

Chap 17 Electric Current and resistance

Dr. Coman

CREDITS

- - College Physics, Serway
 - <http://hyperphysics.phy-astr.gsu.edu>
 - [The McGraw-Hill Companies.](#)
 - Physics with health science applications, Urone, John Wiley and Sons
 - www.prenhall.com/esm_wilson_physics
 - <http://www.walter-fendt.de/ph11e>
 - <http://www.lon-capa.org/~mmp/>
 - [SERWAY COLLEGE PHYSICS 7E MEDIA LIBRARY](#)

Objectives I

- Recognize the quantum nature of the electric charge;
- Explain the interaction between electric charges;
- Use Coulomb's law to solve problems involving charge distributions;
- Explain the concept of force fields
- Use the concept of electric fields to explain action at a distance;



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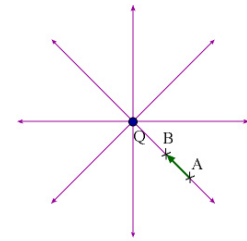
Voltage - electric potential energy

- It may take work to move a charge in an electric field
- Situation: there is an excess of a + charge. q^+ in the vicinity of an object having a positive charge Q .
- The test charge feels a repulsive Coulomb force and therefore has electrical potential energy due to its position.
- If the test charge is free to move from position A to position B, the Coulomb force will do work on it
- The work done on the test charge in moving it from A to B is

$$W = PD = V_{AB} \cdot q \rightarrow$$

$$V_{AB} = \frac{W}{Q}$$

- Automobiles use 12V batteries, flashlights use one or more 1.5V batteries, and household appliances run on 120 or 220V electricity.

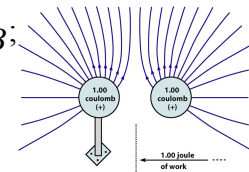


Voltage - electric potential energy

- The potential difference PD that is created by doing 1.0 joule of work in moving 1.0 coulomb of charge is defined as 1.0 volt;
- A volt is a measure of the potential difference between two points: V_{AB} ;

$$V_{AB} = \frac{W}{Q}$$

- Electric potential results from moving a positive coulomb if charge into the electric field of a second positive coulomb of change.
- 1 volt is 1 $\frac{joe}{coulomb}$.

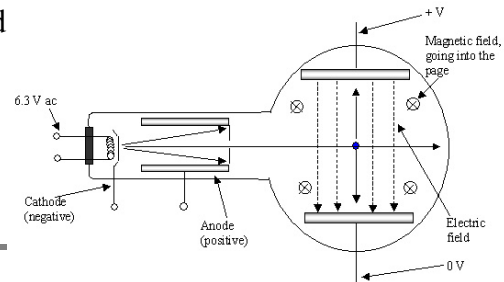


Charges moved by voltages: CRT

- The energy given to a charge by a voltage can be calculated by solving the definition of voltage equation for the change in potential energy:

$$\hat{A} \quad V = \frac{W}{q}$$

- A TV = CRT :
- electrons that are freed from atoms and accelerated toward a phosphor coated screen.
- When the electrons strike the phosphor, part of their energy is converted to visible light.
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Current : the flow of charge

- Electric current means a flow of charge in the same way that a water current flows.
- It is the charge that flows, and the current is defined as the rate flow of the charge.

$$I = \frac{q}{t} \rightarrow \text{the units for } I \text{ are } \frac{C}{s} = \text{Ampere}$$

- Pocket calculator: $I = 0.0003 \text{ A}; V = 3 \text{ V}$
- ECG monitor: $I = 2 \text{ A}; V = 120 \text{ V}$
- Pacemaker: $I = 0.01 \text{ A}; V = 5 \text{ V}$
- Lightning bolt: $I = 20,000 \text{ A}; V = 100,000,000 \text{ V}$
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Conductors and Insulators

- Materials are classified according to their ability to conduct electricity -conductivity.
- Metal atoms usually have their outermost (i.e. valence) electron(s) attached to their parent nucleus rather weakly.
 - can flow freely
 - conductors
- Insulators
 - valence electrons are tightly bound
 - few free electrons, thus no conduction of charge.
 - Glass, rubber, plastics, ceramics,
- Semiconductors are somewhere in between these two extremes: germanium...

Currents : applications Problem

- A defibrillator can sometimes restore a normal heartbeat. Suppose the defibrillator passes 6 A of current through the heart for 0.01 sec. How much charge passes through the heart in this event? (The current and charge passing through the torso are larger).
- Solution:

$$I = \frac{q}{t} \rightarrow q = I \cdot t = 6 \text{ A} \cdot 0.01 \text{ s}$$

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Bodily effects of electric currents

BODILY EFFECT	Direct Current (DC)	60 Hz AC	10 kHz AC
Slight sensation felt at hand(s)	Men = 1.0 mA	0.4 mA	7 mA
	Women = 0.6 mA	0.3 mA	5 mA
Threshold of perception <	Men = 5.2 mA	1.1 mA	12 mA
	Women = 3.5 mA	0.7 mA	
Painful but voluntary muscle control maintained	Women = 41 mA	9 mA	55 mA
	Men = 62 mA	6 mA	37 mA

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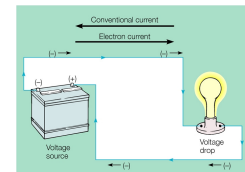
Currents bodily effects 2

BODILY EFFECT	Direct Current (DC)	60 Hz AC	10 kHz AC
Painful unable to let go of wires	Men = 76 mA	16 mA	75 mA
	Women = 51 mA	10.5 mA	50 mA
Severe pain difficulty breathing	Men = 90 mA	23 mA	94 mA
	Women = 60 mA	15 mA	63 mA
Possible heart fibrillation after 3 seconds	Men = 500 mA	100 mA	
	Women = 500 mA	100 mA	

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Direction of Current

- Conventional current describes current as positive charges, q^+ that flow from the positive to the negative terminal of a battery.
- The electron current description is the opposite of the conventional current.
- The electron current describes current as a drift of negative charges, q^- that flow from the negative to the positive terminal of a battery.
- It is actually the electron current that moves charges.



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Ohm's law application

- Ohm's law demonstrates how moisture affects low-voltage electrocutions
- Will the 120 volt common household voltage produce a dangerous shock? It depends!
- Under dry conditions:

$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} = \frac{120V}{100,000 \Omega} = 1.2mA$$

- a barely perceptible level of current.
- Under wet conditions:
 - sweaty and barefoot

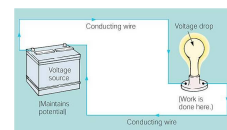
$$\text{Current} = \frac{\text{Voltage}}{\text{Resistance}} = \frac{120V}{1,000 \Omega} = 120 \text{ . } \text{miliA}$$

- sufficient current to cause ventricular fibrillation.
- Wet conditions are common during low-voltage electrocutions.
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Electric circuits

- A simple electric circuit has:
 - a voltage source (such as a generator or battery) that maintains the electrical potential
 - some device (such as a lamp or motor) where work is done by the potential,
 - continuous pathways for the current to follow.
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Ohm's law

- The electric current which will flow through conductors is directly proportional to the voltage applied to them.

$$V = I \cdot R \rightarrow$$

$$R = \frac{V}{I};$$

$$I = \frac{V}{R}$$

- LINK: Ohm's law jar file;

Power exercises II

- A 10Ω lightbulb is connected to a $12 V$ battery. a) What current flows through the bulb ?
- b) What is the power of the bulb ?

- Solution

$$I = \frac{V}{R} = \frac{12 V}{10 \Omega} = 1.2 A$$

$$P = \frac{V^2}{R} = \frac{12 V \cdot 12 V}{10 \Omega} = 14.4 \text{ Watts} = 14.4 \frac{J}{s}$$

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Electrical power

- Represents the rate at which energy is converted from the electrical energy of the moving charges to some other forms
- Rate at which electrical energy is spent;
 $P = V \cdot I$ expressed in $V \cdot A = Watt$

- Since

$$V = I \cdot R \rightarrow I = \frac{V}{R} \rightarrow$$

$$P = V \cdot \frac{V}{R} = \frac{V^2}{R}$$

$$P = I \cdot R \cdot R = I \cdot R^2$$

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$$\boxed{P = VI = \frac{V^2}{R} = I^2 R}$$

Electrical Power exercises

- A lightbulb designed to operate in a $120V$ circuit has a resistance R of 192Ω . At what rate does the bulb use electric energy ?

- Solution:

$$V = 120V$$

$$R = 192 \Omega \rightarrow$$

$$P = \frac{V^2}{R} = \frac{120 \cdot 120V^2}{192 \Omega} = \frac{14400}{192} \text{ Watts}$$

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Cost of electricity

$$\text{cost} = P \cdot t \cdot \text{rate}$$

- What is the monthly cost of leaving a 60 *Watts* lightbulb on continuously if electricity costs \$ 0.10 per *kWh*? What is a *kW · h* ?

$$1 \text{ kW} \cdot \text{h} = 1000 \text{ W} \cdot 3600 \text{ s} = 1000 \frac{\text{J}}{\text{s}} \cdot 3600 \text{ s} = 3,600,000 \text{ J} \rightarrow$$

$$\text{cost} = P \cdot t \cdot \text{rate} = 60 \text{ W} \cdot 1 \text{ m} \cdot 30.5 \frac{\text{d}}{\text{m}} \cdot 24 \frac{\text{h}}{\text{d}} \cdot 3600 \frac{\text{s}}{\text{h}} \cdot \frac{\$ 0.10}{\text{kW} \cdot 1000 \frac{\text{W}}{\text{kW}} \cdot \text{h} \cdot 3600 \frac{\text{s}}{\text{h}}}$$

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$$\text{cost} = 60 \cdot 30.5 \cdot 24 \cdot \frac{0.1}{1000} = \$ 4.4$$

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