PHYSICS DEPARTMENT, IIT DELHI
(MINOR II, PHL 110, Oct. 10, 2011)

Max. Marks: 25
Time: 1 hour

Note: Attempt all questions.

1. An infinitely long cylinder, of radius R, carries a "frozen-in" magnetization, parallel to the axis given by $\vec{M} = ks\,\hat{z}$, where k is a constant and s is the distance from the axis; there is no free current anywhere. Find all the bound currents and calculate the field they produce. (5)

2. A long cable carries current in one direction uniformly distributed over its (circular) cross section. The current returns along the surface (there is a thin insulating sheath of negligible thickness separating the two currents). Find the energy stored in the magnetic field and the self-inductance per unit length. (5)

3. The electric field of a plane wave travelling in free space is described by the following expression:

$$\vec{E} = (\hat{x} + \alpha\hat{y}) \exp\left[i\left\{ \frac{\sqrt{2}\pi}{\lambda_0}(x + \beta y) - \omega t \right\} \right]$$

If the above wave represents an electromagnetic wave, obtain values of α and β. (5)

4. Two coherent plane waves of equal amplitude travelling at an angle θ with respect to each other, are incident on a screen, placed normal to one of them. Obtain the intensity variation of the resulting interference pattern on the screen. Also estimate the fringe width. (5)

5. Each part of this question has one correct answer. Write the correct option each part.

(i) A magnetic material is placed in an external magnetic field. If the total field ($\vec{B}$) inside the material is zero, the value of magnetic susceptibility (χ_m) is (1)

(a) -1.0 (b) 0.0 (c) 0.5 (d) 1.0

(ii) For a time varying field $\vec{B}$ parallel to $\hat{z}$, the induced electric field will be along (1)

(a) $\pm\hat{\theta}$ (b) $\pm\hat{\phi}$ (c) $\pm\hat{r}$ (d) $\pm\hat{z}$

(iii) The energy of a travelling electromagnetic wave is stored (1)

(a) entirely in its electric field.
(b) entirely in its magnetic field.
(c) mostly in its electric field.
(d) equally in its electric and magnetic fields.

(iv) When an electromagnetic wave is incident on an interface separating two dielectric media, the (1)

(a) normal component of $\vec{E}$ is continuous.
(b) tangential component of $\vec{D}$ is continuous.
(c) tangential component of $\vec{H}$ is continuous.
(d) normal component of $\vec{H}$ is continuous.

(v) A plane electromagnetic wave (travelling in a dielectric medium of refractive index $\sqrt{3}$) is incident on the dielectric/air interface. The electric field vector of the wave lies in the plane of incidence. In order to achieve 100% transmission, the angle of incidence should be (1)

(a) 0° (b) 30° (c) 60° (d) 90°.