PH1201 End Semester Examination

Full marks : 40 Time : 2 hrs 30 minutes

Name : DEEPTO DEBNATH Roll No. : 24MS091

Attempt any four questions

The final score will be scaled to 50

Q 1) A total charge Q is distributed over a sphere of radius R. The charge density is spherically symmetric and falls off with distance from the center of the sphere r according to the formula $\rho(r) = \rho_0\left(1 - \frac{r}{R}\right)$. An equal but opposite charge $-Q$ is uniformly distributed in a concentric shell between radii R and $2R$.

(a) Determine the constant ρ_0 in terms of Q and R.

(b) Find the electric field everywhere using Gauss law.

(c) Determine the electrostatic potential as a function of r . [2 + 4 + 4]

Q 2) a)(i) Show that the electric field's normal component is discontinuous across a surface carrying a surface charge density σ. Determine the size of this discontinuity.

(ii) On the other hand, show that the tangential component of an electrostatic field is continuous.

b) Find the r dependence of a spherically symmetric static charge density, $\rho(r)$, such that the magnitude of the corresponding electric field is given by $E(r) = A\left(1 - \exp\left(-\frac{r}{a}\right)\right)$ where a and A are constants. [(3 + 2) + 5]

Q 3) a) A particle of mass m and charge q is initially at rest at the origin in a region with uniform electric and magnetic fields given by $\vec{E} = \alpha\hat{k}$ and $\vec{B} = \beta\hat{k}$ where α and β are constants. Determine the position and the velocity of the particle at time t.

b) A stream of particles, each with charge q and mass m , moving along the positive X axis are sent through a velocity selector where the electric and magnetic fields are $E_0\hat{k}$ and $-B_0\hat{j}$, respectively. The velocity selector is designed to block all particles that travel in any direction other than the X axis. The particles which pass through the velocity selector are then sent into a second region where they travel through a uniform electric field $E_1\hat{i}$ for a distance D. Finally the particles are sent through another region carrying a uniform magnetic field $B_1\hat{k}$. What is the radius of the path these charges travel in now? [4 + 6]

Q 4) a) In class we showed that the magnetic field is a pseudovector - while the electric field is a vector. In order to do this we had assumed - quite naturally, as we thought - that charge is a scalar. However, it turns out that we can just as well assume that charge is a pseudoscalar - so that under parity it obeys $q \mapsto -q$. Show that under this assumption, the electric and magnetic fields must be pseudovector and vector, respectively.

b) Show that even under this assumptions of part (a) above

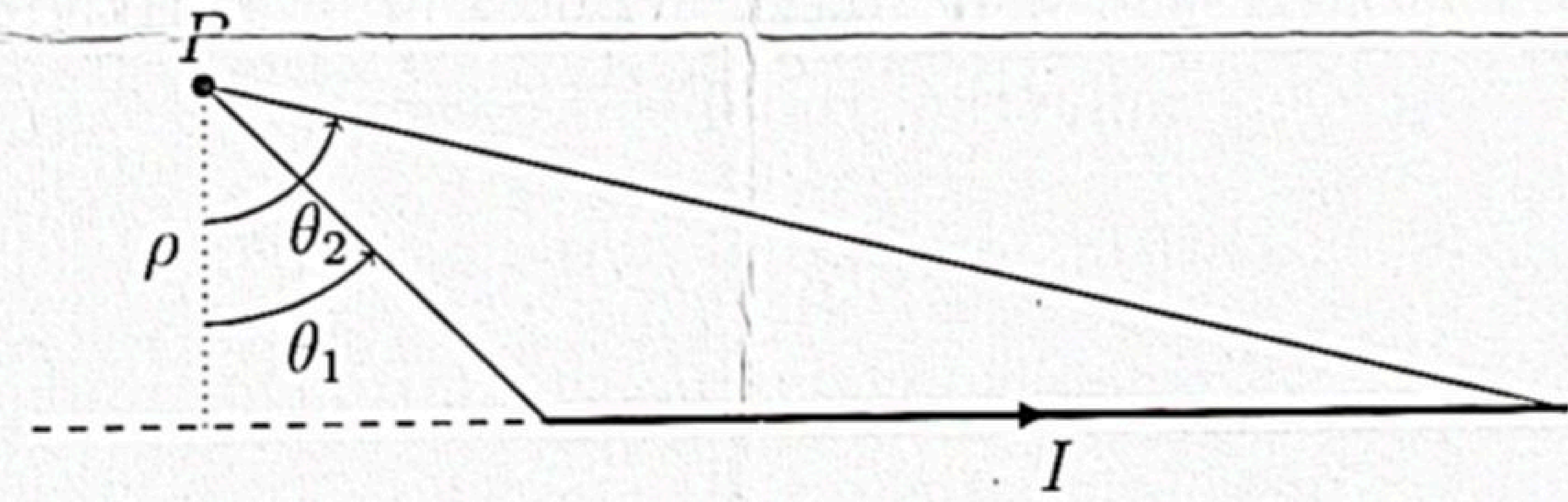
(i) the electric field due to an infinite straight uniformly charged wire would be radial.

(ii) the magnetic field due to an infinite straight current carrying wire would be tangential. [2 + (4 + 4)]

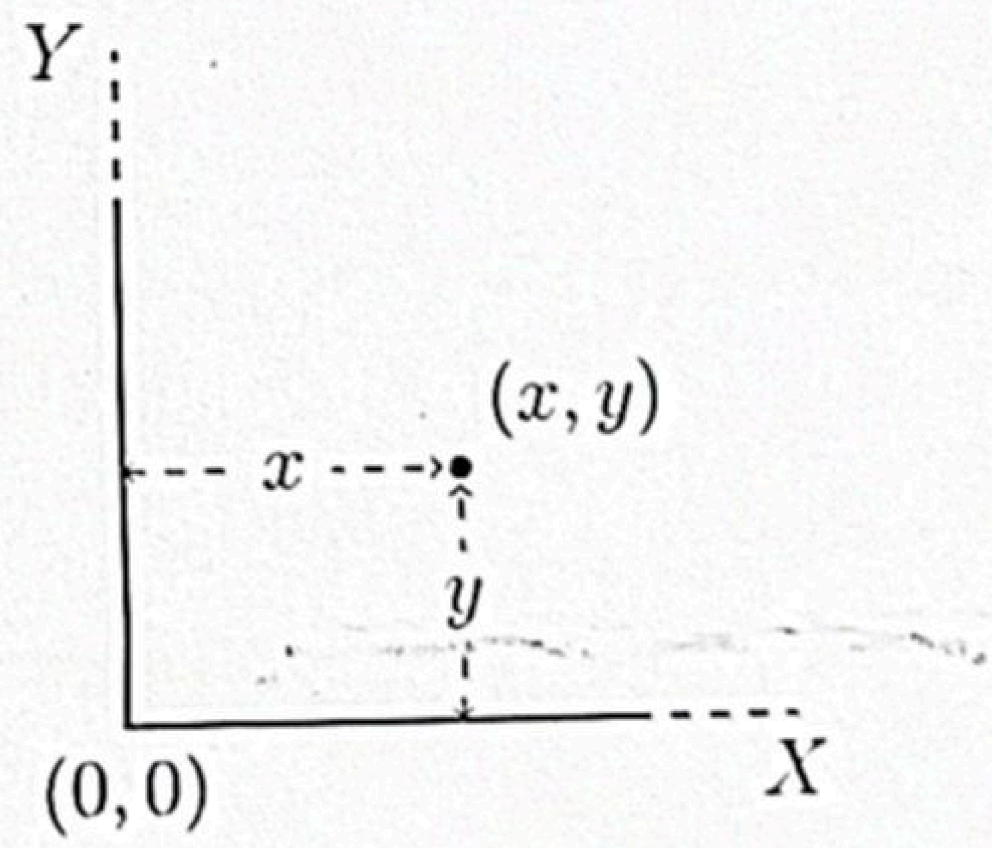
Q 5) We know that the magnetic field caused by a straight segment of wire carrying a current I at a point P is given by

$$\vec{B} = \frac{\mu_0 I}{4\pi} \frac{\sin\theta_2 - \sin\theta_1}{\rho}\hat{\phi}$$

where ρ, θ_1 and θ_2 are indicated in the picture below.



a) An infinite wire is bent so that the two halves make a right angle. The wire carries a current I. We use a coordinate system such that the two halves of the wire lie along the positive X and the Y axes (the bend being at the origin). Determine the magnetic field at a point with coordinates (x, y) in the first quadrant.
Note that the wire extends to infinity along the positive X and Y axes.



b) Determine the magnetic field due to a uniformly wound infinite solenoid with N turns per unit length, carrying a current I, using Ampére's law. [5 + 5]