## Chapter 1

## Module 1 Basic Concepts

### 1.1 Introduction

## State Ohm's Law. Mention its limitations

Ohm's law states that "The potential difference between the two ends of a conductor is directly proportional to the current flowing through it, provided its temperature and other parameters remain unchanged ".

$$
\begin{aligned}
V & \propto I \\
V & =I R
\end{aligned}
$$

Where $\propto, \mathrm{V}$ - voltage (Volts), I - current (Amps) and R is resistance in Ohms ( $\Omega$ )
Limitations of Ohms Law:
It is not applicable

- for non-linear devises such as semiconductors
- non-metallic conductors, such as silicon carbide
- temperature rise is rapid in some metals.

Resistors in series:
Consider two resistors $R_{1}$ and $R_{2}$ in series.


Figure 1.1

$$
\begin{aligned}
V & =V_{1}+V_{2}=I\left(R_{1}+R_{2}\right) \\
\frac{V}{I} & =R_{e q}=R_{1}+R_{2}
\end{aligned}
$$

If n number of resistors $R_{1}, R_{2} \ldots . ., R_{n}$ are connected in series then the equivalent resistance Req is

$$
R_{e q}=R_{1}+R_{2} \ldots . ., R_{n}
$$

Resistors in parallel:
Consider two resistors are connected in parallel.


Figure 1.2
Current in each branch is

$$
\begin{aligned}
& I_{1}=\frac{V}{R_{1}} \\
& I_{2}=\frac{V}{R_{2}}
\end{aligned}
$$

The current I is

$$
\begin{aligned}
I & =I_{1}+I_{2}=\frac{V}{R_{1}}+\frac{V}{R_{2}}=V\left(\frac{1}{R_{1}}+\frac{1}{R_{2}}\right) \\
\frac{I}{V} & =\left(\frac{1}{R_{1}}+\frac{1}{R_{2}}\right)=\frac{1}{R_{e q}}
\end{aligned}
$$

If $n$ number of resistors are connected in parallel then

$$
\frac{1}{R_{e q}}=\frac{1}{R_{1}}+\frac{1}{R_{2}} \cdots \frac{1}{R_{n}}
$$

If only two resistors are connected in parallel then Equivalent resistance $R_{e q}$ is

$$
\begin{aligned}
\frac{1}{R_{e q}} & =\frac{1}{R_{1}}+\frac{1}{R_{2}}=\frac{R_{1}+R_{2}}{R_{1} R_{2}} \\
R_{e q} & =\frac{R_{1} R_{2}}{R_{1}+R_{2}}
\end{aligned}
$$

## KIRCHHOFF'S RULES

1. Current Law or Junction Rule or Kirchhoff'S Current Law (KCL): The algebraic sum of electric currents at any junction in electrical network is always zero.

$$
\sum_{i=1}^{n} I_{n}=0
$$

or The sum of incoming currents towards the junction are equal to sum of outgoing currents at a junction.
This law is a statement of conservation of charge. If current reaching a junction is not equal to the current leaving the junction, charge will not be conserved.
2. II Law or Loop Law or Junction Rule: Kirchhoff'S Voltage Law (KVL): The algebraic sum of changes in potential around any closed loop involving resistors and cells in the loop is zero.
This law represents conservation of energy. If the sum of potential changes around a closed loop is not zero, unlimited energy could be gained by repeatedly carrying a charge around a loop.

Sign convention for the application of Kirchoff's law

1. While traversing in a loop the direction of current is in the same path then the potential drop at a resistance is -IR while in the in opposite direction it is + IR.
2. The emf is taken negative when we traverse from positive to negative terminal of the cell. The emf is taken positive when we traverse from negative to positive terminal of the cell.


Figure 1.3


Figure 1.4

$$
R_{A B} \text { is Negative }
$$

Power: Power is defined as the rate of energy conversion or consumption. Power is the rate at which energy is converted from one form to another. In electrical circuit power is defined as

$$
\text { Power }=\frac{\text { work done }}{\text { time }}=V I=\frac{V^{2}}{R}=I^{2} R
$$

## Example



Figure 1.5
KCL for the junction at node 'a' is
Incoming current at node 'a' is $I_{3}$ and outgoing currents are $I_{1}$ and $I_{2}$.

$$
I_{3}=I_{1}+I_{2}
$$

sum of the currents meeting at node 'a' is zero OR

$$
I_{3}-I_{1}-I_{2}=0
$$

For the node ' d '

$$
\begin{array}{r}
I_{1}+I_{2}=I_{3} \\
I_{1}+I_{2}-I_{3}=0
\end{array}
$$

For the loop 1 abcda

$$
\begin{align*}
-4 I_{1}+9-3 I_{3} & =0 \\
-4 I_{1}+9-3\left(I_{1}+I_{2}\right) & =0 \\
7 I_{1}+3 I_{2} & =9 \tag{1.1}
\end{align*}
$$

For the loop 2 afeda

$$
\begin{align*}
8-5 I_{2}+9-3 I_{3} & =0 \\
17-5 I_{2}-3\left(I_{1}+I_{2}\right) & =0 \\
3 I_{1}+8 I_{2} & =17 \tag{1.2}
\end{align*}
$$

From Equation 1.1 and 1.2

$$
\begin{aligned}
7 I_{1}+3 I_{2} & =9 \\
3 I_{1}+8 I_{2} & =17
\end{aligned}
$$

Solving the above equations

$$
\begin{aligned}
I_{1} & =0.446 A \\
I_{2} & =1.95 A
\end{aligned}
$$

Applying Node voltage method

$$
\begin{gathered}
\frac{V_{a}}{4}+\frac{V_{a}-9}{3}+\frac{V_{a}+8}{5}=0 \\
V_{a}\left[\frac{1}{4}+\frac{1}{3}+\frac{1}{5}\right]-3+\frac{8}{5}=0 \\
V_{a}=1.787 \\
I_{1}=\frac{V_{a}}{4}=\frac{1.787}{4}=0.4464 \\
I_{2}=\frac{V_{a}+8}{5}=\frac{1.787+8}{5}=1.954
\end{gathered}
$$

## Branch Current Rule



Figure 1.6
When two resistors are connected in parallel:
Branch Current is

$$
=\text { Main Current } \frac{\text { Resistance of other branch }}{\text { Sum of resistances }}
$$

$$
\begin{aligned}
& I_{1}=I \frac{R_{2}}{R_{1}+R_{2}} \\
& I_{2}=I \frac{R_{1}}{R_{1}+R_{2}}
\end{aligned}
$$

Also it is given by

$$
\begin{aligned}
& I_{1}=I \frac{R_{P}}{R_{1}} \\
& I_{2}=I \frac{R_{P}}{R_{2}}
\end{aligned}
$$

where I is the main current and $R_{P}$ is the parallel branch effective resistance.

$$
\begin{aligned}
R_{P} & =\frac{R_{1} R_{2}}{R_{1}+R_{2}} \\
I & =\frac{V}{R_{P}+R_{3}}
\end{aligned}
$$

## Example 1

Find the current $i_{1}$ and $i_{2}$ for the circuit shown in Figure


Figure 1.7
Solution:
$12 \Omega$ and $4 \Omega$ are in parallel

$$
\begin{aligned}
R_{T} & =\frac{12 \times 4}{12+4}+2=3+2 \\
& =5 \Omega
\end{aligned}
$$

Total Current I is

$$
\begin{aligned}
I & =\frac{E}{R_{T}+r}=\frac{12}{5+1} \\
& =2 A
\end{aligned}
$$

## Using Method 1

$$
\begin{aligned}
& i_{1}=2 A \frac{4}{4+12}=0.5 A \\
& i_{2}=2 A \frac{12}{4+12}=1.5 \mathrm{~A}
\end{aligned}
$$

## Using Method 2

$$
\begin{aligned}
& i_{1}=2 A \frac{3}{12}=0.5 \mathrm{~A} \\
& i_{2}=2 A \frac{3}{4}=1.5 \mathrm{~A}
\end{aligned}
$$

## Example 2

Find the magnitude of I in ampere


Figure 1.8
Solution:

## Using Method 1



Figure 1.9

$$
I=1 A \frac{6.6666}{60+6.6666} \simeq 0.1 A
$$

## Using Method 2

When the Resistors 10, 15 and $60 \Omega$, are connected in parallel hence

$$
\begin{aligned}
\frac{1}{R_{T}} & =\frac{1}{10}+\frac{1}{20}+\frac{1}{60} \\
& =\frac{6+3+1}{60}=\frac{1}{6} \\
R_{T} & =6
\end{aligned}
$$

Current $I_{2}$ is

$$
\begin{aligned}
I & =1 A \frac{6}{60} \\
& =0.1
\end{aligned}
$$

Find the power dissipated in the $3 \Omega$ resistor


Figure 1.10
Solution: Ans (b): The given circuit is redrawn.


Figure 1.11
3 and $6 \Omega$ are in parallel which is in series with $2 \Omega$

$$
2+(3 \| 6)=2+\frac{6 \times 3}{6 \times 3}=2+2=4 \Omega
$$

$4 \Omega$ and $4 \Omega$ are in parallel which is in series with $1 \Omega$

$$
1+(4 \| 4)=1+\frac{4 \times 4}{4 \times 4}=1+2=3 \Omega
$$

The current I is

$$
\frac{4.5}{3}=1.5 A
$$

$1 \Omega 4.5 \mathrm{~V}$


Figure 1.12
The current $I_{1}$ is

$$
I_{1}=1.5 A \frac{4}{4+4}=0.75 A
$$

The current through $3 \Omega$ is

$$
I_{3}=0.75 A \frac{6}{3+6}=0.5 A
$$

The power dissipated in the $3 \Omega$ is

$$
\left(I_{3}\right)^{2} \times 3=(0.5)^{2} \times 3=0.75 W
$$

For the circuit shown in Figure 1.13 find the value of current $I_{2}$


Figure 1.13
Solution: The total Resistance of the network is

$$
\begin{aligned}
\frac{1}{R_{T}} & =\frac{1}{10}+\frac{1}{15}+\frac{1}{30} \\
& =\frac{6}{30}=\frac{1}{5} \\
R_{T} & =5
\end{aligned}
$$

Current $I_{2}$ is

$$
\begin{aligned}
I_{2} & =1.2 A \frac{5}{15} \\
& =0.4
\end{aligned}
$$

Find the current I flowing in the circuit as shown in Figure 1.14


Figure 1.14
Solution:
The $4 \Omega$ and $4 \Omega$ are in parallel which combination is in series with $4 \Omega$

$$
\frac{4 \times 4}{4+4}=2 \Omega
$$



Figure 1.15
Again $4 \Omega$ and $6 \Omega$ are in parallel

$$
\frac{4 \times 6}{4+6}=2.4 \Omega
$$



Figure 1.16
Current from battery is

$$
I=\frac{4}{2.4+1.6}=1 \mathrm{~A}
$$

The current $I$ is

$$
=1 A \frac{4}{4+6}=0.4 A
$$

Find the magnitude of the current I for the circuit shown in Figure 1.17 is


Figure 1.17
Solution: When the Resistors 10,15 and $30 \Omega$, are connected in parallel hence

$$
\begin{aligned}
\frac{1}{R_{T}} & =\frac{1}{10}+\frac{1}{20}+\frac{1}{60} \\
& =\frac{6+3+1}{60}=\frac{1}{6} \\
R_{T} & =6
\end{aligned}
$$

Current $I_{2}$ is

$$
\begin{aligned}
I & =1 A \frac{6}{60} \\
& =0.1
\end{aligned}
$$

### 1.2 DC-Circuits

2019-DEC (2018 scheme ECE) 1 b) Find $E_{1}$ when the power dissipated in the 5 resistor is 125 W for the circuit shown in Figure 1.18


Figure 1.18

## Solution:



Figure 1.19
Current $I$ in $5 \Omega$ resistor is related as

$$
\begin{aligned}
P_{5} & =I^{2} \times R \\
I^{2} & =\frac{P_{5}}{R}=\frac{125}{5}=25 \\
I & =5
\end{aligned}
$$

Current $I_{1}$ in $8 \Omega$ resistor is

$$
I_{1}=I-I_{1}=5-2.5=2.5 A
$$

Mesh equations are

$$
\begin{aligned}
& E_{1}-8 \times 2.5+2 \times 2.5-E_{2}=0 \\
& E_{2}-2 \times 2.5-5 \times 5=0 \\
& E_{2}=25+5=30
\end{aligned}
$$

$$
E_{1}-8 \times 2.5+2 \times 2.5-E_{2}=0
$$

$$
E_{1}=30-5+20=45
$$

2019-DEC (2018 scheme ECE) 2 a) Two 12V batteries with internal resistances $0.2 \Omega$ and $0.25 \Omega$ respectively are joined in parallel and a resistance of $1 \Omega$ is placed across the terminals. Find the current supplied by each battery.


Figure 1.20
Mesh equations are

$$
\begin{aligned}
12-0.2 \times I_{1}+0.25 \times I_{2}-12 & =0 \\
-0.2 \times I_{1}+0.25 \times I_{2} & =0 \\
& \\
12-0.25 \times I_{2}-1 \times\left(I_{1}+I_{2}\right) & =0 \\
12-1 I_{1}-1.25 \times I_{2} & =0 \\
1 I_{1}+1.25 \times I_{2} & =12
\end{aligned}
$$

$$
\begin{aligned}
-0.2 \times I_{1}+0.25 \times I_{2} & =0 \\
1 I_{1}+1.25 \times I_{2} & =12
\end{aligned}
$$

$$
I_{1}=6 A \quad I_{2}=4.8 A
$$

2019-June (2018 scheme ECE) 1 c) 2013-Jan 1 d) A circuit consists of two parallel resistors having resistances of $20 \Omega$ and $30 \Omega$ respectively connected in series with a $15 \Omega$ resistor. If current through 15 $\Omega$ resistor is 3 A , find
i) Current through the branches
ii) Voltage across whole circuit
iii) Power consumed by $20 \Omega$ and $30 \Omega$ resistors

## Solution:



Figure 1.21
(i) currents in $20 \Omega$ and $30 \Omega$ resistors

$$
\begin{aligned}
& I_{1}=I_{20}=3 \times \frac{30}{20+30} 1.8 A \\
& I_{2}=I_{30}=3 \times \frac{20}{20+30} 1.2 A
\end{aligned}
$$

(ii) the voltage across the whole circuit

$$
V=15 \times 3+30 \times 1.2=81 V
$$

(iii) total power consumed in all resistors

$$
\begin{aligned}
& P_{15}=I^{2} \times R=3^{2} \times 15=135 \mathrm{~W} \\
& P_{20}=1.8^{2} \times 20=64.8 \mathrm{~W} \\
& P_{30}=1.2^{2} \times 30=43.2 \mathrm{~W}
\end{aligned}
$$

Total power is

$$
\begin{aligned}
P_{\text {Total }} & =135 W+64.8 W+43.2 W \\
& ==243
\end{aligned}
$$

2019-June (2018 scheme ECE) 2 b) Find the potential difference between XY for the network as shown in Figure .


Figure 1.22

## Solution:



Figure 1.23

$$
\begin{aligned}
2-3 I_{1}-2 I_{1} & =0 \\
I_{1} & =\frac{2}{5}=0.4 \mathrm{~A} \\
4-3 I_{2}-5 I_{2} & =0 \\
I_{2} & =\frac{4}{8}=0.5 \mathrm{~A}
\end{aligned}
$$

The potential difference between XY is

$$
\begin{aligned}
V_{X Y} & =V_{X P}+V_{P Q}-V_{Q Y}=3 I_{1}+4-3 I_{2} \\
& =3 \times 0.4+4-3 \times 0.5 \\
& =3.7 \mathrm{~V}
\end{aligned}
$$

2019-Jan (2018 scheme ECE) 1 b) Given the network shown in Figure determine $I_{1}$, E $I_{2}$ and I. If voltage across $9 \Omega$ resistor is 27 V


Figure 1.24
Current through $9 \Omega$ resistor is $I_{1}$

$$
I_{1}=\frac{V}{R}=\frac{27}{9}=3 A
$$

The total resistor through $9 \Omega$ branch is

$$
=9+15=24 \Omega
$$

The total voltage drop across $24 \Omega$ resistor is

$$
V=V_{24}=I_{1} \times 24=3 \times 24=72 \mathrm{~V}
$$

Current through $8 \Omega$ resistor is $I_{2}$

$$
I_{2}=\frac{V}{R}=\frac{72}{8}=9 A
$$

Total Current $I$ is

$$
I=I_{1}+I_{2}=3+9=12 \mathrm{~A}
$$

2019-Jan (2018 scheme ECE) 2 c) For the network shown in Figure calculate the power consumed by each resistor.


Figure 1.25

## Solution:

Current through $8 \Omega$ resistor $I_{1}$ is

$$
I_{1}=I \frac{4}{4+8}=9 \frac{4}{4+8}=3 \mathrm{~A}
$$

Current through $4 \Omega$ resistor $I_{2}$ is

$$
I_{2}=I \frac{8}{4+8}=9 \frac{8}{4+8}=6 \mathrm{~A}
$$

Power consumed in $8 \Omega$ resistor is

$$
P_{8}=I_{1}^{2} \times 8=3^{2} \times 8=72 \mathrm{~W}
$$

Power consumed in $4 \Omega$ resistor is

$$
P_{4}=I_{2}^{2} \times 4=6^{2} \times 4=144 W
$$

2019-June 2 a) For the circuit shown in Figure 1.26 i) Find R ii) current through $20 \Omega$ resistance iii) power supplied by source if power dissipated in 40 $\Omega$ is 160 Watts.


Figure 1.26

## Solution:

Power consumed in $40 \Omega$ resistor is related as

$$
\begin{aligned}
P_{40} & =I_{40}^{2} \times 40 \\
I_{40}^{2} & =\frac{P_{40}}{40}=\frac{160}{40}=4 \\
I_{40} & =2 A
\end{aligned}
$$

Voltage across $40 \Omega$ resistor is related as

$$
\begin{aligned}
V_{40} & =I_{40} \times 40 \\
& =2 \times 40=80
\end{aligned}
$$

Current through $6 \Omega$ resistor is

$$
I_{6}=\frac{80}{6}=13.333 A
$$

Current through $30 \Omega$ resistor is

$$
I_{30}=\frac{80}{30}=2.666 A
$$

Total Current through entire circuit is

$$
=I_{40}+I_{30}+I_{6}=2+2.666+13.333=18 A
$$

Total resistance of the circuit is

$$
\begin{aligned}
\frac{1}{R_{P}} & =\frac{1}{30}+\frac{1}{40}+\frac{1}{6} \\
R_{P} & =4.444 \Omega
\end{aligned}
$$

$$
=\frac{20 R}{20+R}+4.444 \Omega
$$

The voltage across entire circuit is

$$
\begin{aligned}
V & =I \times\left(\frac{20 R}{20+R}+4.444\right) \\
\left(\frac{20 R}{20+R}+4.444\right) & =\frac{V}{I}=\frac{150}{5}=8.333 \\
\frac{20 R}{20+R} & =\frac{150}{18}=8.333-4.444=4 \\
20 R & ==80+4 R \\
16 R & ==80 \\
R & ==\frac{80}{16}=5 \Omega
\end{aligned}
$$

Power supplied source is

$$
P=V I=150 \times 18=2700 W \text { atts }
$$

2019-June 1 a) For the circuit shown in Figure 1.27 i) calculate the value of $R$ and applied voltage $V$.


Figure 1.27

## Solution:

The power delivered in $15 \Omega$ resistor is

$$
\begin{aligned}
P & =I^{2} \times R \\
I^{2} & =\frac{P}{R}=\frac{150}{15}=10 \\
I & =3.162 A
\end{aligned}
$$

The current flowing in other $15 \Omega$ resistor is also 3.162 A . The current flowing in R is

$$
I_{R}=15-3.162-3.162=8.676 A
$$

Voltage across $15 \Omega$ resistor is

$$
V=I \times R=3.162 \times 15=47.43 V
$$

The value of $R$ is

$$
R=\frac{V}{I}=\frac{47.43}{8.676}=5.5 \Omega
$$

The applied voltage is

$$
\begin{aligned}
V & =15 \times 5+47.43+15 \times 5 \\
& =75+47.43+75=193.73 \mathrm{~V}
\end{aligned}
$$

2019-June 2 b ) A battery of 40 V and internal resistance of $2 \Omega$ is connected in parallel with a second battery of 44 V and internal resistance of $4 \Omega$. A load resistance of $6 \Omega$ is connected across the ends of the parallel circuit. Calculate the current in each battery and in the load


Figure 1.28

$$
\begin{aligned}
40-2 I_{1}+4 I_{2}-44 & =0 \\
-2 I_{1}+4 I_{2}-4 & =0 \\
-2 I_{1}+4 I_{2} & =4 \\
& \\
44-4 I_{2}-6 I_{3} & =0 \\
44-4 I_{2}-6\left(I_{1}+I_{2}\right) & =0 \\
44-6 I_{1}-10 I_{2} & =0 \\
6 I_{1}+10 I_{2} & =44
\end{aligned}
$$

$$
-2 I_{1}+4 I_{2}=4
$$

$$
6 I_{1}+10 I_{2}=44
$$

$$
I_{1}=3.09 A \quad I_{2}=2.545 A
$$

$$
I_{3}=I_{1}+I_{2}=3.1 A+2.545=5.635 A
$$

Second Method


Figure 1.29


Figure 1.30

$$
I_{2}=31 \frac{1.333}{6+1.333}=5.636 A
$$

2019-Dec 2 a) Two 12 V batteries with internal resistances of $0.2 \Omega$ and $0.25 \Omega$ respectively are joined in parallel and a resistance of $1 \Omega$ is placed across the terminals. Find the current supplied by each battery.


Figure 1.31

$$
\begin{aligned}
12-0.2 I_{1}+0.25 I_{2}-12 & =0 \\
-0.2 I_{1}+0.25 I_{2} & =0
\end{aligned}
$$

$$
\begin{aligned}
& 12-0.25 I_{2}-1 I_{3}=0 \\
& 12-0.25 I_{2}-1\left(I_{1}+I_{2}\right)=0 \\
& 12-1 I_{1}-1.25 I_{2}=0 \\
&-1 I_{1}-1.25 I_{2}=-12 \\
&-0.2 I_{1}+0.25 I_{2}=0 \\
&-1 I_{1}-1.25 I_{2}=-12 \\
& I_{1}=6 A \quad I_{2}=4.8 A \\
& I_{3}=I_{1}+I_{2}=6 A+4.8=10.8 A
\end{aligned}
$$

2019-Jan 2 b) Apply Kirchoff's laws to find potential differnece between X and Y for the network as shown in Figure .


Figure 1.32

## Solution:



Figure 1.33

$$
\begin{aligned}
2-2 I_{1}-2 I_{1} & =0 \\
I_{1} & =\frac{2}{4}=0.5 \mathrm{~A} \\
8-5 I_{2}-3 I_{2} & =0 \\
I_{2} & =\frac{8}{8}=1 \mathrm{~A}
\end{aligned}
$$

The potential difference between XY is

$$
\begin{aligned}
V_{X Y} & =-V_{X P}+V_{P Q}-V_{Q Y}=-2 I_{1}+4-3 I_{2} \\
& =-2 \times 0.5+4-3 \times 1 \\
& =-1+4-3=0 \mathrm{~V}
\end{aligned}
$$

2020-Jan (2015 scheme ECE) 1 c) A circuit consists of two parallel resistors having resistances of $20 \Omega$ and $30 \Omega$ respectively connected in series with a 15 $\Omega$ resistor. If the power dissipation in $15 \Omega$ resistor is 135 Watts, find
i) Current $20 \Omega$ and $30 \Omega$ resistors
ii) Voltage across whole circuit
iii) Power consumed by $20 \Omega$

## Solution:



Figure 1.34
(i) Current in $15 \Omega$ resistor

$$
\begin{aligned}
P & =I^{2} R \\
I^{2} & =\frac{P}{R}=\frac{135}{15}=9 \\
I & =3 A
\end{aligned}
$$

currents in $20 \Omega$ and $30 \Omega$ resistors

$$
\begin{aligned}
& I_{1}=I_{20}=3 \times \frac{30}{20+30} 1.8 \mathrm{~A} \\
& I_{2}=I_{30}=3 \times \frac{20}{20+30} 1.2 \mathrm{~A}
\end{aligned}
$$

(ii) the voltage across the whole circuit

$$
V=15 \times 3+30 \times 1.2=81 \mathrm{~V}
$$

(iii) total power consumed in all resistors

$$
\begin{aligned}
& P_{15}=I^{2} \times R=3^{2} \times 15=135 \mathrm{~W} \\
& P_{20}==1.8^{2} \times 20=64.8 \mathrm{~W} \\
& P_{30}=1.2^{2} \times 30=43.2 \mathrm{~W}
\end{aligned}
$$

Total power is

$$
\begin{aligned}
P_{\text {Total }} & =135 W+64.8 W+43.2 W \\
& =243
\end{aligned}
$$

2015-June 1 b) If the total power dissipated in the circuit shown in Figure 1.35 is 18 W. Find the value of $R$ and its current


Figure 1.35
Solution: The value of R is

$$
\begin{aligned}
P & =\frac{V^{2}}{R_{T}} \\
R_{T} & =\frac{V^{2}}{P}=\frac{12^{2}}{18} \\
& =8 \Omega
\end{aligned}
$$

The main current I is

$$
\begin{aligned}
R_{T} & =\frac{12(16+R)}{12+16+R} \\
8 & =\frac{192+12 R}{28+R} \\
224+8 R & =192+12 R \\
4 R & =32 \\
R & =\frac{32}{4}=8 \Omega
\end{aligned}
$$

The current flowing through resistance $R$ is

$$
\begin{aligned}
I_{R} & =I \frac{12}{12+16+8} \\
& =0.5 \mathrm{~A}
\end{aligned}
$$

2014-Jan 1 c) Find the value of resistance $R$ as shown in Figure 1.36, so that current drawn from the source is 250 mA . All the resistor values are in ohm.


Figure 1.36

## Solution:

The resistance of the network is
$40 \Omega$ and $\mathrm{R} \Omega$ are in parallel which combination is in series with $40 \Omega$

$$
\begin{aligned}
R_{1} & =40+40 \| R=40+\frac{40 R}{40+R} \\
& =\frac{1600+80 R}{40+R}
\end{aligned}
$$



Figure 1.37
The current in $30 \Omega$ branch is

$$
I_{1}=\frac{5}{30}=166.67 \mathrm{~mA}
$$

The current in parallel branch is

$$
I_{2}=250-166.67=83.33 m A
$$

$$
\begin{aligned}
83.33 m A\left(\frac{1600+80 R}{40+R}\right) & =5 \\
\frac{1600+80 R}{40+R} & =60 \Omega \\
1600+80 R & =60(40+R) \\
& =2400+60 R \\
20 R & =800 \\
R & =\frac{800}{20}=40
\end{aligned}
$$

2013-Jan 1 b) Find the resistance of the circuit as shown in Figure $1.38 R_{A D}$.


Figure 1.38

## Solution:

$$
\begin{aligned}
\frac{1}{R_{A B}} & =\frac{1}{2}+\frac{1}{5}+\frac{1}{10} \\
& =\frac{5+2+1}{10}=\frac{8}{10} \\
R_{A B} & =\frac{10}{8}=1.25
\end{aligned}
$$

$$
R_{B C}=\frac{6 \times 4}{6+4}=2.4
$$

$$
R_{A B}+R_{B C}+R_{C D}=1.25+2.4+1.35=5 \Omega
$$

$$
R_{A D}=\frac{5 \times 5}{5+5}=2.5 \Omega
$$

2013-Jan 1 d) In the parallel arrangement of resistors as shown in Figure 1.39 the current flowing in the 8 resistor is 2.5 amperes. Find i) current in other resistors ii) resistor X iii) the equivalent resistance.


Figure 1.39

## Solution:



Figure 1.40
Voltage across the circuit is

$$
V=2.5 \times 8=20 \mathrm{~V}
$$

i) current in other resistors
$I_{3}=\frac{20}{40}=0.5 \mathrm{~A}$
$I_{4}=\frac{20}{25}=0.8 \mathrm{~A}$
$I_{2}=4-\left(I_{1}+I_{3}+I_{4}\right)=4-(2.5+0.5+0.8)=0.2 \mathrm{~A}$
ii) resistor $X$

$$
X=\frac{20}{0.2}=100 \Omega
$$

iii) the equivalent resistance is

$$
\begin{aligned}
\frac{1}{R_{T}} & =\frac{1}{8}+\frac{1}{100}+\frac{1}{40}+\frac{1}{25}=\frac{1}{5} \\
R_{T} & =5 \Omega
\end{aligned}
$$

2012-June 1 a) The current in $5 \Omega$ resistor is.


Figure 1.41

## Solution:

The current in $5 \Omega$ resistor is

$$
I_{5}=3 \times \frac{10}{10+5}=2 A
$$

2012-June 1 d) Find the current in the battery the current in each branch and p.d. across AB in the network shown in Figure 1.42.


Figure 1.42

## Solution:

The total network resistance is

$$
R_{T}=4+\frac{5 \times 14}{5+14}=7.68 \Omega
$$

The total current drawn from the battery is

$$
I_{T}=\frac{10}{7.68}=1.3 \mathrm{~A}
$$

The current $I_{1}$ is

$$
\begin{aligned}
& I_{1}=1.3 \times \frac{14}{14+5}=0.96 \mathrm{~A} \\
& I_{2}=1.3 \times \frac{5}{14+5}=0.34 \mathrm{~A}
\end{aligned}
$$

$$
\begin{aligned}
V_{A B} & =I_{1} \times 3-I_{2} \times 8 \\
& =0.96 \times 3-0.34 \times 8=0.16 \mathrm{~V}
\end{aligned}
$$

2011-Dec 1 d) For the circuit shown in Figure 1.43, find the current in the supplied by each battery and power dissipated in $1 \Omega$ resistor.


Figure 1.43

## Solution:



Figure 1.44
The total network resistance is

$$
\begin{aligned}
& 12-0.25 I_{1}+0.2 I_{2}-12=0 \\
& 12-0.2 I_{2}-1\left(I_{1}+I_{2}\right)=0 \\
& 12-I_{1}-1.2 I_{2}=0 \\
& \\
& 0.25 I_{1}-0.2 I_{2}=0 \\
& I_{1}+1.2 I_{2}=12
\end{aligned}
$$

$$
I_{1}=4.8 \mathrm{~A} \quad I_{2}=6 \mathrm{~A}
$$

The current in $1 \Omega$ resistor is

$$
I_{1}+I_{2}=4.8 A+6 A=10.8 A
$$

Power dissipated in $1 \Omega$ resistor

$$
P_{T}=(10.8)^{2} \times 1=116.64 \mathrm{~W}
$$

2011-June 1 c) A $2 \Omega$ resistor is connected in series with parallel combination of $10 \Omega$ and $15 \Omega$ resistors. Then heat dissipated in kW sec for 1 hour in circuit, when current of 2 A flowing in $2 \Omega$ resistor is

## Solution:



Figure 1.45
Heat dissipated is

$$
\begin{aligned}
& I_{1}=2 \frac{15}{15+10}=1.2 \mathrm{~A} \\
& I_{2}=2 \frac{10}{15+10}=0.8 \mathrm{~A}
\end{aligned}
$$

Heat dissipated is

$$
\begin{aligned}
P_{T} & =\frac{\left(2^{2} \times 2+1.2 \times 10+0.8 \times 15\right) \times 3600}{1000} \\
& =115.5 \mathrm{~kW} \mathrm{~s}
\end{aligned}
$$

2011-Jan 1 b) A $8 \Omega$ resistor is in series with parallel combination of two resistors $12 \Omega$ and $6 \Omega$. The current in the $6 \Omega$ resistor is of 5 A . Determine the total power dissipated in the circuit.

## Solution:



Figure 1.46
The total current I is

$$
\begin{aligned}
5 & =I \frac{12}{12+6} \\
I & =7.5 \mathrm{~A}
\end{aligned}
$$

The current in $12 \Omega$ is

$$
I_{2}=7.5-5=2.5 A
$$

Power dissipated is

$$
\begin{aligned}
P_{T} & =7.5^{2} \times 8+2.5^{2} \times 12+5^{2} \times 6 \\
& =675 \mathrm{~W}
\end{aligned}
$$

2010-May 1 b) Find the values of currents in all the branches of the network shown in Figure 1.47


Figure 1.47

## Solution:



Figure 1.48

$$
\begin{aligned}
0 & =-0.2 I-0.1(I-60)-0.3 I-0.1(I-120) \\
& -0.1(I-150)-0.2(I-80) \\
I & =39 A
\end{aligned}
$$

$$
\begin{aligned}
I_{A B} & =I=39 A \\
I_{B C} & =(I-60)=39-60=-21 A \\
I_{C D} & =I=39 A \\
I_{D E} & =(I-120)=39-120=-90 A \\
I_{E F} & =(I-50)=39-50=-11 A \\
I_{F A} & =(I-80)=39-80=-41 A
\end{aligned}
$$

2010-May 1 b) A current of 20 A flows through two ammeters A and B in series. The potential difference across A is 0.2 V and across B is 0.3 V . Find how the same current will divide between $A$ and $B$ when they are in parallel.

## Solution:



Figure 1.49
First we have to determine the value of resistance of each ammeter when they are connected in series

$$
\begin{aligned}
& R_{A}=\frac{0.2}{20}=0.01 \Omega \\
& R_{B}=\frac{0.3}{20}=0.015 \Omega
\end{aligned}
$$

When they are connected in parallel the current in each branch is

$$
\begin{aligned}
I_{A} & =20 \times \frac{0.015}{0.015+0.01}=12 A \\
I_{B} & =20 \times \frac{0.01}{0.015+0.01}=8 A
\end{aligned}
$$



Figure 1.50

2010-May 2 a) A circuit consists of two parallel resistors having resistances of $20 \Omega$ and $30 \Omega$ respectively, connected in series with a $15 \Omega$ resistor. If the current through $30 \Omega$ resistor is 1.2 A find (i) currents in $20 \Omega$ and $15 \Omega$ resistors (ii) the voltage across the whole circuit (iii) voltage across $15 \Omega$ resistor and $20 \Omega$ resistor (iv) total power consumed in the circuit

## Solution:



Figure 1.51
(i) currents in $20 \Omega$ and $15 \Omega$ resistors

$$
\begin{aligned}
1.2 & =I \times \frac{20}{20+30} \\
I & =3 A \\
I_{1} & =3-1.2=1.8 A
\end{aligned}
$$

(ii) the voltage across the whole circuit

$$
V=1.2 \times 30+15 \times 3=81 V
$$

(iii) voltage across $15 \Omega$ resistor and $20 \Omega$ resistor

$$
\begin{aligned}
& V_{15}=15 \times 3=45 \mathrm{~V} \\
& V_{20}=1.8 \times 20=36 \mathrm{~V}
\end{aligned}
$$

(iv) total power consumed in the circuit

$$
P=V I=81 \times 3=243 W
$$

2014-Model 2 a) Calculate the supply voltage V in the circuit shown in Figure 1.53


Figure 1.52

## Solution:



Figure 1.53

$$
\begin{aligned}
& I_{4}=\frac{10}{5}=2 A \\
& I_{3}=\frac{10}{10}=1 A \\
& I_{2}=I_{3}+I_{4}=2+1=3 A
\end{aligned}
$$

The resistance in the $I_{2}$ branch is

$$
R=5+10+\frac{10 \times 5}{10+5}=18.33 \Omega
$$

Using current division method

$$
\begin{aligned}
I_{2} & =I \frac{10}{10+18.33}=2 \mathrm{~A} \\
I & =3 \frac{28.33}{10}=8.5 \mathrm{~A} \\
I_{1} & =I-I_{2}=8.5-3=5.5 \mathrm{~A}
\end{aligned}
$$

Voltage V is

$$
\begin{aligned}
V & =10 \times I+10 \times I_{1}=2 A \\
& =10 \times 8.5+10 \times 5.5=85+55 \\
& =140 \mathrm{~V}
\end{aligned}
$$

2010-May 1 b) The total power consumed by the network shown in Figure 1.54 is 16 W. Find the value of R and the total power


Figure 1.54

## Solution:



Figure 1.55

## Solution:

The total resistance of the network $R_{T}$ is

$$
\begin{aligned}
& =\frac{V^{2}}{R_{T}} \\
R_{T} & =\frac{V^{2}}{P}=\frac{20^{2}}{70} \\
& =5.714 \Omega
\end{aligned}
$$

From the network the total resistance is related as

$$
\begin{aligned}
R_{T} & =R+\frac{12 \times 8}{12+8} \\
5.714 & =R+4.8 \\
R & =5.714-4.8=0.9 \Omega
\end{aligned}
$$

2010-Jan 1 a) If 100 V is applied across a $200 \mathrm{~V}, 100$ W bulb, the power consumed will be
Solution:

$$
\begin{aligned}
P & =\frac{V^{2}}{R} \\
R & =\frac{V^{2}}{P}=\frac{200^{2}}{100} \\
& =400 \Omega
\end{aligned}
$$

The power consumed is

$$
\begin{aligned}
P & =\frac{V^{2}}{R} \\
R & =\frac{V^{2}}{P}=\frac{100^{2}}{400} \\
& =25 W
\end{aligned}
$$

2010-Jan 1 a) In the circuit shown in Figure 1.56 what is the voltage across cd if (i) switch $S$ is open and (ii) switch $S$ is closed


Figure 1.56

## Solution:

When the switch S is open


Figure 1.57
Apply KVL for the circuit shown in Figure

$$
\begin{aligned}
120-2 I_{1}-10 I_{2} & =0 \\
2 I_{1}+10 I_{2} & =120
\end{aligned}
$$

$$
\begin{aligned}
-1\left(I_{1}-I_{2}\right)-20-100+10 I_{2} & =0 \\
-I_{1}+11 I_{2} & =120
\end{aligned}
$$

$$
\begin{aligned}
2 I_{1}+10 I_{2} & =120 \\
-I_{1}+11 I_{0} & =120
\end{aligned}
$$

$$
-I_{1}+11 I_{2}=120
$$

Solving the above equations

$$
I_{1}=3.75 A \quad I_{2}=11.25 A
$$

The voltage across cd is

$$
\begin{aligned}
V_{c d} & =10 \times I_{2}=10 \times 11.25 \\
& =112.5 \mathrm{~V}
\end{aligned}
$$

When the switch S is closed


Figure 1.58

$$
V_{c d}=100 \mathrm{~V}
$$

2010-Jan 2 a) In the circuit shown in Figure 1.56 what is the voltage across cd if (i) switch $S$ is open and (ii) switch $S$ is closed


Figure 1.59

## Solution:

When the switch S is open


Figure 1.60
Apply KVL for the circuit shown in Figure

$$
\begin{aligned}
120-50 I_{1}-10 I_{2} & =0 \\
50 I_{1}+10 I_{2} & =120
\end{aligned}
$$

$$
\begin{aligned}
-2\left(I_{1}-I_{2}\right)-20-100+10 I_{2} & =0 \\
-2 I_{1}+12 I_{2} & =120 \\
& \\
50 I_{1}+10 I_{2}=120 & \\
-2 I_{1}+12 I_{2}=120 &
\end{aligned}
$$

Solving the above equations

$$
I_{1}=0.387 \quad I_{2}=10.06
$$

The voltage across cd is

$$
\begin{aligned}
V_{c d} & =10 \times I_{2}=10 \times 10.06 \\
& =100.6 \mathrm{~V}
\end{aligned}
$$

When the switch S is closed


Figure 1.61

$$
V_{c d}=100 \mathrm{~V}
$$

2010-Jan 2 a) In the circuit shown in Figure 1.62 determine the direction and magnitude of current flow in the milli-ammeter A, having a resistance of $10 \Omega$


Figure 1.62

## Solution:



Figure 1.63
Apply KVL for the circuit shown in Figure

$$
\begin{aligned}
4-100\left(I_{1}-I_{2}\right)+10 I_{2} & =0 \\
100 I_{1}-110 I_{2} & =4
\end{aligned}
$$

$$
\begin{aligned}
2-25 I_{1}-10 I_{2} & =0 \\
25 I_{1}+10 I_{2} & =2
\end{aligned}
$$

Simultaneous equations are

$$
\begin{aligned}
100 I_{1}-110 I_{2} & =4 \\
25 I_{1}+10 I_{2} & =2
\end{aligned}
$$

Solving above equations

$$
I_{1}=0.069 \quad I_{2}=0.0267 A
$$

