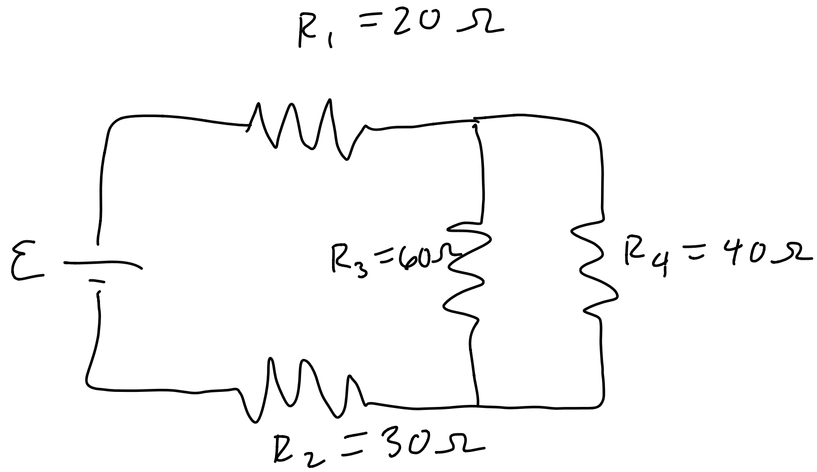
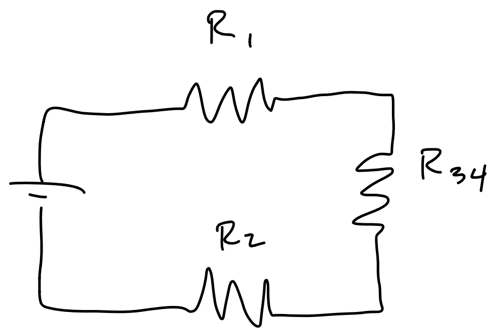
Example:



What is R_{eq}?



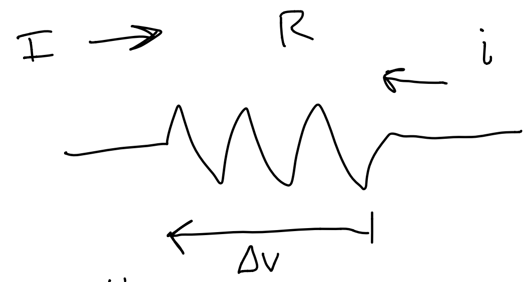
$$R_{eq} = R_1 + R_2 + R_{34}$$

$$\frac{1}{R_{34}} = \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{60} + \frac{1}{40} = \frac{1}{24}, \quad R_{34} = 24\,\Omega$$

$$R_{eq} = 20\,\Omega + 24\,\Omega + 30\,\Omega = 74\,\Omega$$

Question:

Energy dissipated in a resistor



ΔV positive

$\Delta U = -e\Delta V$

$\Delta K = 0$

ΔU goes into heat

Energy gained by resistor $= \Delta E = e\Delta V$

$$\text{Power} = \frac{\Delta E}{\Delta t} = \frac{I\,\Delta t\,\Delta V}{\Delta t} = I\Delta V$$

$$P = I\Delta V$$

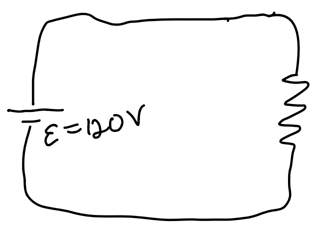
$$\Delta V = IR, \quad P = I^2 R$$

Unit: Watt $\left(\frac{J}{s}\right)$

Example: A 60 W light bulb

What is the current?

USA outlets: $\Delta V = 120 V$



$$P = I \Delta V$$

$$\mathcal{E} - \Delta V = 0$$

$$\frac{P}{\Delta V} = I, \quad \frac{60}{120} = I = 0.5 A$$

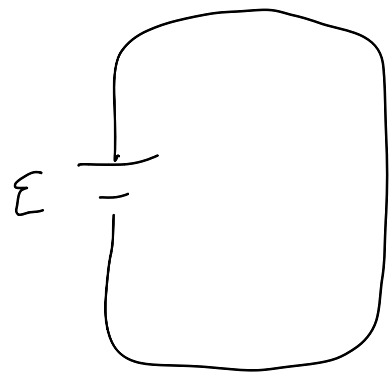
Resistance?

$$I = \frac{\Delta V}{R} \Rightarrow R = \frac{\Delta V}{I} = \frac{120}{0.5} = 240 \Omega$$

Resistance of a 150 W bulb?

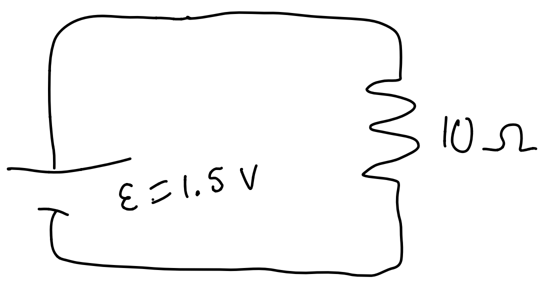
$$R = \frac{\Delta V}{I} = \frac{\mathcal{E}}{I} = \frac{\mathcal{E}}{P/\mathcal{E}} = \frac{\mathcal{E}^2}{P} = \frac{120^2}{150} = 96 \Omega$$

$$P = I\mathcal{E}, \quad I = \frac{P}{\mathcal{E}}$$



$$I = \frac{\mathcal{E}}{R} = \infty$$

$$R = 10^{-3}\,\frac{\Omega}{m}$$



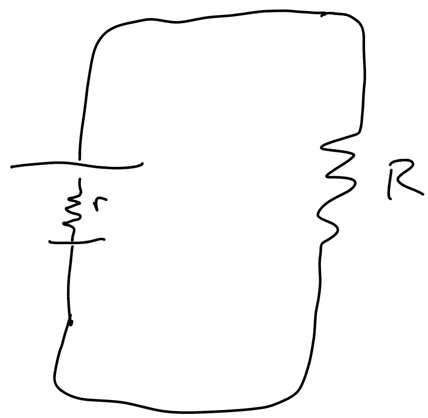
What is I?

$$I = \frac{\mathcal{E}}{R} = 0.15\,A$$

$$I_{meas} = 0.146\,A$$

What is going on?

Resistance <u>inside</u> the battery



$$\Delta V_{BAT} = \varepsilon - Ir$$

$$\varepsilon - Ir - IR = 0, \quad I = \frac{\varepsilon}{r+R}$$

Even if R is 0, $I < \infty$

<u>Short Circuit:</u>

$$I_{max} = \frac{\varepsilon}{r}$$

Above exampe:

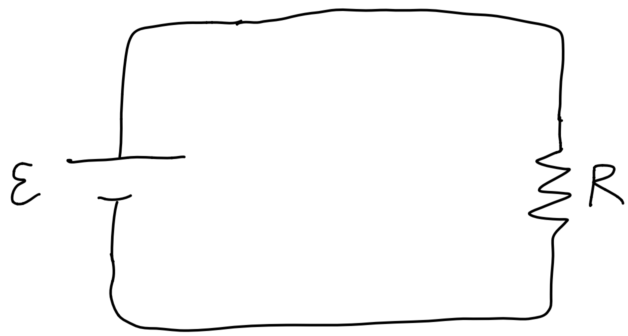
$$I_{obs} = 0.146 = \frac{1.5}{r+10}$$

$$r = 0.25\,\Omega$$

For copper, R of $1\,m \approx 10^{-3}$

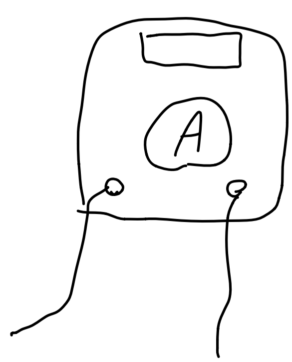
$$I_{max} = \frac{1.5}{0.25} = 6.0\,A$$

How to measure current?



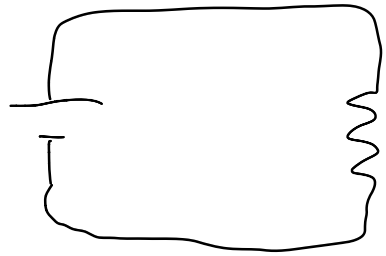
- Compass deflection / magnetic field
- Measure ΔV across a known resistor R_1

  & $I = \frac{\Delta V}{R_1}$

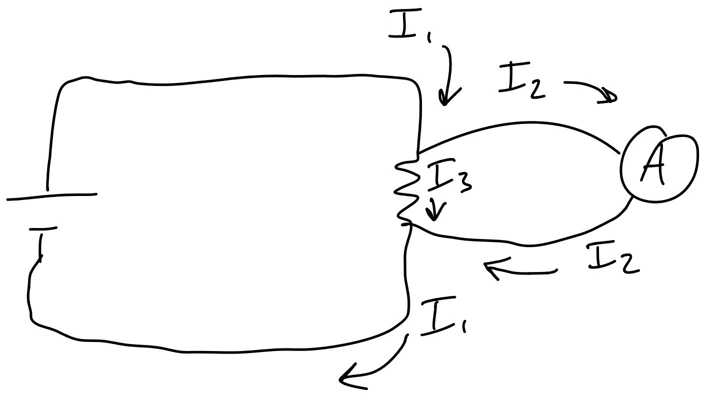


How to connect?

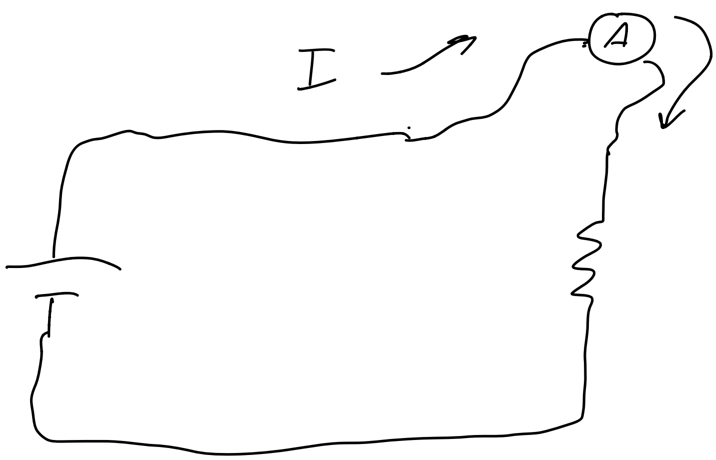
Series or parallel?



Ammeter in Parallel



Ammeter in Series



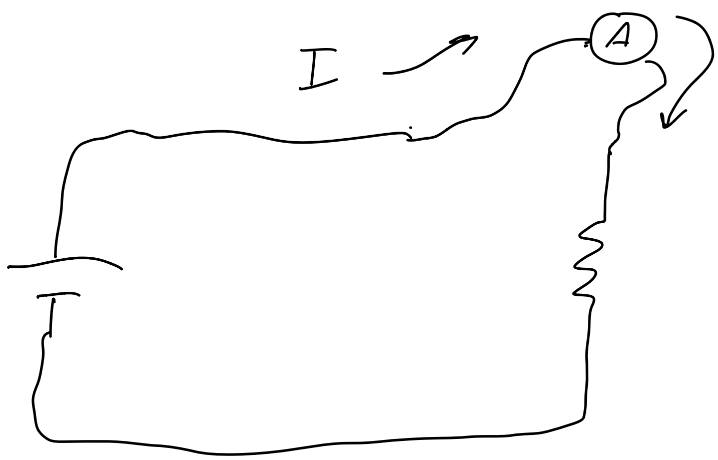
$I = \frac{\mathcal{E}}{R+R_A}$, R_A should be small!

What about a Voltmeter?

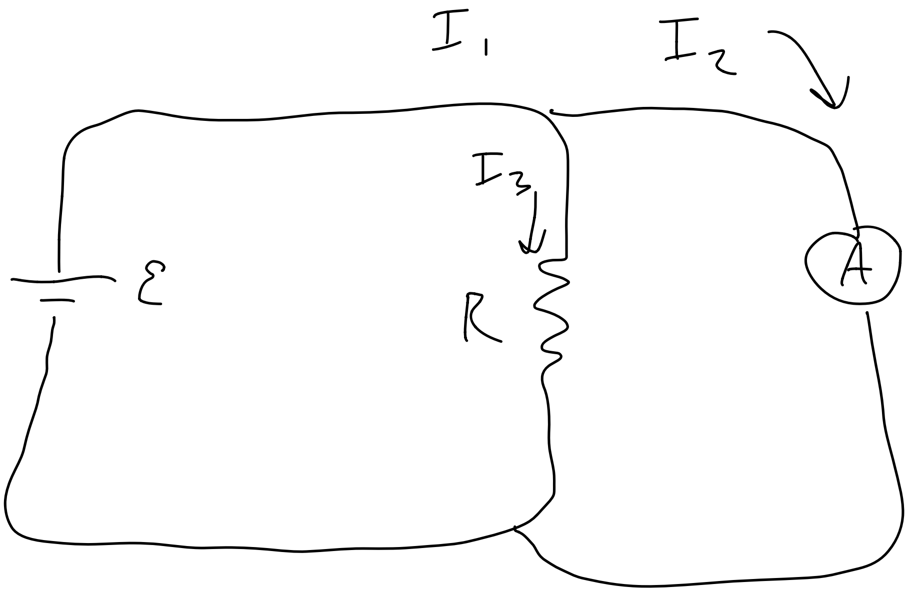
If I know the resistance of the ammeter, I can use

$$\Delta V = I R_A$$

CANT Have it in series



$$\mathcal{E} - I R_A - I R = 0$$

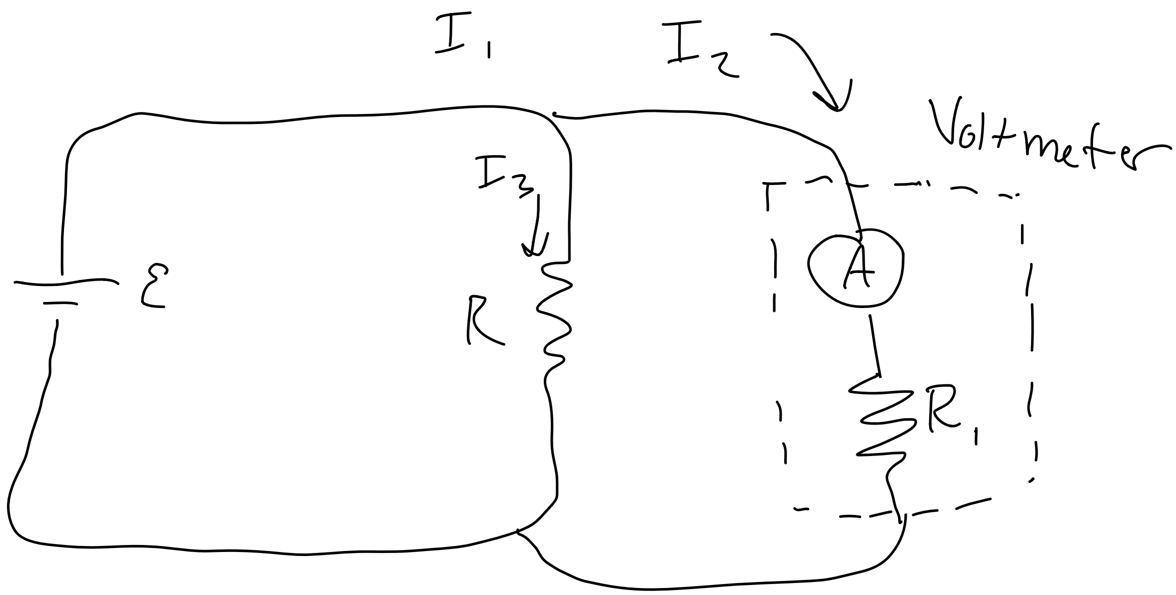


$$I_1 = I_2 + I_3$$

$$I_3 R = I_2 R_A$$

$$I_2 = \frac{R}{R_A} I_3$$

$$\frac{R}{R_A} >> 1$$



$$I_3 R = I_2 (R_A + R_1)$$

$$I_2 = \frac{R}{R_A + R_1} I_3$$

$$R_1 >> R$$

$$I_2 \approx 0$$

Voltmeters need very high resistance

	Ammeter	Voltmeter
Circuit connection	Series	Parallel
Resistance	Low	High