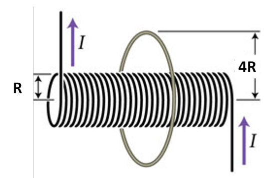
Problems $1-4$ will be discussed during the tutorial hour.

1. A long solenoid of radius R carries a weakly time dependent current $I(t)$. The solenoid is encircled by a symmetrically placed conducting loop of radius $4R$. Calculate the energy inflow to the external loop which replenishes the energy dissipated by joule heating.



2. A capacitor with two circular plates of radius R is being charged by a constant current. Calculate the Poynting vector at radius r inside the capacitor, and verify that its flux equals the rate of change of the energy stored in the region bounded by radius r.

3. Write down the real electric and magnetic field for a monochromatic plane wave of amplitude E_0, frequency ω, and phase angle (δ) zero that is (i) traveling in the negative x direction and polarized in the z direction; (ii) traveling along (1, 1, 1) direction, with polarization parallel to the xz plane. In each case, sketch the wave, and give the explicit Cartesian components of $\vec{k}$ and $\hat{n}$.

4. Two electromagnetic waves traveling along $+z$ and $-z$ direction, respectively, are given by, $E_{x1} = E_0 \sin(\omega t - kz)\hat{x}; B_{y1} = \frac{E_0}{c}\sin(\omega t - kz)\hat{y}$ and $E_{x2} = E_0 \sin(\omega t + kz)\hat{x}; B_{y2} = -\frac{E_0}{c}\sin(\omega t + kz)\hat{y}$. Find out the nature of the wave resulting from superposition of the two traveling waves. Plot the electromagnetic energy density $u_{em}(z,t)$ and the z component of the Poynting vector $S_z(z,t)$ at ωt values of 0, $\pi/4$, $\pi/2$, and $3\pi/4$ and π. Interpret the result.

5. Consider a traveling electromagnetic wave along z direction with $\vec{E}(z,t) = E_x\hat{x} + E_y\hat{y}$, where $E_x = E_{0x}\cos(\omega t - kz)$ and $E_y = E_{0y}\cos(\omega t - kz + \delta)$. Find out the locus of the tip of the electric field vector over a plane perpendicular to the direction of propagation.

6. Consider a solenoid of length l and radius R ($l \gg R$) carrying a surface current density $\mathbf{K} = K\hat{\phi}$. Calculate the energy stored in the volume $V = \pi R^2 l$ of the solenoid. The current is now switched off. Calculate the the power flown out of the surface. Compare the two results.

7. Consider the rectangular toroidal coil (shape of a donut with rectangular cross-section) carrying current $I(t)$ with total N turns, inner radius a, outer radius b and height h [so that the area of the rectangular cross section is $(b-a)h$].
   (a) Calculate the self-inductance of the coil from the induced emf.
   (b) Calculate independently the total energy stored in the magnetic field. Verify your result by calculating the same using the self-inductance.

8. A set-up consists of three very long coaxial parts: (i) a nonconducting cylinder with radius a with total charge Q, (ii) another nonconducting cylinder with radius $b > a$ having total charge $-Q$, and (iii) a solenoid with radius $R > b$, having n turns per unit length and carrying current I. The two cylinders are free to rotate about the common axis and are initially at rest. The current in the solenoid is then switched off.

   (a) Find the total mechanical angular momenta imparted to the charged cylinders by the time the current in the solenoid is decreased to zero. Ignore the $\vec{B}$ fields generated by rotating charged cylinders.

   (b) Now calculate explicitly the total initial angular momentum stored in the field.