1. (20 points) Use Ampère’s law and symmetry to find an expression for the magnetic field $B$ of a tubular cylindrical conductor of inner radius $a$ and outer radius $b$ as shown below. The conductor is made of a material whose permittivity is $\mu$; the other regions of space are air. The current $I$ is assumed to be uniformly distributed between $a$ and $b$, and to flow in the $z$ direction.

2. (20 points) A time-independent but spatially-varying magnetic field $B(x) = u_x \frac{B_0 x}{d}$ exists in a certain region of space. A rectangular loop of conducting wire ranging from $x = vt$ to $x = a + vt$ and $z = 0$ to $z = b$ moves with a velocity $v$ in this field as shown below.

The loop has a small gap, across which an induced voltage $V(t)$ appears. If the field amplitude is $B_0 = 0.1$ T, the length parameters are $d = 1$ cm, $a = 1$ cm, $b = 2$ cm and the velocity is $v = 0.1$ m/sec, evaluate this induced voltage.
3. (20 points) Find an expression for the resistance between two coaxial cylindrical electrodes of length $l$ and radii $a$ and $b$, separated by a conducting medium of resistivity $\rho$ as shown below. The current flow is in the radial direction as indicated. If $a = 2 \text{ mm}$, $b = 4 \text{ mm}$ and $\rho = 3 \text{ }\Omega\text{m}$, how long must $l$ be to achieve a resistance of 50 $\Omega$?

![Diagram of coaxial cylindrical electrodes]

The following questions need little or no math:

4. (20 points) A capacitor of capacitance $C$, with a liquid dielectric of relative permittivity $\epsilon_r$, is connected to an electrostatic source of voltage $V$. The voltage source is then disconnected from the capacitor, and after that the dielectric is drained from the capacitor. Determine the new voltage $V_{\text{new}}$ between the capacitor electrodes when electrostatic equilibrium is reached.

5. (20 points) Two conducting wire loops are placed one above the other coaxially as shown below. A constant (DC) current $I_1$ flows in one of the loops. If the second loop moves vertically towards the first with a constant velocity $v$, which of the following is true (choose one answer from each column)? Give reasons for your answers.

![Diagram of two coaxial wire loops]

(i) A current $I_2$ flowing in the same direction as $I_1$ is induced in the second loop.

(ii) A current $I_2$ flowing in the opposite direction as $I_1$ is induced in the second loop.

(iii) No current is induced in the second loop.

(a) An attractive vertical force exists between the loops.

(b) A repulsive vertical force exists between the loops.

(c) A horizontal (sideways) force exists between the loops.

(d) No force exists between the loops.