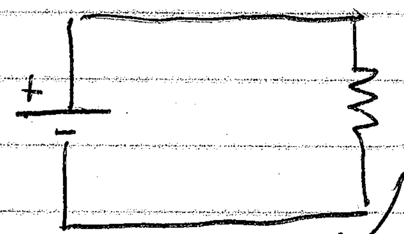
① Phys 1402 2017-07-11 Lec 5

Applying voltage across something pushes current through the thing.

Ex: Flashlight



$\mathcal{E} = 3.0\,V$

$R = 15\,\Omega$

$I = \frac{3V}{15\Omega} = 0.2\,A$

In the resistor, current flows ⊕ to ⊖.
It could be ⊕ flowing ⊕ to ⊖,
or ⊖ flowing ⊖ to ⊕.
Either way, the current is the same direction

Drift Velocity

- Actual charges move slowly. ~1 mm/s.
- Effect of electricity is fast ~300 Mm/s

Calculating drift velocity

$\Delta Q = I \Delta t$

$Q = \rho \ell A$
↳ charge/volume

$v = \ell / \Delta t$

$\Rightarrow v = \frac{I}{\rho A}$

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Ex: Copper has 10^{28} electrons $/m^3$

$$\rho = (-1.6\times10^{-19}\ C)(10^{28}\ \text{per}\ m^3)$$
$$= -1.6\times10^{9}\ C/m^3$$
$$(-1{,}000\ C/cm^3)$$

radius $r = 1\ mm$

current $I = 1.0\ A$

$$v = \frac{I}{\rho A} = \frac{(1.0\ A)}{(-1.6\times10^{9}\ C/m^3)(\pi(0.001\ m)^2)}$$

$$= -0.0002\ m/s = -0.2\ mm/s$$

Very slow and opposite to dir of current.

<u>Resistivity</u> (See Ohm's Law prelab)

- Intrinsic version of resistance. (Independent of shape & size)

$$R = \frac{\rho l}{A}$$ ← resistivity (ρ)

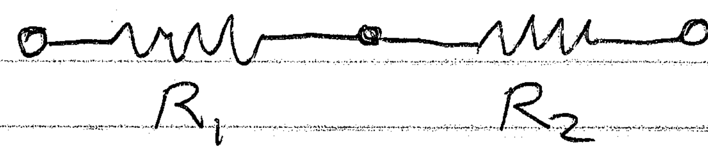
- Longer → more R
- Thinner → more R

Components in combination

Building Blocks:

Series • Two things connected at one junction with no fork in between.

Ex:



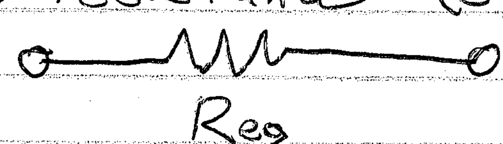
• All current that goes thru R_1 must also go thru R_2.

Series: $I_1 = I_2 = \dots$

• Each component takes some energy from each charge.
Each component takes (or gives) some voltage.

Series $V_{Tot} = V_1 + V_2 + \dots$

• Effective resistance (equivalent R)

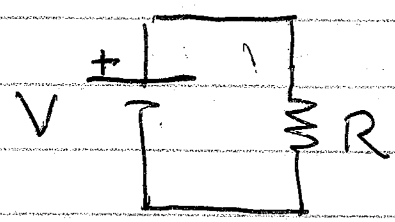


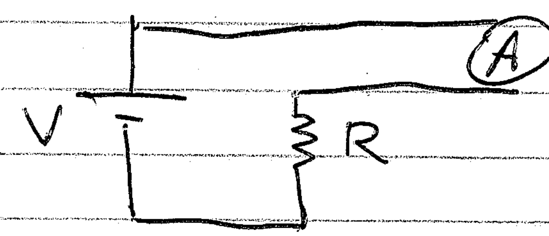
$$R_{eq} = \frac{V_{TOT}}{I} = \frac{(V_1 + V_2 + \dots)}{I} = \frac{IR_1 + IR_2 + \dots}{I}$$

Series $R_{eq} = R_1 + R_2 + \dots$

Measuring Things

- Our instrument must have the same value as the experiment.
- In series, components have the same I.
- Use series to measure current.



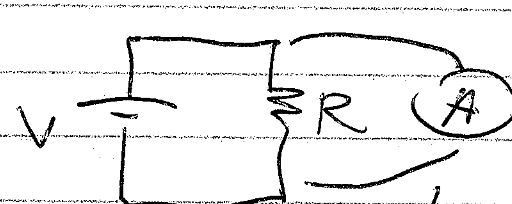


- All current of the Ammeter goes thru R.

- When we measure, we don't want to disturb the circuit.
  - $V_{Tot} = V_{meter} + V_R$
  - Need $V_{meter} \approx 0$, V_R is the same in both circuits.
  - How? Ammeter is a wire w/ $R=0$.

- Current flows freely thru Ammeter.

Incorrect Hookup



BAD!

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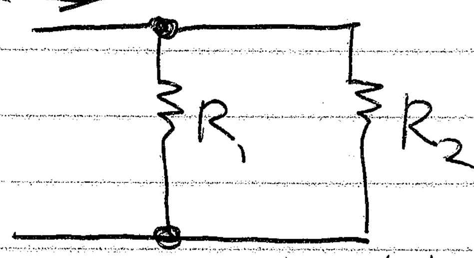
Parallel • Components connected at both ends.

Ex: I_{in} →



- Any given charge could take either path. Either way, the voltage must be the same.

Parallel: $V_1 = V_2 = \ldots$

- The charges that enter (I_{in}) must choose a path (R_1 or R_2). So the count of charges in each path adds up to the total.

Parallel: $I_{tot} = I_1 + I_2 + \cdots$

- The equivalent is more complex:

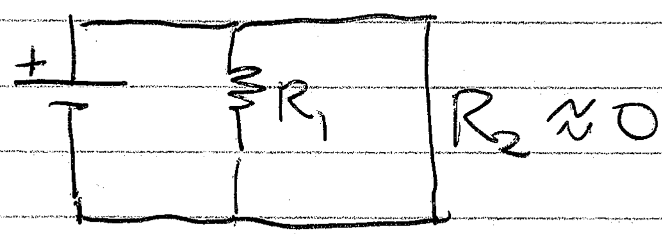
$$R_{eq} = \frac{V}{I_{tot}} = \frac{V}{I_1 + I_2 + \cdots} = \frac{V}{\frac{V}{R_1} + \frac{V}{R_2} + \cdots}$$

$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \cdots} = \left(\frac{1}{R_1} + \frac{1}{R_2} + \cdots\right)^{-1}$$

Series Resistors Add.
If one is HUGE, it dominates the total.
Adding a tiny value doesn't do much.

Parallel Resistors Add Inversely.

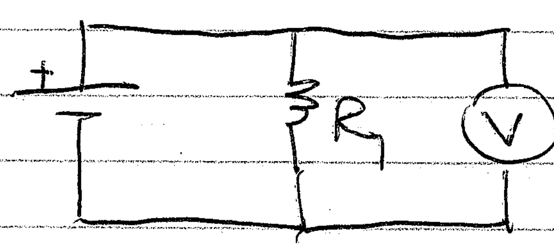
- A tiny resistor has a HUGE inverse.
  A tiny R in parallel dominates.
  Ex: Short Circuit



$$R_{eq} = \left(\frac{1}{R_1} + \frac{1}{R_2}\right)^{-1} = \left(\frac{1}{R_1} + \infty\right)^{-1} = \frac{1}{\infty} = 0$$

All current takes the R=0 path.

- A HUGE R in parallel has a tiny inverse

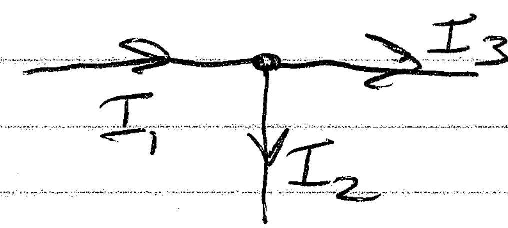


- Same Voltage
- No current in (V)
- (V) huge R

Kirchoff's Laws

- Generalization of series & parallel Laws for I and V.

- Current Law - what goes in must come out.



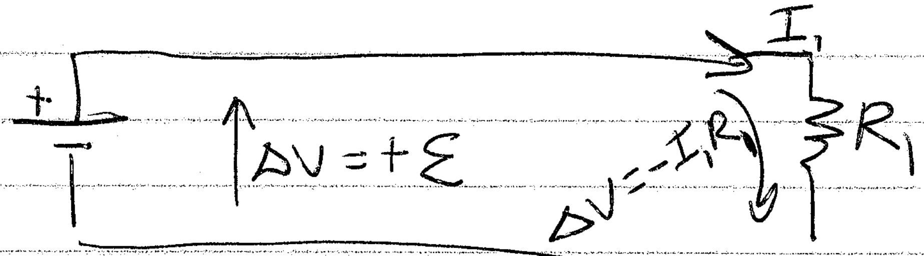
$$I_1 = I_2 + I_3$$

- Voltage Law - what goes up must come down

Up → positive ΔV Down → negative ΔV

Pick any Loop. Find ΔV's, even if they have variables in them. Write their total and set it equal to zero.

Battery: $\Delta V = \pm \mathcal{E}$
Resistor: $\Delta V = \pm IR$



$$\Delta V_B + \Delta V_R = 0$$
$$+\mathcal{E} - I_1 R_1 = 0$$
$$\mathcal{E} = I_1 R_1$$
$$I_1 = \mathcal{E}/R_1$$

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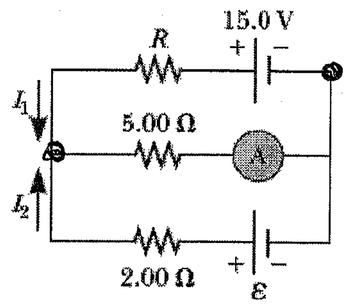
The ammeter shown in the figure below reads 2.08 A. Find I_1, I_2, and $\mathcal{E}$. (Assume R = 6.90 Ω.)

I_1 = [ ] 0.667 A

I_2 = [ ] 1.41 A

$\mathcal{E}$ = [ ] 13.2 V



Left node: $I_1 + I_2 = (2.08\,A)$

Top Loop: CCW from upper-right corner

$(+15V) - I_1 R - (2.08A)(5.0\,\Omega) = 0$

$(15\,V) - (10.4\,V) = I_1 (6.90\,\Omega)$

$\frac{4.6\,V}{6.9\,\Omega} = I_1 = 0.667\,A$

Question Details

Name (QID): **SerCP10 18.P.017. (3487981)**

Usable/Draft: **Usable**

Locked: **Yes**

Mode: **Numerical**

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Textbook

Serway and Vuille, "College Physics", ed.10

Chapter

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