Problems: Week 6

6-1. What is EMF (electromotive force)? [Hint: It is not a force]

6-2. In order to place a charge Q on a capacitor C_0 the battery must do $\frac{Q^2}{2C_0}$ joules of work. Where does all this energy go? Why?

6-3. Use the result of 6-2 for a parallel plate capacitor with air or vacuum between the plates to show that 1m^3 of an $\underset{\rightarrow}{E}$-field stores $\frac{1}{2}\varepsilon_0 E^2$ joules of energy.

6-4. A current of 1amp exists in a resistor for 4 min. How many (a) coulombs and (b) electrons pass through any cross-section?

6-5. If the resistor of problem 6-4 is a cylinder of radius 0.001m, what is the current density?

6-6. Two conductors A and B are made of the same material and have the same length. However, A is solid and has a diameter of 1m, B is hollow with an outer diameter of 2mm and an inner diameter of 1mm. Calculate the resistance ratio R_A / R_B.

6-7. A wire with resistance 6Ω is drawn out so that its length is tripled. If neither density nor the resistivity change, what will be the resistance of the longer wire?

6-8. Using the result of 3-6, if there is a current of 1amp in a Cu wire of diameter 1mm, what will be the drift speed (V_D) of the electrons? [$|e| = 1.6\times10^{-19}\,C$]? Why?

6-9. If in 6-8 the diameter is doubled by what factor will V_D change? Why?

6-10. When the resistance(R) is independent of the current one writes the so-called Ohm's Law

$$V = IR \qquad \text{-- (1)}$$

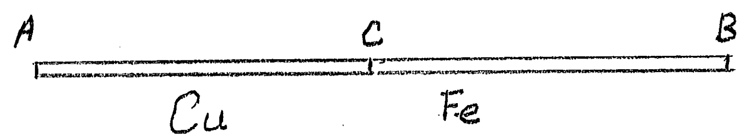
Now $I = \underset{\to}{J} \cdot \underset{\to}{A}$ where $\underset{\to}{J}$ is the current density and A the area of the conductor, $R = \frac{l}{\sigma A}$ where l is the length and σ the electrical conductivity. Show that Eq. (1) implies the fundamental relationship $\underset{\to}{J} = \sigma \underset{\to}{E}$ where $\underset{\to}{E}$ is the field driving the current.

6-11. The conductivity of copper is $5.9 \times 10^7 (\Omega - m)^{-1}$. Use the result of problem 3-6 (for n) to estimate the time τ between collisions in Cu if

$$\sigma = \frac{ne^2\tau}{m}$$

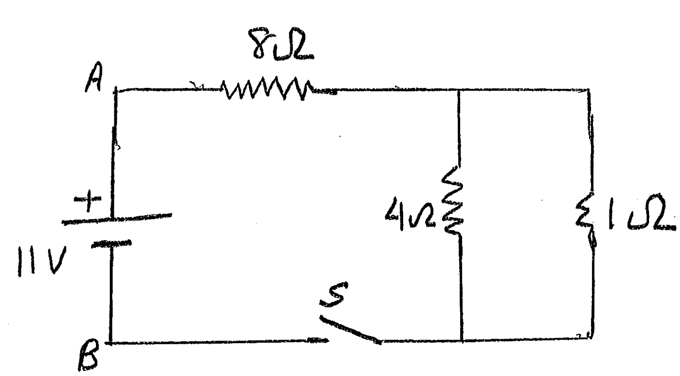
$e = 1.0 \times 10^{-19}\, C$; $m = 9 \times 10^{-31}\, kg$

6-12. At room temperature the resistivities of Copper and Iron are $1.7 \times 10^{-8} \Omega - m$ and $10 \times 10^{-8} \Omega - m$. A composite wire is made up of 1m each of Cu and Fe connected as shown. The diameters are 1mm. (i) What is the total resistance? (ii) What is the current if there is a voltage difference of 10V between A and B? (iii) What is the potential at C?

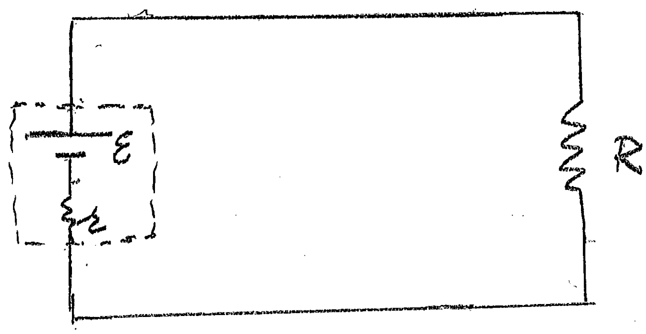


6-13. How much thermal energy per hour is generated by the current in problem 6-12? Why?

6-14. In the circuit shown, what is the equivalent resistance across AB? Next, close the switch and calculate (i) the currents in the resistors and (ii) the potential drop across each resistor.



6-15. In the circuit shown "r" is the internal resistance of the battery. Calculate the power dissipated in the load R and show that the power becomes very small when R << r or R >> r.



6-16. In problem 6-12 if the wires are connected as shown here, now what is the resistance AB and the current in each if $V_{AB} = 10V$?