Two type of materials

- Conductor: A conductor allows electric current to pass through. Example: Copper, iron, nickel, graphite, etc. Conductors are also known as metals. Wires and strips of metals conduct electricity with almost no resistance.

- Insulator: An insulator does not allow electric current to pass through. Example: Air, glass, rubber, plastic, dry wood, etc.

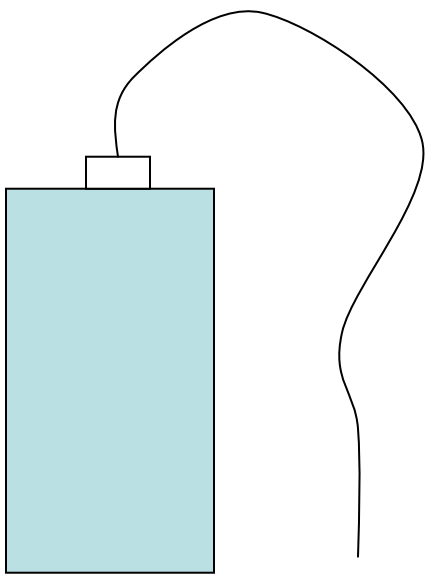
Current

- Current is formed by moving charges.
- For current flow, you need:

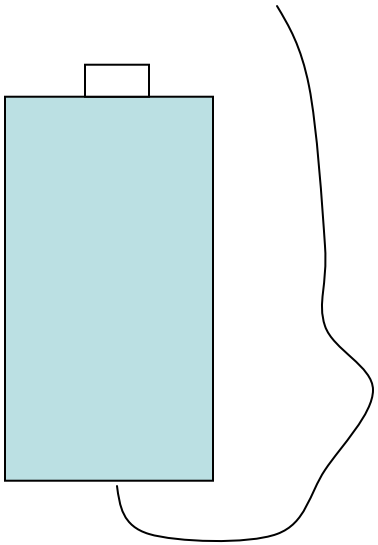
  (i) A supply, such as a battery, to “pump” the current.

  (ii) A closed path joining the two ends of the supply.

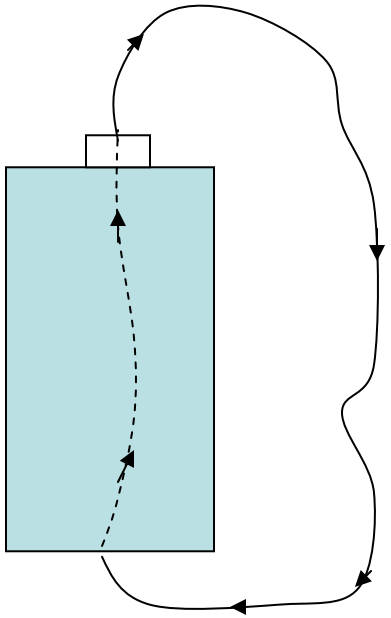
Current flow



No Current !



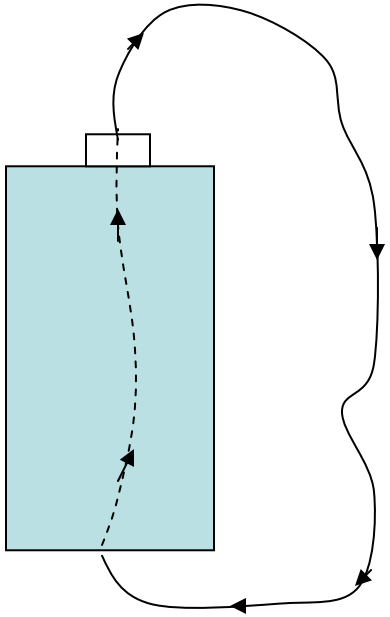
No Current !



Current Flow

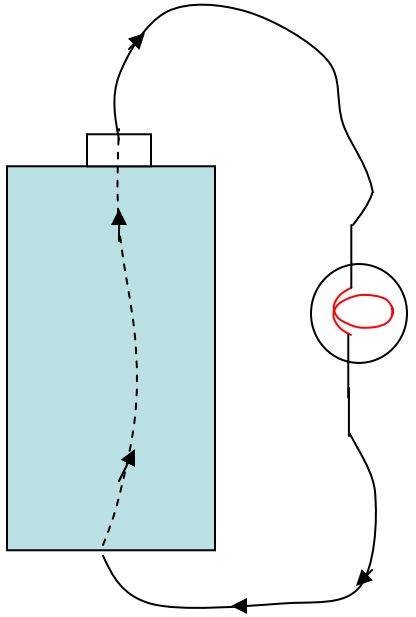
Outside the battery, current flows from one terminal to the other, and then gets “pumped” back to the first terminal within the battery. For the circuit shown on the right, the current is the same everywhere.

Needs of resistance



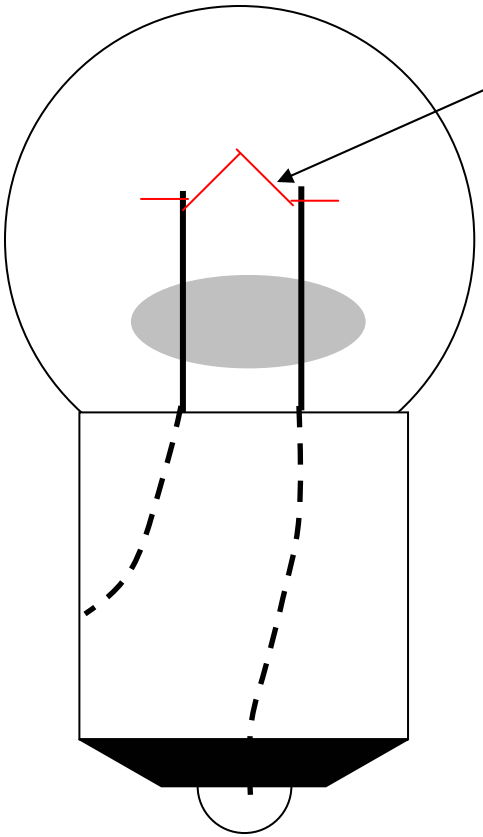
If the conducting path has very small resistance (like a wire), current will be very large and the wire will get hot!!

Adding a resistance, like a bulb decreases the current and therefore the heating of the wire. Now the filament in the bulb gets very hot from the current!



Use a light bulb
$\Rightarrow$ Light and Heat.

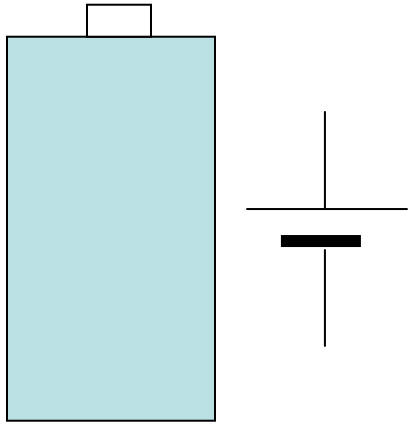
Structure of a light bulb



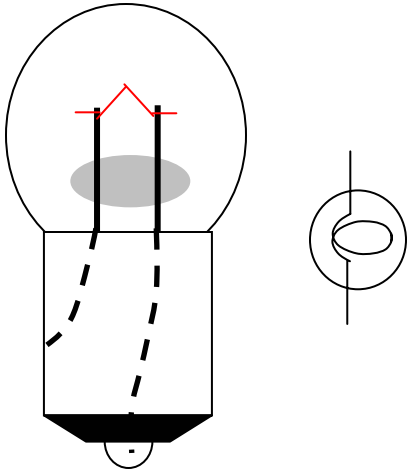
Filament is the high resistance part ⇒ light and heat.

The greater the current through the filament, the brighter it will be.

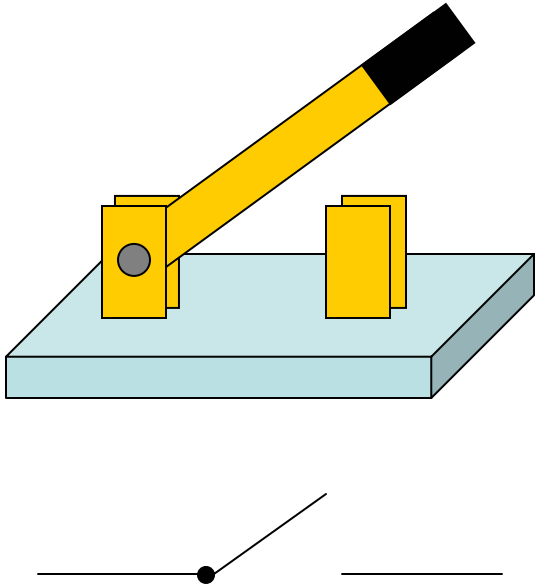
Symbols used in circuit diagram



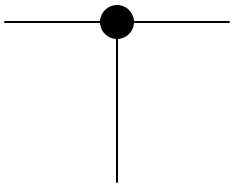
Battery



Light bulb



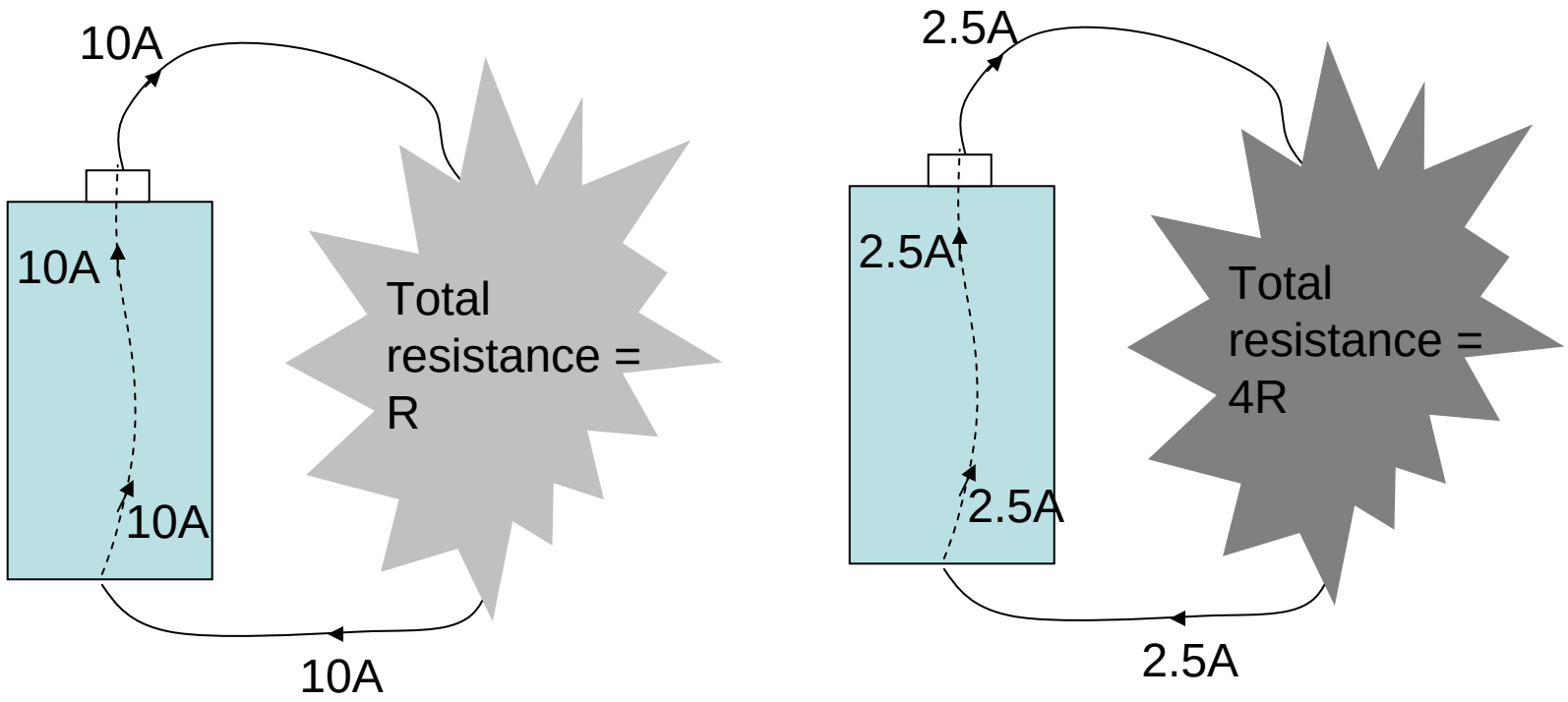
Switch

Use lines ——— for connecting wires and dots  for connections between wires..

Resistance and current through a battery

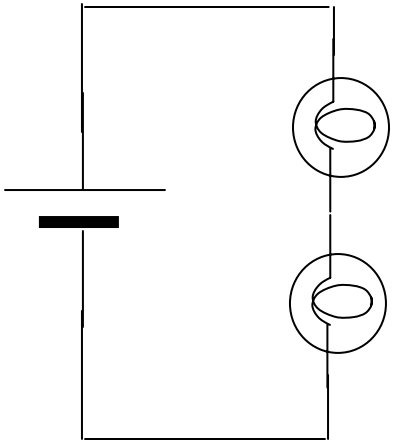
- The current through a battery is *inversely proportional* to the total resistance connected to its two terminals.
- The larger the total resistance, the smaller is the current through the battery.
- It is correct to say an insulator has a very large resistance, and a conductor has nearly zero resistance.

Resistance and current through a battery

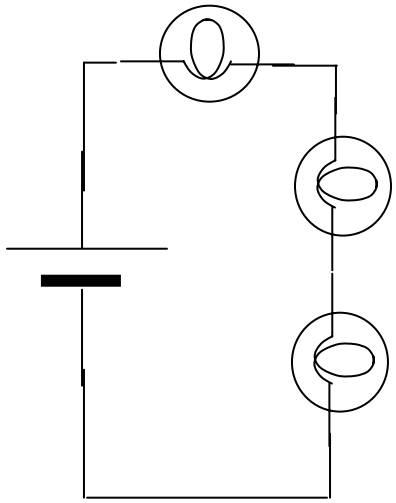


The current through a battery is *inversely proportional* to the total resistance connected to its two terminals: doubling the resistance results in halving the current, etc. (The letter “A” stands for one unit of current.)

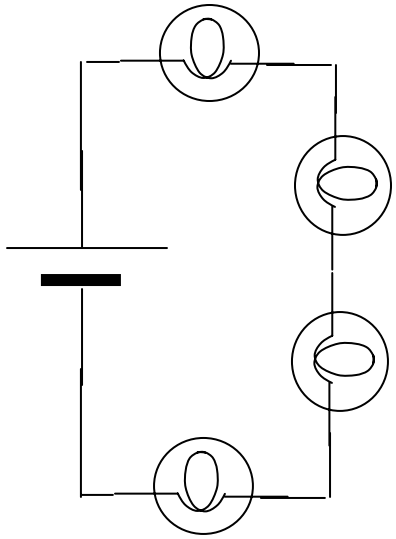
Series Circuit



Two light bulbs connected in series



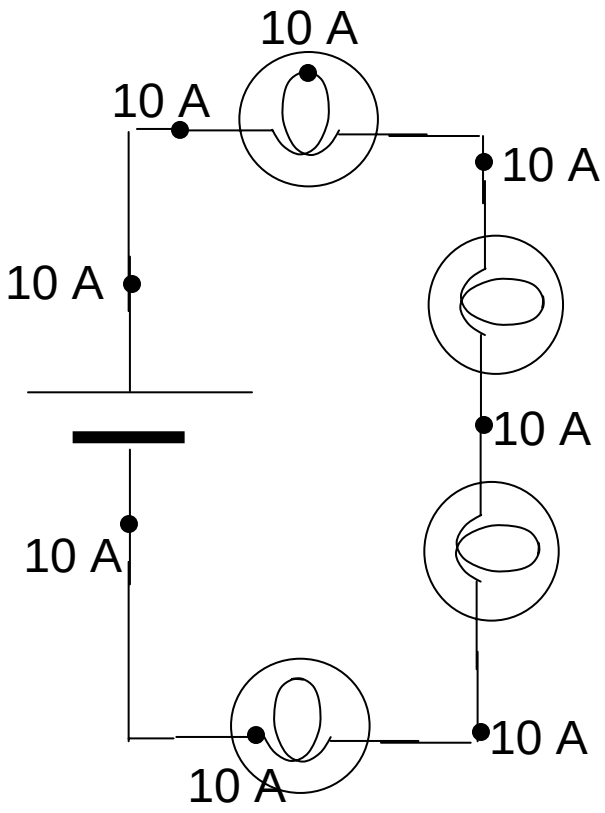
Three light bulbs connected in series



Four light bulbs connected in series

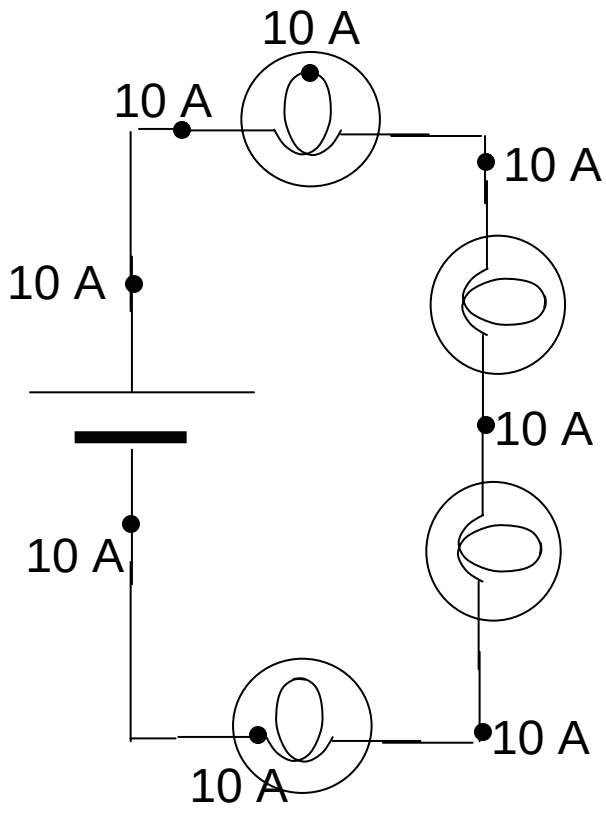
If you walk along a series circuit, starting from the positive end of the battery, you will not encounter any branches and you will end up at the negative end of the battery by the same track.

Properties of series circuit - I



The current at every point in a series circuit (including the battery) is the same.

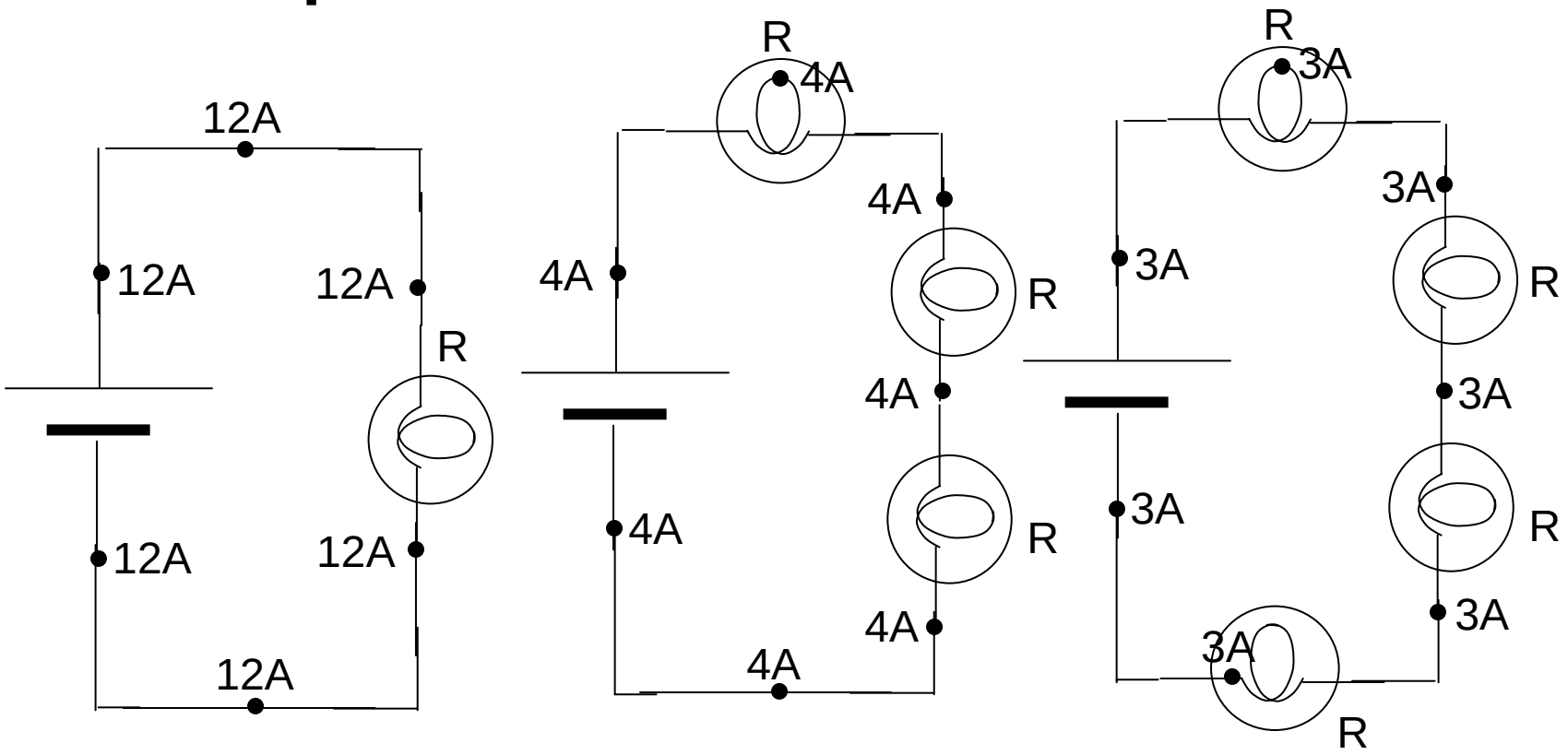
Properties of series circuit - I



The current at every point in a series circuit (including the battery) is the same.

However, this current depends on the number of light bulbs in the circuit.

Properties of series circuit - II



Total resistance = R

Current = 12A

Total resistance = 3R

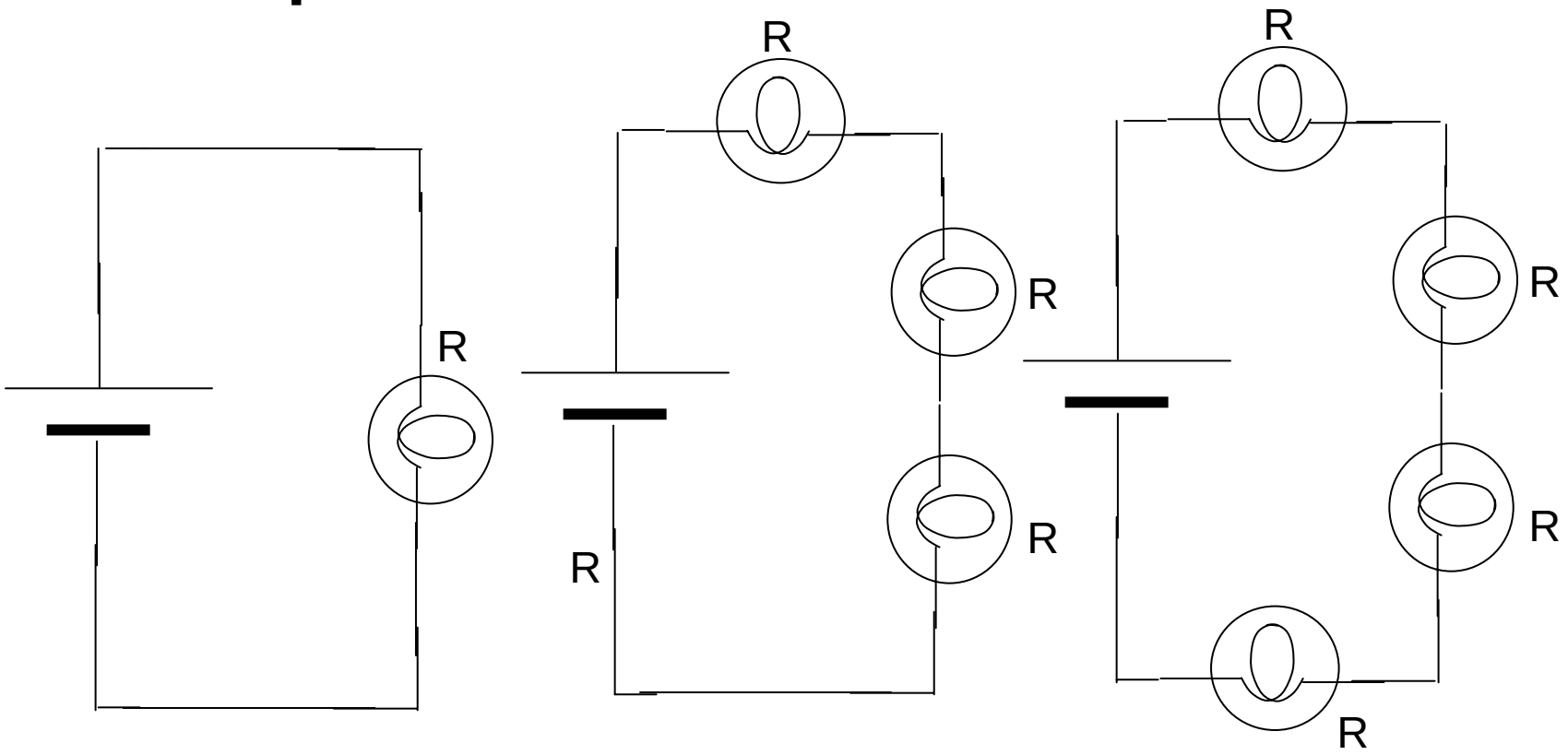
Current = 4A

Total resistance = 4R

Current = 3A

The current through the circuit is *inversely proportional* to the sum of resistances of each light bulb.

Properties of series circuit - III



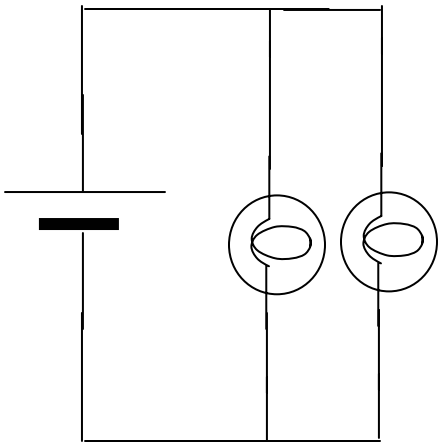
Total resistance = R

Total resistance = 3R

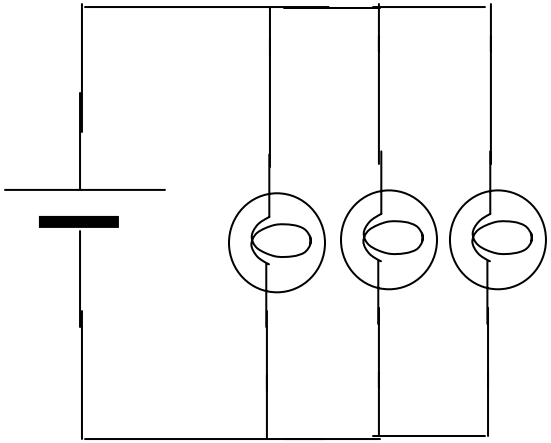
Total resistance = 4R

The total resistance is the sum of the resistance of each light bulb.

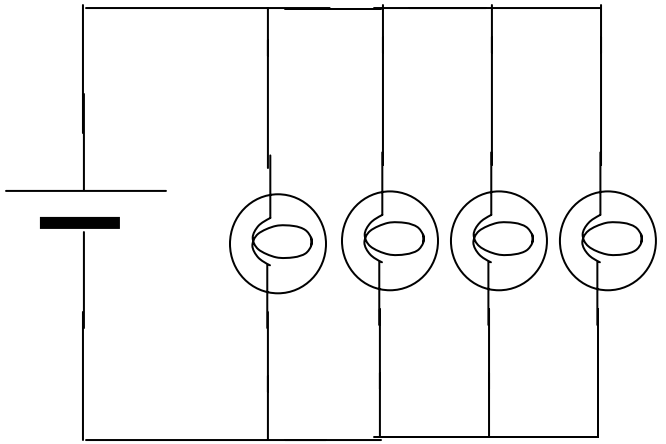
Parallel Circuit



Two light bulbs connected in parallel



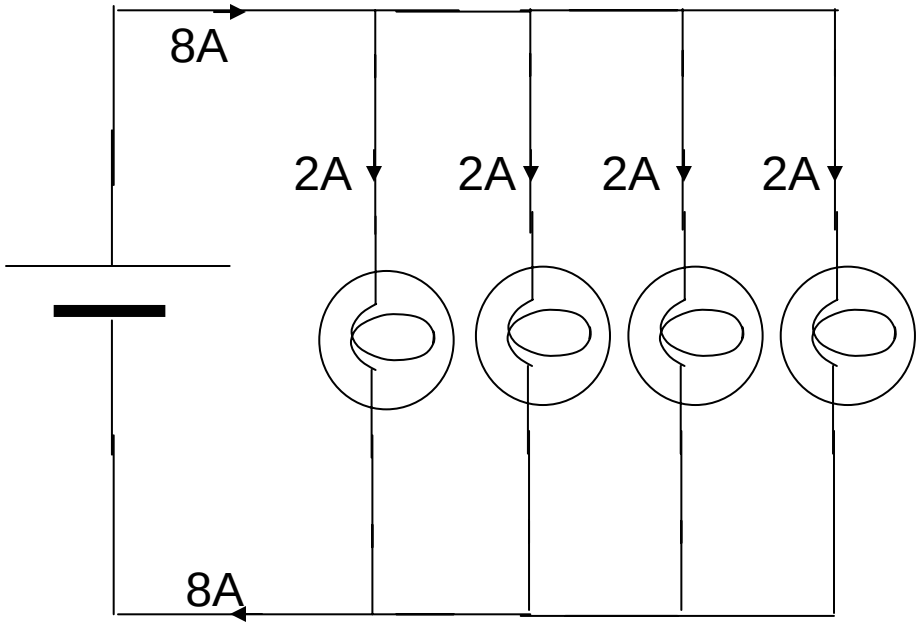
Three light bulbs connected in parallel



Four light bulbs connected in parallel

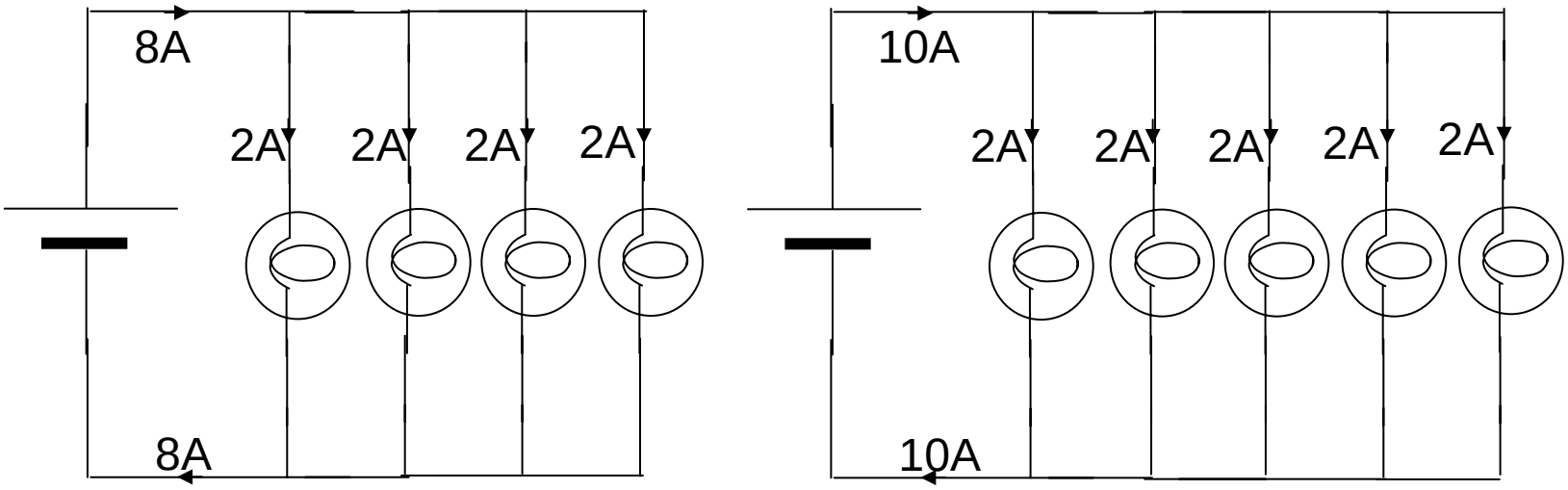
Both terminals of a bulb in a parallel circuit is connected to a terminal of a bulb in another branch of the circuit.

Properties of Parallel Circuit - I



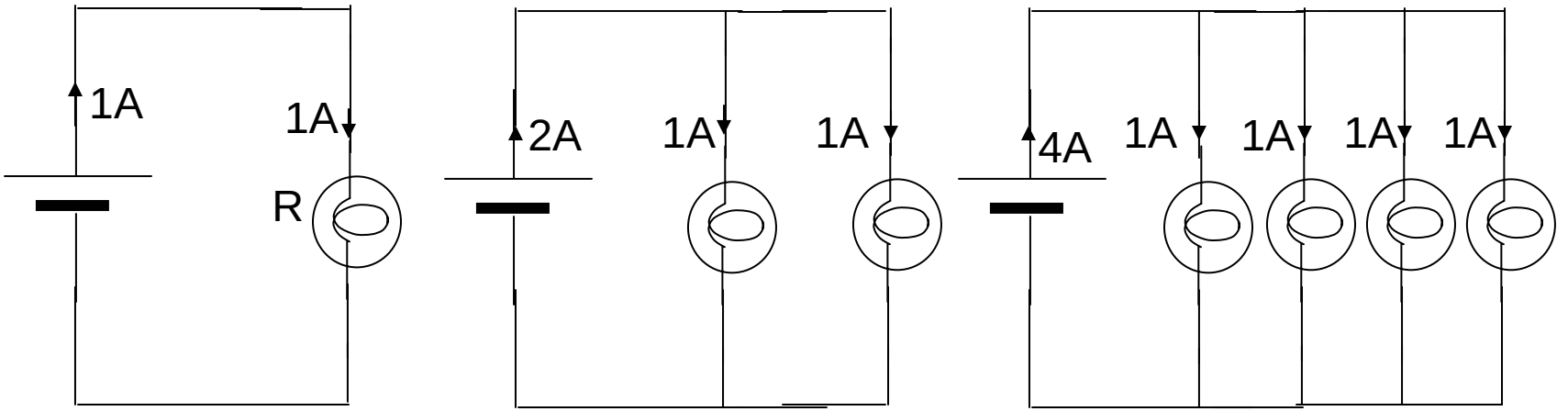
Current through the battery is the sum of the currents in each branch.

Properties of Parallel Circuit - II



Adding (or removing) one branch will not affect the current in the other branches (*for an ideal battery*), but will affect the current through the battery.

Properties of Parallel Circuit - III



Current through battery = 1A

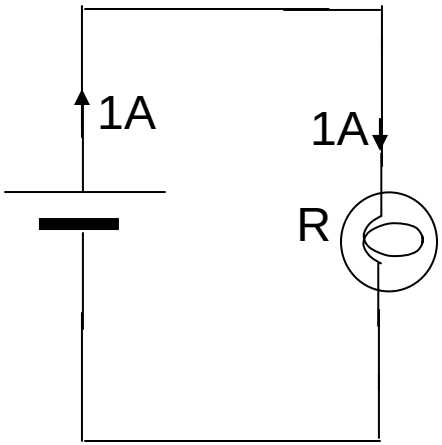
Current through battery = 2A

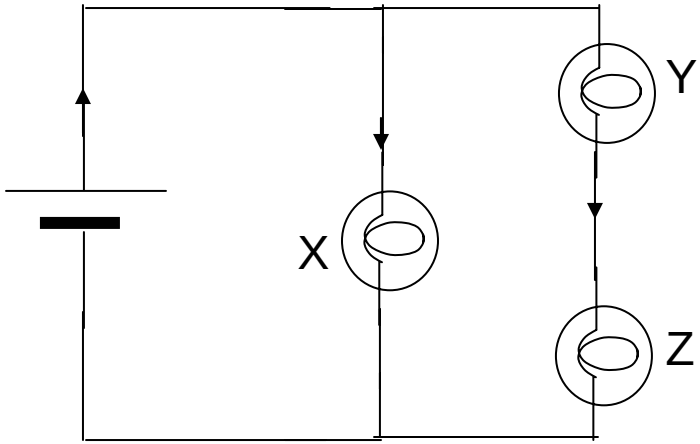
Current through battery = 4A

Notice that *the current through the battery* is the same as it would be if there were one bulb with a resistance of R/4. That is, *n*-parallel bulbs, each with resistance R, is *electrically equivalent* to a single bulb of resistance R/n.

Example 1

Start with:

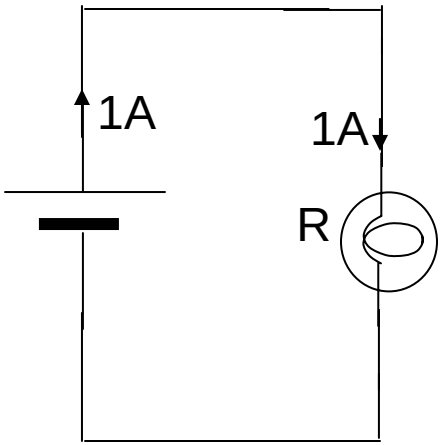


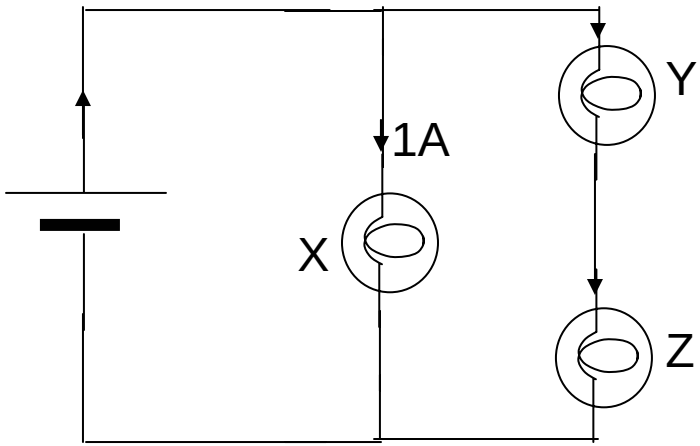


Current through bulb X=
Current through bulb Y=
Current through bulb Z=
Current through battery=

Example 1

Start with:

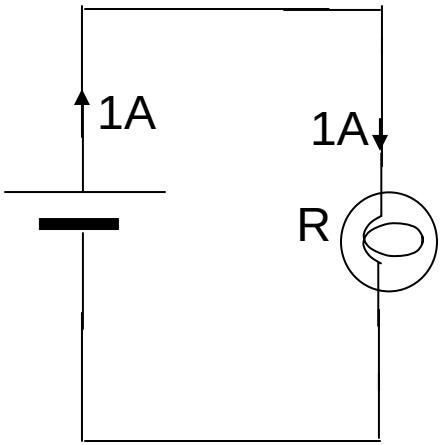


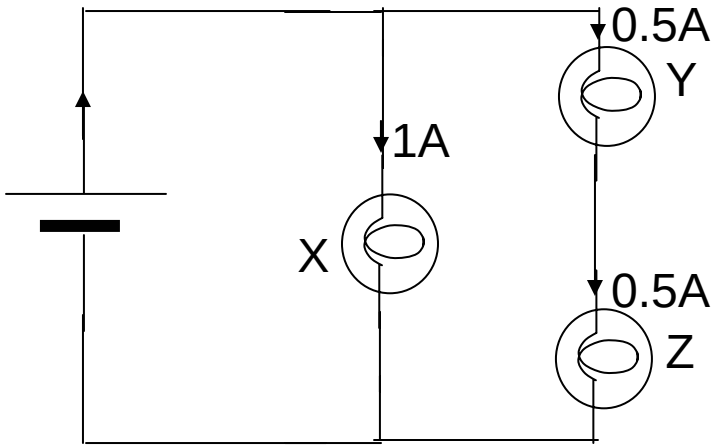


Current through bulb X= 1A
Current through bulb Y=
Current through bulb Z=
Current through battery=

Example 1

Start with:

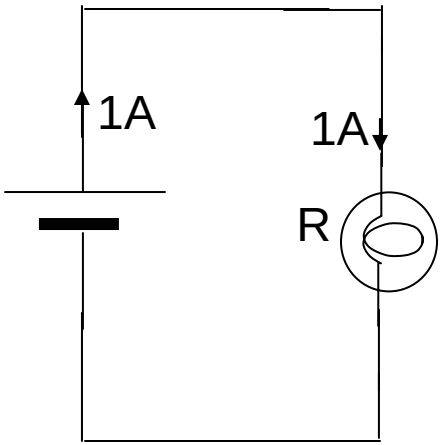


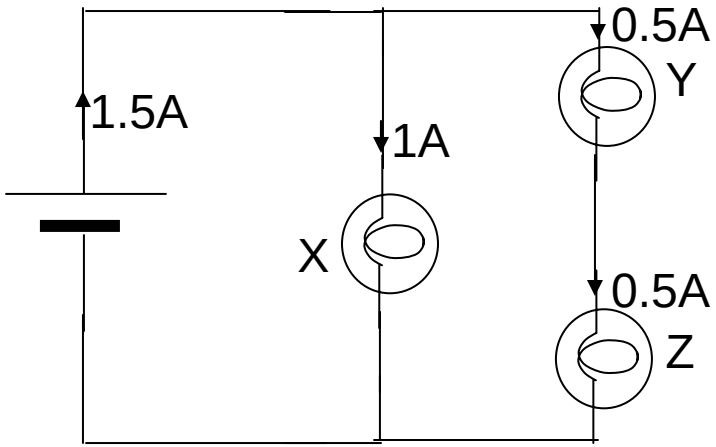


Current through bulb X= 1A
Current through bulb Y= 0.5A
Current through bulb Z= 0.5A
Current through battery=

Example 1

Start with:

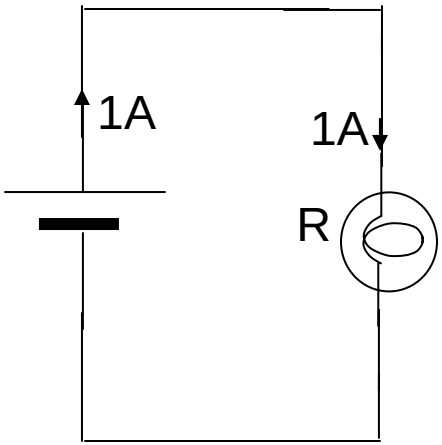


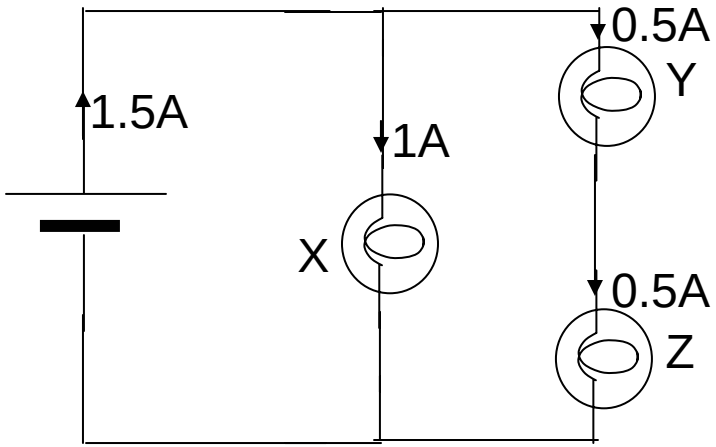


Current through bulb X= 1A
Current through bulb Y= 0.5A
Current through bulb Z= 0.5A
Current through battery=1A+0.5A=1.5A

Example 1

Start with:

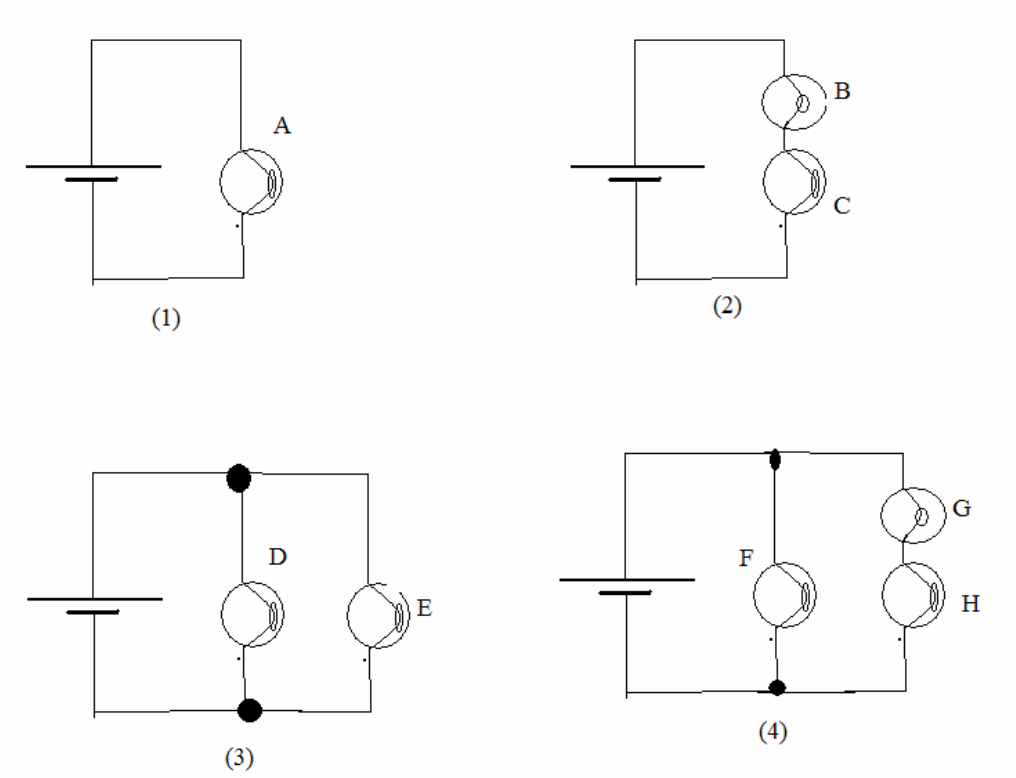




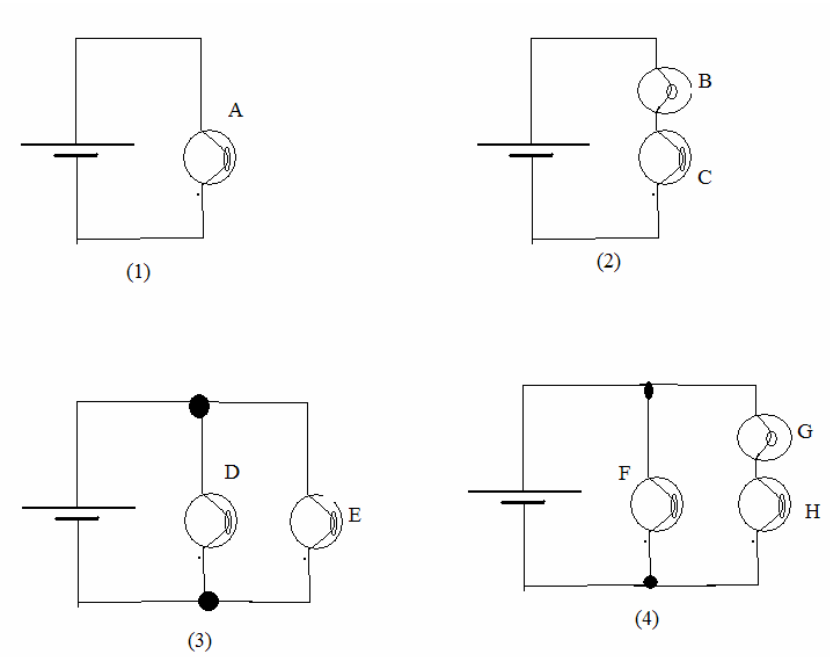
Current through bulb X= 1A
Current through bulb Y= 0.5A
Current through bulb Z= 0.5A
Current through battery=1A+0.5A=1.5A

X is the brightest. Y and Z are equal in brightness and they are dimmer.

Example 2 – Problem 3.5



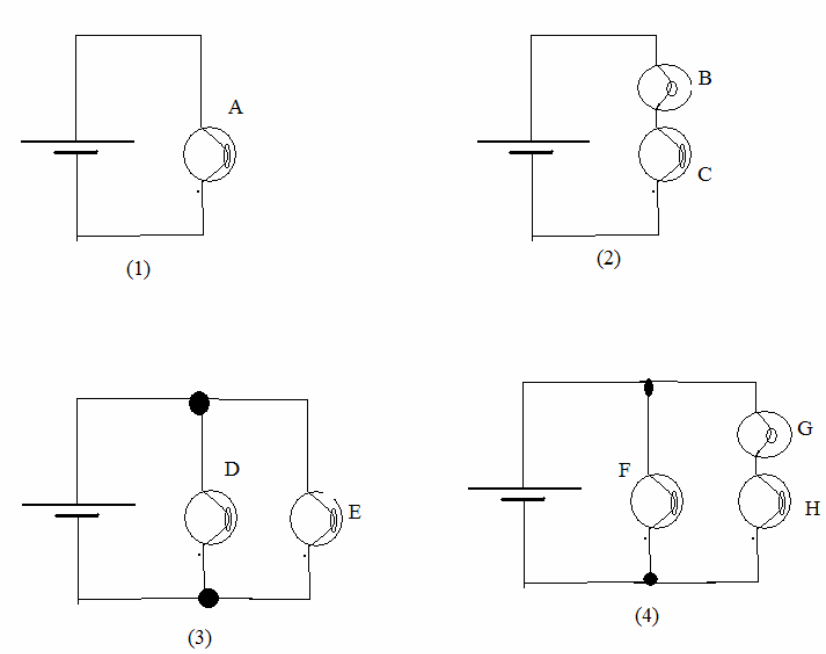
Example 2 – Problem 3.5



<u>Rank the Bulbs in Terms of Brightness</u>

- We have seen that adding components in parallel doesn't change the brightness of the original bulb. Therefore A has the same has the same brightness as D,E, and even F: A=D=E=F.
- All bulbs in series have the same current and brightness, but are less bright than a single bulb. Therefore B=C, but they are less than A: A>B=C.
- Suppose you started from circuit (2), and now added a bulb in parallel to the BC branch, to make circuit (4). Since adding a parallel branch doesn't affect the original branch, G=H=B=C.

Example 2 – Problem 3.5



FINAL BRIGHTNESS RESULT: A=D=E=F > G=H=B=C.

<u>Rank the Bulbs in Terms of Brightness</u>

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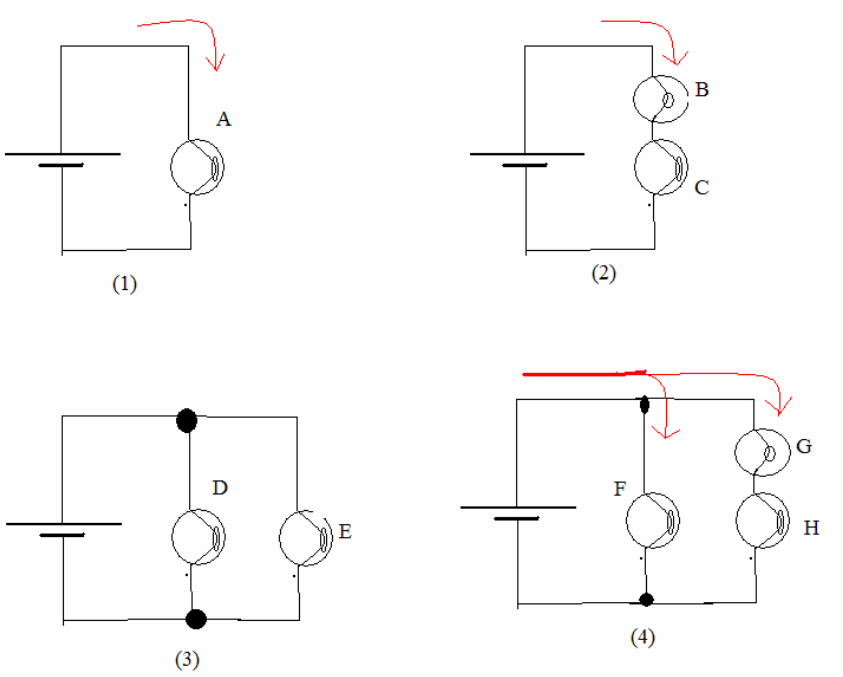
Example 2 – Problem 3.5

(FINAL BRIGHTNESS RESULT:
A=D=E=F > G=H=B=C.)

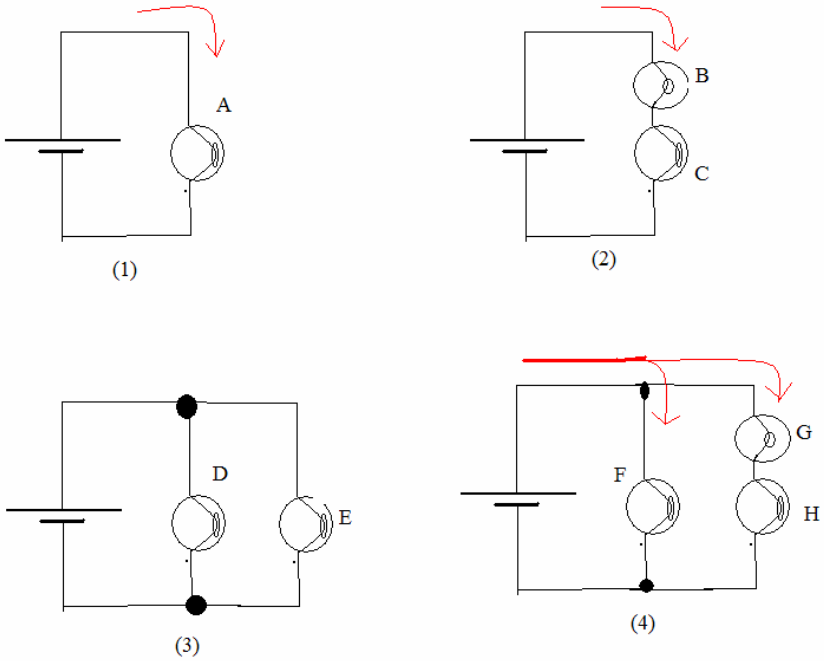


<u>Rank the Circuits in Terms of Current Through the Batteries</u>

- Since B is less bright than A, the current in A is greater than the current in B. The current in A = the current in battery (1) and the current in B = the current in battery (2); note that the current in B also passes through C, so battery (2) only has to "supply it once". Therefore battery current 1 > battery current (2).
- Since D and E have the same brightness as A, they each have the same current. However battery (3) must supply both D and E, while battery (1) only supplies A. Therefore, battery current (3) > battery current (1).

Example 2 – Problem 3.5

(FINAL BRIGHTNESS RESULT:
A=D=E=F > G=H=B=C.)



FINAL BATTERY CURRENT RESULT: (3) > (4) > (1) > (2).

<u>Rank the Circuits in Terms of Current Through the Batteries</u>

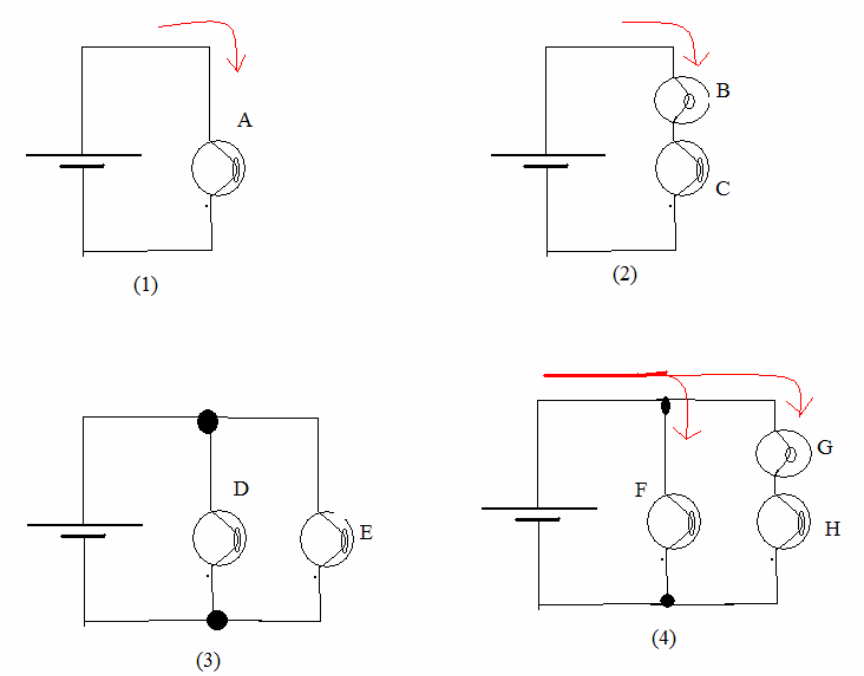
Results so far:

Current (3) > Current (1) > Current (2)

- The brightness of G = brightness of B, so these have the same currents, which is less than the current in A. (H has the same brightness and current as G, but battery (4) only has to “supply this once.” Similarly, F has the same current as D,E, and A. Since battery (4) supplies the currents to F and G, it is supplying more current than battery (1) but less than (3).

Example 2 – Problem 3.5

FINAL BATTERY CURRENT
RESULT: (3) > (4) > (1) > (2).



Rank the Circuits in Terms of Total Obstacle to Current Flow (i.e Effective Total Resistance)

Since the effective resistance is inversely proportional to the total current supplied by the battery, the circuit with the greatest current has the smallest resistance:

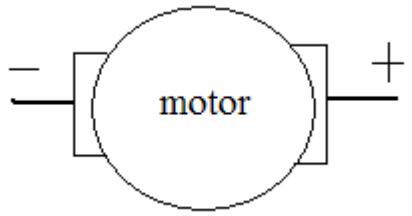
Therefore, the order of effective total resistance is:

(2) > (1) > (4) > (3)

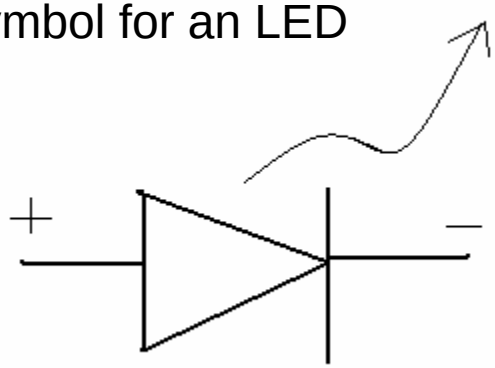
Current has Direction

- Electric current corresponds to the flow of charged particles (usually electrons), and therefore has a “direction”.
- However, the heat generated in an electrical wire and the light generated by a bulb only depend on the amount of current and not on the direction it is flowing.
- Two devices for which the direction of the current does matter are the electric motor and light emitting diode (or LED). In particular, the direction the motor is turning switches when the current direction is switched. The LED only lights up for a current of one polarity.

Symbol for a motor:

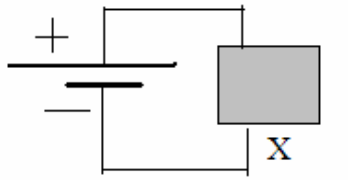


Symbol for an LED

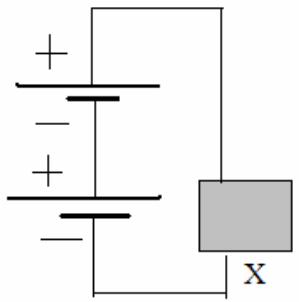


Batteries in Series

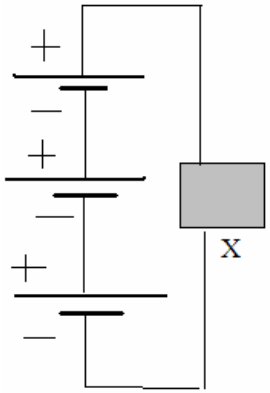
A way to increase the current through a device (e.g. bulb, LED, motor, … -- shown as box “X” in the figures below) is to add batteries in series. When the current through a bulb or LED increases, the intensity of the light increases. When the current through a motor increases, its speed increases. In some cases (e.g. the LED) the intensity doesn’t simply double when you double the number of batteries – these are called non-linear devices. In the case of the LED, it emits no light with one battery, but glows intensely with two.



“X” attached to one battery.

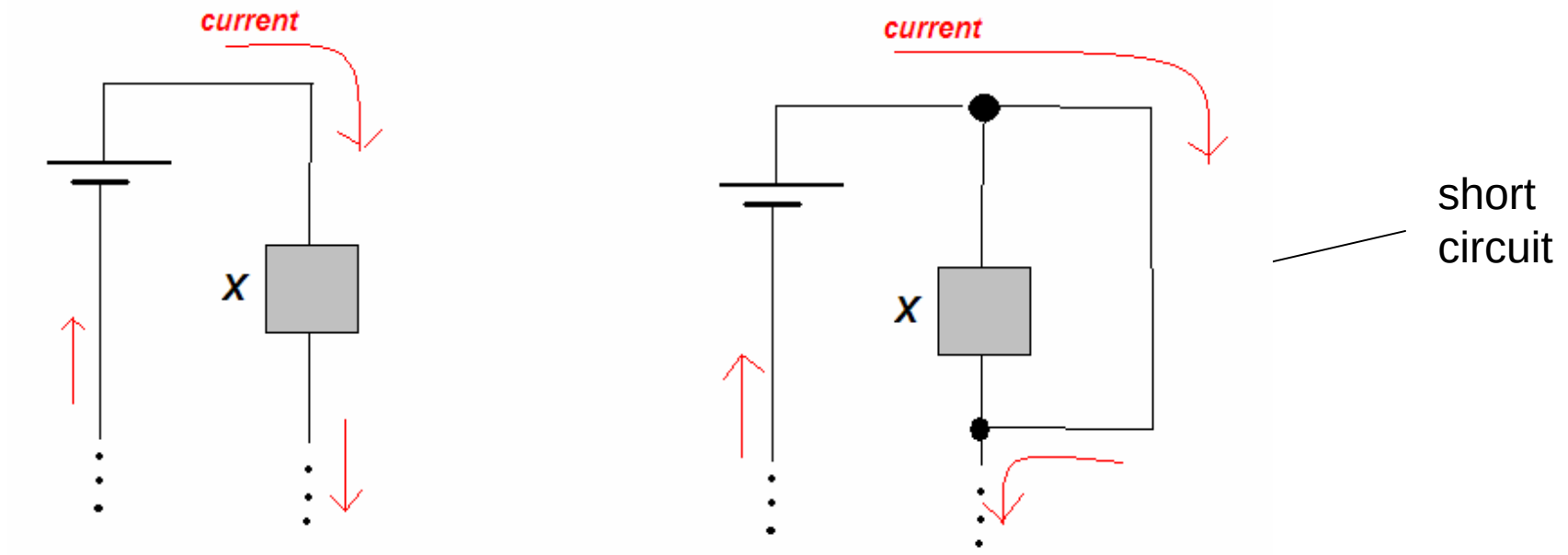


“X” attached to two batteries.



“X” attached to three batteries

Short Circuit



- In the circuit on the left, “X” is some resistive component (e.g. bulb, motor, LED, …) or combination of resistive components. (The dots indicate that the circuit is completed below.)

- If a good conductor (e.g. a wire) with ~ zero resistance is connected between the terminals of “X”, as shown on the right, the current will flow completely through this zero resistance and *no current will flow through “X”*. The conductor is called a “*short circuit*” – i.e. it presents a short cut allowing the current to bypass the resistance of “X”.