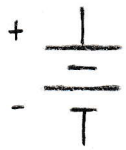
DRAWING #1: BATTERIES

BATTERIES

THE MOST COMMON SOURCE OF ELECTRIC POTENTIAL IS A BATTERY.

SYMBOL IN CIRCUIT DIAGRAMS:



BATTERY

DRAWING #2: OHM'S LAW (RECAP)

OHM'S LAW SHOWS THAT A CURRENT IN A CONDUCTOR ARISES FROM A POTENTIAL DIFFERENCE V BETWEEN THE END POINTS:

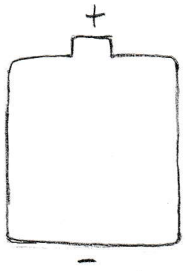
$$I = \frac{V}{R} \qquad V = \phi(a) - \phi(b)$$

... HOWEVER, WE HAVEN'T YET SPECIFIED HOW THIS POTENTIAL ARISES.

NOTE: KEEP IN MIND THAT WE NEED TO WORK OUT THE DIRECTION OF I MANUALLY.

DRAWING #3: BATTERIES 1

THE MOST COMMON SOURCE OF A POTENTIAL DIFFERENCE (AT LEAST IN THE CIRCUITS THAT WE ARE DISCUSSING) IS A BATTERY;



← THE TERMINAL WITH A HIGH ELECTRIC POTENTIAL IS CALLED THE <u>POSITIVE TERMINAL</u>

← THE TERMINAL WITH A LOW ELECTRIC POTENTIAL IS CALLED THE <u>NEGATIVE TERMINAL</u>

THE POTENTIAL IN A BATTERY IS ESTABLISHED BY SEPARATING POSITIVE AND NEGATIVE CHARGES BETWEEN TWO TERMINALS.

CHARGE SEPARATION IN A BATTERY OCCURS BY CHEMICAL REACTIONS...

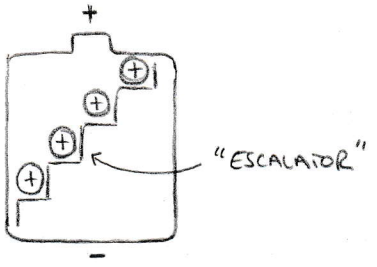
... A BATTERY CONSISTS OF CHEMICALS CALLED ELECTROLYTES, AND CHEMICAL REACTIONS BETWEEN THEM MOVE POSITIVE CHARGE TO ONE TERMINAL AND NEGATIVE CHARGE TO THE OTHER, CREATING A CHARGE, AND HENCE POTENTIAL, DIFFERENCE.

(NOTE: A DEAD BATTERY IS WHEN THESE CHEMICAL ELEMENTS GET USED UP)

DRAWING #4: BATTERIES 2

THE CHEMISTRY DETAILS OF A BATTERY ARE BEYOND THE SCOPE OF OUR DISCUSSION.

... FOR OUR PURPOSES, IT IS MORE USEFUL TO CONSIDER THE CHARGE ESCALATOR MODEL:



IN THIS MODEL, WE CONSIDER THAT A BATTERY SEPARATES THE CHARGE BY "LIFTING" POSITIVE CHARGE FROM THE NEGATIVE-TO-POSITIVE TERMINAL (VIA AN "ESCALATOR").

THIS LIFTING REQUIRES WORK TO BE DONE ON THE CHARGES (THE ENERGY FOR THIS WORK IS PROVIDED BY THE CHEMICAL REACTIONS).

IN AN IDEAL BATTERY, THERE ARE NO INTERNAL ENERGY LOSSES, AND THE WORK DONE TO MOVE A CHARGE q FROM THE NEGATIVE TO POSITIVE TERMINAL W IS EQUAL TO THE GAIN IN ELECTRICAL POTENTIAL ENERGY U:

$$W = \Delta U$$

THE WORK DONE PER UNIT CHARGE IS CALLED THE ELECTROMOTIVE FORCE (emf) $\mathcal{E}$ OF THE BATTERY:

$$\frac{W}{q} = \mathcal{E}$$

(NOTE: THIS IS NOT AN ACTUAL FORCE)

RECALL (FROM ELECTROSTATICS) THAT THE WORK PER UNIT CHARGE IS RELATED TO A DIFFERENCE IN ELECTRICAL POTENTIAL; WE CAN SEE THIS BY WRITING:

$$\frac{W}{q} = \left(\frac{\Delta U}{q} = V\right) = \mathcal{E} \qquad \text{HENCE:} \quad V = \mathcal{E}$$

EXAMPLE:

A BATTERY CONSTRUCTED TO HAVE AN emf OF 9.0V MEANS THAT ITS CHEMICAL REACTIONS DO 9.0 J OF WORK TO SEPARATE 1C OF CHARGE, AND THIS CREATES A POTENTIAL DIFFERENCE OF 9.0 V BETWEEN THE POSITIVE AND NEGATIVE TERMINALS.

DRAWING #5: HOW A CIRCUIT WORKS

IT IS IMPORTANT TO KEEP IN MIND HOW A BATTERY CAUSES A CURRENT TO FLOW AROUND A CIRCUIT:

(1) A BATTERY IS A SOURCE OF POTENTIAL DIFFERENCE

(2) WHEN A WIRE IS CONNECTED TO A BATTERY, A POTENTIAL DIFFERENCE IS CREATED AT BOTH ENDS OF THE WIRE

(3) THIS POTENTIAL DIFFERENCE CREATES AN ELECTRIC FIELD INSIDE THE WIRE

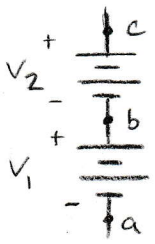
(4) THE ELECTRIC FIELD ESTABLISHES A CURRENT IN THE WIRE

(5) THE MAGNITUDE OF THE CURRENT IS DETERMINED BY BOTH THE POTENTIAL DIFFERENCE AND THE WIRE'S RESISTANCE.

DRAWING #6: BATTERIES IN SERIES

BATTERIES CAN BE ALIGNED END-TO-END TO "CREATE" A BIGGER POTENTIAL DIFFERENCE:

(THIS IS CALLED ALIGNING THEM "IN SERIES")



(NOTE: DO NOT ALIGN BATTERIES "IN PARALLEL"; IT LEADS TO INCONSISTENT EQUATIONS)

THE POTENTIAL DIFFERENCE OVER EACH BATTERY IS:

$$V_1 = \phi(b) - \phi(a)$$

$$V_2 = \phi(c) - \phi(b)$$

ASSUMING IDEAL WIRES, WE CAN WRITE THE POTENTIAL DIFFERENCE BETWEEN POINTS a AND c AS:

$$\begin{aligned} V_{ac} &= V_1 + V_2 \\ &= \big(\phi(b) - \phi(a)\big) + \big(\phi(c) - \phi(b)\big) \\ &= \phi(c) - \phi(a) \end{aligned}$$

THEREFORE TWO BATTERIES ACT AS A SINGLE BATTERY WITH A VOLTAGE OF $(V_1 + V_2)$.

IF WE HAVE N BATTERIES IN SERIES, THEIR EQUIVALENT VOLTAGE IS:

$$V_{eq} = \sum_{i=1}^{N} V_i \qquad \text{(SERIES BATTERIES)}$$