Fundamentals of Corrosion Mathematics and Electricity

AUCSC – 5/9/2017

Rules

- Set cell phones to silent operation
- If you get a call, feel free to walk out, and walk back in when you're done
- If you have a question, leave your hand up for about 10 seconds, then use your voice

Disclaimer 1

- We will be concentrating on some fundamental mathematical and electrical concepts
- Math is like any other skill –
  IT REQUIRES PRACTICE
- I can introduce the information, but you "learn" it by attempting the problems (and struggling) all by yourself.

Disclaimer 2

- This is the “fundamental” course.
- If you are familiar with:
  - Ohms Law
  - Resistors in series
  - Resistors in parallel

  You may find yourself uninterested

  I will TRY to make this interesting.

Agenda

- Units
- circuit theory

- Ohms Law
- series and parallel circuit theory

- Evening session (7:00) – do it again

UNITS

- Introduce “conversion factors” in order to change from one unit system to another.
- Miles to feet (and back)
- Dollars to nickels (and back)
- Millivolts to volts (and back)
- Amps to milliamps (and back)

First Concept

- ANY number times "1" is always the same number

- EXAMPLE

  5 * 1 = 5

  23 * 1 = 23

  142 * 1 = 142

- You can keep multiplying the number by "one" with no change

- EXAMPLE

  5 * 1 * 1 * 1 = 5

  23 * 1 * 1 * 1 * 1 = 23

Second Concept

- A number divided by itself is equal to "1"

- There are some cases where this is not true, but you don't need to worry about it.

$$\frac{0}{0} = end\ of\ creation$$

EXAMPLES

$$\frac{5}{5} = 1$$

$$\frac{23}{23} = 1$$

$$\frac{142}{142} = 1$$

Let's Elaborate on the Second Concept

- I introduced the second concept using pure numbers – 5, 23, 142

- Let's use distance instead of pure numbers.

- If I run 5280 feet.
- And "you" run 1 mile.
- Who runs farther?
- Same distance.
- 1 mile = 5280 feet
- Then:

$$\frac{1 mile}{5{,}280\ feet} = 1$$

UNITS make a big difference

$$\frac{1}{5280} = 0.0001894 \qquad \frac{1 mile}{5280\, feet} = 1$$

$$\frac{1}{2000} = 0.0005 \qquad \frac{1 ton}{2000 lbs} = 1$$

$$\frac{1}{24} = 0.0416 \qquad \frac{1 day}{24 hours} = 1$$

Building the conversion factor

- The unit you WANT goes on top
- The unit you HAVE goes on the bottom
- If you have feet and want miles

$$\frac{1 mile}{5280\, feet} = 1$$

- If you have weeks and want days

$$\frac{7 days}{1 week} = 1$$

Real life examples

- We have all we need to convert units.
- Convert 15000 feet to miles.
- The units must “cancel” – it’s your clue

$$15{,}000\ feet * \frac{1 mile}{5{,}280\ feet} = \frac{2.84\ \not{feet} - mile}{\not{feet}}$$

The wrong conversion factor

$$15{,}000\ feet * \frac{5{,}280\ feet}{1 mile} = \frac{79{,}200{,}000\ feet - feet}{mile}$$

- If you use the “inverse” of the conversion factor you get two clues.
- First the units don’t look right. They don’t cancel.
- Second the number can be “way off”
  - The sun is 93,000,000 miles from earth

The other direction

- If we want to convert miles to feet, we flip the “conversion factor”
- Given 8.62 miles, find out how many feet that is.

$$8.62\,\text{miles} * \frac{5280\,\text{feet}}{1\,\text{mile}} = 45{,}513.6\,feet$$

Another simple example

- How many nickels in $39.70?

$$39.70 dollars * \frac{20 nickels}{1 dollar} = 794 nickels$$

- Get the conversion factor upside-down, and you'll see the mistake three ways.

$$39.7 dollars * \frac{1 dollar}{20 nickels} = 1.985 \frac{dollar - dollar}{nickel}$$

Number's too low . Fractional nickel. Goofy unit.

We can string conversion factors together

- I have 6.425 miles of pipeline.
- Convert that distance to “inches”.
(don’t need to know how many inches in a mile)

$$6.425 miles * \frac{5280\,ft}{1 mile} * \frac{12 in}{1\,ft} = 407{,}088 inches$$

The units will keep “cancelling”

- Or even convert to millimeters
(don’t need to know how many mm in a mile)

$$6.425 miles * \frac{5280\,ft}{1 mile} * \frac{12 in}{1\,ft} * \frac{25.4 mm}{1 in} = 10{,}340{,}035 mm$$

Volts

- Volt – named after Count Alessandro Volta who invented the modern battery and discovered “methane”.
- 1 Volt = 1 $kg\text{-}m/C\text{-}s^2$ ^
- Voltage is equivalent to pressure in a fluid system

Voltage Conversion

- There are 1000 mV in 1 Volt. Then:

$$\frac{1000\,mV}{1\,Volt} = 1 \qquad \frac{1\,Volt}{1000\,mV} = 1$$

- Examples:

$$2.5V * \frac{1000\,mV}{1V} = 2500\,mV \qquad 630\,mV * \frac{1V}{1000\,mV} = 0.63V$$

$$-1.7V * \frac{1000\,mV}{1V} = -1700\,mV \qquad 2300\,mV * \frac{1V}{1000\,mV} = 2.3V$$

Amps

- Named after a French physicist Andre Ampere
- 1 Amp = 1 Coulomb per second
- The fluid equivalent of an amp is volumetric flow – gallons per minute, cubic feet per sec
- There are 1000 milliamps in one amp.
- So the conversion factor are:

$$\frac{1A}{1000mA} = 1 \qquad \frac{1000mA}{1A} = 1$$

Mnemonic Device

- "grandMa is <u>one</u> <u>A</u>bsolutely <u>M</u>agnificent <u>P</u>erson"
- Grand - 1000
- Ma – milliamp
- Is – equals
- 1 AMP
- 1000 mA = 1 AMP - OR -

$$\frac{1000mA}{1A} = 1 \qquad \frac{1A}{1000mA} = 1$$

Conversion Examples - amps

$$-1.71A * \frac{1000mA}{1A} = -1710mA$$

$$630mA * \frac{1A}{1000mA} = 0.63A$$

$$2.5A * \frac{1000mA}{1A} = 2500mA$$

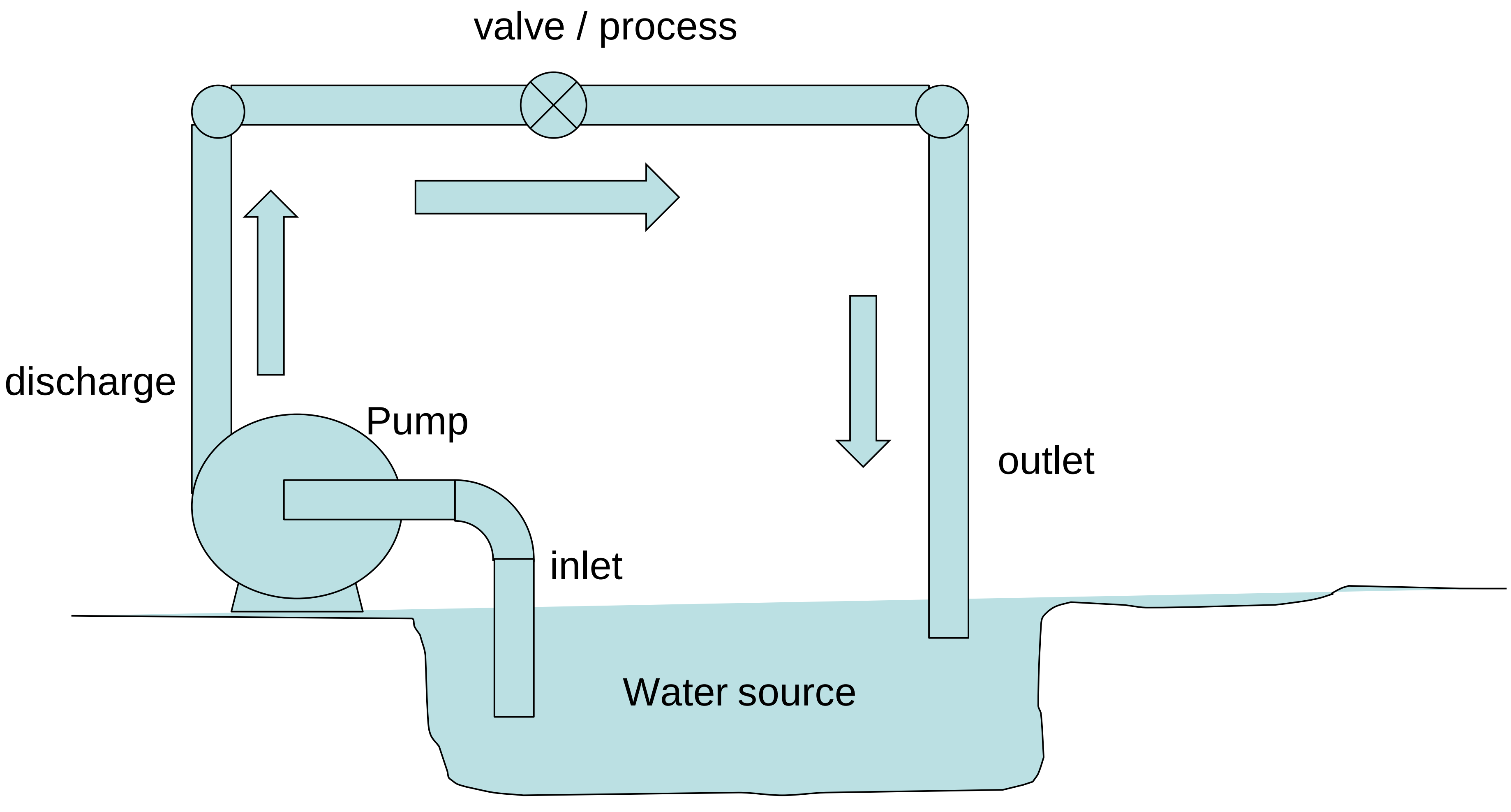
$$-823mA * \frac{1A}{1000mA} = -0.823A$$

Segue

- So far we’ve talked about converting units
- Now let’s talk about circuits

- We’ll start with something more familiar than electricity

Let's start with water instead of electricity



Fluid “circuit”

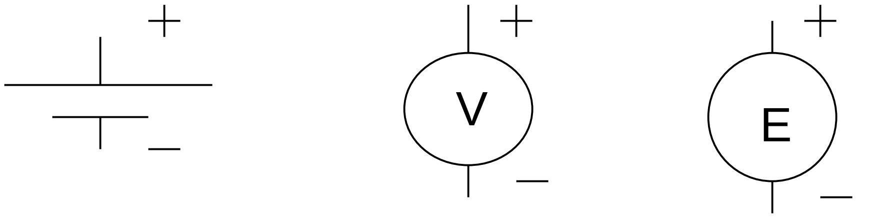
- External power goes into the pump
- Pump picks up water
- Water “does something”
- The water is discharged to its source
- <u>Flow (GPM) at all points is CONSTANT</u>.
- <u>Pressure CHANGES throughout</u>

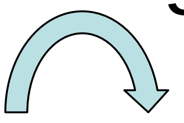
Measurement

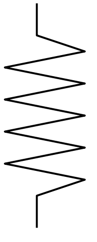
- Pressure is measured with out disturbing the flow – pressure gauge tap
- Flow rate is measured by diverting the flow through a meter.
- U/S flow meters

Electricity Symbols

- Voltage source

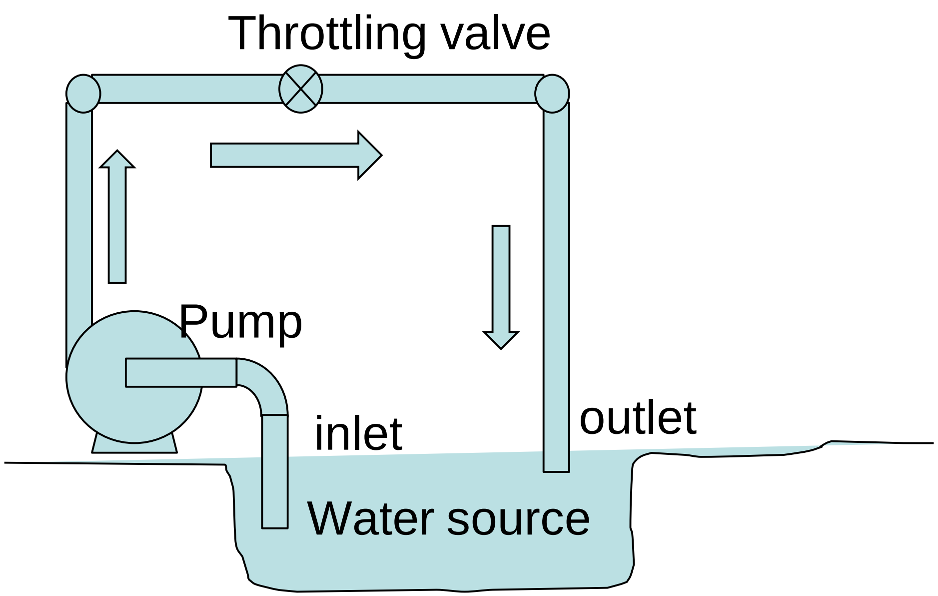


- Current flowing – usually represented with an arrow  and an "I"

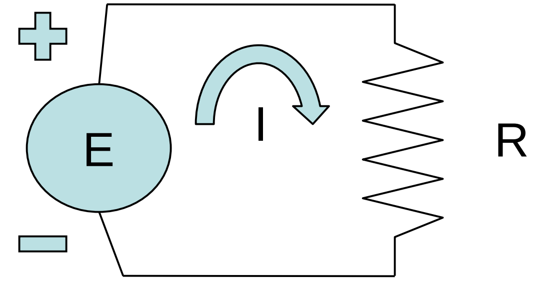
- Resistor  R

Equivalence to Electricity

- Pressure = Voltage or Potential (E)
- Flow = Current or Amperage (I)



Pressure changes around circuit
Flow rate remains constant



Voltage changes around circuit
Current remains constant

Equivalence

FLUIDS

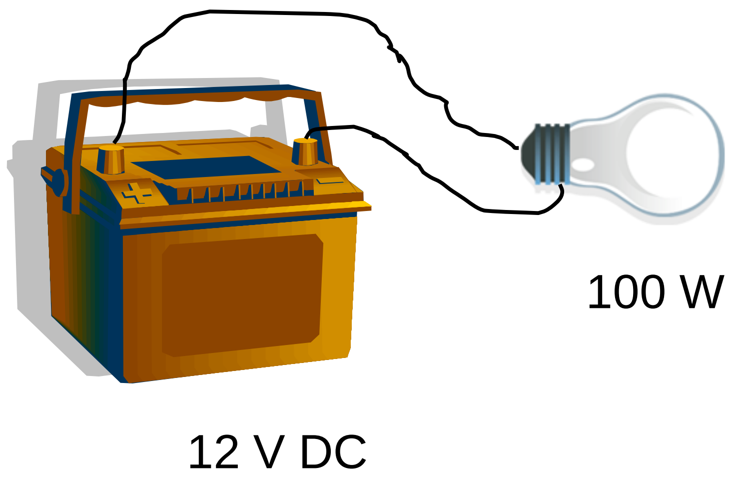
- Pressure
  - Pounds per square inch
  - Measured without diverting flow
- Flow
  - Gallons per minute
  - Measured by diverting the flow

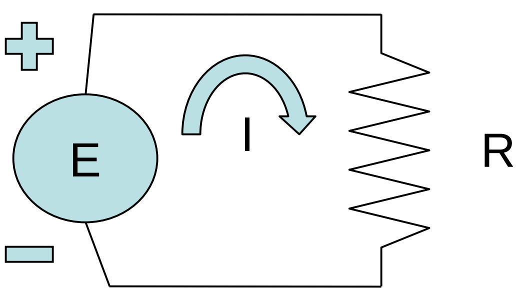
ELECTRICITY

- Voltage / Potential
  - Volts
  - Measured without diverting current
- Current
  - Amps (Coulombs per sec)
  - Measured by diverting the current

A simple circuit

- 12 V DC car battery attached to a light bulb
- Electrical current flows from battery (+) through light bulb filament back to ground (-) on battery



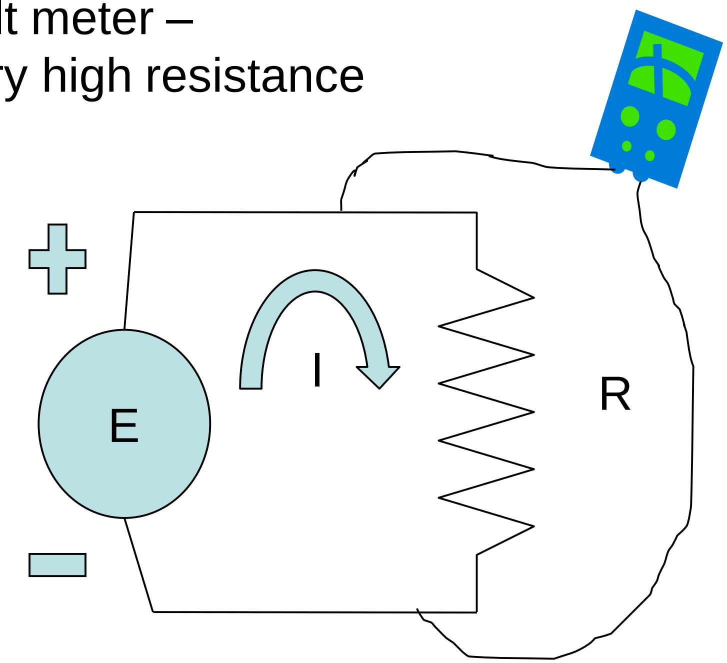


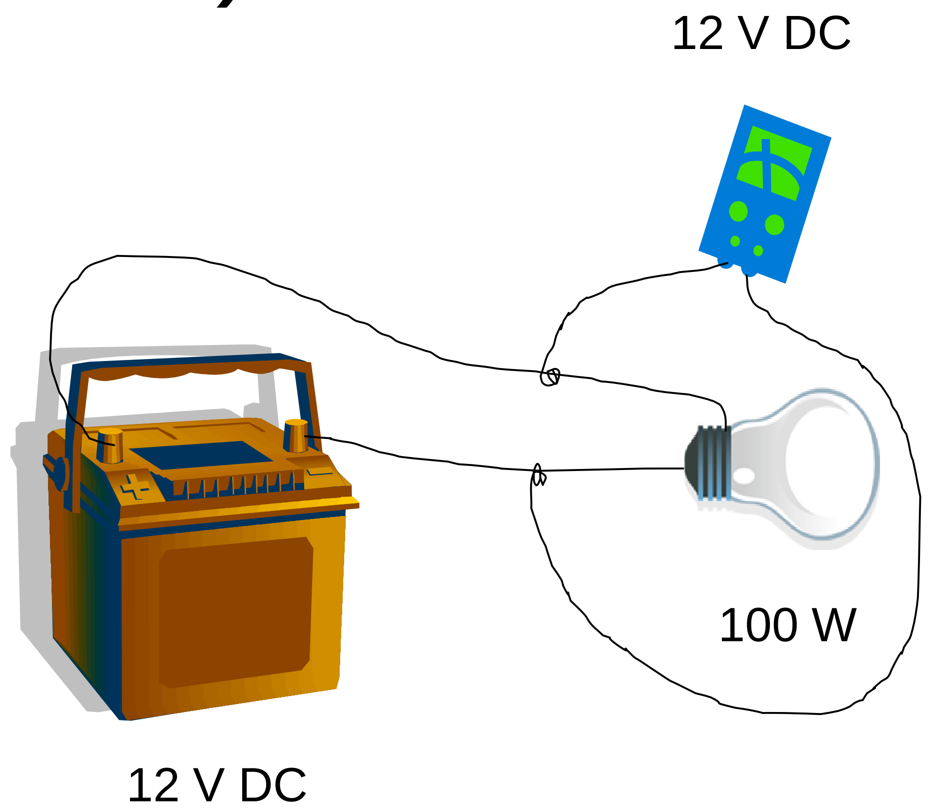
Measuring electrical voltage (potential)

In order to measure voltage, no current goes through the meter

The meter is kept separate from the current flow.

Volt meter –
very high resistance



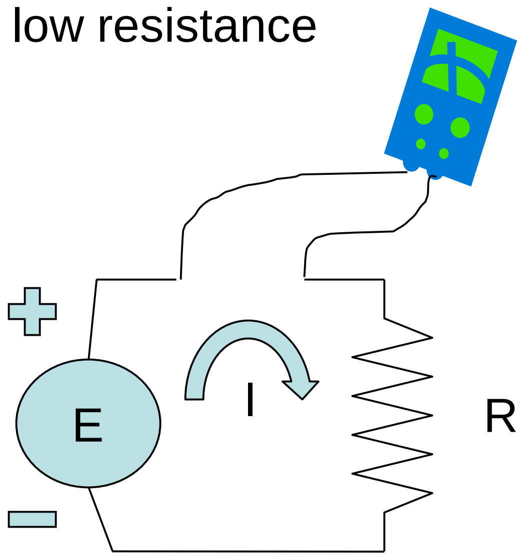


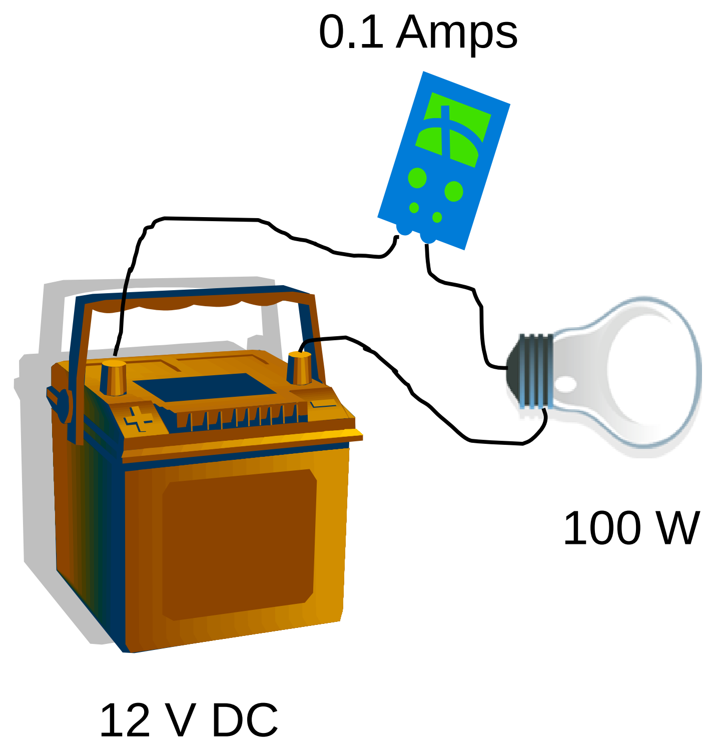
Measuring electrical current

In order to measure current,
all current must go through a meter

The meter is inserted and becomes part of the circuit.

Amp meter –
very low resistance





INDUCTION meter

Circuits that most people are familiar with

- What is the difference between a “normal” circuit breaker and a “ground fault” circuit interrupter?
- A “normal” circuit breaker opens (breaks) when TOO MUCH current is flowing
- A “ground fault” breaker opens when flow on the “hot” side is DIFFERENT from flow on the “ground” side

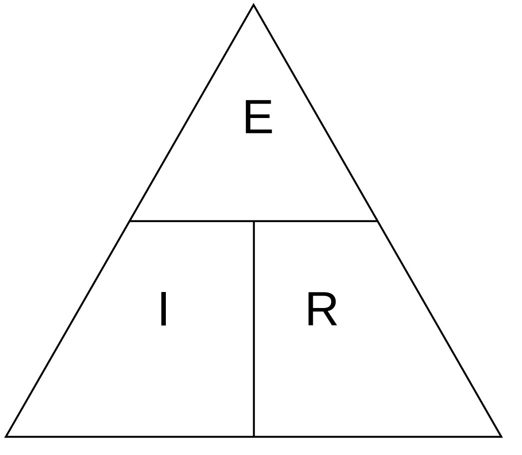
Ohm's Law

A potential of 1 volt across a resistance of 1 ohm causes 1 amp of current to flow

$E = I * R$

$I = E / R$

$R = E / I$



OHM’s LAW

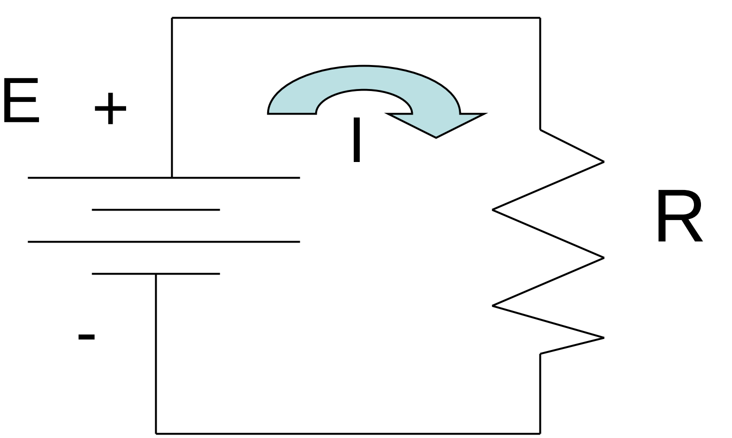
- Using the triangle.
- Cover the variable that you need to find.
- The “known” variables will be in the configuration you need.
- Need to know “I”?
- Cover the I and you’re left with $\frac{E}{R}$.
- Therefore I = $\frac{E}{R}$

Units and Ohm's Law

- ALWAYS convert units to Amps, volts, and Ohms.
- Do NOT use milliamps, millivolts, or kilo-ohms.

Ohm's Law Applied

- If the voltage (E) is 1 Volt and the resistance (R) is 1000 ohms, how much current (I) is flowing?

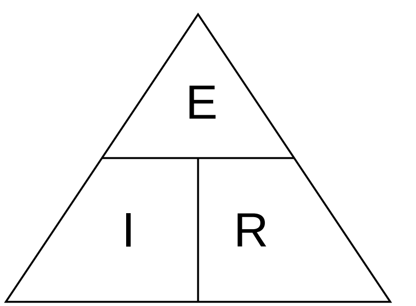


- I = E/R = E ÷ R
- I = 1V/1000ohms
- I = .001 Amps

E = IR

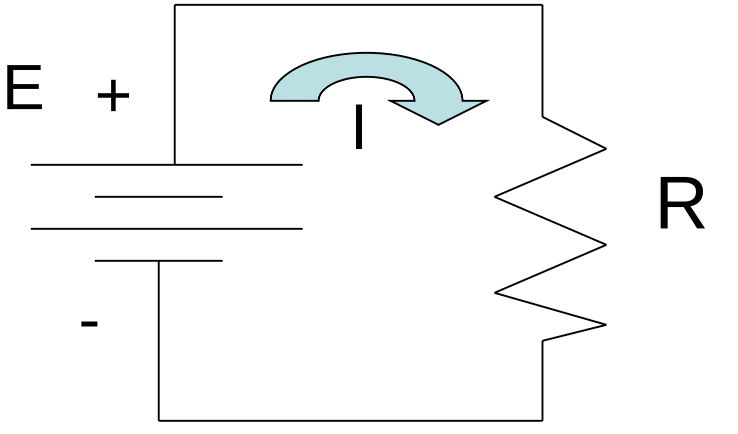
R = E/I

I = E/R



Ohm's Law Example 1

- If the voltage (E) is 10.5 Volts and the resistance (R) is 5 ohms, how much current (I) is flowing?

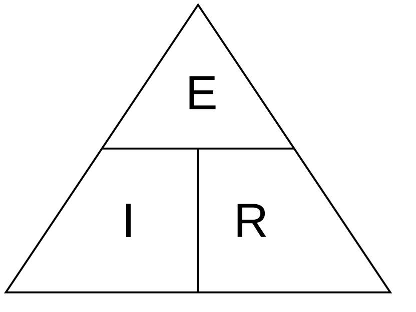


- I = E/R = E ÷ R
- I = 10.5V ÷ 5ohms
- I = 2.1 Amps

E = IR

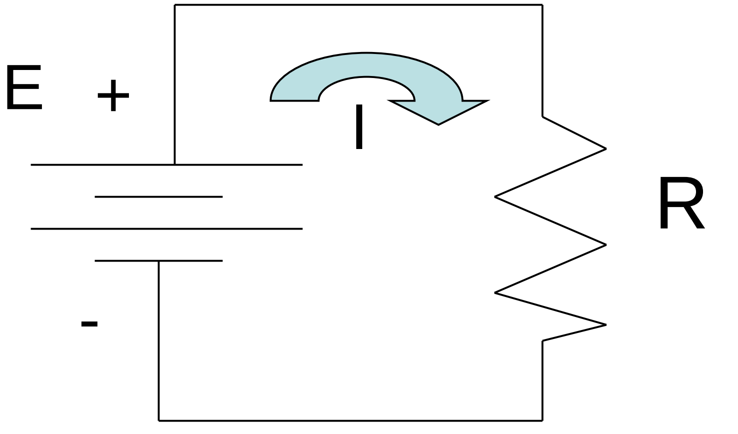
R = E/I

I = E/R



Ohm's Law Example 2

- If the voltage (E) is 1.6 Volts and the current (I) is 2 amps, what is the resistance in the circuit?

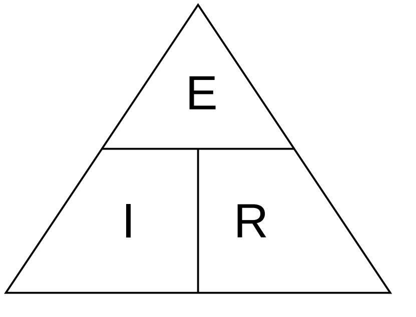


- R = E ÷ I
- R = 1.6V ÷ 2 amps
- R = 0.8 ohms

E = IR

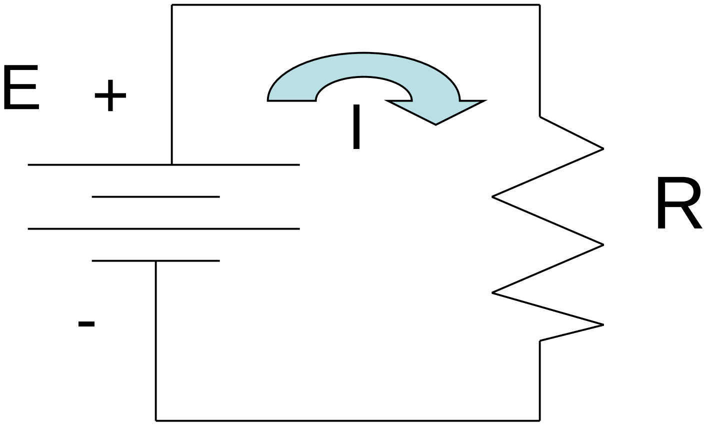
R = E/I

I = E/R



Ohm’s Law Example 3

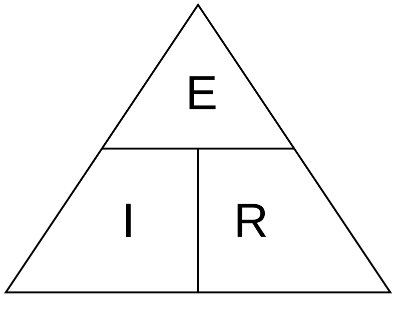
- If the current (I) is 100 mA and the resistance (R) is 1.5 ohms, what is the voltage across the resistor?
- E = I*R
- I = 100 mA = 0.1A
- R = 1.5 ohms
- E = 0.1 * 1.5
- E = 0.15V



E = I*R

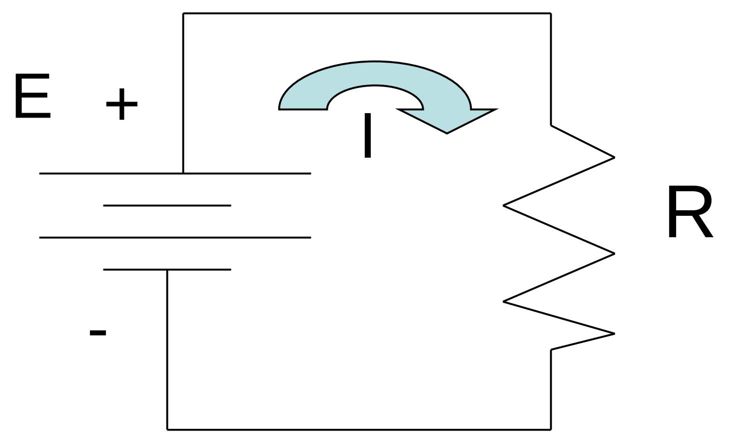
R = E/I

I = E/R



Example 3 – mistake included

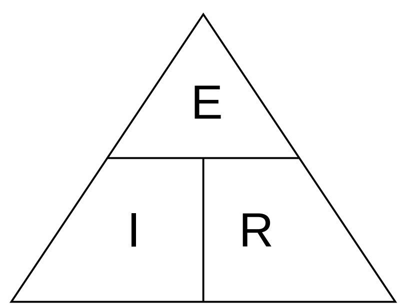
- If the current (I) is 100 mA and the resistance (R) is 1.5 ohms, what is the voltage across the resistor?
- E = I*R
- I = 100 mA
- R = 1.5 ohms
- E = 100 * 1.5
- E = 150 V (not 0.15V)



E = I*R

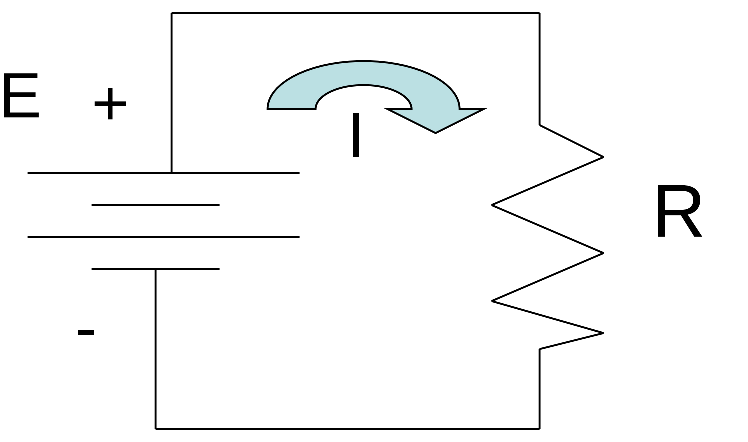
R = E/I

I = E/R



Ohm’s Law Example 4

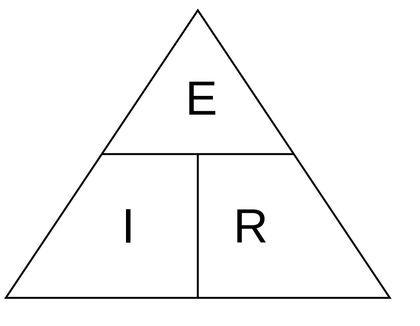
- If the current (I) is 2.5 mA and the voltage (E) is 2.5 volts, what is the resistance of the circuit?
- R = E ÷ I
- I = 2.5 mA = 0.0025A
- E = 2.5 volts
- R = 2.5 ÷ .0025
- R = 1000 ohms



E = I*R

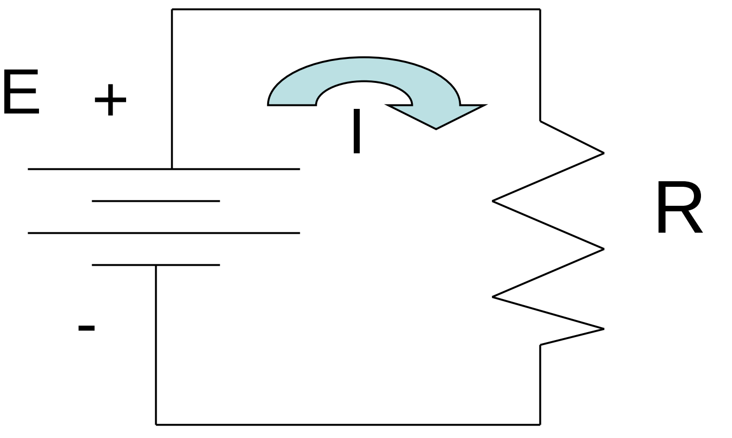
R = E/I

I = E/R



Example 4 – mistake included

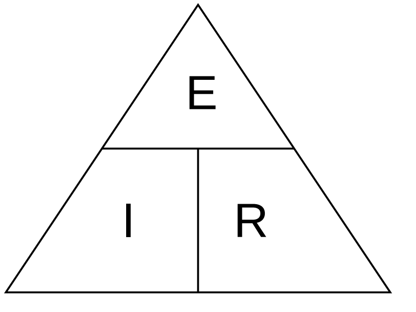
- If the current (I) is 2.5 mA and the voltage (E) is 2.5 volts, what is the resistance of the circuit?
- R = E ÷ I
- I = 2.5 mA
- E = 2.5 volts
- R = 2.5 ÷ 2.5
- R = 1 ohm (wrong)



E = I*R

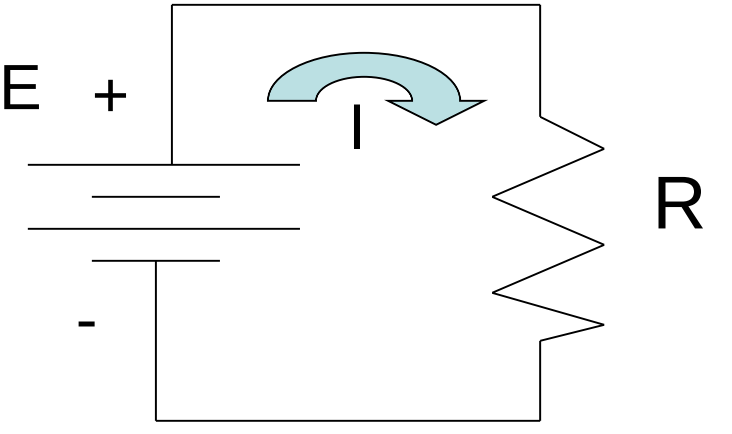
R = E/I

I = E/R



Ohm's Law Example 5

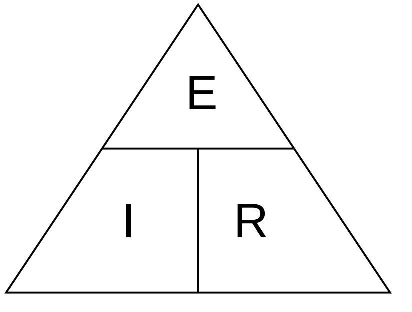
- If the current (I) is 20 A and the resistance (R) is 2 ohms, what is the voltage across the resistor?
- E = I*R
- I = 20 A
- R = 2 ohms
- E = 20 * 2
- E = 40 V



E = I*R

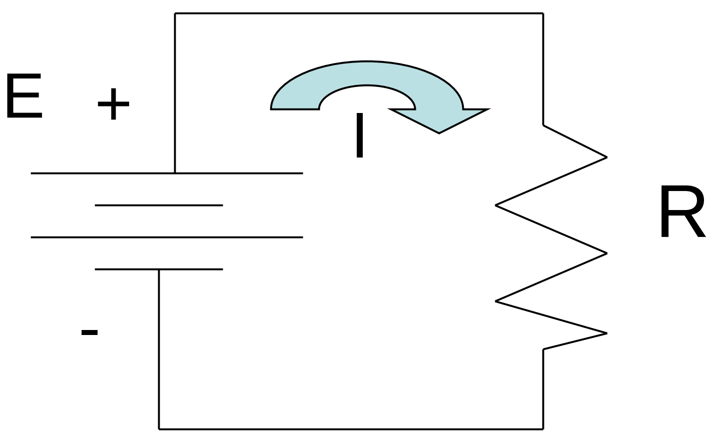
R = E/I

I = E/R



Ohm’s Law Example 6

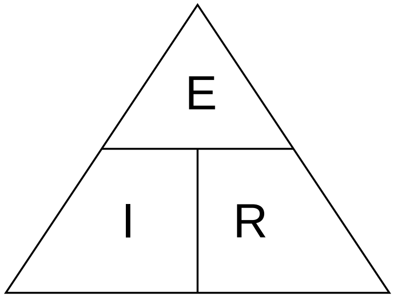
- If the voltage (E) is 12 Volts and the resistance (R) is 4 ohms, how much current (I – in milliamps) is flowing?
- I = E ÷ R
- I = 12V ÷ 4 ohms
- I = 3 Amps
- I = 3 A * (1000mA/1A)
- I = 3000 mA



E = IR

R = E/I

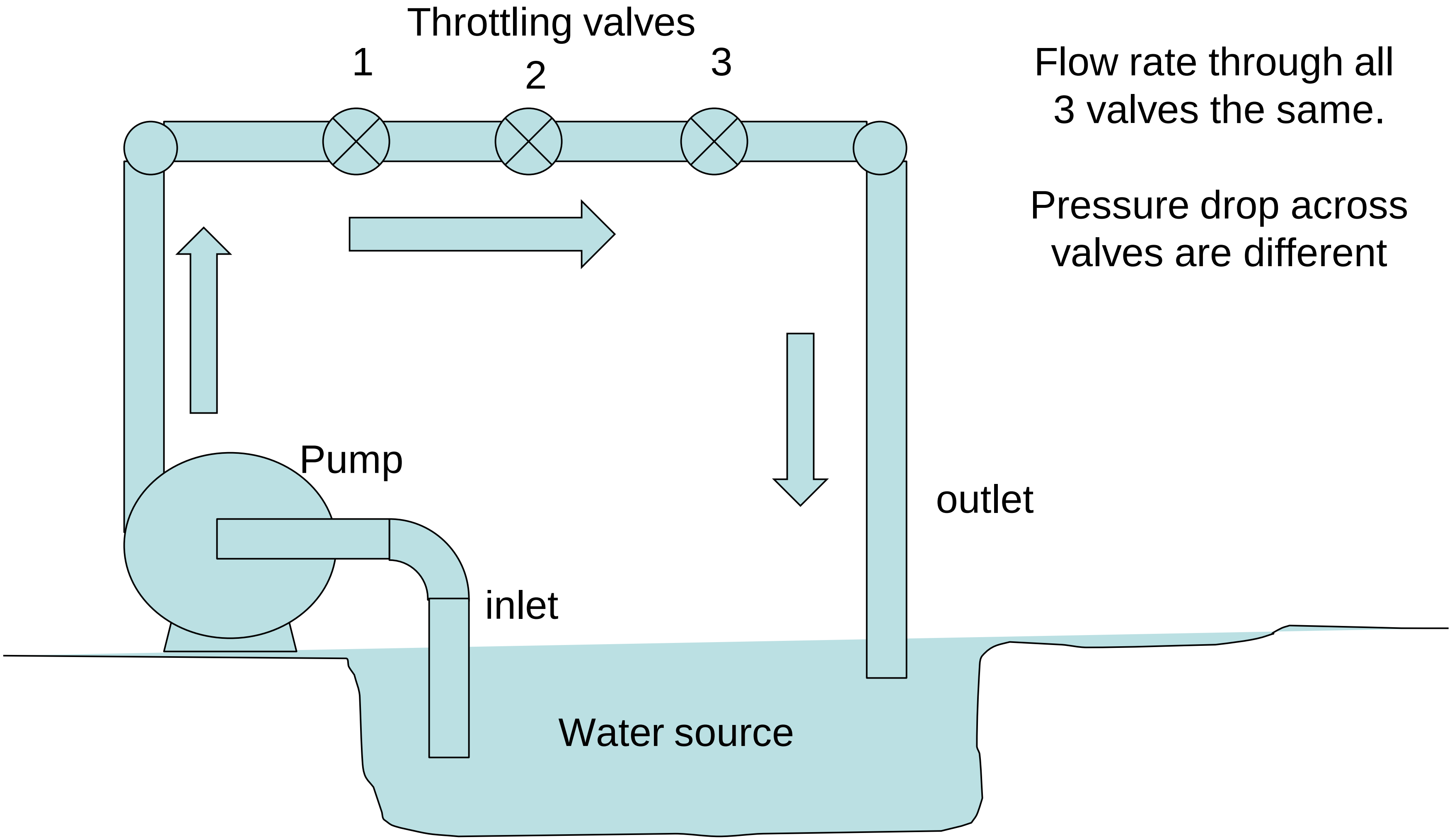
I = E/R



Electric Circuit Analysis

- Resistors in a circuit can be connected in series
  - Current is the same through all resistors
  - Voltage drop across different resistances is different
- Resistors in a circuit can be connected in parallel
  - Current through different resistors is different
  - Voltage drop across all resistors is the same

Series Piping

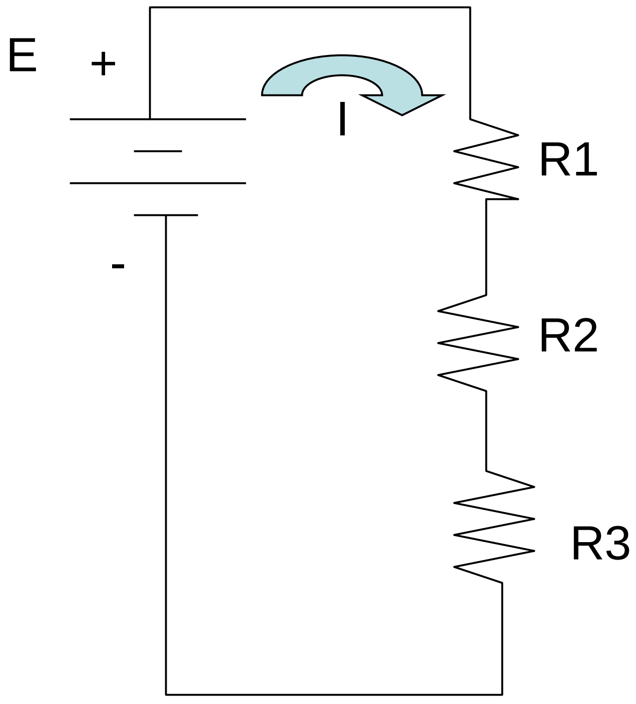


Flow rate through all 3 valves the same.

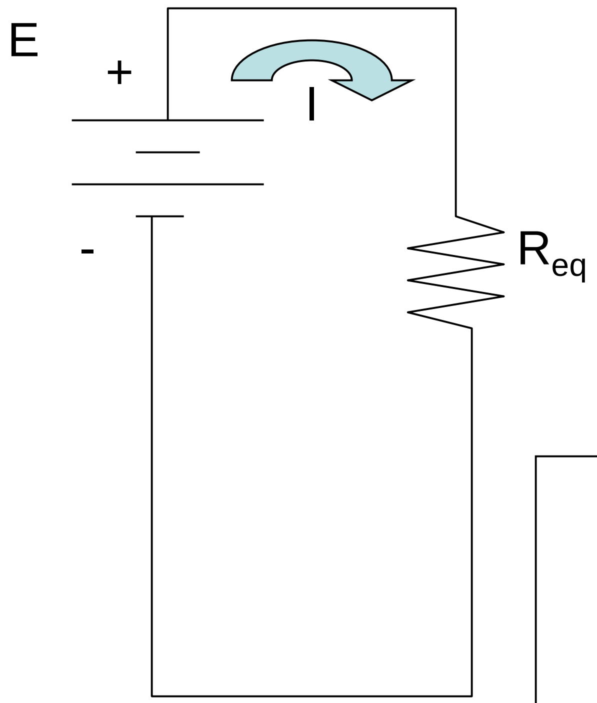
Pressure drop across valves are different

Resistors in Series

- All the current flows through all the resistors
- Depending on the resistance values, the voltage drop across each R is different.
- What is the equiv R?



Resistors in Series
what is the equivalent resistance?



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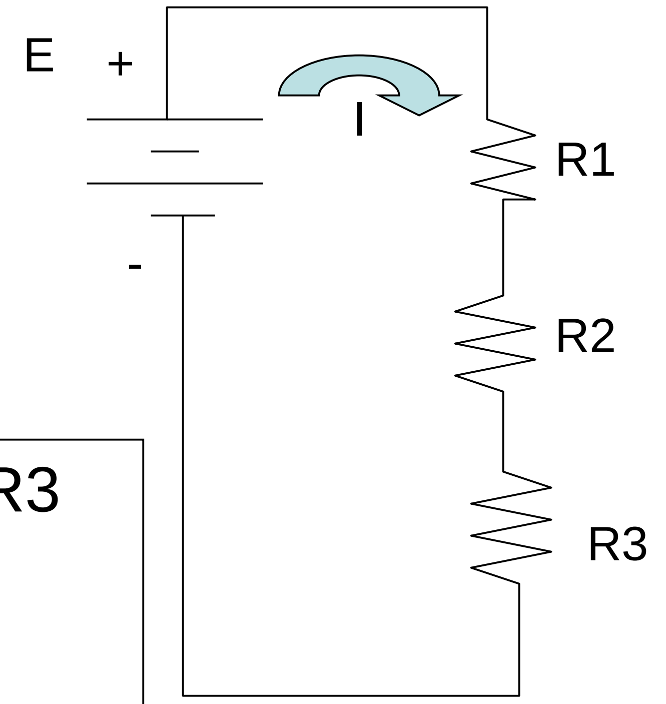


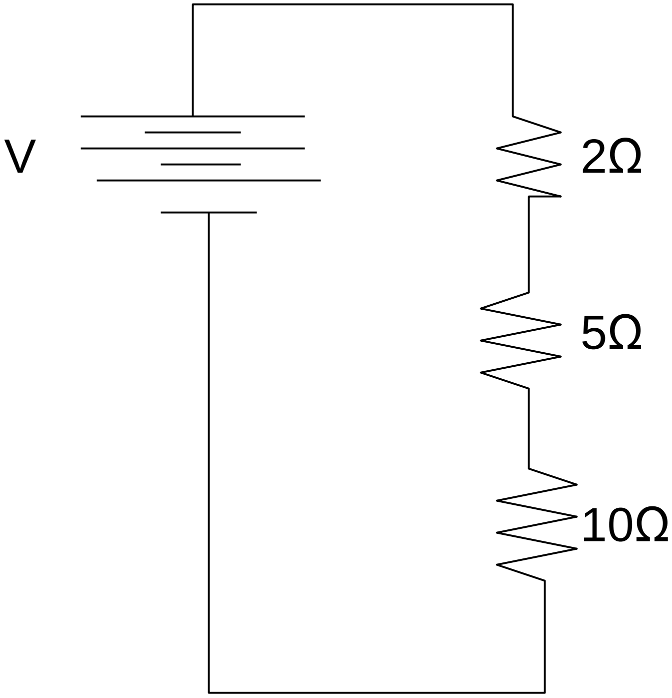
Req = R1 + R2 +R3

The equivalent resistance is greater than the largest resistor.

Series example

$Req = 2\ \Omega + 5\ \Omega + 10\ \Omega$

$Req = 17\ \Omega$

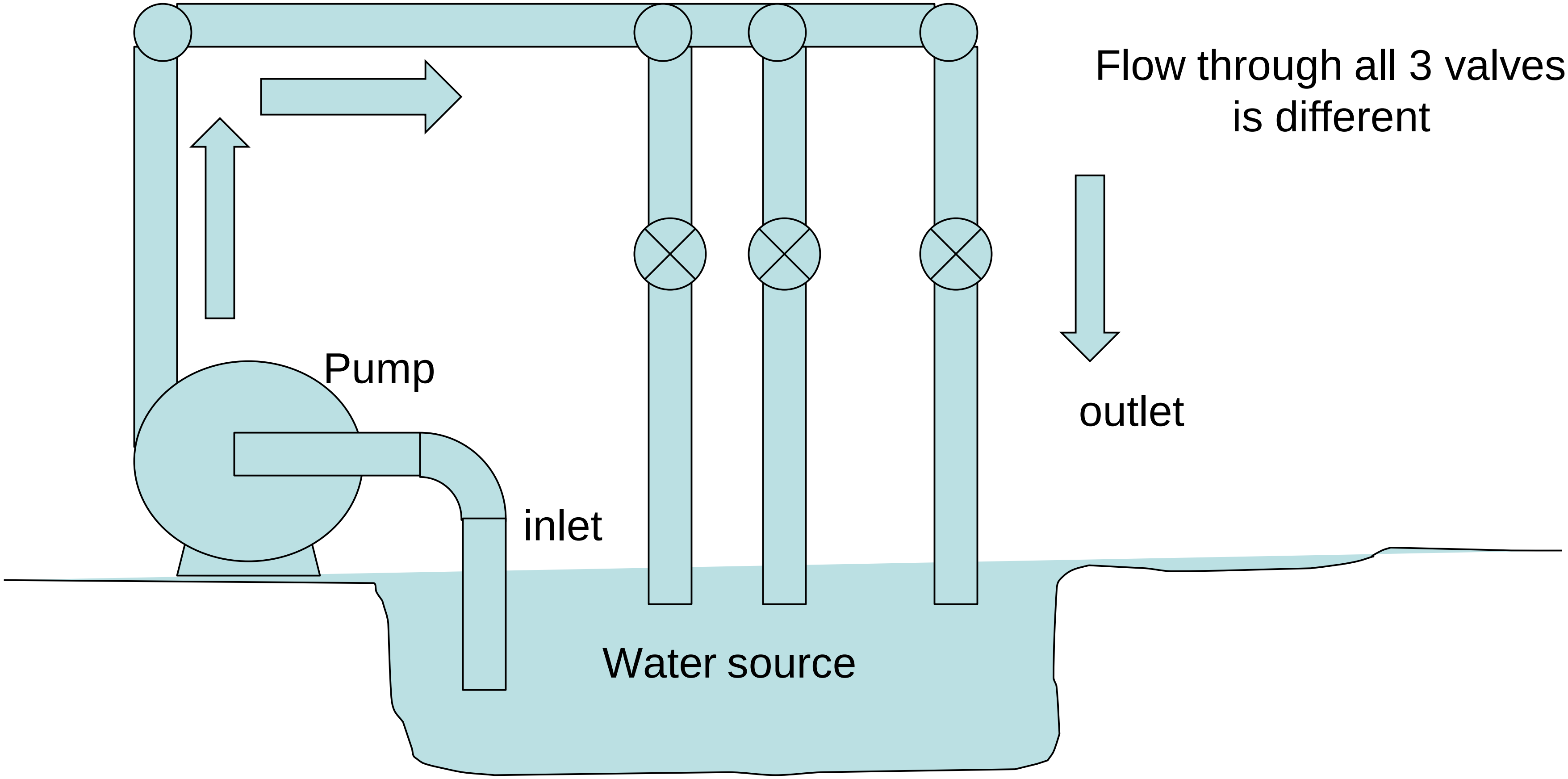


The equivalent resistance is HIGHER than the highest individual resistor.

Parallel Piping

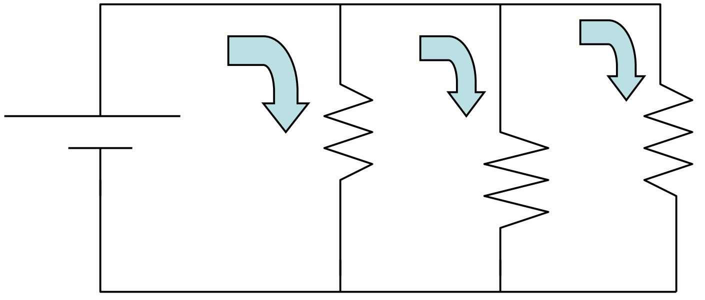
Pressure drop across
all 3 valves is the same

Flow through all 3 valves
is different

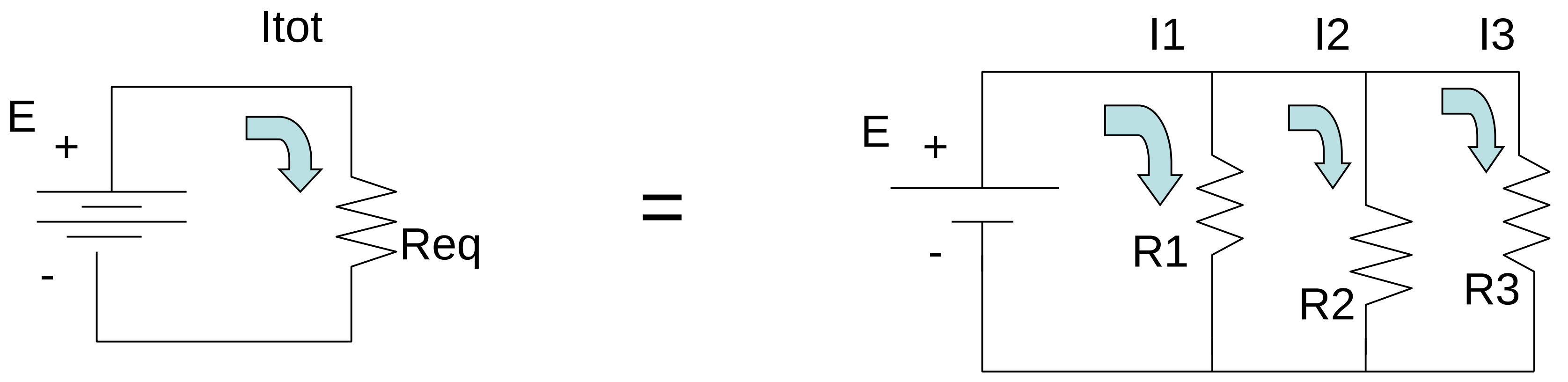


Resistors in Parallel

- Different currents flow through the resistors
- The voltage drop across each R is the same.
- What is the equiv R?



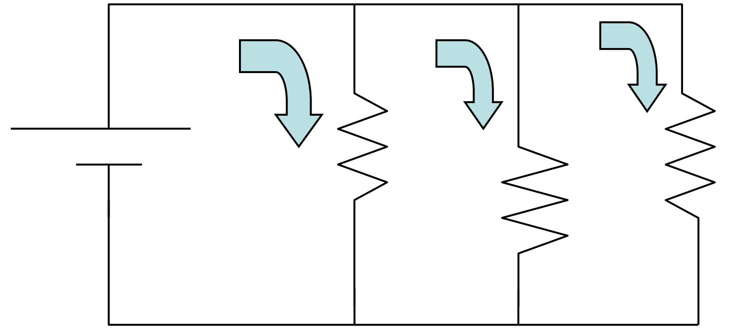
Resistors in Parallel



1/Req = 1/R1 + 1/R2 + 1/R3

An interesting property of parallel resistors

$$\frac{1}{Req} = \frac{1}{2\,\Omega} + \frac{1}{5\,\Omega} + \frac{1}{10\,\Omega}$$



$$\frac{1}{Req} = 0.5\,\Omega^{-1} + 0.2\,\Omega^{-1} + 0.1\,\Omega^{-1}$$

$$\frac{1}{Req} = 0.8\,\Omega^{-1}$$

Req = 1 / 0.8 Ω^{-1}

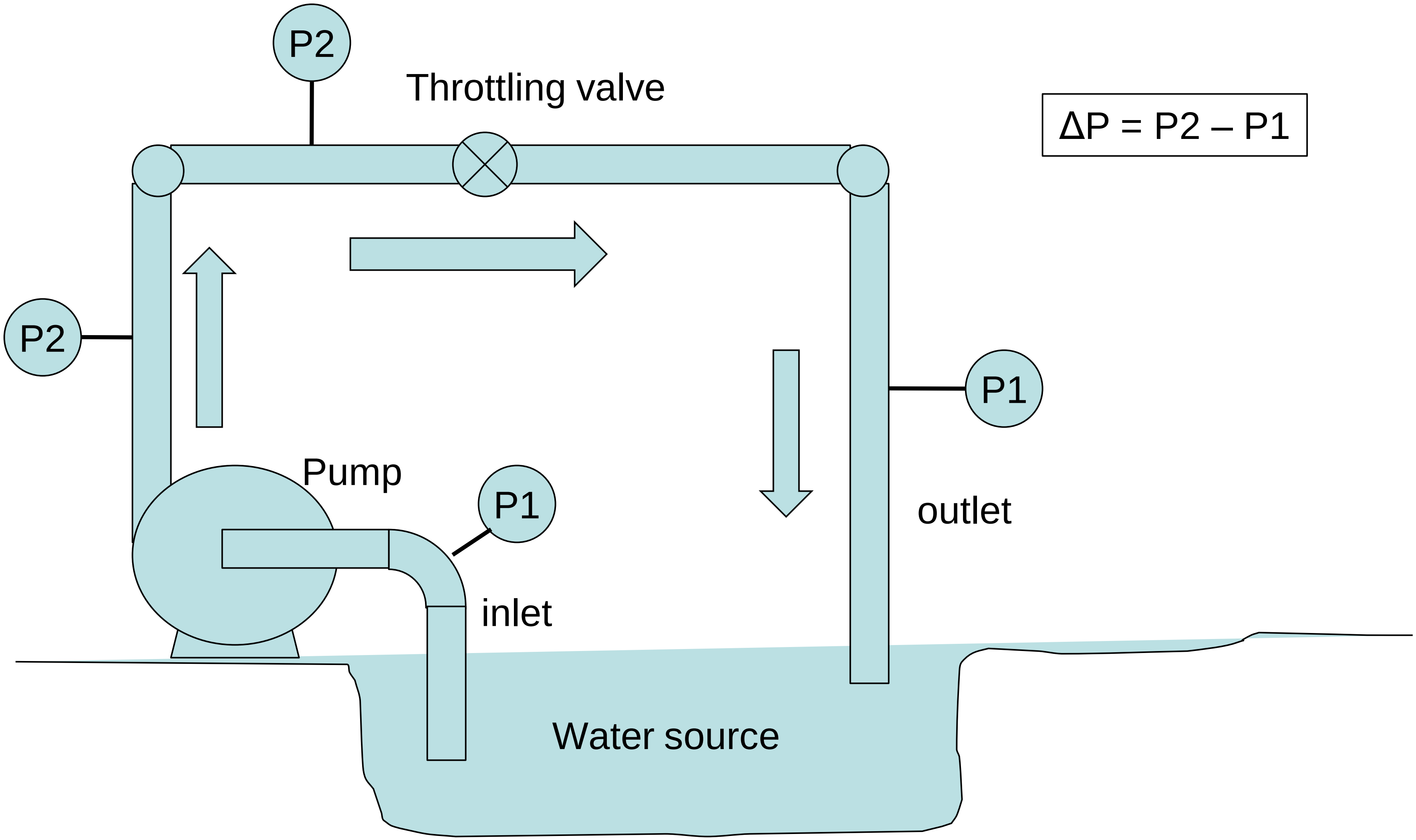
Req = 1.25 Ω

The Equivalent resistance is LOWER than the lowest resistance.

END PRESENTATION

- Repeat session at 7 pm

Pressure



P2
Throttling valve
ΔP = P2 – P1
P2
P1
Pump
P1
outlet
inlet
Water source

Flow

- Measuring flow rate is accomplished by diverting the flow through a meter.
- Flow is the same rate “volume per unit time” at ALL points in the system
- Typical flow rate is “gallons per minute”
- Flow rate out = flow rate in
  - If that was not true, then fluid is accumulating somewhere in the system

Fluid circuit - continued

- The flow rate (gallons/minute) is the same at all points in the circuit
  - water cannot be compressed
- The pressure increase at the pump is the same as the pressure decrease across the throttling valve
- The flow rate into the pump is the same as the flow rate through the valve is the same as the flow rate back to the reservoir.

The light bulb example

- I really didn’t use a multi-meter to determine the right numbers for my initial example.
- P = V * i $\rightarrow$ 100W = 110V * i
- i = 100 W / 110 V = 0.91 A

- Now using Ohm’s Law $$R = \frac{V}{i}$$
- R = 110 V / .91 A = 121 Ω