PHYS 1441 – Section 001
Lecture #10

Tuesday, June 23, 2020

Dr. Jaehoon Yu

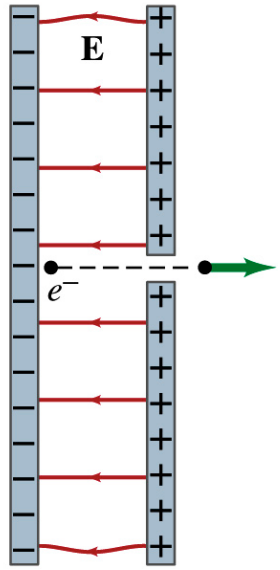
- Chapter 25
  - Electric Power
  - Alternating Current
  - Microscopic View of Electric Current
  - Ohm's Law in Microscopic View
  - EMF and Terminal Voltage

Announcements

- We will have a mid-term grade discussion Thursday, June 25. We will have a class till 11:30am, followed by the discussion on zoom➔ Need to figure out how to do this in a sufficiently private manner
  - Last name A – K:11:30 – 12:00
  - Last name L – Y: 12:00 – 12:30
- Warning: I will mark those of you still connected at the end of the class but not answering to my call missing the class

Reminder: Special Project #3

- **Particle Accelerator**. A charged particle of mass **M** with charge **-Q** is accelerated in the uniform field **E** between two parallel charged plates whose separation is **D** as shown in the figure on the right. The charged particle is accelerated from an initial speed $\mathbf{v_0}$ near the negative plate and passes through a tiny hole in the positive plate.



  - Derive the formula for the electric field E to accelerate the charged particle to a fraction f of the speed of light c. Express E in terms of **M, Q, D**, f, **c** and $\mathbf{v_0}$.
  - (a) Using the Coulomb force and the kinematic equations. (8 points)
  - (b) Using the work-kinetic energy theorem. (8 points)
  - (c) Using the formula above, evaluate the strength of the electric field E to accelerate an electron from 0.1% of the speed of light to 90% of the speed of light. You need to look up and write down the relevant constants, such as mass of the electron, charge of the electron and the speed of light. (5 points)
- Must be handwritten and not copied from anyone else!
  - Follow the SP naming convention: SP3-first-last-summer20.pdf which includes all pages in one file ➔ Be sure to write your name onto the project report!
- Due beginning of the class tomorrow, Wednesday, June 24

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 Tuesday, June 30
  - Scan all pages of your special project into the pdf format
  - Save all pages into one file with the filename SP4-YourLastName-YourFirstName.pdf
  - Send me the file in an email with the subject SP4 Submission

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									
Fans											
Air Conditioners											
Fridgers, Freezers											
Computers (desktop, laptop, ipad)											
Game consoles											
Total				0		0	0	0	0	0	0

Temperature Dependence of Resistivity

- Do you think the resistivity depends on temperature?
  - Yes
- Would it increase or decrease with the temperature? (Poll 11)
  - 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

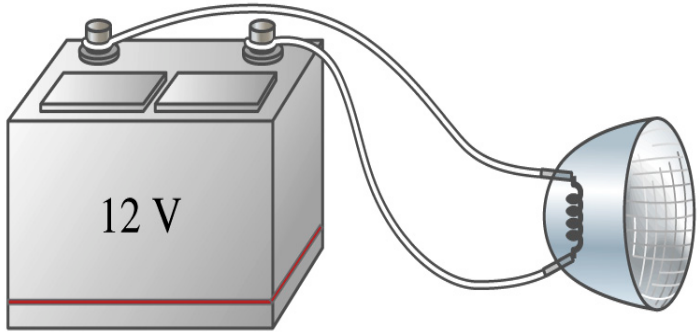
- Why is the electric energy useful?
  - It can transform into different forms of energy easil
    - Motors, pumps, etc, transform electric energy to me
    - Heaters, dryers, cook-tops, etc, transforms electrici
    - Incandescent light bulb filament transforms electric
      - Only about 10% of the energy turns to light ar
      - Typical household light bulb and heating elem ohms to a few hundred ohms
- How does electric energy transforms to therm
  - Flowing electrons collide with the vibrating atoms c
  - In each collision, part of electron's kinetic energy is collides with.
  - The kinetic energy of wire's atoms increases, and t increases.
  - The increased thermal energy can be transferred a 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** $P = I^2R = \frac{V^2}{R}$
  - What is the unit? (Poll 10) **Watts = J/s**
  - What kind of quantity is the electrical power? (Poll 1)
    - 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.

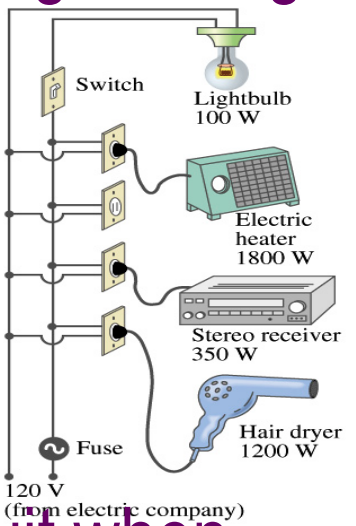
$$P = \frac{V^2}{R}$$

Solve for R

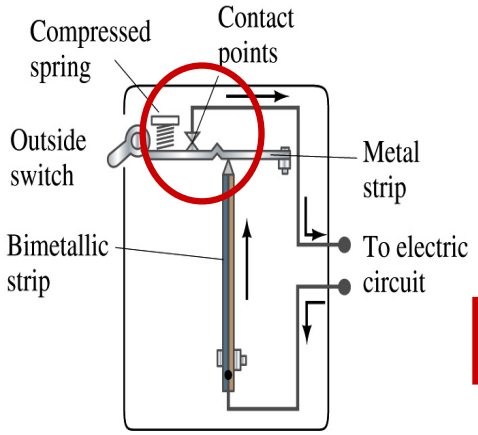
$$R = \frac{V^2}{P} = \frac{(12V)^2}{40W} = 3.6\Omega$$

Power in Household Circuits

- Household devices usually have small resistance
  - But since they draw current, if they become 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

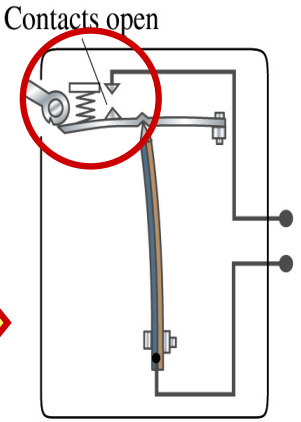


- How do we prevent this?
  - Put in a switch that would disconnect the circuit when overloaded
    - Fuse or circuit breakers
    - They open up the circuit when the current is over certain value



(b) Circuit breaker (closed)

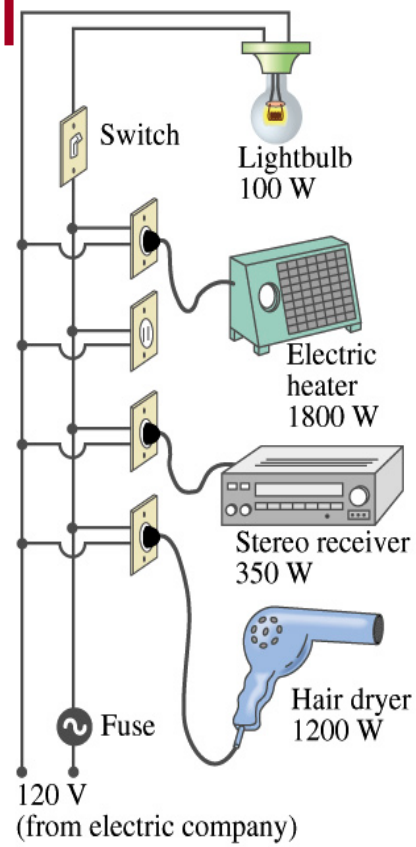
Overload



(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.



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

$$P = IV \quad \text{Solve for I} \quad I = P/V$$

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? $P_T = P_B + P_H + P_S + P_D = 100W + 1800W + 350W + 1200W = 3450W$