PHYS 1444 – Section 001
Lecture #11

Thursday, June 20, 2019
Dr. Jaehoon Yu

- Chapter 25
  - Electric Power
  - Alternating Current
  - Microscopic View of Electric Current
  - Ohm's Law in Microscopic View
  - EMF and Terminal Voltage

Nobel Meeting Photos

- Good job for asking most the questions, class!

Announcements

- Quiz #3
  - Beginning of the class Monday, June 24
  - Covers CH25.1 through what we learn today
  - BYOF: You may bring one 8.5x11.5 sheet (front and back) of **handwritten** formulae and values of constants for the exam
  - No derivations, word definitions, setups or solutions of any problems!
  - No additional formulae or values of constants will be provided!
- We will have a mid-term grade discussion today, Thursday, June 20. We will have a class till 11:30am, followed by the discussion in my office (CPB342).
  - Last name A – K:11:30 – 12:00
  - Last name L – Y: 12:00 – 12:30

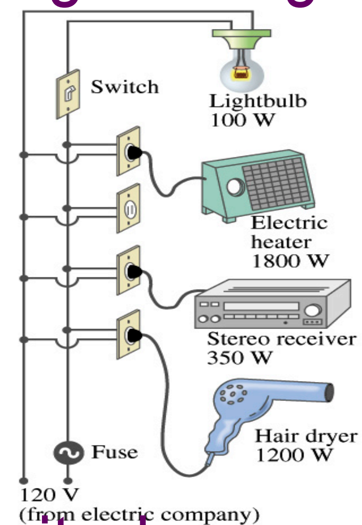
Special Project #4

- Make a list of the power consumption and the resistance of all electric and electronic devices at your home and compile them in a table. (10 points total for the first 10 items and 0.5 points each additional item.)
- Estimate the cost of electricity for each of the items on the table using your own electric cost per kWh (if you don't find your own, use $0.12/kWh) and put them in the relevant column. (5 points total for the first 10 items and 0.2 points each additional items)
- Estimate the the total amount of energy in Joules and the total electricity cost per day, per month and per year for your home. (8 points)
- Due: Beginning of the class Thursday, June 27

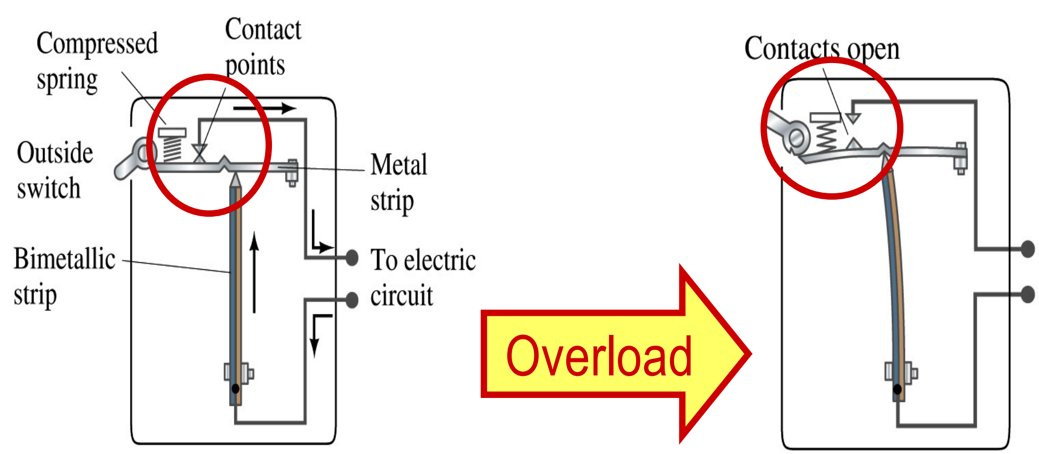
Item Name	Rated power (W)	Number of devices	Number of Hours per day	Daily Power Consumption (kWh)	Energy Cost per kWh (cents)	Daily Energy Consumption (J).	Daily Energy Cost ($)	Monthly Energy Consumption (J)	Monthly Energy Cost ($)	Yearly Energy Consumption (J)	Yearly Energy Cost ($)
Light Bulbs	30	4									
	40	6									
	60	15									
Heaters	1000	2									
	1500	1									
	2000	1									
Fans											
Air Conditioners											
Fridgers, Freezers											
Computers (desktop, laptop, ipad)											
Game consoles											
Total				0		0	0	0	0	0	0

Power in Household Circuits

- Household devices usually have small resistance
  - But since they draw current, if they become large enough, wires can heat up (overloaded)
    - Why is using thicker wires safer?
      - Thicker wires has less resistance, lower heat
  - Overloaded wire can set off a fire at home



- How do we prevent this?
  - Put in a switch that would disconnect the circuit when overloaded
    - Fuse or circuit breakers
    - They open up the circuit when the current is over certain value

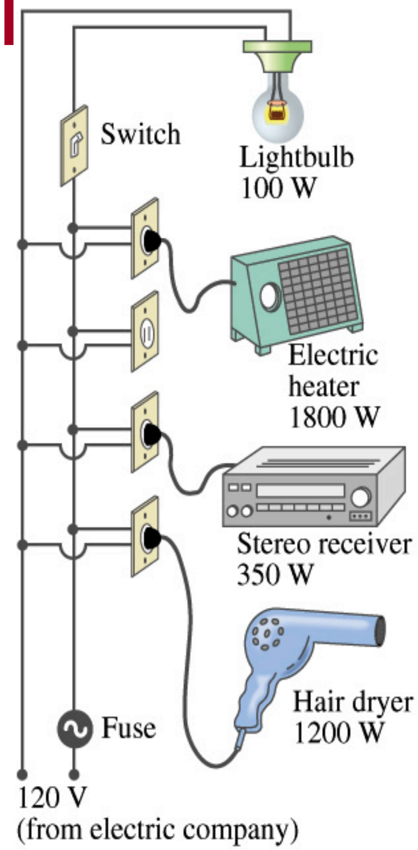


(b) Circuit breaker (closed)

(c) Circuit breaker (open)

Example 25 – 11

Will a fuse blow?: Determine the total current drawn by all the devices in the circuit in the figure.



The total current is the sum of current drawn by individual device.

$$P = IV$$ Solve for I $$I = P/V$$

Bulb $I_B = 100W/120V = 0.8A$

Heater $I_H = 1800W/120V = 15.0A$

Stereo $I_S = 135W/120V = 2.9A$

Dryer $I_D = 1200W/120V = 10.0A$

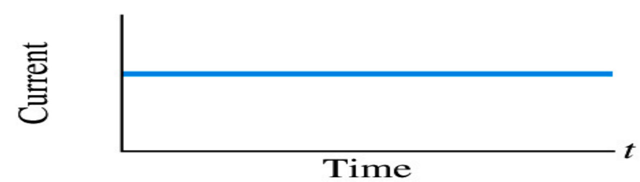
Total current

$$I_T = I_B + I_H + I_S + I_D = 0.8A + 15.0A + 2.9A + 10.0A = 28.7A$$

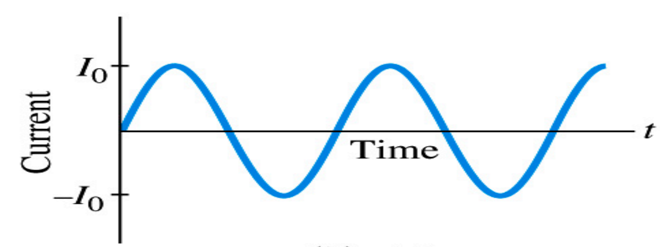
What is the total power? $P_T = P_B + P_H + P_S + P_D = 100W + 1800W + 350W + 1200W = 3450W$

Alternating Current

- Does the direction of the flow of current change while a battery is connected to a circuit?
  - No. Why?
    - Because its source of potential difference stays put.
  - This kind of current is called the Direct Current (DC), and it does not change its direction of flow while the battery is connected.
    - How would DC look as a function of time?
      - A straight line
- Electric generators at electric power plant produce alternating current (AC)
  - AC reverses direction many times a second
  - AC is sinusoidal as a function of time
- Most the currents supplied to homes and business are AC.



(a) DC

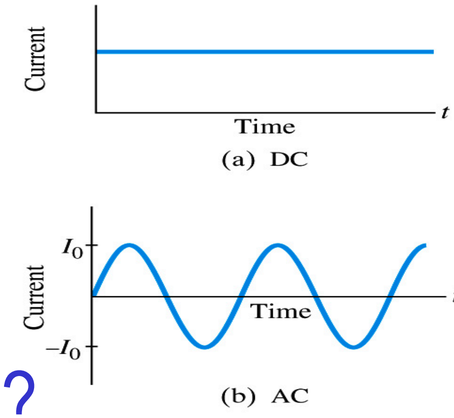


(b) AC

The Alternating Current

- The voltage produced by an AC electric generator is sinusoidal
  - This is why the current is sinusoidal
- Voltage produced can be written as

$$V = V_0 \sin 2\pi f t \ = V_0 \sin \varpi t$$



- What are the maximum and minimum voltages?
  - V_0 ($-V_0$) and 0
  - The potential oscillates between $+V_0$ and $-V_0$, the peak voltages or amplitude
  - What is f?
    - The frequency, the number of complete oscillations made per second. What is the unit of f? What is the normal size of f in the US?
      - f=60Hz in the US and Canada.
      - Many European countries have f=50Hz.
  - $\omega=2\pi f$

Alternating Current

- Since V=IR, if a voltage V exists across a resistance R, the current I is

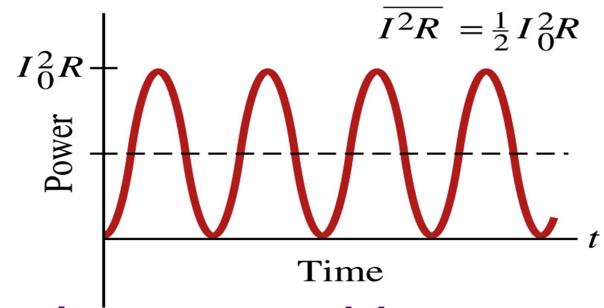
What is this?

$$I = \frac{V}{R} = \frac{V_0}{R} \sin 2\pi f t = I_0 \sin \varpi t$$

- What are the maximum and minimum currents?
  - I_0 ($-I_0$) and 0.
  - The current oscillates between $+I_0$ and $-I_0$, the peak currents or amplitude. The current is positive when electron flows to one direction and negative when they flow opposite.
  - AC is as many times positive as negative. What's the average current?
    - Zero. So there is no power and no heat is produced in a heater?
      - Yes there is! The electrons actually flow back and forth, so power is delivered.

Power Delivered by Alternating Current

- AC power delivered to a resistance is:



$$\boxed{P = I^2 R = I_0^2 R \sin^2 \varpi t}$$

  - Since the current is squared, the power is always positive
- The average power delivered is $\boxed{\bar{P} = \frac{1}{2} I_0^2 R}$
- Since the power is also $P=V^2/R$, we can obtain

$$\boxed{P = \left(V_0^2 / R\right) \sin^2 \varpi t}$$

Average power

$$\boxed{\bar{P} = \frac{1}{2}\left(\frac{V_0^2}{R}\right)}$$

- The average of the square of current and voltage are important in calculating power:

$$\boxed{\overline{I^2} = \frac{1}{2} I_0^2} \qquad \boxed{\overline{V^2} = \frac{1}{2} V_0^2}$$

Power Delivered by Alternating Current

- The square root of each of these are called root-mean-square, or rms:

$$\boxed{I_{rms} = \sqrt{\overline{I^2}} = \frac{I_0}{\sqrt{2}} = 0.707 I_0}$$

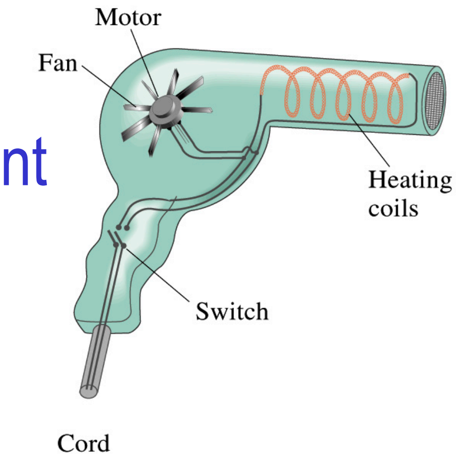
$$\boxed{V_{rms} = \sqrt{\overline{V^2}} = \frac{V_0}{\sqrt{2}} = 0.707 V_0}$$

- rms values are sometimes called the effective values
  - These are useful quantities since they can substitute current and voltage directly in power, as if they are in DC

$$\boxed{\overline{P} = \frac{1}{2} I_0^2 R = I_{rms}^2 R} \qquad \boxed{\overline{P} = \frac{1}{2}\frac{V_0^2}{R} = \frac{V_{rms}^2}{R}} \qquad \boxed{\overline{P} = I_{rms} V_{rms}}$$

  - **In other words, an AC of peak voltage V_0 or peak current I_0 produces as much power as DC voltage of V_{rms} or DC current I_{rms}.**
  - So normally, rms values in AC are specified or measured.
    - US uses 115V rms voltage. What is the peak voltage?
    - $V_0 = \sqrt{2} V_{rms} = \sqrt{2} \cdot 115V = 162.6V$
    - Europe uses 240V
    - $V_0 = \sqrt{2} V_{rms} = \sqrt{2} \cdot 240V = 340V$

Example 25 – 13



Hair Dryer. (a) Calculate the resistance and the peak current in a 1000-W hair dryer connected to a 120-V AC line. (b) What happens if it is connected to a 240-V line in Britain?

The rms current is: $I_{rms}=\frac{\bar{P}}{V_{rms}}=\frac{1000W}{120V}=8.33A$

The peak current is: $I_0=\sqrt{2}I_{rms}=\sqrt{2}\cdot 8.33A=11.8A$

Thus the resistance is: $R=\frac{\bar{P}}{I_{rms}^2}=\frac{1000W}{(8.33A)^2}=14.4\Omega$

(b) If connected to 240V in Britain …

The average power provide by the AC in UK is

$$\bar{P}=\frac{V_{rms}^2}{R}=\frac{(240V)^2}{14.4\Omega}=4000W$$

So? The heating coils in the dryer will melt!