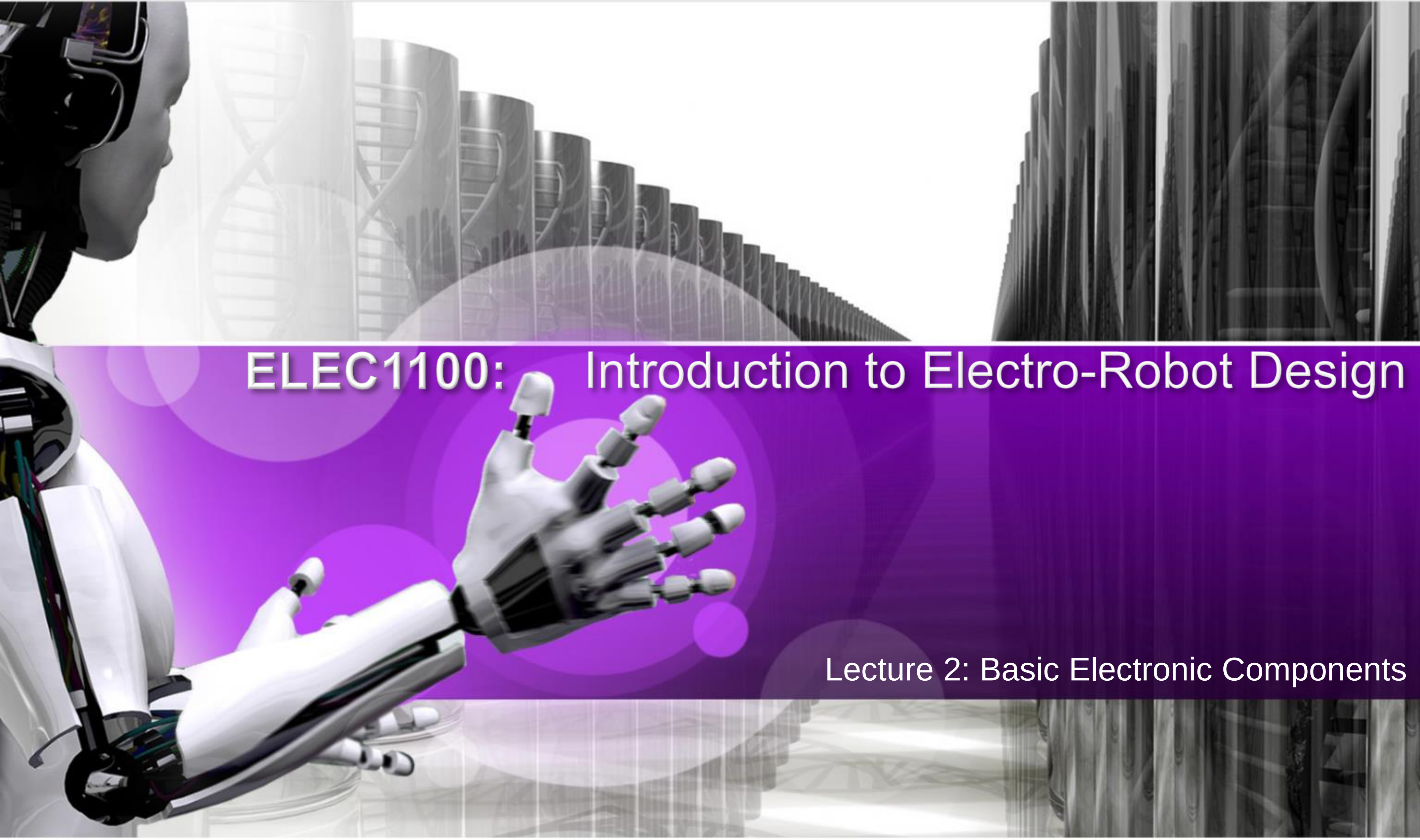
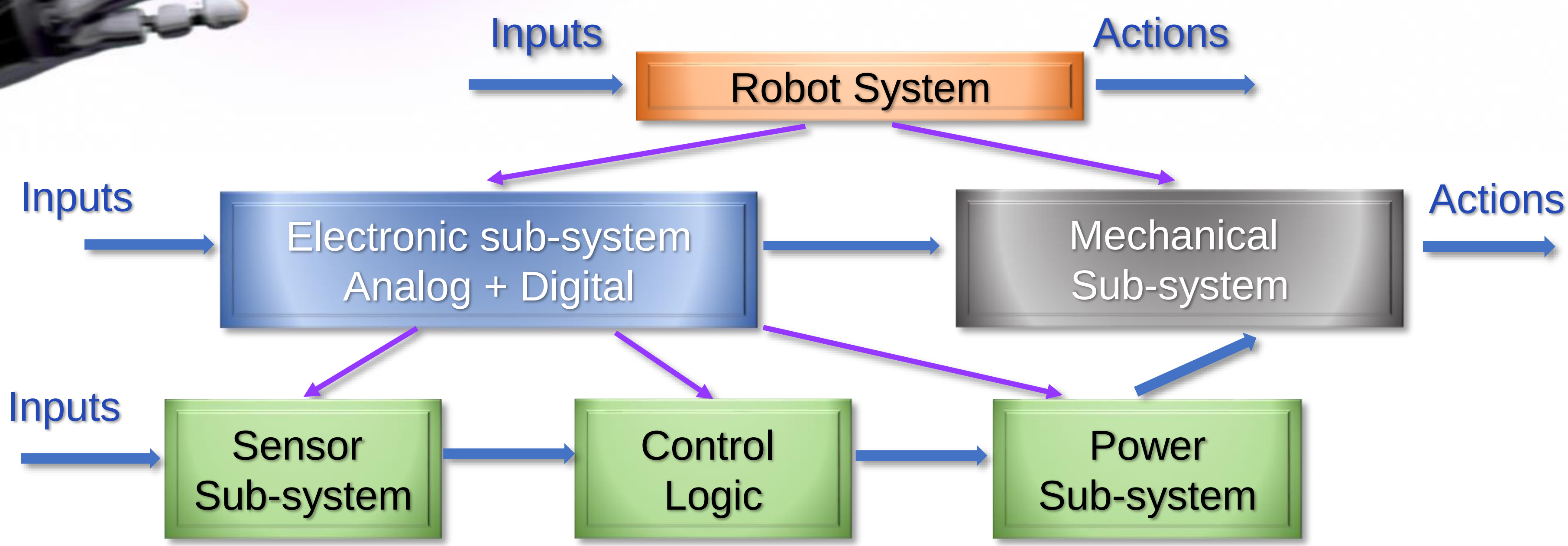


ELEC1100: Introduction to Electro-Robot Design

Lecture 2: Basic Electronic Components

SONG Shenghui and MURCH Ross, Dept. of ECE, HKUST

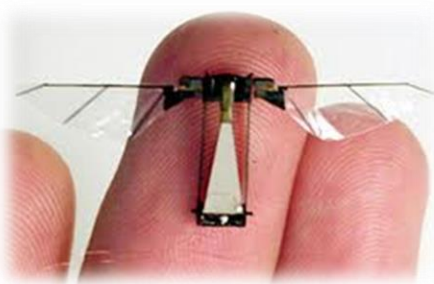
ELEC1100 ROADMAP



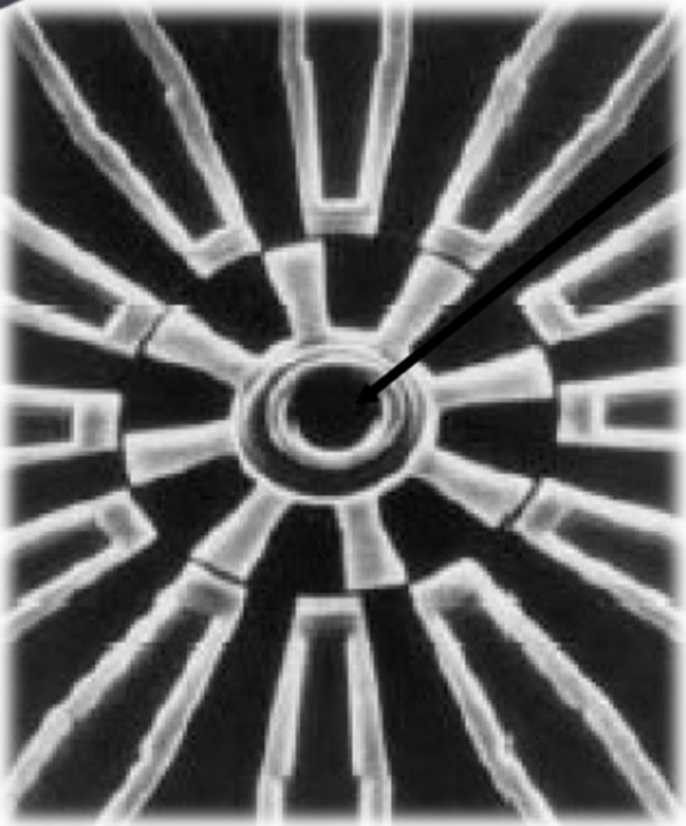
Basic electronics:
Wk1: Basic Electronics - Charge/Current/Voltage/Resistor

ECE AND ROBOTICS

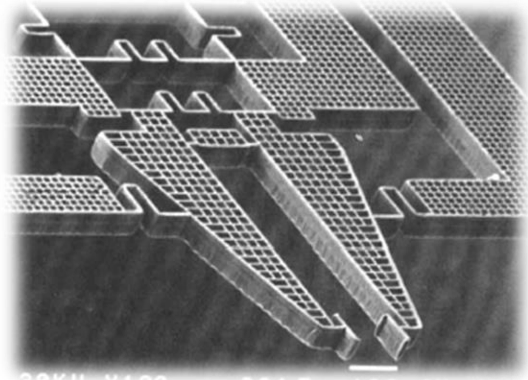
- Different areas of ECE relevant to Robotics
  - Nanoelectronics – fundamental hardware
  - Micro-electro-mechanical systems (MEMS) – micro-robots, sensors
  - Integrated-Circuit and Systems – control system
  - Photonics – sensors
  - Multimedia and signal processing – information processing
  - System and Automation – control system
  - Wireless communication and networking – robot communications
  - Computer Engineering – decision making

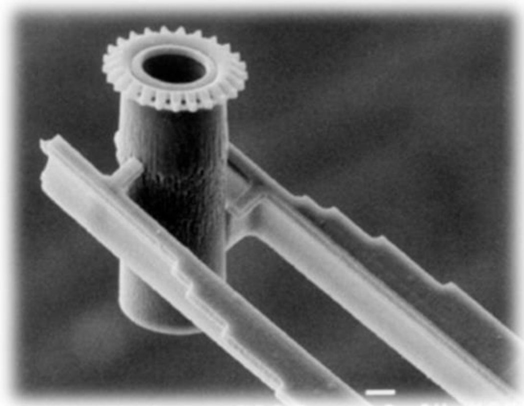


MICRO ROBOT EXAMPLES

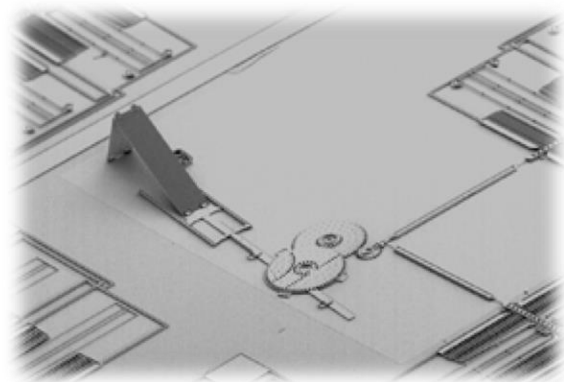


Electrostatic Micro Motor





Micro Tweezers

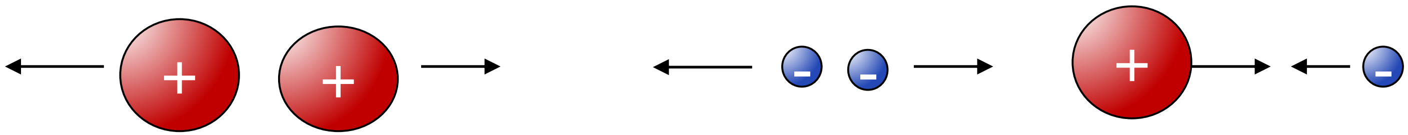


Micro Manipulator

BASIC ELECTRICAL QUANTITIES

- Atom structure
  - fundamental element of matter
  - consists of protons, neutrons, and electrons
  - +ve charge (proton)
  - –ve charge (electron)

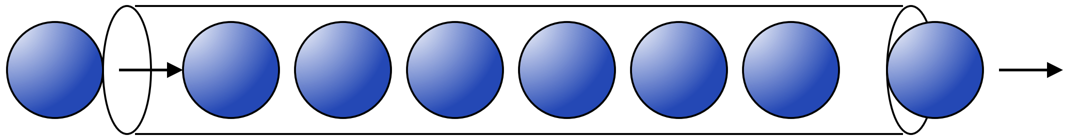
- Opposite charges attract, like charges repel



  - An atom is electrically neutral: same number of protons and electrons
  - Smallest amount of charge: q (charge for 1 electron) $-q = -1.6\times10^{-19}$C
  - Electrons at the farthest orbit can be added and removed from the orbit easier than that in other orbits

CONDUCTORS AND INSULATORS

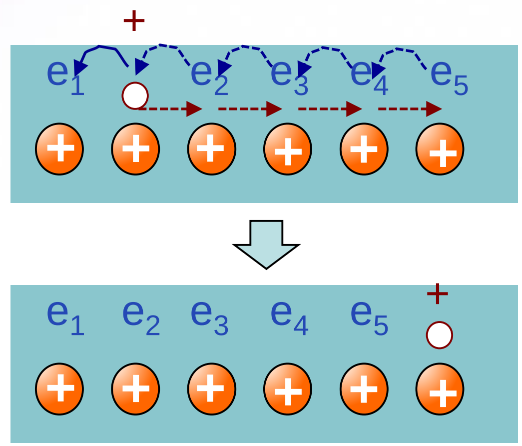
- Some atoms require less energy to remove the outer electrons for conduction – Conductors
  - Materials through which charge flows readily: low resistance
- Some atoms are difficult to lose electrons – Insulators
  - Materials that do not allow charge to move easily: high resistance
- Charges flow through a conductor:



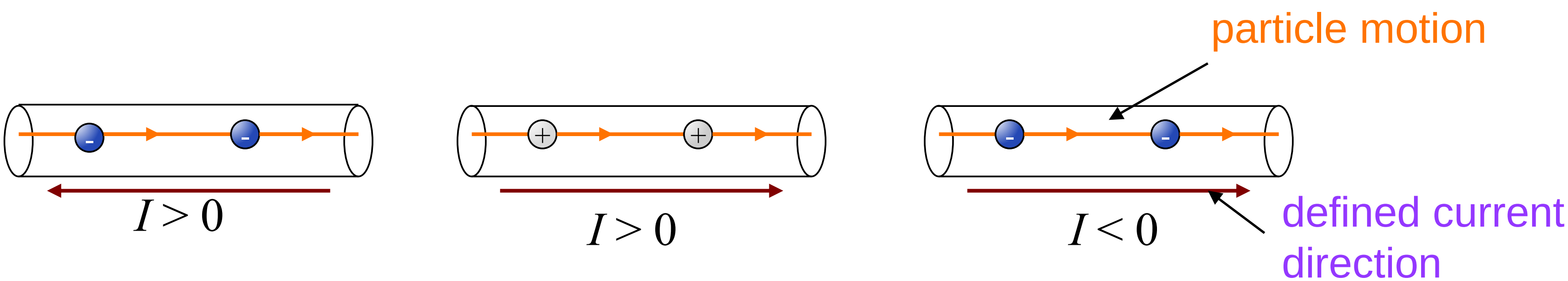
CURRENT

- Current is the orderly movement of charged particles and is equal to the rate of flow of charges
- Symbol: I
- Unit: ampere (A)
- 1 ampere = transfer of one coulomb in one second (1C/s)
- Direction of current flow:
  - Electron is negative charge by definition
  - So positive current flow (i.e. $I > 0$) is opposing the flow of electrons

EXPLANATION OF CURRENT FLOW



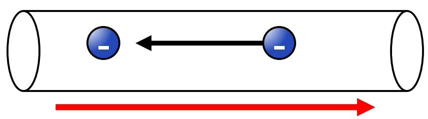
- The current generated by a negative charge moving to the left is equivalent to the current generated by a positive charge moving to the right.
- Current convention



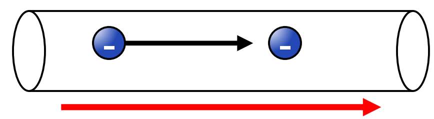
QUIZ [1]: CURRENT FLOW

- For the following diagrams, select all with current flowing in the positive direction according to the red arrow

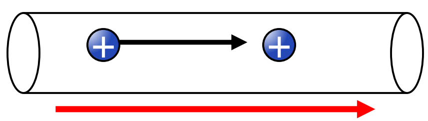
(1)



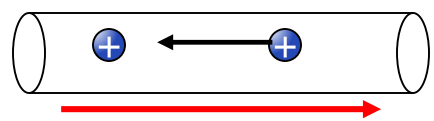
(2)



(3)



(4)



CURRENT AND CHARGE

- Current is the rate of flow of charge
  - Average current is given by $I = \dfrac{\Delta q}{\Delta t}$

- Examples
  - Q1: An electric heater operated from a dc source that provides 8.2×10^{21} electrons in 10 seconds. How much current in amperes (A) is flowing through the heater?

  - Some numbers you need to know:
    - one electron contain 1.6×10^{-19}C of charge
    - 1 amperes is also equal to 1C/s

CURRENT AND CHARGE: EXERCISE [1]

- Current is the rate of flow of charge
  - Average current is given by $I = \frac{\Delta q}{\Delta t}$
- Examples
  - Q1: An electric heater operated from a dc source that provides 8.2×10^{21} electrons in 10 seconds. How much current in amperes (A) is flowing through the heater?

  - Answer:

$$I = \frac{\Delta q}{\Delta t} = \frac{1.6\times10^{-19}C\times8.2\times10^{21}}{10s} = 131.2\text{A}$$

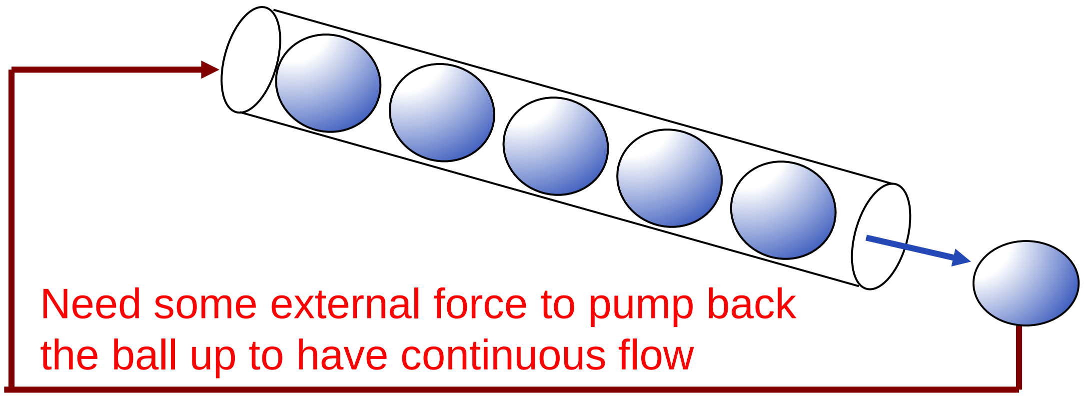
CURRENT AND CHARGE: EXERCISE [2]

- Current is the rate of flow of charge
  - Average current is given by $I = \frac{\Delta q}{\Delta t}$
- Examples
  - Q2: If a battery delivers a current of 50A when the car is started, and the starting time is 4 seconds, how many electrons flow out of the battery?
  - Answer:

$$I = \frac{\Delta q}{\Delta t} \Rightarrow 50A = \frac{1.6\times10^{-19}C\times n}{4s} \Rightarrow n = \frac{50A\times4s}{1.6\times10^{-19}C} = 1.25 \times 10^{21}$$

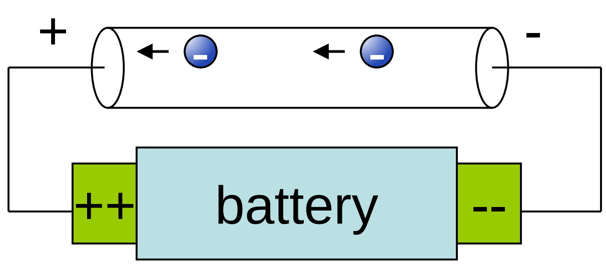
VOLTAGE [1]

- In order to have current flow between two points, we need to have a "voltage difference" between these two points
- Analogy to water flow or ball flow inside a tube
  - In order to have the balls flow, the tube needs to be tilted and the gravitational force will make the balls flow
  - The gravitational potential energy depends on the difference in the height of the two ends of the tube



VOLTAGE [2]

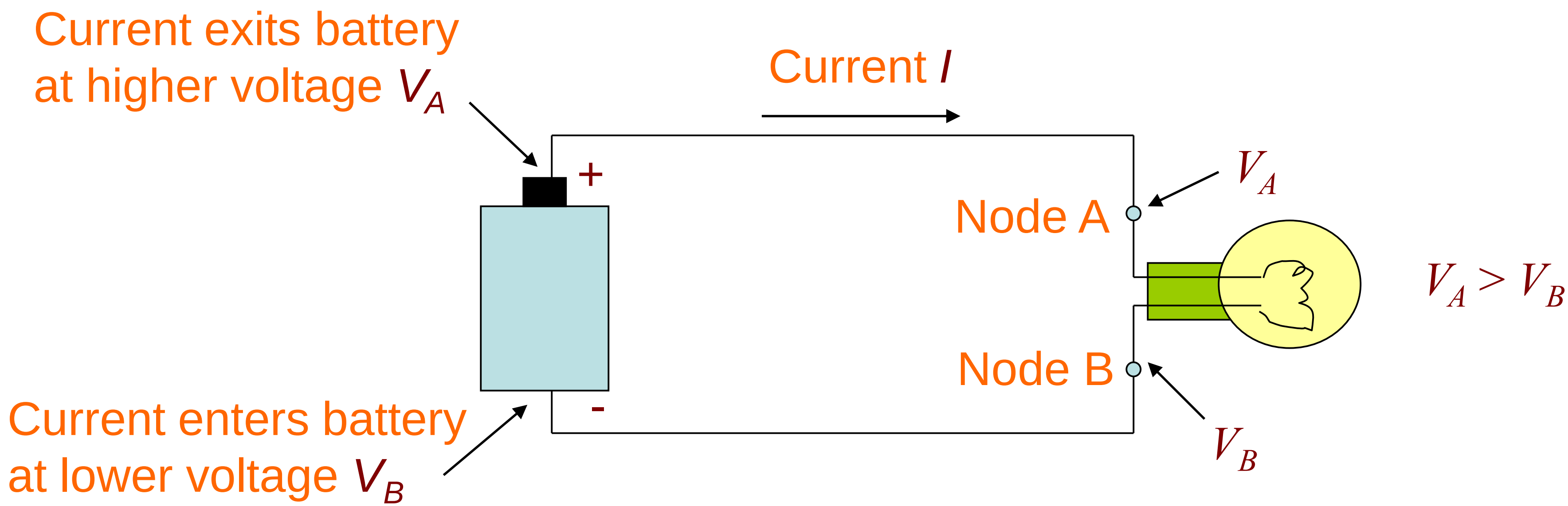
- To have current flow between two points, we need to have a connection (wire) and a voltage difference between them
- The two points have different polarity and hence have potential difference
  - We need some external source to move back the +ve charge from the -ve terminal to +ve terminal or -ve charge from the +ve terminal to -ve terminal in order to have continuous current flow
  - Example: a battery uses chemical energy to move the electrons



The voltage difference that a battery generates between its +ve and -ve terminals is a function of its internal chemistry, e.g., voltage of an AAA battery is about 1.5 Volt

VOLTAGE [3]

- Symbol: V;
- Unit: volt or V
- Voltage source example: a battery
- Node voltage: the potential difference between two nodes of a circuit.



RESISTANCE [1]

- Resistance is the ability of a conducting material to resist the flow of charge (or current)
- For the same voltage difference between two points
  - Large resistance → small current
  - Small resistance → large current
- Ideal wire → ideal conductor → no resistance
- Ideal insulator → infinite resistance
- Real components → finite amount of resistance

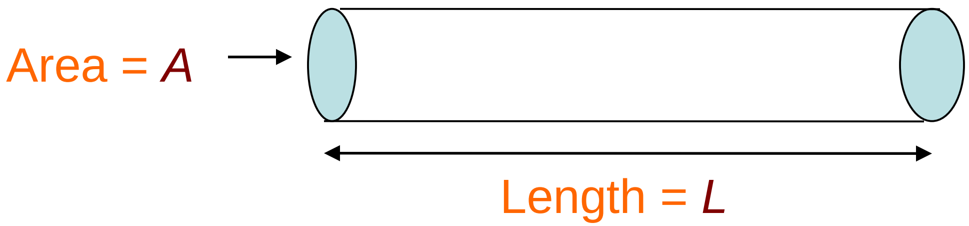
RESISTANCE [2]

- ❖ Effect of resistance

- ❖ Resistance can be added to avoid large current
- ❖ All loads (e.g. light bulbs, motors) and even wires have resistance

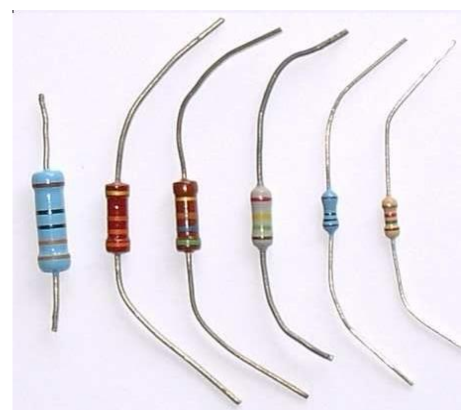
RESISTANCE [3]

- Symbol: R;
- Unit: ohm or Ω
- Resistance of a wire



Resistivity (depends on material)

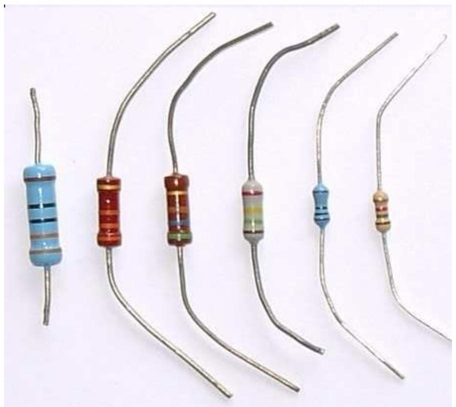
$$R = \rho \times \frac{L}{A}$$

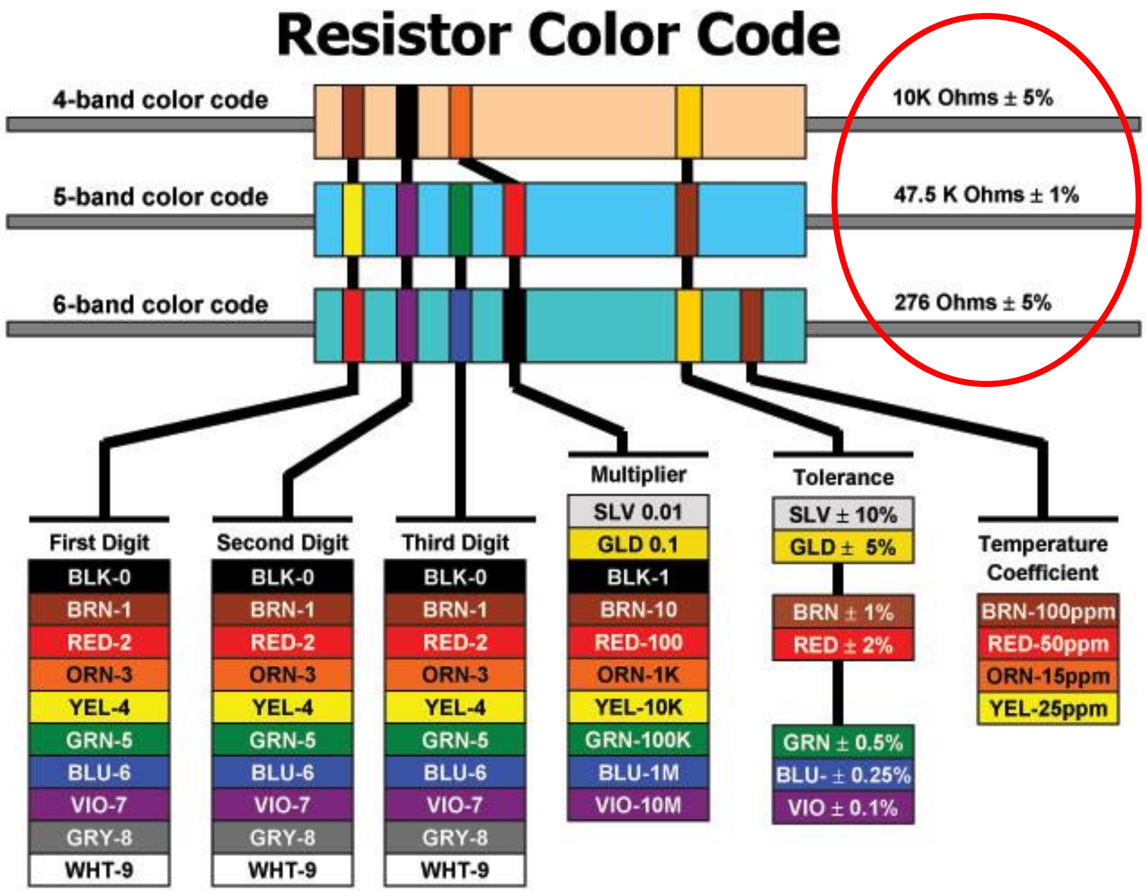


- Resistors can be added to a circuit to limit current flow

RESISTANCE [4]

❖ Color code for resistor values





METRIC PREFIX

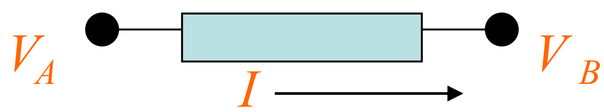
- Can be used for volt, ampere and ohm

	atto = a = 10^{-18}
peta = P = 10^{15}	femto = f = 10^{-15}
tera = T= 10^{12}	pico = p = 10^{-12}
giga = G = 10^{9}	nano = n = 10^{-9}
mega = M = 10^{6}	micro = μ = 10^{-6}
kilo = k = 10^{3}	milli = m = 10^{-3}

- e.g. 10 MΩ = 10000000 Ω; 5 mA = 0.005 A

OHM'S LAW AND I-V CURVE

- Ohm's Law: current as a function of voltage

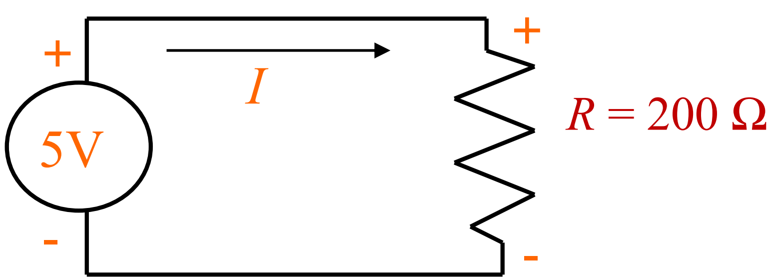


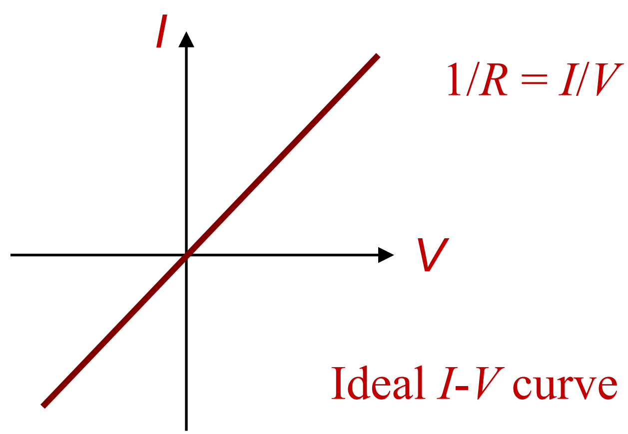
$V = V_A - V_B$

- Question: given *V*, what is *I*?

$$V = I \times R \quad \text{or} \quad I = \frac{V}{R}$$

- I-V curve

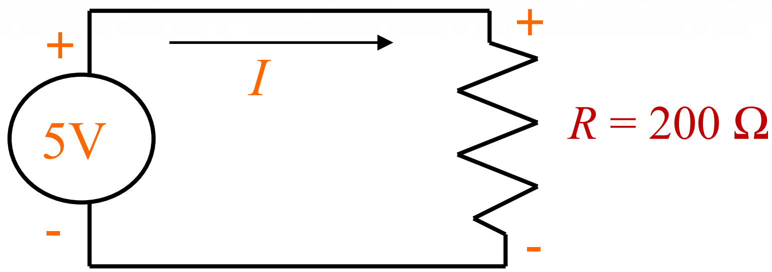




Ideal *I-V* curve

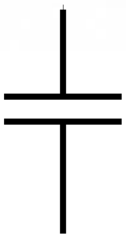
QUIZ [2]: OHM'S LAW

❖ For the following circuit, calculate the current



CAPACITOR

- A capacitor is a charge storage element



symbol

polyester film capacitor

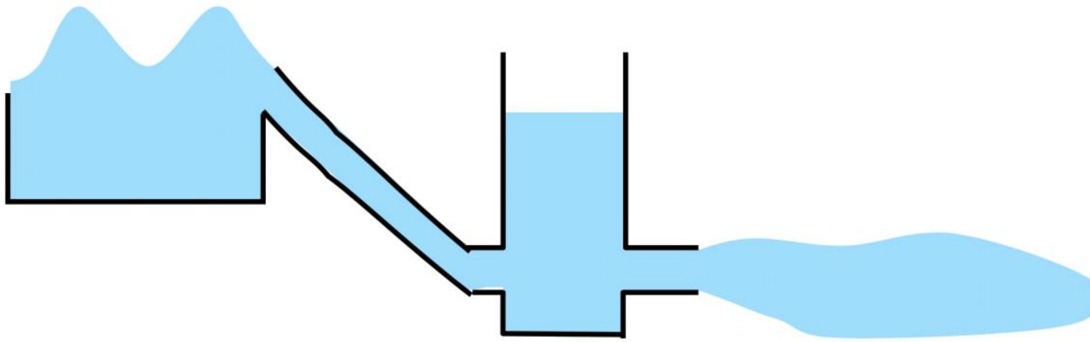
ceramic capacitor

electrolytic capacitor

in circuit board

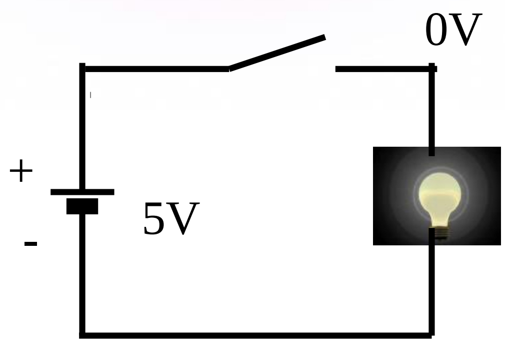
- Analogy

Pool

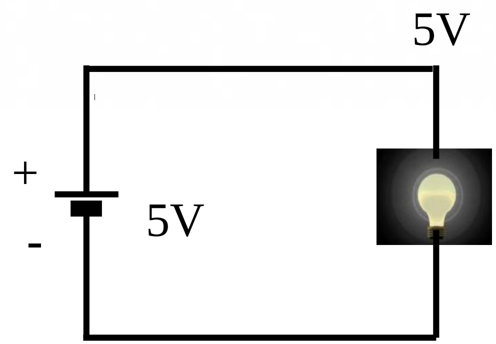


CAPACITOR ACTIONS

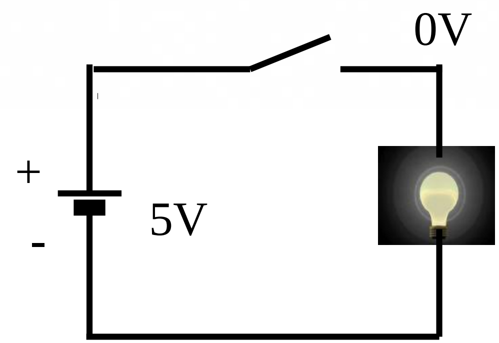
- Without capacitor



Switch is off; lamp is off

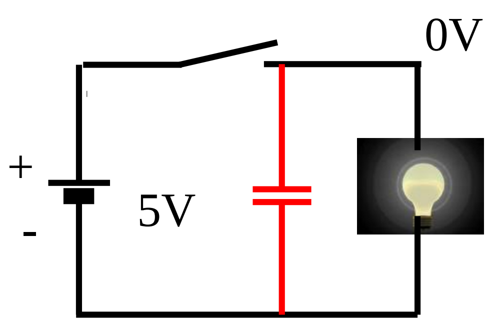


Switch is on; lamp is on

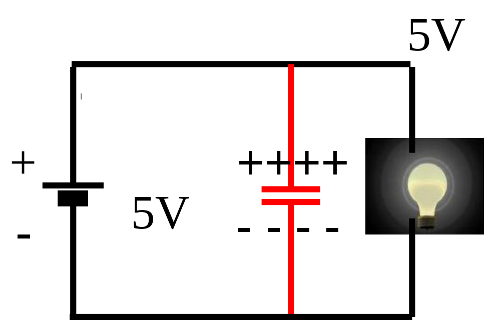


Switch is off; lamp is off

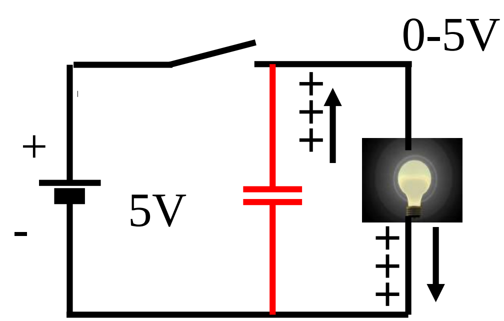
- With capacitor



Lamp is off; capacitor is electrically neutral



Lamp is on; capacitor is charged

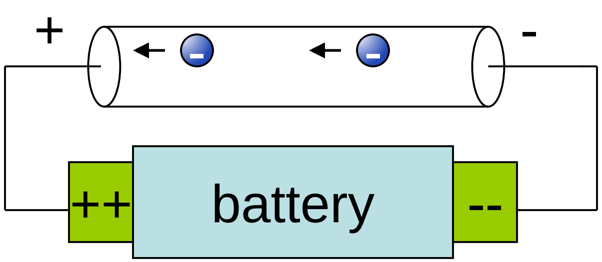


Lamp keeps on for a while; capacitor is discharged

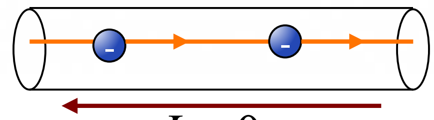
LECTURE SUMMARY

❖ Source of charges

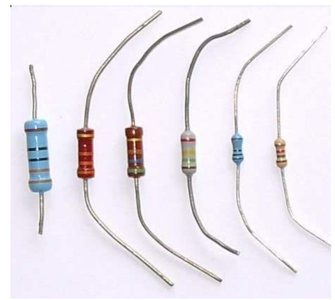
❖ Voltage source



❖ Charge motion and current



❖ Resistor and Ohm's law



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

❖ New element learned

Capacitor:
stabilize system

NEXT LECTURE

- Concept of power and energy
- Power delivery system

QUESTIONS?