Physics

Network Analysis

Ohm's law : Ohm's law is a law that states that the voltage across a resistor is directly proportional to the current flowing through the resistance

1. Circuit . A circuit is a closed conducting path through which an electric current either flows or is intended flow.

2. Parameters. The various elements of an electric circuit are called its parameters like resistance, inductance and capacitance. These parameters may be lumped or distributed.

3. Liner Circuit. A linear circuit is one whose parameters are constant i.e. they do not change with voltage or current.

4. Non-linear Circuit. It is that circuit whose parameters change with voltage or current.

5. Bilateral Circuit. A bilateral circuit is one whose properties or characteristics are the same in either direction. The usual transmission line is bilateral , because it can be made to perform its function equally well in either direction.

6. Unilateral Circuit. It is that circuit whose properties or characteristics change with the direction of its operation. A diode rectifier is a unilateral circuit, because it cannot perform rectification in both directions.

7. Electric Network. A combination of various electric elements, connected in any manner whatsoever, is called an electric network.

8. Passive Network is one which contains no source of e.m.f. in it.

9. Active Network is one which contains one or more than one source of e.m.f.

10. Node is a junction in a circuit where two or more circuit elements are connected together.

11. Branch is that part of a network which lies between two junctions.

12. Loop. It is a close path in a circuit in which no element or node is encountered more than once.

13. Mesh. It is a loop that contains no other loop within it

Kirchhoff’s Laws

1. **Kirchhoff’s Point Law or Current Law (KCL) : in any electrical network, the algebraic sum of the currents meeting at a point (or junction) is zero..**

Similarly, in Fig. 2.2 (*b*) for node *A*

$$+I + (-I_1) + (-I_2) + (-I_3) + (-I_4) = 0 \quad \text{or} \quad I = I_1 + I_2 + I_3 + I_4$$

We can express the above conclusion thus : $\Sigma I = 0$ ....at a junction

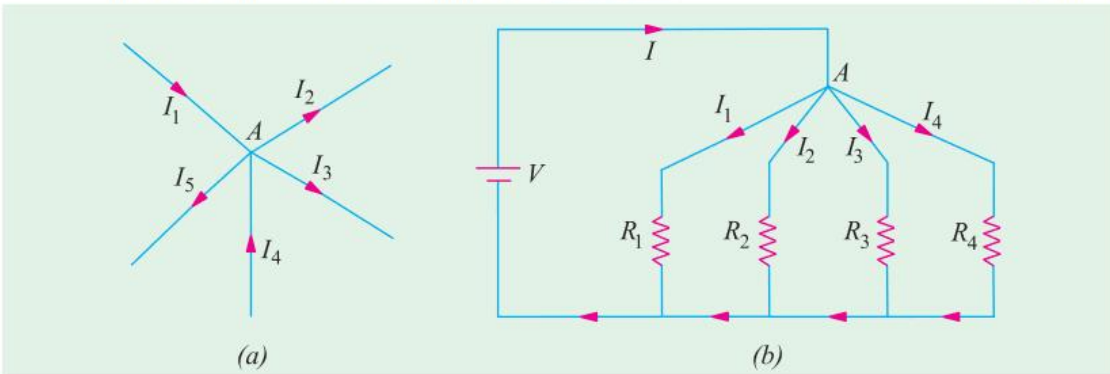


Fig. 2.2

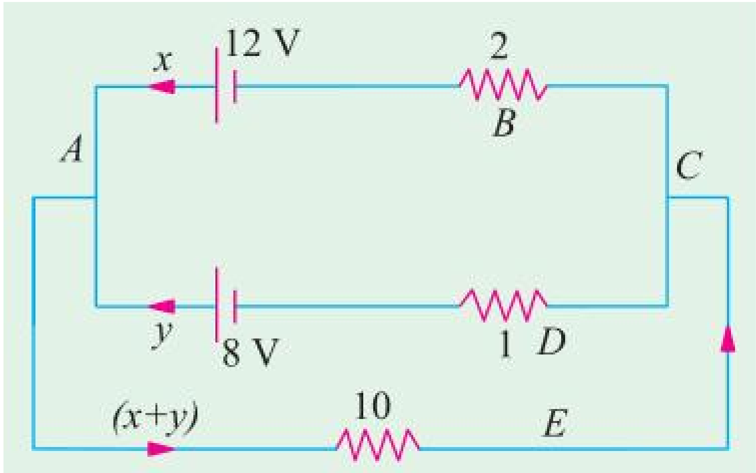
2. **Kirchhoff’s Mesh Law or Voltage Law (KVL)**

It states as follows :

The algebraic sum of the products of currents and resistances in each of the conductors in any closed path (or mesh) in a network plus the algebraic sum of the e.m.fs. in that path is zero.In other words,

$$\Sigma\, IR + \Sigma\, \text{e.m.f.} = 0$$

Example 2.11. *Two batteries A and B are connected in parallel and load of 10 Ω is connected across their terminals. A has an e.m.f. of 12 V and an internal resistance of 2 Ω ; B has an e.m.f. of 8 V and an internal resistance of 1 Ω. Use Kirchhoff’s laws to determine the values and directions of the currents flowing in each of the batteries and in the external resistance. Also determine the potential difference across the external resistance.*



Solution. Applying KVL to the closed circuit ABCDA of Fig. 2.13, we get

$-12 + 2x - 1y + 8 = 0$ or $2x - y = 4$ ...(i)

Similarly, from the closed circuit ADCEA, we get

$-8 + 1y + 10(x + y) = 0$ or $10x + 11y = 8$ ...(ii)

From Eq. (i) and (ii), we get

$x = 1.625$ A and $y =$ −−−−−0.75 A

The negative sign of y shows that the current is flowing into the 8-V battery and not out of it. In other words, it is a charging current and not a discharging current.

Current flowing in the external resistance = $x + y = 1.625 - 0.75 = 0.875$ A

P.D. across the external resistance = $10 \times 0.875 = 8.75$ V

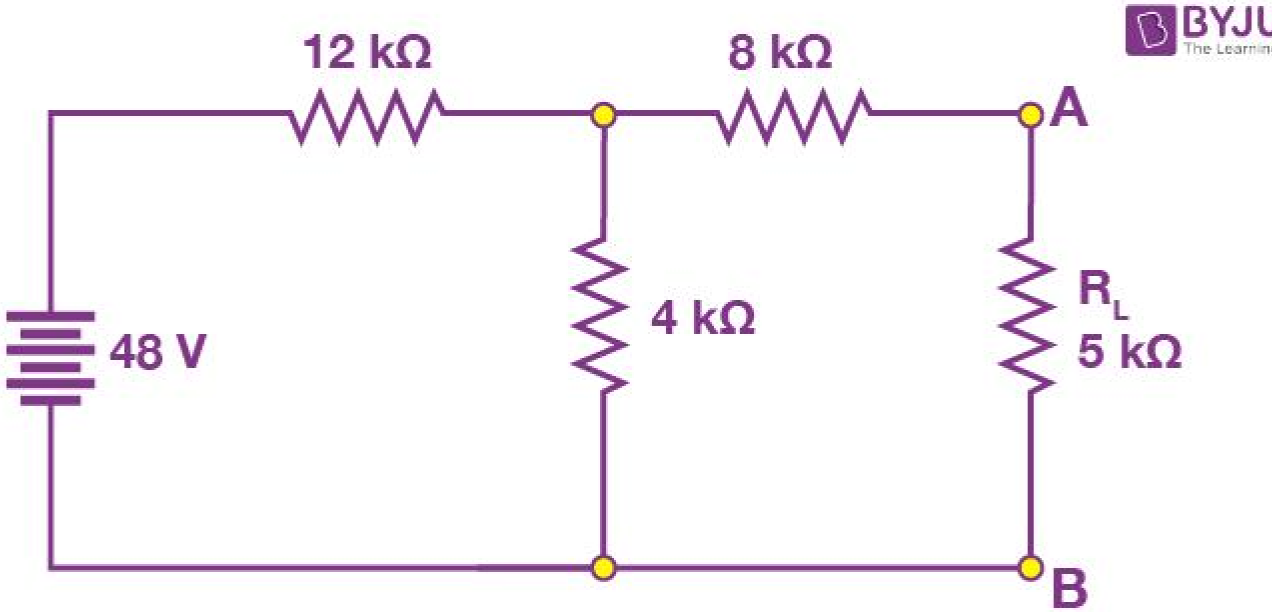
Thevenin's theorem:

➔ **Thevenin's theorem simplifies complex electricall circuit into a single voltage source and resistor combination , providing an easier way to analyze and understand circuit behavior.**

Steps :

1. **Find the Thevenin Resistance by removing all voltage sources and load resistor.**
2. **Find the Thevenin Voltage by plugging in the voltages.**
3. **Use the Thevenin Resistance and Voltage to find the current flowing through the load**

Example : Find V_{TH}, R_{TH} and the load current I_L flowing through and load voltage across the load resistor in the circuit below using Thevenin's Theorem.



Solution:

Step 1: Remove the 5 kΩ from the circuit.

Step 2: Measure the open-circuit voltage. This will give you the Thevenin's voltage (V_{TH}).

Step 3: We calculate Thevenin's voltage by determining the current that flows through 12 kΩ and 4 kΩ resistors.

As both the resistors are in series, the current that flows across them can be calculated as follows:

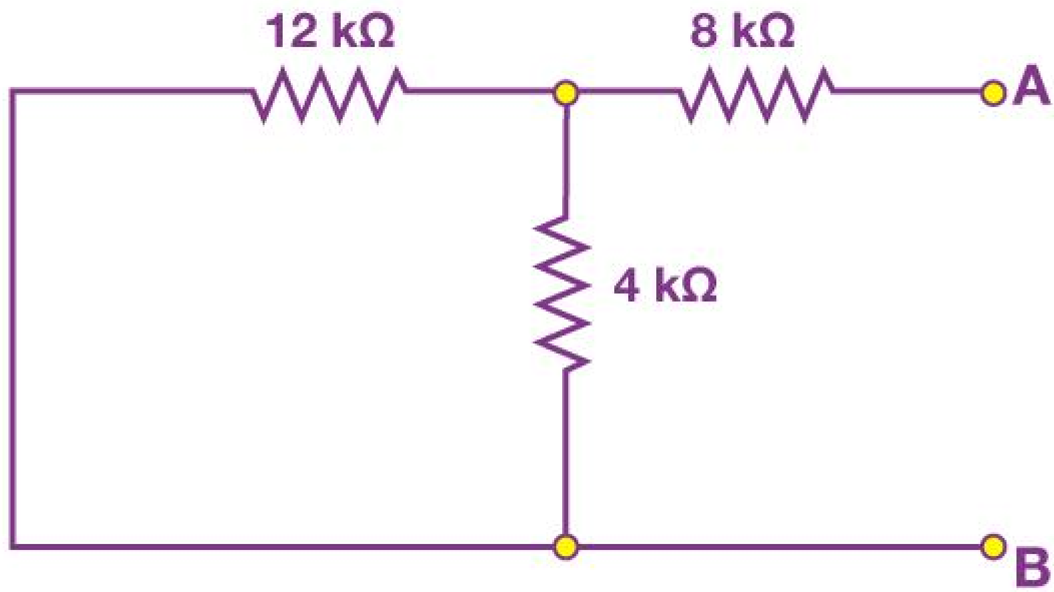
I = 48 V /(12 kΩ + 4 kΩ) = 3 mA

The voltage across the 4 kΩ resistors can be calculated as follows:

3 mA x 4 kΩ = 12 V

As there is no current flowing through the 8 kΩ resistor, so there is no voltage drop across it and hence the voltage across the terminals AB is same as the voltage across the 4 kΩ resistor. Therefore, 12 V will appear across the AB terminals. Hence, the Thevenin's voltage, V_{TH} = 12 V.

Step 4: Short the voltage sources as shown in the figure below:



Step 5: Calculate the Thevenin's Resistance

By measuring the open circuit resistance, we can measure Thevenin's resistance.

We notice that the 8 kΩ resistor is in series with the parallel connection of 12 kΩ and 4 kΩ resistors. Therefore, the equivalent resistance or the Thevenin's resistance is calculated as follows:

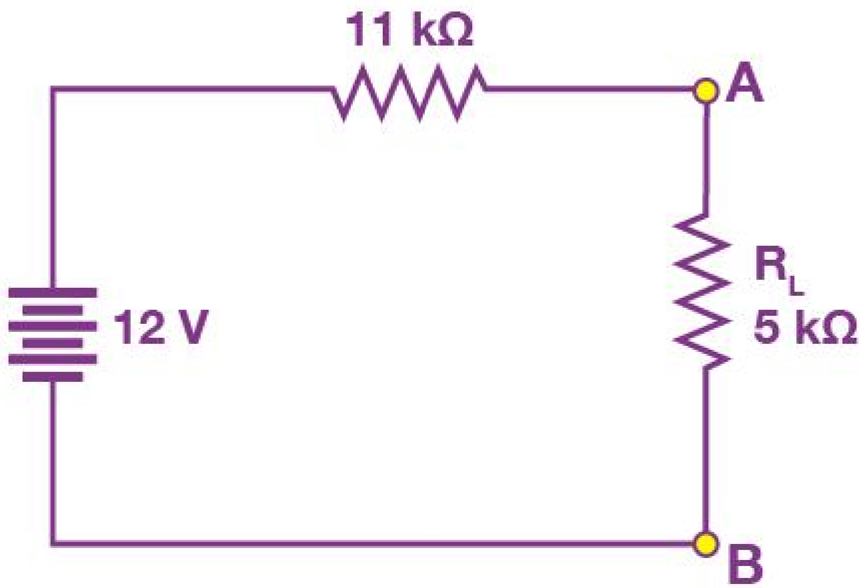
8kΩ + (4k Ω || 12kΩ)

R_{TH} = 8 kΩ + [(4 kΩ x 12 kΩ) / (4 kΩ + 12 kΩ)]

R_{TH} = 8 kΩ + 3 kΩ

R_{TH} = 11 kΩ

Step 6: Now, connect the R_{TH} in series with Voltage Source V_{TH} and the load resistor as shown in the figure.



Step 7: For the last step, calculate the load voltage and load current using Ohm's law as follows:

$I_L = V_{TH} / (R_{TH} + R_L)$

$I_L = 12\ V / (11\ k\Omega + 5\ k\Omega) = 12\ V/16\ k\Omega = 0.75\ mA$

The load voltage is determined as follows:

$V_L = 0.75\ mA \times 5\ k\Omega = 3.75\ V$

Thevenin Theorem Applications

- Thevenin's theorem is used in the analysis of power systems.
- Thevenin's theorem is used in source modelling and resistance measurement using the Wheatstone bridge.

Thevenin Theorem Limitations

- Thevenin's theorem is used only in the analysis of linear circuits.
- The power dissipation of the Thevenin equivalent is not identical to the power dissipation of the real system.

Norton’s theorem

➔ **Norton's theorem states that any linear circuit can be simplified to an equivalent circuit consisting of a single current source and parallel resistance that is connected to a load.**

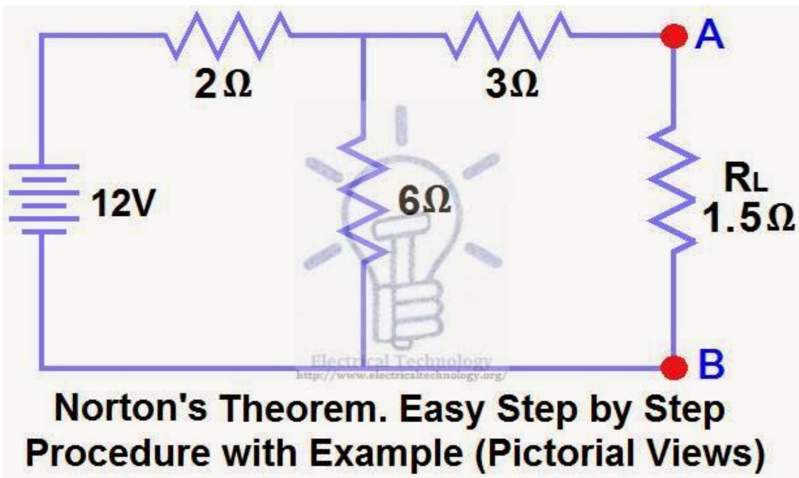
Steps:

Step 1: Remove the load resistor and replace it with a short circuit.

Step 2: Calculate the Norton current—the current through the short circuit.

Step 3: Replace the power sources. All voltage sources are replaced with short circuits, and all current sources are replaced with open circuits.

Example : Find R_N, I_N, the current flowing through and Load Voltage across the load resistor in fig (1) by using Norton’s Theorem.

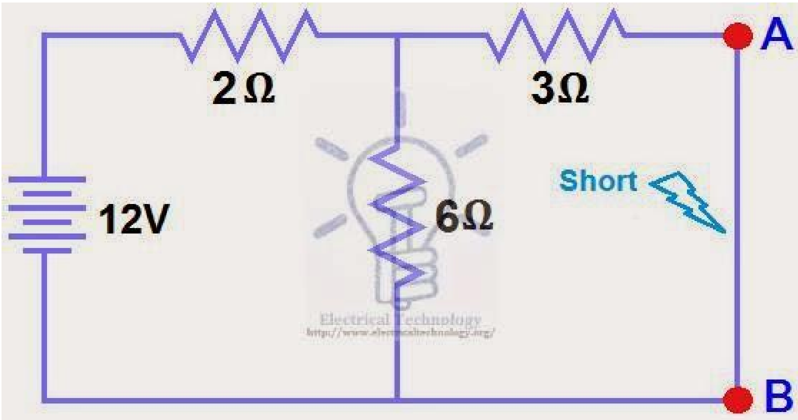


Norton’s Theorem: Step by Step Procedure with Examples

Solution:-

STEP 1.

Short the 1.5Ω load resistor as shown in (Fig 2).



STEP 2.

Calculate / measure the Short Circuit Current. This is the Norton Current (I_N).

We have shorted the AB terminals to determine the Norton current, I_N. The 6Ω and 3Ω are then in parallel and this parallel combination of 6Ω and 3Ω are then in series with 2Ω.

So the total resistance of the circuit to the Source is:-

2Ω + (6Ω || 3Ω) ….. (|| = in parallel with).

R_T = 2Ω + [(3Ω x 6Ω) / (3Ω + 6Ω)] → I_T = 2Ω + 2Ω = 4Ω.

R_T = 4Ω

$I_T = V \div R_T$

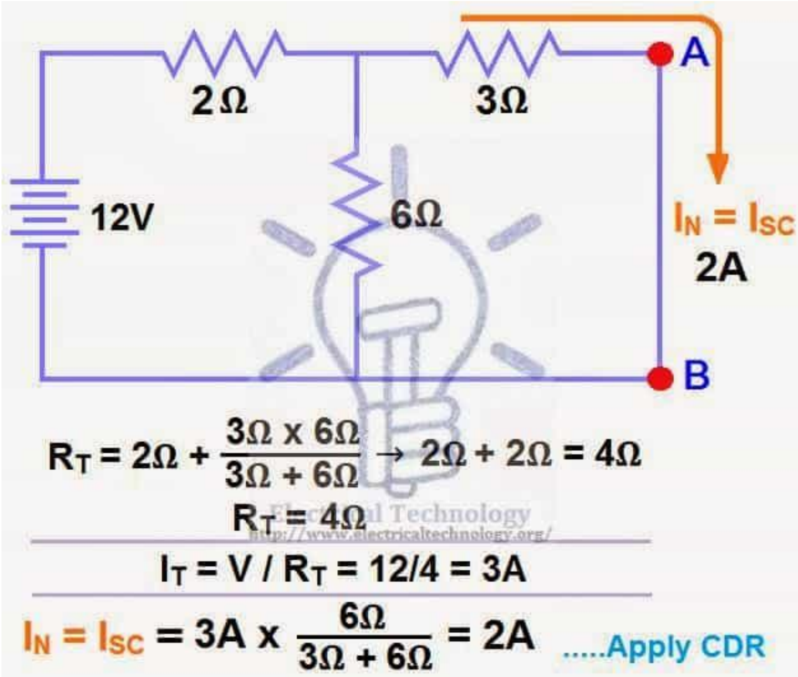
I_T = 12V ÷ 4Ω

I_T = 3A..

Now we have to find $I_{SC} = I_N$ … Apply CDR… (Current Divider Rule)…

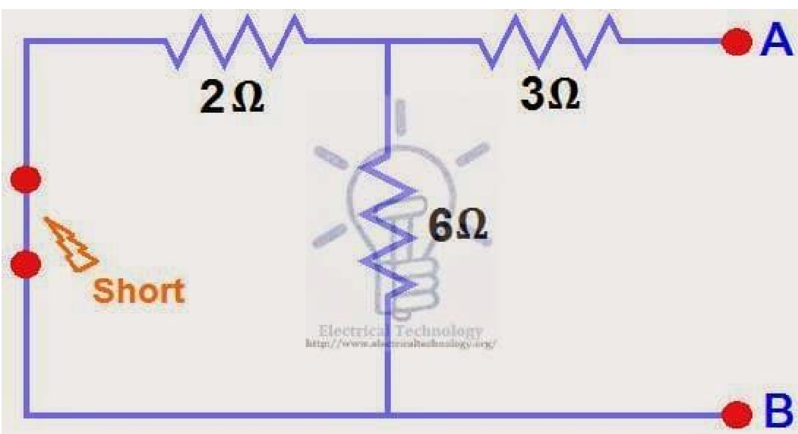
$I_{SC} = I_N$ = 3A x [(6Ω ÷ (3Ω + 6Ω)] = 2A.

$I_{SC} = I_N$ = 2A.



STEP 3.

Open Current Sources, Short Voltage Sources and Open Load Resistor. Fig (4)



STEP 4.

Calculate /measure the Open Circuit Resistance. This is the Norton Resistance (R_N)

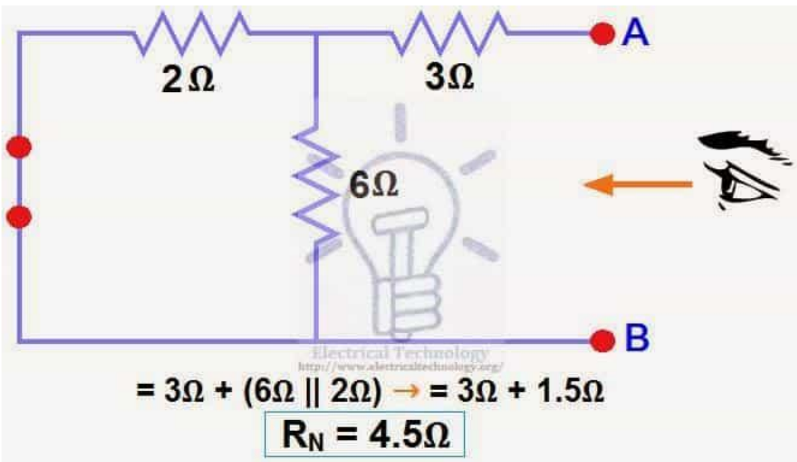
We have Reduced the 12V DC source to zero is equivalent to replace it with a short in step (3), as shown in figure (4) We can see that 3Ω resistor is in series with a parallel combination of 6Ω resistor and 2Ω resistor. i.e.:

$$3\Omega + (6\Omega \parallel 2\Omega) \; \ldots\ldots (\parallel = \text{in parallel with})$$

$$R_N = 3\Omega + [(6\Omega \times 2\Omega) \div (6\Omega + 2\Omega)]$$

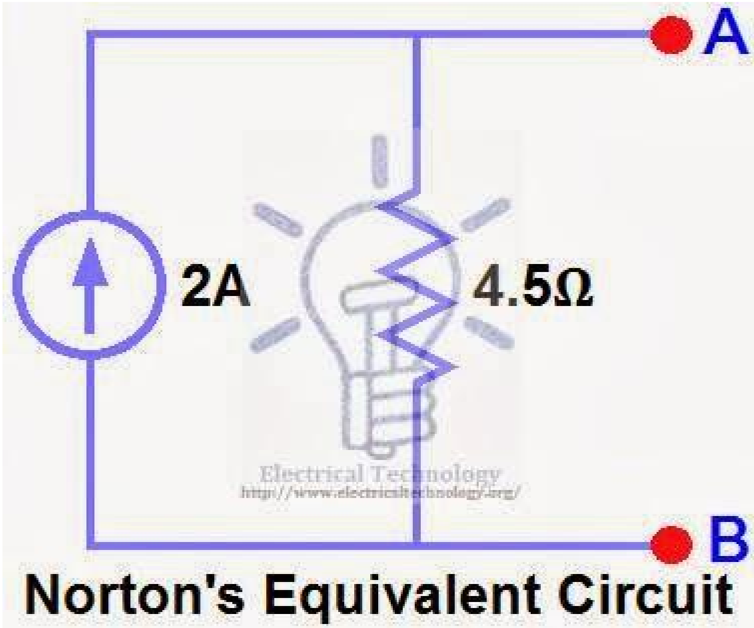
$$R_N = 3\Omega + 1.5\Omega$$

$$\mathbf{R_N = 4.5\Omega}$$



STEP 5.

Connect the R_N in Parallel with Current Source I_N and reconnect the load resistor. This is shown in fig (6) i.e. Norton Equivalent circuit with load resistor.



Norton Equivalent Circuit

STEP 6.

Now apply the last step i.e. calculate the load current through and Load voltage across the load resistor by Ohm's Law as shown in fig 7.

Load Current through Load Resistor…

$$\mathbf{I_L = I_N \times [R_N \div (R_N + R_L)]}$$

= 2A x (4.5Ω ÷ 4.5Ω + 1.5Ω) → = 1.5A

I_L = 1. 5A

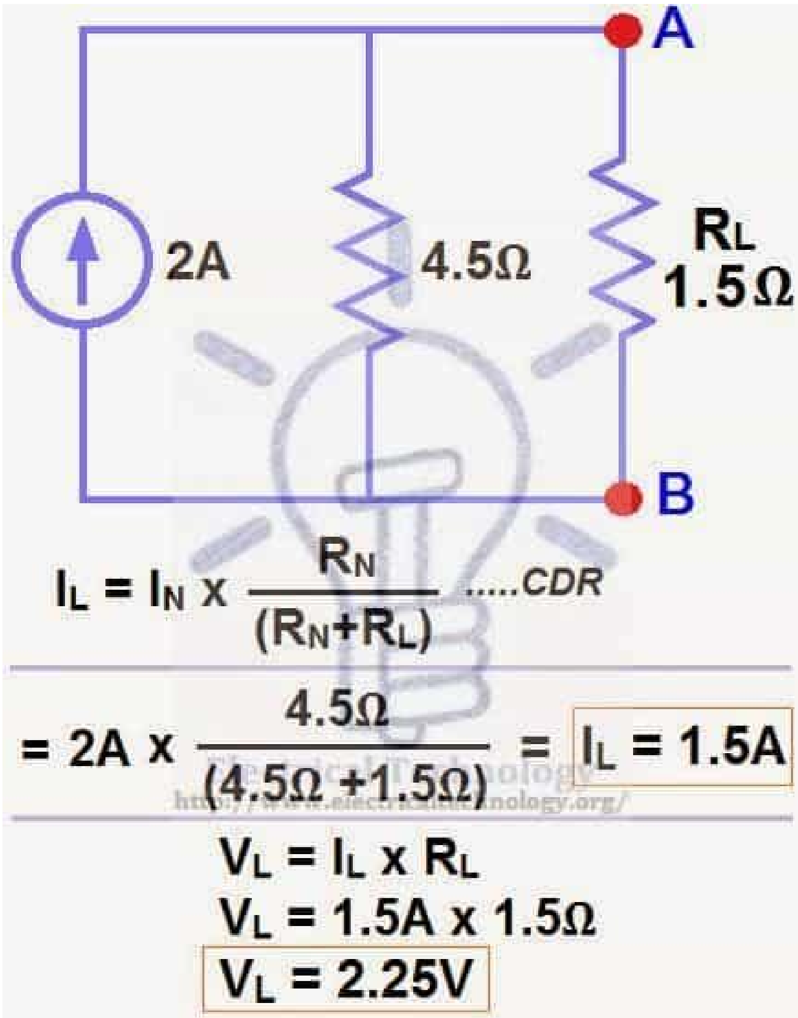
And

Load Voltage across Load Resistor…

$$\mathbf{V_L = I_L \times R_L}$$

V_L = 1.5A x 1.5Ω

V_L= 2.25V

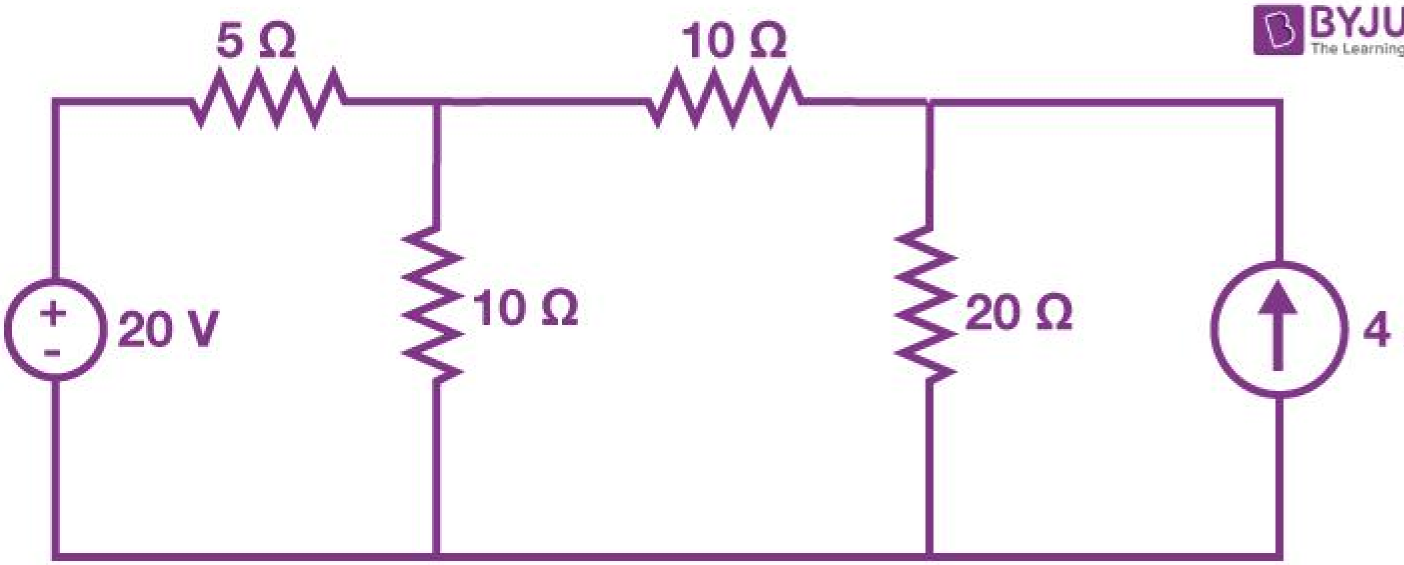


Superposition theorem

➔ **The superposition theorem is a theorem that states that the voltage or current in any part of a linear circuit with multiple sources is equal to the sum of the voltages or currents caused by each source acting alone.**

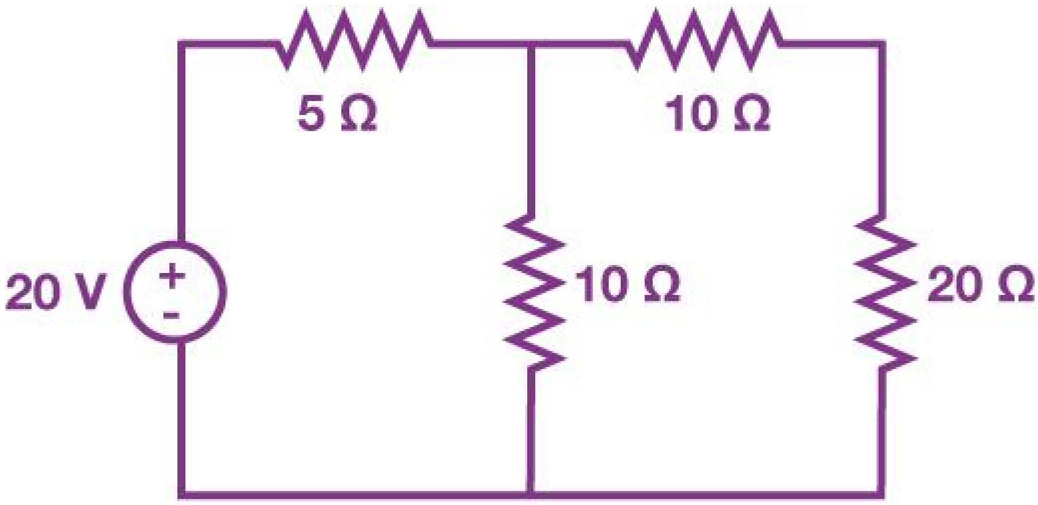
Superposition Theorem Solved Example

Example 1: Find the current flowing through 20 Ω using the superposition theorem.



Solution:

Step 1: First, let us find the current flowing through a circuit by considering only the 20 V voltage source. The current source can be open-circuited, hence, the modified circuit diagram is shown in the following figure.



Step 2: The nodal voltage V_1 can be determined using the nodal analysis method.

The nodal equation at node 1 is written as follows:

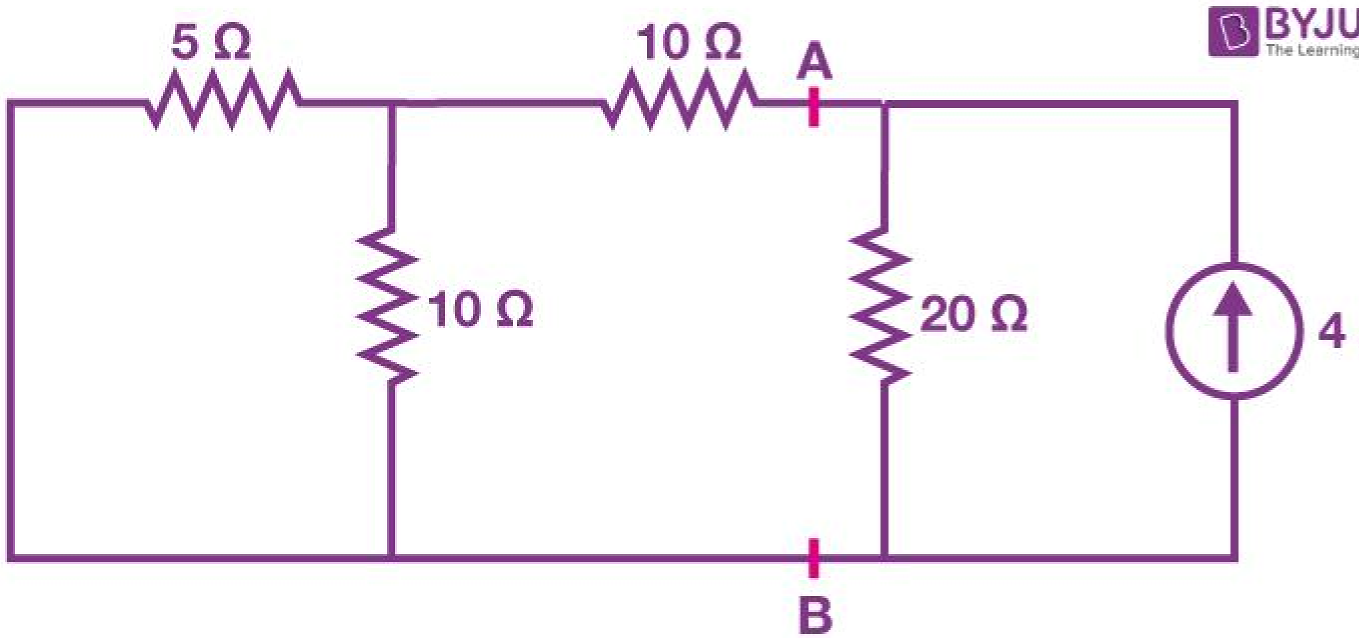
The current flowing through the 20 Ω resistor can be found using the following equation:

Substituting the value of the V_1 in the above equation, we get

$I_1 = 0.4$ A

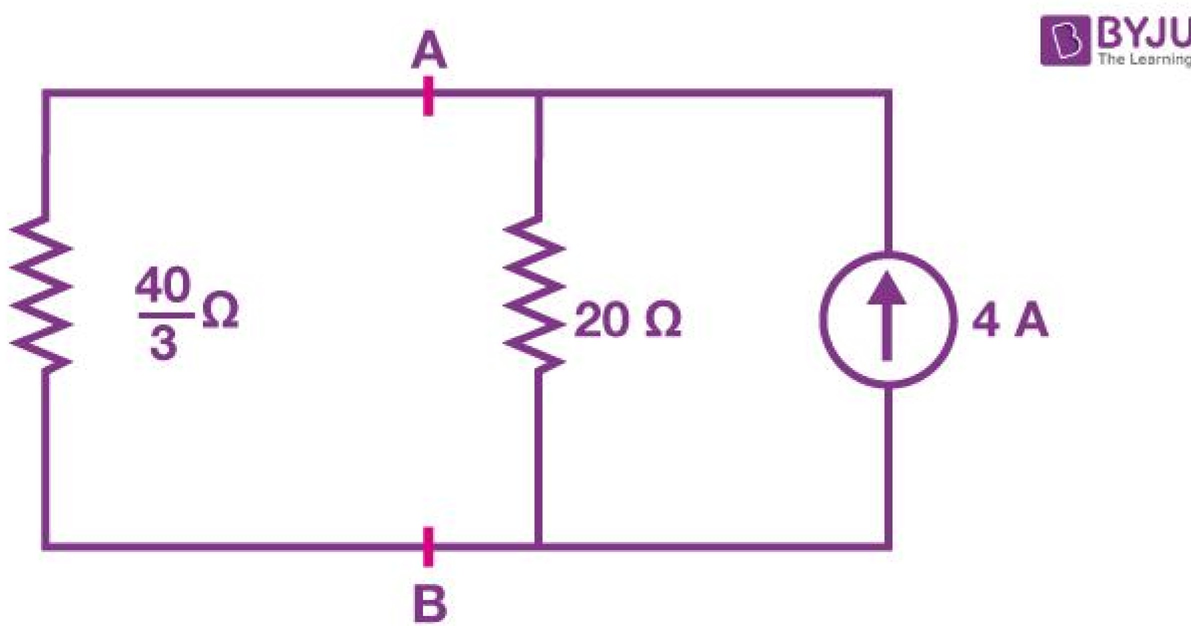
Therefore, the current flowing through the 20 Ω resistor to due 20 V voltage source is 0.4 A.

Step 3: Now let us find out the current flowing through the 20 Ω resistor considering only the 4 A current source. We eliminate the 20 V voltage source by short-circuiting it. The modified circuit, therefore, is given as follows:



In the above circuit, the resistors 5 Ω and 10 Ω are parallel to each other, and this parallel combination of resistors is in series with the 10 Ω resistor. Therefore, the equivalent resistance will be:

Now, the simplified circuit is shown as follows:



The current flowing through the 20 Ω resistor can be determined using the current division principle.

Substituting the values, we get

Therefore, the current flowing through the circuit when only 4 A current source is 1.6 A.

Step 4: The summation of currents I_1 and I_2 will give us the current flowing through the 20 Ω resistor. Mathematically, this is represented as follows:

$I = I_1 + I_2$

Substituting the values of I_1 and I_2 in the above equation, we get

$I = 0.4+1.6 = 2$ A

Therefore, the current flowing through the resistor is 2 A.

What is the Maximum Power Transfer Theorem?

Maximum Power Transfer Theorem explains that to generate maximum external power through a finite internal resistance (DC network), the resistance of the given load must be equal to the resistance of the available source.

The Maximum Power Transfer Theorem aims to figure out the value R_L, such that it consumes maximum power from the source.

$I = \frac{V_{Th}}{R_{Th}+R_L}$

The total power connected to the resistive load,

$$P_L = I^2 R_L = \left(\frac{V_{Th}}{R_{Th}+R_L}\right)^2 \times R_L$$

For maximum ->

$$\frac{dP_L}{dR_L} = 0$$

$$\frac{V_{Th}^2(R_{Th}-R_L)}{(R_{Th}+R_L)^3} = 0$$

$$(R_{Th} - R_L) = 0$$

➔ $R_{Th} = R_L$

Laws of Resistance

The resistance R offered by a conductor depends on the following factors :

(i) It varies directly as its length, l.

(ii) It varies inversely as the cross-section A of the conductor.

(iii) It depends on the nature of the material.

(iv) It also depends on the temperature of the conductor.

$$R \propto \frac{l}{A} \quad \text{or} \quad R = \rho\frac{l}{A}$$

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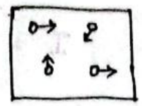
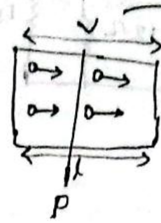
$\sigma = \cancel{nele}\ n e \mu_e$





$i = \frac{dQ}{dt}$

No of electron crossing per second $= n \times v \times A$

charge $= n \times v \times A \times e$

$\# \; I = nAve$

$= nAe \times \mu_e E = nAe\,\mu_e \times \frac{V}{l}$

$v = \mu_e E$

$E = \frac{V}{l}$

$R = \frac{V}{I} = \frac{l}{A} \times \left(\frac{1}{ne\mu_e}\right) = \frac{l}{A} \times \rho$

$\therefore \boxed{\rho = \frac{1}{ne\mu_e}}$ (resistivity) ; $\boxed{\sigma = n_e \mu_e}$ (conductivity)

e = charge of e

A = Cross section area

n = electron density /m³

l = Length of conductor

v = drift velocity $= \mu_e E$

Example 1.1. *A conductor material has a free-electron density of 10^{24} electrons per metre^3. When a voltage is applied, a constant drift velocity of 1.5×10^{-2} metre/second is attained by the electrons. If the cross-sectional area of the material is 1 cm^2, calculate the magnitude of the current. Electronic charge is 1.6×10^{-19} coulomb.* **(Electrical Engg. Aligarh Muslim University)**

Solution. The magnitude of the current is

$$i = nAev \text{ amperes}$$

Here, $n = 10^{24}$; $A = 1 \text{ cm}^2 = 10^{-4} \text{ m}^2$

$e = 1.6 \times 10^{-19}$ C ; $v = 1.5 \times 10^{-2}$ m/s

$\therefore \quad i = 10^{24} \times 10^{-4} \times 1.6 \times 10^{-19} \times 1.5 \times 10^{-2} =$ **0.24 A**

Example 1.2. *Find the velocity of charge leading to 1 A current which flows in a copper conductor of cross-section 1 cm^2 and length 10 km. Free electron density of copper = 8.5 × 10^{28} per m^3. How long will it take the electric charge to travel from one end of the conductor to the other?*

Solution. $i = neA\nu$ or $\nu = i/neA$

$\therefore \quad \nu = 1/(8.5 \times 10^{28} \times 1.6 \times 10^{-19} \times 1 \times 10^{-4}) = 7.35 \times 10^{-7}$ m/s = **0.735 μm/s**

Time taken by the charge to travel conductor length of 10 km is

$$t = \frac{\text{distance}}{\text{velocity}} = \frac{10 \times 10^3}{7.35 \times 10^{-7}} = 1.36 \times 10^{10} \text{ s}$$

Now, 1 year = 365 × 24 × 3600 = 31,536,000 s

$$t = 1.36 \times 10^{10}/31{,}536{,}000 = \mathbf{431 \text{ years}}$$

Example 51.4. *What length of a round copper wire of diameter 1 mm will have a resistance of 1k Ω if copper conductivity is 60 MS/m. A cylindrical piece of silicon having a diameter of 1 mm is doped with 10^{20} m^{-3} atoms of phosphorous which are fully ionized. What length of this silicon would be required to give a resistance of 1 k Ω if electronic mobility in silicon is 0.1 m^2 / V-s ?*

(Electronic Devices & Circuits, Pune Univ. 1994)

Solution. $R = 1 \text{ k}\Omega = 1000\ \Omega,\ \sigma = 60 \times 10^6 \text{ S/m},\ A = \pi d^2/4 = \pi \times (1 \times 10^{-3})^2/4\text{m}^2$

$R = l/\sigma A$

$l = \sigma AR = 60 \times 10^6 \times (\pi \times 10^{-6}/4) \times 1000 = 47{,}100$ m = **47.1 km**

For Silicon Wire

$$\sigma = n_i e\mu_e = 10^{20} \times 1.6 \times 10^{-19} \times 0.1 = 1.6 \text{ S/m}$$
$$l = \sigma AR = 1.6 \times (\pi \times 10^{-6}/4) \times 1000$$
$$= 1.26 \times 10^{-3} = \mathbf{1.26 \text{ mm}}$$

Example 51.5. *Calculate the intrinsic conductivity of silicon at room temperature if n = 1.41 × 10^{16} m^{-3}, μ_e = 0.145 m^2/V-s, μ_h = 0.05 m^2/V-s and e = 1.6 × 10^{-19} C. What are the individual contributions made by electrons and holes ?* **(Electronic Engg., Nagpur Univ. 1991)**

Solution. As seen from Art. 1.27, the conductivity of an intrinsic semiconductor is given by

$$\sigma_i = n_i e\,\mu_e + n_i e\,\mu_h$$
$$= 1.41 \times 10^{16} \times 1.6 \times 10^{-19} \times 0.145 + 1.41 \times 10^{16} \times 1.6 \times 10^{-19} \times 0.05$$
$$= 0.325 \times 10^{-3} + 0.112 \times 10^{-3} \text{ S/m} = \mathbf{0.437 \times 10^{-3} \text{ S/m}}$$

Contribution by electrons = **0.325 × 10^{-3} S/m**

Contribution by holes = **0.112 × 10^{-3} S/m**

Example 51.7. *An N-type silicon has a resistivity of 1500 Ω-m at a certain temperature. Compute the electron-hole concentration given that n_i = 1.5 × 10^{16} m^{-3}, μ_e = 0.14 m/V-s, μ_h = 0.05 m^2/V-s and e = 1.6 × 10^{-19} C.*

Solution. Being *N*-type silicon, it is assumed that $n \gg p$

$\therefore \quad \sigma = e(n\mu_e + p\mu_h) = n_e\,\mu_e$

$\therefore \quad \rho = 1/n_e\mu_e$ or $15 = 1/n \times 1.6 \times 10^{-19} \times 0.14$ or $n = \mathbf{3.1 \times 10^{20} \text{ m}^{-3}}$

Now, $\quad np = n_i^2$ or $p = n_i^2/n = (1.5 \times 10^{16})^2/(3.1 \times 10^{20}) = \mathbf{2 \times 10^{12} \text{ m}^{-3}}$

The conductivity of a semiconductor refers to its ability to conduct electric current.

Specific conductivity, also known as specific conductance or conductivity, refers to a measure of a material's ability to conduct an electric current. It is denoted by the symbol σ (sigma). Specific conductivity is different from electrical conductivity, which is represented by the symbol κ (kappa).

The specific conductivity (σ) of a material is calculated using the formula:

$$\sigma = \kappa \times \frac{1}{\text{Concentration of Charge Carriers}}$$

AC Fundamental

Properties of Waves

The properties mentioned below are applicable for all types:

Amplitude (A): The maximum displacement of a particle of the medium from its mean position is called Amplitude. Its S.I unit is meter.

Time period (T): The time required to complete one complete oscillation to and fro about its mean position by a particle of the medium is the time period T of the wave. It is measured in seconds.

Wavelength (λ): The distance between two successive crests or trough for a wave is termed wavelength. Its S.I unit is meter.

Frequency (n): The number of oscillations performed by a particle in one sec is termed as the frequency of waves. Its S.I unit is Hertz (Hz).

Frequency is the reciprocal of the time period

Velocity (v): The distance covered by a wave per unit of time is called the velocity of the wave. During the period (T), the wave covers a distance equal to the wavelength (λ).

$V = V_m \sin \omega t$ V

$I = I_m \sin(\omega t \pm \phi)$ A

For R ckt: $\boxed{I = V/R}$ A

For L ckt: $\boxed{I = V/X_L}$ A

For C ckt: $\boxed{I = V/X_C}$ A

$X_L = \omega L$, $X_C = \frac{1}{\omega C}$ Ω

$\boxed{X_L = 2\pi f L}$, $\boxed{X_C = \frac{1}{2\pi f C}}$ Ω

$\boxed{\omega = 2\pi f}$

* For R-L ckt: $I = V/Z$ A

$\boxed{Z = R + jX_L}$, $\boxed{Z = \sqrt{R^2 + X_L^2}}$ Ω

$\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$

* For R-C ckt: $I = V/Z$ A

$\boxed{Z = R - jX_C}$, $\boxed{Z = \sqrt{R^2 + X_C^2}}$

$\phi = \tan^{-1}\left(\frac{-X_C}{R}\right)$

* For R-L-C ckt: $I = V/Z$ A

$\boxed{Z = R + j(X_L - X_C)}$ Ω

$\boxed{Z = \sqrt{R^2 + (X_L - X_C)^2}}$ Ω

$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

* Power factor $= \cos\phi$ (lagging or leading)

$\boxed{V_R = I \times R}$ $\boxed{V_L = I \times (X_L \angle 90)}$ V

$\boxed{V_C = I \times (X_C \angle -90)}$ V

* Active Power, $P = I^2 R$ W or KW

$\boxed{P = |V| \cdot |I| \cos\phi}$ W or KW

* Reactive Power, $\boxed{Q = |V| \cdot |I| \sin\phi}$ VAR

* Apparent Power, $\boxed{S = \sqrt{P^2 + Q^2}}$ VA or KVA

$\boxed{V_{rms} = V_m/\sqrt{2}}$ $\boxed{I_{rms} = I_m/\sqrt{2}}$

Z = Impedance X = Reactance

X_L = Inductive Reactance

X_C = Capacitive Reactance

ω = angular velocity

t = time f = frequency

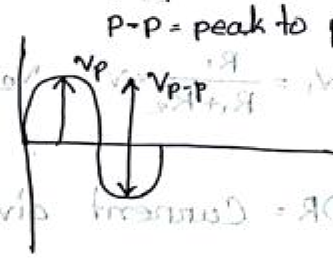
Physic class note-1

Electrical technology part-1

P = peak

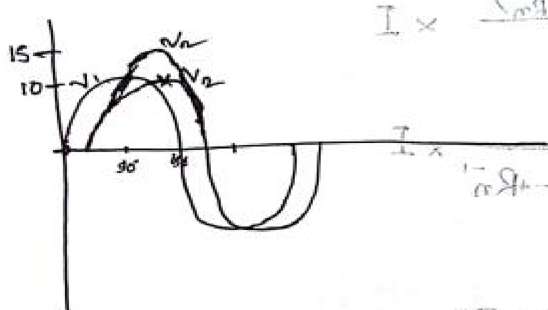
P-P = peak to peak

$R \propto L$ $R = \rho \frac{L}{A}$ $f = \frac{1}{T}$



$v_1 = 10 \sin 90°$

$v_2 = 15 \sin 120°$



v_2 is leading v_1 by 30°

v_1 is lagging v_2 by 30°

Leading/Lagging terminology for sinusoidal waves

Is there a method to identify which wave is leading and which wave is lagging from their *equations?*

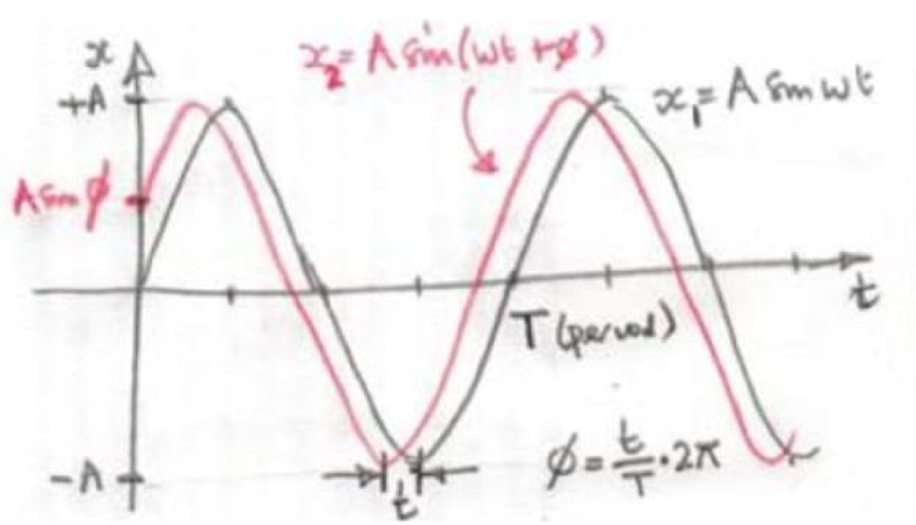
For example, if the two waves are $A\sin(\omega t+\pi/6)$ and $A\sin(\omega t+2\pi)=A\sin(\omega t)$

(by trigonometric relations), is the second wave leading in phase or lagging in phase compared to the first? Or we can say both is true?

What is the convention to be followed when we say "wave A leads wave B..." ?

you start from $y1=A\sin(\omega t)$ and compare it with $y2=A\sin(\omega t+\phi)$ you find that time $t=0$

motion 1 has a displacement of $y1=0$ and motion 2 has a displacement of $y1=\sin\phi$



You will see that whatever motion 2 does motion 1 does a little later in time so motion 2

leads motion 1 by phase angle ϕ .So the more positive ϕ represents the motion which is leading.

However it is also true the motion 1 lags motion 2 by phase angle ϕ. The way you have written the two motions your second motion leads your first motion by $2\pi-\pi6$. However if your two motions had been given as $A\sin(\omega t+\pi6)$ and $A\sin(\omega t)$ and no other information was given you would say that the first motion leads second motion by phase angle $\pi6$.

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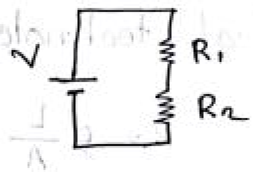
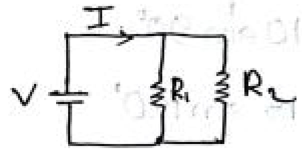
VDR = Voltage Divider law (series)

$$V_1 = \frac{R_1}{R_1+R_2} \times V \qquad V_2 = \frac{R_2}{R_1+R_2} \times V$$



CDR = Current divider Rule (parallel)

$$I_1 = \frac{R_2}{R_1+R_2} \times I \qquad I_2 = \frac{R_1}{R_1+R_2} \times I$$



$$I_i = \frac{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots + \frac{1}{R_n}\right)^{-1}}{R_i} \times I$$

$$= \frac{R_i^{-1}}{R_1^{-1} + R_2^{-1} + R_3^{-1} + \cdots + R_n^{-1}} \times I$$

$$V_i = \frac{R_i}{R_1 + R_2 + R_3 + \cdots + R_n} \times V$$

$$V_{avg} = 0.63\, V_m$$

$$V_{rms} = 0.7\, V_m$$

$\checkmark$ Aavarage value $= \dfrac{\int_0^{\pi} A_m \sin\theta \, d\theta}{\pi}$

$= \dfrac{-A_m [\cos\theta]_0^{\pi}}{\pi}$

$= \dfrac{-A_m [\cos\pi^\circ - \cos 0^\circ]}{\pi}$

$= \dfrac{-A_m (-1-1)}{\pi}$

$= \dfrac{2A_m}{\pi}$

$\therefore V_{avg} = 0.636 V_m$

$V_{avg(is\,symmetric)} = \dfrac{\text{Area of half cycle}}{\text{Base length of half cycle}}$

symmetric

$V_{rms} = \sqrt{\dfrac{\int_0^{\pi} v^2 d\theta}{\pi}}$

$= \sqrt{\dfrac{\int_0^{\pi} V_m^2 \sin^2\theta \, d\theta}{\pi}}$

$= V_m \sqrt{\dfrac{\int_0^{\pi} \sin^2\theta d\theta}{\pi}}$

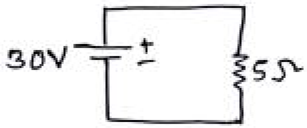
$= \dfrac{V_m}{\sqrt{\pi}} \sqrt{\dfrac{1}{2} \times \int_0^{\pi} 2\sin^2\theta d\theta}$

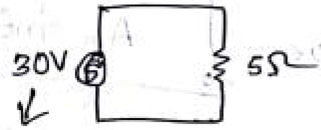
$= \dfrac{V_m}{\sqrt{\pi}} \sqrt{\dfrac{1}{2} \int_0^{\pi} (1-\cos 2\theta) \, d\theta}$

$= \dfrac{V_m}{\sqrt{2\pi}} \sqrt{\left[\theta - \dfrac{\sin 2\theta}{2}\right]_0^{\pi}} = \dfrac{V_m}{\sqrt{2\pi}} \sqrt{[\pi - 0]}$

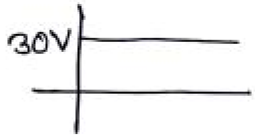
$= \dfrac{V_m}{\sqrt{2}}$

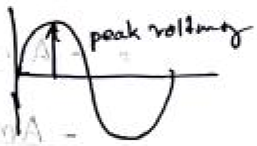
$\therefore V_{rms} = 0.707 V_m$





V = rms





$$V_{rms} = \frac{V_{peak}}{\sqrt{2}} = \frac{V_m}{\sqrt{2}}$$

$I_{dc} = i_{rms}$

$$P_{avg} = \frac{V_{rms}^2}{R} = I_{rms}^2 R = P_{dc}$$

$$I_{rms} = \sqrt{\frac{\int_0^\pi I_m^2 \sin^2\theta \, d\theta}{\pi}}$$

$$= \frac{I_m}{\sqrt{\pi}} \times \sqrt{\frac{1}{2}\int_0^\pi 2\sin^2\theta \, d\theta}$$

$$= \frac{I_m}{\sqrt{\pi}} \times \frac{1}{\sqrt{2}} \sqrt{\int_0^\pi 2\sin^2\theta \, d\theta}$$

$$= \frac{I_m}{\sqrt{2\pi}} \times \sqrt{\left[\theta - \frac{\cancel{\cos}\sin 2\theta}{2}\right]_0^\pi}$$

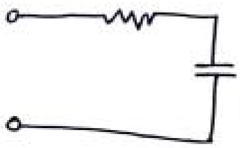
$$= \frac{I_m}{\sqrt{2\pi}} \times \sqrt{\pi}$$

$$= \frac{I_m}{\sqrt{2}}$$

$$\therefore I_{rms} = \frac{I_m}{\sqrt{2}}$$

$$Avg = \sqrt{\frac{\text{area of half cycle of square form}}{\text{lenth of half cycle}}}$$

AC: RC (Resistor & capacitor) circuits



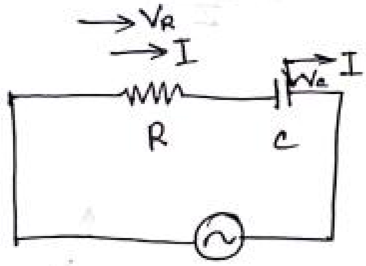
$V_c = V_m \sin\theta$

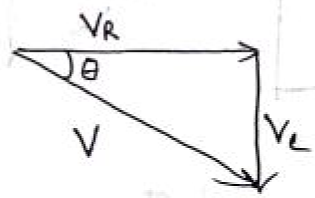
$$i_c = C\frac{dv}{dt}$$

$$= C \frac{d}{dt} V_m \sin(\omega t)$$

$$= CV_m\omega \cos\omega t$$

$$= CV_m\omega \sin(\omega t + 90)$$





$$\therefore V = \sqrt{V_R^2 + V_c^2}$$

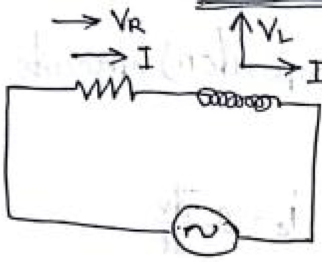
$$= \sqrt{(I_R R_b)^2 + (I_R X_c)^2}$$

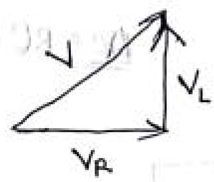
$$= I_R \sqrt{R^2 + x_c^2}$$

angle $= \theta = \tan^{-1} \frac{X_c}{R} = \frac{V_c}{V_R}$

powerfactor $= \cos\theta = \frac{R}{Z}$

RL circuit (Resistance and Inductor)

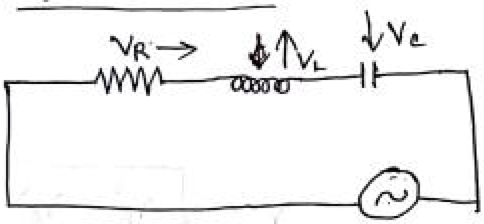


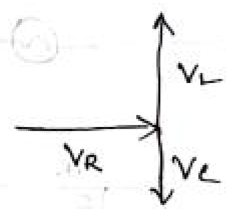


$$V = \sqrt{(V_R)^2 + (V_L)^2}$$
$$= \sqrt{(IR)^2 + (IX_L)^2}$$
$$= I\sqrt{R^2 + X_L^2}$$

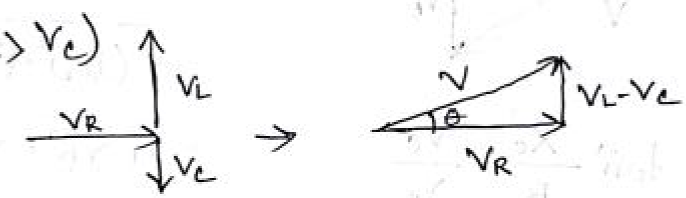
$$\therefore I = \frac{V}{\sqrt{R^2 + X_C^2}}$$
$$= \frac{V}{Z}$$

RLC circuit





if $(V_L > V_C)$



$$\therefore V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$
$$= I\sqrt{R^2 + (X_L - X_C)^2}$$

Electromagnetic Induction

BKP PHY 08-08-2023

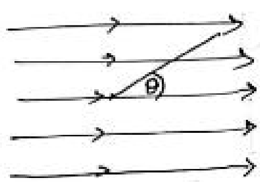
Magnetic field area around a magnet of magnetic object is experienced. or an electric charge in which magnetic force is


Lines of force:

Magnetic flux: is a measurement of the total magnetic field which passes through a given area.

$$\boxed{\varphi = AB\cos\theta}$$

B = magnetic field
A = area
θ = angle between perpendicular between area and magnetic field



Faraday's induction law: The emf induced in a circuit is directly proportional to the rate of change of flux through the circuit.

$$\text{flux, } \mathcal{E} = -N \frac{d\varphi}{dt}$$

Lenz's law: The friction of electric current induced in a conductor by a magnetic field is such that the magnatic field induceed opposes changes in the initial magnetic field.

$$e = -N\frac{d\phi}{dt}$$

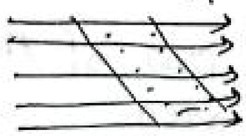
$$= -N\,AB\frac{d}{dt}\cos\omega t$$

$$= NAB\,\omega\sin\omega t$$

$e_{max} \rightarrow$ when $\sin\omega t = 1 \Rightarrow \theta = 90^\circ$ & 270°

$e_{min} \rightarrow$ when $\theta = 0^\circ$ & 180°

$A = 2\times10^{-2}\,m^2$



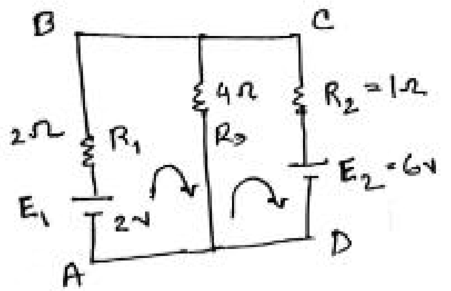
$V = 250V$

$N = ?$

$B = 0.15T$

$250 = N \times 2\times10^{-2} \times 0.15 \times 2\pi \times 60$

$N = 21.048$



Mesh Theory

(i) Assign current in clock wise direction

(ii) indicate polarity

(iii) Apply KVL

$E_1 - 2I_1 - 4(I_1 - I_2) = 0$

$\Rightarrow E_1 = 2I_1 + 4(I_1 - I_2)$

$\Rightarrow 2 = 2I_1 + 4I_1 - 4I_2$

$\Rightarrow 1 = 3I_1 - 2I_2$

$\therefore I_1 = 17/7$ A

$I_2 = 22/7$ A

$6 - 4(I_2 - I_1) - I_2 = 0$

$\Rightarrow 4I_2 - 4I_1 + I_2 = 6$

$\Rightarrow 5I_2 - 4I_1 = 6$

$\Rightarrow -$

BKP PHY 10-08-2023

Electric field:

q ——— r ——— q_0 $\quad F = \frac{1}{4\pi\epsilon_0} \times \frac{qq_0}{r^2}$

$$E = \frac{F}{q_0}$$

Electric Flux: is the measured of flow of the electric field through a given area.

$$\varphi = EA\cos\theta$$

$$d\varphi = E\,dA\cos\theta$$

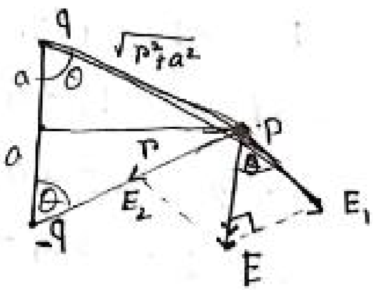
$$= \vec{E}\cdot d\vec{A}$$

Electric dipole: +q ——— 2a ——— -q

d

Electric dipole moment: $q \times d$

Electric field of electric dipole:



$$E_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{r^2+a^2}$$

$$E = 2E_1\cos\theta$$

$$\cos\theta = \frac{PE}{PE_1}$$

$$\cos\theta = \frac{a}{\sqrt{r^2+a^2}}$$

$$\cancel{E = \sqrt{E_1^2+E_2^2+2E_1E_2\cos\theta}}$$

$$E = E_1\cos\theta$$

$$\Rightarrow E = 2E_1\cos\theta$$

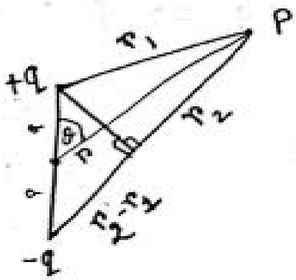
$$= 2\frac{1}{4\pi\epsilon_0}\frac{q}{r^2+a^2}\cdot\frac{a}{\sqrt{r^2+a^2}} = \frac{2aq}{4\pi\epsilon_0}\cdot\frac{1}{(r^2+a^2)^{\frac{3}{2}}}$$

if $r >> a$

$$E \cong \frac{1}{4\pi\epsilon_0}\frac{2aq}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{p}{r^3}$$

$$V \cancel{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{r}$$

Potential of a Dipole



$$V_{+q} = \frac{1}{4\pi\epsilon_0}\frac{q}{r_1}$$

$$V_{-q} = \frac{1}{4\pi\epsilon_0}\frac{-q}{r_2}$$

$$V = \frac{1}{4\pi\epsilon_0}\left(\frac{q}{r_1} - \frac{q}{r_2}\right) = \frac{q}{4\pi\epsilon_0}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

if $r >> 2a$

$r_2 - r_1 = 2a\cos\theta$

$\cos\theta = \frac{r_2 - r_1}{2a}$

$r_1 r_2 = r^2$

$$V = \frac{1}{4\pi\epsilon_0}\frac{2aq\cos\theta}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{p\cos\theta}{r^2}$$

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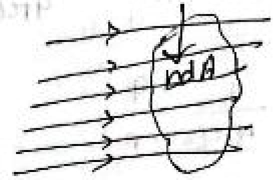
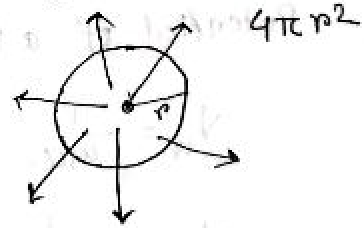
17-08-2023

$$\phi = \oint da = \oint \vec{E}\, d\vec{A}$$
$$= \oint E\, dA \cos\theta$$



$$\phi \propto q \Rightarrow \phi = \frac{q}{\epsilon_0}$$



$$\epsilon_0 E A = q$$

$F = q_0 E$

$$\epsilon_0 \times E \times 4\pi r^2 = q$$

$$\boxed{\therefore E = \frac{1}{4\pi\epsilon_0} \times \frac{q}{r^2}}$$

$$\frac{F}{q_0} = \frac{1}{4\pi\epsilon_0} \frac{q}{r^2} \quad \therefore \boxed{F = \frac{1}{4\pi\epsilon_0} \times \frac{q_0 q}{r^2}}$$

CT | Thursday : 24-08-2023

KVL, Thevenins, Norton

29-08-2023

BKP

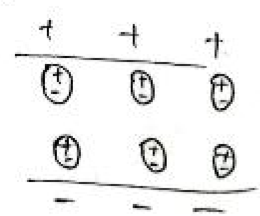
Permittivity ⇒ (ϵ) is a measure of Polarization polarizability of a die electric.

Relative permittivity ⇒ $\epsilon_r = \frac{\epsilon}{\epsilon_0}$ | $E = \frac{V}{d}$

Electric displacement $D = \epsilon_0 E$

$D = \epsilon_0 \epsilon_r E$

(in medium)

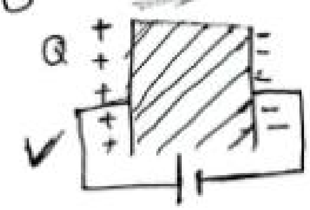


Capacitance is the ability of a component or circuit to collect and store energy in the form of an electrical charge.

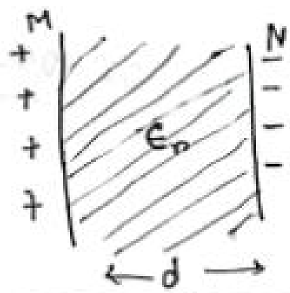
Capacitors are energy-storing devices available in many sizes and shapes.

Electric displacement / Flux density $\rightarrow D = \frac{\psi}{A}$

<u>Capacitor:</u> Consists of two conducting surface separated by a die electric.



Capacitance, $C = \frac{Q}{V}$

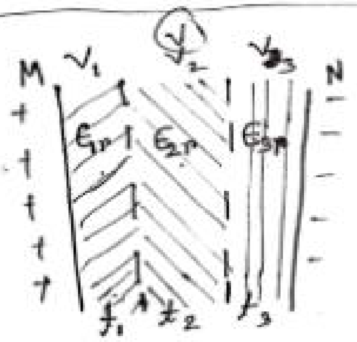


$\psi = Q$; $D = \frac{\psi}{A} = \frac{Q}{A}$ | $E = \frac{V}{d}$

$$\frac{Q}{A} = \epsilon \left(\frac{V}{d}\right)$$

$$C = \epsilon \frac{A}{d}$$

$$\Rightarrow C = \epsilon_0 \epsilon_r \frac{A}{d}$$



(3 kind of dielectric)

$$V = V_1 + V_2 + V_3$$

$$= E_1 t_1 + E_2 t_2 + E_3 t_3$$

$$= \frac{D}{\epsilon_0 \epsilon_{1r}} t_1 + \frac{D}{\epsilon_0 \epsilon_{2r}} t_2 + \frac{D}{\epsilon_0 \epsilon_{3r}} t_3$$

$$= \frac{Q}{A\epsilon_0 \epsilon_{1r}} t_1 + \frac{Q}{A\epsilon_0 \epsilon_{2r}} t_2 + \frac{Q}{A\epsilon_0 \epsilon_{3r}} t_3$$

V = worked done in shifting 1 Q of charge from one plate to another

$$V = \frac{Q}{A\epsilon_0} \left(\frac{t_1}{\epsilon_{1r}} + \frac{t_2}{\epsilon_{2r}} + \frac{t_3}{\epsilon_{3r}} \right)$$

$$C = \frac{A\epsilon_0}{\left(\frac{t_1}{\epsilon_{1r}} + \frac{t_2}{\epsilon_{2r}} + \frac{t_3}{\epsilon_{3r}} \right)} \qquad \left(C = \frac{Q}{V}\right)$$

$dq = c\,dv$

$q = Cv$

$dw = v\,dq$

$= cv\,dv$

$\therefore w = \int_0^v cv\,dv = c\int_0^v v\,dv = c\left[\frac{v^2}{2}\right]_0^v$

$= \frac{c}{2}(v^2 - 0) = \frac{1}{2}cv^2$

$\boxed{\therefore w = \frac{1}{2}cv^2}$

BkP PHY 05-09-2023

CT-② | 14-09-2023 (Thursday)
A.C. Fundemental.

How to increase capacitance

Capacitance can be increased when:

1. **A capacitor's plates (conductors) are positioned closer together.**
2. **Larger plates offer more surface area.**
3. **The dielectric is the best possible insulator for the application.**

Credit :

1.Akib Zaman

2.Mosabbeer Hossain

3.Alvee

Special credit goes to Bimol Kumal Pramanik SIR

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