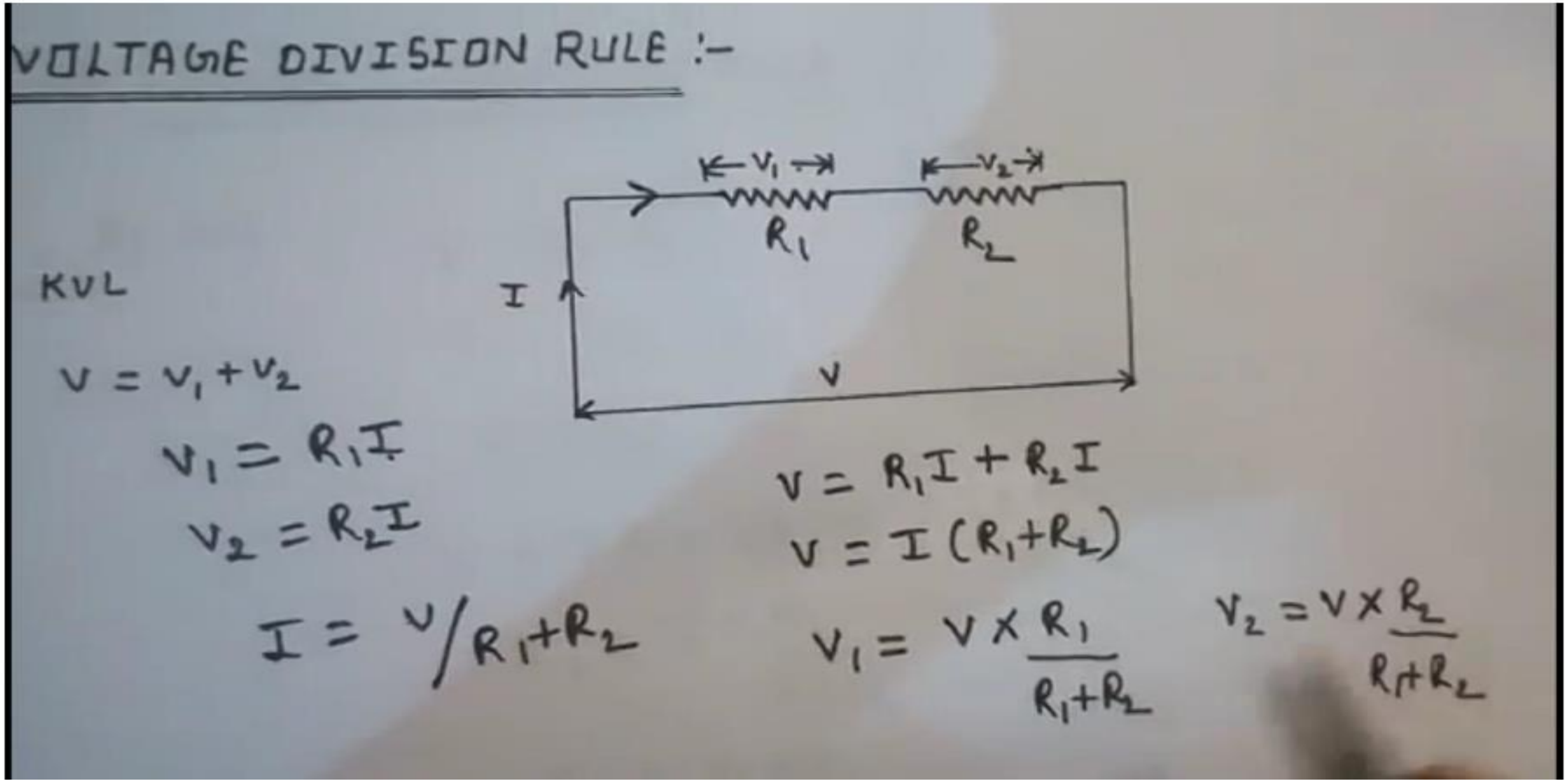
Voltage Division Rules

1. Voltage Division Rule

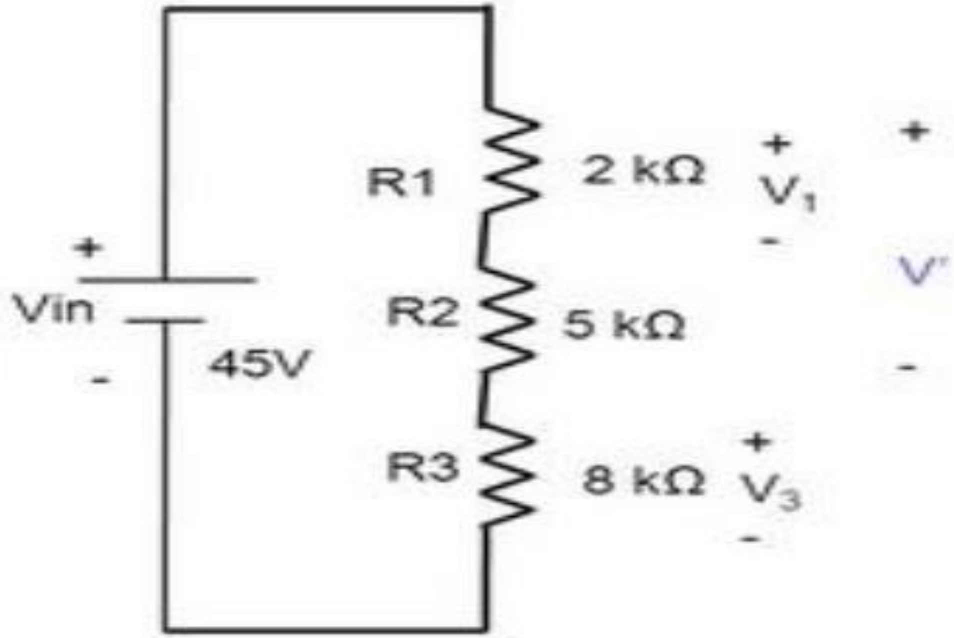
The **voltage** is divided between two series resistors in direct proportion to their resistance.



Voltage Division Rules

Voltage Divider Rule –Example 2

Using the voltage divider rule, determine the voltage V_1 and V_3 for the series circuit



Voltage Division Rules

Voltage Divider Rule –Example 2

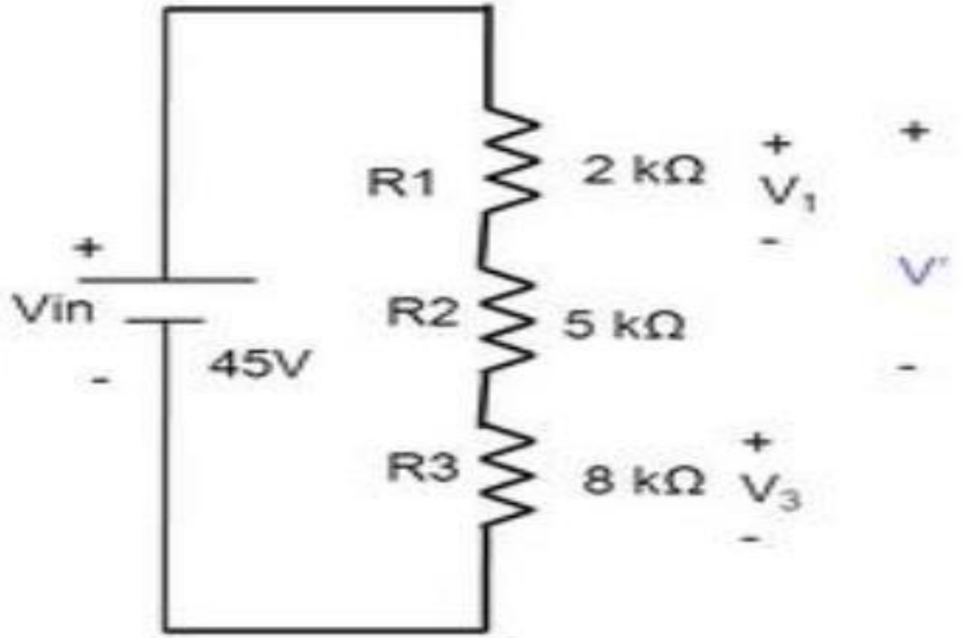
Using the voltage divider rule, determine the voltage V_1 and V_3 for the series circuit

$$V_1 = \frac{R_1 V_{in}}{R_T} = \frac{(2k\Omega)(45V)}{2k\Omega + 5k\Omega + 8k\Omega} = \frac{(2k\Omega)(45V)}{15k\Omega}$$

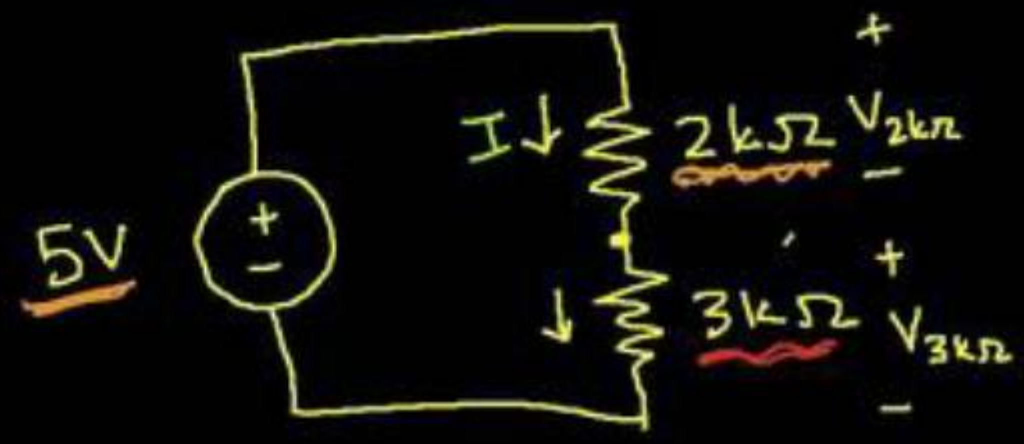
$$= \frac{(2\times10^3\Omega)(45V)}{15\times10^3\Omega} = \frac{90}{15} = 6V$$

$$V_3 = \frac{R_3 V_{in}}{R_T} = \frac{(8k\Omega)(45V)}{2k\Omega + 5k\Omega + 8k\Omega} = \frac{(8\times10^3\Omega)(45V)}{15\times10^3\Omega}$$

$$= \frac{360}{15} = 24V$$



Voltage Division Rules



Current Division Rule

Current division refers to the splitting of **current** between the branches .

parallel → V → same

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

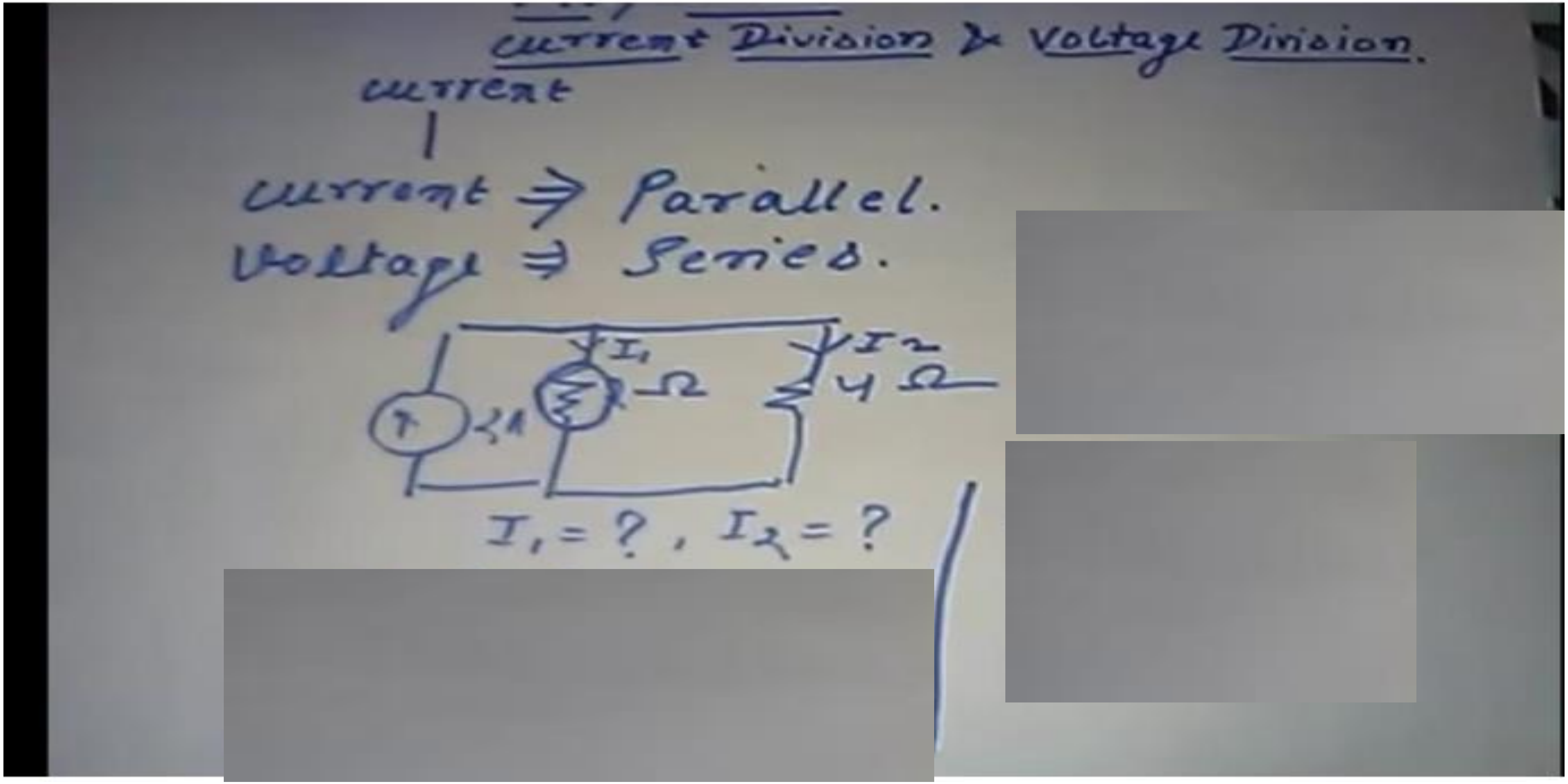
$$V = I R_{eq} \Rightarrow V = \frac{I R_1 R_2}{R_1 + R_2}$$

$$I_1 = \frac{V}{R_1} = \frac{I \cancel{R_1} R_2}{(R_1 + R_2) \cancel{R_1}} = \frac{I}{R_1 + R_2} R_2$$

$$I_2 = \frac{V}{R_2} = \frac{I}{R_1 + R_2} \cdot R_1$$

Current Division Rule

Examples-1



Current Division Rule

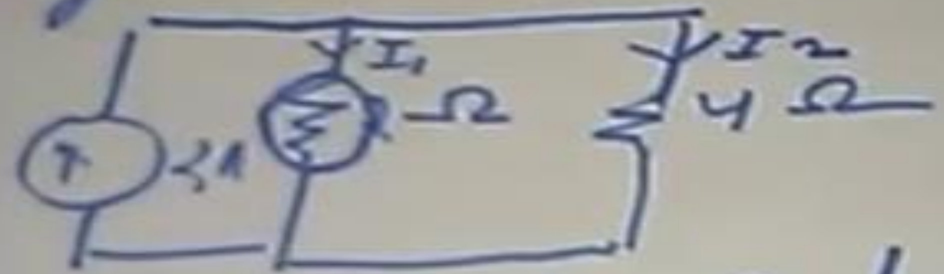
Examples-1

Current Division & Voltage Division.

current

current ⇒ Parallel.

Voltage ⇒ Series.



$I_1 = ?\ ,\ I_2 = ?$

$$I_1 = \left(\frac{4}{2+4}\right) \times 2$$

$$I_1 = \frac{4}{6} \times 2 = \frac{4}{3}\ \text{Amp.}$$

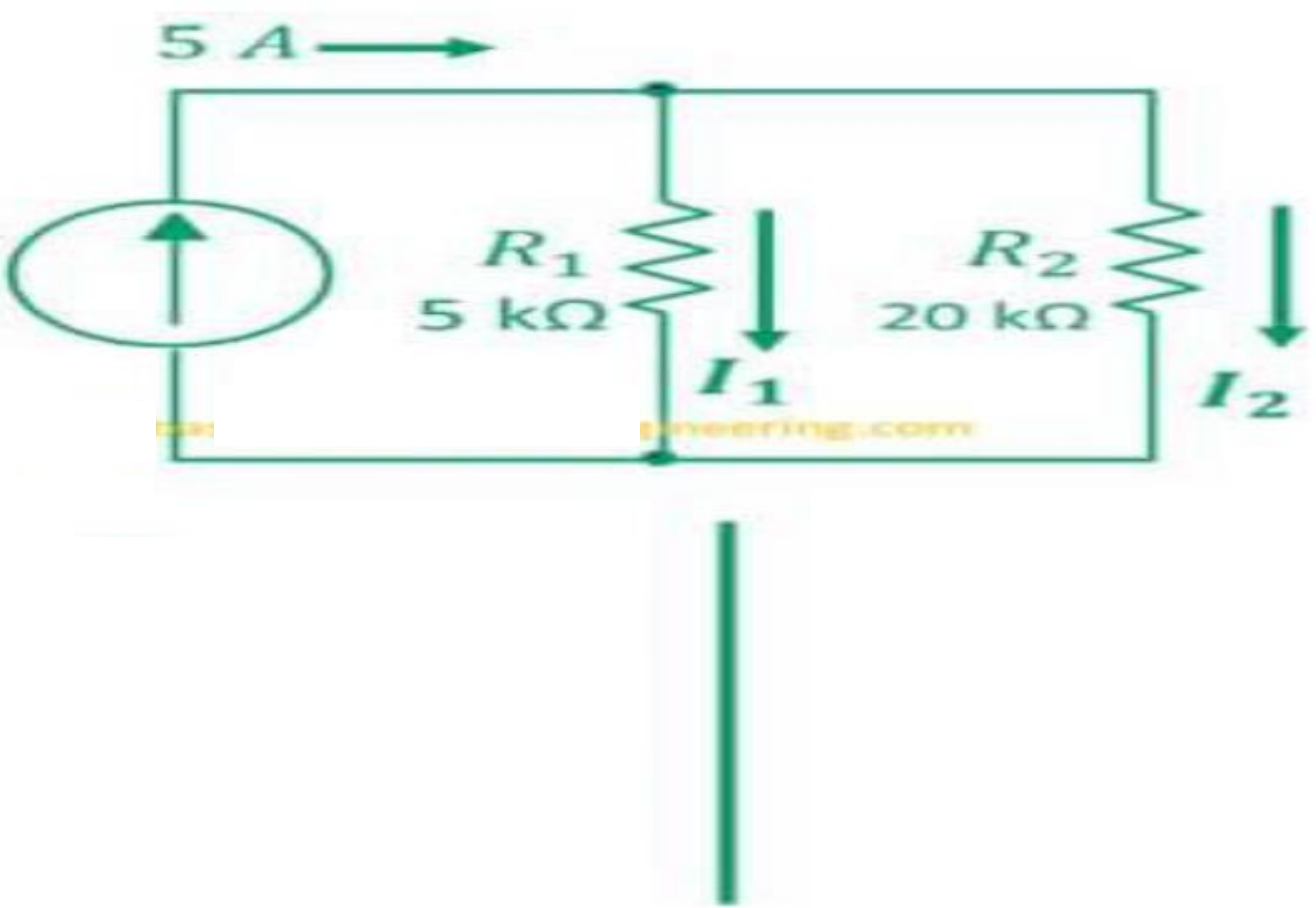
$$I = I_1 + I_2$$

$$= \frac{4}{3} + \frac{2}{3} = \frac{6}{3} = 2A$$

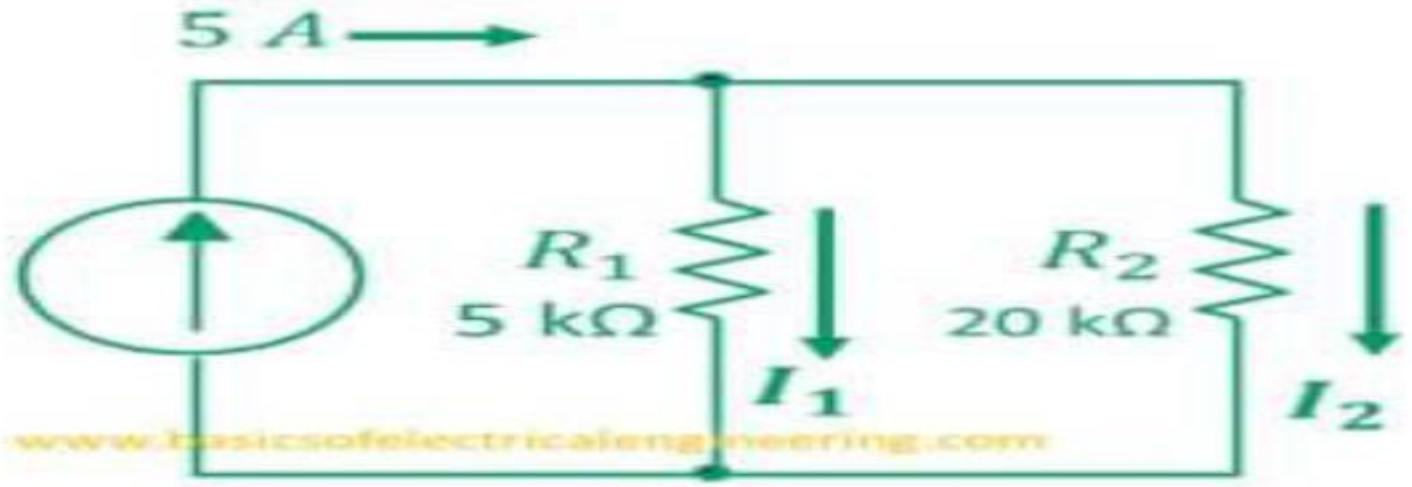
$$I_2 = \left(\frac{2}{6}\right) \times 2$$

$$I_2 = \frac{2}{3}$$

Current Division Rule



Current Division Rule



$$I_1 = \frac{R_2}{R_1 + R_2} * I_t$$

$$I_1 = \frac{20\ k\Omega}{25\ k\Omega} * 5\ A$$

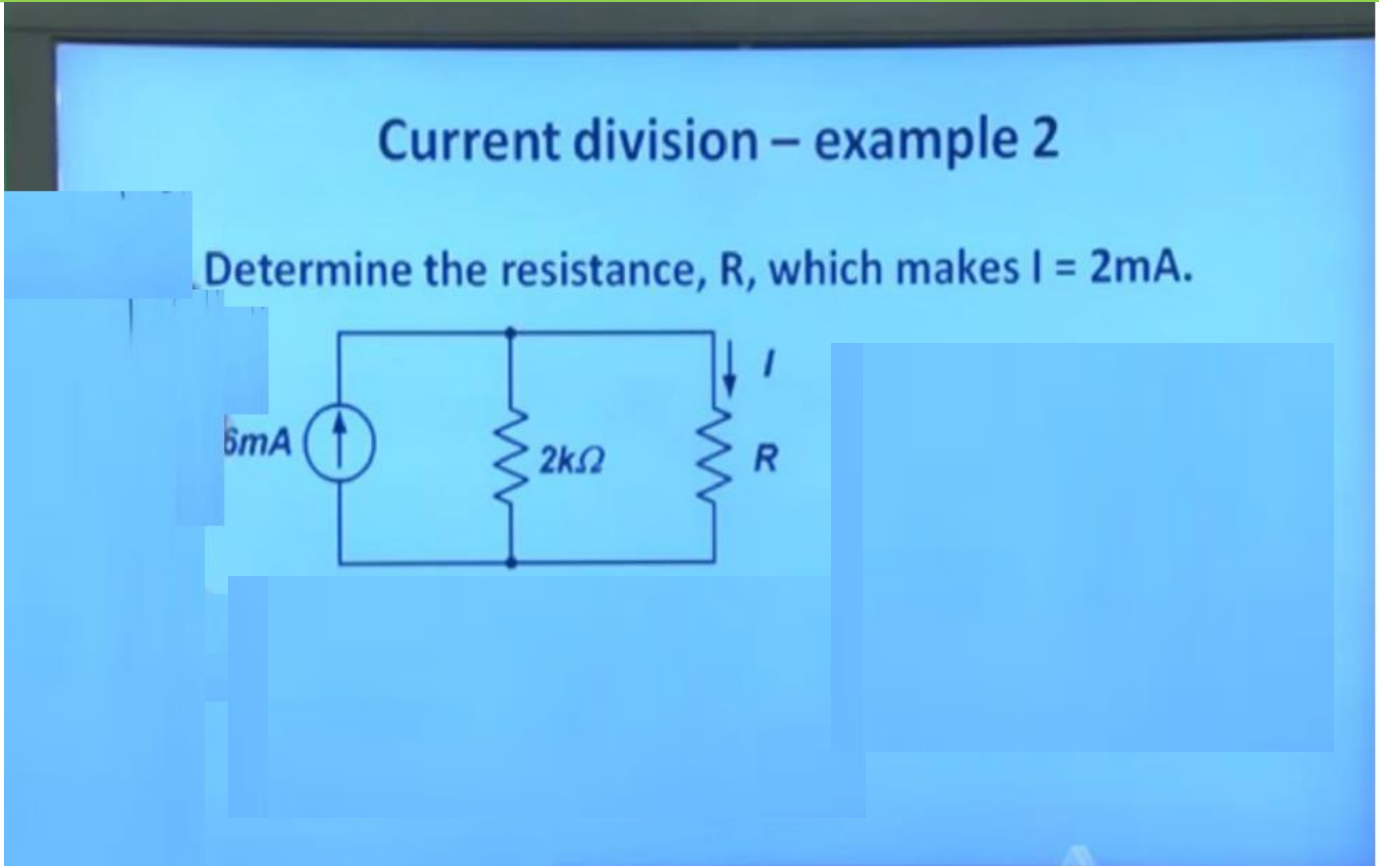
$$I_1 = 4\ A$$

$$I_2 = \frac{R_1}{R_1 + R_2} * I_t$$

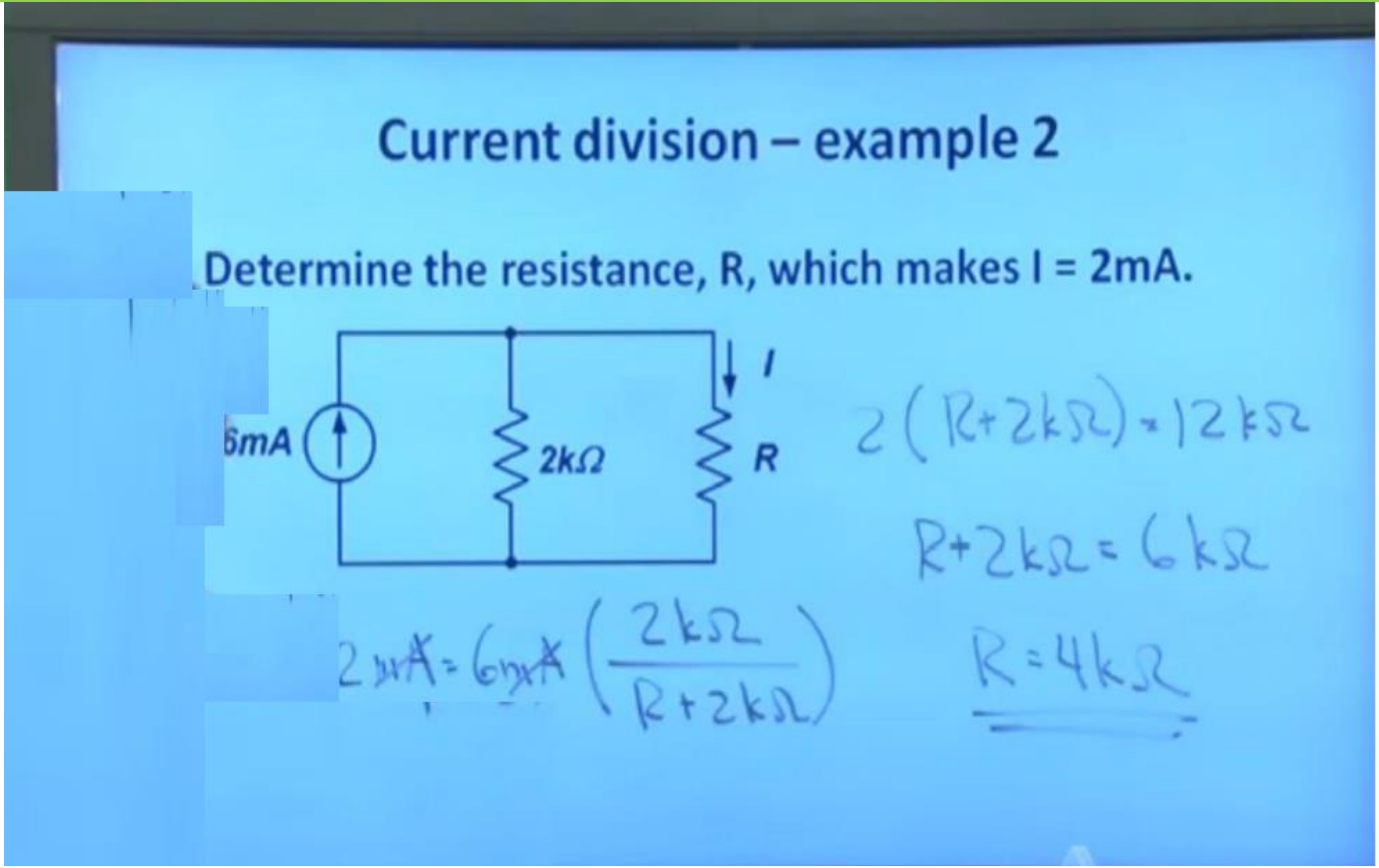
$$I_2 = \frac{5\ k\Omega}{25\ k\Omega} * 5\ A$$

$$I_2 = 1\ A$$

Current Division Rule

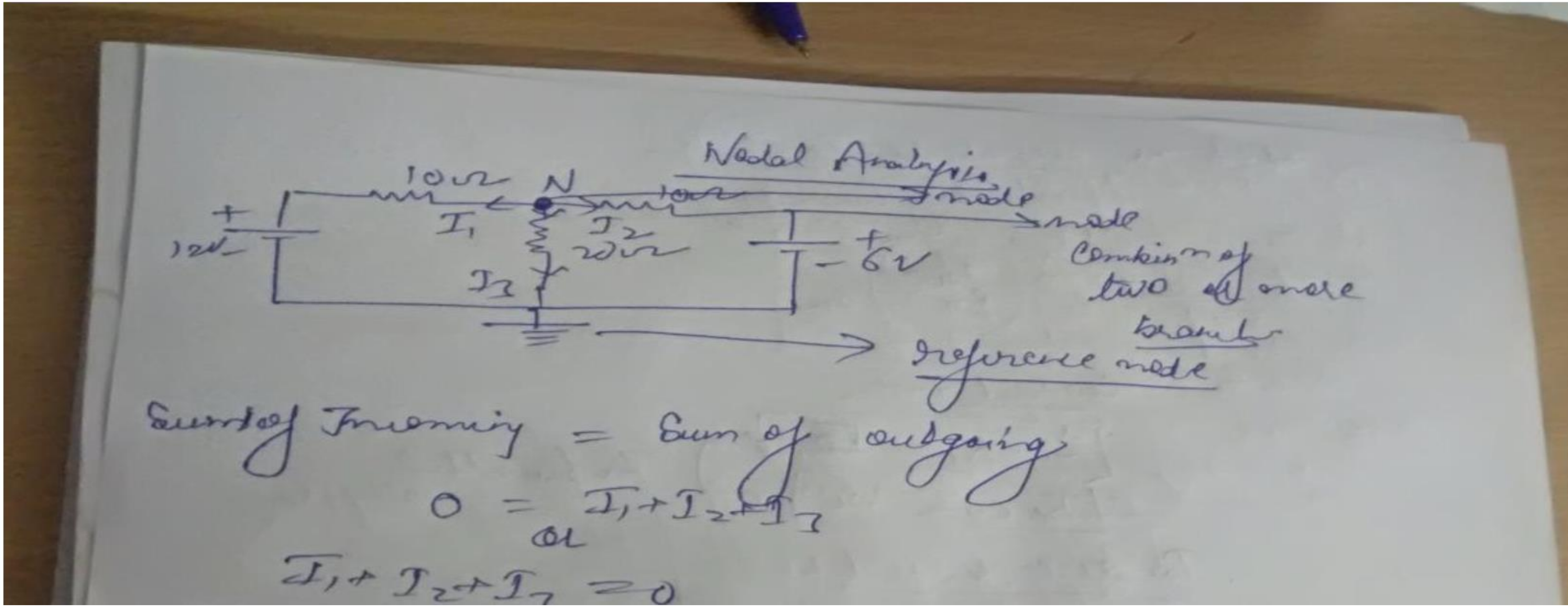


Current Division Rule



Nodal Analysis

Nodal analysis is a method that provides a general procedure for analyzing circuits using node voltages as the circuit variables. **Nodal Analysis** is also called the **Node-Voltage Method**.



Nodal Analysis

or

$$I_1 + I_2 + I_3 = 0$$

$$\boxed{\frac{N-12}{10} + \frac{N-0}{20} + \frac{N-6}{10} = 0}$$

$$\frac{2N - 24 + N + 2N - 12}{20} = 0$$

$$\boxed{5N - 36 = 0}$$

$$\boxed{N = \frac{36}{5} \Rightarrow 7.2V}$$

$$I_1 = \frac{N-12}{10} \Rightarrow \frac{7.2-12}{10} \Rightarrow \frac{-4.8}{10} \Rightarrow -.48$$

$-.48$

or

$\underline{.48}$

$$I_2 = \frac{N}{20} \Rightarrow \frac{7.2}{20} \Rightarrow .36A$$

$$I_3 = \frac{N-6}{10} \Rightarrow \frac{7.2-6}{10} \Rightarrow \frac{1.2}{10} \Rightarrow .12A$$

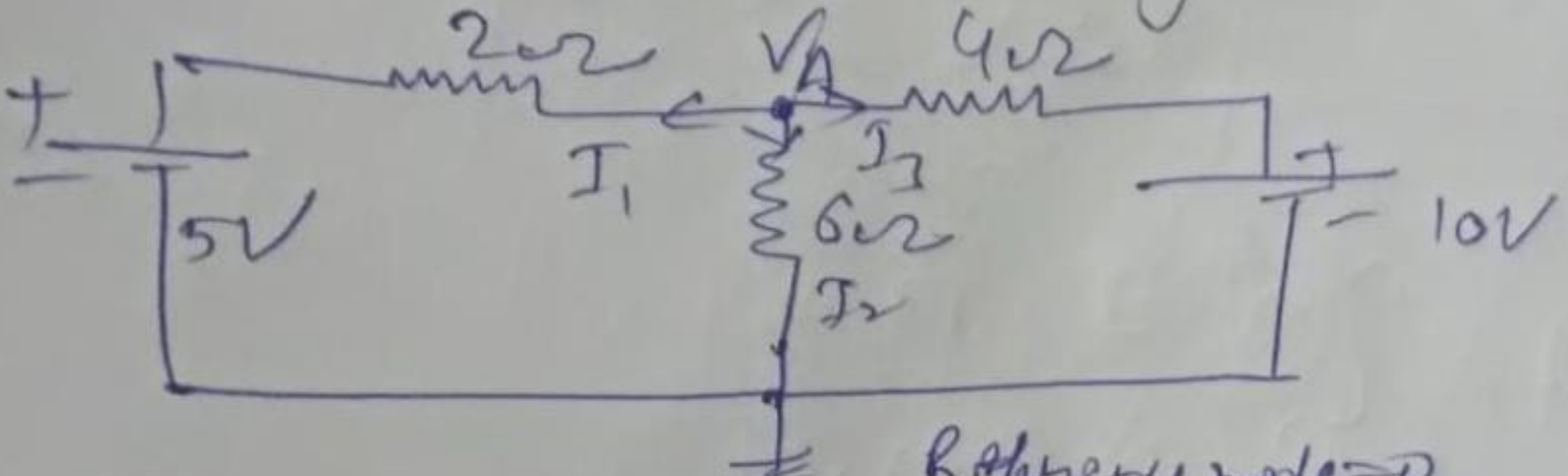
Nodal Analysis

2)

Nodal Voltage Analysis

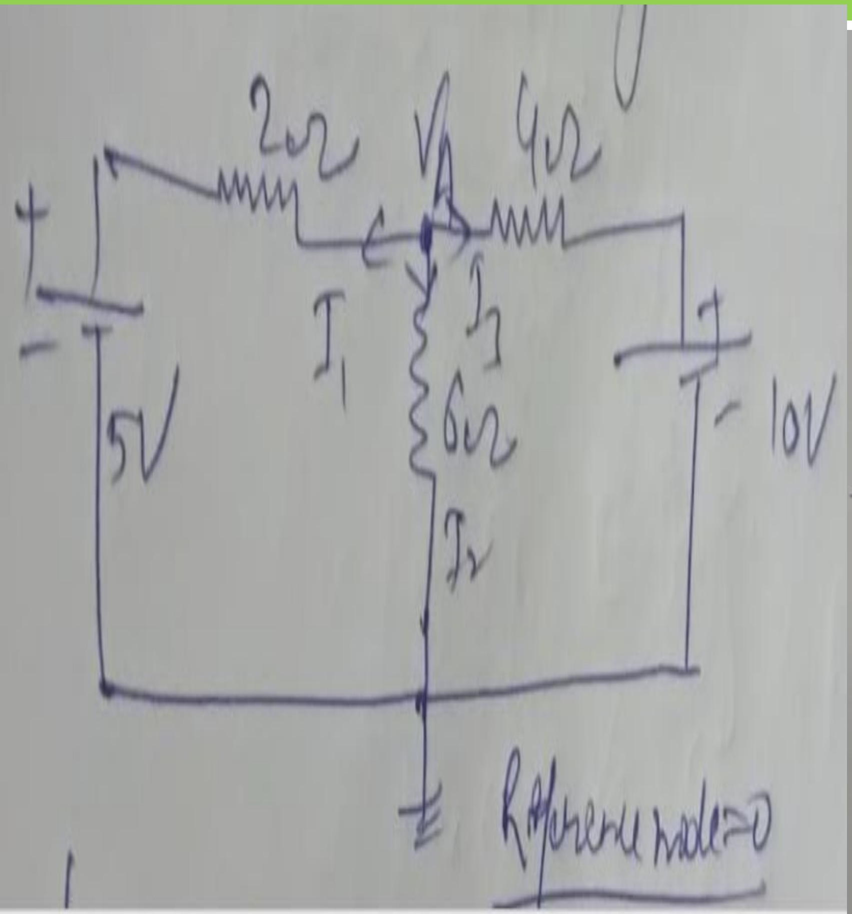
Nodal Analysis

Nodal Voltage



Reference node = 0

Nodal Analysis



(outgoing)

$I_1 + I_2 + I_3 = 0$ {Incoming}

$$\frac{V_A - 5}{2} + \frac{V_A}{6} + \frac{V_A - 10}{4} = 0$$

$$\frac{6V_A - 30 + 2V_A + 3V_A - 30}{12} = 0$$

$$11V_A - 60 = 0$$

$$\boxed{V_A = \frac{60}{11}} \Rightarrow 5.45$$

$$I_1 = \frac{\frac{60}{11} - 5}{2} \Rightarrow \frac{.45}{2} \Rightarrow .2272A$$

$$.9090$$

$$I_2 = \frac{60}{11 \times 6} \Rightarrow$$

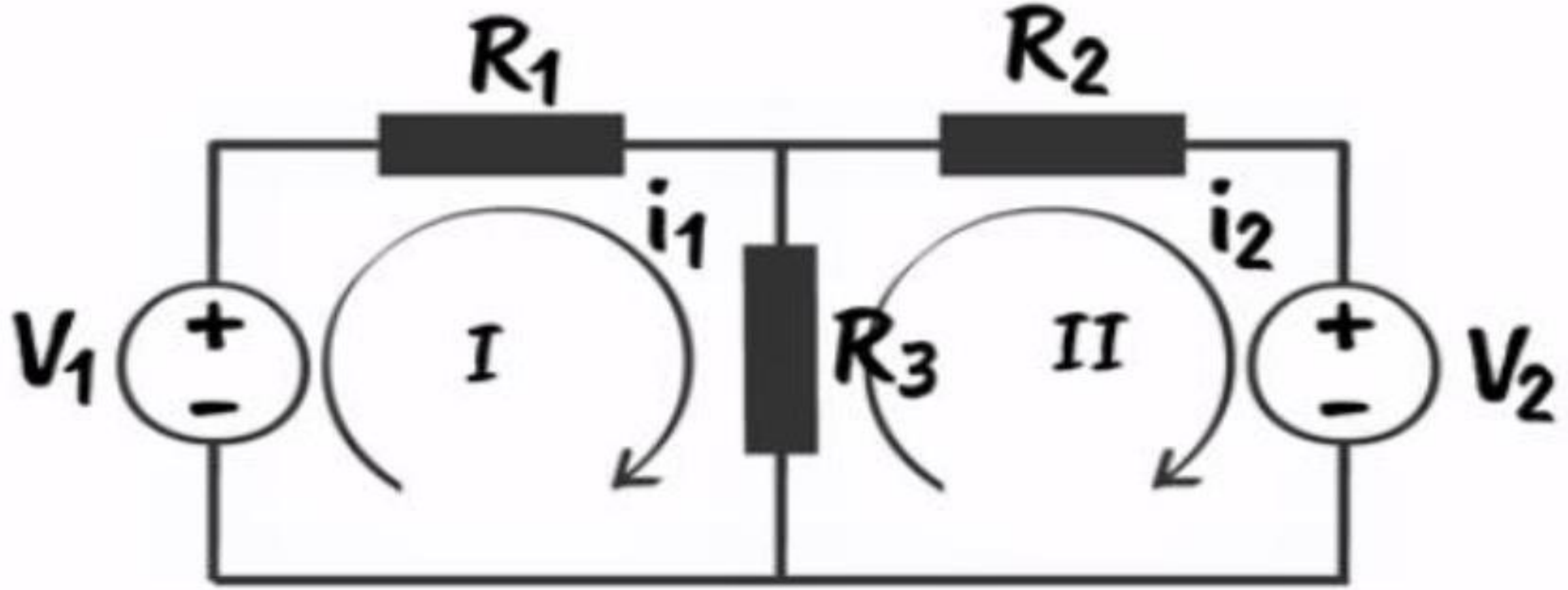
$$I_3 = \frac{\frac{60}{11} - 10}{4} \Rightarrow \frac{5.45 - 10}{4} \Rightarrow \frac{-4.55}{4} \Rightarrow -1.13$$

1.13

so

Mesh Analysis

Mesh analysis is a method that is used to solve circuits for the currents at any place in the electrical circuit.

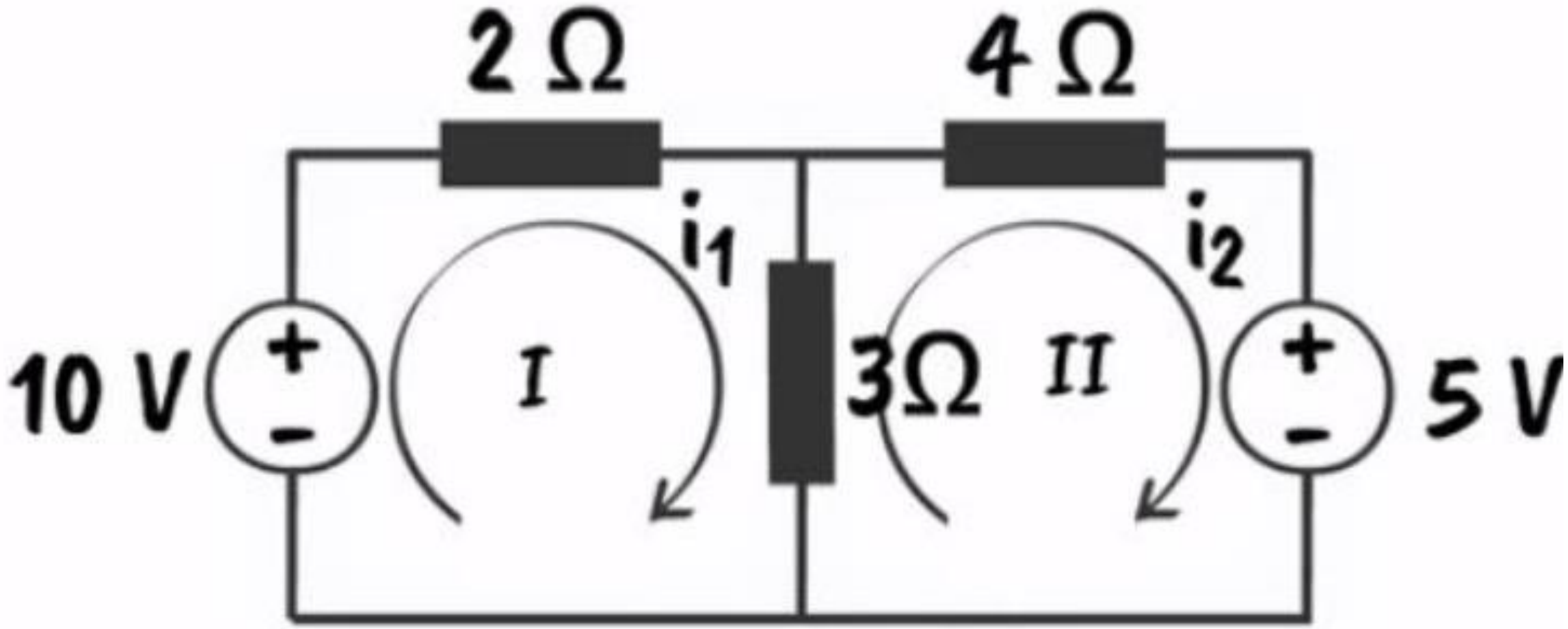


KVL

$$V_1 - i_1R_1 - (i_1 - i_2)R_3 = 0 \text{ ---(1)}$$

$$-(i_2 - i_1)R_3 - i_2R_2 - V_2 = 0 \text{ ---(2)}$$

Mesh Analysis

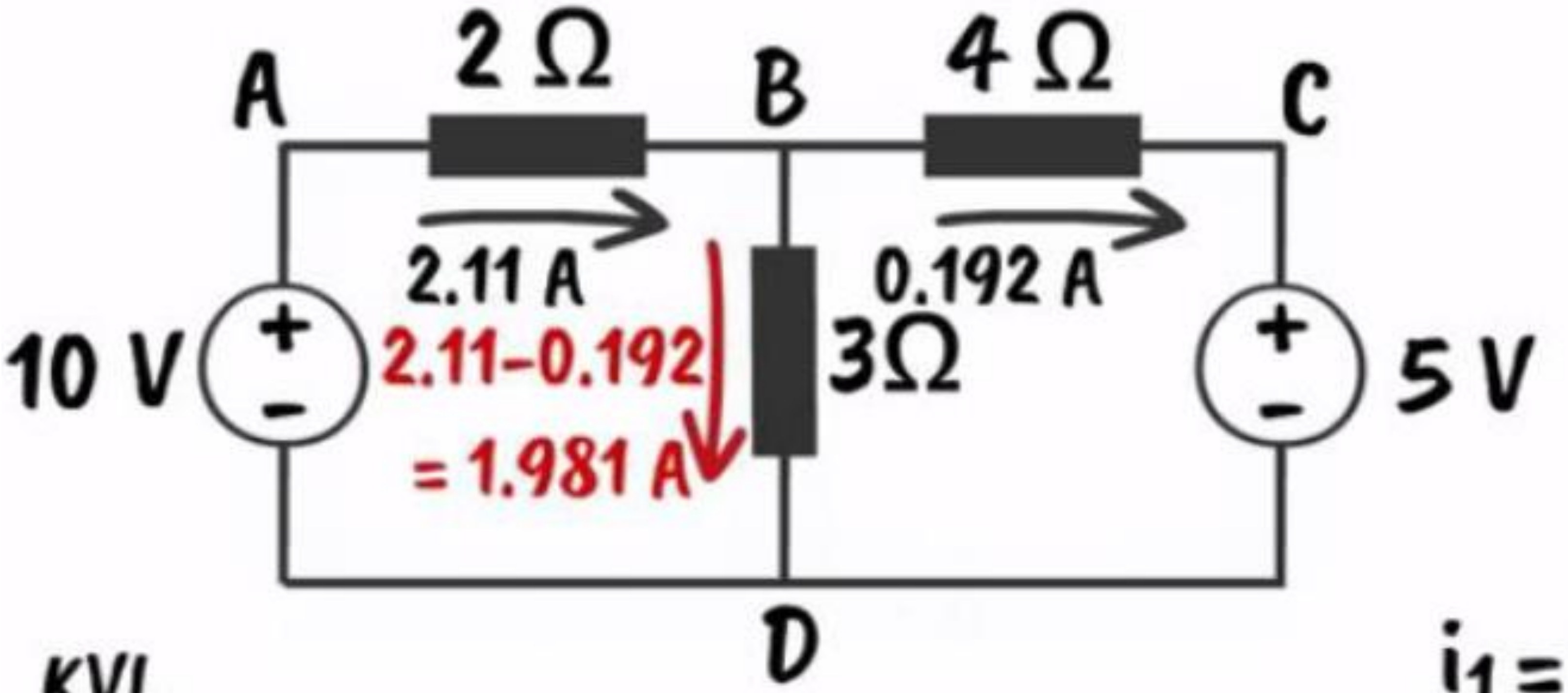


KVL

$$10 - i_1 2 - (i_1 - i_2)\, 3 = 0 \text{ ---(3)}$$

$$-(i_2 - i_1)\, 3 - i_2 4 - 5 = 0 \text{ ---(4)}$$

Mesh Analysis



KVL

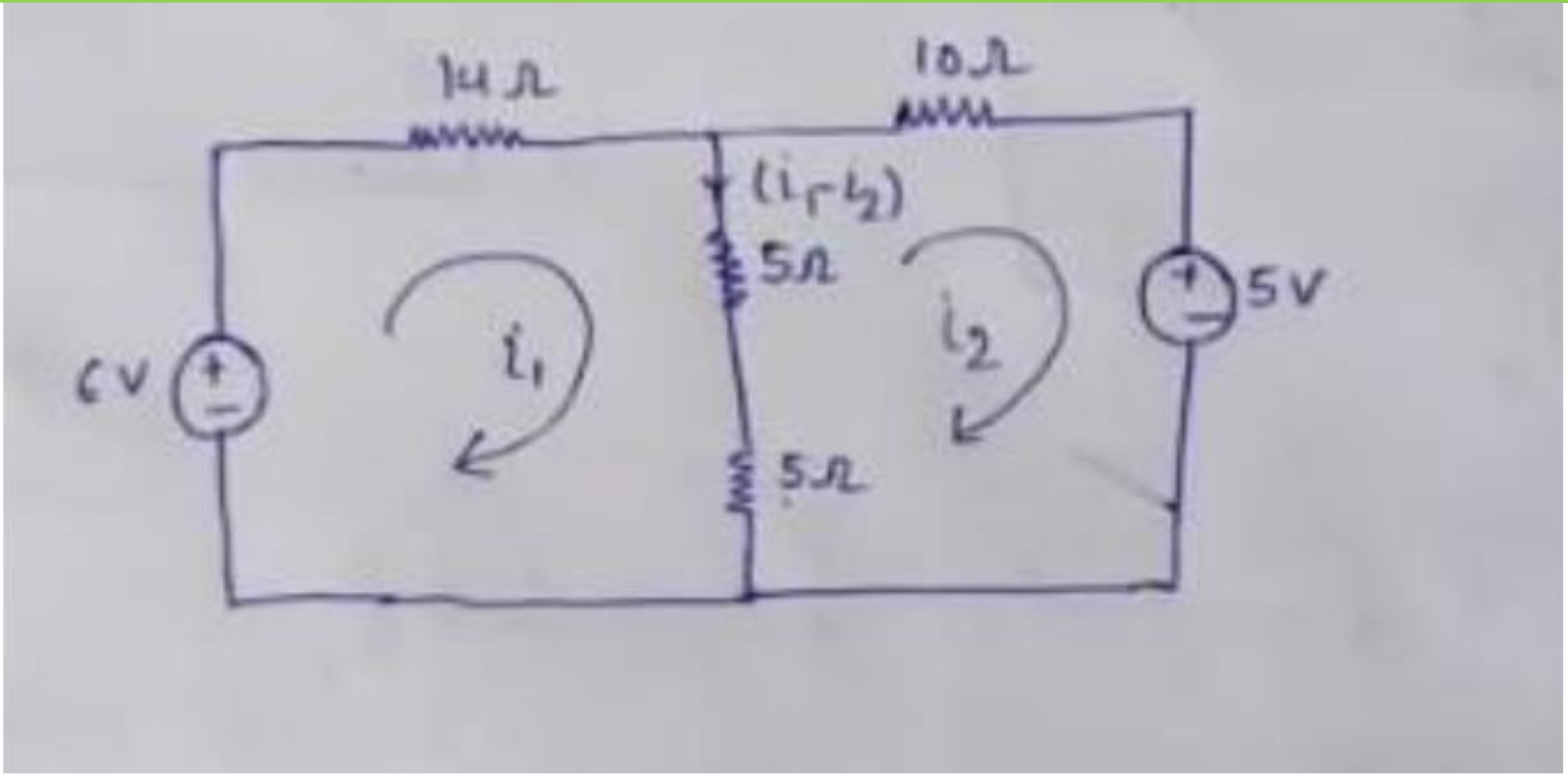
$$10 - i_1 2 - (i_1 - i_2)\,3 = 0 \quad ---(3)$$

$$-(i_2 - i_1)\,3 - i_2 4 - 5 = 0 \quad ---(4)$$

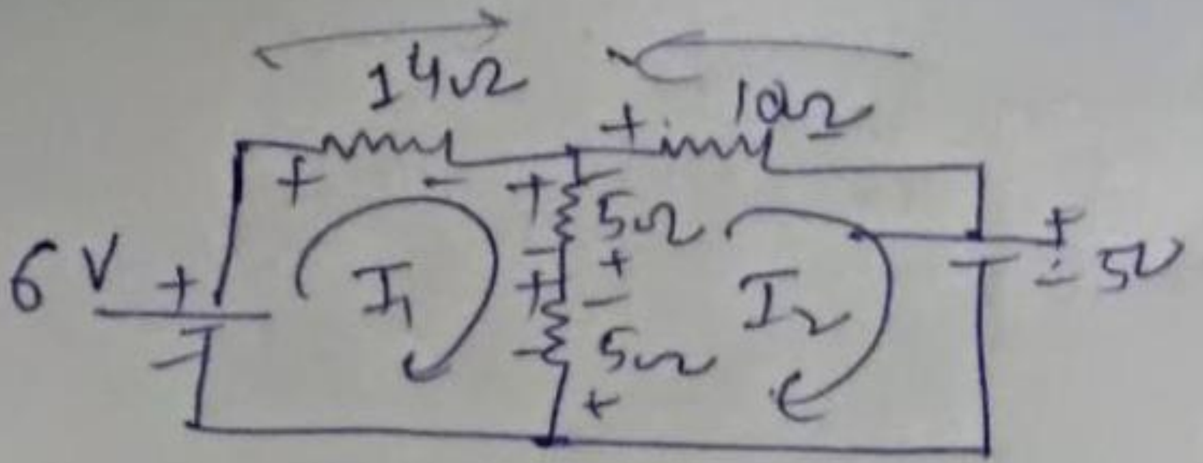
$i_1 = 2.11$ A

$i_2 = 0.192$ A

Mesh Analysis



Mesh Analysis



$$+6 - 14I_1 - 5(I_1 - I_2) - 5(I_1 - I_2) = 0$$

$$-10I_2 - 5 - 5(I_2 - I_1) - 5(I_2 - I_1) = 0$$

$$I_1 = 184.2\,mA$$

$$I_2 = -157.89\,mA$$

$$I_2 = 157.89\,mA$$

$$I_1 + I_2 \Rightarrow 341.79\,mA$$

Mesh Analysis

$$6 - 14I_1 - 5I_1 + 5I_2 - 5I_1 + 5I_2 = 0$$

$$6 - 24I_1 + 10I_2 = 0$$

$$-24I_1 + 10I_2 = -6 \Rightarrow \boxed{24I_1 - 10I_2 = 6}$$

$$-10I_2 - 5 - 5I_2 + 5I_1 - 5I_2 + 5I_1 = 0$$

$$-20I_2 + 10I_1 = 5$$

$$\boxed{-4I_2 + 2I_1 = 1}$$

$$1/2 \times \boxed{2I_1 - 4I_2 = 1}$$

$$24I_1 - 48I_2 = 12 \quad (1)$$

$$24I_1 - 10I_2 = 6$$

$$-\qquad +\qquad -$$

$$-38I_2 = \cancel{18}\ 6$$

$$\boxed{I_2 = \frac{-6}{38}} \Rightarrow -0.1578A$$

$$I_2 \Rightarrow -.157.89A$$

$$24I_1 - 10\times\frac{-6}{38} = 6$$

$$24I_1 = 6 + \frac{60}{38}$$

$$24I_1 = 6 - 1.578$$

$$I_1 = 0.1842A$$

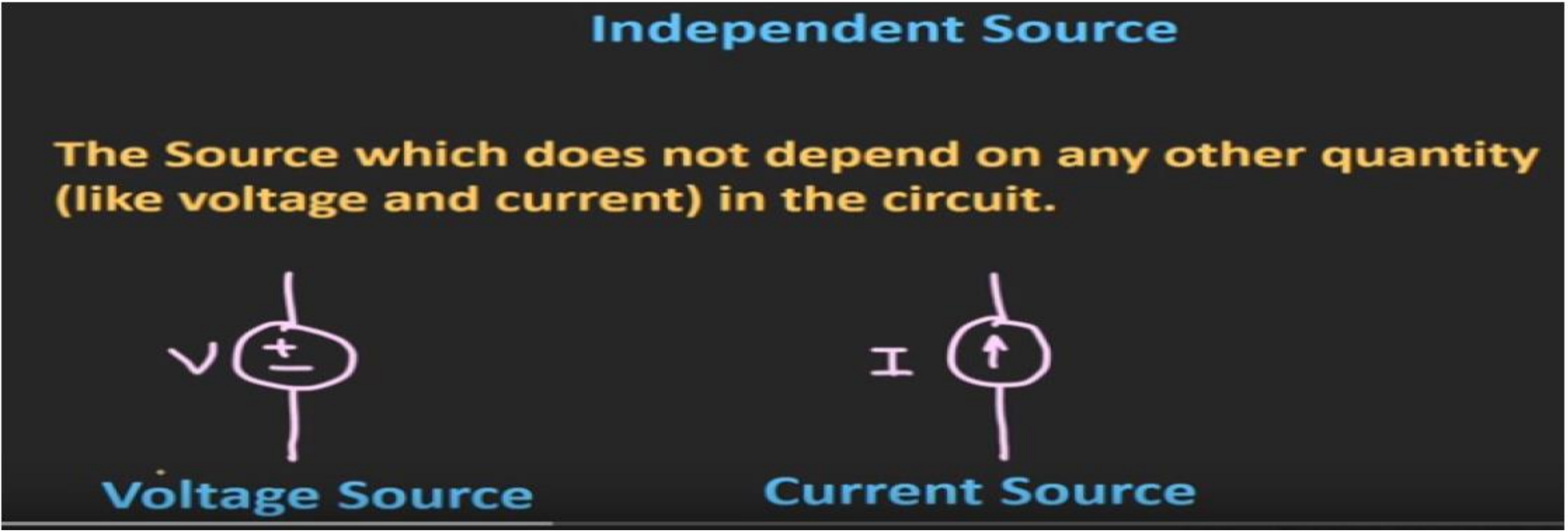
$$I_1 = 184.2mA$$

$$I_2 = -157.89mA$$

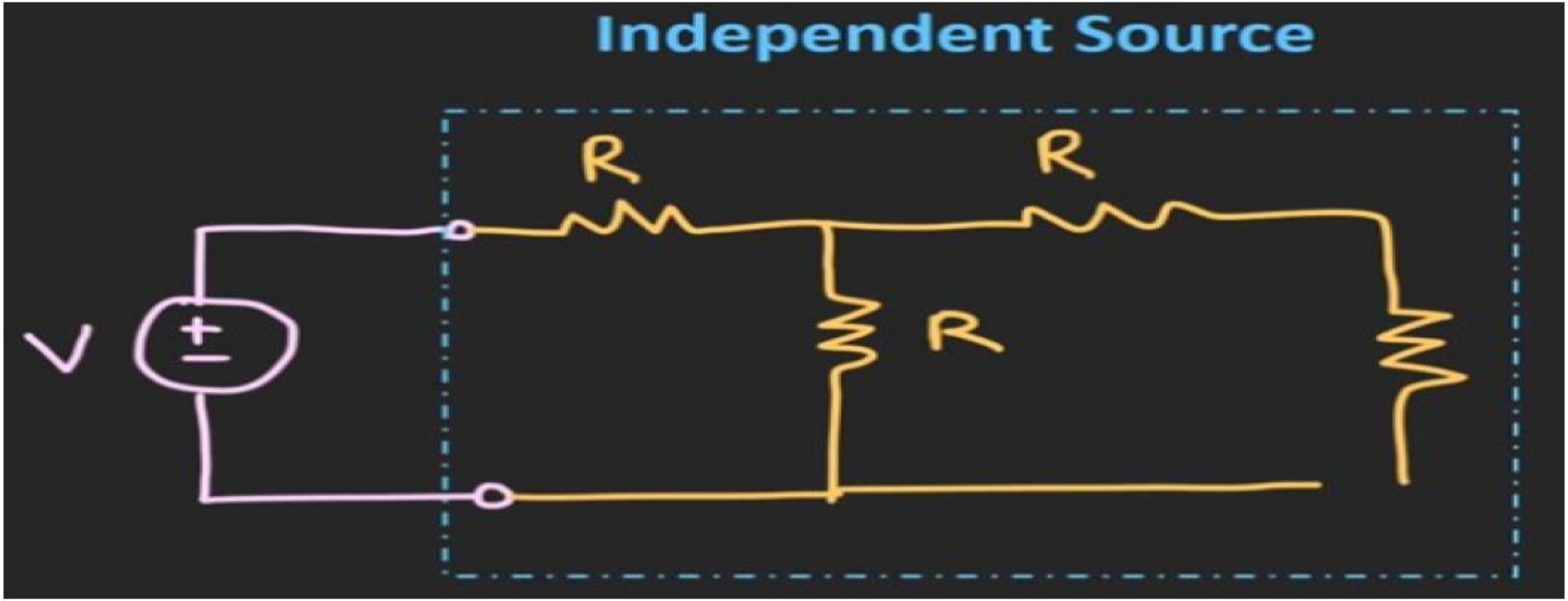
$$I_2 = 157.89mA$$

$$I_1 + I_2 \Rightarrow 341.79mA$$

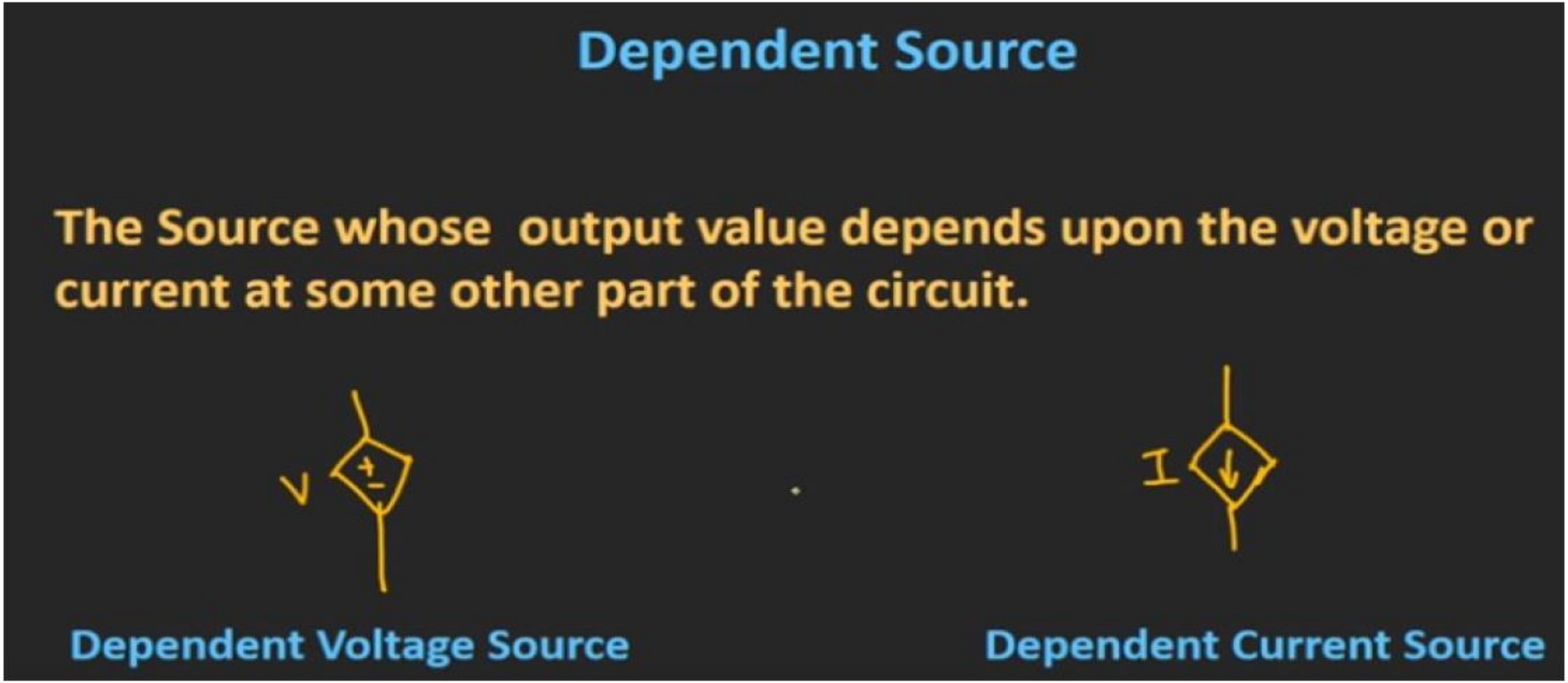
Independent Source



Independent Source

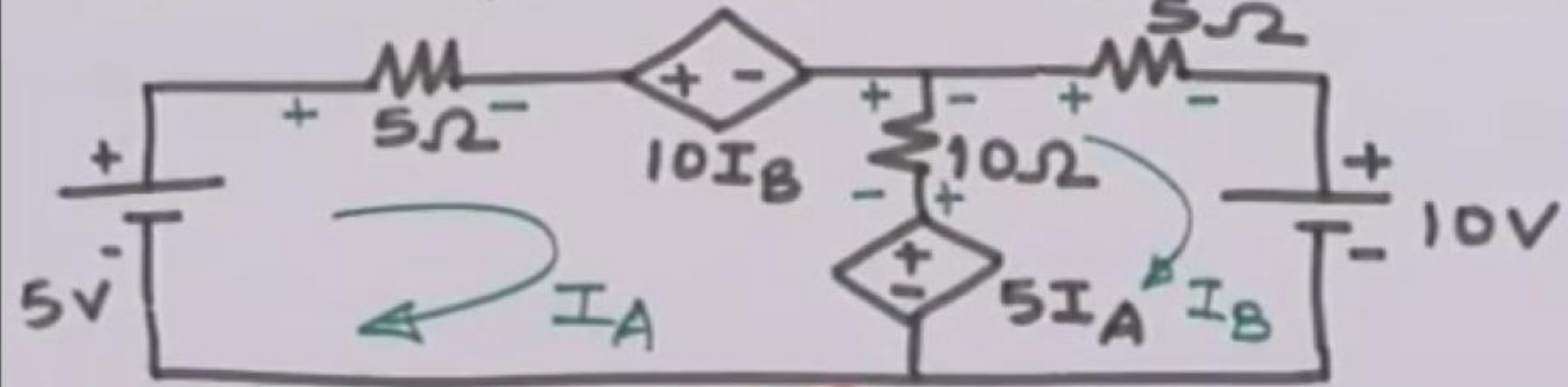


Dependent Source



Discussions

Obtain I_A and I_B using Mesh Analysis



Apply KVL to mesh ①

$$5 - 5I_A - \cancel{10I_B} - 10I_A + \cancel{10I_B} - 5I_A = 0$$

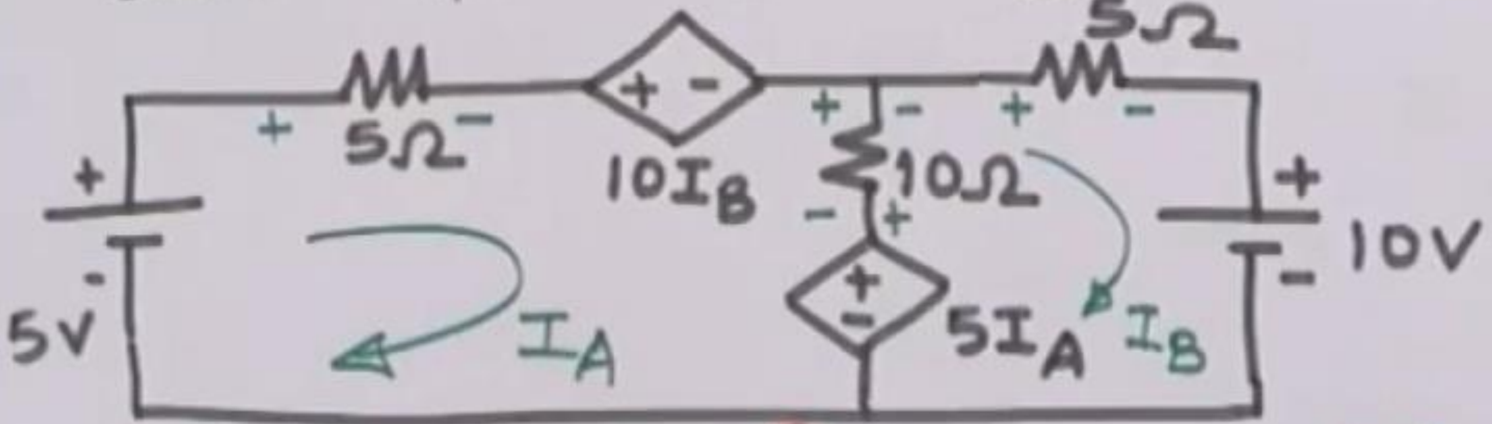
$$5 - 20I_A = 0$$

$$5 = 20I_A$$

$$\boxed{I_A = 0.25A}$$

Discussions

Obtain I_A and I_B using Mesh Analysis.



Apply KVL to mesh 1

$$5 - 5I_A - \cancel{10I_B} - 10I_A + \cancel{10I_B} - 5I_A = 0$$

$$5 - 20I_A = 0$$

$$5 = 20I_A$$

$$\boxed{I_A = 0.25A}$$

Apply KVL to mesh 2

$$-5I_B - 10 + 5I_A - 10I_B + 10I_A = 0$$

$$\therefore 15I_A - 15I_B = 10$$

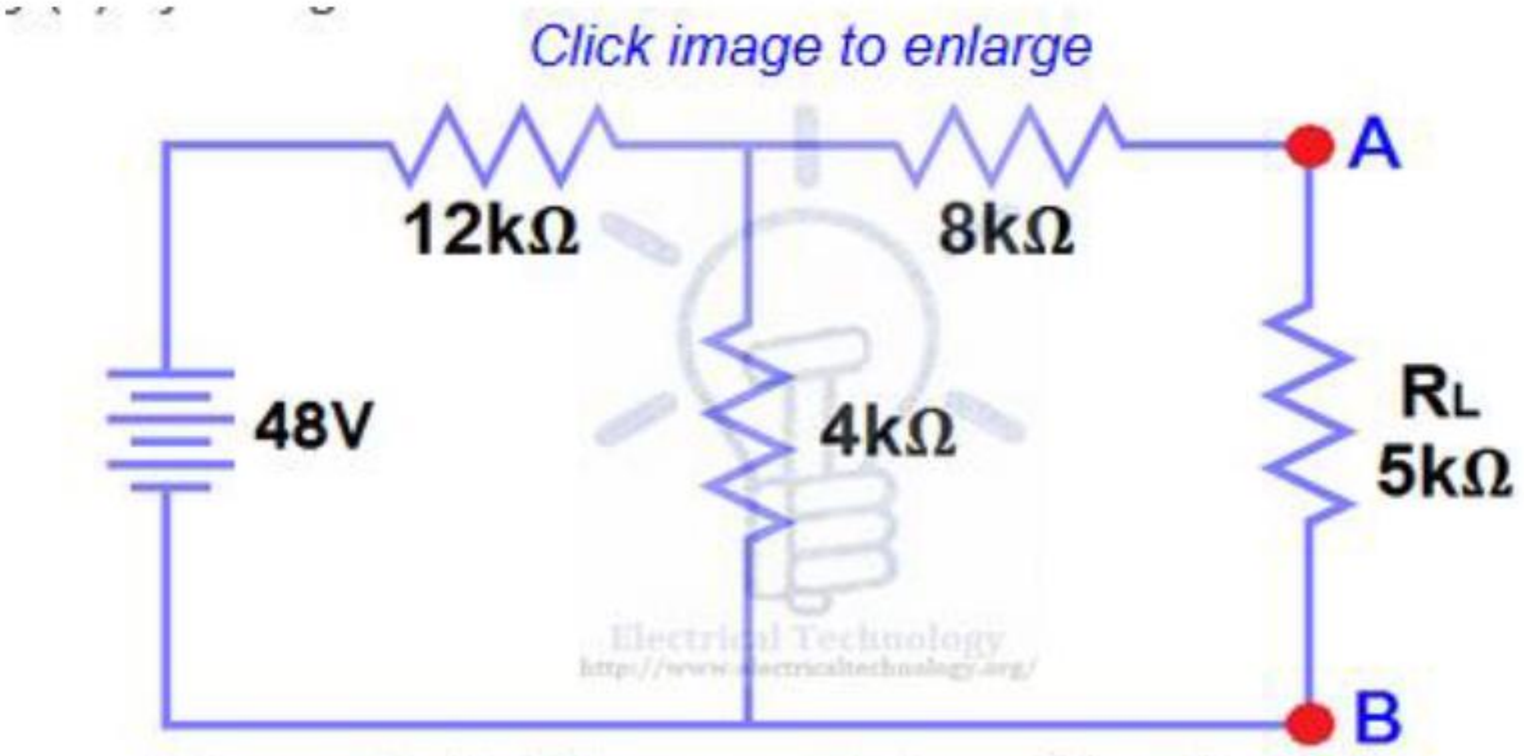
$$\therefore 15(0.25) - 15I_B = 10$$

$$3.75 - 10 = 15I_B$$

$$\therefore \boxed{I_B = -0.4167A}$$

Thevenin Theorem

Calculate current across 5Kohm using thevenin theorem



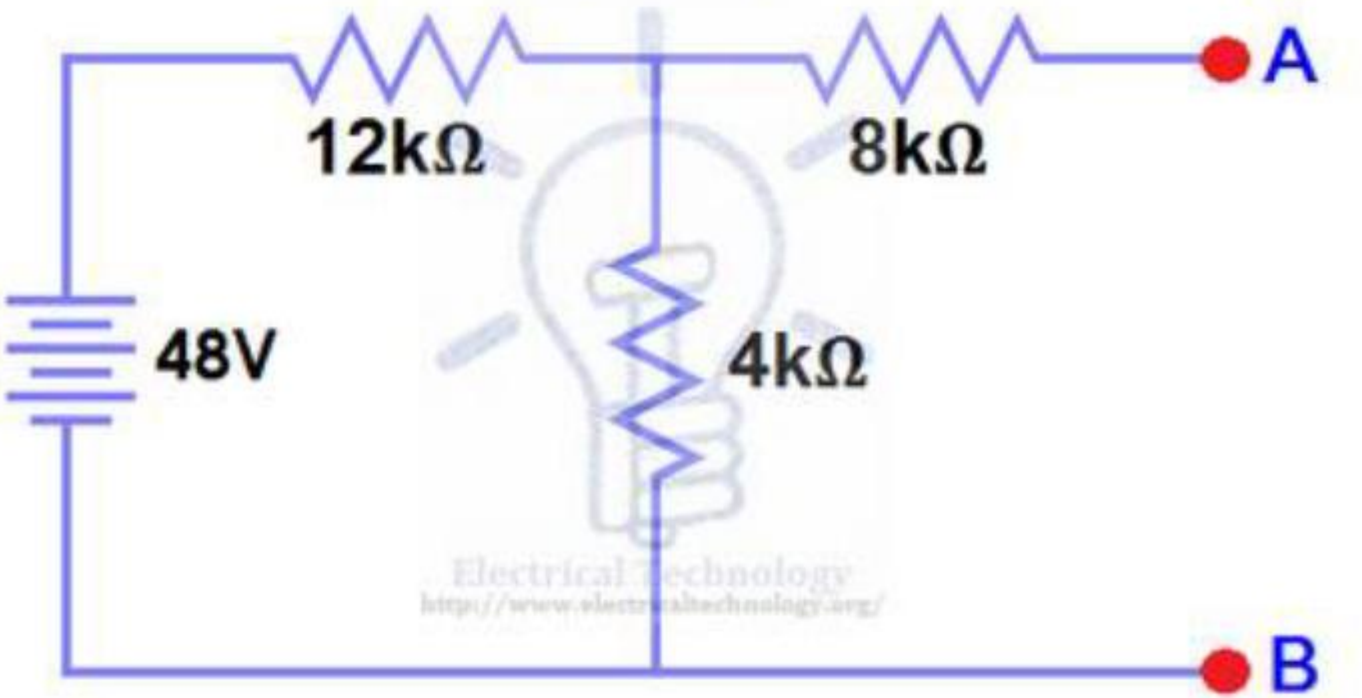
Thevenin's Theorem. Easy Step by Step Procedure with Example (Pictorial Views)

Thevenin Theorem

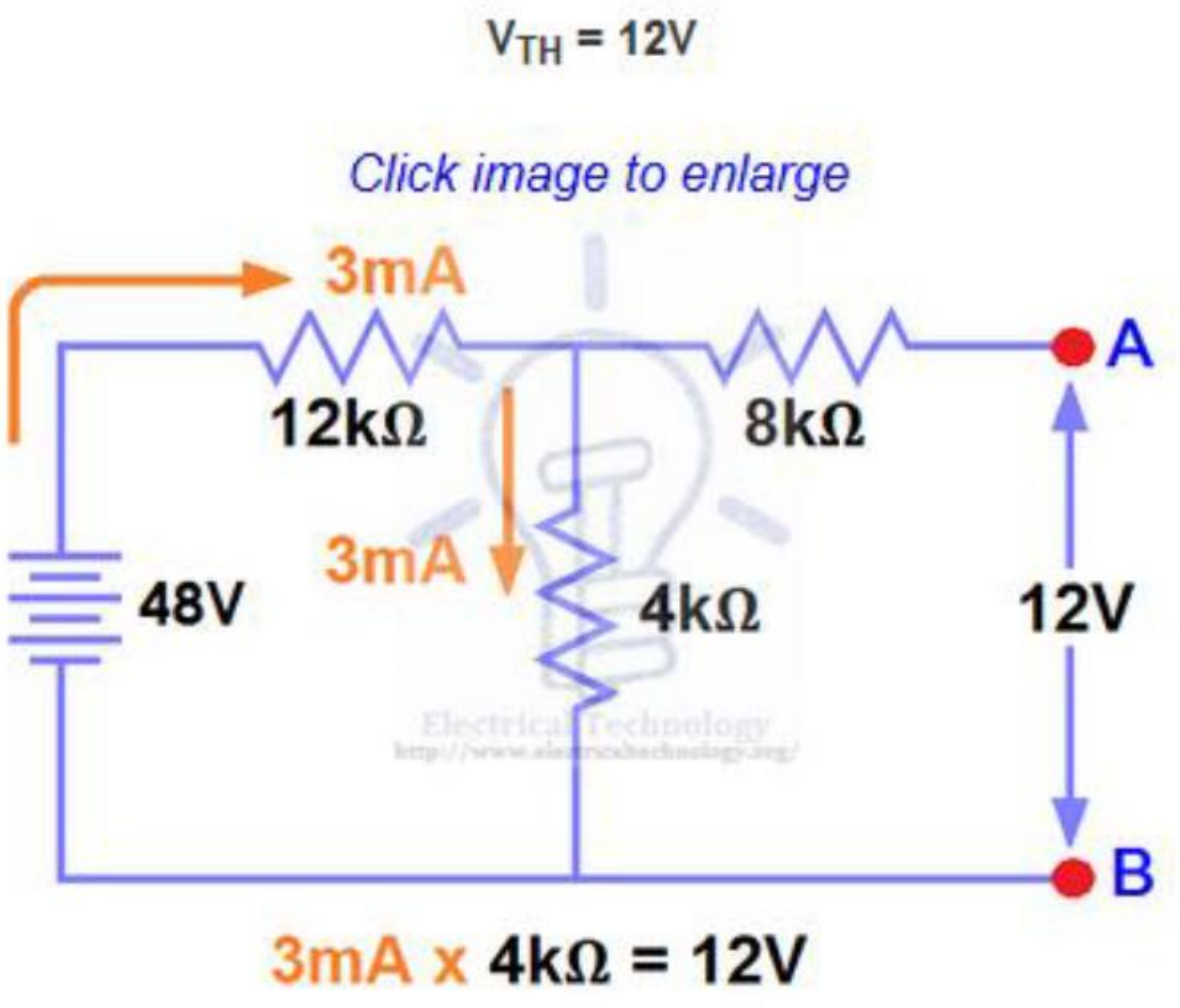
Step 1.

Open the **5kΩ load resistor** (Fig 2).

Click image to enlarge



Thevenin Theorem



Total Voltage/ Total Resistance= Total Current

***No Current flow through- 8kohm**

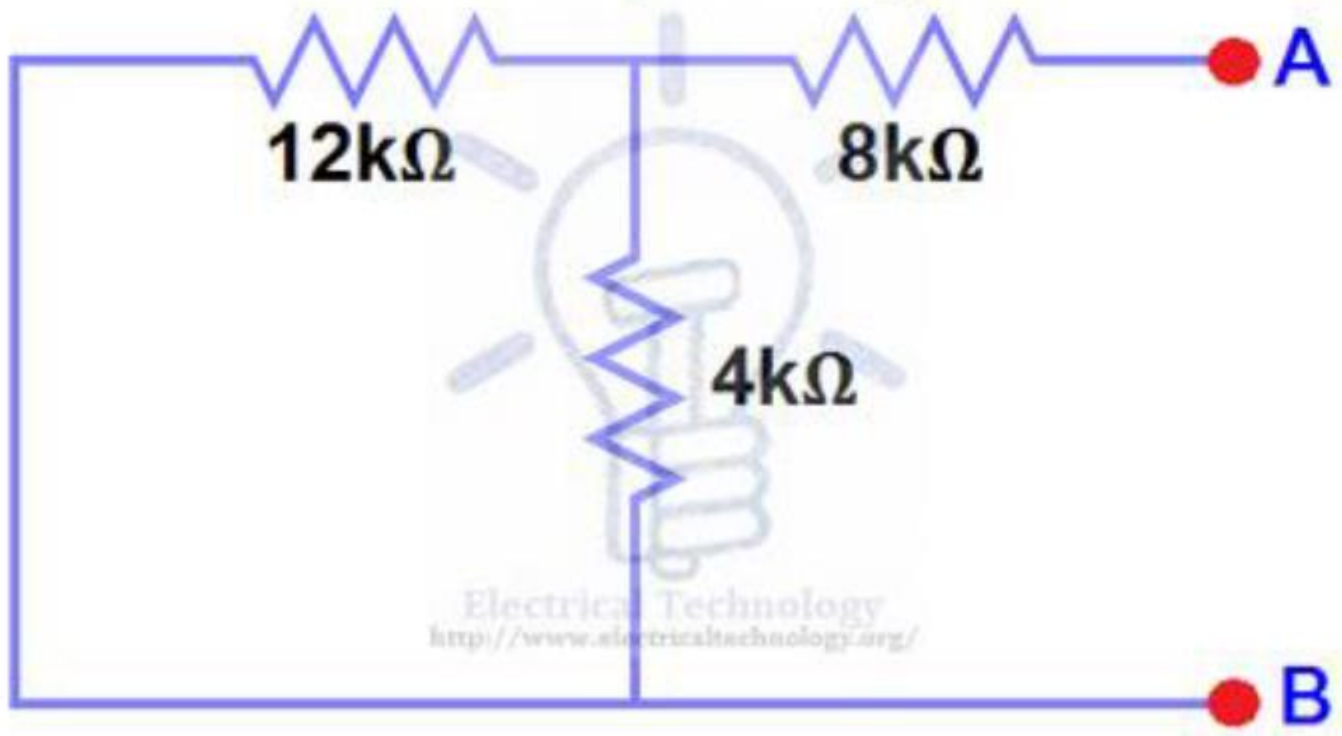
***Voltage Across 4kohm will be same- As Across A and B terminal**

Thevenin Theorem

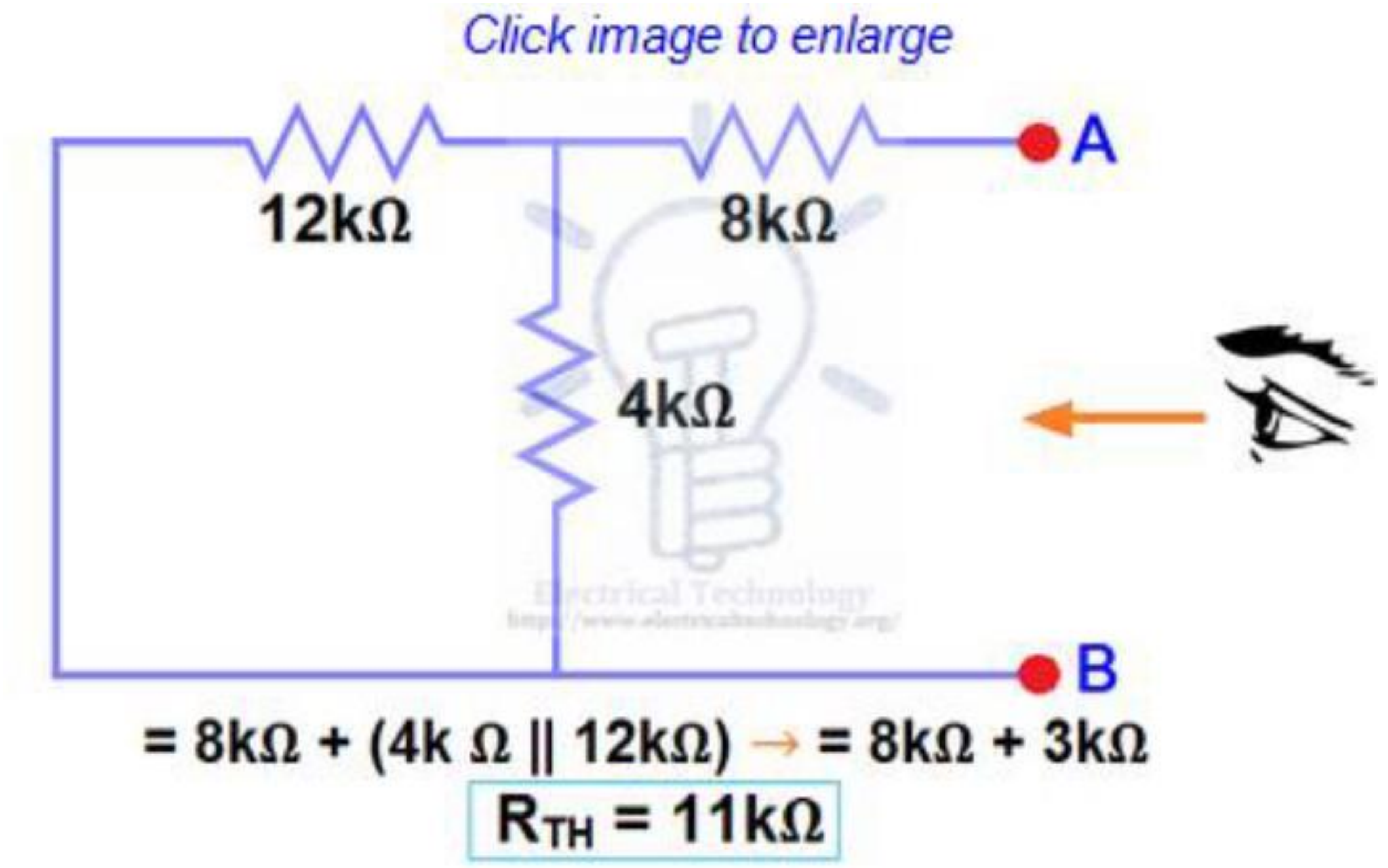
Step 3.

Open current sources and **short voltage sources** as shown below. Fig (4)

Click image to enlarge



Thevenin Theorem

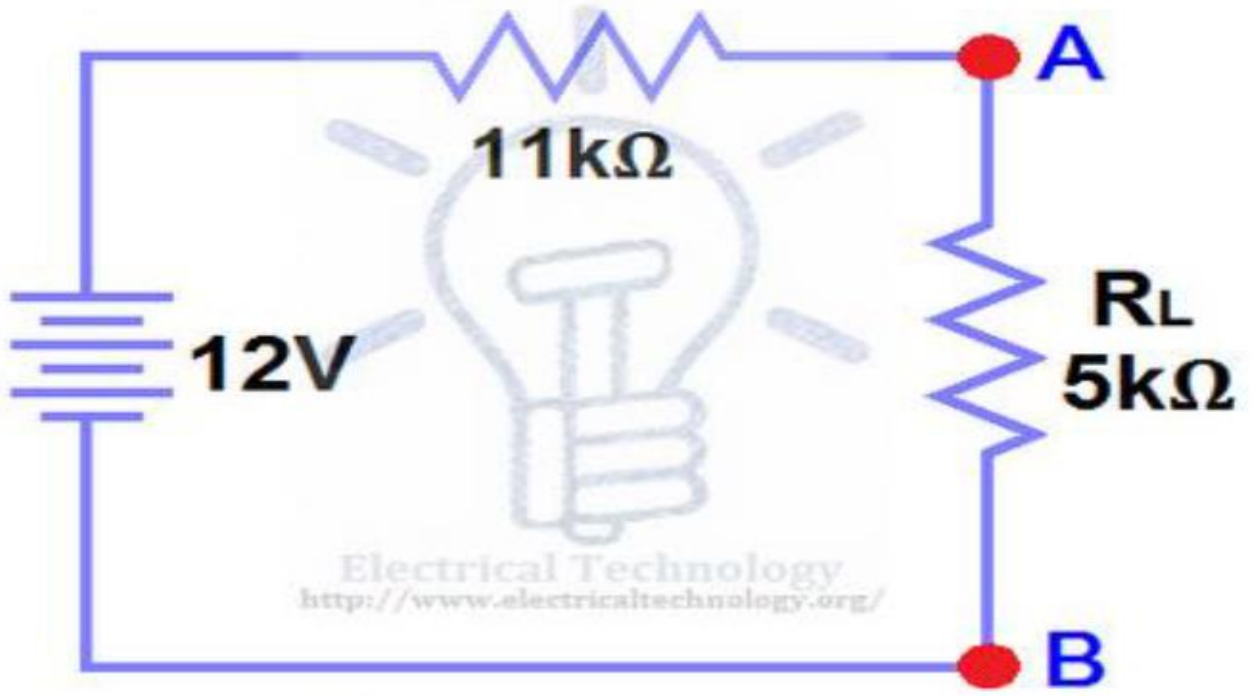


Thevenin Theorem

Step 5.

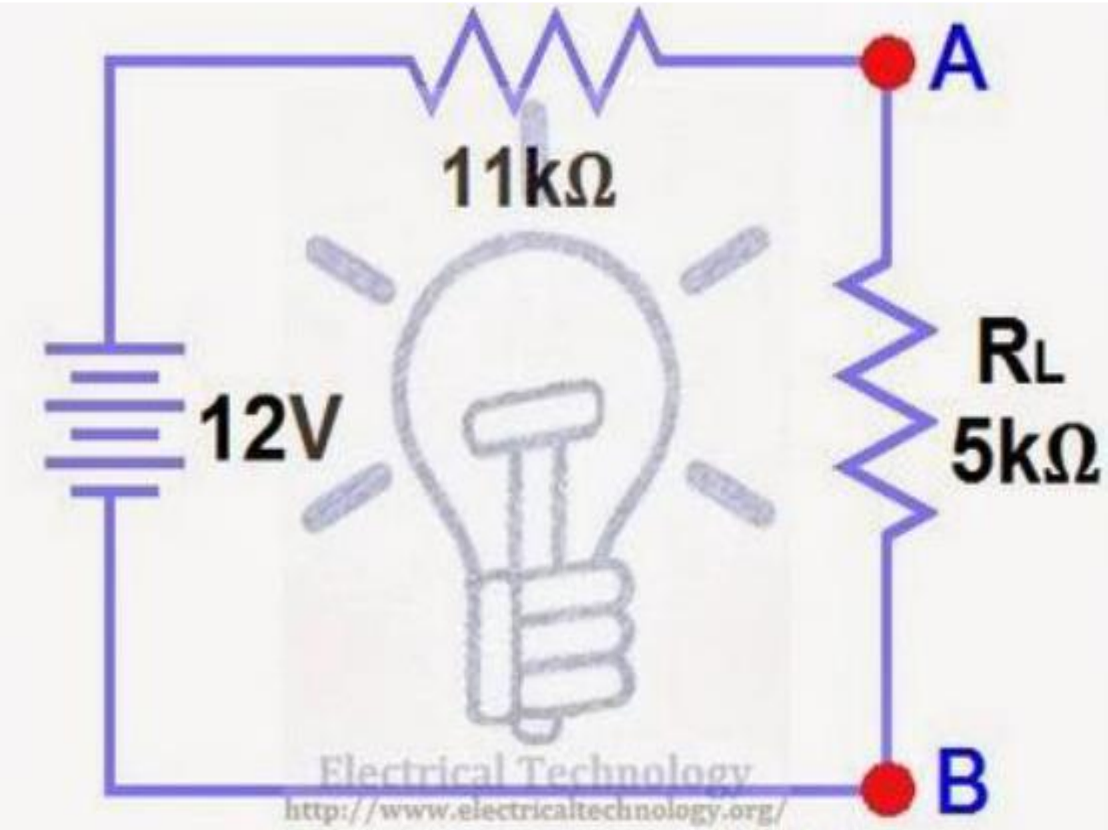
Connect the R_{TH} in series with Voltage Source V_{TH} and re-connect the load resistor. This is shown in fig (6) i.e. Thevenin circuit with load resistor. This the Thevenin's equivalent circuit

Click image to enlarge



Thevenin's equivalent circuit

Thevenin Theorem



$$I_L = \frac{V_{TH}}{R_{TH} + R_L} = \frac{12V}{11k\Omega + 5k\Omega}$$

$$\boxed{I_L = 0.75mA}$$

$$V_L = I_L \times R_L$$

$$V_L = 0.75mA \times 5k\Omega$$

$$\boxed{V_L = 3.75V}$$

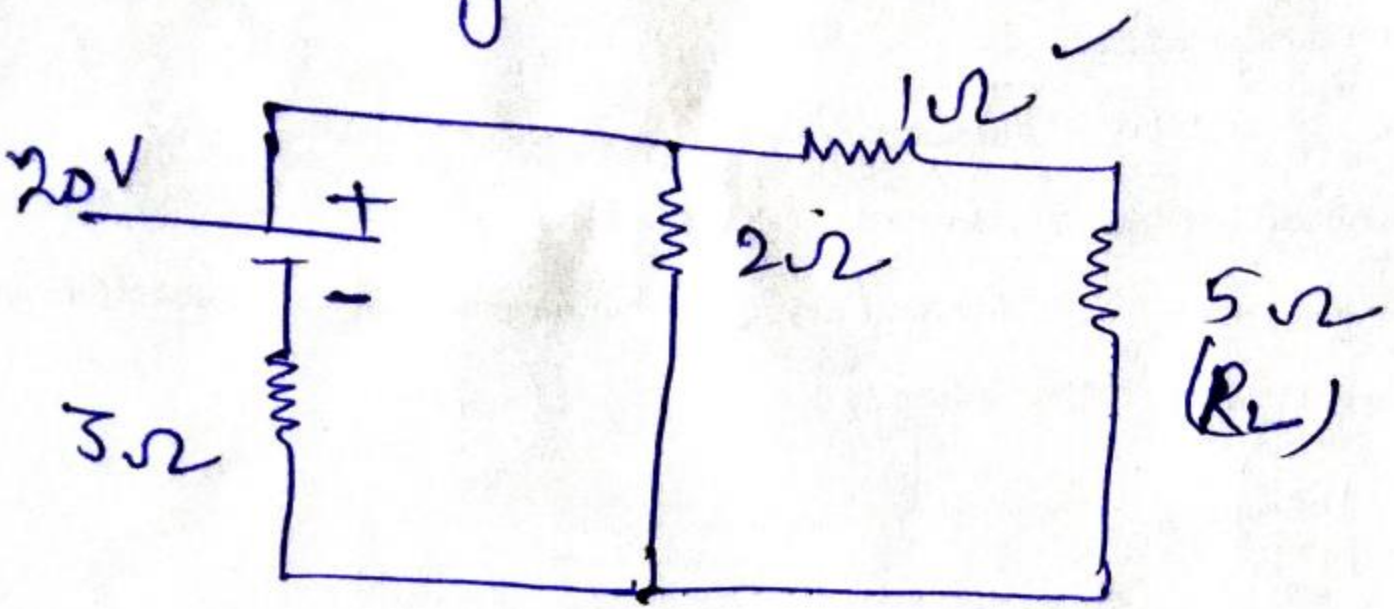
Norton Theorem

NORTON Theorem

1

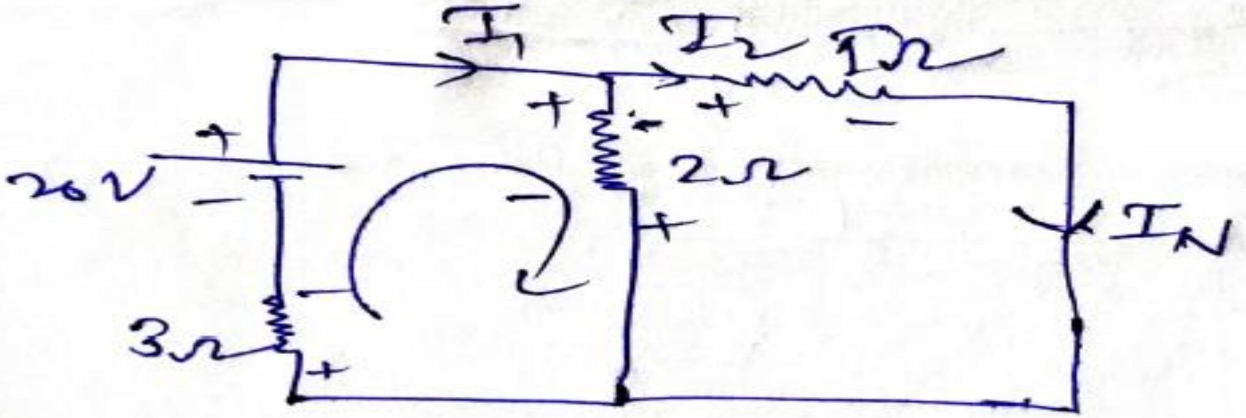
Q: find the current through 5 Ω using norton's theorem?

1



Norton Theorem

Soln:- Remove load resistor & short the terminal



$$+20 - 2(I_1 - I_2) - 3I_1 = 0 \longleftarrow (1)$$

$$-1.I_2 - 2(I_2 - I_1) = 0 \longrightarrow (2)$$

$$\Rightarrow -I_2 - 2I_2 + 2I_1 = 0 \Rightarrow \boxed{2I_1 = 3I_2}$$

$$I_1 = 1.5I_2$$

put in Eq (1)

$$+20 - 2(1.5I_2 - I_2) - 3I_1 = 0$$

$$+20 - 2(0.5I_2) - 3I_1 = 0$$

$$+20 - I_2 - 3I_1 = 0$$

$$\longrightarrow +20 - I_2 - 3(1.5I_2)$$

$$+20 - I_2 - 4.5I_2 = 0$$

Norton Theorem

(2)

$$+20 - I_2 - 4.5I_2 = 0$$

$$20 = 5.5I_2$$

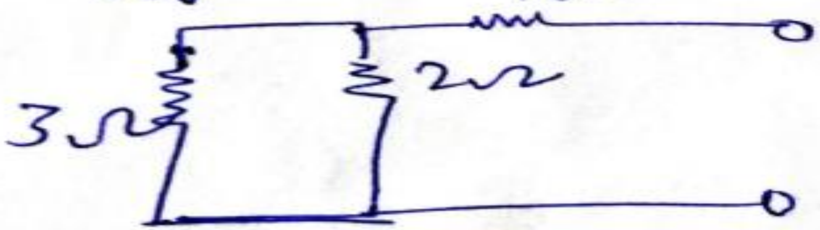
$$\boxed{\frac{20}{5.5} = I_2} \Rightarrow \boxed{3.63 = I_2}$$

$$I_1 = 1.5I_2$$

$$\boxed{I_1 \Rightarrow 1.5 \times 3.63 \Rightarrow 5.45A}$$

$$\boxed{I_N = I_2 = 3.63A}$$

R_N Remove Load

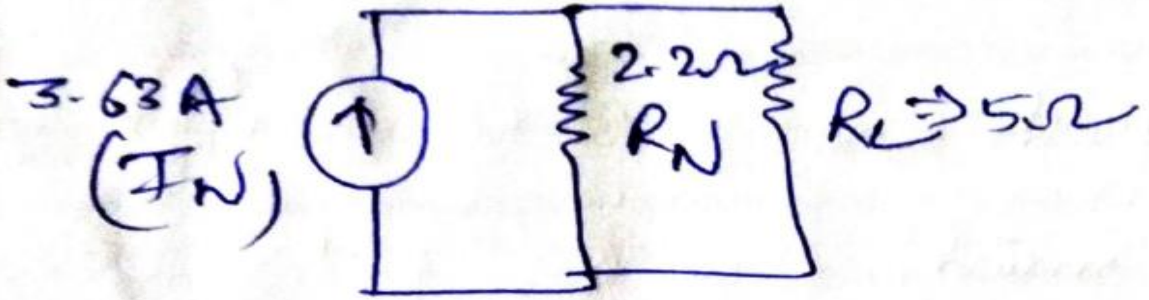


$$\Rightarrow \frac{3 \times 2}{3+2} + 1$$

$$\Rightarrow \frac{6}{5} + 1 \Rightarrow 2.2\Omega$$

Norton Theorem

3



3

$$I_{R_L} \Rightarrow \frac{I_N \cdot R_N}{R_N + R_L}$$

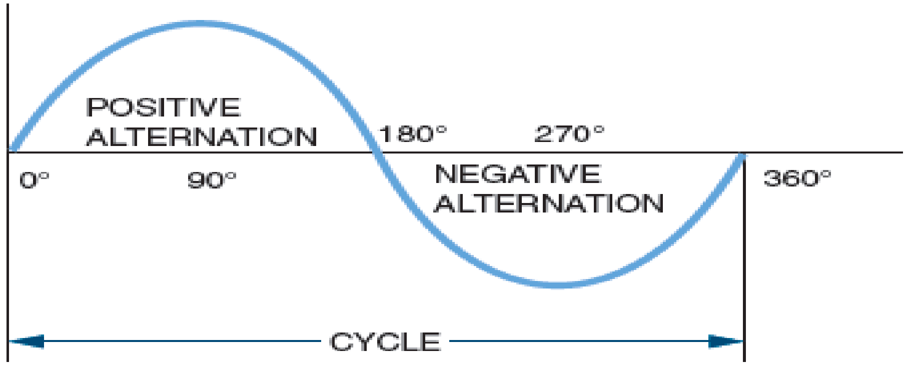
$$\Rightarrow \frac{3.63 \times 2.2}{2.2 + 5}$$

$$I_{R_L} \Rightarrow 1.109A$$

Fundamentals of A.C. circuits

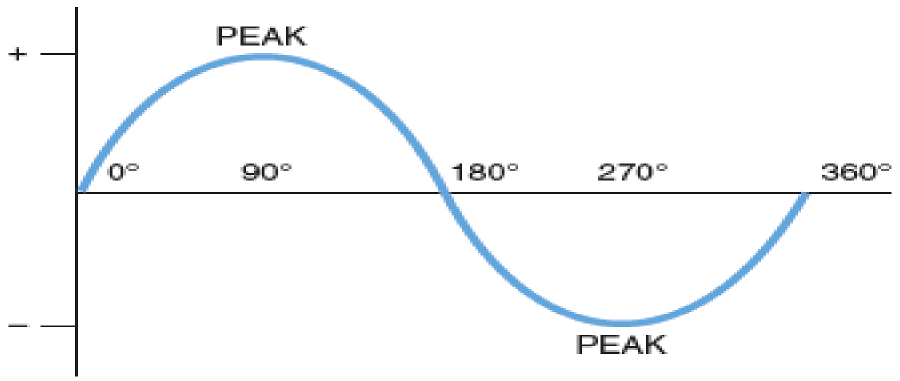
Fundamentals of A.C. circuits

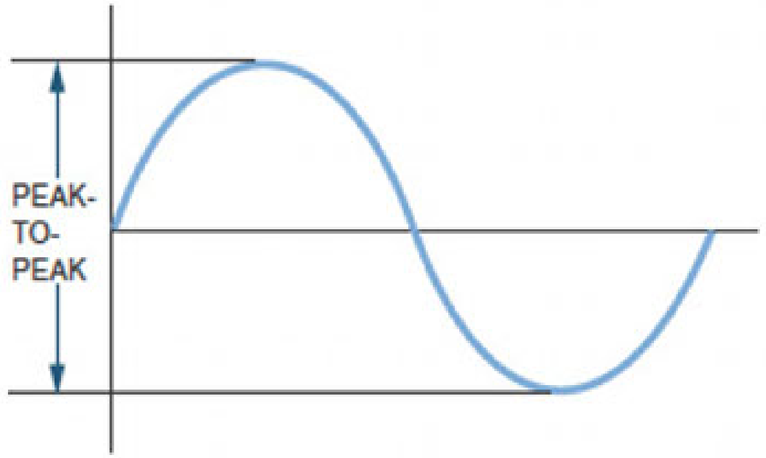
1. Each time an AC generator moves through one complete revolution, it is said to complete one cycle.
2. The two half of a cycle are referred as alternations.
3. One complete cycle per second is defined as a hertz.



AC Values

- **Peak value**: Absolute value of the point with the greatest amplitude.
- **Peak to Peak value**: Vertical distance b/w 2 peaks.
- The amplitude of an AC waveform is its height as depicted on a graph over time. An amplitude measurement can take the form of peak, peak-to-peak.





Fundamentals of A.C. circuits

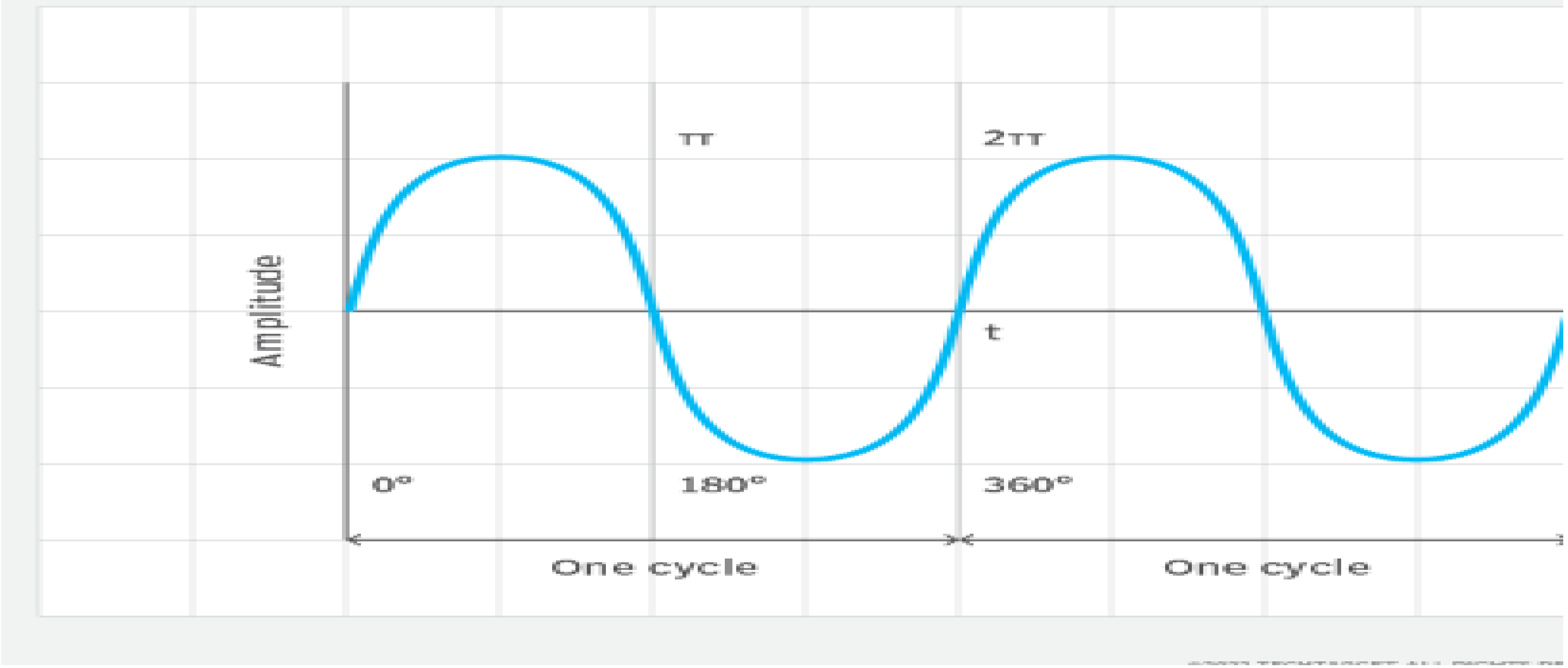
- A phase is the position of a wave at a point in time (instant) on a waveform cycle.

- It provides a measurement of exactly where the wave is positioned within its cycle, using either degrees (0-360) or radians (0-2π).

Fundamentals of A.C. circuits

- The wave starts at the 0-degree phase and has no amplitude.

- The wave reaches positive peak amplitude at the 90-degree phase.



AC Values (cont'd.)

- **Effective value of alternating current** is the amount that produces same degree of heat in a resistance as produced by direct current. It is also referred as rms value.

$$\mathbf{E_{rms} = 0.707E_p}$$

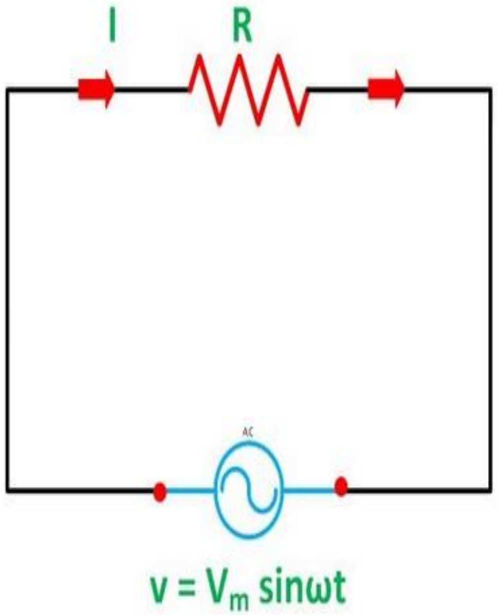
where: E_{rms} = rms or effective voltage value

Average Value of alternating current

$I_{av} = 0.637\ I_m$

The average current of a sinusoidal waveform is determined by multiplying the peak voltage value by **0.637.**

Pure Resistive AC Circuit



$$v = V_m \mathrm{Sin}\omega t \ldots\ldots\ldots\ldots\ldots(1)$$

$$i = \frac{v}{R} = \frac{V_m}{R}\sin\omega t \ldots\ldots\ldots(2)$$

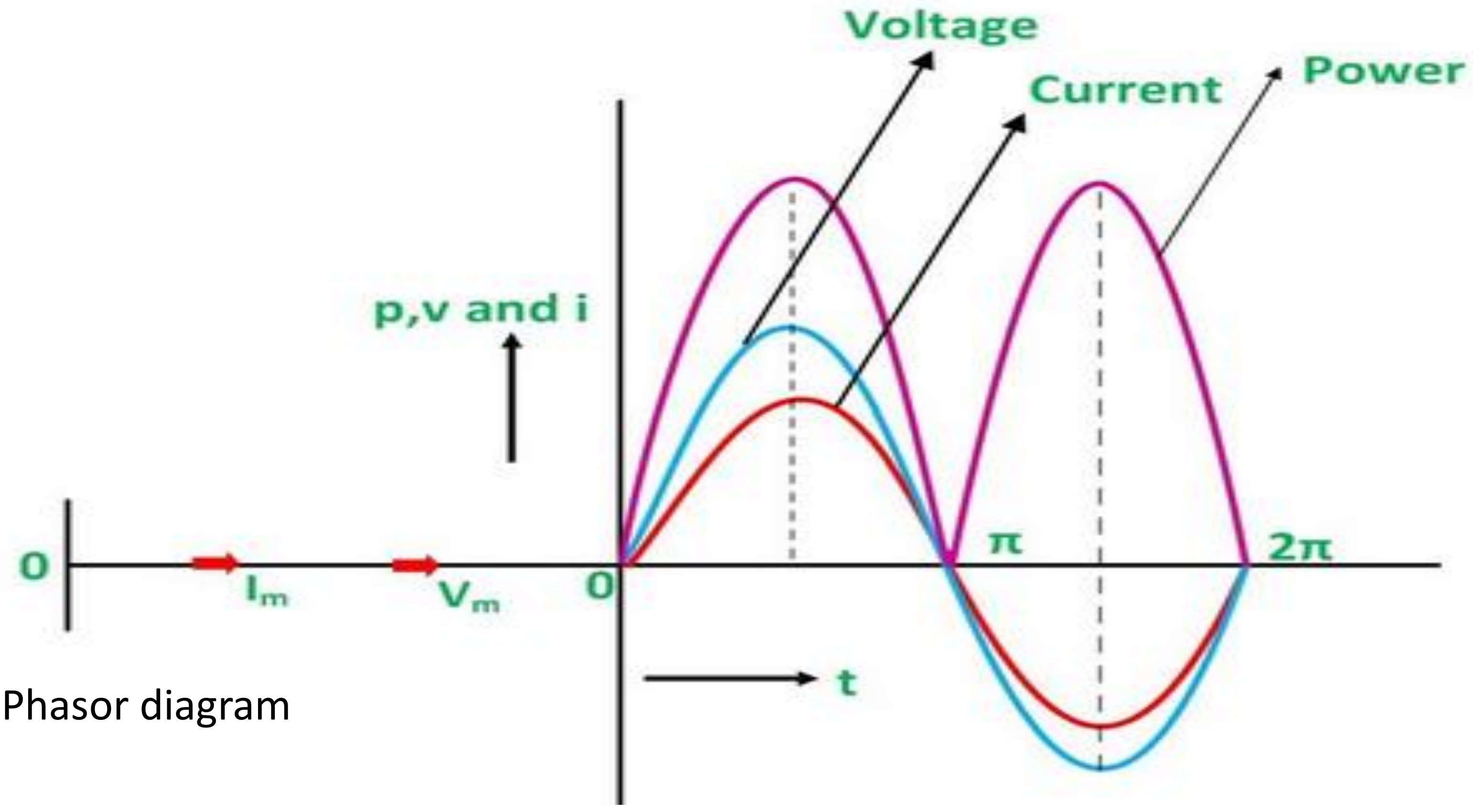
$$i = I_m \sin\omega t \ldots\ldots\ldots.(3)$$

$$v = V_m \text{Sin}\omega t \,..............(1)$$

$$i = I_m \sin\omega t \ldots \ldots \ldots .(3)$$

Instantaneous power, p= vi

$$p = (V_m \sin\omega t)(I_m \sin\omega t)$$



Phasor diagram

Waveform

PN Junction Diode

- **Semiconductor:** A semiconductor material has an electrical conductivity value falling between that of a conductor, such as metallic copper, and an insulator, such as glass.

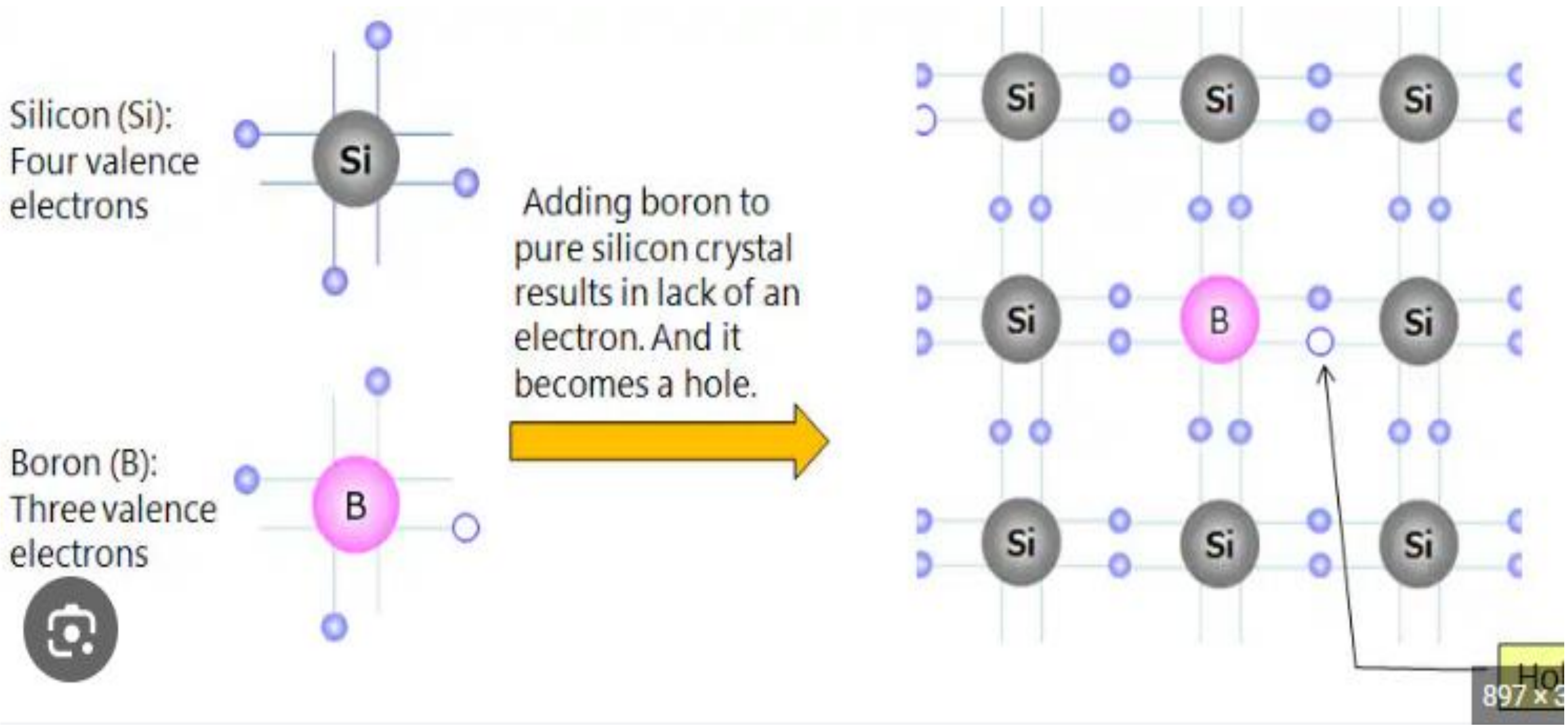
- The semiconductor in its pure form is known as **intrinsic semiconductor**.

- When a chemical impurity is added to an intrinsic semiconductor, then the resulting semiconductor is known as **extrinsic semiconductor**.

PN Junction Diode

- **P type SEMICONDUCTOR:**
- A p-type semiconductor is an intrinsic semiconductor doped with boron or indium.
- The majority of carriers in p-type semiconductors are holes.
- Electrons are minority carriers in a p-type semiconductor.
- In a p-type semiconductor, the hole density is much greater than the electron density.
- In an n-type semiconductor an intrinsic semiconductor doped with phosphorus or antimony as impurity.

PN Junction Diode



PN Junction Diode

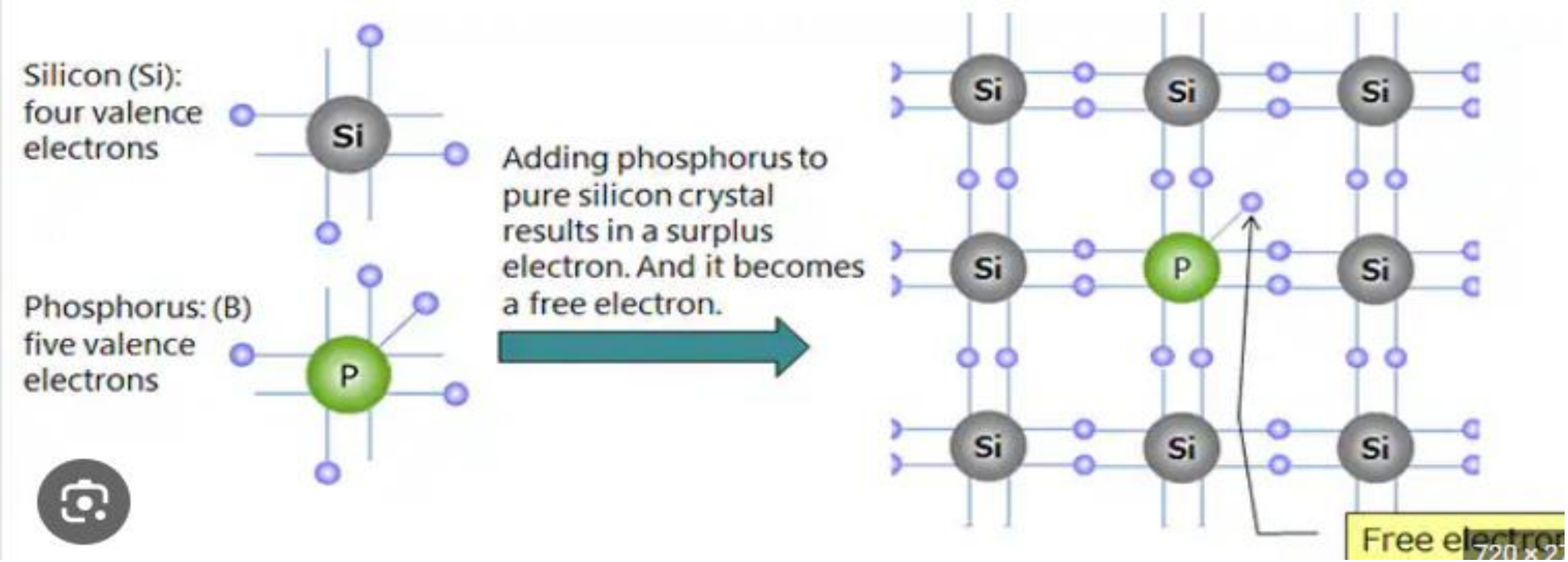
- **N TYPE SEMICONDUCTOR:**

- The majority of charge carriers in n-type semiconductors are electrons.

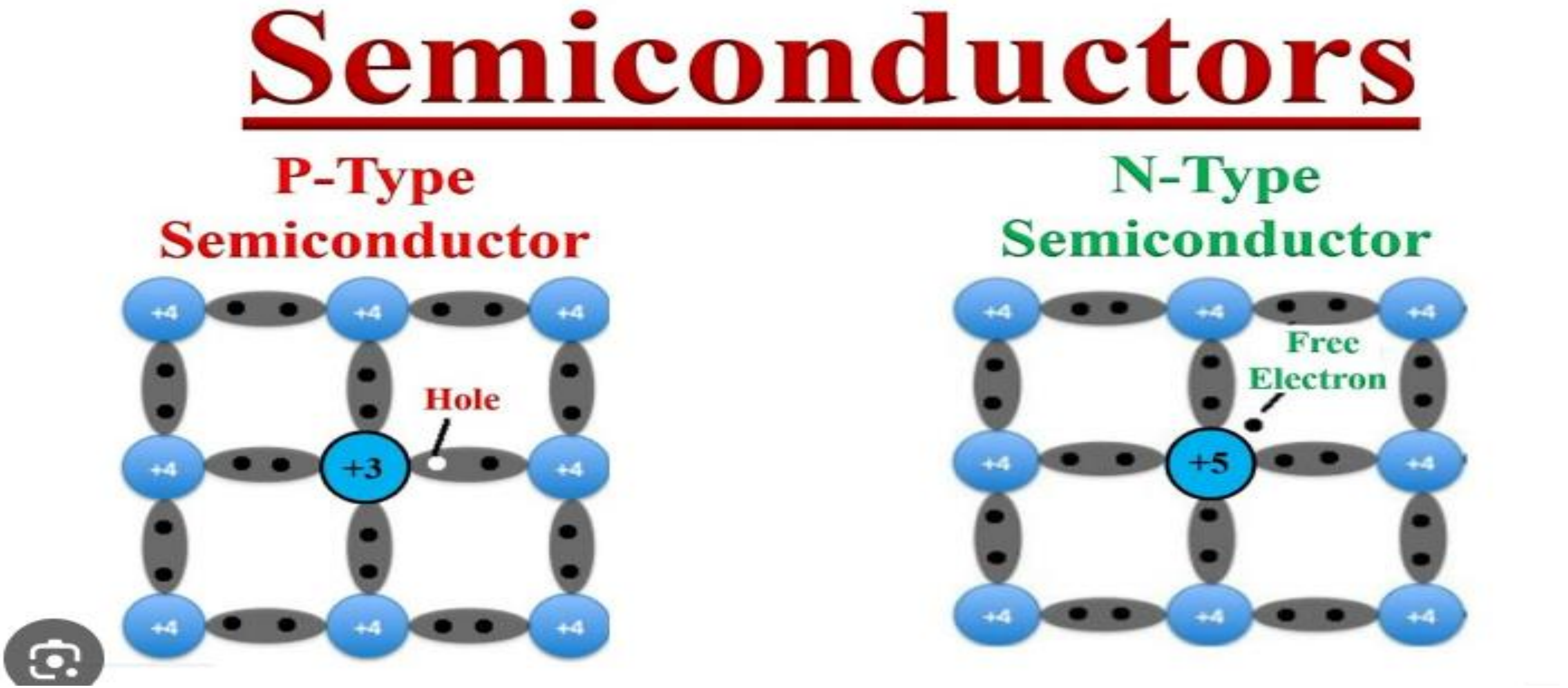
- Holes are minority carriers in a n type semiconductor.

- In the n type of semiconductor, the electron density is much greater than the hole density.

PN Junction Diode

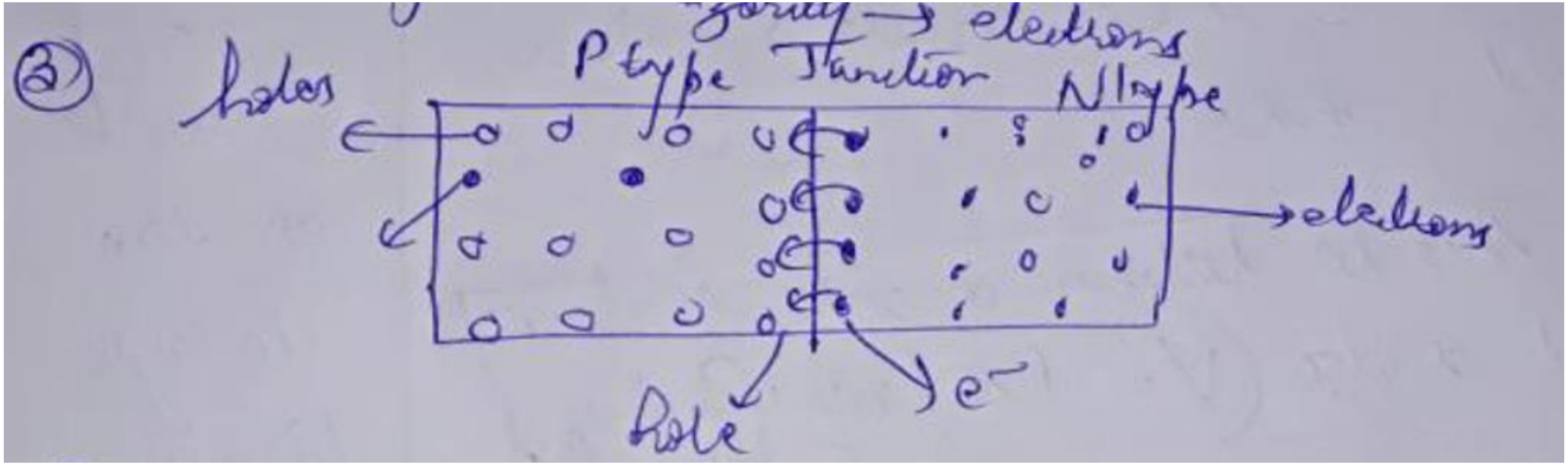


PN Junction Diode



PN Junction Diode

- Joining P type and N Type semiconductor create a device is called P-N Junction diode.
- P type-- majority- Holes
- N Type- Majority- Electrons



PN Junction Diode

4. Electrons Move Towards holes

5. It moves itself & Diffuse. So, it neutralise holes.

6. Electrons move so there exist some current which is called as diffusion current. {moment current}

7. This process is called as diffusion & current is known as diffusion current.

8. In P Type holes vanish/ neutralise electrons near the junction which are not present now.

PN Junction Diode

9. Electrons move due to which positive ions are created.

10. Shortage of charges in layer is called Depletion layer.{Deplete}

11. Here + to - create an electric field.

PN Junction Diode

12. Due to distance d with electric field creates V=Ed (with the help of E and d, we will have V)

13. This potential difference is known as potential barrier.

14. Due to + higher potential and - lower potential

15. Remaining electrons can not go due to large distance.

16. They need more energy to do so.

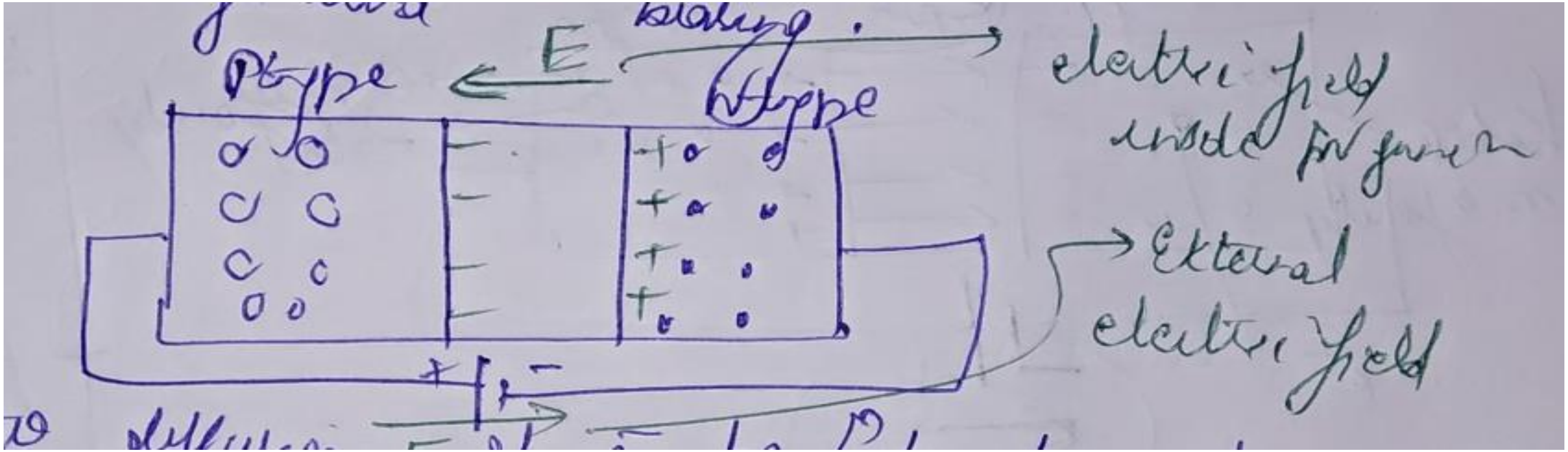
Biasing of Diode

- Whenever PN Diode is connected with battery then this situation is called as biasing.

- **Forward Biasing**

- P with positive terminal and n section is connected with negative terminal. So, this is called as forward biasing.

Biasing of Diode



Biasing of Diode

- Due to Diffusion of electrons to holes so layer of N Type have positive ions and

P Type have negative ions.

- Resultant electric field will be less because of opposite direction. So overall electric field decreases.

- Due to this potential barrier decrease & depletion layer becomes small.

- n section electrons will move easily due to battery when electrons diffuse into holes

so current start flowing.

Biasing of Diode

- **Reverse Bias**

- p type-- connected---with-- negative Terminal

- n type-- connected-- with- positive terminal

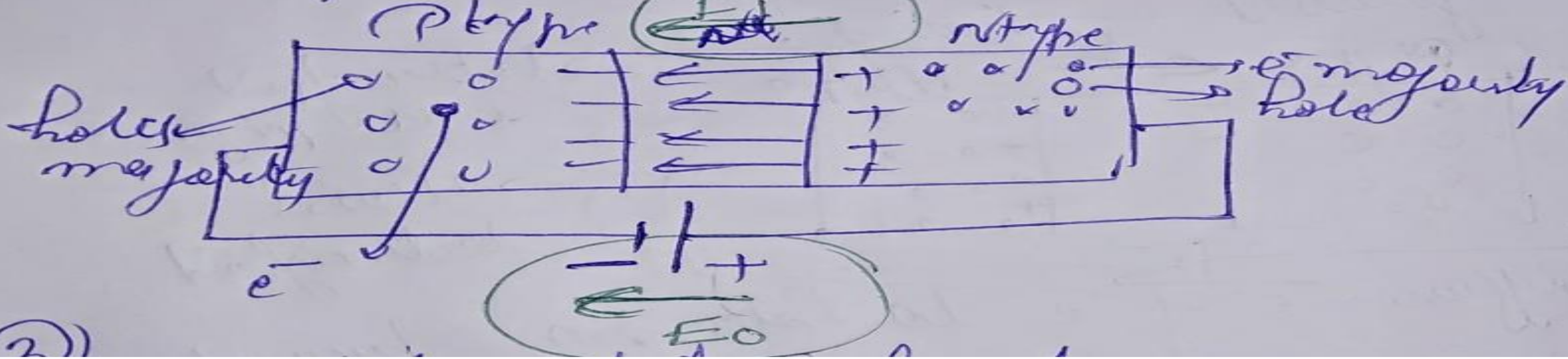
- Inside electric field and outside electric field are in same direction. So net
- electric field will increase.

- Hence, depletion layer increases

- Need more voltage to jump the electrons. So, very small amount of current will flow.

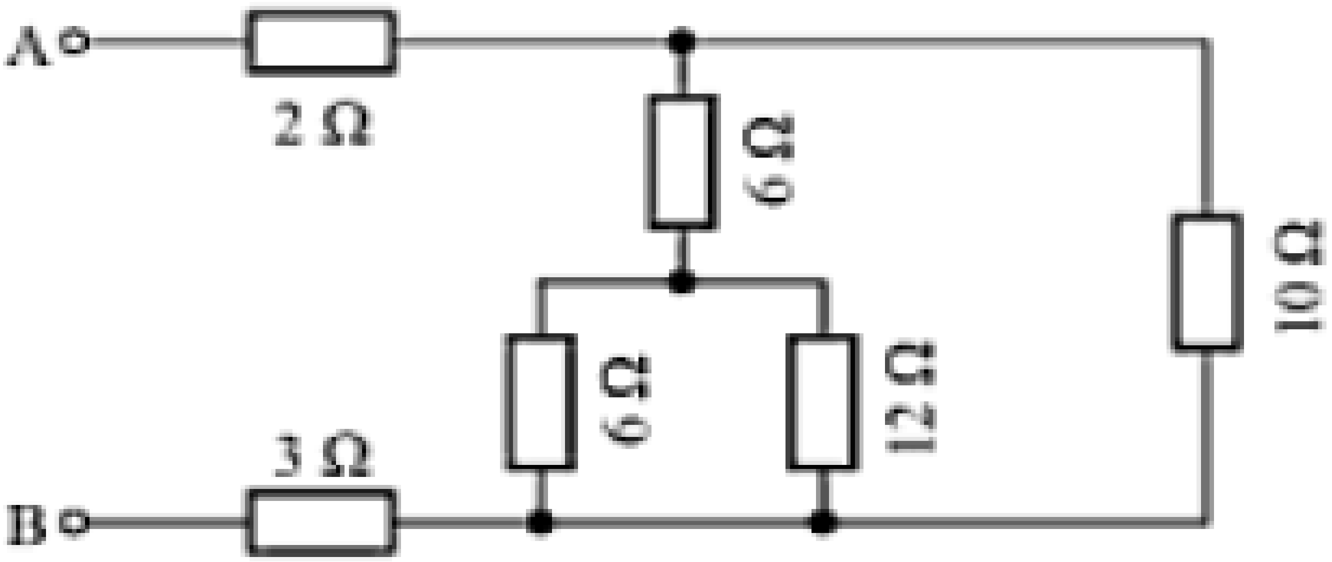
Biasing of Diode

(1) p type → (−) terminal
n type → (+) terminal } Reverse biasing



(2)

Discussions



(b)

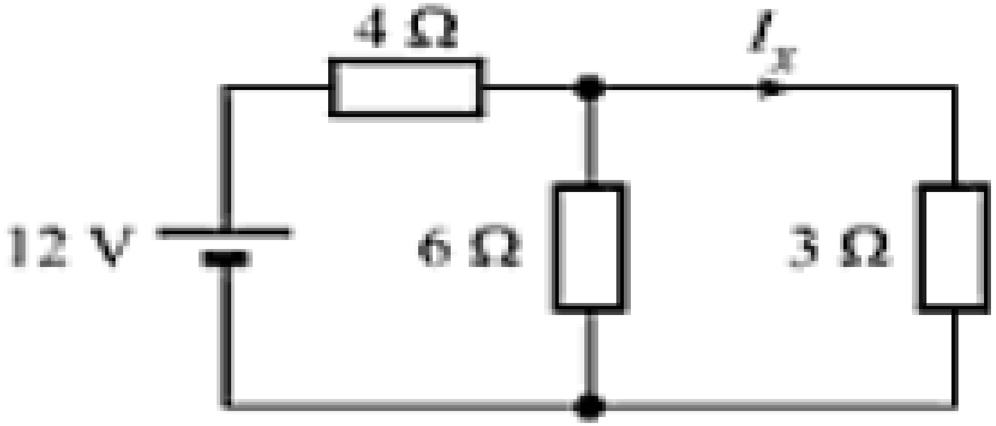
Discussions

(*b*) The resistance between terminals A and B is

$$R_{AB} = 2 + [\{6 + (6 \parallel 12)\} \parallel 10] + 3 = 2 + [\{6 + 4\} \parallel 10] + 3 = 2 + [10 \parallel 10] + 3$$

$$= 2 + 5 + 3 = 10\ \Omega$$

Discussions



Total resistance

Current across all resistors

Voltage across each resistors

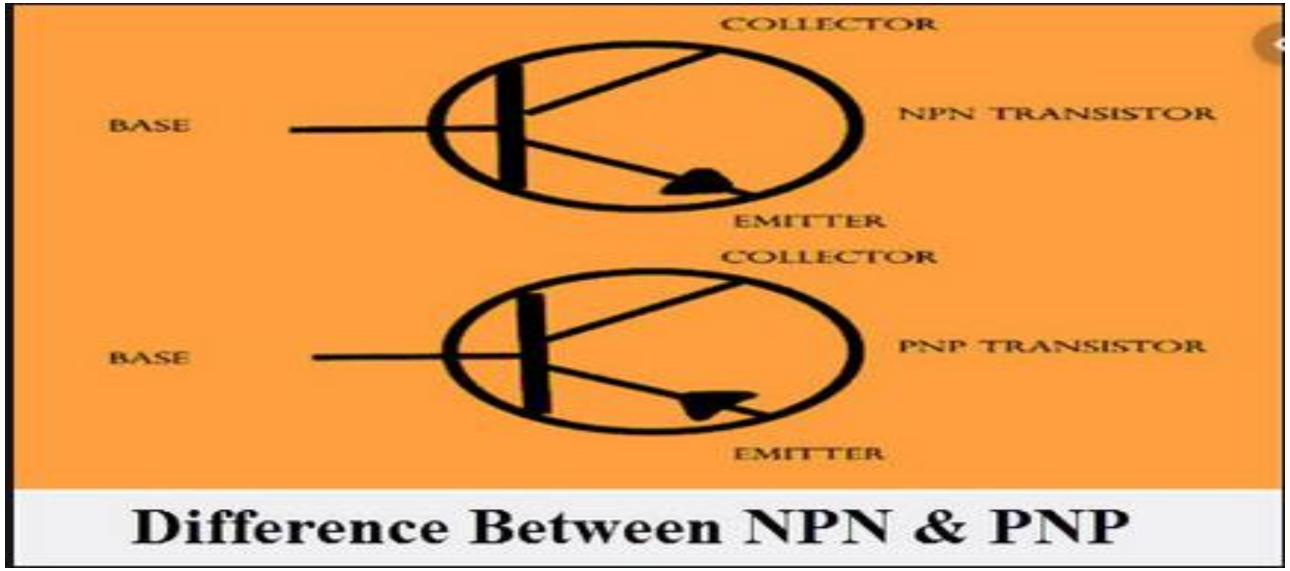
Bipolar Junction Transistor(BJT)

Bipolar Junction Transistor(BJT)

The transistor is made of two PN junction diode.

Types:

NPN and PNP



The transistor in which one p-type material is placed between two n-type materials is known as NPN transistor.

In NPN transistor, the direction of movement of an electron is from the emitter to collector region due to which the current constitutes in the transistor.

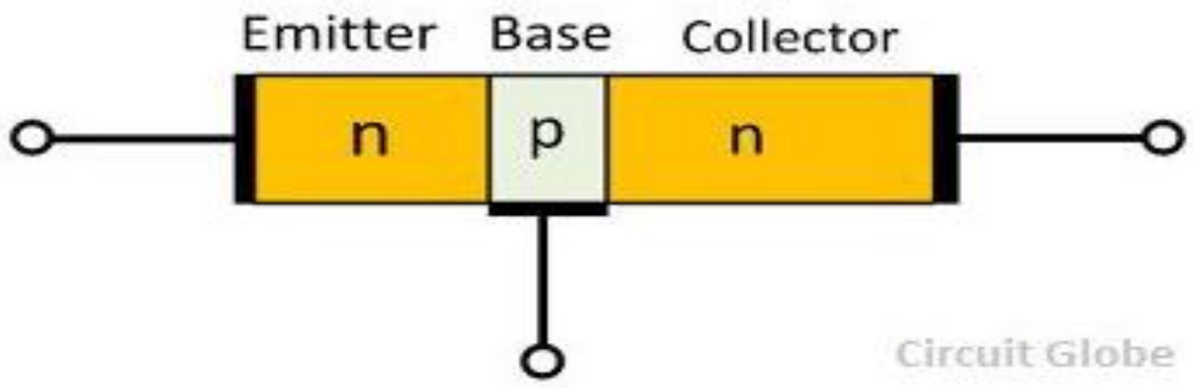
Such type of transistor is mostly used in the circuit because their majority charge carriers are electrons which have high mobility as compared to holes.

Name	Size	Doping
Emitter	Between Base and collector-	High
Base	less	less
Collector	Huge	Between Base and emitter

Construction of NPN Transistor

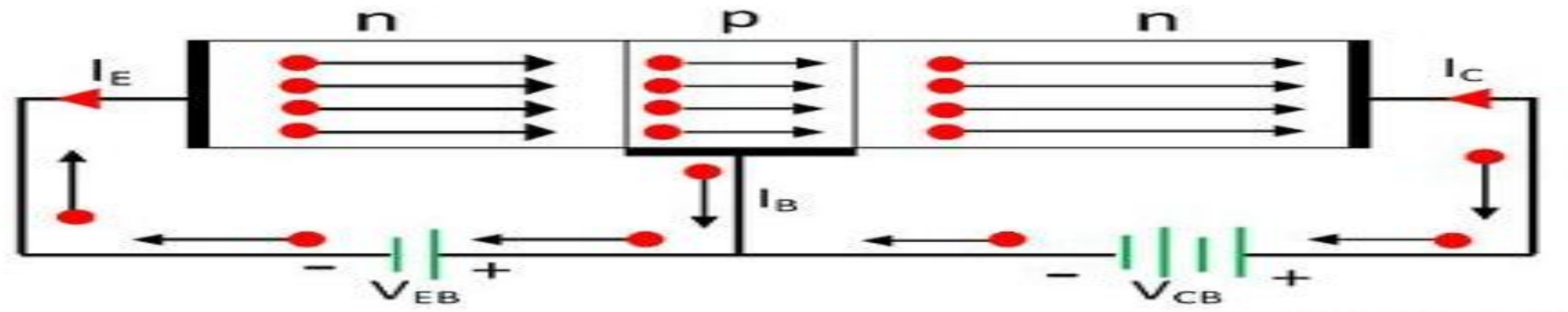
The NPN transistor has two diodes connected back to back.

The diode on the left side is called an emitter-base diode, and the diodes on the right side are called collector-base diode.



Working of NPN Transistor

The forward biased is applied across the emitter-base junction, and the reversed biased is applied across the collector-base junction.



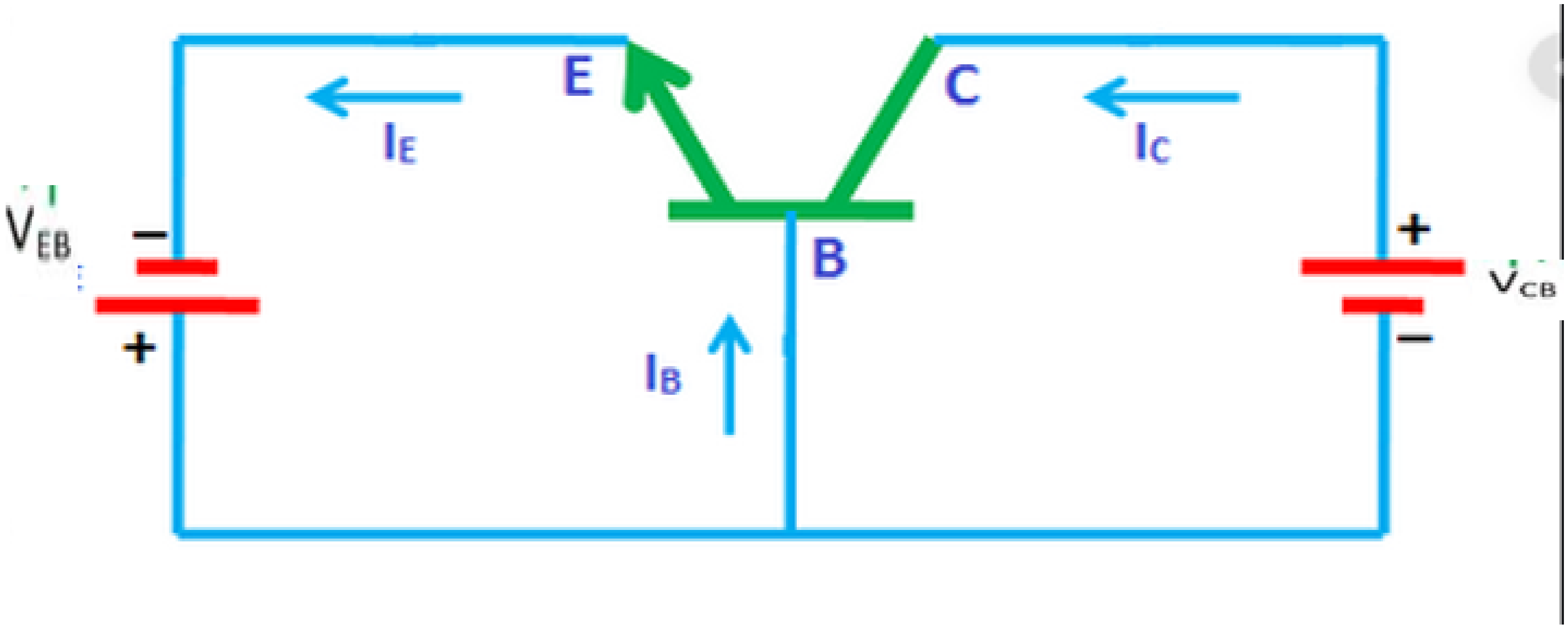
When the forward bias is applied across the emitter, the majority charge carriers move towards the base.

This causes the emitter current I_E. The electrons enter into the P-type material and combine with the holes.

The base of the NPN transistor is lightly doped. Due to which only a few electrons are combined and remaining constitutes the base current I_B.

The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction. Thus attract or collect the electrons at the collector.

Thus, we can say that the emitter current is the sum of the collector or the base current.



$$\boxed{I_E = I_B + I_C}$$

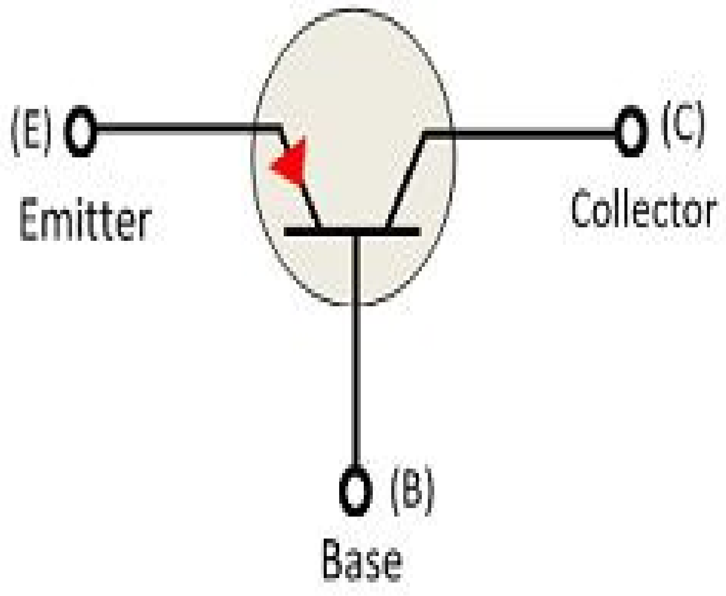
PNP Transistor

PNP Transistor

- The transistor in which one n-type material is doped with two p-type materials such type of transistor is known as **PNP transistor**.
- The PNP transistor has two crystal diodes connected back to back.
- The left side of the diode in known as the emitter-base diode and the right side of the diode is known as the collector-base diode.
- The hole is the majority carriers of the PNP transistors which constitute the current in it.

Symbol of PNP Transistor

The symbol of PNP transistor is shown in the figure below. The inward arrow shows that the direction of current in PNP transistor is from the emitter to collector.

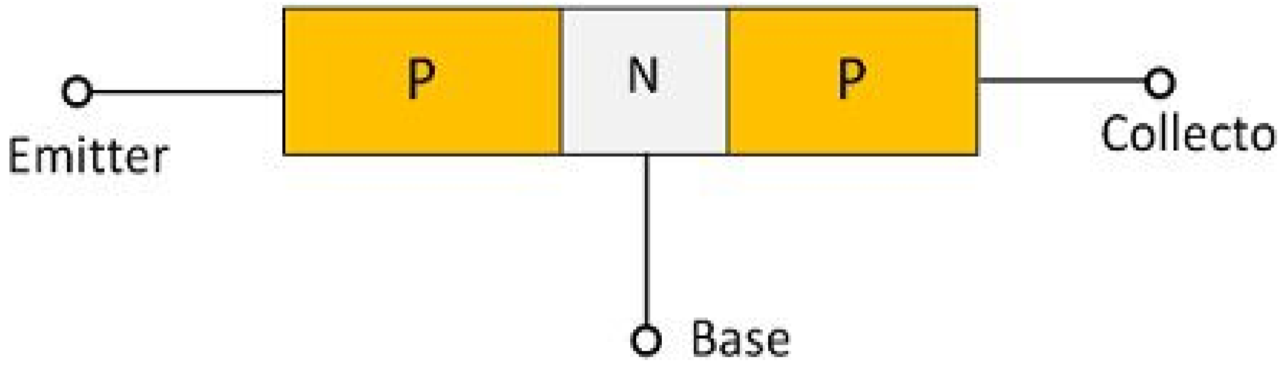


PNP Transistor

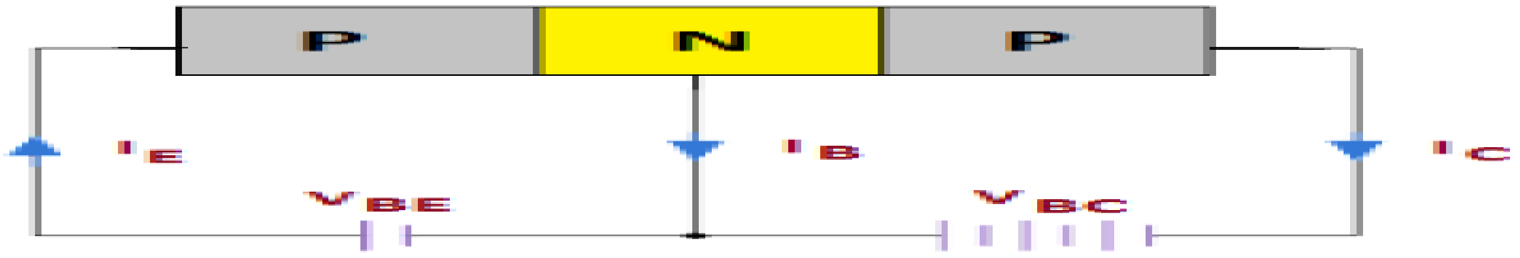
Construction of PNP Transistor

- The construction of PNP transistor is shown in the figure below.

- The emitter-base junction is connected in forward biased, and the collector-base junction is connected in reverse biased.



Working of PNP Transistor



Construction

The emitter-base junction is connected in forward biased due to which the emitter pushes the holes in the base region. These holes constitute the emitter current.

When these holes move into the N-type semiconductor material or base, they combined with the electrons.

The base of the transistor is thin and very lightly doped.

Hence only a few holes combined with the electrons and follow base path while remaining are moved towards the collector. Hence develops the base current.

The collector base region is connected in reverse biased.

The holes which collect around the depletion region when coming under the impact of negative polarity collected or attracted by the collector.

This develops the collector current.

Thus, we can say that the emitter current is the sum of the collector or the base current.

$$\boxed{I_E = I_B + I_C}$$

Discussions

Determine I_x in the circuit shown in Fig. 3.50 u

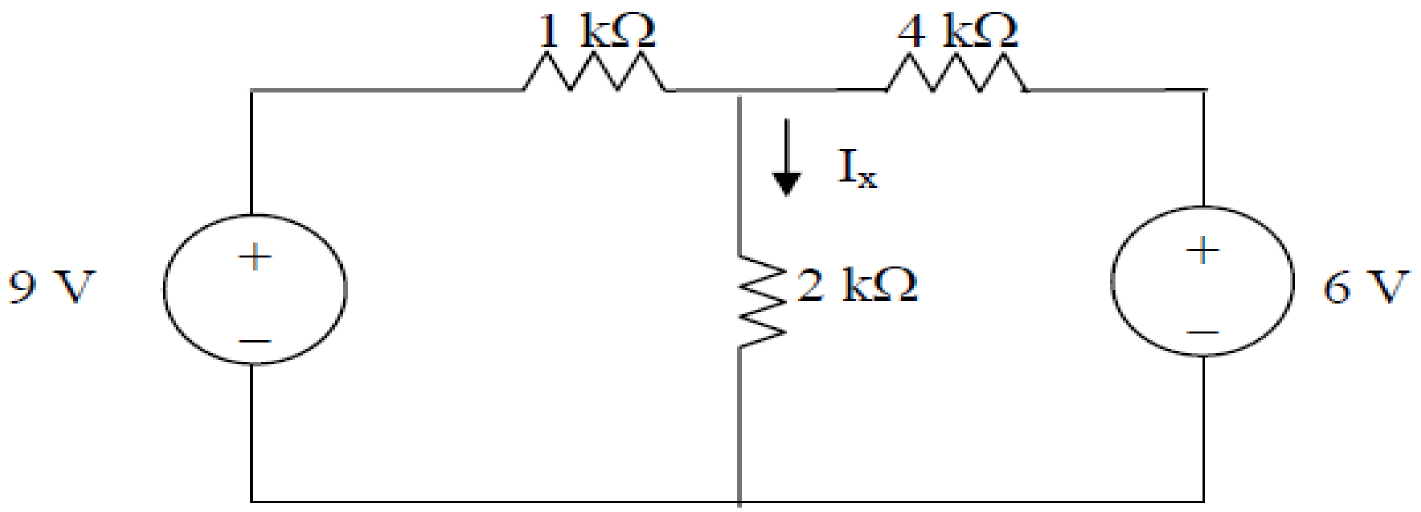


Figure 3.50 For Prob. 3.1.

Discussions

Determine I_x in the circuit shown in Fig. 3.50

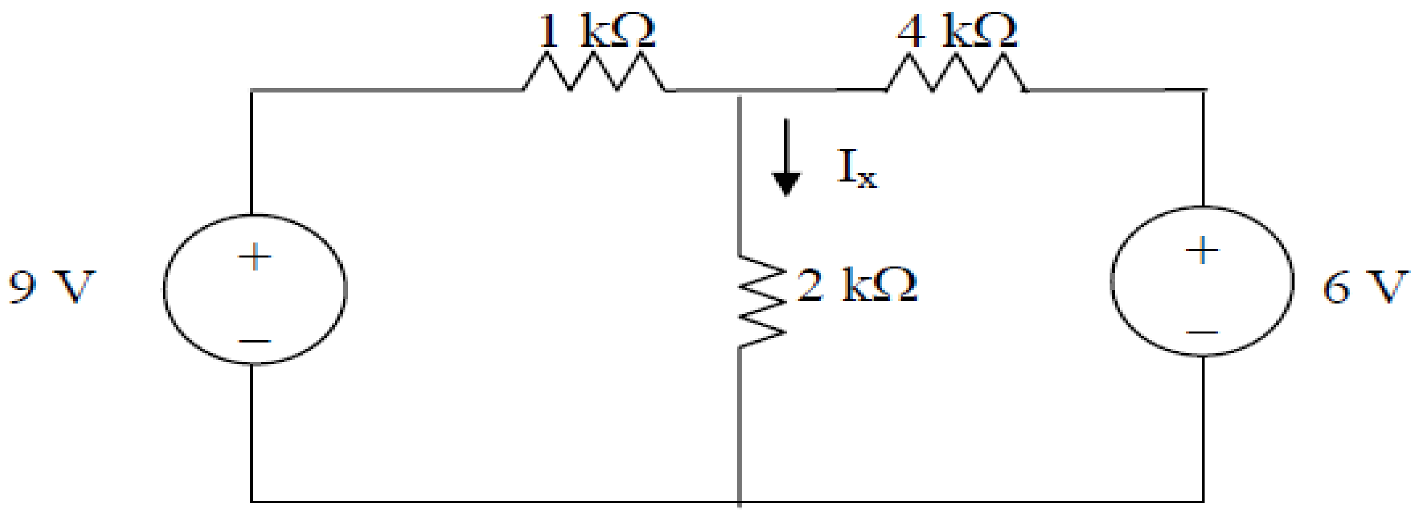


Figure 3.50 For Prob. 3.1.

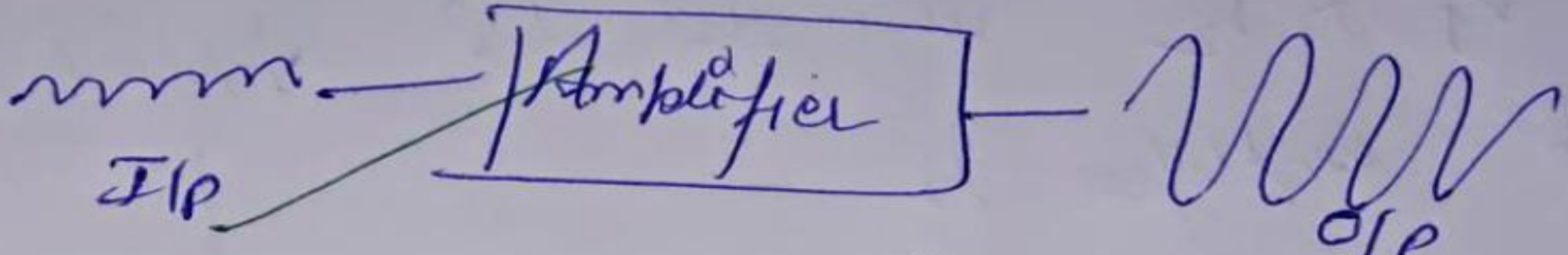
$\longrightarrow \quad V_x = 6 \qquad I_x = \frac{V_x}{2k} = \underline{3\ mA}$

Operational Amplifier (OPAMP)

OP-AMP

Operational Amplifier {Op-amp in 741C}

(1) It is basically an amplifier [to amplify the input signal]



Operational Amplifier (OPAMP)

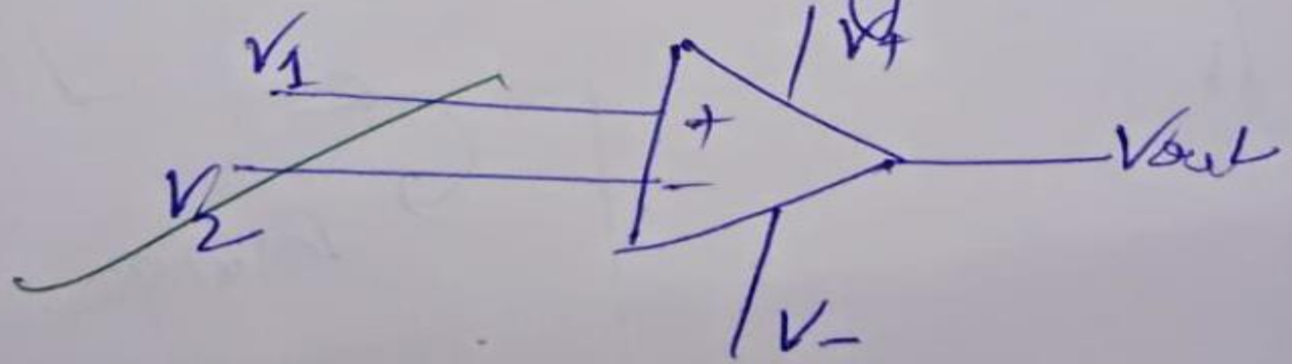
- We can perform addition, subtraction using amplifier.

- Just by connecting few resistors- It is possible to perform the mathematical operations.

Operational Amplifier (OPAMP)

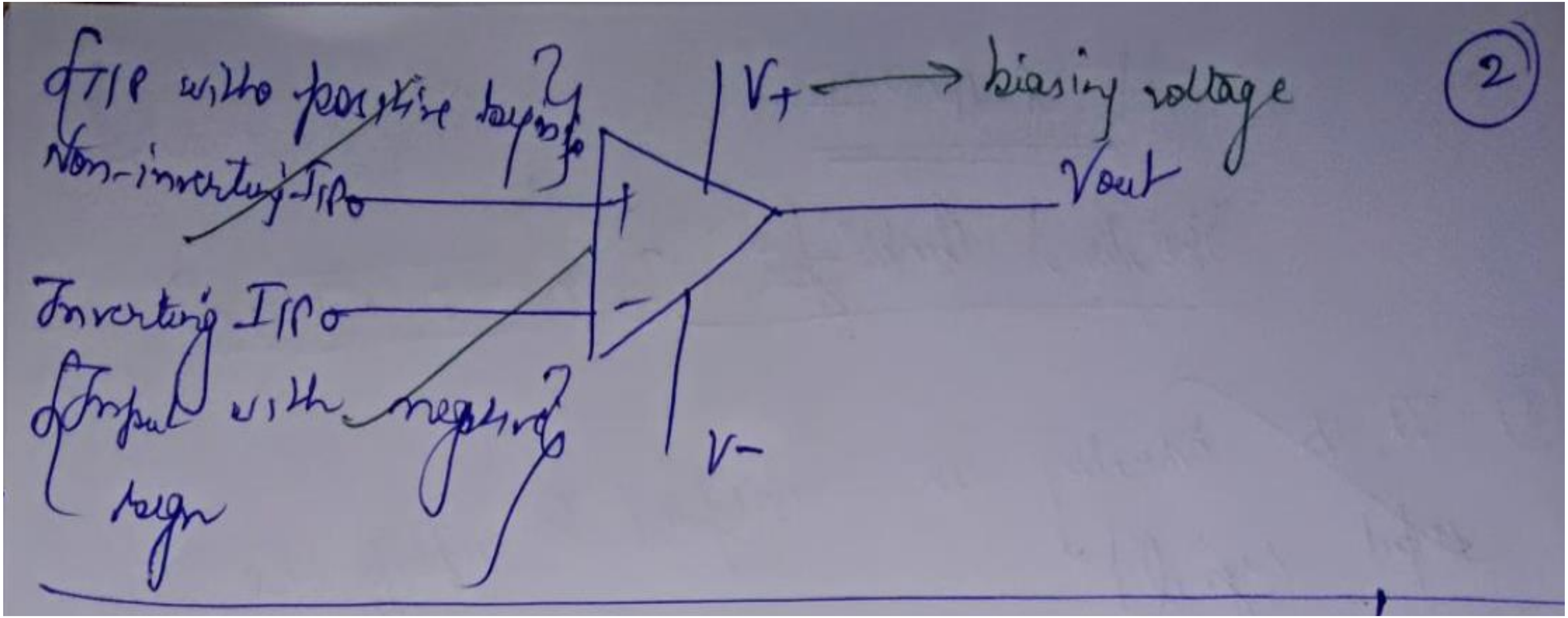
(3) ~~That's~~ why it is called as operational amplifier.

(4) Circuit Symbol of OP-Amp



It consists of two inputs & one o/p.

Operational Amplifier (OPAMP)

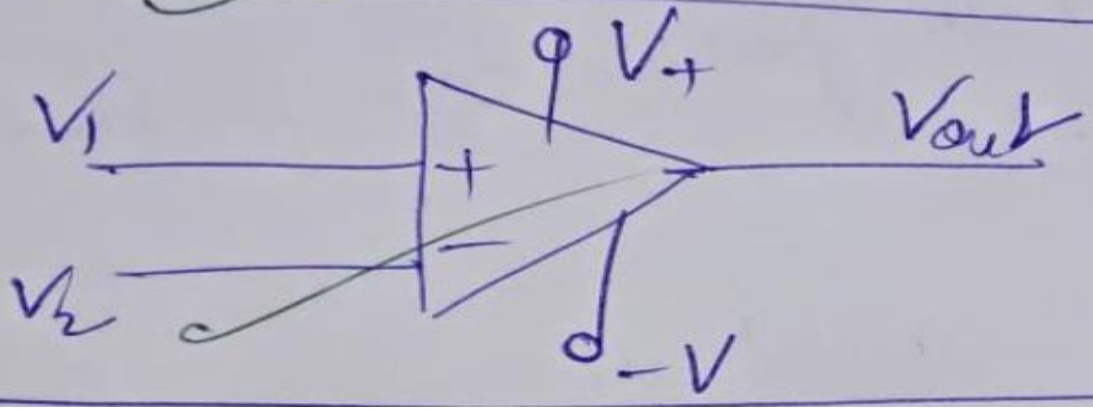


Operational Amplifier (OPAMP)

1) Suppose v_1 & v_2 are the I/P applied to the operational amplifier &

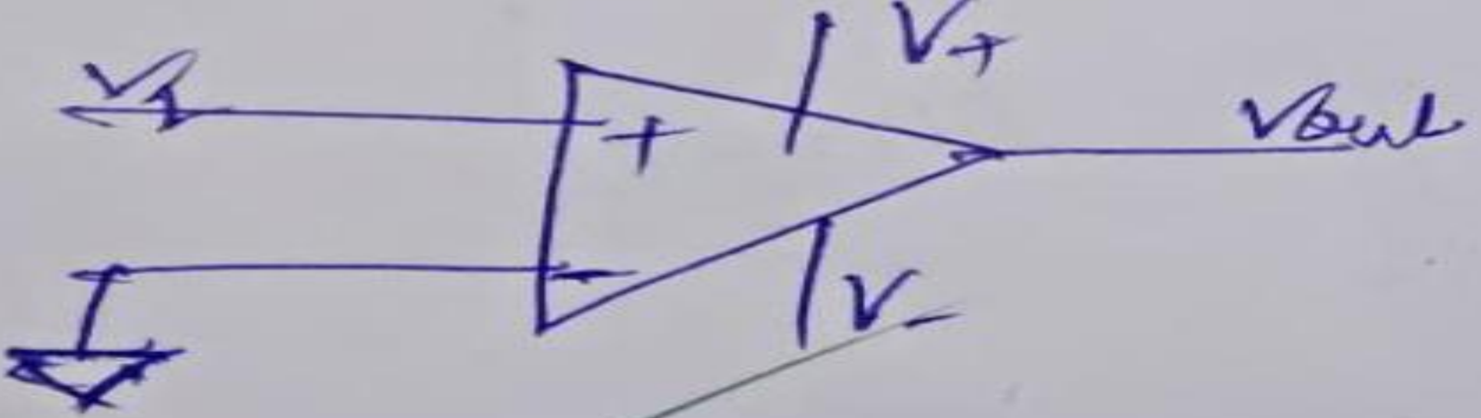
2) Gain of amplifier is A then

$$\boxed{V_{out} = A(V_1 - V_2)}$$



Operational Amplifier (OPAMP)

Case 1:-

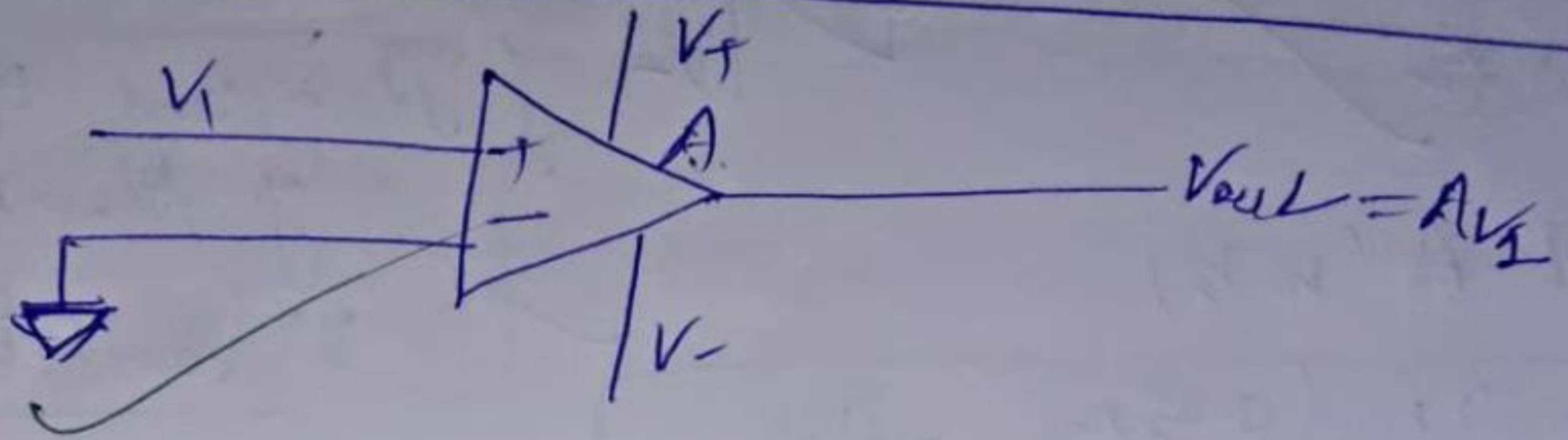


$\boxed{V_2 = 0}$ ground

$v_{out} = A(V_1 - V_2)$ {here $V_2 = 0$}

$\boxed{v_{out} \Rightarrow A(V_1)}$

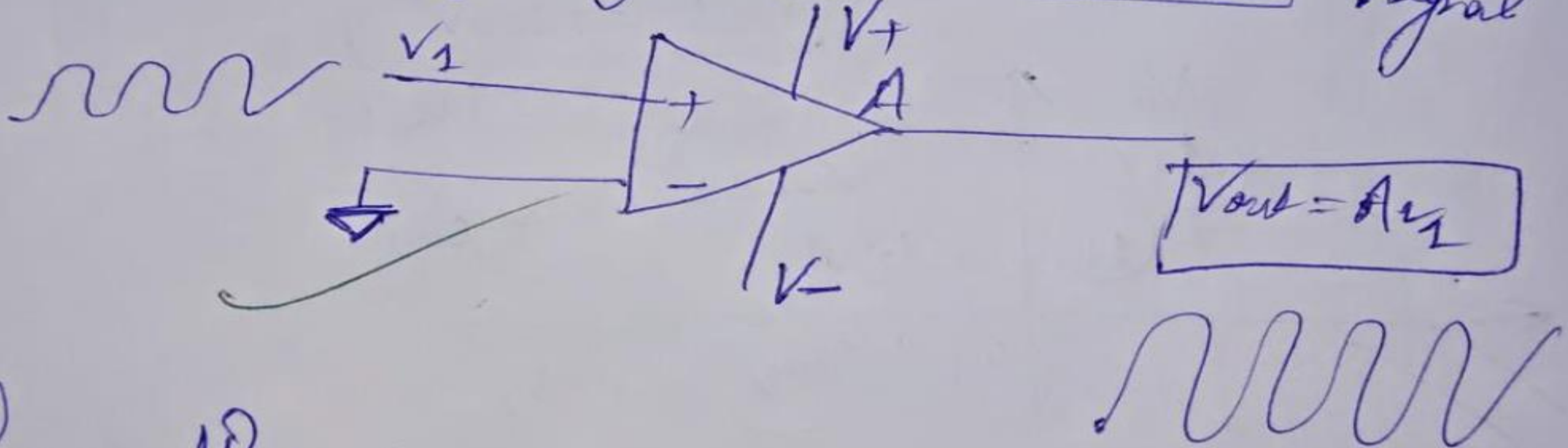
Operational Amplifier (OPAMP)



1) A is known as open loop gain ~~β~~ because there doesnot exist any feedback from output to ~~the~~ input.

Operational Amplifier (OPAMP)

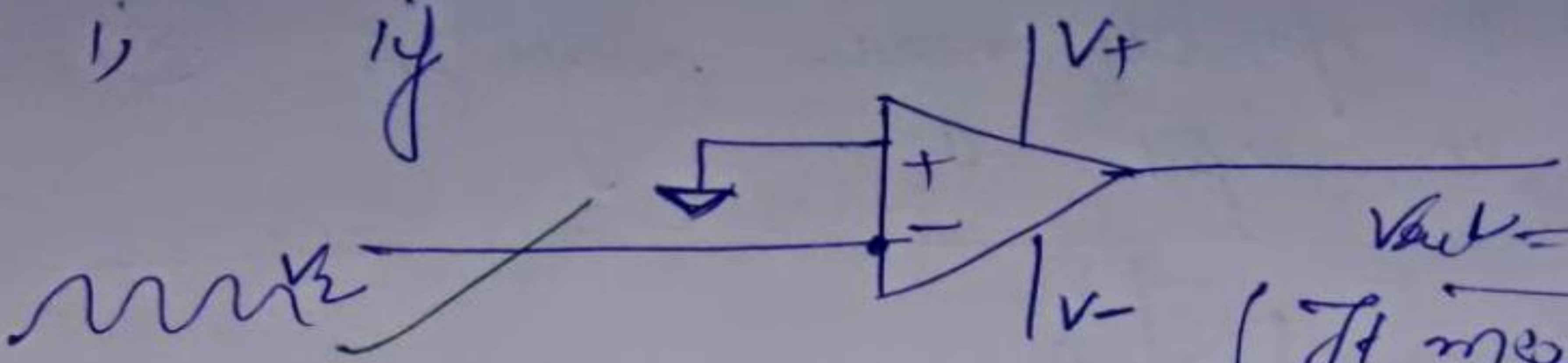
3) Suppose if you provide sinusodal signal



here phase is same as input voltage.

Operational Amplifier (OPAMP)

4



$V_{out} = -A V_2$

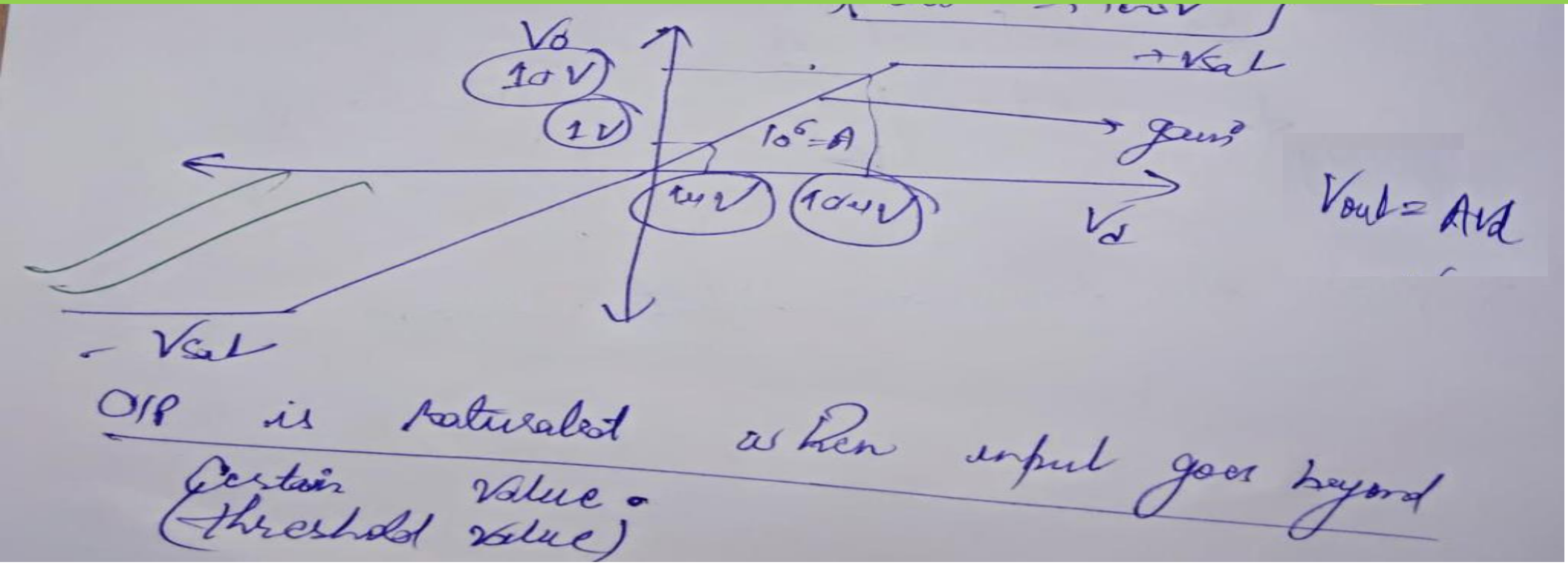
It means O/P is out of phase by 180°.

$\therefore \sin(180+\theta) \rightarrow -\sin\theta$

$V_{out} = A(V_1 - V_2)$

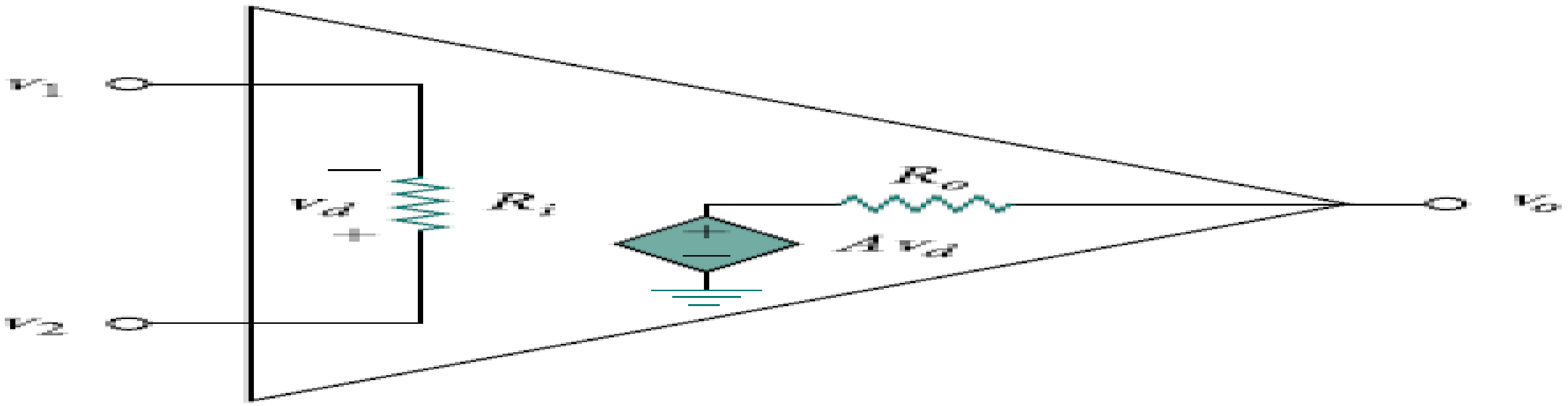
$\boxed{V_{out} \Rightarrow A(0 - V_2) \Rightarrow -AV_2}$

Operational Amplifier (OPAMP)



Saturation Curve/Ideal Voltage Transfer Characteristics

<u>Operational Amplifier (OPAMP) Equivalent Circuit</u>



The output *vo* is given by= $$v_o = Av_d = A(v_2 - v_1)$$

(non-inverting voltage-Inverting voltage)

The differential input voltage *vd* is given by $$v_d = v_2 - v_1$$

***A* is called the *open-loop voltage gain* because it is the gain of the op amp without any external feedback from output to input.**

where v_1 is the voltage between the inverting terminal and ground and v_2 is the voltage between the noninverting terminal and ground.

TABLE 5.1 Typical ranges for op amp parameters.

Parameter	Typical range	Ideal values
Open-loop gain, A	10^5 to 10^8	∞
Input resistance, R_i	10^6 to 10^{13} Ω	∞ Ω
Output resistance, R_o	10 to 100 Ω	0 Ω
Supply voltage, V_{cc}	5 to 24 V	

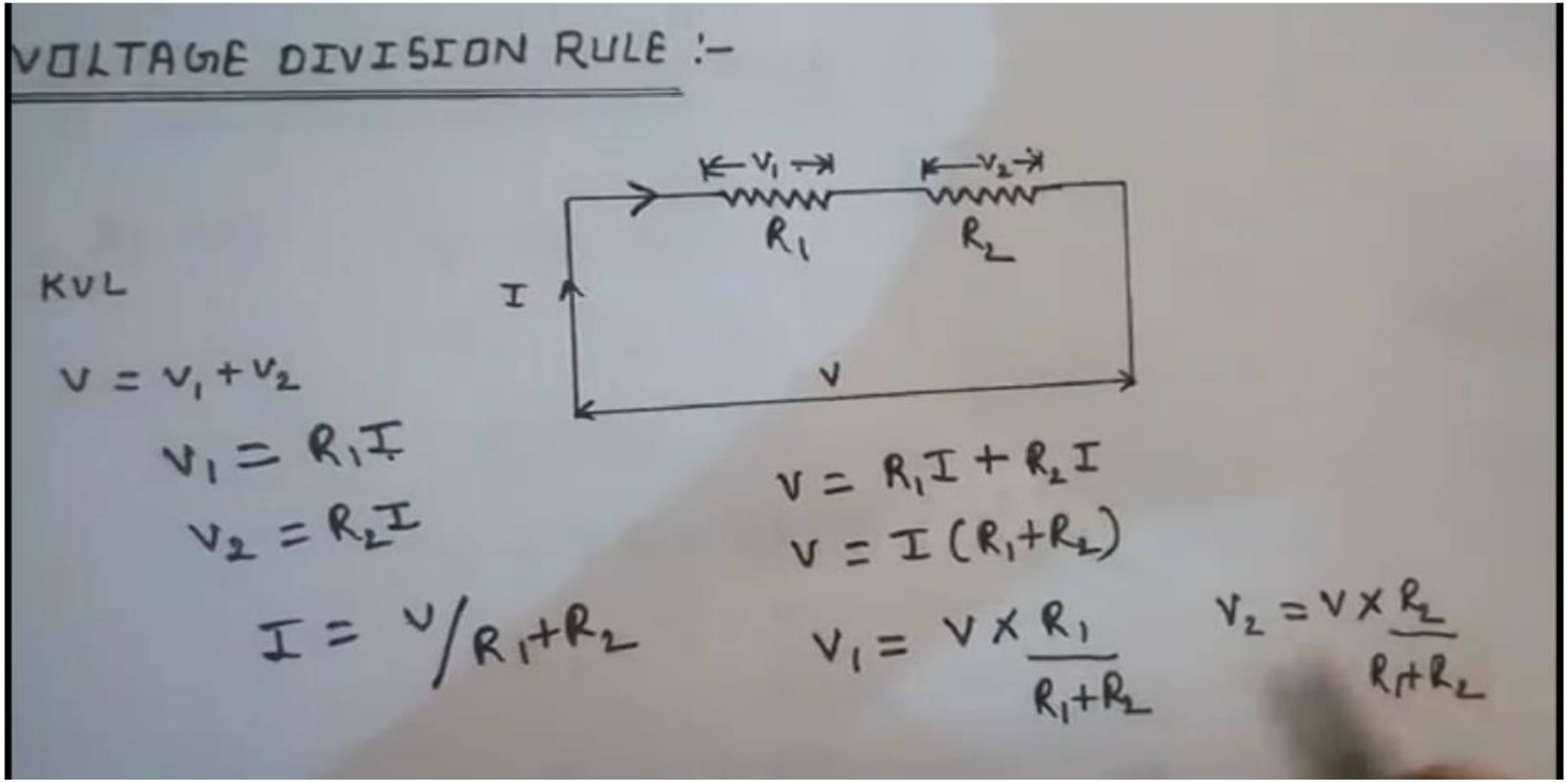
Discussions

- ❖ Explain Voltage Division Rule ?

Voltage Division Rules

1. Voltage Division Rule

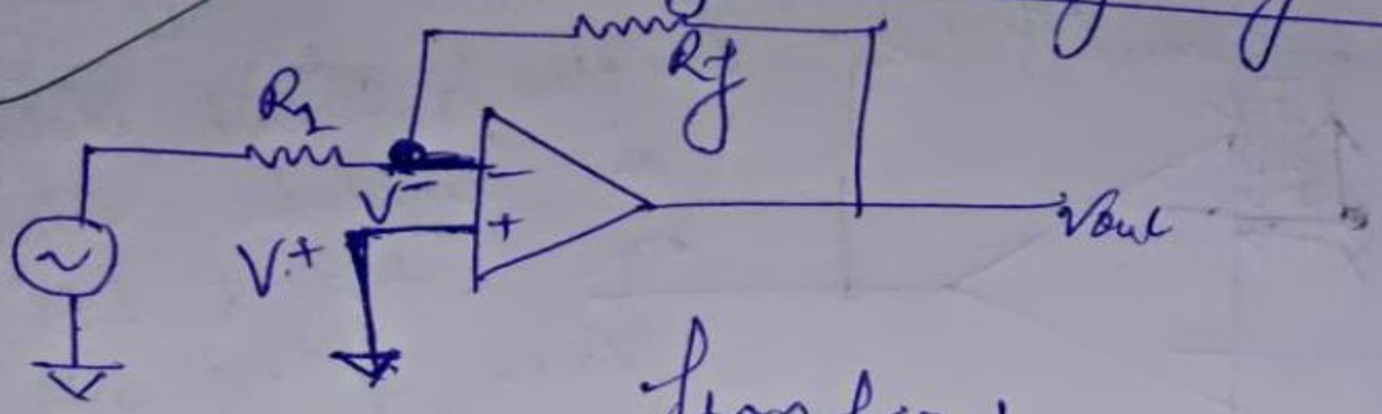
The **voltage** is divided between two series resistors in direct proportion to their resistance.



Operational Amplifier (OPAMP)

1

Concept of Virtual ~~grou~~ ground



from fig. 1

(1) Open loop gain $A_{OL} = 10^6$ {general range}

(2) It generates o/p Vout of 10V {generally Op-amp o/p near about this}

$\boxed{V_{out} = 10V}$

Operational Amplifier (OPAMP)

(3) formula OP Amp

$V_{out} = A \cdot V_d$ [gain times differential voltage]

$\boxed{V_{out} = A \cdot V_d}$ { $V_d = V^+ - V^-$ }

V^+ non inverting, V^- Inverting

$\boxed{10 = 10^6 V_d}$

$\boxed{10 \times 10^{-6} = V_d}$

$\boxed{10\mu V = V_d} \Rightarrow \boxed{10\mu V = V^+ - V^-}$ which is very very small so

$\boxed{V^+ - V^- \simeq 0V}$

$V^+ - V^- = 0$

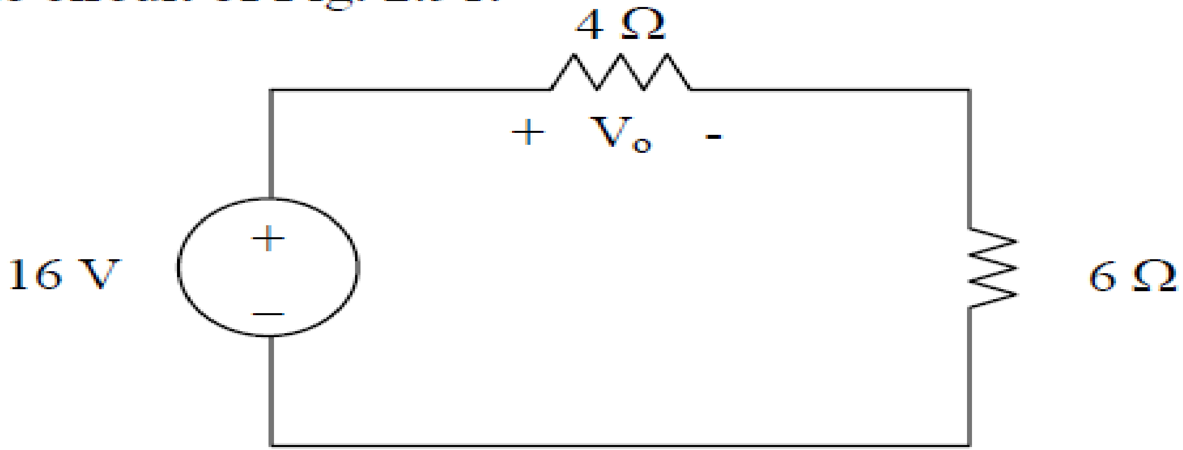
$\boxed{V^+ = V^-}$ {Non-inverting voltage & inverting voltages are equal}

$V^+ = 0$ {ground} from fig-1

so $\boxed{V \equiv 0}$ since it is zero so we calling virtual ground.

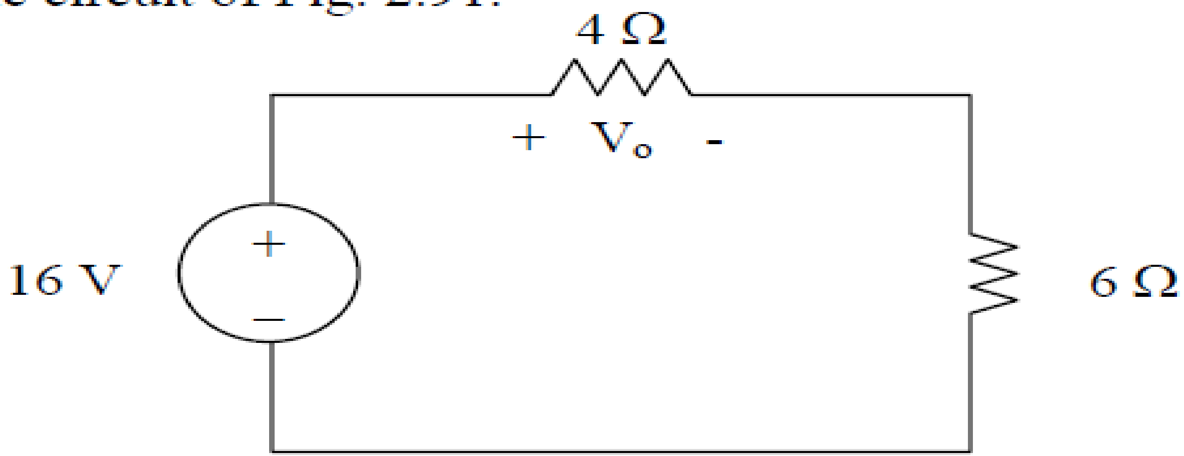
Discussions

Calculate V_o in the circuit of Fig. 2.91.



Discussions

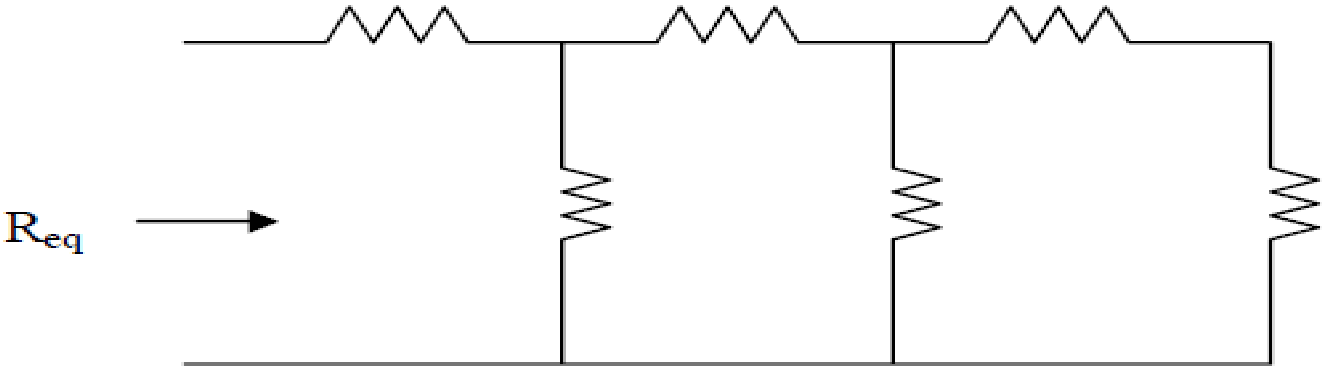
Calculate V_o in the circuit of Fig. 2.91.



$$V_o = \frac{4}{4+16}(16\text{V}) = \underline{6.4\ \text{V}}$$

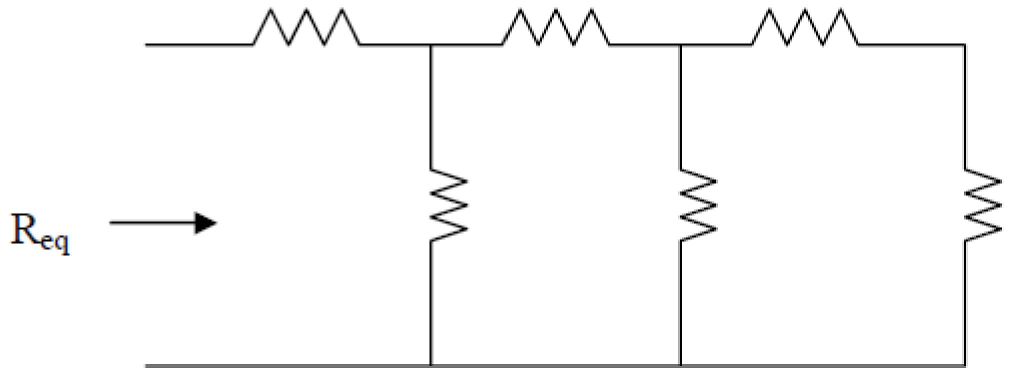
Discussions

All resistors in Fig. 2.93 are 1 Ω each. Find R_{eq}.



Discussions

All resistors in Fig. 2.93 are 1 Ω each. Find R_{eq}.

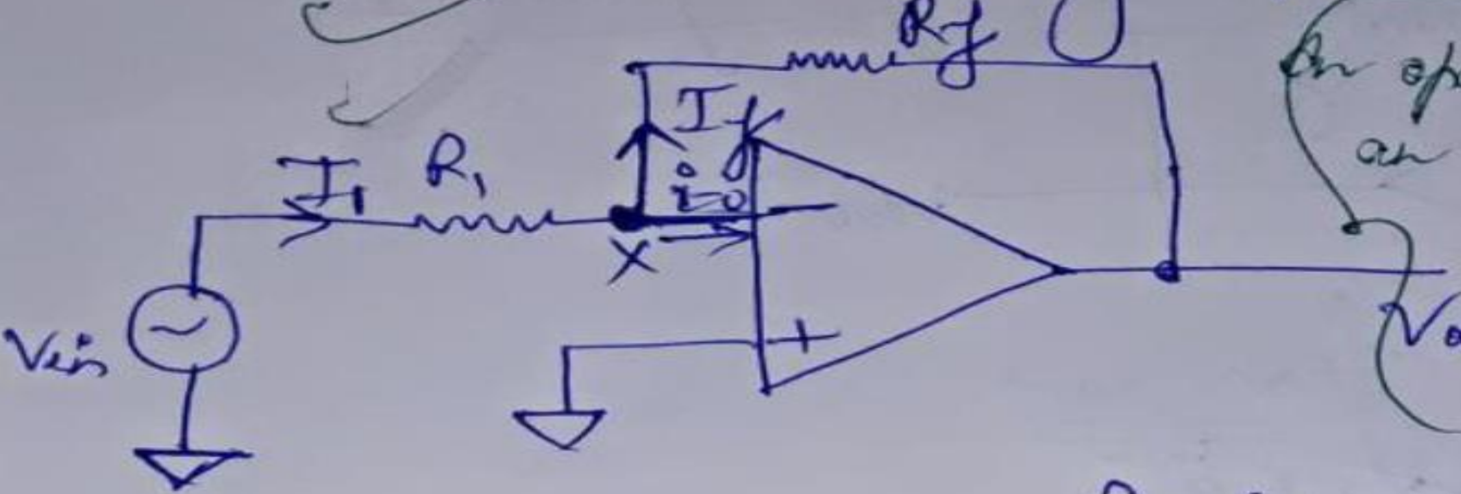


$R_{eq} = 1 + 1//(1 + 1//2) = 1 + 1//(1+ 2/3) =1+ 1//5/3 = \underline{\mathbf{1.625\ \Omega}}$

Inverting Operational Amplifier

(2)

Inverting Operational Amplifier



An opamp circuit that produces an amplified output that is 180° out of phase with input signal.

{At point X} $i = 0$ { ~~ideally no I go~~ ~~because of~~ here due to very high input impedance no current flow's inside OP-Amp }

$\boxed{I_1 = I_f}$

$\boxed{\text{Apply KCL}}$

Inverting Operational Amplifier

{At point x} $i = 0$ {~~ideally no I go~~ ~~because of~~ here due to very high input impedance no current flow is inside OP-AMP}

$\boxed{I_1 = I_f}$ $\boxed{\text{Apply KCL}}$

$$\frac{V_{in} - X}{R_1} = \frac{X - V_{out}}{R_f}$$

here due to virtual ground $X = 0V$

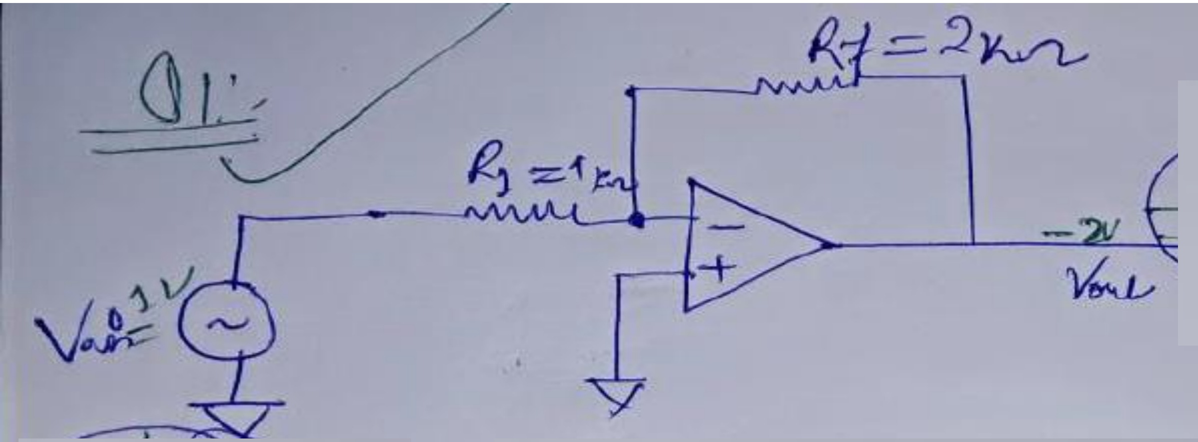
$$\frac{V_{in} - 0}{R_1} = \frac{-V_{out}}{R_f}$$

$$\boxed{\frac{-R_f}{R_1} \Rightarrow \frac{V_{out}}{V_{in}}} \Rightarrow \frac{V_{out}}{V_{in}} = \frac{-R_f}{R_1} = A_{CL}$$

A → gain, CL → closed loop

* $\boxed{\text{closed loop gain}}$

Inverting Operational Amplifier



$$\frac{V_{out}}{V_{in}} = \frac{-2\times10^3}{1\times10^3} \Rightarrow -2$$

$$\boxed{V_{out} = -2V_{in}}$$

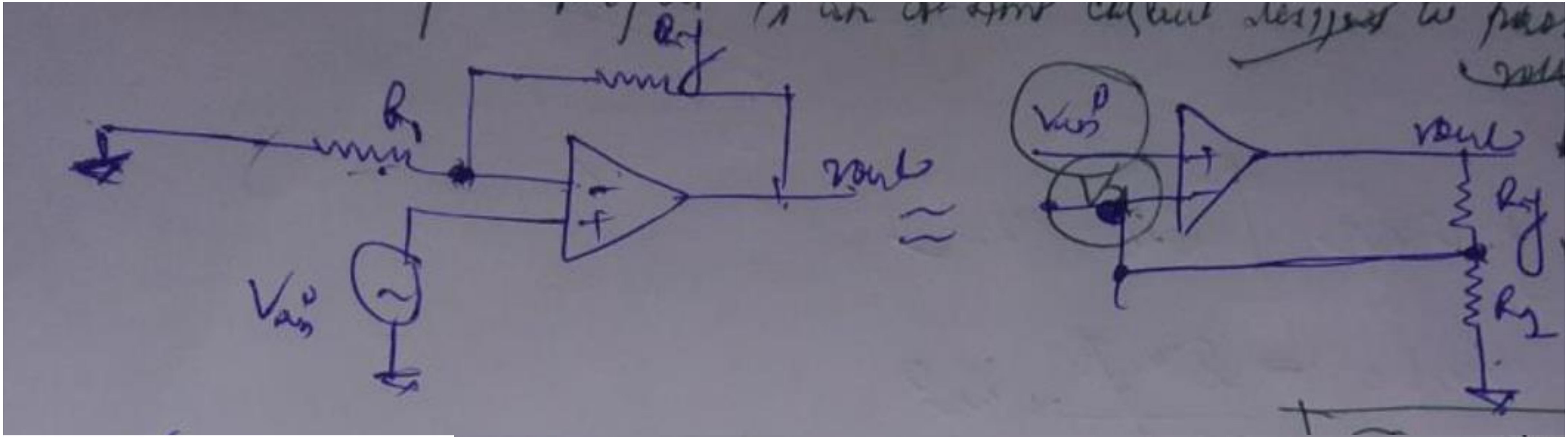
$$\boxed{V_{out} = -2\times1 \Rightarrow -2V}$$

Non- Inverting Operational Amplifier

- A non inverting Amplifier is an OPAMP which is designed to provide positive voltage gain.

- Here, input is applied to non-inverting terminals.

Non- Inverting Operational Amplifier



Voltage at V_x :-

(1) $$\boxed{V_x = \frac{R_1}{R_1 + R_f} \times V_{out}}$$

Non- Inverting Operational Amplifier

Voltage at V_x :-

(1) $\boxed{V_x = \frac{R_1}{R_1 + R_f} \times V_{out}}$

(2) Due to virtual shorting concept $(V^+ = V^-)$

(3) So $V_{in} = V_x$

(4) $V_{in} = V_x = \left(\frac{R_1}{R_1 + R_f}\right) V_{out}$

Non- Inverting Operational Amplifier

(4) $$V_{in} = V_x = \left(\frac{R_1}{R_1 + R_f}\right) V_{out}$$

(5) $$V_{in} = \left(\frac{R_1}{R_1 + R_f}\right) V_{out}$$

(6) $$\frac{V_{out}}{V_{in}} = \frac{R_1}{R_1} + \frac{R_f}{R_1} \Rightarrow 1 + \frac{R_f}{R_1}$$

(7) $$\boxed{V_{out} = \left(1 + \frac{R_f}{R_1}\right) V_{in}}$$