PROBLEM SET 5

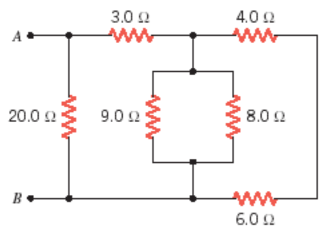
Due: 13 October 2020, 12.30 p.m.

Problem 1. Two conducting wires in the shape of cylinders of the same cross-sectional area, at $0°$ C have resistivities ρ_{01}, ρ_{02} and temperature coefficients of resistivity α_1 and α_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.

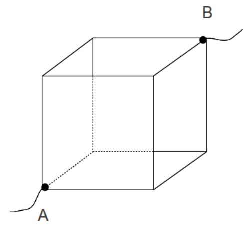
(*4 points*)



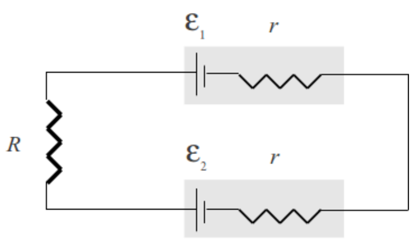
Problem 3. Twelve identical resistors, each of resistance R, are connected to form a cube-shaped circuit (see the figure). Find the equivalent resistance between points A and B.

Hint. Use symmetry.

(*4 points*)



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



(a) Find the current through the resistor R,

(b) and the total rate of dissipation of electrical energy in the resistor R and in the internal resistance of the batteries.

(c) In one of the batteries, chemical energy is being converted into electrical energy. In which one it is happening, and at what rate?

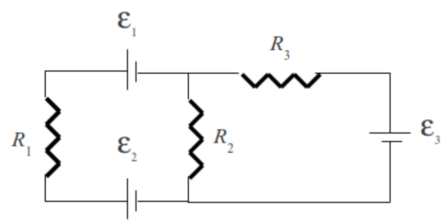
(d) In one of the batteries, electrical energy is being converted into chemical energy. In which one it is happening, and at what rate?

(e) Show that the overall rate of production of electrical energy is equal to the overall rate of consumption of electrical energy in the circuit.

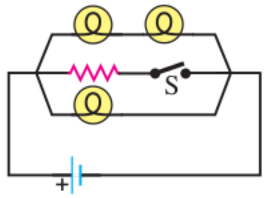
(*5 × 1 points*)

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

(*4 points*)

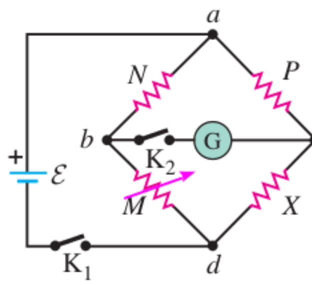


Problem 6. For the circuit shown in the figure below what happens to the brightness of the bulbs when the switch S is closed if the battery (a) has no internal resistance and (b) has non-negligible internal resistance? Explain why.



(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 X 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 $q(t_{\mathrm{d}})$ differs from zero by no more than the charge of one electron.

(a) Find t_{d} if $C = 0.92\ \mu$F, $R = 670$ kΩ, and $Q_{\max} = 7\ \mu$C.

(b) 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)