Prof. Anchordoqui

Problems set # 6 **Physics 169** March 24, 2015

1. Find the current I in the circuit shown Fig. 1.

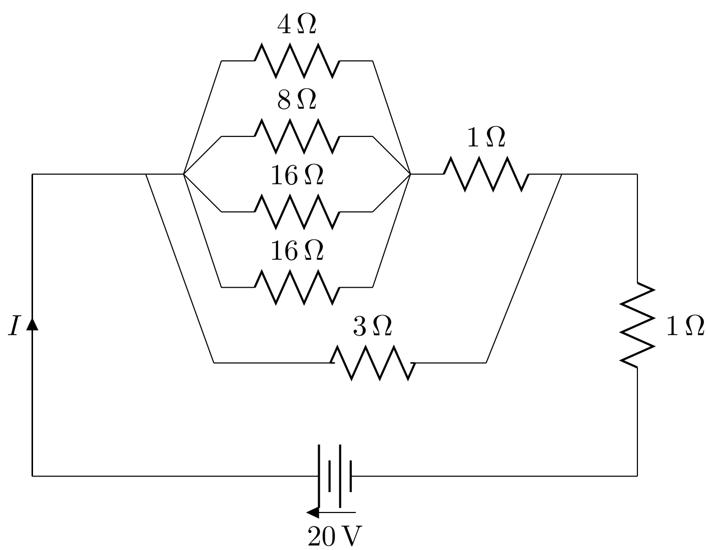

Figure 1: Problem 1.

2. In the circuit shown in Fig. 2, the power produced by bulb$_1$ and bulb$_2$ is 1 kW and 50 W, respectively. Which light has the higher resistance? (Assume the resitance of the light bulb remains constant with time.)

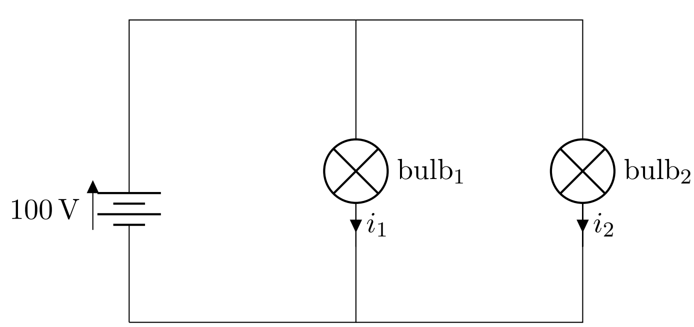

Figure 2: Problem 2.

3. A regular tetrahedron is a pyramid with a triangular base. Six $R = 10.0\ \Omega$ resistors are placed along its six edges, with junctions at its four vertices, as shown in Fig. 3. A 12.0-V battery is connected to any two of the vertices. Find *(i)* the equivalent resistance of the tetrahedron between these vertices and *(ii)* the current in the battery.

4. Find the equivalent resistance in the limit $n \to \infty$ for the circuits shown in Figs. 4 and 5.

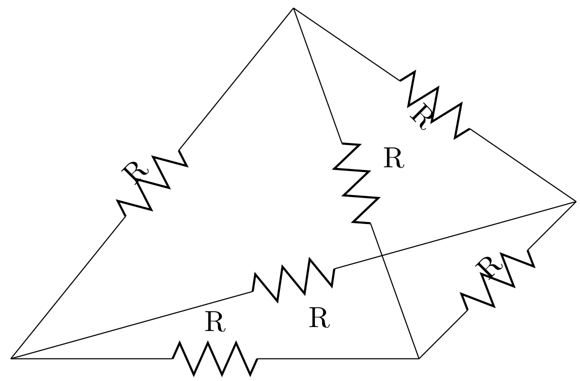

Figure 3: Problem 3.

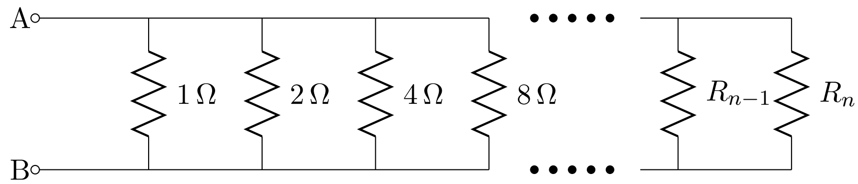

Figure 4: Problem 4 *(i)*.

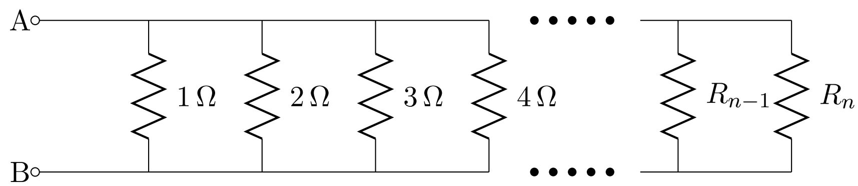

Figure 5: Problem 4 *(ii)*.

5. Determine the magnitude and directions of the currents through $R_1 = 22\ \Omega$ and $R_2 = 15\ \Omega$ in the circuit of Fig. 6. The batteries have an internal resistance of $r = 1.2\ \Omega$.

6. Determine the magnitude and directions of the currents in each resistor shown in Fig. 7. The batteries has emfs of $\varepsilon_1 = 9$ V and $\varepsilon_2 = 12$ V and the resistors have values of $R_1 = 25\ \Omega$, $R_2 = 18\ \Omega$, and $R_3 = 35\ \Omega$.

7. For the circuit shown in Fig. 8, calculate *(i)* the current in the 2.00 Ω resistor and *(ii)* the potential difference between points a and b.

8. Consider the circuit shown in Fig. 9, with the start up switch T_1 open (for a long time). Now, close the switch and wait for a while. What is the change in the total charge of the capacitor?

9. The circuit in Fig. 10 has been connected for a long time. *(i)* What is the voltage across the capacitor? *(ii)* If the battery is disconnected, how long does it take the capacitor to discharge to one tenth of its initial voltage?

10. Find the voltage across A and B (i.e. V_{AB}) as a function of time in the circuit shown in

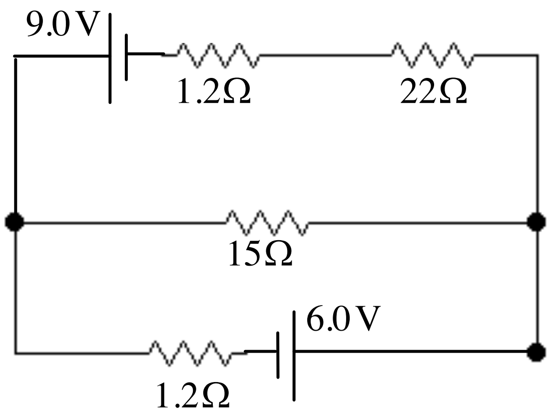

Figure 6: Problem 5.

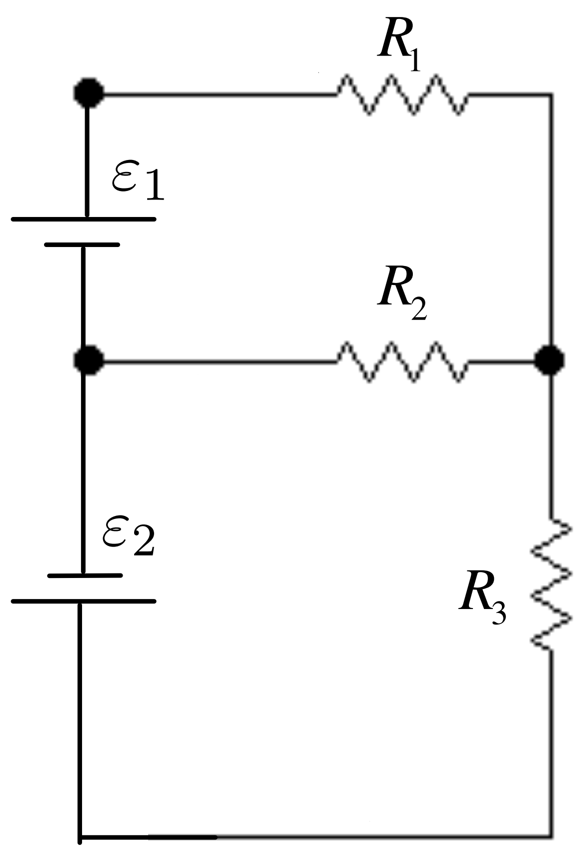

Figure 7: Problem 6.

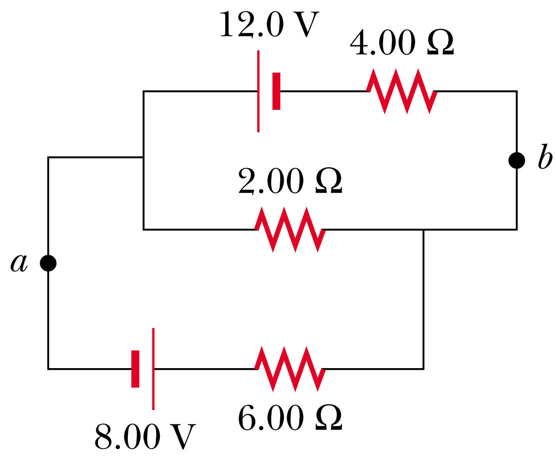

Figure 8: Problem 7.

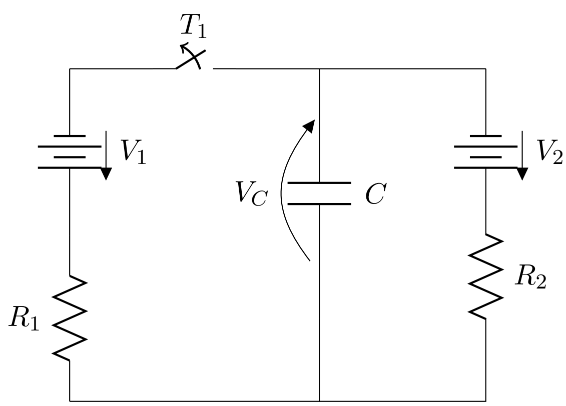

Figure 9: Problem 8.

Fig. 11.

Enrichment Probelms

11. The switch in Fig. 12*(a)* closes when $\Delta V_c > 2\Delta V/3$ and opens when $\Delta V_c < \Delta V/3$. The voltmeter reads a voltage as plotted in Fig. 12*(b)*. What is the period T of the waveform in terms of R_1, R_2, and C?

12. This problem illustrates how a digital voltmeter affects the voltage across a capacitor in an RC circuit. A digital voltmeter of internal resistance r is used to measure the voltage across a capacitor after the switch in Fig. 13 is closed. Because the meter has finite resistance, part of the current supplied by the battery passes through the meter. *(i)* Apply Kirchhoff's rules to this

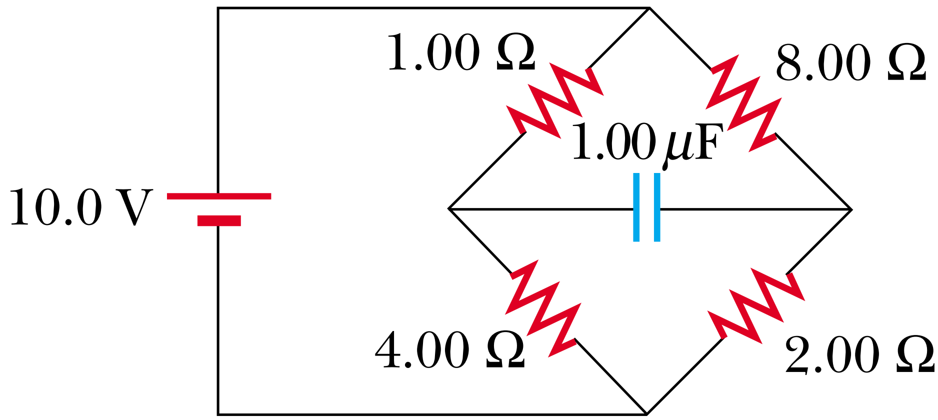

Figure 10: Problem 9.

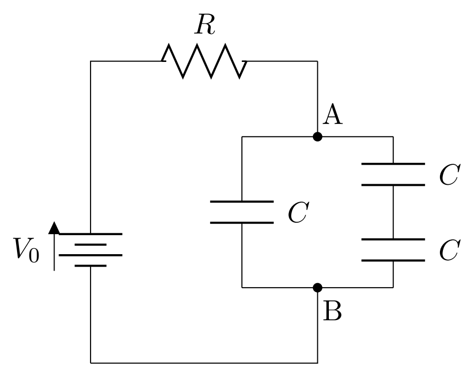

Figure 11: Problem 10.

circuit, and use the fact that $i_C = dq/dt$ to show that this leads to the differential equation

$$R_{\mathrm{eq}}\frac{dq}{dt} + \frac{q}{C} = \frac{r}{r+R}\mathcal{E},$$

where $R_{\mathrm{eq}} = rR/(r+R)$. *(ii)* Show that the solution to this differential equation is

$$q = \frac{r}{r+R}C\mathcal{E}\left(1 - e^{-t/(R_{\mathrm{eq}}C)}\right)$$

and that the voltage across the capacitor as a function of time is

$$V_C = \frac{r}{r+R}\mathcal{E}(1 - e^{-t/(R_{\mathrm{eq}}C)}).$$

(iii) If the capacitor is fully charged, and the switch is then opened, how does the voltage across the capacitor behave in this case?

13. When two slabs of n-type and p-type semiconductors are put in contact, the relative affinities of the materials cause electrons to migrate out of the n-type material across the junction to the p-type material. This leaves behind a volume in the n-type material that is positively charged and

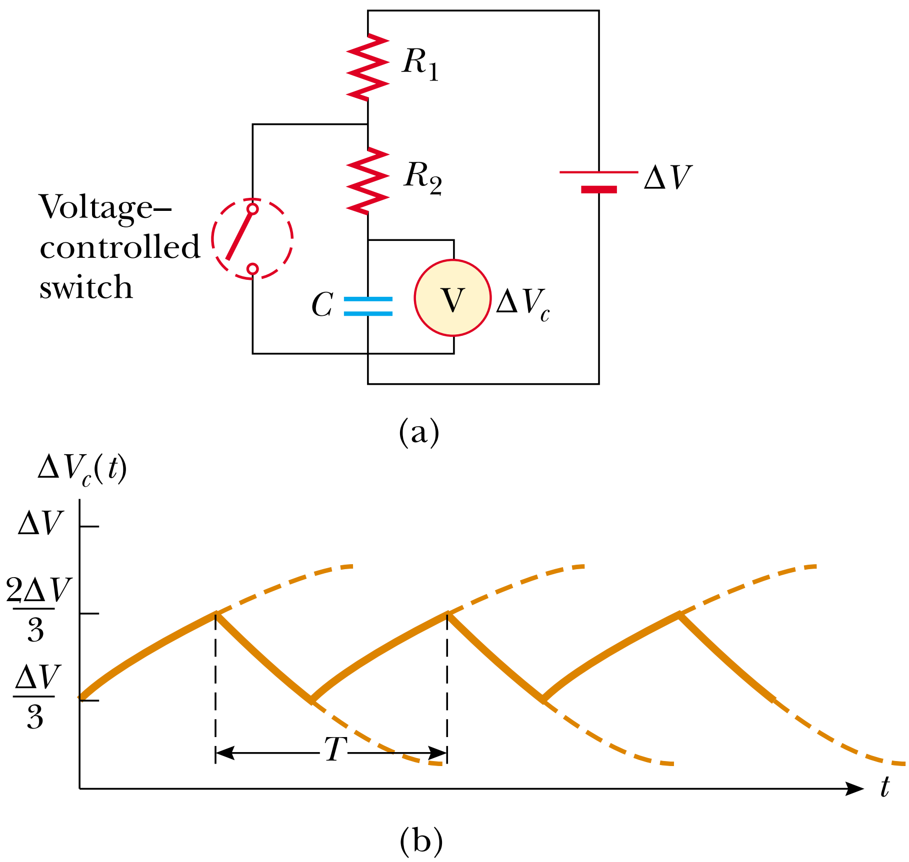

Figure 12: Problem 11.

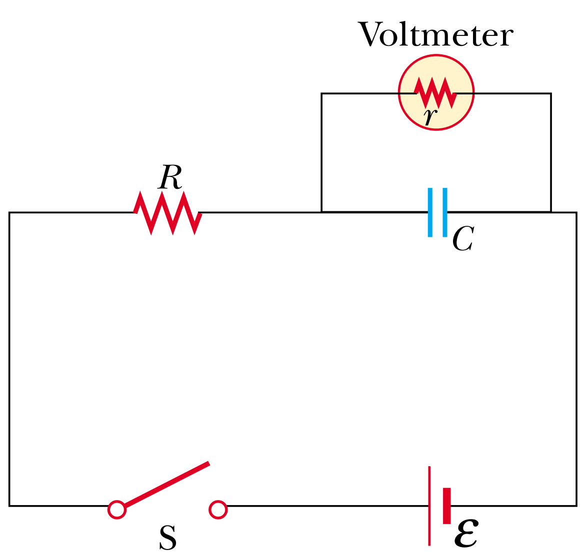

Figure 13: Problem 12.

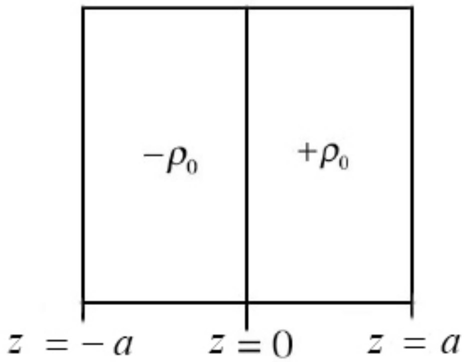

Figure 14: Problem 13.

creates a negatively charged volume in the p-type material. Let us model this as two infinite slabs of charge, both of thickness a with the junction lying on the plane $z = 0$. The n-type material lies in the range $0 < z < a$ and has uniform charge density $+\rho_0$. The adjacent p-type material lies in the range $-a < z < 0$ and has uniform charge density $-\rho_0$; see Fig. 14. Hence:

$$\rho(x, y, z) = \rho(z) = \begin{cases} +\rho_0 & 0 < z < a \\ -\rho_0 & -a < z < 0 \\ 0 & |z| > a \end{cases} .$$

(i) Find the electric field everywhere. *(ii)* Find the potential difference between the points P_1 and P_2. The point P_1 is located on a plane parallel to the slab a distance $z_1 > a$ from the center of the slab. The point P_2 is located on plane parallel to the slab a distance $z_2 < -a$ from the center of the slab.