**Question 1**: An infinitely long, thin, insulating wire carries a uniform, positive linear charge density \( \lambda \). Consider a cylindrical surface of radius \( R \) and length \( \ell \), coaxial with the wire. (See Figure.) Calculate the electric flux \( \phi \) through the part, \( S_1 \), of the lateral cylindrical surface that subtends an angle \( \theta \) at the axis, and \( \phi \) through the rest of the lateral cylindrical surface that is labeled as \( S_2 \) in the figure.

**Question 2**: An infinitely large, thin, insulating sheet with a uniform, positive surface charge density, \( \sigma \), is placed parallel to the \( y-z \) plane at \( x = 0 \). \( \text{(i)} \) Using Gauss' law, find the magnitude and direction of the electric field in the two regions; \( \text{I} : x < 0 \), and \( \text{II} : x > 0 \). Make sure that you draw Gaussian surfaces and indicate the directions of \( \vec{E} \) in your figure. \( \text{(ii)} \) Find the electric potential, \( V(x) \), in regions I and II. Take \( V = 0 \) at \( x = 0 \).

**Question 3**: Consider the circuit shown in the figure. Initially the switch \( S \) is in the neutral position, the capacitor "\( C_1 \)" has charge \( Q_0 \), and the capacitor "\( C_2 \)" is uncharged. \( \text{(i)} \) Now the switch \( S \) is thrown to the position \( a \). Find the final charges \( q_1 \) and \( q_2 \) of the two capacitors \( C_1 \) and \( C_2 \), respectively. (Draw a figure and clearly indicate the sign of charges on each of the capacitor plates.) \( \text{(ii)} \) The switch \( S \) is then thrown from the position \( a \) to the position \( b \). Find the final charges \( Q_1 \) and \( Q_2 \) of the two capacitors \( C_1 \) and \( C_2 \), respectively. (Draw a figure and clearly indicate the sign of charges on each of the capacitor plates.)

**Question 4**: A thin, straight, conducting wire of length \( \ell \) carries a steady current \( I_1 \). Another thin, conducting wire, carrying a sinusoidal current, \( I_2 = I_0 \sin(\omega t) \), forms a circular loop of radius \( R \), centered at the wire. The straight wire lies on the \( x \) axis, and the circular loop lies in the \( y-z \) plane, with their centers located at the origin, as shown in the figure. Calculate the magnitude and direction of the net magnetic force acting on the straight wire.

**Question 5**: Consider the semi-infinite straight wire shown in the figure. The wire carries a steady current \( I \). \( \text{(i)} \) Using Biot-Savart law, derive the magnitude of the magnetic field, \( \vec{B} \), at the point \( P \) shown in the figure. \( \text{(ii)} \) Draw a figure and indicate the direction of magnetic field at the point \( P \) in your figure.
**Question 6**: A very long conducting cylindrical shell of inner radius $a$ and outer radius $b$ carries a uniformly distributed total current $I$. Find the magnetic field vector, $\vec{B}(r)$, in the two regions, (i) $a < r < b$, and (ii) $r > b$, by using Ampere’s law. ($r$ is the distance from the axis of the shell.)

Make sure that you draw figures and show each of your choice of Amperian loops and the direction of the $\vec{B}$ and $d\vec{s}$ vectors clearly.

**Question 7**: Consider a very long, conducting, straight wire, lying along the $y$ axis, and two horizontal conducting rails, lying parallel to the $x$ axis. (See Figure.) The wire carries a steady current $I_0$. The left end of the rails, which are at a distance $D$ from the straight wire, are connected by a resistor $R$. A conducting rod of mass $m$ and length $\ell$ is initially located at $x = D$, and is pulled with a constant velocity $\nu$ to the right on the rails. Both the rod and the rails have negligible resistance and there is no friction between them. (i) Find the induced current, $I(t)$, in the rod as a function of time $t$. (ii) Draw a figure and clearly indicate the direction of the induced current in the rod. Explain your reasoning.

**Question 8**: A uniform magnetic field, $\vec{B}(t)$, is present in a cylindrical volume of radius $R$, whose cross section is shown in the figure. The magnitude of the magnetic field, $B(t)$, increases with time, $t$, according to $\frac{dB}{dt} = k$, where $k$ is a positive constant. Consider a conducting loop of wire, that consists of a straight part of length $2R$, and a semi-circular arc of radius $R$, whose center, $O$, is located at the axis of the cylindrical region. (i) Find the induced emf, $E$, in the whole loop. (ii) Find the induced emf, $E_1$, in the straight part of the loop. (iii) Find the induced emf, $E_2$, in the semi-circular part of the loop. (Draw a figure and clearly indicate the directions of the emf in each case. Explain your reasoning.)