PHYS 1441 – Section 002
Lecture #14

Wednesday, Oct. 21, 2020

Dr. Jaehoon Yu

- CH25
  - Electric Power
  - Alternating Current
  - Microscopic View of Electric Current
  - Ohm's Law in Microscopic View

Announcements

- Reading assignments: CH25 – 9, 25 – 10 and CH26 – 7
- Special seminar on COVID – 19: **3:30pm this Sunday, Oct. 25**
  - Dr. Linda Lee; Roll call will begin at 3:15pm.
  - Extra credit for participating in the seminar and asking relevant questions
- We will have mid-term a grade discussion next **Wednesday, Oct. 28**, starting 11:30am ending at 4:30pm on a separate zoom link
  - Mark your preference in the doodle poll which is limited to 15 students in each 30min slot – Poll: https://doodle.com/poll/zpad5me89scp2whd
  - Grade discussion zoom link: https://uta.zoom.us/j/98724294579?pwd=MlBJQXF3RnNZamtUbzQ3b3FXd2VIdz09
- Mid-term exam results
  - Class average: 59.7/102
    - Equivalent to 58.5/100 (Term 1: 65.7/100)
  - Top score: 102/102
- Warning: I will mark those of you still connected at the end of the class but not answering to my call missing the class

Evaluation Policy

- Homework: 25%!!!
- Exams
  - Final Comprehensive Exam (11am, Wed., 12/16/20): 23%
  - Mid-term Comprehensive Exam (1pm, Mon., 10/19/20): 20%
  - One better of the two term Exams (9/23/20 and 11/11/20): 12%
  - Missing an exam is not permissible unless pre-approved
    - No makeup test
    - <u>You will get an F if you miss any of the exams without a prior approval no matter how well you've been doing in class!</u>
- Lab score: 10%
- Pop-quizzes: 10%

00%

- Extra credits: 10% of the total
- Grading will be done on a sliding scale on the final scores

SP#5 – Civic Duty II: Election Participation

- Election on **Nov. 3** with **early voting Tue. Oct. 13 – Fri. Oct. 30**
- For those with legal voting rights: You can submit three access code green sheet for 20 points total – one your own and two others who voted, 5 points each. Any additional ones will earn 2 points each
- For those without legal voting rights: You can submit for the first four access code green sheets for 20 points total, 5 points each and any additional combinations 2 points each.
- Be sure to tape one side of the access code (or “I Voted” sticker if the voting was not using an electronic machine) on a sheet of paper with the date, the precinct number, the name of the person voted
- None of the stickers can be from the same person on someone else’s extra credit or on your own. All of those with any of the identical persons on your extra credit sheet will get 0 credit.
- Deadline: Beginning of the class **Monday, Nov. 9 (poll 13)**

Access code sheet/Sticker

This must be accompanied with date of the vote, the county name, the precinct number, the full name of the person voted and the signature of the person

SP #6 – Statistical Analysis : COVID19

- Make comparisons of COVID-19 statistics between the U.S., South Korea, Italy and Texas from https://coronaboard.com on spreadsheet
  - Total 44 points: 1 point for each of the top 20 cells and 2 points for each of the 12 cells for testing
- Fill the US Historic event analysis table at the bottom half of the sheet (2 points per cell, 24 points total) and make a >3 sentence statement on COVID19 with respect to other events (6 points)
- What are the 3 fundamental quantitative requirements for opening up (2 points each, 6 points total)?
  - **Must be quantitative! (e.g. number of tests per capita per day, positivity rate, etc)**
- Assess the readiness of the three fundamental requirements U.S. (Do NOT just take politician's words!). Must provide the independent scientific entity's reference you took the information from. (2 point each, total 6 points)
- Evaluate **quantitatively** the success/failure of the US responses to COVID-19 in 5 sentences. **Must provide quantitative reasons behind your conclusion!** (2 points each sentence, 10 points total)
- Assess **quantitatively** the effectiveness of wearing masks (4 points) and at least 4 reasons for it being effective (1 point each, 0.5 point extra after the first 4).
- **Due: 11pm, this Friday, Oct. 23**
  - Submit one pdf file SP6-YourLastName-YourFirstName.pdf, including the spreadsheet
  - Spreadsheet has been posted on canvas. Download ASAP.

SP6 spreadsheet

PHYS1444-002, Fall 20, Special Project #6, Statistical Analysis - COVID19

Name:			Date & time of your COVID-19 Data:		
Items		**U.S.A**	**South Korea**	**Italy**	**Texas**
Total Population					
COVID-19 Confirmed cases	Total				
	Cases per 1M people				
COVID-19 Deaths	Total				
	Death per 1M people				
COVID-19 Testing to date	Total				
	Per 1M people				
	Positivity Rate				

		COVID-19	**H1N1**	**Vietnam War**	**World War II**
US Historic Event Analysis	Time period (mm/dd/yy - MM/DD/YY)				
	Duration in Months				
	Total deaths				
	Death per month				

Special Project #7: Electric Power Usage

- 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 Monday, Nov. 2
  - Scan all pages of your special project into the pdf format
  - Save all pages into one file with the filename SP7-YourLastName-YourFirstName.pdf
  - Submit on CANVAS

PHYS1442-002, Fall 20, Special Project #7

Your Name						Electricity Rate					$/kWh	
Item Name	**Rated power (W)**	**Number of devices**	**Number of Hours per day**	**Daily Power Consumption (kWh)**	**Energy Cost per kWh (cents)**	**Daily Energy Consumption (J).**	**Daily Energy Cost ($)**	**Monthly Energy Consumption (J)**	**Monthly Energy Cost (S)**	**Yearly Energy Consumption (J)**	**Yearly Energy Cost ($)**	
Light Bulbs	30	4										
	40	6										
	60	15										
Heaters	1000	2										
	1500	1										
	2000	1										
Home Appliances (Fans, vacuum cleaners, hair dryers, pool pumps, etc)												
Air Conditioners												
Kitchen Appliances (Fridges, freeezers, cook tops, microwave ovens, toaster ovens, etc)												
Computing devices (desktop, laptop, ipad, mobile phones, printers, chargers, etc))												
Tools (power tools, electric mower, electric cutter, etc)												
Medical Devices (blood pressure machine, thermometer, etc)												
Transporations (electric cars, electric bicycles, electric motor cycles, etc												
Total												

Temperature Dependence of Resistivity

- Do you think the resistivity depends on temperature? (poll 14)
  - Yes
- Would it increase or decrease with the temperature? (poll 15)
  - Increase
  - Why?
  - Because the atoms are vibrating more rapidly as temperature increases and are arranged in a less orderly fashion. So?
    - They interfere more with the flow of electrons.
- If the temperature change is not too large, the resistivity of metals usually increase nearly linearly w/ temperature

$$\rho_T = \rho_0\left[1+\alpha\left(T-T_0\right)\right]$$

  - α is the temperature coefficient of resistivity
  - α of some semiconductors can be negative due to increased number of freed electrons.

Electric Power

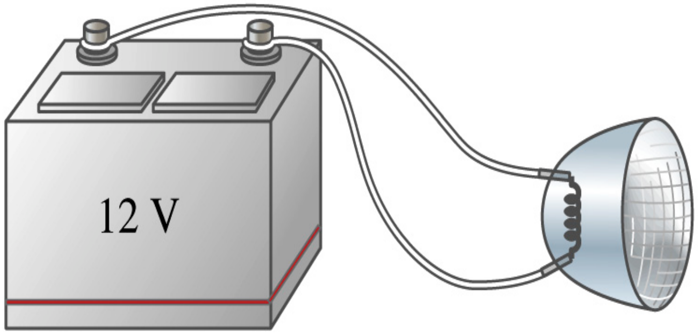
- Why is the electric energy useful?
  - It can transform into different forms of energy easily.
    - Motors, pumps, etc, transform electric energy to mechanical energy
    - Heaters, dryers, cook-tops, etc, transforms electricity to thermal energy
    - Incandescent light bulb filament transforms electric energy to light
      - Only about 10% of the energy turns to light and the 90% lost via heat
      - Typical household light bulb and heating elements have resistance of order a few ohms to a few hundred ohms
- How does electric energy transforms to thermal energy?
  - Flowing electrons collide with the vibrating atoms of the wire.
  - In each collision, part of electron's kinetic energy is transferred to the atom it collides with.
  - The kinetic energy of wire's atoms increases, and thus the temperature of the wire increases.
  - The increased thermal energy can be transferred as heat through conduction and convection to the air in a heater or to food on a pan, through radiation to bread in a toaster or radiated as light.

Electric Power

- How do we find out the power transformed by an electric device?
  - What is definition of the power?
    - The rate at which work is done or the energy is transformed
- What is the energy transformed when an infinitesimal charge dq moves through a potential difference V?
  - dU=Vdq
  - If dt is the time required for an amount of charge dq to move through the potential difference V, the power P is
  - $P = dU/dt = V\,dq/dt$ ← **What is this?**
  - Thus, we obtain $P = VI$. **In terms of resistance** $P = I^2 R = \frac{V^2}{R}$
  - What is the unit? (Poll 3) **Watts = J/s**
  - What kind of quantity is the electrical power? (Poll 2)
    - Scalar
  - P=IV can apply to any devices while the formula with resistance can only apply to devices that have resistance.

Example 25 – 8

Headlights: Calculate the resistance of a 40-W automobile headlight designed for 12V.



40-W Headlight

Since the power is 40W and the voltage is 12V, we use the formula with V and R.

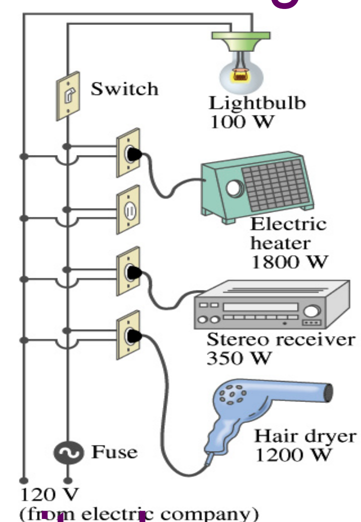
$$P = \frac{V^2}{R}$$

Solve for R

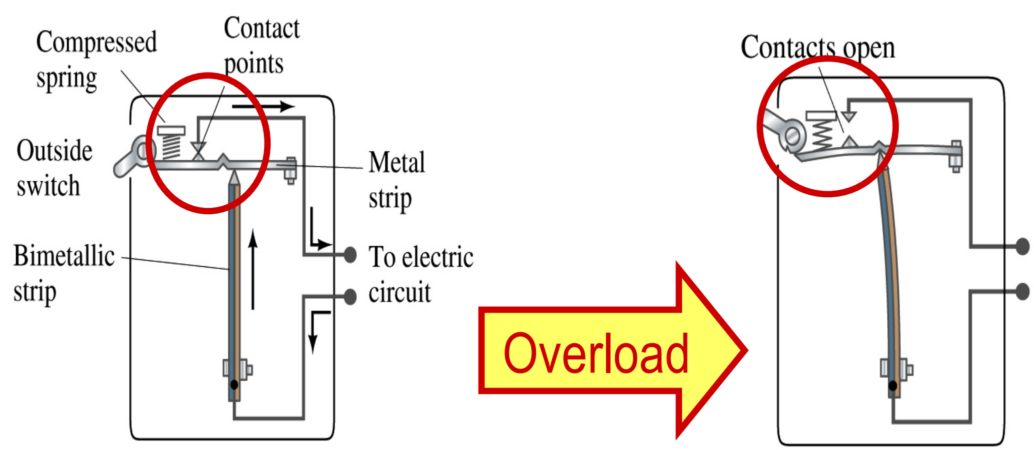
$$R = \frac{V^2}{P} = \frac{(12V)^2}{40W} = 3.6\Omega$$

Power in Household Circuits

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



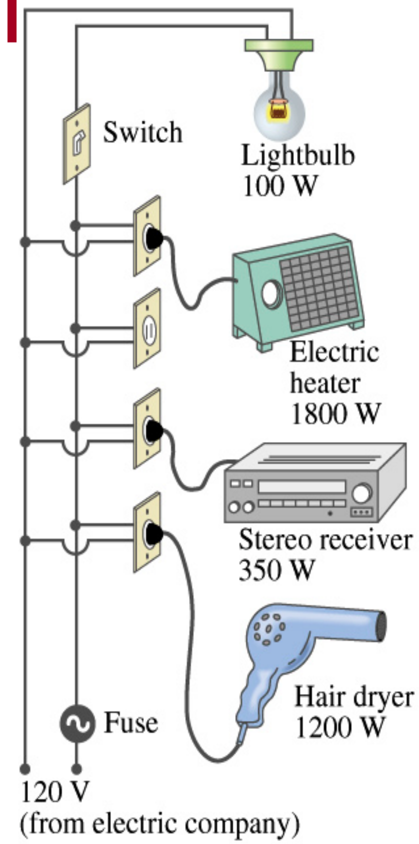
- How do we prevent this?
  - Put in a switch that would disconnect the circuit when overloaded
    - Fuse or circuit breakers
    - They open up the circuit when the current is over certain value



(b) Circuit breaker (closed)

(c) Circuit breaker (open)

Example 25 – 11



Will the fuse blow?: Determine the total current drawn by all the devices in the circuit in the figure. Will a 20A fuse blow?

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

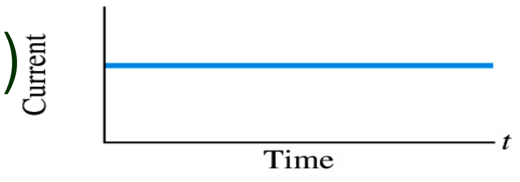
Total current

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

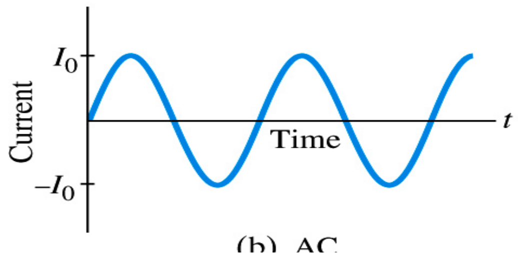
What is the total power? $P_T = P_B + P_H + P_S + P_D = 100W + 1800W + 350W + 1200W = 3450W$

Alternating Current

- Does the direction of the flow of current change while a battery is connected to a circuit? (poll 14)
  - No. Why?
    - Because its source of potential difference stays put, once connected
  - 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? (poll 16)
      - A straight line at the same value
- Electric generators at electric power plant produce alternating current (AC)
  - AC reverses direction many times a second (poll 16)
  - AC is sinusoidal as a function of time
- Most the currents supplied to homes and business are AC.



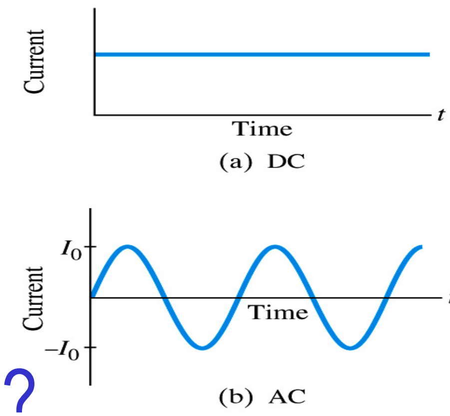
(a) DC



(b) AC

The Alternating Current

- The voltage produced by an AC electric generator is sinusoidal
  - This is why the AC current is sinusoidal (Poll 17)



- Voltage produced can be written as

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

- 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 (poll 17)

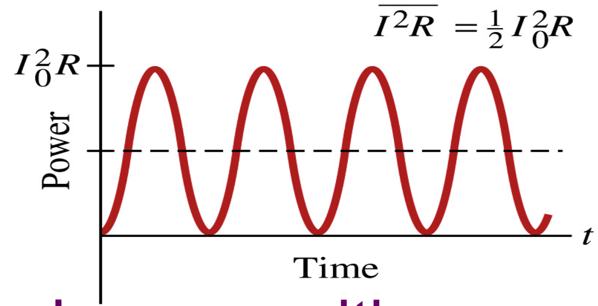
What is this? → $\frac{V_0}{R}$

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

- 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:



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

  – Since the current is squared, the power is always positive

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

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

Average power

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

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

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

Power Delivered by Alternating Current

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

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

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

- 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

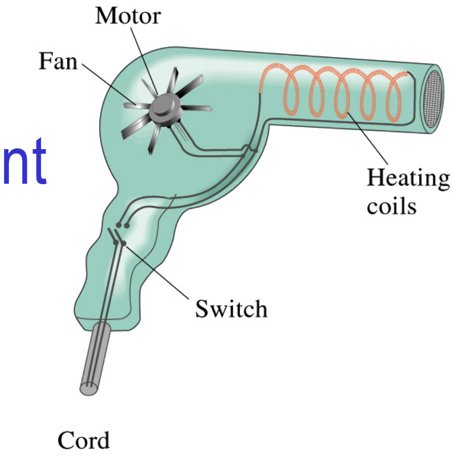
$$\bar{P} = \frac{1}{2} I_0^2 R = I_{rms}^2 R$$

$$\bar{P} = \frac{1}{2}\frac{V_0^2}{R} = \frac{V_{rms}^2}{R}$$

$$\bar{P} = I_{rms} V_{rms}$$

  - **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!