Physics 208 **EXAM 1** **September 26, 2003**

NAME: SOLUTIONS

SECTION #: ______

TA: ______

Problem	Points	Score
1	25	
2	15	
3	15	
4	25	
5	20	
Total	100	

- No books or notes are permitted. Use only the formula sheet provided with the exam.
- Write your final answer in the box provided.
- All answers should include units.
- To get credit for a problem you need to show your work in the space provided. If no work is shown you will get no credit, even if the answer in the box is correct. You are expected to work all problems using the basic laws of physics and the equations provided on the formula sheet. If you happen to remember the answer to a particular problem or know a shortcut formula you must still work the problem to get full credit.
- If you need more space, use the back of one of the sheets, and make a note that the work is continued on the back.
- Turn your exam in to your TA when you are finished.

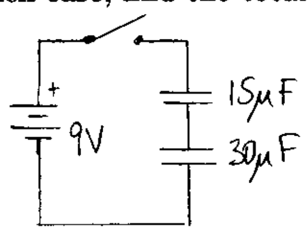
1) Three shorter questions:

(a) The capacitors in the circuits shown below are initially uncharged. At some point the switch is closed. For each case, find the total amount of charge that flows through the switch.

$\frac{1}{C_{eff}} = \frac{1}{15\mu F} + \frac{1}{30\mu F}$

$C_{eff} = 10\mu F$

$Q = C_{eff} \cdot V$



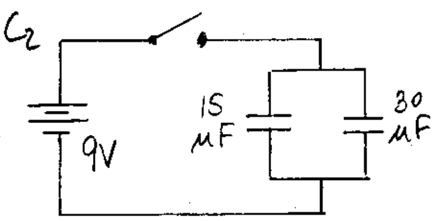
Answer: 90μC

$C_{eff} = C_1 + C_2$

$= 45\mu F$

$Q = C \cdot V$

$= 405\mu C$



Answer: 405μC

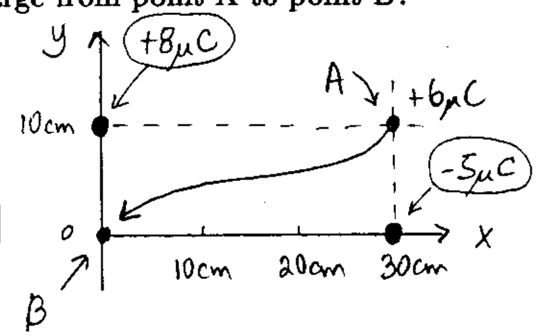
(b) How much work would you have to do to move the 6 μC charge from point A to point B?

$V_A = \left(\frac{1}{4\pi\epsilon_0}\right)\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right] = (9\times10^9)\left[\frac{8\mu C}{0.3} + \frac{(-5\mu C)}{0.1}\right]$

$= -2.10\times10^5 V$

$V_B = \left(\frac{1}{4\pi\epsilon_0}\right)\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right] = (9\times10^9)\left[\frac{8\mu C}{0.1} + \frac{(-5\mu C)}{0.3}\right]$

$= 5.7\times10^5 V$

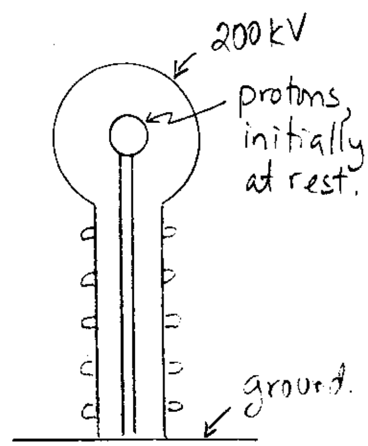


ΔU = gain in PE = work done

$= (6\times10^{-6} C)[5.7 - (-2.1)]\times10^5 = 4.68 J$

$\boxed{4.68 J}$

(c) In a Cockcroft-Walton accelerator, protons (charge 1.6×10^{-19} C and mass 1.67×10^{-27} kg) are accelerated through vacuum from a high-voltage terminal at 200,000 volts to ground (zero voltage). Find the speed of the protons when they reach ground potential.



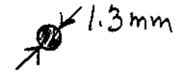
The potential energy $q \cdot \Delta V$ is converted into kinetic energy

$\frac{1}{2}mv^2 = q\Delta V \qquad v = \left[\frac{2q\Delta V}{m}\right]^{\frac{1}{2}}$

$= 6.2\times10^6 m/s$

$\boxed{6.2\times10^6 m/s}$

2) Ordinary #16 wire has a diameter of 1.3 mm. Find the total power dissipated along a 20 m length of #16 copper wire carrying a current of 10 A. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega\cdot$m.



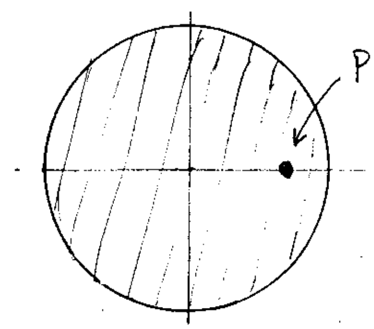
$$R = \rho L / A = (1.7 \times 10^{-8}\,\Omega\cdot m)(20\,m) / \left(\tfrac{\pi}{4}\right)(.0013\,m)^2$$

$$= 0.256\,\Omega$$

$$P = I^2 R = (10\,A)^2 (0.256\,\Omega)$$

$$\boxed{25.6 \text{ Watts}}$$

3) An infinitely long cylinder of radius 20 cm has charge distributed uniformly throughout it's volume at a density of $20\,\mu$C/m^3. Use Gauss's Law to find the electric field at a point 15 cm from the center of the cylinder.



Imagine a surface of length L and radius R = 15 cm. The charge inside is

$$Q = \rho \cdot \text{Vol} = (20\,\mu C/m^3)(L)\cdot(\pi R^2)$$

The outward flux is

$$\Phi = E \cdot A = E \cdot 2\pi R \cdot L$$

$\Rightarrow$

$$E \cdot 2\cancel{\pi}\cancel{R} \cdot \cancel{L} = \frac{1}{\epsilon_0}\,\rho \cdot \cancel{L} \cdot \cancel{\pi} R^{\cancel{2}}$$

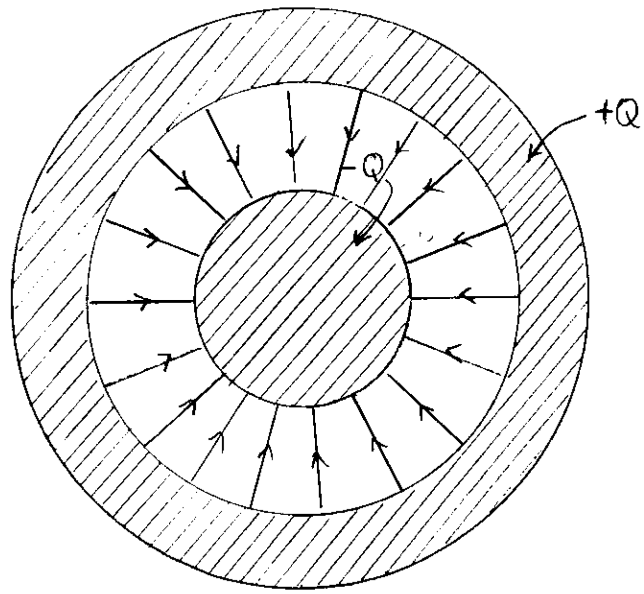
$$E = \left(\frac{\rho}{2\epsilon_0}\right)\cdot R = \frac{(20 \times 10^{-6}\,C/m^3)(0.15\,m)}{(2)(8.85 \times 10^{-12}\,C^2/N\cdot m^2)}$$

$$= 1.695 \times 10^5\ V/m$$

$$\boxed{1.7 \times 10^5\ V/m}$$

4) The figure below shows two concentric conducting spheres. The inner sphere is solid and has a radius R_a. The outer sphere has inside radius R_b and outside radius R_c. A larger sphere carries a net positive charge Q, and the solid sphere has an equal and opposite charge $-Q$.

(a) Make a drawing that shows the electric field lines everywhere in space.



The field is zero within the conductors and also outside (since the total charge is zero)

(b) Starting with equations from the formula sheet, show how you would find the potential difference between the two conductors. [HINT: $\int r^{-2}dr = -r^{-1}$]

$E = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{Q}{r^2}$ ← magnitude of $\vec{E}$ for $R_a < r < R_b$

$$\Delta V = \int_{R_a}^{R_b}\left(\frac{1}{4\pi\epsilon_0}\right)\frac{Q}{r^2}\,dr = \frac{Q}{4\pi\epsilon_0}\left(-\frac{1}{r}\right)\Bigg|_{R_a}^{R_b}$$

$$\boxed{\Delta V = \frac{Q}{4\pi\epsilon_0}\left[\frac{1}{R_a} - \frac{1}{R_b}\right]}$$ (outer shell is at the higher pot.)

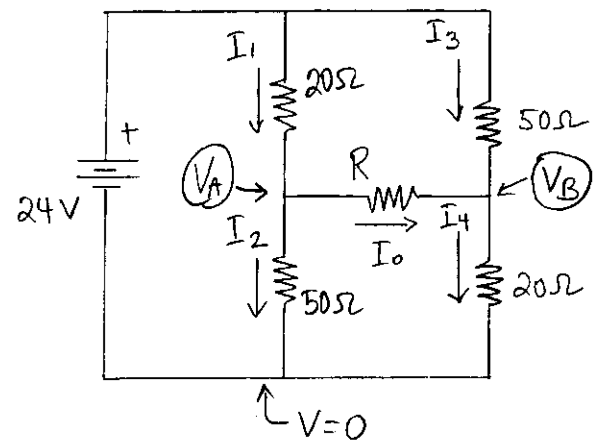
(c) Find ΔV for $R_a = 10\,\text{cm}$, $R_b = 20\,\text{cm}$, $R_c = 25\,\text{cm}$, and $Q = 5\mu\text{C}$.

$$\Delta V = (9\times10^9)(5\times10^{-6})\left[\frac{1}{0.1\text{m}} - \frac{1}{0.2\text{m}}\right]$$

$$= 2.25\times10^5\,\text{V}$$

$$\boxed{2.25\times10^5\,\text{V}}$$

5) **In the circuit shown at the right the current I_0 through resistor R is measured to be 0.15 A. Determine the value of R.**



Current Rule

① $I_1 = I_0 + I_2$

② $I_3 + I_0 = I_4$

Voltage Rule

③ $24V - 20\Omega \cdot I_1 - 50\Omega \cdot I_2 = 0 \Rightarrow 20 I_1 + 50 I_2 = 24$

Combine with ①

$$20(I_0 + I_2) + 50 I_2 = 24$$

$$70 I_2 = 24V - 20 I_0 = 24V - 3V = 21V.$$

$$\underline{I_2 = 0.3A} \Rightarrow \underline{V_A} = 50\Omega \cdot I_2 = \underline{15V.}$$

④ $24V - 50 I_3 - 20 I_4 = 0 \Rightarrow 20 I_4 + 50 I_3 = 24$

Combine with ②

$$20(I_0 + I_3) + 50 I_3 = 24 \Rightarrow$$

$I_3 = 0.3A$ (which we could have guessed from the symmetry)

$$I_4 = I_0 + I_3 = 0.45A$$

$$\underline{V_B} = 20\Omega \times 0.45A = \underline{9V}$$

Voltage drop across R is 6V

$$\Rightarrow \quad R = V/I = 6V/0.15A$$

$$\boxed{40\Omega}$$