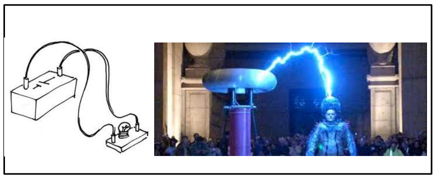
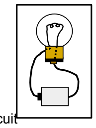
Electric circuits



Lecture 22 :
Electric circuits

Reminders:
HW 9 due Monday 12th at midnight
Tuesday is review
Start making a 3rd formula card
Info on web about exam

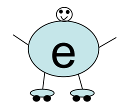
Circuits so far



Wires: Make complete circuit necessary for steady flow of electrons
Usually have negligible (zero) resistance

Battery: Maintains a voltage difference ΔV between terminals
Provides each electron with $q\Delta V$ = eV of EPE to spend in circuit
Provides push for electrons around circuit (bigger V, bigger push)

Bulb: Filament is a high resistance wire
KE of electrons converted into heat via collisions

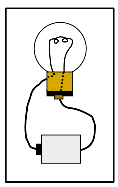


Electronman rules for analyzing circuits

a) No electron deaths/births
b) No passing of electrons
c) Electrons have energy (high at start, low at end)
d) Different conducting materials have different resistances

Think like an electron!

Circuit language



Resistance (R) of a circuit element is measure of how hard it is for electrons to pass through.
Units: Ohms (Ω)

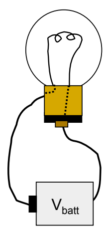
Current (I) : charge per second flowing past a point in the circuit
(= # electrons per second × charge on electron)
Units : Amps (1 A = 1 C/s)

Voltage (difference) (ΔV)

a) **Across battery:** Measure of EPE given to each e^- as it passes through battery. EPE given = eV. Related to pushing force on electrons in circuit
b) **Across a resistor (wire, filament etc):** Measure of EPE lost by each e^- as it passes through. EPE lost = eV.
Unless told otherwise voltage difference across connecting wire = 0.
Units: Volts (V)

Note: All quantities specific to one component.
Don't mix and match!

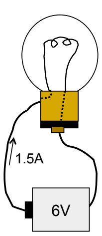
Ohm's Law: $\Delta V = IR$
- R: Resistance of component
- I: Current through component
- ΔV: Voltage dropped across component



What if increase voltage difference across battery?

a. Rate at which electrons pass through filament stays the same
b. Rate at which electrons pass through filament decreases
c. Rate at which electrons pass through filament increases

Ohm's Law: $\Delta V = IR$



If the battery on the left has a voltage (difference) of 6V and it is pushing a current of 1.5 A through the bulb, what is the resistance of the bulb?

a) 9 Ω
b) 6 Ω
c) 4 Ω
d) 1.5 Ω
e) 0 Ω

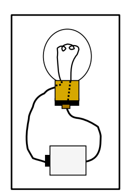
Electrical Power

What is the electrical power used up by each component in circuit?
POWER tells us how HOT something gets or how BRIGHT a bulb is

P = I ΔV
- ΔV: Voltage dropped across component
- I: Current through component
- P: Electrical power dissipated (used up) in component

Don't mix and match!

Also Ohm's Law: $\Delta V = IR$
Substitute into power law to get different forms:



$P = \Delta V^2/R$
- I = V/R
- Useful if you know V and R but not I (parallel circuits)

$P = I^2R$
- V = IR
- Useful if you know I and R but not V (series circuits)

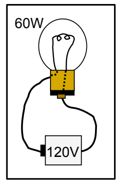
P = I ΔV
- Useful if you know I and V but not R

Power question

I have a 60W bulb plugged into the mains.
Assume that the mains supply is like a 120V battery

What current flows through the bulb?

a) 120 A
b) 60 A
c) 0.5 A
d) 2 A
e) 7200 A



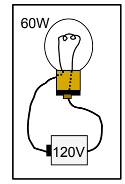
Power question

I have a 60W bulb plugged into the mains.
Assume that the mains supply is like a 120V battery

What current flows through the bulb?

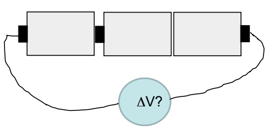
What is the resistance of the bulb filament?

a) 240 Ω
b) 2 Ω
c) 0.5 Ω
d) 30 Ω
e) Can't determine



Batteries in series

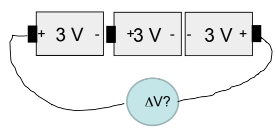
Batteries provide a voltage difference between their terminals
If each battery below is an identical 3V battery, what is the total voltage across the following arrangement?

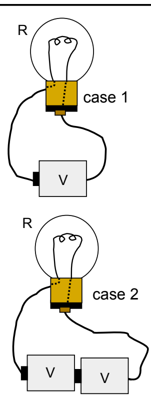


a) 3V
b) 0V
c) 9V
d) 6V
e) Other

Batteries in series

Batteries provide a voltage difference between their terminals
If each battery below is an identical 3V battery, what is the total voltage across the following arrangement?

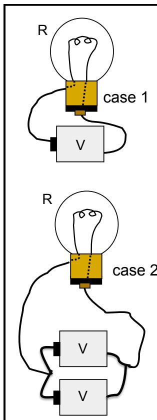




Batteries in series (nose to tail)

Compare the brightness of the bulbs in case 1 and case 2.
All bulbs and batteries are identical

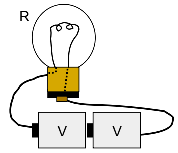
a. 2 twice as bright as 1
b. 2 same brightness but runs twice as long
c. 2 **more** than twice as bright as 1
d. 2 produces no light



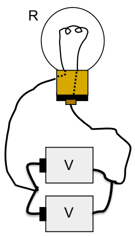
Batteries in parallel

Compare the brightness of the bulbs in case 1 and case 2.
All bulbs and batteries are identical

a. 2 twice as bright as 1
b. 2 same brightness
c. 2 more than twice as bright as 1
d. 2 produces no light



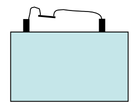
Summary:
- **Series:** more energy for each electron! (brighter)
  how you make a 9 V out of D-Cells, or AAAs



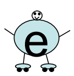
- **Parallel:** longer lasting
  difference between AAAs and D cells

Car battery demo 1

Ohms Law (V=IR) and Power (P = I ΔV)



Connect paper clip across terminals.
What will happen?
a) nothing,
b) drain battery slightly,
c) melt paper clip,
d) melt wires,
e) both c. and d.

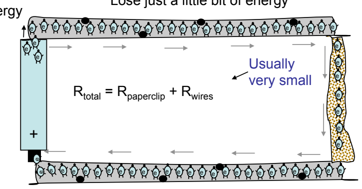


This is a task for Electron man!

Circuits – Think like an electron

1. Start: Lots of energy

2. Wires: Not much to bump into – Low R.
Lose just a little bit of energy

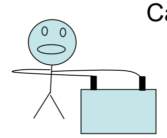


3. Paper clip
Lots to bump into
Higher R
Lose lots of energy.
Energy goes into the things bumped, so paperclip heats up.

4. End: Exhausted! Energy used up getting through course.

- Same current through wires and clip.
- $R_{paperclip} >> R_{wires}$
- Almost all energy into paper clip.

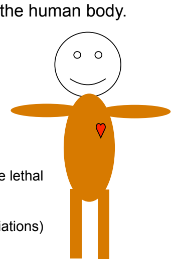
Car battery demo 2



Student volunteer grabs terminals with hands.
A. Nothing.
B. Will get zapped (flames etc.) like paperclip
C. will get mild jolt,
D. other

How to figure out? 1st step in process?

Avoiding electrocution- ohms law applied to the human body.



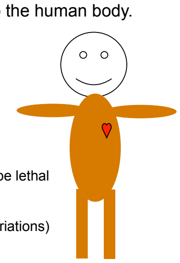
Extent of injuries are determined by 2 factors:
a) The amount of **current** that flows
b) Where it flows through the body

Rules of thumb:
- 1-5 mA you can barely feel
- 10 mA is painful
- 100 mA causes muscle contraction in the heart, can be lethal

Resistance of dry skin ~10^5 ohms
Resistance of wet skin ~ 1000 ohms (but with wide variations)

So: if 10,000 volts is applied briefly across a person's dry chest, what happens?
a. no effect
b. Risky
c. vaporize person

Avoiding electrocution- ohms law applied to the human body.



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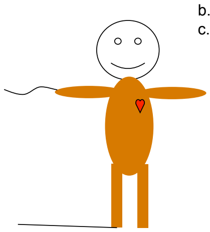
Resistance of dry skin ~10^5 ohms
Resistance of wet skin ~ 1000 ohms (but with wide variations)

So: if **100 volts** is applied briefly across a person's dry chest, what happens?
a. no effect
b. Risky
c. vaporize person

Don't try this at home

Applying 120 volts between right arm and right foot

a. no effect
b. fibrillation and electrocution
c. painful but probably no significant damage



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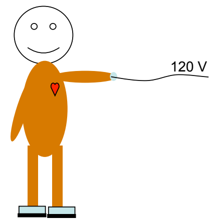

Applying 120 volts to wet left hand, right hand in pocket and wearing rubber sole shoes

a. little effect
b. fibrillation and electrocution
c. painful but probably no significant damage

Where's the circuit?

Is this a doctored photo?

Where do electrons flow?

Could we possibly do this here?