

2. Suppose an electronic device with resistance  $R$  needs between 1.4 and 2.0 volts to operate. Two AA batteries with  $\epsilon = 1.5\text{V}$  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  $q = 2.5\text{ A hr}$ , how long will the current flow?

$$a) i_1 r_1 - i_2 r_2 + \epsilon_2 - \epsilon_1 = 0$$

$$i_1 = i_2$$

$$i_2 r_2 - (i_1 + i_2) r = \epsilon_2 = 0$$

$$.25 i_2 - (i_2 + i_2)(.50) - 1.5 = 0$$

$$i_2 = .015\text{ A}$$

$$CF = 2(.015) = .030\text{ A}$$

Current Flow

$$b) q = 2.5\text{ A hr}$$

$$I = 2q / t$$

$$t = 2q / I$$

$$t = 2(2.5) / .030$$

$$t = 166.67\text{ hr}$$

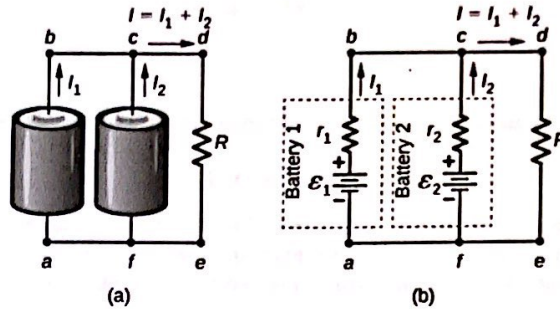


Figure 2: Two AA batteries are connected in parallel to power a calculator represented by  $R$ . (a) The batteries are connected in parallel. (b) A circuit diagram representing the circuit in (a).

#### 4 Chapter 11: Magnetic Forces and Fields

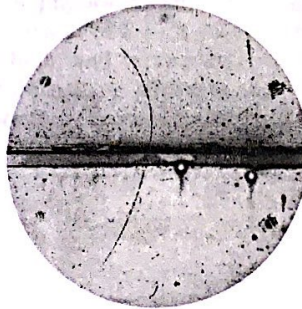


Figure 3: The trajectory of a sub-atomic particle through a cloud chamber.

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 electron, from the radius of curvature. Why is that strange? (c) Imagine the B-field had a strength of  $0.05\text{ T}$  and the velocity of the particle was  $10^6\text{ m/s}$ . What was the force on the particle, and in what direction was the force?

$$a) \text{ positive}$$

b) It is strange because it has the mass of an electron but it is positively charged unlike the electron which is negatively charged.

$$c) F = qvB \sin \theta$$

$$F = 1.6 \times 10^{-19} \times 10^6 \times 0.05 \times \sin 90$$

$$F = 8.0 \times 10^{-15}\text{ N}$$

Force is left  
(Fleming's left hand rule)

## 2 Chapter 9: Current and Resistance

1. An ECG monitor must have an RC time constant less than  $100\mu\text{s}$  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 patient's chest) is  $1.00\text{ k}\Omega$ , 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  $1.00\text{ k}\Omega$ , and the typical maximum amplitude of the patient's heartbeat is  $60\text{ mV}$ , when does the voltage rise to  $30\text{ mV}$  in the EKG monitor (using the C you found in (a))?

a)  $\tau = RC$

$$(1.0 \times 10^3 \Omega) C < 1.0 \times 10^{-4} \text{ s}$$

$$\Rightarrow C < 1 \times 10^{-7} \text{ F}$$

$$C < 100 \text{ nF}$$

$$\boxed{\text{Max cap.} = 100 \text{ nF}}$$

b) No, because the value of time constant is  $\tau < 1.0 \times 10^{-4} \text{ s}$ , which can be used with lower capacitance.

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

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

The wall outlets in the USA have  $f = 60\text{ Hz}$  and  $V_0 = 120\text{ V}$ . We have the freedom to choose  $\phi$  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  $1\text{ k}\Omega$  resistor? (c) What is the average power delivered to a  $1\text{ k}\Omega$  resistor?

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

$$V(t) = 120 \sin(2\pi t + 0)$$

$$V(t) = 0 \text{ when } \sin(2\pi t) = 0 \Rightarrow t = 0, 0.5, 1, \dots$$

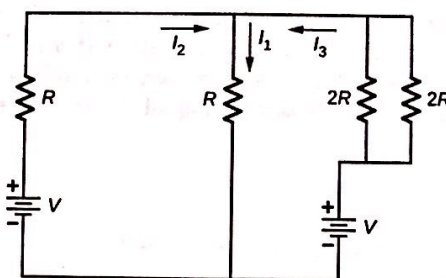
b)  $P_{\text{max}} = \frac{1}{10^3} \times (120)^2 = \frac{14400}{10^3} = \boxed{14.4 \text{ W}}$

c)  $P_{\text{avg}} = \left\langle \frac{V(t)^2}{R} \right\rangle$   
 $= \frac{1}{2} \cdot \frac{V_0^2}{R}$   
 $= \frac{1}{2} \times 14.4 = \boxed{7.2 \text{ W}}$

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  $3.00\text{ A}$  and a voltage of  $110\text{ V}$ , a lamp that contains a  $100\text{-W}$  bulb, an overhead light with a  $60\text{-W}$  bulb, and various other small devices adding up to  $3.00\text{ W}$ . 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?

$$\frac{63 \text{ W} \cdot 360 \text{ h}}{1000} = \frac{22680 \text{ Wh}}{1000} = 22.68 \text{ kWh} \cdot (0.2) = \boxed{\$4.536}$$

## 3 Chapter 10: Direct-Current (DC) Circuits



$$\frac{V-12}{1000} + \frac{V}{1000} + \frac{V-12}{1000} = 0$$

$$3V = 24 \quad \Rightarrow V = 8 \text{ V}$$

$$i_1 = 0 \text{ mA} \quad i_2 = 4 \text{ mA} \quad i_3 = 4 \text{ mA}$$

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

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

$$(8^2 + 4^2 + 4^2) \times 10^{-6} \times 1000 = \boxed{0.096 \text{ W}}$$