Physics 223&: Engineering Physics III Practice Final Exam

Show all your work for full credit. Clearly indicate your final answers with appropriate units.

1) A point charge $q_1 = 5.0\mu C$ is fixed at the origin, and a second charge $q_2 = -3.0\mu C$ is located at $x = 4.0m$.
   a) Calculate the magnitude and direction of the force on q_2 due to q_1.
   b) Suppose a third charge, $q_3 = 2.0\mu C$, is placed at $(4.0m, 3.0m)$. What is the net force on q_3?
   c) Briefly explain the difference between how conductors and insulators would respond if these charges were brought near them.

2) A charge $Q = 6.0\mu C$ is distributed uniformly over a spherical shell of radius $R = 0.5m$.
   a) Calculate the electric field at $r = 0.25m$, $r = 0.5m$, and $r = 1.0m$.
   b) If a test charge $q = 2.0\mu C$ is placed at $r = 1.0m$, what force does it experience?
   c) Explain the relationship between the electric field and force in this scenario.

3) A long, thin rod of charge has a linear charge density $\lambda = 5.0\mu C/m$.
   a) Use Gauss's Law to find the electric field at a distance $r = 0.2m$ from the rod.
   b) Why is symmetry important when applying Gauss's Law?
   c) A spherical shell of radius $R = 1.0m$ encloses the rod. What is the total flux through the sphere?

4) A parallel-plate capacitor has a separation of $d = 0.01m$ and a voltage difference $V = 100.0V$.
   a) Calculate the electric field between the plates.
   b) If a $1.0\mu C$ charge is moved from one plate to the other, what is the change in potential energy?
   c) Discuss how the potential relates to the potential energy in this setup.

5) A capacitor with capacitance $C = 10.0\mu F$ stores $Q = 500.0\mu C$ of charge.
   a) Calculate the energy stored in the capacitor.
   b) A dielectric with a relative permittivity $\varepsilon_r = 4.0$ is inserted. How does the energy change?
   c) Explain how a uniform electric field can be derived from a potential difference.

6) A cylindrical resistor of length $L = 2.0m$ and cross-sectional area $A = 0.01m^2$ has resistivity $\rho = 10^{-6}\Omega m$.
   a) Calculate the resistance of the cylinder.
   b) If a current of $I = 5.0A$ flows through it, find the voltage across the resistor.
   c) Describe how conductivity differs from resistivity.

7) A series RC circuit with $R = 100.0\Omega$ and $C = 20.0\mu F$ is connected to a $12.0V$ battery.
   a) Calculate the time constant of the circuit.
   b) How long will it take for the capacitor to charge to $8.0V$?
   c) Explain the physical significance of the time constant.

8) A solenoid has $n = 100.0$ turns$/m$ and carries a current of $I = 2.0A$.
   a) Find the magnetic field inside the solenoid.
   b) A charged particle with $q = 1.0\mu C$ moves with velocity $v = 100.0\frac{m}{s}$ perpendicular to the field. Calculate the force on the particle.
   c) Explain how Ampere's Law applies to the solenoid.

9) A circular loop of radius $r = 0.2m$ is placed in a uniform magnetic field that changes from $B = 0$ to $B = 0.5T$ in $t = 0.1s$.
   a) Calculate the induced EMF in the loop.
   b) If the loop has resistance $R = 10.0\Omega$, find the induced current.
   c) State Lenz's Law and describe its role in this problem.

10) An RLC circuit consists of $R = 50.0\Omega$, $C = 10.0\mu F$, and $L = 0.1H$ connected to an AC source with $V = 120.0V$ and $f = 60.0$ Hz.
   a) Calculate the capacitive and inductive reactances.
   b) Impedance is a generalization of the idea of resistance and is defined as $Z = R + jX$, where Z is the impedance of an element, R is the resistance, j is the imaginary unit, and X is the reactance. If in a series circuit, impedances add such that $Z_{12} = Z_1 + Z_2$, determine the total impedance of the circuit.
   c) What is the current in the circuit? *Hint: Ohm's Law*