Electricity (Part II)

Electrodynamics

In this lecture

- ★Electrodynamics
- ★Electric Current
- ★Conductors and Insulators
- ★Semiconductor
- ★Superconductors
- ★Electric Circuits
- ★Electric Power
- ★DC and AC electricity

Electrodynamics

"The study of electric charges in motion"

Electric Current

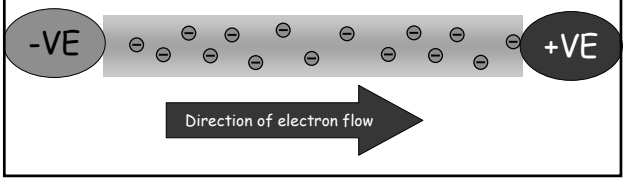
- What happens when we apply an electric potential to a conducting material?
  - charge moves along the wire
- This is called an *Electric Current*

Electric Current is the Flow of electrons

Electric Current

Direction of electric current

- Which way is the current flowing?



Conductors & Insulators

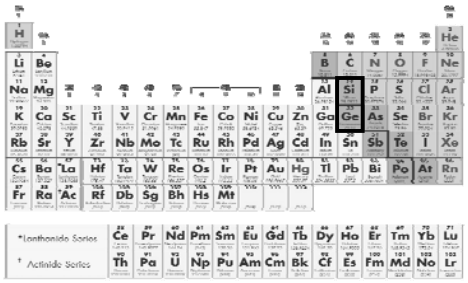
- Conductor
  - Material through which electrons flow easily
- Insulator
  - Material that does not allow electron flow

Semiconductors

- In 1946 William Shockley demonstrated semiconduction
- Materials that under some conditions behave as insulators, whereas under other conditions behaves as conductors
- Led to first transistor & then integrated circuits

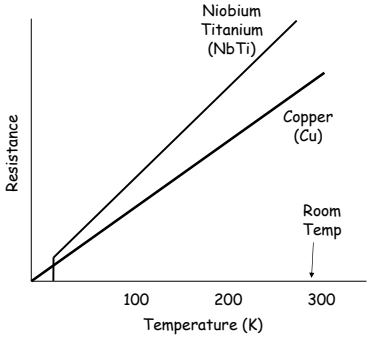
Semiconductors

- Principle semiconducting materials are Silicon (Si) and Germanium (Ge)

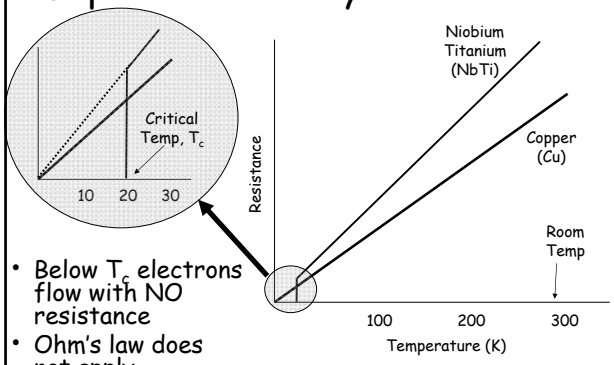


Superconductivity

- At room temperature ALL materials resist the flow of electricity
- Resistance decreases as the temperature of the material is decreased



Superconductivity



- Below T_c electrons flow with NO resistance
- Ohm's law does not apply

Electrical States of Matter

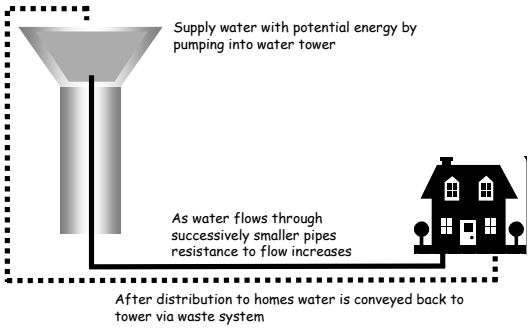
State	Example	Characteristics
Superconductor	Niobium titanium	No resistance to electron flow Current flows without potential
Conductor	Copper Aluminium	Variable resistance Current flows when potential is applied Obeys Ohm's law
Semiconductor	Silicon Germanium	Can be conductive Can be resistive
Insulator	Rubber Glass	Does NOT permit e^- flow

Electric Circuits

- Electrons flow on surface of wire.
- Modifying the wire
  - Changing the diameter or
  - Changing the material (circuit elements)
  - Modifies the electrical resistance
- Electric Circuit results when conductor is made into a closed path

Electric Circuits

Analogy: Public Water System



Electric Current

- Measure of the number of electrons flowing in a circuit
- Units: *Ampere (A)*
- One ampere = One coulomb per second
- Increasing resistance reduces current

Electric Current

- Example: How many electrons flow through a conductor per second if it is carrying 1 ampere?

Ohm's Law

- Electric potential is measured in Volts (V)
- Electrical resistance is measured in Ohms (Ω)
- Behaviour of electric circuits is described by Ohm's Law

"Voltage across the total circuit is equal to the current multiplied by the total resistance"

Ohm's Law

$$V = I\ R$$

Where V is the electric potential in volts,
I is the electric current in amperes,
R is the electrical resistance in ohms.

Can be rearranged…

$$R = V/I \qquad I = V/R$$

Example

- If a current of 0.05 A flows through a conductor that has a resistance of 1K Ω, what is the voltage across the conductor?

$$V = I\ R$$
$$V = 0.05 \times 1000$$
$$V = 50\ volts$$

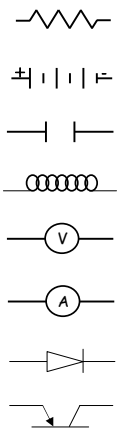
Example

The plug on house hold appliance contains a 2.5 A fuse. What is the maximum total resistance that the appliance can have without blowing the fuse?

$$R = V/I$$
$$R_{max} = 240/2$$
$$R_{max} = 120\Omega$$

Electric Circuits

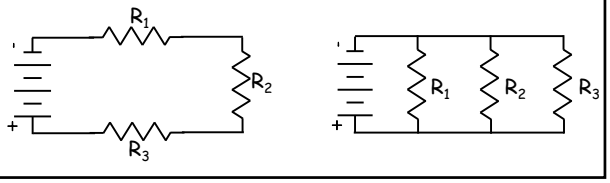
- Generally, electric circuits are very complicated
- Contain many different types of element



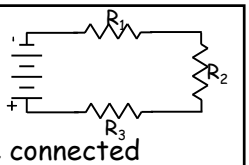
Electric Circuits

- Usually electric circuits can be reduced to one of two basic types:

Series or Parallel



Series Circuits

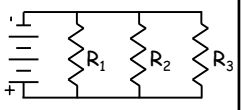


- All circuit elements are connected along the same conductor

Rules

1. Total resistance is equal to the sum of the individual resistances
2. Current through each element is the same & equal to the total circuit current
3. Sum of voltage across each element is equal to the total circuit voltage

Parallel Circuits

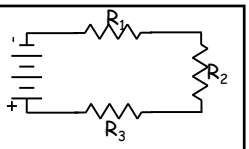


- All circuit elements bridge conductors rather than lie along it

Rules

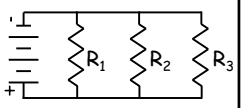
1. Sum of the currents through each element is equal to the total circuit current
2. Voltage across each element is the same and is equal to the total voltage across the circuit
3. Total resistance is inversely proportional to the sum of the reciprocals of the resistance of each element

Example



- A series circuit contains three resistive elements with values 4, 5 & 15 Ω. If the voltage across the circuit is 240V, what is the total resistance, total current, the current through each resistor and the voltage across each resistor?

Example



- If the previous example was a parallel circuit, what would the values of total resistance, total current, the voltage across each element and the current across each element?

Electric Power

- Power: Rate of doing work
  - (Joules per second)
- Units used to measure electrical power
  - Watts (W)

Example

- Electricity is sold in units of kW hours. If the unit cost from SWEB is 10p, how much does it cost to run a 40W light bulb for one year?

Electrical Power

$$P = I\,V$$

Where P is the electric power in watts,
I is the electric current in amperes,
V is the electrical potential in volts.

Can be rearranged…

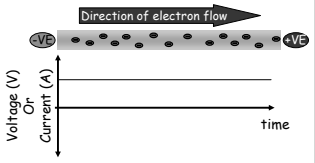
$$V = I\,R \quad \Rightarrow \quad P = I^2 R$$

Example

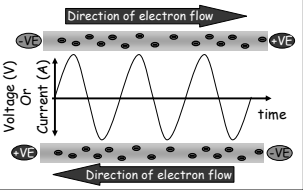
An X-ray generator is supplied with 240V and draws 50A of current. What is the consumed power?

Direct & Alternating Current

Direct Current (DC)
- Constant potential
- Electrons flow in one direction



Alternating Current (AC)
- Sinusoidal potential
- Electrons oscillate back and forth



Summary

★Electrodynamics
★Electric Current
★Conductors and Insulators
★Semiconductor
★Superconductors
★Electric Circuits
★Electric Power
★DC and AC electricity

Practice Questions

PAM2011: Lecture 6 Problem Sheet Solutions

1. What is the total electrical resistance when resistive elements of 1, 2, 3 & 4 kΩ are connected in (a) series and (b) parallel?
2. If the resistive circuits in question 1 each draw 10 A, what will the voltage be across the 4 kΩ in (a) the series circuit and (b) the parallel circuit?
3. How much power is consumed by the circuit in question 2?
4. Which direction do electrons flow with respect to current?
5. What is the effect on resistance of a length of wire if the thickness is increased?