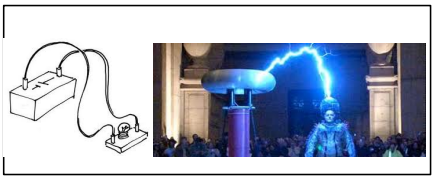
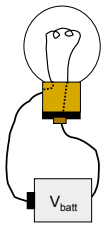
Electric circuits



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

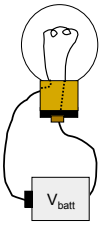


Resistance is a measure of how hard it is for electrons to pass through an object
(… or how much stuff they will run into.)

What if we increase resistance (R) of filament?

The rate at which electrons pass through the filament…

a. stays the same
b. decreases
c. increases

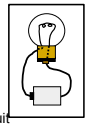


What if increase resistance (R) of filament… add more stuff to hit… Rate at which electrons pass through filament

a. stays the same
b. decreases
c. increases

- Increase R ⇒ More stuff to run into, average speed slower, fewer e- per time.
- $\Delta V = IR \Rightarrow I = \Delta V_{batt}/R_{bulb}$

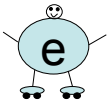
Circuits so far



Wires: Complete circuit necessary
Usually 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
(bigger V, bigger push for electrons)

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

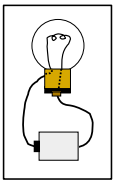


Electronman rules for analyzing circuits

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 measures how hard it is for electrons to pass through.
Units: Ohms (Ω)

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

Voltage (difference) (ΔV)

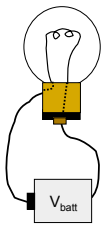
a) Across battery: EPE given to each e^- as it passes throug battery.
EPE given = eV. Related to pushing force on electrons

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)

Ohm's Law: ΔV = IR

Resistance of component
Current through component
Voltage dropped across component

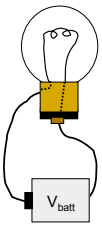
Note: All quantities specific to one component.
Don't mix and match!



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: ΔV = IR



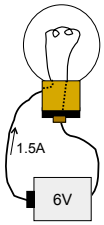
What if increase voltage difference across battery?

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

More EPE given to electrons in battery …electrons have more KE in circuit … higher average speed ….more electrons per time.

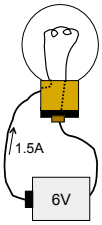
Electrons have bigger pushing force around circuit……more KE……higher average speed……more electrons per time

$\Delta V = IR \Rightarrow I = \Delta V_{batt}/R_{bulb}$



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



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a) 9 Ω
b) 6 Ω
c) 4 Ω
d) 1.5 Ω
e) 0 Ω

$\Delta V = IR \Rightarrow R = \Delta V/I$
Voltage across bulb = 6V
(no energy/voltage lost in connecting wires)
Current through bulb = 1.5A
$\Rightarrow$ Resistance of bulb = 6/1.5 = 4Ω

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

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

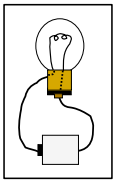
Don't mix and match!

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

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

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

$P = I\,\Delta V$
- Useful if you know I and V but not R

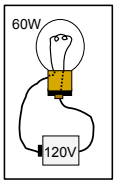


Power question

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



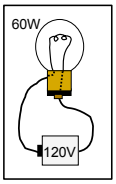
Power question

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?

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

Know P and V and want I
$\Rightarrow$Use $P = I\,\Delta V$
$\Rightarrow I = P/\Delta V = 60/120 = 0.5A$



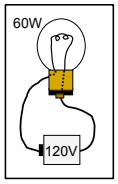
Power question

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?
0.5A

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



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? 0.5A

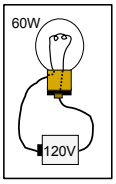
What is the resistance of the bulb filament?

a) 240 Ω

Method 1:
- Know P and ΔV, want R
- Use: $P = \Delta V^2/R$
- $R = \Delta V^2/P = 120*120/60 = 240\Omega$

Method 2:
- Know ΔV and I (from previous question)
- Use $\Delta V = IR$
- $R = \Delta V/I = 120/0.5 = 240\Omega$

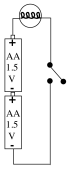
Often several ways to calculate circuit answers:
- Useful for checking your answers
- Practice enables to you choose quickest method

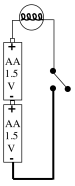


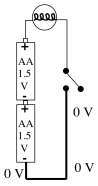
Batteries in series

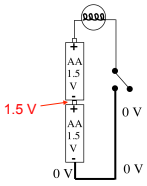
A flashlight requires 2 AA (1.5V) batteries, and is arranged as shown. The bulb…

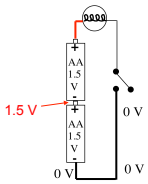
A: has 1.5 V across it, & glows
B: has 3 V across it, & glows
C: has 3 V across it, & is dark
D: has 0 V across it, & is dark
E: has 0 V across it, &glows

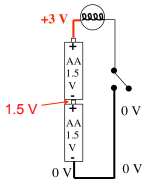


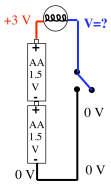


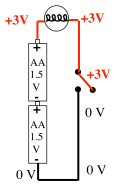






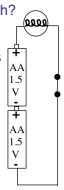


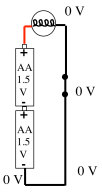


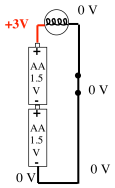


What about when I close the switch?
Now the bulb…

A: has 1.5 V across it, & glows
B: has 3 V across it, & glows
C: has 3 V across it, & is dark
D: has 0 V across it, & is dark
E: has 0 V across it, &glows

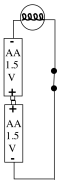


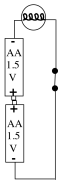


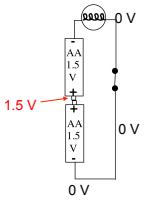


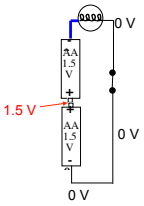
What if I reverse one battery?
Now the bulb…

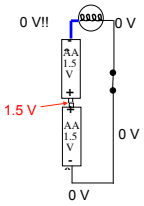
A: has 1.5 V across it, & glows
B: has 3 V across it, & glows
C: has 3 V across it, & is dark
D: has 0 V across it, & is dark
E: has 0 V across it, &glows





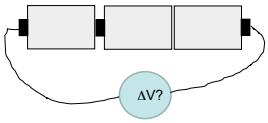






Batteries in series

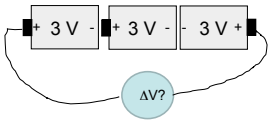
If each battery below is an identical 3V battery, what is the total voltage across the following arrangement?



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?



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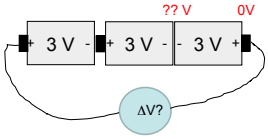

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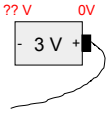

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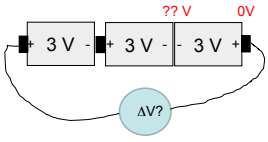

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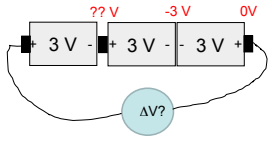

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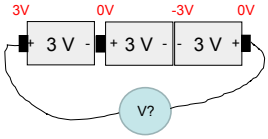
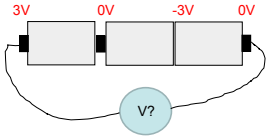


a) 3V
b) 0V
c) 9V
d) 6V
e) Other

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?



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Batteries in series

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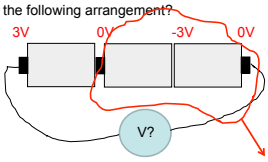
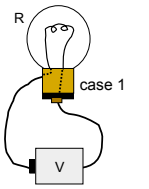


a) 3V
b) 0V
c) 9V
d) 6V
e) Other

- Tail to tail (or nose to nose) configuration of batteries not a good idea
- Voltage differences cancel out
- Could cause explosion of a non-rechargeable battery
  (current is being forced through 3rd battery in the wrong direction)

First we have 1.5 V across a bulb, later we put 3 V across the SAME bulb. What happened to the POWER dissipated by the bulb?

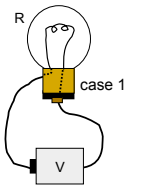
A) Stayed the same
B) Doubled
C) Quadrupled
D) Not sure/something else



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



Batteries in series (nose to tail)

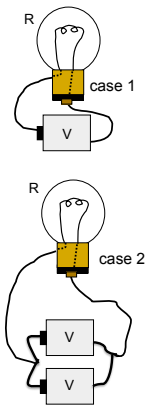
c. case 2 is more than twice as bright

Electrical power into bulb = EM power out.

Method 1: $P_{in} = \Delta V_{bulb}^2/R$
Case1: $P_{in} = \Delta V^2/R$
Case 2: $P_{in} = (2\ \Delta V)^2/R = 4\ V^2/R$

(In addition, since filament is hotter in case 2 a greater fraction of the radiated EM power is in visible range.)

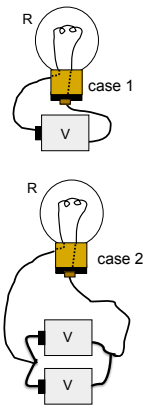
Method 2:
$P_{in} = I_{bulb} \times \Delta V_{bulb}$
Both I and V double in case 2 $\Rightarrow P_{in} = \times 4$



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



Batteries in parallel

Compare the brightness of the bulbs in case 1 and case 2.
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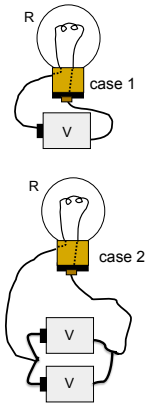
Why?
Think like an electron.
In either battery in case two, the electron has the same Electric potential energy = EPE = q ΔV

Note: an electron doesn't get to go through both batteries, it's one or the other

Same energy to deposit in identical bulbs
What is the difference then?



Batteries in parallel

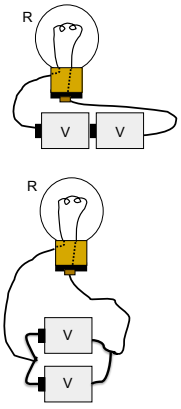
What is the difference then?

Each battery can produce a given amount of Current (electrons/ second) for a certain amount of time

Note: rating on batteries is in Amp-Hours! (what is an amp-hour?)

Zoinks.. With two batteries I have a greater reservoir of electrons to draw from.

Case 2: last twice as a long!

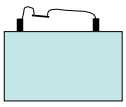


Summary:
- Series: more energy for each electron! (brighter)
how you make a 9 V out of D-Cells, or AAAs

- 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.

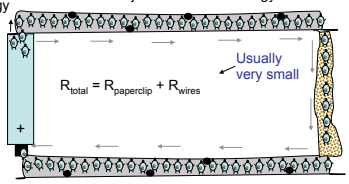
c)Melt paper clip.
How to figure out, how to explain?
When analyzing circuits – think like an electron!

This is a task for Electron man!

Circuits – Think like an electron

1. Start: Lots of energy

2. Wires: Not much to bump into – VERY 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.