Welcome back!

Come play with demos

New homework will be posted tonight, due next Wednesday

Please get your iclickers out if you have them
(if you don’t, write your answers on paper and I will look at them as we do each clicker question)
If a potential difference is applied across two points on an object
There is an E field
If there are free charges, current flows

in many cases, current increases linearly with potential difference
“Ohm’s law”

The constant of proportionality is called the resistance
Determined by material, geometry of the object, temperature, points of application of the potential

As current flows, energy is transferred to heat and light at rate $I \cdot V$
“power dissipated”
A potential difference of 50 V is applied across a wire and a current of 0.5 A flows. When the potential difference is increased to 100 V, the current increases to 2.0 A. Does the wire obey Ohm’s law?

(a) Yes  
(b) No  
(c) Not enough information is given to decide  
(d) If I put one of the other answers, I would just be guessing
A potential difference of 50 V is applied across a wire and a current of 0.5 A flows. What is the power dissipated by the current in the wire?

(a) 1250 W
(b) 25 W
(c) 12.5 W
(d) 10 mW
(e) Not enough information is given to determine
(f) If I put one of the other answers, I would just be guessing
A potential difference of 50 V is applied across a wire and a current of 0.5 A flows. Assuming the wire obeys Ohm’s law, what is the resistance of the wire?

(a) 100 Ω
(b) 25 Ω
(c) 0.04 Ω
(d) 0.01 Ω
(e) If I put one of the other answers, I would just be guessing
A potential difference of 50 V is applied across a wire and a current of 0.5 A flows. Assuming the wire obeys Ohm’s law, what is the resistance of the wire?

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Introduction to circuits
Q: When does current flow through a wire?
A: When there is a potential difference between the ends.

Electric field inside the wire -> force that drives the motion of free charges.

To maintain a steady current, need two things:
(1) at least one closed loop path for moving charges: a CIRCUIT
(2) a way to boost charges from low potential back to high potential.
Circuit diagram: devices + connecting lines ("wires")
potential on "wire" between devices is CONSTANT

Devices: resistor

Note that in our idealized circuits, "wires" have zero resistance!
Q: When does current flow through an object?
A: When there is a potential difference across it

Need a device that can have boost charges from low potential back to high potential = BATTERY

In battery, current flows from low potential to high potential
Mechanical analogy: Playground

Parent lifts toddlers from ground to top of slide
Toddlers slide down slide (with friction) & stop at bottom

Toddler = charge
Parent = battery
Slide = resistor
Ideal battery maintains specified voltage $\mathcal{E}$ between + and − terminal. The same no matter how much current flows through the battery. Here, the current is zero.
Ideal battery maintains specified voltage $\mathcal{E}$ between + and – terminal

charges arrive at small terminal at rate given by current $i$

battery does work $q \mathcal{E}$ on charges to place them at + terminal

Rate of energy delivery by battery = $i \mathcal{E}$

charges flow through the resistor and lose energy $q \mathcal{E}$

Rate of energy loss = $i \mathcal{E}$
Ideal battery maintains specified voltage $\mathcal{E}$ between + and – terminal.
Potential difference between the ends of the resistor is also $\mathcal{E}$

Current $i$ flows from + to – potential.

Assume Ohm’s law: resistor has resistance $R$: $i = \frac{\mathcal{E}}{R}$
- $i$ doubles if $\mathcal{E}$ doubles
- rate of energy loss: $i\mathcal{E} = \frac{\mathcal{E}^2}{R} = i^2R$

SAME AS THE RATE AT WHICH THE BATTERY DELIVERS ENERGY TO THE CIRCUIT
Resistors that obey Ohm’s law $V = iR$
$V \rightarrow I = \frac{V}{R}$ from higher to lower pot
$I \rightarrow V = iR$, decreasing in direction of current

Bulbs are resistors, obey Ohm’s law
brightness = power = $IV = \frac{V^2}{R}$
Bulbs usually labeled by power (100W) at standard voltage
higher power rating = lower resistance

Any conducting object in a circuit will be a resistor
e.g. human body
Only difference between bulbs A & B is that B’s filament is thicker. Each is in a simple circuit with a 120 V battery.

A) B will be brighter because it has higher resistance.
B) B will be dimmer because it has higher resistance.
C) B will be brighter because it has lower resistance
D) B will be dimmer because it has lower resistance
E) Equal brightness.
Only difference between bulbs A & B is that B’s filament is thicker. Each is in a simple circuit with a 120 V battery.

A) B will be brighter because it has higher resistance.
B) B will be dimmer because it has higher resistance.
C) B will be brighter because it has lower resistance.
D) B will be dimmer because it has lower resistance.
E) Equal brightness.
What happens to the brightness of a bulb in a simple circuit with an ideal battery if a second identical bulb is added in parallel?

(A) Gets brighter  
(B) Stays the same  
(C) Gets dimmer  
(D) Goes out
What happens to the brightness of a bulb in a simple circuit with an ideal battery if a second identical bulb is added in parallel?

(A) Gets brighter
(B) Stays the same
(C) Gets dimmer
(D) Goes out

Potential difference is the same; current through battery doubles
What happens if the two bulbs have different resistance?

Bulbs are resistors, obey Ohm’s law
brightness = power = IV = V^2/R
Bulbs usually labeled by power (100W) at standard voltage

Let’s check!
Resistors in series

Current is the same in the two resistors

\[ V = V_1 + V_2 = i \, R_1 + i \, R_2 = i \, (R_1 + R_2) \]
\[ V/i = R_1 + R_2 \]

Combination behaves like a resistor of resistance \( R_1 + R_2 \)
What happens to the brightness of a bulb in a simple circuit with an ideal battery if a second identical bulb is added in series?

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\[ P = \epsilon^2 R \]

\[ R_{\text{eff}} = R_1 + R_2 = 2R \]

\[ I = \frac{\epsilon}{R_{\text{eff}}} = \frac{\epsilon}{2R} \]

\[ P_1 = I^2 R = \frac{\epsilon^2 R}{4} \]

total current goes down  
Brightness of first bulb goes down
What happens if the two bulbs have different resistance?

Bulbs are resistors, obey Ohm’s law
brightness = power = IV = V²/R
Bulbs usually labeled by power (100W) at standard voltage
higher power rating = lower resistance

Let’s do the calculation!
Analyzing circuits, part 1

FIRST STEP: draw and label the current arrows
Voltage change across each circuit element:
Battery: $+\mathcal{E}$ from small plate (-) to large plate (+)
Resistor: decreases by $iR$ in direction of current arrow

LOOP RULE: total voltage change around loop is ZERO
What happens if the two bulbs have different resistance?

Bulbs are resistors, obey Ohm’s law
brightness = power = $IV = \frac{V^2}{R}$
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Let’s do the calculation!
Circuit rules

Voltage change across each circuit element:
Battery: $+\varepsilon$ from small plate (-) to large plate (+)
Resistor: decreases by $iR$ in direction of current arrow

LOOP RULE: total voltage change around loop is ZERO
\[ E - iR_1 - iR_2 = 0 \]
\[ i = \frac{E}{R_1 + R_2} \]

Voltage drop across each resistor is \( ER_n/(R_1+R_2) \) \( n=1,2 \)
The two resistors divide up the voltage drop -- Larger resistance gets bigger share

\[ P = IV \]

Same resistance
Both get dimmer (I and V down by 2)

Larger resistance is brighter than lesser: 40 W bulb is brighter than 100 W bulb -- check with demo
E – i \( R_1 \) – i \( R_2 \) = 0
\[ i = \frac{E}{(R_1 + R_2)} \]

Current is the same as for a circuit with a single resistor of \( R_1 + R_2 \)

Power delivered by the battery is also the same

If I put a box around the two resistors to make a device, no way to know if it’s two resistors or one

Connected in SERIES
(same current in the 2 resistors)
If the potential at point P is 100 V, what is the potential at point Q?
Energy delivered / lost by each circuit element

50 V battery is charging

\[ 150 \text{ V} \quad \begin{array}{c} Q \end{array} \quad \begin{array}{c} 3.0 \Omega \end{array} \quad \begin{array}{c} 2.0 \Omega \end{array} \quad \begin{array}{c} 50 \text{ V} \end{array} \quad P \]