CIRCUITS

4.3 • MESH ANALYSIS

Module-2	
Two port networks: Short- circuit Admittance parameters, Open- circuit Impedance parameters, Transmission parameters, Hybrid parameters (Textbook 3: 11.1, 11.2, 11.3, 11.4, 11.5) **Laplace transform and its Applications**: Step Ramp, Impulse, Solution of networks using Laplace transform, Initial value and final value theorem (Textbook 3: 7.1, 7.2, 7.4, 7.7, 8.4)	
Teaching-Learning Process	Chalk and Talk **RBT Level:** L1, L2, L3
Module-3	
Basic Concepts and representation: Types of control systems, effect of feedback systems, differential equation of physical systems (only electrical systems), Introduction to block diagrams, transfer functions, Signal Flow Graphs (Textbook 4: Chapter 1.1, 2.2, 2.4, 2.5, 2.6)	
Teaching-Learning Process	Chalk and Talk, YouTube videos **RBT Level:** L1, L2, L3

Module-4	
Time Response analysis: Time response of first order systems. Time response of second order systems, time response specifications of second order systems (Textbook 4: Chapter 5.3, 5.4) **Stability Analysis:** Concepts of stability necessary condition for stability, Routh stability criterion, relative stability Analysis (Textbook 4: Chapter 5.3, 5.4, 6.1, 6.2, 6.4, 6.5)	
Teaching-Learning Process	Chalk and Talk, Any software tool to show time response **RBT Level:** L1, L2, L3

Module-5	
Root locus: Introduction the root locus concepts, construction of root loci (Textbook 4: 7.1, 7.2, 7.3) **Frequency Domain analysis and stability**: Correlation between time and frequency response and Bode plots (Textbook 4: 8.1, 8.2, 8.4) **State Variable Analysis:** Introduction to state variable analysis: Concepts of state, state variable and state models. State model for Linear continuous –Time systems, solution of state equations. (Textbook 4: 12.2, 12.3, 12.6)	
Teaching-Learning Process	Chalk and Talk, Any software tool to plot Root locus, Bode plot **RBT Level:** L1, L2, L3

Suggested Learning Resources:

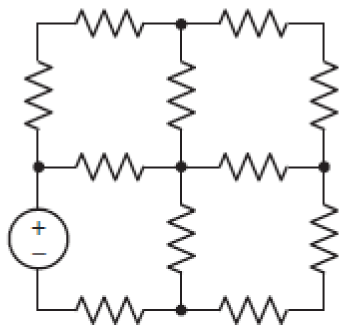
Text Books

1. Engineering circuit analysis, William H Hayt, Jr, Jack E Kemmerly, Steven M Durbin, Mc Graw Hill Education, Indian Edition 8e.
2. Networks and Systems, D Roy Choudhury, New age international Publishers, second edition.
3. Network Analysis, M E Van Valkenburg, Pearson, 3e.
4. Control Systems Engineering, I J Nagrath, M. Gopal, New age international Publishers, Fifth edition.

4.3 • MESH ANALYSIS

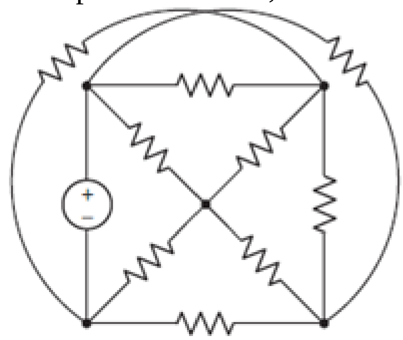
If the diagram of a circuit is drawn on the on a plane surface in such a way that no branch passes over or under any other branch, then that circuit is said to be a ***planar circuit.***

Thus, Fig. *a* shows a planar network, Fig *b* shows a non planar network,



(*a*)

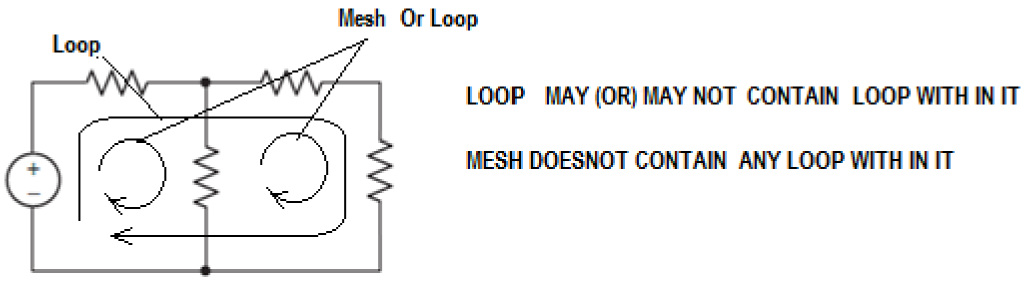
Planar networks



(*b*)

Non planar networks

- The mesh is a property of a planar circuit.
- We define a *mesh* as a loop that does not contain any other loops within it.
- A point at which two or more elements have a common connection is called a *node.*
- The set of nodes and elements that we have passed through is defined as a *path.*
- If the node at which we started is the same as the node on which we ended, then the path is, by definition, a closed path or a *loop*
- If a network is planar, mesh analysis can be used to accomplish the analysis. This technique involves the concept of a *mesh current,*
- We define a *mesh* as a loop that does not contain any other loops within it.



Step for Mesh Analysis

1. **Determine if the circuit is a planar circuit.** .

2. **Count the number of meshes** (M).

Redraw the circuit if necessary.

3. **Label each of the *M* mesh currents.**

For easy solution assume all mess currents to flow clockwise analysis.

4. **Write a KVL equation around each mesh.**

5. **Express any additional unknowns such as voltages or currents other than mesh currents in terms of appropriate mesh currents.**

This situation can occur if current sources or dependent sources appear in our circuit.

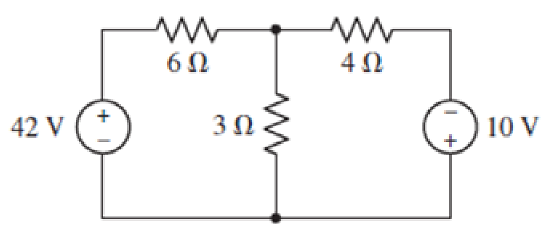
6. **Organize the equations.**

Group terms according to mesh currents.

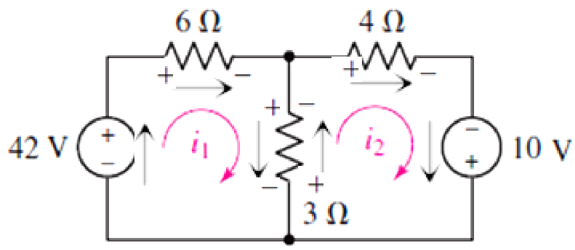
7. **Solve the system of equations for the mesh currents**

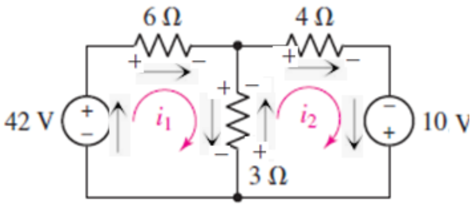
Examples deal with circuits powered exclusively by independent voltage sources.

EX: 1) Apply mesh analysis find the current supplied by both sources



(*a*)





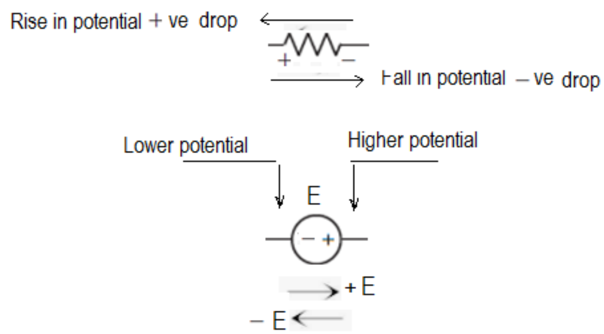
Apply KVL to mesh (1)

$+42 - 6i_1 - 3(i_1 - i_2) = 0$ .... (1)

Apply KVL to mesh (2) .... (2)

$+10 - 3(i_2 - i_1) - 4i_2 = 0$

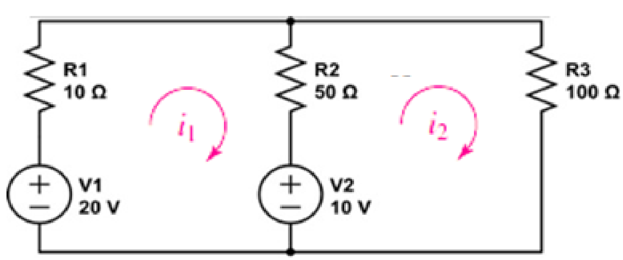
Go along the direction of the mesh current and mark the polarity of the resistances current entering positive leaving negative



Solving Eq. 1 and 2

$i_1 = 6\text{ A}$ $\quad i_2 = 4\text{ A}$ $\quad$ and $\quad (i_1 - i_2) = 2\text{ A}$

2) Determine i_1 and i_2 in the circuit in Fig



Apply KVL to mesh (1)

$$-10I_1 - 50(I_1 - I_2) - 10 + 20 = 0$$

$$-60I_1 + 50I_2 = -10$$

Apply KVL to mesh (2)

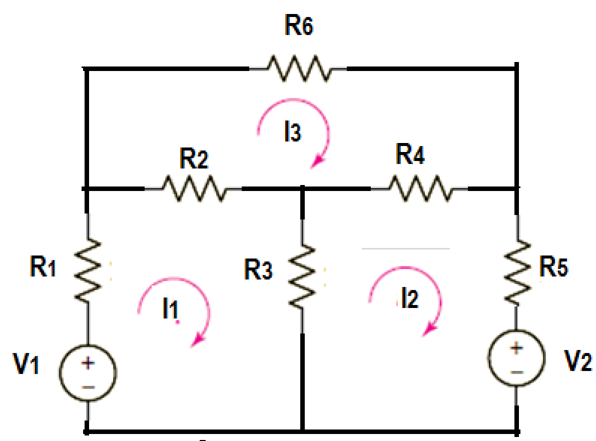
$$10 - 50(I_2 - I_1) - 100I_2 = 0$$

$$+50I_1 - 150I_2 = -10$$

$$I_1 = 0.3077A$$

$$I_2 = 0.169A$$

3) Write mesh Eq for the circuit below



Apply KVL to mesh (1)

$V_1 - I_1 R_1 - R_2 (I_1 - I_3) - R_3 (I_1 - I_2) = 0$ .... (1)

Apply KVL to mesh (2)

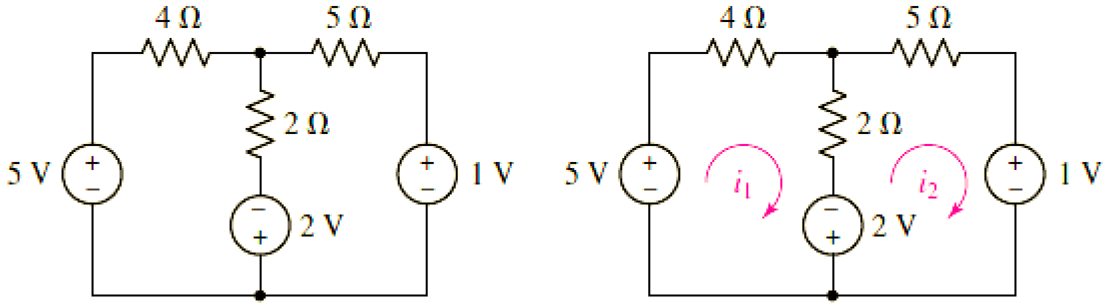
Apply KVL to mesh (2)

$-V_2 - R_3 (I_2 - I_1) - R_4 (I_2 - I_3) - R_5 I_2 = 0$ .... (2)

Apply KVL to mesh (3)

$- R_6 I_3 - R_4 (I_3 - I_2) - R_2 (I_3 - I_1) = 0$ .... (3)

4) Determine the power supplied by the 2 V source of Fig.*a*.



(*a*) (*b*)

KVL equation for loop or mesh-1

$$5 - 4i_1 - 2(i_1 - i_2) + 2 = 0 \quad \text{.................(1)}$$

KVL equation for loop or mesh-2

$$-2 - 2(i_2 - i_1) - 5i_2 - 1 = 0 \quad \text{......................(2)}$$

Solving,

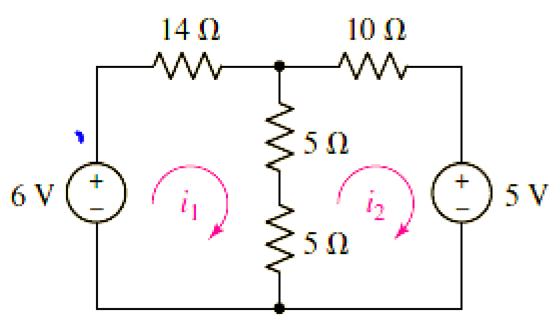
$$i_1 = 1.132 \text{ A}$$

$$i_2 = -0.1053 \text{ A.}$$

Power supplied 2 V battery $= 2 \times (i_1 - i_2)$

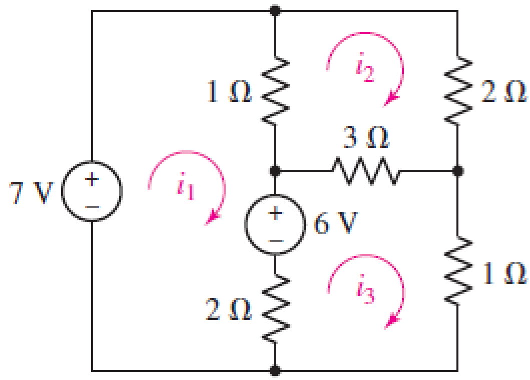
$= 2 \times 1.237 = 2.474$ W.

Ex: 5) Determine *i*1 and *i*2 in the circuit in Fig



Ans: +184.2 mA; −157.9 Ma

6): Use mesh analysis to determine the three mesh currents in the Circuitof Fig.



Apply KVL to mesh – 1

$$7 - 1(i_1 - i_2) - 6 - 2(i_1 - i_3) = 0$$

$$-\ 3i_1 + i_2 + 2i_3 = 1 \quad \ldots\ldots\ldots\ldots\ldots(1)$$

Apply KVL to mesh – 2

$$-1(i_2 - i_1) - 2i_2 - 3(i_2 - i_3) = 0$$

$$1i_1 - 6i_2 + 3i_3 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ (2)$$

Apply KVL to mesh – 3

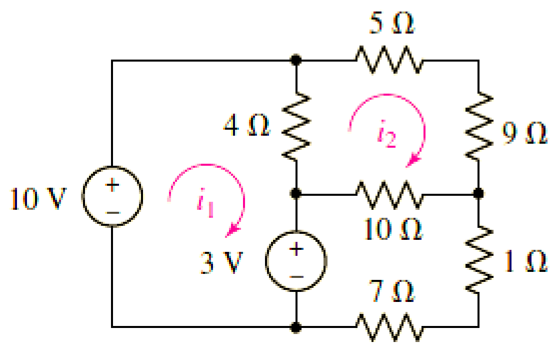
$$-2(i_3 - i_1) + 6 - 3(i_3 - i_2) - 1i_3 = 0$$

$$+2i_1 + 3i_2 - 6i_3 = -6 \quad \ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Solving eq. 1,2 & 3

$$i_1 = 3\text{ A},\ i_2 = 2\text{ A, and } i_3 = 3\text{ A.}$$

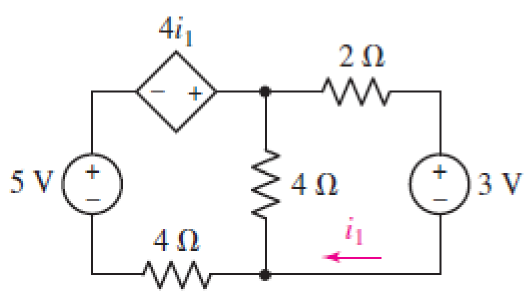
7) Determine *i*1 and *i*2 in the circuit of Fig



Ans: 2.220 A, 470.0 mA.

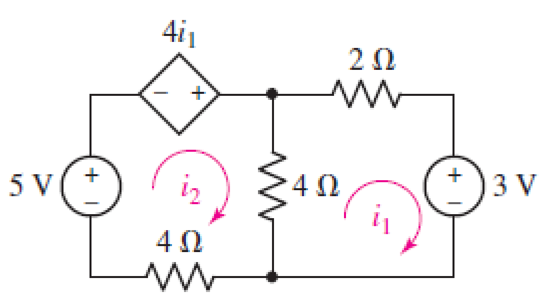
Examples deal with circuits powered by independent sources included in the circuit

EX: 1) Determine the current *i*1 in the circuit of Fig a.



(*a*)

The current i_1 is actually a mesh current, in clockwise direction



(*b*)

Apply KVL to left mesh

$$+5 + 4i_1 - 4(i_2 - i_1) - 4i_2 = 0$$

$$+8i_1 - 8i_2 = -5 \quad \text{.................(1)}$$

Apply KVL to right mesh

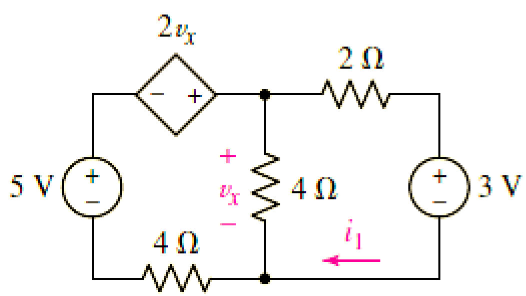
$$-\ 4(i_1 - i_2)\ -2i_1\ -3 = 0$$

$$-\ 6i_1 + 4i_2 = +\ 3 \quad \text{.................(2)}$$

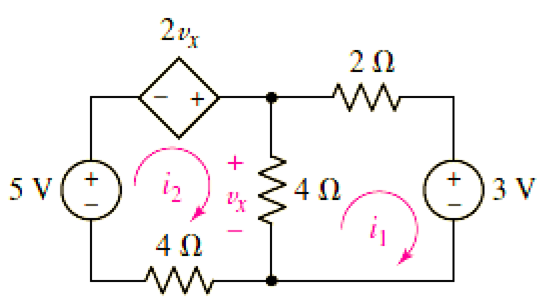
Solving Eq. 1 & 2

$$i_2 = 375 \text{ mA, so } i_1 = -250 \text{ mA.}$$

EX:2) Determine the current *i*1 in the circuit of Fig. 4.*a*.



(*a*)



(*b*)

Apply KVL to left mesh

$$+5 + 2v_x - 4(i_2 - i_1) - 4i_2 = 0 \quad \text{.................(1)}$$

Apply KVL to right mesh

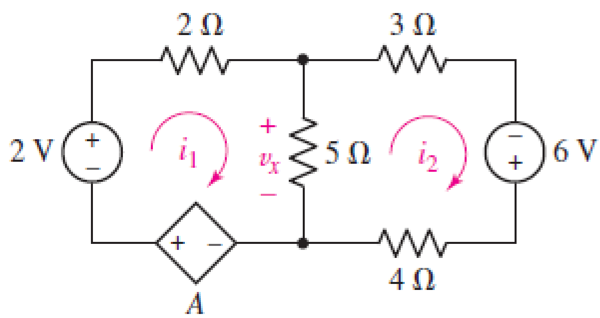
$$-4(i_1 - i_2) - 2i_1 - 3 = 0 \quad \text{..................(2)}$$

$$\boxed{v_x = 4(i_2 - i_1)}$$

Substitute in Eq,-1 $4i_1 = 5$

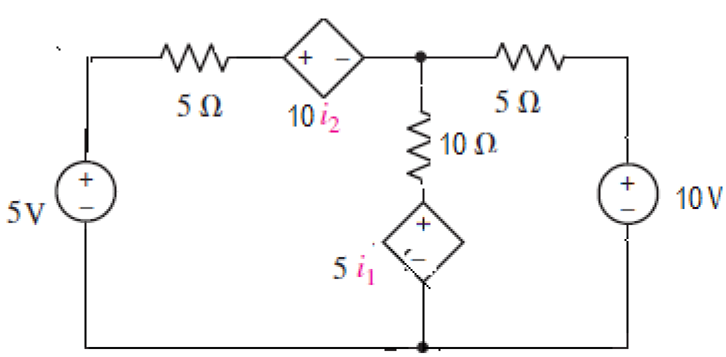
$i_1 = 1.25$ A.

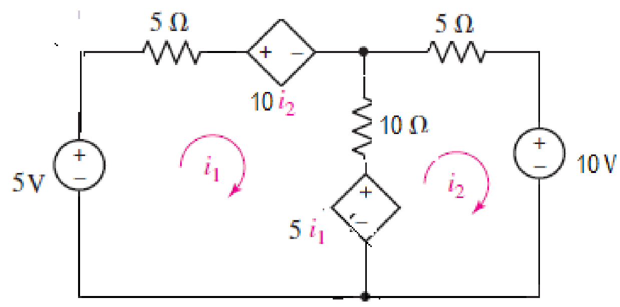
EX; 3) Determine i_1 in the circuit of Fig. if the controlling quantity A is equal to (*a*) $2i_2$; (*b*) $2v_x$.



Ans: (*a*) 1.35 A; (*b*) 546 mA.

4) Obtain I_1 and I_2 using mesh analysis.





Apply KCL for mesh -1

$5 - 5i_1 - 10i_2 - 10(i_1 - i_2) - 5i_1 = 0$

$5 - 20i_1 = 0$

$\therefore \boxed{i_1 = 0.25\ A}$

Apply KCL for mesh - 2

$-5i_2 - 10 + 5i_1 - 10(i_2 - i_1) = 0$

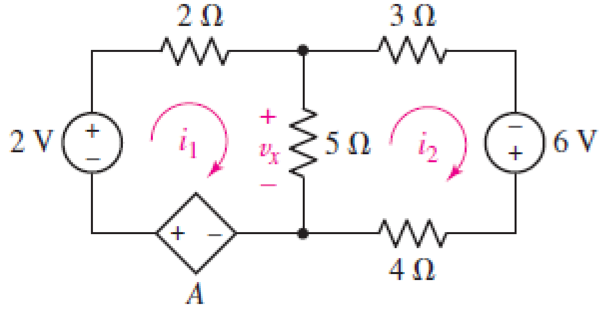
$15i_1 - 15i_2 = 10$

substitute the valve

of $i_1 = 0.25$ A Then

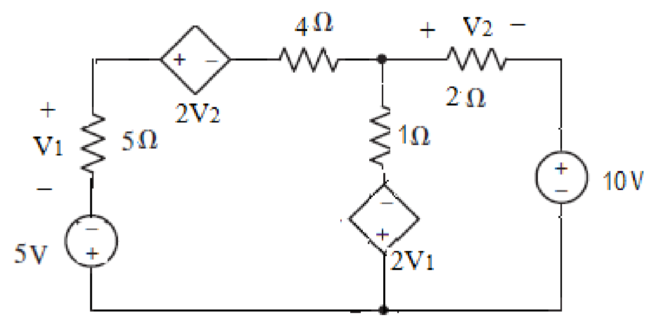
$i_2 = -0.416$ A

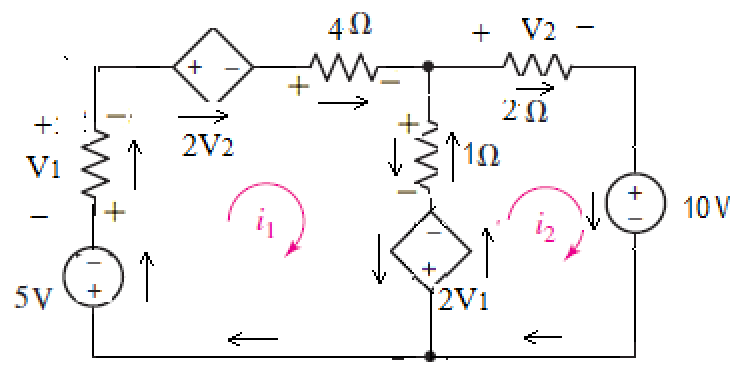
5) Determine i_1 in the circuit of Fig. if the controlling quantity A is equal to (*a*) $2i_2$; (*b*) $2v_x$.

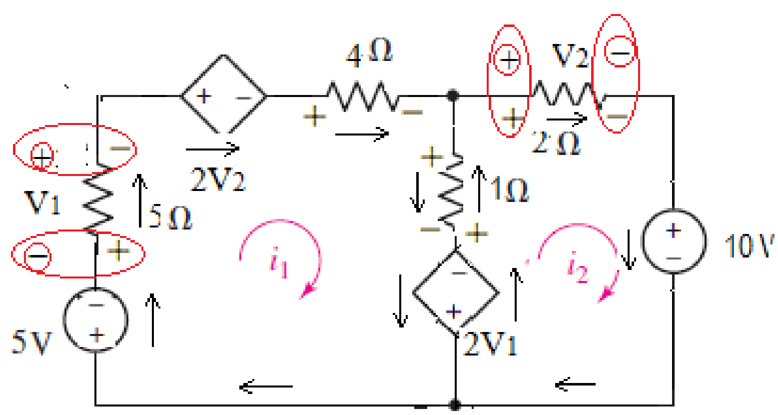


Ans: (*a*) 1.35 A; (*b*) 546 mA.

5) Find mesh currents using mesh analysis.







Apply KVL to mesh 1

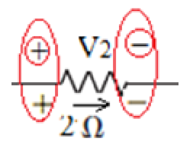
$$-5-5i_1-2V_2-4i_1-1(i_1-i_2)+2V_1=0$$

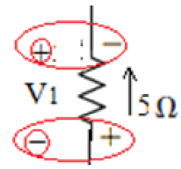
$$\boxed{V_2=2i_2} \qquad \boxed{V_1=-5i_1}$$

$$-5-5i_1-2(2i_2)-4i_1-1(i_1-i_2)+2(-5i_1)=0$$

$$-20i_1-3i_2=5 \quad \dots\dots\dots\dots \quad (1)$$

Reference





observe the polarity of V_2 and 2 ohm resistor are same therefore take + sign for $2i_2$ $\boxed{V_2=2i_2}$

observe the polarity of V_1 and 5 ohm resistor are opposite therefore take – sign for $5i$ $\boxed{V_1=-5i_1}$

If the polariies are same take +ve

If the polarities are different take - ve

Apply KVL to mesh 2

$$-2i_2-10-2V_1-1(i_2-i_1)=0$$

$$\boxed{V_1=-5i_1}$$

$$-2i_2-10-2(-5i_1)-1(i_2-i_1)=0$$

$$11i_1-3i_2=0 \quad \dots\dots\dots\dots\dots\dots \quad (2)$$

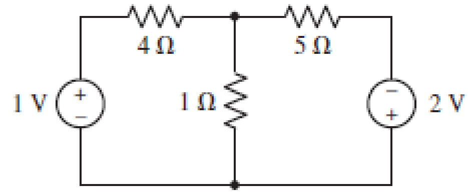
From Eq. 1 and 2

$$\boxed{i_1=0.1613\text{ A}}$$

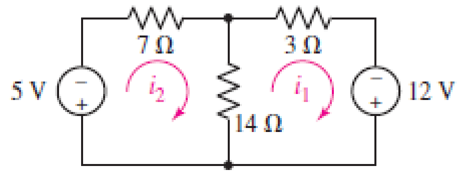
$$\boxed{i_2=-2.41\text{ A}}$$

PRACTICE

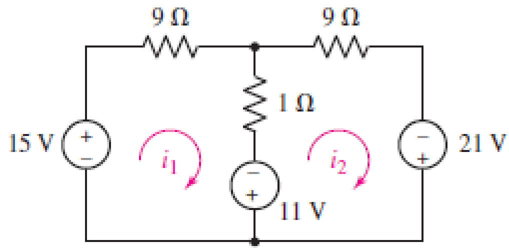
1) Determine the currents flowing out of the positive terminal of each voltage source in the circuit of Fig



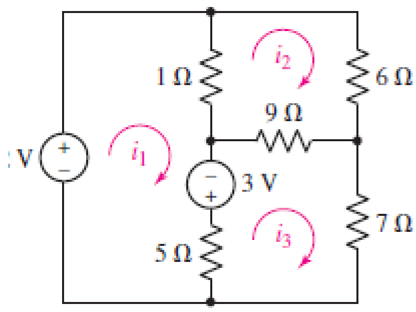
2) Obtain numerical values for the two mesh currents *i*1 and *i*2 in the circuit shown in Fig.



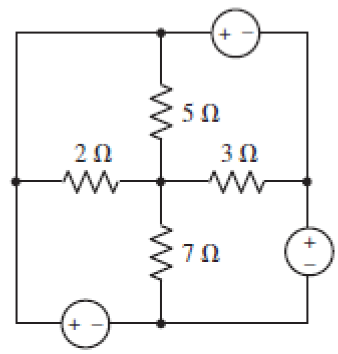
3) Use mesh analysis as appropriate to determine the two mesh currents labeled in Fig



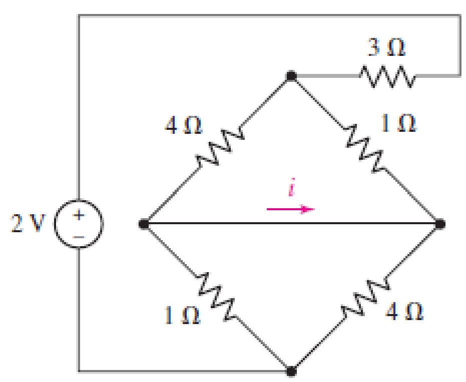
4) **Determine numerical values for each of the three mesh currents as labeled in the circuit diagram of Fig.**



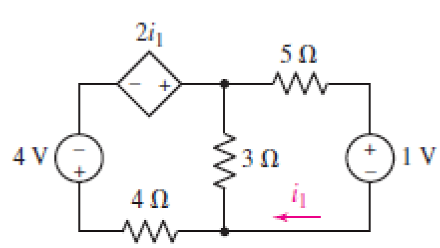
5) Choose nonzero values for the three voltage sources of Fig. so that no current flows through any resistor in the circuit.



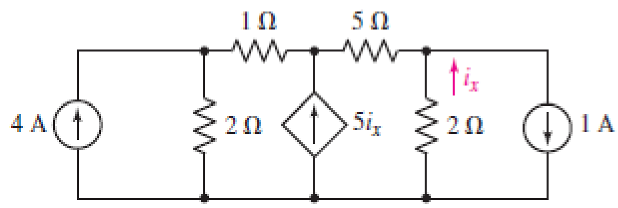
6) Employing mesh analysis procedures, obtain a value for the current labeled *i* in the circuit represented by Fig.



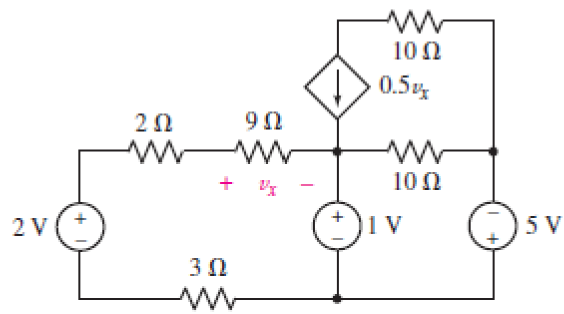
7**) Determine the power dissipated in the 4 *ohms* resistor of the circuit shown in Fig**



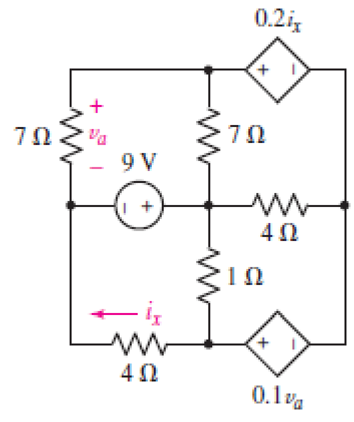
***8 a*) Employ mesh analysis to determine the power dissipated by the 1 *ohm* resistor in the circuit represented schematically by Fig. (*b*) Check your answer using nodal analysis.**



9) Define three clockwise mesh currents for the circuit of Fig. and employ mesh analysis to obtain a value for each.



10) Employ mesh analysis to obtain values for i_x and v_a in the circuit of Fig.



…………………………………………..