3041- CO- 2
Network Theorems and Transformers

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CO2

Apply various network theorems for simplifying electric circuits and networks and illustrate the operations of transformers.

Module Outcomes	Description	Duration (Hours)	Cognitive Level
M2.01	Illustrate various network theorems	3	Understanding
M2.02	Apply various network theorems for solving electrical and electronics circuits	6	Applying
M2.03	Explain principle and operations of Transformers	3	Understanding
M2.04	List the types and applications of Transformers.	2	Remembering

CO 2 - NETWORK THEOREMS AND TRANSFORMERS

Ohm’s law - Kirchhoff’s law – Mesh analysis – Node analysis- Superposition theorem -

Thevenin's theorem - Maximum power transfer theorem (Solve simple problems)

Transformers: working principle of transformer - construction of transformer - elementary

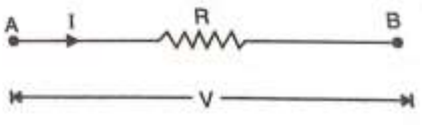
theory of an ideal transformer - voltage transformation ratio and rating of a transformer -

emf equation derivation - losses in transformers - types, applications of transformers

Ohm's Law

- At constant temperature, the ratio of potential difference (V) between any two points on a conductor to the current (I) flowing between them, is constant.
- that is, $\frac{V}{I} = R$, a constant

where R is the resistance of the conductor between the two points.



- Ohm's law can be expressed as

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

Example 1

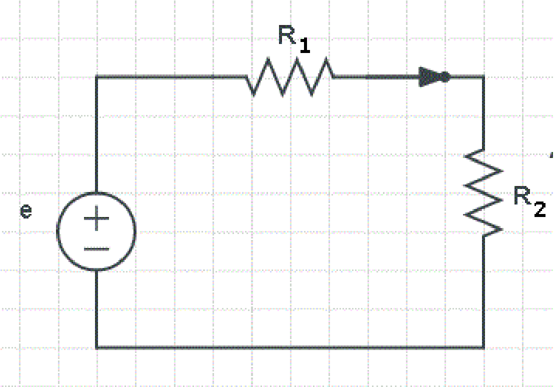
Find the current I through a resistor of resistance R = 2 Ω if the voltage across the resistor is 6 V

R = 2 Ω
V= 6V
By Ohms law
I = V/R

∴ I = 6/2 = 3 A

Example 2

n the circuit below resistors R1 and R2 are in series and have resistances of 5 Ω and 10 Ω, respectively. The voltage across resistor R1 is equal to 4 V. Find the current passing through resistor R2 and the voltage across the same resistor.



Here

$R1 = 5\ \Omega$, $R2 = 10\ \Omega$ and $Vr1 = 4V$

use Ohm's law $V = R\ I$ to find the current I_1 passing through R1

$4 = 5\ I_1$

Solve for I1

$I1 = 4 / 5 = 0.8$ A

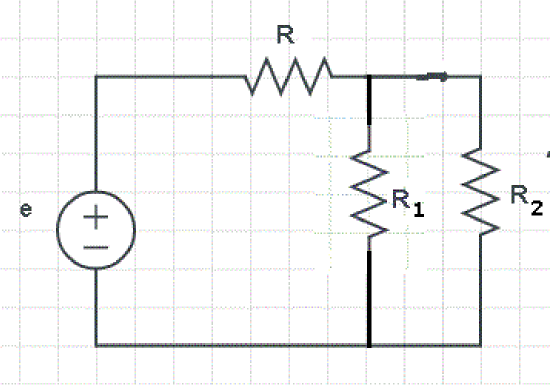
The two resistors are in series and therefore the same current passes through them. Hence the current I2 through R2 is equal to 0.8 A.

We now use Ohm's law to find the voltage V2 across resistor R2.

$V2 = R2\ I2 = 10\ (0.8) = 8$ V

Example 3

In the circuit below resistors R1 and R2 are in parallel and have resistances of 8 Ω and 4 Ω, respectively. The current passing through R1 is 0.2 A. Find the voltage across resistor R2 and the current passing through the same resistor.



Use Ohm's law V = RI to find the voltage V_1 across resistor R_1.

V_1 = 8* (0.2) = 1.6 V

The voltage across resistor R_1 and the voltage across resistor R_2 are the same because R_1 and R_2 are in parallel.

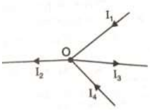
We now use Ohm's law to find current I_2 passing through resistor R2.

1.6 = 4* I_2
Solve for I2
I_2 = 1.6 / 4 = 0.4 A

- Kirchhoff's Current Law(KCL).
- Kirchhoff's Voltage Law(KVL).

Kirchhoff's Current Law(KCL)(Junction Rule/ Node rule)

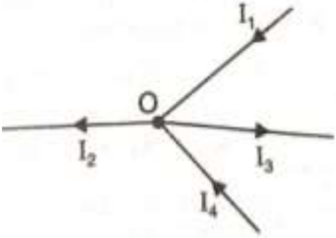
- The algebraic sum of currents meeting at a junction in an electrical circuit is zero.



- Apply KCL to the junction O in fig, we get
  $I_1 + I_4 + (-I_2) + (-I_3) = 0$
  $I_1 + I_4 = I_2 + I_3$
- The sum of currents flowing towards any junction in an electrical circuit is equal to the sum of currents flowing away from that junction.

Sign conversion

A current entering the juction is taken as positive while a current leaving the junction is taken as negative.



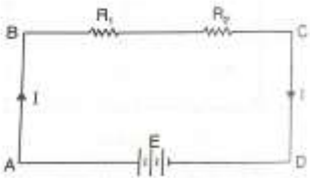
Current entering the junction : $+I_1$ and $+I_4$

Current leaving the junction : $-I_2$ and -I3

Kirchhoff’s Voltage Law(KVL)(Loop Rule)

In any closed electrical circuit or mesh, the algebraic sum of all the emfs and voltage drops in resistors is equal to zero .

- ie, Algebraic sum of emf + Algebraic sum of voltage drops = 0
-



- Going around the circuit ABCDA, there is no increase or decrease in potential .
- Which means that algebraic sum of the emfs of all sources plus the algebraic sum of voltage drops in the resistances must be zero.

Sign Convention

A rise in potential should be considered positive and fall in potential should be considered negative.

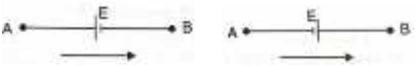
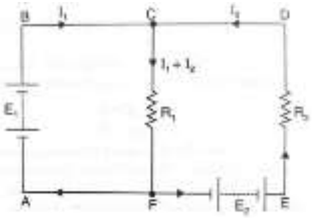


Figure 1 : -E, +E

Figure 2 : -V, +V

- Sign of emf independent of direction of current
- Sign of voltage drop depends on the direction of current

Illustration of Krichhoff's Law



- Magnitude of current in any branch of the circuit can be found out by applying KCL.
- Thus at junction C, the incoming currents to the junction are, I_1 and I_2.
- Then the current in the branch CF will be $I_1 + I_2$.

- KVL can be applied to closed circuits to get the desired equations.
- Consider the loop ABCDFA,

$$-(I_1 + I_2)R_1 + E_1 = 0 \tag{1}$$

$$E_1 = (I_1 + I_2)R_1 \tag{2}$$

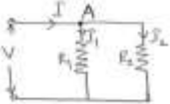
- Consider the loop CDEFC,

$$I_2R_2 + (I_1 + I_2)R_1 - E_2 = 0 \tag{3}$$

$$I_2R_2 + (I_1 + I_2)R_1 = E_2 \tag{4}$$

Network Theorems(contd...)

Current division Rule.



Apply KCL at A,

$$I = I_1 + I_2$$

$$\therefore \; I_1 = I - I_2$$

$$I_2 = I - I_1$$

$$I = I_1 + I_2$$

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

$$= V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)$$

$$= V\left(\frac{R_1 + R_2}{R_1 R_2}\right)$$

$$V = I\left(\frac{R_1 R_2}{R_1 + R_2}\right) \longrightarrow (2)$$

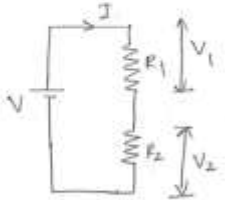
$$I_1 = \frac{V}{R_1} = \frac{I\,(R_1 R_2)}{(R_1 + R_2)R_1}$$

$$I_1 = I\,\frac{R_2}{R_1 + R_2}$$

Similarly, $I_2 = I\,\dfrac{R_1}{R_1 + R_2}$

Network Theorems(contd...)

Voltage division rule



Apply KVL in this loop

$$V = IR_1 + IR_2$$

$$V_1 = IR_1 \quad , \quad V_2 = IR_2$$

$$V = V_1 + V_2$$

$$V = I(R_1 + R_2)$$

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

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

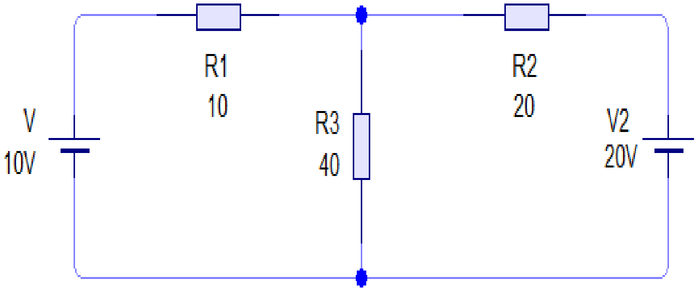
Similarly,

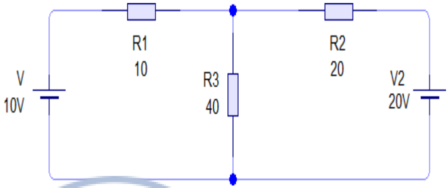
$$V_2 = \frac{V}{R_1 + R_2} \times R_2 = \frac{R_2}{R_1 + R_2} V$$

EXERCISE

- Exercise 1

Find the current flow through each resistor using mesh analysis for the circuit below





STEP 1

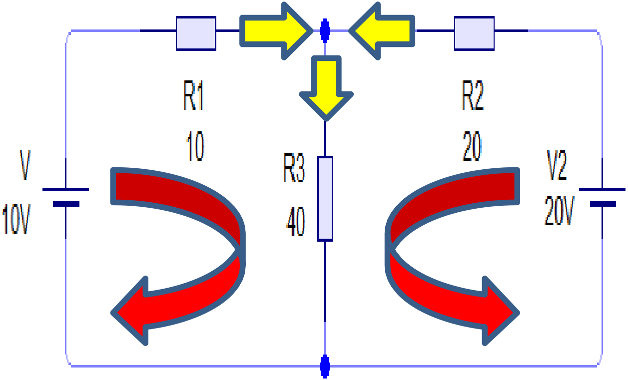
- Assign a distinct current to each closed loop of the network

STEP 2

- Apply KVL around each closed loop of the network

STEP 3

- Solve the resulting simultaneous linear equation for the loop currents



STEP 1

$Loop1:$

$I_1R_1 + I_1R_3 + I_2R_3 = V_1$

$10I_1 + 40I_1 + 40I_2 = 10$

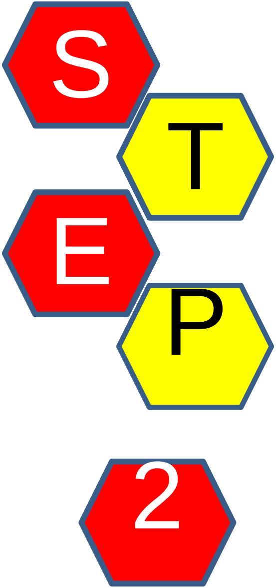
$50I_1 + 40I_2 = 10 - - -$
$-equation1$

$Loop2:$

$I_2R_2 + I_2R_3 + I_1R_3 = V_2$

$20I_2 + 40I_2 + 40I_1 = 20$

$40I_1 + 60I_2 = 20 - - - -equation2$



STEP 3

Solve equation 1 and equation 2 using Matrix

$$50I_1 + 40I_2 = 10$$

$$40I_1 + 60I_2 = 20$$

Matrixform :

$$\begin{bmatrix} 50 & 40 \\ 40 & 60 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 10 \\ 20 \end{bmatrix}$$

$$\Delta = \begin{vmatrix} 50 & 40 \\ 40 & 60 \end{vmatrix} = 3000 - 1600 = 1400$$

$$\Delta I_1 = \begin{vmatrix} 10 & 40 \\ 20 & 60 \end{vmatrix} = 600 - 800 = -200$$

$$\Delta I_2 = \begin{vmatrix} 50 & 10 \\ 40 & 20 \end{vmatrix} = 1000 - 400 = 600$$

$$I_1 = \frac{\Delta I_1}{\Delta} = \frac{-200}{1400} = -0.143A$$

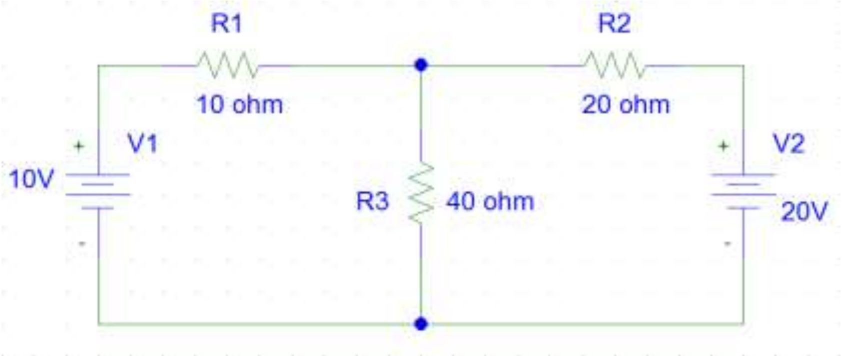
$$I_2 = \frac{\Delta I_2}{\Delta} = \frac{600}{1400} = 0.429\,A$$

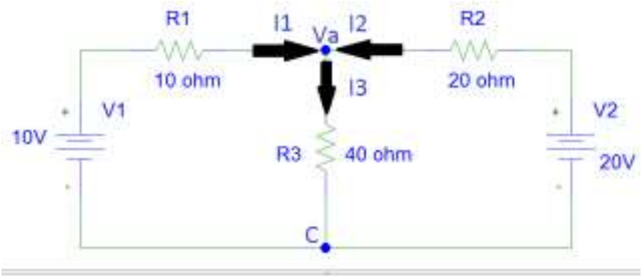
FromKCL :

$$I_3 = I_1 + I_2 = -0.143A + 0.429A = 0.286A$$

Exercise 2:

Find the current flow through each resistor using node analysis for the circuit below.





REMEMBER THE STEPS EARLIER??

Determine the number of common nodes and reference node within the network.

1 common node (Va) and 1 reference node C

Assign current and its direction to each distinct branch of the nodes in the network (refer o the figure)

Apply KCL at each of the common nodes in the network

KCL: I1 + I2 = I3

$$\frac{(10-Va)}{10}+\frac{(20-Va)}{20}=\frac{Va}{40}$$

$$1-\frac{Va}{10}+1-\frac{Va}{20}=\frac{Va}{40}$$

$$\frac{Va}{40}+\frac{Va}{10}+\frac{Va}{20}=2$$

$$Va\left(\frac{1}{40}+\frac{1}{10}+\frac{1}{20}\right)=2$$

$$Va\left(\frac{7}{40}\right)=2$$

$$Va=11.428V$$

$$I_1=\frac{(10-11.428)}{10}=-0.143A$$

$$I_2=\frac{(20-11.428)}{20}=0.429A$$

$$I_3=\frac{11.428}{40}=0.286V$$

Exersize 3::

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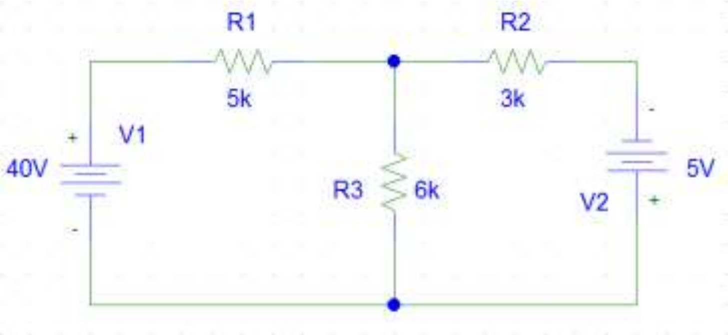

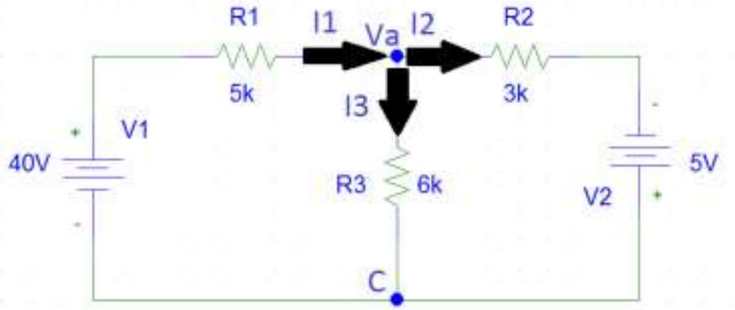

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Assign current and its direction to each distinct branch of the nodes in the network (refer o the figure)

Apply KCL at each of the common nodes in the network

KCL: I1 = I2 + I3

$$\frac{(40-Va)}{5k} = \frac{(Va-(-55))}{3k} + \frac{Va}{6k}$$

$$\frac{40}{6k} - \frac{Va}{6k} = \frac{Va}{3k} + \frac{55}{3k} + \frac{Va}{6k}$$

$$\frac{(-Va)}{5k} - \frac{Va}{3k} - \frac{Va}{6k} = \frac{55}{3k} - \frac{40}{5k}$$

$$-Va\left(\frac{1}{5k} + \frac{1}{3k} + \frac{1}{6k}\right) = \frac{55}{3k} - \frac{40}{5k}$$

$$-Va\,(700 \times 10^{-6}) = 10.33 \times 10^{-3}$$

$$Va = -14.757V$$

$$I_1 = \frac{(40-(-14.757))}{5k} = 10.95mA$$

$$I_2 = \frac{(-14.757+55)}{3k} = 13.41mA$$

$$I_3 = \frac{(-14.757)}{6k} = -2.46mA$$

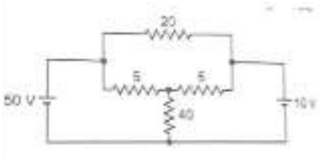
Superposition Theorem

- In a linear, bilateral dc network containing more than one energy source, the resultant potential difference across or current through any element is equal to the algebraic sum of potential differences or currents for that element produced by each source acting alone with all other independent ideal voltage sources replaced by short circuits and all other independent ideal current sources replaced by open circuits.

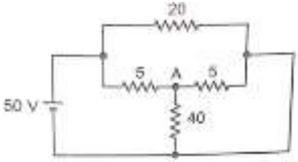
  Procedure

  - Select one source in the circuit and replace all other ideal voltage source by short circuit and ideal current source by open circuits.
  - Determine the voltage or current through desired branch
  - Repeat the steps for remaining sources.
  - Add all voltages or currents

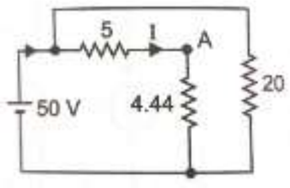
Exersize 1. Using superposition theorem, find the current through the 40Ω *resistor in the circuit shown in figure. All resistances are in ohms.*



- First the 10V battery is replaced by a short.

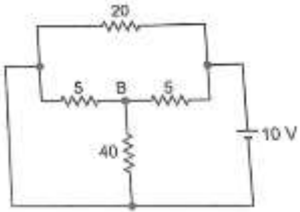


- Now the right hand 5Ω resistance is parallel with 40Ω resistance, then the combined resistance is given by
  $R_{eff} = \frac{5\times40}{5+40} = 4.44\Omega$

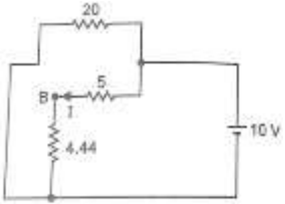


- The 4.44Ω resistance is in series with the left hand 5Ω, then the total resistance will be (5 + 4.44 = 9.44Ω)
- Then current through the 9.44Ω branch will be
  $I = \frac{50}{9.44} = 5.296A$
- But at point A the current, actually divides between the 5Ω resistance and 40Ω resistance.
- So by current division rule, the current through 40Ω resistance is given by
  $I_1 = I \times \frac{5}{5+40} = 5.296 \times \frac{5}{45} = 0.589A$

- Now the 50V battery is replaced by a short so that the 10V battery act alone.

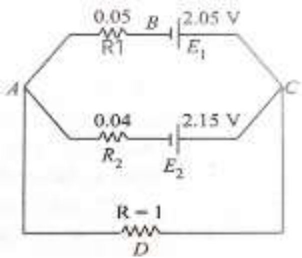


- The left hand 5Ω is in parallel with 40Ω, therefore we get,

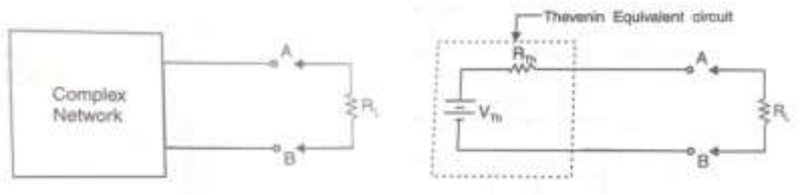


- Now the 5Ω is in series with 4.44Ω resistance.
- The effective resistance will be 9.44Ω.
- The current through the 9.44Ω resistance due to the 10V battery will be
  $I = \frac{10}{9.44} = 1.059A$
- But actually at point B the current divides between 5Ω and 40Ω.
- So the current through the 40Ω resistance will be
  $I_2 = I \times \frac{5}{5+40} = 1.059 \times \frac{5}{45} = 0.118A$
- By Superposition theorem the total current through the 40Ω will be
  $I_1 + I_2 = 0.589 + 0.118 = 0.707A$

Exercise 2: Using superposition theorem, find the current in resistance R shown in figure. All resistances are in ohms.

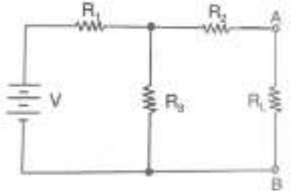


Thevenin's Theorem



- Any linear, bilateral network having terminals A and B can be replaced by a single source of emf V_{TH} in series with a single resistance R_{TH}.
- The emf V_{TH} is the open circuit voltage across the terminals A and B
- The resistance R_{TH} is the resistance of the network measured between the terminals A and B with load removed and the sources of emf replaced by their internal resistances.

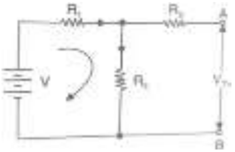
Explanation



- Consider the circuit shown in figure
- Look at the circuit behind terminals A and B
- According to Thevenin's theorem, it can be replaced by a single source of emf V_{TH} in series with a single resistance R_{TH}

To Find V_{TH}

- The emf V_{TH} is the voltage across the terminals AB with load removed.
- There is no current in R_2, therefore V_{TH} is the voltage appearing across R_3

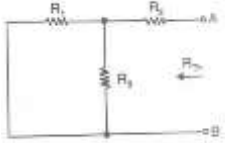


- Thevenin's voltage is given by

$$V_{TH} = \frac{R_3}{R_1 + R_3} \times V \qquad (5)$$

To Find R_{TH}

- Remove the load R_L and replace the battery by short circuit.

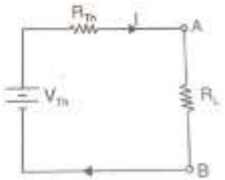


- Then resistance between the terminals A and B is the equal to R_{TH}

- The resistance, R_{TH} is given by,

$$R_{TH} = R_2 + \frac{R_1 R_3}{R_1 + R_3} \tag{6}$$

- When load is connected between the terminals A and B, then the current in R_L is given by

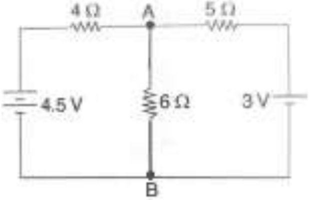


$$I = \frac{V_{TH}}{R_{TH} + R_L} \tag{7}$$

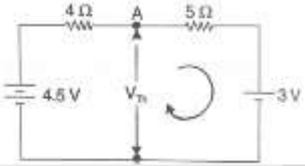
Procedure for finding Thevenin's equivalent circuit

- Open the two terminals between which we want to find the Thevenin's equivalent circuit.
- Find the open circuit voltage across the two open terminals, which is V_{TH}.
- Determine the resistance between the two open terminals with all ideal voltage sources are replaced by shortcircuit and all ideal current sources are replaced by open circuit, which is R_{TH} .
- Connect V_{TH} and R_{TH} in series.
- Place the load resistor and find the load current.

Uexersize 1: sing Thevenin's theorem, find the current in 6Ω *resistor shown in figure.*



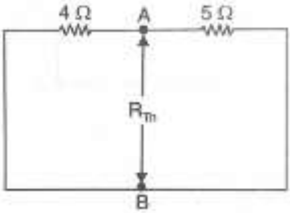
- To find the current through 6Ω resistor, we shall find the Thevenin's equivalent circuit at the terminals AB.
- For that we have to find out V_{TH} and R_{TH}
- V_{TH} is the open circuit voltage across the terminals AB.



- Net voltage in the circuit is given by $4.5 - 3 = 1.5V$
- Total resistance will be equal to $4 + 5 = 9\Omega$
- Net current in the circuit is given by $Circuitcurrent = \frac{1.5}{9} = 0.167A$
- Now the voltage, V_{TH} is given by

$$V_{TH} = 4.5 - 0.167 \times 4 = 3.83V \tag{8}$$

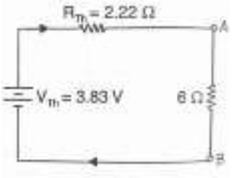
- R_{TH} is the resistance at the terminals AB with load(6Ω resistor) removed and batteries are replaced by short



- 4Ω and 5Ω are parallel so,

$$R_{TH} = \frac{4 \times 5}{4 + 5} = 2.22\Omega \tag{9}$$

- Now Thevenin's equivalent circuit becomes,

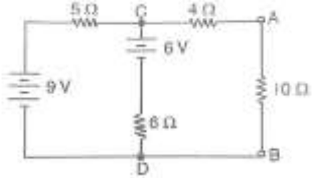


- Current through 6Ω resistor can be found out as,

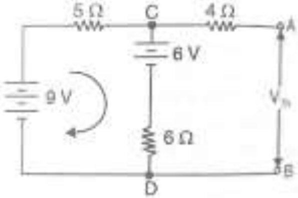
$$I = \frac{V_{TH}}{R_{TH} + R_L} \tag{10}$$

$$I = \frac{3.83}{2.22 + 6} = 0.466A \tag{11}$$

Exersize 1: Using Thevenin's theorem, find the p.d across the terminals AB in figure.



- Thevenin's voltage is given by
  V_{TH} = Voltage across the terminals AB with load removed



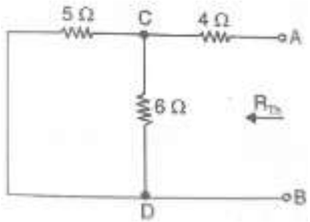
Network Theorems(contd...)

- Net voltage in the circuit is given by
  $9 - 6 = 3V$
- Total resistance will be equal to $6 + 5 = 11\Omega$
- Net current in the circuit is given by
  $Circuitcurrent = \frac{3}{11} = 0.27A$
- Now the voltage, V_{TH} is given by

$$V_{TH} = 9 - 0.27 \times 5 = 7.65V \quad (12)$$

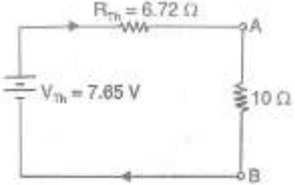
Network Theorems(contd...)

- R_{TH} is the resistance at the terminals AB with load($10\Omega resistor$) removed and the batteries are replaced by short



$$R_{TH} = 4 + \frac{5 \times 6}{5 + 6} = 6.72\Omega \quad (13)$$

- Now Thevenin's equivalent circuit becomes,



- Current through 10Ω resistor can be found out as,

$$I = \frac{V_{TH}}{R_{TH} + R_L} \tag{14}$$

$$I = \frac{7.65}{6.72 + 10} = 0.457A \tag{15}$$

- P.D. across 10Ω resistor is given by
  $V_{10} = 0.457 \times 10 = 4.57V$

Maximum Power Transfer Theorem

- In d.c circuits, the maximum power is transferred from a source to load when the load resistance is made equal to the Thevenin's equivalent resistance of the circuit.

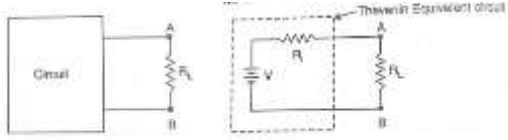
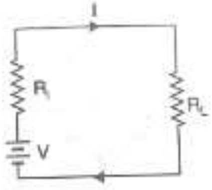


Figure 3 : 1, 2

- Fig(1) shows a circuit supplying power to load R_L
- The circuit can be replaced by Thevenin's equivalent circuit consisting of Thevenin's voltage V_{TH} in series with Thevenin's resistance R_i as shown in fig(2).
- According to maximum power transfer theorem, maximum power will be transferd from the circuit to the load when R_L is made equal to R_i.

Proof



- Consider a voltage source V of internal resistance R_i delivering power to the load R_L.
- Circuit current is given by,

$$I = \frac{V}{R_L + R_i} \tag{16}$$

- Power delivered to load,

$$P = I^2 R_L \tag{17}$$

Network Theorems(contd...)

$$P = \left(\frac{V}{R_L + R_i} \right)^2 R_L \quad (18)$$

- For a given source, generated voltage, V and internal resistance R_i are constant.
- Therefore, power delivered to the load depends on R_L.
- To find the value of R_L for which the value of P is maximum, differentiate the eqn(18) w. r. t R_L and set the result equal to zero.

Thus, $$\frac{dP}{dR_L} = V^2\left[\frac{(R_L+R_i)^2 - 2R_L(R_L+R_i)}{(R_L+R_i)^4}\right] = 0$$

or $$(R_L+R_i)^2 - 2\,R_L\,(R_L+R_i) = 0$$

or $$(R_L+R_i)\,(R_L+R_i-2R_L) = 0$$

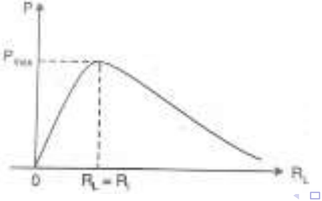
or $$(R_L+R_i)\,(R_i-R_L) = 0$$

Since $R_L + R_i$ cannot be zero,

$\therefore$ $$R_i - R_L = 0$$

or $$R_L = R_i$$

or **Load resistance = Internal resistance of the source**



Transformer

INTRODUCTION

- A transformer is a static device that changes ac electric power at one voltage level to ac electric power at another voltage level through the action of electromagnetic field
- There are two or more stationary electric circuits that are coupled magnetically.
- It involves interchange of electric energy between two or more electric circuits
- Transformers provide much needed capability of changing the voltage and current levels easily.
  - They are used to step-up generator voltage to an appropriate voltage level for power transfer.
  - Stepping down the transmission voltage at various levels for distribution and power utilization.

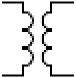
WHAT IS TRANSFORMER

- A transformer is a static piece of apparatus by means of which an electrical power is transferred from one alternating current circuit to another electrical circuit without change of frequency
- There is no electrical contact between them
- The desire change in voltage or current without any change in frequency

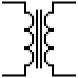
NOTE :

It works on the principle of mutual induction

- Symbolically the transformer denoted as Tr

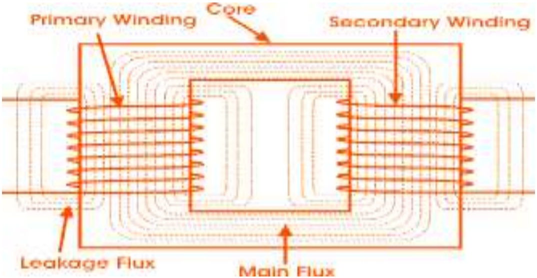


Transformer
Two windings and an air core
Generic symbol



Transformer with laminated core

- The transformer two inductive coils ,these are electrical separated but linked through a common magnetic current circuit
- These two coils have a high mutual induction
- One of the two coils is connected of alternating voltage .this coil in which electrical energy is fed with the help of source called primary winding (P) shown in fig.
- The other winding is connected to a load the electrical energy is transformed to this winding drawn out to the load .this winding is called secondary winding(S) shown in fig.



- The primary and secondary coil wound on a ferromagnetic metal core
- The function of the core is to transfer the changing magnetic flux from the primary coil to the secondary coil
- The primary has N1 no of turns and the secondary has N2 no of turns
- The turns plays major important role in the function of transformer

WORKING PRINCIPLE

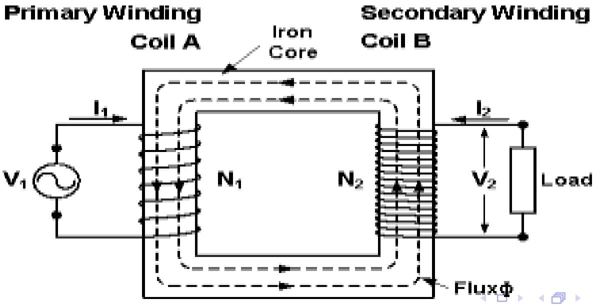
- The transformer works in the principle of mutual induction

"The principle of mutual induction states that when the two coils are inductively coupled and if the current in coil change uniformly then the e.m.f. induced in the other coils. This e.m.f can drive a current when a closed path is provide to it."

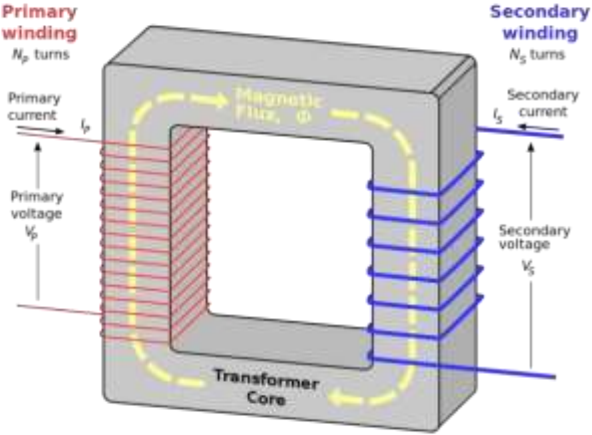
- When the alternating current flows in the primary coils, a changing magnetic flux is generated around the primary coil.
- The changing magnetic flux is transferred to the secondary coil through the iron core
- The changing magnetic flux is cut by the secondary coil, hence induces an e.m.f in the secondary coil

- Now if load is connected to a secondary winding, this e.m.f drives a current through it
- The magnitude of the output voltage can be controlled by the ratio of the no. of primary coil and secondary coil

The frequency of mutually induced e.m.f as same that of the alternating source which supplying to the primary winding



-:Transformer Construction:-

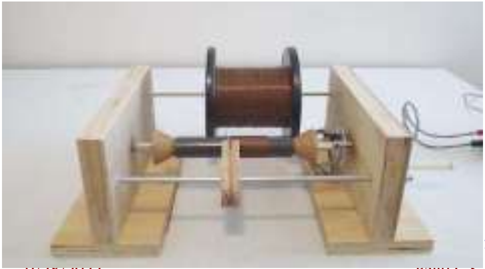


CONSTRUCTION OF TRANSFORMER

- These are two basic of transformer construction
- Magnetic core
- Windings or coils
- **Magnetic core**
- The core of transformer either square or rectangular type in size
- It is further divided into two parts vertical and horizontal
- The vertical portion on which coils are wounds called limb while horizontal portion is called yoke. these parts are
- Core is made of laminated core type constructions, eddy current losses get minimize.
- Generally high grade silicon steel laminations (0.3 to 0.5mm) are used

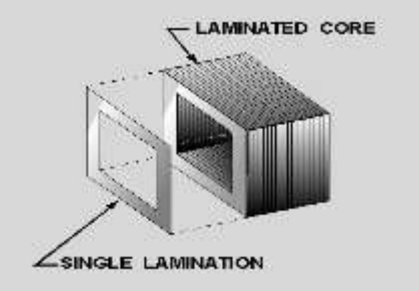
WINDING

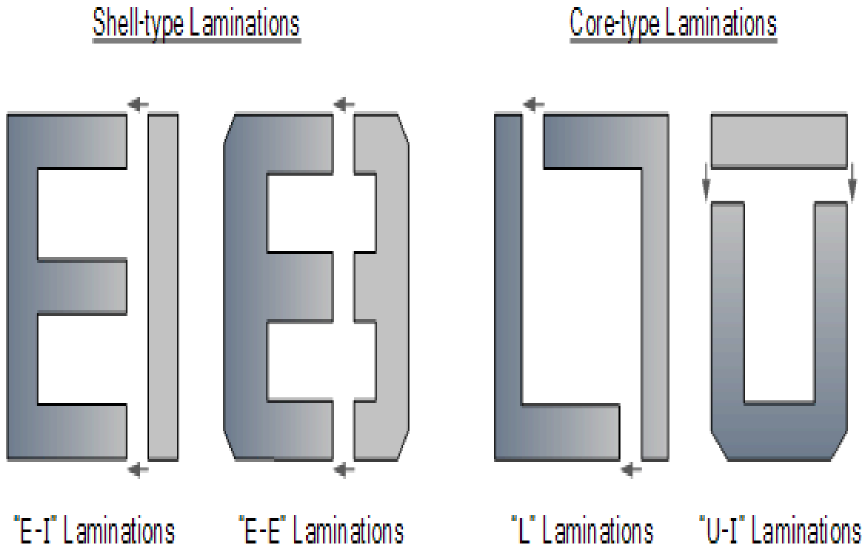
- Conducting material is used in the winding of the transformer
- The coils are used are wound on the limbs and insulated from each other
- The two different windings are wounds on two different limbs
- The leakage flux increases which affects the performance and efficiency of transformer
- To reduce the leakage flux it is necessary that the windings should be very close to each other to have high mutual induction



CORE TYPE CONSTRUCTION

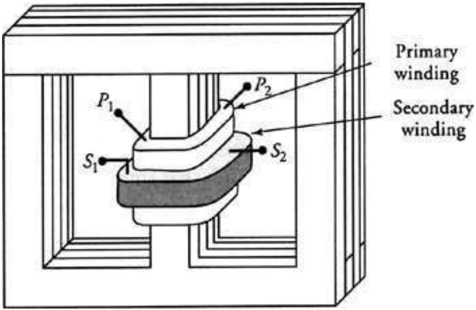
- In this one magnetic circuit and cylindrical coils are used
- Normally L and T shaped laminations are used
- Commonly primary winding would on one limb while secondary on the other but performance will be reduce
- To get high performance it is necessary that other the two winding should be very close to each other

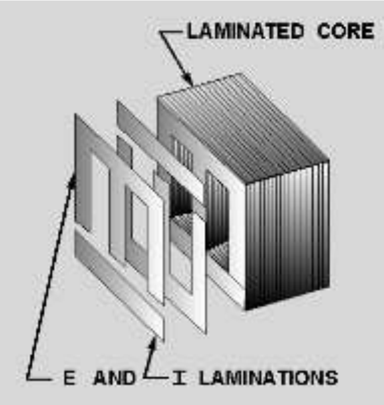


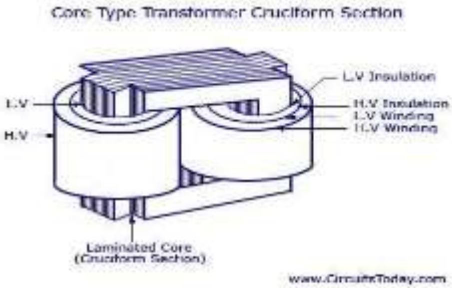

Shell-type Laminations
Core-type Laminations
"E-I" Laminations
"E-E" Laminations
"L" Laminations
"U-I" Laminations

SHELL TYPE CONSTRUCTION

- In this type two magnetic circuit are used
- The winding is wound on central limbs
- For the cell type each high voltage winding lie between two voltage portion sandwiching the high voltage winding
- Sub division of windings reduces the leakage flux
- Greater the number of sub division lesser the reactance
- This type of construction is used for high voltage


Primary winding
Secondary winding
P_1
P_2
S_1
S_2


LAMINATED CORE
E AND I LAMINATIONS


Core Type Transformer Cruciform Section
L.V Insulation
L.V
H.V Insulation
L.V Winding
H.V
H.V Winding
Laminated Core
(Cruciform Section)
www.CircuitsToday.com

-:EMF Equation of Transformer

Let

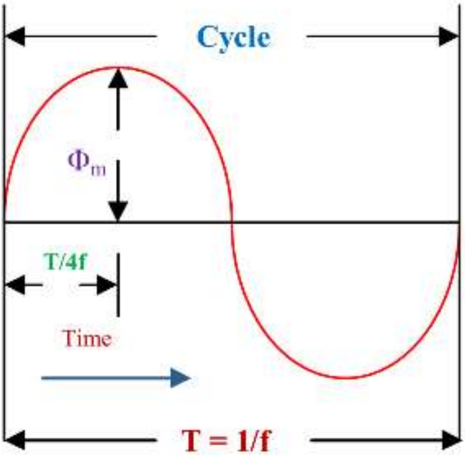
$N1$ = *No. of turns in primary*

$N2$ = *No. of turns in secondary*

Φm = *Maximum flux in core in webers*

$= Bm \times A$

f = *Frequency of a.c. input in Hz*



As shown in figure flux increases from its zero value to maximum value Φ*m in one quarter of the cycle i.e. in 1/4 f second.*

∴ Average rate of change of flux $= \Phi_m / _{(T/4)}$

$= \Phi m\ (1/\ 4f)$

$= 4\ f\ \Phi m$ Wb/s or volt

Now, rate of change of flux per turn means induced e.m.f. in volts.

∴ Average e.m.f./turn = $4\ f\ \Phi m$ volt

If flux Φ varies sinusoidally, then r.m.s. value of induced e.m.f. is obtained by multiplying the average value with form factor.

Form factor =r.m.s. value/ avg. value = 1.11

∴ r.m.s. value of e.m.f./turn = $1.11 \times 4 f \Phi m$

$= 4.44 f \Phi m$ volt

- Now, r.m.s. value of the induced e.m.f. in the whole of primary winding

= (induced e.m.f/turn) × No. of primary turns

- $E1 = 4.44 f N1 \Phi m = 4.44 f N1 BmA$.........(1)

Similarly, r.m.s. value of the e.m.f. induced in secondary is,

- *$E2 = 4.44 f N2 \Phi m = 4.44 f N2 BmA$..........(2)*
- *From thje equation 1 and 2*

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} = 4.44 f \Phi m$$

Voltage Transformation ratio (k)

From equations (*i*) and (*ii*), we get

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$$

This constant K is known as voltage transformation ratio.

(*i*) If $N_2 > N_1$ *i.e.* $K > 1$, then transformer is called ***step-up*** transformer.

(*ii*) If $N_2 < N_1$ *i.e.* $K < 1$, then transformer is known as ***step-down*** transformer.

Again, for an *ideal* transformer, input VA = output VA.

$$V_1 I_1 = V_2 I_2 \text{ or } \frac{I_2}{I_1} = \frac{V_1}{V_2} = \frac{1}{K}$$

Hence, currents are in the inverse ratio of the (voltage) transformation ratio.

Rating of Transformer

Generally the rating of a machine should indicate the power supplied by it. But incase of transformer, the output power is not constant.
It keeps changing with the load. The output power factor is also a function of load.
Hence rating of a transformer is expressed in terms of voltage and current as follows:

Rating of transformer = Primary voltage x primary current

or = Secondary voltage x secondary current

Continued…

As the voltage and current may or may not be in phase, the units of transformer rating are **Volt Ampere (VA) or kiloVolt-Ampere (kVA) or Mega Volt Ampere (MVA).**

$\therefore$ Rating in VA or kVA or MVA = $V_1 \times I_1 = V_2 \times I_2$

- There are two type of losses in a transformer;

  1. Copper Losses
  2. Iron Losses or Core Losses or Insulation Losses

- Copper losses (I^2R)depends on Current which passing through transformer winding while Iron Losses or Core Losses or Insulation Losses depends on Voltage.

Continued…

- Hence the total losses depends on the volt ampere (VA) and not on the power factor. Therefore rating of transformer is in VA or kVA and not in kW.

The complete rating of a transformer:

- The complete rating of a transformer includes the ratio of primary and secondary voltages, kVA rating and supply frequencies as follows:

  3300 V/ 240 V , 5 kVA , 50 Hz

  where, 3300 V is primary voltage V_1
  240 V is secondary voltage V_2
  5 kVA is kVA rating and
  50 Hz is the supply frequency.

- **Copper losses** :

It is due to power wasted in the form of I^2R due to resistance of primary and secondary. The magnitude of copper losses depend upon the current flowing through these coils.

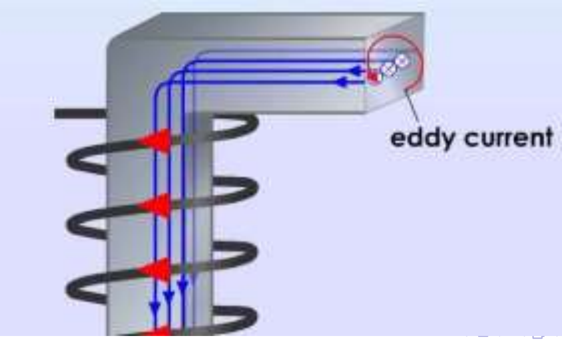
The iron losses depend on the supply voltage while the copper depend on the current .the losses are not dependent on the phase angle between current and voltage .hence the rating of the transformer is expressed as a product o f voltage and current called VA rating of transformer. It is not expressed in watts or kilowatts. Most of the timer, is rating is expressed in KVA.

Hysteresis loss :

During magnetization and demagnetization ,due to hysteresis effect some energy losses in the core called hysteresis loss

Eddy current loss :

The leakage magnetic flux generates the E.M.F in the core produces current is called of eddy current loss.



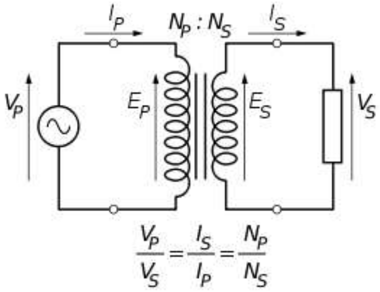
IDEAL TRANSFORMER

- A transformer is said to be ideal if it satisfies the following properties, but no transformer is ideal in practice.
- It has no losses
- Windings resistance are zero
- There is no flux leakage
- Small current is required to produce the magnetic field

While the practical transformer has windings resistance , some leakage flux and has lit bit losses
$V1/ V2 = E1/E2 = I1/ I2$

For an ideal transformer on no load, $E_1 = V_1$ and $E_2 = V_2$.
where, V_1 /V_p = supply voltage of primary winding

V_2 / Vs= terminal voltage of secondary winding



APPLICATION AND USES

- The transformer used in television and photocopy machines
- The transmission and distribution of alternating power is possible by transformer
- Simple camera flash uses fly back transformer
- Signal and audio transformer are used couple in amplifier

Todays transformer is become an essential part of electrical engineering

Thank You

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