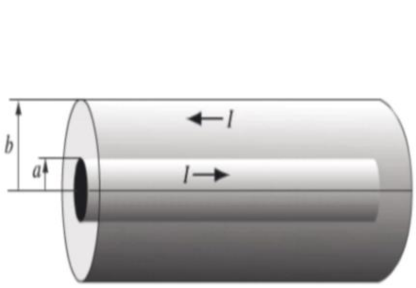
ELECTRODYNAMICS (H2) FINAL EXAM, DURATION: 3HRS, TOTAL MARKS: 60

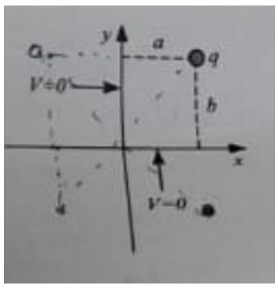
1. Two infinite sheets with uniform electric charge densities $+\sigma$ and $-\sigma$ intersect at a right-angles. Find:
   (a) the magnitude
   (b) the direction of the electric field everywhere.
   (c) Sketch the electric field lines.
   [2 + 2 + 2]

2. A conducting sphere has charge Q□. A point charge Q□ is kept at a height h from the surface of the sphere at a point A. The point charge moves to a new location B that is diametrically opposite to A. If the height h is constant through the journey, what is the work done on the point charge by the electric field of the sphere.

   [2]

3. There is a very long coaxial cable of inner radius a and outer radius b. A current I flows down the surface of the inner cylinder and back along the outer cylinder as shown in the left figure 1. Find the magnetic field in different regions. Calculate the energy stored in a section of length ℓ.
   [3 + 5]





4. Two infinite grounded conducting planes meet at right angles as shown in the right figure 1. A point charge q (you can take any sign for the charge) is kept at (a, b).
   (a) Set up the image configuration and calculate the potential.
   (b) Calculate the charges induced on the conducting planes.

   [5 + 5]

5. The potential due to a pure dipole p that lies at the origin of a coordinate system and points along the $\hat{z}$ direction is

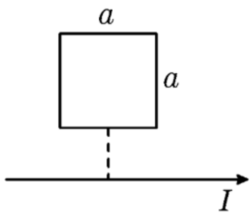
   $$V_{\text{dip}}(r,\theta) = \frac{1}{4\pi\varepsilon_0}\frac{\mathbf{r}\cdot\mathbf{p}}{r^3} = \frac{1}{4\pi\varepsilon_0}\frac{|\mathbf{p}|\cos\theta}{r^2}$$

   Show that the electric field due to the dipole is:

$E_{dip}(r,\theta) = \frac{|\vec{p}|}{4\pi\epsilon_0 r^3}(2\cos\theta\,\hat{r} + \sin\theta\,\hat{\theta})$

[5]

6. A point charge q is situated at a large distance r from a neutral atom of polarizability α. Find the force of attraction between the charge and the atom. [5]
7. A square loop of sides a*a* lies on a table, a distance s*s* from a very long straight wire, which carries a current I*I*, as shown in figure 2.
   a) Find the flux B⃗*B* through the loop.
   b) If the loop is pulled directly away from the wire, at a speed v*v*, what is the electromotive force that is generated, and in which direction (clockwise or anti-clockwise) does the current flow?
   c) Which direction the current flows if the wire is pulled to the right and parallel to the wire at the same speed?
   [4 + 3 + 1]



8. The electric field of an electromagnetic wave in vacuum is given as:
   $$E_x = 0, \quad E_y = 30\cos\left(2\pi \times 10^8 t - \frac{2\pi}{3}x\right), \quad E_z = 0,$$
   where $E_{x,y,z}$ are in volts/meter, t in seconds, and x in meters. Determine **(i)** the frequency, **(ii)** the wavelength, **(iii)** the direction of propagation of the wave, **(iv)** the direction of magnetic field, and **(v)** calculate the average energy per unit area per unit time transported by this wave. Write answers in proper units.
   [1+1+1+2]
9. Consider a plane monochromatic wave in vacuum traveling along the $\hat{z}$ direction
   (a) Show that the energy stored in the electric and magnetic fields are equal.
   (b) Calculate the total energy density stored in the wave and show that the energy density travels along $\hat{z}$ at the speed of light.

   [4 + 5]