Sample Final Exam 5/6/2021
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1. Consider a spherical capacitor with radii $r_1 < r_2$.

   1.a If the capacitor has charge Q find the field between the plates as a function of r.

   1.b What is the field, as a function of r, for $r > r_2$?

   1.c What is the field, as a function of r, for $r < r_1$?

   1.d What is the potential between the plates?

   1.e What is the surface charge density on the inner sphere?

   1.f How much energy is stored in this capacitor.

2. A circuit has two 200 Ω resistors in parallel connected to a 100 Ohm resistor in series. The resistors are attached to a 12 Volt battery with unknown internal resistance. The circuit has a current of .05 Amperes.

   2.a What is the equivalent resistance of the three resistors?

   2.b What is the internal resistance of the battery.

   2.c What is the power lost to heat in the battery.

   2.d What is the voltage measured across the battery terminals?

3. Consider a circuit with an inductor of inductance L in series with a resistor of resistance R and a battery with EMF V and no internal resistance. The circuit is broken by a switch. The switch is turned on.

   3.a What is the current through this circuit as a function of time?

   3.b What is the maximum current in the circuit.

   3.c How long does it take for the current to reach 90% of its maximum value.

   3.d How much energy is stored in the inductor when the current reaches its maximum value.

4. A cyclotron has a radius R and a uniform perpendicular magnetic field B.

   4.a What value of ω should the cyclotron operate at in order to accelerate a particle of mass m?

   4.b What is the particles speed as a function of r.

   4.c At what is the kinetic energy of the particle when it emerges from the cyclotron?

   4.d What changes if the accelerating electric field is doubled?

5. Consider a square wire loop with sides of length L. A spatially uniform oscillating magnetic field $\mathbf{B} = \mathbf{B}_0 sin(\omega t)$ goes through the loop, where $\mathbf{B}_0$ makes a 30 degree angle with the normal to the loop.

   5.a What is the magnetic flux through this loop as a function of time?

   5.b What is the EMF induced in the loop as a function of time.

   5.c Discuss the direction of the current as a function of time

   5.d Assume that the loop has capacitance C, inductance L, and resistance R. What frequency of the magnetic field will maximize the current through the loop?

6 A plane electromagnetic wave is moving in the $\hat{\mathbf{x}}$ with electric field $\mathbf{E}$ polarized in the $\hat{\mathbf{z}}$ direction.

   6.a What is the direction of the corresponding magnetic field?

   6.b What is the magnitude of the corresponding magnetic field?

   6.c This wave is normally incident square hole of side L. How much (RMS) energy is deposited by the electromagnetic wave in the hole per unit time?

   6.d How does the answer to c change if the frequency of the wave is doubled?

$$k = 8.99 \times 10^9 (Nm^2/C^2) \qquad \epsilon_0 = 8.85 \times 10^{-12} (C^2/Nm^2)$$