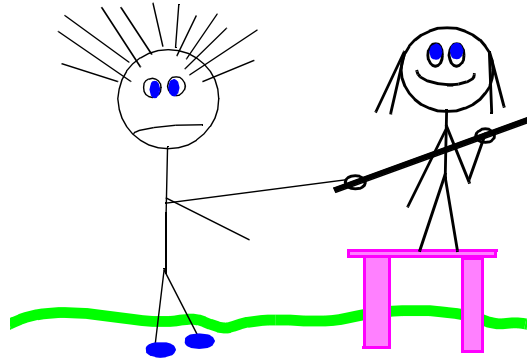


Electric Conduction

Which twin is grounded?



Conductors = materials in which an electric current can flow. Conductors have low electrical resistivities.

Insulators = materials in which electric current has difficulty flowing. Insulators have high electrical resistivities.

Semi-Conductors = materials in between conductors and insulators in their abilities to conduct electric current.

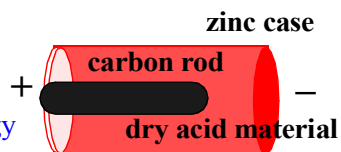
When silicon is mixed with a small amount of impurities it becomes a semiconductor.

Battery

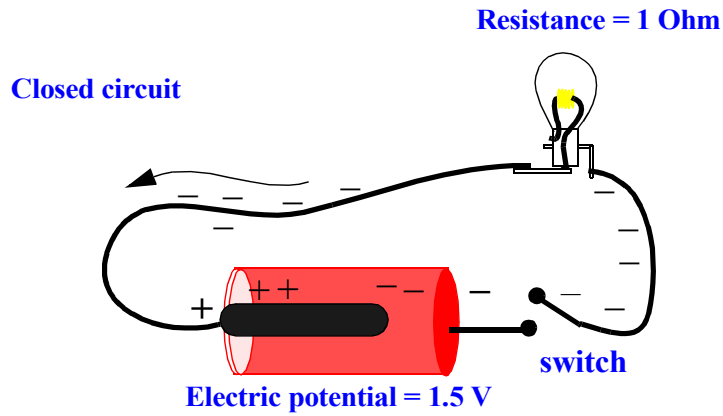
Battery is a source of electric potential energy for each charge that moves through circuit.

Battery
stores energy

Converts
chemical
to electrical energy

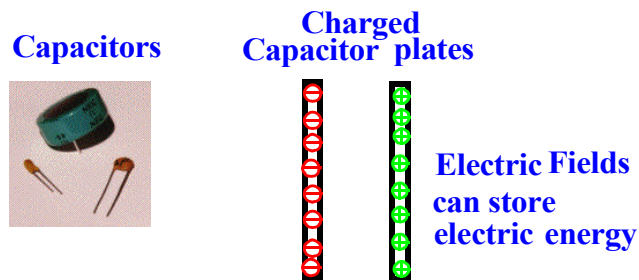


What happens inside the battery when in a closed electric circuit?

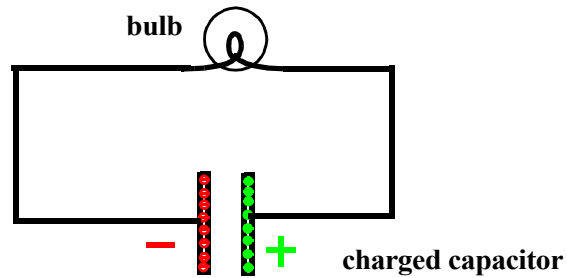


Electric potential acts like 'pressure' on each charge causing charges to move around a closed circuit. Electric potential is measured in Volts.

Charged Capacitors produce Electric Potential Energy



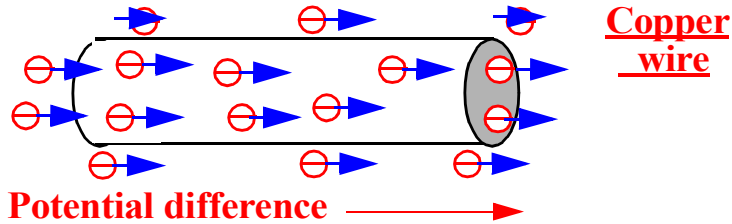
Electric Circuit?



Moving Electric Charges

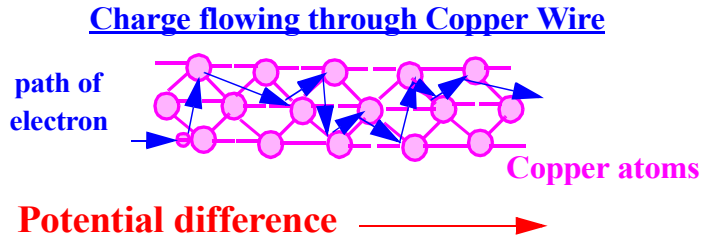
Electric current is the rate that charge moves through a circuit.

Enlarged view of a current-carrying wire:



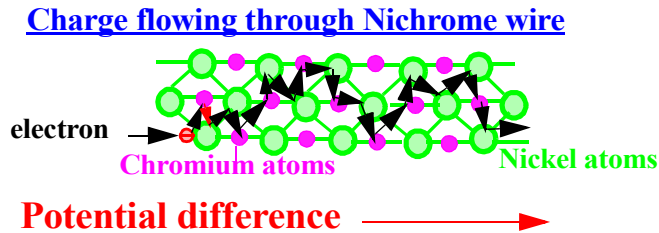
Metals like copper have billions of free electrons

Even more enlarged view of wire:



What is Required to Move Electric Charge?

Filaments in Light bulbs are made of Nichrome metal.



Nichrome has greater electrical resistance than copper.

What happened to the steel wool when you connected a piece into your test circuit?

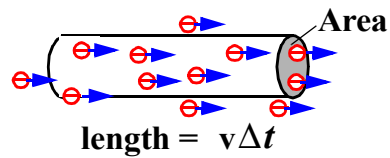
When things heat up, they glow or radiate light (electromagnetic energy).

At what speed do electrons flow through wire in a direct current (dc) circuit?

Electric current is the rate that charge flows in a circuit.

$$I = \frac{\Delta q}{\Delta t} \quad \frac{\text{Coulomb}}{\text{second}}$$

Volume of segment of wire is



$$Vol = Av\Delta t = \text{area} \times \text{length}$$

The number of charges flowing in a segment of the wire is

$$n \times \text{volume} \quad \text{where } n \text{ is the number of charges per unit volume.}$$

Current is the number of charges flowing through the wire per unit time

$$I = \frac{\Delta q}{\Delta t} = \frac{qn v \Delta t A}{\Delta t} = qn v A$$

So the speed of the electrons flowing through the wire is.

$$v = \frac{I}{qnA}$$

If an electric current of 16 Amperes is flowing through a wire in a circuit what speed are the electrons flowing through the wire? Assume that there are 10^{29} free electrons/ m^3 in the wire, and the end of the wire has an area of 10^{-6} m^2 . The electric charge of a single electron is -1.6×10^{-19} Coulomb.

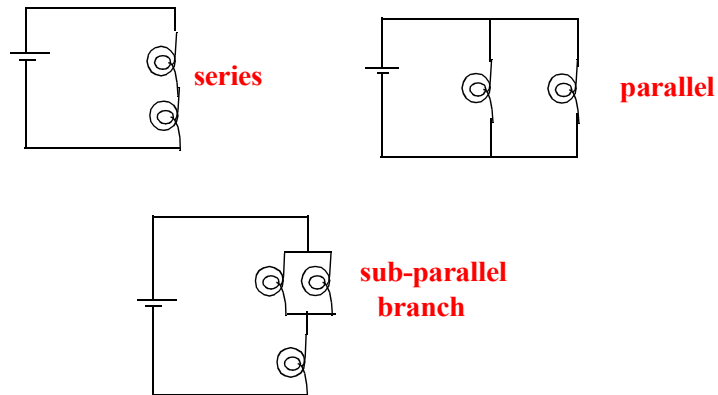
Simple Electric Circuit

Battery is energy source & creates a potential difference which creates an electric field if there is a closed electric circuit.

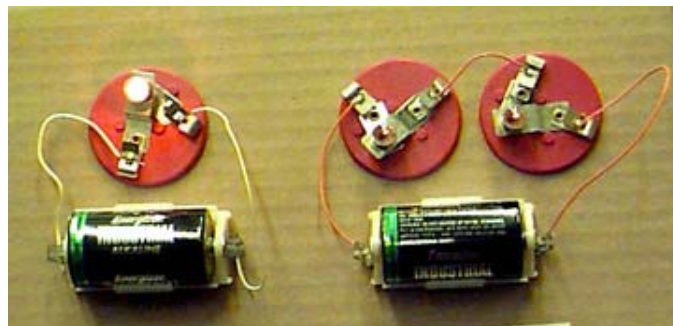
Electrons accelerated by electric field (between collisions with copper atoms).

Circuit which has general flow of electrons in one direction is direct current (dc) circuit.

3 Basic Bulb Arrangements

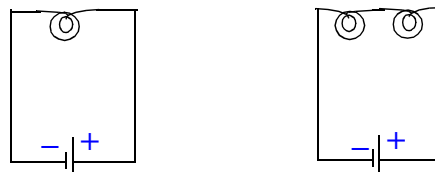


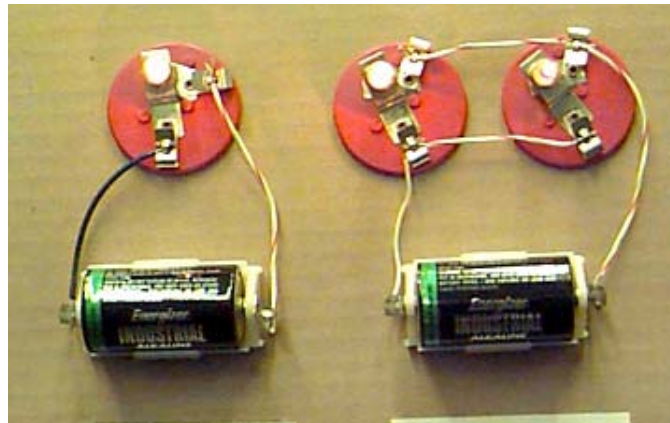
ELECTRIC Direct Current (DC) CIRCUITS



Circuit Diagrams

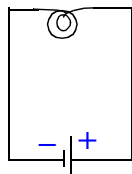
bulbs connected in **series** with battery



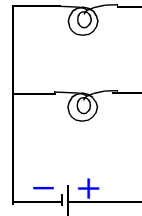


Circuit Diagrams

series



parallel



Ohm's Law

Ohm's Law = relation between current, resistance and voltage in an electric circuit.

$$V = IR$$

1 volt of electric potential provided by a battery produces a current of 1 Ampere if the resistance in the circuit is 1 Ohm.

The lower the resistance to electric current, the greater the current.

Voltage (potential difference) is like pressure in a hose, where water in hose is like an electric current. Energy sources in circuits (battery, power company source, capacitor, etc.) produce the voltage.

Resistance of bulb filament like a steep hill. Resistance is an obstacle to the flow of charge in a circuit, and measured in Ohms. Total resistance in a circuit (i load) depends on the arrangement of bulbs (and other circuit elements).

Current is the rate that electric charge flows through a circuit, measured in Amperes. In simple circuits bulb brightness is proportional to the amount of current flowing through it.

Electric Power

$$P = I^2 R$$

The greater the resistance and current in an electric circuit, the greater the power delivered to the circuit.

A current of 1 Amp in a circuit with a resistance of 1 Ohm delivers a power of 1 Watt.

Electric Energy = Power x time.

Electric Power companies sell us Electric Energy usually measured in kiloWatt-hours.

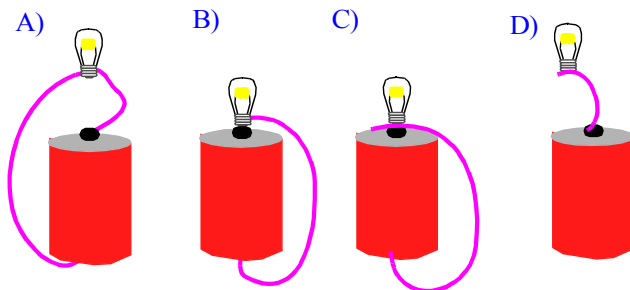
If a 100 Watt light bulb has a resistance of 100 Ohms, how much current does the light bulb draw from the circuit?

If a toaster has a resistance of 6 Ohms and is plugged into the 120 volt power supplied to your home, how much current does the toaster draw? How much power does your toaster deliver?

Suppose you received an electric shock by touching a wire with a wet hand while standing in a mud puddle. The resistance of wet skin is lower (about 1000 Ohms) than the resistance of dry skin (about 500,000 Ohms). Would you draw more or less current by touching a "live" wire with a dry or a wet hand? What are the important factors in determining how big a "jolt" you get in an electric shock?

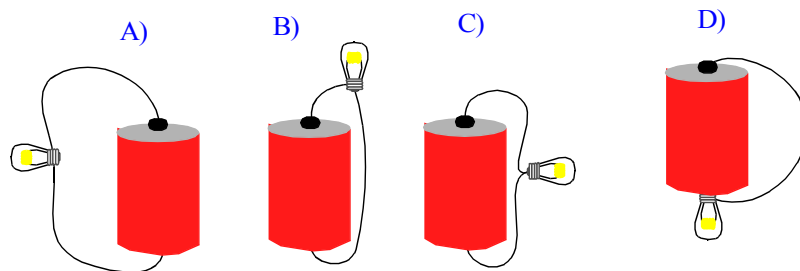
PRS Questions

Which arrangement(s) will light the bulb?



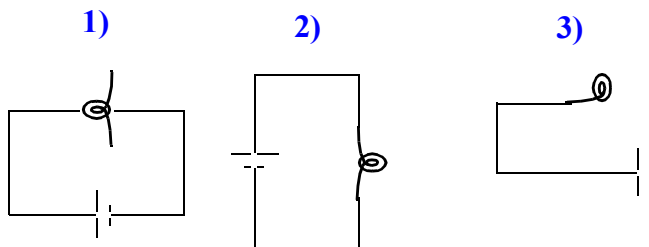
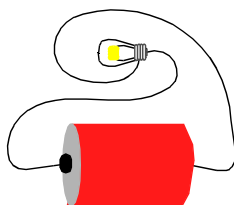
- | | |
|------------|------------|
| 1) A, C, D | 2) A, B, C |
| 2) A, D | 3) B, C |
| 4) A | 5) B |

Which arrangement(s) will light the bulb?

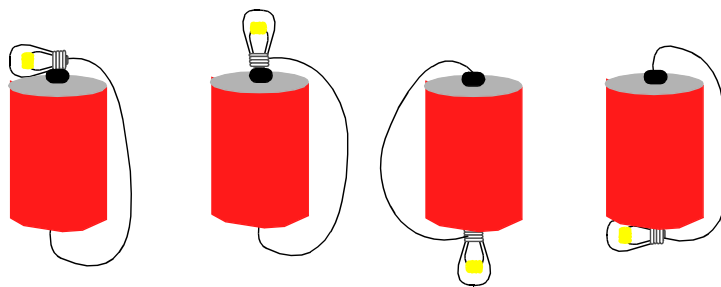


- | | |
|------------|------------|
| 1) A, C, D | 2) A, B, C |
| 2) A, D | 3) B, D |
| 4) B | 5) B, C |

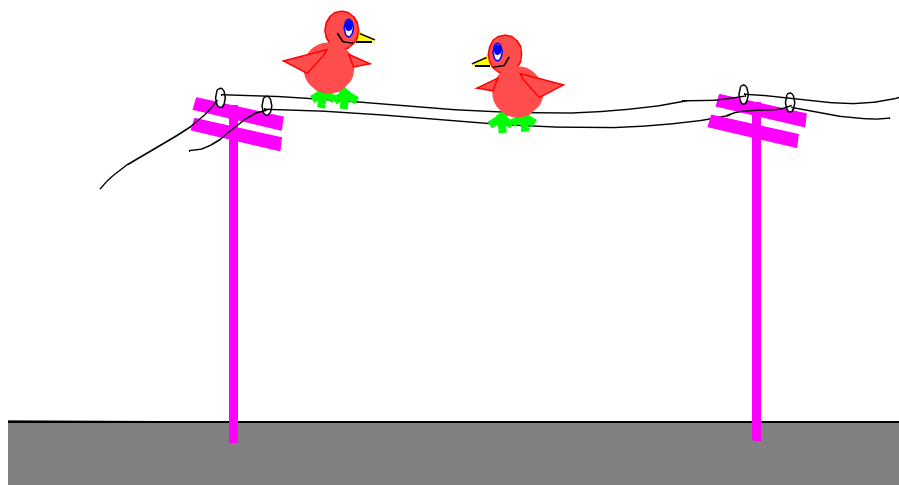
The correct circuit diagram for this arrangement of a bulb a battery and two wires is



Four ways to light the bulb with one battery and one wire.

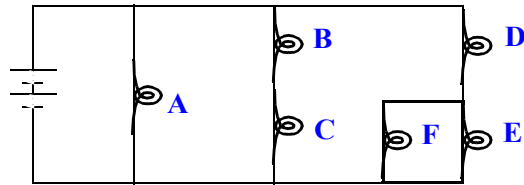


Why can birds perch on a 100,000 Volt power line with no adverse effects?



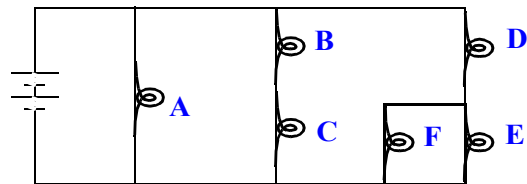
- 1) They put one foot down before the other, so current doesn't go through both feet at once.
- 2) Since there's little potential difference between their two feet, hardly any current flows through them.
- 3) Power lines are coated with a special resistance material that allows birds to stand on the line.
- 4) Even though there may be 100,000 volts through the line, very little current actually flows so the birds are relatively safe.

When bulb D is replaced by a wire, bulb F will become



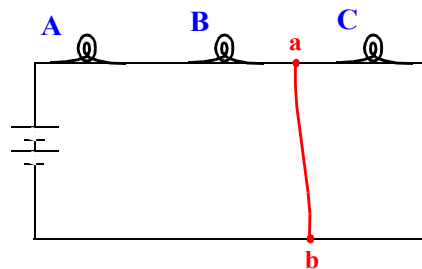
- 1) the same brightness as B
- 2) brighter than B, and the same brightness as A
- 3) fainter than B, and the same brightness as A
- 4) short-circuited, and not light at all

When bulb D is unscrewed and removed from the circuit, bulb F will



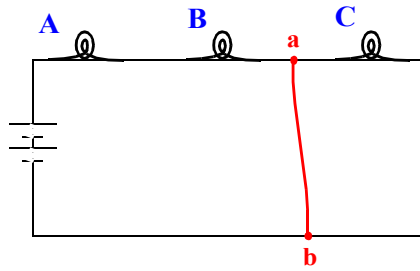
- 1) get brighter
- 2) get fainter, but still be lit
- 3) go out completely

If a wire were placed in the circuit shown connecting points a and b, the current through the battery will



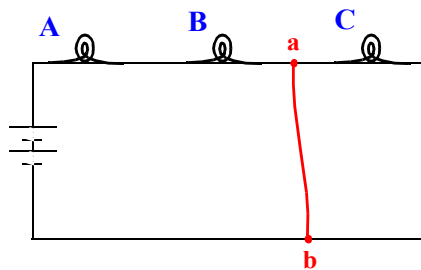
- 1) increase
- 2) decrease
- 3) stay the same

If a wire were placed in the circuit shown connecting points a and b,



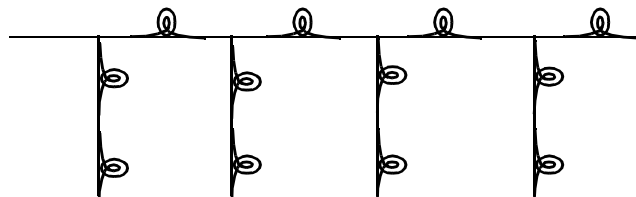
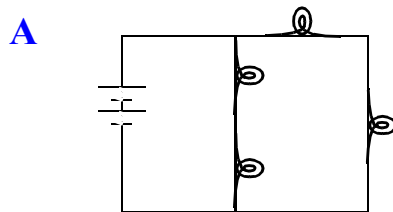
- 1) bulbs A, B and C will all get dimmer
- 2) bulbs A and B will get dimmer, and C will get brighter
- 3) bulb C will dim, but not go completely out, and A and B will brighten
- 4) bulb C will go completely out, and A and B will brighten

If a wire were placed in the circuit shown connecting points a and b, the power output of the circuit will



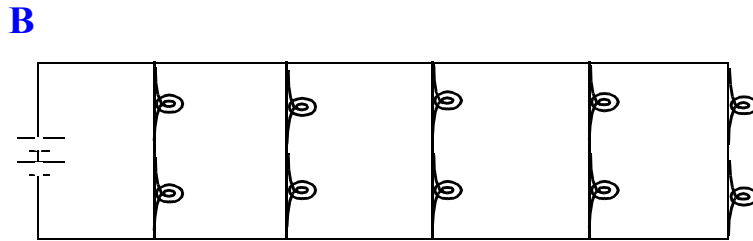
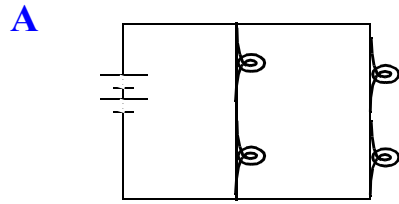
- 1) increase
- 2) decrease
- 3) stay the same

Which circuit draws the most current from the batteries?



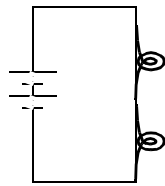
- 1) circuit A
- 2) circuit B
- 3) both the same

Which circuit has the brightest light bulbs?

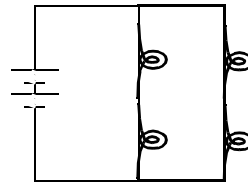


- 1) circuit A
- 2) circuit B
- 3) both the same

Each bulb has a resistance of $1\ \Omega$, and each battery has a voltage (potential difference) of $1\ \text{V}$. How much current do the bulbs in each circuit draw from the batteries?



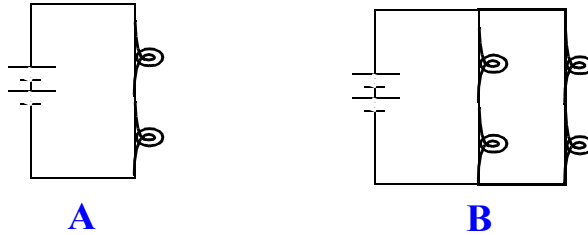
A



B

- 1) $1\ \text{Amp}$ in each circuit
- 2) $1/2\ \text{Amp}$ in A and $1\ \text{Amp}$ in B
- 3) $2\ \text{Amp}$ in A and $1\ \text{Amp}$ in B
- 4) $1/2\ \text{Amp}$ in A and $1/2\ \text{Amp}$ in B

Each bulb has a resistance of $1\ \Omega$, and each battery has a voltage (potential difference) of $1\ \text{V}$.



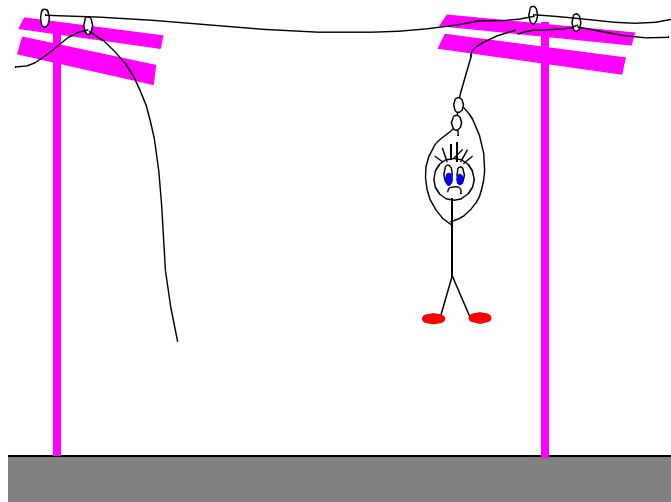
How much power does each bulb radiate in each circuit?

- 1) 1 Watt in each circuit
- 2) $1/2$ Watt in A and 2 Watt in B
- 3) 1 Watt in A and $1/2$ Watt in B
- 4) $1/2$ Watt in A and 1 Watt in B

Electric meters are regularly read by people from your local electric power company, so they know how much to bill you. These electric meters measure the amount of

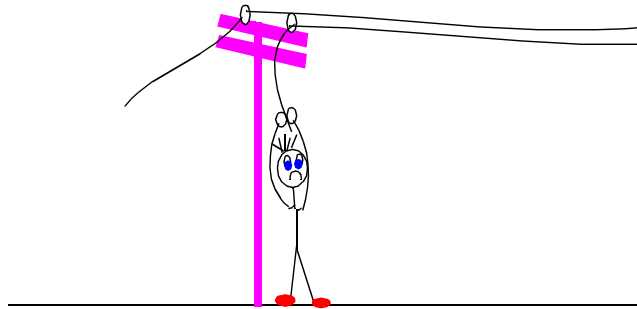
- 1) energy you use.
- 2) power you use.
- 3) force you use.
- 4) both 1 and 2 above.
- 5) both 2 and 3 above.
- 6) both 1 and 3 above.

Will this student hanging from a live power line while holding the wire with his bare hands receive an electric shock?

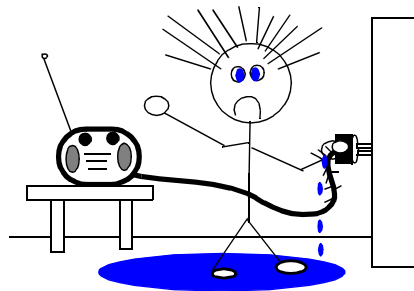


- 1) Yes, because the current will flow from one hand into the wire and through his other hand.
- 2) Yes, because the power line has a very high voltage which will produce a very large shock.
- 3) No, because the potential difference in the wire between his hands is essentially zero.
- 4) No, because the air is an insulator not a conductor.

A "shock" requires a difference in electric potential between one part of your body and another, and a "closed" circuit.



Suppose you received an electric "shock" by touching a wire with a wet hand while standing in a mud puddle. If you touched the "live" wire with a dry hand, you would



- 1) draw more current from the circuit, and receive a larger shock
- 2) draw less current from the circuit, and receive a smaller shock
- 3) wet or dry hands make no difference in the size of the shock you would receive.

Moist skin reduces resistance to the flow of electric charge about a factor of 500 times compared to the resistance of dry skin. So 500 times more current flows through your body if you touch a bare wire with wet hands.

By Ohm's law, $I = \frac{V}{R}$ the current you draw is inversely proportional to your resistance

(determined almost entirely by "first contact surface"--your hand)

Size of electric shock not only depends on resistance, but also on the total amount of charge passing through your body.

Electric power was defined as

$$P = IV \quad (\text{units} = \text{amps} \times \text{volts} = \text{Watts})$$

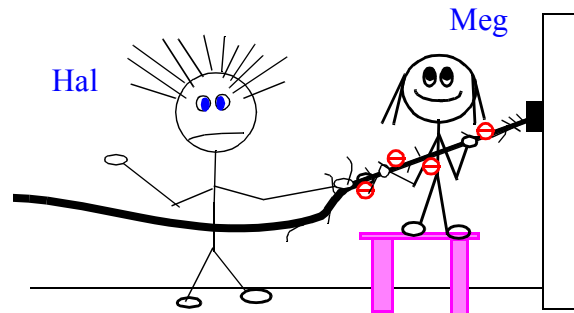
and energy is how long the power is sustained:

Electric Energy = Power x time (units = Watt-hrs)

Power companies sell us Electric Energy and is measured in kiloWatt-hours.

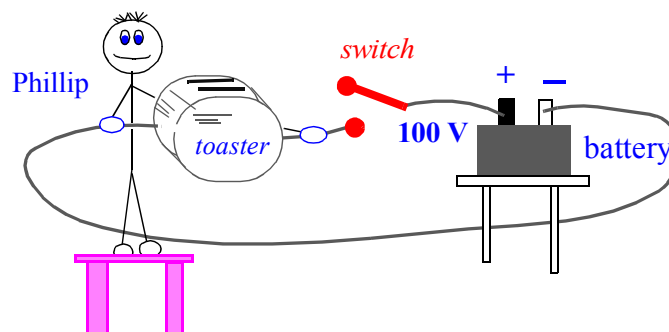
So you receive a larger "shock" when your resistance is low (wet hands), the energy carried by each electric charge is high ($E/q = \text{voltage}$) and the electric current through your body is sustained for a long time (energy is large).

Which twin is "grounded"?



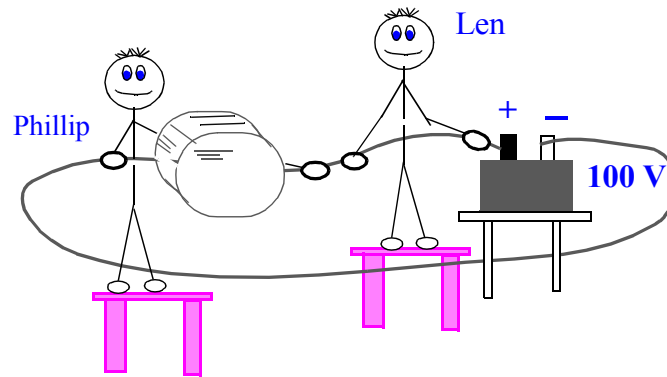
- 1) Hal
- 2) Meg
- 3) both
- 4) neither

A toaster is connected into a circuit containing a battery and a switch as shown. Phillip stands on a wooden bench and grasps the bare wire at two places with the toaster in between his hands. Phillip is going to get



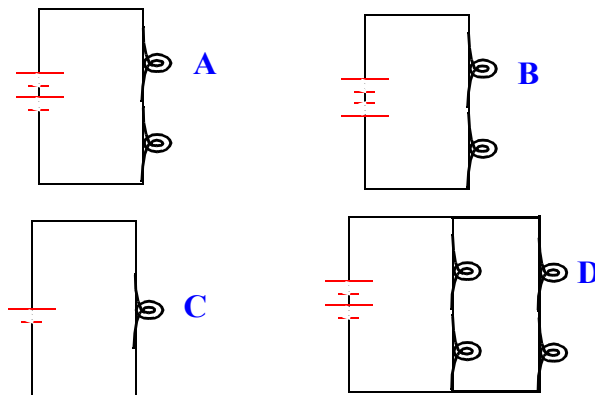
- 1) a shock if the switch is open
- 2) a shock if the switch is closed
- 3) a shock if the switch is open or closed
- 4) no shock at all in any of these cases

What would happen if Len also grabs the wire with his hands separated by the same distance?



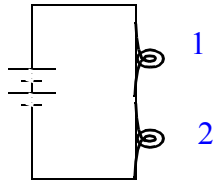
- 1) Len will get a shock and use up all the current preventing it from flowing to Phillip and the toaster.
- 2) Len and Phillip will both get shocks, but Phillip's shock will be milder than when he alone was holding the wire.
- 3) Len and Phillip will both get shocks, and Phillip's shock will be stronger than when he alone was holding the wire.
- 4) Len will not get a shock, and Phillip will get same shock as before.

In this circuit the bulbs and batteries are identical. Which bulbs have the same brightness?



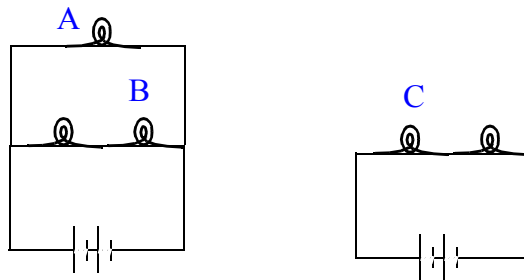
- 1) A and D
- 2) A, B, and D
- 3) A, C and D
- 4) B, C and D
- 5) A, B and C

In the closed circuit below the current through the second bulb is



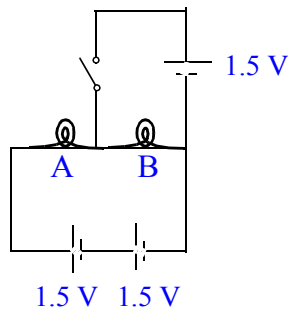
- 1) equal to
 - 2) half
 - 3) smaller than, but not necessarily half
- the current through the first bulb.

Which bulb is brightest?



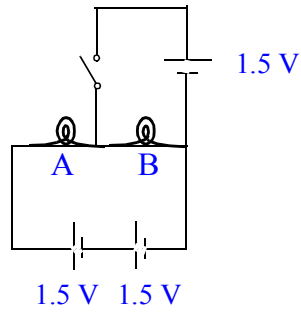
- 1) A
- 2) B
- 3) C

The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

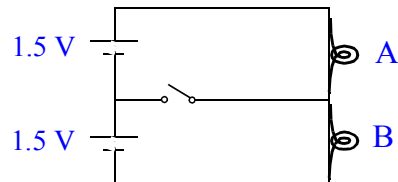
The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

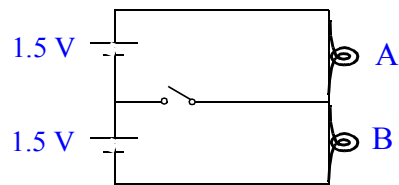
Because the light bulbs are identical, the potential difference across each is 1.5 V. So nothing happens when the switch is closed.

The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

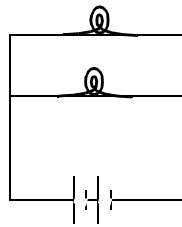
The light bulbs in the circuit are identical. When the switch is closed,



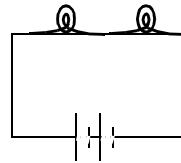
- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

The potential difference across the branch of the circuit with the switch is zero. So there is no current through it when the switch is closed, and nothing changes.

If the bulbs and batteries are identical, which circuit puts out more light?



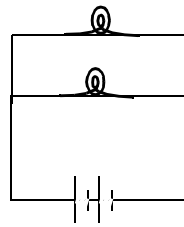
circuit I



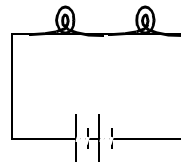
circuit II

- 1) circuit I
- 2) circuit II
- 3) both emit the same amount of light

If the bulbs and batteries are identical, which circuit puts out more light?



circuit I



circuit II

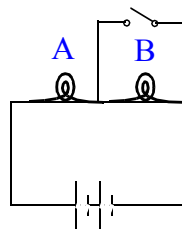
- 1) circuit I
- 2) circuit II
- 3) both emit the same amount of light

Resistance of two bulbs in parallel is smaller than two bulbs in series. So current through the batteries is greater for circuit I than circuit II. Power indicates brightness or amount of light output. Since power is related to current, I , resistance, R , and voltage, V , by

$$P = I^2R = IV$$

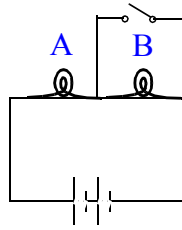
circuit I puts out more power and therefore more light.

The bulbs are identical. When the switch is closed, the brightness of bulb A



- 1) increases
- 2) remains unchanged
- 3) decreases

The bulbs are identical. When the switch is closed, the brightness of bulb A

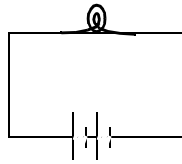


- 1) increases
- 2) remains unchanged
- 3) decreases

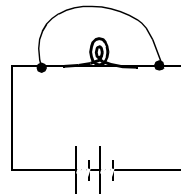
Bulb B goes out because virtually all of current goes through the wire. So the total resistance in the circuit decreases, and the current through bulb A increases, making it brighter.

Initially charge flows through the light bulb. Suppose a wire is connected across the bulb as shown. After the wire is connected,

before



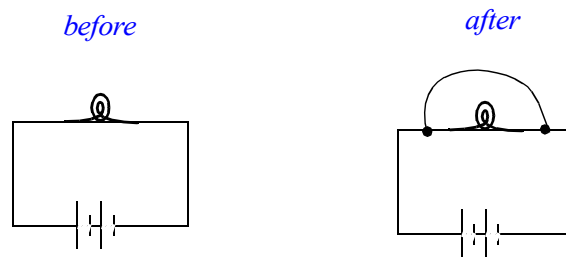
after



- 1) essentially all the charge continues to flow through the bulb
- 2) about half the charge flows through the wire, and the other half continues through the bulb
- 3) essentially all the charge flows through the wire

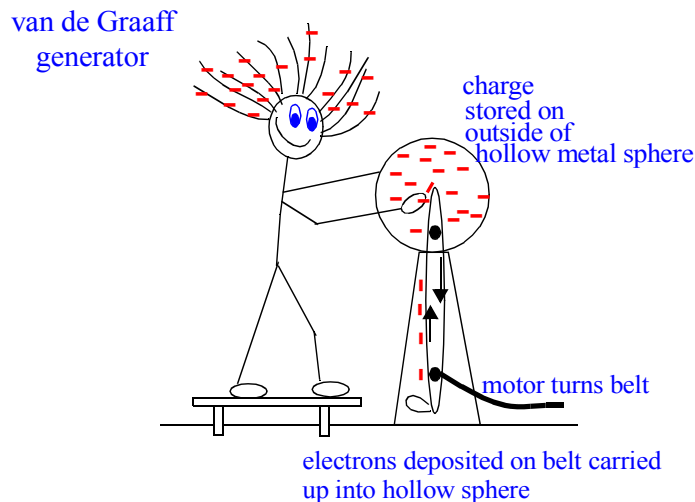
The bulb has resistance to charge flow, while the wire is essentially a perfect conductor of electric charge. With wire in place, the voltage across the bulb becomes zero, so essentially all charge flow is through the wire. We say the bulb is "shorted out".

Initially charge flows through the light bulb. Suppose a wire is connected across the bulb as shown. After the wire is connected,



- 1) essentially all the charge continues to flow through the bulb
- 2) about half the charge flows through the wire, and the other half continues through the bulb
- 3) essentially all the charge flows through the wire

The reason you can touch a 100,000 volt van de Graaff generator with little harm even though the voltage is high is that there is the relatively little charge stored on the outside of the sphere, so little current passes through you.

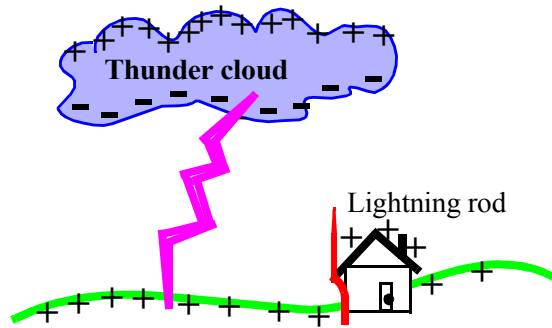


Electric power, $P = I^2R = IV$ times time = Electric Energy determines the strength of the electric shock to your body.

Resistance of human body is about 100,000 Ohms (dry hands)
and about 1,000 Ohms (wet hands)

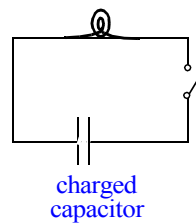
Even Voltage is very large on a van den Graaff generator (500,000 Volts), the total number of charges on the surface of the sphere is very small, so very few charges actually flow through your body.

The primary purpose of a lightning rod is to



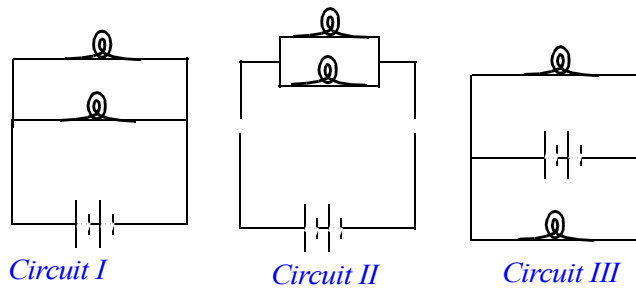
- 1) attract lightning and guide it to the ground
- 2) discharge the building to which it is attached
- 3) induce in the building to which it is attached a charge opposite to the charged clouds overhead

A simple circuit consists of a bulb, a charged capacitor and a switch. Immediately after the switch is closed, the light bulb in the circuit



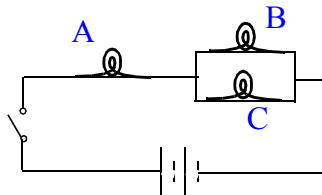
- 1) glows brightly for a few seconds then fades
- 2) glows dimly for a few seconds then brightens
- 3) glows as long as the switch remains closed
- 4) does not glow

Circuits I, II and III are all



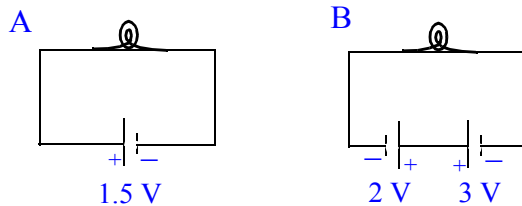
- 1) the same circuit
- 2) different circuits
- 3) the same, except for Circuit III
- 4) the same, except for Circuit II

After the switch is closed in the circuit shown, Bulb A is



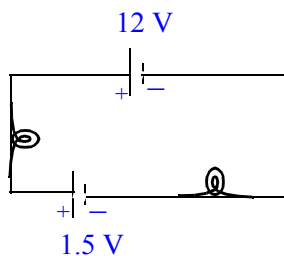
- 1) much brighter than
 - 2) a little brighter than
 - 3) as bright as
 - 4) as bright as
 - 5) a little dimmer than
- Bulbs B and C

In which circuit is the bulb brightest?



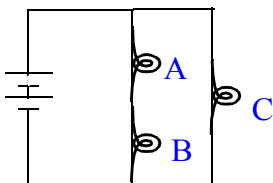
- 1) Circuit A
- 2) Circuit B
- 3) They both have the same brightness
- 4) Not enough information

Which way does current flow in the circuit?



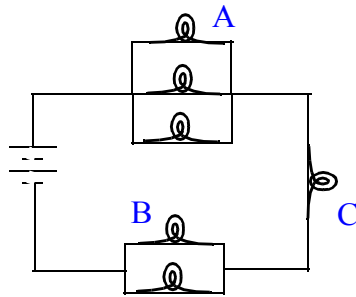
- 1) Counterclockwise
- 2) Clockwise
- 3) It alternates directions since the batteries are opposing each other.

Which bulb is brightest?



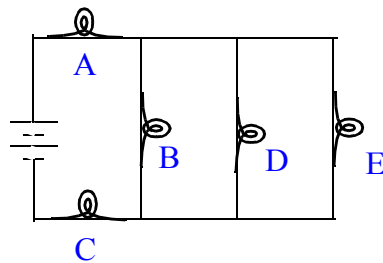
- 1) A
- 2) B
- 3) C
- 4) A and B are the same, but brighter than C

Which bulb is 2nd brightest?



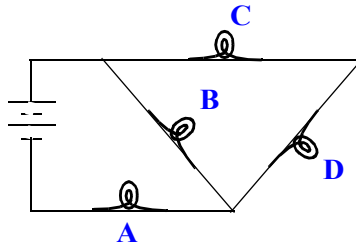
- 1) A
- 2) B
- 3) C

Which statement is true?



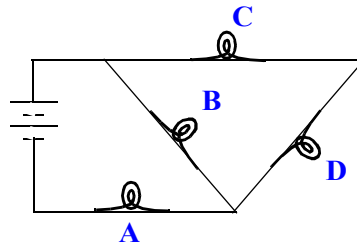
- 1) Bulb D is brighter than E, but the same as A
- 2) Bulb D is brighter than A but the same as E
- 3) Bulb A is brighter than C
- 4) Bulb D is fainter than A and the same as E

Which bulb is 2nd brightest?



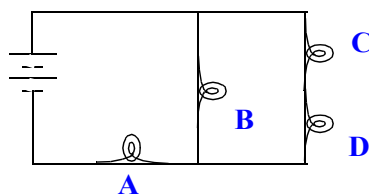
- 1) Bulb A
- 2) Bulb B
- 3) Bulb C
- 4) Bulb D

Which bulb is 2nd brightest?



- 1) Bulb A
- 2) Bulb B
- 3) Bulb C
- 4) Bulb D

Hint: Redraw the circuit.



Amount of current drawn from battery depends on total 'load' (all the bulbs and how arranged). All current goes through A, so A is the brightest bulb in the circuit.

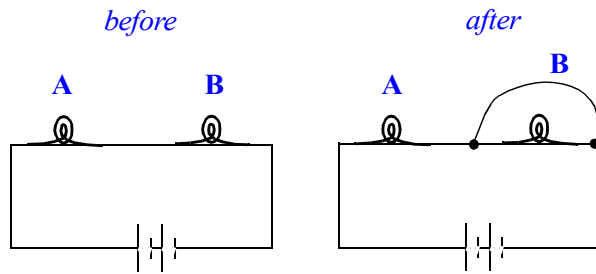
Current splits to go to the two parallel branches.

Bulbs C and D share one parallel branch, and B is an independent parallel branch. B is brighter than C and D.

So B is second brightest bulb in the circuit.

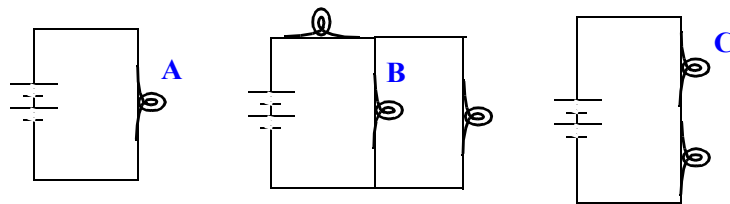
Two light bulbs A and B are connected in series in a circuit. Suppose a wire is connected across bulb B as shown.

When the wire is connected across B, bulb A will



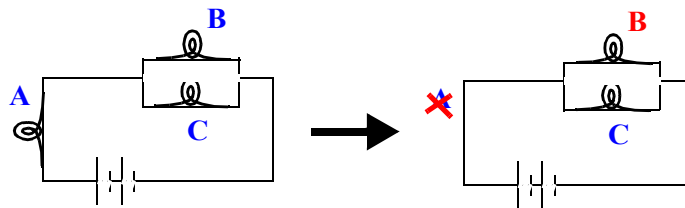
- 1) be brighter
- 2) be the same as before
- 3) be less bright than before
- 4) go out

Rank the bulbs in order of decreasing brightness.



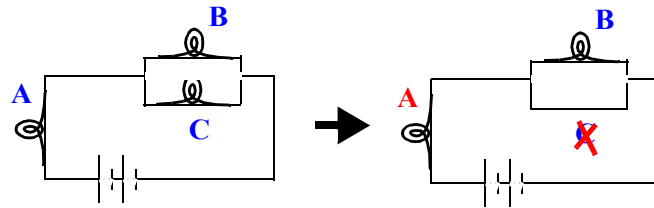
- 1) A, B, C
- 2) B, A, C
- 3) C, A, B
- 4) A, C, B
- 5) B, C, A

What will happen to the brightness of B if A is removed from the circuit and replaced by a wire?



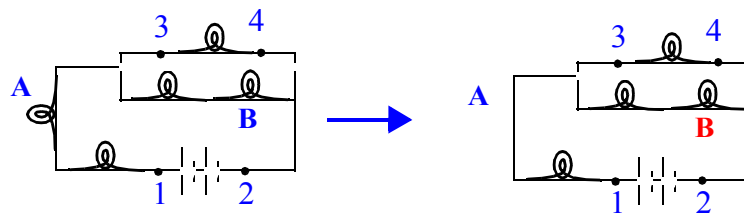
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if C is removed from the circuit and replaced by a wire?



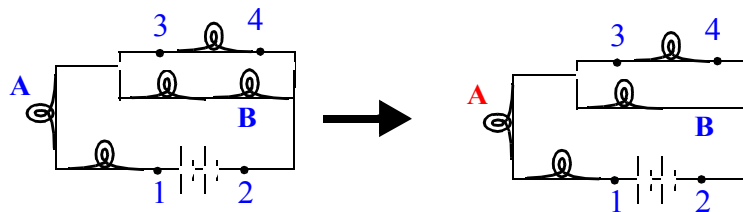
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of B if A is removed from the circuit and replaced by a wire?



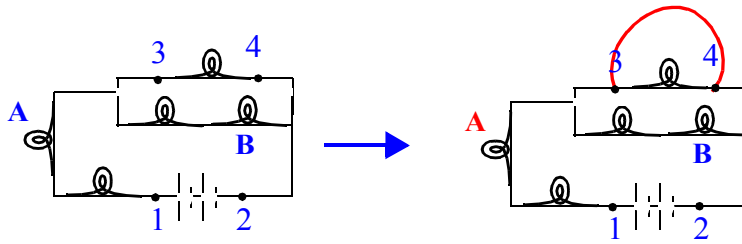
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if B is removed from the circuit and replaced by a wire?



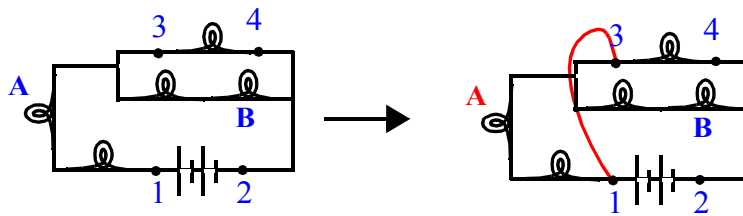
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if a wire is placed in the circuit from 3 to 4?



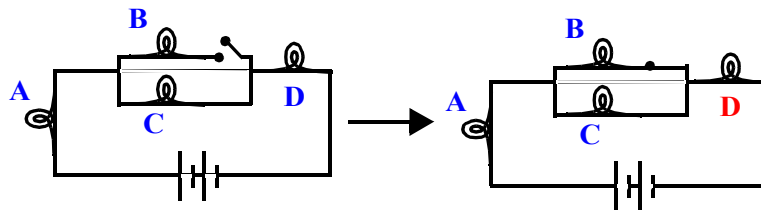
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if a wire is placed in the circuit from 1 to 3?



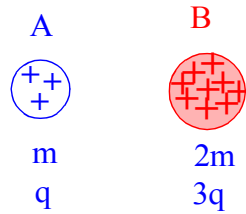
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of D when the switch is closed?



- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

Sphere B has 2 times the mass and 3 times the net electric charge of A. With what acceleration will sphere A move away from B?



- 1) 3 times B's acceleration
- 2) twice B's acceleration
- 3) the same acceleration
- 4) half B's acceleration
- 5) 1/3 B's acceleration

Two fundamental laws: Newton's 2nd Law: $F = ma$

Coulomb's Law:
$$F = k \frac{q_1 q_2}{r^2}$$

Equate the forces to get the acceleration:

$$m_A a_A = k \frac{q_A q_B}{r^2}$$

Ratio of accelerations:

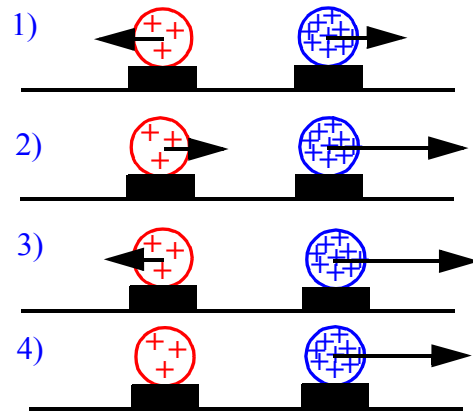
$$\frac{m_A a_A}{m_B a_B} = \frac{q_A q_B}{r^2} \cdot \frac{r^2}{q_A q_B}$$

OR

Use Newton's 3rd Law: Electric force of repulsion between the two balloons is equal and opposite, so only difference is in the masses.

B is twice the mass of A, so for same force, B undergoes one half the acceleration. (Newton's 1st Law)

Uniformly charged spheres are firmly fastened to styrofoam bases free to move across a frictionless surface. The charge on the right sphere is 3 times larger than the charge on the left sphere. Which of the following force diagrams correctly shows the strength of the electric forces?

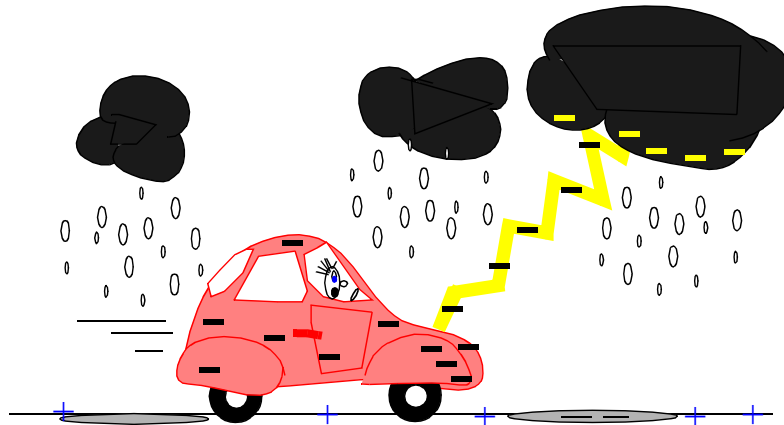


5) None of the above

Ignoring monthly service fees, our monthly gas bills are proportional to the number of gas molecules we have consumed. Similarly, the water bill is proportional to the number of water molecules we have used. When the electric company sends us a bill each month, the amount we are billed for electricity is proportional to

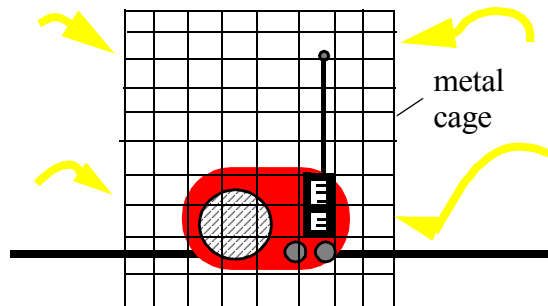
- 1) the total number of electrons we have used
- 2) the total amount of current we have drawn
- 3) the power we have used in our house
- 4) nothing, the electric company is cheating us!
- 5) something else.

If a car is struck by lightning, the resulting electric field inside the car is



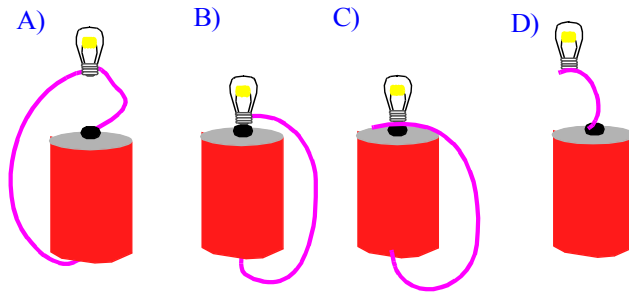
- 1) normally huge, but for a brief time
- 2) normally huge for a time longer than the lightning stroke itself
- 3) small enough to be safe for a person inside
- 4) zero

If a portable radio is placed inside a metal cage, the radio



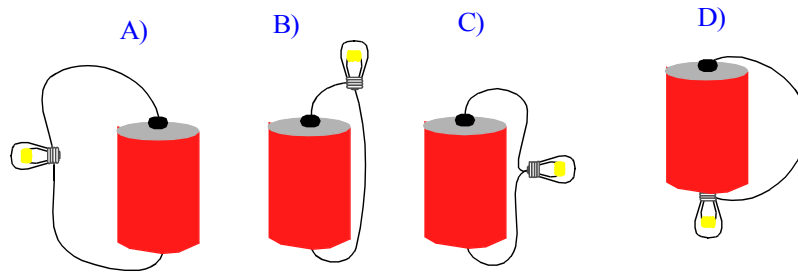
- 1) will continue to receive radio signals and transmit sound through the cage
- 2) will no longer receive radio signals, but can still transmit sound through the cage
- 3) will continue to receive radio signals, but can not transmit sound through the cage.

Which arrangement(s) will light the bulb?



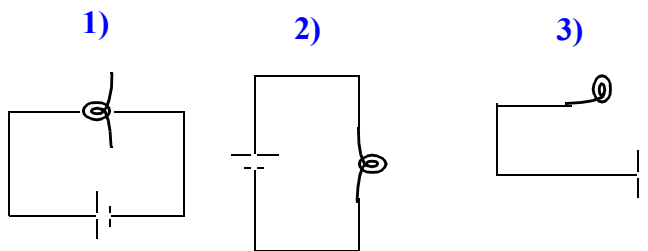
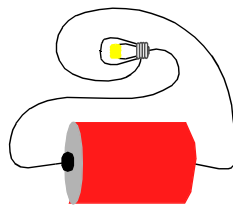
- | | |
|------------|------------|
| 1) A, C, D | 2) A, B, C |
| 2) A, D | 3) B, C |
| 4) A | 5) B |

Which arrangement(s) will light the bulb?

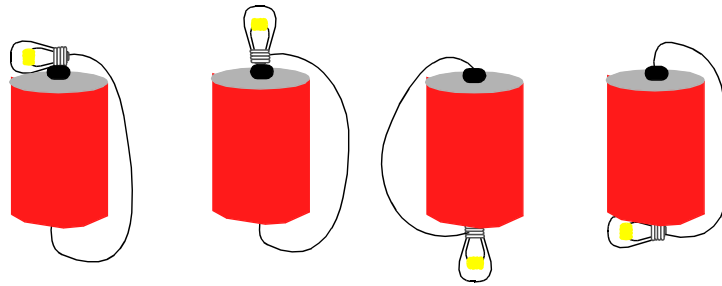


- | | |
|------------|------------|
| 1) A, C, D | 2) A, B, C |
| 2) A, D | 3) B, D |
| 4) B | 5) B, C |

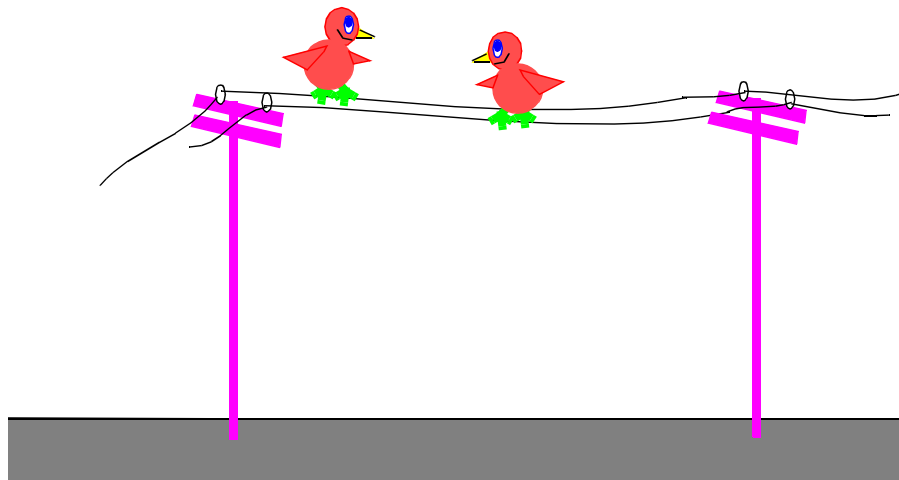
The correct circuit diagram for this arrangement of a bulb a battery and two wires is



Four ways to light the bulb with one battery and one wire.

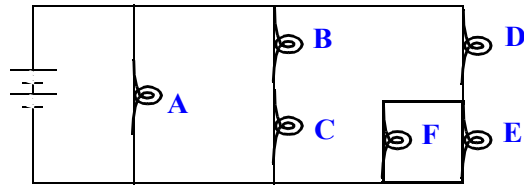


Why can birds perch on a 100,000 Volt power line with no adverse effects?



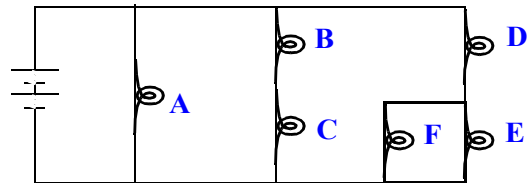
- 1) They put one foot down before the other, so current doesn't go through both feet at once.
- 2) Since there's little potential difference between their two feet, hardly any current flows through them.
- 3) Power lines are coated with a special resistance material that allows birds to stand on the line.
- 4) Even though there may be 100,000 volts through the line, very little current actually flows so the birds are relatively safe.

When bulb D is replaced by a wire, bulb F will become



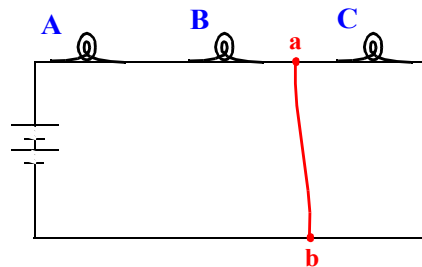
- 1) the same brightness as B
- 2) brighter than B, and the same brightness as A
- 3) fainter than B, and the same brightness as A
- 4) "short-circuited", and not light at all

When bulb D is unscrewed and removed from the circuit, bulb F will



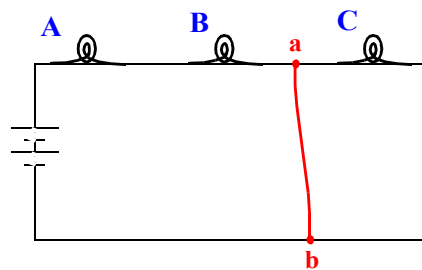
- 1) get brighter
- 2) get fainter, but still be lit
- 3) go out completely

If a wire were placed in the circuit shown connecting points a and b, the current through the battery will



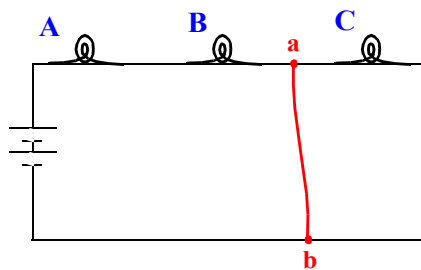
- 1) increase
- 2) decrease
- 3) stay the same

If a wire were placed in the circuit shown connecting points a and b,



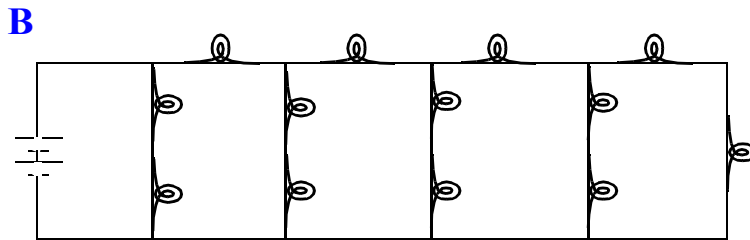
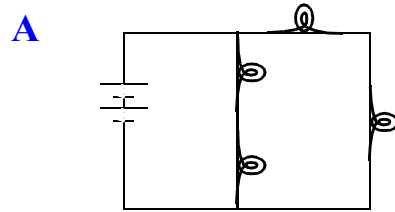
- 1) bulbs A, B and C will all get dimmer
- 2) bulbs A and B will get dimmer, and C will get brighter
- 3) bulb C will dim, but not go completely out, and A and B will brighten
- 4) bulb C will go completely out, and A and B will brighten

If a wire were placed in the circuit shown connecting points a and b, the power output of the circuit will



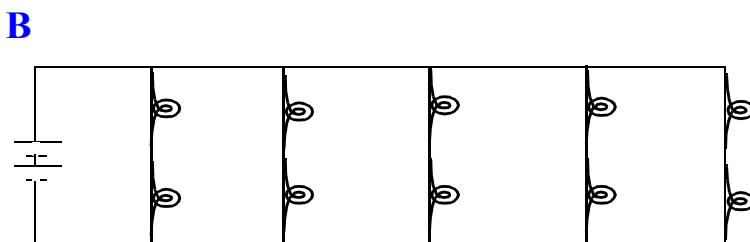
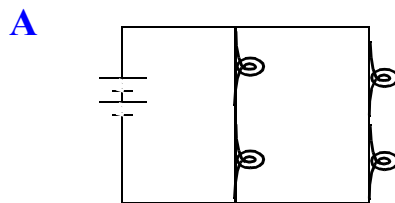
- 1) increase
- 2) decrease
- 3) stay the same

Which circuit draws the most current from the batteries?



- 1) circuit A
- 2) circuit B
- 3) both the same

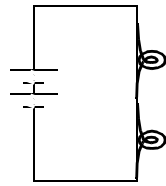
Which circuit has the brightest light bulbs?



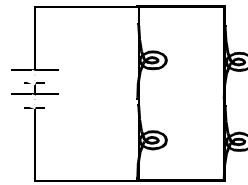
- 1) circuit A
- 2) circuit B
- 3) both the same

Each bulb has a resistance of 1Ω , and each battery has a voltage (potential difference) of 1 V.

How much current do the bulbs in each circuit draw from the batteries?



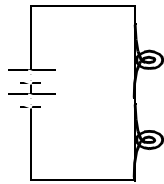
A



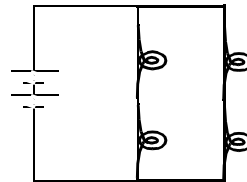
B

- 1) 1 Amp in each circuit
- 2) 1/2 Amp in A and 1 Amp in B
- 3) 2 Amp in A and 1 Amp in B
- 4) 1/2 Amp in A and 1/2 Amp in B

Each bulb has a resistance of $1\ \Omega$, and each battery has a voltage (potential difference) of 1 V.



A



B

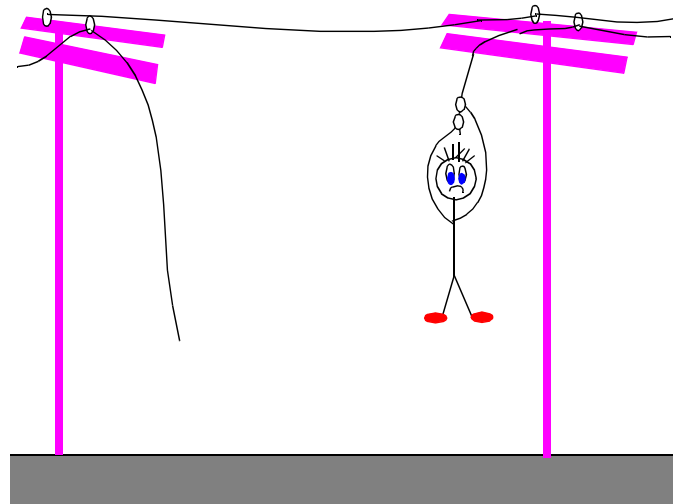
How much power does each bulb radiate in each circuit?

- 1) 1 Watt in each circuit
- 2) 1/2 Watt in A and 2 Watt in B
- 3) 1 Watt in A and 1/2 Watt in B
- 4) 1/2 Watt in A and 1 Watt in B

Electric meters are regularly read by people from your local electric power company, so they know how much to bill you. These electric meters measure the amount of

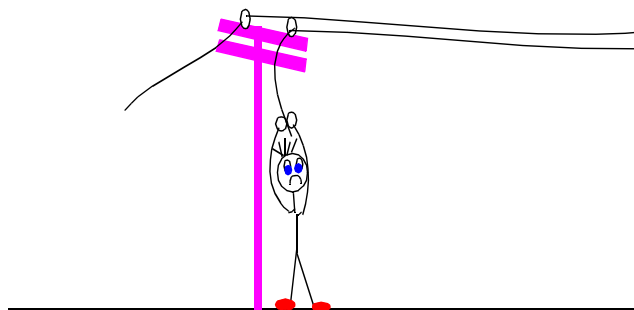
- 1) energy you use.
- 2) power you use.
- 3) force you use.
- 4) both 1 and 2 above.
- 5) both 2 and 3 above.
- 6) both 1 and 3 above.

Will this student hanging from a "live" power line while holding the wire with his bare hands receive an electric shock?

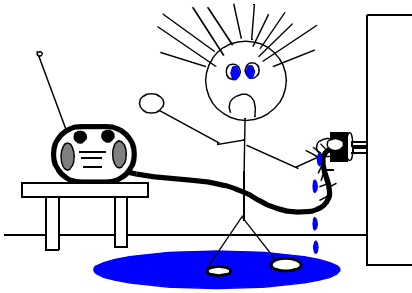


- 1) Yes, because the current will flow from one hand into the wire and through his other hand.
- 2) Yes, because the power line has a very high voltage which will produce a very large shock.
- 3) No, because the potential difference in the wire between his hands is essentially zero.
- 4) No, because the air is an insulator not a conductor.

A "shock" requires a difference in electric potential between one part of your body and another, and a "closed" circuit.



Suppose you received an electric "shock" by touching a wire with a wet hand while standing in a mud puddle. If you touched the "live" wire with a dry hand, you would



- 1) draw more current from the circuit, and receive a larger shock
- 2) draw less current from the circuit, and receive a smaller shock
- 3) wet or dry hands make no difference in the size of the shock you would receive.

Moist skin reduces resistance to the flow of electric charge about a factor of 500 times compared to the resistance of dry skin. So 500 times more current flows through your body if you touch a bare wire with wet hands.

By Ohm's law, $I = \frac{V}{R}$ the current you draw is inversely proportional to your resistance (determined almost entirely by "first contact surface"--your hand)

Size of electric shock not only depends on resistance, but also on the total amount of charge passing through your body.

Electric power was defined as

$$P = IV \quad (\text{units} = \text{amps} \times \text{volts} = \text{Watts})$$

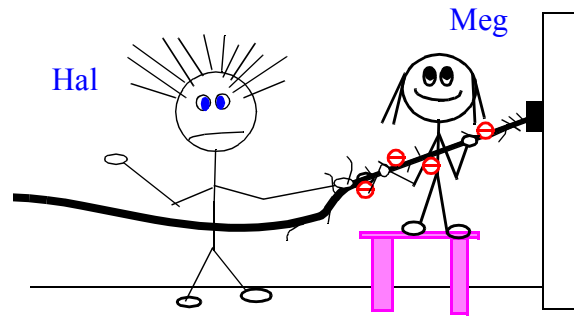
and energy is how long the power is sustained:

$$\text{Electric Energy} = \text{Power} \times \text{time} \quad (\text{units} = \text{Watt-hrs})$$

Power companies sell us Electric Energy and is measured in kiloWatt-hours.

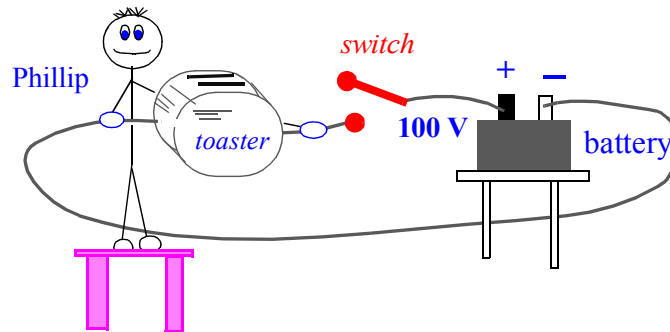
So you receive a larger "shock" when your resistance is low (wet hands), the energy carried by each electric charge is high ($E/q = \text{voltage}$) and the electric current through your body is sustained for a long time (energy is large).

Which twin is grounded?



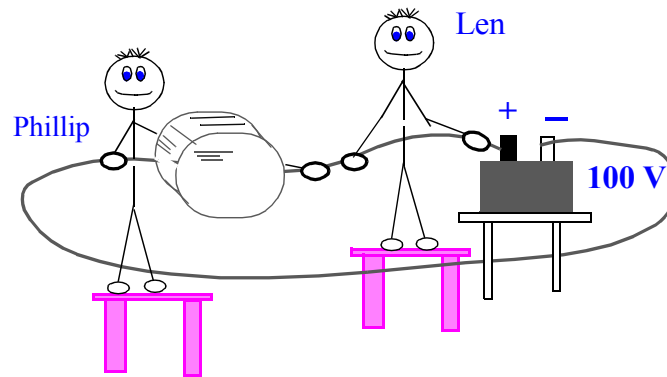
- 1) Hal
- 2) Meg
- 3) both
- 4) neither

A toaster is connected into a circuit containing a battery and a switch as shown. Phillip stands on a wooden bench and grasps the bare wire at two places with the toaster in between his hands. Phillip is going to get



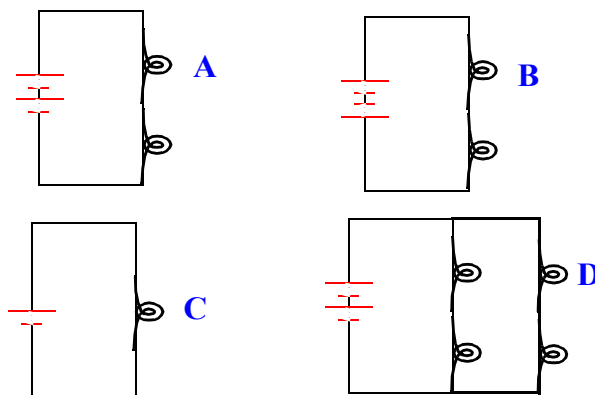
- 1) a shock if the switch is open
- 2) a shock if the switch is closed
- 3) a shock if the switch is open or closed
- 4) no shock at all in any of these cases

What would happen if Len also grabs the wire with his hands separated by the same distance?



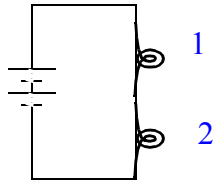
- 1) Len will get a shock and use up all the current preventing it from flowing to Phillip and the toaster.
- 2) Len and Phillip will both get shocks, but Phillip's shock will be milder than when he alone was holding the wire.
- 3) Len and Phillip will both get shocks, and Phillip's shock will be stronger than when he alone was holding the wire.
- 4) Len will not get a shock, and Phillip will get same shock as before.

In this circuit the bulbs and batteries are identical. Which bulbs have the same brightness?



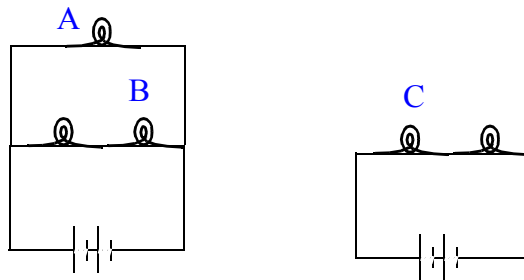
- 1) A and D
- 2) A, B, and D
- 3) A, C and D
- 4) B, C and D
- 5) A, B and C

In the closed circuit below the current through the second bulb is



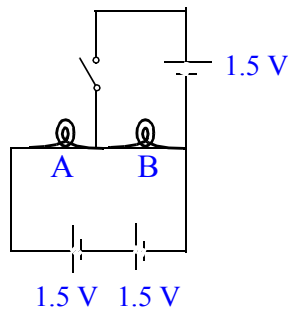
- 1) equal to
 - 2) half
 - 3) smaller than, but not necessarily half
- the current through the first bulb.

Which bulb is brightest?



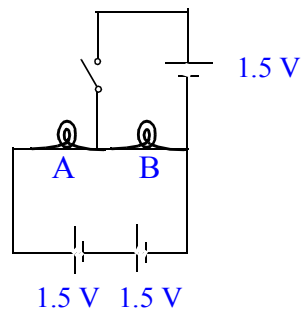
- 1) A
- 2) B
- 3) C

The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

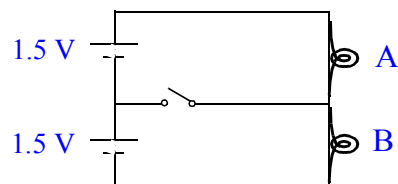
The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

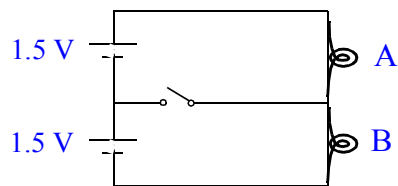
Because the light bulbs are identical, the potential difference across each is 1.5 V. So nothing happens when the switch is closed.

The light bulbs in the circuit are identical. When the switch is closed,



- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

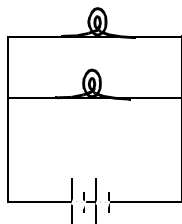
The light bulbs in the circuit are identical. When the switch is closed,



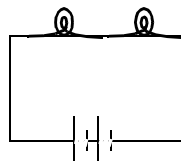
- 1) both go out
- 2) brightness of A increases
- 3) brightness of A decreases
- 4) brightness of B increases
- 5) brightness of B decreases
- 6) nothing changes

The potential difference across the branch of the circuit with the switch is zero. So there is no current through it when the switch is closed, and nothing changes.

If the bulbs and batteries are identical, which circuit puts out more light?



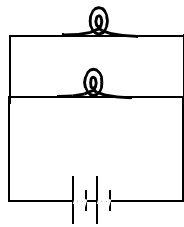
circuit I



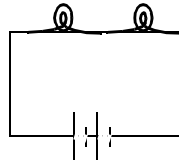
circuit II

- 1) circuit I
- 2) circuit II
- 3) both emit the same amount of light

If the bulbs and batteries are identical, which circuit puts out more light?



circuit I



circuit II

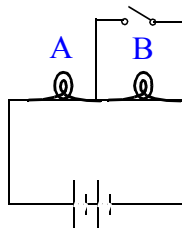
- 1) circuit I
- 2) circuit II
- 3) both emit the same amount of light

Resistance of two bulbs in parallel is smaller than two bulbs in series. So current through the batteries is greater for circuit I than circuit II. Power indicates brightness or amount of light output. Since power is related to current, I , resistance, R , and voltage, V , by

$$P = I^2R = IV$$

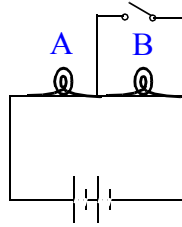
circuit I puts out more power and therefore more light.

The bulbs are identical. When the switch is closed, the brightness of bulb A



- 1) increases
- 2) remains unchanged
- 3) decreases

The bulbs are identical. When the switch is closed, the brightness of bulb A

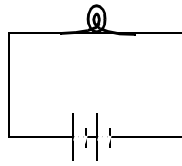


- 1) increases
- 2) remains unchanged
- 3) decreases

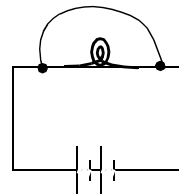
Bulb B goes out because virtually all of current goes through the wire. So the total resistance in the circuit decreases, and the current through bulb A increases, making it brighter.

Initially charge flows through the light bulb. Suppose a wire is connected across the bulb as shown. After the wire is connected,

before



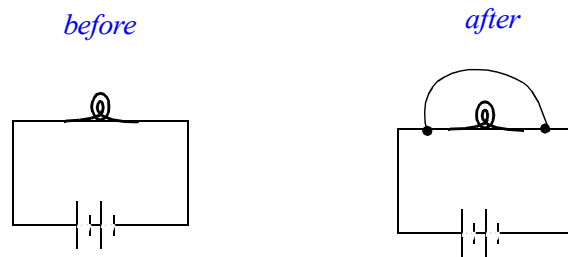
after



- 1) essentially all the charge continues to flow through the bulb
- 2) about half the charge flows through the wire, and the other half continues through the bulb
- 3) essentially all the charge flows through the wire

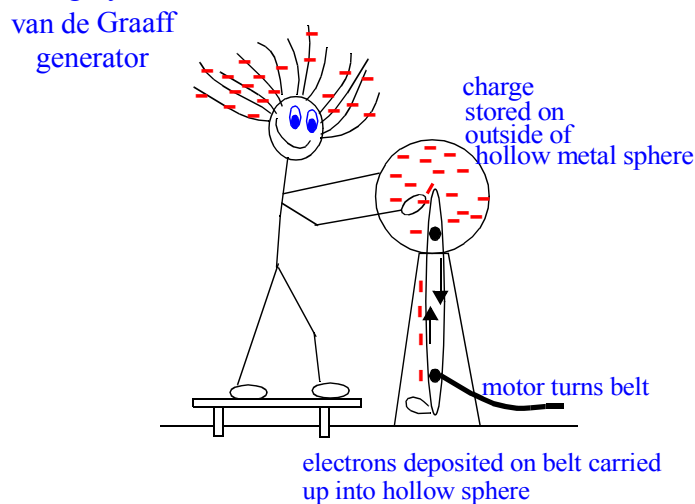
The bulb has resistance to charge flow, while the wire is essentially a perfect conductor of electric charge. With wire in place, the voltage across the bulb becomes zero, so essentially all charge flow is through the wire. We say the bulb is 'shorted out'.

Initially charge flows through the light bulb. Suppose a wire is connected across the bulb as shown. After the wire is connected,



- 1) essentially all the charge continues to flow through the bulb
- 2) about half the charge flows through the wire, and the other half continues through the bulb
- 3) essentially all the charge flows through the wire

The reason you can touch a 100,000 volt van de Graaff generator with little harm even though the voltage is high is that there is the relatively little charge stored on the outside of the sphere, so little current passes through you.

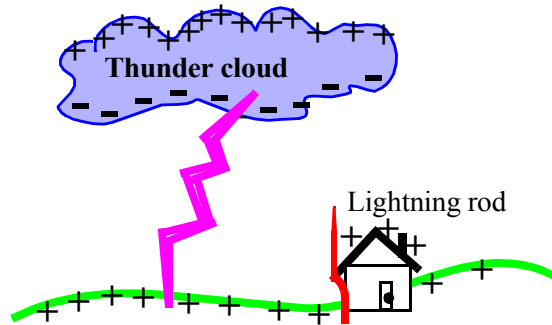


Electric power, $P = I^2R = IV$ times time = Electric Energy determines the strength of the electric shock to your body.

Resistance of human body is about 100,000 Ohms (dry hands)
and about 1,000 Ohms (wet hands)

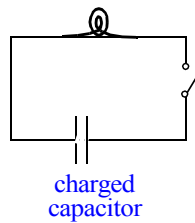
Even Voltage is very large on a van den Graaff generator (500,000 Volts), the total number of charges on the surface of the sphere is very small, so very few charges actually flow through your body.

The primary purpose of a lightning rod is to



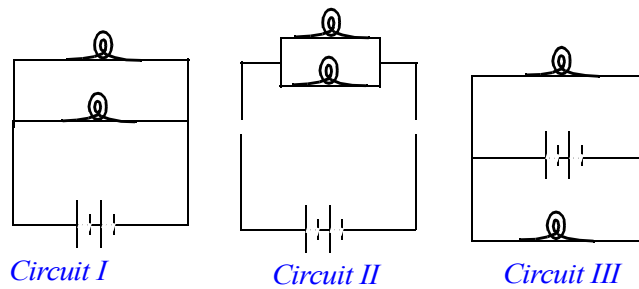
- 1) attract lightning and guide it to the ground
- 2) discharge the building to which it is attached
- 3) induce in the building to which it is attached a charge opposite to the charged clouds overhead

A simple circuit consists of a bulb, a charged capacitor and a switch. Immediately after the switch is closed, the light bulb in the circuit



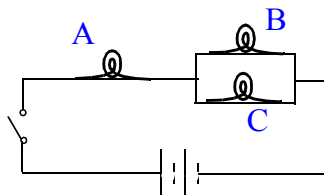
- 1) glows brightly for a few seconds then fades
- 2) glows dimly for a few seconds then brightens
- 3) glows as long as the switch remains closed
- 4) does not glow

Circuits I, II and III are all



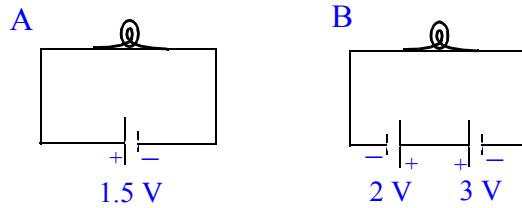
- 1) the same circuit
- 2) different circuits
- 3) the same, except for Circuit III
- 4) the same, except for Circuit II

After the switch is closed in the circuit shown, Bulb A is



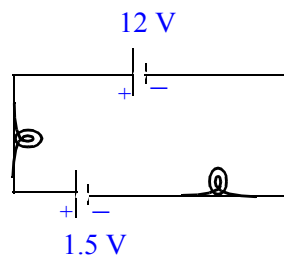
- 1) much brighter than
 - 2) a little brighter than
 - 3) as bright as
 - 4) as bright as
 - 5) a little dimmer than
- Bulbs B and C

In which circuit is the bulb brightest?



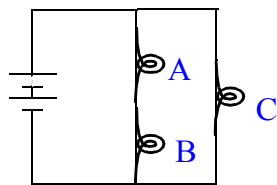
- 1) Circuit A
- 2) Circuit B
- 3) They both have the same brightness
- 4) Not enough information

Which way does current flow in the circuit?



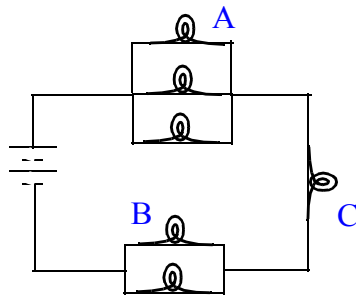
- 1) Counterclockwise
- 2) Clockwise
- 3) It alternates directions since the batteries are opposing each other.

Which bulb is brightest?



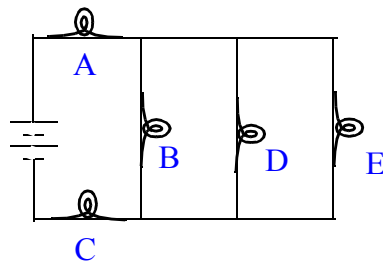
- 1) A
- 2) B
- 3) C
- 4) A and B are the same, but brighter than C

Which bulb is 2nd brightest?



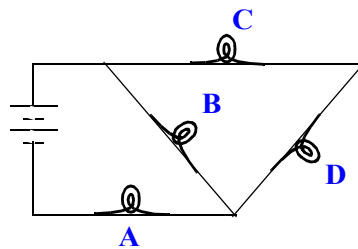
- 1) A
- 2) B
- 3) C

Which statement is true?



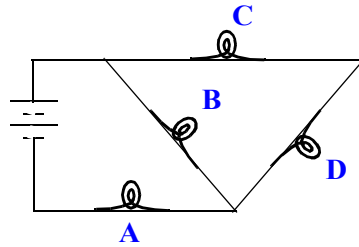
- 1) Bulb D is brighter than E, but the same as A
- 2) Bulb D is brighter than A but the same as E
- 3) Bulb A is brighter than C
- 4) Bulb D is fainter than A and the same as E

Which bulb is 2nd brightest?



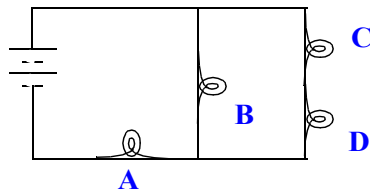
- 1) Bulb A
- 2) Bulb B
- 3) Bulb C
- 4) Bulb D

Which bulb is 2nd brightest?



- 1) Bulb A
- 2) Bulb B
- 3) Bulb C
- 4) Bulb D

Hint: Redraw the circuit.



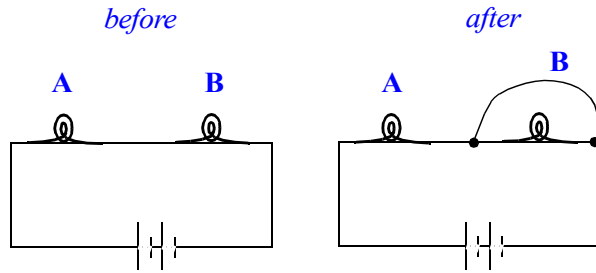
Amount of current drawn from battery depends on total load (all the bulbs and how arranged). All current goes through A, so A is the brightest bulb in the circuit.

Current splits to go to the two parallel branches.

Bulbs C and D share one parallel branch, and B is an independent parallel branch. B is brighter than C and D.

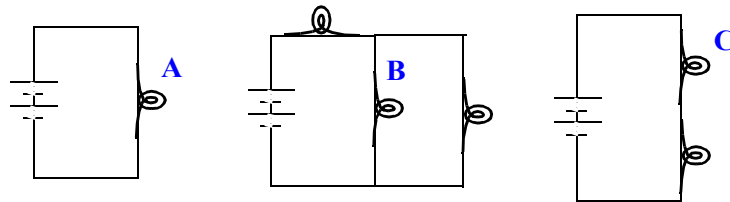
So B is second brightest bulb in the circuit.

Two light bulbs A and B are connected in series in a circuit. Suppose a wire is connected across bulb B as shown. When the wire is connected across B, bulb A will



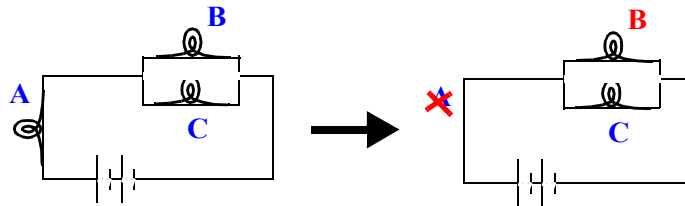
- 1) be brighter
- 2) be the same as before
- 3) be less bright than before
- 4) go out

Rank the bulbs in order of decreasing brightness.



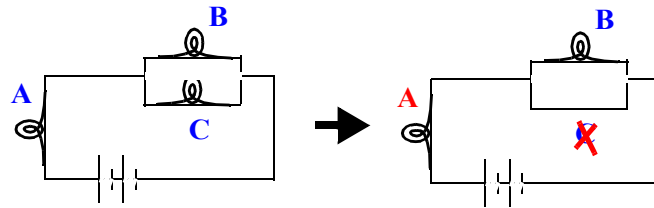
- 1) A, B, C
- 2) B, A, C
- 3) C, A, B
- 4) A, C, B
- 5) B, C, A

What will happen to the brightness of B if A is removed from the circuit and replaced by a wire?



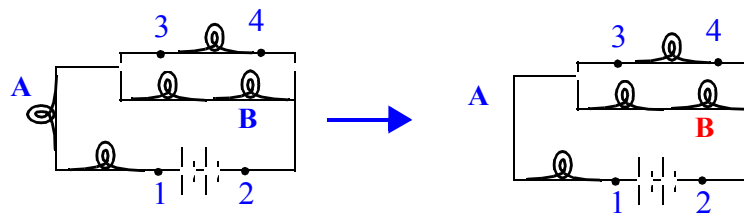
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if C is removed from the circuit and replaced by a wire?



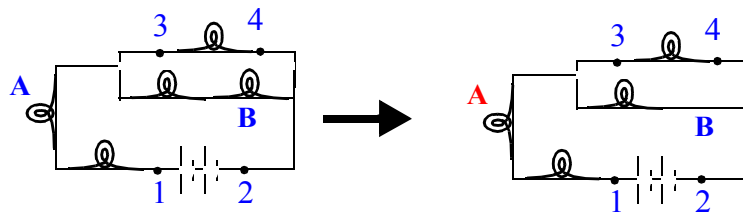
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of B if A is removed from the circuit and replaced by a wire?



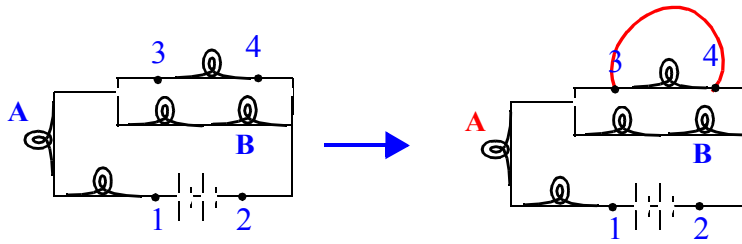
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if B is removed from the circuit and replaced by a wire?



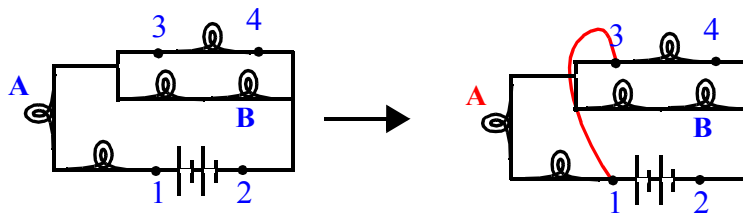
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if a wire is placed in the circuit from 3 to 4?



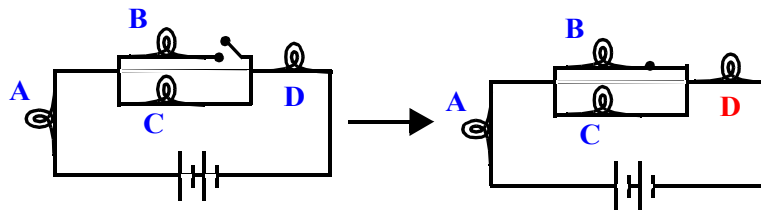
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of A if a wire is placed in the circuit from 1 to 3?



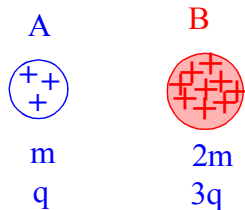
- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

What will happen to the brightness of D when the switch is closed?



- 1) get brighter
- 2) get fainter
- 3) stay the same
- 4) go out completely

Sphere B has 2 times the mass and 3 times the net electric charge of A. With what acceleration will sphere A move away from B?



- 1) 3 times B's acceleration
- 2) twice B's acceleration
- 3) the same acceleration
- 4) half B's acceleration
- 5) 1/3 B's acceleration

Two fundamental laws: Newton's 2nd Law: $F = ma$

$$\text{Coulomb's Law: } F = k \frac{q_1 q_2}{r^2}$$

Equate the forces to get the acceleration:

$$m_A a_A = k \frac{q_A q_B}{r^2}$$

Ratio of accelerations:

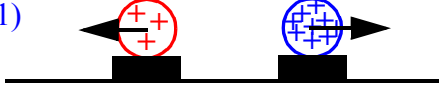



$$\frac{m_A a_A}{m_B a_B} = \frac{q_A q_B}{r^2} \cdot \frac{r^2}{q_A q_B}$$

OR

Use Newton's 3rd Law: Electric force of repulsion between the two balloons is equal and opposite, so only difference is in the masses.

B is twice the mass of A, so for same force, B undergoes one half the acceleration. (Newton's 1st Law)

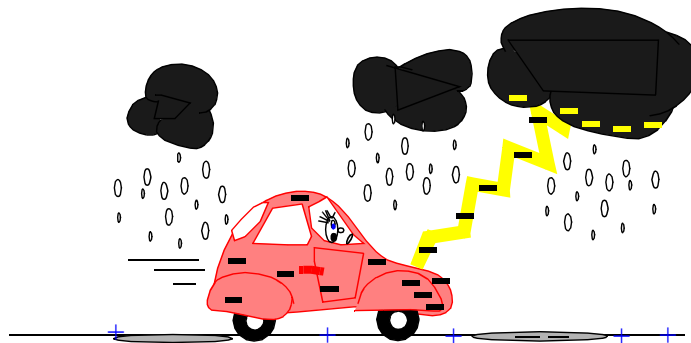
Uniformly charged spheres are firmly fastened to styrofoam bases free to move across a frictionless surface. The charge on the right sphere is 3 times larger than the charge on the left sphere. Which of the following force diagrams correctly shows the strength of the electric forces?

- 1) 
- 2) 
- 3) 
- 4) 
- 5) None of the above

Ignoring monthly service fees, our monthly gas bills are proportional to the number of gas molecules we have consumed. Similarly, the water bill is proportional to the number of water molecules we have used. When the electric company sends us a bill each month, the amount we are billed for electricity is proportional to

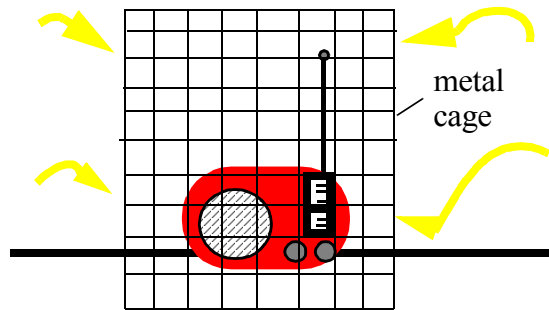
- 1) the total number of electrons we have used
- 2) the total amount of current we have drawn
- 3) the power we have used in our house
- 4) nothing, the electric company is cheating us!
- 5) something else.

If a car is struck by lightning, the resulting electric field inside the car is



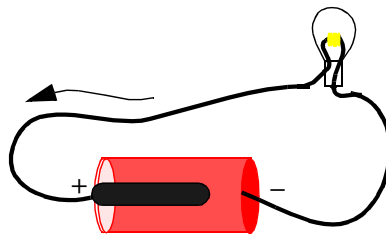
- 1) normally huge, but for a brief time
- 2) normally huge for a time longer than the lightning stroke itself
- 3) small enough to be safe for a person inside
- 4) zero

If a portable radio is placed inside a metal cage, the radio



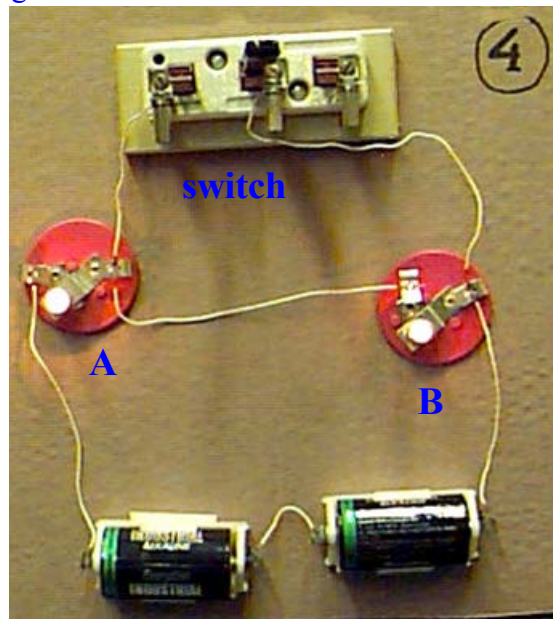
- 1) will continue to receive radio signals and transmit sound through the cage
- 2) will no longer receive radio signals, but can still transmit sound through the cage
- 3) will continue to receive radio signals, but can not transmit sound through the cage.

In an electric circuit, what causes electrons to flow in the copper wire?

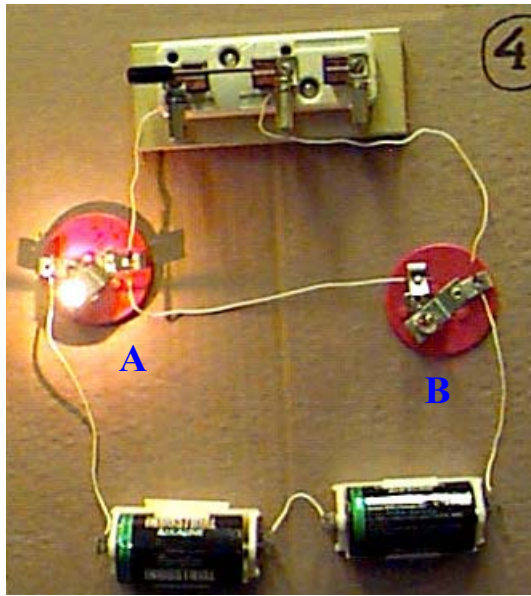


- 1) An imbalance of charges in the wire
- 2) More potential energy at one end of the wire than the other
- 3) A potential difference across the ends of the wire

What will happen to the brightness of bulb B when the switch is closed?



- 1) it will get brighter
- 2) it will get dimmer
- 3) it will go out completely



This is a short circuit