EEE 101 Basic Electrical and Electronic Circuits

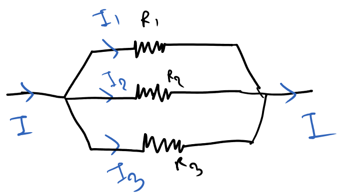
Tuesday, June 22, 2021 12:10 AM

Circuit Analysis

Monday, June 14, 2021 11:36 AM

Current, voltage, Resistance

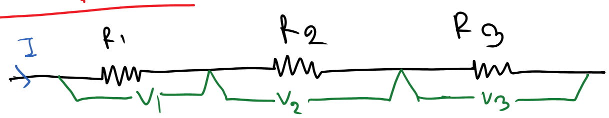
Current Divider Law



$$I \propto \frac{1}{R}$$

$$\boxed{I_i = \frac{\frac{1}{R_i}}{\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}} \times I}$$

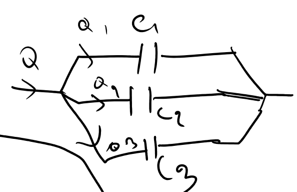
Voltage Divider Law



$$V \propto R$$

$$\boxed{V_1 = \frac{R_i}{R_1+R_2+R_3} \times V}$$

Charge Divider Rule



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

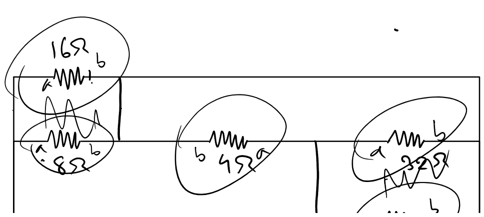
$$Q \propto C$$

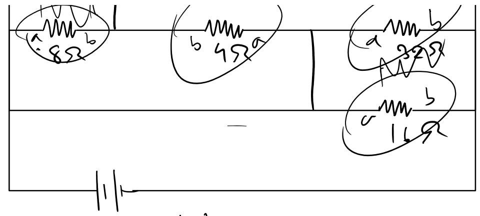
$$\boxed{Q_1 = \frac{C_1}{C_1+C_2+C_3} \times Q}$$

$$V \propto \frac{1}{C}$$

$$\boxed{V_1 = \frac{\frac{1}{C_1}}{\frac{1}{C_1}+\frac{1}{C_2}+\frac{1}{C_3}} \times V}$$

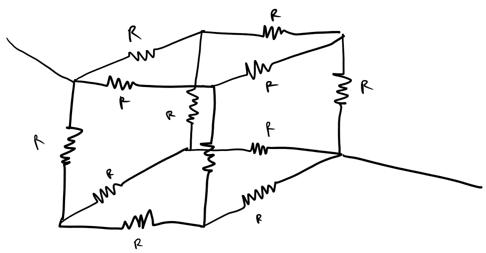
Resistance Math



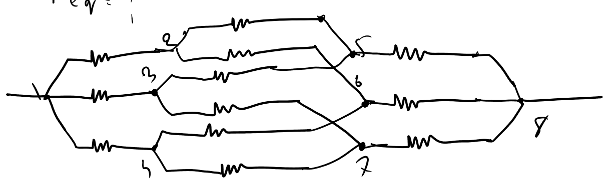


32V

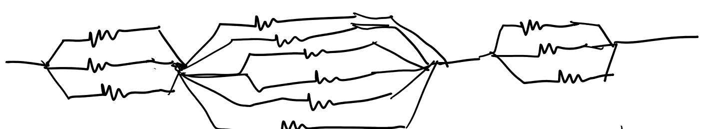
All are in parallel. R_{eq} = 16 || 8 || 4 || 16 || 32



$R_{eq} = ?$



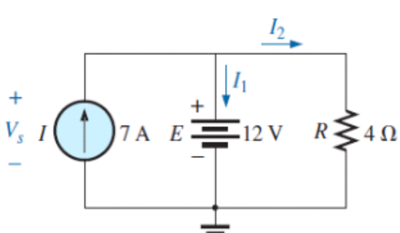
2, 3, 4 same potential with 5, 6, 7



$$R_{eq} = \left(\left(\frac{1}{R}+\frac{1}{R}+\frac{1}{R}\right) + \left(\frac{6}{R}\right) + \left(\frac{3}{R}\right)\right)^{-1}$$

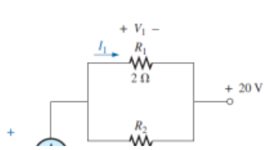
$$= \frac{R}{3} + \frac{R}{6} + \frac{R}{3}$$

Current Source



$V_s = ?$
$I_1 = ?$
$I_2 = ?$

$I_2 = \frac{12}{4} = 3$, $I_1 = 4$, $V_s = 12$



$V_s = ?$, $I_1 = ?$ $I_1 = \frac{4}{2} = 2$

$V_s - V_1 = 20$

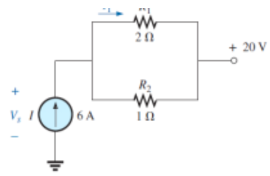


FIG. 8.4
Example 8.3.

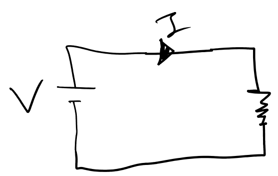
$V_s - V_1 = 20$

$R_p = \frac{2}{3}$ $\quad V_1 = 4$

$V_1 = \cancel{6}^{\,2} \times \frac{2}{3} = 4$ $\quad V_s = 24$

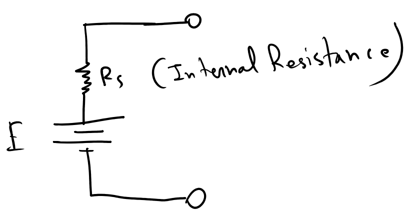
Ideal voltage source

- Provides any current necessary



$I = \frac{V}{R}$

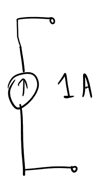
Real voltage source



Current Source

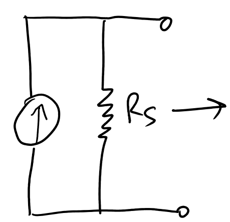
Ideal

provide whatever voltage necessary

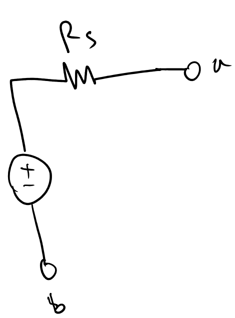


$V = IR$

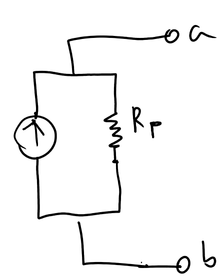
Real



Source conversion



$\equiv$



$V = I R_s$ $\qquad I = \frac{V}{}$

$V = I R_s$

condition
$R_p = R_s$

$I = \frac{V}{R_p}$

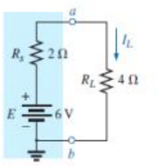


FIG. 8.7
Practical voltage source and load for Example 8.4.

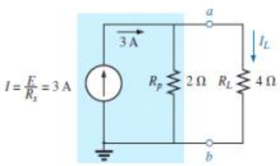


FIG. 8.8
Equivalent current source and load for the voltage source in Fig. 8.7.

the equivalence between a current source and a voltage source exists only at their external terminals.

The internal characteristics of each are quite different.

EXAMPLE 8.4 For the circuit in Fig. 8.7:

a. Determine the current I_L.
b. Convert the voltage source to a current source.
c. Using the resulting current source of part (b), calculate the current through the load resistor, and compare your answer to the result of part (a).

Solutions:

a. Applying Ohm's law:

$$I_L = \frac{E}{R_s + R_L} = \frac{6\text{ V}}{2\,\Omega + 4\,\Omega} = \frac{6\text{ V}}{6\,\Omega} = \mathbf{1\text{ A}}$$

b. Using Ohm's law again:

$$I = \frac{E}{R_s} = \frac{6\text{ V}}{2\,\Omega} = \mathbf{3\text{ A}}$$

and the equivalent source appears in Fig. 8.8 with the load reapplied.

c. Using the current divider rule:

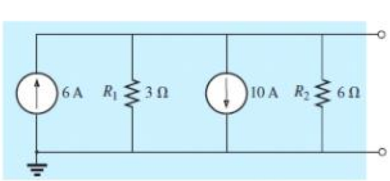
$$I_L = \frac{R_p I}{R_p + R_L} = \frac{(2\,\Omega)(3\text{ A})}{2\,\Omega + 4\,\Omega} = \frac{1}{3}(3\text{ A}) = \mathbf{1\text{ A}}$$

We find that the current I_L is the same for the voltage source as it was for the equivalent current source—the sources are therefore equivalent.

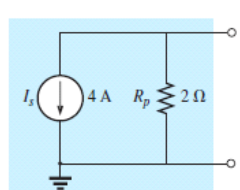
As demonstrated in Fig. 8.5 and in Example 8.4, note that

a source and its equivalent will establish current in the same direction through the applied load.

**** two or more current sources in parallel can be replaced by a single current source having a magnitude determined by the difference of the sum of the currents in one direction and the sum in the opposite direction. The new parallel internal resistance is the total resistance of the resulting parallel resistive elements.****

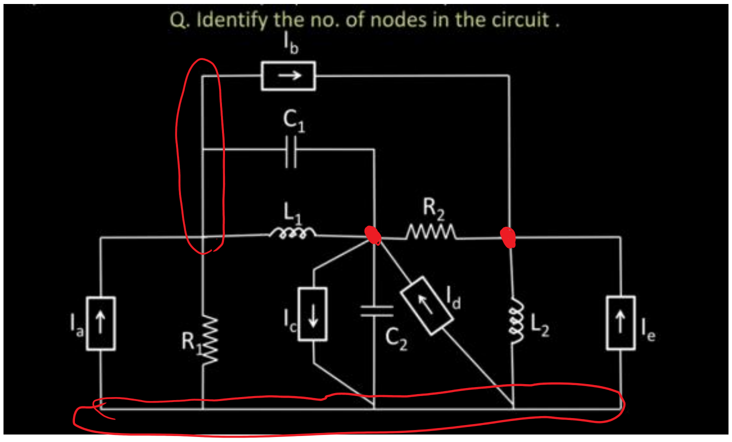


⇒



Nodal Analysis

Node: It's a point or junction in the circuit where two or more than two elements are connected

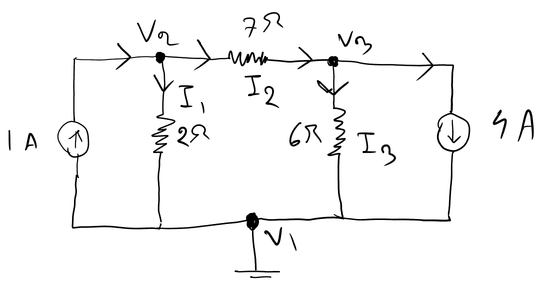


If you forgot the idea of identifying nodes: [click here]

Ans = 4 , if nodes have same potential then , It can be marked together

Steps of Nodal Analysis:

1. Identify the nodes
2. Consider a reference node (ground धरा)
3. KCL, Ohm
4. Current Direction



let $V_1 = 0$;

$$I_1 = \frac{V_2 - 0}{2}, \quad I_2 = \frac{V_2 - V_3}{7}, \quad I_3 = \frac{V_3 - 0}{6}$$

Node 2: $1 - I_2 - I_1 = 0$

$$\Rightarrow I_1 + I_2 = 1$$

$$\Rightarrow \frac{V_2}{2} + \frac{V_2 - V_3}{7} = 1$$

$$\Rightarrow 7V_2 + 2V_2 - 2V_3 = 14$$

$$\Rightarrow 9V_2 - 2V_3 = 14 \quad \text{—— (iv)}$$

Node-3: $I_2 - I_3 = 4$

$$\Rightarrow \frac{V_2 - V_3}{} - \frac{V_3}{} = 4$$

$$\Rightarrow \frac{V_2 - V_3}{7} - \frac{V_3}{6} = 4$$

$$6V_2 - 13V_3 = 168 \quad \text{———— (v)}$$

Node-1: $-1 + I_1 + I_3 + 4 = 0$

$$\Rightarrow I_1 + I_3 = -3$$

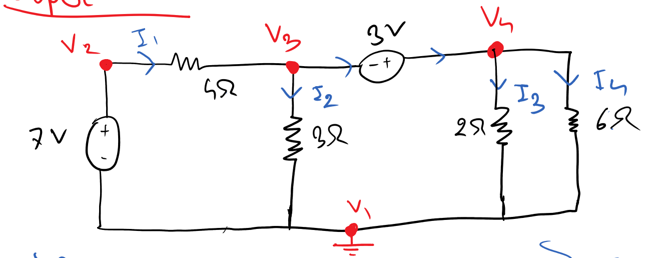
$$\Rightarrow \frac{V_2}{2} + \frac{V_3}{6} = -3$$

$$\Rightarrow 3V_2 + V_3 = -18 \quad \text{———— (vi)}$$

Solving (4, 5, 6)

$V_1 = 0$,
$V_2 = -2$ V
$V_3 = -14$ V

Super Node



* ২টি node এর মাঝখানে voltage থাকলে ২টাকে একসাথে ধরি. (Super Node)

$V_1 = 0$

$V_2 - V_1 = 7 \Rightarrow V_2 = 7$, $\quad V_4 - V_3 = 3 \quad \text{———— (i)}$

$$I_1 = \frac{V_3 - 7}{4}, \quad I_2 = \frac{-V_3}{3}, \quad I_3 = \frac{-V_4}{2}, \quad I_4 = \frac{-V_4}{6}$$

Super Node $V_3 + V_4$: $I_1 = I_2 + I_3 + I_4$

$$\frac{V_3 - 7}{4} = \frac{-V_3}{3} - \frac{V_4}{2} - \frac{V_4}{6}$$

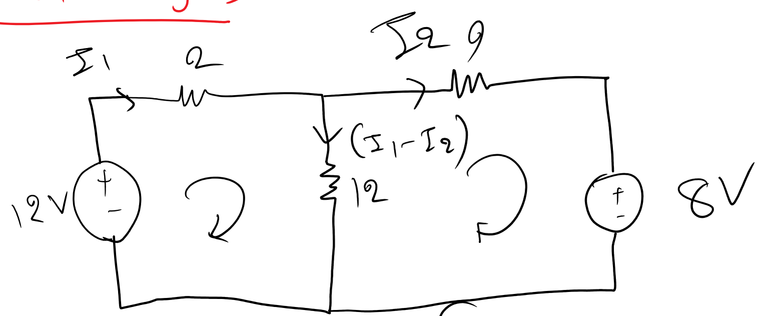
$$\Rightarrow 8V_4 + 7V_3 = 2 \quad \text{———— (ii)}$$

Solving (i) & (ii) ⇒

$V_4 =$

$V_3 =$

Mosh analysis



Steps: KVL (2Ω (12Ω loop →

KVL for Mesh - 1 :

$$2I_1 + 12(I_1 - I_2) = 12 \Rightarrow 14I_1 - 12I_2 = 12 \quad \text{——— (i)}$$

KVL for Mesh - 2 :

$$9I_2 + 8 + 12(I_1 - I_2) = 0$$

$$\Rightarrow 12I_1 - 21I_2 = 8$$

$$\therefore I_1 = 1.04\,A, \quad I_2 = 0.21\,A$$

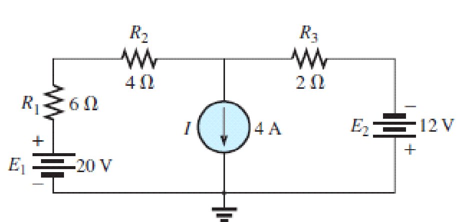


FIG. 8.33

Q. Using Mesh analysis find out the currents in the figure.

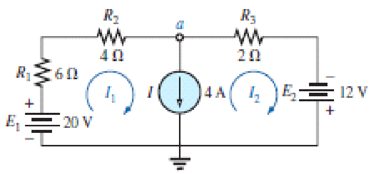


FIG. 8.34
Defining the mesh currents for the network in Fig. 8.33.

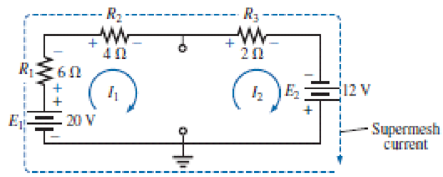


FIG. 8.35
Defining the supermesh current.

Solution: First, the mesh currents for the network are defined, as shown in Fig. 8.34. Then the current source is mentally removed, as shown in Fig. 8.35, and Kirchhoff's voltage law is applied to the resulting network. The single path now including the effects of two mesh currents is referred to as the path of a *supermesh current.*

Applying Kirchhoff's law:

$$20\text{ V} - I_1(6\ \Omega) - I_1(4\ \Omega) - I_2(2\ \Omega) + 12\text{ V} = 0$$

or

$$10I_1 + 2I_2 = 32$$

Node a is then used to relate the mesh currents and the current source using Kirchhoff's current law:

$$I_1 = I + I_2$$

The result is two equations and two unknowns:

$$\begin{aligned} 10I_1 + 2I_2 &= 32 \\ I_1 - I_2 &= 4 \end{aligned}$$

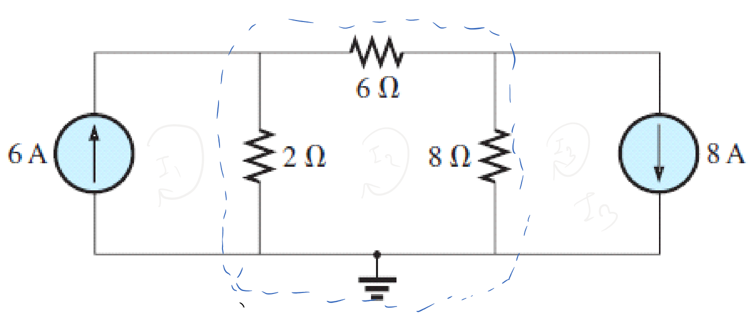
Applying determinants:

$$I_1 = \frac{\begin{vmatrix} 32 & 2 \\ 4 & -1 \end{vmatrix}}{\begin{vmatrix} 10 & 2 \\ 1 & -1 \end{vmatrix}} = \frac{(32)(-1) - (2)(4)}{(10)(-1) - (2)(1)} = \frac{40}{12} = \mathbf{3.33\ A}$$

and

$$I_2 = I_1 - I = 3.33\text{ A} - 4\text{ A} = \mathbf{-0.67\ A}$$

In the above analysis, it may appear that when the current source was removed, $I_1 = I_2$. However, the supermesh approach requires that we stick with the original definition of each mesh current and not alter those definitions when current sources are removed.



By removing current source, we get a super mesh.

KVL in Supermesh:

$$6I_2 + (I_2 - I_3)8 + (I_2 - I_1)2 = 0$$

$$\Rightarrow 16I_2 - 8I_3 - 2I_1 = 0$$

from the 1st and last mesh:

$I_1 = 6$

$I_3 = 8$

$\therefore I_2 = 4.75$

$\therefore I_{8\Omega} = I_2 - I_3 = -3.75\,A$

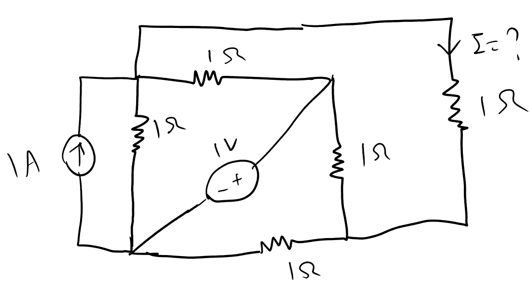
$I_{2\Omega} = I_2 - I_1 = 1.25\,A$

Superposition Theorem

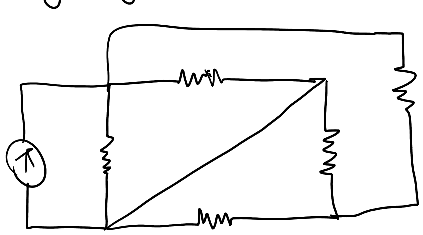
- Voltage source হলে short
- Current Source " open
- Do node analysis if current source.
- Do Mesh " if voltage " .

Here is the PDF of Superposition theorem

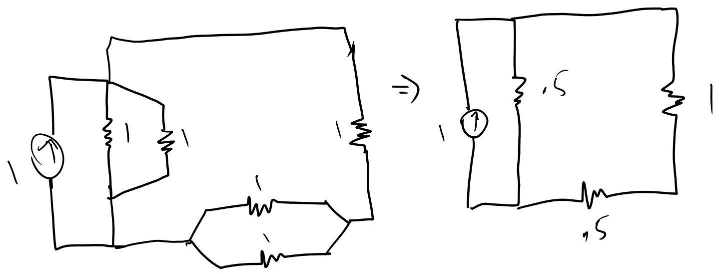
Q. Find I in the following diagram with the help of superposition theorem

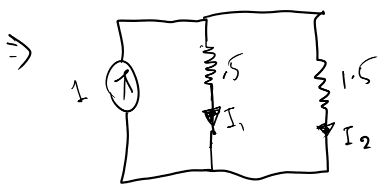


So, Applying Superposition theorem,
Considering only current source,



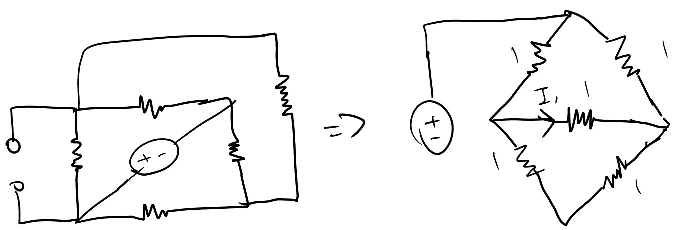
$\Downarrow$





$$I_2 = \frac{0.5}{1.5 + .5} \times 1 = .25\,A$$

Now, considering only voltage source,



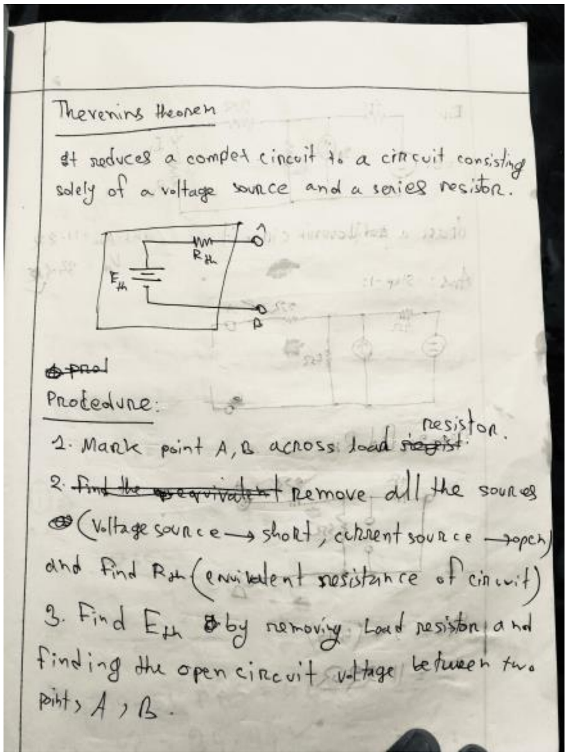
$$\frac{1}{1} = \frac{1}{1}$$

So, $I = 0$

$\therefore$ total current $= .25\,A + 0\,A$

$= 0.25\,A$

Thevenin's theorem



Thevenins theorem

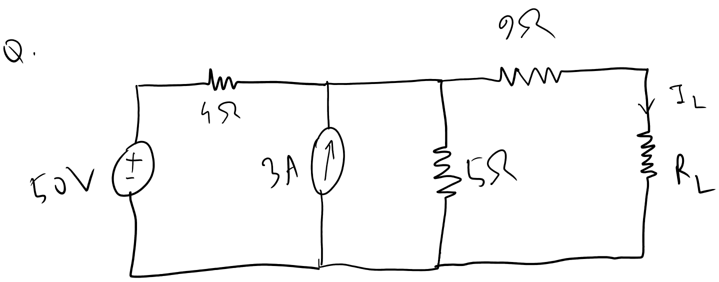
It reduces a complex circuit to a circuit consisting solely of a voltage source and a series resistor.

~~prod~~

Procedure:

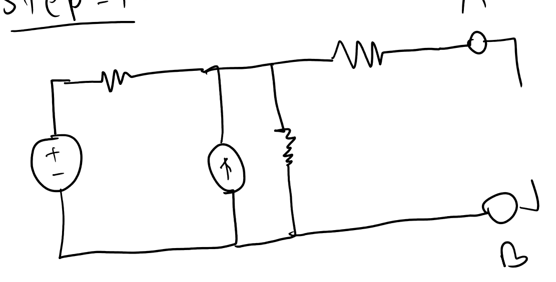
1. Mark point A, B across load ~~resist~~ resistor.
2. ~~Find the equivalent~~ Remove all the sources (Voltage source → short, current source → open) and find R_{th} (equivalent resistance of circuit)
3. Find E_{th} by removing Load resistor and finding the open circuit voltage between two points A, B.

Q.

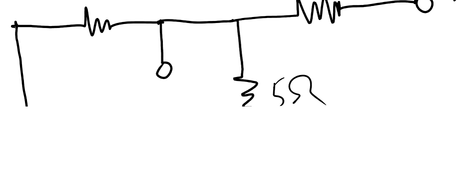


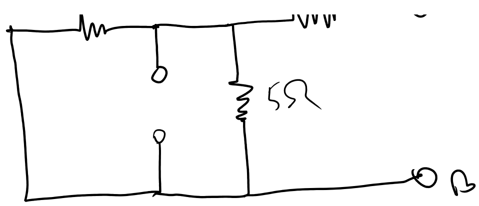
draw a thevenin's circuit

Ans: Step-1:



Step-2: find R_{th}

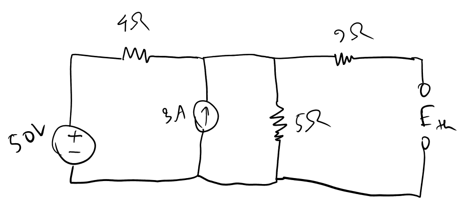




$$R_{th} = 9 + (4 \parallel 5)$$
$$= 11.22$$

Step-3: Find E_{th}

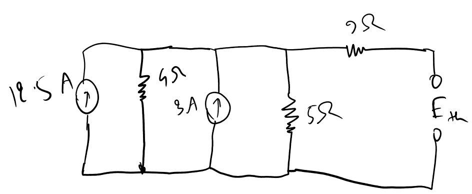
I'll use node analysis,

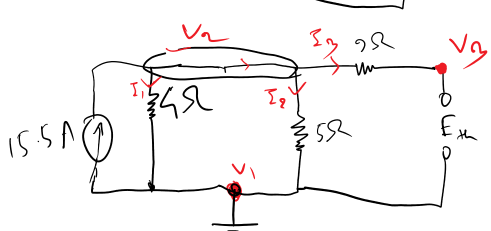


$R_p = 4\Omega$

$I = \frac{50}{4} = 12.5$

Converting voltage source to current source





here, $E = V_3 - V_1$

Ohm's Law: $I_1 = \frac{V_2}{4}$, $I_2 = \frac{V_2}{5}$, $I_3 = \frac{V_3 - V_2}{9}$

Node V_1: $I_1 + I_2 + I_3 = 15.5$ — (i)

Node V_2: $-I_1 - I_2 + 15.5$

Node V_1: $I_1 + I_2 + I_3 = 15.5$ — (i)

Node V_2: $-I_1 - I_2 + 15.5$

$I_1 + I_2 = 15.5$ — (ii)

So $I_3 = 0$ [from (i) & (ii)]

$\therefore V_2 = V_3$ [from ohm's law]

(ii) $\Rightarrow \frac{V_2}{4} + \frac{V_2}{5} = 15.5$

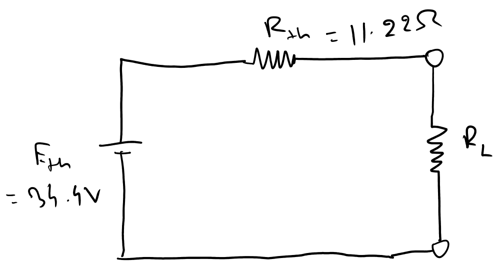
$5V_2 + 4V_2 = 15.5 \times 20$

$\Rightarrow 9V_2 = 15.5 \times 20$

$V_2 = 34.44\,V$

$\therefore E_{th} = 34.44\,V$, $R_{th} = 11.22\,\Omega$

So, given thevenin's circuit,



Applications of Thevenin's theorem

Now, if we change R_L's value, we will immedietly find the current through and voltage across this R_L

Like, if $R_L = 2\,\Omega$,

Then, $I_L = \frac{E_{th}}{R_{th}+R_L} = 2.60A$

If $R_L = 4\,\Omega$,

Then, $I_L = \frac{E_{th}}{R_{th}+R_L} = 2.26A$

Now, if Thevenin's theorem wasn't available, then we would have to re-calculate the whole circuit in order to find I_L again.

So, when we focus on a particular element of a circuit and want to know about the effects of it's change, we will apply Thevenin's theorem.

Norton's circuit:

Here is the PDF of this topic

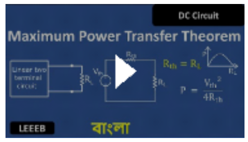
MAXIMUM POWER TRANSFER THEOREM:

Maximum Power Transfer Theorem (Bangla Tutorial) Part -01 | DC Circuit

Maximum power transfer theorem states that,

MAXIMUM POWER TRANSFER THEOREM:

[Maximum Power Transfer Theorem (Bangla Tutorial) Part -01 | DC Circuit]

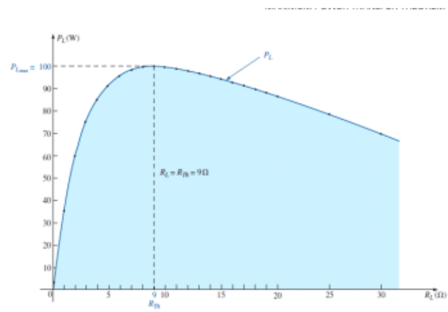


Maximum power transfer theorem states that, maximum power is transferred to the load resistance when load resistance will be equal to Thevenin's resistance.

$P = P_{max}$ when,
$R_L = R_{Th}$
$P_{max} = I^2 R_L$
$I = \dfrac{E_{th}}{R_{th} + R_L}$
$P_{max} = \left(\frac{E_{th}}{R_{th}+R_L}\right)^2 R_L$
$P_{max} = \dfrac{E_{th}^2}{4R_L}$

Proof:

We know,
$P = I^2 R \;----(1)$
For a Thevenin's Circuit
$I = \dfrac{E_{th}}{R_{th} + R_L} \;----(2)$
So,
$P = \left(\frac{E_{th}}{R_{th}+R_L}\right)^2 R_L$
From equation (1) and (2) we find that
$P \propto R_L$
And $R_L \propto \frac{1}{I}$
So $P \propto \frac{1}{R_L}$



So the function is firstly increasing and then decreasing with respect to R_L (shown in the graph)

We need to find the maximum point of the graph.
We will use differentiation to find the maximum

For maximum,

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

$$\frac{d\left(\left(\frac{E_{th}}{R_{th} + R_L}\right)^2 R_L\right)}{dR_L} = 0$$

$$E_{th}^2 \frac{d}{dR_L}\left(\left(\frac{1}{R_{th} + R_L}\right)^2 R_L\right) = 0$$

$(R_{th}+R_L)(R_{th} - R_L) = 0$
$(R_{th}+R_L) \neq 0$
So, $R_L = R_{th}$
And therefore,

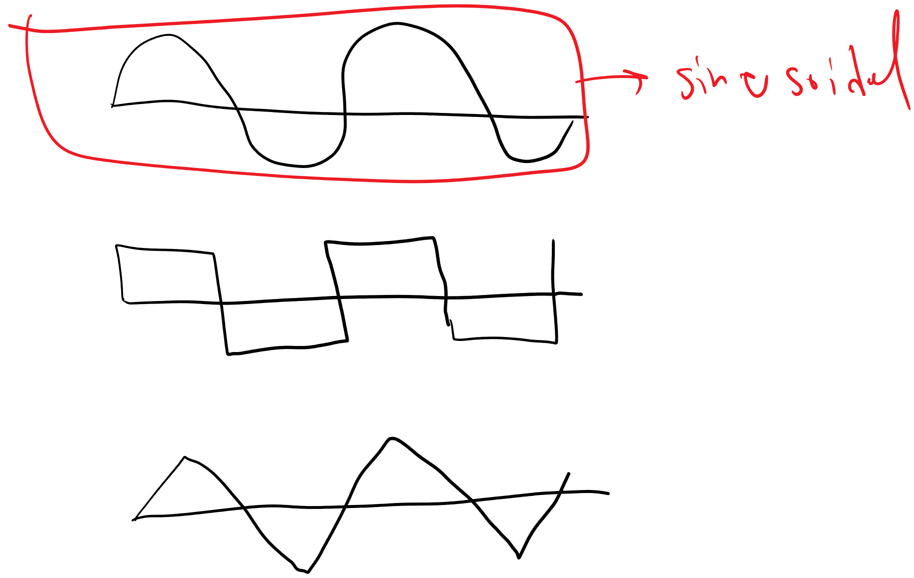
$$\boxed{P_{max} = \frac{E_{th}^2}{4R_L}}$$

[Dependent and Independent source]

Sinusoidal Alternating Waveform

Saturday, June 19, 2021 12:48 PM

Alternating waveform



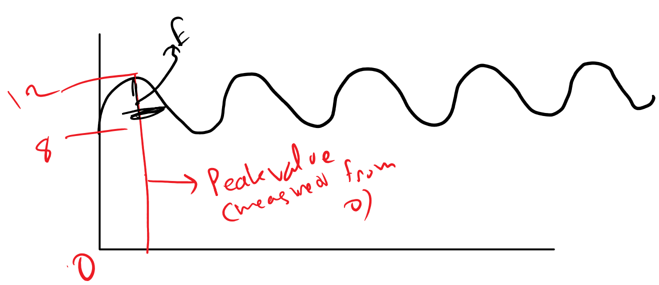
Sinusoidal Alternating Waveform:

$$I = I_m sin\alpha = I_m sin\omega t$$

$$E = E_m sin\alpha = E_m sin\omega t \quad \left(here, \omega = \frac{2\pi}{T}\right)$$

E: instantaneous value

E_m: Peak Amplitude



For the sinusoidal waveform in Figure: 1,

a. What is the peak value?
b. What is the instantaneous value at 0.3 s and 0.6 s?
c. What is the peak-to-peak value of the waveform?
d. What is the period of the waveform?
e. How many cycles are shown?
f. What is the frequency of the waveform?

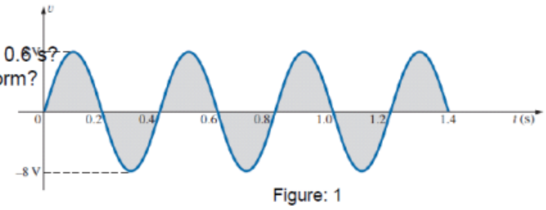


Figure: 1

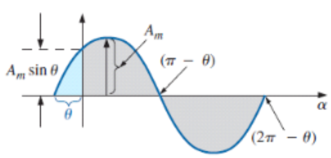
a. **8 V.**
b. At 0.3 s, **8 V;** at 0.6 s, **0 V.**
c. **16 V.**
d. **0.4 s.**
e. **3.5 cycles.**
f. **2.5 cps,** or **2.5 Hz.**

Phase Relation:

If the waveform is shifted to the right or left of θ degree, the expression becomes,

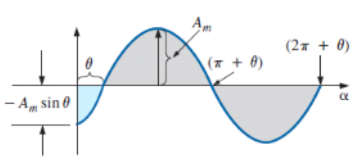
$$A_m \sin(\omega t \pm \theta)$$

Where θ is the angle that the waveform has been shifted



This is called leading by θ angle
So the equation becomes,

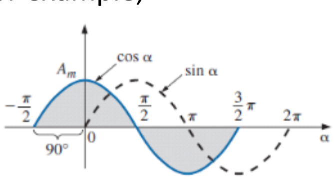
$$y = A_m \sin(\omega t + \theta)$$



This is called lagging by θ angle
So the equation becomes,

$$y = A_m \sin(\omega t - \theta)$$

If two waveforms cross the axis at the same point with the same slope, they are in phase.
For example,



Here, sin wave and cosine wave is in phase
The relationship is,

$\sin(\alpha) = \cos(\alpha - 90°) = \cos\left(\alpha - \frac{\pi}{2}\right)$ here cos is lagging

Or,

$\cos(\alpha) = \sin(\alpha + 90°) = \sin\left(\alpha + \frac{\pi}{2}\right)$ here sin is leading

$$\cos\alpha = \sin(\alpha + 90°)$$
$$\sin\alpha = \cos(\alpha - 90°)$$
$$-\sin\alpha = \sin(\alpha \pm 180°)$$
$$-\cos\alpha = \sin(\alpha + 270°) = \sin(\alpha - 90°)$$
etc.

What is the phase relationship between the sinusoidal waveforms of the following set?

$$i = -\sin(\omega t + 30°)$$
$$v = 2\sin(\omega t + 10°)$$

$\cos\alpha = \sin(\alpha + 9$
$\sin\alpha = \cos(\alpha - 9$

Steps

- Make sure the waveforms are of the same frequency.
- When determining the phase relationship between two waveforms make sure they are both in the same format. That is, both should be either in sine or cosine format.
- Both waveforms should either have positive or negative amplitude. If one has positive amplitude and the other has negative, any one of them should be shifted 180 degrees to make both positive (or negative).

Sol^n:

$$i = -\sin(\omega t + 30°)$$
$$= -\sin(\omega t + 30° + 180°)$$
$$= \sin(\omega t + 210°)$$

And $v = 2\sin(\omega t + 10°)$

$\boxed{\text{i is leading v by } 200°}$

Average Value of Alternating current

Average value $= \frac{Area}{Length}$

Time of one full cycle = T

Area $= \int_0^T Idt$

$= I_m \int_0^T \sin(\omega t)\, dt$

$= I_m \left[-\frac{1}{\omega}\cos(\omega t)\right]_0^T$

$= \frac{-\mathrm{I_m}}{\omega}\{\cos\left(\frac{2\pi}{T}T\right) - \cos(0)\}$

$= 0$

So, average value in full cycle $= 0$

Time of half cycle $= \frac{T}{2}$

Area $= \int_0^{\frac{T}{2}} Idt$

$= I_m \int_0^{\frac{T}{2}} \sin(\omega t)\, dt$

$= I_m \left[-\frac{1}{\omega}\cos(\omega t)\right]_0^{\frac{T}{2}}$

$= -\frac{I_m}{\omega}\left[\cos\left(\omega\frac{T}{2}\right) - \cos(0)\right]$

$$= -\frac{I_m}{\omega}(\cos(\pi) - 1)$$
$$= \frac{2I_m}{\omega}$$
$$= \frac{I_m}{\pi}T$$

$$\boxed{\text{So, Average value in half cycle} = \frac{Area}{Time} = \frac{\frac{I_m}{\pi}T}{\frac{T}{2}} = \frac{2I_m}{\pi}}$$

However, if the waveform is periodic and symmetrical then it will have a average value

And the average value will be = 0 + $\left|\frac{|high|+|low|}{2} - |high|\right|$

The reason is described in the corresponding PDF page 23

Effective Value of Alternating current (RMS)

As AC changes its direction , the mean value of current is zero. But AC will always deliver some power regardless of its direction. Because,

$$P = I^2R$$

Here, I^2 doesn't depend on the direction

So, $I = I_m \sin \omega t,$

$$I^2 = I_m^2 \sin^2 \omega t$$

$$\sin^2 \omega t = \frac{1 - \cos 2\omega t}{2}$$

$$I^2 = \frac{I_m^2(1 - \cos 2\omega t)}{2}$$

$$= \frac{I_m^2 - I_m^2 \cos 2\omega t}{2}$$

$$= \frac{I_m^2}{2} - \frac{I_m^2 \cos 2\omega t}{2}$$

$$\boxed{\therefore P = \frac{I_m^2}{2}R - \frac{I_m^2 \cos 2\omega t}{2}}$$

for average, $\cos 2\omega t = 0$

for average, $\cos 2\omega t = 0$

$$\boxed{P_{avg} = \frac{I_m^2 R}{2}} \rightarrow \text{for AC current}$$

Again, Average power is same for ac and dc

$$P_{ac} = P_{dc} = \frac{I_m^2 \cancel{R}}{2} = I_{dc}^2 \cancel{R}$$

$$\Rightarrow \boxed{I_{dc} = \frac{I_m}{\sqrt{2}}} \quad = .707 I_m$$

dc equivalent is effective value,

So, $$\boxed{I_{rms} = \frac{I_m}{\sqrt{2}}}$$

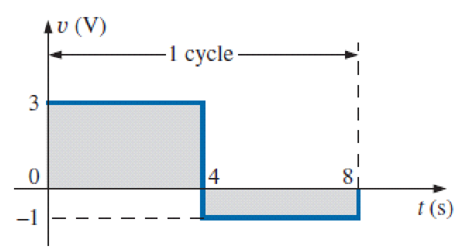


Figure 1

Steps to determine RMS value of a non-sinusoidal waveform.
Consider the waveform of Figure: 1.

Step 1: Obtain the square of the waveform (Figure: 2).

Step 2: Obtain the average (mean) of the squared waveform.

Step 3: Obtain the square root of the average (mean) of the squared waveform.

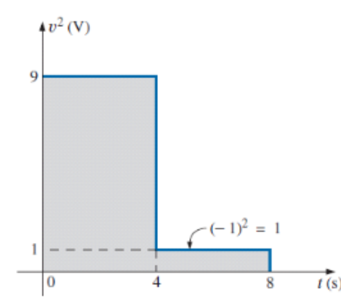


Figure 2

$$V_{rms} = \sqrt{\frac{3^2 \cdot (4) + (-1)^2 (4)}{8}}$$
$$= 2.24V$$

Diodes

Sunday, June 20, 2021 12:43 PM

n-type material

Considering silicon as base material, An n -type material is created by introducing impurity elements that
have five valence electrons (pentavalent), such as antimony , arsenic , and phosphorus.

Note that the four covalent bonds
are still present. There is, however, an additional fifth electron due to the impurity atom, which is unassociated with any particular covalent bond. This remaining electron, loosely bound to its parent (antimony) atom, is relatively free to move within the newly formed n -type material.

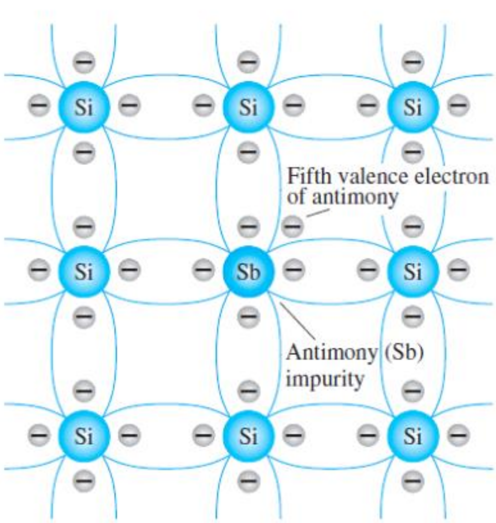


FIG. 1.7
Antimony impurity in n-type material.

It is important to realize that even though a large number of free carriers have been established in the n -type material, it is still electrically neutral since ideally the number of positively charged protons in the nuclei is still equal to the number of free and orbiting negatively charged electrons in the structure.

Here, Diffused impurities with five valence electrons are called donor atoms.