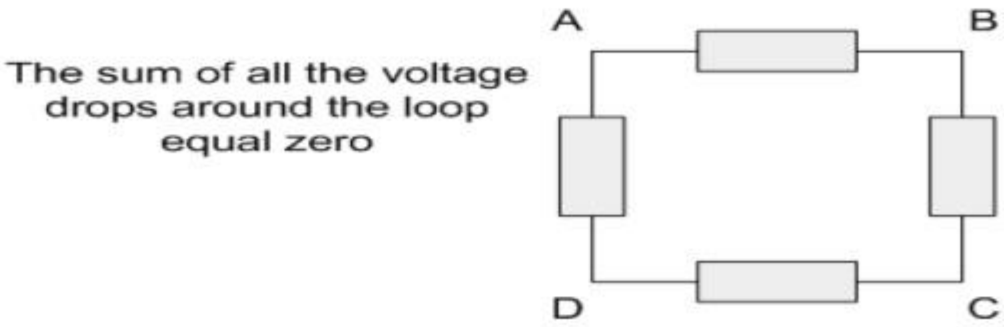
**Kirchoff's Second Law - The Voltage Law, (KVL)**

*"*In any closed loop network, the total voltage around the loop is equal to the sum of all the voltage drops within the same loop*"* which is also equal to zero. In other words the algebraic sum of all voltages within the loop must be equal to zero. This idea by Kirchoff is known as the Conservation of Energy**.**

Starting at any point in the loop continue in the same direction noting the direction of all the voltage drops, either positive or negative, and returning back to the same starting point. It is important to maintain the same direction either clockwise or anti-clockwise or the final voltage sum will not be equal to zero.

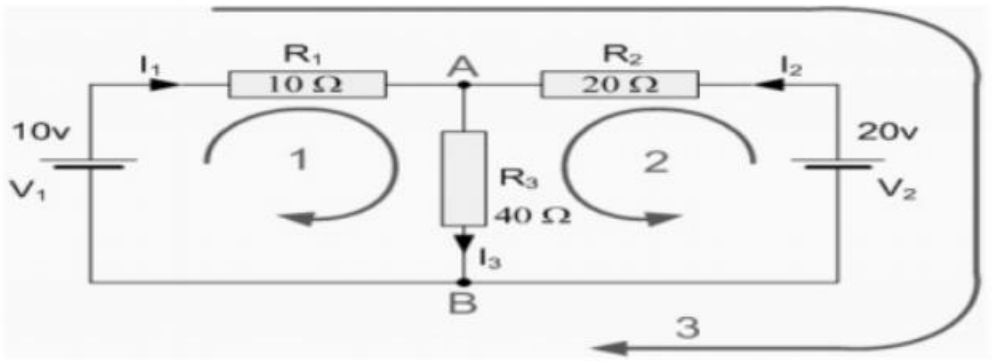
We can use Kirchoff's voltage law when analyzing series circuits.




$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

**Problem: 1**

Find the current flowing in the 40Ω Resistor,



**Solution:**

The circuit has 3 branches, 2 nodes (A and B) and 2 independent loops.

Using Kirchoff's Current Law, KCL the equations are given as;

At node A: $I_1 + I_2 = I_3$

At node B: $I_3 = I_1 + I_2$

Using Kirchoff's Voltage Law, KVL the equations are given as;

Loop 1 is given as: $10 = R_1 \times I_1 + R_3 \times I_3 = 10I_1 + 40I_3$

Loop 2 is given as: $20 = R_2 \times I_2 + R_3 \times I_3 = 20I_2 + 40I_3$

Loop 3 is given as: $10 - 20 = 10I_1 - 20I_2$

As I3 is the sum of $I_1 + I_2$ we can rewrite the equations as;

Eq. No 1: $10 = 10I_1 + 40(I_1 + I_2) = 50I_1 + 40I_2$

Eq.No 2: $20 = 20I_1 + 40(I_1 + I_2) = 40I_1 + 60I_2$

We now have two "Simultaneous Equations" that can be reduced to give us the value of both $I_1$ and $I_2$

Substitution of $I_1$ in terms of $I_2$ gives us the value of $I_1$ as -0.143 Amps

Substitution of $I_2$ in terms of $I_1$ gives us the value of $I_2$ as +0.429 Amps

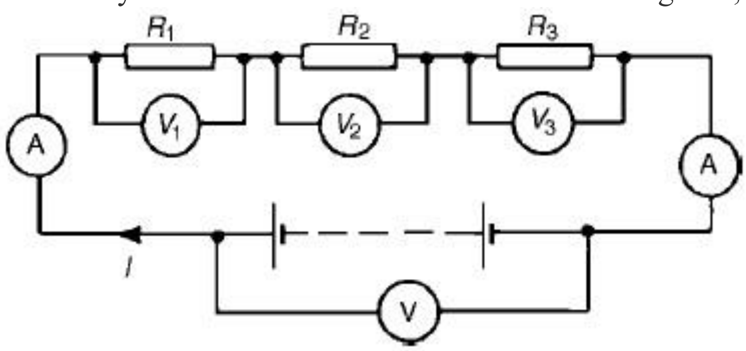
As: $I_3 = I_1 + I_2$

The current flowing in resistor $R_3$ is given as: -0.143 + 0.429 = 0.286 Amps and the voltage across the resistor $R_3$ is given as : 0.286 x 40 = 11.44 volts

**Resistors in series and parallel circuits:**

**Series circuits:**

Figure shows three resistors R1, R2 and R3 connected end to end, i.e. in series, with a battery source of V volts. Since the circuit is closed a current I will flow and the p.d. across each resistor may be determined from the voltmeter readings V1, V2 and V3




**In a series circuit**

(a) the current I is the same in all parts of the circuit and hence the same reading is found on each of the two ammeters shown, and

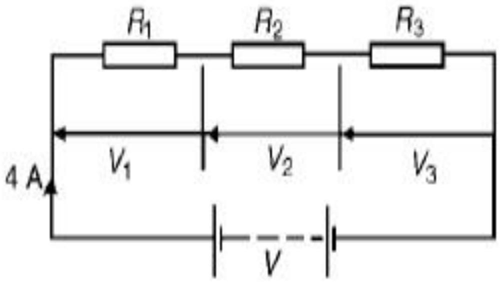
(b)the sum of the voltages V1, V2 and V3 is equal to the total applied voltage, V, i.e.
V = V1 +V2 +V3
From Ohm's law:

V1 = IR1, V2 = IR2, V3 = IR3 and V = IR where R is the total circuit resistance. Since V =V1 + V2 + V3

then IR =IR1 + IR2 + IR3 Dividing throughout by I gives R = R1 + R2 + R3

Thus for a series circuit, the total resistance is obtained by adding together the values of the separate resistances.

**Problem 1:** For the circuit shown in Figure 5.2, determine (a) the battery voltage V, (b) the total resistance of the circuit, and (c) the values of resistance of resistors R1, R2 and R3, given that the p.d.'sR1, R2acrossandR3are5V, 2V and 6V respectively.



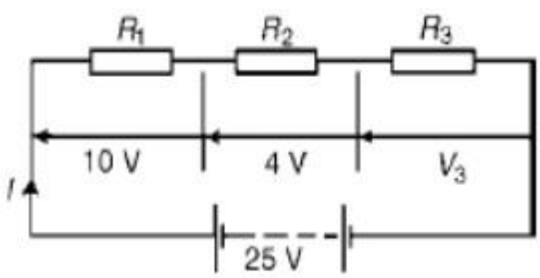

(a) Battery voltage V =V1 + V2 + V3 =5 + 2 + 6=13V
(b)Total circuit resistance R= V/ I
= 13/4=3.25Ω
(c) Resistance R1 = V1/ I
= 5/4

=1.25 Ω Resistance R2 = V2/ I

= 2/4 =0.5 Ω

Resistance R3 = V3/ I = 6/4 =1.5 Ω

**Problem 2.** For the circuit shown in Figure determine the p.d. across resistor *R*3. If the total resistance of the circuit is 100_, determine the current flowing through resistor *R*1. Find also the value of resistor *R*2.



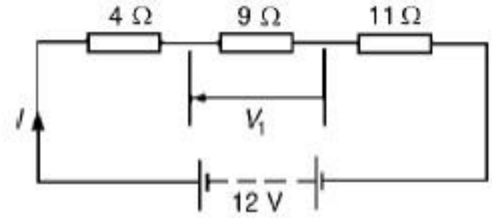

P.d. across R3, V3 =25 −10 −4=11V Current I = V/ R

= 25/100

=0.25A, which is the current flowing in each resistor Resistance R2 = V2/ I

= 4/0.25 =16 Ω

**Problem 3:** A 12V battery is connected in a circuit having three series-connected resistors having resistances of 4 Ω, 9 Ωand 11 Ω. Determine the current flowing through, and the p.d. across the 9 Ωresistor. Find also the power dissipated in the 11 Ωresistor.




Total resistance R=4 + 9 + 11=24 Ω Current I = V/ R

= 12/24

=0.5A, which is the current in the 9 Ωresistor. P.d. across the 9_ resistor, *V*1 = *I* × 9 = 0.5 × 9

= 4.5V

Power dissipated in the 11 Ωresistor, *P* = *I*2*R*=0.52(11)

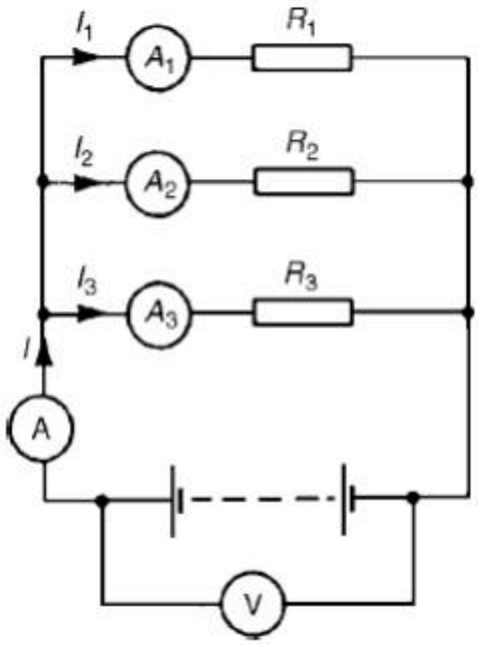
= 0.25(11)

= 2.75W

**8. PARALLEL NETWORKS:**

**Problem 1:** Figure shows three resistors, R1, R2 and R3 connected across each other, i.e. in parallel, across a battery source

of V volts.




**In a parallel circuit:**

(a) the sum of the currents I1, I2 and I3 is equal to the total circuit current, I, i.e. I =I1 +I2 +I3, and

the source p.d., V volts, is the same across each of the
From Ohm's law:
I1 = V/R1
, I2 = V/R2

, I3 = V/R3 and I = V/R

where R is the total circuit resistance. Since I =I1 + I2 + I3

then

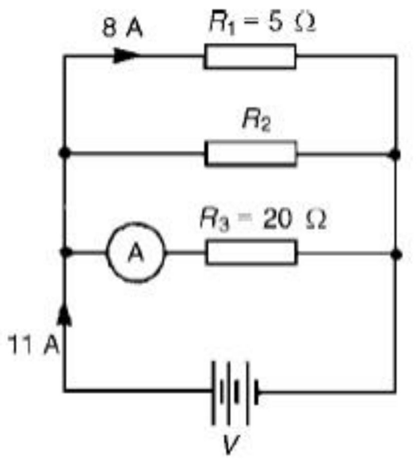
V/R= V/R1+ V/R2+ V/R3 Dividing throughout by V gives:

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

This equation must be used when finding the total resistance R of a parallel circuit. For the special case of two resistors in parallel

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

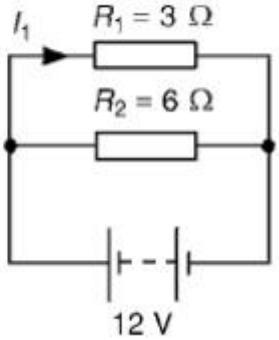
**Problem 2:** For the circuit shown in Figure , determine (a) the reading on the ammeter, and (b) the value of resistor R2.




P.d. across R1 is the same as the supply voltage V.
Hence supply voltage, V =8 × 5=40V

(a) Reading on ammeter, I = V R3= 40/20=2A

Current flowing through R2 =11−8−2=1A
Hence, R2 = V/I2= 40/1=40 Ω

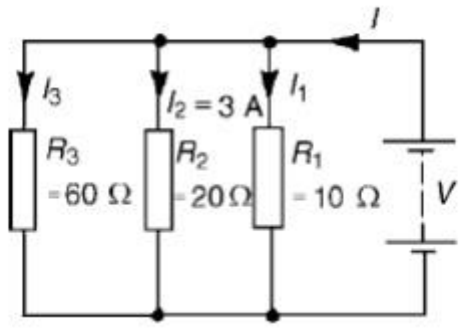



(a) The total circuit resistance R is given by 1/R= 1/R1+ 1/R2= 1/3+ 1/6

1/R= 2 + 1/6= 3/6 Hence, R = 6/3= 2 Ω

(b) Current in the 3 Ωresistance, I1 = V R1= 12/3= 4A

**Problem 3:** For the circuit shown in Figure find (a) the value of the supply voltage V and (b) the value of current I.



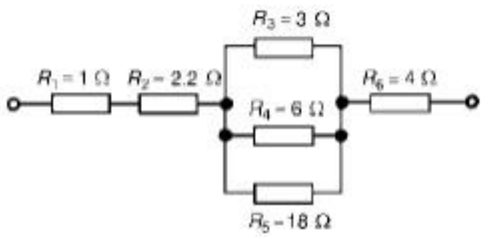

(a) P.d. across 20 Ωresistor = I2R2 = 3× 20 = 60V, hence supply voltage V =60V since the circuit is connected in parallel.

(b)Current I1 = V/R1= 60/10= 6A; I2 = 3A
I3 = V/R3= 60/60= 1A

Current I =I1+I2+I3 and hence I =6+3+1=10A Alternatively,

1/R= 1/60+ 1/20+ 1/10= 1 + 3 + 6/60= 10/60 Hence total resistance R= 6010=6 Ω Current I = V/R= 60/6=10A

**Problem 4:** Find the equivalent resistance for the circuit shown in Figure




*R*3, *R*4 and*R*5 are connected in parallel and their equivalent resistance *R* is given by: 1/*R*= 1/3+ 1/6+ 1/18=6 + 3 + 1/18= 10/18

Hence *R*= 18/10=1.8 Ω

The circuit is now equivalent to four resistors in series and the equivalent circuit resistance =1+2.2+1.8+4=9 Ω