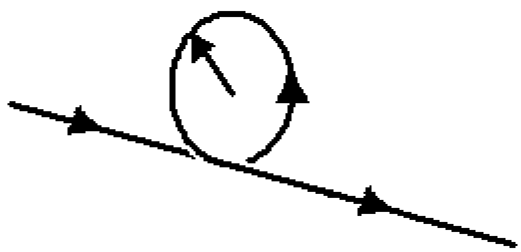
Short Problem 1:

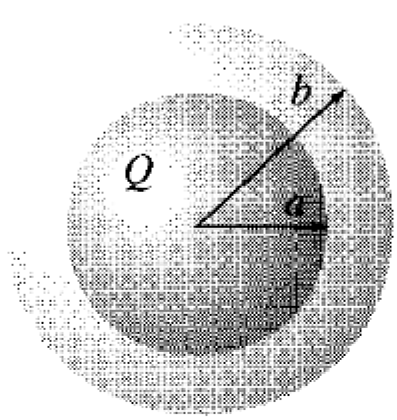
An infinitely long straight wire is modified such that it includes a circular loop whose plane is perpendicular to the direction of the (otherwise long, straight) wire. The wire is insulated, and carries a current *I*, and the radius of the circular loop is *R*. Find the magnitude and direction of the magnetic field ***B*** at the center of the loop.



Short Problem 2:

A spherical conductor, of radius *a*, carries a charge *Q*. It is surrounded by linear dielectric material of susceptibility χ_e, out of radius *b*. Find the energy of this configuration and compare it with case without the dielectrics.

(a) Calculate electric displacement (**D**) in the air part, the dielectric part and the conductor using Gauss's law in the presence of Dielectrics.
(b) Calculate the electric field (**E**).
(c) Calculate the total energy and compare it with case without the dielectric (increase or decrease)



Long Problem 1:

An electromagnetic wave is incident from the left side of an interface between two different media. As a result, two electromagnetic waves travel away from the interface (see the diagram below). Assume that all the waves are traveling in either the $\pm$ x directions and that the interface is in the y-z plane (x = 0).

Assume that the electric field of the incident wave is given by:

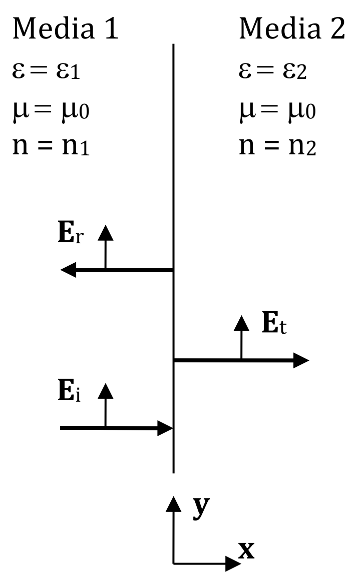
$\mathbf{E}_i = A_0\, \hat{y}\; e^{i(k_1 x - \omega t)}$

Assume that the electric fields of the two waves going away from the interface are given by:

$\mathbf{E}_r = A_r\, \hat{y}\; e^{i(-k_1 x - \omega t)}$

$\mathbf{E}_t = A_t\, \hat{y}\; e^{i(k_2 x - \omega t)}$

Where $k_1 = \omega(\mu_0\varepsilon_1)^{1/2}$ and $k_2 = \omega(\mu_0\varepsilon_1)^{1/2}$ and $\hat{y}$ is the unit vector in the y direction.



a) Find the magnitude and direction of the magnetic fields ($\mathbf{H}_i$, $\mathbf{H}_r$, $\mathbf{H}_t$) associated with the three waves in terms of the electric fields ($\mathbf{E}_i$, $\mathbf{E}_r$, $\mathbf{E}_t$) given above.

b) Use the boundary conditions that the tangential component of the total **E** field is continuous at the boundary and the tangential component of the total **H** field is continuous at the boundary to find the amplitudes A_r and A_t in terms of A_0, ε_1 and ε_2 (or A_0, n_1 and n_2).

c) Find the net, time-averaged, power per unit area crossing the boundary in terms of A_0, ε_1 and ε_2 (or in terms A_0, n_1 and n_2).

Long problem 2:

The current I flows down a resistor as shown in the figure. The potential difference between the ends is V and the length of the wire is L. what is the total power flowing into it? Compare the result from Joule heating law.

(a) Assuming the electric field is uniform, what is the electric field parallel to the wire?
(b) Use the Ampere's law to calculate the magnetic field at the surface ($r=a$) of the wire ($\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 I,$)
(c) Calculate the Poynting flux flowing into the wire through the circumferential surface ($\mathbf{S} \equiv \frac{1}{\mu_0}(\mathbf{E} \times \mathbf{B}).$)
(d) Calculate the energy per unit time passing in through the circumferential surface ($\int \mathbf{S} \cdot d\mathbf{a}$) and compare it with the energy dissipated in the resistor through Joule heating law.