

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 mV , when does the voltage rise to 30 mV in the EKG monitor (using the C you found in (a))?

a) $C = 1 \times 10^{-7}\text{ F}$

b) wouldn't be hard

c) $t = 69.31\mu\text{s}$

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 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 $1\text{ k}\Omega$ resistor? (c) What is the average power delivered to a $1\text{ k}\Omega$ resistor?

a)

b) $P = 14.4\text{ W}$

c)

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?

Power of (frige) = $P = 330\text{ W}$ total power consumption = 493 W in one hour

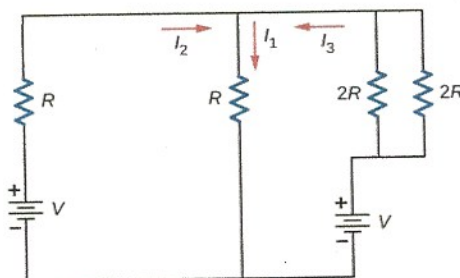
12 hour $W_{\text{tot}} = 12 \times 493 = 5,916\text{ Wh}$

1 month $W_{\text{t}} = 30 \times 493 = 177,480$

the cost for one month = $\frac{177,480}{1,000\text{ kWh}} = 177.48\text{ dollars}$

$= \$35.5$

3 Chapter 10: Direct-Current (DC) Circuits



$I_2 = 4\text{ mA}$
 $I_3 = 4\text{ mA}$
 $I_1 = 8\text{ mA}$
 $P_{\text{tot}} = 96\text{ mW}$

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?

2. Suppose an electronic device with resistance R needs between 1.4 and 2.0 volts to operate. Two AA batteries with $\mathcal{E} = 1.5\text{V}$ 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)
$$\begin{aligned} I_2 &= 0.015\text{ A} \\ I_1 &= 0.015\text{ A} \\ I &= 0.030\text{ A} \end{aligned}$$

b)
$$t = 166.6\text{ hrs}$$

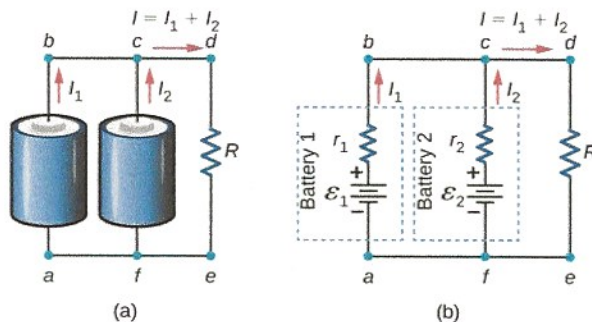


Figure 2: Two AA batteries are connected *in parallel* to power a calculator represented by R . (a) The batteries are connected in parallel. (b) A circuit diagram representing the circuit in (a).

4 Chapter 11: Magnetic Forces and Fields

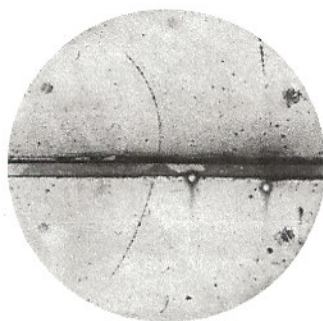


Figure 3: The trajectory of a sub-atomic particle through a cloud chamber.

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 T and the velocity of the particle was 10^6 m/s . What was the force on the particle, and in what direction was the force?

a) the charge is positive

c)
$$F = 8 \times 10^{-14}\text{ N} \quad \text{—upwards}$$

b)

Work for Midterm 2

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3/27/2020

Midterm 2.

1) RC $t = 100 \mu s$ $R = 1.00 \text{ k}\Omega$

a) $t = R \cdot C$ $100 \mu s$ b) no it would be hard

$$C = t/R$$

$$= 100 \times 10^{-6} / 1 \times 10^3$$

$$\boxed{C = 1 \times 10^{-7} \text{ F}}$$

c) $V_C(t) = \mathcal{E}_i (1 - e^{t/\tau})$ $\tau = 100 \mu s$

$$30 = 60 (1 - e^{t/(100 \mu s)})$$

$$\frac{1}{2} = 1 - e^{t/100}$$

$$e^{t/100} = \frac{1}{2}$$

$$\ln\left(\frac{1}{2}\right) = -\ln 2$$

$$t = 100 \ln 2$$

$$\boxed{t = 69.31 \mu s}$$

2) a) $V(t) = V_0 \sin(2\pi f t + \phi)$ $f = 60 \text{ Hz}$ $V_0 = 120 \text{ V}$

$$V(t) = 0 \quad t = ? \quad V(t) = 120 \sin(2\pi f t)$$

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

$$0 = \sin(2\pi f t)$$

b) $P = V^2/R$

$$V_{\text{max}} = V(t) = V_0 \sin(2\pi f t)$$

$$V_{\text{max}} = 120 \sin(2\pi f t)$$

$$V_{\text{max}} = 120 \text{ V}$$

$$P = \frac{120^2}{1000}$$

$$\boxed{P = 14.4 \text{ W}}$$

c) ?

3 $I = 3.00 \text{ A}$ $V = 110 \text{ V}$ 100 W 60 W , 3.00 W
 0.2 kilo W-h

power for the fridge $= 110 \text{ V} \times 3.0 \text{ A}$
 $P = 330 \text{ W}$

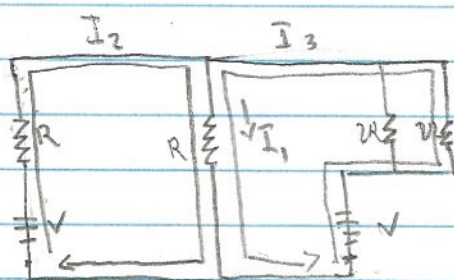
the total power consumption $= (330 + 100 + 60 + 3.0)$
 $= 493 \text{ W}$ in one hour

for 12 hour $W_+ = 12 \times 493 = 5,916 \text{ Wh}$

for a month $W_b = 30 \times 493 = 177,480$

the cost $= 0.2 \text{ dollars for } 1 \text{ kWh}$

$\frac{177,480}{1,000 \text{ Wh}} = 177.48 \text{ Wh} \times 0.2 = \35.5



$I_1 = I_2 + I_3$

$\mathcal{E}_1 - I_2 R - I_1 R = 0$

$\mathcal{E}_1 = I_2 R - I_2 R - I_3 R$

$\mathcal{E}_1 = I_2 x + I_3 R$

$R + R = x$

$2R = x$

$\mathcal{E}_2 - I_3 R - I_1 R = 0$

$\mathcal{E}_2 = I_3 R + I_2 R + I_3 R$

$= 2I_3(R) + I_2 R$

$\mathcal{E}_2 = 2(I_3 x + I_2 R)$

$\frac{\mathcal{E}_2 - I_2 R}{2x} = I_3$

$I_3 = \frac{\mathcal{E}_2 - I_2 R}{2R} = \frac{\mathcal{E}_2 - I_2}{2} = \boxed{I_3 = 4 \text{ mA}}$

$I_1 = 4 \text{ mA} + 4 \text{ mA}$

$\boxed{I_1 = 8 \text{ mA}}$

Power $= I_1^2 R + I_2^2 R + I_3^2 R$

$= 8 \text{ mA}^2 (1 \text{ k}) + 4 \text{ mA}^2 (1 \text{ k}) + 4 \text{ mA}^2 (1 \text{ k})$

$\boxed{P_{\text{tot}} = 96 \text{ mW}}$

$\mathcal{E}_1 = I_2 x + \left(\frac{\mathcal{E}_2 - I_2 R}{2x} \right) R$

$\mathcal{E}_1 = I_2 x + \mathcal{E}_2 \frac{R}{2x} - I_2 \frac{R^2}{2x}$

$\mathcal{E}_1 - \mathcal{E}_2 \frac{R}{x} = I_2 \left(x - \frac{R^2}{2x} \right)$

$\frac{\mathcal{E}_1 - \mathcal{E}_2 \frac{R}{x}}{x - \frac{R^2}{2x}} = I_2$

$\frac{2x\mathcal{E}_1 - \mathcal{E}_2 R}{2x^2 - R^2} = I_2$

$\frac{2x\mathcal{E}_1 - \mathcal{E}_2 R}{2x^2 - R^2} = \frac{2\mathcal{E}_1 - \mathcal{E}_2}{3 \text{ k}} = 0.004 \text{ amp} = 4 \text{ mA}$

$\boxed{I_2 = 4 \text{ mA}}$

② $\mathcal{E}_1 = 1.5\text{V}$ $r = 0.25\Omega$ } connect in parallel

$\mathcal{E}_2 = 1.5\text{V}$ $r = 0.25\Omega$

$R = 50\Omega$ $I = ?$

$I = I_1 + I_2$

$R_{\text{int}}^{-1} = \frac{1}{0.25} + \frac{1}{0.25} + \frac{1}{50}$

$R_{\text{int}}^{-1} = 8.02\Omega$

$\mathcal{E}_1 - I_1 r_1 - I_2 r_2 - \mathcal{E}_2 = 0$

$1.5 - I_1 \times 0.25 + I_2 \times 0.25 - 1.5 = 0$

$I_2 \times 0.25 = I_1 \times 0.25$

$I_2 = \frac{I_1 \times 0.25}{0.25}$

$I_2 = I_1$

$I_2 = 0.015\text{A}$

$I_1 = 0.015\text{A}$

$I = I_1 + I_2$

$I = 0.015 + 0.015$

$I = 0.030\text{A}$

$\mathcal{E}_2 - I_2 \times r_2 - IR = 0$

$1.5 - I_2 \times 0.25 - (I_1 + I_2)R = 0$

$I_2 r_2 + (I_1 + I_2)R = \mathcal{E}_2 = 0$

$I_2 (r_2 + 2R) - \mathcal{E}_2 = 0$

$I_2 (0.25 + 2 \times 50) = 1.5$

$I_2 = \frac{1.5}{0.25 + 2 \times 50}$

$I_2 = 0.015\text{Amps}$

b) $q = 7.5\text{A hr}$

$t = \frac{q}{I}$

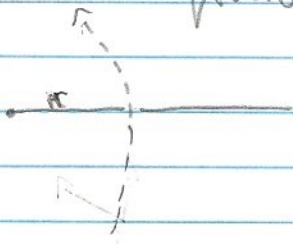
$t = \frac{24}{I} = \frac{2(2.5)}{0.030}$

$t = 166.6\text{ hrs}$

4

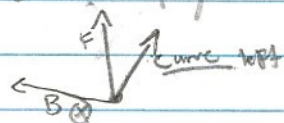
(1a) B \otimes into the page

$$F = q(\vec{v} \times \vec{B})$$



force is up making the charge positive

moving to the left B is into the page
making force up.



(b) $F = q(v \times B) = \frac{mv^2}{r}$

$$qvB = \frac{mv^2}{r}$$

$$r = \frac{mv}{Bq}$$

(c) $B = 0.05T \quad v = 10^6 \text{ m/s}$

$$F = q(v \times B)$$

$$F = (1.6 \times 10^{-19})(10^6)(0.05)$$

$$F = 8 \times 10^{-14} \text{ N} \quad \text{- upwards}$$