

L 27 Electricity and Magnetism [4]

- simple electrical circuits – direct current DC
- Alternating current (AC) vs direct current (DC)
- electric power distribution
- household electricity
 - household wiring
 - Protection circuits - GFCI's
 - Electrocutation hazards
- the kilowatt-hour (what you pay for)

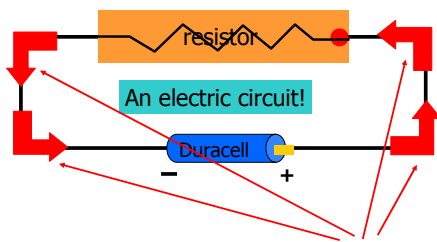
1

Electric circuits

- a circuit must provide a closed path for the current to circulate around
- when the electrons pass through the light bulb they lose some of their energy → the conductor (resistor) heats up
- we refer to conductors as resistors because they impede (resist) the flow of current.
- the battery is like a pump that re-energizes them each time they pass through it
- the direction of current flow is defined, by convention, to be the direction that positive charges would flow
- it is the direction opposite to the direction of electron flow.

2

Direction of current flow



The electrons go one way but the current goes the other way by convention.

3

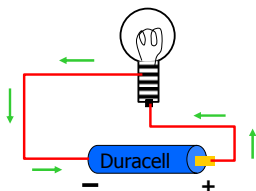
What is DC?

- With DC or direct current the current always flows in the same direction
- this is the type of current you get when you use a battery as the voltage source.
- the direction of the current depends on how you connect the battery
- the electricity that you get from the power company is not DC it is AC (alternating).

4

Direct Current DC

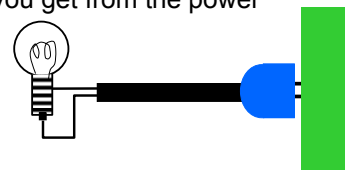
- a circuit containing a battery is a DC circuit
- in a DC circuit the current always flows in the **same direction**



5

Alternating Current (AC)

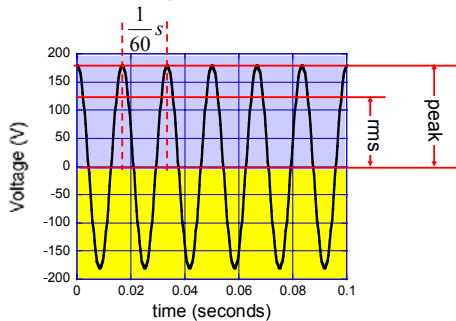
- In an AC circuit the current **reverses direction** periodically
- AC is what you get from the power companies



- Tesla and Edison fought over this, and Tesla won!

6

How does the line voltage change in time?



7

AC current

- The line voltage reverses polarity 60 times a second (60 Hertz) [see](#)
- the current through the bulb reverses direction 60 times a second also
- for heaters, hair dryers, irons, toasters, waffle makers, the fact that the current reverses makes no difference
- battery chargers (e.g., for cell phones) convert the AC to DC

8

Why do we use AC ?? (DC seems simpler ??)

- AC power is easier to generate
- late 1800's → the war of the currents
- Edison (DC) vs Tesla (Westinghouse) (AC)
- Edison opened the first commercial power plant for producing DC in NY in 1892
- Tesla who was hired by George Westinghouse believed that AC was superior
- Tesla was right, but Edison never gave up!

9

Why AC is better than DC

- DC power is provided at one voltage only
- AC power can be stepped up or down to provide any voltage required
- DC is very expensive to transmit over large distances compared to AC, so many plants are required
- DC power plants must be close to users
- AC plants can be far outside cities
- by 1895 DC was out and AC was in

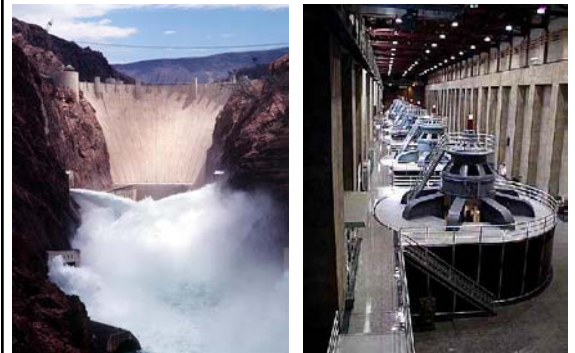
10

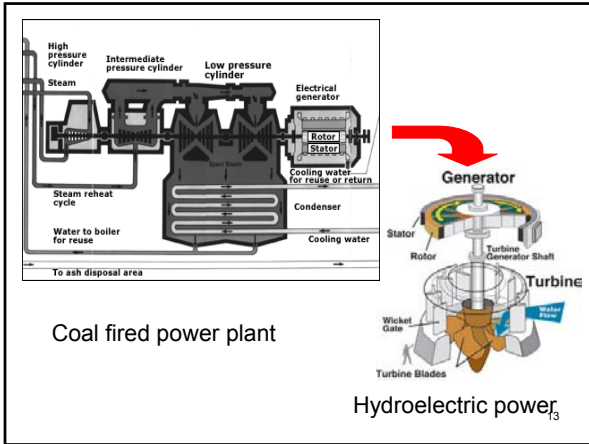
The electric generator

- When a coil of wire is rotated inside a magnet, electricity is produced
- <http://www.wvic.com/how-gen-works.htm>
- this electricity is AC
- the voltage depends on how much wire the coil has and how fast it is rotated.
- devices called **transformers** can make the voltage bigger or smaller
- transformers only work with AC ←

11

Hoover Dam





Wind Power

- Large wind turbine has diameter of about a football field
- Generates several megawatts of power
- Investment 1M\$/MW

UI power plant is 25 MW

14

Bodily Effects of Electrical Currents

BODILY EFFECT	DIRECT CURRENT (DC)	60 Hz AC	10 kHz AC
Slight sensation felt at hand (s)	Men = 1.0 mA Women = 0.6 mA	0.4 mA 0.3 mA	7 mA 5 mA
Threshold of perception	Men = 5.2 mA Women = 3.5 mA	1.1 mA 0.7 mA	12 mA 8 mA
Painful, but voluntary muscle control maintained	Men = 62 mA Women = 41 mA	9 mA 6 mA	55 mA 37 mA
Painful, unable to let go of wires	Men = 76 mA Women = 51 mA	16 mA 10.5 mA	75 mA 50 mA
Severe pain, difficulty breathing	Men = 90 mA Women = 60 mA	23 mA 15 mA	94 mA 63 mA
Possible heart fibrillation after 3 seconds	Men = 500 mA Women = 500 mA	100 mA 100 mA	

http://www.allaboutcircuits.com/vol_1/chpt_3/4.html

15

Transformers

This is a typical step-down transformers used to bring the line voltage down from 5000 V to 240 V before it gets to your home

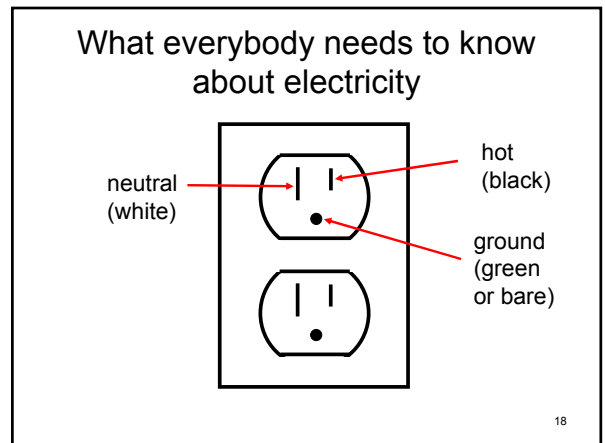
In your home two voltages are available: 240 V & 120 V. The 240 is used for the high power appliances like the clothes dryer, oven, etc. The 120 V is for everything else.

16

Circuit overload

- if you have too many things plugged into the same circuit, the voltage may drop.
- you may notice that a lamp plugged into the same outlet as a hair dryer dims a bit when you turn on the hair dryer because a hair dryer draws a lot of current
- according to Ohm $V = I R$, a big I can cause enough drop in the voltage to be noticeable!

17



Electric outlets

- The current is supposed to flow from the hot side to the neutral, if too much current flows the fuse blows or the circuit breaker trips.
- the ground is there for protection → to provide a safe path for current in the event of a short circuit
- on some circuits (kitchens and bathrooms) there is additional protection → **GFCI** → **ground fault circuit interrupt**. If current accidentally flows through anything other than the hot or neutral it interrupts the circuit very quickly

19

Man says live wire in bath was to save marriage

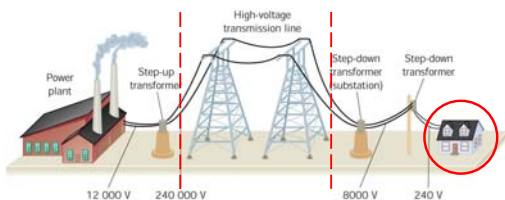
Thursday, October 28, 2004 Posted: 7:53 AM EDT (1153 GMT)

LA CROSSE, Wisconsin (AP) -- A man who said he threw a live electrical wire into his wife's bath hoping a near-death experience would save their marriage was convicted of attempted first-degree intentional homicide Wednesday.

William Dahlby said in court he was only trying to scare his wife the evening of May 9. He told jurors the wire was hooked to a "**ground fault interrupter**" designed to cut the electricity when the cord encountered water. His wife was not hurt.

20

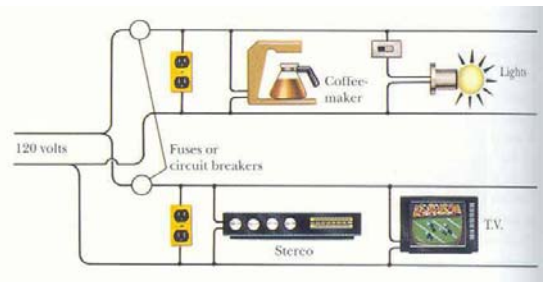
Electric power generation and distribution



- electrical power **$P = IV$** , energy per unit time
Joules/s = **WATTS** (watts = amps x volts)
- It is more efficient to transmit electrical power at **high voltage and low current**.
- The losses along the transmission lines are reduced compared to transmission at low V.

21

House wiring



all circuits are connected in parallel

22

electrical power

- the power is how much electrical energy used per second = 1 Watt (1000 W = 1 kW)
- **Power = current x voltage**
- the appliances required high power, like your electric range or clothes dryer operate at the higher voltage, so less current is used.
- **we pay for the total energy (not power) used each month - KW-hours (KWH)**

23

Paying for electricity

- You pay for the total amount of electrical energy that is used
- the energy is measured in kilowatt-hours
- **the kilowatt (kW) = 1000 W is the energy used per unit time**
- When kW are multiplied by a time unit (hrs) we get total energy

24

\$\$\$ example \$\$\$

- At a rate of **10 cents per kWh**, how much does it cost to keep a 100 W light bulb on for one day?
- **Solution:** First **100 W = 0.1 kW**, one full day has 24 hours, so
cost = 0.1 kW x 24 hours x **\$0.10/kWh**
= \$0.24 = 24 ¢
→ for one month that amounts to \$7.20

25

Your carbon footprint

- Power (Watts) = energy used per unit time (J/s)
- **energy(KWH) = power × time = kilowatts (kW) × hours**
- **1 kilowatt = 1000 Watts**
- 1 ton of coal produces about 6000 KWH of electric power
- an average US household uses about 10,000 KWH of electricity per year
- **we pay for the number of KWH used each month**
- It takes 10,000/6000 = 1.66 tons (**3000 lbs**) of coal per year for each household
- US coal reserves: 300 billion tons!

26

Incandescent vs. Fluorescent ?

- Incandescent lights (ordinary light bulbs) produce a lot of heat as well as light and are inefficient
- **Fluorescent lights produce the same amount of light output while using less power**
- Why do they take several seconds to come to full power → they contain a small amount of mercury which must heat up to form a vapor
- **Fluorescent lights may not work as outdoor lights in cold climates, like Iowa winters!**

27