Department of Physics, IIT Delhi

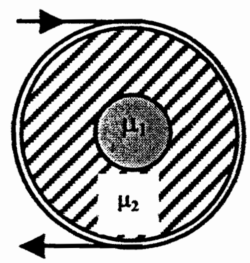
PHL110: Fields and Waves	**Major**	**May 1, 2008**
Please answer all the questions.	**Time: 2 hours**	**Max. Marks: 50**

1(a) A static electricfield distribution is of the form $\vec{E} = A\frac{\exp(-br)}{r^2}\hat{r}$, here A and b are constants. Find (i) the charge density $\rho(r)$ of the source of this field and (ii) the charge enclosed $Q(r)$ in a radius r. **4**

(b)A semi-infinite dielectric slab ($\varepsilon = 2\varepsilon_0$) fills the half space z < 0, with its top surface in the x-y plane the upper half space being a vacuum. A line charge, with charge per unit length λ is placed along the x axis on its surface. Find the electric field produced by it. **3**

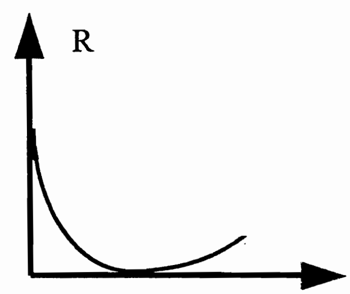
2(a) An infinite cylindrical magnet of radius a = 20mm has magnetization $\vec{M} = \hat{z}5\text{x}10^5(a-s)$ A/m, where s is distance from the axis of the magnet. Calculate the magnetic flux density $\vec{B}$ every where. **4**

(b) An infinitely long solenoid of circular cross-section with radius R and n turns per unit length has a current I flowing through it. It is completely filled by two concentric cylinders, the inner one of radius a ($a < R$) has magnetic permeability μ_1, and the outer which fills the region between a and R has magnetic permeability μ_2 (cross section being shown in the figure). Find (i) the magnetic field $\vec{B}$ inside and outside the solenoid (ii) the energy density due to the magnetic field inside the solenoid, and (iii) the inductance per unit length of the solenoid. **6**

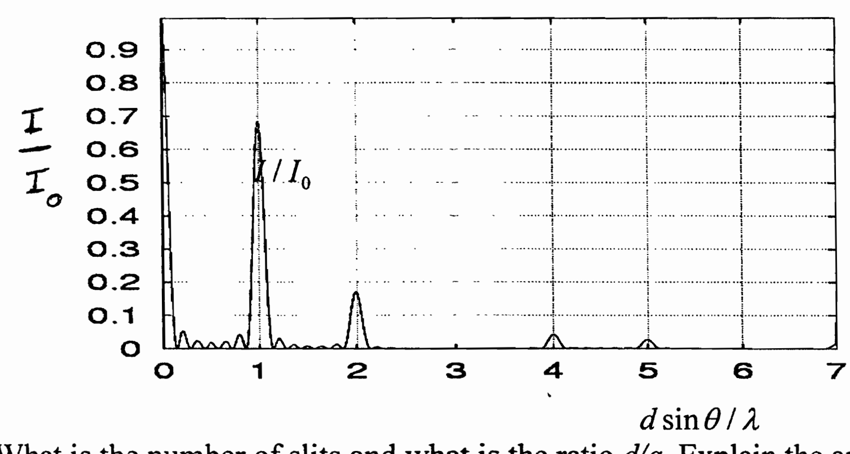


3.(a) The electric field of a plane wave is given by $\vec{E} = (10\hat{x}+15\hat{y})\sin(8\pi\times10^{14}t - 4\pi\times10^{6}z)$V/m. Find (i) the wavelength and the refractive index (ii) the magnetic field $\vec{B}$ (iii) the intensity of the wave. **6**

(b) The reflection coeficient R, of a plane-polarized wave in air reflected from glass ($n = \sqrt{3}$) is shown in the figure. What is the polarization of the wave? What is the value of R at $\theta = 0$? What is the value of θ at R =0? **3**



4(a) An aperture contains a certain number of identical and parallel long narrow slits each of width a separated by a distance d. The Fraunhofer diffraction pattern of this aperture is shown in the figure below.



What is the number of slits and what is the ratio d/a. Explain the answers. **3**

(b) Consider a right circularly polarized wave incident at 30° on an air-glass ($n_G = 1.5$) interface. Obtain the polarization of the reflected wave and an expression for the reflected electric field. **3**

5(a) A light beam of wavelength $\lambda = 400\,\text{nm}$ falls on a metallic surface causing the emission of photoelectrons. If the stopping voltage is 1.5V, calculate (i) the speed of the fastest electrons (ii) the work function of the surface (iii) the maximum wavelength of light, which will cause photoelectric emission from this surface. **5**

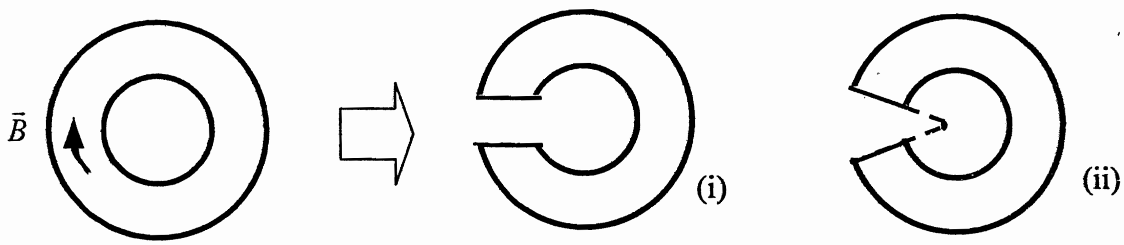
(b) An X ray photon whose initial frequency is 1.5×10^{19} Hz emerges from a collision with an electron with a frequency of 1.2×10^{19} Hz. How much kinetic energy (K.E) was imparted to the electron? What is the angle by which the outgoing photon is scattered with respect to the incoming photon? **3**

6(a) An elementary particle at rest has a lifetime of 7×10^{-19} s. Calculate the uncertainty in its rest mass? **2**

(b) Calculate the expectation value of the kinetic energy, and momentum, for the wave function $\psi(x) = Cx\exp(-\alpha x), \quad 0 \le x \le \infty$. **5**

7. Explain/answer the following giving brief reasons. [**No reasons = no marks**]

(a) A ferromagnetic ring of rectangular cross-section has a uniform circumferential field. It is now cut in one of the two ways shown in the figure below by dotted lines. In which case will the field continue to be



circumferential and why? **1**

(b) A small iron piece has a large number of randomly oriented domains, each of which has a magnetization $\vec{M}$. The net magnetization in the saturation state (Assume $T \ll T_C$) of the iron piece is (i) much smaller than $\vec{M}$ (ii) much greater than $\vec{M}$ (iii) nearly equal to $\vec{M}$. **1**

(c) A beam of light is passed through a polarizer. If the polarizer is rotated about the axis of the beam, the output intensity is found to show maxima and nonzero minima. What are the possible states of polarization which will give this result? **1**

Formulae & Constants: e = 1.6×10^{-19} Coulomb, electron rest mass m = 9.1×10^{-31} kg, h = 6.6×10^{-34} J/s

$\varepsilon_0 = 8.85 \times 10^{-12}\,\text{C}^2/\text{Nm}^2$, $\mu_0 = 4\pi \times 10^{-7}\,\text{N/A}^2$ $\quad \vec{\nabla}\cdot\left(\dfrac{\hat{r}}{r^2}\right) = 4\pi\delta^3(\vec{r})$. $\quad R = \left|\dfrac{\tilde{E}_R}{\tilde{E}_I}\right|^2, \quad T = \left|\dfrac{\tilde{E}_T}{\tilde{E}_I}\right|^2$

For polarization in plane of incidence $\tilde{E}_R = \left(\dfrac{\alpha - \beta}{\alpha + \beta}\right)\tilde{E}_I, \quad \tilde{E}_T = \left(\dfrac{2}{\alpha + \beta}\right)\tilde{E}_I, \quad \alpha = \left(\dfrac{\cos\theta_T}{\cos\theta_I}\right), \quad \beta = \left(\dfrac{\mu_I n_T}{\mu_T n_I}\right)$

For polarization perpendicular to the plane of incidence $\tilde{E}_R = \left(\dfrac{1 - \alpha\beta}{1 + \alpha\beta}\right)\tilde{E}_I, \quad \tilde{E}_T = \left(\dfrac{2}{1 + \alpha\beta}\right)\tilde{E}_I,$