Answer the all four problems. Partial credits are based on the clarity and the quality of the work you show.

\[
\vec{E} = \frac{kq}{r^2}\hat{r}, \quad k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9 \text{NM}^2\text{C}^{-2}, \quad \vec{F} = q\vec{E}, \quad \oint \vec{E} \cdot d\vec{A} = \frac{Q_m}{\varepsilon_o},
\]

\[
V = \frac{kq}{r}, \quad V = \int \frac{kdq}{r}
\]

\[
dV = \frac{du}{q} = -\vec{E} \cdot dl = -(E_x dx + E_y dy + E_z dz), \quad \vec{E} = -\nabla V = -(\frac{\partial V}{\partial x} \hat{i} + \frac{\partial V}{\partial y} \hat{j} + \frac{\partial V}{\partial z} \hat{k}),
\]

\[
V = Ed, \quad C = \frac{Q}{V}, \quad U = \frac{1}{2} \sum q_i V_i, \quad U = \frac{1}{2} CV^2 = \frac{1}{2} \frac{Q^2}{C}, \quad u_e = \frac{1}{2} eE^2, \quad \varepsilon = KE_e
\]

\[
V = IR, \quad P = IV = I^2 R, \quad I = \frac{dQ}{dt} = nqvA, \quad J = I / A, \quad E = \rho J, \quad R = \frac{\rho l}{A}, \quad R = R_1 + R_2 + \ldots, \quad \frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots
\]

\[
I = I_o \exp(-\frac{t}{RC}), \quad F = qv \times B, \quad dF = ldl \times B, \quad \mu = NA\hat{n}, \quad \tau = \mu \times B
\]

\[
B = \frac{\mu_o}{4\pi} qv \times \hat{r}, \quad dB = \frac{\mu_o}{4\pi} ldl \times \hat{r}, \quad \mu_m = \frac{B^2}{2\mu_o}, \quad B = \mu_o nI
\]

\[
\oint B \cdot dl = \mu_o (I + \varepsilon_o \frac{d\Phi_E}{dt}), \quad \mu_o = 4\pi \times 10^{-7} \text{Tm} / \text{A},
\]

\[
\oint E \cdot dl = -\frac{d\Phi_M}{dt}, \quad \Phi_M = \oint B \cdot dA, \quad \Phi_M = LI
\]

\[
\varepsilon = Blv, \quad \varepsilon = -\frac{d\Phi_M}{dt}, \quad \varepsilon = -L \frac{dl}{dt}, \quad I = I_o \exp(\frac{-R}{L} t)
\]

\[
A_{sph} = 4\pi r^2, \quad V_{sph} = \frac{4}{3} \pi r^3, \quad dV_{sph} = 4\pi r^2 dr
\]

\[
A_{cyl} = 2\pi r L, \quad A_{cil} = \pi r^2, \quad dV_{cyl} = 2\pi r dr L
\]

\[
dq = \lambda dl = \sigma dA = \rho dV
\]
A small coil of \( N \) turns has its plane perpendicular to a uniform magnetic field \( \vec{B} \) as shown. The coil is connected to a current integrator, a device used to measure the total charge passing through it. Find the charge passing through the coil if the coil is rotated through \( 180^\circ \) about its diameter.
The wire in the figure is infinitely long and carries a current $I$. Calculate the magnitude and the direction of the magnetic field at point $P$. 

![Diagram of a long wire carrying current](image-url)
A long, cylindrical wire of radius $a$ carries current $I$ uniformly distributed over its cross-sectional area. A) Find the magnetic field everywhere ($r<a$, and $r>a$); B) Find the magnetic field energy per unit length within the wire.
A long straight wire carries a constant current $I$. A square conducting loop of length $L$ is moving at a velocity $V$, as shown in the figure. At the instant when the near side of the loop to the wire is $x$, find the direction and magnitude of the induced current in the loop. Assume the resistance of the loop is $R$. 

![Diagram of a long straight wire and a square conducting loop with a current $I$ and a velocity $V$. The distance $x$ from the near side of the loop to the wire is labeled.]