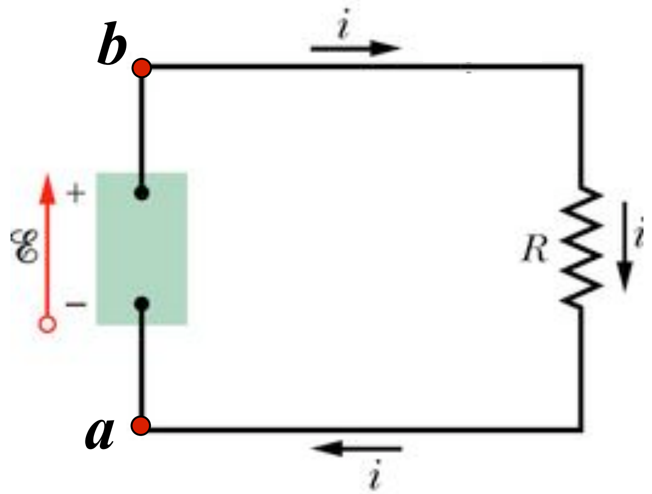
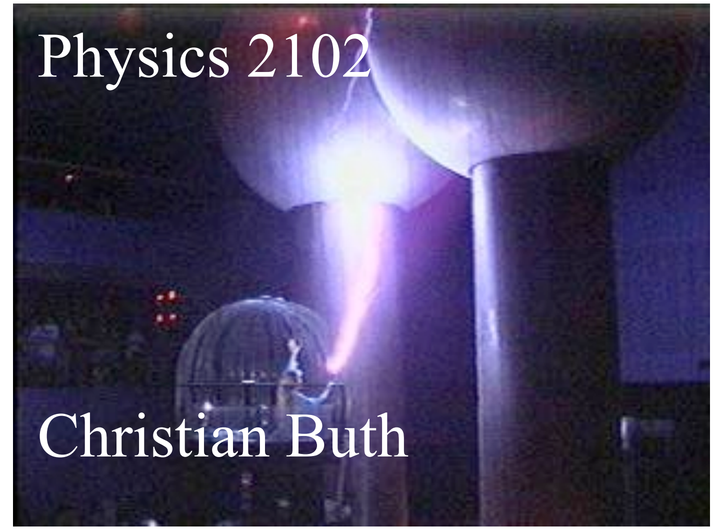
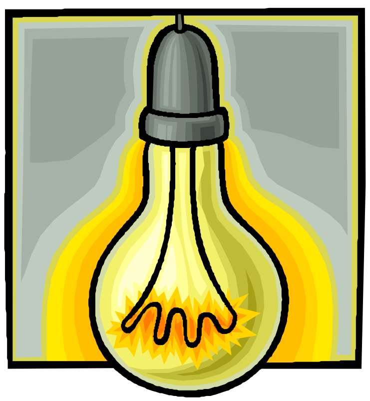




Physics 2102
Lecture 16
DC Circuits 2



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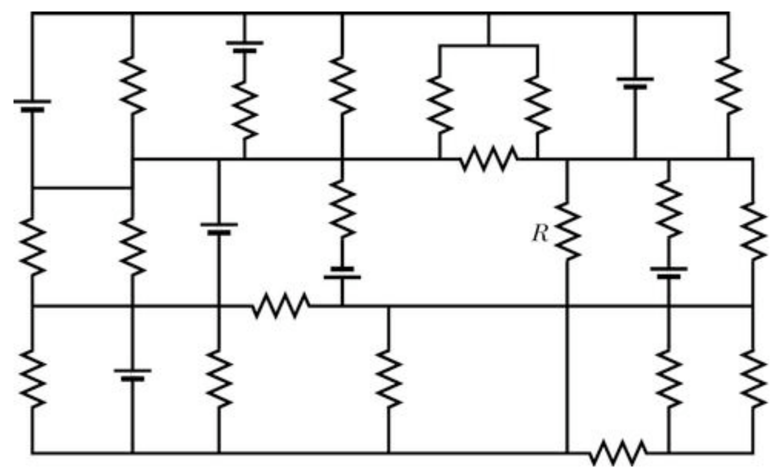


Review

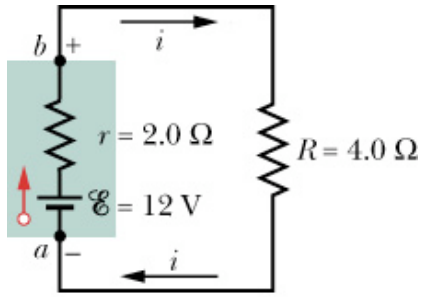
- **Electromotive force devices** (emf) maintain a potential between their terminals

- **Kirchhoff's loop rule** (KLR):

KLR : The algebraic sum of the changes in potential encountered in a complete traversal of any loop in a circuit is equal to zero.

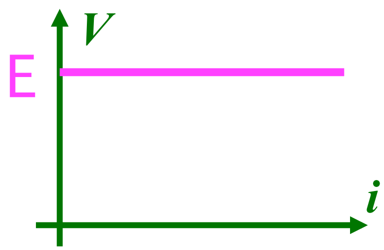
- When walking through an emf, add $+\mathcal{E}$ if you flow with the current or $-\mathcal{E}$ otherwise

- When walking through a resistor, add $-iR$, if flowing with the current or $+iR$ otherwise



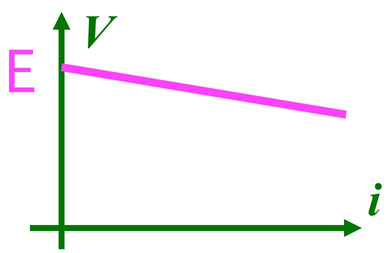
$V = \mathcal{E}$

Ideal emf device



$V = \mathcal{E} - ir$

Real emf device



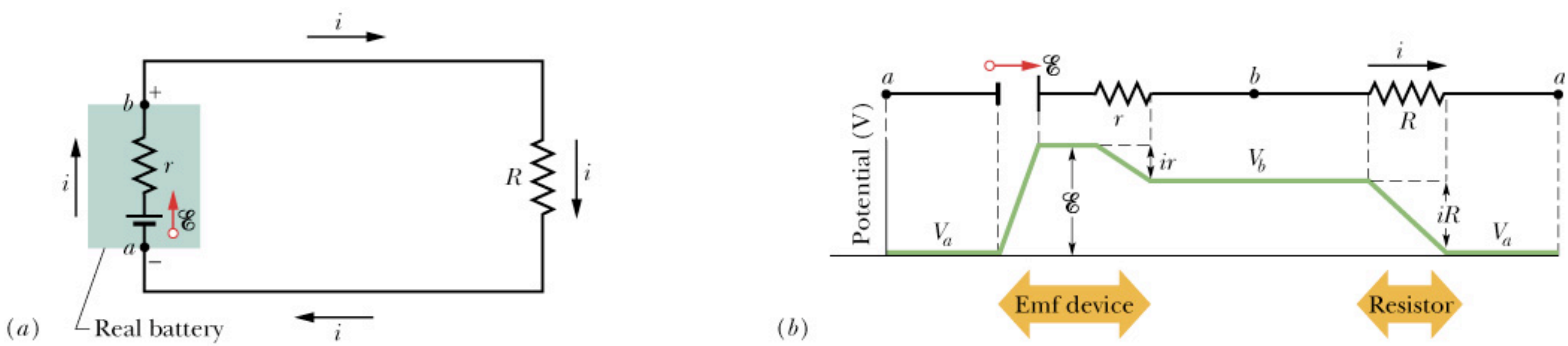
Ideal and Real Emf Devices

An emf device is said to be **ideal** if the voltage V across its terminals a and b does **not** depend on the current i that flows through the emf device: $V = \mathcal{E}$.

An emf device is said to be **real** if the voltage V across its terminals a and b **decreases** with current i according to the equation $V = \mathcal{E} - ir$.
The parameter r is known as the "**internal resistance**" of the emf device.

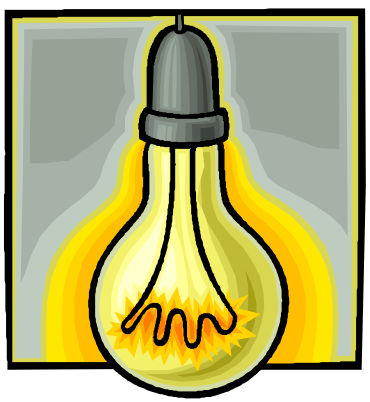
Single Loop with Real Battery

- **Real battery** with internal resistance r
- **KLR:** $\mathcal{E}-ir-iR=0$ yielding $i = \mathcal{E} / (R + r)$
- For **ideal battery** $r = 0$



Incandescent light bulbs

(a) Which light bulb has a smaller resistance: a 60W, or a 100W one?
(b) Is the resistance of a light bulb different when it is on and off?
(c) Which light bulb has a larger current through its filament: a 60W one, or a 100 W one?
(d) Would a US light bulb be any brighter if used in Europe, using 240 V outlets?
(e) Would a US light bulb used in Europe last more or less time?
(f) Why do light bulbs mostly burn out when switched on?



Resistors in Series

Two resistors are "in series" if they are connected such that the **same current** flows in both.

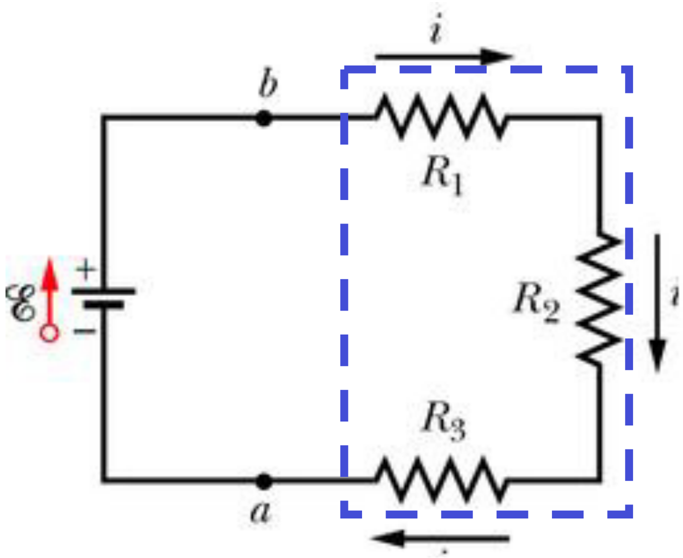
The "equivalent resistance" is a single imaginary resistor that can replace the resistances in series.

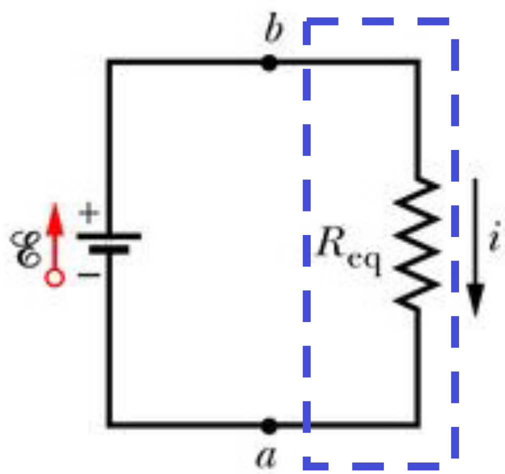
"Walking the loop" results in :

$\mathcal{E} - iR_1 - iR_2 - iR_3 = 0 \rightarrow i = \mathcal{E}/(R_1+R_2+R_3)$

In the circuit with the equivalent resistance,

$\mathcal{E} - iR_{eq} = 0 \rightarrow i = \mathcal{E}/R_{eq}$

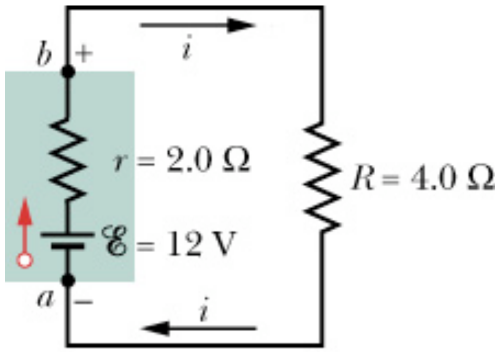




Thus,

$$R_{eq} = \sum_{j=1}^{n} R_j$$

Behave like capacitors in parallel!



Potential Difference Between Two Points :

Consider the circuit shown in the figure. We wish to calculate the potential difference $V_b - V_a$ between point b and point a.

$V_b - V_a =$ sum of all potential changes ΔV along the path from point a to point b.

We choose a path in the loop that takes us from the initial point a to the final point b.

$V_f - V_i =$ sum of all potential changes ΔV along the path.

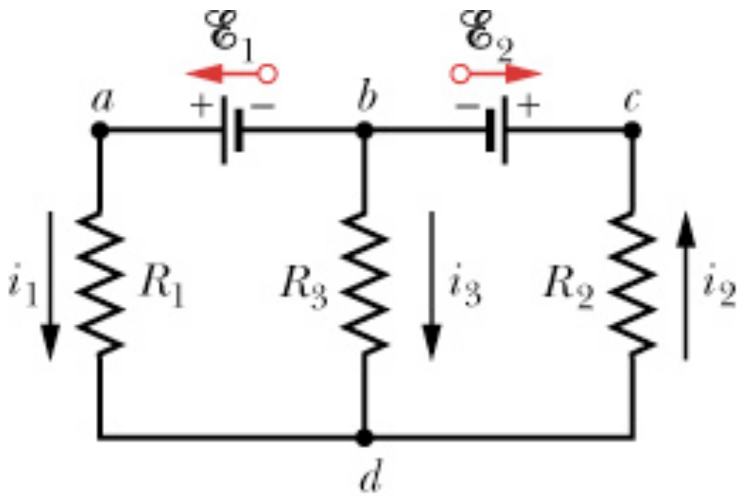
There are two possible paths: We will try them both.

Left path: $V_b - V_a = \mathcal{E} - ir$

Right path: $V_b - V_a = iR$

Note : The values of $V_b - V_a$ we get from the two paths are the same.

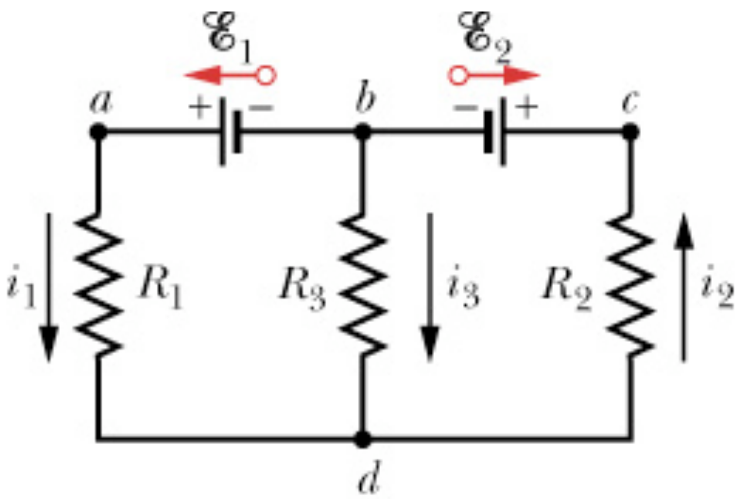
Multiloop Circuits 1



- Three branches: *bad*, *bdc*, *bd*
- **Assign current directions** arbitrarily (negative currents mean opposite direction)
- Charge is conserved at point *d* thus $i_1 + i_3 = i_2$ (**Kirchhoff's junction rule**: KJR)

KJR : The sum of the currents entering any junction is equal to the sum of the currents leaving the junction.

Multiloop Circuits 2



- **Need three equations** for three currents:
- 1. At *d* **KJR**: $i_1 + i_3 = i_2$
- 2. **KLR** *bad*: $E_1 - i_1 R_1 + i_3 R_3 = 0$
- 3. **KLR** *bdc*: $-i_3 R_3 - i_2 R_2 - E_2 = 0$
- 4. **KLR** *badc*: $E_1 - i_1 R_1 - i_2 R_2 - E_2 = 0$ (does not provide new information)
- **Solve** linear system of equations

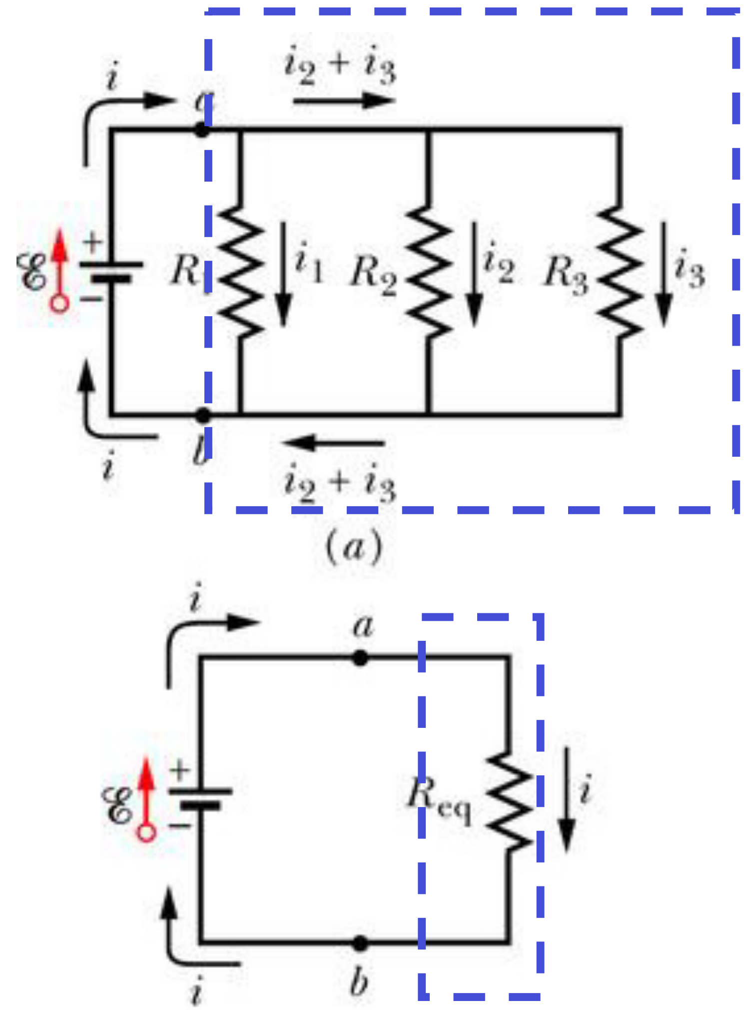
Resistors in Parallel

Two resistors are "in parallel" if they are connected such that there is the **same potential** drop through both.
The "equivalent resistance" is a single imaginary resistor that can replace the resistances in parallel.

"Walking the loops" results in :
$\mathcal{E} - i_1 R_1 = 0$, $\mathcal{E} - i_2 R_2 = 0$, $\mathcal{E} - i_3 R_3 = 0$
The total current delivered by the battery is $i = i_1 + i_2 + i_3 = \mathcal{E}/R_1 + \mathcal{E}/R_2 + \mathcal{E}/R_3$.
In the circuit with the equivalent resistor, $i = \mathcal{E}/R_{eq}$. Thus,

$$\frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$$

Same as capacitors in series.

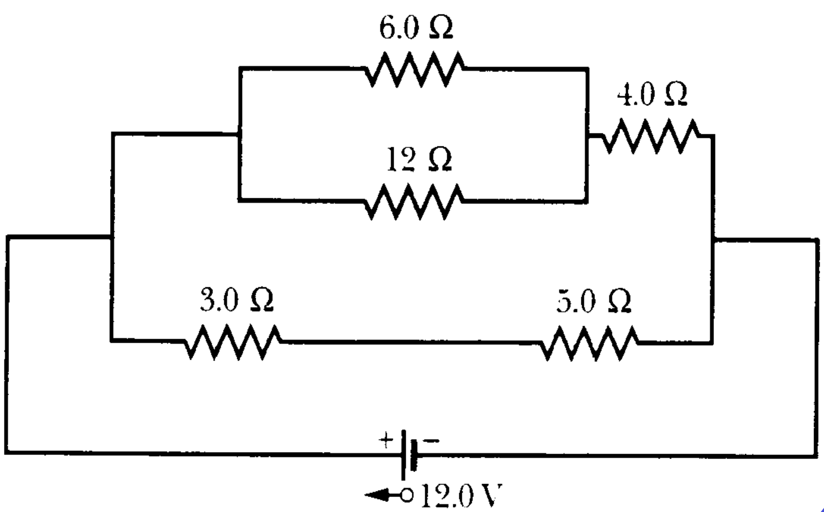


(a)

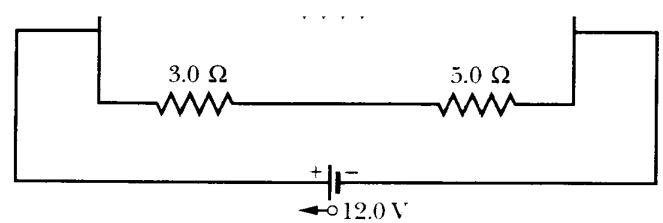
(b)

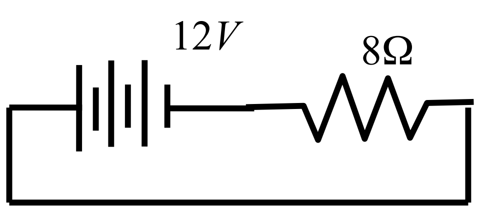
Example

38E. A circuit containing five resistors connected to a batter with a 12.0 V emf is shown in Fig. 28-38. What is the potentia difference across the 5.0 Ω resistor?



Bottom loop: (all else is irrelevant)

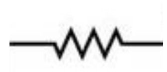
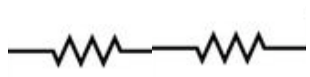
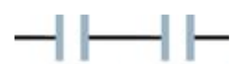
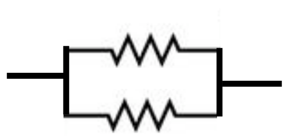
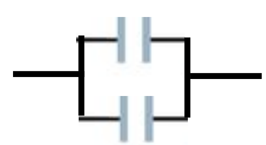




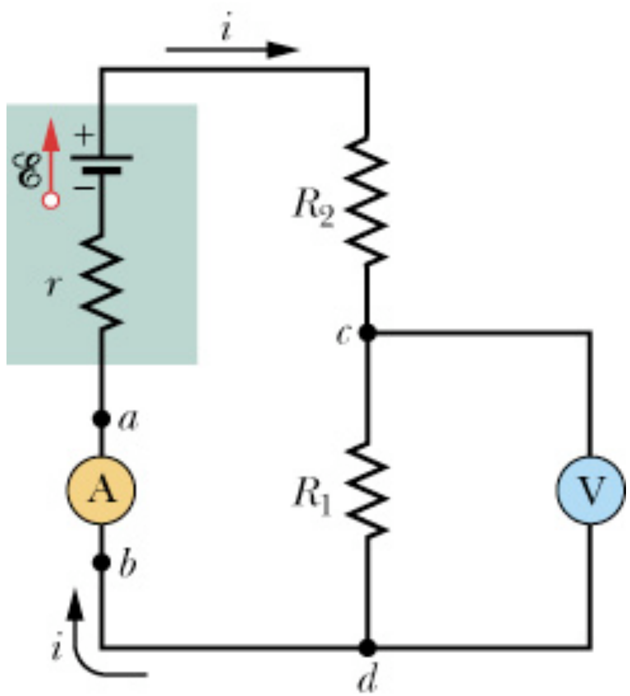
$$i = \frac{V}{R} = \frac{12V}{8\Omega} = 1.5A$$

Which resistor gets hotter?

Resistors and Capacitors

	Resistors	**Capacitors**
		
<u>Key formula</u>:	$V=iR$	$Q=CV$
<u>In series</u>:	same current	same charge
	$R_{eq}=\sum R_j$	$1/C_{eq}=\sum 1/C_j$
		
<u>In parallel</u>:	same voltage	same voltage
	$1/R_{eq}=\sum 1/R_j$	$C_{eq}=\sum C_j$
		

Ammeter and Voltmeter



- Ammeter measures **current**
- All current flows **through** ammeter
- Resistance must be **small**

- Voltmeter measures **voltage**
- Most current **bypasses** voltmeter
- Resistance must be large

Summary

- The potential of ideal emf devices does not depend on the current; real emf devices have **internal resistance**
- **Kirchhoff's junction rule:**

KJR : The sum of the currents entering any junction is equal to the sum of the currents leaving the junction.

- **Resistors in parallel** replace by equivalent resistance

$$\frac{1}{R_{eq}} = \sum_{j=1}^{n} \frac{1}{R_j}$$

- **Resistors in series** replace by equivalent resistance

$$R_{eq} = \sum_{j=1}^{n} R_j$$

- **Ammeter** measures current; **voltmeter** measures voltage