Physics 7B (Sec. 2) Final Examination May 16, 2003

You may use one (1) sheet of paper, not larger than $8\frac{1}{2}$" x 11" (both sides), as a memory aid, but no other papers, and no books, may be used. The examination totals 440 points.

(20) (1) Given a parallel plate capacitor (with vacuum between the plates) connected to a source of emf which varies harmonically with time t. The area of each plate is A m^2, and, at time t, the surface charge density (on either plate) has a magnitude of $\sigma(t)$ $C\,m^{-2}$. (a) Assuming that the electric field in the region between the plates is normal to the plates and uniform in space, calculate the displacement current I_D through the capacitor; (b) Show explicitly that your answer to (a) has the correct units. [(a) = (b) = 10 pts]

(30) (2) Given a long straight cylindrical conductor of radius R carrying a current of I Amperes (with constant current density). (a) Calculate the magnitude $B(r)$ of the magnetic field (due to the current) at points <u>inside</u> the wire (that is, for values of $r \leq R$, where r is measured from the center of the wire; (b) Make a graph (clearly labeled) of $B(r)$ as a function of r for $r \leq R$. [(a) = 20, (b) = 10 points]

(50) (3) Suppose 1.00 kg of liquid water is converted (at 100°C) to steam (at 100° C) by boiling at a constant atmospheric pressure of 1.01×10^5 Pa; the steam pushes up on a piston. The volume of the water changes from 1×10^{-3} m^3 to 1.671 m^3 in the phase change from liquid water to steam. (a) Calculate the work done by the

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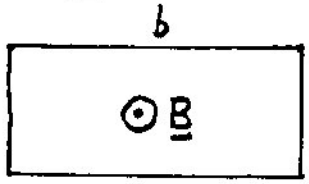
(3) [continued] expanding gas; (b) Calculate the amount Q of heat entering the system during the process. The heat of fusion (at 0°C) of water is 333 kJ/kg. The heat of vaporization (at 100°C) of water is 2260 kJ/kg; (c) Calculate the change ΔU in the internal energy of the system during the process. [(a) = (b) = 20; (c) = 10]

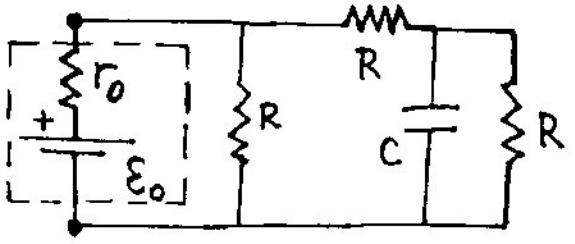
(40)(4) Given a rectangular loop of wire in a uniform external magnetic field $\underline{B}$ directed normally out of the plane of the paper. Starting at time $t = 0$, the magnitude $B \equiv |\underline{B}|$ increases with time as



$$B = B_0 t^2$$

where B_0 is a constant. (a) Calculate the value of the emf $\mathcal{E}$ induced in the loop when $t = 2$ sec; (b) The induced emf $\mathcal{E}$ produces a current I' in the loop; I' produces a magnetic field $\underline{B}'$. Calculate the direction of $\underline{B}'$; (c) Give the direction of the induced current I' [(a) = 20, (b) = (c) = 10]

(40)(5) Given the circuit shown, where r_0 is the internal resistance of the battery of emf $\mathcal{E}_0$. The battery is connected to the "load" of resistors and a capacitor, as shown. (a) Calculate the value of the resistance R (expressed in terms of some of the other circuit parameters) for which the power dissipated in the load is a maximum; (b) Calculate the maximum value of the power dissipated [(a) = (b) = 20 points]



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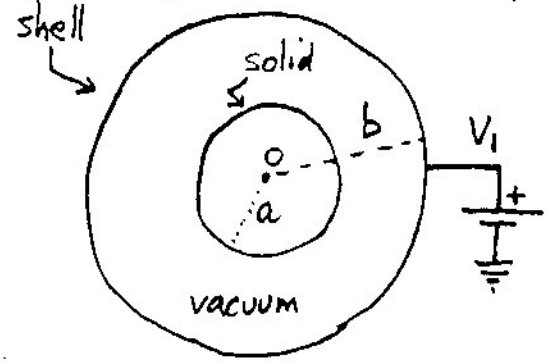
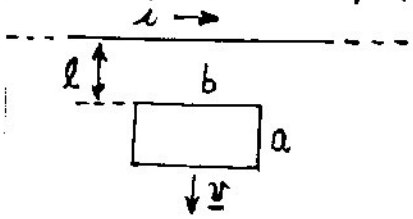
(50)(6) Given a solid spherical conductor of radius a, on which there is a uniform positive surface charge density of σ C m^{-2}. As shown in the drawing, the solid spherical conductor is surrounded by a thin concentric conducting shell of radius b. The thin shell is maintained at a constant electric potential of V_1 volts by a battery. Calculate the electric potential $V(r)$ at a point a radial distance r from the center O of the solid conductor, where $a < r < b$. (You may assume that the electric field in the vacuum between solid conductor and shell is radial and is not dependent on direction from the center O.)



(40)(7) A coil of self-inductance 230×10^{-3} H. has a resistance of 18.5 ohms. The coil is connected in series with a capacitor of capacitance C Farads. The two components across an AC voltage of frequency 3360 Hz. (a) Calculate the value of C for which the phase difference between the current and voltage in the circuit is zero; (b) If the rms value of the current in the circuit is 10 Amperes, calculate the peak value $\mathcal{E}_0$ of the applied voltage. [(a) = 20, (b) = 20 points]

(60)(8) The rectangular loop of wire shown moves with constant velocity $\underline{v}$ normally away from a long wire carrying a current i. The wire and the loop remain in the plane of the paper during the motion. The loop is at a distance l from the wire when the loop begins to move. Calculate the emf $\mathcal{E}(t)$ induced in the loop as a function of time t.



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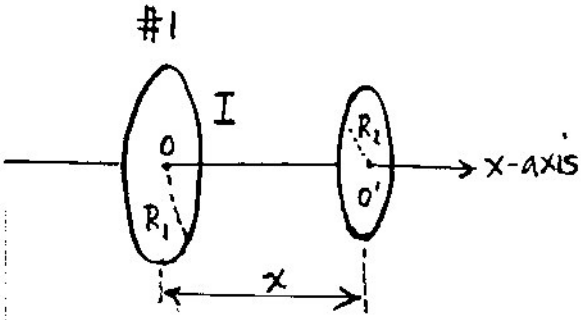
(50)) Given two circular loops of wire, both normal to the x-axis, as shown. The radius of the larger loop #1 is R_1 and the radius of the smaller loop #2 is R_2. The two loops are a distance x apart.



Loop #1 has a current I flowing in it. Calculate the mutual inductance M of the two loops as a function of x. You may consider the magnetic field (due to the current in loop #1) at the position of loop #2 to be constant over the area of loop #2.

(60)(10) An infinitely long conducting wire is bent into a right angle at its center; the wire carries a current i. The wire lies in the xy-plane with the vertex of the right angle at the origin. Consider a point P on the bisector of the right angle and located at a distance $(a\sqrt{2})$ from the origin. Calculate the magnitude B of the magnetic field $\underline{B}$ at point P. (You may leave your answer in the form of a definite integral.)