# CHAPTER 4

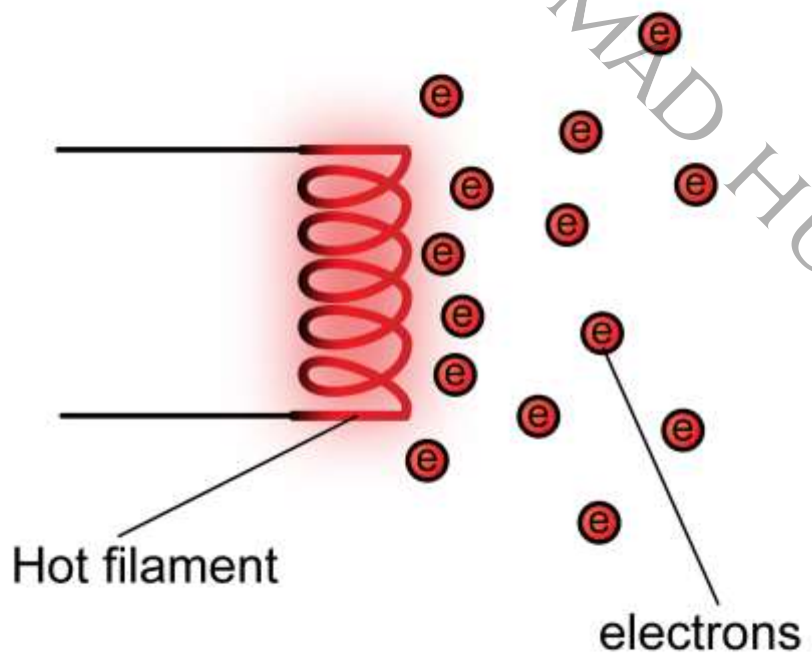
ELECTRONICS

# 4.1 CATHODE RAY OSCILLOSCOPE

# What is thermionic emission?

- The process of emission of charged particles from a heated metal surface.






The charged particles are normally electrons.

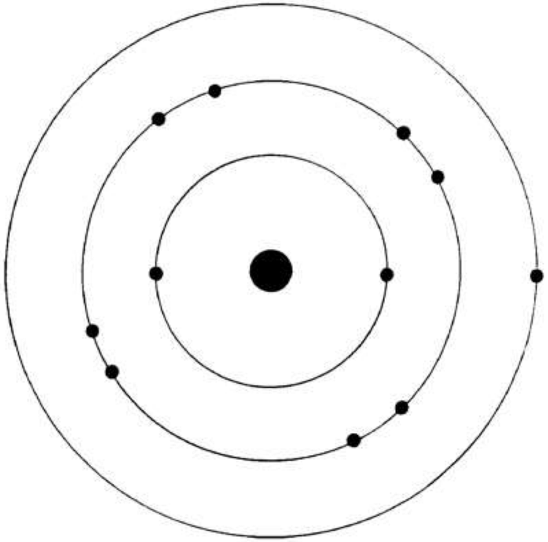
Thermo (temperature) + Ion (charged carrier)

# Factors affecting the rate of emission:

- Rate of emission: number of electrons emitted in 1 second
- 4 factors:
  - Temperature of the heated metal
    - The higher the temperature, the higher the emission rate.
  - Surface area of the heated metal
    - The larger the surface area of the heated metal, the higher the emission rate.
  - Types of metal
    - The rate of thermionic emission differs in different types of metal.
  - Coated material on the metal surface
    - Example: The rate of emission will increase when the metal surface is coated by a layer of barium oxide or strontium oxide.

# How does thermionic emission occur?

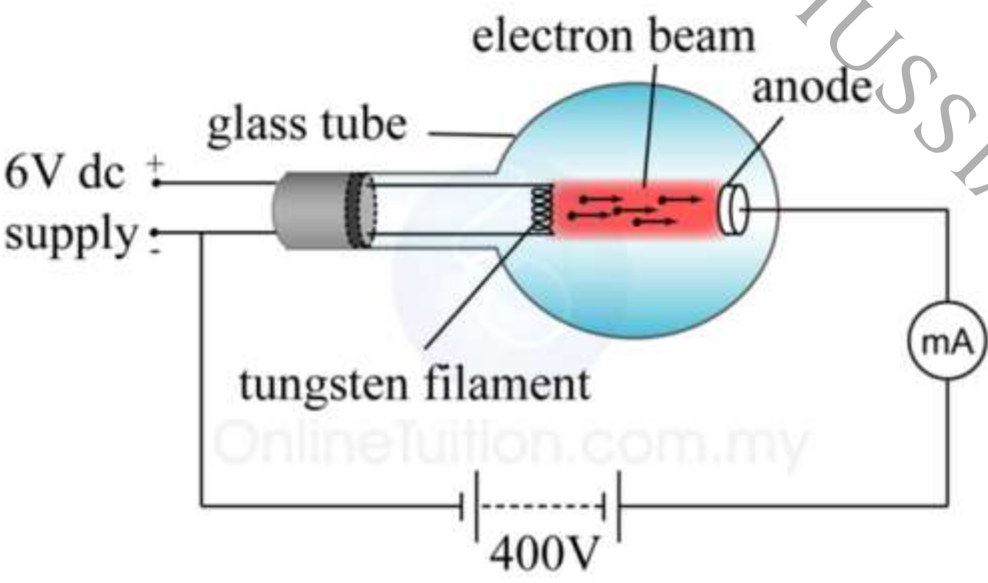
1. Metal consists of a large number of electrons.
2. These electrons are free to move but cannot leave the metal surface because they are held back by attractive forces of the atomic nucleus.
3. When the metal is heated to a certain temperature, some of the electrons gain sufficient energy to escape from the metal to become free electrons.



# Thermionic Diode

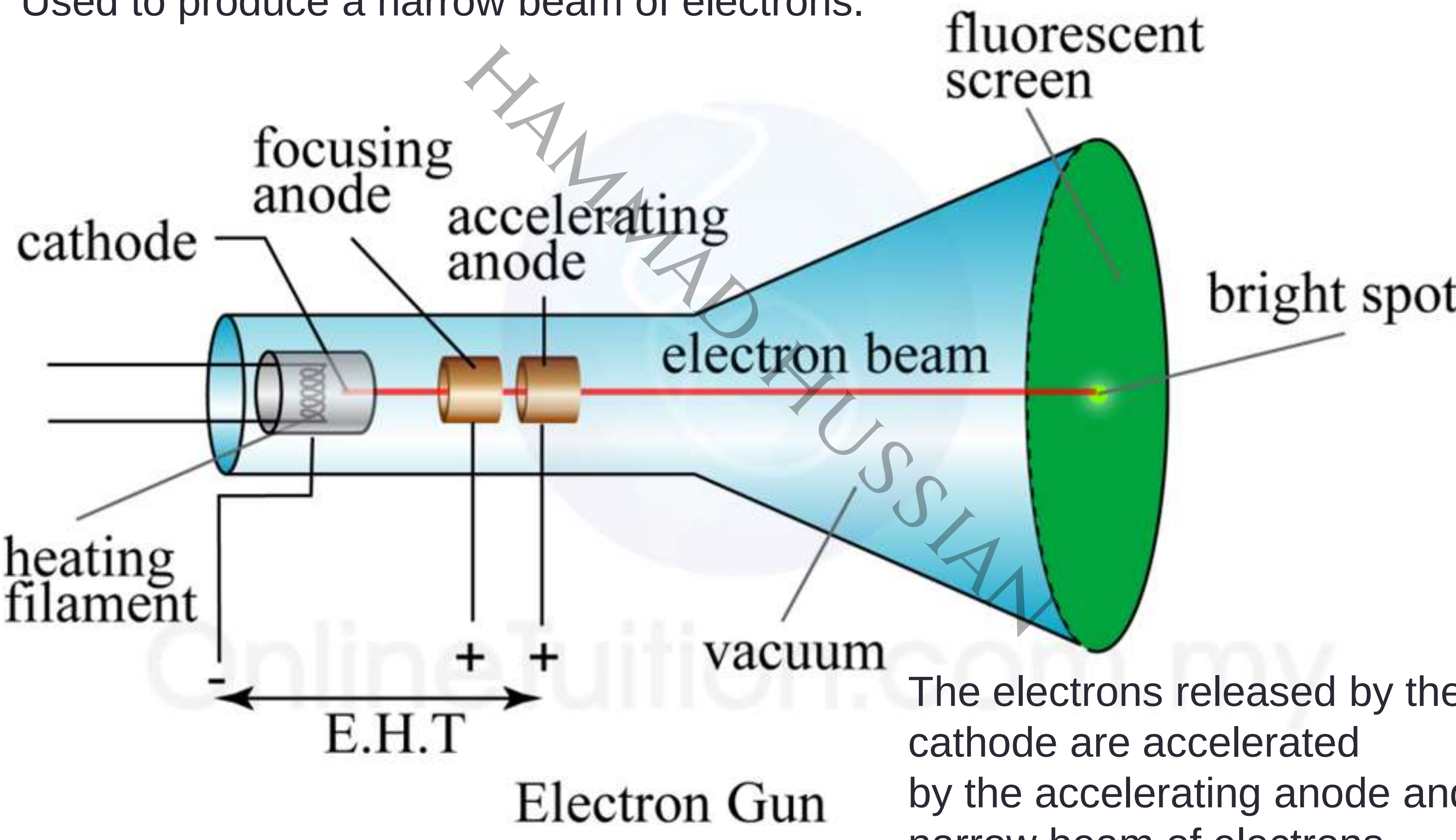
- Diode: An electrical component that only allows current flow in *one direction*.
- Electrons are only released from the tungsten filament (when it is hot) and move toward the anode which is connected to the positive terminal.





# Electron Gun

Used to produce a narrow beam of electrons.

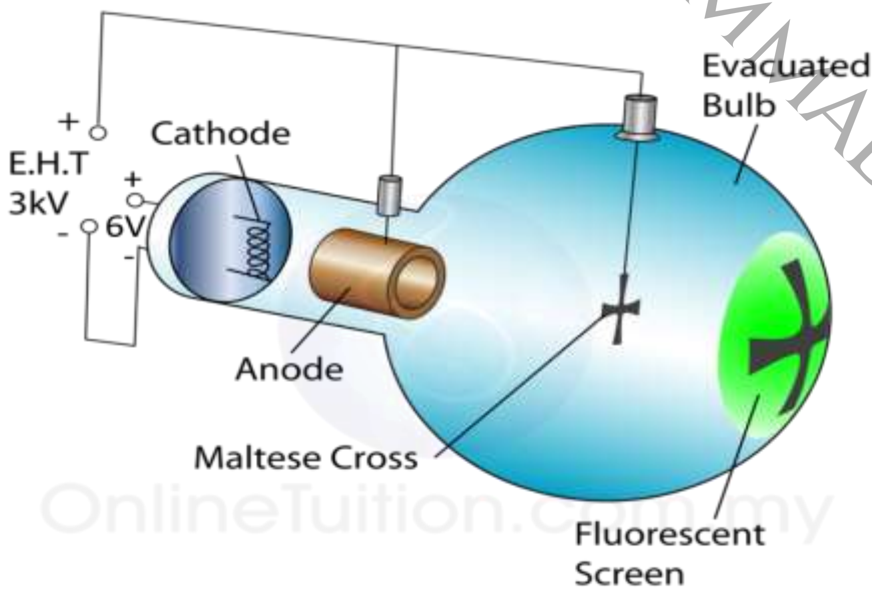



The electrons released by the cathode are accelerated by the accelerating anode and form a narrow beam of electrons.

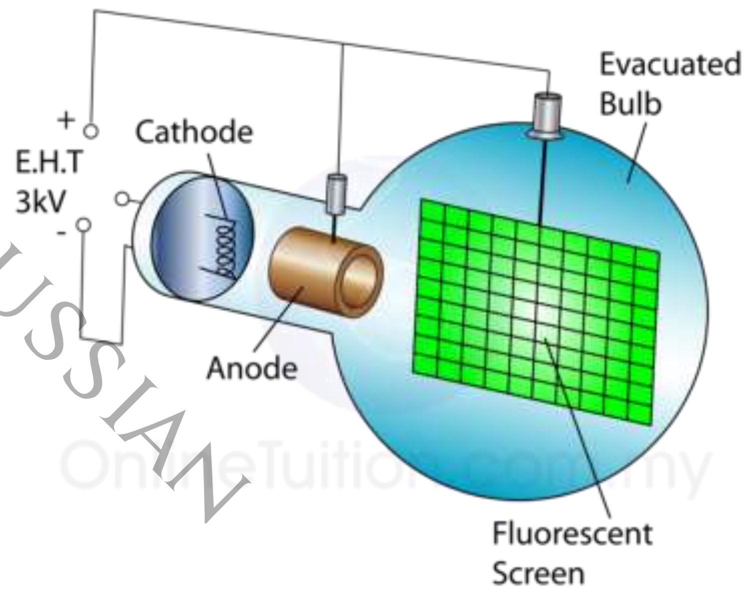
The beam produced is called a ***cathode ray***.

# Properties of cathode ray

- Maltese Cross Tube & Deflection Tube




Maltese cross tube




Deflection tube

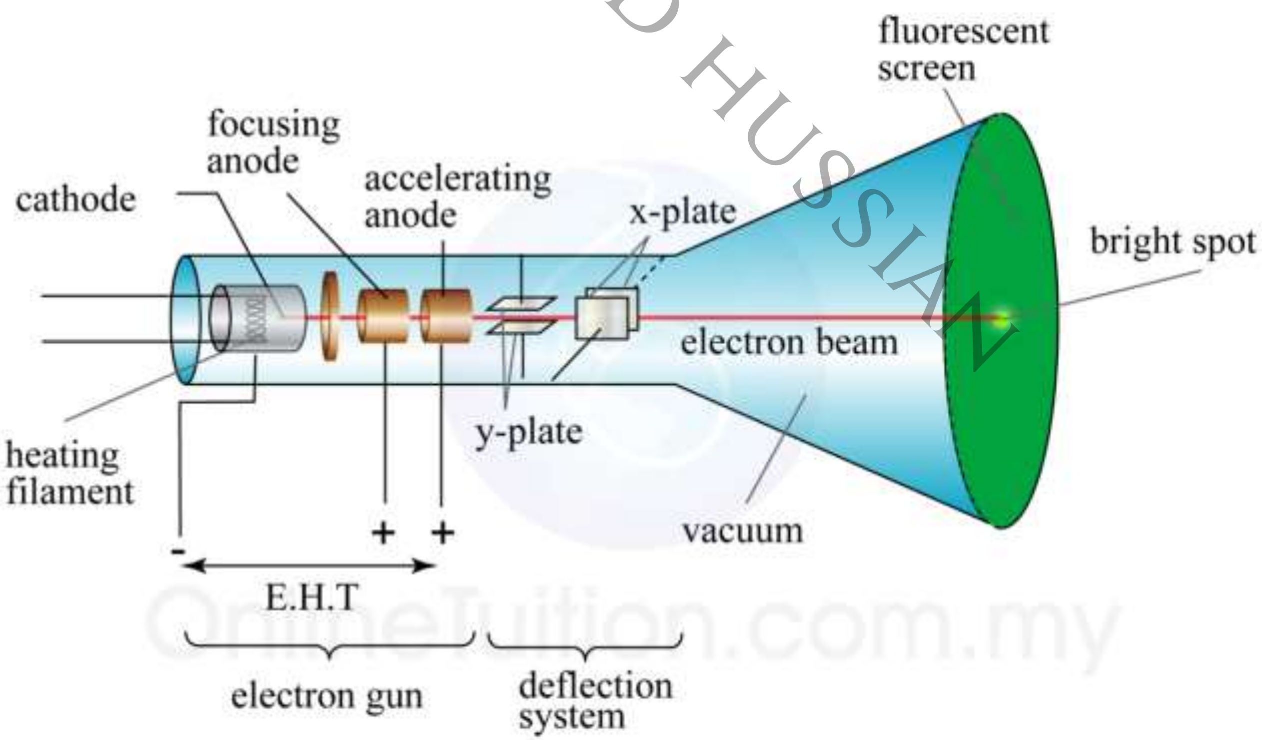
# Properties of cathode ray

1. Negatively charged particles called electrons.
2. Travel in straight lines and cast sharp shadows.
3. Travel at high speed with high kinetic energy.
4. Can cause fluorescence. (Kinetic energy of electrons -→ light energy) Example: television, computer.
5. Can be deflected by electric and magnetic field.

# Cathode ray oscilloscope (CRO)

- Three components:
  - Electron gun
  - Deflecting plates
  - Fluorescent screen





# Electron Gun

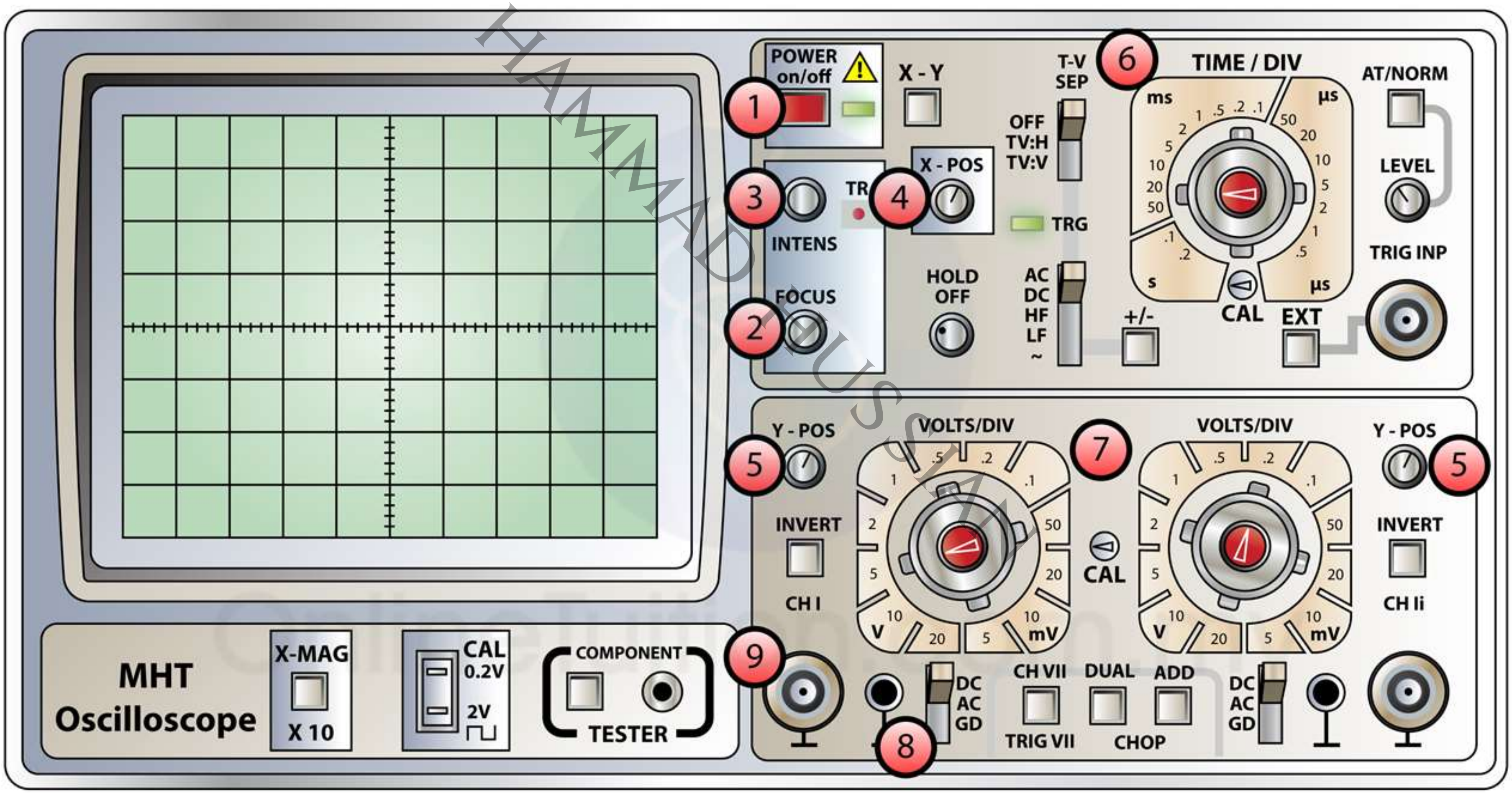
| Parts | Function |
|---|---|
| Filament | To heat the cathode. |
| Cathode | Release electrons when heated by the filament. |
| Control Grid** | Grid is connected to a negative potential. The more negative the potential, the more electrons will be repelled from the grid, thus fewer electrons will reach the anode and the screen.<br>The number of electrons reaching the screen determines the brightness of the light.<br>Therefore, the negative potential of the grid can be used as a ***<u>brightness control.</u>*** |
| Focusing and accelerating anode | Anode at the positive terminal accelerates the electrons and the electrons are focused into a fine beam as they passed through the anode. |

# Deflecting plates

| Parts | Function |
| --- | --- |
| Y-plate | Cause deflection in the vertical direction when a voltage is applied across them. |
| X-plate | Cause deflection in horizontal direction when a voltage is applied across them. |

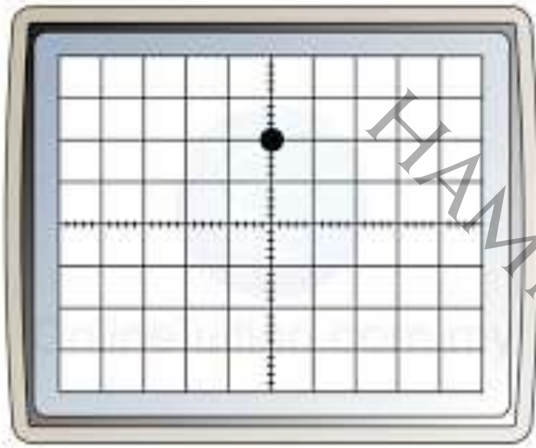
# Fluorescent screen

1. Screen is coated with a fluorescent salt. Eg: zinc sulphide.
2. When the electrons hit the screen, the fluorescent salt will produce a flash of light and hence, a bright spot on the screen.

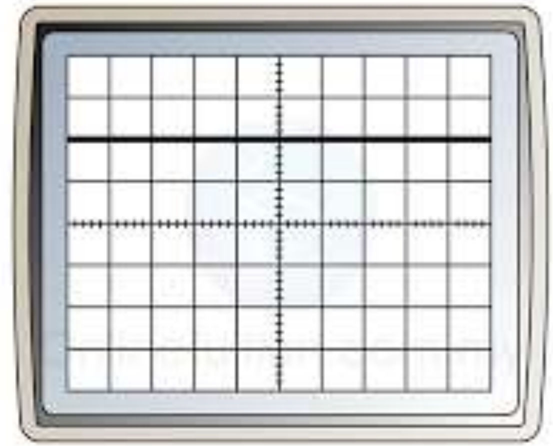

POWER on/off
X - Y
T-V SEP
TIME / DIV
AT/NORM
OFF
TV:H
TV:V
X - POS
LEVEL
INTENS
TRG
TRIG INP
HOLD OFF
AC
DC
HF
LF
FOCUS
+/-
CAL
EXT
Y - POS
VOLTS/DIV
VOLTS/DIV
Y - POS
INVERT
INVERT
CAL
CH I
CH Ii
MHT
Oscilloscope
X-MAG
X 10
CAL 0.2V
2V
COMPONENT
TESTER
DC
AC
GD
CH VII
DUAL
ADD
TRIG VII
CHOP
DC
AC
GD
1
2
3
4
5
6
7
8
9
5

| | Function |
|---|---|
| 1. Power switch | To switch on & turn off the oscilloscope. |
| 2. Focus control | To control the focus of the spot on the screen. |
| 3. Intensity control | To control brightness of the spot on the screen. |
| 4. X-offset<br>5. Y-offset | Moves the whole trace side to side on screen.<br>Moves the whole trace up and down on screen. |
| 6. Time based control (time/div) | A measure of time for the oscilloscope. When the time-based control, a sawtooth voltage appeared on the X-plates. The electron beam sweep across the screen at a constant speed. By knowing the period of each cycle, T, we can know how fast the beam is sweeping across the screen. |
| 7. Y gain control (volts/div) | The “Volts/Div.” wheels amplify an input signal so that for a division a given voltage level is in valid. A “division” is a segment, a square on the screen of the oscilloscope. |

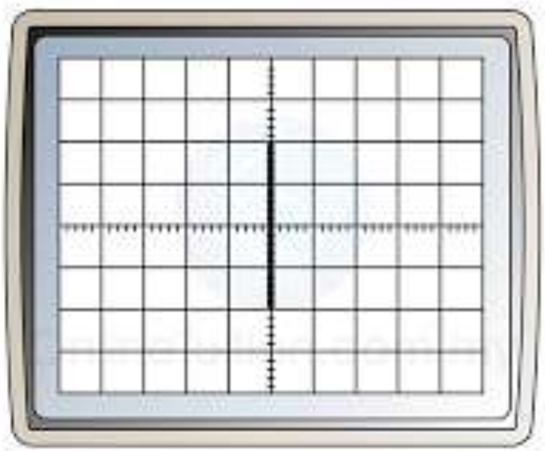
| | Function |
|---|---|
| 8. DC/AC switch | d.c. – d.c. and a.c. voltage displayed<br>a.c. – only a.c. voltage displayed |
| 9. X-input and Y-input | Electric input connected to X-plate and Y-plate. |



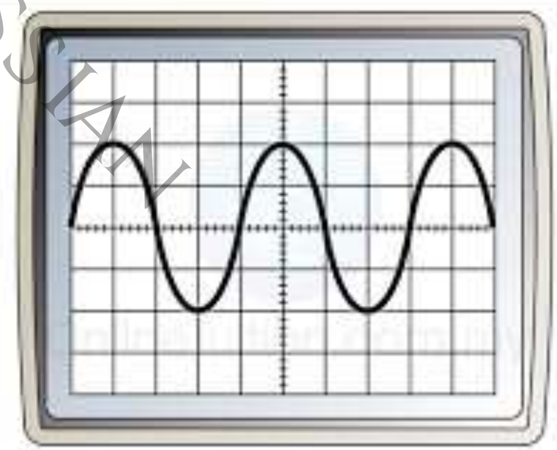
Direct Current (Time Base Switched Off)



Direct Current (Time Base Switched On)

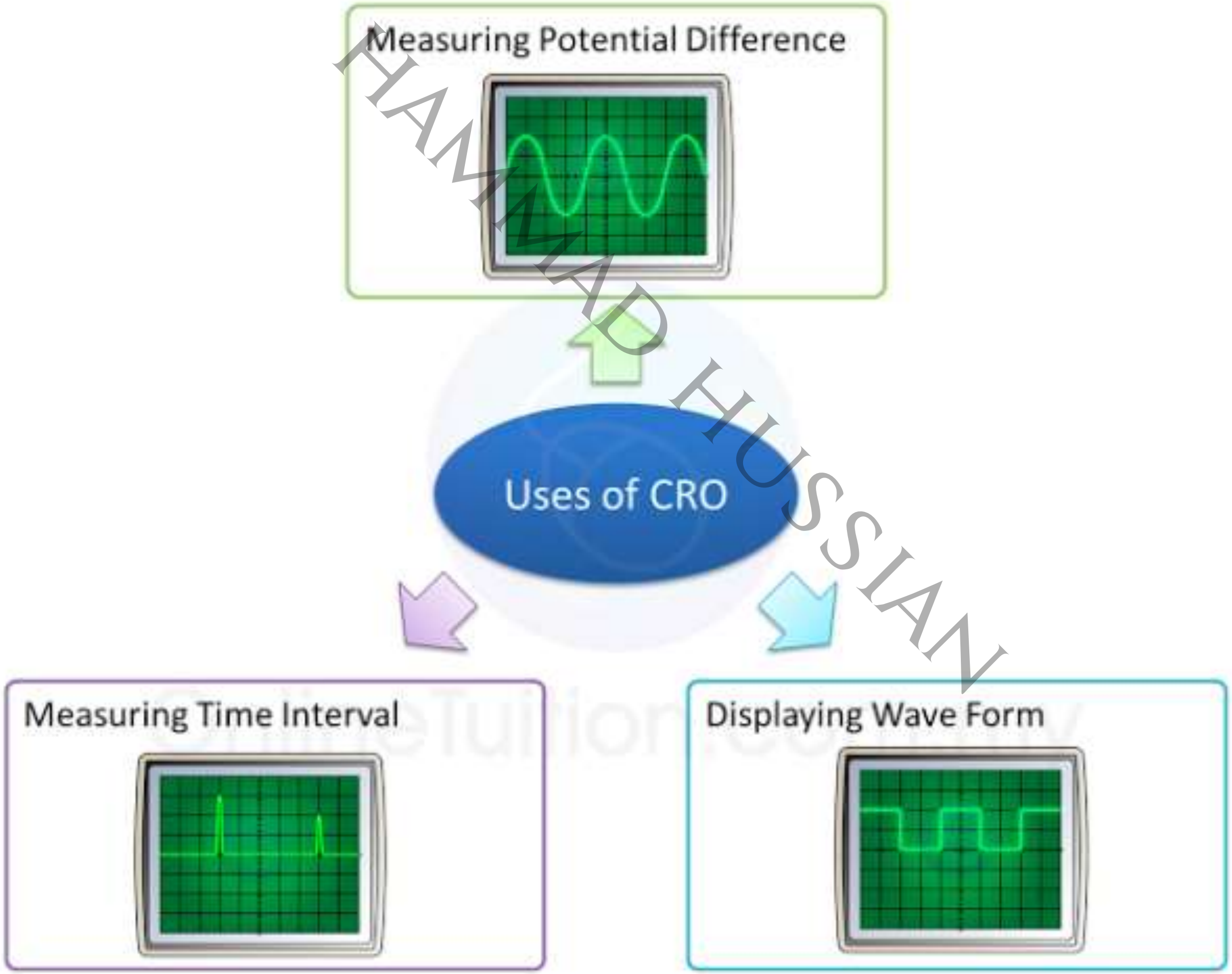


Alternating Current (Time Base Switched Off)



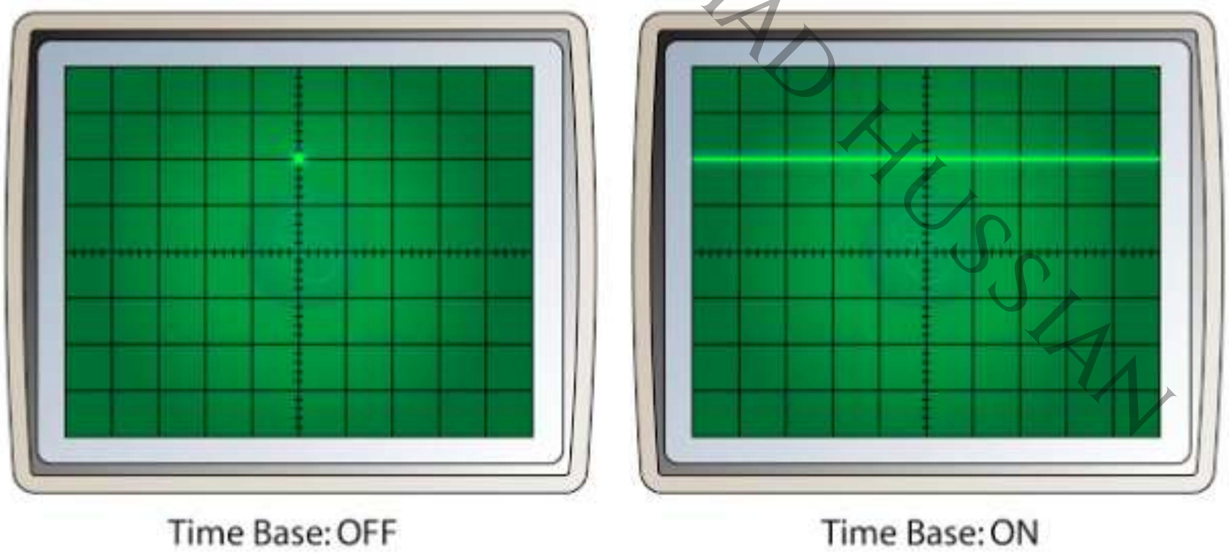
Alternating Current (Time Base Switched On)

# Uses of cathode ray oscilloscope



# Measuring potential difference

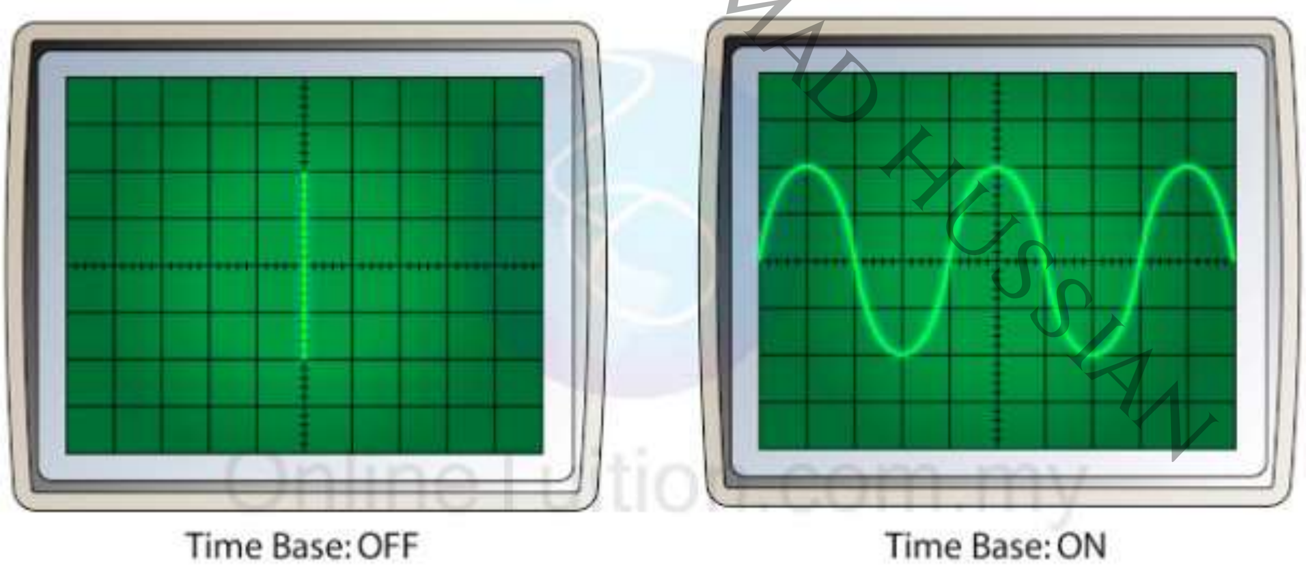
- DC voltage
- = Displacement of the bright spot from zero position x selected range of the Y-gain control




What is the value of the dc voltage in both of the figure if the Y-gain control is 2V/division?

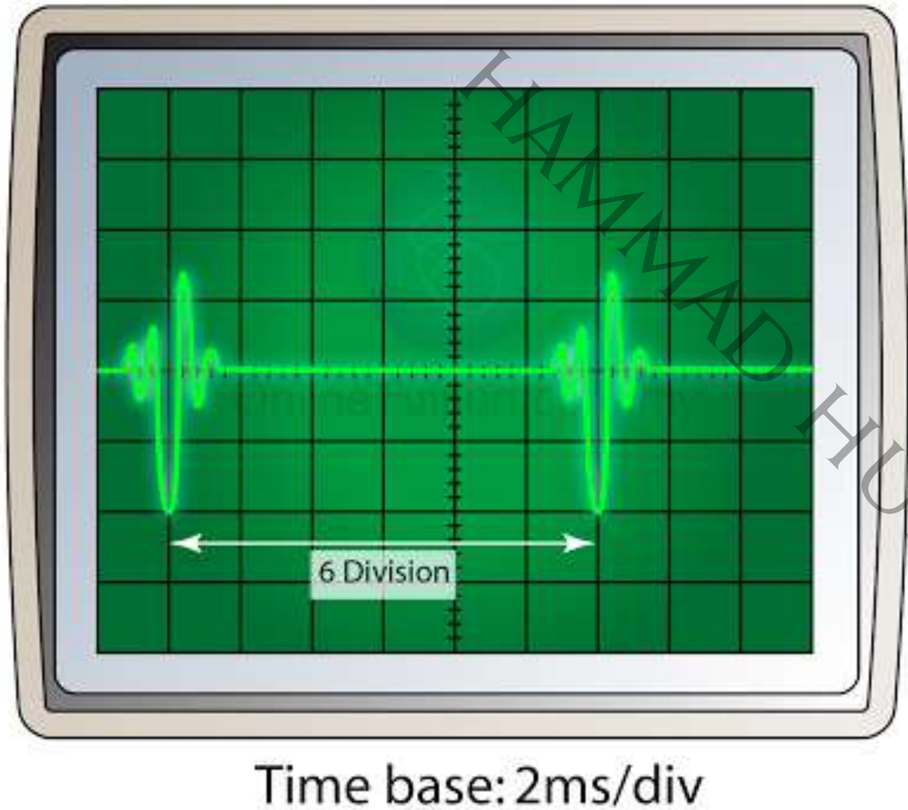
# Measuring potential difference

- AC voltage
- = Height of the vertical trace from zero position x selected range of Y-gain control




Y-gain = 2V/div
What is the peak ac voltage?

# Measure short time intervals



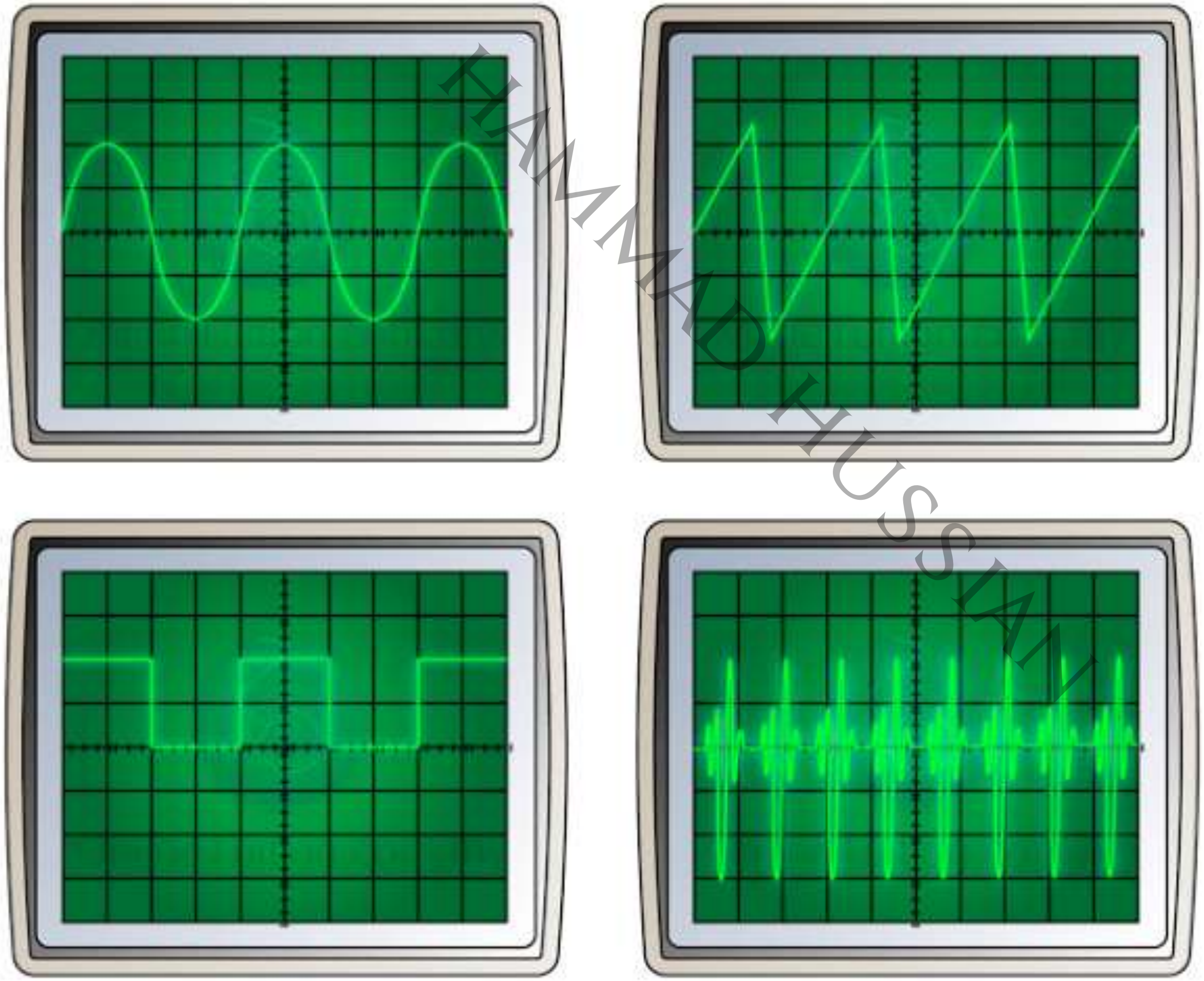



Try:
Time based: 10ms/div
Time taken = ?

Time based: 15ms/div
Time taken = ?

Example:
t = 6 x 2 ms
 = 12 ms
 = 0.12 s

# Displaying wave forms



# Problem solving based on CRO display

<u>**Example 1**</u>

**Diagram 1 shows a trace produced by an ac power supply which is connected to Y-input of an CRO setting at 20 V/div and 5 ms/div.**

**Calculate:**

**(a) Period**

**(b) Frequency**

**(c) Peak voltage**

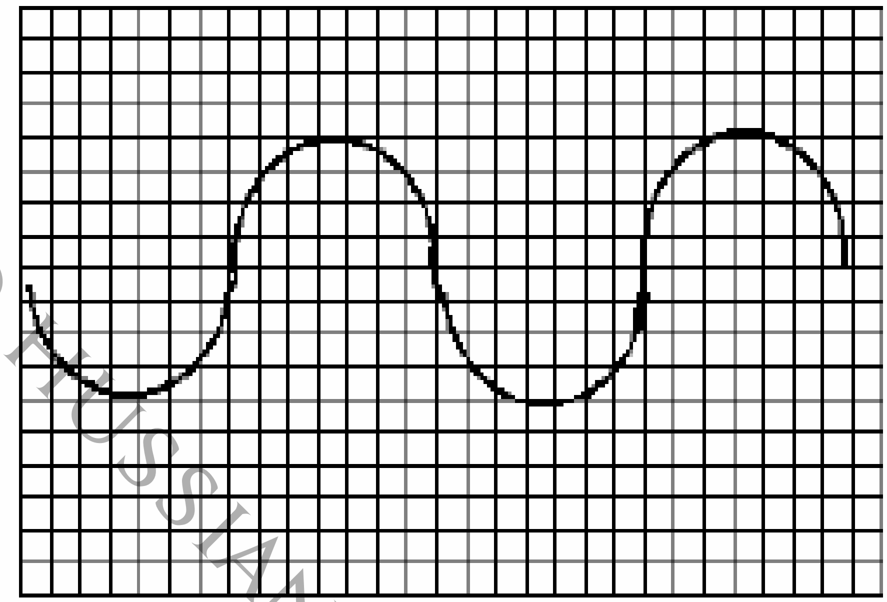


*Diagram 1*

**Example 2**

Diagram 2 shows a trace produced by an a.c power supply connected to a CRO with the time base is switched of. The Y-gain is set to 20 V/div. Find the peak voltage.

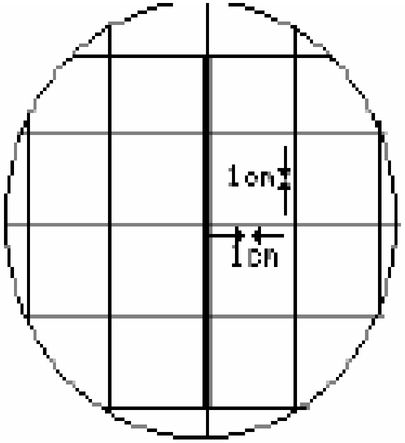



diagram 2

**Example 3**

Diagram 3 shows a wave produced by an audio generator displayed the screen of a CRO. The length between the two crests is 3 cm.

(a) If the time-base is set to 5 ms/div, find the frequency.

(b) What is the period of the wave?

(c) When the frequency of the wave is double, what is the length between the two crests?

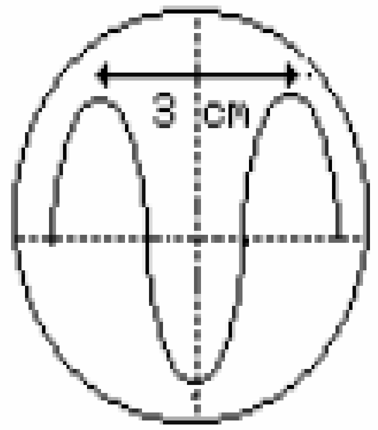



Diagram 3

# 4.2 SEMICONDUCTORS

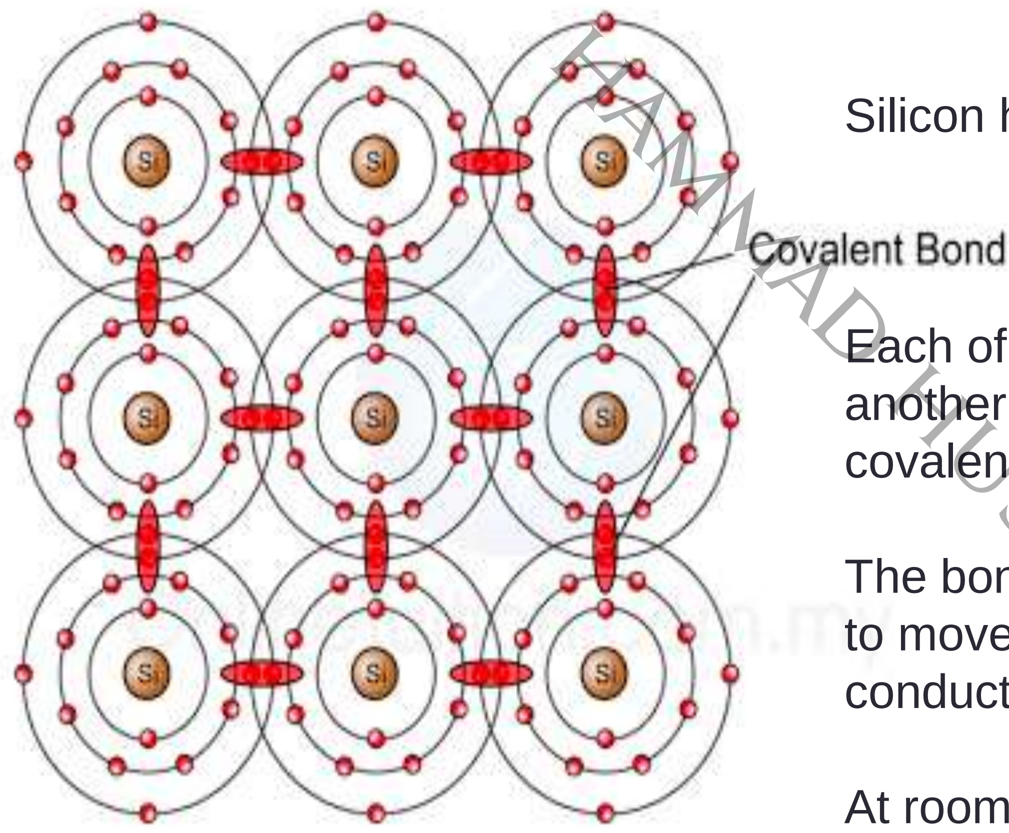
# Semiconductors

- A class of crystalline solid with conductivity between a conductor and an insulator.
- Examples:
  - Silicon
  - Germanium
  - Boron
  - Tellurium
  - Selenium
- Electrical conductivity in semiconductors occurs because there are two types of charged carriers:
  - Free electrons (negatively charged)
  - Holes (positively charged)

# Describe semiconductors in terms of resistance

<table>
<tr><th>Metal</th><th>Insulator</th></tr>
<tr><td>Good conductors of electricity because they have free electrons that can move easily between atoms<br>Resistance of metal is generally very low.</td><td>Poor conductors of electricity because they have too few free electrons to move about.<br>Resistance of insulators is very high.</td></tr>
<tr><td colspan="2">Semiconductors<br>Electrical conductivity is between that of a conductor and an insulator.<br>Resistance is between that of a conductor and an insulator.<br>At 0 Kelvin, it behaves as an insulator. When temperature increases, the conductivity of electricity will increase because its resistance will be lowered.</td></tr>
</table>

# Silicon crystal




Silicon has 4 valence electrons.

Each of these 4 electrons are shared with another 4 silicon atoms to form 4 pairs of covalent bonds.

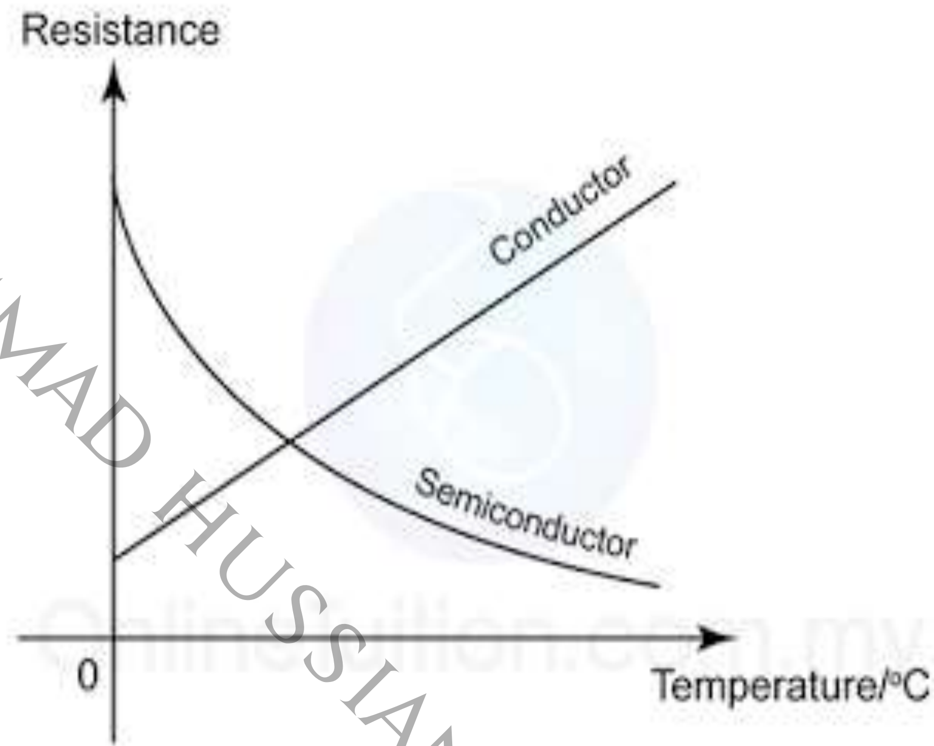
The bonded valence electrons are not free to move. Therefore, silicon is not a good conductor at room temperature.

At room temperature, a silicon crystal acts like an insulator because only a few free electrons and holes are present.

# Free electrons and holes

- When a bonded electron absorbs heat energy, it is promoted to a higher energy level.
- These electrons are free to move.
- A vacancy (hole) is left in the valence shell.
- A hole (positively charged) has the tendency to pull (attract) electrons.
- Both the free electrons and the holes help to conduct electricity.

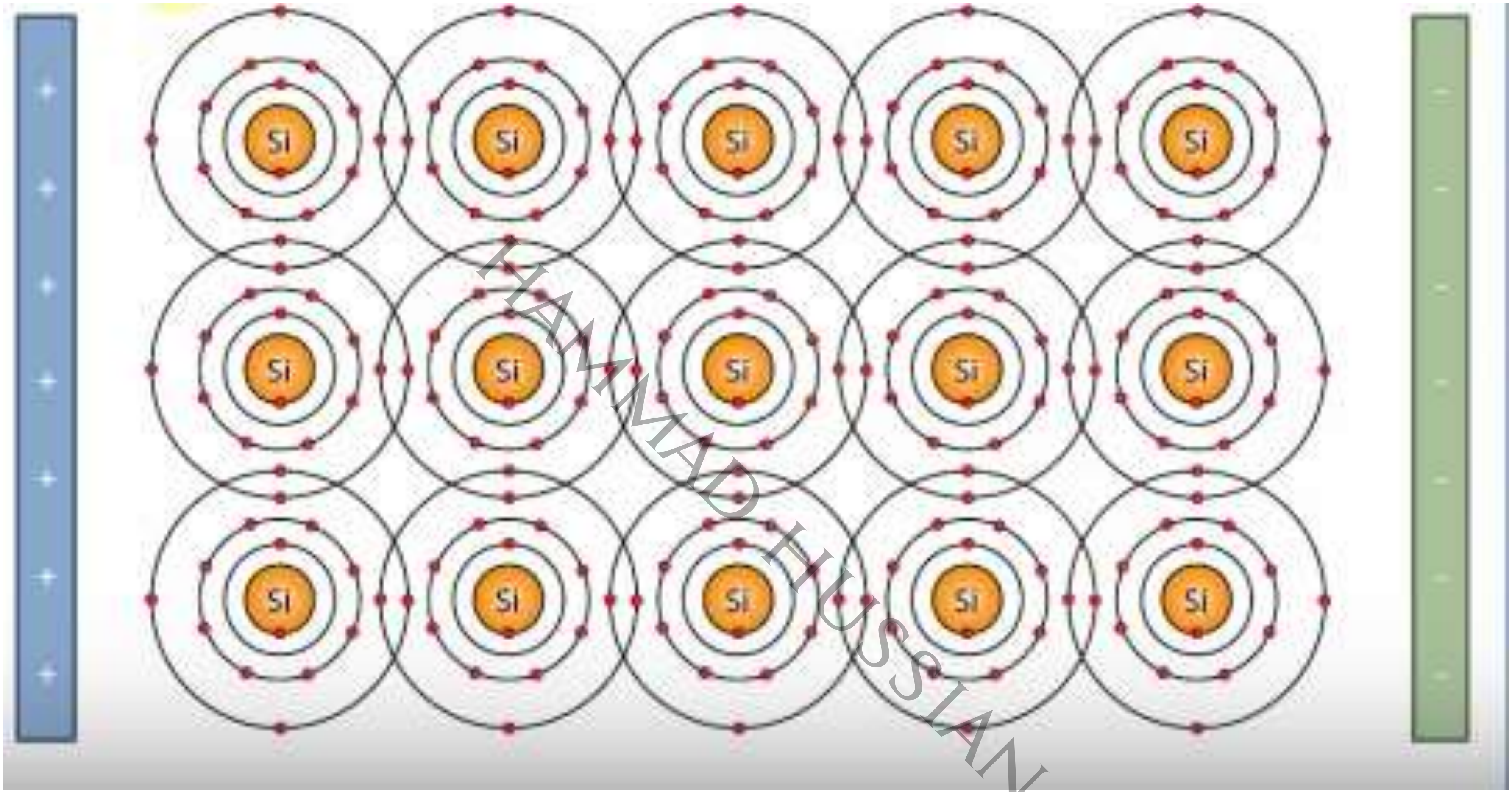
# Resistance change due to temperature change




As temp. increases, more and more electrons are being promoted to higher energy levels and thus, more holes are created. Therefore, the electrical conductivity of a semiconductor increases as the temp. increases.



The graph shows the change in resistance of a conductor and a semiconductor against the change in temp.
The resistance of a semiconductor decreases as temp. increases.





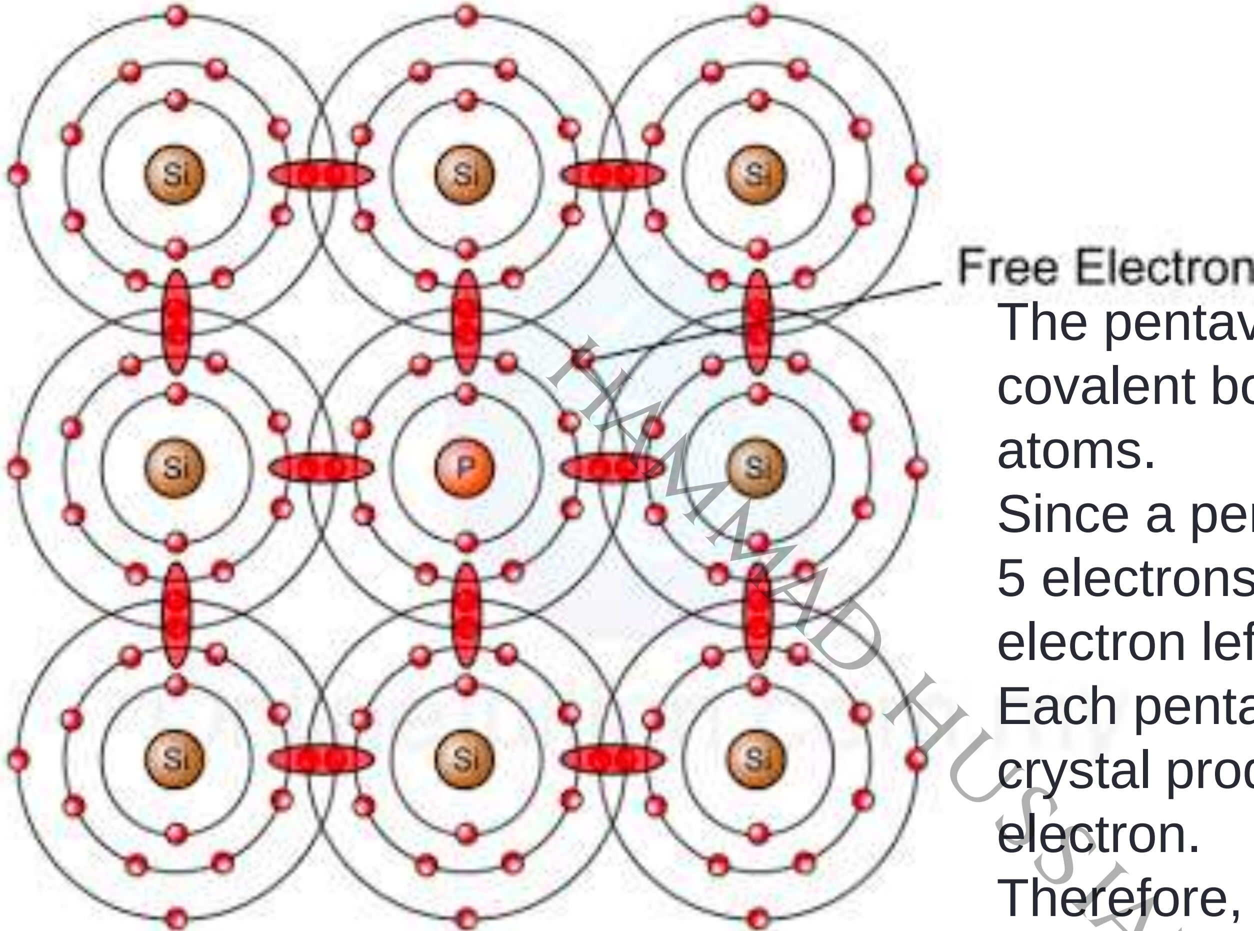

When a potential difference is applied to a semiconductor, the electrons and holes will start to flow.
Electrons will flow to the negative terminal while the holes will flow to the positive terminal.

# Doping

- A process of adding small amount of ***impurities*** to a semiconductor to ***increase its electrical conductivity.***
- Impurities added are called dopants.
- Two types of semiconductor depending on the type od impurities that are added:
  - N-type semiconductor
  - P-type semiconductor

# N-type semiconductor

- Add pentavalent atoms into a semiconductor.
- Pentavalence atoms are atoms that have 5 electrons in the valence shall.
- Example:
  - Antimony
  - Phosphorus




The pentavalence atom form 4 covalent bonds with the silicon atoms.

Since a pentavalence atom has 5 electrons, there is an extra electron left as a free electron.

Each pentavalent in the silicon crystal produces one free electron.

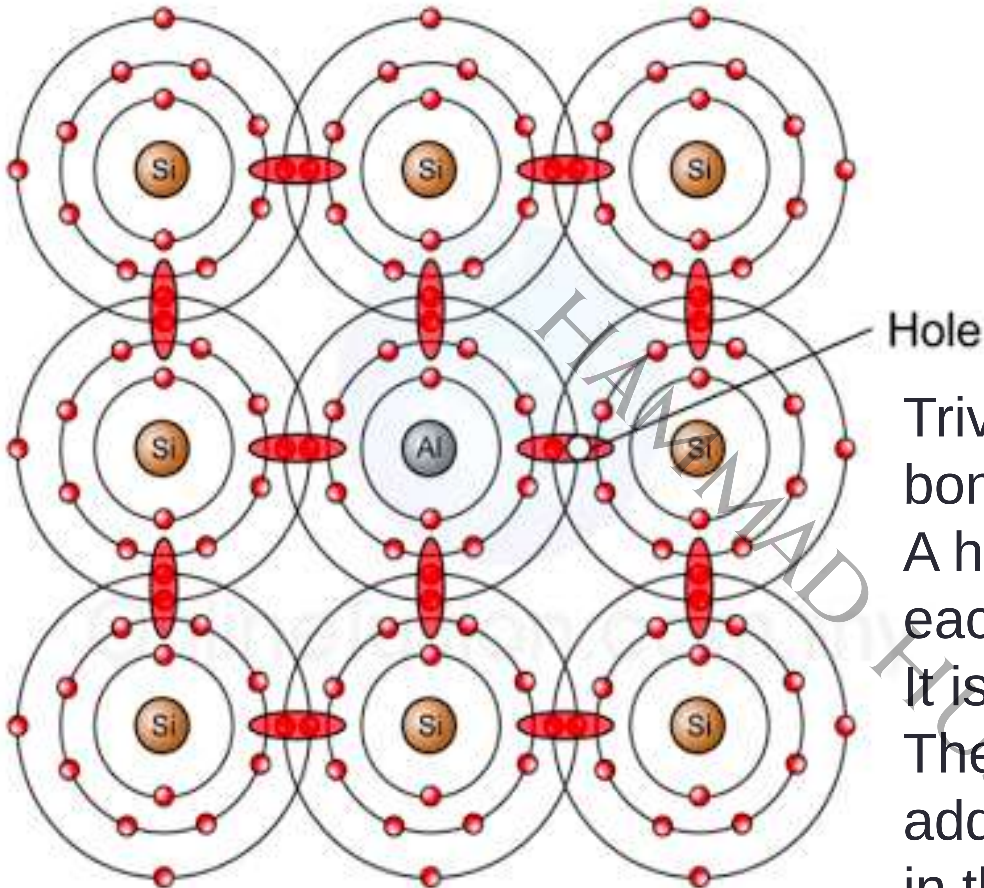
Therefore, the pentavalence atom is called a donor.



The more pentavalence impurity is added, the more free electron is produced, hence the greater conductivity of the semiconductor. Electrons outnumber the holes, thus this semiconductor is called an n-type semiconductor. N stands for negative.

# P-type semiconductor

- Add trivalent atoms into a semiconductor.
- Trivalent atoms – atoms with 3 valence electrons.
- Examples:
  - Aluminium
  - Boron
  - Gallium




Trivalent atom forms 4 covalent bonds with the silicon atoms.
A hole exists in the valence orbit of each trivalent atom.
It is called an acceptor atom.
The more trivalent impurity is added, the more holes are created in the semiconductor, hence the greater the conductivity of the semiconductor.
The holes outnumber the free electrons, thus this semiconductor is called a p-type semiconductor. P stands for positive.

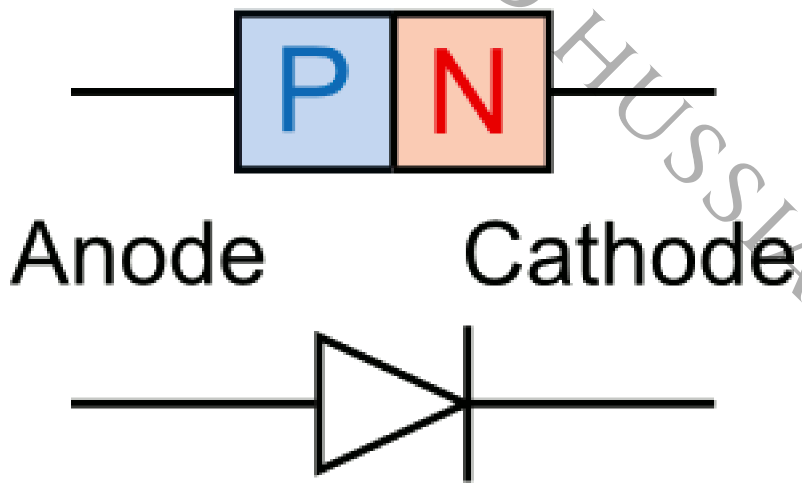
# Compare n-type and p-type semiconductor



| | p-type semiconductor | n-type semiconductor |
|---|---|---|
| Doping Material | Trivalent:<br>aluminum, boron, and gallium | Pentavalent:<br>antimony, and phosphorus |
| Role of doping material | Atom receiver | Atom donor |
| Majority Charge Carrier | Holes | Free electrons |
| Minority Charge Carrier | Free electrons | Holes |

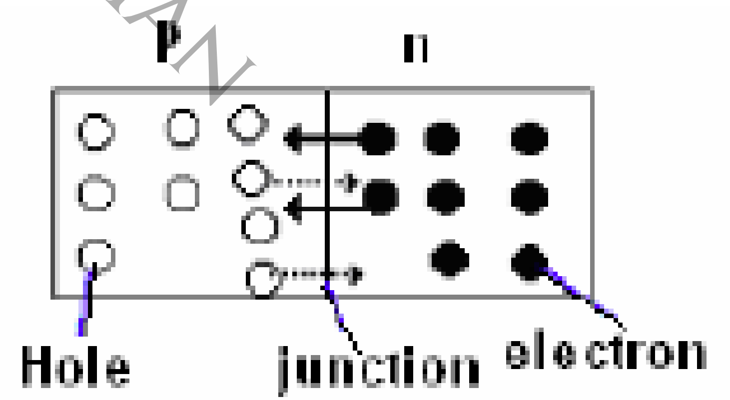
# Semiconductor diodes

- Simplest semiconductor device.
- Made by joining a p-type and n-type semiconductor.
- Allows current to flow in only ONE DIRECTION.



# p-n junction

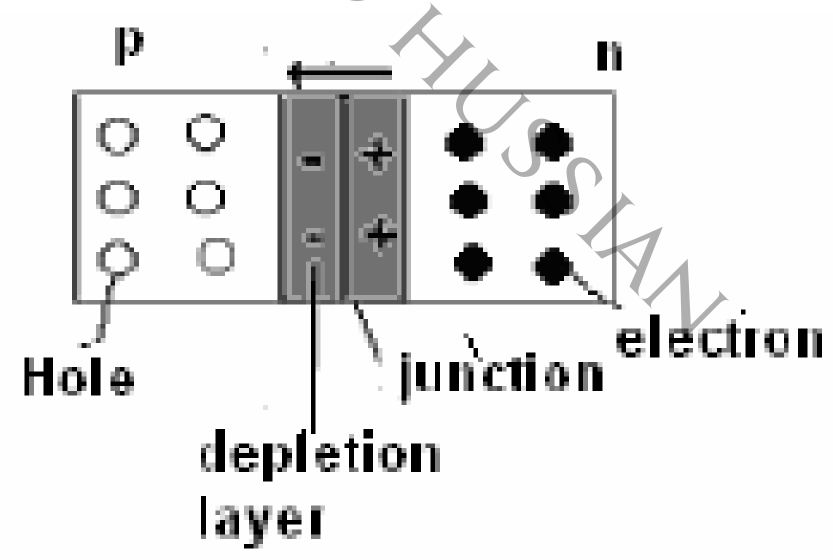
- The boundary between the p-type and n-type region.
- At the p-n junction, electrons from the n-side move to the p-side and recombine with the holes.
- Holes from the p-side move to the n-side and recombine with the electrons.
- As a result of this flow, the n-side has a net positive charge, and the p-side has a net negative charge.



# Depletion layer

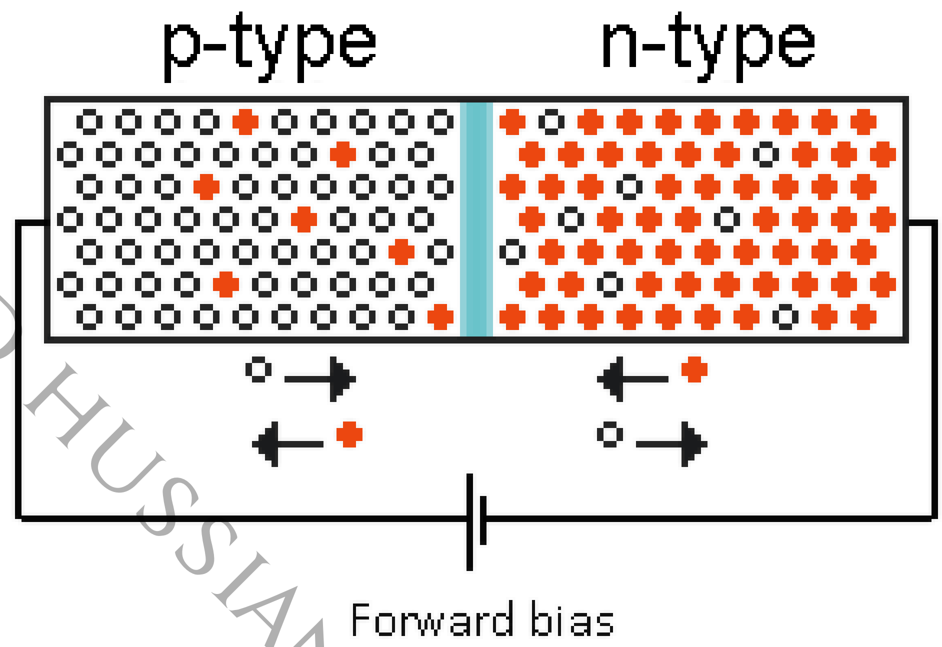
- The region around the junction is left with neither holes nor free electrons.
- This neutral region has no charged carriers.
- Poor conductor of electricity.





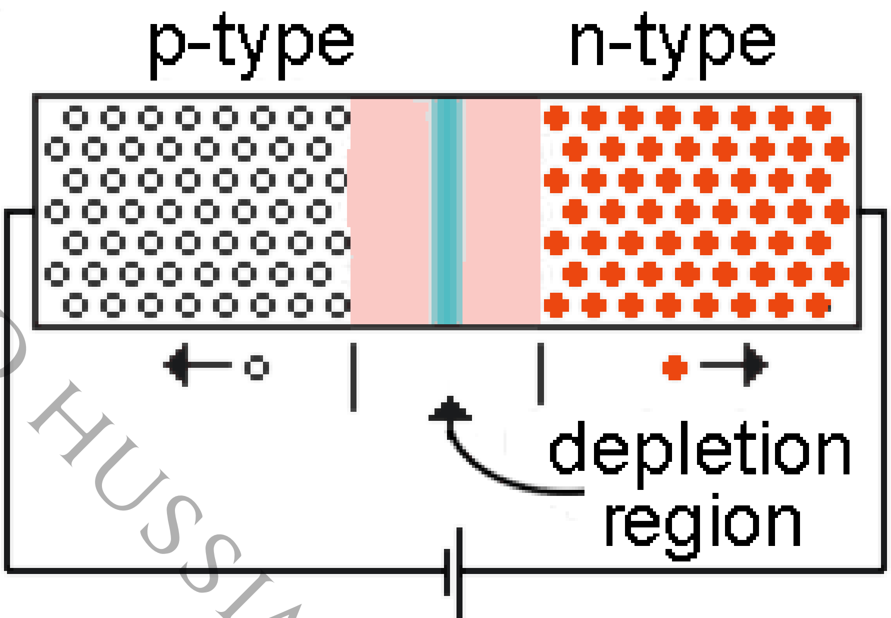
# Forward bias

- The p-type diode is connected to the +ve terminal and the n-type is connected to the –ve terminal of a battery.
- The diode conducts current because the holes from p-type material and electrons from n-type material are able to cross over the junction.
- The light bulb lights up.



# Reverse bias

- The n-type is connected to the +ve terminal and the p-type is connected to the –ve terminal of the battery.
- The reversed polarity causes a very small current to flow as both electrons and holes are pulled away from the junction.
- When the potential difference due to the widen depletion region equals the voltage of the battery, the current will cease.
- The light bulb does not light up.




Reverse bias

# Diodes as rectifiers

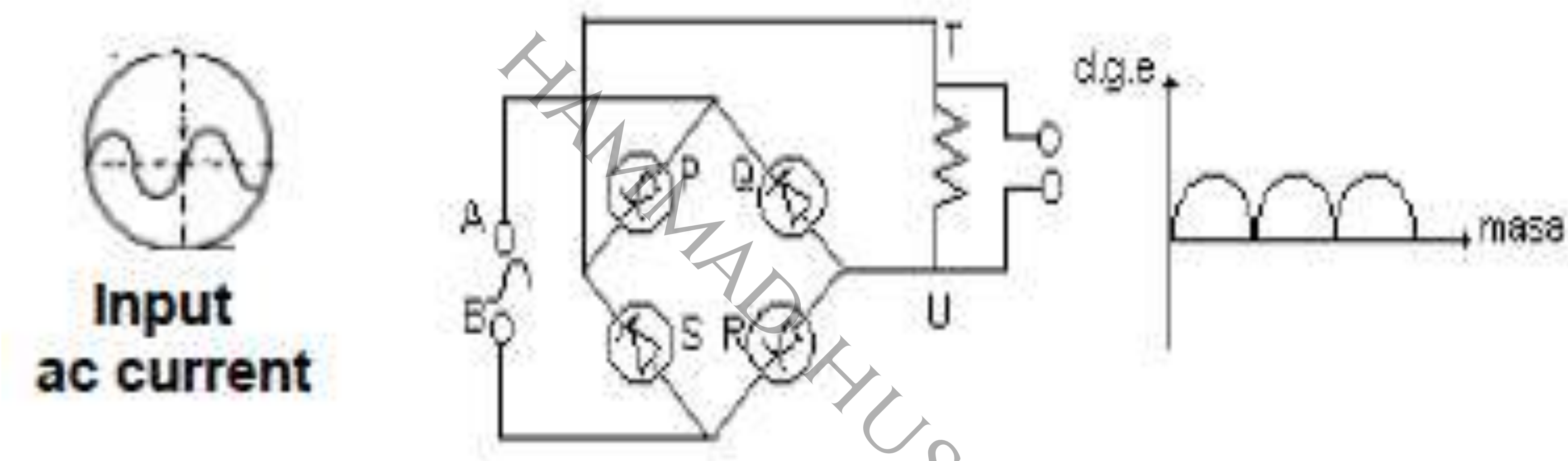
- Converts alternating current (AC) to direct current (DC).
- Rectification: A process of converting an AC into a DC by using a diode.
- Two types:
  - Half-wave rectification
  - Full-wave rectification

# Half-wave rectification


Half-wave rectification: the negative part of the current is prevented from passing.

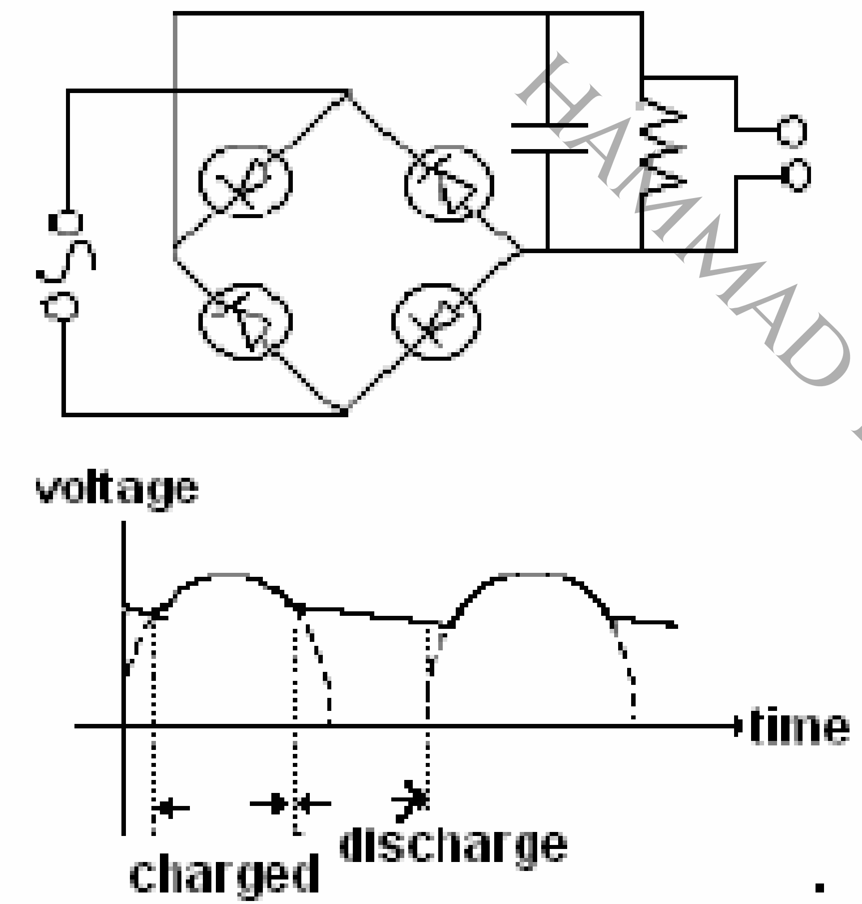
- When a diode is connected in series with the resistor, any current that passes through the resistor must also pass through the diode.
- Since diode can only allow current to flow in one direction, therefore the current will only flow in the first half-cycle when the diode in forward bias.
- The current is blocked in the second half-cycle when the diode is in reverse bias.

# Full-wave rectification




- A process where both halves of every cycle of an alternating current is made to flow in the same direction.
- In the first half, the current flows from A to P to TU to R to B
- In the second half, the current flows from B to S to TU to Q to A.
- The direction of the ac current passing through the resistor for each half cycle is the same ie T to U.

# Smoothing



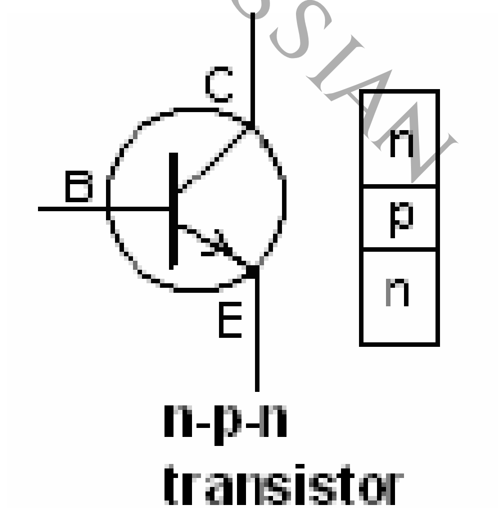

- When the current pass through the resistor and capacitor, the capacitor is charged and stores energy.
- When there is no current pass through the resistor and capacitor, the capacitor discharge and the energy from it is used to produce voltage across the resistor. As a result it produces a smooth dc output.

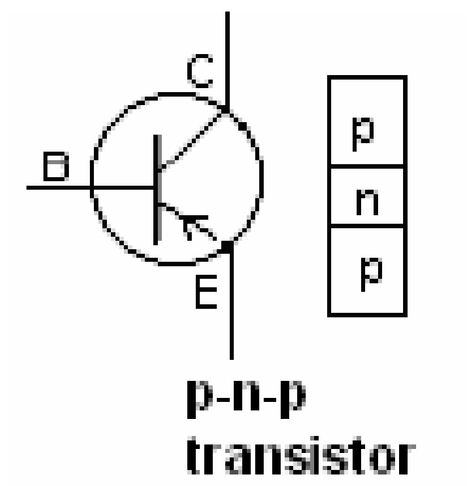
# 4.3 TRANSISTOR

# Transistor

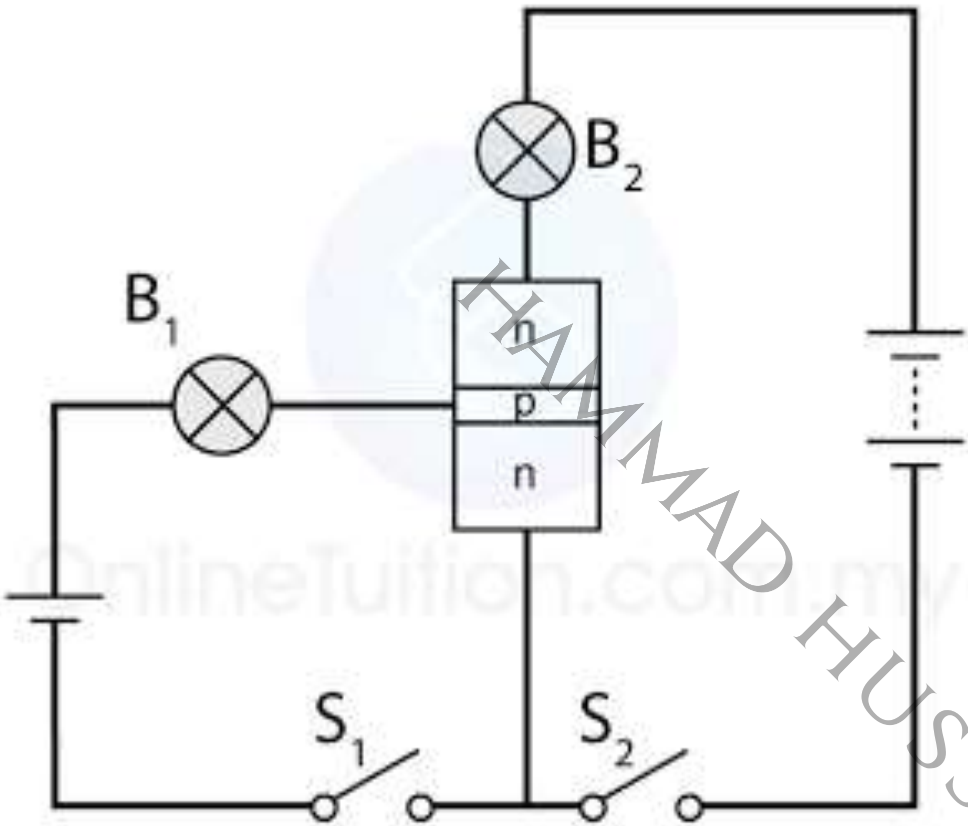
- A transistor is a double p-n junctions with three terminals:
  - emitter (e),
  - base (b)
  - collector (c).
- The emitter emits charged carriers through the thin base layer to be collected by the collector.
- Two types of transistor:
  - Npn transistor
  - Pnp transistor

The arrow on the emitter shows the direction of current flow.



- In npn transistor, the emitter sends NEGATIVE electrons to the collector.
- In pnp transistor, the emitter sends POSITIVE holes to the collector.
- The current in the collector lead is called collector current, $I_c$.
- The base current, $I_B$, is used to control the collector current through the transistor. The base current can be used to switch the collector current on & off.



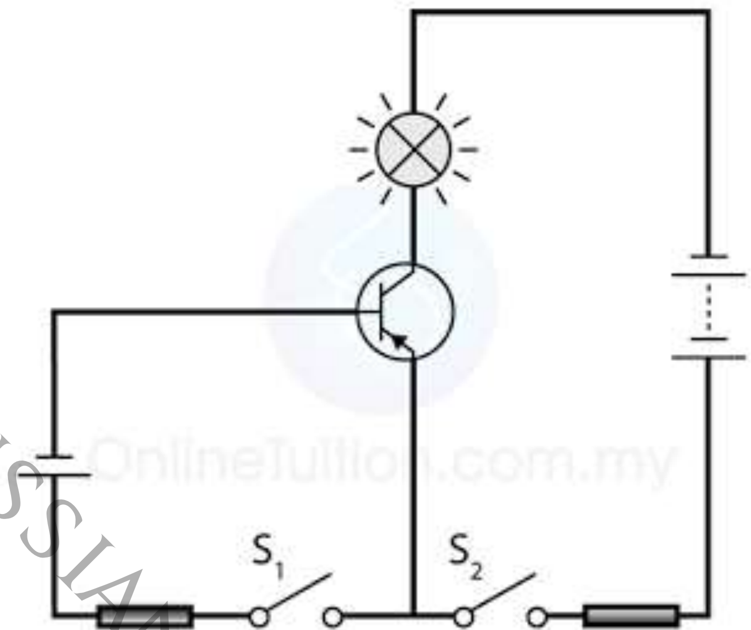

Collector circuit is controlled by the case circuit.
Current will only flow in the collector circuit when the base circuit is switched on.

| S1 | S2 | B1 | B2 |
|---|---|---|---|
| Open | Open | Does not light up | Does not light up |
| Close | Open | Light up | Does not light up |
| Open | Close | Does not light up | Does not light up |
| Close | Close | Light up | Light up |

# How to connect a transistor

- Transistor should always be connected in such a way that:
  - Emitter base circuit is always forward bias
  - Collector base circuit is always reverse bias

Example:



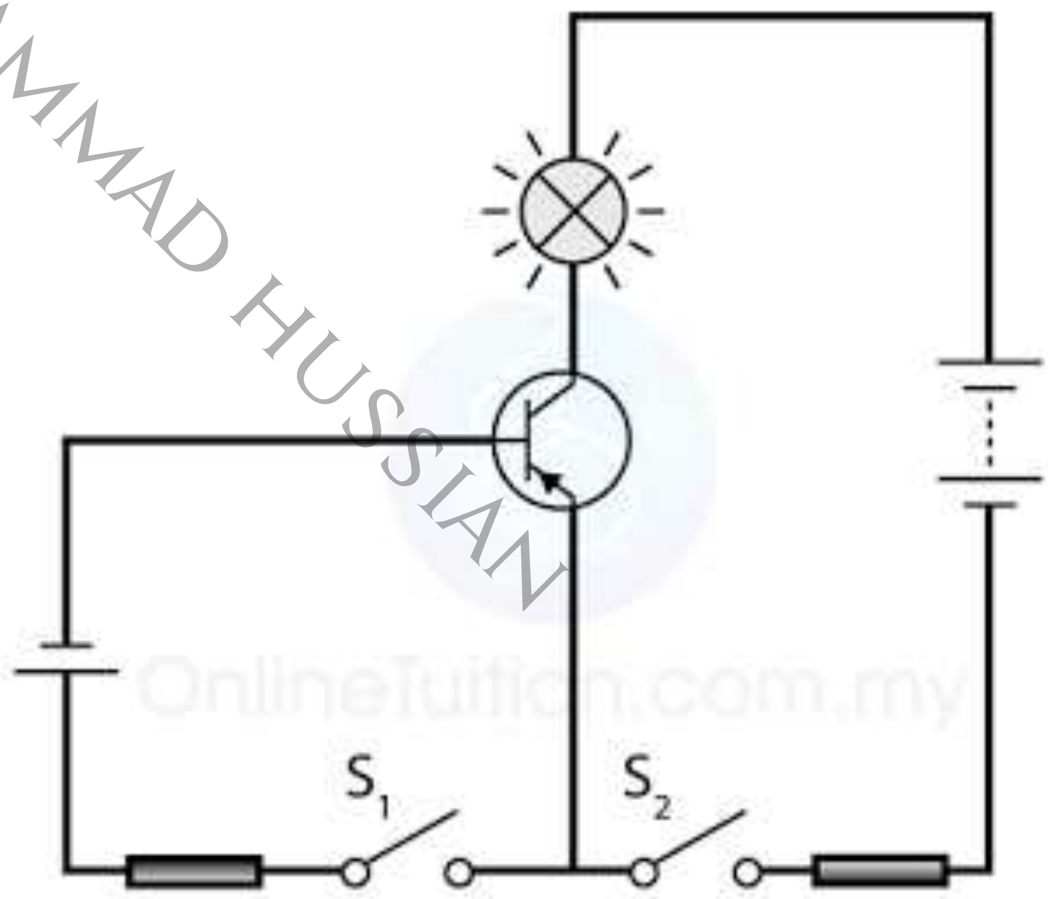

Emitter-Base: Forward Bias

Collector-Base: Reverse Bias

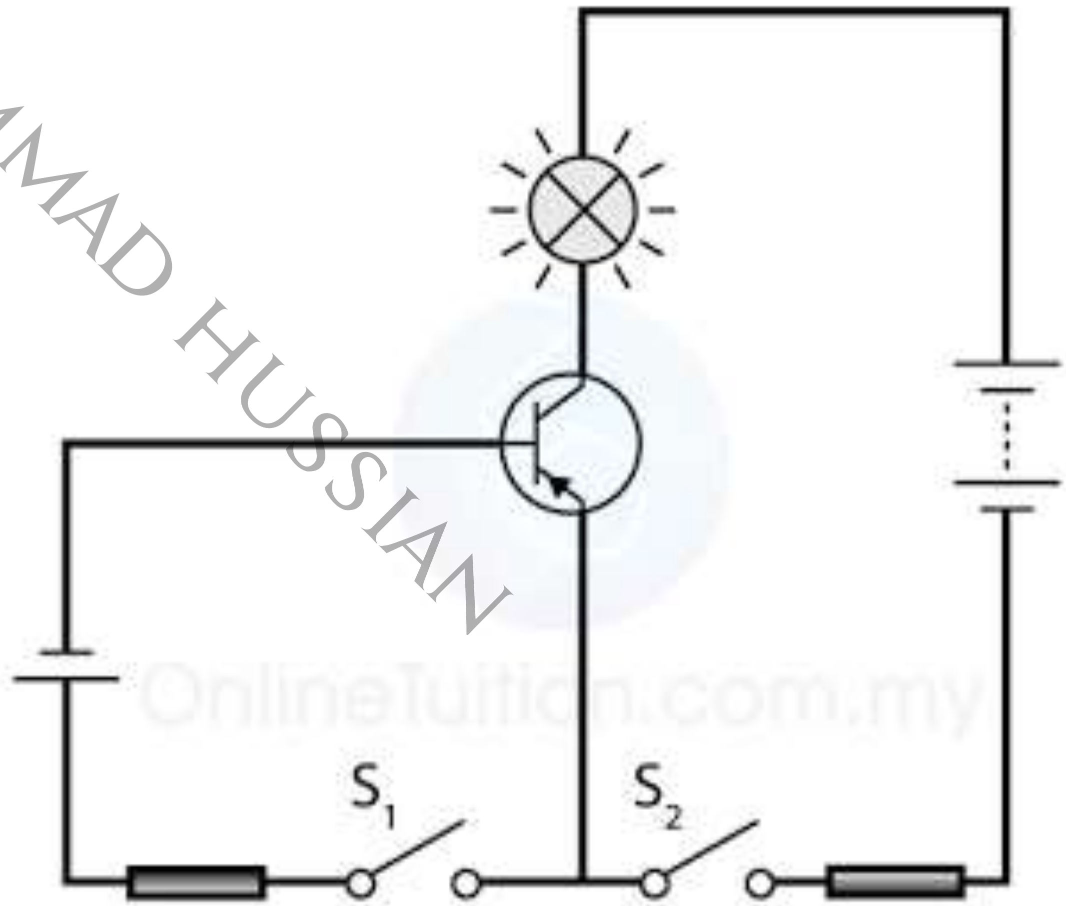
Connection: CORRECT

- Example:

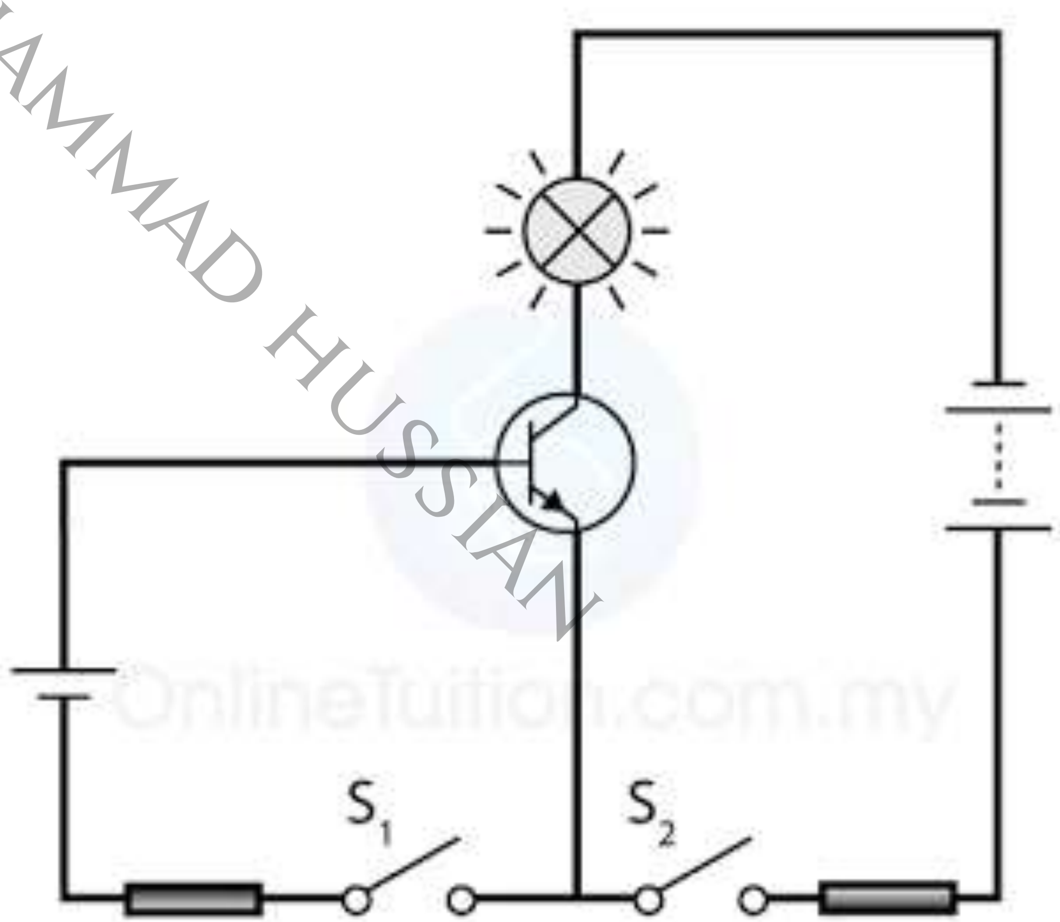




- Example



- Example:



Transistor as a CURRENT AMPLIFIER:
A small change in the base current results in a big change in the collector current.

- $I_C$ >>>>>>>>> $I_B$
- Unit for $I_B$ is μ**A ;** unit for $I_C$ is mA.

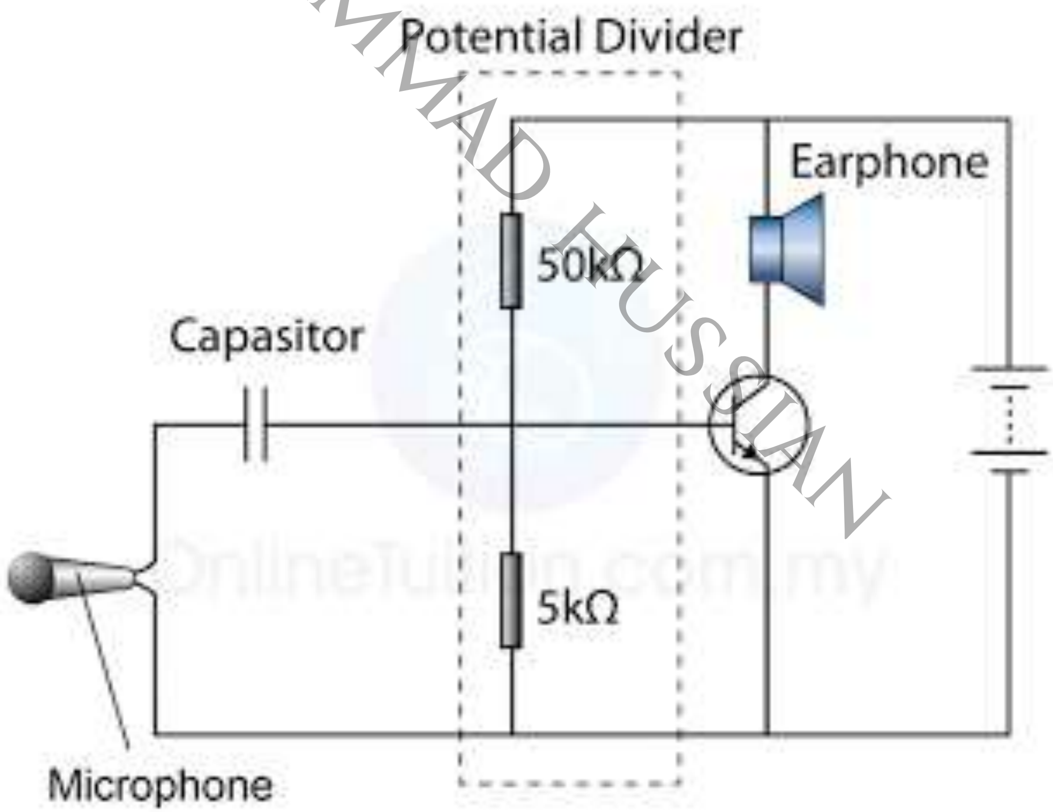
$$\textbf{Current Amplication} = \frac{\textbf{Collector current}}{\textbf{base current}}$$

$$I_E = I_B + I_C$$

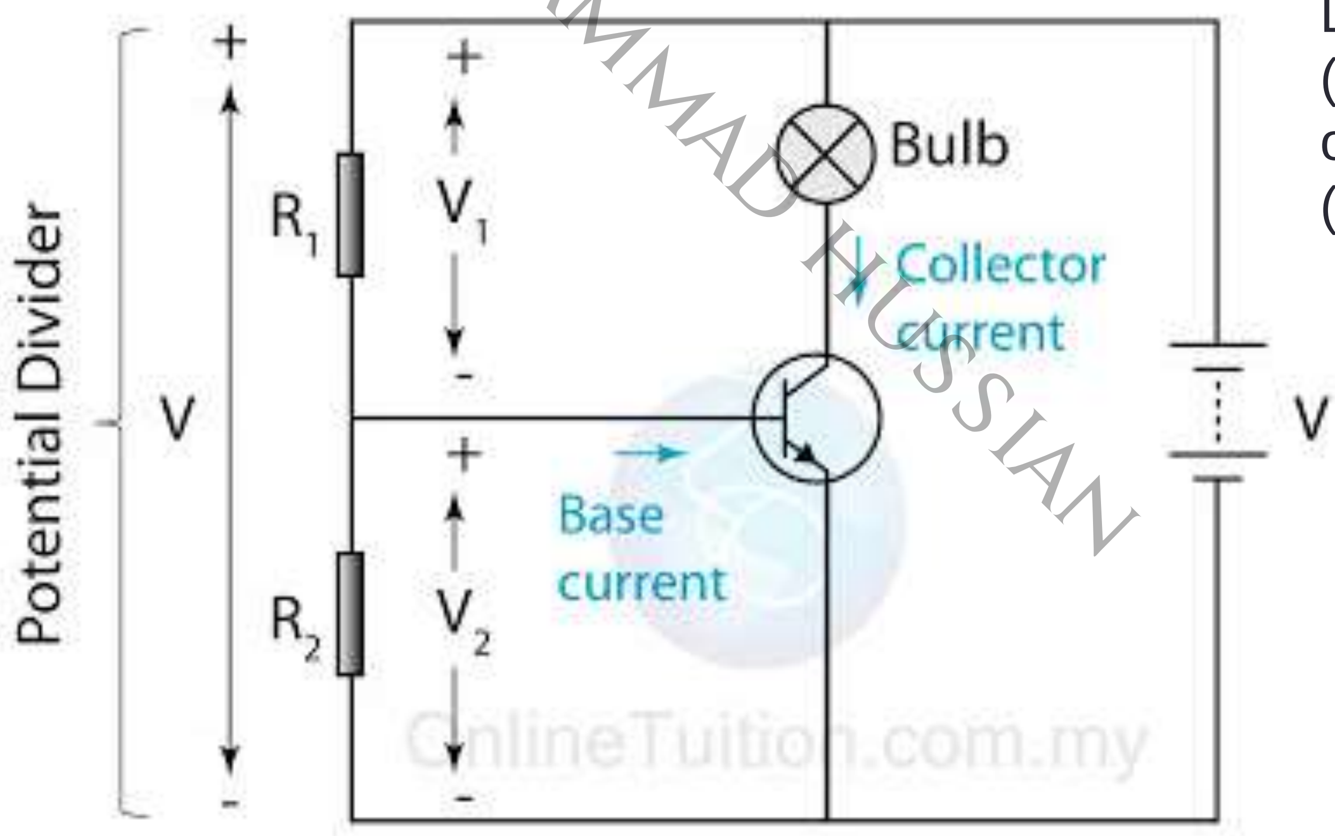
$$I_e > I_c > I_B$$

Transistor as an AUTOMATIC SWITCH:
If there is no current flow in the case circuit, there is also no current flow in the collector circuit.
If $I_B$=0, then $I_C$=0, transistor is switch off.
If $I_B$ flows, then $I_C$ flows, transistor is switch on.

- Example of transistor as AMPLIFIER.



- Example of transistor as AUTOMATIC SWITCH




Light (LED), heat (thermistor)
or sound (microphone).

- Voltage across the base can be controlled by a potential divider.
- According to the potential divider rule, the voltage across resistor $R_1$ and $R_2$ can be calculated by the formula:

$$V_1 = \frac{R_1}{R_1 + R_2} \times V$$

$$V_2 = \frac{R_2}{R_1 + R_2} \times V$$

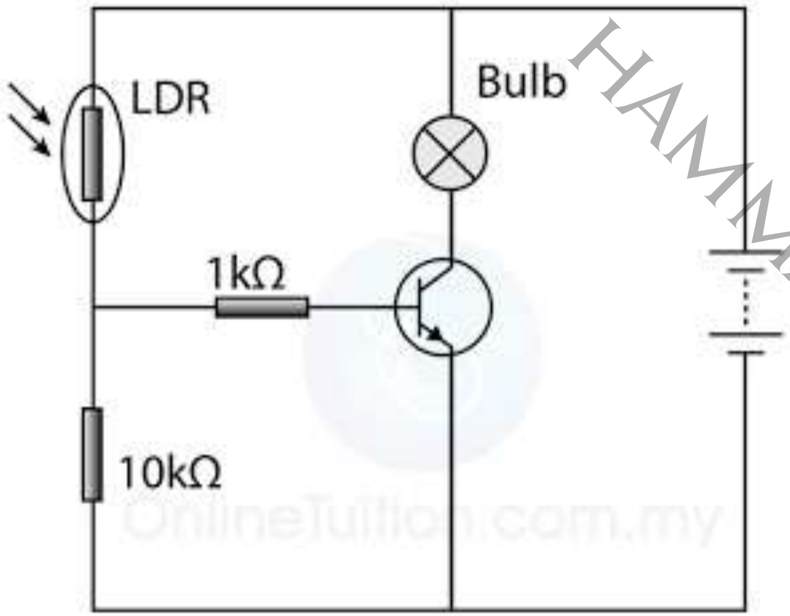
Thus, by varying the resistance of $R_1$ and $R_2$, we can control the voltage across the base $V_2$, and turn the light bulb on and off.

# LDR – Light dependent resistor

- A resistor sensitive to light.
- VERY HIGH resistance in darkness and a VERY LOW resistance in light.

- In a Light Operating Switch, we connect and LDR to a potential divider.
- The voltage across the base vary according to the intensity of light in the surrounding.

# Example 1



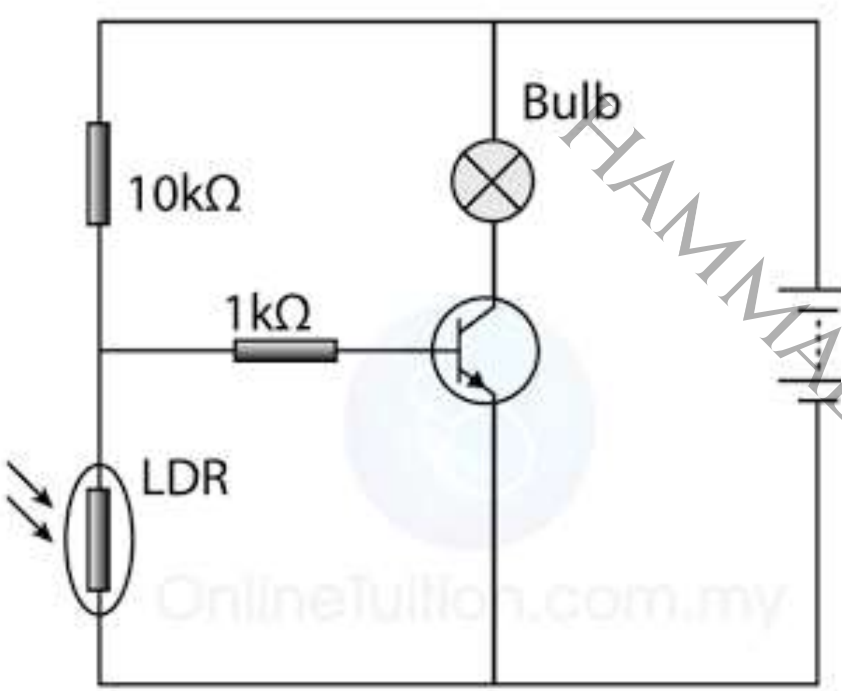

| Bright Surrounding: | Dark Surrounding |
|---|---|
| Resistance of LDR: **Low** | Resistance of LDR: **High** |
| Base voltage: **High** | Base voltage: **Low** |
| Base current: **High** | Base current: **Low** |
| Collector current: **High** | Collector current: **Low** |
| Bulb: **ON** | Bulb: **OFF** |



**Conclusion**

The bulb will be switched on when the surrounding is bright and switched off when the surrounding is dark.

# Example 2




| **Bright Surrounding:** | **Dark Surrounding** |
|---|---|
| Resistance of LDR: **Low** | Resistance of LDR: **High** |
| Base voltage: **Low** | Base voltage: **High** |
| Base current: **Low** | Base current: **Low** |
| Collector current: **Low** | Collector current: **High** |
| Bulb: **OFF** | Base current: **ON** |

**Conclusion**

The bulb will be switched on when the surrounding is dark and switched off when the surrounding is bright.

# 4.4 LOGIC GATE

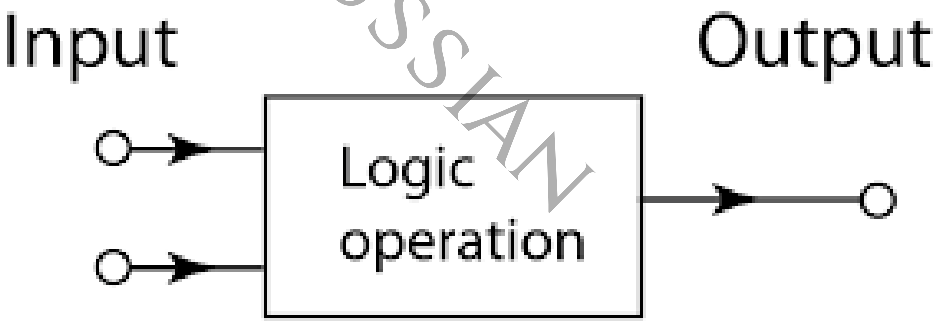
# Logic Gates

- A circuit that has one or more input signals but only produces ONE OUTPUT SIGNAL.
- Each input and output can be either high (logic 1) or low (logic 0).
- 0 represents 0 Voltage, and 1 represents a non-zero voltage.
- Function in daily lives: Security lamps, alarm systems, washing machines.
- Switching on and off are controlled by electronic switched made up of logic gates.

# Types of logic gates

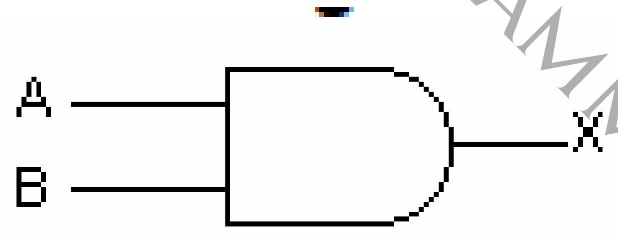
- AND gate
- OR gate
- NOT gate
- NAND gate
- NOR gate





# AND gate

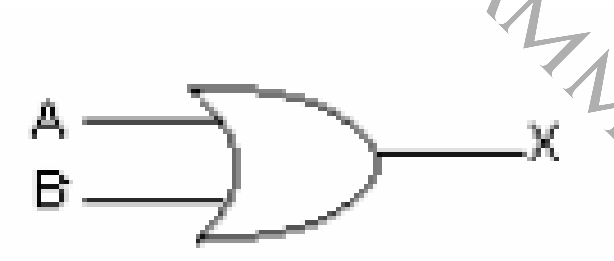
- For input to be ON, input A & B must be ON.




| INPUT | | OUTPUT |
|---|---|---|
| A | B | X |
| 0 | 0 | 0 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 1 |

# OR gate

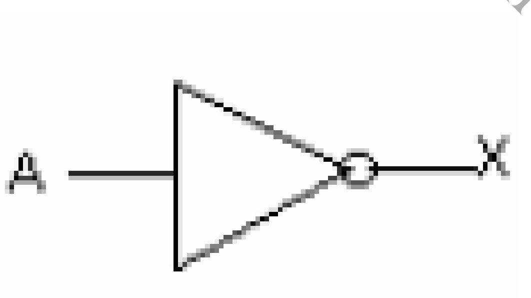
- For output to be ON, at least one input must be ON.




| INPUT | | OUTPUT |
|---|---|---|
| A | B | X |
| 0 | 0 | 0 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 1 |

# NOT gate

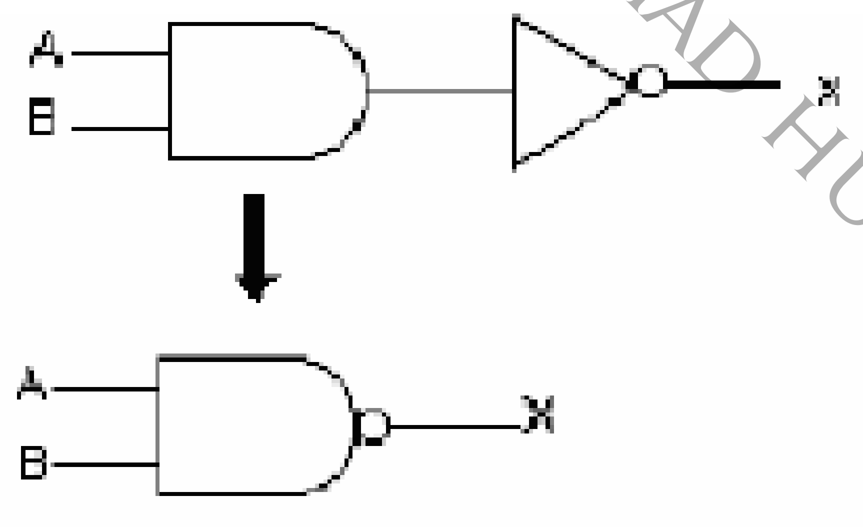
- Output in ON when the input is OFF; and vice versa.




| INPUT | OUTPUT |
|---|---|
| A | X |
| 0 | 1 |
| 1 | 0 |

# NAND gate

- It is same as an AND gate with its output inverted by a NOT gate.

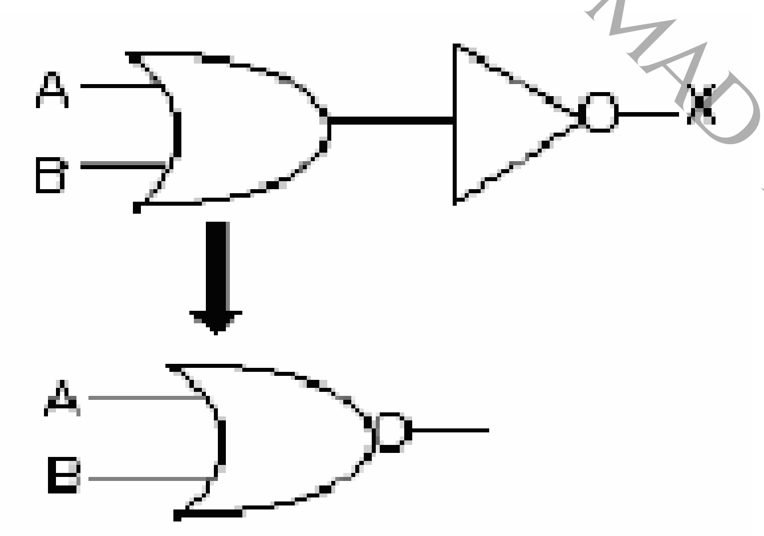



| INPUT | | OUTPUT |
|---|---|---|
| A | B | X |
| 0 | 0 | 1 |
| 0 | 1 | 1 |
| 1 | 0 | 1 |
| 1 | 1 | 0 |

# NOR gate

- It is the same as an OR gate with its output inverted by a NOT gate.

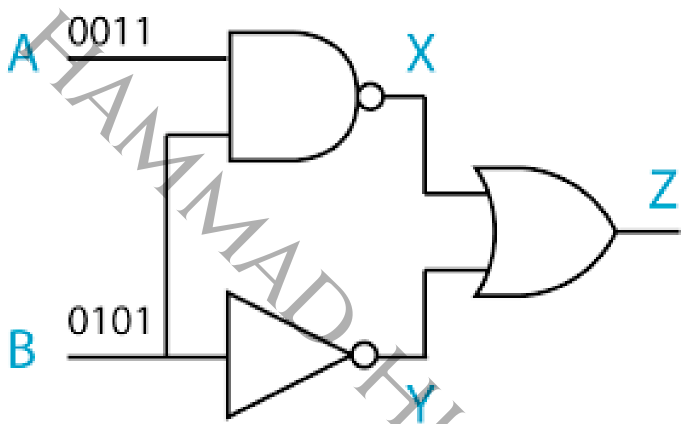





| INPUT | | OUTPUT |
|---|---|---|
| A | B | X |
| 0 | 0 | 1 |
| 0 | 1 | 0 |
| 1 | 0 | 0 |
| 1 | 1 | 0 |

# Combination of logic gates

- Example 1



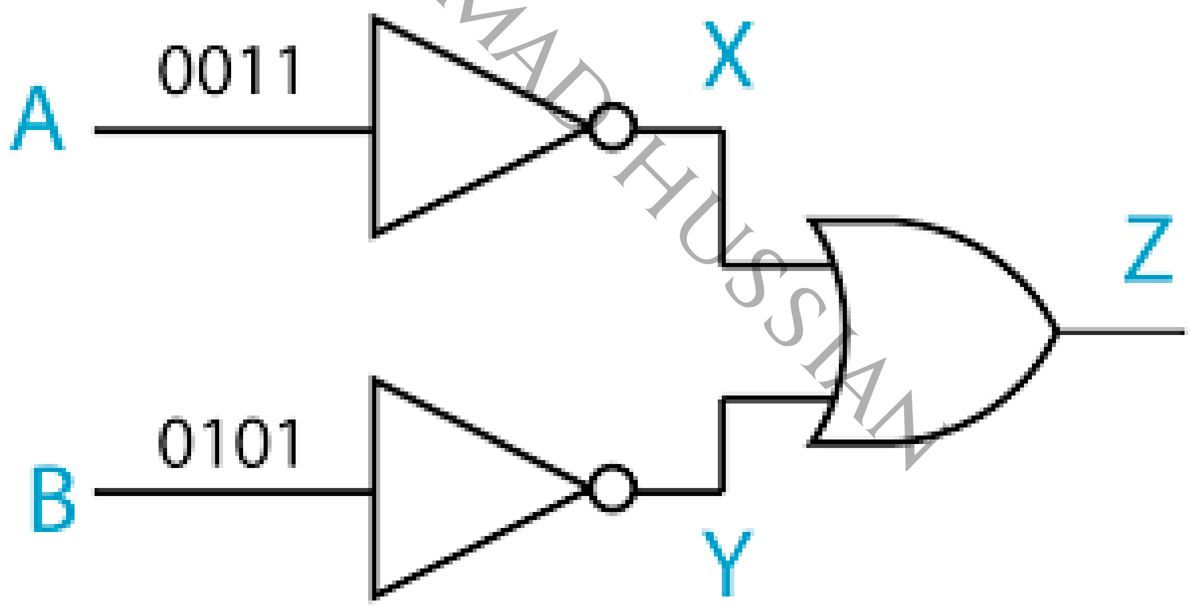



In the combination of logic gate above, find the outputs X, Y and Z of of the inputs A and B.

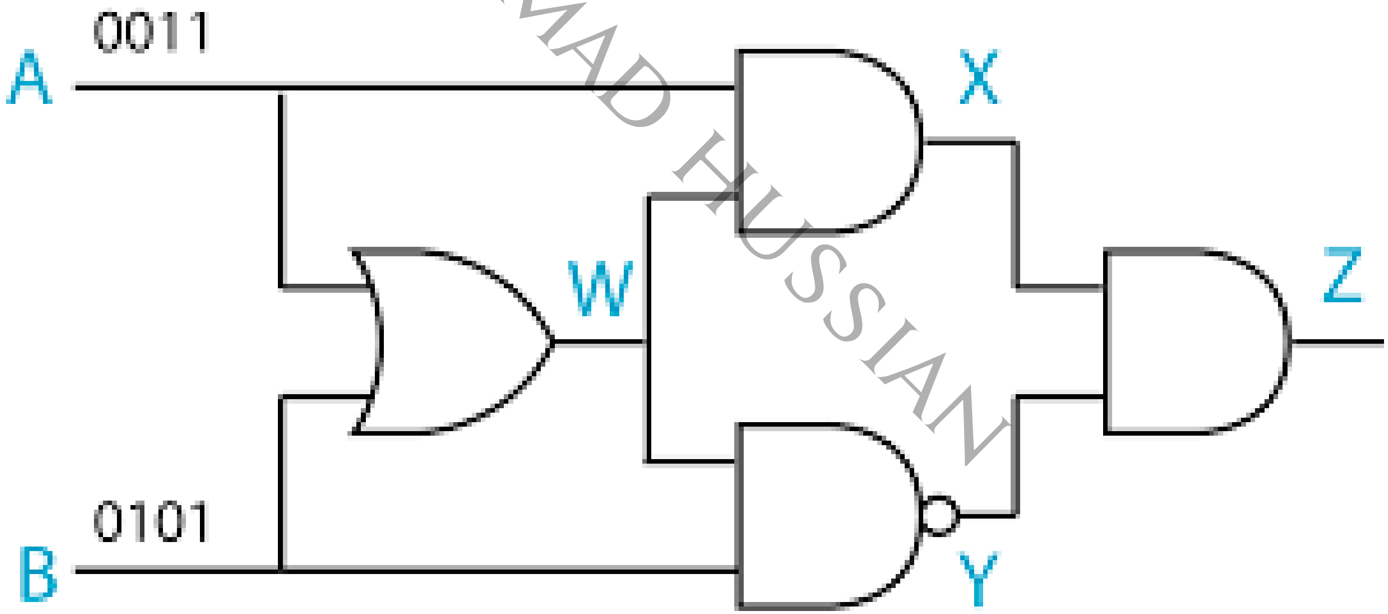
**Answer**:

| INPUT | | OUTPUT | | |
|---|---|---|---|---|
| A | B | X | Y | Z |
| 0 | 0 | 1 | 1 | 1 |
| 0 | 1 | 1 | 0 | 1 |
| 1 | 0 | 1 | 1 | 1 |
| 1 | 1 | 0 | 0 | 0 |

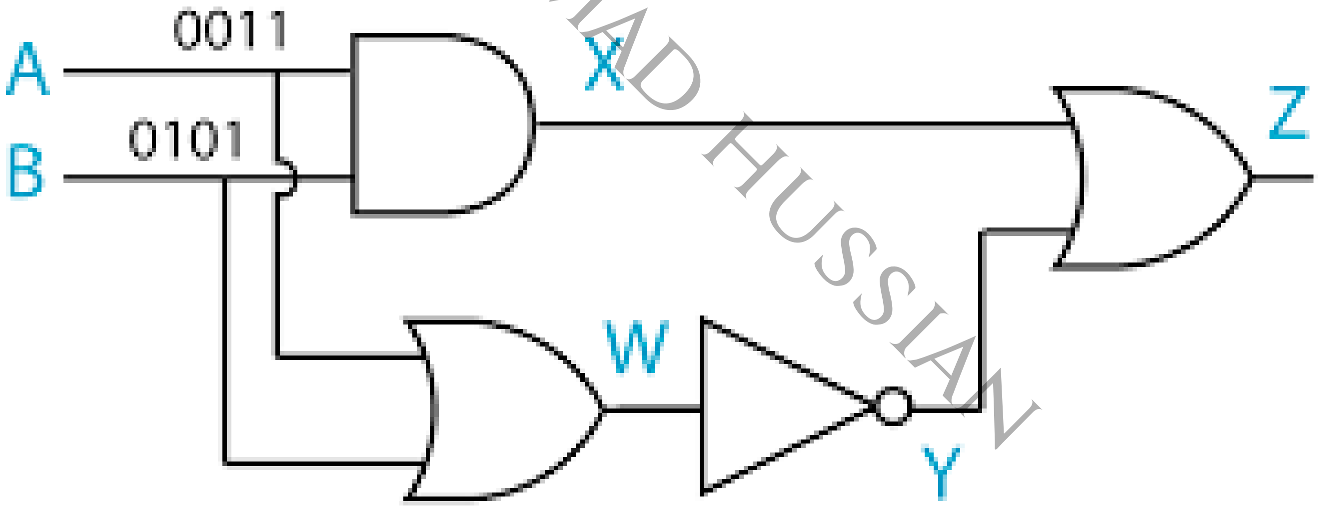
- Example 2



- Example 3



- Example 4



# Formula list

Speed of Electron

$$\frac{1}{2}mv^2 = eV$$

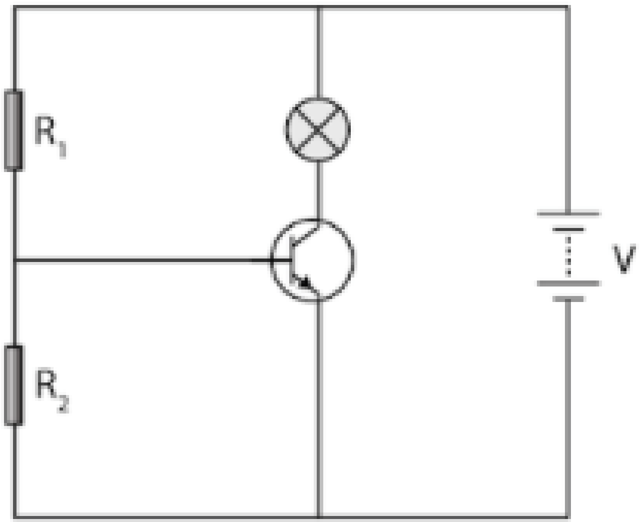
$$v = \sqrt{\frac{2eV}{m}}$$

Vertical scale = Y-gain control

Horizontal scale = Time base

Period = Time for 1 complete Oscillation

Frequency, $f = \frac{1}{T}$




Potential difference across resistor $R_1$

$$= \frac{R_1}{R_1 + R_2} \times V$$

Potential difference across resistor $R_2$

$$\frac{R_2}{R_1 + R_2} \times V$$