ELECTRICAL NETWORKS

OUR WORK UP TO THIS POINT HAS BEEN ON DEVELOPING THE COMPLETE SET OF EQUATIONS THAT DESCRIBE ELECTRICITY AND MAGNETISM (ELECTROMAGNETISM), THE MAXWELL EQUATIONS.

WE NOW WISH TO APPLY THESE EQUATIONS TO THE PRACTICAL APPLICATION OF ELECTRICAL NETWORKS (TO BE DESCRIBED / DEFINED IN MORE DETAIL).

DRAWING #2: ELECTRICITY

ELECTRICITY

ELECTRICITY IS THE SET OF PHYSICAL PHENOMENA ASSOCIATED WITH THE PRESENCE AND FLOW OF ELECTRIC CHARGE.

ELECTRICITY IS A VERY CONVENIENT WAY OF TRANSFERRING ENERGY...

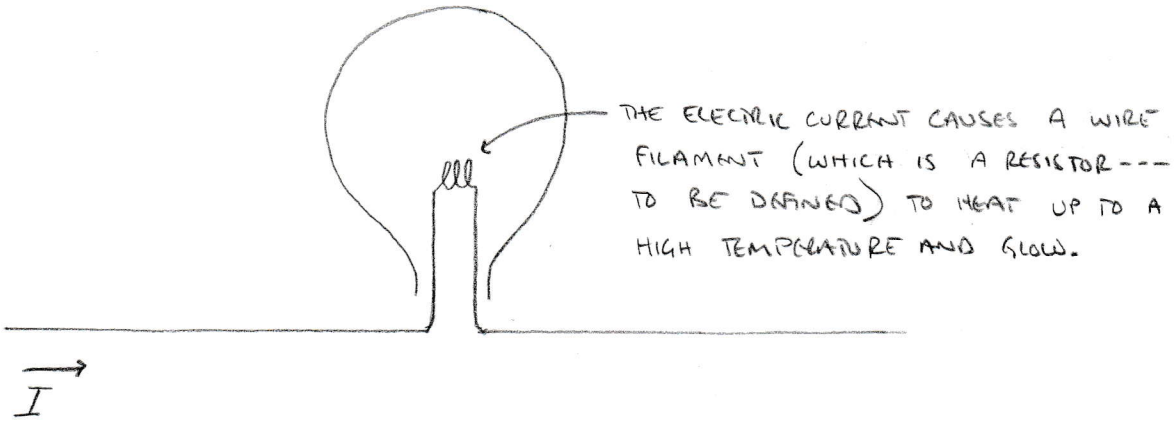
... AND THIS IS USED IN MANY, AND A GROWING NUMBER OF USES:

- LIGHTING
- ELECTRIC HEATING
- ELECTRICAL APPLIANCES
- TELECOMMUNICATIONS
- ELECTRIC MOTORS
- ELECTRONIC DEVICES

... AND THE LIST GOES ON AND ON...

EXAMPLE: THE INCANDESCENT LIGHT BULB

THE INVENTION OF THE INCANDESCENT LIGHT BULB IN THE 1870s LED TO LIGHTING BECOMING ONE OF THE FIRST PUBLICALLY-AVAILABLE APPLICATIONS OF ELECTRICAL POWER.



(NOTE: THOMAS EDISON DID NOT INVENT THE INCANDESCENT LAMP... JUST THE FIRST GOOD ONE.)

DRAWING #3: ELECTRONIC COMPONENTS I

ELECTRONIC COMPONENTS

IN ORDER TO DO SOMETHING WITH ELECTRICITY, WE NEED TO BE ABLE TO CONTROL THE MOTION OF THE CHARGES (AND POTENTIALLY THEIR ASSOCIATED FIELDS).

ANY BASIC DISCRETE DEVICE IN AN ELECTRONIC SYSTEM USED TO CONTROL (OR AFFECT) THE MOTION OF CHARGES OR THEIR ASSOCIATED FIELDS IS CALLED AN ELECTRONIC COMPONENT.

EXAMPLE: WE JUST TWO EXAMPLES OF THIS WHEN WE WERE CONSIDERING THE INCANDESCENT LIGHT BULB:

- A WIRE, USED TO ALLOW THE CURRENT TO FLOW
- A RESISTOR (THE FILAMENT) USED TO PROVIDE THE GLOW (BY HEAT)

OF PARTICULAR INTEREST (TO US) ARE PASSIVE (ELECTRICRONIC) COMPONENTS --- THOSE THAT DON'T REQUIRE AN EXTERNAL SOURCE FOR THEIR OPERATION.

(IN CONTRAST TO ACTIVE COMPONENTS --- THOSE THAT RELY ON AN EXTERNAL SOURCE --- OR ELECTROMECHANICAL COMPONENTS --- THOSE THAT CARRY OUT OPERATIONS USING MOVING PARTS, USUALLY REQUIRING AN ELECTRICAL CONNECTION)

DRAWING #4: ELECTRONIC COMPONENTS 2

THERE ARE A NUMBER OF TYPES OF ELECTRONIC COMPONENTS, AND THEY EACH CONTROL THE MOTION OF CHARGES (OR THEIR ASSOCIATED FIELDS) IN DIFFERENT WAYS...

... FOR OUR PURPOSES, THERE ARE ONLY A HANDFUL OF IMPORTANT COMPONENTS.

NOTE: THE FOLLOWING PROVIDES A BRIEF DESCRIPTION OF EACH OF THESE COMPONENTS; WE WILL LATER DEVELOP A MORE COMPLETE DESCRIPTION OF THEM, USING OUR KNOWLEDGE OF ELECTROMAGNETISM.

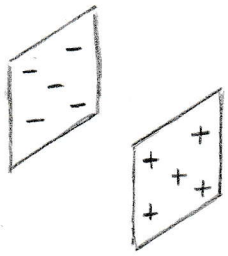
NOTE: THEIR COMPLETE DESCRIPTION, WHILE DESCRIBING THE PHYSICS OF THESE COMPONENTS, OFTEN CONTAINS IRRELEVANT INFORMATION. THERE ARE THEREFORE STANDARD SYMBOLS THAT ARE USED TO ILLUSTRATE THEM.

DRAWING #5: ELECTRONIC COMPONENTS 3: WIRES

EXAMPLE: WIRES

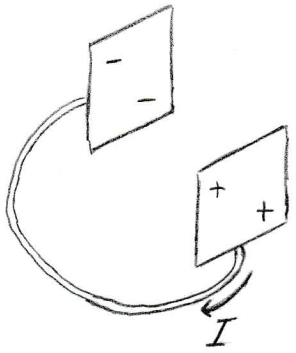
WIRES ARE USED TO DIRECT THE FLOW OF CHARGE FROM ONE LOCATION TO ANOTHER.

SUPPOSE THAT WE HAD TWO METAL PLATES, ONE WITH AN EXCESS NEGATIVE CHARGE AND ONE WITH AN EQUAL AND EXCESS POSITIVE CHARGE:



IF THESE PLATES WERE ISOLATED, THEY WOULD EACH STAY CHARGED INDEFINITELY.

IF THEY WERE TO BE CONNECTED BY A WIRE (A CONDUCTOR), CHARGE WOULD TRANSFER BETWEEN THE PLATES (VIA THE WIRE) AND THEY WOULD EACH BECOME NEUTRAL:



NOTE: THE CURRENT I POINTS IN THE DIRECTION THAT POSITIVE CHARGES WOULD FLOW ... THOUGH IT IS NEGATIVE CHARGES (ELECTRONS) THAT DO FLOW.

ONE WAY OF LOOKING AT THIS IS THAT POSITIVE CHARGE WILL WANT TO FLOW FROM A REGION OF HIGH ELECTRIC POTENTIAL TO LOW ELECTRIC POTENTIAL (KEEP IN MIND THE NOTE ABOVE THOUGH!).

(NOTE: AN ELECTRIC POTENTIAL DIFFERENCE MEANS THAT THERE IS AN ELECTRIC FIELD, WHICH WILL EXERT A FORCE ON THE CHARGES.)

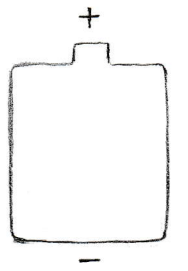
WIRES ARE SYMBOLIZED USING A LINE:

WIRE

DRAWING #6: ELECTRICAL COMPONENTS 4: BATTERIES

EXAMPLE: BATTERIES

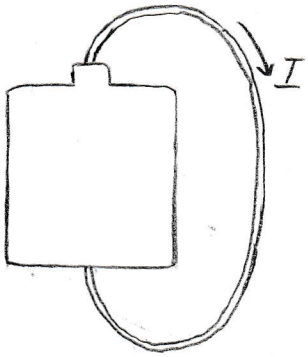
THE MOST COMMON SOURCE OF ELECTRIC POTENTIAL IS A BATTERY:



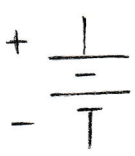
← THE TERMINAL WITH A HIGH ELECTRIC POTENTIAL IS CALLED THE POSITIVE TERMINAL

← THE TERMINAL WITH A LOW ELECTRIC POTENTIAL IS CALLED THE NEGATIVE TERMINAL

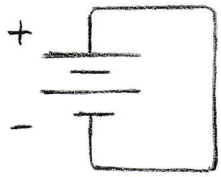
BECAUSE OF THE POTENTIAL DIFFERENCE, IF A WIRE WAS CONNECTED TO THE TWO TERMINALS, CHARGE WOULD FLOW:



BATTERIES ARE SYMBOLIZED AS:



BATTERY



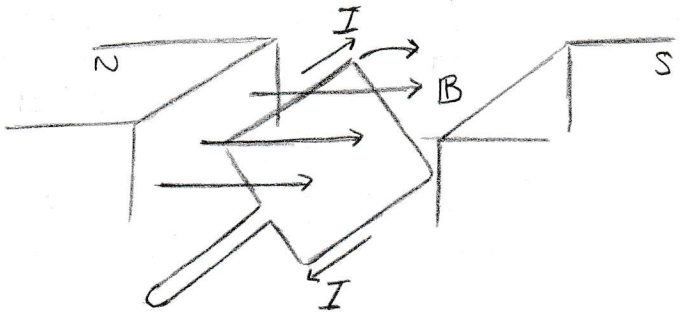
BATTERY CONNECTED TO A WIRE

DRAWING #6.1 : ELECTRICAL COMPONENTS 4.1 : ALTERNATING CURRENT SOURCE

EXAMPLE : ALTERNATING CURRENT SOURCE

IT IS ALSO POSSIBLE TO HAVE A "SOURCE" OF ALTERNING CURRENT (NOTE: IT IS NOT REALLY A SOURCE OF CONTINUOUS CURRENT).

FOR EXAMPLE: AN ALTERNATING-CURRENT GENERATOR



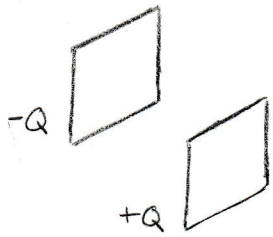
CIRCUITS POWERED BY AN ALTERNATING CURRENT (AC) SOURCE ARE CALLED AC CIRCUITS.

AN ALTERNATING-CURRENT SOURCE IS SYMBOLIZED AS:

DRAWING #7: ELECTRICAL COMPONENTS 5: CAPACITORS

EXAMPLE: CAPACITORS

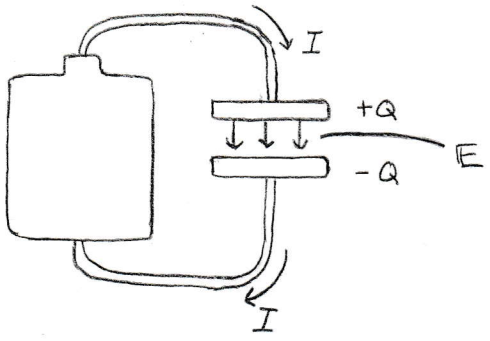
THE ARRANGEMENT OF TWO ELECTRODES, CHARGED EQUALLY AND OPPOSITELY IS CALLED A PARALLEL-PLATE CAPACITOR:



CAPACITORS CAN BE USED TO STORE ELECTRICAL ENERGY (TEMPORARILY) IN AN ELECTRIC FIELD. (NOTE: CAPACITANCE IS THE CAPACITY OF A BODY TO STORE AN ELECTRIC CHARGE.)

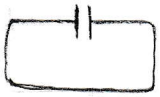
(NOTE: WE'VE SEEN HOW THIS ENERGY CAN BE USED TO MAKE THE ELECTRONS FLOW FROM ONE PLATE TO THE OTHER.)

NOTE: A CAPACITOR CAN BE CHARGED BY A BATTERY:

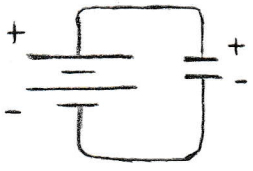


A CAPACITOR IS SYMBOLIZED AS:

CAPACITOR



CAPACITOR AND WIRE

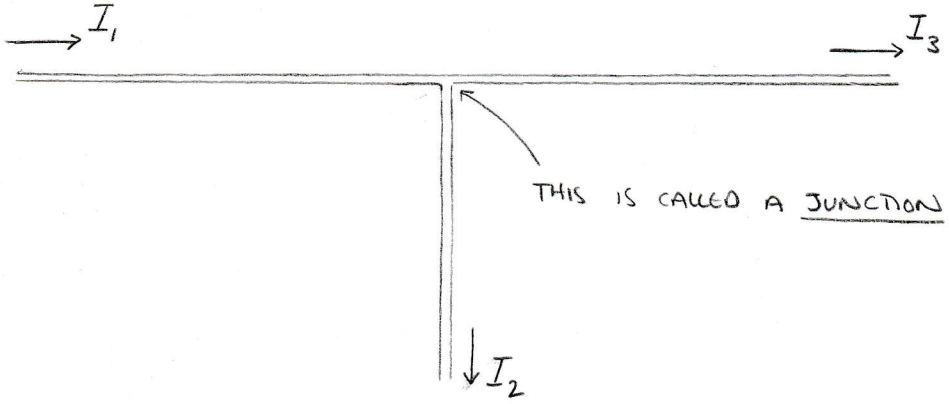


BATTERY, CAPACITOR, AND WIRE

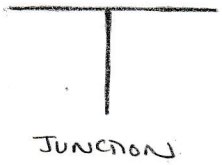
DRAWING #8: ELECTRICAL COMPONENTS 6: JUNCTIONS

EXAMPLE: JUNCTIONS

IN SOME CASES, WE MAY WANT TO DIRECT THE FLOW OF CURRENT THROUGH A WIRE ALONG TWO (OR MORE) PATHS:



A JUNCTION IS SYMBOLIZED AS:



DRAWING #9: ELECTRICAL COMPONENTS #7: SWITCHES

EXAMPLE: SWITCHES

IT IS ALSO SOMETIMES DESIRABLE TO START OR STOP THE FLOW OF CHARGE...

... THIS CAN BE ACCOMPLISHED USING A SWITCH:

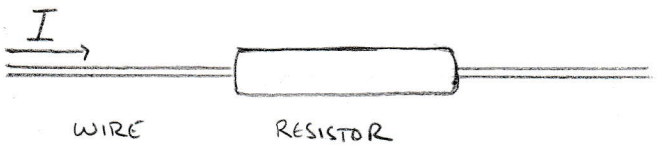
A SWITCH IS SYMBOLIZED AS:

DRAWING #10: ELECTRICAL COMPONENTS #8: RESISTORS

EXAMPLE: RESISTORS

SOME MATERIALS ARE "BETTER" CONDUCTORS THAN OTHERS. RECALL OUR MODEL FOR ELECTRON CONDUCTION... A MATERIAL WITH A GREATER NUMBER DENSITY OF ELECTRONS WILL HAVE A GREATER FLOW OF CHARGE ($J = \rho v_d = n_e e v_d$); A MATERIAL WHERE THE CHARGES HAVE A LARGER TIME BETWEEN (RANDOM) COLLISIONS WILL HAVE A BETTER FLOW OF CHARGE.

A POOR CONDUCTOR IS CALLED A RESISTOR:



NOTE: THE SAME AMOUNT OF CURRENT FLOWS THROUGH THE RESISTOR AS THE WIRE, BUT THE ELECTRIC POTENTIAL DROPS.

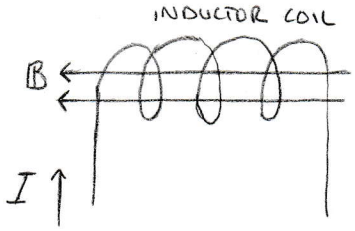
NOTE: WE SAW A RESISTOR BEFORE (THE FILAMENT IN AN INCANDESCENT BULB).

A RESISTOR IS SYMBOLIZED AS:

DRAWING #11: ELECTRICAL COMPONENTS #9: INDUCTORS

EXAMPLE: INDUCTORS

JUST AS CAPACITORS CAN BE USED TO STORE (POTENTIAL) ENERGY IN AN ELECTRIC FIELD, AN INDUCTOR CAN BE USED TO STORE ENERGY IN A MAGNETIC FIELD:



(NOTE: THIS IS A SOLENOID)

(NOTE: IF WE INCREASE THE CURRENT, THERE WILL BE AN INDUCED MAGNETIC FIELD THAT WILL OPPOSE THE CHANGE IN MAGNETIC FLUX.)

AN INDUCTOR IS SYMBOLIZED AS:

DRAWING #12: ELECTRICAL COMPONENTS #10: BULBS

EXAMPLE: BULBS

A BULB IS SYMBOLIZED AS:

DRAWING #13: ELECTRICAL NETWORKS AND CIRCUITS

AN INTERCONNECTION OF ELECTRICAL COMPONENTS IS CALLED AN ELECTRICAL NETWORK.

AN ELECTRICAL CIRCUIT IS A NETWORK CONSISTING OF A CLOSED LOOP, GIVING A RETURN PATH FOR THE CURRENT.

EXAMPLE: AN ELECTRICAL CIRCUIT: