



### PROBLEM SET 5

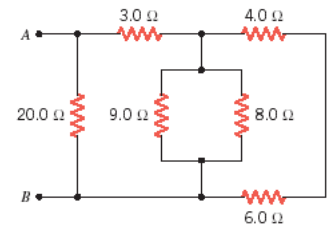
Due: 19 October 2021, 2.30 p.m.

**Problem 1.** Two conducting wires in the shape of cylinders of the same cross-sectional area, at  $0^\circ \text{C}$  have resistivities  $\rho_{01}$ ,  $\rho_{02}$  and temperature coefficients of resistivity  $\alpha_1$  and  $\alpha_2$ , respectively. What is the effective temperature coefficient of resistivity if the conductors are connected (a) in series, (b) in parallel.

(3/2 + 3/2 points)

**Problem 2.** For the system of resistors shown in the figure, find the equivalent resistance between points  $A$  and  $B$ .

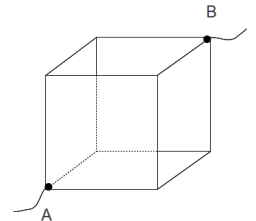
(4 points)



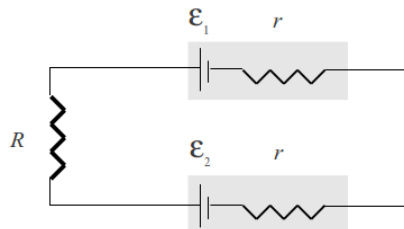
**Problem 3.** Twelve identical resistors, each of resistance  $R$ , are connected to form a cube-shaped circuit (see the figure). Find the equivalent resistance between points  $A$  and  $B$ .

*Hint.* Use symmetry.

(4 points)



**Problem 4.** Consider the circuit shown in the figure below ( $\mathcal{E}_1 = 12 \text{ V}$ ,  $\mathcal{E}_2 = 8 \text{ V}$ ,  $r = 1 \Omega$ ,  $R = 8 \Omega$ ).

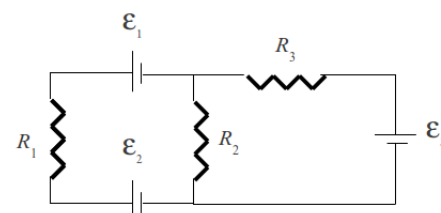


- Find the current through the resistor  $R$ ,
- and the total rate of dissipation of electrical energy in the resistor  $R$  and in the internal resistance of the batteries.
- In one of the batteries, chemical energy is being converted into electrical energy. In which one it is happening, and at what rate?
- In one of the batteries, electrical energy is being converted into chemical energy. In which one it is happening, and at what rate?
- Show that the overall rate of production of electrical energy is equal to the overall rate of consumption of electrical energy in the circuit.

(5 × 1 points)

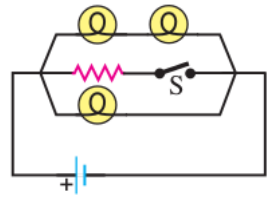
**Problem 5.** For the circuit shown in the figure below, find the current through each of the resistors. For numerical calculations assume:  $R_1 = 2 \Omega$ ,  $R_2 = 4 \Omega$ ,  $R_3 = 5 \Omega$ ,  $\mathcal{E}_1 = 20 \text{ V}$ ,  $\mathcal{E}_2 = 14 \text{ V}$ ,  $\mathcal{E}_3 = 36 \text{ V}$ . The internal resistance of the emfs is negligible.

(4 points)



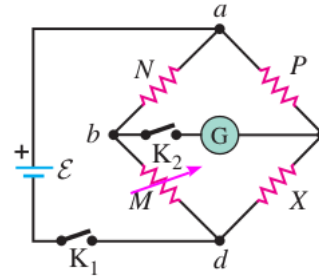
**Problem 6.** For the circuit shown in the figure below what happens to the brightness of the bulbs when the switch  $S$  is closed if the battery (a) has no internal resistance and (b) has non-negligible internal resistance? Explain why.

(2 + 3/2 points)



**Problem 7.** Four resistors are connected to form a Wheatstone bridge – a circuit that can be used to measure unknown resistance  $X$ , provided the resistances of  $N$ ,  $M$  and  $P$  are known. The idea of the measurement method is to tune (with the switches  $K_1$  and  $K_2$  closed) the variable resistance  $M$  so that the potential difference between points  $b$  and  $c$  is zero and the galvanometer does not show any current. The bridge is then said to be *balanced*. Show that in this configuration  $X = MP/N$ .

(4 points)



**Problem 8.** Strictly speaking, the formula  $q(t) = Q_{\max}e^{-t/RC}$  implies that an infinite amount of time is required to discharge a capacitor in a  $R$ – $C$  circuit completely. Yet for practical purposes, a capacitor may be considered to be fully discharged after a finite time  $t_d$ , defined as the time when the charge on the capacitor  $q(t_d)$  differs from zero by no more than the charge of one electron.

- Find  $t_d$  if  $C = 0.92 \mu\text{F}$ ,  $R = 670 \text{ k}\Omega$ , and  $Q_{\max} = 7 \mu\text{C}$ .
- For a given  $Q_{\max}$  is the time required to reach this state always the same number of time constants, independent of  $R$  and  $C$ . Why or why not?

(1 + 2 points)