PHYS 1444 – Section 002
Lecture #14

Monday, Oct. 23, 2017

Dr. Jaehoon Yu

- Chapter 25
  - Microscopic View of Electric Current
  - EMF and Terminal Voltage
- Chapter 26
  - Kirchhoff's Rules
  - EMFs in Series and Parallel
  - RC Circuits
- Chapter 27: Magnetism and Magnetic Field

Today's homework is homework #8, due 11pm, Monday, Oct. 30!!

Announcements

- Mid-term grade discussions
  - From 12:00 – 2:30pm, this Wednesday, Oct. 25 in my office (CPB342)
  - Last name starts with A – D (12 – 12:30), E– K (12:30 – 1), L – O (1 – 1:30), P – S (1:30 – 2:00), T – Z (2-2:30)
- Grade scheme reminder
  - Homework: 25%
  - Final exam: 23%
  - Midterm exam: 20%
  - Better of the two term exams: 12%
  - Lab: 10%
  - Quizzes: 10%
  - Extra Credit: 10%

Special Project #5

- Make a list of the power consumption and the resistance of all electric and electronic devices at your home and compiled them in a table. (5 points total for the first 10 items and 0.25 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. (2 points total for the first 10 items and 0.1 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. (6 points)
- Due: Beginning of the class Wednesday, Nov. 1

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

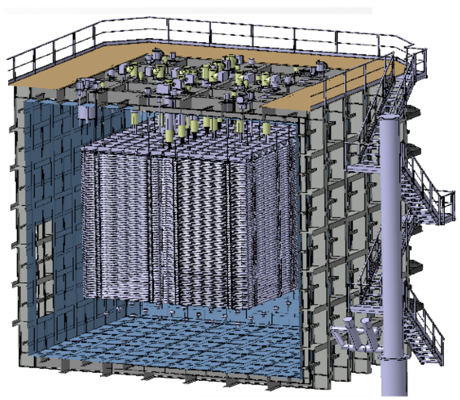
DUNE Dual Phase Strategic Approach

1. 3x1x1m^3 42t active volume Pilot detector
2. 6x6x6m^3 600t protoDUNE Dual Phase
3. 10kt DUNE Dual Phase LArTPC

3x1x1m^3 Pilot

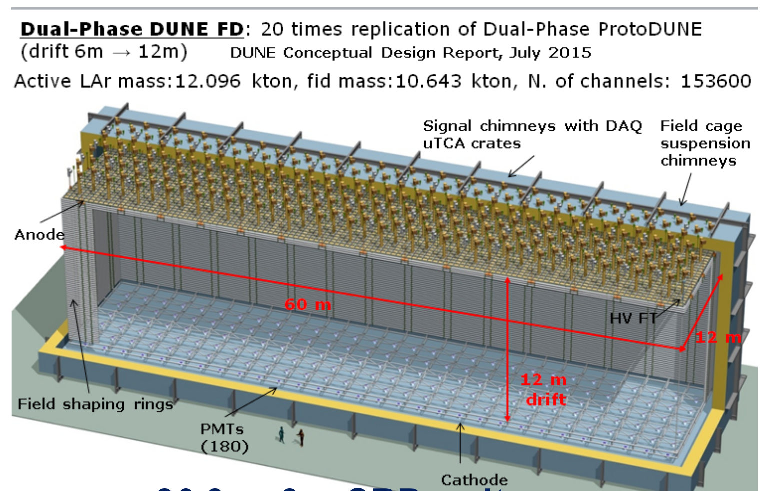
- 3mx1m CRP units
- 50 field shaping rings
- 4 signal FT chimneys
- 4 suspension chimneys
- 12 PMTs
- 1280 readout channels

protoDUNE DP 6x6x6m^3



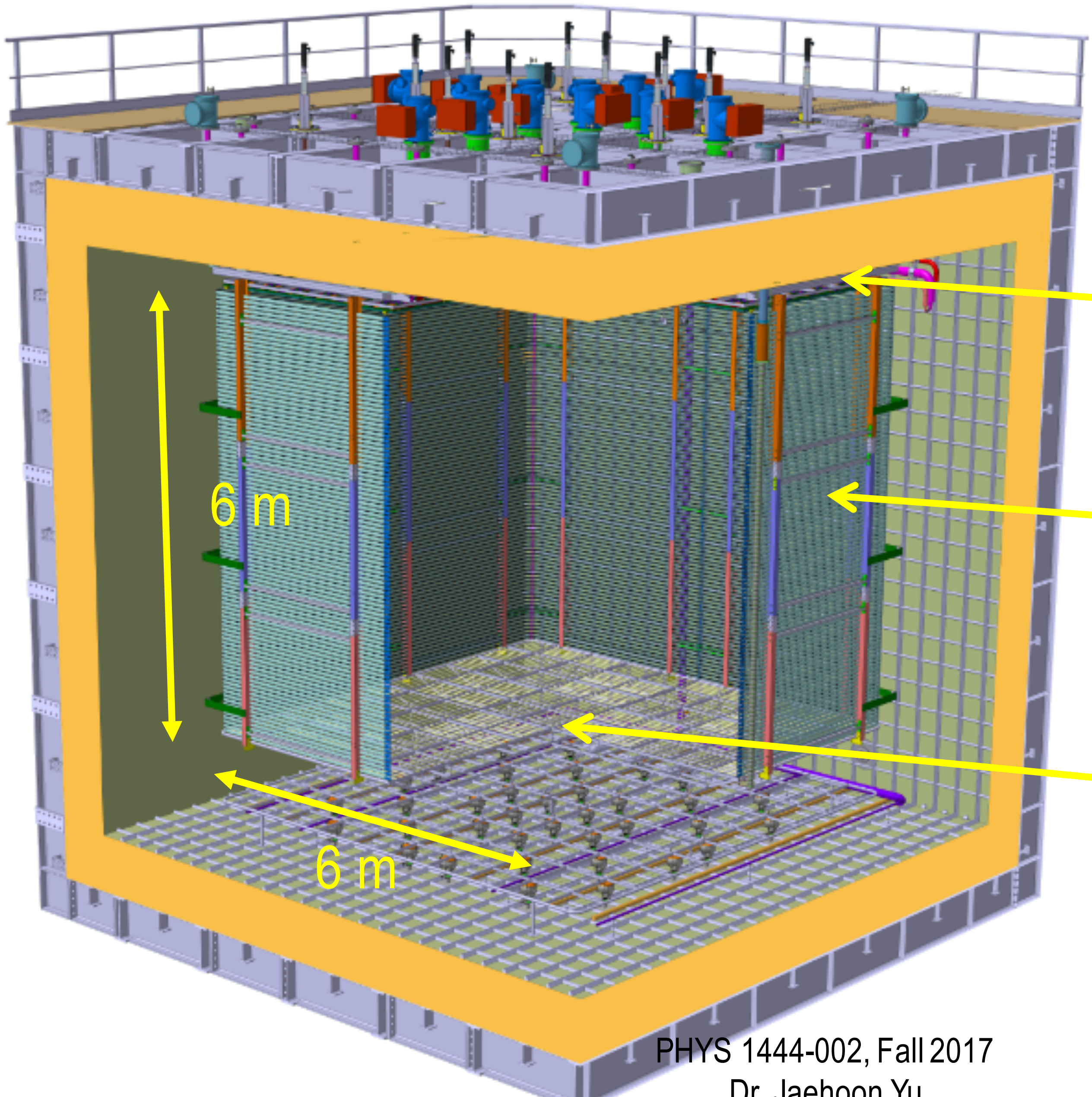
- 4 3mx3m CRP units
- 98 field shaping rings
- 12 signal FT chimneys
- 12 suspension chimneys
- 36 PMTs
- 7680 readout channels

10kt DUNE Dual Phase



- 80 3mx3m CRP units
- 200 field shaping rings
- 240 signal FT chimneys
- 240 suspension chimneys
- 180 PMTs
- 153600 readout channels

protoDUNE DP Detector–Cryostat Integration



Charge Readout Planes

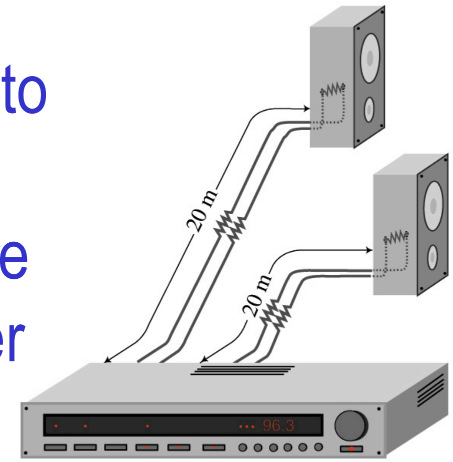
Field Cage (common structural elements with SP)

Cathode

ProtoDUNE DP Cryostat

Example 25 – 5

Speaker wires: Suppose you want to connect your stereo to remote speakers. (a) If each wire must be 20m long, what diameter copper wire should you use to keep the resistance less than 0.1-Ω per wire? (b) If the current on each speaker is 4.0A, what is the voltage drop across each wire?



The resistivity of a copper is $\rho_{Cu} = 1.68\times10^{-8}\,\Omega\cdot m$ Table 25.1

From the formula for resistance, we can obtain the formula for area

$$R = \rho\frac{l}{A} \quad \text{Solve for A} \quad A = \rho\frac{l}{R} = \pi r^2$$

$$\text{Solve for d} \quad d = 2r = 2\sqrt{\frac{\rho l}{\pi R}} = 2\sqrt{\frac{1.68\times10^{-8}\,\Omega\cdot m\cdot 20m}{\pi\cdot 0.1\Omega}} = 2.1\times10^{-3}m = 2.1mm$$

From Ohm's law, V=IR, we obtain

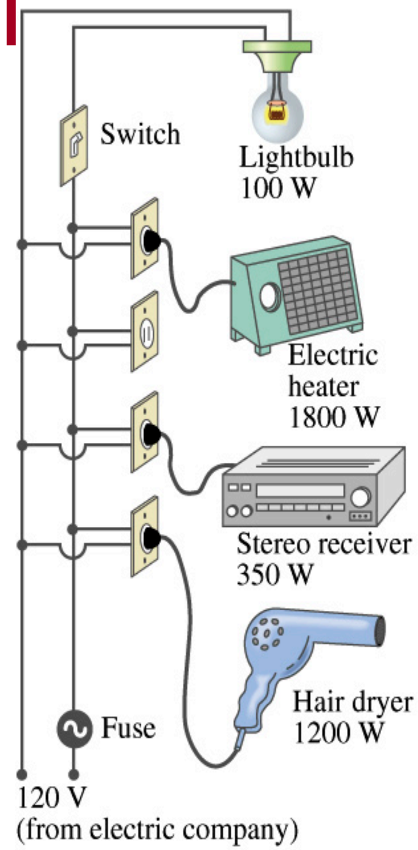
$$V = IR = 4.0A\cdot 0.1\Omega = 0.4V$$

Electric Power

- How do we find out the power transformed by an electric device?
  - What is the 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 $\boxed{P = VI}$. **In terms of resistance** $\boxed{P = I^2 R = \frac{V^2}{R}}$
  - What is the unit? **Watts = J/s**
  - What kind of quantity is the electrical power?
    - Scalar
  - P=IV can apply to any devices, while the formula with the resistance can only apply to devices that has resistance.

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

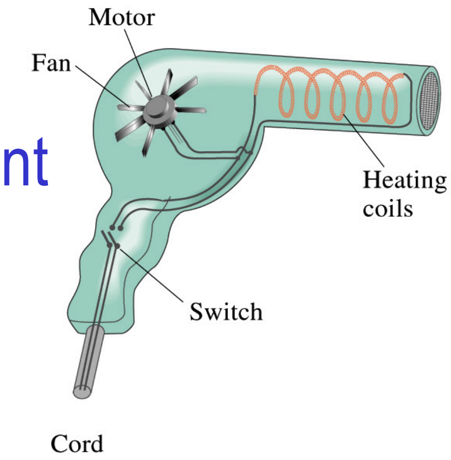
Dryer $I_D = 1200W/120V = 10.0A$

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

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 …

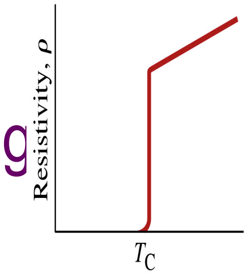
The average power provide by the AC in UK is

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

So? The heating coils in the dryer will melt!

Superconductivity

- At the temperature near absolute 0K, resistivity of certain material becomes 0.
  - This state is called the "superconducting" state.
  - Observed in 1911 by H. K. Onnes when he cooled mercury to 4.2K (-269^{o}C).
    - Resistance of mercury suddenly dropped to 0.
  - In general superconducting materials become superconducting below a transition temperature (T_c).
  - The highest temperature superconductivity seen is 160K
    - First observation above the boiling temperature of liquid nitrogen is in 1987 at 90k observed from a compound of yttrium, barium, copper and oxygen.
- Since much smaller amount of material can carry just as much current more efficiently, superconductivity can make electric cars more practical, computers faster, and capacitors store higher energy



Critical Temperature of Superconductors

Critical temperature (T_c), crystal structure and lattice constants of some high-T_c superconductors

Formula	Notation	T_c (K)	No. of Cu-O planes in unit cell	Crystal structure
$YBa_2Cu_3O_7$	123	92	2	Orthorhombic
$Bi_2Sr_2CuO_6$	Bi-2201	20	1	Tetragonal
$Bi_2Sr_2CaCu_2O_8$	Bi-2212	85	2	Tetragonal
$Bi_2Sr_2Ca_2Cu_3O_{10}$	Bi-2223	110	3	Tetragonal
$Tl_2Ba_2CuO_6$	Tl-2201	80	1	Tetragonal
$Tl_2Ba_2CaCu_2O_8$	Tl-2212	108	2	Tetragonal
$Tl_2Ba_2Ca_2Cu_3O_{10}$	Tl-2223	125	3	Tetragonal
$TlBa_2Ca_3Cu_4O_{11}$	Tl-1234	122	4	Tetragonal
$HgBa_2CuO_4$	Hg-1201	94	1	Tetragonal
$HgBa_2CaCu_2O_6$	Hg-1212	128	2	Tetragonal
$HgBa_2Ca_2Cu_3O_8$	Hg-1223	134	3	Tetragonal

Electric Hazards: Leakage Currents

- How does one feel shock by electricity?
  - Electric current stimulates nerves and muscles, and we feel a shock
  - The severity of the shock depends on the amount of current, how long it acts and through what part of the body it passes
  - Electric current heats the tissue and can cause burns
- Currents above 70mA on a torso for a second or more is fatal, causing heart to function irregularly, “ventricular fibrillation”.
- A dry human body between two points on opposite side of the body is about 10^4 to 10^6 Ω.
- When wet, it could be $10^3\Omega$.
- A person in good contact with the ground who touches 120V DC line with wet hands can get the current:

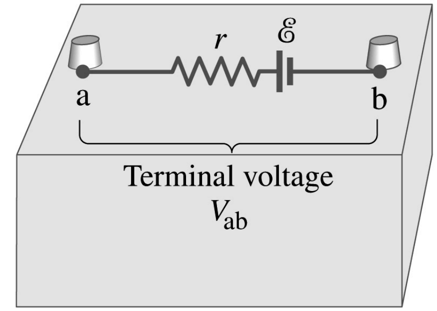
$$I = \frac{V}{R} = \frac{120V}{1000\Omega} = 120mA$$

  - Could be lethal

EMF and Terminal Voltage

- What do we need to have current in an electric circuit?
  - A device that provides a potential difference, such as a battery or a generator
    - They normally convert some types of energy into the electric energy
    - These devices are called source of electromotive force (emf)
      - This is does NOT refer to a real “force”.
- Potential difference between terminals of an emf source, when no current flows to an external circuit, is called the emf ($\mathscr{E}$) of the source.
- The battery itself has some **internal resistance** (r) due to the flow of charges in the electrolyte
  - Why does the headlight dim when you start the car?
    - The starter needs a large amount of current but the battery cannot provide charge fast enough to supply current to both the starter and the headlight

EMF and Terminal Voltage



- Since the internal resistance is inside the battery, we can never separate them out.
- So the terminal voltage difference is $V_{ab}=V_a-V_b$.
- When no current is drawn from the battery, the terminal voltage equals the emf which is determined by the chemical reaction; $V_{ab}=\mathcal{E}$.
- However when the current I flows naturally from the battery, there is an internal drop in voltage which is equal to Ir. Thus the actual **delivered** terminal voltage is $\boxed{V_{ab}=\varepsilon-Ir}$