Circuits

Circuits

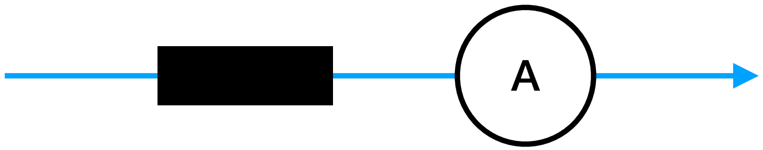
Introduction

Some materials contain charged particles which are free to move around, for example metals contain free electrons.

If we connect a battery to a metal these electrons will flow in a loop from one side of the battery to the other. We call this flow of charge an electrical current. We call the loop a circuit.

Current (I)

an ammeter shows the current flowing through it



We talk about the current through a component

Current is the rate of flow of charge around the circuit, its units are therefore Coulombs per second A.K.A Ampères (Amps).

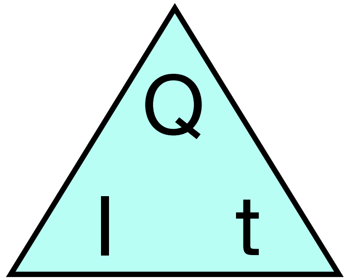
definition of current

current is the rate of flow of charge

or

current = charge transferred / time taken

$I = Q / t$



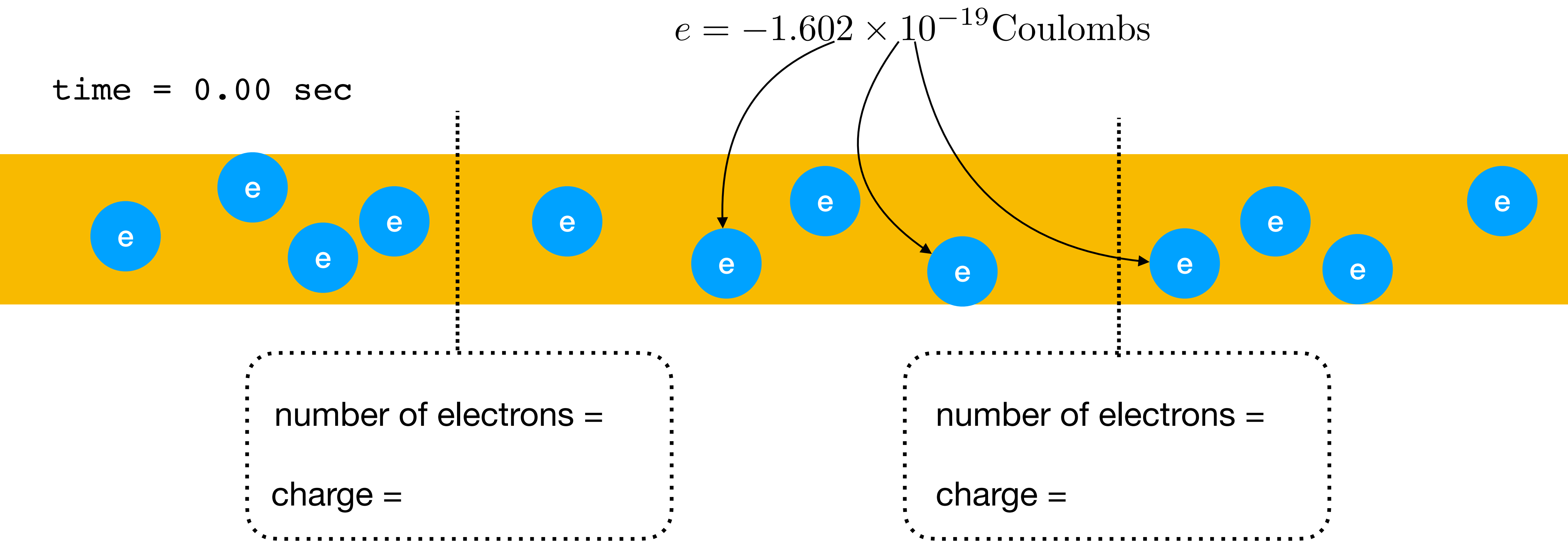
find the charge that passes when a current of 12A flows for 4 minutes...

charge = I*t

charge = 12 * 4*(60)

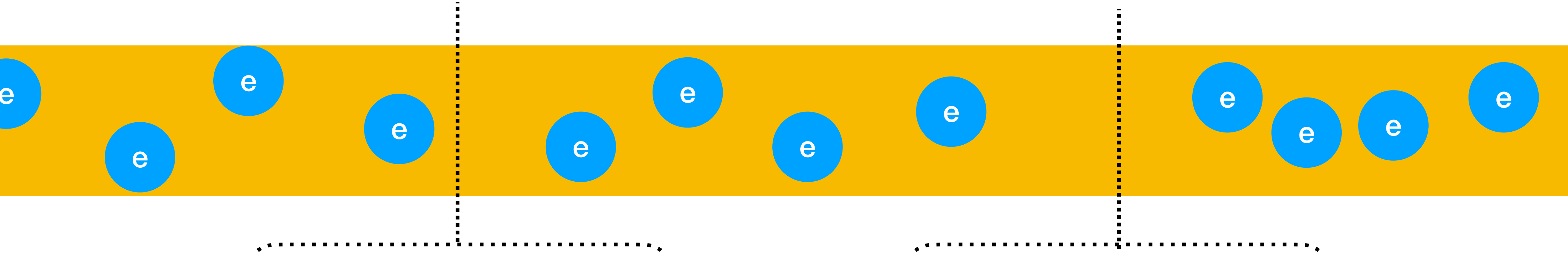
charge = 2,880 Coulombs

electrons flowing through a wire



electrons flowing through a wire

`time = 2.00 sec`



number of electrons = 4

charge = 4 * e Coulombs

number of electrons = 4

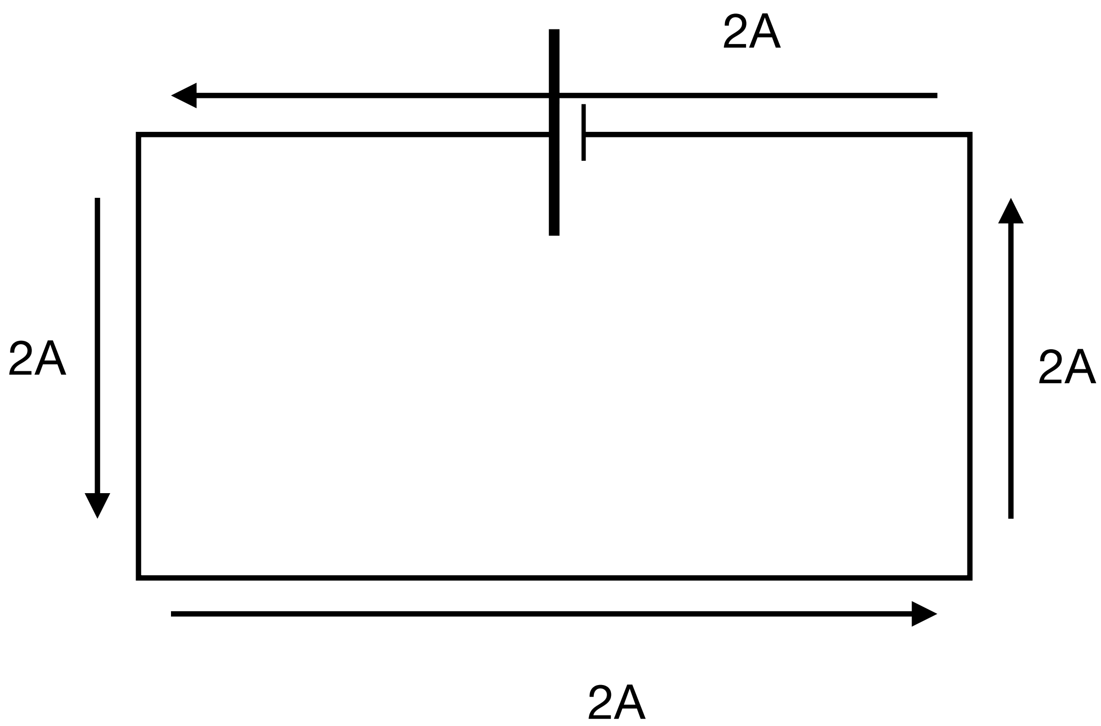
charge = 4 * e Coulombs

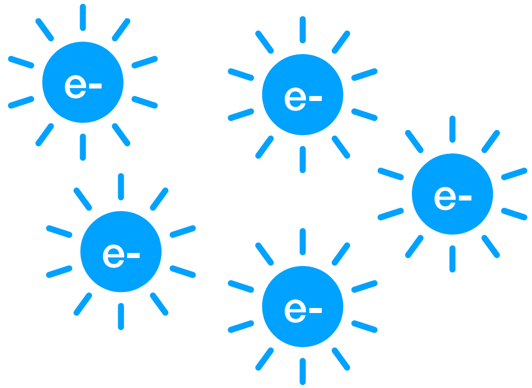
so the current is 4*e / 2 Amps

Normally the number of electrons is enormous, not 4.

Current

Current doesn't bunch up or spread out, it's incompressible

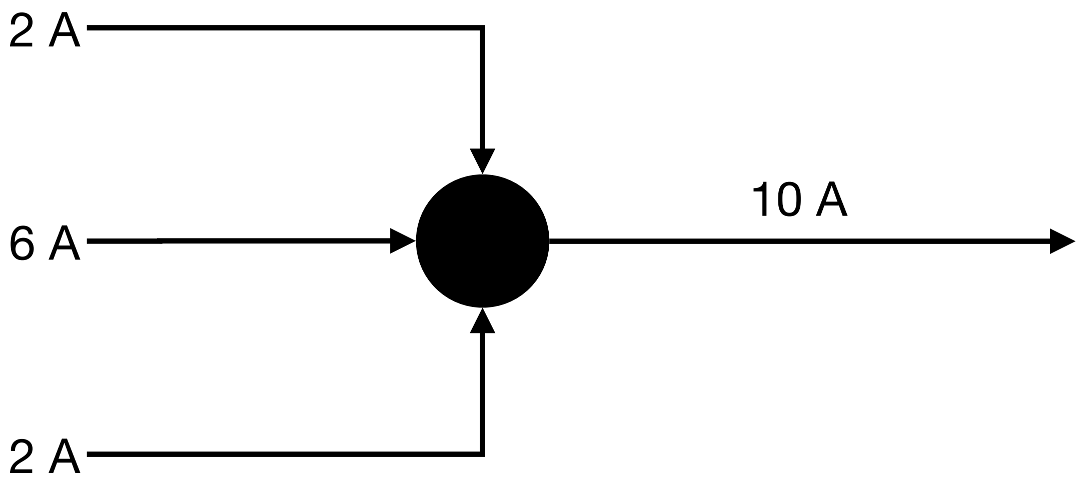




electrons repel each other because they all have the same charge.

the junction rule

Kirchoff's first law



current into a junction = current out

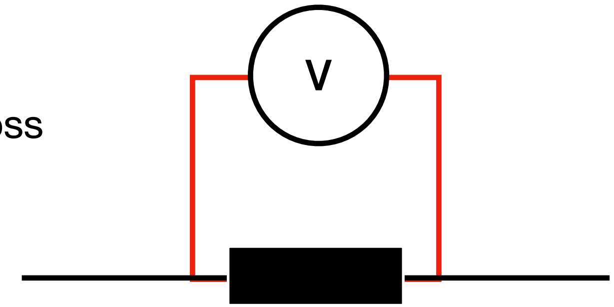
Voltage (V)

Voltage pushes charge around a circuit.

Voltage is the amount of energy each Coulomb of charge gets when it passes through the battery, its units are Joules per Coulomb A.K.A Volts.

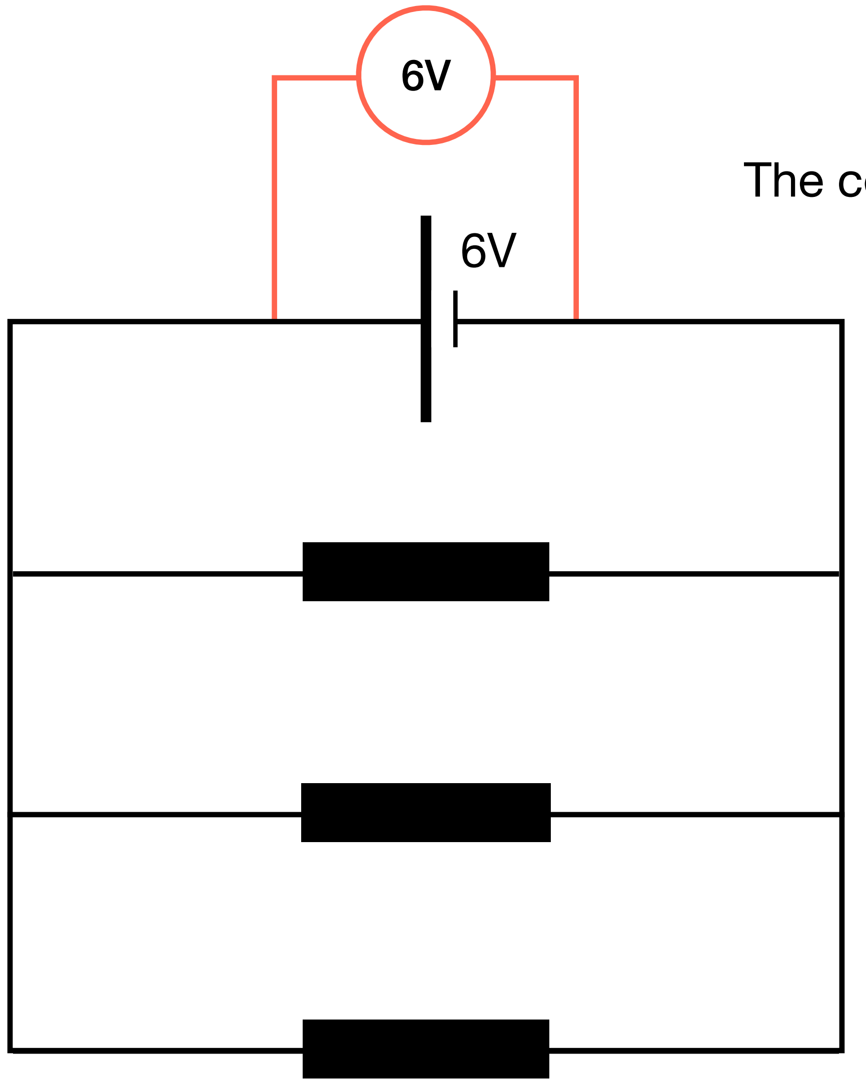
The voltage across a component like a rersistor is how many Joules each Coulomb of charge loses when it passes through it.

a voltmeter shows the voltage across it

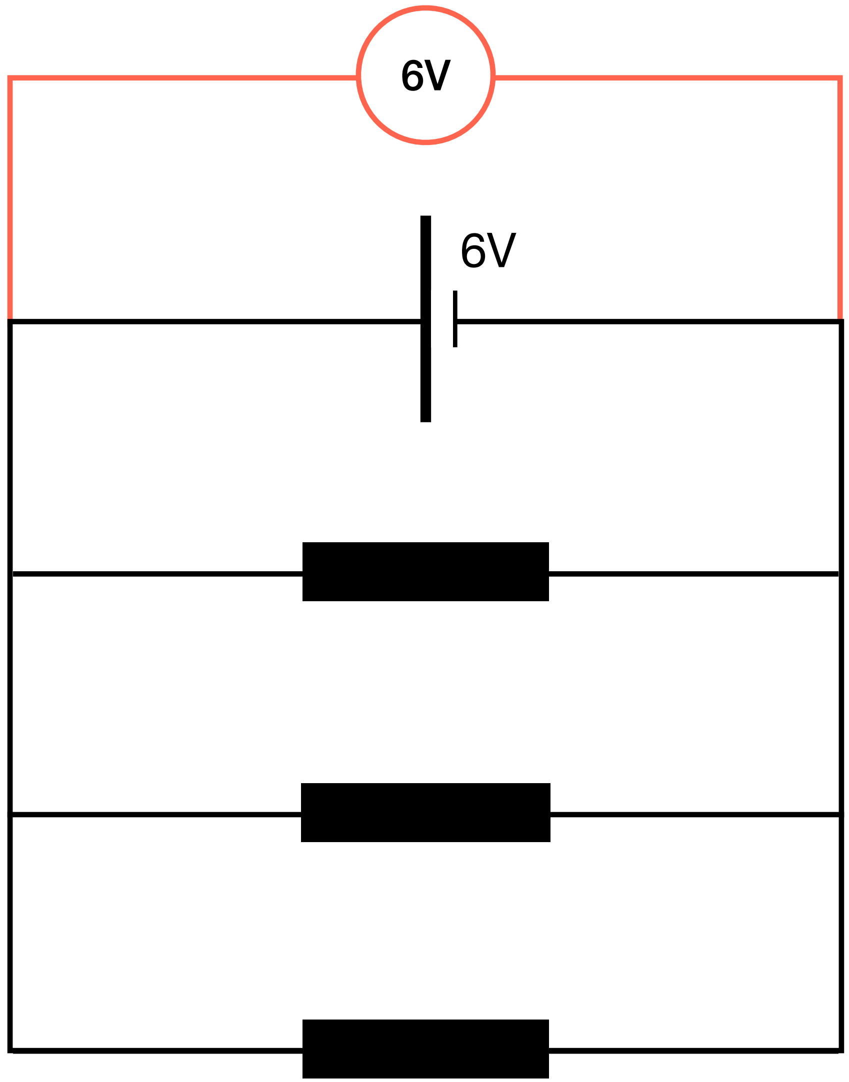


'potential diference' is another name for voltage

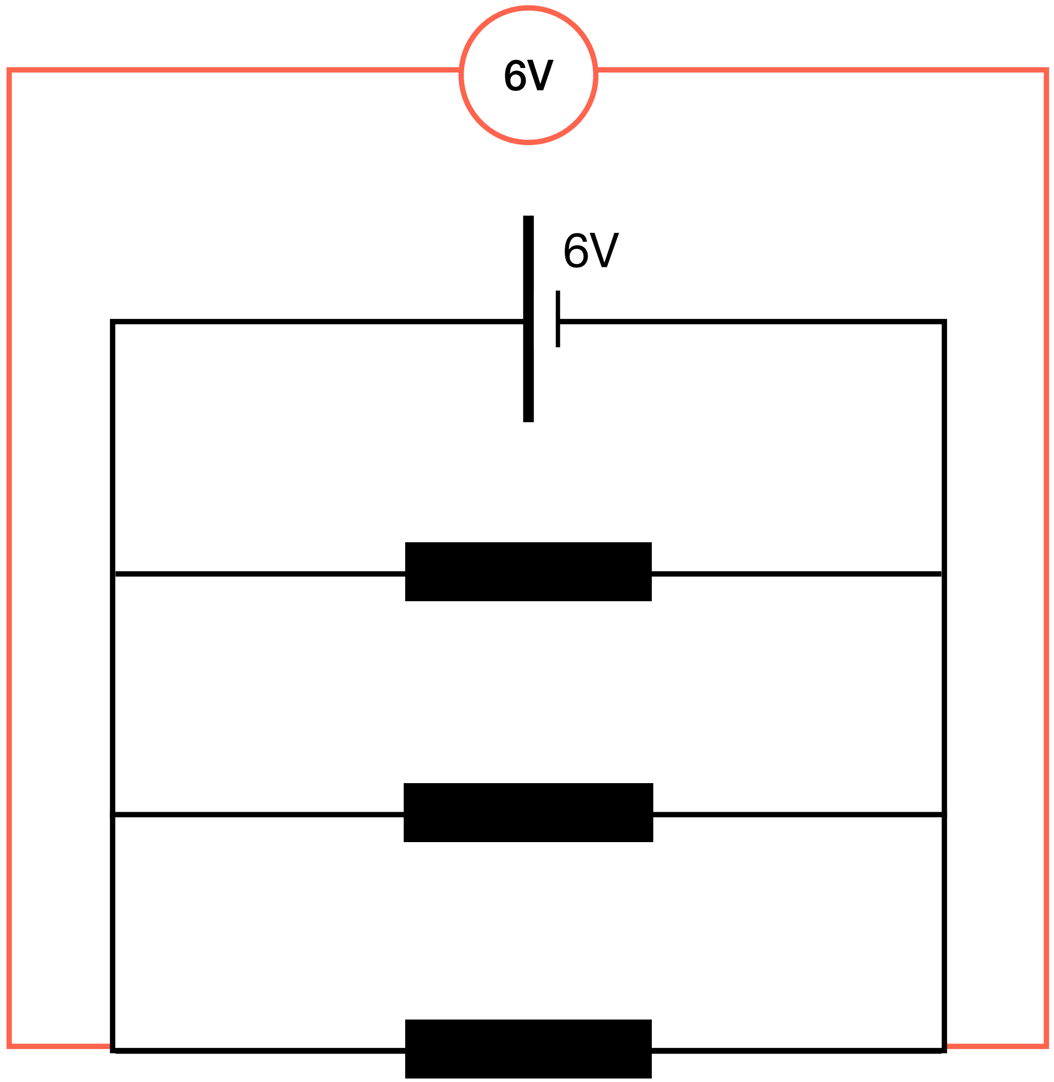
We talk about the voltage across a component



The cell voltage is 6V

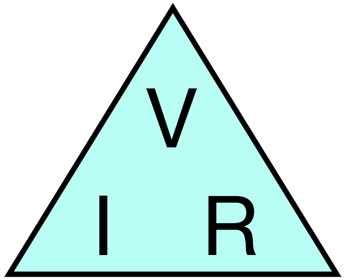


no change



still 6V because the voltmeter is still connected to either side of the cell

Ohm’s Law



Voltage across a component

Current through a component

Resistance of the component

$$V = I\,R$$

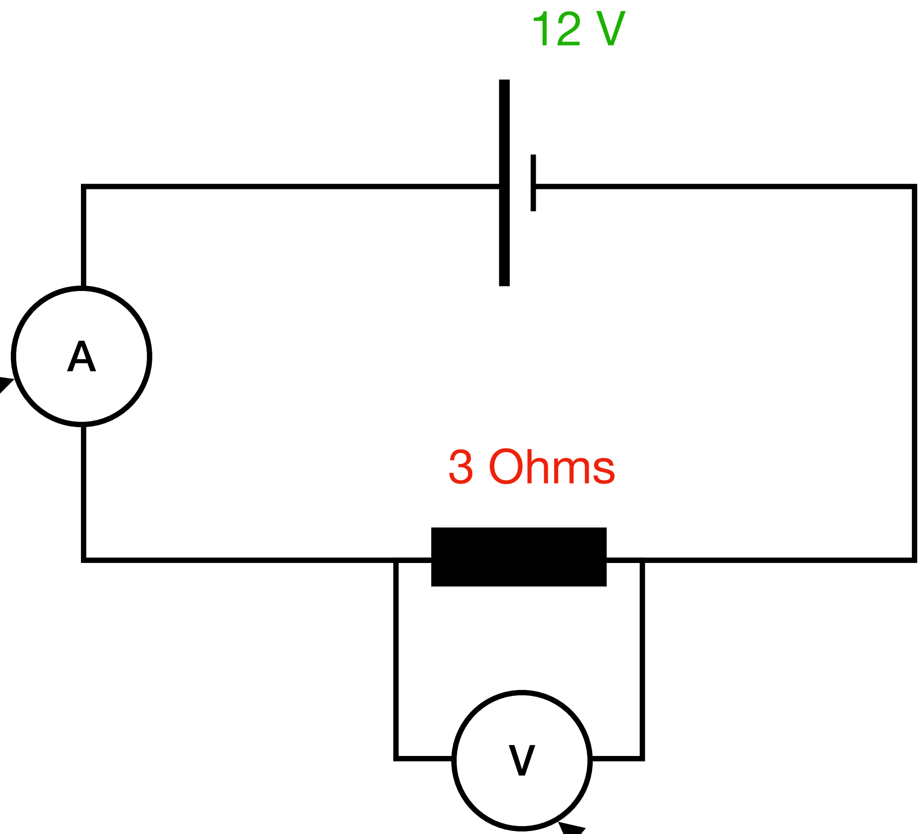
Volts
a.k.a
Joules / Coulomb

Amps
a.k.a
Coulombs / second

Ohms

The voltage across something is equal to the current through it times its resistance.

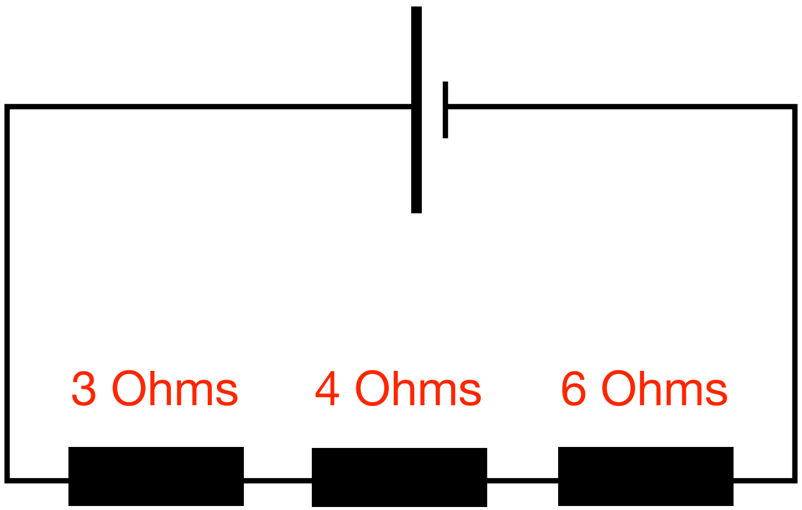
Example



1.
I = V / R
I = 12 / 3
I = 4A

V = IR
V = 4 x 3
V = 12 V

resistors in series



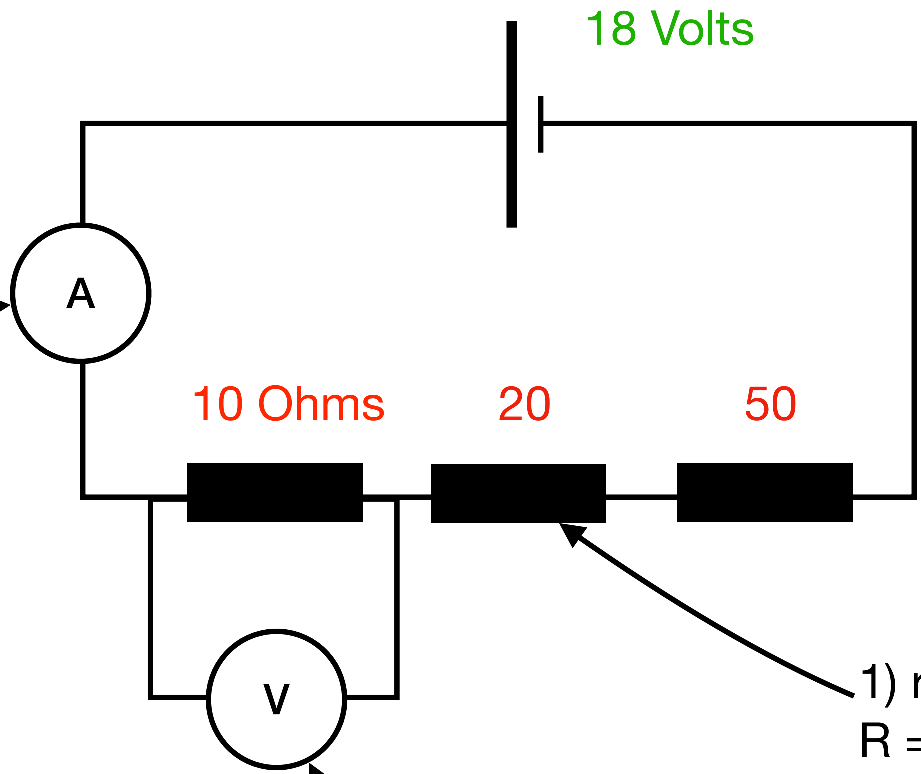
These are in series; one after the other.
The voltage across each may differ
but the current through each is the same.

$$R_T = R_1 + R_2 + R_3 + \cdots$$

Total resistance = 3 + 4 + 6 = 13 Ohms

Series Example

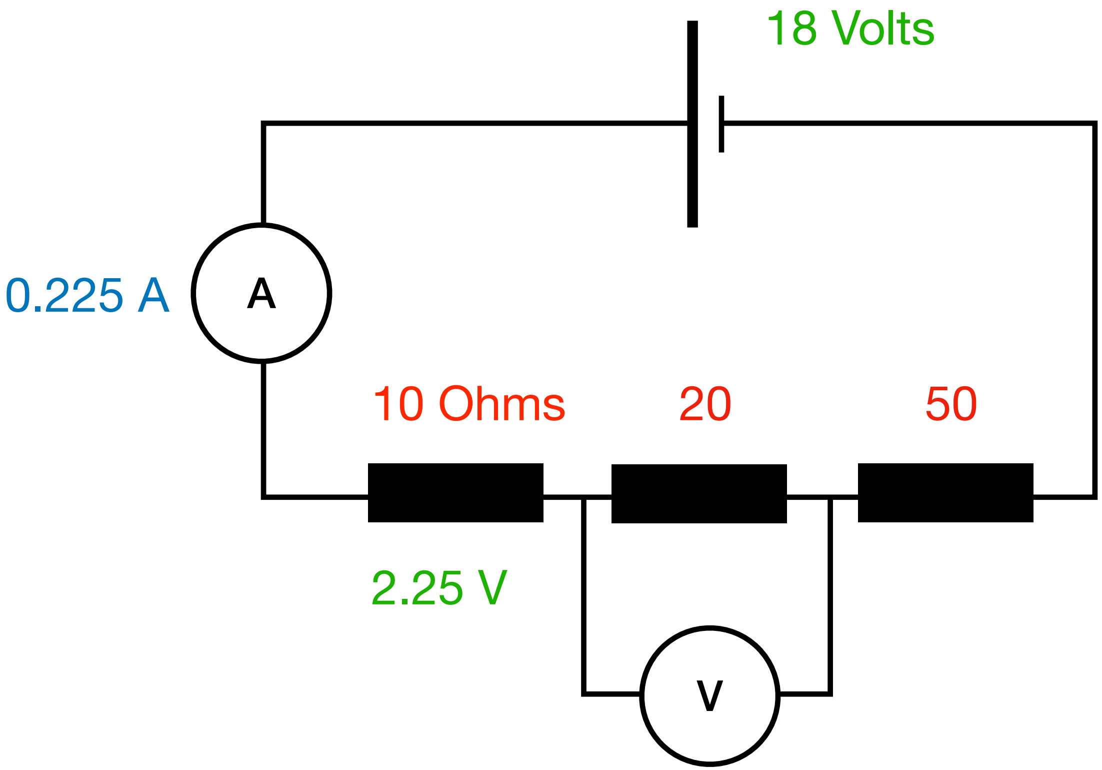
2) Ohm's law:
I = V/R
I = 18/80
I = 0.225 A



1) resistors in series
R = 10 + 20 + 50 =
80 Ohms

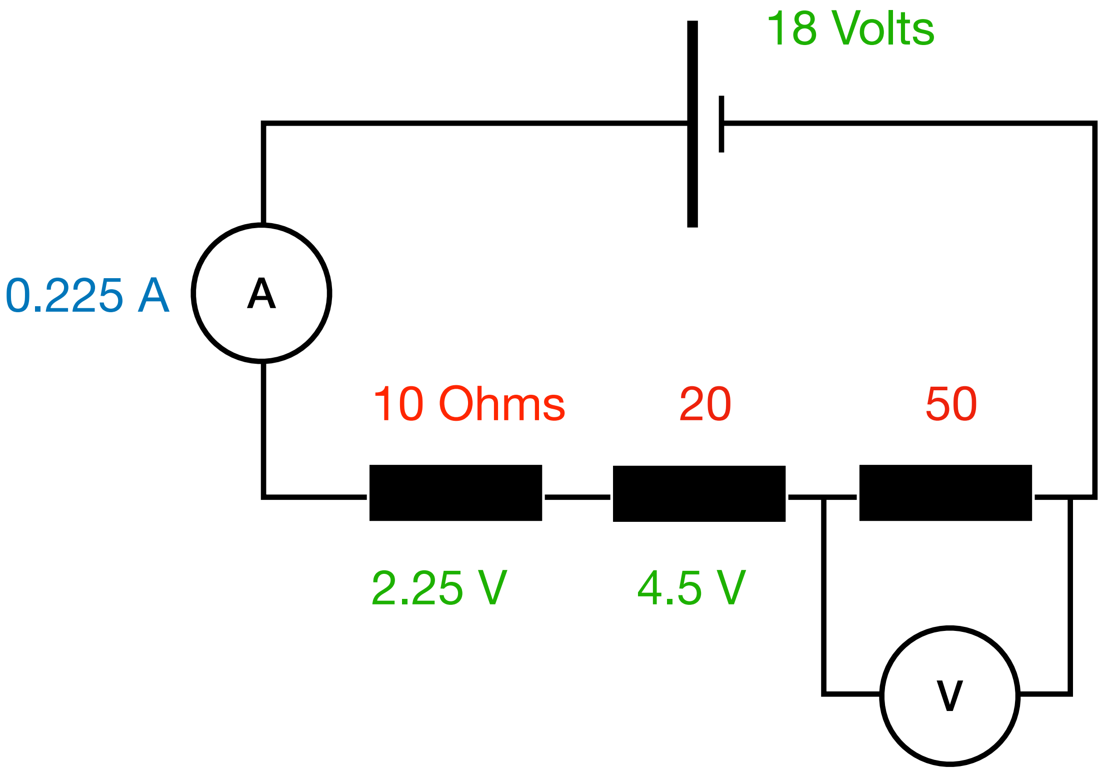
3) Therefore voltage = IR = 0.225 x 10 =   2.25 V

Series Example



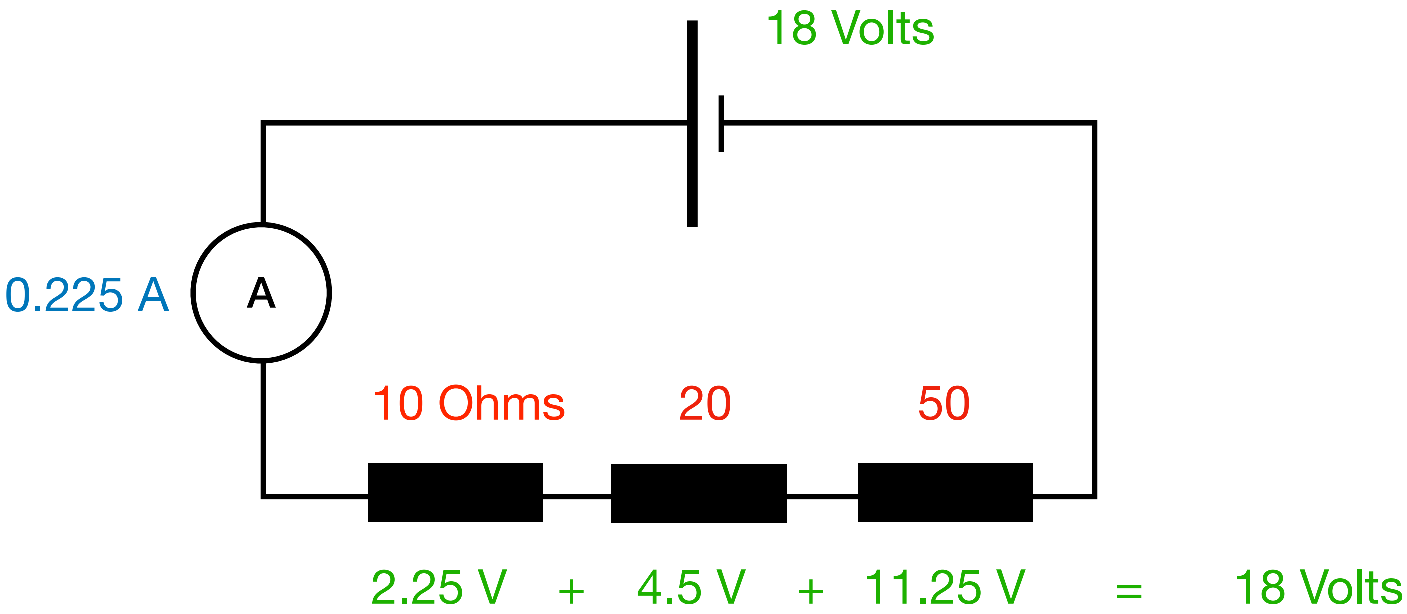
V = IR = 0.225 * 20 = 4.5 V

Series Example



V = IR = 0.225 * 50 = 11.25 V

Series Example



around any closed loop the sum of the battery voltages = the sum of the IR

Potential Divider

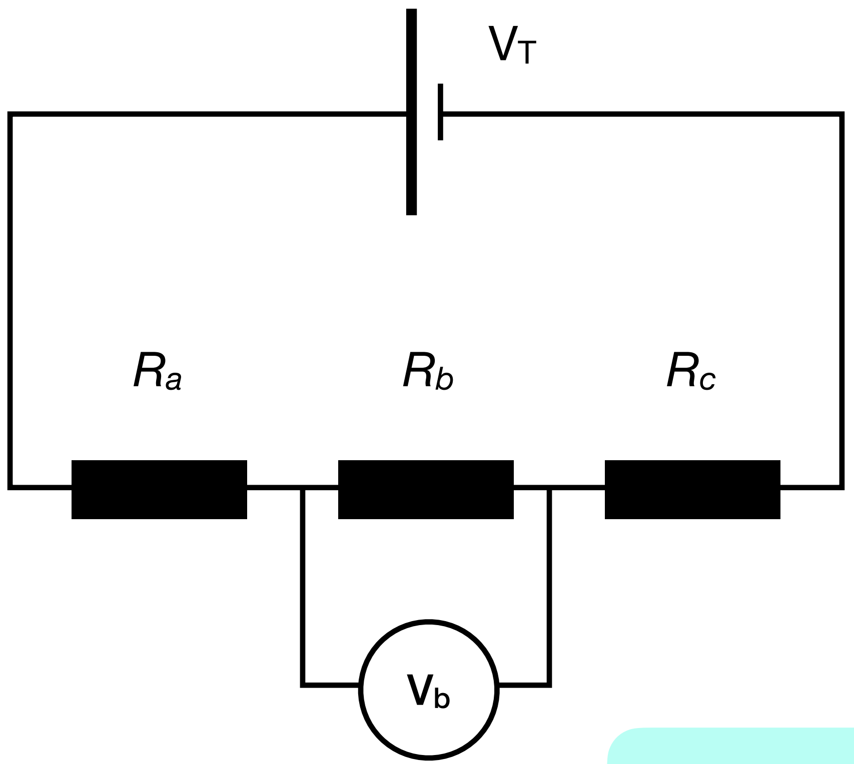
In this example we have found that bigger resistances get bigger voltages.

10 Ohms   20 Ohms   50 Ohms   =   1 : 2 : 5

2.25 V   4.50 V   11.25 V   =   1 : 2 : 5

a bunch of resistances in series is called a potential divide circuit and there’s a useful equation…

Potential Divider



$$V_b = \frac{R_b}{R_T} V_T$$

Potential Divider

a simpler example

Rt = 60 Ohms

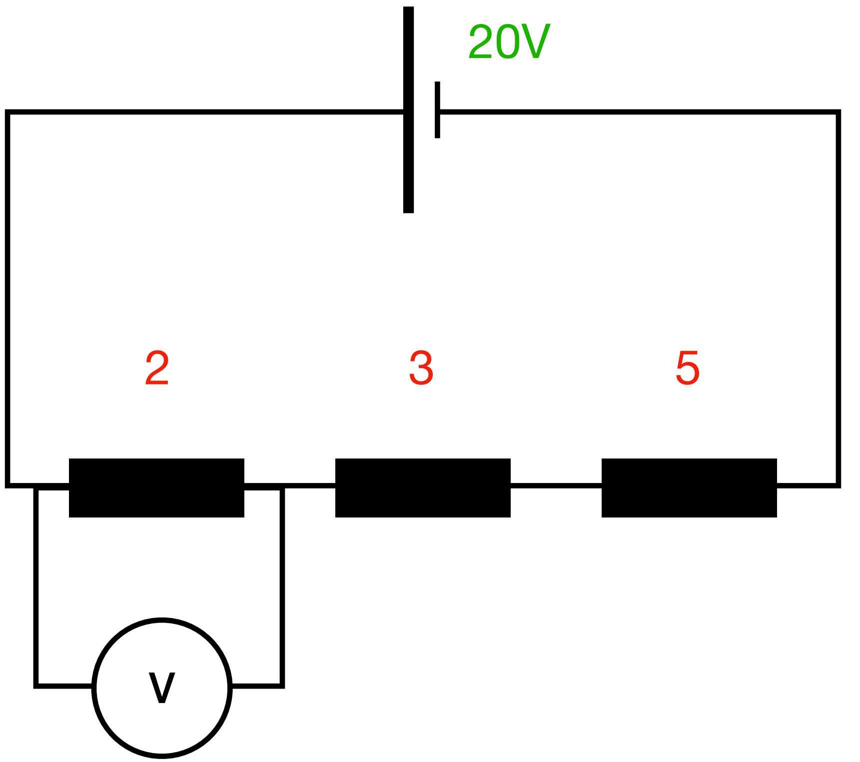
Voltage = 18V

10 Ohms 50 Ohms = 1 : 5

2.25 V 11.25 V = 1 : 5

a bunch of resistances in series is called a potential divide circuit and there’s a useful equation…

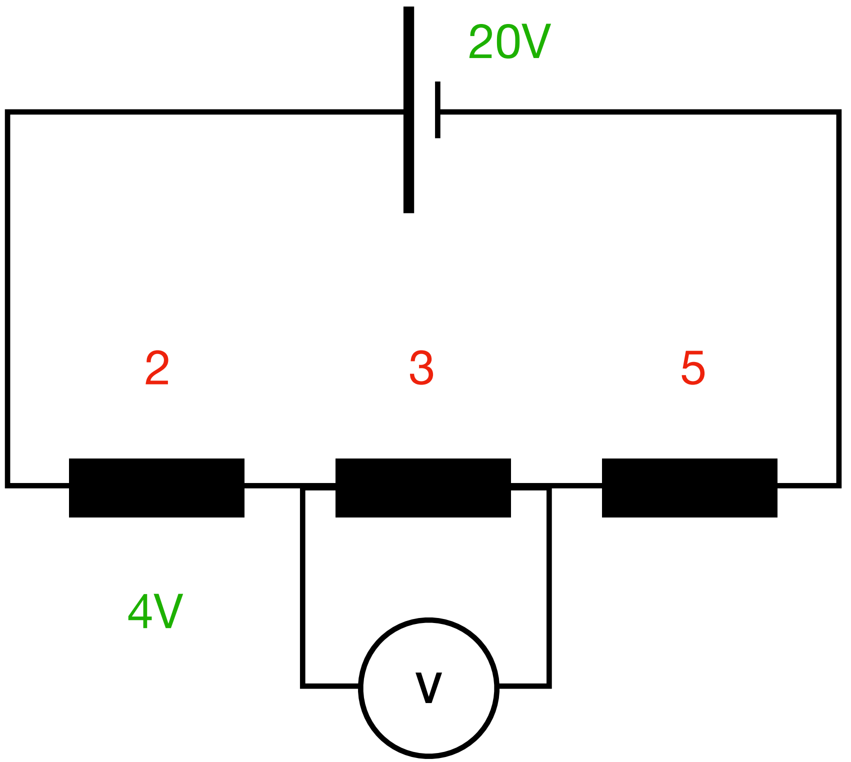
Potential Divider



$$V_b = \frac{R_b}{R_T} V_T$$

2/10 * 20 = 4V

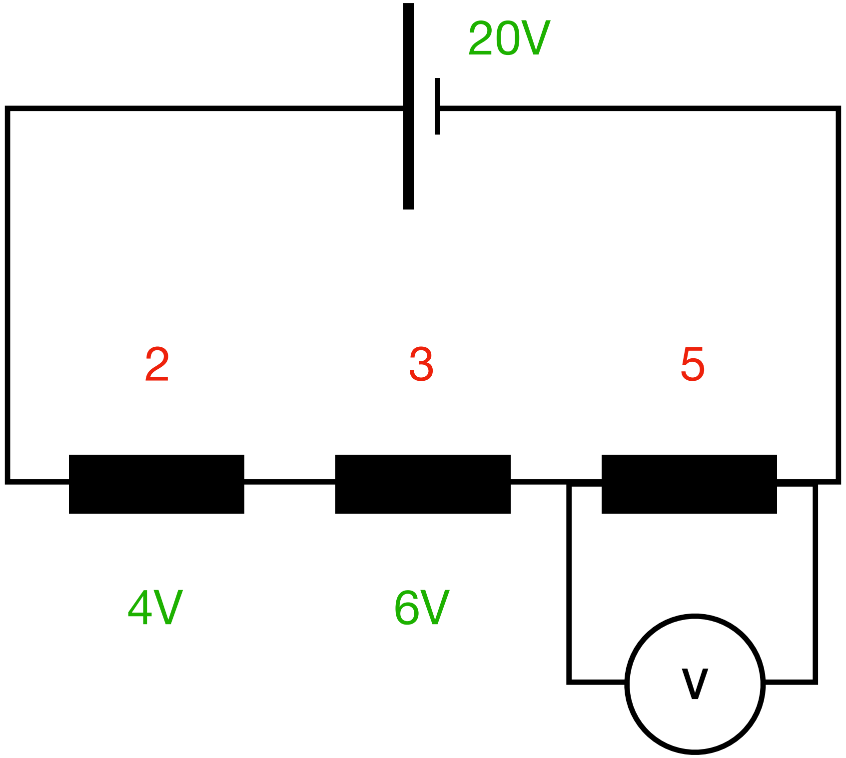
Potential Divider



$$V_b = \frac{R_b}{R_T} V_T$$

3/10 * 20 = 6V

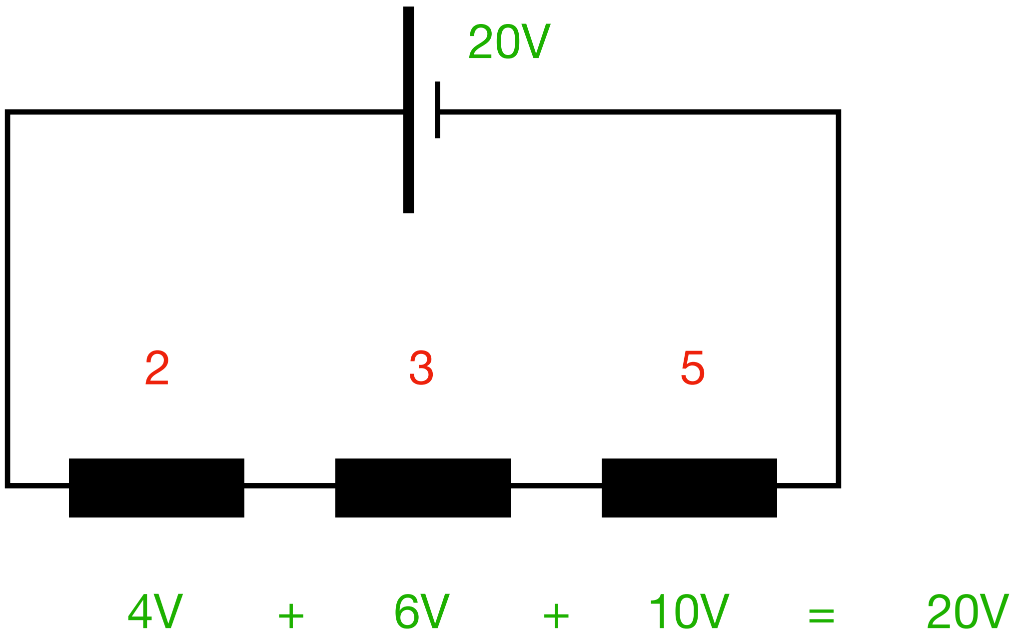
Potential Divider



$$V_b = \frac{R_b}{R_T} V_T$$

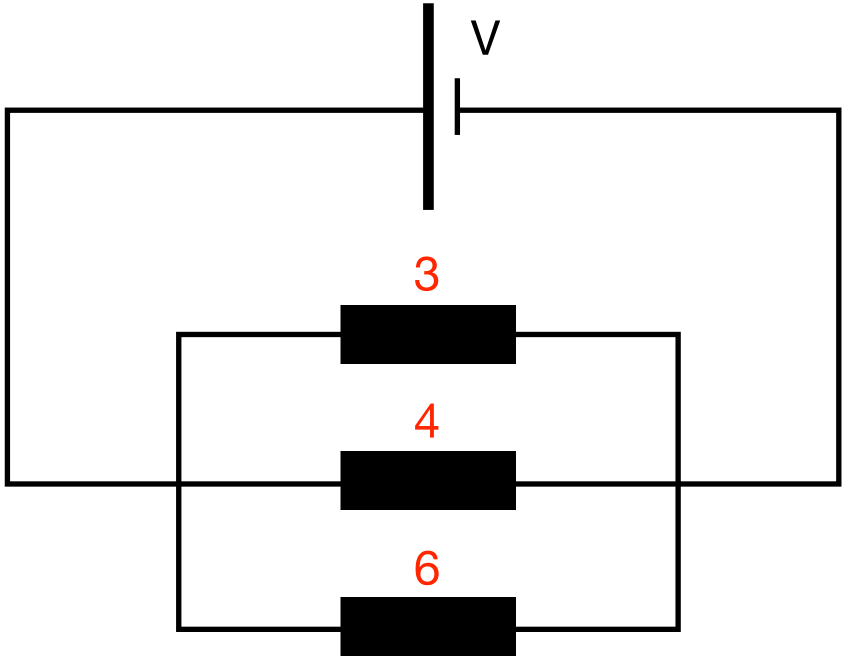
5/10 * 20 = 10V

Potential Divider



$$V_b = \frac{R_b}{R_T} V_T$$

resistors in parallel

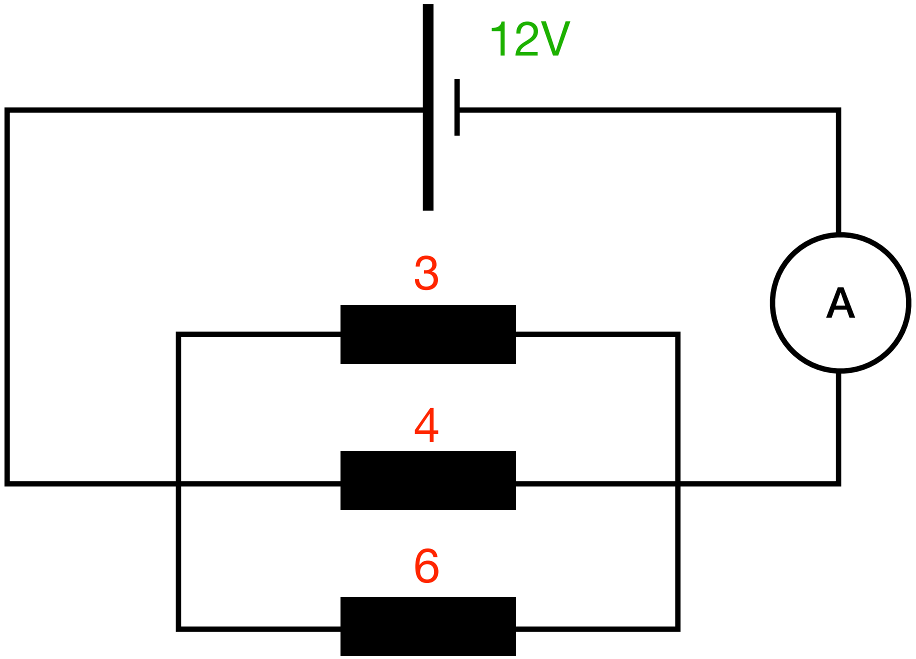


These are in parallel.
The voltage across each is the same but the current through each may differ.

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$

$$\frac{1}{R_T} = \frac{1}{3} + \frac{1}{4} + \frac{1}{6} = \frac{4}{3}\Omega$$

Parallel Example



1) RT = 4/3 Ohms

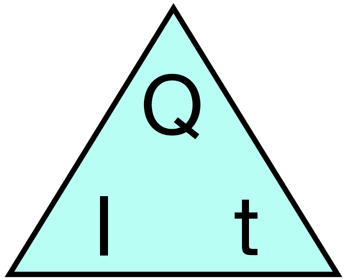
2)
I = V/R
I = 12 / (4/3)
I = 9A

3) Finding the current through each resistor is easy

I = V/R = 12/3 = 4A
I = V/R = 12/4 = 3A
I = V/R = 12/6 = 2A

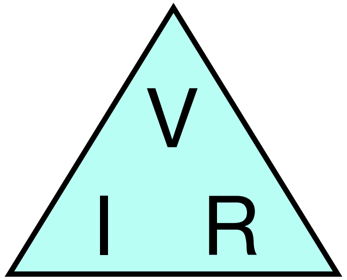
N.B these add to 9A, the total current.

Equations



Charge transferred = Current * time

C A s



Voltage = Current * Resistance

V A Ohms

$$R_T = R_1 + R_2 + R_3 + \cdots$$

$$V_b = \frac{R_b}{R_T} V_T$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$$