ENGG 1100 Introduction to Engineering Design

Lecture 3: Basic Electronics & Lab Safety

Miss NGAN Lai Yin

Department of Electronic Engineering

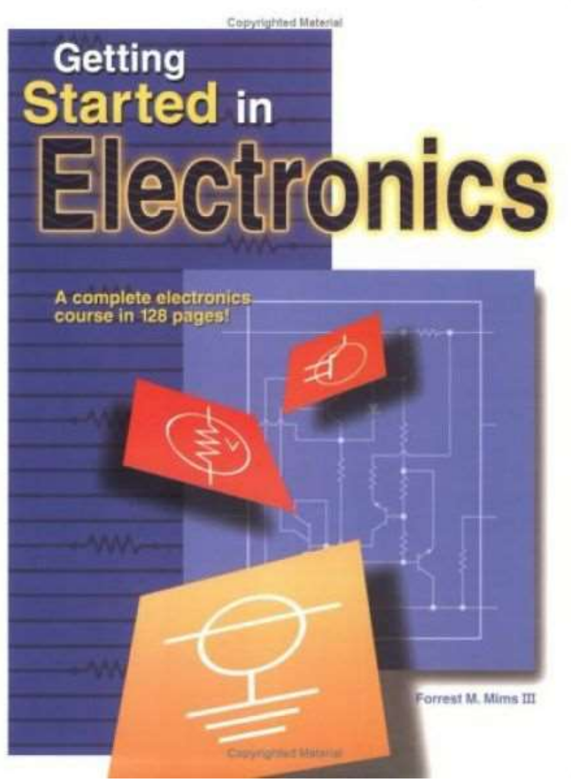
January 22, 2018

Objectives

- To understand basic circuits concepts, namely, voltage, current and resistors.
- To introduce to you how voltage and current are measured.
- To talk about laboratory safety.

References

- An optional, very friendly, reference:
  Forest M. Mims III, Getting Started in Electronics

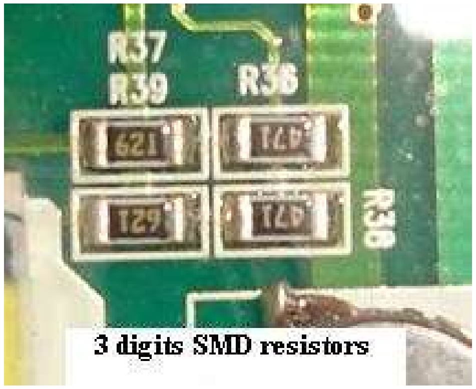


Introduction

Some Electronic Components

- **Resistors** - providing resistance

Source:
http://en.wikipedia.org/wiki/Resistor



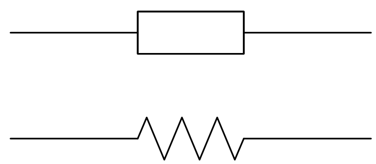
Source:
http://www.electronicrepairguide.com/smd-resistor-code.html

- **Capacitors** - storehouse for charges

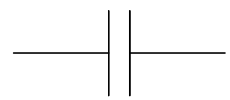
Source:
http://en.wikipedia.org/wiki/Capacitor

Electronic Component Symbols

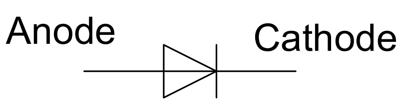
- Electronic components are represented using ***standardized symbols***



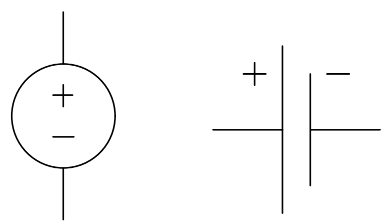
(a) Resistor



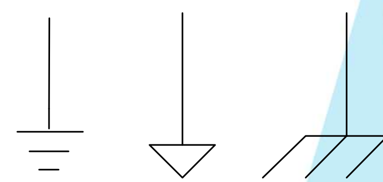
(b) Capacitor



(c) Diode



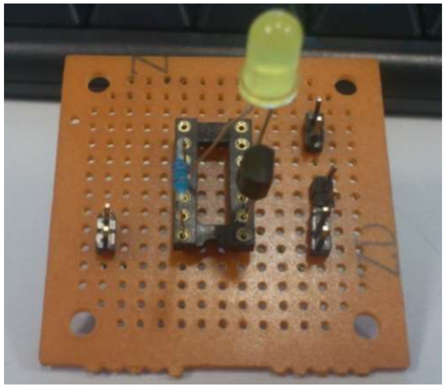
(d) DC Power Source

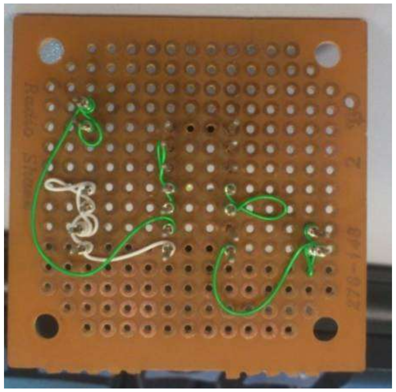


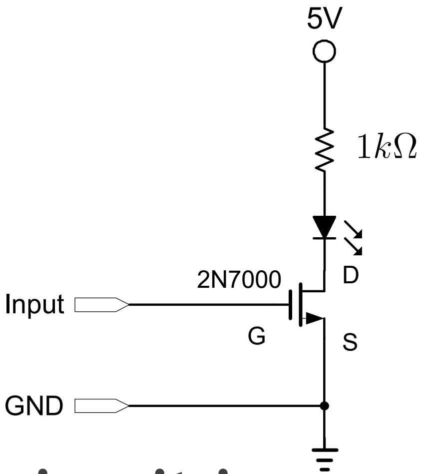
(e) Ground

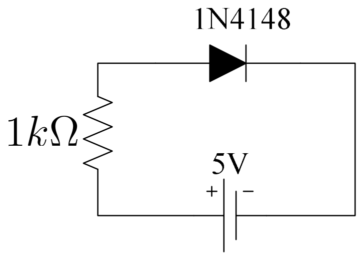
Circuits and Schematics

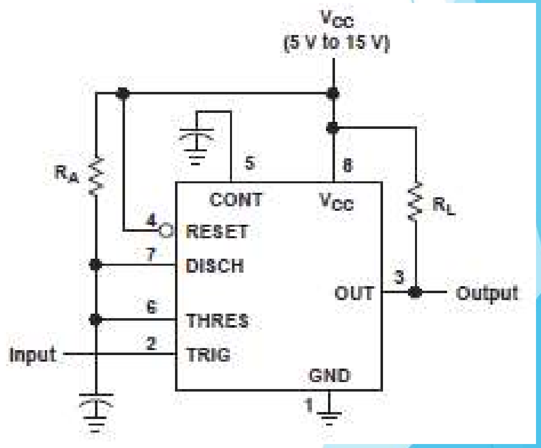
- What do the real circuits and schematics look like …



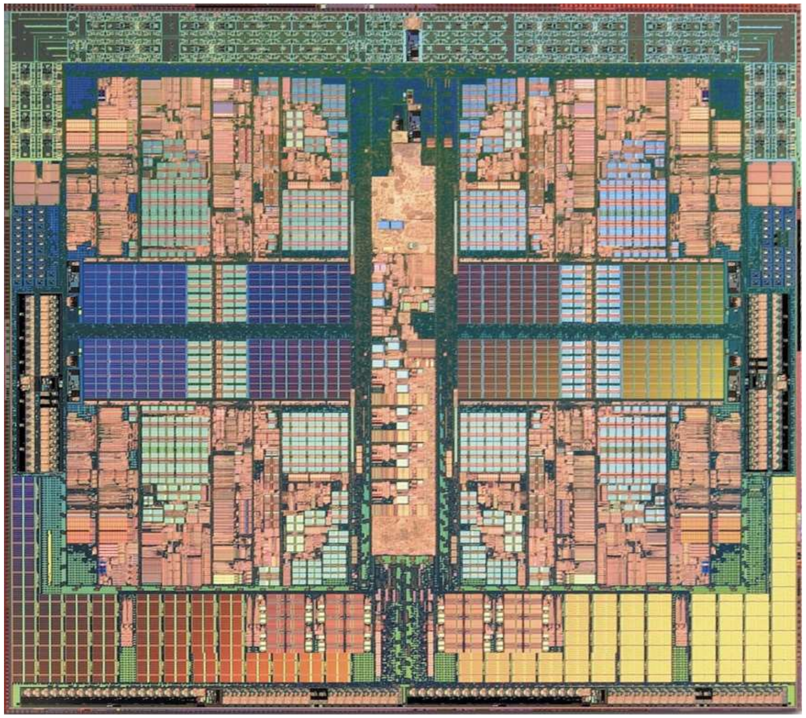








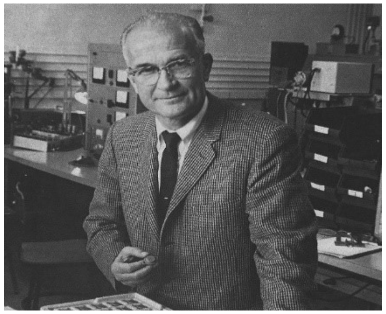
- A circuit is a connection of different electronic components.



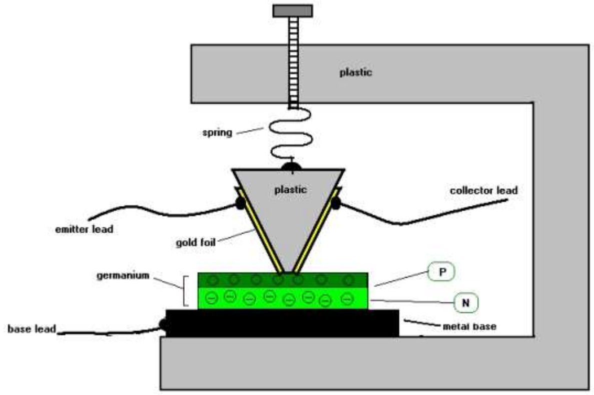
Quad-core CPU

Pentium 4 CPU

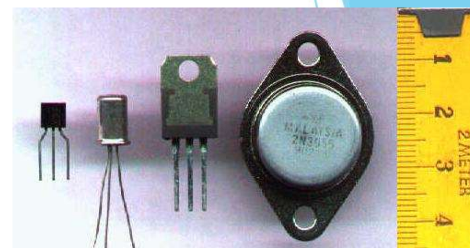
Transistors and Integrated Circuits



William Schockley
(Inventor of transistor)



Point-contact transistor invented in 1947 at Bell lab.

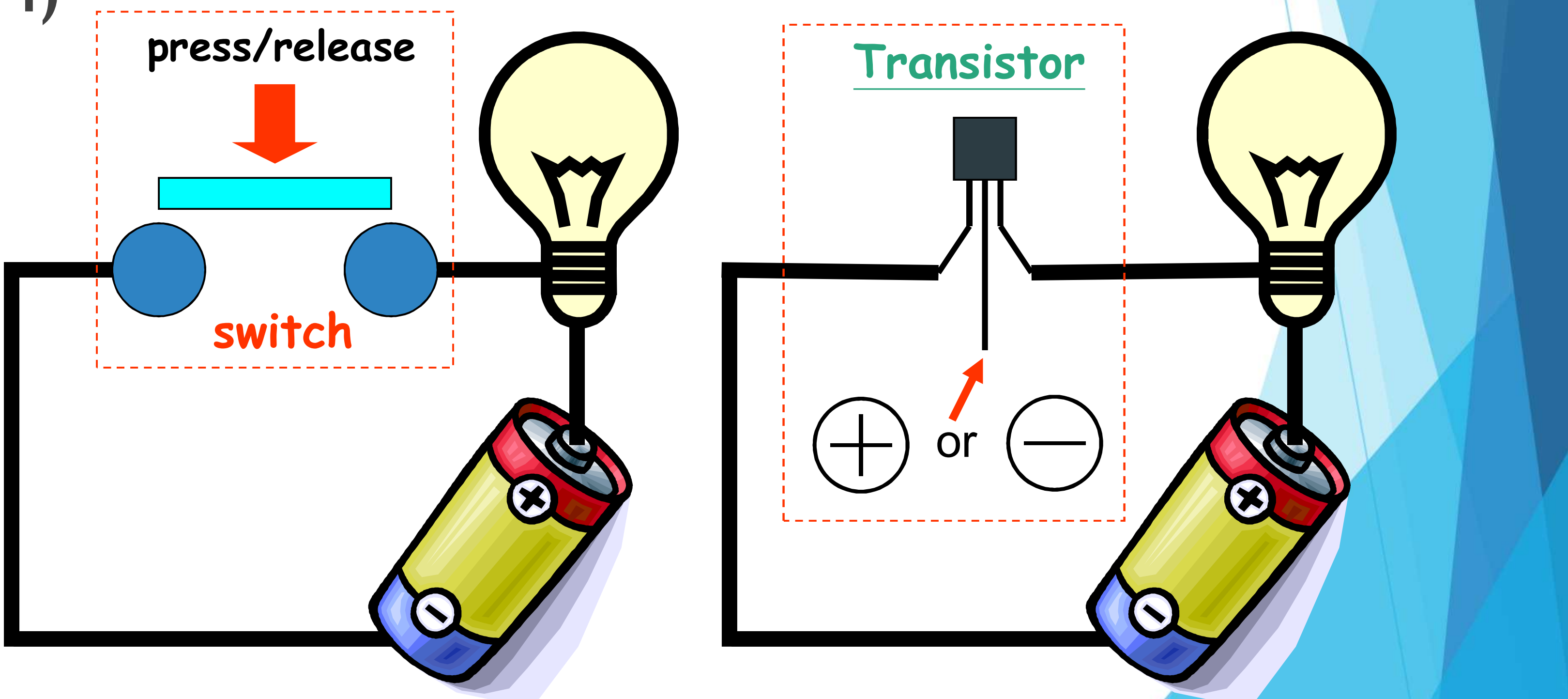


Transistors

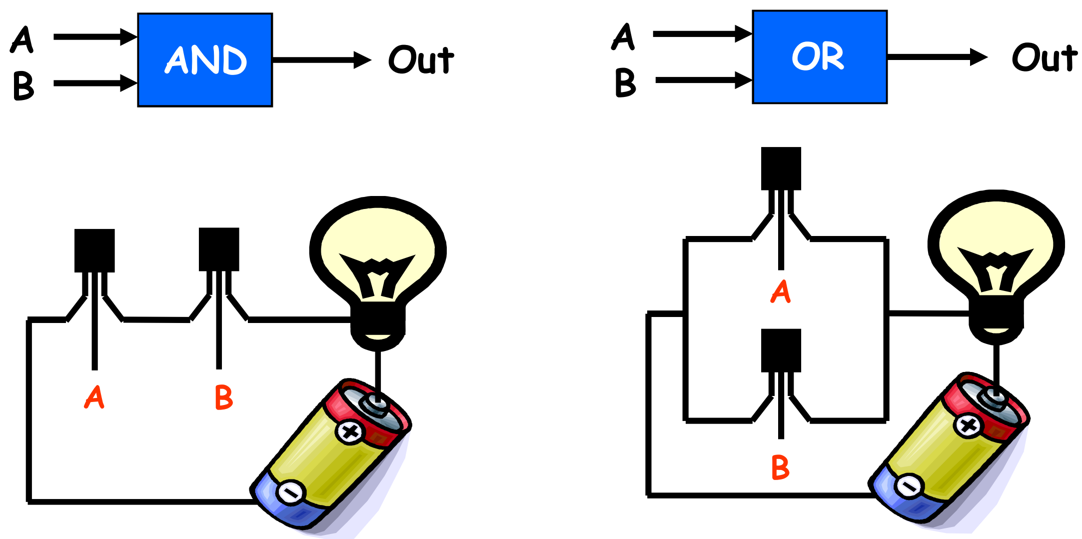
IC = Scaling down the size of the components and put all components in a small area

What does a transistor do?

- Transistors play an indispensable role in electronics and other areas.
- Simply speaking, a transistor works like an electronic switch. (It can also perform signal amplification, e.g. in Hi-Fi)

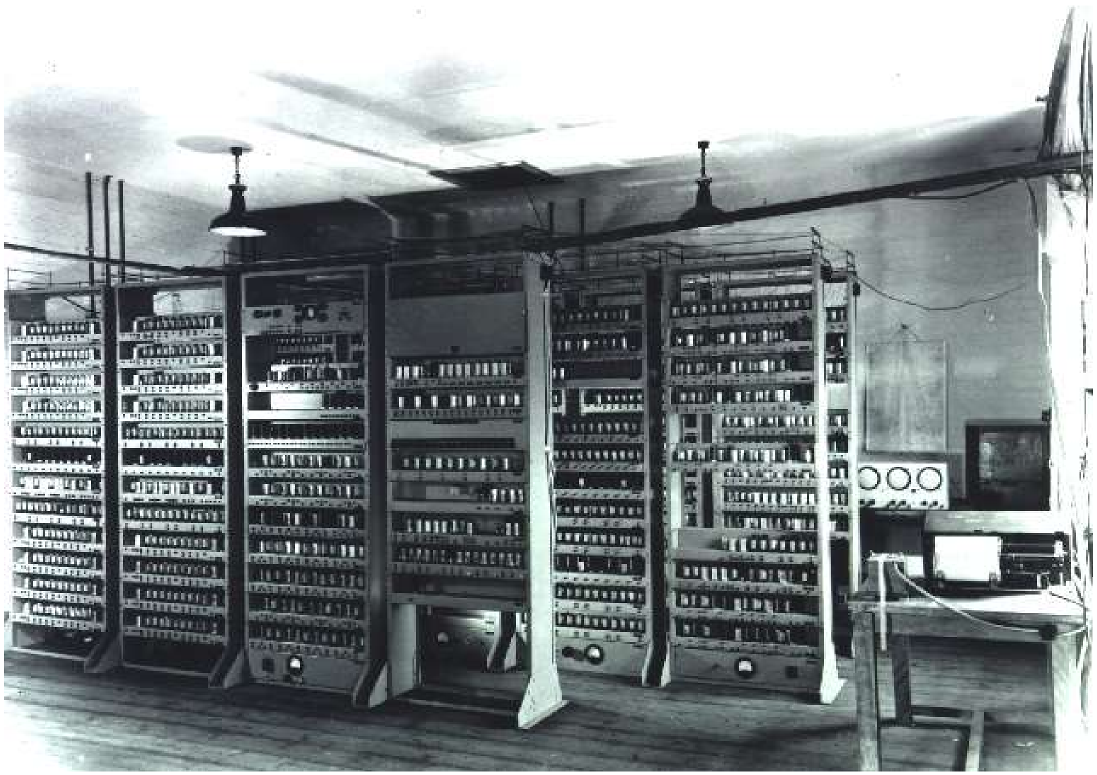


- Transistors, together with other components, like resistors, capacitors, inductors, diodes, etc. enable us to build many different circuits.
- Example: Use of transistors enables digital logics.



- With digital logistics, we can compute.
- And with the ability to compute, we have modern computers (and that includes your smart phones).

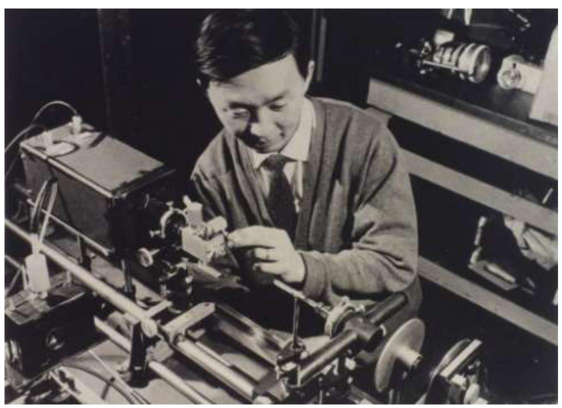
- So, we build things bigger and bigger to compute, and yet size smaller and smaller.



Electronic Delay Storage Automatic Calculator in 1949 (Addition, subtraction, multiplication, square, prime numbers, etc.)

Modern gadgets
(much faster, much smaller)

- Electronics provides “primal elements” behind almost all modern technology.
- Roughly speaking, it gives us the key building blocks for fields like wireless communications, optical communications, information technology, biomedical engineering, and many, many more.

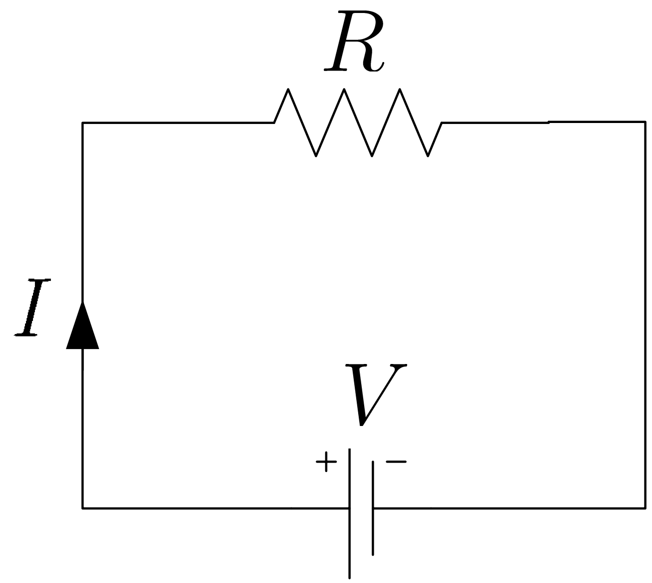


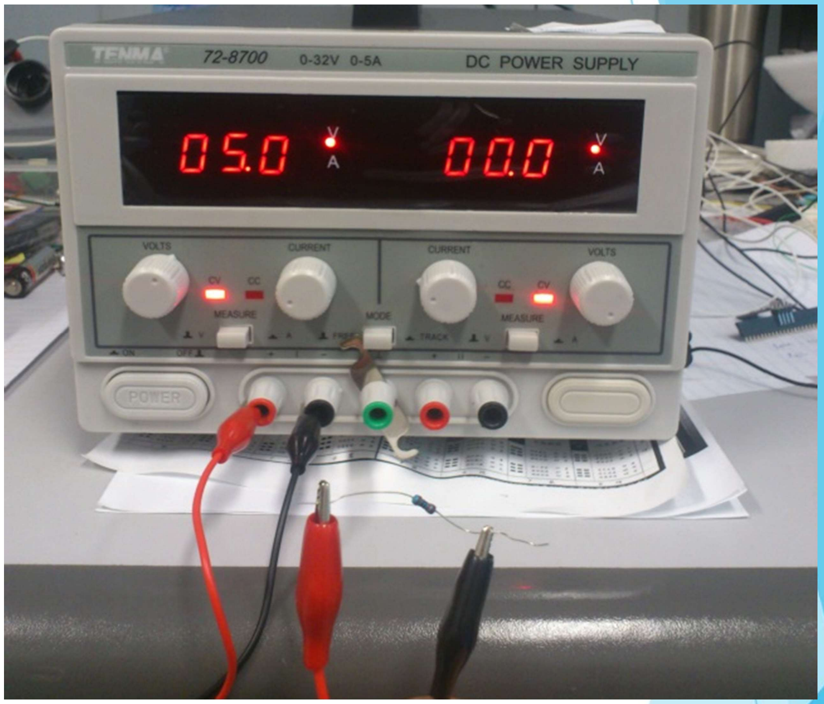
Resistors, Voltage and Current

ENGG1100 Lecture 3

Resistor Circuits

- Consider the following simple resistor circuit:

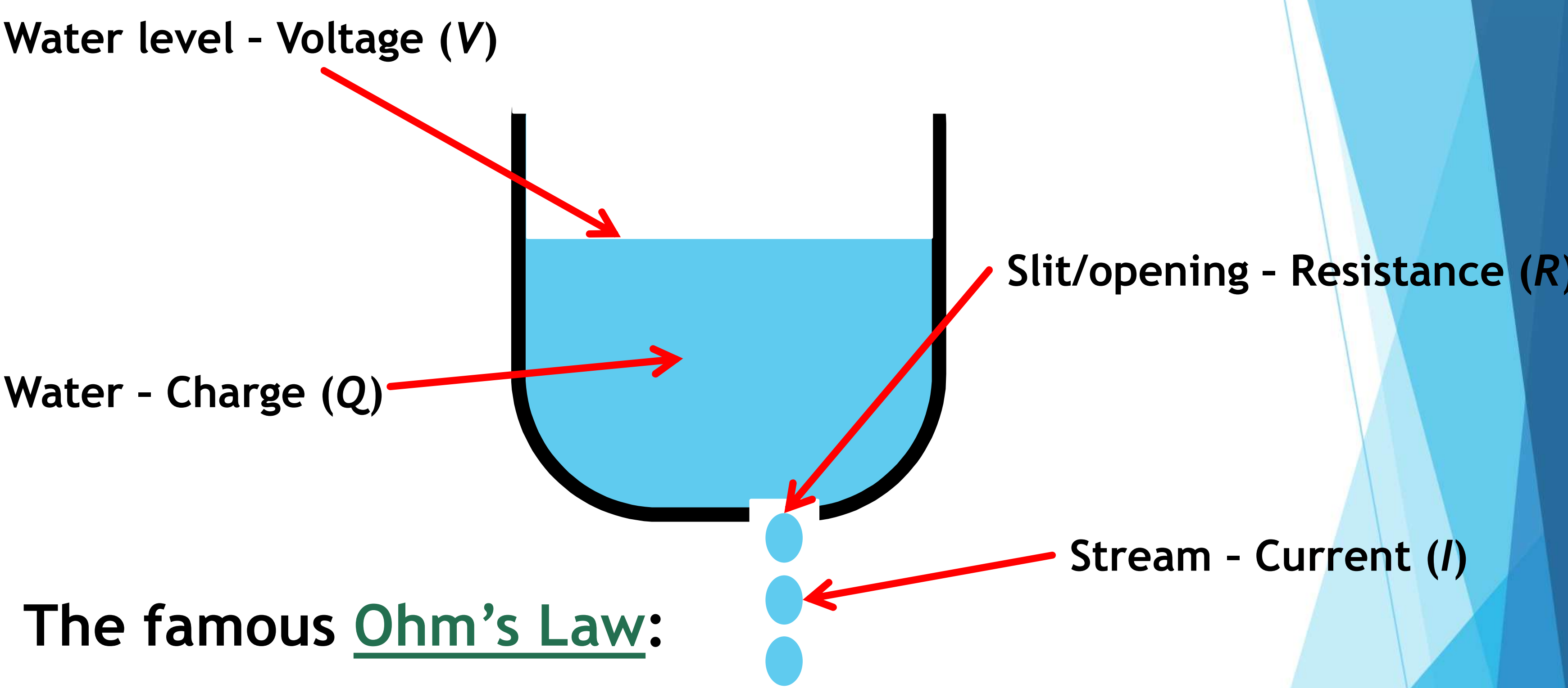




- The famous <u>Ohm's Law</u>:

$$V = IR$$

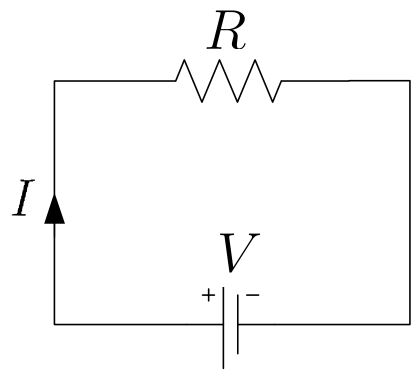
A Circuit and its Water Analogy



The famous Ohm's Law:

$$V = IR$$

Voltage, Current and Resistance

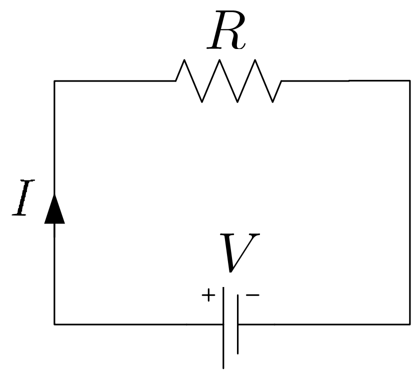


- Current
  - Describes the flow of positive charges through the circuit
  - Measured in units of Amperes (A)
  - By theory, defined as

$$I = \frac{dQ}{dt}$$

where I is the current, Q is the charge in Coulombs (C).

Voltage, Current and Resistance

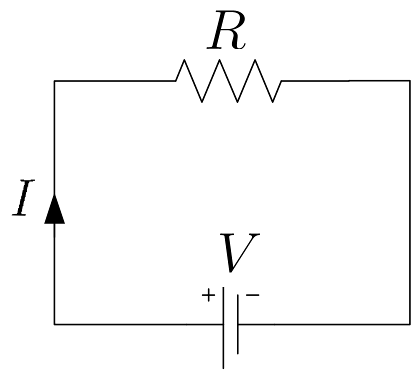


- **Voltage**
  - Describes the potential for current to flow in the circuit
  - Measured in units of Volts (V)
  - Relates to energy, measured in Joules (J)
  - The energy required to move a particle with Q Coulombs from a place of 0 V to a place with V Volts is

$$E = QV$$

where E represents the energy in Joules (J).

Voltage, Current and Resistance



- **Resistor**
  - is a device that resists the flow of current
  - Allows current to flow, but the amount depends on the value of the resistor and the voltage applied
  - The value of the resistor, or simply resistance, is measured in units of Ohms (Ω)
  - By Ohm's Law, we have

$$V = IR$$

where R represents the resistance (in Ω).

Voltage, Current and Resistance

- Power
  - is the rate of energy dissipation with respect to time
  - is the units of Joules per second, or Watts (W)
  - is given by

$$P = \frac{dE}{dt} = IV$$

where P represents the power (in W).

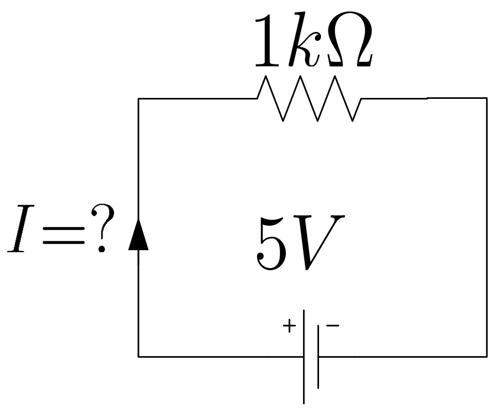
  - By Ohm's Law, we have

$$P = \frac{V^2}{R} = I^2 R$$

Basic Circuit Analysis

- The Ohm's Law

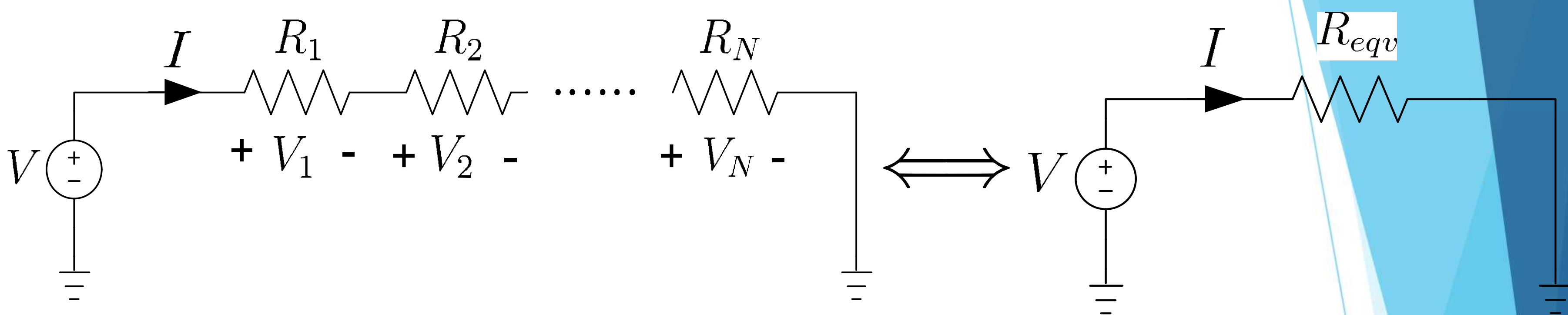
$$\boxed{V = IR}$$



$$5 = I(1000)$$

$$\Rightarrow I = \frac{5}{1000} = 5mA$$

Resistors in Series



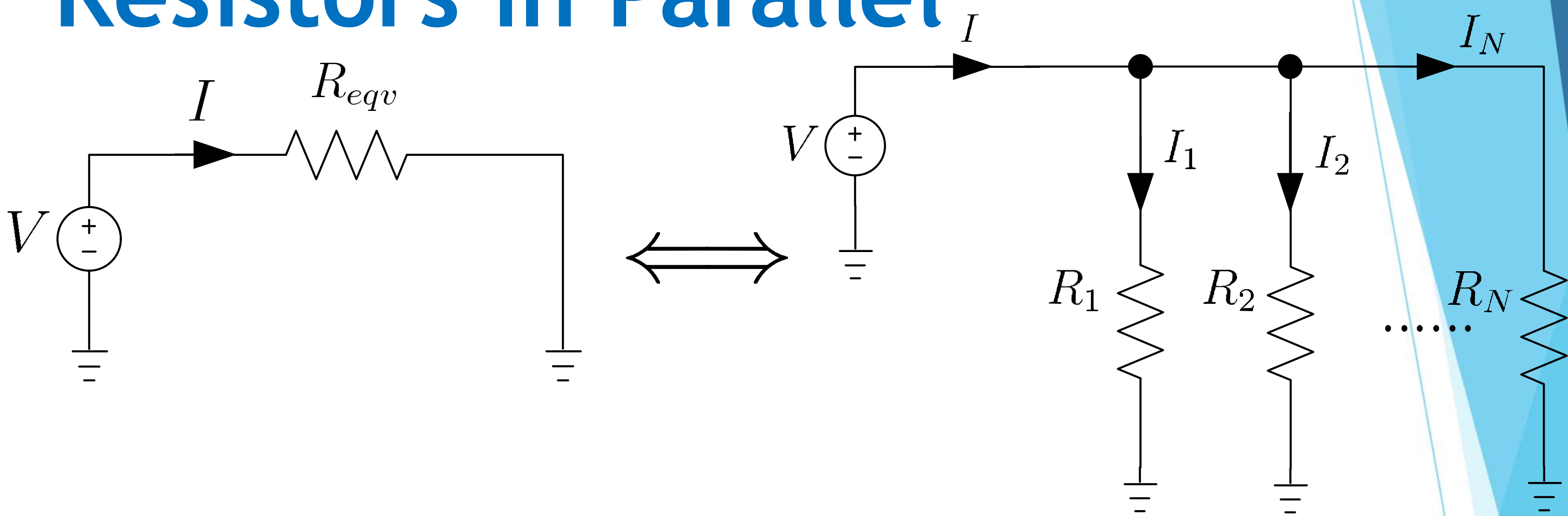
- We have $V = IR_1 + IR_2 + \cdots + IR_N$

$$= I(R_1 + R_2 + \cdots + R_N) = I\sum_{i=1}^{N} R_i$$

- Equivalent Resistance:

$$R_{eqv} = R_1 + R_2 + \cdots + R_N = \sum_{i=1}^{N} R_i$$

Resistors in Parallel



- Voltage on each resistor is the same: $V = I_i R_i$
- Current coming in = Current coming out:

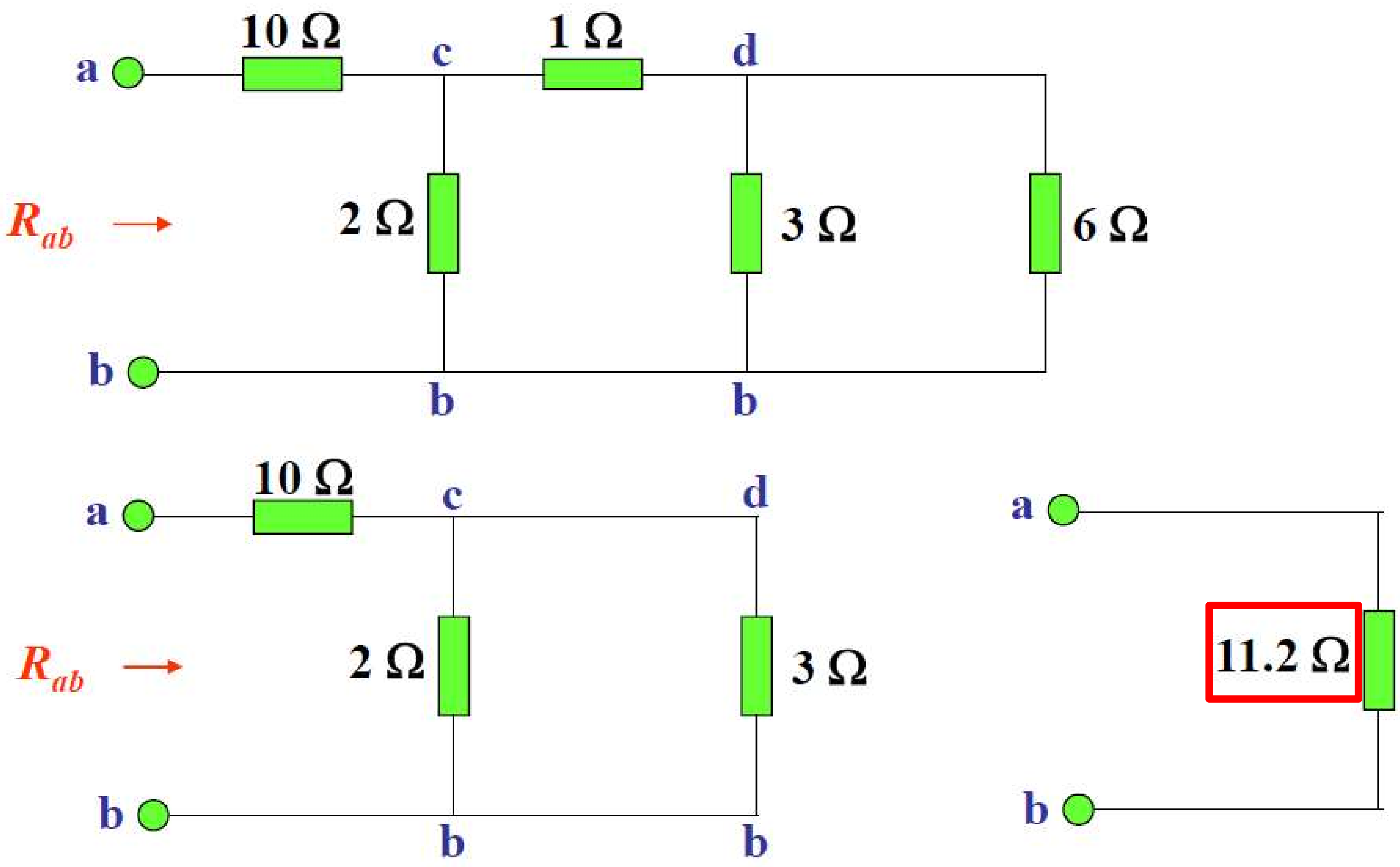
$$I = I_1 + I_2 + \cdots + I_N = \sum_{i=1}^{N} I_i$$

- Equivalent Resistance:

$$\frac{1}{R_{eqv}} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots + \frac{1}{R_N} = \sum_{i=1}^{N} \frac{1}{R_i}$$

Example

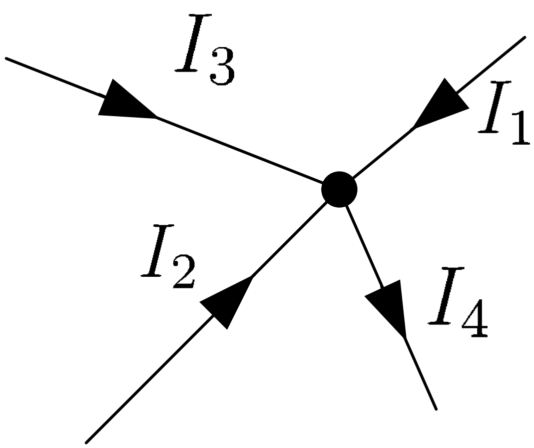
- Calculate the equivalent resistance R_{ab} in the circuit



Kirchhoff's Circuit Laws

- Two important theorems for circuit analysis

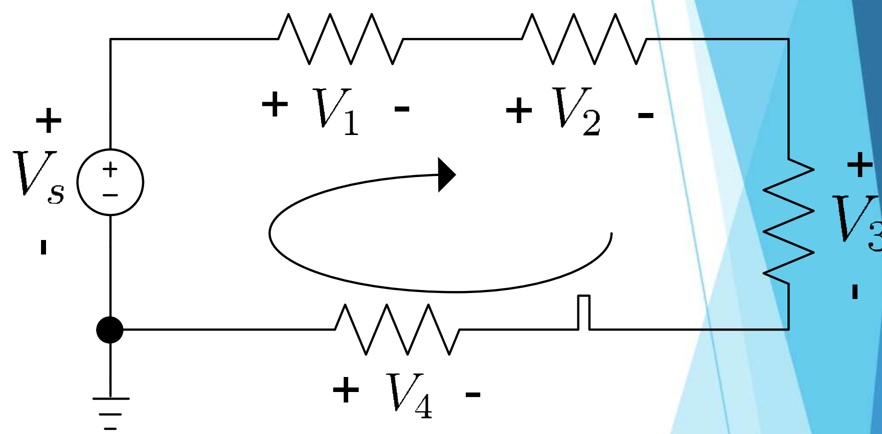
Kirchhoff's Current Law (KCL)



$$I_1 + I_2 + I_3 - I_4 = 0$$

Net Current entering a Node = 0

Kirchhoff's Voltage Law (KVL)



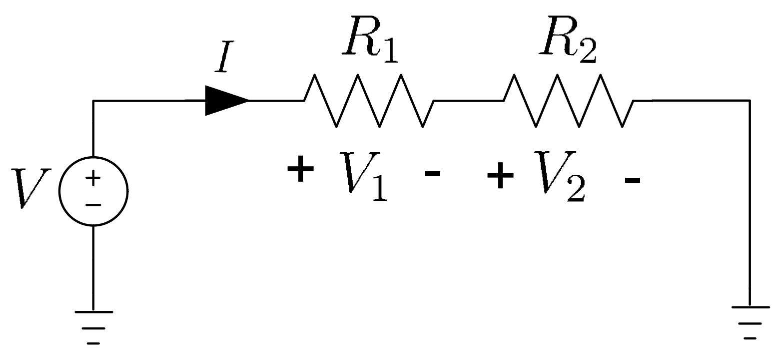
$$-V_s + V_1 + V_2 + V_3 - V_4 = 0$$

Net Voltage in a Loop = 0

(**CAUTION**: Mind the direction/sign of current and voltage)

Application - Voltage Divider

- Consider the resistors in series again: (Let $N = 2$)



- The supplied voltage V is divided into two parts

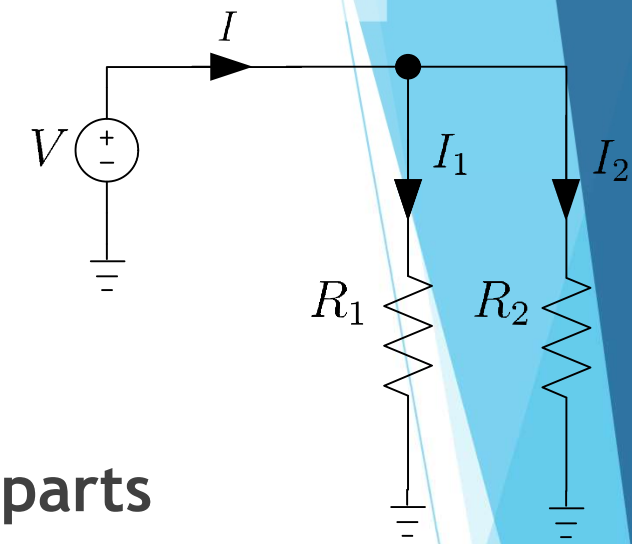
$$I = \frac{V}{R_{eqv}} = \frac{V}{R_1 + R_2}$$

$$\Rightarrow \quad V_1 = \frac{R_1}{R_1 + R_2} V \text{ and } V_2 = \frac{R_2}{R_1 + R_2} V$$

- This principle is called the Voltage Divider

Application - Current Divider

- Consider the resistors in parallel: (Let $N = 2$)



- The current I is divided into two parts

$$I = I_1 + I_2 \text{ with } I_1 = \frac{V}{R_1} \text{ and } I_2 = \frac{V}{R_2}$$

$$\Rightarrow \quad I_1 = \frac{IR_{eqv}}{R_1} = \frac{IR_2}{R_1 + R_2} \text{ and } I_2 = \frac{IR_{eqv}}{R_2} = \frac{IR_1}{R_1 + R_2}$$

- More current flows in the branch with less resistance
- This principle is called the Current Divider

Additional Note

Units and Dimensions

- International System of Units (SI) takes the convenience of the base 10 (decimal) system.
- A prefix may be added to a unit to produce a multiple (power of 10) of the original unit.

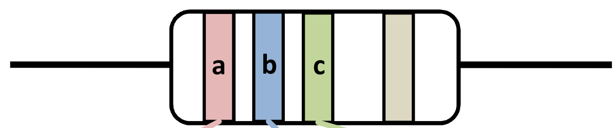
Name	deca-	hecto-	kilo-	mega-	giga-	tera-	peta-
Symbol	da	h	k	M	G	T	P
Factor	10^{1}	10^{2}	10^{3}	10^{6}	10^{9}	10^{12}	10^{15}

Name	deci-	centi-	milli-	micro-	nano-	pico-	femto-
Symbol	d	c	m	μ	n	p	f
Factor	10^{-1}	10^{-2}	10^{-3}	10^{-6}	10^{-9}	10^{-12}	10^{-15}

Example 1: 10 mA = 10×10^{-3} A = 0.01A
Example 2: 0.3 MΩ = 0.3×10^{6} Ω = 300 000 Ω

Electronic Color Code

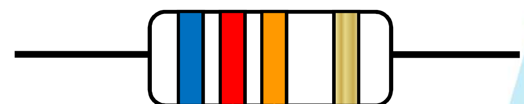
- Resistor



Resistance = [(a 's value) x 10 + (b 's value)] x (c 's multiplier)

Color	Value	Multiplier
Black	0	×1
Brown	1	×10
Red	2	×100
Orange	3	×1 000
Yellow	4	×10 000
Green	5	×100 000
Blue	6	×1 000 000
Purple	7	×10 000 000
Grey	8	×100 000 000
White	9	×1 000 000 000

Example:



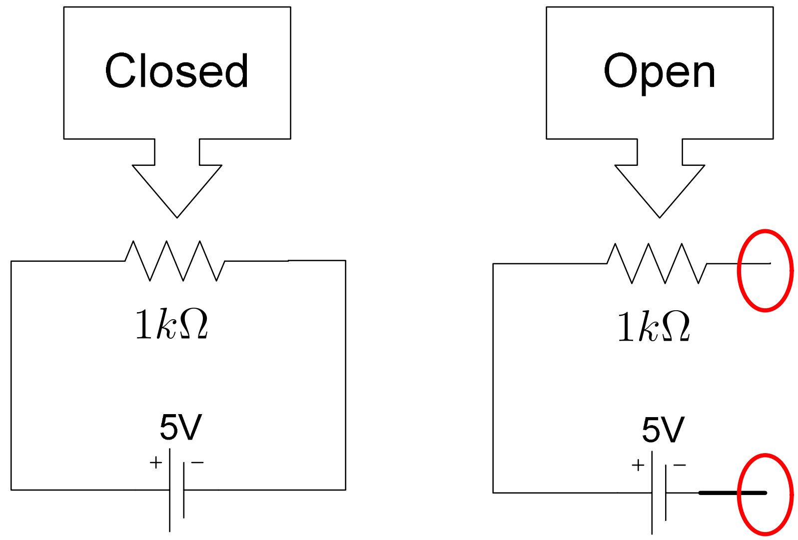
Resistance = Blue Red Orange

= 6 2 × 1000

= 62000 Ω

Basic Rules for Connecting a Circuit

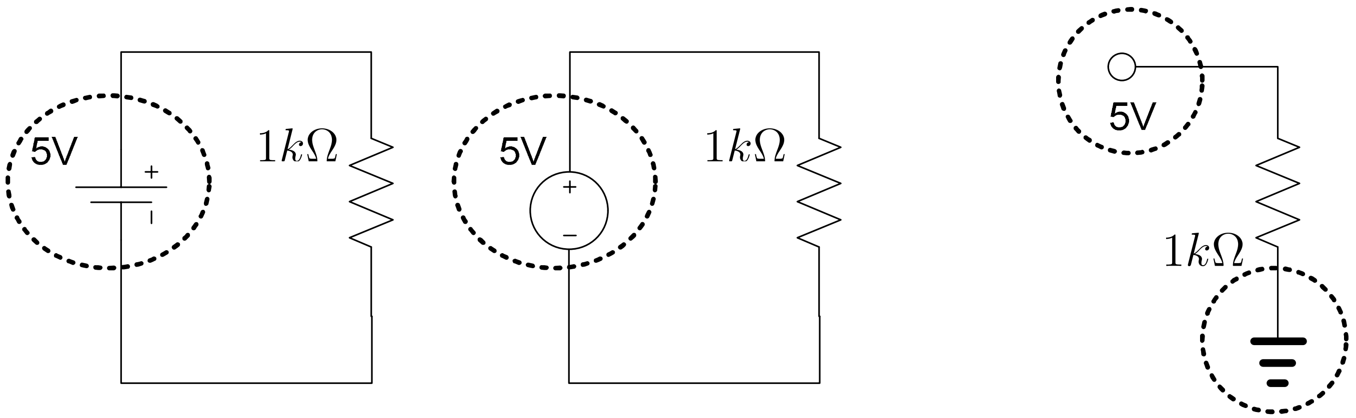
- **Rule #1**: A circuit must contain a closed loop



- Without a closed loop, a circuit is said to be open
- An open circuit cannot function as there is no returning path for current

Basic Rules for Connecting a Circuit

- **Rule #2**: A circuit (usually) contain a power source



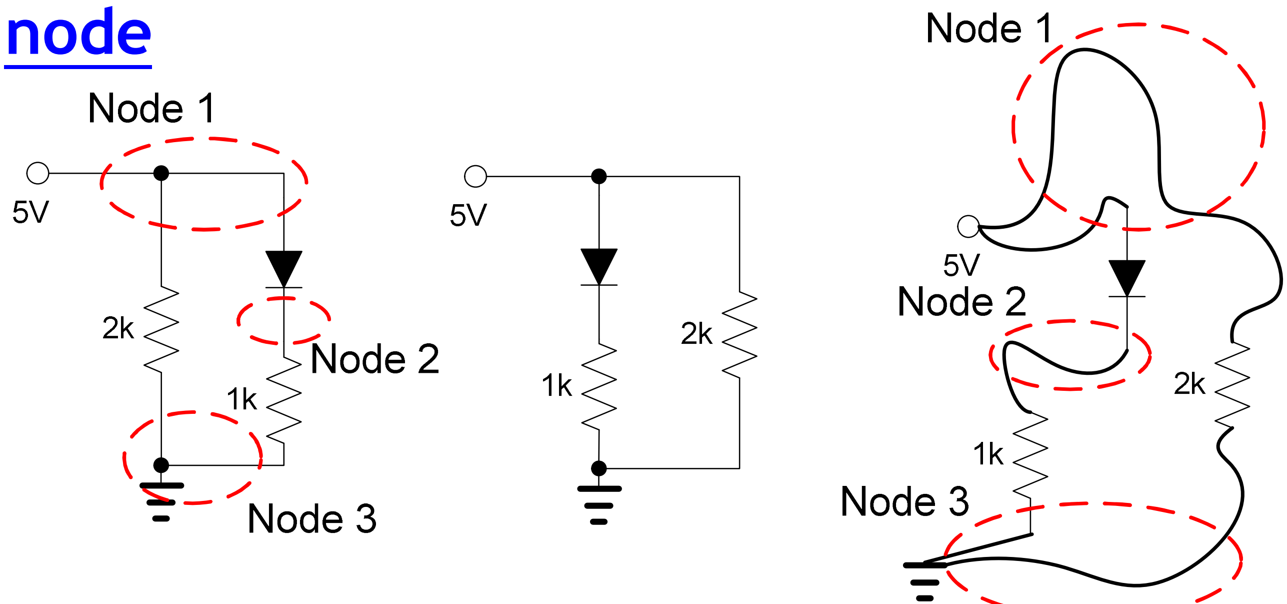
a) a battery b) a DC source c) nodal representation

Showing different ways of representing a power source

- The power source provides power to make the circuit functions

Basic Rules for Connecting a Circuit

- **Rule #3**: Electronic components are connected to a <u>node</u>



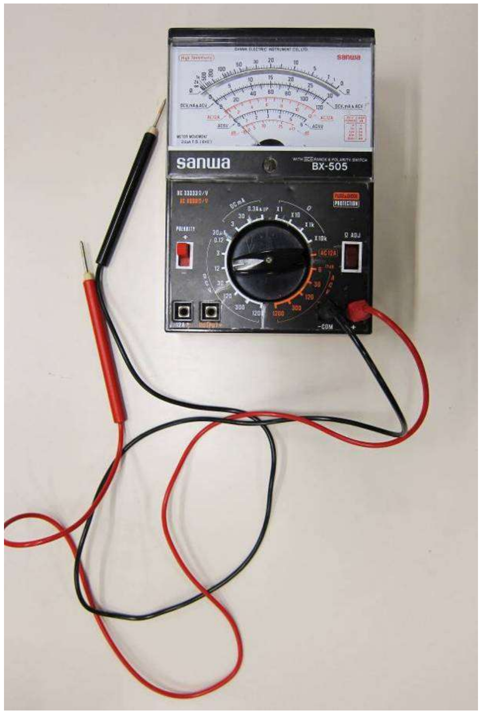
Three seemingly different schematics.
They are actually describing the same circuit.

- The lines in a schematic serve only one purpose - to make connections between components

Measurement of Voltage, Current and Resistance

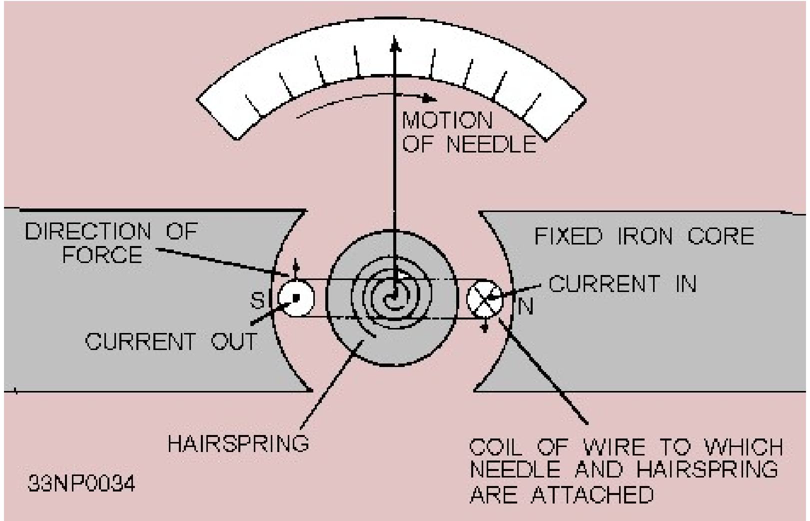
Measurement of Voltage & Current

- **Multimeters** are all-in-one devices that measure different electrical quantities
  - Current (I), voltage (V), resistance (R) in one device.



Application - Ammeter

- Ammeters are devices that measure the Current (I)



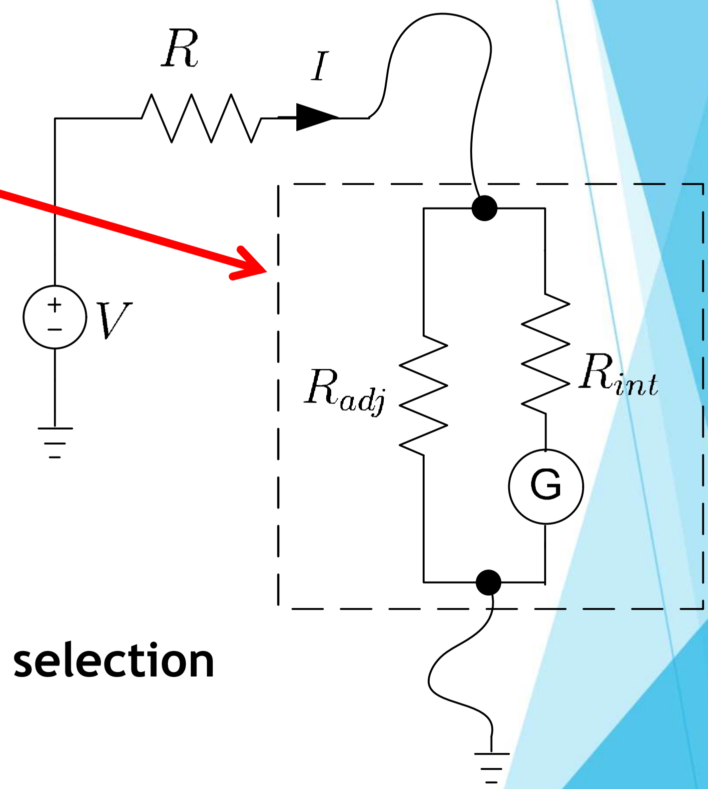
Source: http://www.tpub.com/neets/book16/68.htm

- Galvanometer (found in the analog ammeters)
  - The needle movement is proportional to the current
  - Typical range: from 0A to 1mA

Application - Ammeter

- Using an ammeter to measure current at a point:
  - "Break" the circuit and insert the ammeter

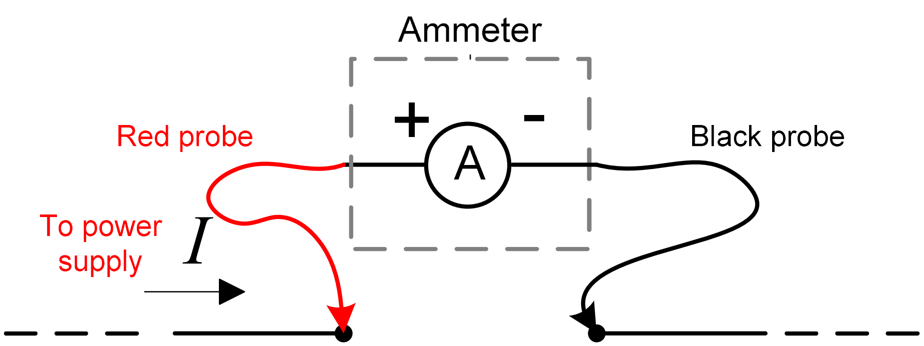
Equivalent model of an ammeter



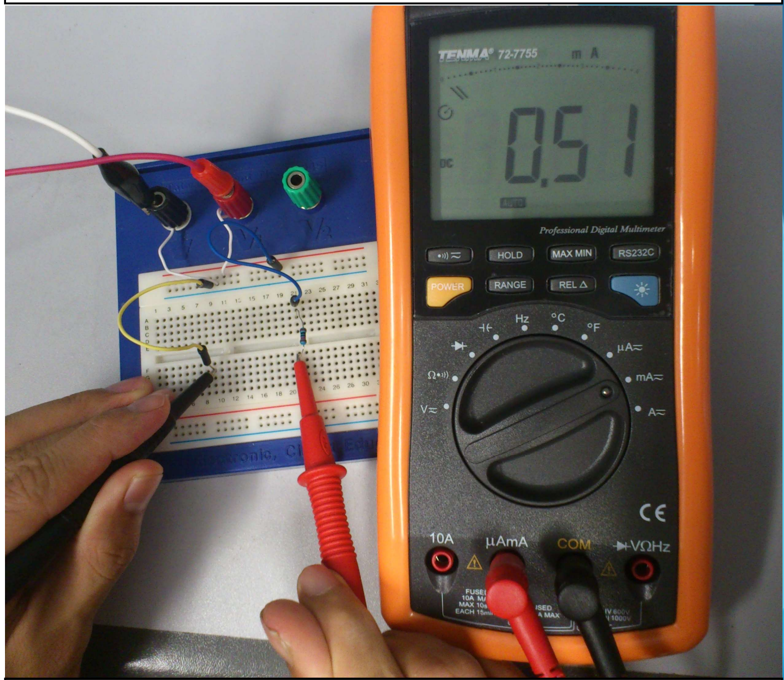
R_{int} - The internal resistance of the galvanometer

R_{adj} - can be adjusted for range selection (current divider)

Application - Ammeter



The current reading is 0.51 mA

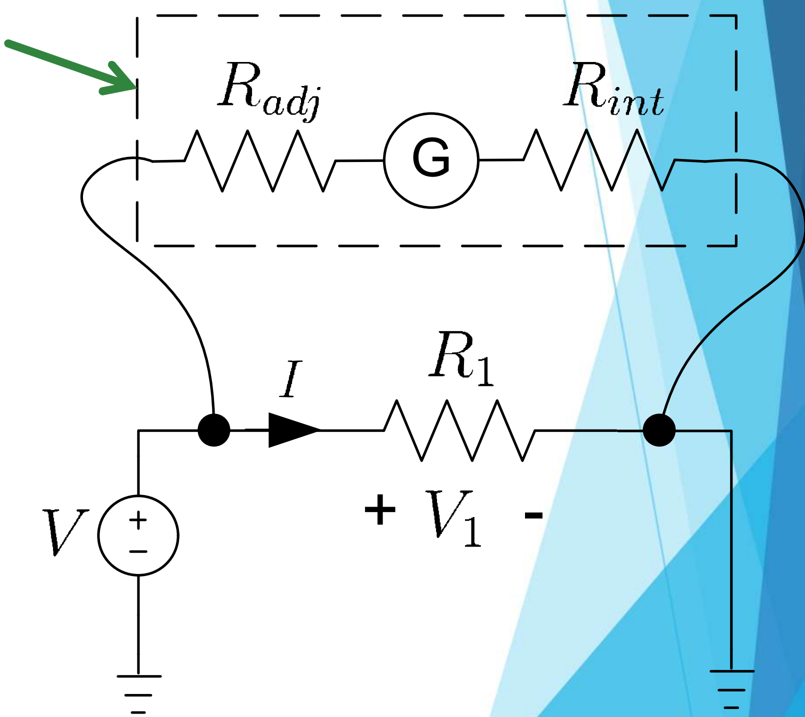


Circuit connected in series

Application - Voltmeter

- **Voltmeters** are devices that measure the **Voltage (V)**:
  - Voltage is defined relatively -> must be measured "between two points"

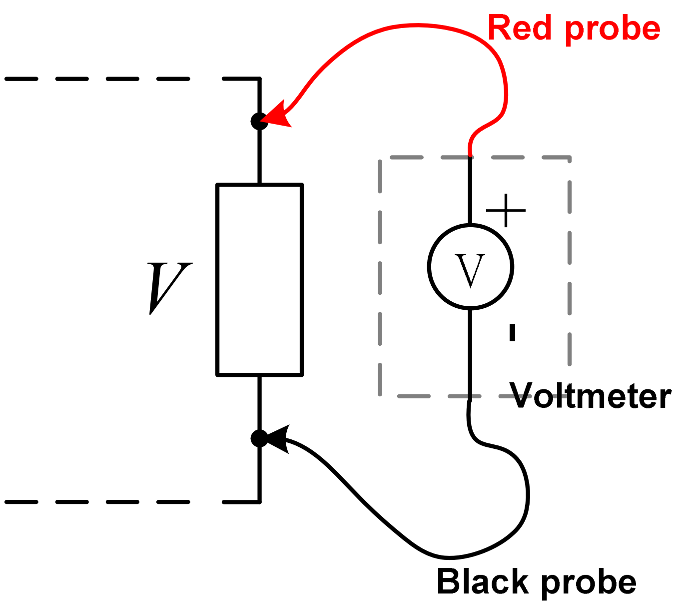
Equivalent model of a voltmeter



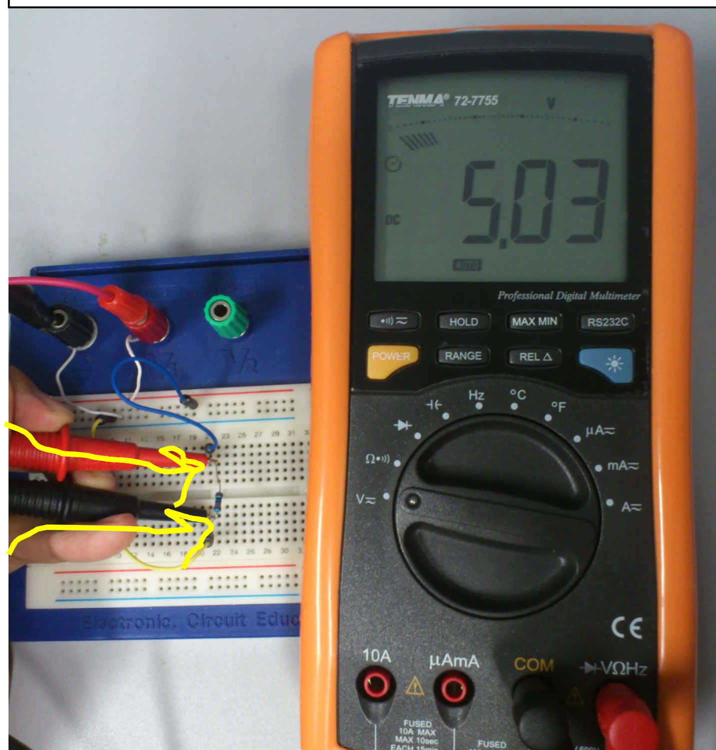
R_{adj}

- very large, typical range = 200k Ω - 1M Ω
  $\rightarrow$ only a small current will flow through the voltmeter (current divider)
- can be adjusted to select the range

Application - Voltmeter



The voltage reading is 5.03 V

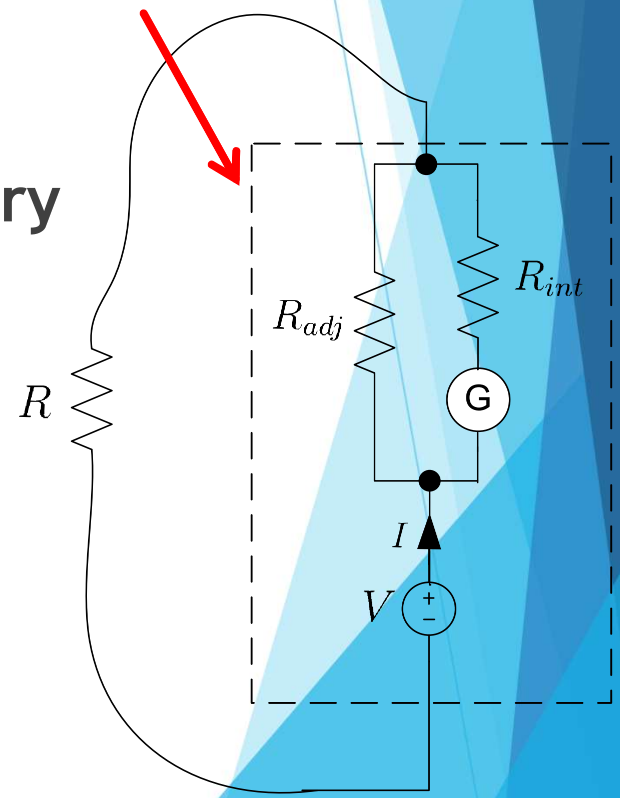


Circuit connected in parallel

Application - Ohmmeter

- Ohmmeters are devices that measure the Resistance (R):
  - Resistance is also defined between two points
  - Just like the voltmeter

Equivalent model of an ohmmeter



- An ohmmeter = An ammeter + Battery

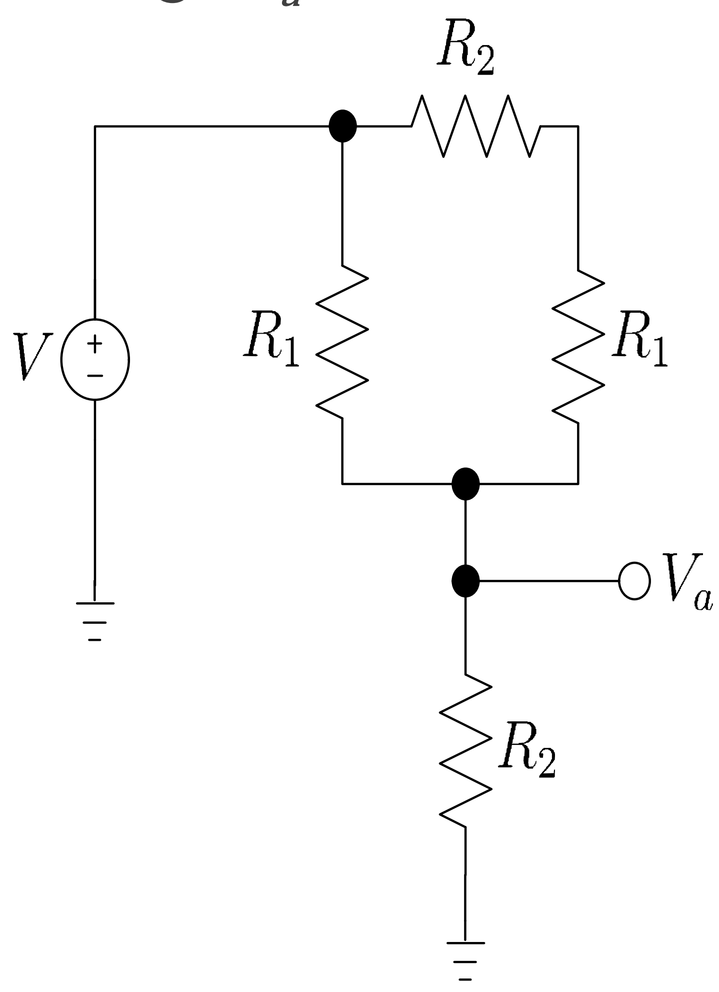
- From Ohm's Law,

$$R = \frac{V}{I}$$

Take-Home Exercises

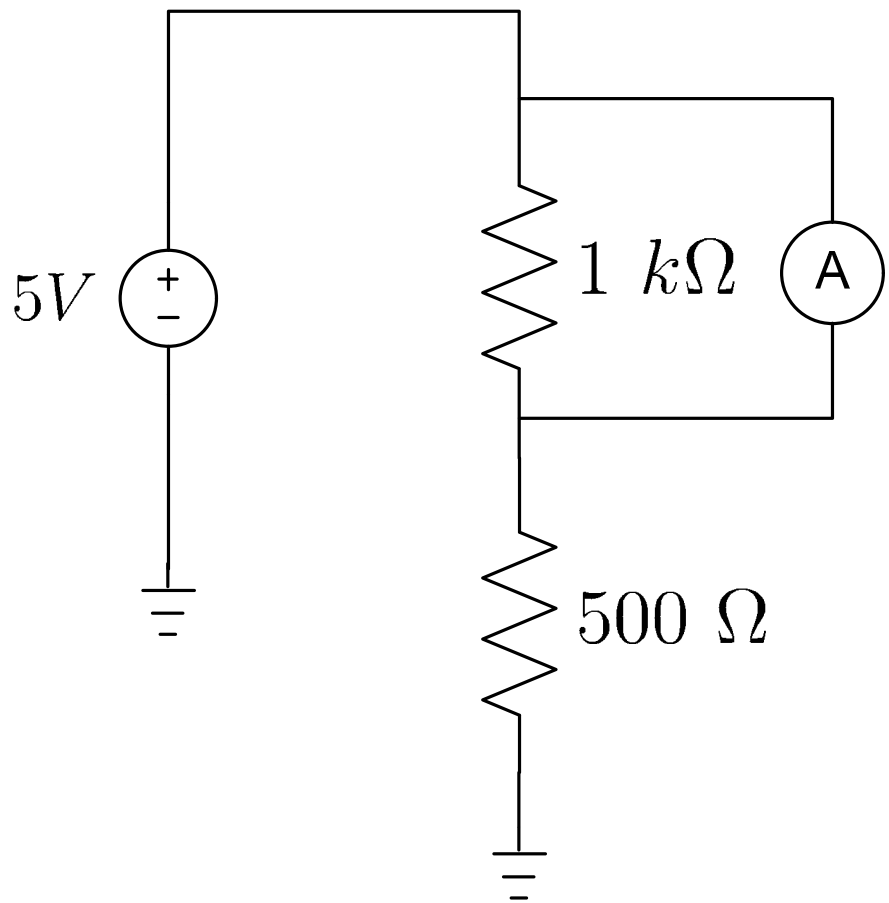
Question 1

- Express the voltage V_a as a function of V, R_1 and R_2



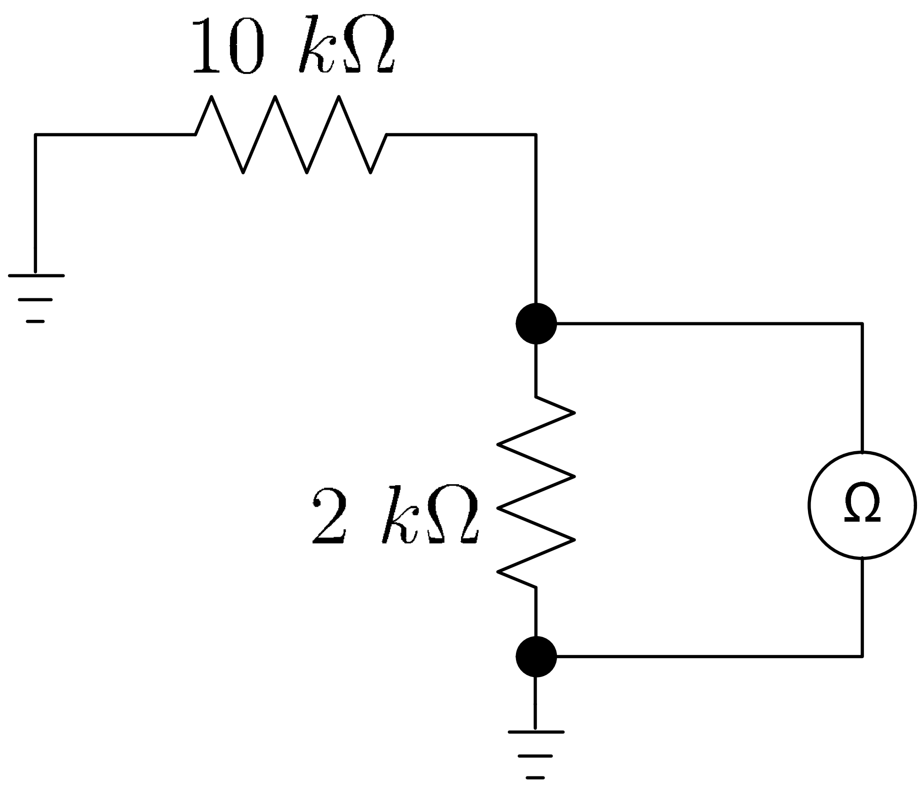
Question 2

- What is the current measured by the ammeter?



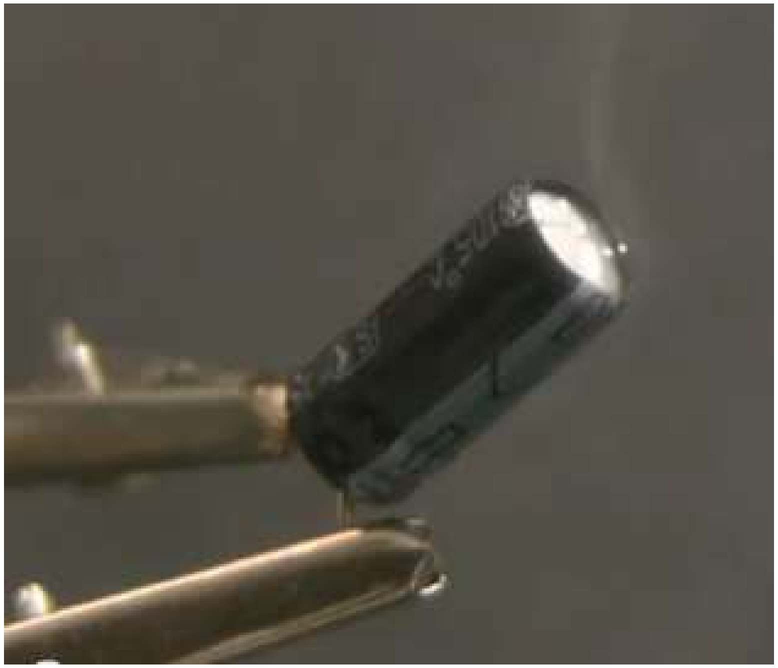
Question 3

- What is the resistance measured by the ohmmeter?



Laboratory Safety

- You probably don't want to do this in the lab ...



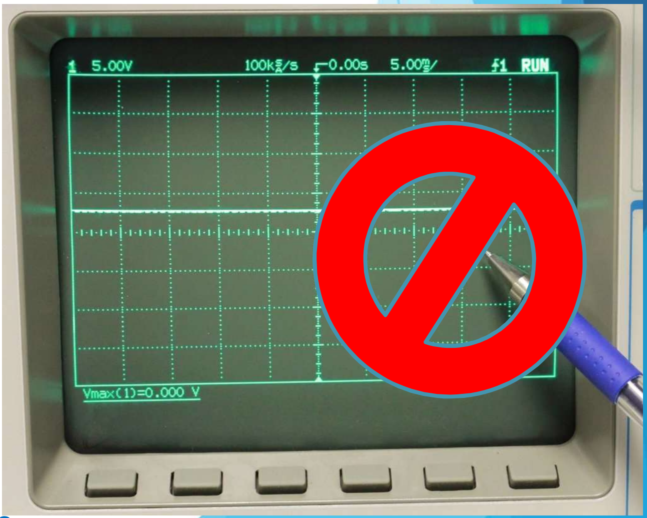
http://www.youtube.com/watch?v=JCPXckfT-6g

Appropriate Dressing

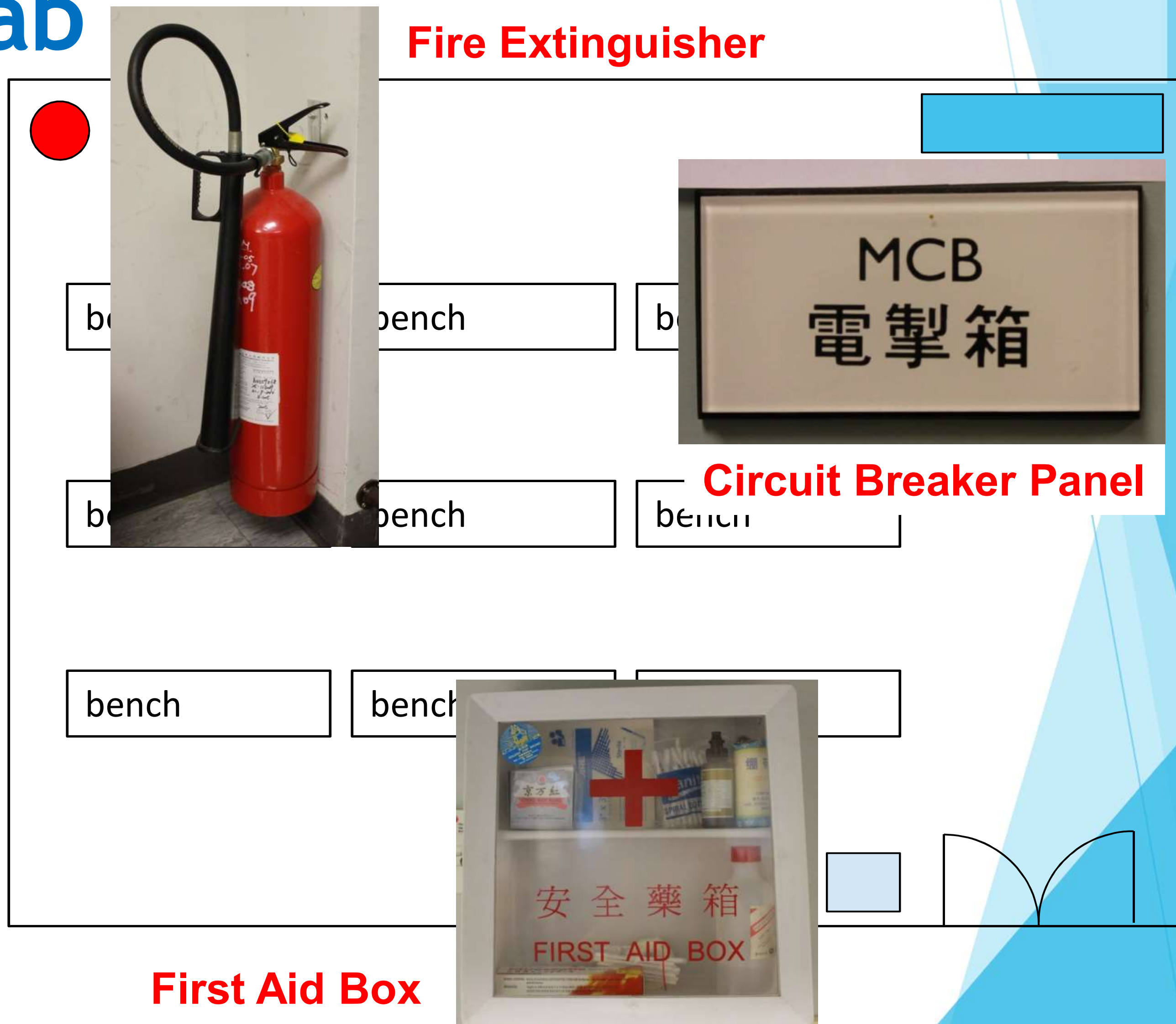
- **Hair**: Long hair must be tied or restrained to prevent accidental contact with lab equipment
- **Dressing**: Loose or hanging clothing must not be worn (ties, scarves)
- **Footwear**: due to the risk of electric shock, bare feet are never allowed in any lab area at any time
- **Soldering**:
  - Anyone doing any soldering work in the laboratory areas must wear a shirt, long pants or long skirt, socks and covered shoes
  - Prevent the possibility of severe burns resulting from the splashing or dripping of hot liquefied solder

Proper Attire

- Lab benches must be kept in neat order and returned to the condition found when you are finished
- We are sharing the labs with other courses and students. Don’t be selfish!
- No food and drink should be consumed at the lab benches
- Do not use a pen as pointer when reading meters or oscilloscope
- No horseplay!
- Beware of slops, trips and falls



Understanding the Floor Plan of your Lab



Know Your Equipment

- Always print and study the lab manual before coming to the lab, ask your TAs if you have any questions
- Do not drop any equipment
- Make circuit connections with all the power sources off
- Activate adjustable power sources at a low level when powering an untested circuit
- Make sure that all components and instrumentation have the proper ratings and are used on the appropriate range

Minor Injury

- Turn off any equipment/machinery involved
- Perform appropriate first aid
- Inform lab instructor, seek medical assistance as appropriate
  - Call the University Health Center (UHS) on 3943 6423 on weekdays.

Emergency Procedure: Electrical Shock

- Do not touch someone who is electrocuted
- If it is possible to do so safely, turn off the power supply
- Otherwise, use a piece of lumber or other non-conducting material to separate the person from the energized conductor
- Check the afflicted person for pulse and respiration
- Only qualified individuals should attempt CPR.
- In cases of electrocution, medical assistance should be summoned immediately

Emergency Procedure: Fire

- Turn on a fire alarm if you have any doubt that you may fail to put out the fire. Turn on a fire alarm for any serious emergency such as toxic gas release or explosion
- Use a laboratory fire extinguisher on incipient fires. When possible, use CO2 units instead of dry chemical units where instruments are involved to minimize damage
- Take an extinguisher with you to check out an area where there may be a fire
- After using a fire extinguisher, turn it in for replacement
- If an individual's clothing is on fire, roll them on the floor and wrap them in a coat or blanket if possible
- If you hear a fire alarm in your building, leave the building immediately

Emergency Procedure: Medical Assistance

- For urgent medical attention, go straight to the Accident & Emergency Department of any major hospitals
- The nearest Accident & Emergency Department to the Chinese University is the Prince of Wales Hospital in Shatin, NT
  - Telephone: 2632 3250
  - For ambulance service, dial 2735 3355 (Fire Services Department) or 999. Identify yourself and give your exact location
- It is advisable to notify the Security Office at 3943 7999 so that the ambulance may be directed to the exact location more readily

References

- University Safety & Environment Office (USEO)

  http://www.cuhk.edu.hk/useo

- University Health Service

  http://www.cuhk.edu.hk/uhs

- Laboratory Safety Guidelines (Arizona State University)

- ECE Department Undergraduate Laboratory: Safety and Operations Manual (Clarkson University)