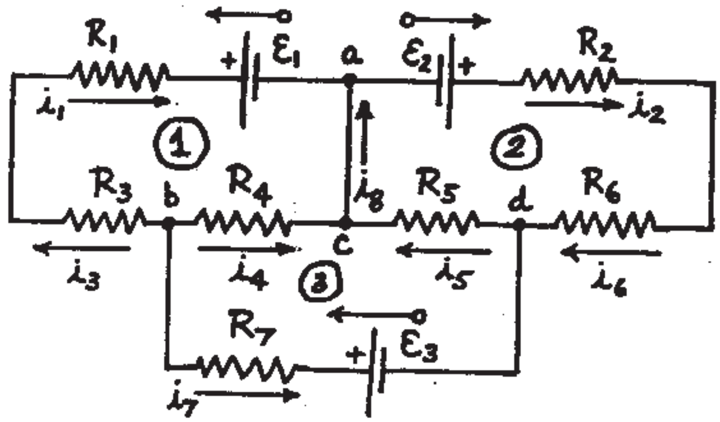
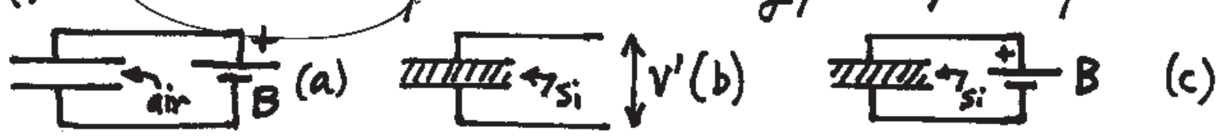
Physics 7B (Sec. 2) Midterm Exam #2 April 8, 2003

You may use one (1) card, not larger than 3"×5" (both sides) but no other papers, and no books. The exam duration is 90 minutes and the exam totals 220 points.

(20) (1) Given the circuit shown, in which $\mathcal{E}_1$, $\mathcal{E}_2$, and $\mathcal{E}_3$ are known emfs and $R_1 - R_7$ are known resistances. Write down, using Kirchoff's Laws, eight (8) equations which can be solved for the currents $i_1 - i_8$. Use the current directions shown. (It is NOT necessary to solve the equations.)



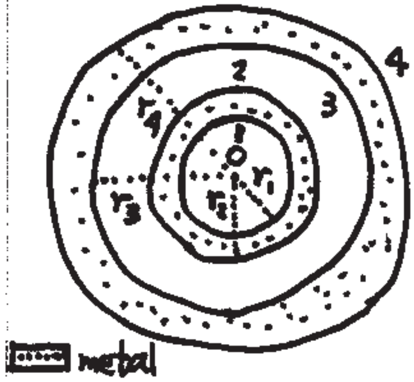
(30) (2) Given two circular parallel conducting plates, each of radius 8.2 cm



separated by 1.3 mm of air (dielectric constant equal to unity) as shown in (a) above, in which battery B supplies a potential difference of 120 volts. (a) Calculate the charge Q on either plate; (b) The battery is then removed (and not replaced) and a slab of silicon (dielectric constant 11.7) is inserted between and fills, the plates, as shown in (b) above. Calculate the potential difference V' between the plates; (c) The battery B is then replaced, as shown in (c) above. Calculate the charge Q' on the plates (a long time) after B is replaced; (d) If $Q' \neq Q$, explain the difference. [(a) = (b) = 10; (c) = (d) = 5]

(continued →)

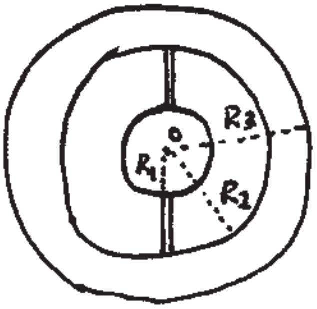
(40) (3) Two concentric thick conducting metal spherical shells are initially uncharged (meaning that there is no net excess charge). An excess charge of $(+Q)$ Coulombs is placed on the inner shell. (The surfaces of the shells are numbered 1, 2, 3, 4, and have increasing radii r_1, r_2, r_3, r_4. (a) Calculate the charge induced on each of the surfaces 1, 2, 3, 4. In each case, explain your reasoning; (b) Calculate the potential difference $(V_3 - V_2)$ between surfaces 3 and 2; (c) Is surface 3 or surface 2 at the higher electric potential? Justify your answer; (d) Calculate the capacitance of the system of conductors composed of surfaces 2 and 3. [Part (a) = 10, (b) = 15, (c) = 5, (d) = 10 points]



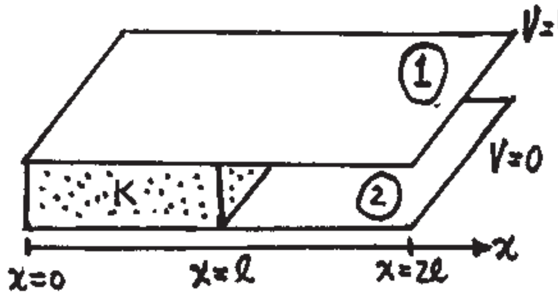
(40) (4) Given a thick non-conducting spherical shell of inner radius a and outer radius b, containing positive electric charge of volume charge density $\rho(r)$ [in $C m^{-3}$], where $\rho(r) = \rho_0 r^{-1}$. The quantity ρ_0 is a constant and the distance r from the center O of the shell is such that $a \leq r \leq b$. Assume that the electric field $\underline{E}$ due to this charge is everywhere radial in direction, and that $|\underline{E}|$ depends only on r, and not on direction. (a) Calculate the electric energy density $u_E(r)$, [in $J m^{-3}$], at a distance r from the center O; (b) Make a plot of $u_E(r)$ as a function of r for the case $b = 10a$. [Part (a) = 25, (b) = 15 points]

(continued →)

(50)(5) Given a disc of radius R_1 surrounded by an annular ring of radii R_2 and R_3, as shown. The disc and ring are made of a non-conducting plastic, and are connected together by two non-conducting strips of negligible size. The disc and ring each bear an electric surface charge of density σ $C m^{-2}$. (a) Calculate the electric potential $V(z)$ at a point P a perpendicular distance z above the center O of the disc. Assume $V=0$ as $z \to \infty$; (b) Calculate the component E_z of the electric field at point P, in the direction normal to the plane of the disc; (c) Explain the significance of the sign of E_z found in (b). [(a) = (b) = 20, (c) = 10]



(40)(6) Given a parallel plate capacitor whose metal plates (separated by vacuum) are a distance d apart and have a potential difference of V_0 volts between them. Half of the volume between the plates is then filled with a dielectric of dielectric constant K (shown dotted in the figure). Assuming that both metal plates are equipotential surfaces, does the uniform electric field E_2 in the dielectric have the same magnitude as the uniform electric field E_1 in the unfilled region of the capacitor? Justify your answer with an explanation; (b) Based on your answer to (a), make a plot showing the surface charge density σ [in $C m^{-2}$] on plate (1) as a function of distance x, for the case in which $K = 2$. [Part (a) = 25 points, (b) = 15 points]



7B MIDTERM #2 SPRING 2003

INTEGRALS

$$\int \frac{dx}{(x^2+a^2)^{3/2}} = \frac{x}{a^2(x^2+a^2)^{1/2}} + C$$

$$\int \frac{x\,dx}{(x^2+a^2)^{3/2}} = \frac{-1}{(x^2+a^2)^{1/2}} + C$$

$$\int \frac{dx}{(x^2+a^2)^{1/2}} = \ln\left(x + [x^2+a^2]^{1/2}\right) + C$$

$$\int \frac{x\,dx}{(x^2+a^2)^{1/2}} = (x^2+a^2)^{1/2} + C$$

$$\int x(x^2+a^2)^{1/2}\,dx = \frac{1}{3}(x^2+a^2)^{3/2} + C$$

$$\int x(x^2+a^2)^{3/2}\,dx = \frac{1}{5}(x^2+a^2)^{5/2} + C$$

where a = constant ; C = constant of integration