PHYS 1444 – Section 002
Lecture #14

Monday, Mar. 30, 2020

Dr. Jaehoon Yu

The science of COVID-19

CH25

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

CH 26

- EMF and Terminal Voltage
- Resistors in Series and Parallel

Mon

Today's homework is homework #9, due 11pm, Monday, Apr. 13!!

Reminder: Basic Rules of the Online Classes

- I will take attendance as if we are in the class room!
  - Turn on your mic when joining the class but then **mute** once you have answered to the roll call!
- All mics must be muted unless you have a question
  - I will unmute all of you when I ask you a question for interactivity!
- If you have a question, turn on your mic, pronounce your name and ask your question
- Use **appropriate languages** on mic and on chat!
  - You can only chat with me
- You will be assigned into random breakout rooms for example problem solving. Please discuss amongst yourselves to take advantage of the session!
- No recording of the lecture is permitted!

Announcements

- Reading Assignments: CH25.9 and 25.10
- Mid-term exam results
  - Class average: 54.3/101 ➔ equivalent to 53.8/100
    - Previous exam result: 59.7/100
  - Top score: 94.1/101
- Reminder: Grading scheme
- Homework: 25%!!!
- Exams
  - Final Comprehensive Exam (5/6/20): 23%
  - Mid-term Comprehensive Exam (3/25/20): 20%
  - One better of the two term Exams (2/19/20 and 4/15/20): 12%
  - Will get an F if you missed any exams!
- Lab score: 10%
- Pop-quizzes: 10%

100%

- Extra credits: 10% of the total

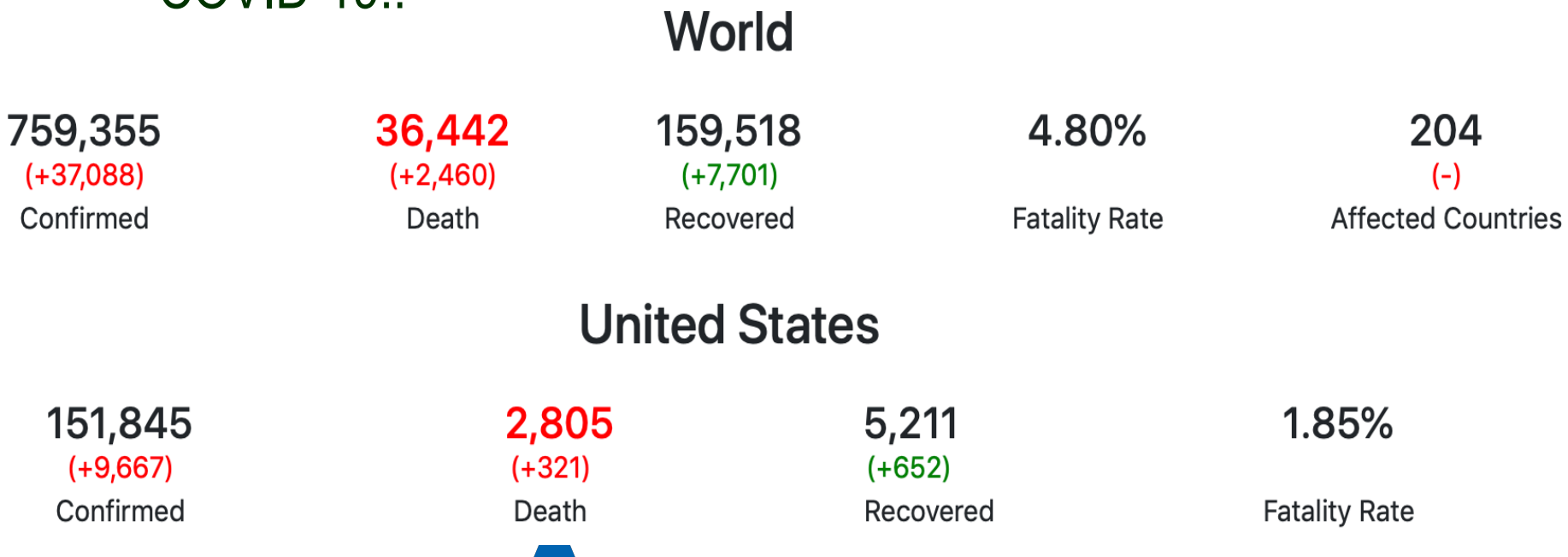
Special Project #4

- 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 Monday, Apr. 13
  - Scan all pages of your special project into the pdf format
  - Save all pages into one file with the filename SP5-YourLastName-YourFirstName.pdf
  - Send me the file no later than 1pm Monday, Apr. 13

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 (S)
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

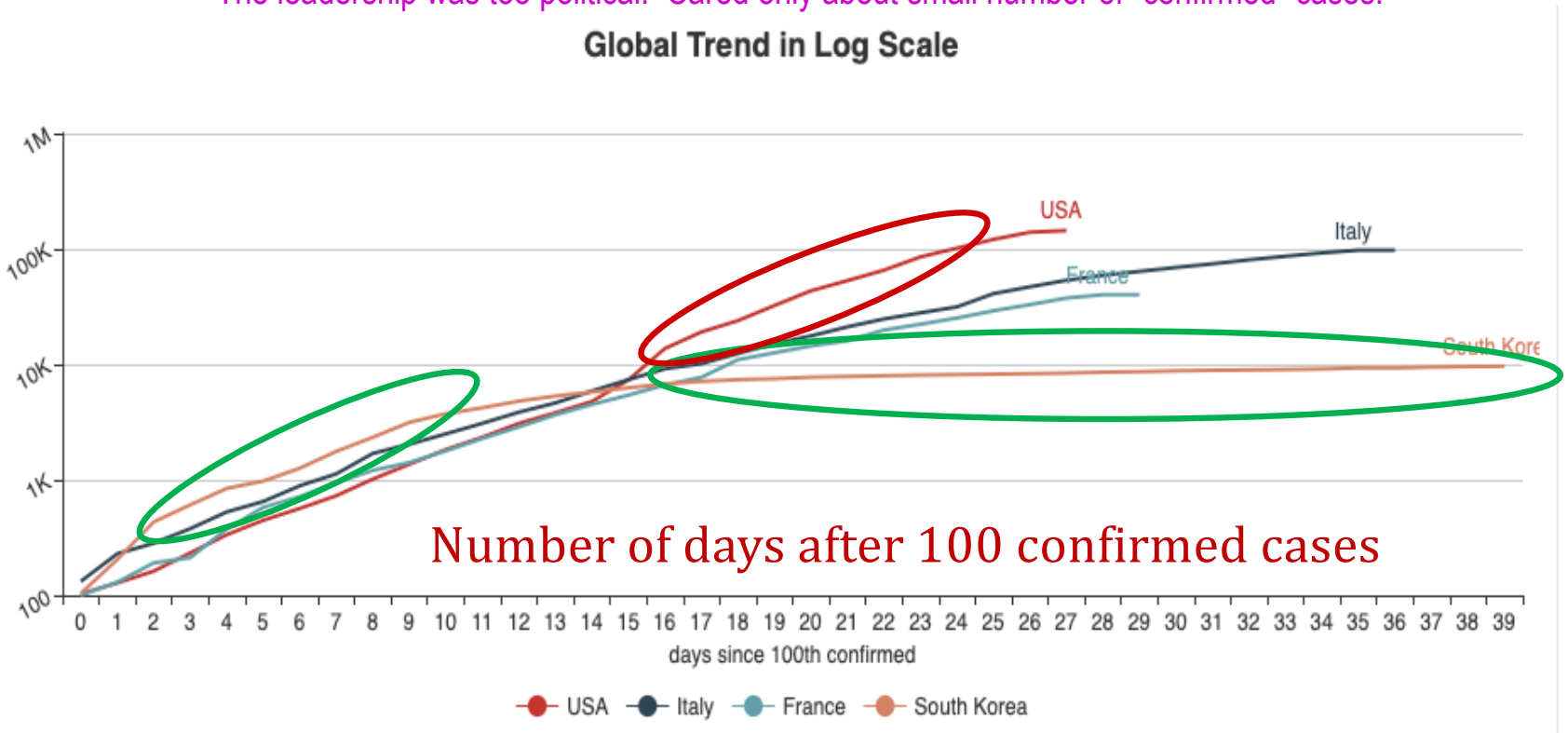
The Science of COVID-19 – I

- The novel coronavirus, COVID-19 is extremely deadly
  - Not well understood
  - Very infectious and affects all ages!! ➔ doubling every week!
  - Deadly: Death rate at 4.8%, about 50 times higher than the flu (~0.1%!!)
    - Last year the flu took 37,000 lives ➔ Imagine what it would be with COVID-19!!



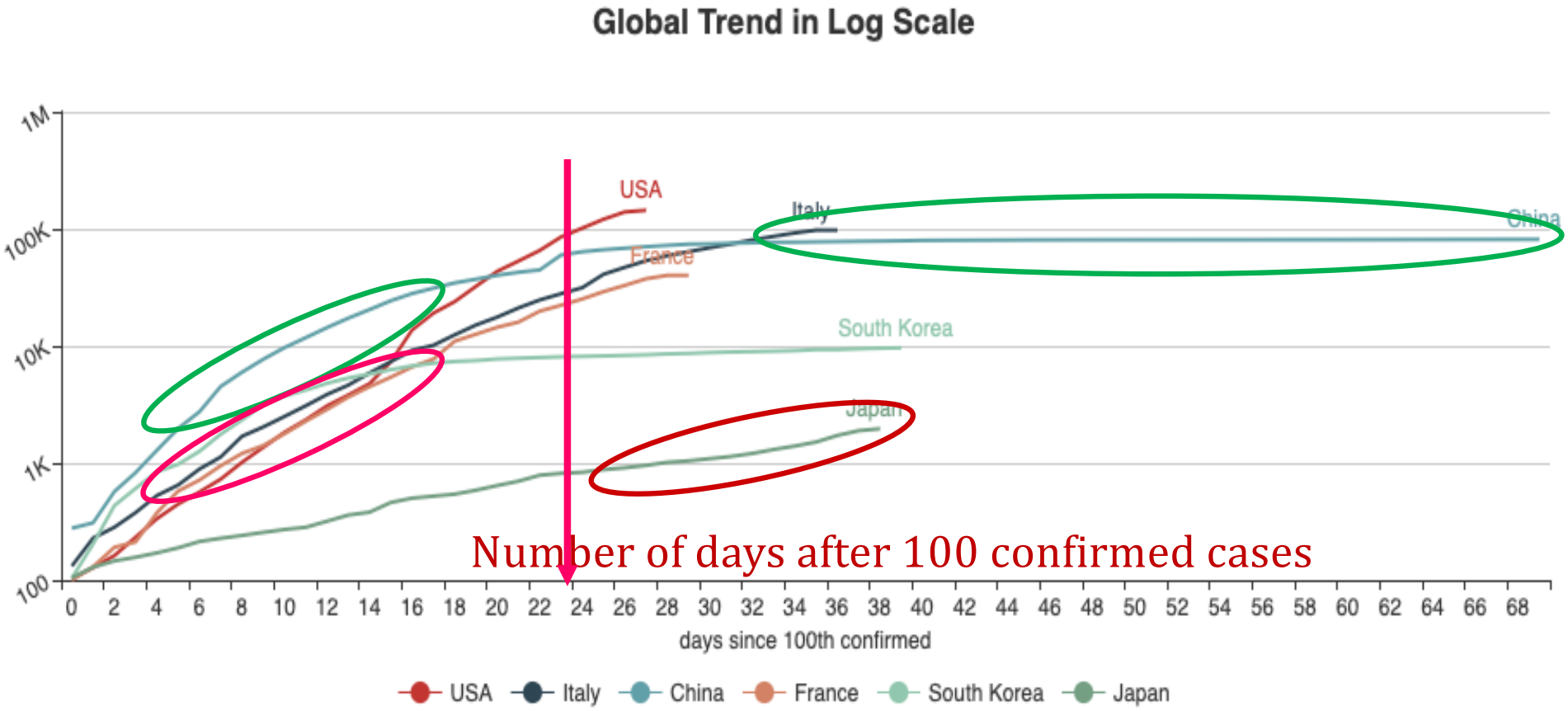
The Science of COVID-19 – II

- The chart of "confirmed" infections on semi-log scale
  - What do you observe?
  - South Korea and US quite peculiar
    - SK took an aggressive testing, tracking and social distancing early! Keep people informed w/ absolute transparency! ➔ Prevented large number of deaths (161 as of this morning! ➔ equivalent to 966 in the US)
    - US did not take any aggressive action for over two months! (>2800 deaths!)
      - The leadership was too political! Cared only about small number of "confirmed" cases!



The Science of COVID-19 – III

- The chart of "confirmed" infections on semi-log scale
  - Most the countries follow similar trend
  - It took China for about a month since 100 cases before flattening out the curve
  - Japan's number starts low but keeps growing
    - Even more political than the US!



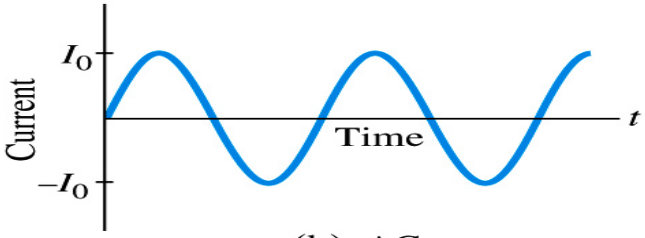
The Science of COVID-19 – Lessons

- What we do must base on good for humanity
- Scientists interested in the "TRUTH" not the appearances
  - This is because we can get a handle on difficult battles like COVID-19 only if we have a full understanding of what it is!
  - No spinning since it dilutes the truth and scares people
- Leadership MUST be based on humanity and the fundamental human decency
  - Compassion and empathy towards fellow human beings!
  - Courage to take the ultimate responsibilities!
  - Lives must take higher priorities over anything else
    - Makes perfect logical sense since without getting a good handle on COVID-19, this tragedy will unnecessarily be prolonged, and the economy will suffer longer!
  - Make decisions based on sound science and with absolute transparency
- You must pay attention to scientists NOT politicians!
- You then make a sound decision and reward properly!
  - Requires your own thoughts and value systems!!

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 current look as a function of time?
      - Straight line
- The 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

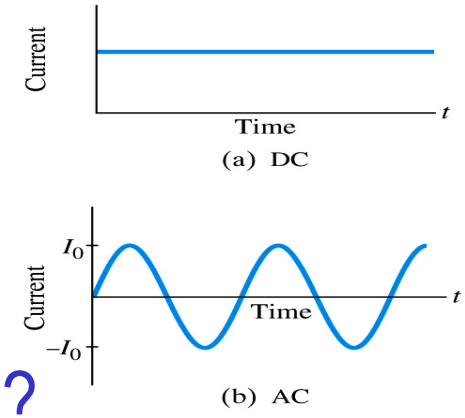


(b) AC

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

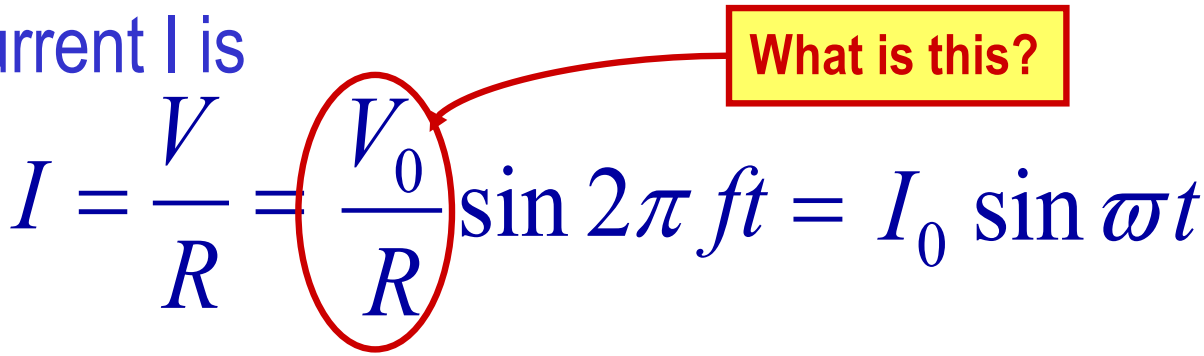
$$V = V_0 \sin 2\pi ft = V_0 \sin \varpi t$$



- What are the maximum and minimum voltages?
  - Max: V_0 ($-V_0$) and Min: 0
  - The potential oscillates between $+V_0$ and $-V_0$, the peak voltage or the 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.
  - $\omega = 2\pi f$: *angular frequency*

Alternating Current

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

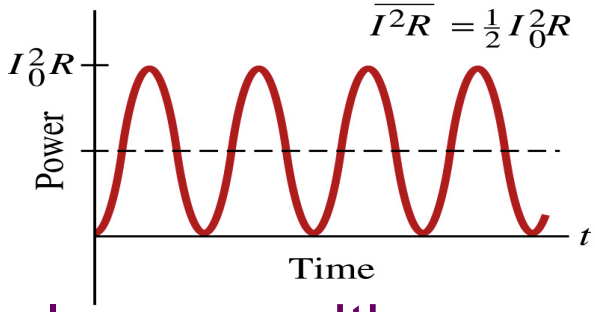


- What are the maximum and minimum currents?
  - Max=I_0 ($-I_0$) and Min=0 A.
  - The current oscillates between $+I_0$ and $-I_0$, the peak currents or the amplitude. The current is positive when electron flows to one direction and negative when they flow the opposite.
  - AC is as many times positive 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:

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



  - 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

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

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:

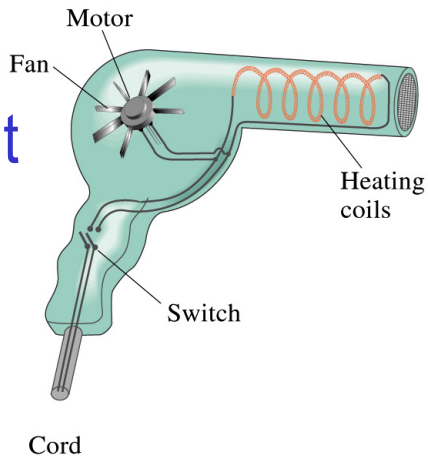
$$I_{rms} = \sqrt{I^2} = \frac{I_0}{\sqrt{2}} = 0.707 I_0 \qquad V_{rms} = \sqrt{V^2} = \frac{V_0}{\sqrt{2}} = 0.707 V_0$$

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

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

  - 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 …

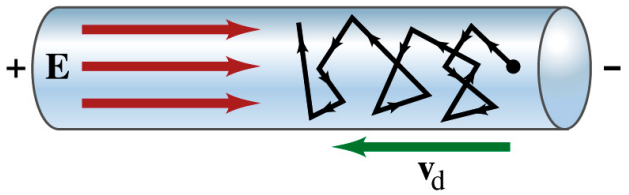
The average power provide by the AC in UK is

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

So? The heating coils in the dryer will melt!

Microscopic View of Electric Current

- When voltage is applied across the ends of a wire
- Electric field is generated by the potential difference
- Electrons feel the force and get accelerated
- Electrons soon reach to a steady average speed due to collisions with atoms in the wire, called drift velocity, $\mathbf{v}_d$
- The drift velocity is normally much smaller than electrons' average random speed.

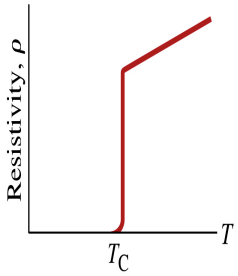


Microscopic View of Electric Current

- The drift velocity of electrons in a wire is only about 0.05mm/s. How could we get light turned on immediately then?
  - While the electrons in a wire travel slow, the electric field travels essentially at the speed of light. Then what is all the talk about electrons flowing through?
    - It is just like water. When you turn on the facet, water flows right off the facet despite the fact that the water travels slow.
    - Electricity is the same. Electrons fill the conductor wire and when the switch is flipped on or a potential difference is applied, the electrons close to the positive terminal flows into the device.
    - Interesting, isn't it? Why is the field travel at the speed of light then?

Superconductivity

- At the temperature near absolute 0K, resistivity of certain materials become 0.
  - This state is called the "superconducting" state.
  - Observed in 1911 by H. K. Onnes when he cooled mercury to 4.2K (-269°C). ➔ 1913 Nobel physics prize
    - 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:
  - Could be lethal

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