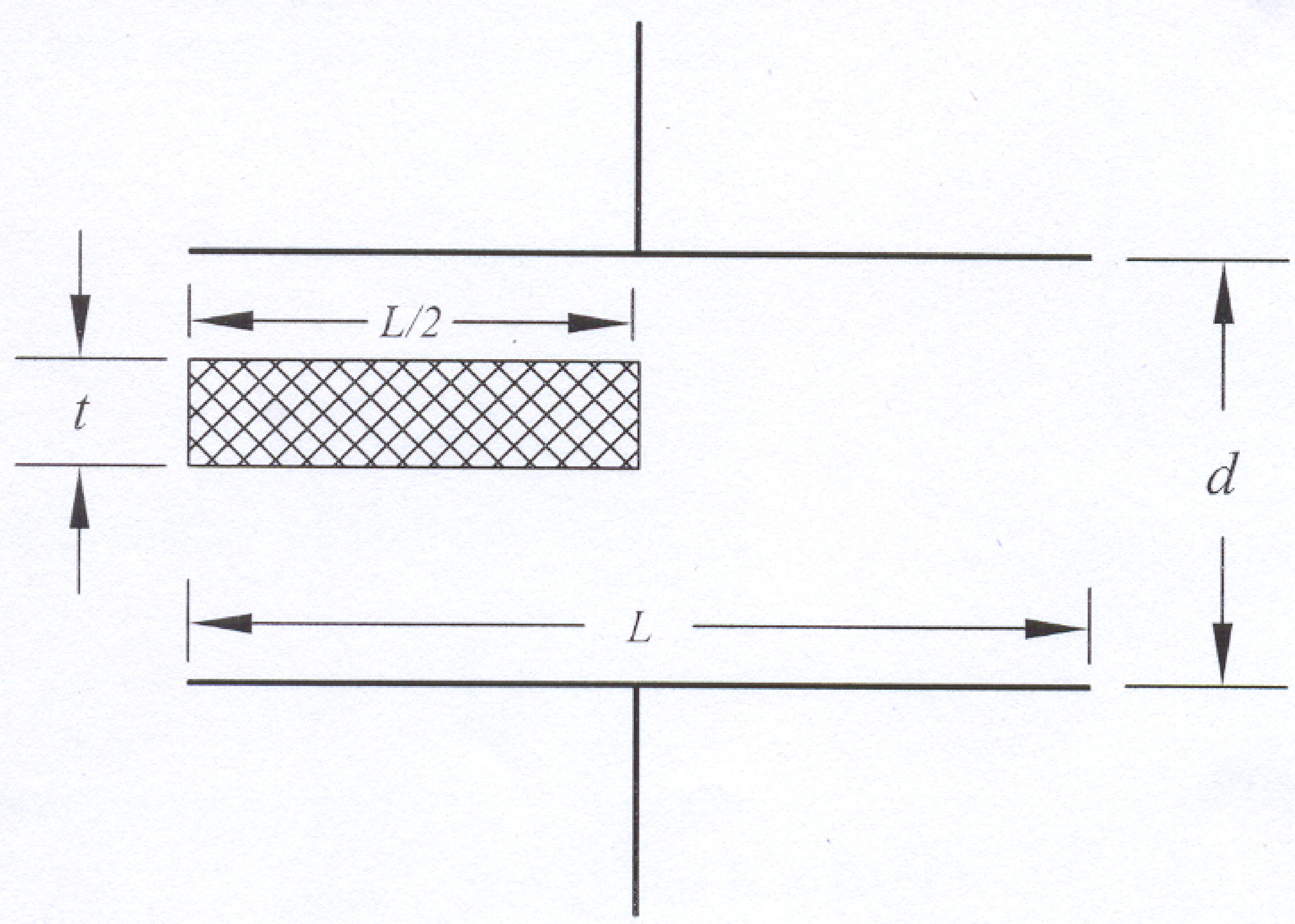
End-Semester Examination

Physics III, B.Math (II Year), 2002-03

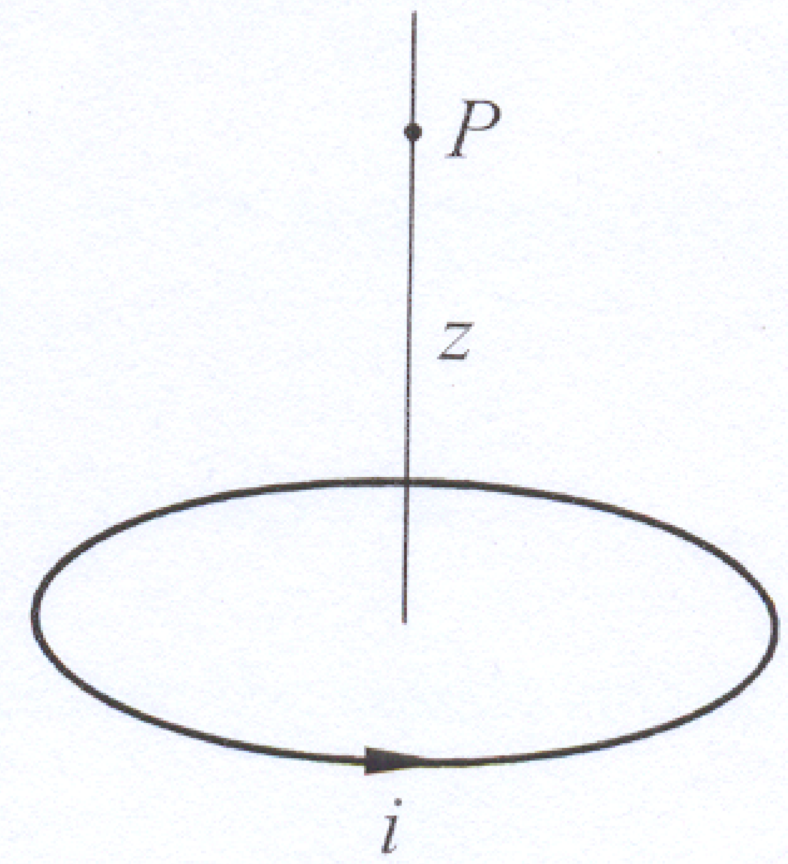
1. An infinite line of charge has a semi-circular kink of radius R as shown. The straight and semi-circular sections have uniform charge density λ per unit length. Find the electric field at the centre, P, of the semi-circle.



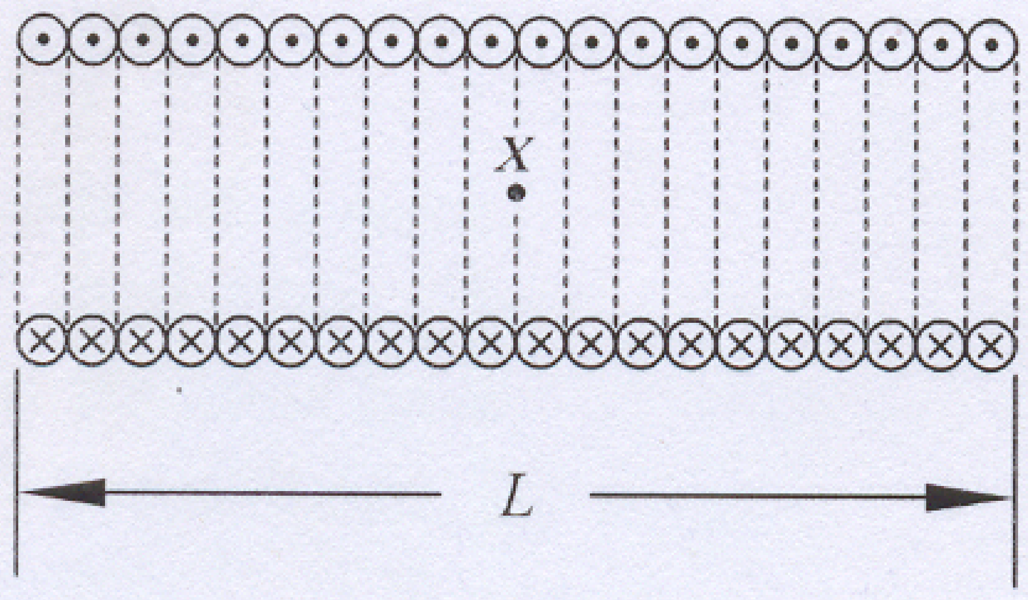
2. A parallel plate capacitor has square plates of side L and separation d. A rectangular dielectric slab with sides L and $L/2$, thickness t and dielectric constant κ is introduced between the plates as shown in the diagram. Find the capacitance of the arrangement. Check that your answer has the correct limits as $t \to 0$ and $t \to d$.



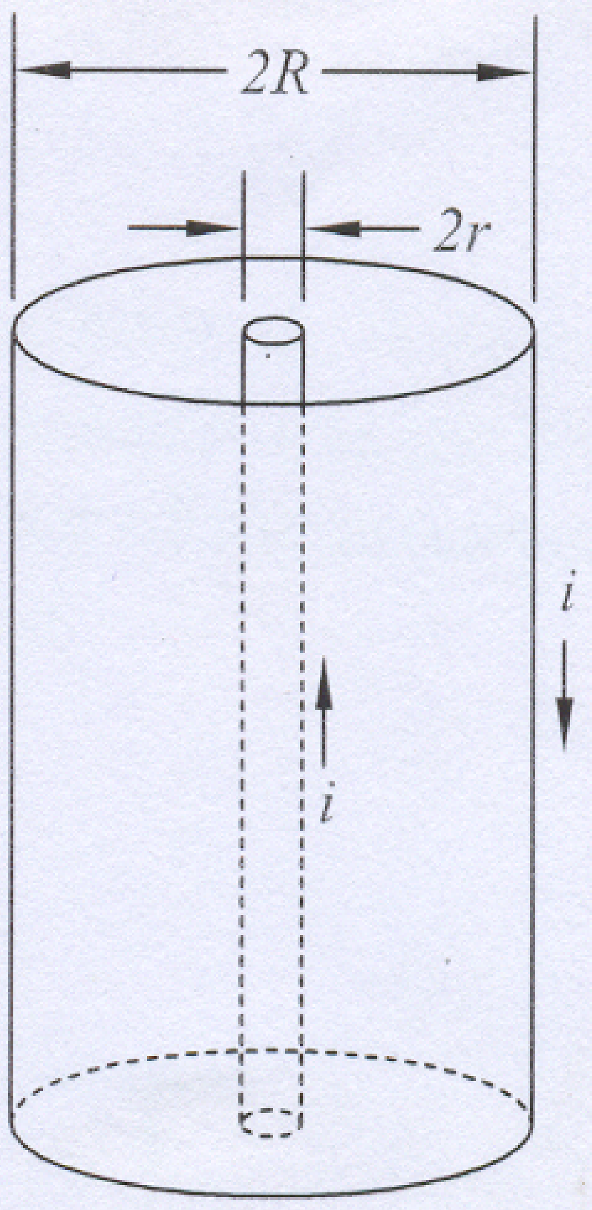
3. Consider a circular current carrying loop of radius r carrying a current i. Find the magnetic field at a point P on the axis at a distance z from the centre of the loop.



Use the above result to find the magnetic field at the centre, X, of a long solenoid of radius r, length L and n turns per unit length carrying a current i. Assume that n is very large and $L >> r$.



4. A long coaxial cable consists of a centre conductor of radius r and an outer concentric conductor of radius R. The inner and outer conductors carry currents of magnitude i in opposite directions. Show that the energy contained in the magnetic field per unit length of the coaxial cable diverges as $r \to 0$.



5. Show that in the presence of charges

$$\mathbf{J}.\mathbf{E} + \nabla.\mathbf{S} + \partial u/\partial t = 0$$

where **J** is the current density and

$$\mathbf{S} = (1/\mu_0)\, \mathbf{E} \times \mathbf{B}$$
$$u = (\varepsilon_0/2)\, \mathbf{E}.\mathbf{E} + (1/2\mu_0)\, \mathbf{B}.\mathbf{B}$$

Compare this with the continuity equation in free space and interpret the additional term in the equation in terms of the work done by the electromagnetic fields on the charges.

6. Consider the circuit shown in the accompanying diagram with `loop equation'

$$V - iR - (q/C) - L\,(di/dt) = 0$$

Show that this equation describes the conservation of energy.