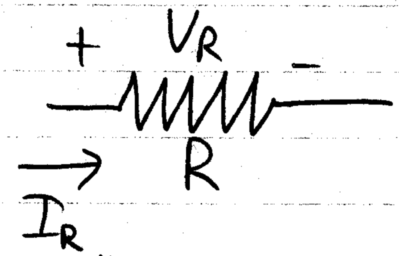
Chapter 2 Circuit Analysis

Element and Connection Constraints.

A *device* is the real thing, an *element* is the *model* that has ideal behavior.

Simplest element:

Resistor - R -



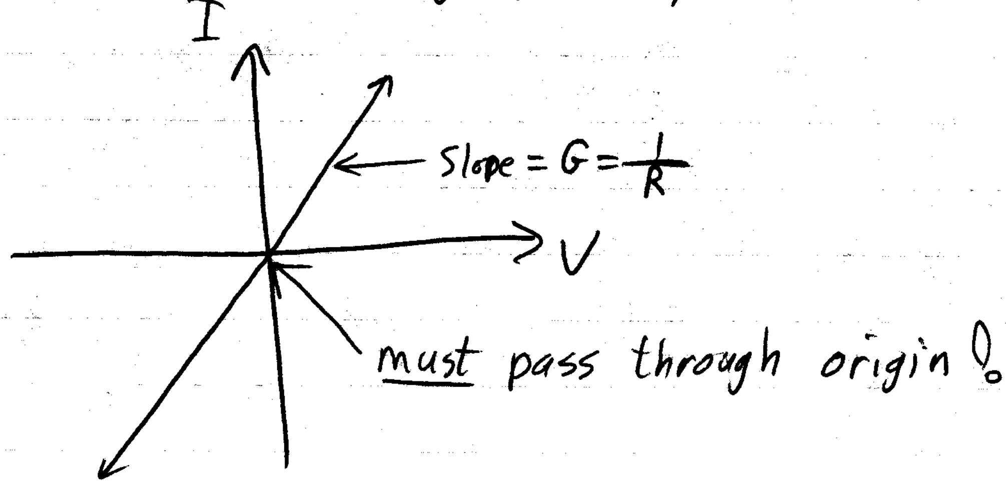
resistance
unit: Ohms (Ω) $= \frac{1V}{1A}$

$$V_R = R I_R \quad \text{or} \quad v_R = R i_R$$

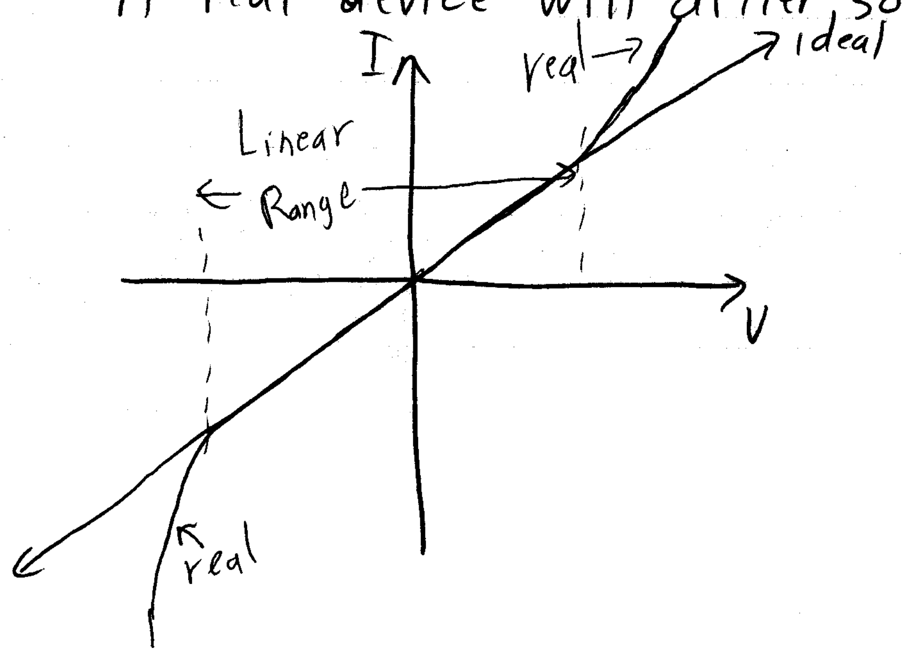
Inverse: $I_R = G V_R = \frac{1}{R} V_R \qquad i_R = G v_R$

Conductance
$G = \frac{1}{R}$
unit: Siemen (S)
used to be mhos ($\mho$)

- This is called the "I-V relation," and is sometimes shown graphically:



- A real device will differ somewhat:



- A resistor is <u>bilateral</u>, or odd <u>symmetric</u>, wrt V.

"Reverse the voltage, reverse the current."

Power? $P_R = +VI = +(IR)I = +I^2R$

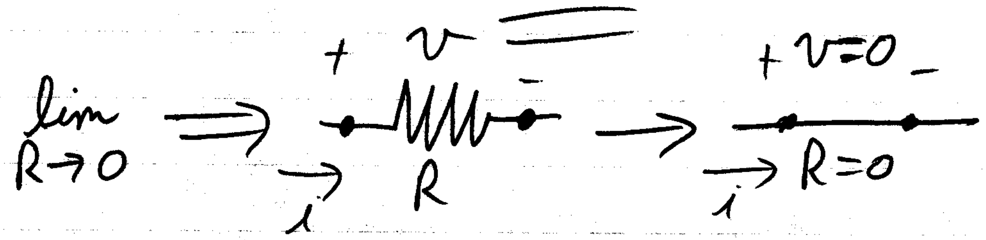
or $P_R = +V\left(\frac{V}{R}\right) = +\frac{V^2}{R}$

These only apply to resistors!

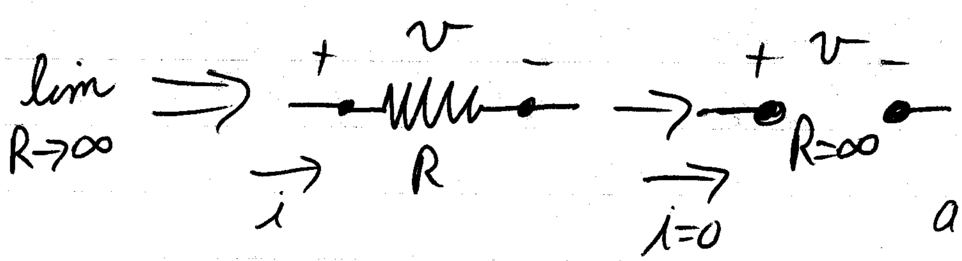
Note that no matter what sign V or I have, the power is positive: Resistors only dissipate power

Real resistors have limits, most typically on the amount of power they can dissipate, ranging from a few milliWatts to kiloWatts. The more power they can dissipate the bigger and more expensive they are. For many years you could only get $\frac{1}{8}$W, $\frac{1}{4}$, $\frac{1}{2}$, 1W and higher, but miniaturization of components has led to .01 W (10mW) and smaller R's being made.

This is a good time to introduce 2 limits that are vital for you to understand:



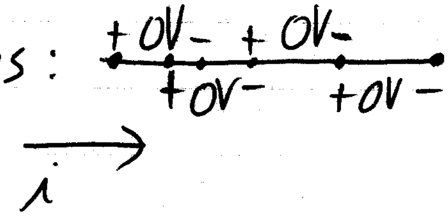
A wire or a Short-Circuit



A gap, or an Open-Circuit

We should say something now about ideal

Wires:



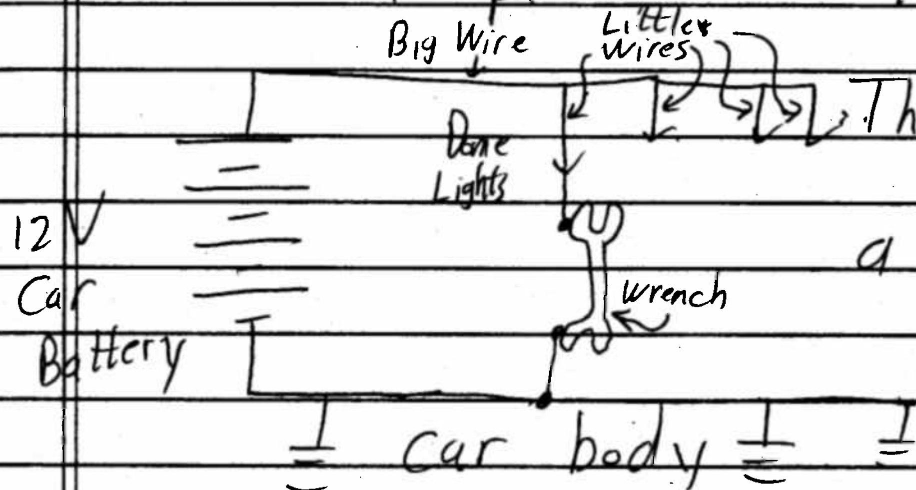
these allow infinite currents to flow (if called for mathematically) but have zero voltage drop between any two points.

Real wires have a small, but finite, resistance. They do dissipate some energy, and again the larger they are the more current they can carry and the more they cost.

Part of the reason for Circuit Analysis is to predict how much current every wire will be carrying and make it the right size, usually with some "margin of safety".

In case you think this is only a manufacturing issue, wanting to shave material costs wherever possible to make things more cheap~~ly~~, note 2 things:

1.) If you have ever worked on a car and read any instructions about how to do a procedure safely, you may have seen that they always say to disconnect the # wire to the + pole of the battery as the first step. This is because ~~the~~ a car battery can supply 1000 or more Amps if a short is placed across its terminals.



This means that if a wrench slips and touches a terminal that is connected to the battery, say the dome light, and a ground (any metal piece of the car body or frame) it will try to conduct 1000 or more Amps through it. If the wires are big enough to carry that much current, the wrench can explode (Look for "exploding wires" on YouTube or Google.)

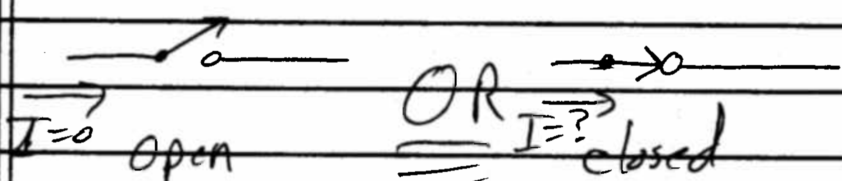
If the wires are smaller, then they will heat up, melt their insulation, and maybe catch on fire. Not a good thing to have happen inside your car.

Too rapid a discharge can also make your battery heat rapidly, leading to an violent rupture and splattering of battery acid all over the car, the engine, and YOU! This brings us to the second case:

2.) Some batteries, particularly Li Ion batteries of some types, have high enough energy densities that if they are shorted out they can melt or even burst into flames. It has happed to cell phones, laptops, cars, and even airplanes!!!

Zero-to-Infinite Resistance Devices (Switches).

An even simpler device than a resistor, in concept but not mathematically, is a switch which has either zero Ω (closed, or shorted) or $\infty\ \Omega$ (open):

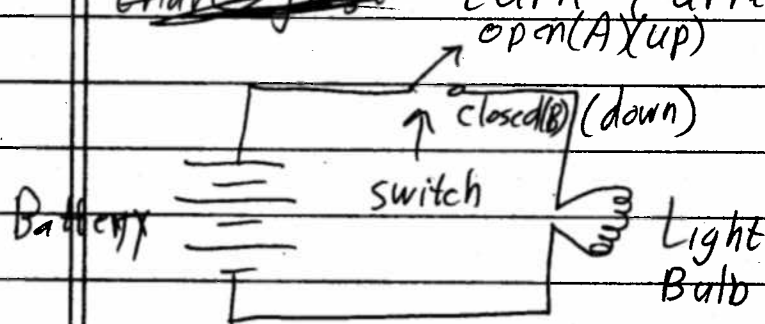


So, given a switch you ask yourself 2 questions:

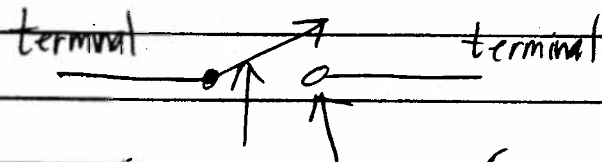
1.) If the Switch is Open, there is zero current through it. What does that do to the rest of the circuit?

7.) If the switch is Closed, the current may be anything. What does the rest of the circuit determine the current to be?

Sometimes we want a switch ~~to do more~~ simply ~~than just~~ turn current on or off:



Parts of a switch:



pole (Moving part thru which current may flow)

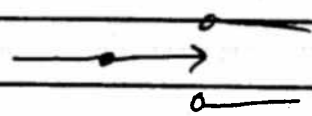
throw (position in which a current is allowed to Flow in at least one ckt)

This is a Single Pole, Single Throw (SPST) Switch (off-On) or (Off-Mom)

As you already know, there are many types of switches:

toggle, slide, pushbutton, rotary, etc.

They may be more complicated than SPST:

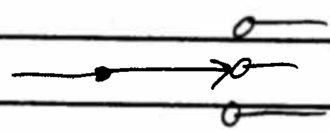


Single Pole, Double Throw
SPDT
(On-On) or (On-Off-On)

or (Off-On-On)

or (On-Off-Mom)

or (Mom-Off-Mom)



Single Pole, Triple Throw
SPTT or SP3T

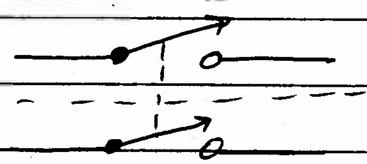
⋮

SP4T

SP5T

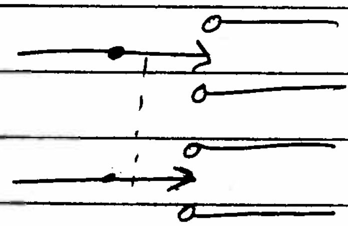
⋮

We may want to control more than one circuit or parameter:



does not cross over

Double Pole, Single Throw (DPST) (Off-On)



Double Pole, Double Throw (DPDT) (On-On) or (On-Off-On) etc.

Real Switches are described first by #Poles + #Throws, Action (Toggle, etc.) and also by ~~the~~ how much current they can carry when closed (i.e., how big are the conductors inside?) and by the maximum Voltage they can withstand when open (i.e, how far apart are the conductors when open?)