Chapter = 18

Electronics

18.1 Brief Review of p-n junction and its characteristics

P-n Junction

One of the most important building block of electronic devices is the p-n junction.

Formation

A p-n junction is formed when a crystal of Silicon or Germanium is grown in such a way that its one half is doped with a trivallent impurity (3-electrons in the valance shell e.g Al).

The other half is doped with a pentavalent impurity (5-electrons in the valance shell e.g Phosphorous).

The half with a trivalent impurity is called p-region and the other half with pentavalent impurity is called n-region.

In p-region

i Holes are majority chargecarriers
ii Free-electrons are minority charge carries.

In n-region

i Free-electrons are majority charge carriers.
ii Hole are minority charge carriers.

Deplection Region

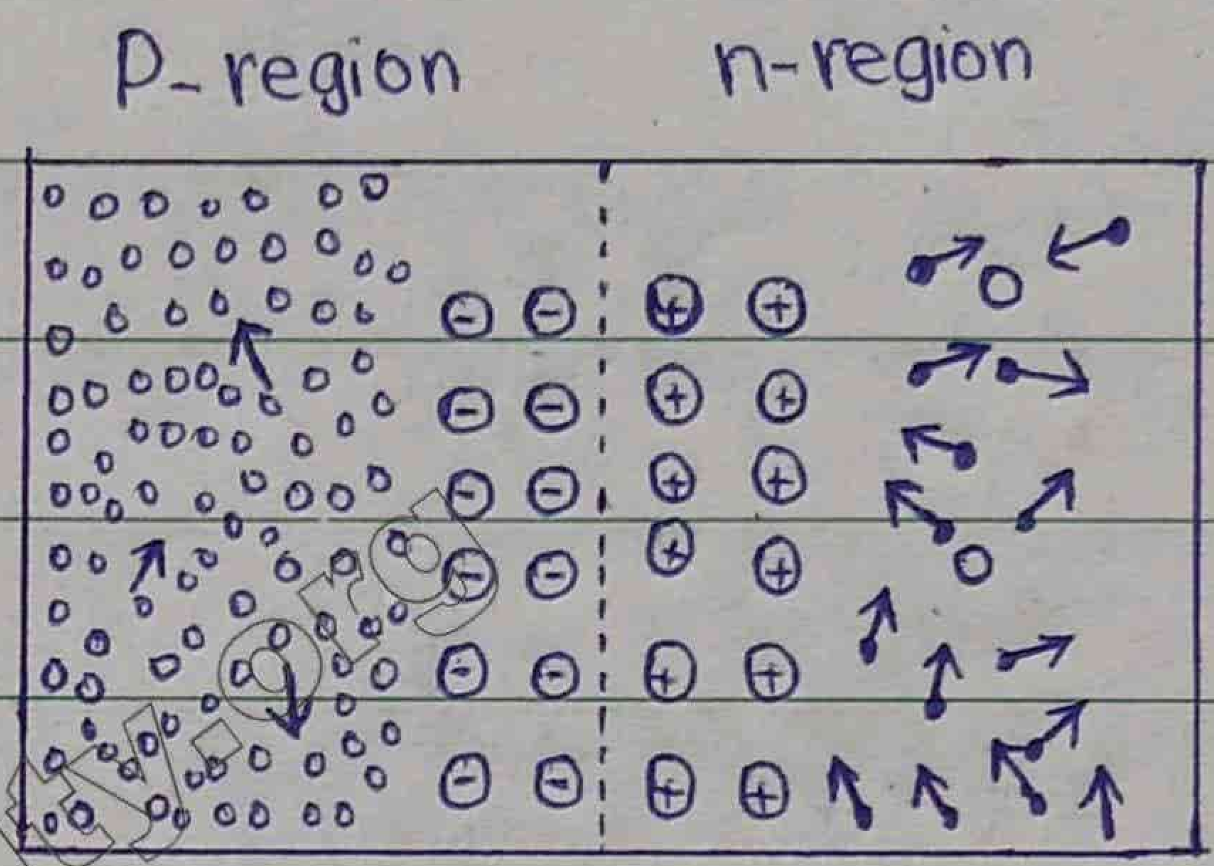
Just after the Formation of p-n junction.

1- Free Electrons start difusing from n-region to p-region leaving a layer of +ve fixed ions in n-region

2. Holes diffuse from p-region to n-region leaving behind a layer of -ve fixed ions in p-region.

These two layers stop further diffusion of free electrons and holes across the p-n junction.

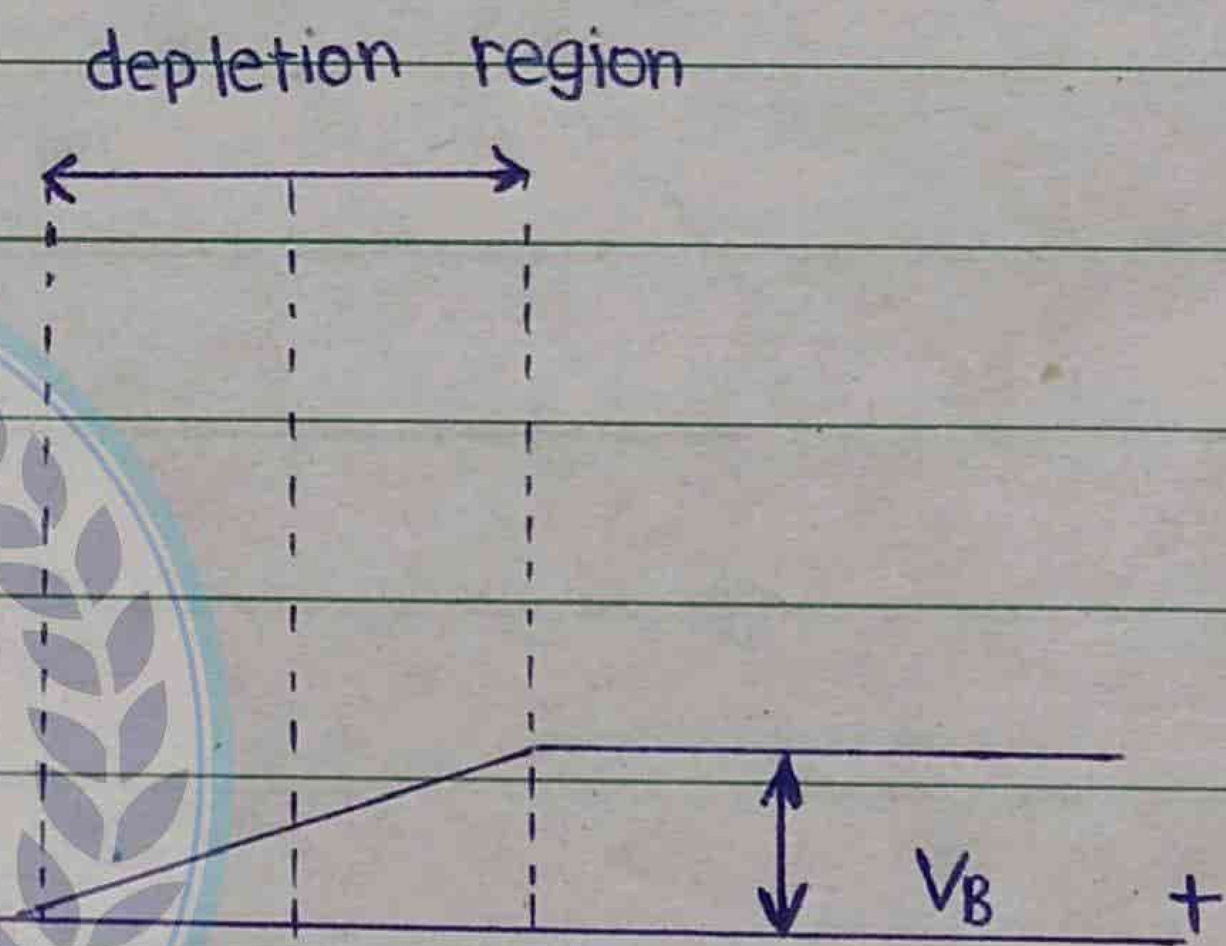
A chargeless region is formed around the junction in which charge carriers are not present. This region is called deplection region. In fig



i) ; Black dots represent free electrons.

ii) : Small circules represent holes.

iii) ; ⊕ and ⊖ sign shows the positive and negative ions which constitute the depletion region.



iv) ; Width of the deplection region is of the order of micro meters $(\mu m) = 10^{-6}$ m.

Potential Barrier

A potential barrier i.e, a potential difference is created due to the positively and negatively charged layers of ions on either side of p-n junction. Its value is

0.7 V for Siclicon

0.3V for Germanium

This potential difference is called Potential Barrier because it stops further diffusion of free electrons and holes across the junction

Biasing of a p-n junction

"It is the application of some electric potential across the p-n junction.

A p-n junction is based in two ways.

1- Forward Biasing

2. Reverse Biasing

1- Forward Biasing of a p-n junction diode

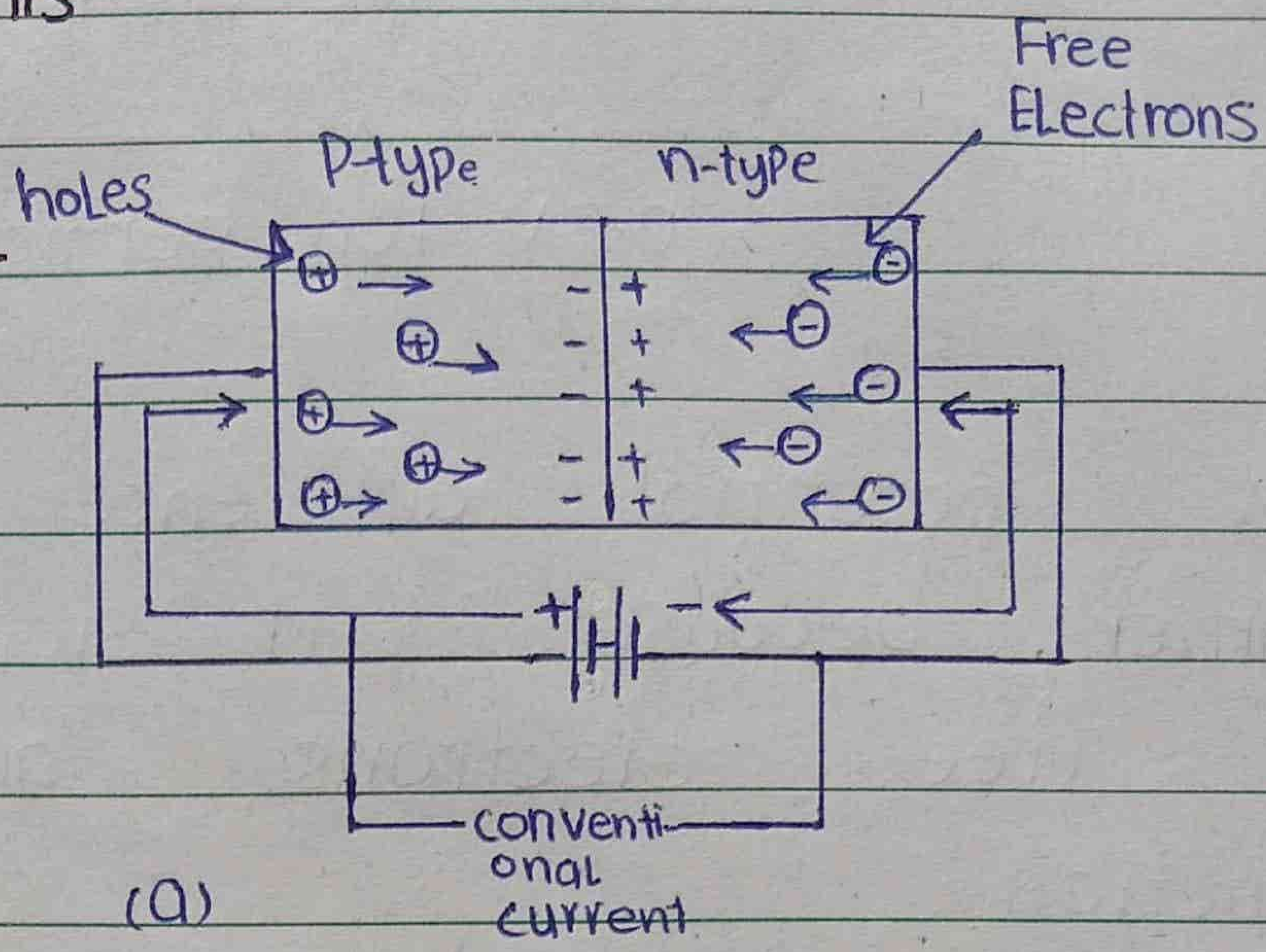
"A junction diode is forward baised when:

i): p-region is connected to +ve terminal of battery.

ii); n- region is connected to -ve terminal of battery.

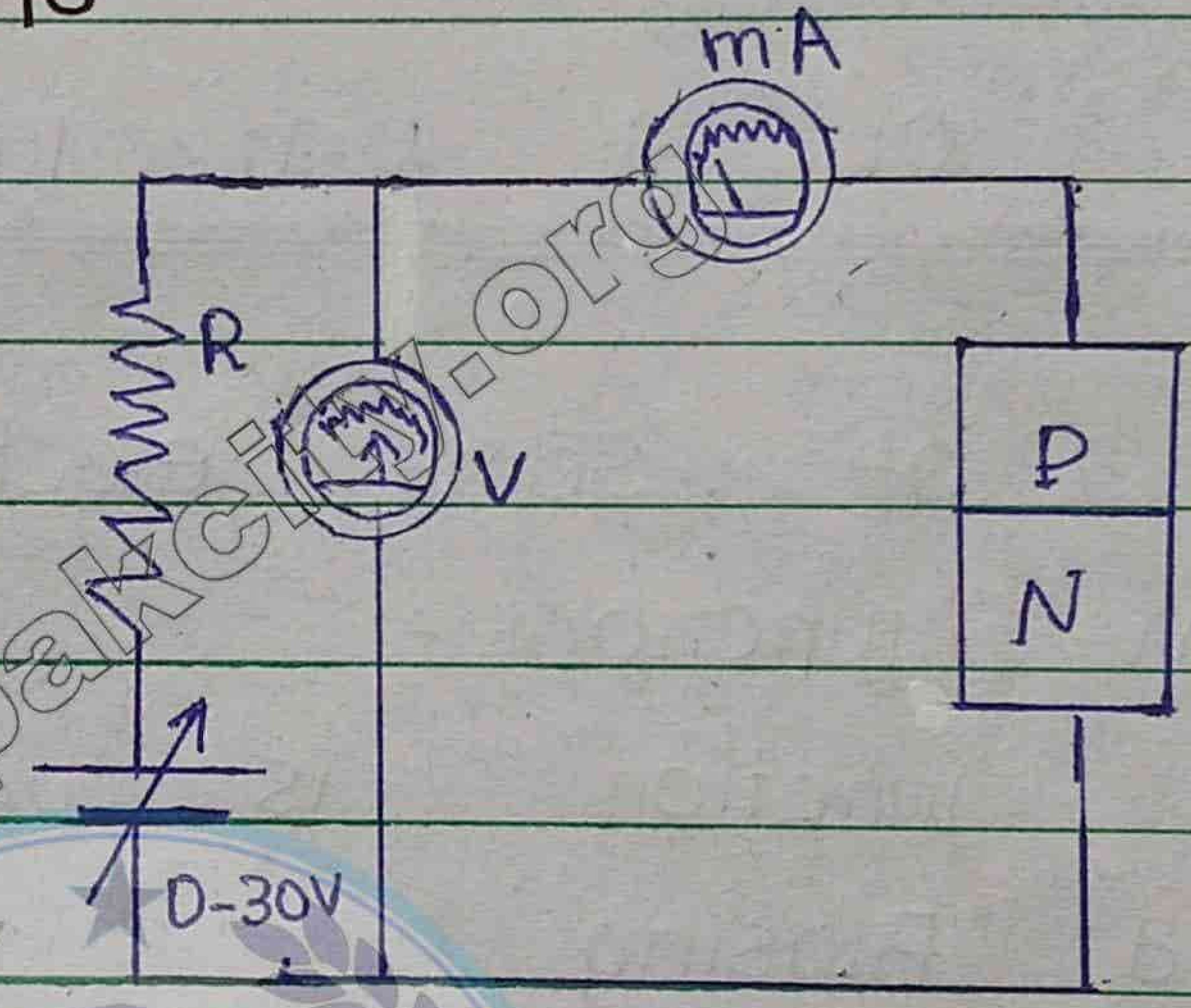
Explanation

Due to this potential difference applied, energy is supplied to the free electrons in the n-region and holes in p-region.



(a)

When this energy is sufficient to overcome the potential barrier, a current of the order of few milliamperes starts flowing across the p-n junction.



(b)

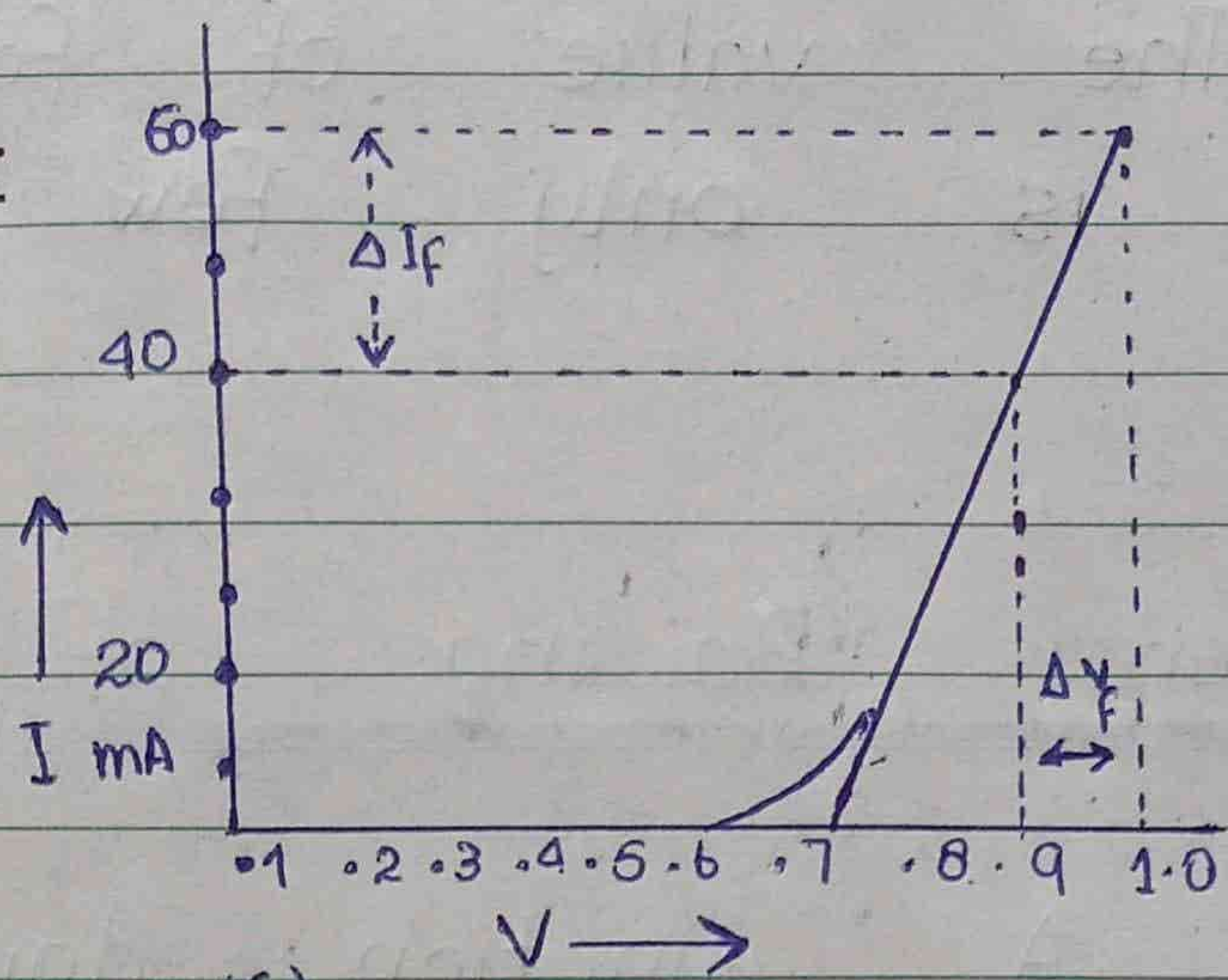
"Depeletion region becomes narrow."

Forward Characteristics of p-n junction diode.

The variation of current through the junction with the biase voltage can be studied by the circuit shown in Fig (b)

Graph between V and I

The value of current for different values of bais voltage is noted and a current, bias voltage graph is plotted. This graph is called forward characteristics of a p-n junction diode.



(C)

Fig (c) shows a graph for a typical low power silicon diode.

Forward Resistance: r_f

If forward bias voltage is increased ΔV_f, the current increases by ΔI_f.

Forward resistance r_f is:

$$r_f = \frac{\Delta V_f}{\Delta I_f}$$

Definition

"The resistance offered by p-n junction when it is conducting is called Forward resistance."

The value of Forward resistance r_f is only few ohms.

2- Reverse Baising of p-n junction diode.

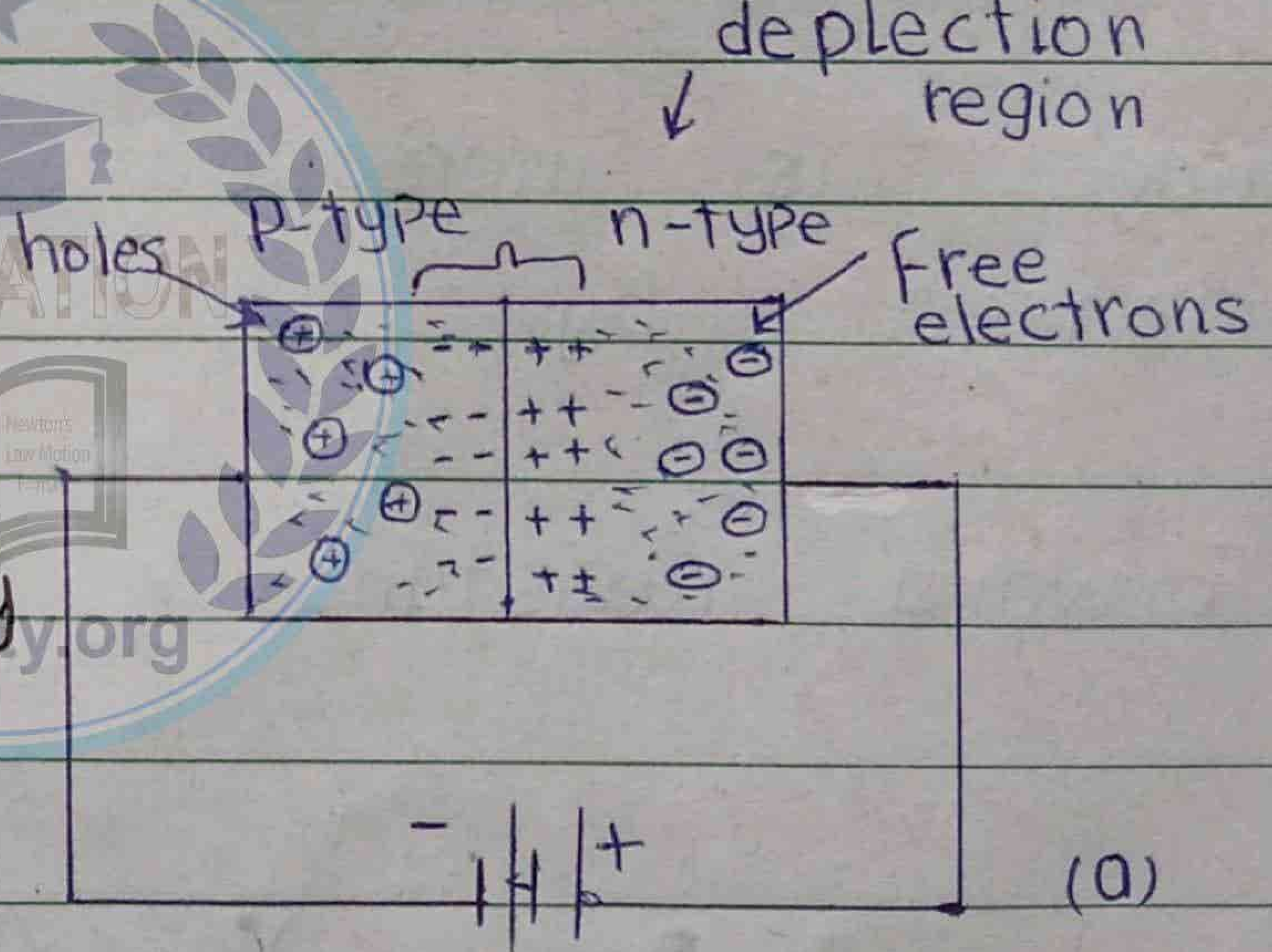
A junction doide is reverse baised when:

i P-region is connected to negative terminal of battery.

ii N-region is connected to Positive terminal of battery.

Explanation

When p-n junction is reversed baised no current flows due to majority charge carriers.



However a very small current of the order of few (μA) microamperes flows across the junction due to the flows of minority charge carriers. It is known as reverse current or Leakage current.

In reverse biased state free electrons and holes are repelled father from the "depletion region becomes wide."

Reverse Characteristics of a p-n Junction diode.

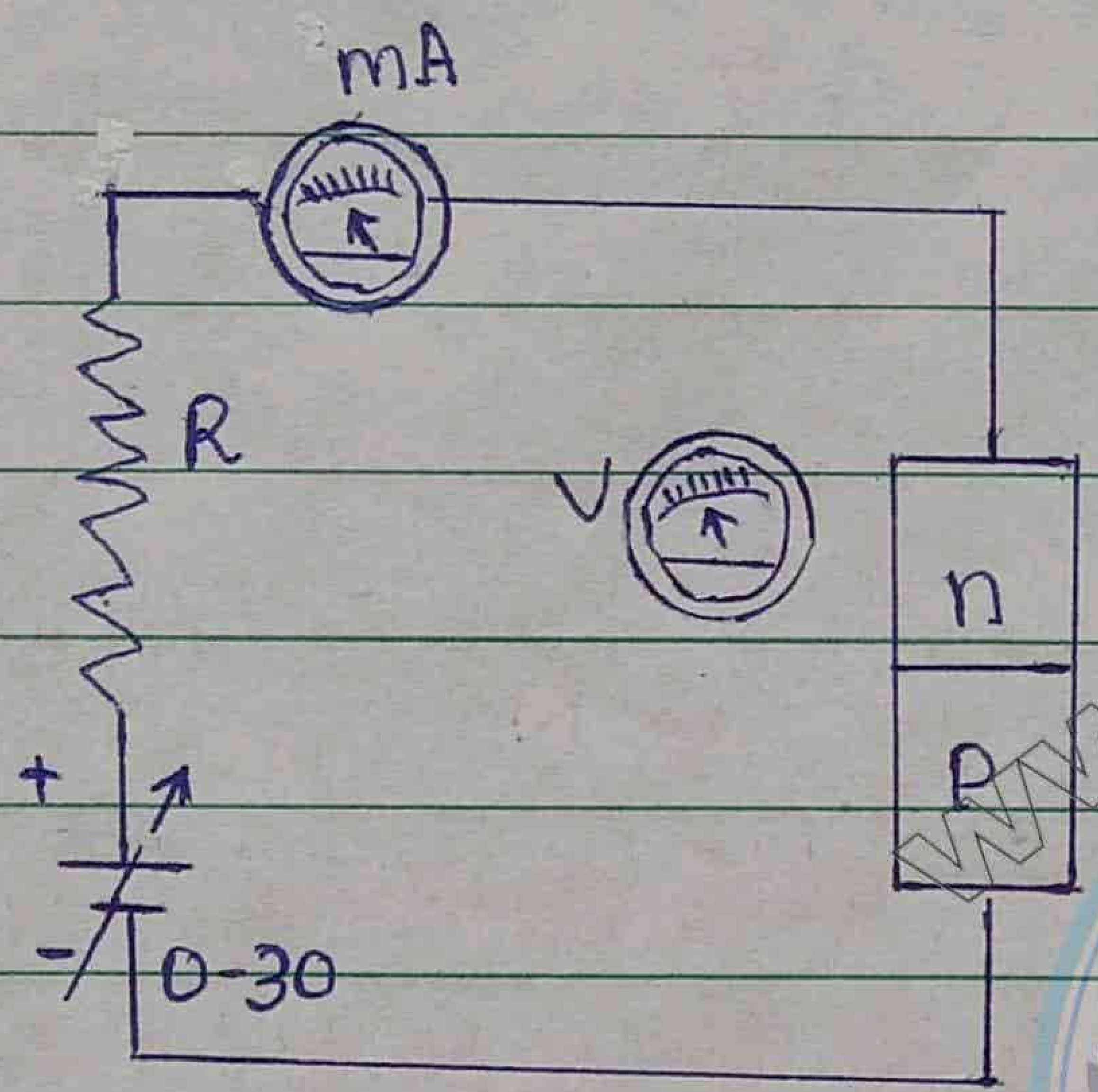


Fig (b)

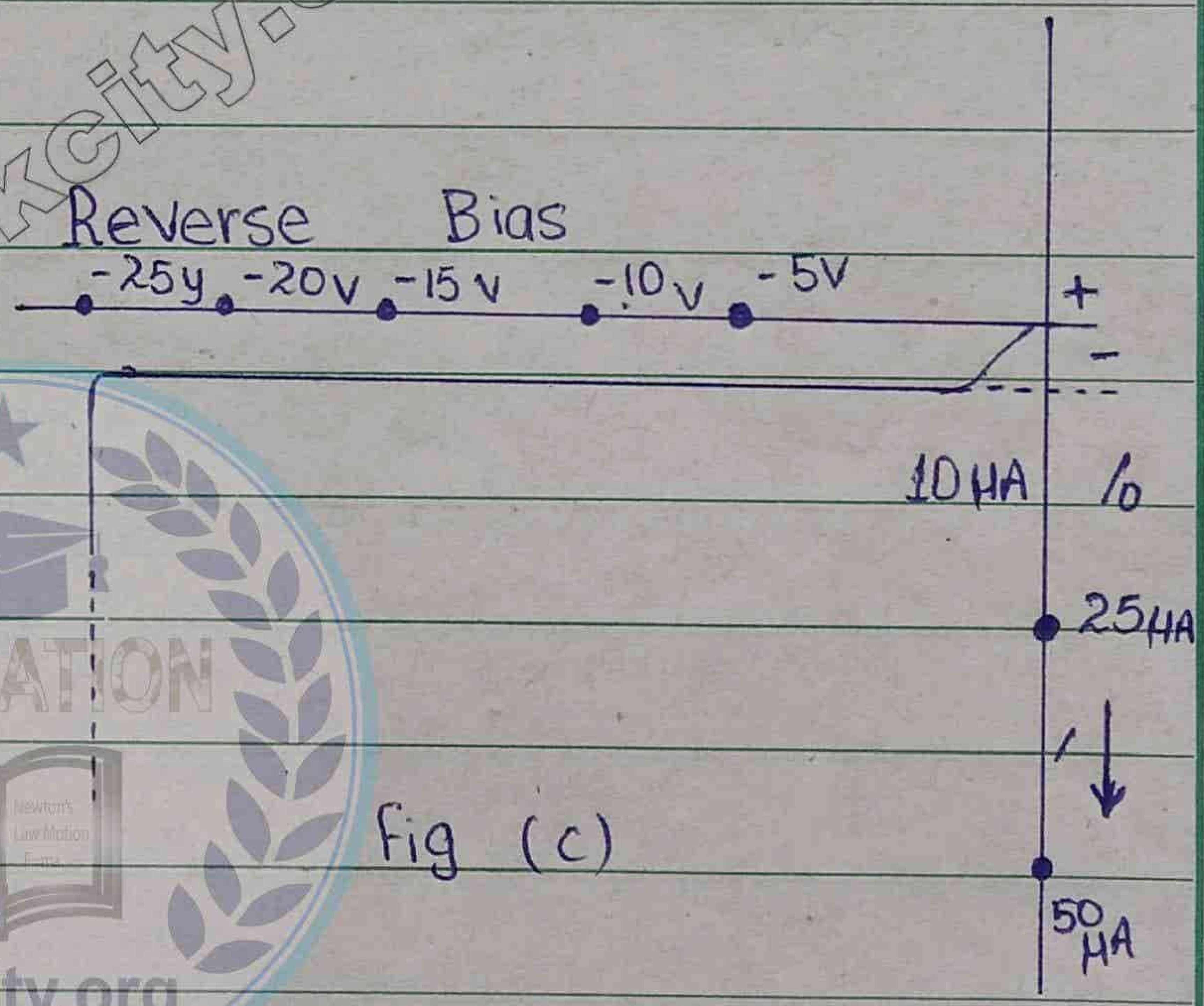


Fig (c)

The variation of reverse current with the applied voltage can be studied by the circuit shown in Fig (b)

Graph between V and I

Fig (c) Shows the reverse characteristics of p-n junction. It can be seen that as the reverse voltage is increased from 0, the reverse current quickely rises to its saturation valu I_0. As the reverse voltage is further increased, the reverse current remains almost constant.

Here the resistance offered by the p-n junction diode is very high of the order of several mega ohms.

Break Down Voltage

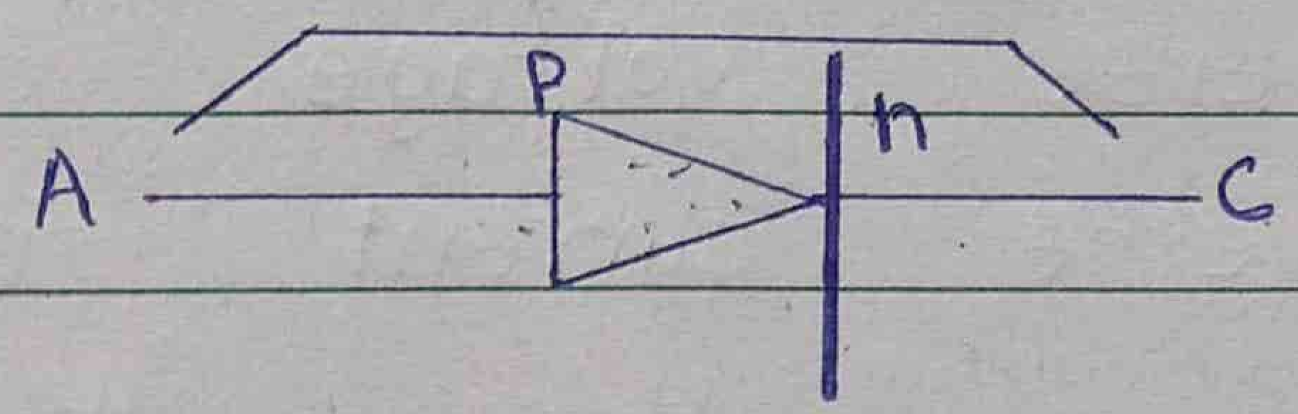
As the reverse voltage is increased, the kinetic energy of the minority charge carriers also increases and break the covalent bonds.

As the covalent bonds break more electron hole pairs are produced. Thus minority charge carriers begin to multiply due to which reverse current begin to increase till a point is reached when the junction breaks down and reverse current rises sharply.

After break down the reverse current will rise to a very high value which will damage the junction.

p-n junction resistance is also known as Semi-conducter diode.
Its symbol is shown in fig

1- The arrow head represents p-region and known as anode A.



2- The vertical line represents the n-region and is known as Cathode C.

When the diode is forward biased current flows in the direction of arrow.

18.2 Rectification

Definition

"Conversion of alternating current AC into direct current DC is called rectification."

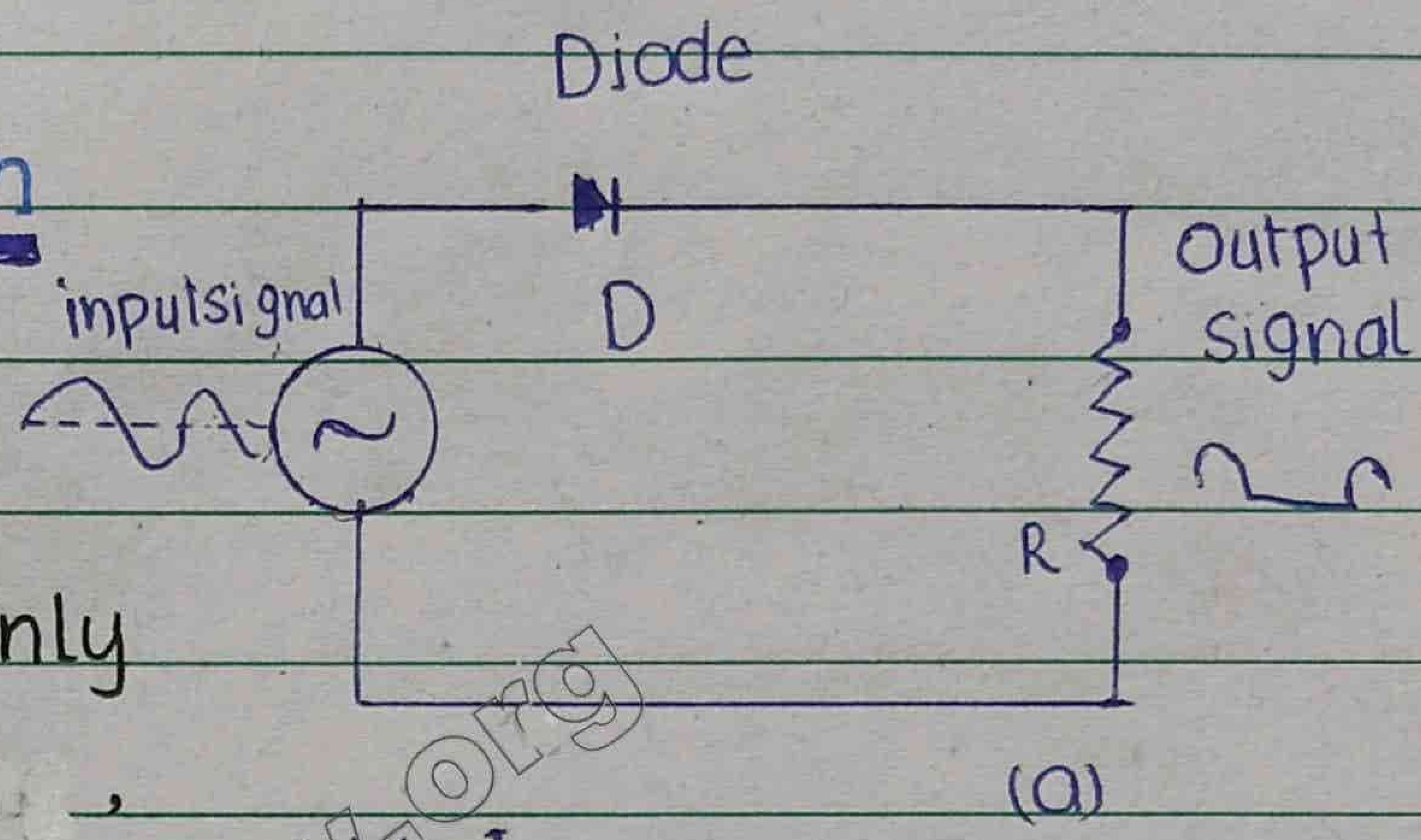
Rectifier

Semiconductor devices used for the conversion of AC into DC are called recifiers."

Two types of Recification :

1- Half Wave Recification
2- Full Wave Recification

Half Wave Rectification



" Rectification in which current flows only during the alternate , half cycle is known as half wave rectification."

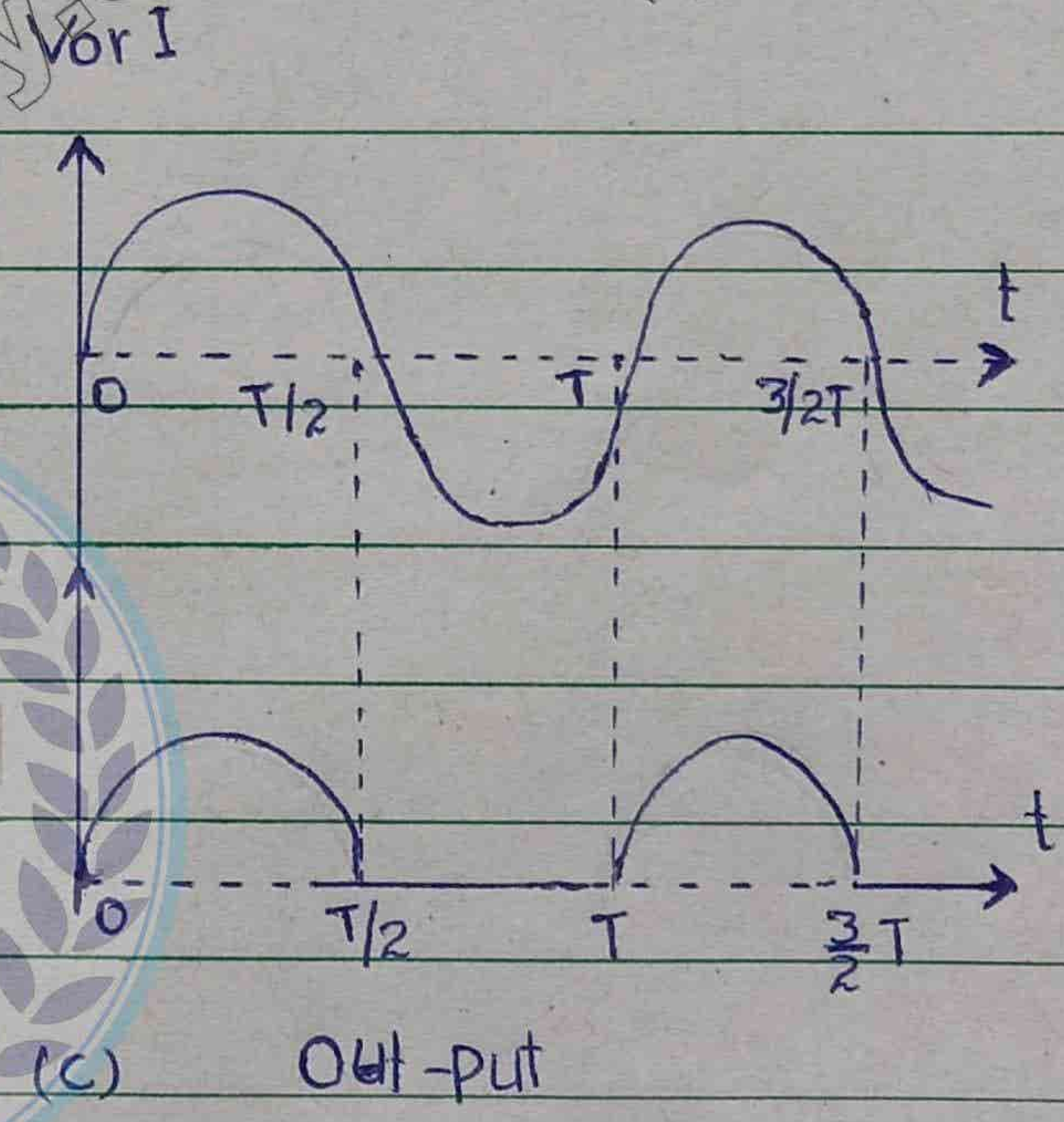


Fig (a) shows that doide D and Load resistance are connected in series with an alternating voltage Source of time period T.

Opreation

(i) During the positive half cycle of the input alternating voltage i.e, during the internal $0 \rightarrow T/2$, the diode D is forward biased and a current flows through R. The flows of current accros it which changes according to the input drop signal.

ii During the negative half cycle i.e. during the time interval $T/2 \longrightarrow T$, the diode is reverse biased and no current flows through R. The potential drop across R is almost zero. The same situation occurs during the next cycle and so on.

The current through R flows in only one direction which means it is a direct current. This current flows in pulses. The voltage which appears across the load resistance R is called as output voltage.

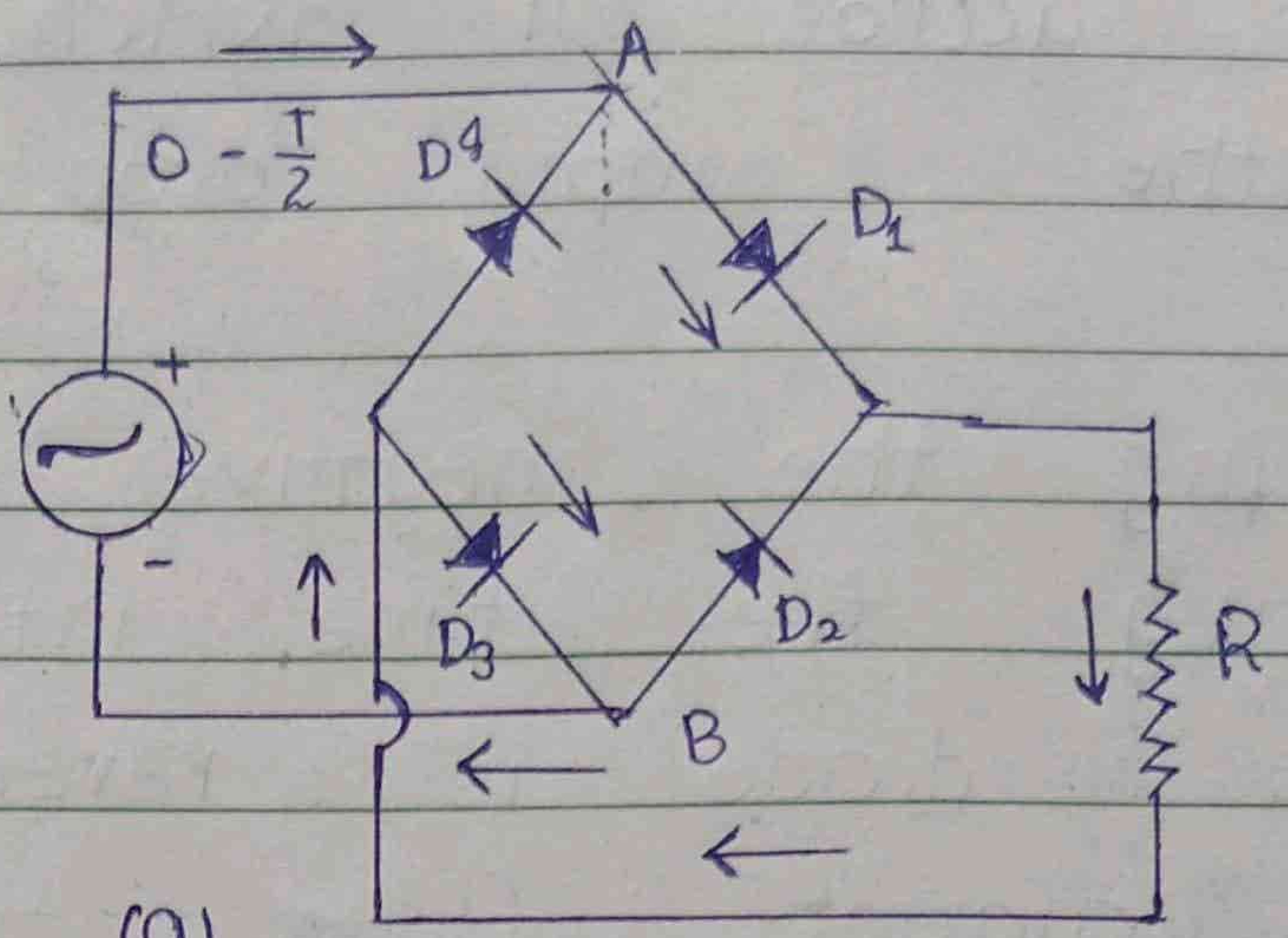
Full Wave Rectification

"Rectification in which out put current flows in the same direction during both half cycle of input voltage is known as full wave rectification."

Operation

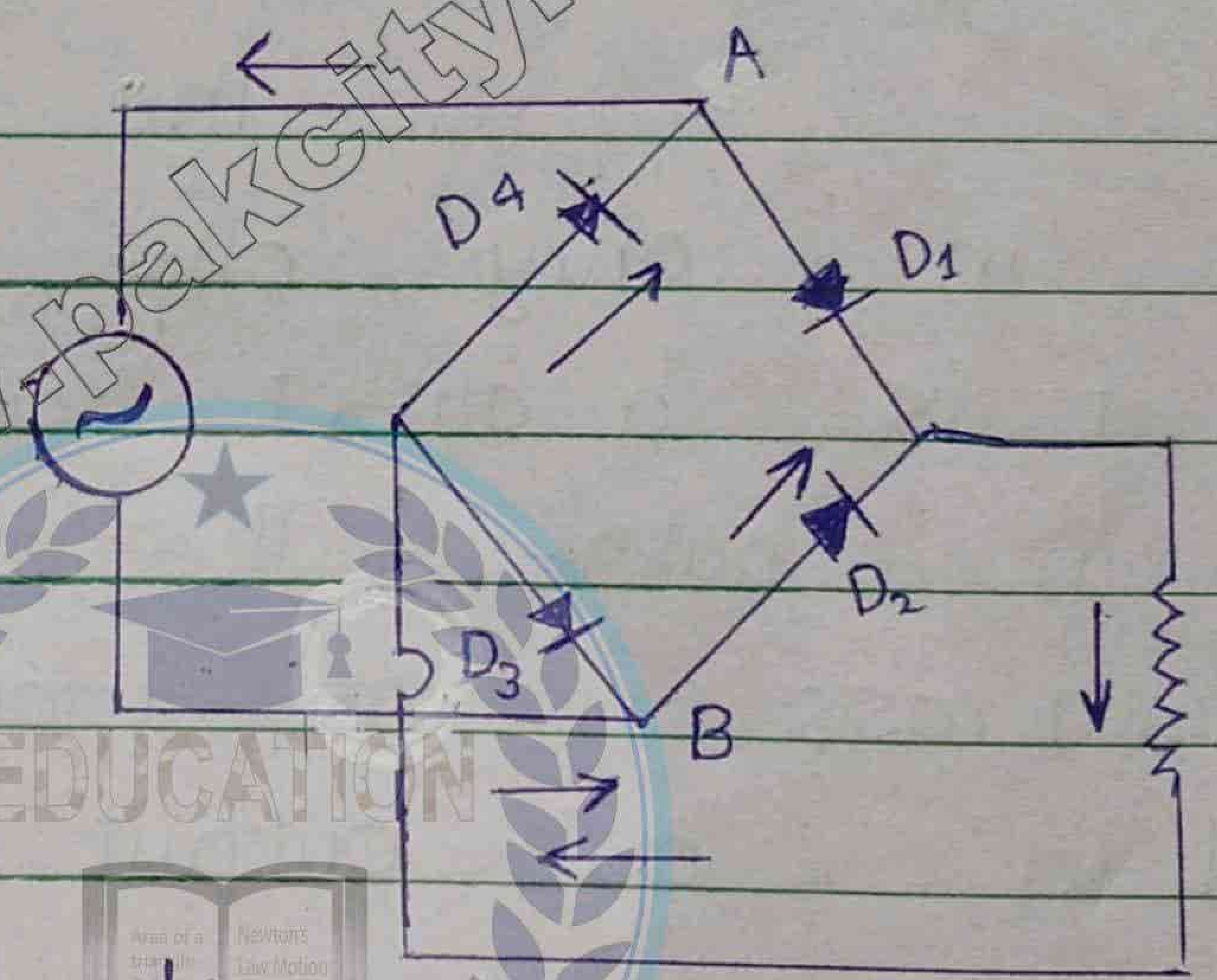
Figure Shows that 4-diode are connected in a bridge type arrangement.

We know that a doide conducts only when it is forward biased.



(a)

i) During the positive half ycle i.e, during the time $0 \to T/2$ the terminal A of the bridge is positive with respect to the terminal B.



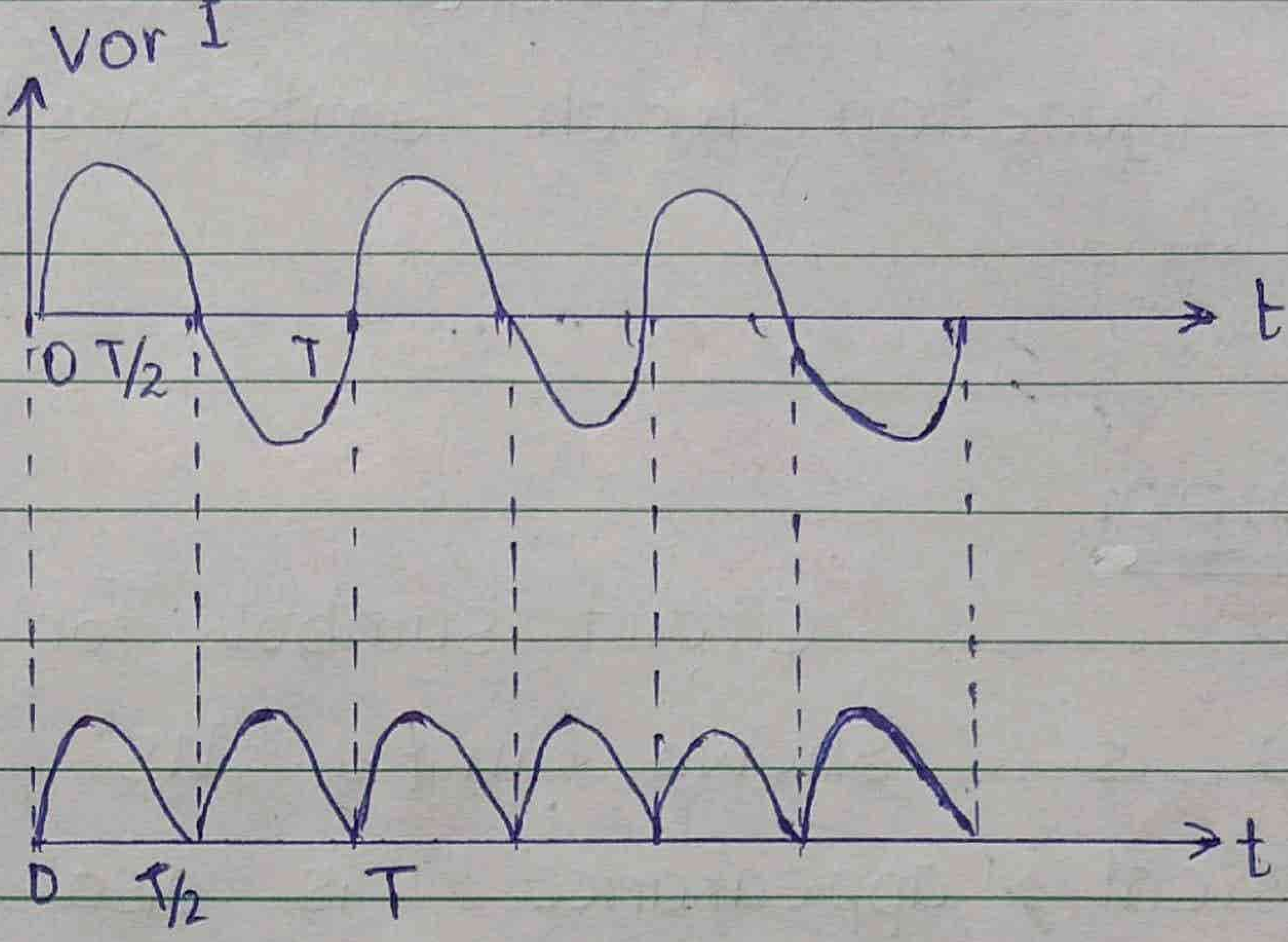
(b)

The diods D_1 and D_3 become forward biased and conduct. A current flows through the circuit in the direction shown by arrows in Fig(a).

ii) During the negative half cycle i,e, during the time interval

T/2 → T, terminal A is negative and terminal B is positive.

The diodes D_2 and D_4 conduct and current flows through the circuit in the path shown by arrows in Fig (b)



(c)

The direction of current flow through the load resistance R is the same in both the halves of the cycle. Thus both havels of the alternating input voltage send a unidirection current through R.

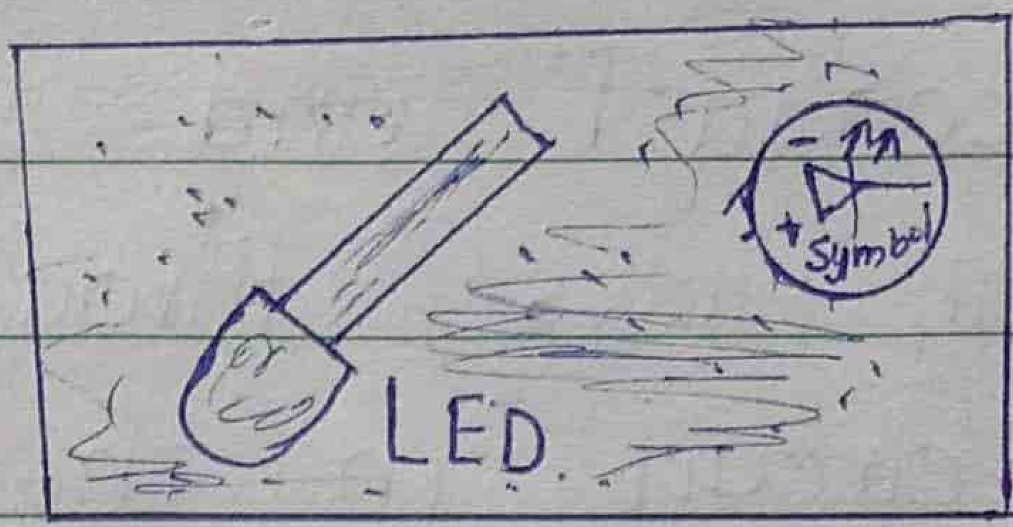
The input and output voltages are show in fig (c).

Output voltages is not smoth. It is pulsating. It can be made smoth by using a circuit as known "Filter Circuit."

18.3 Specially Designed p-n Junctions

1 Light Emitting Diode : (LED)

" It is a forward biased p-n junction which emits visible light."



Symbol

Circuit symbol for L.E.D is shown in fig. Its physical appearance is also shown.

8 A seven segment display
0123456789

Construction

Light emitting diodes are made from special semiconductors such as Galium-Arsenide-phosphide (Ga As P), Galium Arsenide (Ga As), Galium phosphide (Ga P).

When an electron combines with a hole during forward biased condition, a photon of visible light is emitted. The colour of emitted light depends on the type of material used.

Uses

i LED's are used as small light sources e.g. indicators.

ii) Infra red LED's are used in burglar-alarm system.

iii) They are used for solid state video-displays.

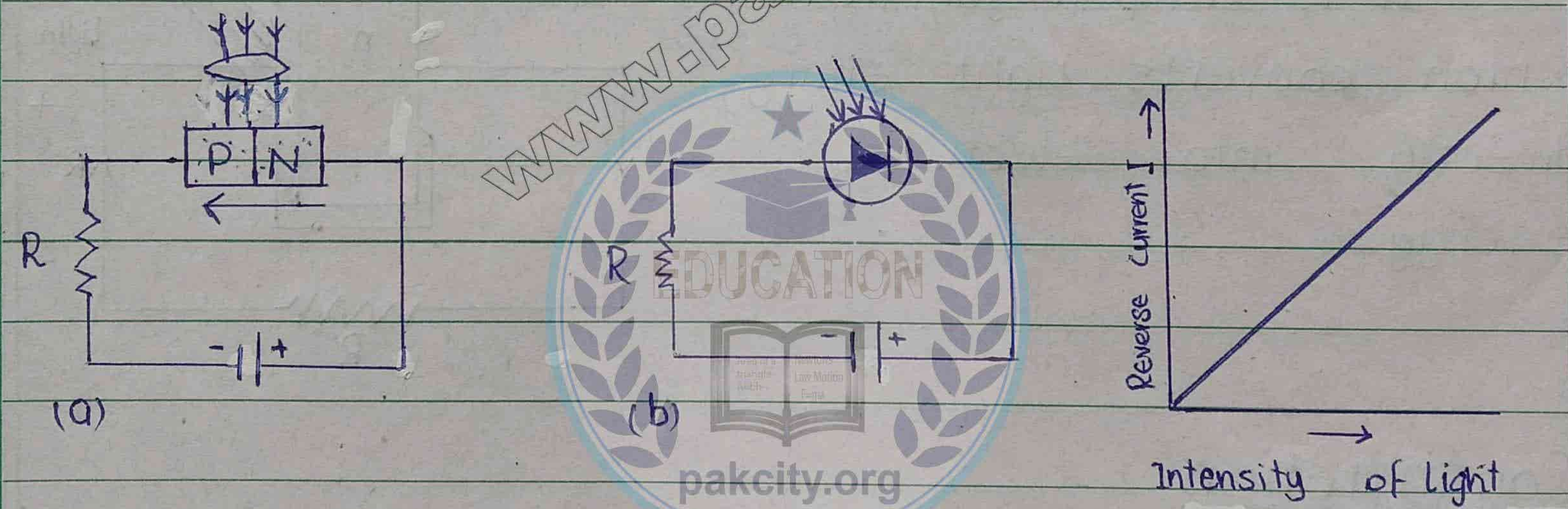
iv) A specially formed array of seven LED's is used for displaying digits.

2. Photo Diode

"It is used for detection of light."

Operation

Photo diode operates in "Revese biase" condition.



When no light falls on the junction, the revese current I almost zero (neglible). When p-n junction is exposed to light the reverse current increases with the intensity of light.

A photo diode can turn its current ON and OFF in Nano seconds.

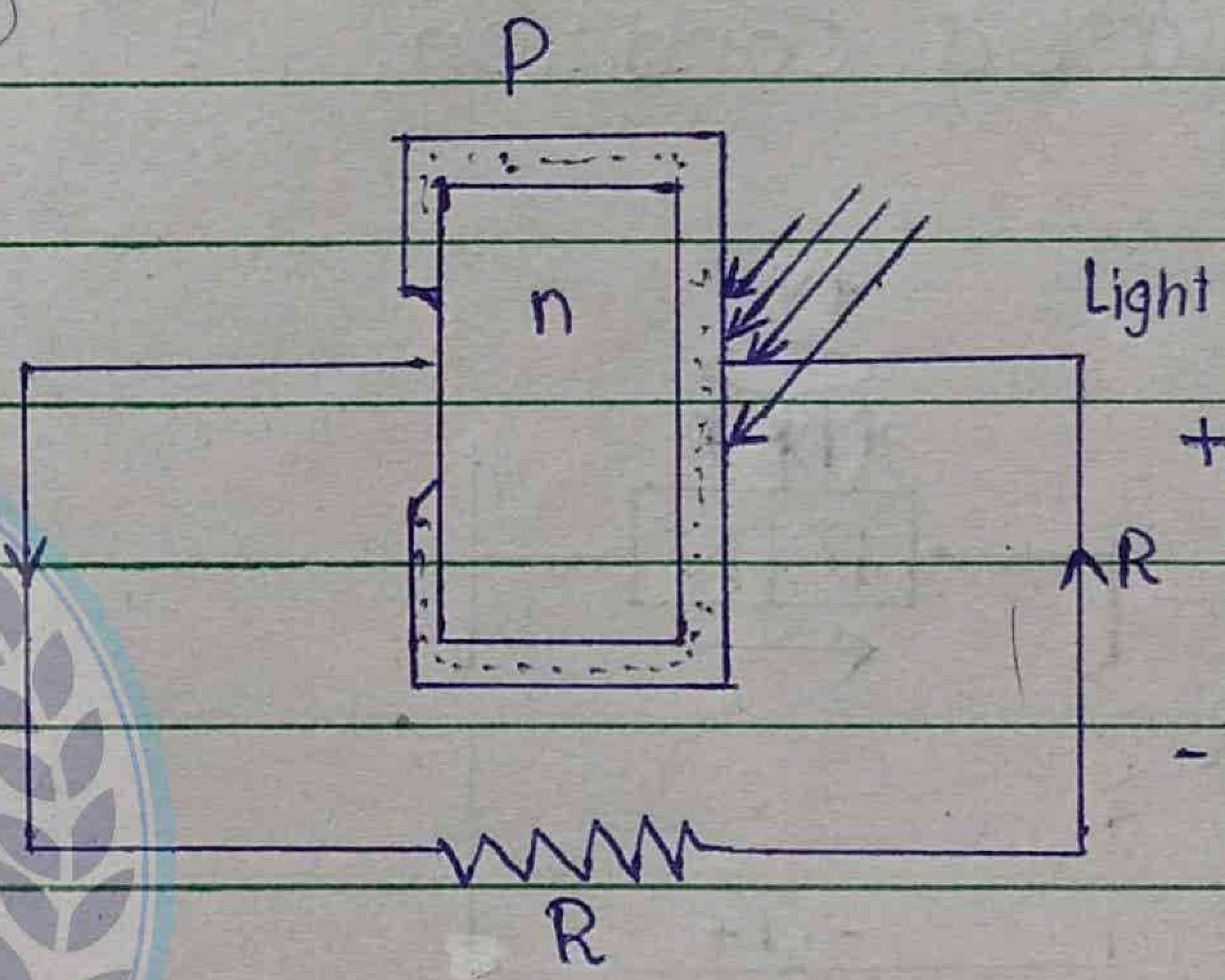
Hence it is one of fastest photo detection devices.

Applications

i) Detection - both visible and invisible radiations.
ii) Automatic Switching
iii) Logic Circuits
iv) Optical Communication equipment etc.

3 Photo Voltaic Cell

"It is a p-n junction which converts light energy directly into electrical energy."



Construction

It consists of a thick n-type region co ered by a thin p-type layer.

When such a p-n junction having no external biase (see fig.) is exposed to light, absorbed photons generates electron-hole pairs. As a result in both p and n regions. when they diffuse close to the junction.

potential barrier sweeps them across to the junction. It causes a current flow through the external circuit R.

The current is proportional to the intensity of light.

A singal silicon photo voltaic cell produces current of the order of few milliamperes.

18.4 Transistors

Definition

Transistor is a semiconducter device consisting of three electrons, namely emitter, base and collector.

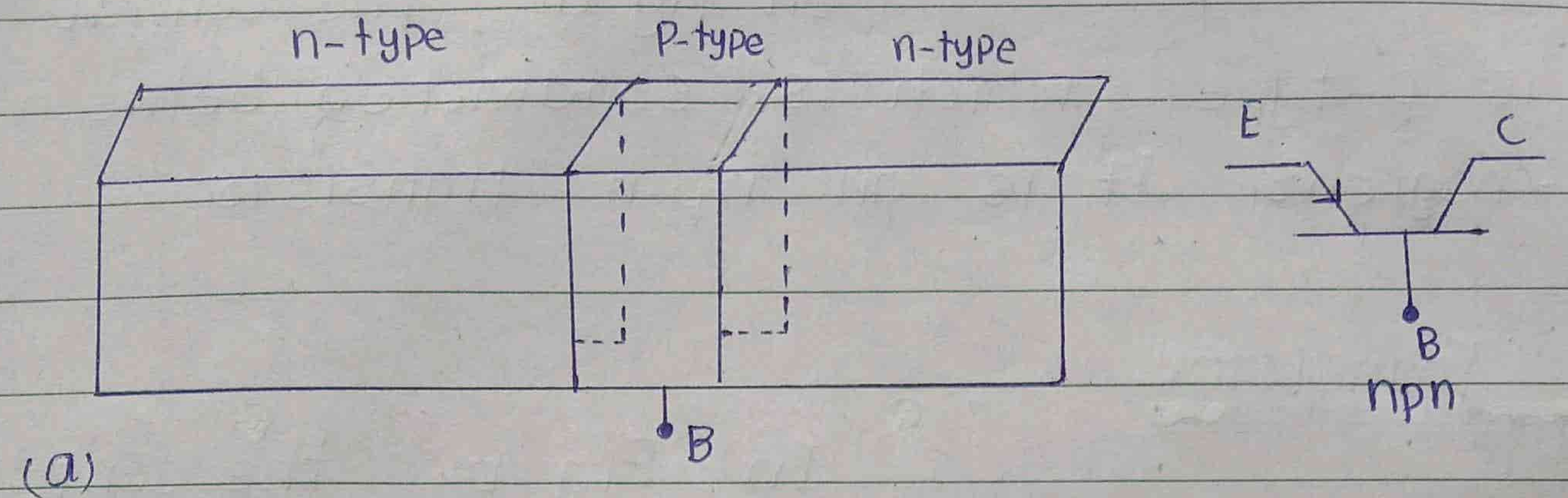
Uses

It is used as an amplifier, a switch and as an oscillator (converts DC into AC)

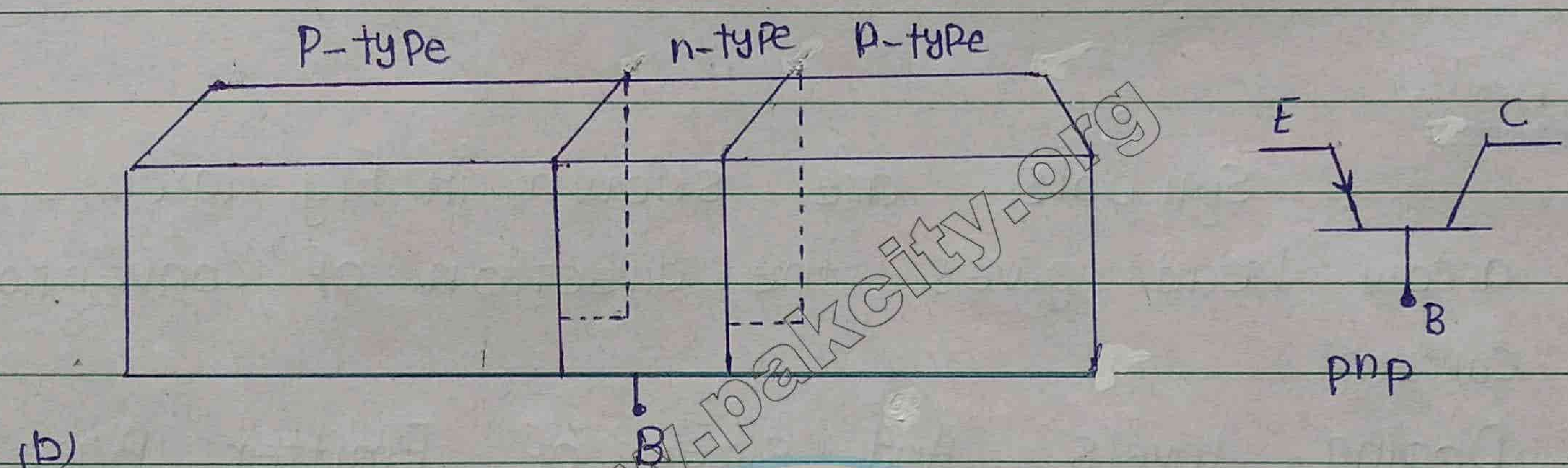
Advantages

Low cost, Less power consumption and reliable.

Construction



npn transistor.



Pnp transistor

"A transistor consists of a single crystal of germanium or silicon which is grown in such a way that it has three regions as shown in Fig.

The central region is known as Base and the other two regions are called Emitter and Collector.

Types

Transistors are of two types.

N-p-n Transistor

In Fig (a) the central region is p-type which is sandwiched between two n-regions. It is an n-p-n-transistor.

P-n-p Transistor

In Fig (b) the central region is n-type, which is sandwhiched between two p-regions. It is a p-n-p Transistor.

Symbol

Symbols are shown in Fig (a)(b). The arrow head gives the direction of conventional current

Doping levels And sizes of Emitter, Base and Collector.

Usually the basis very thin of the order of 10^{-6} m.

The emitter and collecter have greater concentration of impurity, (more doping levels) as compared to base.

The emitter has greater concentration of impurity as compared to collector.

Collector is comparatively Larger than emitter.

Transistor Biasing

For normal operation

i) Emitter - Base junction is Forward biased.

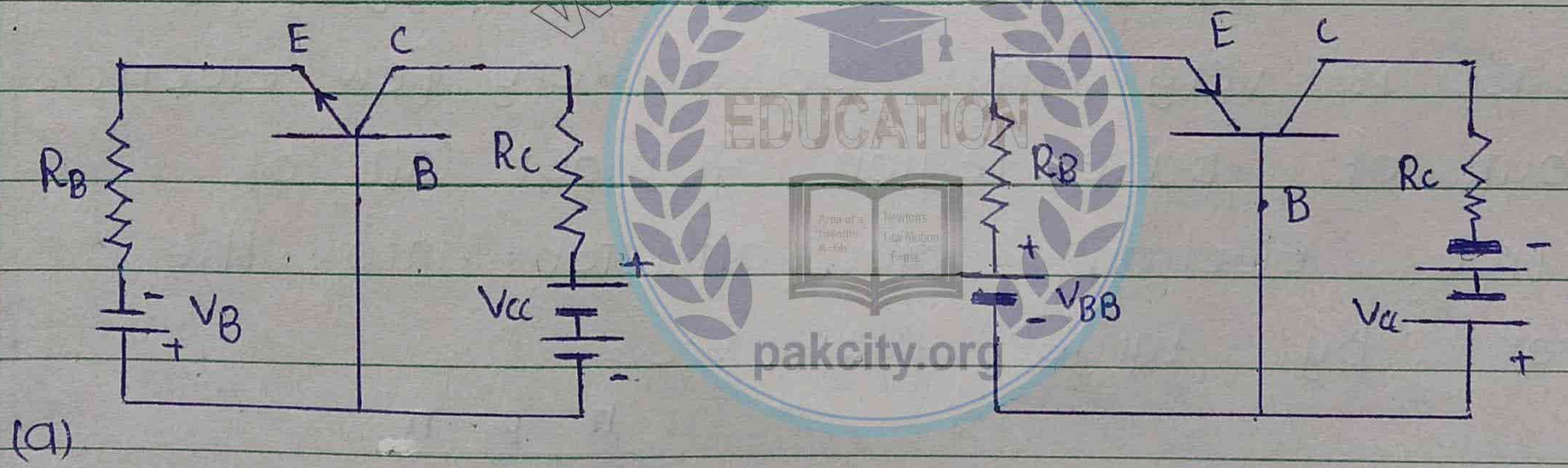
ii) Collector-Base junction is Reverse biased.

Transistor Operation

A transistor is a combination of two back to back p-n junctions:

i) Emitter - base junction

ii) Collector - base junction



(a) N-p-n transistor (b) p-n-p transistor

For the normal operation of the transistor, batteries V_{BB} and V_{CC} are connected in such a way that its emitter-base junction is forward baised and collector-base junction.

is reverse biased.

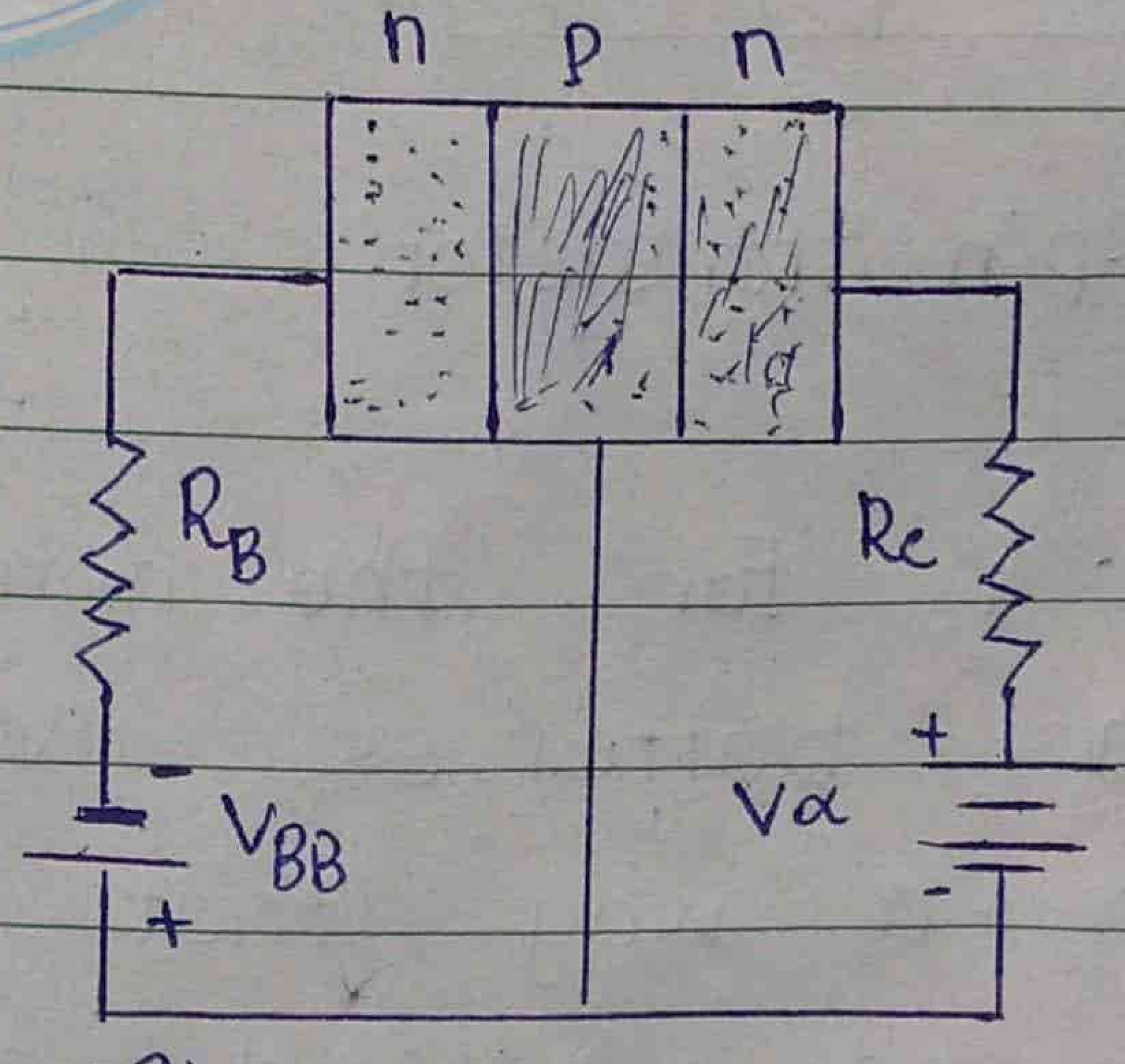
V_{cc} is of higher value than V_{BB}.

Fig (a) and (b) show the biasing arrangements for n-p-n and a p-n-p transistor. The polarities of the biasing batteries V_{BB} and V_{cc} are opposite in two types of transistors

Current Flow in an n-p-n Transistor

In Fig. An n-p-n transistor is connected in common base configuration. Its emitter-base junction is forward biased, Where as collector-base junction is reverse biased.

Emitter injects a large number of electrons in the base region. Since the base is very thin so a very few electrons flow out of base-region. Al most all of the free electrons are attacted into the collector by large +ve V_{cc}.

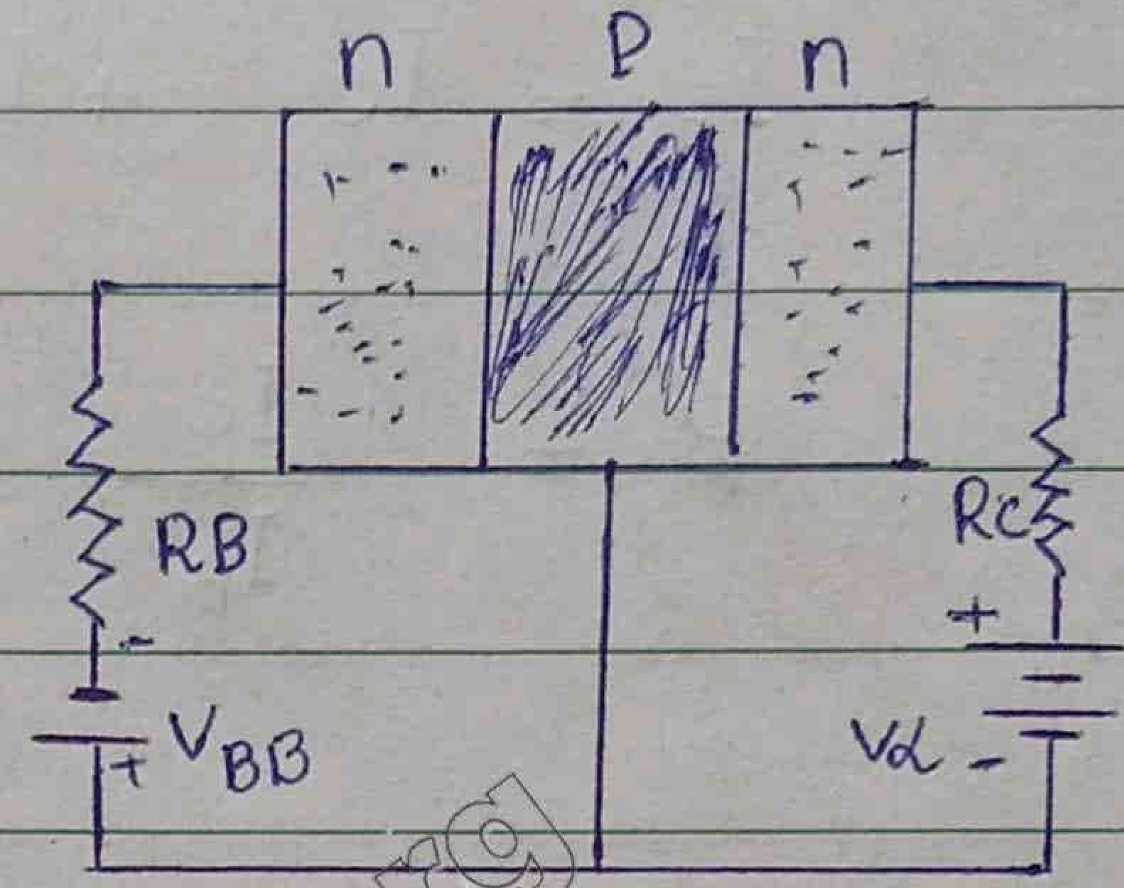


(a)

Thus an electronic current I_E flows from the emitter into the base. A very small part of it, current I_B, flows out of base and the remaning current I_c flows out of the collector.

The flow of electronic current are shown in Fig.

It is clear from the circut diagrams that emitter current is always equal to the sum of collector current I_c and base current I_B.

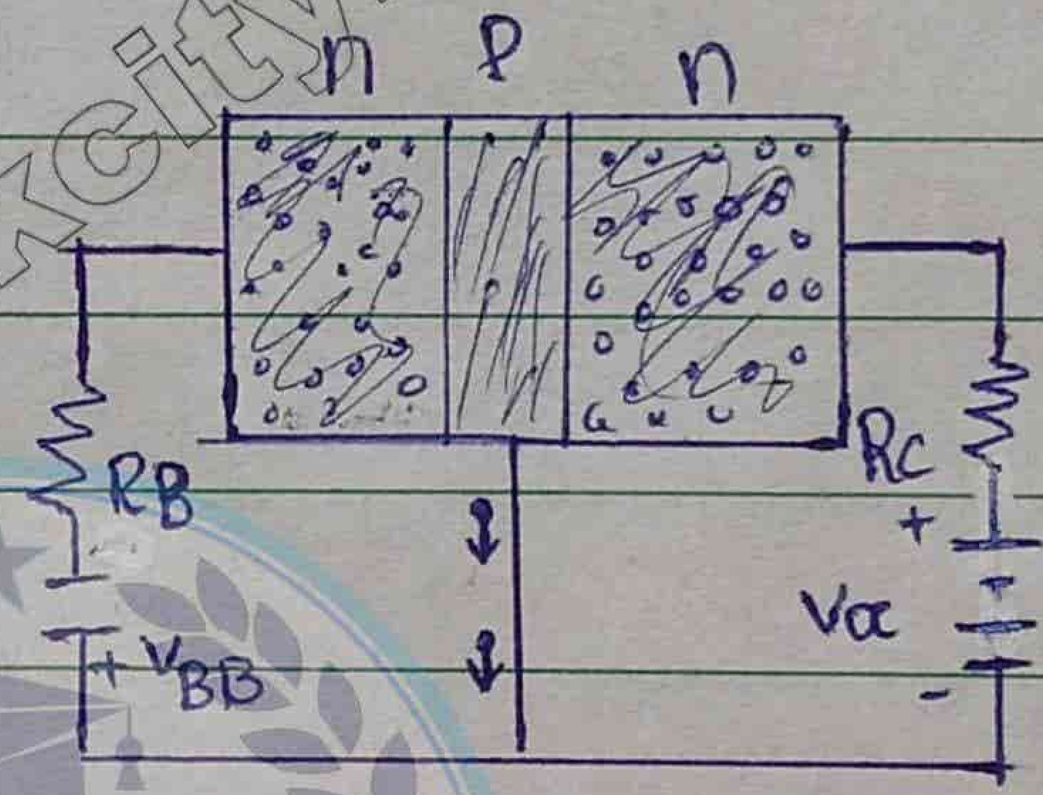


(b)

$$I_E = I_c + I_B$$

Here

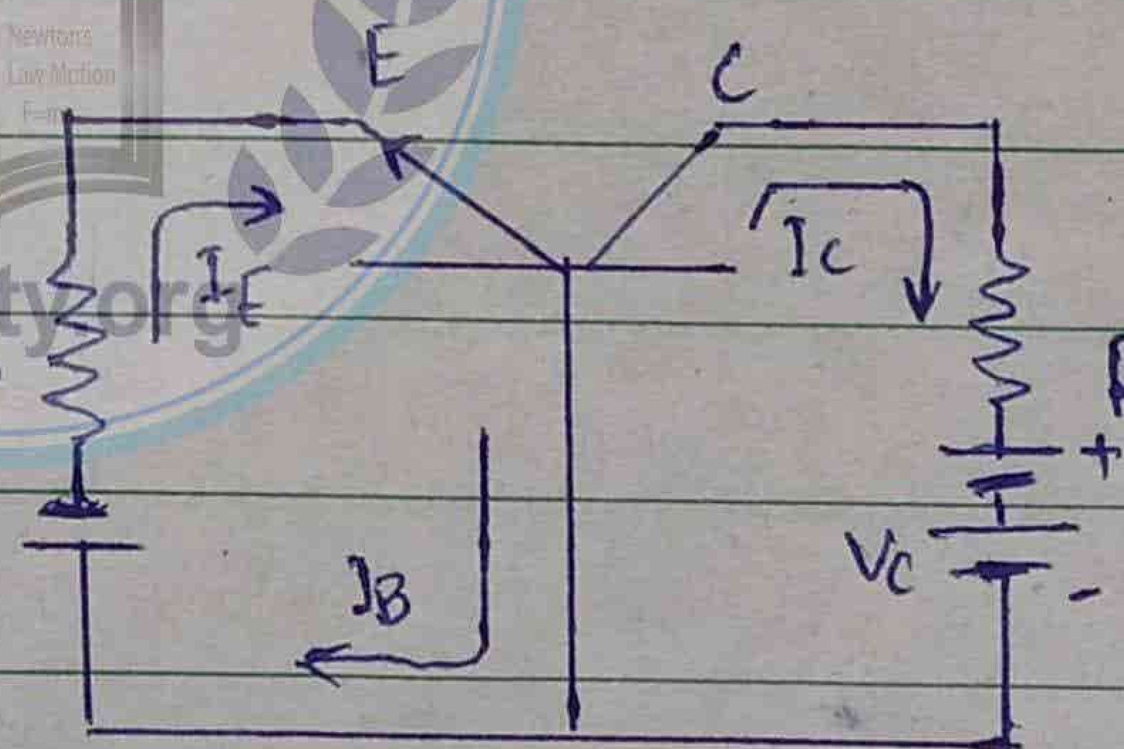
$$I_B << I_c$$



(c)

Current Gain : B

For a given transmitor the ratio of collector current I_c to base current I_B is nearly constant



(d) flow of electronic current

$$\beta = \frac{I_c}{I_B}$$

This ratio β is called Current Gain Factor of the transistor.

"Value of β is quiet Large; of the order of hundreds

Fundamental Equations of Transistors:

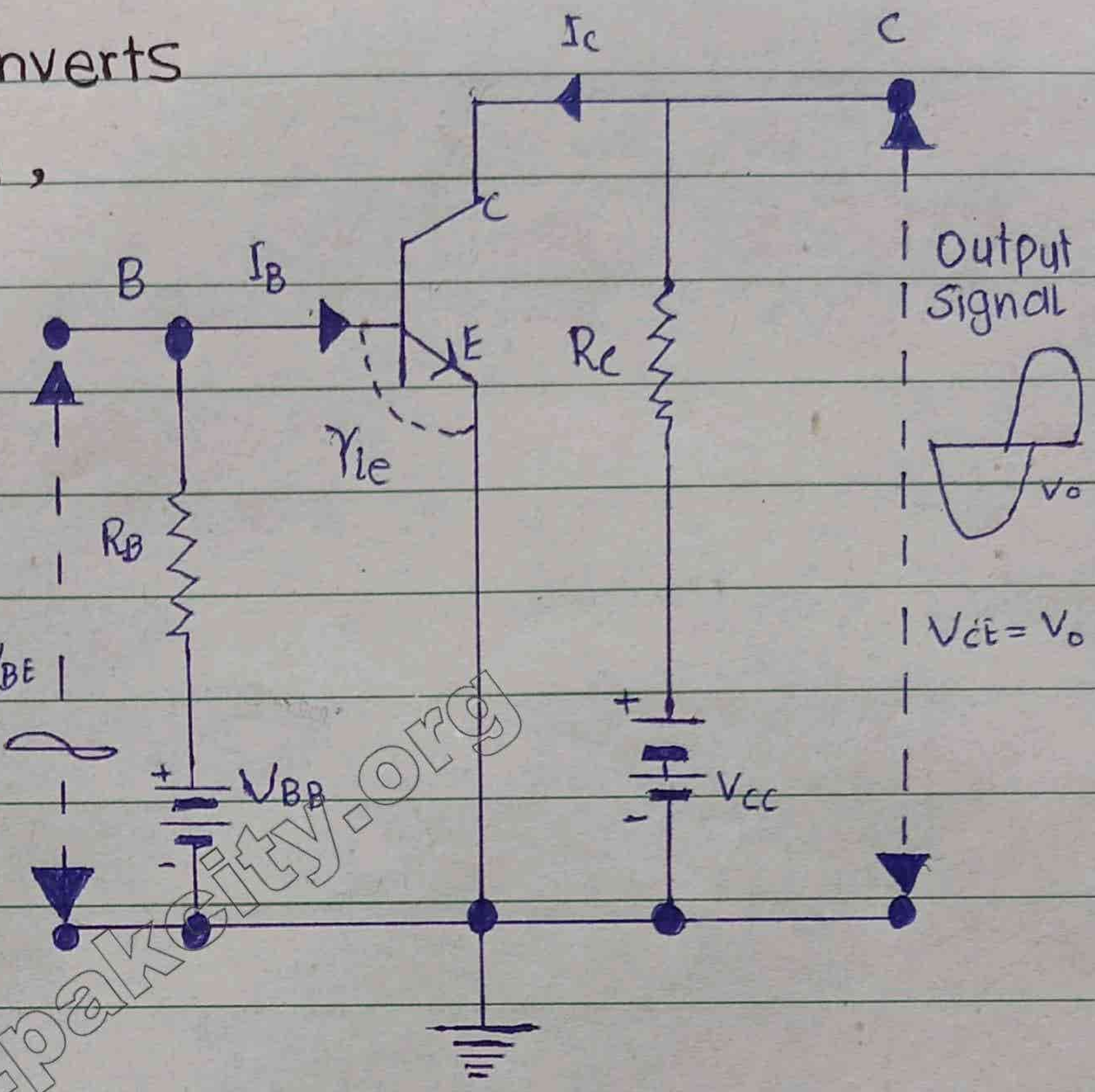
1) $I_E = I_C + I_B$

2) $\beta = \frac{I_C}{I_B}$

18.5 Transistor as an Amplifier

In most of the circuits, transistors are basically used as amplifiers.

" An amplifier converts signal of low voltage, curent or power to a signal of high Voltage current or power."



Circuit Diagram.

Circuit shows an npn-transistor as voltage amplifier in Common-Emitter configration.

1. Base-Emitter junction is forward biased by the battery V_{BB}.

2. Collector-Emitter junction is reverse biased by the battery Vcc.

V_{BE} = Input Voltage

V_c = V_o = Output voltage

Calculation for Gain. (voltage Gain)

Base current:

$$I_B = \frac{V_{BE}}{ie}$$

r_{ie} = base-emitter resistance of the transistor

As

$$\beta = \frac{I_c}{I_B}$$

[β = Current Gain factor]

$$I_c = \beta I_B$$

Put the value of I_B

$$I_c = \beta \frac{V_{BE}}{r_{ie}}$$

Using KVL (Kirch hoff's voltage rule to the output Loop.

$$V_{CC} = I_c R_c + V_{CE}$$

$$V_{CE} = V_{CC} - I_c R_c$$

$$V_o = V_{CC} - I_c . R_c$$

Put the value of I_c.

$$V_o = V_{CC} - \beta \frac{V_{BE}}{r_{ie}} . R_c$$

$$V_o = V_{cc} - \beta V_{BE} \frac{R_c}{r_{ie}}$$

When a singal small voltage ΔV_{in} is applied at the input terminal B. Then,

i) Input voltage changes: from V_{BE} to $(V_{BE} + \Delta V_{in})$

ii) Base-current changes: from I_B to $(I_B + \Delta I_B)$

iii) Collector current changes: from I_c to $(I_c + \Delta I_c)$

As a result

iv) Out-put voltage changes: from V_o to $(V_o + \Delta V_o)$

As a result the equation changes

from $V_o = \left[V_{cc} - \beta V_{BE} \frac{R_c}{r_{ie}}\right] \longrightarrow (1)$

to $(V_o + \Delta V_o) = \left[V_{cc} - \beta (V_{BE} + \Delta V_{in}) \frac{R_c}{r_{ie}}\right] \longrightarrow (2)$

Subtract eq (1) from eq (2)

$$(V_o + \Delta V_o) - V_o = \left[V_{cc} - \beta (V_{BE} + \Delta V_{in}) \frac{R_c}{r_{ie}}\right] - \left[V_{cc} - \beta V_{BE} \frac{R_c}{r_{ie}}\right]$$

$$\cancel{V_o} + \Delta V_o - \cancel{V_o} = \cancel{V_{cc}} - \cancel{\beta V_{BE} \frac{R_c}{r_{ie}}} - \beta \Delta V_{in} \frac{R_c}{r_{ie}} - \cancel{V_{cc}} +$$

$$= \cancel{\beta V_{BE} \frac{R_c}{r_{ie}}}$$

$$\Delta V_o = \beta \Delta V_{in} \frac{R_c}{r_{ie}}$$

Voltage Gain :

$$A = \frac{\Delta V_o}{\Delta V_{in}}$$

$$= -\beta \frac{R_c}{r_{ic}}$$

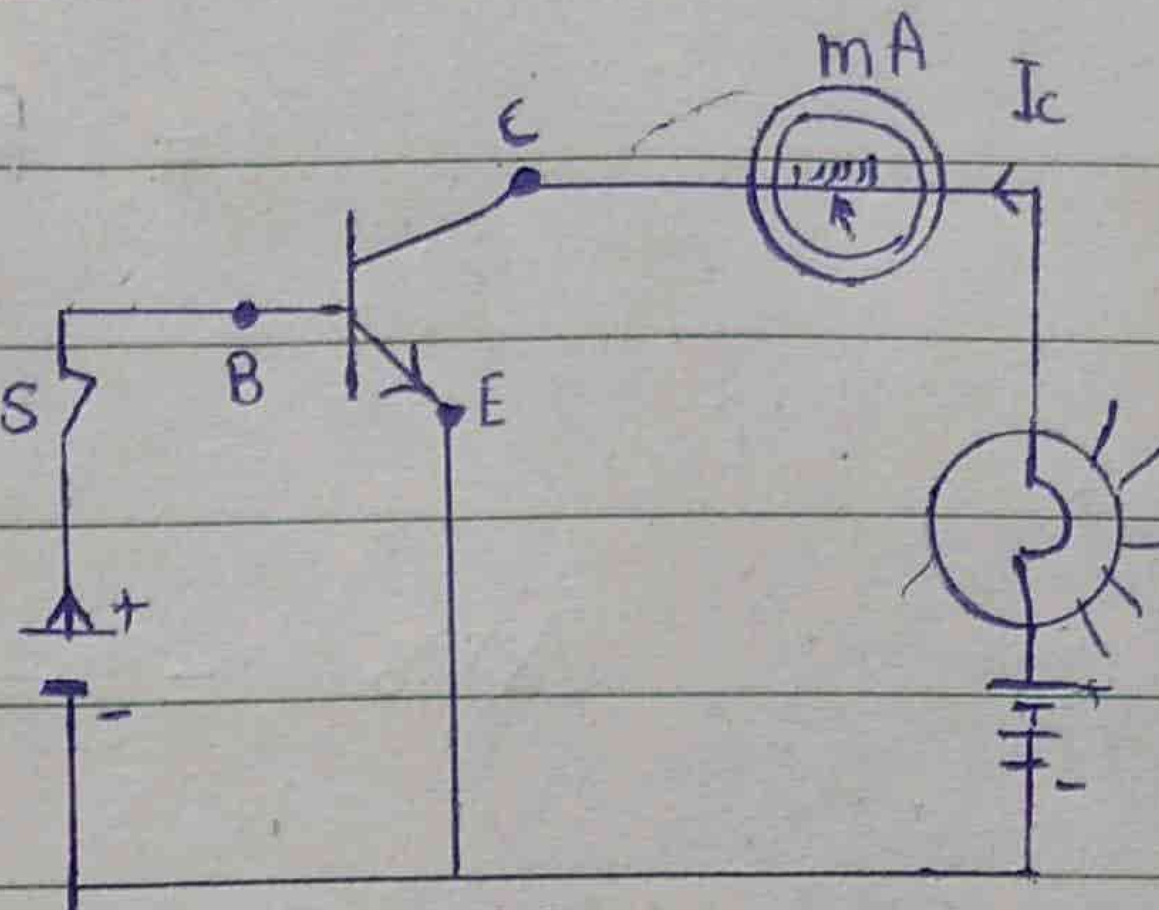
$$\boxed{A = -\beta \frac{R_c}{r_{ic}}}$$

1): Gain A is of the order of hunderds.

2): Negative sign shows that there is a phase shift of 180° between input and output signals.

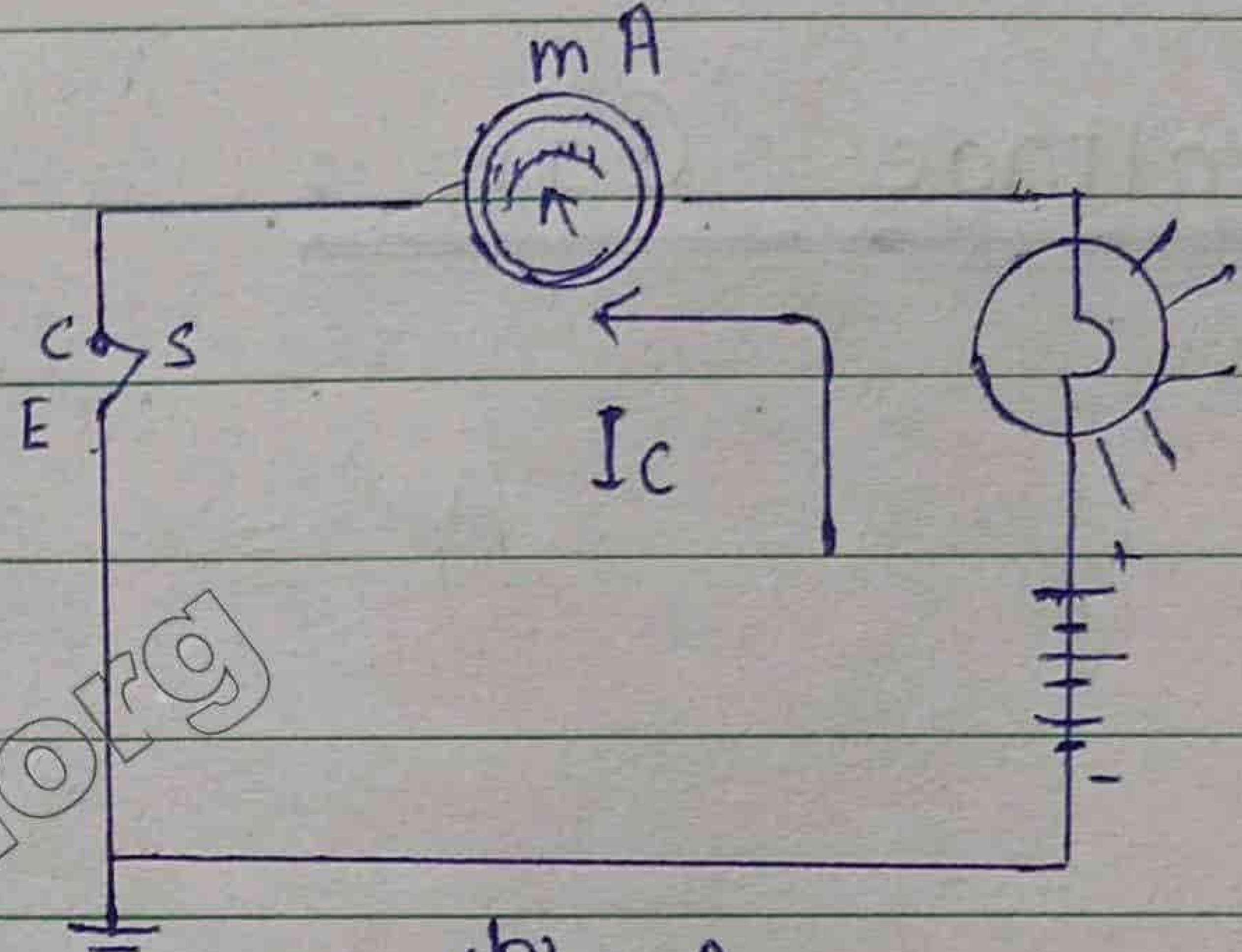
18.6 Transistor as a switch

Circuit in the fig show the use of a transistor as a switch.



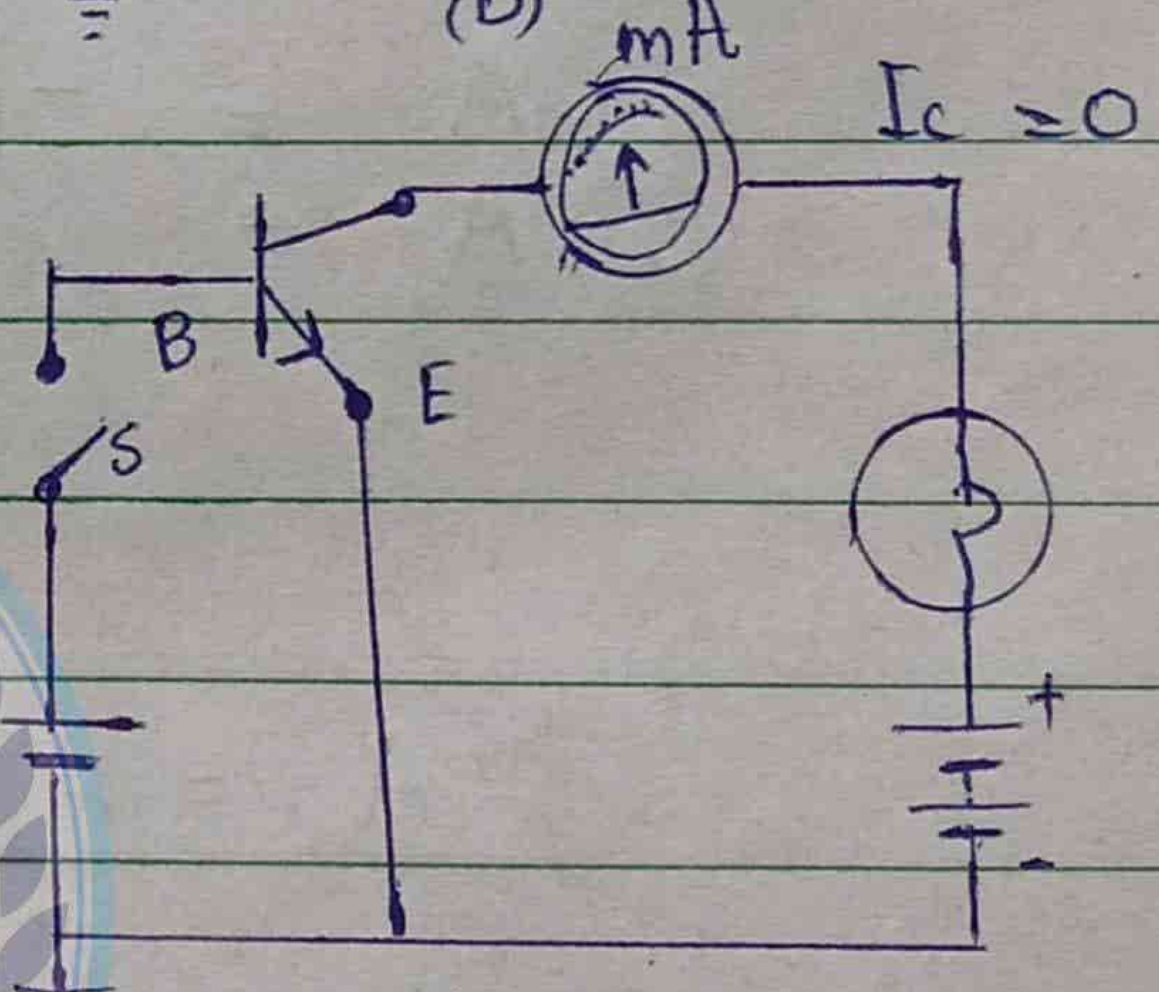
(a)

i) There collector 'C' and emitter 'E' behave as terminals of the switch.



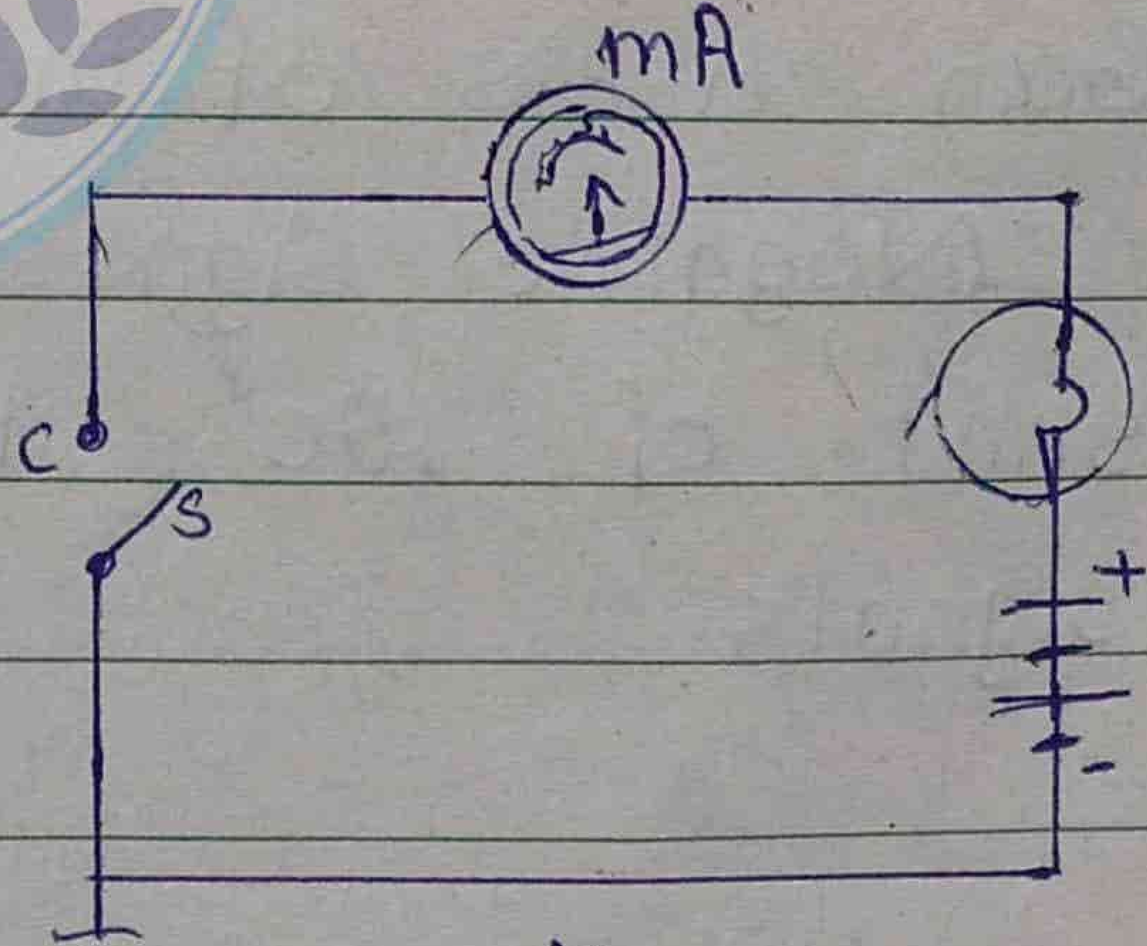
(b)

ii) The circuit in which the current is to be turned ON and OFF is connected across the terminals C and E.



(c)

iii) Base 'B' and emitter 'E' act as control terminals which turn ON and OFF the switch.



(d)

Operation :

1- Turning the switch ON

In order

to turn ON the switch, a large potential V_B is applied between the control terminals B and E. A large current I_B is injected into the base circuit due to which a heavy current I_c flows in the C-E circuit.

This large value of collector current I_c is possible only when the resistance between 'C' and 'E' is small that the potential drop across CE is nearly 0.1 Vot.

In fig (a) emitter is at ground. So we can consider that collector is also at ground and C-E circuit can be reduced to circuit shown in fig (b).

CE switch is closed and the blub glows due to flow of large collector current I_c.

2- Turning the switch OFF

To turn the switch OFF the base current I_B is set zero $[I_B = 0]$ by opening the base circuit as shown in Fig (c).

As

$$\beta = \frac{I_c}{I_B}$$

$$I_c = \beta I_B$$

As

$$I_B = 0$$

$$I_c \quad \beta(0) \quad 0$$

So C-E circuit becomes open as shown in fig.

Now the resistance between C and E becomes nearly infinity which opens the CE switch.

$$R_c = \frac{V_{CE}}{I_c}$$

$$R_c = \frac{V_{CE}}{0}$$

$$R_c = \infty$$

Uses

"An electronic Computer is basically a vast arrangement of electronic switches which are made from transistor."

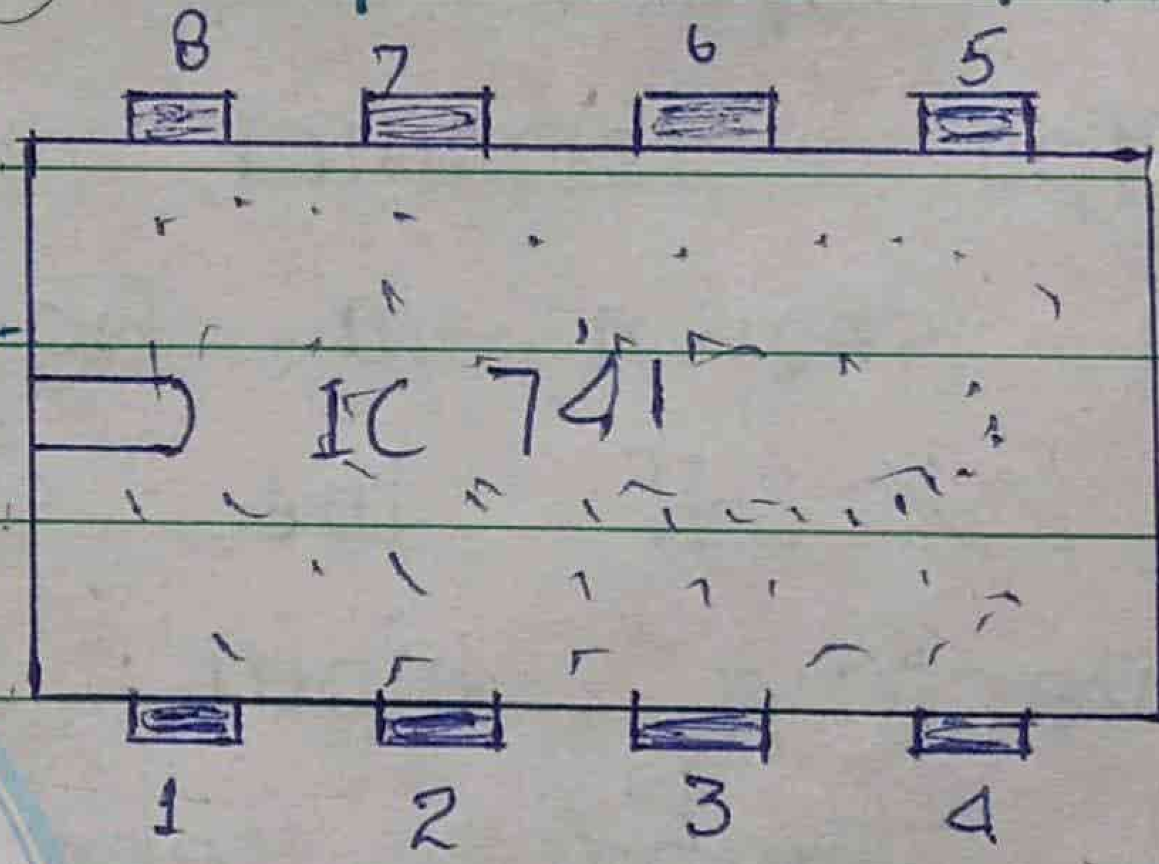
18.7 Operational Amplifier

Definition

The amplifier is integrated on a small silicon chip enclosed in a capsule is called operational amplifier (op-amp).

Construction

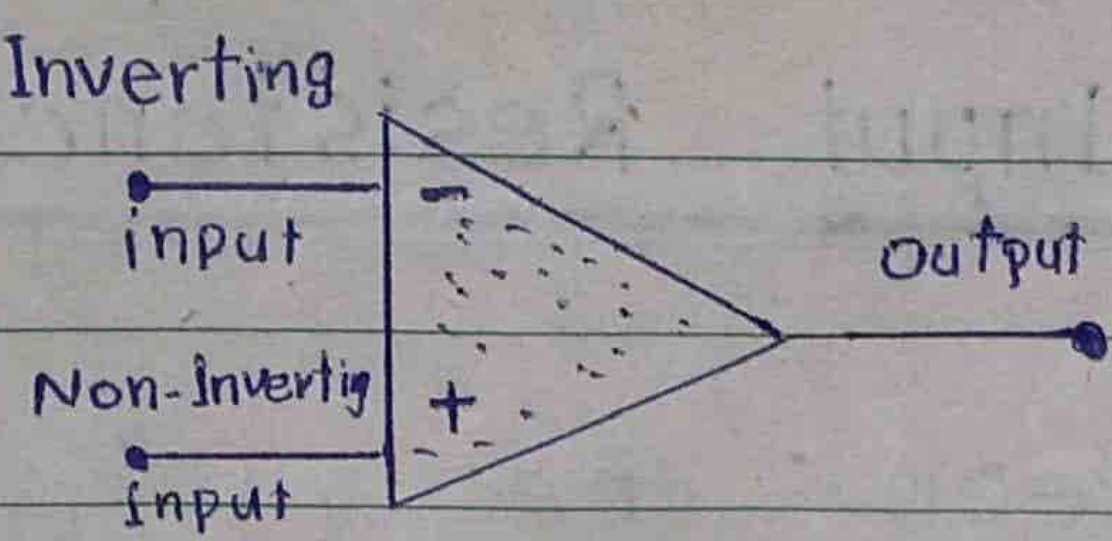
The whole amplifier is integrated on a small silicon chip and is enclosed in a capsule instead of making amplifier circuit by separate components. Pins appearing outside the capsule are used for making necessary connections as shown in fig.



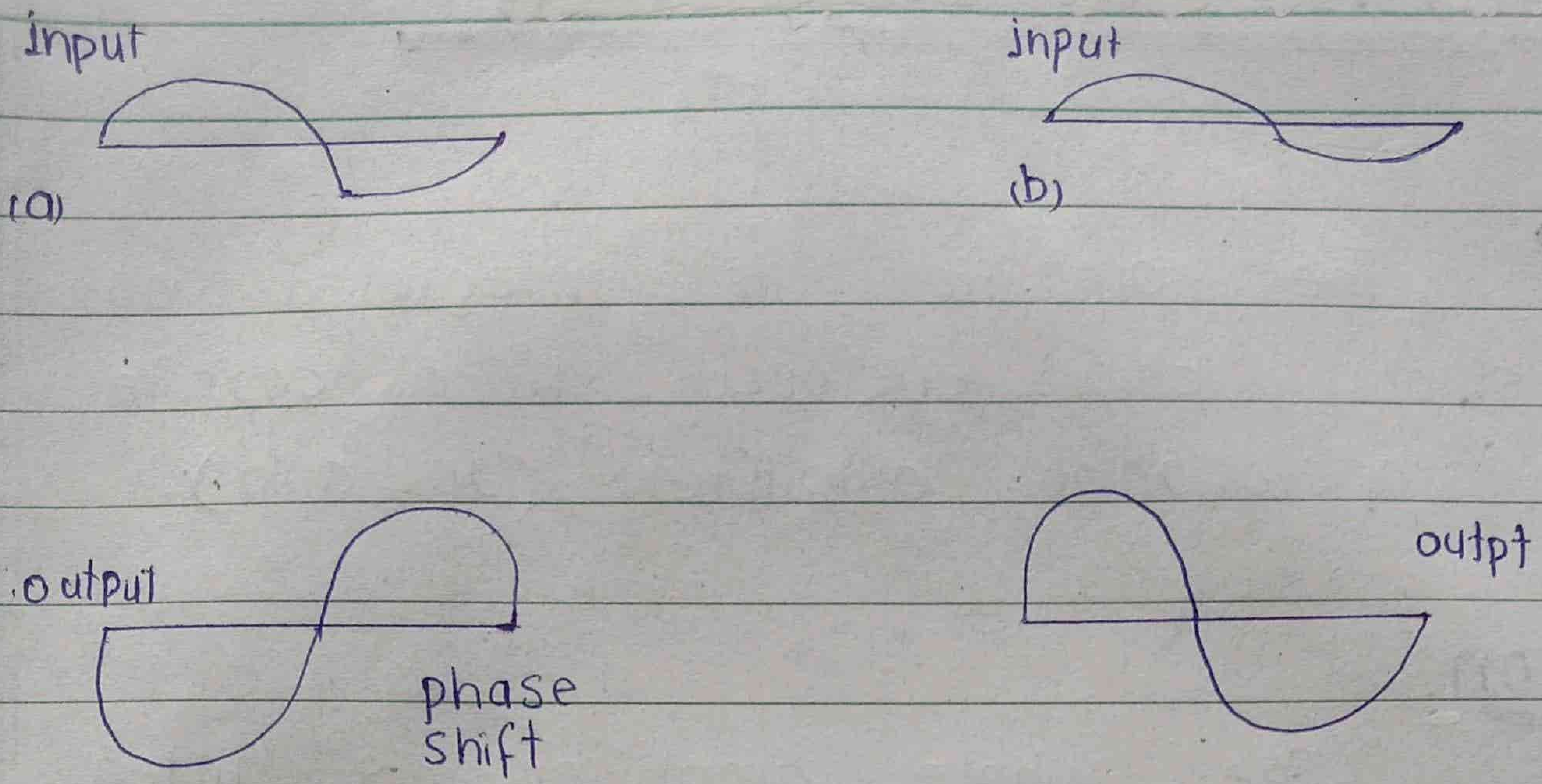
Symbol for Op-amp

Its symbol is shown in fig.

i): The terminal with negative sign is known as the inverting input (−).



ii): The terminal with positive sign is known as the non-inverting input (+).



A signal applied at the inverting (–) input appears after amplification at the output terminal with a phase shift of 180° as shown in fig (a).

If the signal is applied at the non inverting input (+), It is amplified at the output terminal with out any change of phase as shown in fig (b).

Characteristics of op-amp

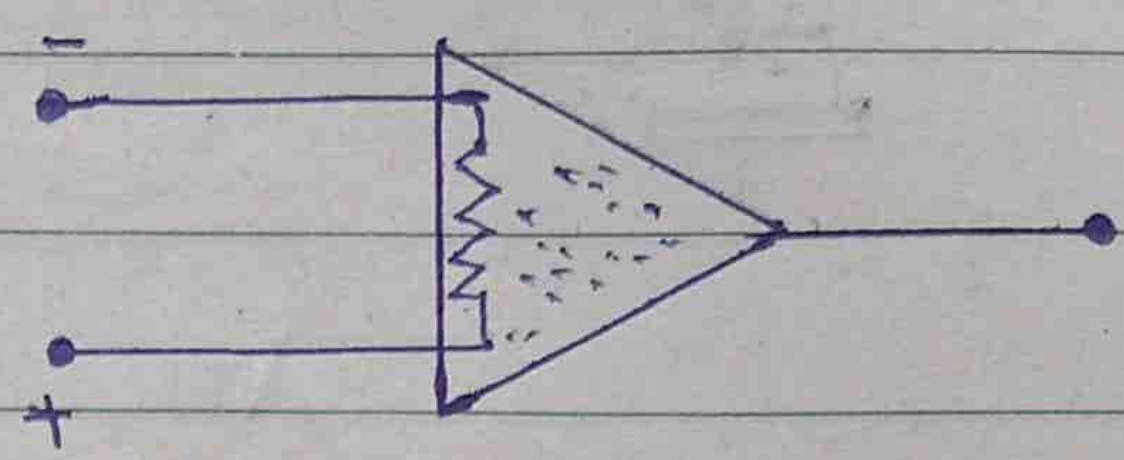
1): Input Resistance

It is the resistance between the (+) and (–) input of the amplifier. Its value is very high i.e. of the order of "several mega ohms".

Due to the high value of the input

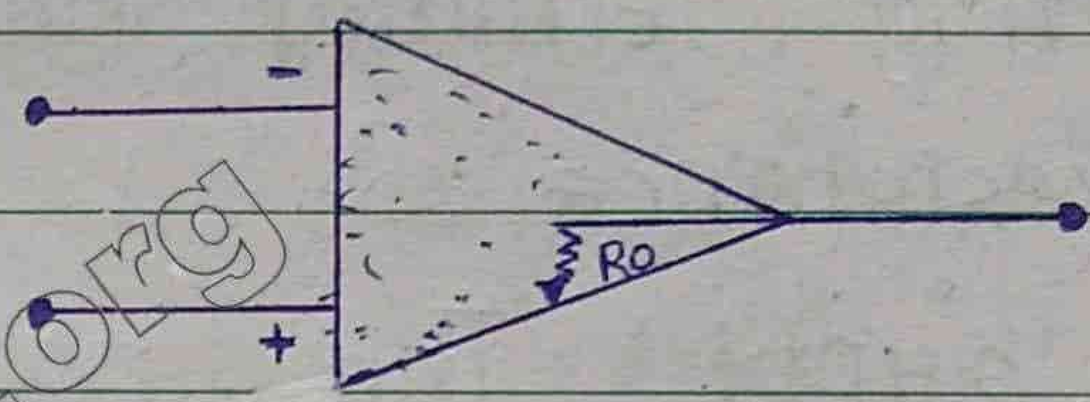
resistance R_{in}, practically no current flows between the two input terminals.

It is very important characteristic of op-amp.



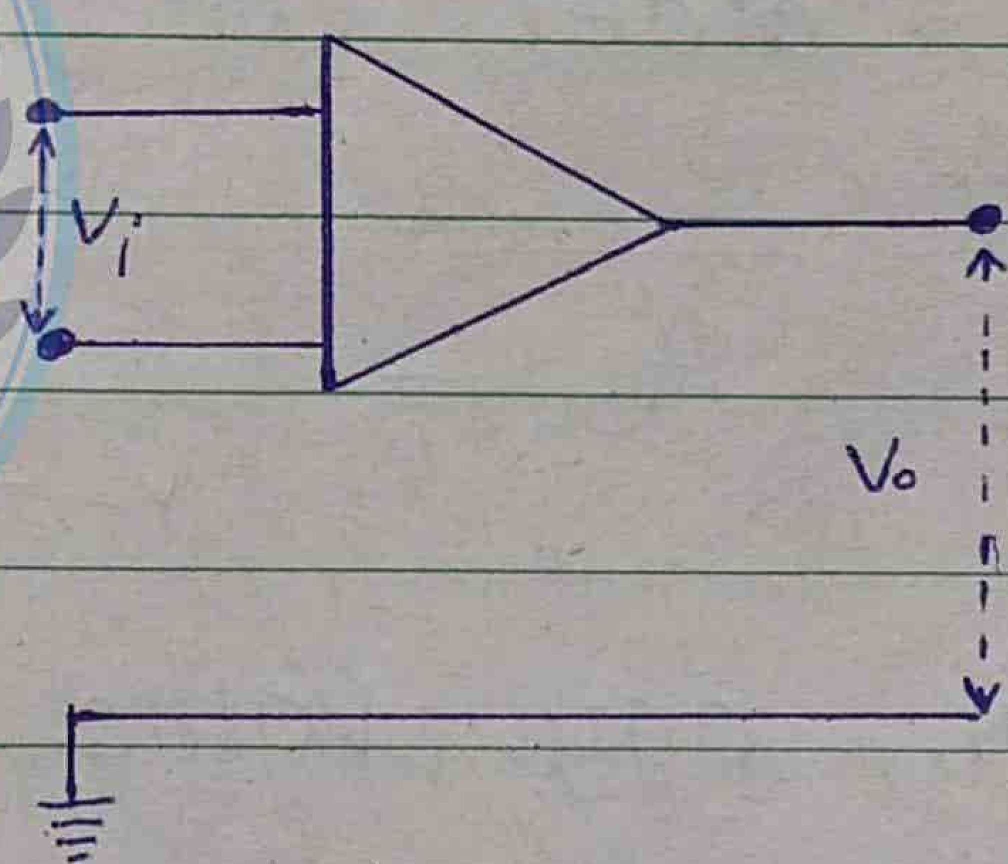
2): Output Resistance

It is the resistance between the output terminal and ground. Its value is only few ohms.



3): Open Loop Gain

It is the ratio of output voltage V_o to the voltage difference V_i between non-inverting and inverting inputs when there is no external connection between the output and inputs.

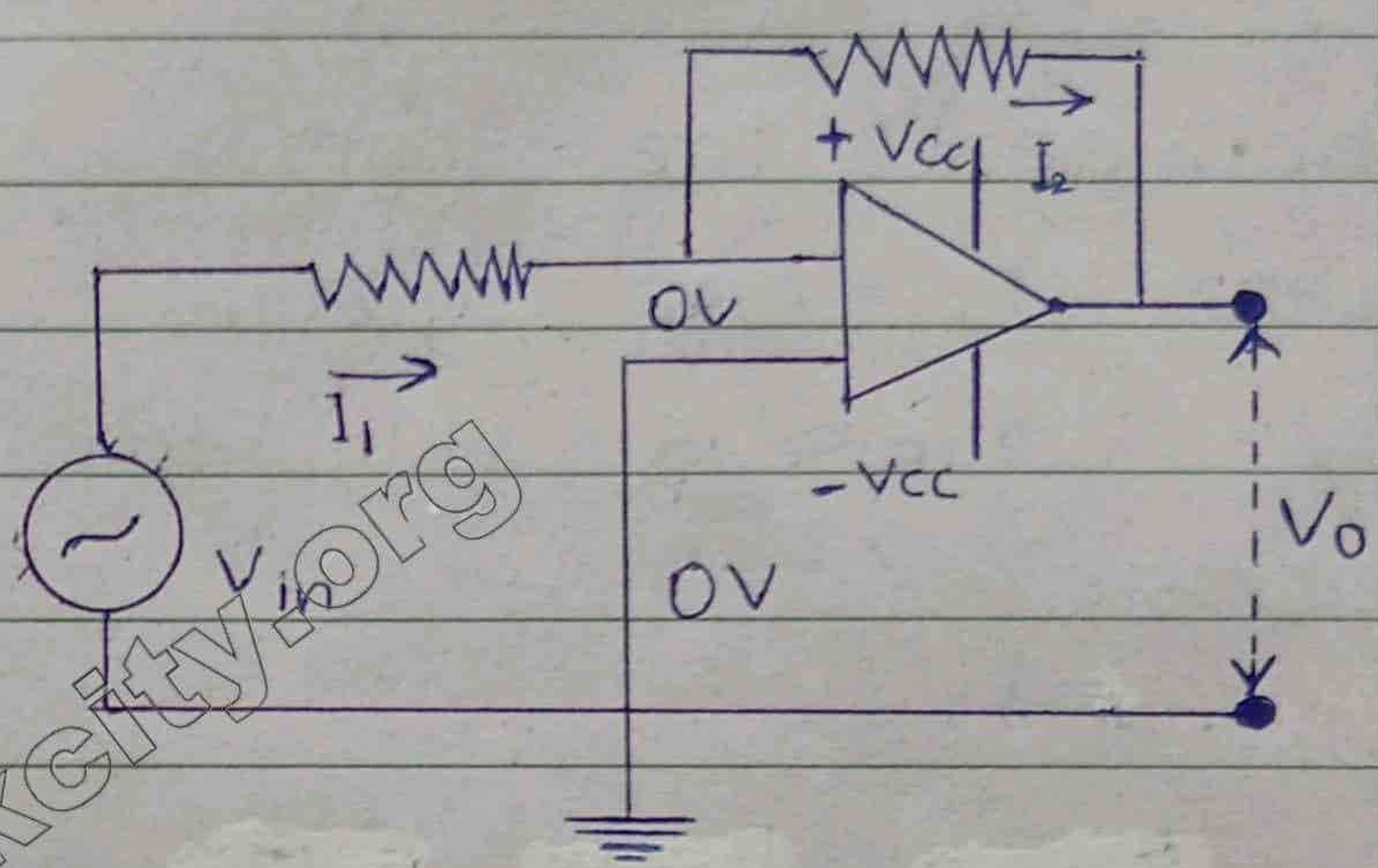


$$A_{oL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$

Open loop gain is very high. It is of order of 10^5.

18.8 Op-Amp as Inverting Amplifier

An op-amp is used as an inverting amplifier in the circuit as shown in fig. The input signal V_i is applied at inverting terminal throgh a resistance R_1. V_o is its output. The potential of non-inverting terminal is zero because it is grounded.



As gain A_{OL} is very high, of the order of 10^5
So,

$$A_{OL} = \frac{V_o}{V_+ - V_-} = \frac{V_o}{V_i}$$

For any value of V_o, $V_+ - V_- \approx 0$
or
$$V_+ \approx V_-$$
Since V_+ is at ground potential.
V_- is virtually at ground potential
$$V_- \approx 0$$

i) : current through $R_1 = I_1 = \dfrac{V_i - V_o}{R_1} = \dfrac{V_i - 0}{R_1}$

$$I_1 = \frac{-V_i}{R_1} \longrightarrow (1)$$

ii): current throgh $R_2 = I_2 = \frac{V_- - V_o}{R_2} = \frac{0 - V_o}{R_2}$

$$I_2 = \frac{-V_o}{R_2} \longrightarrow (2)$$

As no current flows through (−) and (+) terminals, so according to Kirchhoff's current rule.

$$I_1 = I_2$$

$$\frac{V_i}{R_1} = \frac{-V_o}{R_2}$$

$$\frac{V_o}{V_i} = \frac{-R_2}{R_1} \longrightarrow (3)$$

As Gain of inverting amplifier = $\frac{\text{Output}}{\text{Input}}$

$$G = \frac{V_o}{V_i}$$

From eq. (3).

$$G = \frac{-R_2}{R_1}$$

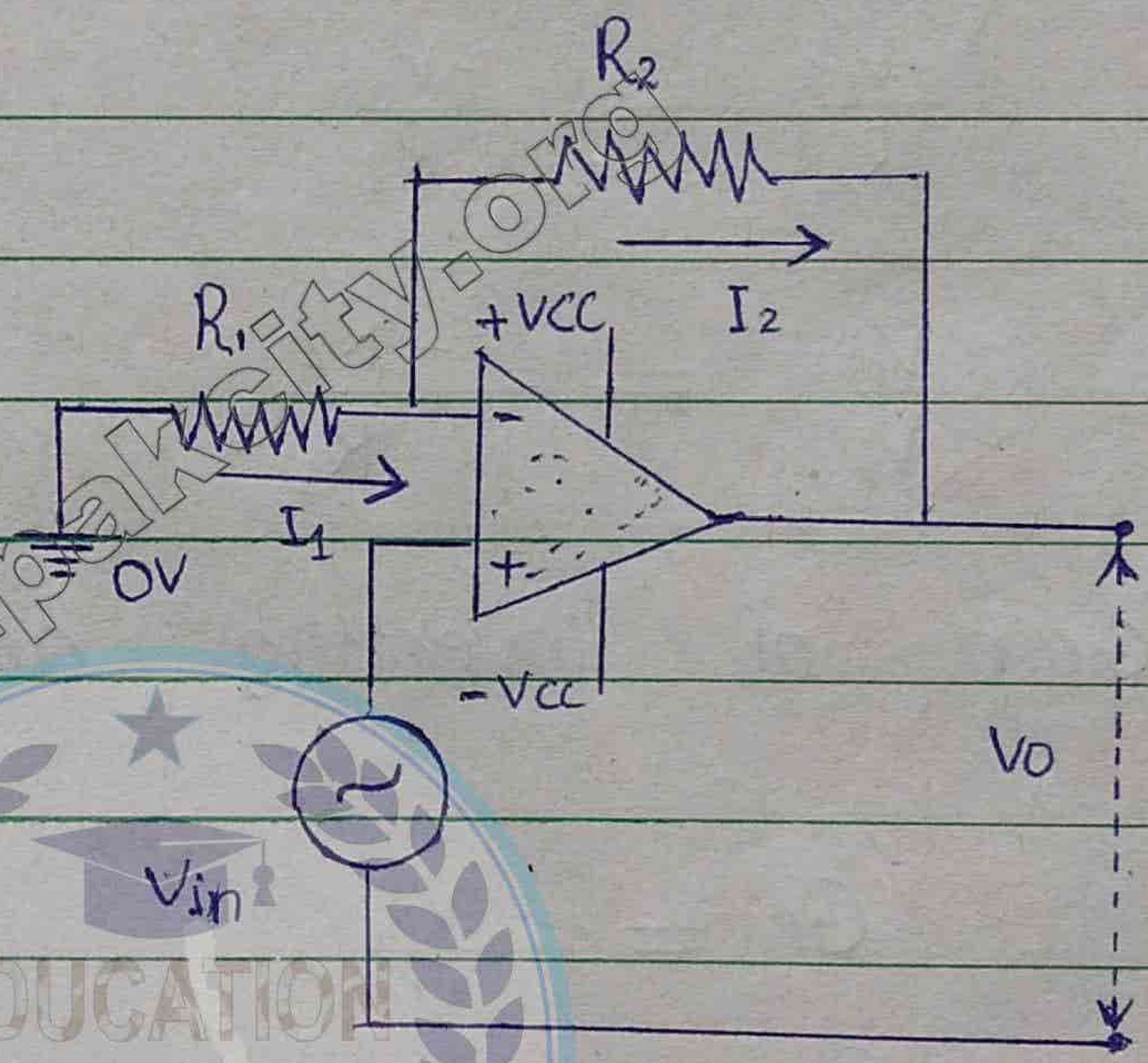
−ve sign shows that there is a phase shift of 180° between input and output signal.

18.9 Op - Amp as Non-inverting Amplifier

OP- amp used as non-inverting amplifier is shown in fig.

Working and Theory

The input signal V_i is applied at the non-inverting terminal (+). Due to high open loop gain of amplifier the inverting (−) and non-inverting (+) input are virtually at the same potential.



That is

$$V_- \approx V_+ = V_i$$

Voltage gain

Now from fig, current through R_1 is I_1 which is given as.

$$I_1 = \frac{0 - V_-}{R_1} = \frac{0 - V_i}{R_1} \longrightarrow (1)$$

$$\boxed{I_1 = -\frac{V_i}{R_1}}$$

Current through $R_2 = I_2 = \frac{V_- - V_+}{R_2} = \frac{V_i - V_o}{R_2}$

$$I_2 = \frac{V_i - V_o}{R_2} \longrightarrow (2)$$

By kirchhoff's current rule.

$$I_1 = I_2$$

From eq (1) and (2)

$$\frac{-V_i}{R_1} = \frac{V_i - V_o}{R_2}$$

$$\frac{R_2}{R_1} = -\frac{V_i - V_o}{V_i} = \frac{-V_o}{V_i} + \frac{V_o}{V_i}$$

$$\frac{R_2}{R_1} = -1 + \frac{V_o}{V_i}$$

$$1 + \frac{R_2}{R_1} = \frac{V_o}{V_i}$$

But Gain $= \frac{V_o}{V_i}$

$$G = 1 + \frac{R_2}{R_1}$$

Results

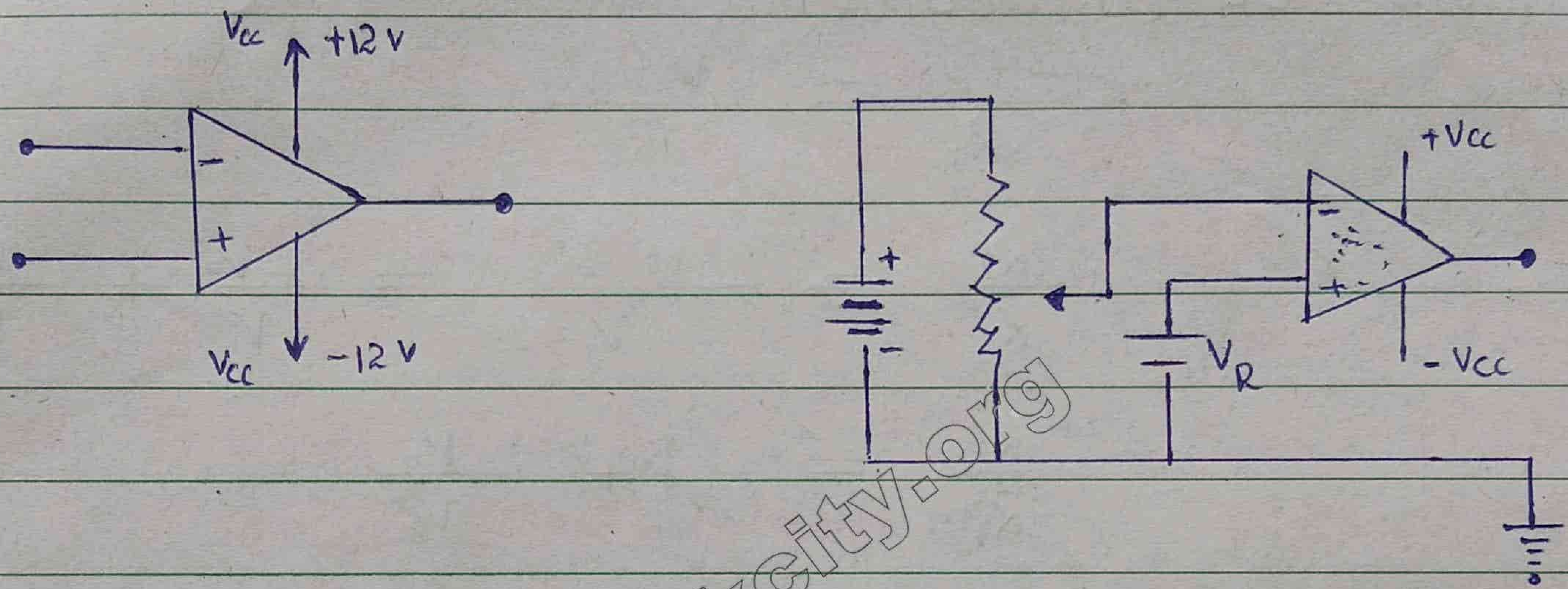
★ Gain of the amplifier depends on the two externally connected resistances R_1 and R_2. It is independent of the internal structure of the op-amp.

"G" is positive. It shows that the input and output signals are in phase.

18.10 Op-Amp as a comparator

Op_amp usually requires two power supplies of equal voltage but of opposite polarity.

Most of op_amp operate with $V_{cc} = \pm 12V$



As the open loop gain of the op_amp is very high (10^5) even a very small potential difference between the inverting and non-inverting inputs is amplified to such a large extent that the amplifier gets saturated i.e., its output either becomes equal to $+V_{cc}$ or $-V_{cc}$.

This characteristic of op_amp is used to compare two voltages.

Fig. shows the circuit of an op-amp used as a comparator.

V_R = It is the reference voltage which is connected with (+) terminal.

V = It is the voltage which is to be compared with V_R. V is connected with (−) terminal.

When,

$V_- > V_+$ or $V > V_R$ then $V_o = -V_{cc}$

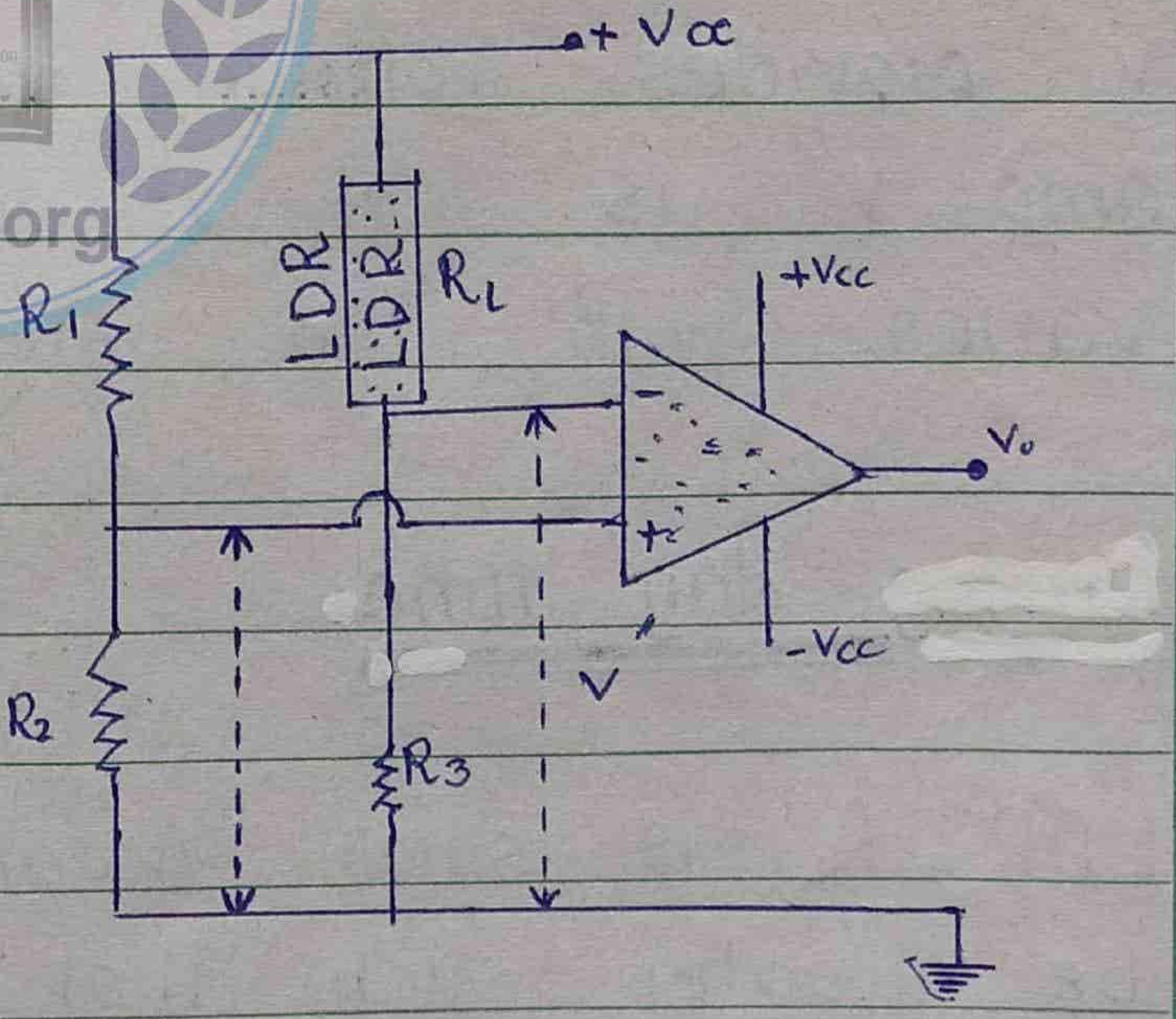
$V_- < V_+$ or $V < V_R$ then $V_o = +V_{cc}$

18.11 Comparator as a night switch

It is observed that when a op-amp is used as a comparator. the street light at night can also be automatically switched on when intensity of light falls below a certain limit.

Working

The circuit for the operation of comparato as night is shown in fig, in this Figure the resistances "R_1" and "R_2" from a potential divider The potential drop across "R_2" provids the



reference voltage V_R to the (+) input of the op_amp.

Thus,

$$V_R = \text{current in } (R_1 + R_2) \times R_2$$

$$V_R = \frac{V_{cc}}{(R_1 + R_2)} \times R_2$$

$$V_R = \frac{R_2}{(R_1 + R_2)} \times V_{cc} \longrightarrow (1)$$

Light dependent resistance

LDR is a light dependent resistance R_L value of R_L depends upon the intensity of light falling upon it. R_L and R_3 from another potential divider.

The potential drop V' across R_3 is

$$V' = \frac{R_3}{R_L + R_3} \times V_{cc} \longrightarrow (2)$$

V' provides voltage to (−) input of the op-amp. V' is not a constant voltage, but it varies with the intensity of light.

During day time

When light is falling upon LDR, R_L is small. According to eq. (2). V' will be greater such that $V' > V_R$ so that $V_o = -V_{cc}$.

The output of the op_amp is

connected with a relay system which gets energy (i.e. power) only when $V = +V_{cc}$ and then it turns on the street lights. Thus during the day when $V = -V_{cc}$ the light will not be switched ON

During night

After sunset as it gets darker R_L becomes larger and V' decreases. When V' becomes just less than V_R then the output of op-amp switches to $+V_{cc}$ (i.e. $V_o = +V_{cc}$) which energies the relay system and hence the street lights are switched or (turned) ON.

18.12 Digital System

Definition

A digital system deals with quantities or variables which have only two discrete values or states.

Examples of Quentities

i) ; A switch can be either open or closed.
ii) ; The answer of a question can be either yes or no.

iii) : A bulb can be either off or on.
iv) ; A certain statement can be either true or false.

Represention of Quantized states

	1	2	3	4	5	6
one of the state	True	High	1	yes	on	clsod
The other state	False	Low	0	No	off	open

Mathematical Use

Mathematical use of the quantities can be made if they are represented by binary digits 1 and 0. This why the system is called binary system.

In digital system.

A high voltage is represented by , 1
A Low voltage is represented by , 0
A lighed bulb is represented by , 1
An off bulb is represented by , 0
A closed swith is represented by , 1
An open swith is represented by , 0

Boolean Algebra

We require a special algebra know a Boolean Algebra for mathematical manipulation of quantities which have values 1 and 0. The values 1 and 0 are known a Boolean Variables.

"Boolean Algebra is based upon three basic operations":

i, ; AND operation.
ii, ; OR operation.
iii, ; NOT operation.

These operations are called "Logic operations."

18.13 Fundamental Logic Gates

Definition

"The electronic circuits which implement the various logic operations are called logic gates."

Explanation

A logic gate is an electronic circuit which makes logic decisions. It has one or more inputs but only one output. The output signal appears only for certain combinations of input signals. In these getes the high and low states known as 1 and 0 are simulated by certain voltage levels.

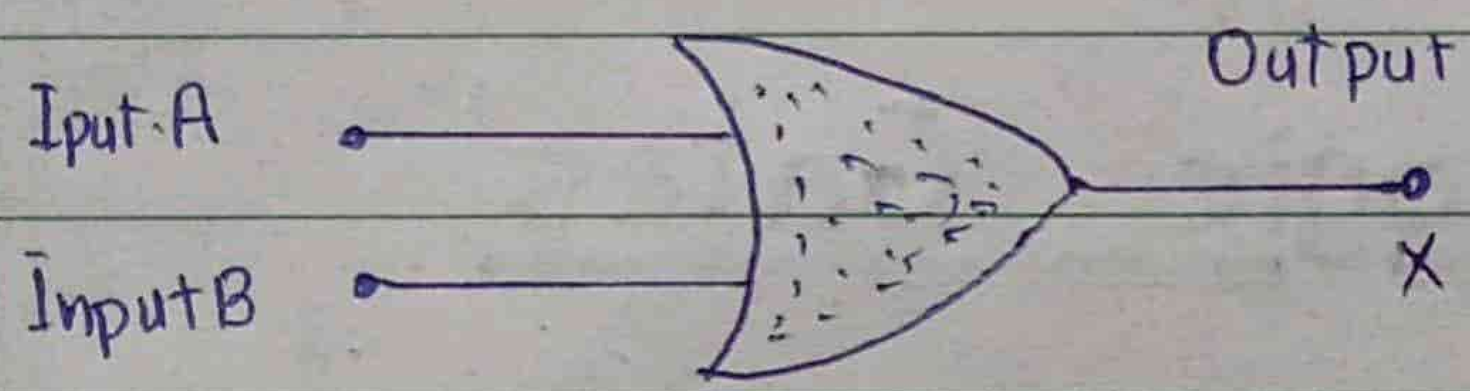
i) OR Gate

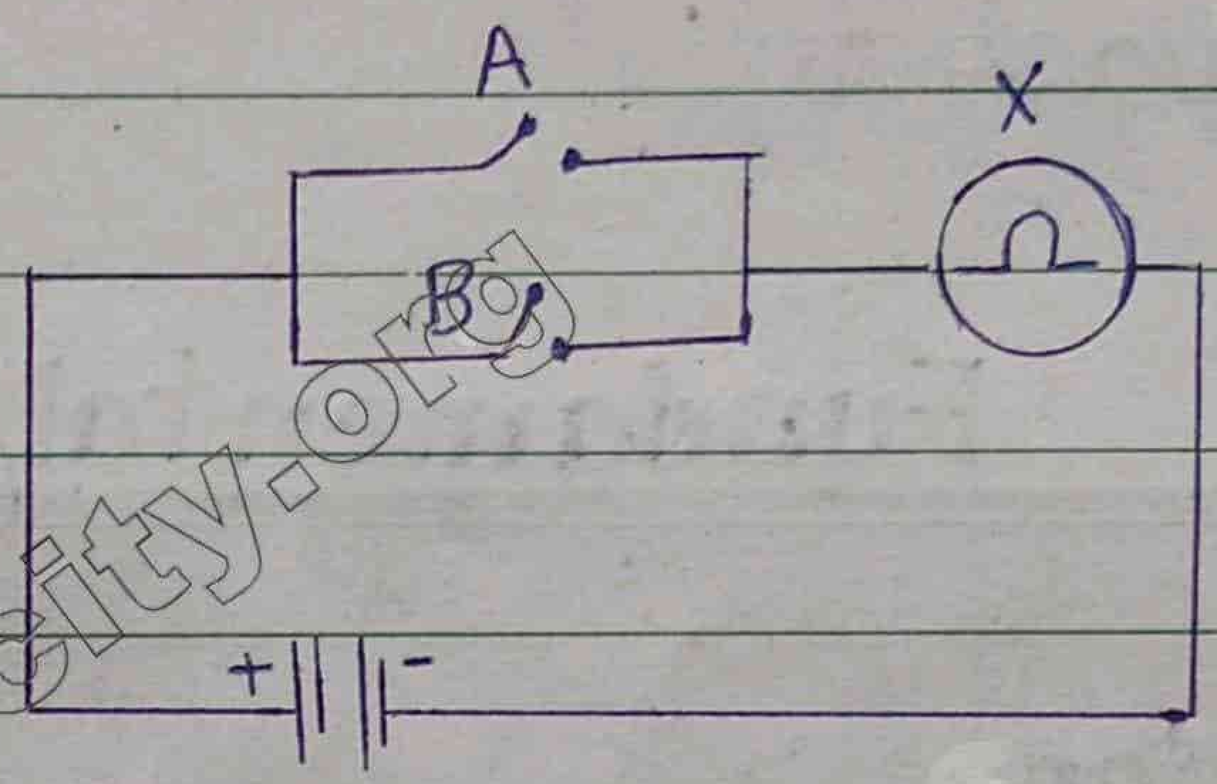
Definition

"Such a gate which implements the logic of OR operation (working) is called OR gate."

Symbol

It is shown in Fig.





OR Gate

Truth table

A	B	Output $X = a + b$
0	0	0
0	1	1
1	0	1
1	1	1

Boolean Expression

$$A + B = X$$

"A or B equals X"

ii): AND Gate

Definition

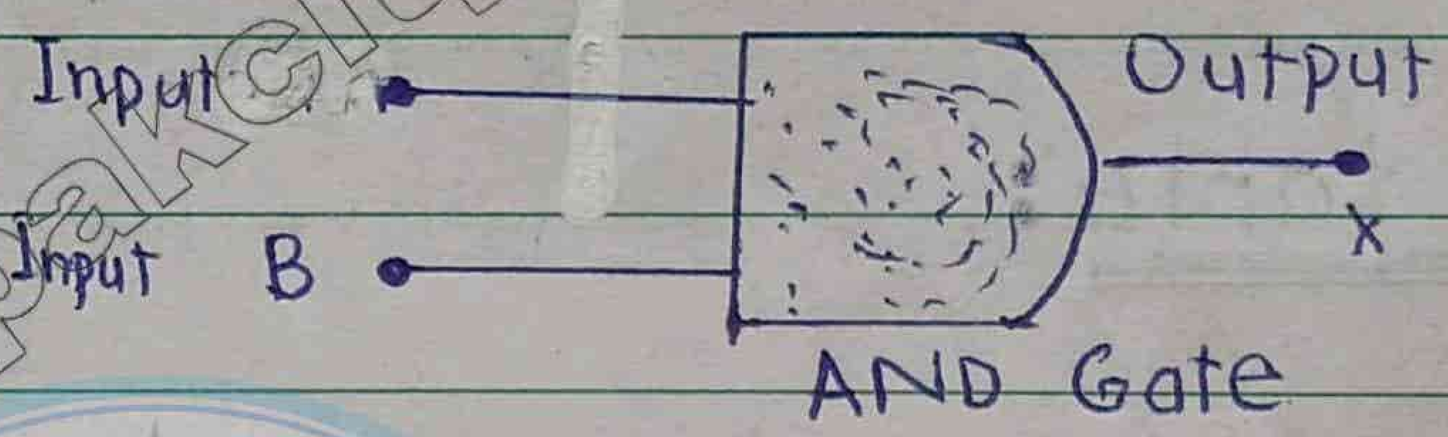
"A gates which has two or more inputs and implements the logic of AND operation is called AND gate."

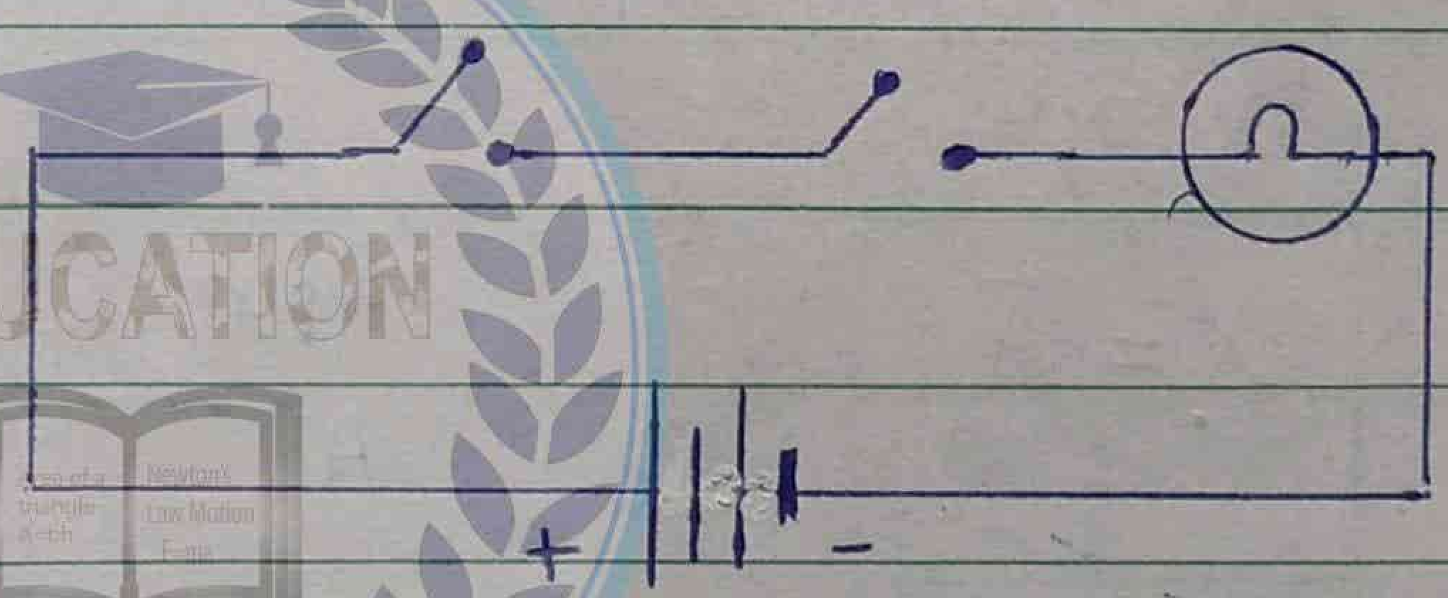
Symbol

The symbolic representation of AND gete is shown in fig.

Truth table

A	B	Output $X = AB$
0	0	0
0	1	0
1	0	0
1	1	1





Boolean Expression

$$X = A \cdot B$$

"X equals A and B"

iii): NOT Gate

A NOT gate has one input and one output. NOT gate performs the operation of inversion or complementation. This is why it is called inverter.

"It changes the logic level to its opposite level."

"It change 0 to 1 and 1 to 0."

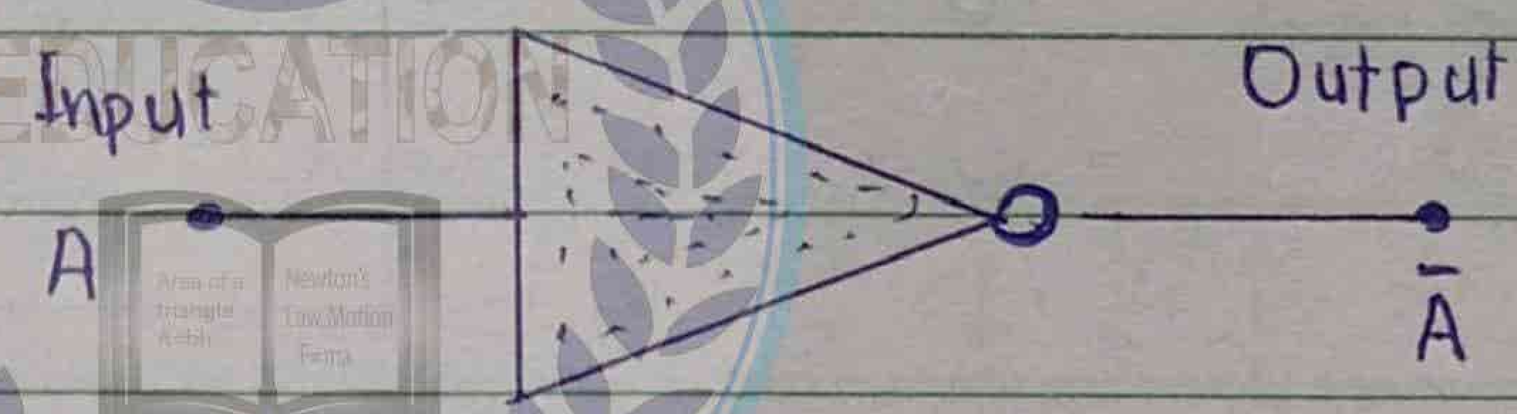
Whenever a bar is placed on any variable it shows that the value of variable has been inverted. eg $\bar{1} = 0$ or $\bar{0} = 1$

Symbol

The bubble (O) in the symbol shows the operation of inversion.

Truth table

A	output $X = \bar{A}$
0	1
1	0



Not gate

Boolean Expression

$$\bar{A} = X$$

"Not of A equals X"

18.14 Other Logic Gates

iv): NOR Gate

Definition

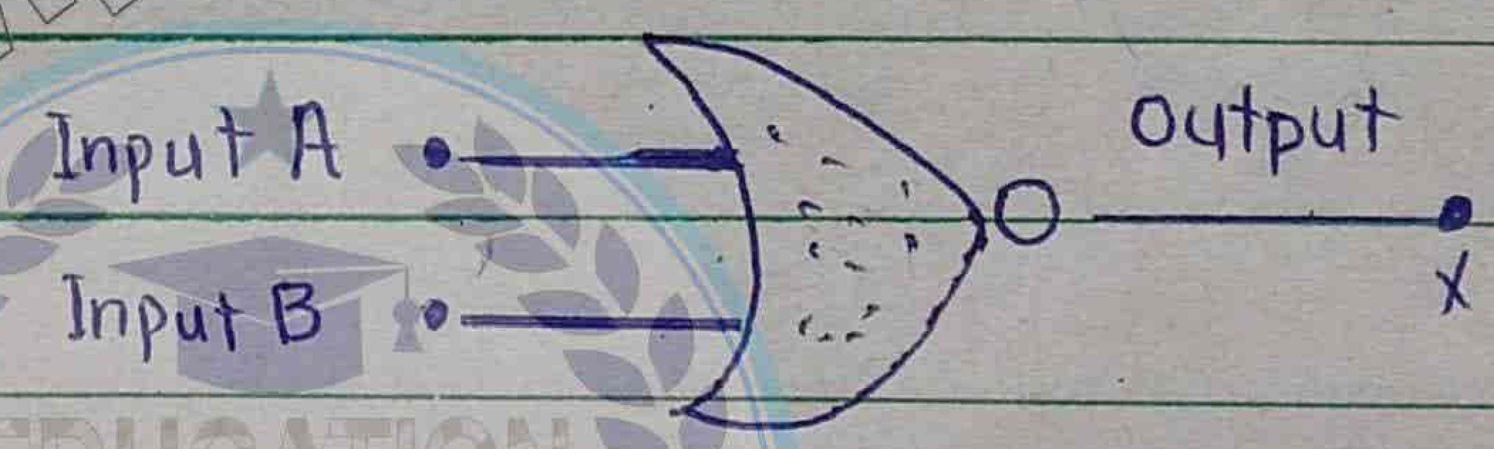
"Such a gate which inverts the output of OR gate is called NOR gate."

Symbol

The symbol of NOR is shown in fig.

Truth table

A	B	Output
0	0	1
0	1	0
1	0	0
1	1	0



Boolean Expression

$$\overline{A+B} = X$$

NOR gate gives an output 1 only when all of its inputs are at 0.

v): NAND Gate

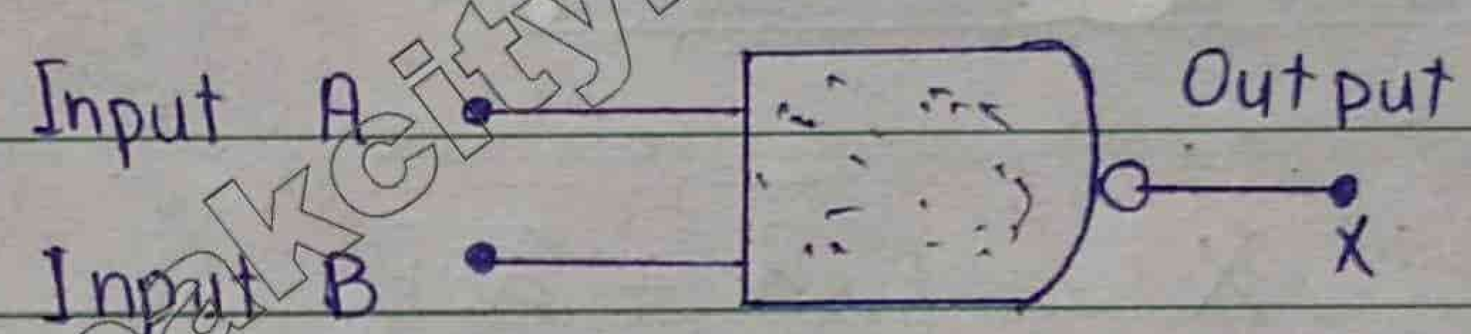
"Such a gate which inverts the output of AND gate is called as NAND gate."

Symbol

The symbol representation is shown in fig.

Truth table

A	B	output
0	0	1
0	1	1
1	0	1
1	1	0



Nand Gate

Boolean Expression

$$X = \overline{A \cdot B}$$

X equals not of A and B.

vi): Exclusive OR Gate (XOR)

Definition

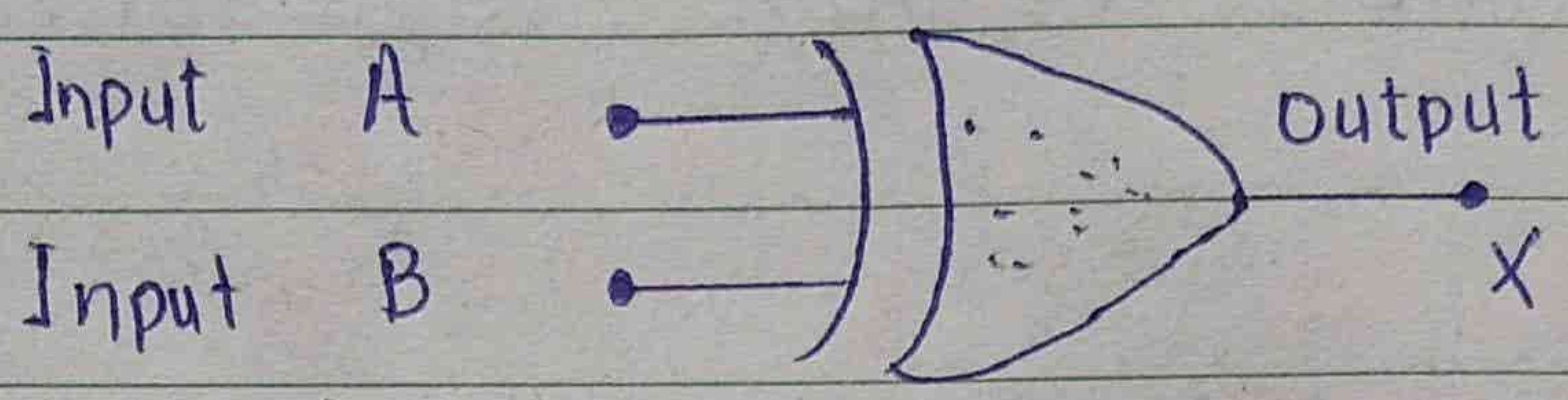
A gate which is a combination AND, OR and NOT gates is called XOR gate.

Symbol

The symbol representation of XOR gate is shown in fig.

Truth table

A	B	output
0	0	0
1	0	1
0	1	1
1	1	0



XOR gate

Boolean Expression

$$X = A \cdot \overline{B} + \overline{A} \cdot B$$

i): The first term $A \cdot \overline{B}$ is obtained by ANDing A with NOT of B.

ii): The function X is obtained by ORing these two terms.

vii): Exclusive NOR Gate

Definition

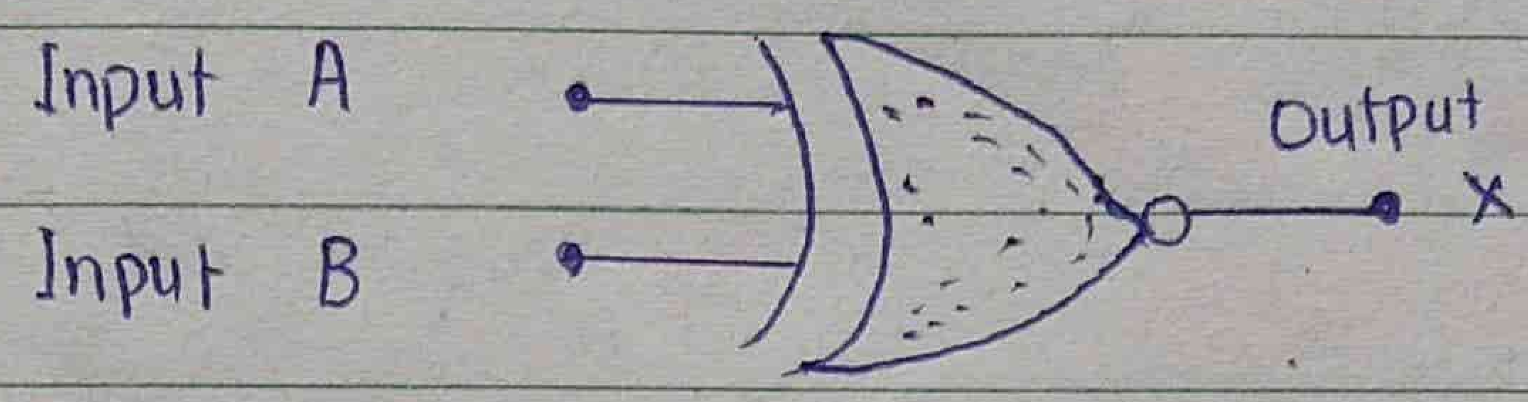
The gate which is obtained by inverting the output of XOR gate is called Exclusive NOR gate.

Symbol

The symbol of XNOR gate is shown by the fig.

Truth table:

A	B	Output
0	0	1
0	1	1
1	0	1
1	1	0



X NOR gate.

Construction:

It is constructed by combination of NOT, AND and NOR gates as shown in fig.

Boolean expression:

$$X = A\bar{B} + \bar{A}B$$

Its output is "1" when its two inputs indentical and "0" when two inputs different.

18.15 Applications of Gates in Control System

Gates have wide applications in control system. They control the function of a system by monitoring some physical parameters of a system such as temperature pressure or some physical quantity of the system. Since gates operate (work) with electrical voltages only, so some sensors are required.

Sensors

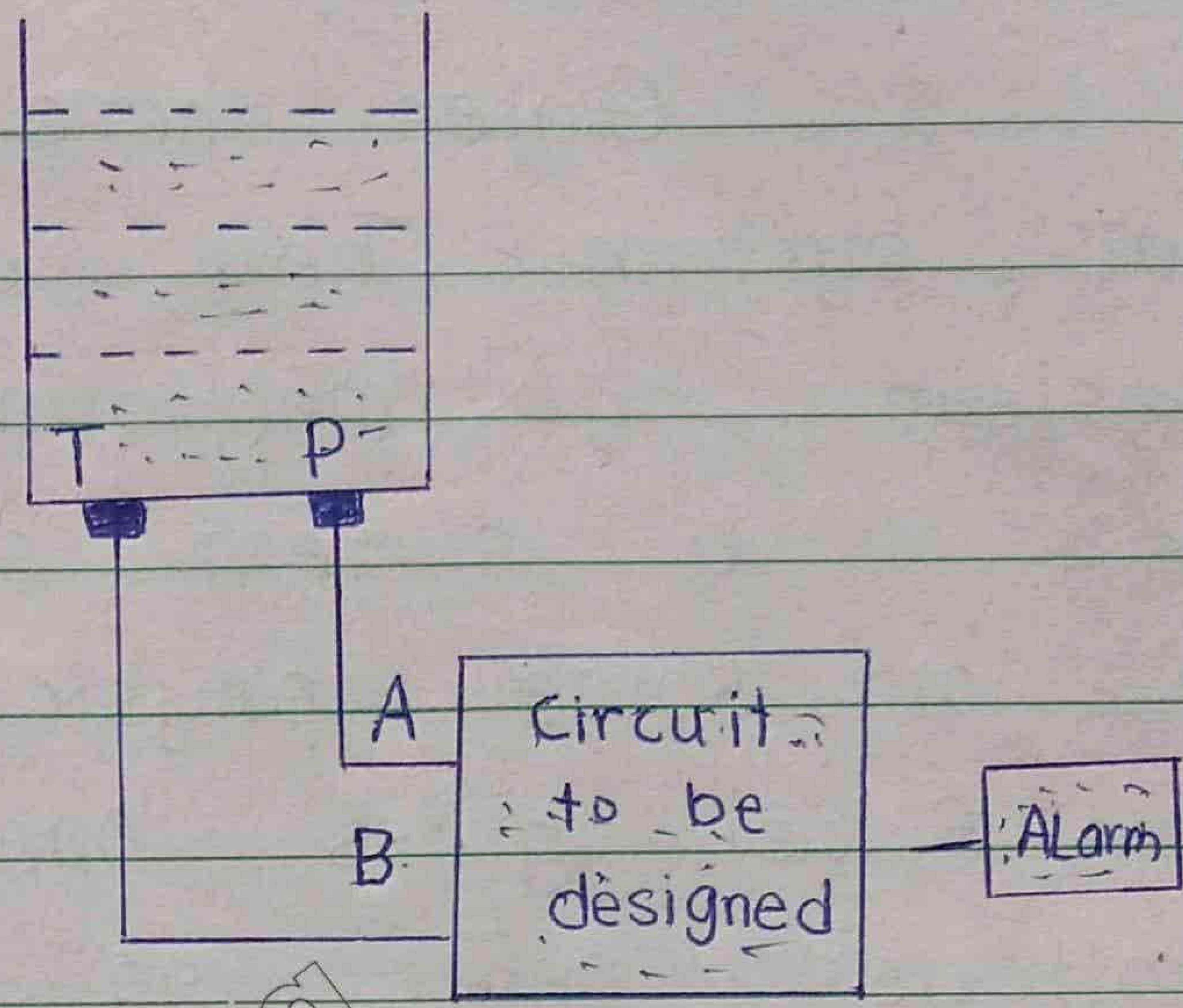
"The devices which convert various physical quantities into electric voltage are called sensors."

Examples of Sensors

- In the example of night switch, Light Department Resistance (LDR) is a sensor for light because it can convert changes in the intensity of light into electric voltage.
- A thermister is a sensor for temperature.
- A microphone is a sound sensor.

Monitoring system of P and T

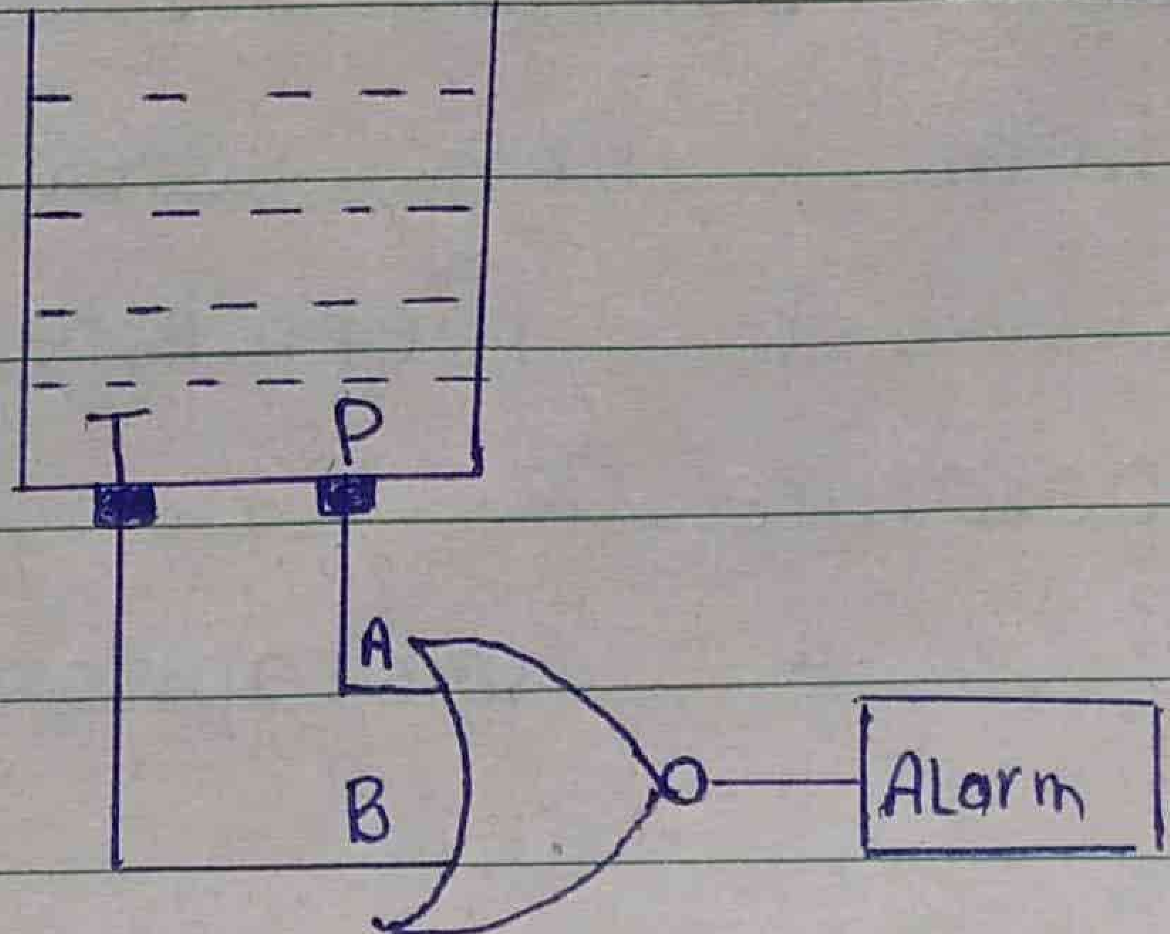
Sensors are used to monitor the pressure and temperature of a chemical solution stored in a Vat. The circuiting for each sensor is such that it produces High or 1 when either the temperature exceeds a specific value.



A circuit is to be designed which will ring an alarm when either the temperature or pressure or both cross the maximum specified limit. The alarm requires a LOW (0) voltage for its activation.

Block Diagam

The block diagam of the problem is shown in fig. In circuit "C" to be designed. Its input A and B are fed by the temperature and pressure sensors T and P fitted into the Vat.



Truth table

This table is similar to that of "NOR" gate. Hence the circuit "C" in fig "A" should be NOR gate as shown in fig "B".

A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

Chapter 18

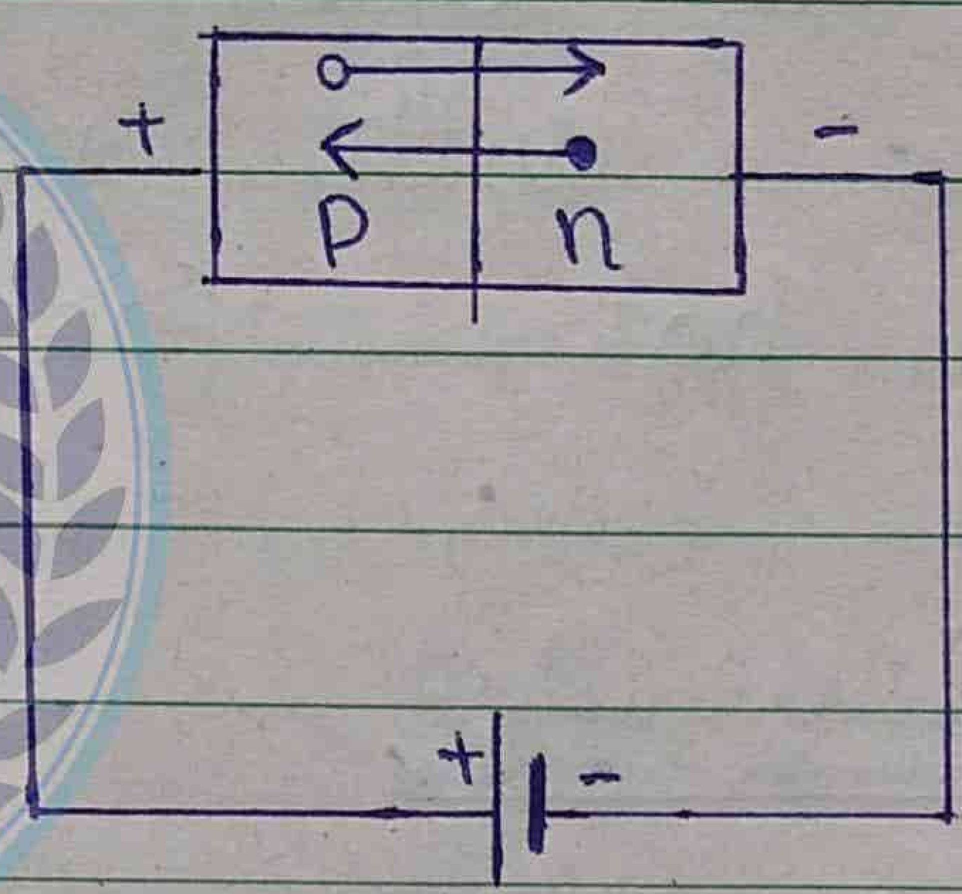
Questions

Question 18.1

Answer

In the forward baised condition, electrons in n-type region move from n to p-region while holesin p-region move from p to n-region.

This is shown in fig and it is due to applied baised voltage.



* represent hole
* represent electron.

Question 18.2

Answer

N-type and p-type semiconductor matrials consist of neutral atoms. So n-type and p-type substance have no net charge.

Question 18.3

Answer

Potential barrier for Ge = 0.3 volt
" Si = 0.7 volt

1- In case of Ge the potential difference greater than 0.3 volts is required for forward biasing.

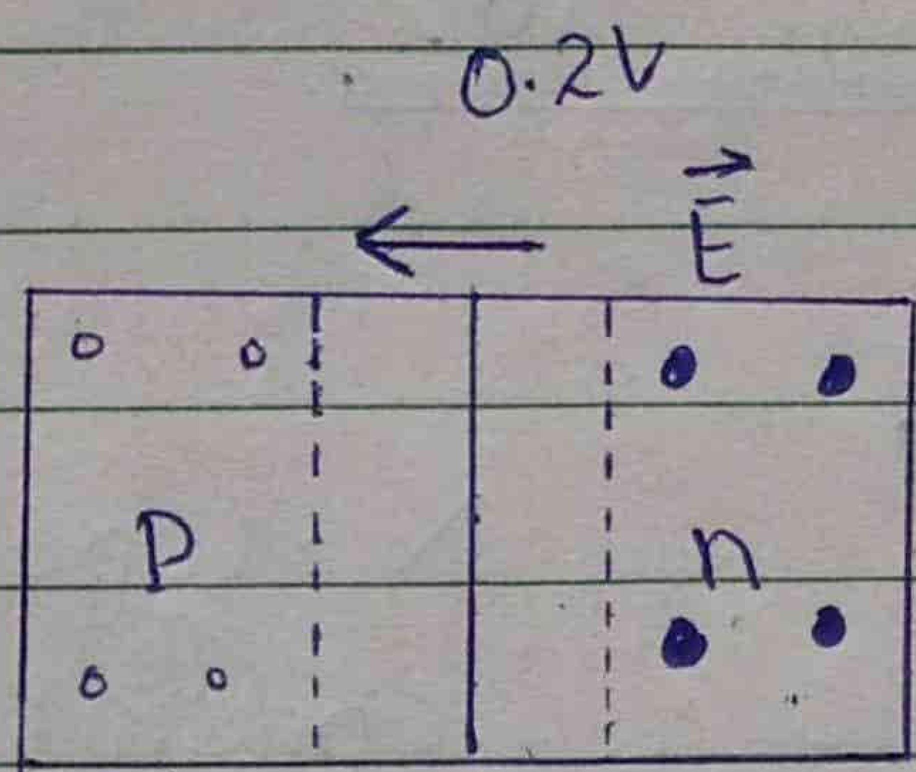
2. In case of Si the potential difference greater than 0.7 volts is required for forward baising.

When anode of a diode is 0.2 volt positive with respect to its cathod. It is not forward Biased.

Question 18.4

Answer

In deplection region there is an electric field present, due to the potential barrier.



So in the presence of electric field $\vec{E}$ in this region no charge carriers are present in this region.

Question 18.5

Answer

In forward baised condition width of depletion region decreases.
In reverse baise condition, the width of depletion region increases.

Question 18.6

Answer

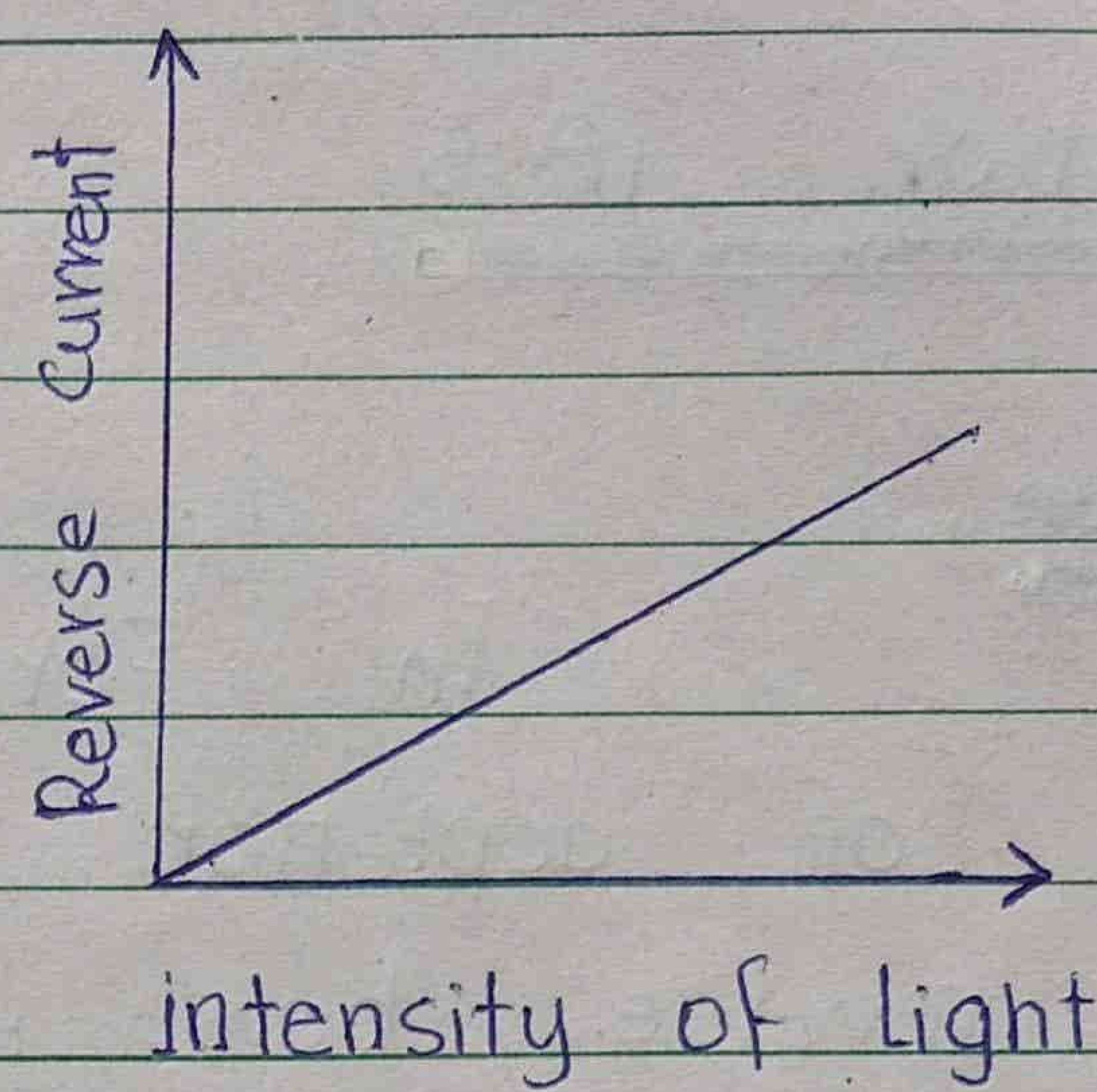
When an ordinary silicon diode is forward biased, the recombination of electrons and holes produces energy which is in the form of heat.
So no energy in the visible region of electromagnetic wave is produced.
So it does not produce light.

Question 18.7

Answer

A photo diode is used for the detection of light and is opreated in reverse biased state so that the current is neglible in the absence of light due to reverse biased state.

Now as light falls on it, then reverse current increases and hence light is detected.



This is shown in graph.

Question 18.8

Answer

i Base region is very thin. Its size is about 10^{-6} m.
Doping level of base region is very small as compared to the emitter and collector. There fore the recombination of electrons with holes in the base region is small. Hence base current is small.

$$I_B \simeq \text{Small}$$

Question 18.9

Answer

For the normal operation of a transistor

i Input junction is forward baised.

ii Output junction is reverse baised.

In case of a common emitter circuit input is applied at base-emitter junction and output is taken from collector emitter junction.

So,

1. Base-emitter junction is forward baised
2. collector-emitter junction is reverse baised.

Question 18.10

Answer

Principle of Virtual ground.

As the input resistance of an operational amplifier is very high; of the order of several mego ohms (M Ω).
So, practically no current flows across the inverting (−) and (+) non inverting

terminal of an Op-amp.

If (+) terminal is grounded then than the (-) terminal is virtually grounded i,e , at 0V.

No Potential difference between (+), (-) terminals. $V_+ - V_- \approx 0$ $V_- \approx V_+$

$V = IR = 0$	If $V_+ = 0V$
$R = 0$	then $V_- = 0V$

Chapter = 18

Examples

Example - 18.1

Solution

$I_C = 10mA$

$I_C = 10 \times 10^{-3} A$

$I_B = 40 \mu A$

$I_B = 40 \times 10^{-6} A$

$B = ?$

$B = \frac{I_C}{I_B}$

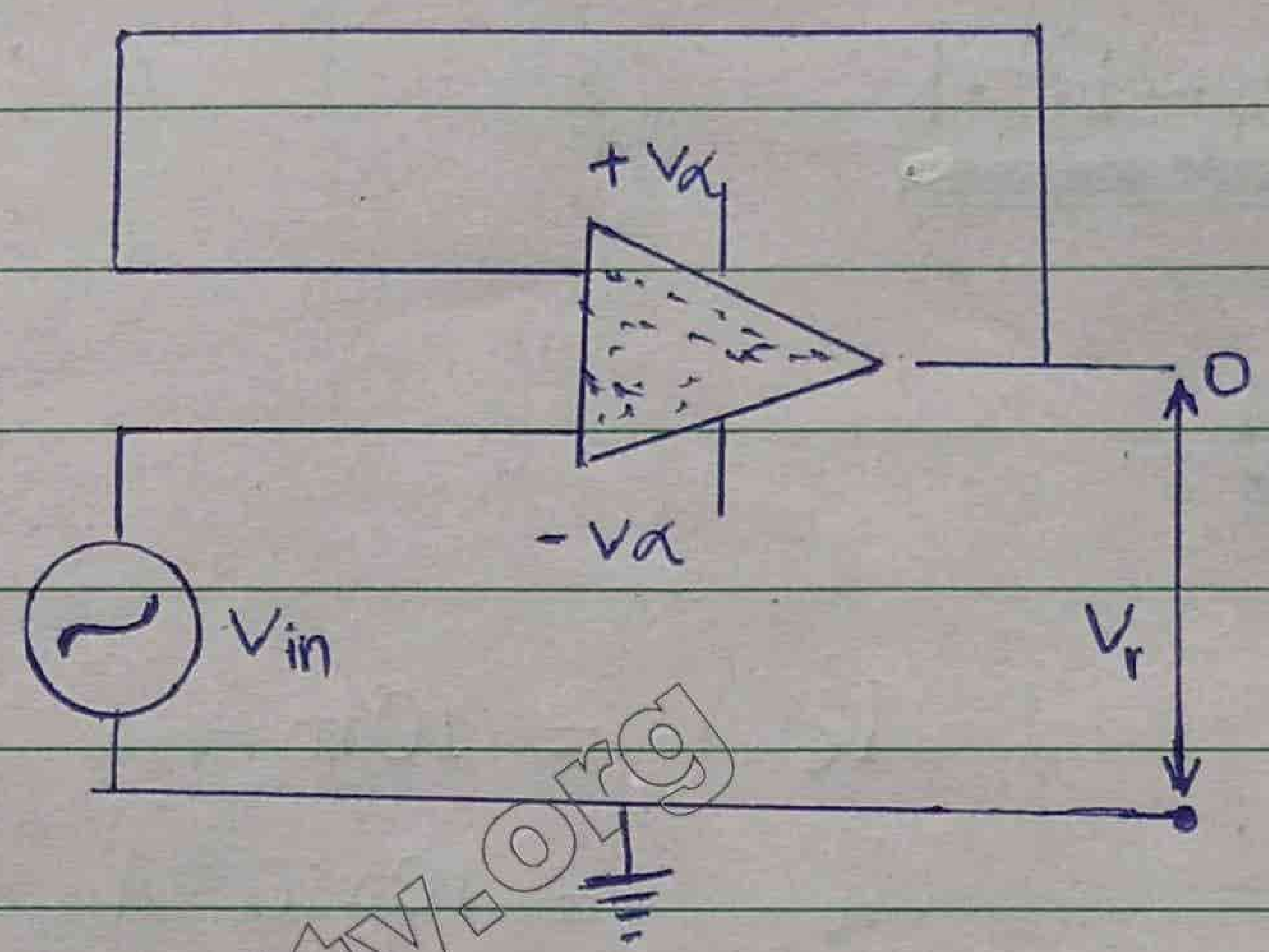
$B = \frac{10 \times 10^{-3}}{40 \times 10^{-6}}$

$B = 250$

Example _ 18.2

Solution

As input is connected to non-inverting input. so op-amp acts as a non inverting amplifier.



Here

$R_1 = \infty$

$R_2 = 0$

$\text{Gain} = 1 + \frac{R_2}{R_1}$

$\text{Gain} = 1 + \frac{0}{\infty}$

$\text{Gain} = 1 + 0$

$\text{Gain} = 1$

Chapter = 18

Problems

Problem 18.1

Solution

$I_B = 100 \mu A$

$I_B = 100 \times 10^{-6} A$

$I_c = ?$

$I_e = ?$

$\beta = 100$

Ratio $\frac{I_c}{I_E} = ?$

As $\beta = \frac{I_c}{I_B} \Longrightarrow I_c$

$= \beta . I_B$

$= 100 \times 100 \times 10^{-6}$

  www.pakcity.org

$= 0.01\ A$

$I_C = 10 \times 10^{-3}\ A$

$I_C = 10\ mA$

$I_E = I_B + I_C$

$= 100 \times 10^{-6} + 10 \times 10^{-3}$

$= 0.0101\ A$

$I_E = 10.1 \times 10^{-3}\ A$

$I_E = 10.1\ mA$

$\text{Ratio} = \frac{I_C}{I_E}$

$= \frac{10\ mA}{10.1\ mA}$

$\frac{I_C}{I_E} = 0.99$

Problem – 18.2

Solution

$I_c = 10\,mA$

$I_c = 10 \times 10^{-3} A$

$\beta = 200$

$V_{BE} = 0.6V$

$V = 9V$

$R_B = ?$

As $\beta = \frac{I_c}{I_B}$

$I_B = \frac{I_c}{\beta}$

$I_B = \frac{10 \times 10^{-3}}{200}$

$I_B = 5 \times 10^{-5} A$

Apply KVL (Kirch hoffs Voltage e Rule) to the input loop.

$V_{CC} = I_B R_B + V_{BE}$

$$V_{CC} = I_B R_B + V_{BE}$$

$$I_B R_B = V_{CC} - V_{BE}$$

$$R_B = \frac{V_{CC} - V_{BE}}{I_B}$$

$$R_B = \frac{9 - 0.6}{5 \times 10^{-5}}$$

$$R_B = 168000\ \Omega$$

$$R_B = 168 \times 10^{3}\ \Omega$$

$$\boxed{R_B = 168\ k\Omega}$$

Problem - 18.3

Solution

$$B = 00$$

$$R_B = 800k\ \Omega$$

$$V_{CC} = 9V$$

i) $I_B = ?$

ii) $I_C = ?$

iii) Potential drop across $R_c = V_c = ?$

iv) $V_{CE} = ?$

i Apply KVL to input Loop:

$$V_{CC} = I_B R_B + V_{BE}$$

$$V_{CC} = I_B R_B + 0$$

$$I_B = \frac{V_{CC}}{R_B}$$

$$I_B = \frac{9}{800 \times 10^3}$$

$$I_B = 1.125 \times 10^{-5} A$$

$$I_B = 11.25 \times 10^{-6} A$$

$$I_B = 11.25 \mu A$$

ii $I_c = ?$

As $$B = \frac{I_c}{I_B}$$

$$I_c = B I_B$$

$$I_c = 100 \times 11.25\ \mu A$$

$$I_c = 100 \times 11.25 \times 10^{-6}$$

$$I_c = 1.125 \times 10^{-3} A$$

$$\boxed{I_c = 1.125\ mA}$$

iii) Potential drop across $R_C = V_C = ?$

Potential drop across = R_c

" $= V_c$

$= I_c R_c$

" " " $= 1.125 \times 10^{-3} \times 1 \times 10^{3}$

Potential drop across $R_C = 1.125\,V$

iv) Apply KVL to out put Loop:

$$V_C = I_C R_C + V_{CE}$$

$$V_{CE} = V_{CC} - I_C R_C$$

$$V_{CE} = 9 - 1.125 \times 10^{-3} \times 1 \times 10^{3}$$

$$V_{CE} = 9 - 1.125$$

$$\boxed{V_{CE} = 7.875V}$$

Problem - 18.4

Solution

Apply Kirch hoffs Current rule:

$$I_1 + I_2 = I_3$$

$$\frac{5-0}{10\times10^3} + \frac{-2-0}{4\times10^3} = \frac{0-V_o}{20\times10^3}$$

$\times$ by 10^3

$$\frac{5}{10} + \frac{-2}{4} = \frac{V_o}{20}$$

$$0.5 - 0.5 = \frac{V_o}{20}$$

$$0 = \frac{V_o}{20}$$

$$V_o = 0\times20$$

$$\boxed{V_o = 0}$$

Problem - 18.5

Solution

$R_1 = 10k\,\Omega$

$R_1 = 10 \times 10^3\,\Omega$

$R_2 = 40k\,\Omega$

$R_2 = 40 \times 10^3\,\Omega$

$G = ?$

$G = 1 + \frac{R_2}{R_1}$

$G = 1 + \frac{40 \times 10^3}{10 \times 10^3}$

$G = 1 + \frac{40}{10}$

$G = 1 + 4$

$G = 5$

Problem -18.6

Solution

$$A = ?$$

$$R_c = 5\ k\Omega$$

$$R_c = 5 \times 10^3\ \Omega$$

$$r_{ie} = 2.5\ k\Omega$$

$$r_{ie} = 2.5 \times 10^3\ \Omega$$

$$B = 100$$

As

Gain $A = -B \frac{R_c}{r_{ie}}$

$$A = -100 \frac{5 \times 10^3}{2.5 \times 10^3}$$

$$A = 100 \times \frac{5}{2.5}$$

$$A = -100 \times 2$$

shows $A = 200$

- (-ve) a phase shift of 180°