2 Chapter 9: Current and Resistance

1. An ECG monitor must have an RC time constant less than 100μs to be able to measure variations in voltage over small time intervals. (a) If the resistance of the circuit (due mostly to that of the patients chest) is 1.00 kΩ, what is the maximum capacitance of the circuit? (b) Would it be difficult in practice to limit the capacitance to less than the value found in (a)? (c) If the patient's resistance really is 1.00 kΩ, and the typical maximum amplitude of the patient's heartbeat is 60 mV, when does the voltage rise to 30 mV in the EKG monitor (using the C you found in (a))?

a) $t = 100\mu s \rightarrow 1\times10^{-4}$ s

$\Omega = 1.00 k\Omega \rightarrow 1\times10^{3} \Omega$

$t = Cr \rightarrow C = \frac{t}{r}$

$C = \frac{1\times10^{-4}}{1\times10^{3}} = \boxed{1\times10^{-7} F}$

b) No, it wouldn't be difficult to limit the capacitance.

c) $V_C(t) = \epsilon_1(1-\exp(-t/T)) \rightarrow V = V_0(1-\exp(-t/T))$

$\Omega = 1\times10^{3}$ $T = 1\times10^{-4}$

$V_0 = .06V$

$V = .03V$

$0.03 = 0.06(1-\exp(t/1\times10^{-4}))$

$0.5 = \exp(-t/1\times10^{-4})$

$\ln(.5) = \ln(\exp(-t/1\times10^{-4}))$

$-0.693 = \frac{-t}{1\times10^{-4}}$

$-6.931\times10^{-5} = t$

$\boxed{t = -6.931\times10^{-5}}$

2. Imagine an *alternating current* (AC) system, as opposed to the DC systems we normally consider. In AC circuits, the voltage follows a form

$$V(t) = V_0 \sin(2\pi f t + \phi) \quad (1)$$

The wall outlets in the USA have $f = 60$ Hz and $V_0 = 120$ V. *We have the freedom to choose ϕ in this example, much like choosing the zero-point of voltage.* (a) Suppose $\phi = 0$. At what times will $V(t) = 0$? (b) What is the max power delivered to a 1kΩ resistor? (c) What is the *average* power delivered to a 1kΩ resistor?

a) $f = 60Hz, V_0 = 120v, \phi = 0, V(t) = 0$

$V(t) = V_0 \sin(2\pi f t + \phi)$

$0 = 120\sin(2\pi(60)t)$

$0 = \sin(120\pi t)$

$120\pi t = \pi$

$120t = 1$

$\boxed{t = \frac{1}{120}}$

b) $1000\Omega \rightarrow 1\times10^{3}\Omega$

$P_{Max} = \frac{V_0^2}{R} = \frac{(120)^2}{1000} = \frac{1.44\times10^4}{1000} = \boxed{1.44\times10^{1} \text{ Watts}}$

c) P_{Avg} would be = 0W as voltage rangs from 120Ω to -120Ω

3. **For those of us stuck at home!** A physics student has a single-occupancy dorm room. The student has a small refrigerator that runs with a current of 3.00 A and a voltage of 110 V, a lamp that contains a 100-W bulb, an overhead light with a 60-W bulb, and various other small devices adding up to 3.00 W. In Southern California, electricity costs about 0.2 dollars per kiloWatt-hour. How much money does this student spend if the total wattage is on for 12 hours per day for one month?

$P = IV$

$P_t = (3(110)) + (100+60+3)$

$= 493$ watts

$E_t = 493(12)(30)$

$= 1.7748\times10^{5}$ W/hr $\rightarrow$ 177.48 kW/hr

$(177.48)(.2) = \boxed{\$35.50}$

3 Chapter 10: Direct-Current (DC) Circuits

$V - I_2R - I_1R = 0$

$V - I_3R - I_1R = 0$

$I_1 = I_2 + I_3$

$\cancel{V} - I_2R - \cancel{I_1R} = \cancel{V} - I_3R - \cancel{I_1R}$

$-I_2R = -I_3R$

$I_2 = I_3$

$I_1 = 2I_2$

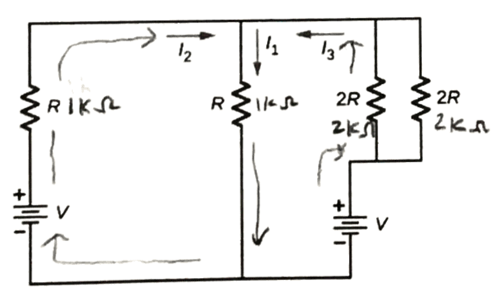

Figure 1: A circuit with two batteries and three resistors.

$V = 12v, \Omega = 1k\Omega$

$12 - i_2(1000) - i_1(1000) = 0$

$-i_2 - i_1 = \frac{12}{1000}$

$-3i = -0.012$

$i_2 = 0.004A$

$\therefore i_3 = 0.004A$

$\boxed{i_1 = 2i_2 = i_2 + i_3 = 0.008A}$

1. Solve for i_1, i_2, and i_3 in Fig. 1, if $R = 1k\Omega$, and $V = 12.0$ Volts. What power is consumed in the resistors?

Power Consumption would be .008W each for the two resistors in Parallel.

$\boxed{R \text{ in } I_1: .064W, \; R \text{ in } I_2: 0.016W}$

2. Suppose an electronic device with resistance R needs between 1.4 and 2.0 volts to operate. Two AA batteries with $\epsilon = 1.5$V and $r = 0.25\Omega$ are connected (Fig. 2) in parallel with the device. (a) If $R = 50\Omega$, what is the current flow? (b) If the batteries each have a charge $q = 2.5$ A hr, how long will the current flow?

a) $\epsilon = 1.5v$

$r = .25\Omega$

$R = 50\Omega$

b) $q = 2.5\ \text{Ahr}$, $I = \frac{q}{t}$, $t = \frac{q}{I}$

$t = \frac{2.5}{2.9925\times10^{-2}} = \boxed{83.542\ \text{hr}}$

$\epsilon - I_2 r - (I_1 + I_2)50 = 0$

$\epsilon - I_2 r - (2I_2)50 = 0$

$1.5 - I_2(.25) - (2I_2)50 = 0$

$-I_2(.25) - (2I_2)50 = -1.5$

$-100.25 I_2 = -1.5$

$\boxed{I_2 \approx 1.496\times10^{-2}\ A \quad \therefore I_1 \approx 1.496\times10^{-2}\ A \quad \therefore I \approx 2.9925\times10^{-2}\ A}$

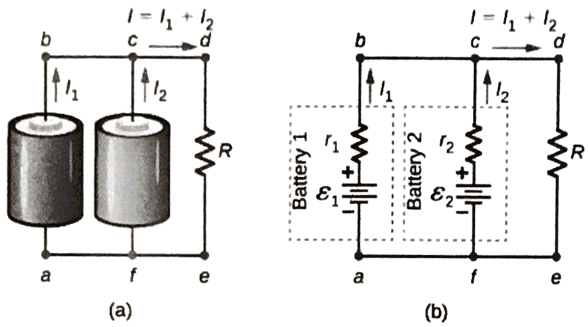

Figure 2: Two AA batteries are connected *in parallel* to power a calculator represented by R. (a) The batteries are connected in parallel. (b) A circuit diagram representing the circuit in (a).

4 Chapter 11: Magnetic Forces and Fields

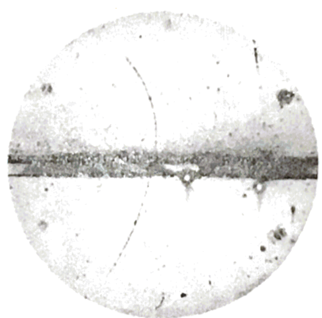

Figure 3: The trajectory of a sub-atomic particle through a cloud chamber.

1. The experimental result depicted in Fig. 3 shows the trajectory of a sub-atomic particle that is revealed by a device called a *cloud chamber.* The particle bends to the *left* after passing through a lead plate. (a) The magnetic field is *into the page.* What is the sign of the charge of this particle? (b) It was later deduced that this particle had the mass of an elecron, from the radius of curvature. Why is that strange? (c) Imagine the B-field had a strength of 0.05 T and the velocity of the paricle was 10^6 m/s. What was the force on the particle, and in what direction was the force?

a) Positive

b) Due to the mass of the particle being the same as an electron, it is strange as electrons are negatively charged.

c) $B = 0.05T$, $V = 10^6 m/s$, $F = ?$

$F = q\vec{v}\times\vec{B} = 1.6\times10^{-19}\cdot 10^6 \cdot 0.05 = \boxed{8\times10^{-15}\ N}$ | Moving to left, $-x$ direction