O P JINDAL SCHOOL, SAVITRINAGAR

CLASS NOTES

CLASS XII PHYSICS — TOPIC : CURRENT ELECTRICTY

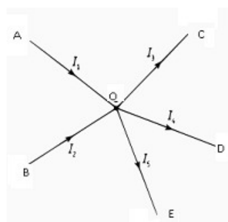
Date : 25 /04/20 — SUBTOPIC: KIRCHHOFF'S LAW

Kirchhoff's First law:

(i) Junction law : Junction Law is also known as Kirchhoff's First Law.

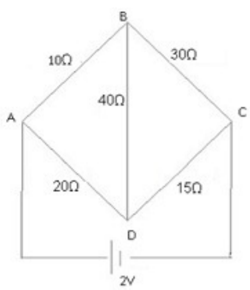
It states that at the junction,sum of current entering the junction is equal to the sum of current leaving the junction.

Consider a case where I_1 and $I_2$are the currententering the junction and,currentI_4 and I_5 are exiting out of the junction.

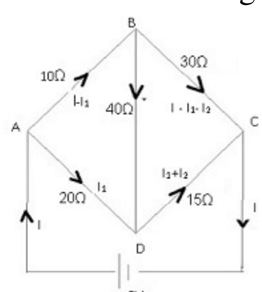


According to Kirchhoff's law; $I_1+ I_2 =I_3+ I_4+ I_5$

Problem 1 :- Determine the value current in 40 Ω resistance. Refer figure.



Answer: First we have to apply KCL 1 to the network. See figure 2nd.



Note that there are three unknown variables (I, I_1, I_2) and therefore we need to solve three equations simultaneously to find this unknown variable.

Apply KCL to Circuit ABDA

$\sum IR = \sum Emf$

$(I - I_1)*10 + I_2*40 - 20I = 0$

$10*I - 30*I_1 +40*I_2 = 0$ ------------------------- (1)

Apply KCL to Circuit BCDB

$(I - I_1 - I_2)*30 - (I_1+I_2)*15 - I_2*40 = 0$
$30*I - 45*I_1 - 85*I_2 = 0$ ------------------------ (2)
Apply KCL to Circuit ADCEA

$I_1*20 + (I_1+I_2)*15 = 2$
$35*I_1 + 15*I_2 = 2$ ----------------------------- (3)
Now solve these three equations

$I = 87/785$ A

$I_1 = 41/785$ A
$I_2 = 9/785$ A
So the current in 60 Ohms resistance is 9/785 A from B to D.

Kirchhoff's Second law:

(2) Loop law

Loop law is also known as Kirchhoff's Second Law.

It states that in a closed loop, algebraic sum of Emfs are equal to the algebraic sum of product of resistances and respective currents flowing through them.

Consider a simple circuit having Emfs = E_1 and E_2; R_1 and R_2 =resistances; current =I_1 and I_2.

Then according to this law : $E_1+E_2=I_1R_1+ I_2R_2$

For example:-

Consider given figure,let Emfs be E_1 and E_2 internal resistances be R_1, R_2 and R_3.

Steps to use Kirchhoff's law:-

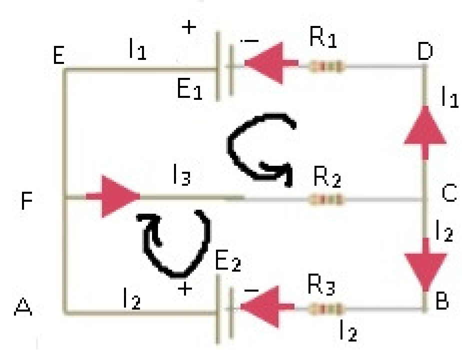
- Choose the loop to apply Kirchhoff's law.
- Assume any direction.
- Emf is +ive if assumed direction leaving +ive terminal of battery.
- IR is +ive if the current in the assumed direction.

Consider closed loop ABCDFA, using the assumptions;
$E_2=+R_2I_3 +R_3I_2$;where I_3=current flowing through R_3

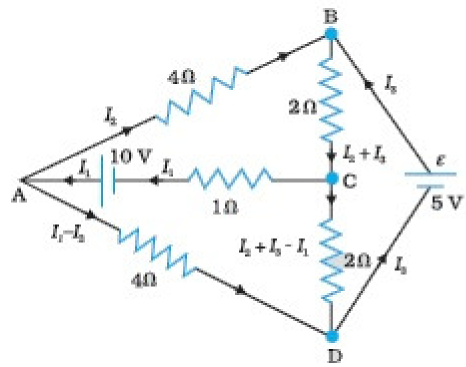
Closed loop FCDEF, $+E_1= +I_1R_1 + I_3R_2$
Closed loop ABDEA, $-E_1 + E_2 = -I_1R_1 +I_2R_3$

If the direction of current is taken opposite then
Closed loop ABCDFA ;- $-E_2=-R_2I_3-R_3I_2$

FCDEF; $-E_1= -I_1R_1 - I_3R_2$
ABDEA; $+E_1 - E_2 = +I_1R_1 -I_2R_3$



Problem 2 :- Determine the current in each branch of the network shown in Fig.



Answer:- Each branch of the network is assigned an unknown currentto be determined by the application of Kirchhoff's rules. To reducethe number of unknowns at the outset, the first rule of Kirchhoff isused at every junction to assign the unknown current in each branch.

We then have three unknowns I_1, I_2 and I_3 which can be found byapplying the second rule of Kirchhoff to three different closed loops.

Kirchhoff's second rule for the closed loop ADCA gives,

$10 – 4(I_1 – I_2) + 2(I_2 + I_3 – I_1) – I_1 = 0$ that is, $7I_1 – 6I_2 – 2I_3 = 10$ (a)
For the closed loop ABCA, we get

$10 – 4I_2 – 2 (I_2 + I_3) – I_1 = 0$that is, $I_1 + 6I_2 + 2I_3 = 10$ (b)
For the closed loop BCDEB, we get

$5 – 2 (I_2 + I_3) – 2 (I_2 + I_3 – I_1) = 0$that is, $2I_1 – 4I_2 – 4I_3 = –5$ (c)
Equations (a, b, c) are three simultaneous equations in threeunknowns. These can be solved by the usual method to give;

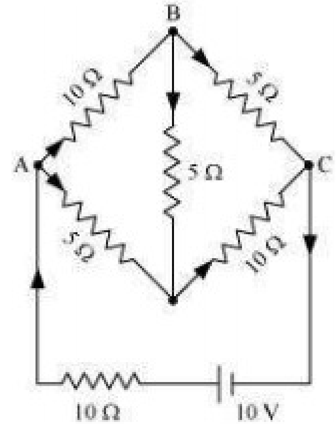
$I_1 = 2.5A$, $I_2 = (5/8)$ A, $I_3 = (15/8)$ A
The currents in the various branches of the network are

AB:(5/8) A, CA: (5/2) A, DEB: (15/8) A

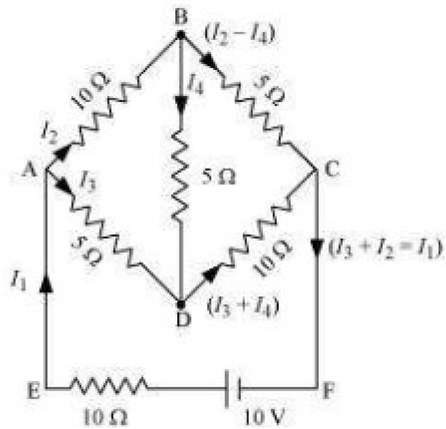
AD: (15/8) A, CD: 0 A, BC: (5/2) A

It is easily verified that Kirchhoff's second rule applied to theremaining closed loops does not provide any additional independentequation, that is, the above values of currents satisfy the secondrule for every closed loop of the network. For example, the total voltagedrops over the closed loop BADEB: (5V) + ((5/8) x 4) V – ((15/8) x 4) V equal to zero, as required by Kirchhoff's second rule.

Problem 3 :- Determine the current in each branch of the network shown in given fig?



Answer:- Current flowing through various branches of the circuit is represented in the given figure.



I_1 = Current flowing through the outer circuit
I_2 = Current flowing through branch AB
I_3 = Current flowing through branch AD
$I_2 - I_4$ = Current flowing through branch BC
$I_3 + I_4$ = Current flowing through branch CD
I_4 = Current flowing through branch BD
By Loop law:-

For the closed circuit ABDA, potential is zero i.e.

$10I_2 + 5I_4 - 5I_3 = 0$
$2I_2 + I_4 - I_3 = 0$
$I_3 = 2I_2 + I_4 \ldots (1)$
For the closed circuit BCDB, potential is zero i.e.

$5(I_2 - I_4) - 10(I_3 + I_4) - 5I_4 = 0$
$5I_2 + 5I_4 - 10I_3 - 10I_4 - 5I_4 = 0$
$5I_2 - 10I_3 - 20I_4 = 0$
$I_2 = 2I_3 + 4I_4 \ldots (2)$
For the closed circuit ABCFEA, potential is zero i.e.

$-10 + 10 (I_1) + 10(I_2) + 5(I_2 - I_4) = 0$
$10 = 15I_2 + 10I_1 - 5I_4$
$3I_2 + 2I_1 - I_4 = 2 \ldots (3)$
From equations (1) and (2), we obtain

$I_3 = 2(2I_3 + 4I_4) + I_4$

$I_3 = 4I_3 + 8I_4 + I_4$
$-3I_3 = 9I_4$
$-3I_4 = +I_3$ … (4)
Putting equation (4) in equation (1), we obtain

$I_3 = 2I_2 + I_4$
$-4I_4 = 2I_2$
$I_2 = -2I_4$ … (5)
It is evident from the given figure that,

$I_1 = I_3 + I_2$ … (6)
Putting equation (6) in equation (1), we obtain

$3I_2 + 2(I_3 + I_2) - I_4 = 2$
$5I_2 + 2I_3 - I_4 = 2$ … (7)
Putting equations (4) and (5) in equation (7), we obtain

$5(-2I_4) + 2(-3I_4) - I_4 = 2$
$-10I_4 - 6I_4 - I_4 = 2$
$17I_4 = -2$
$I_4 = -(2/17)$
Equation (4) reduces to

$I_3 = -3(I_4)$
$= -3(-2/17) = (6/17)$ A

$I_2 = -2(I_4)$
$= -2(-2/17) = (4/17)$ A

$I_2 - I_4 = (4/17) - (-2/17) = (6/17)$ A
$I_3 + I_4 = (6/17) + (-2/17) = (4/17)$ A
$I_1 = I_3 + I_2 = (6/17) + (4/17) = (10/17)$ A
Therefore, current in branch AB= (4/17) A

In branch BC = (6/17) A

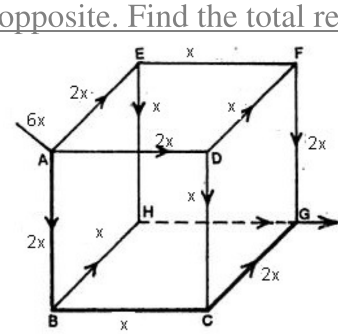
In branch CD = (4/17) A

In branch AD= (6/17) A

In branch BD = (-2/17) A

Total Current =(4/17) +(6/17)+(-4/17)+(6/17)+(-2/17)=(10/17) A

Problem 4 :- welve equal wires of resistance(r) are joined to form a skeleton cube. The current enters at one corner and leaves at the diagonally opposite. Find the total resistance between corners?



Answer:- Here, 12 resistances are arranged such that they form a cube.Now each of the 12 wires represents a resistor of value 'R'.We need to calculate the resistance across face diagonal corners. Now,let us assume that we have attached a voltage source across(or Emf V) the ends of points A and B and then the current starts to flow in the network.We have also assumed that, a current of '6x' flows through point A and thus splits up equally into three parts of current '2x' each(as resistance is same in each arm) and each '2x' current further splits into two equal parts of current 'x' each. We need to calculate the equivalence resistance(r) across the terminal AG which is the corner diagonal of the cube.

Applying Kirchhoff's law in loop ABCGA, we get

$V=2xR+xR+2xrR$

So, $V=5xR$ (1)

Now from also from Ohm's law

$V=r.6x$ (2)

Here,'V' is the potential difference applied,'6x'is the total current supplied and 'r' is the net resistance of the circuit.So, by putting the value of V from (1) in(2),we get

$5xR=r.6x$

Therefore $r=(5/6)R$