ESc201: Introduction to Electronics

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Recap: Techniques of Circuit Analysis

Nodal Analysis

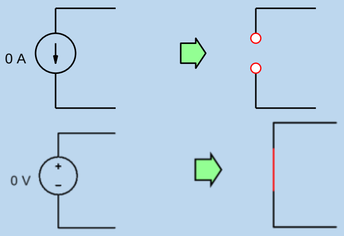
1. Identify and number the nodes
2. Pick Ground node/Reference node wisely, if it is not already specified
3. Writing KCL Equations in Terms of the Node Voltages

Mesh Analysis

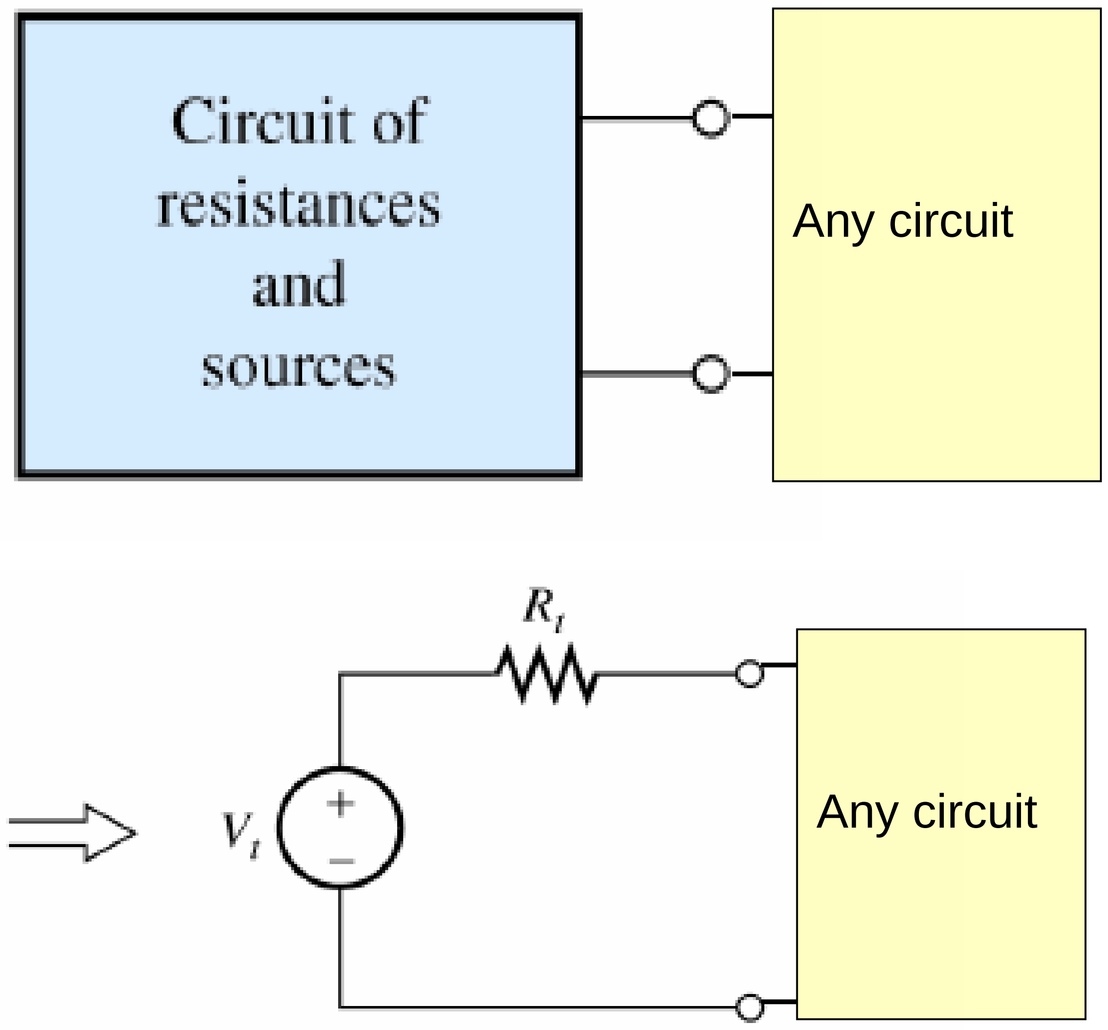
1. Assign mesh currents i_1, i_2, …, in to the n meshes.
2. Apply KVL to each of the n meshes. Use Ohm's law to express the voltages in terms of the mesh currents.
3. Solve the resulting n simultaneous equations to get the mesh currents.

Superposition Method for Linear Circuits

The superposition principle states that the total response is the sum of the responses to each of the independent sources acting individually.

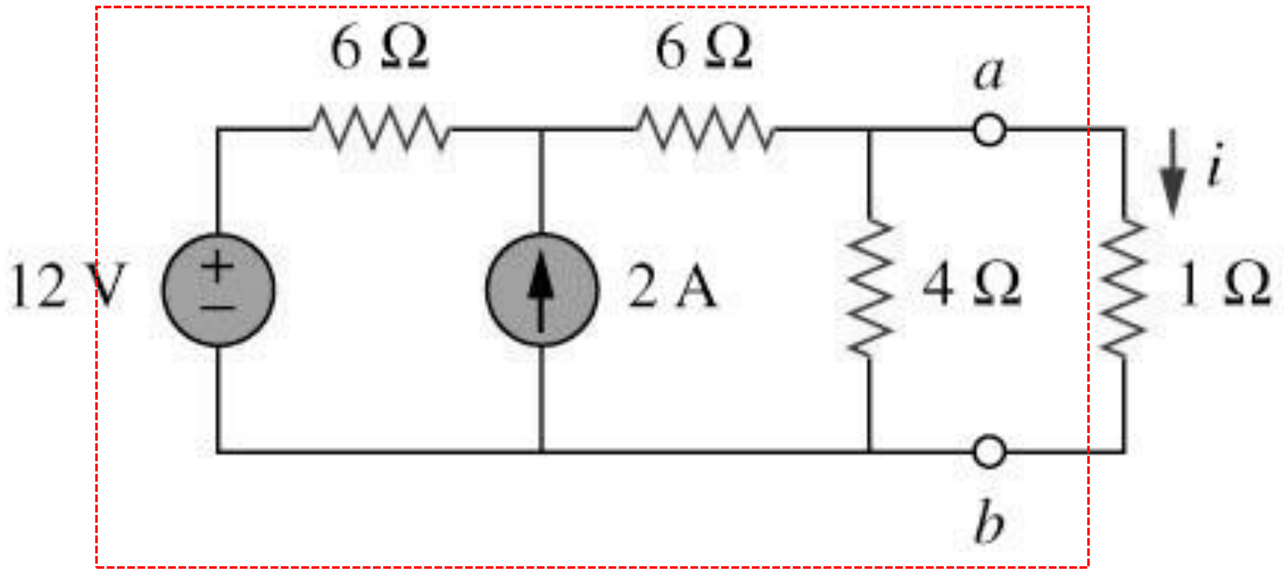


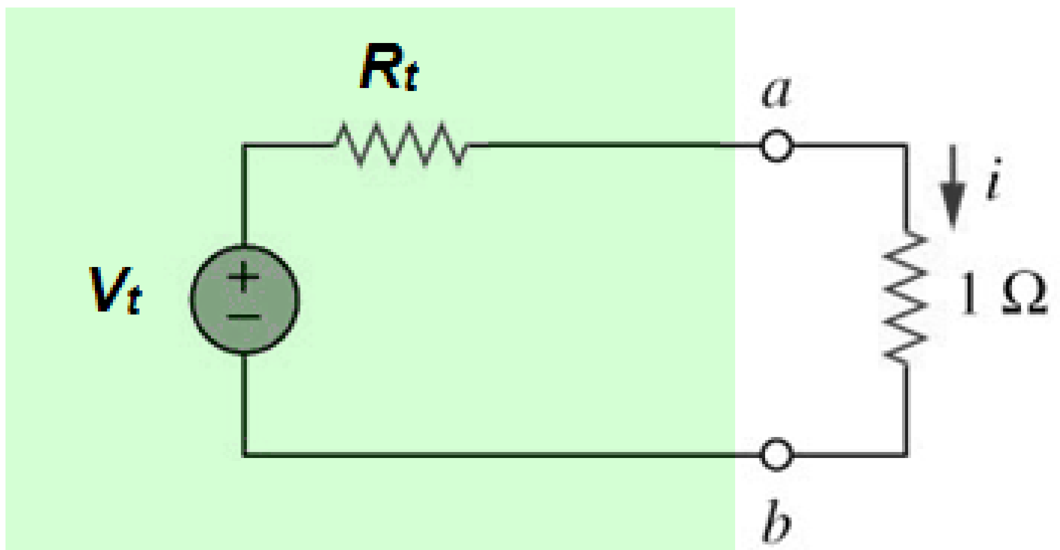
Thévenin Equivalent Circuits



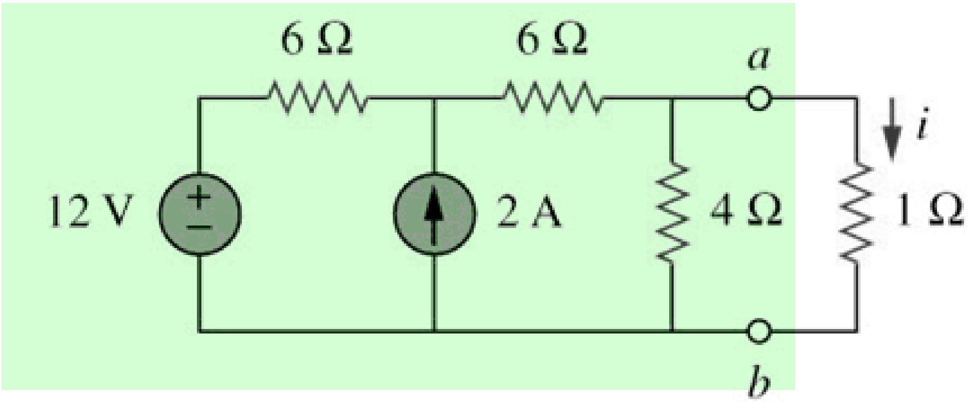
Thévenin equivalent circuit

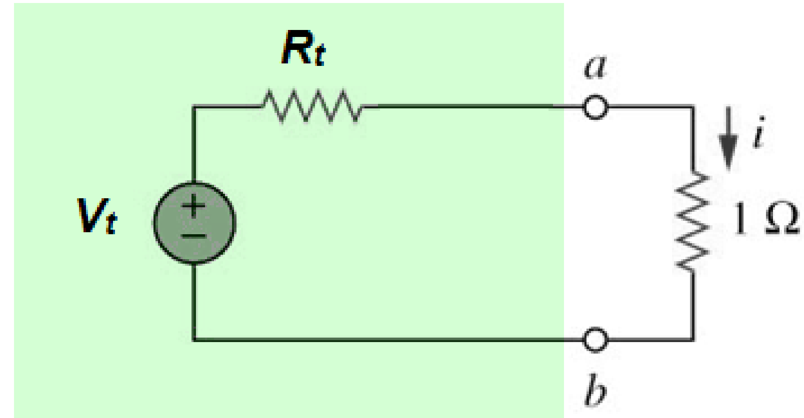
Thévenin Equivalent Circuits

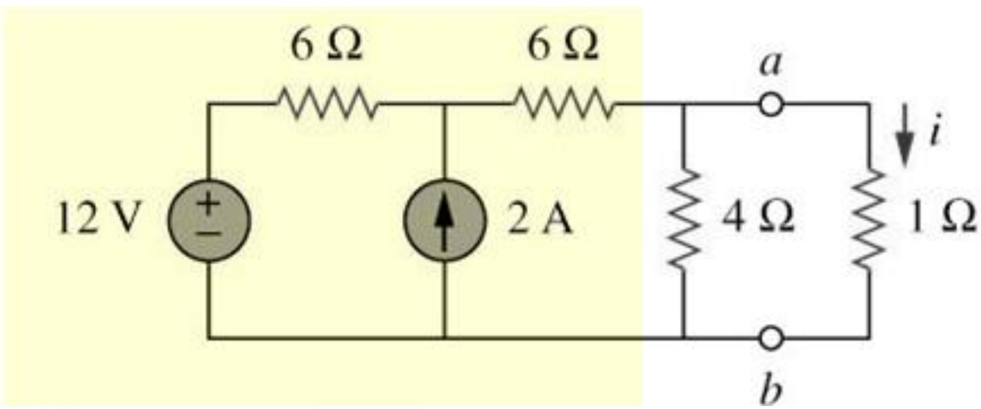


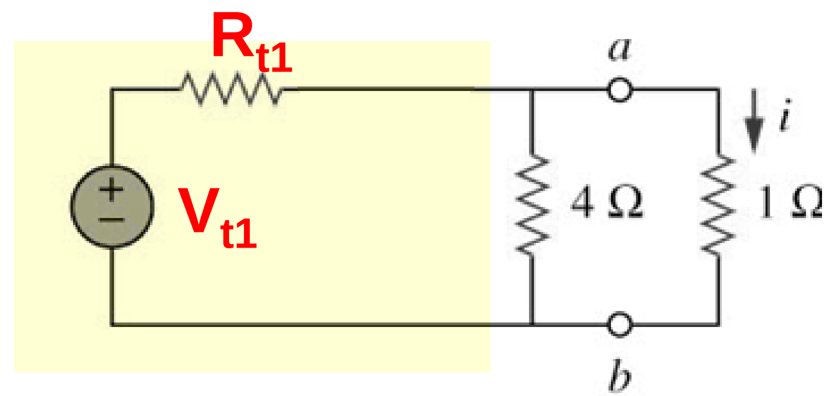


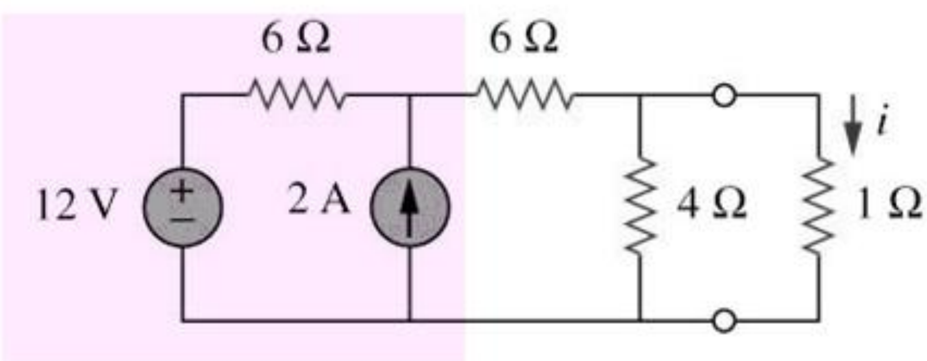
We can apply Thevenin’s theorem to any part of the circuit

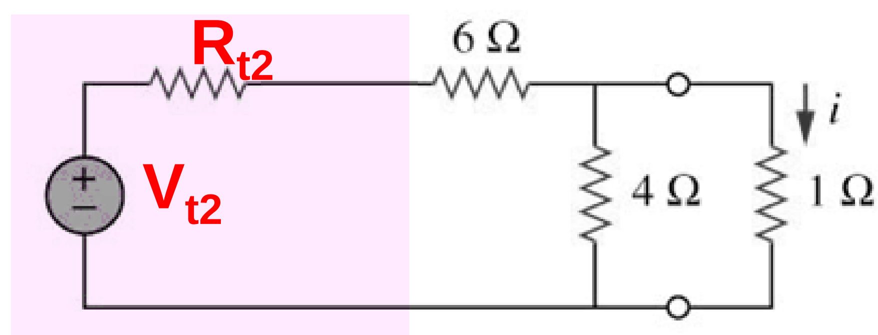




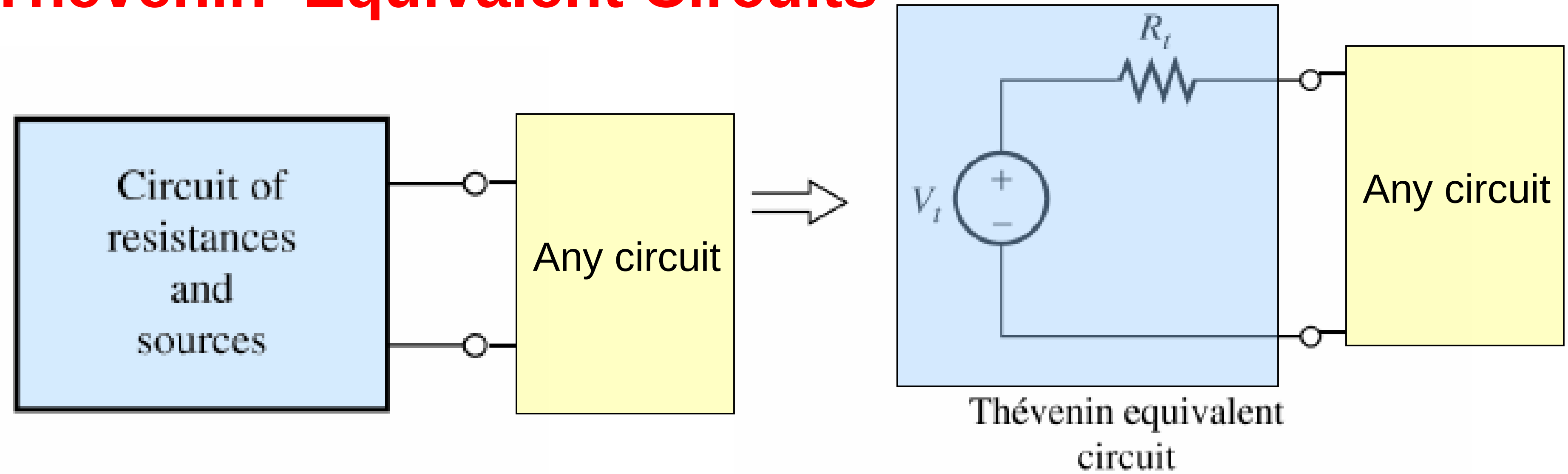




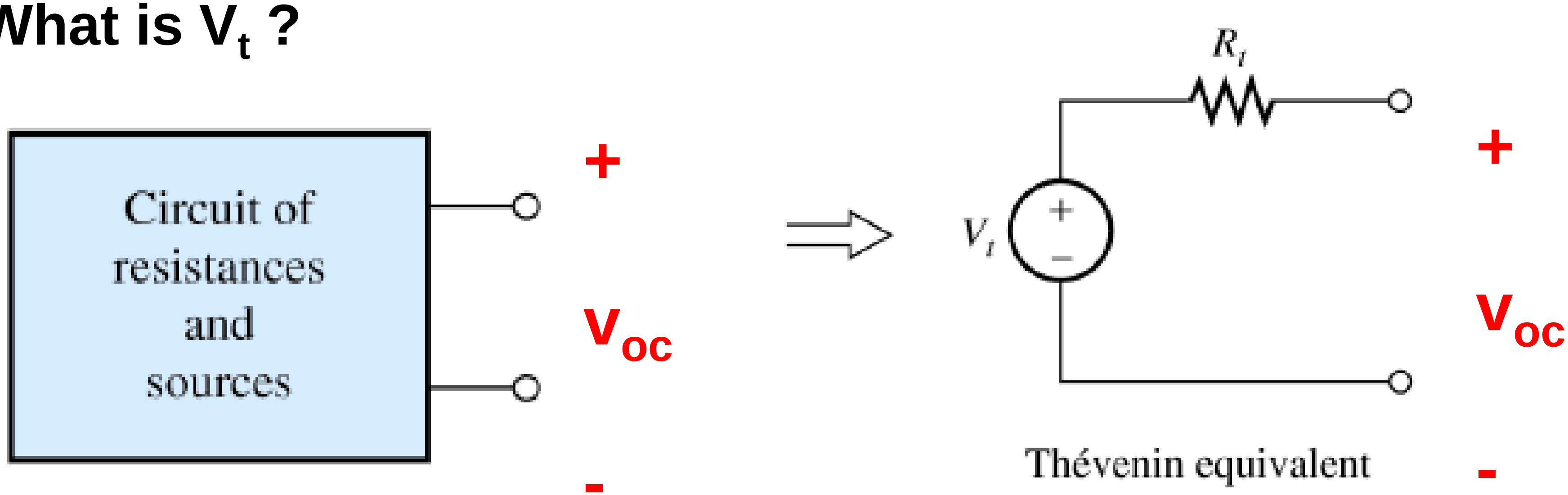




Thévenin Equivalent Circuits

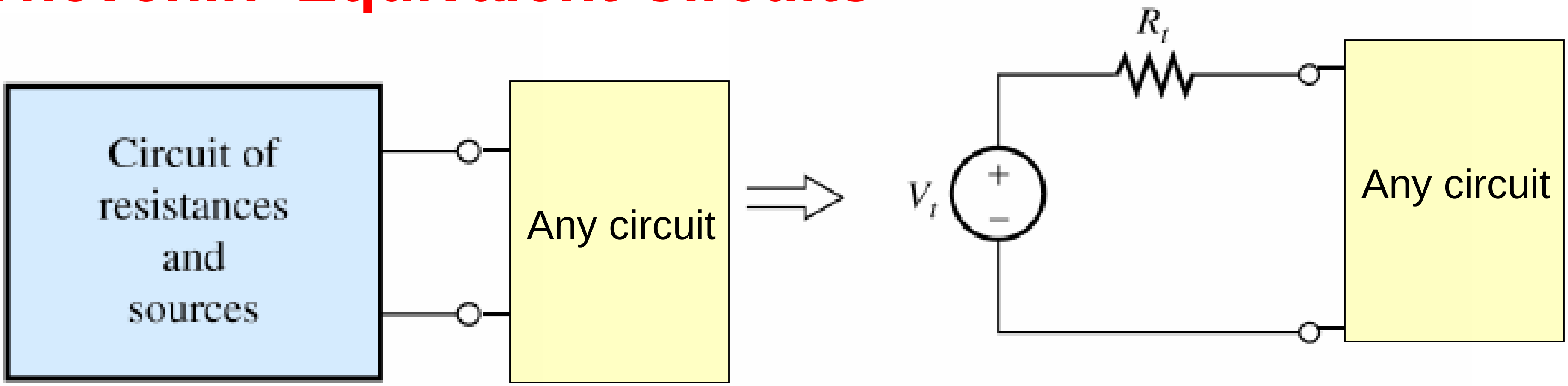


What is V_t ?



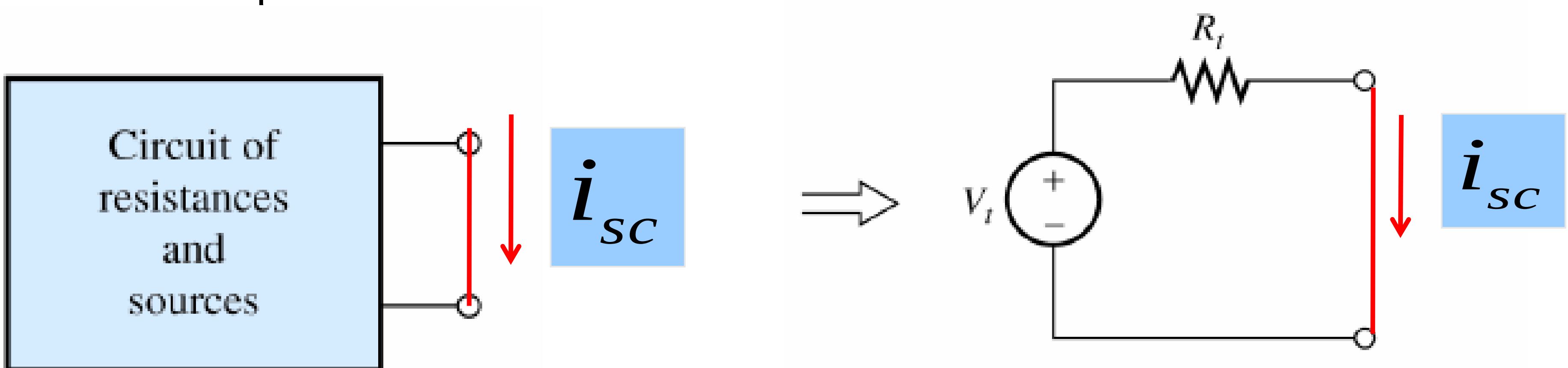
$$V_t = v_{oc}$$

Thévenin Equivalent Circuits



Thévenin equivalent circuit

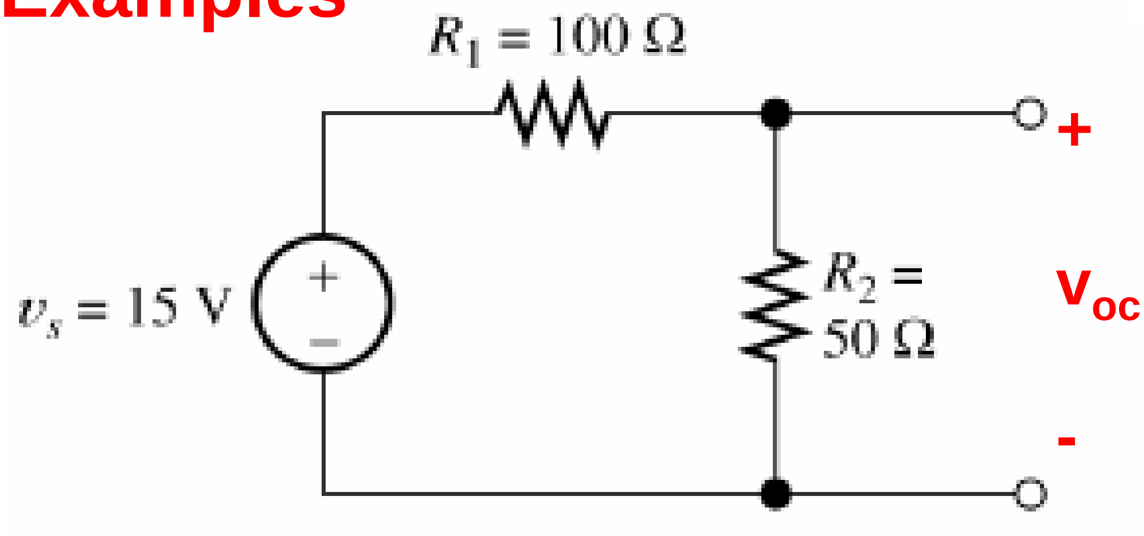
What is R_t ?

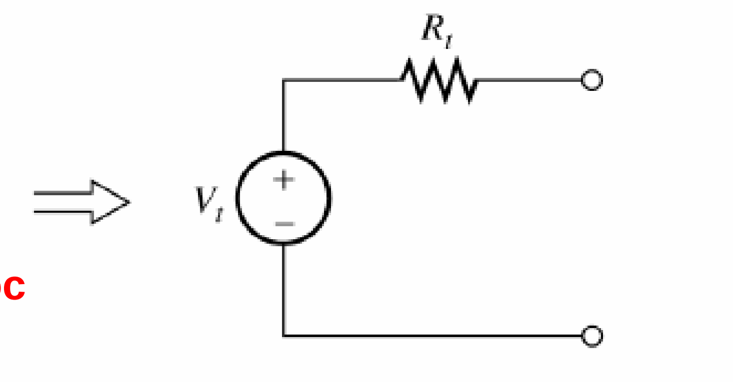


Thévenin equivalent circuit

$$R_t = \frac{V_t}{i_{sc}} = \frac{v_{oc}}{i_{sc}}$$

Examples

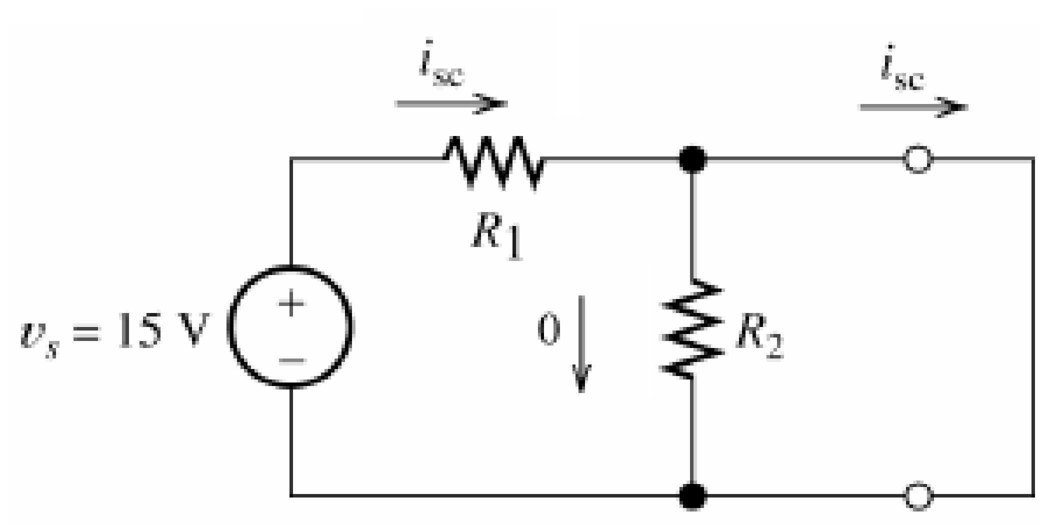




Thévenin equivalent circuit

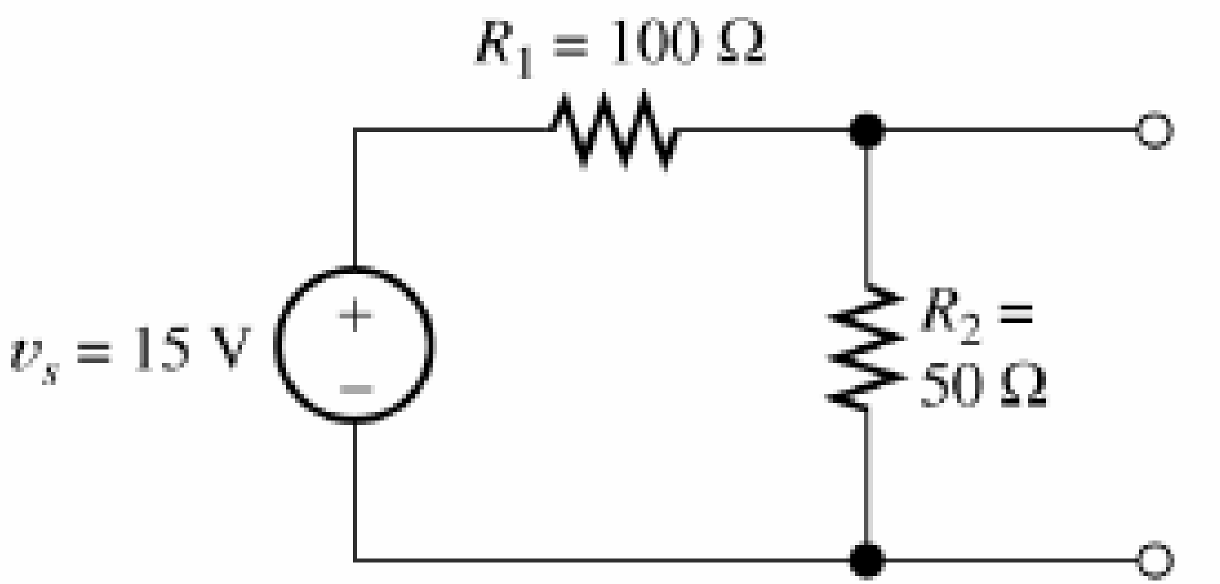
$$V_t = v_{oc}$$

$$V_t = \frac{R_2}{R_2 + R_1} \times 15 = 5$$

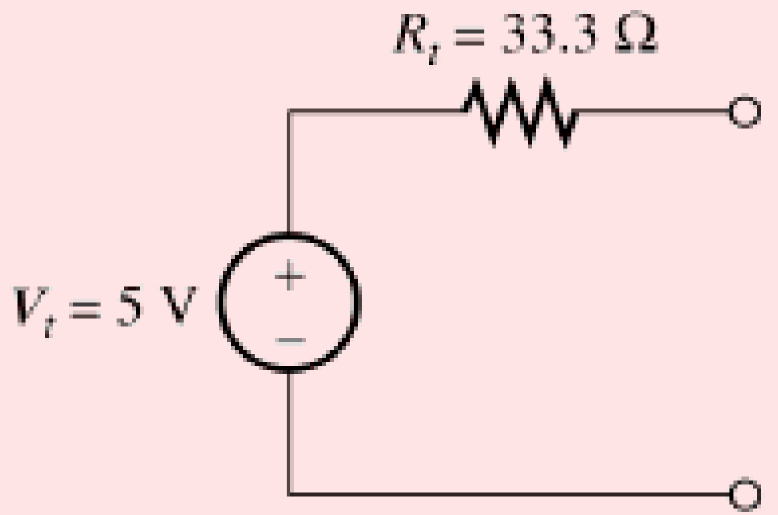


$$i_{sc} = \frac{v_s}{R_1} = 0.15A$$

$$R_t = \frac{v_{oc}}{i_{sc}} = 33.3\Omega$$

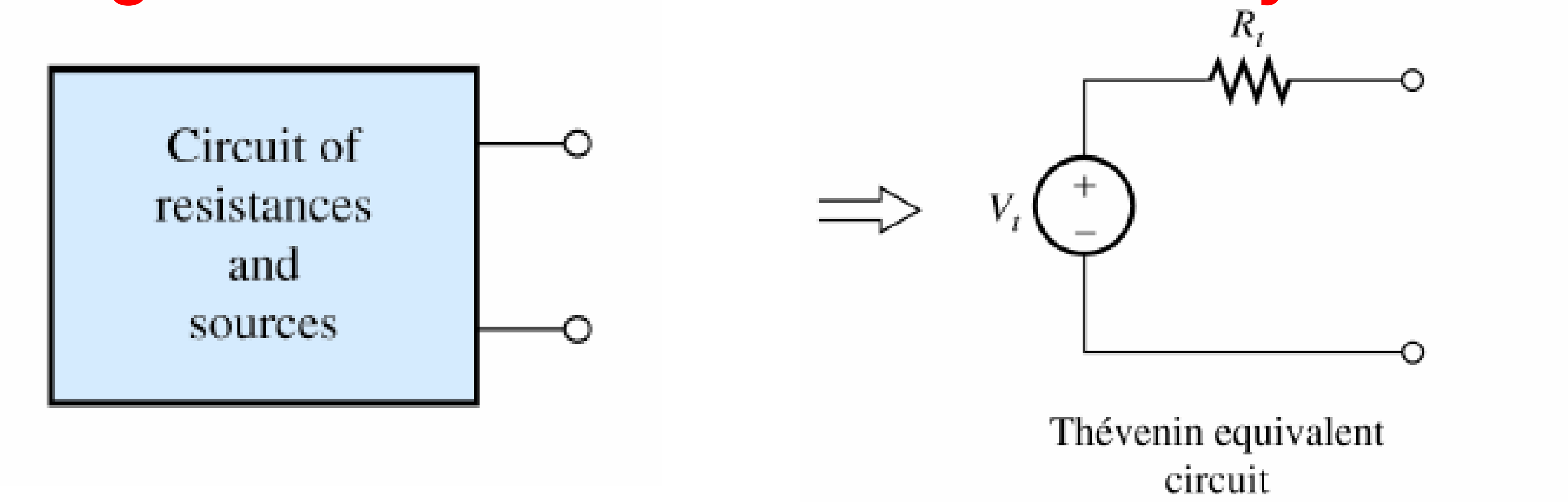


$$V_t = 5$$

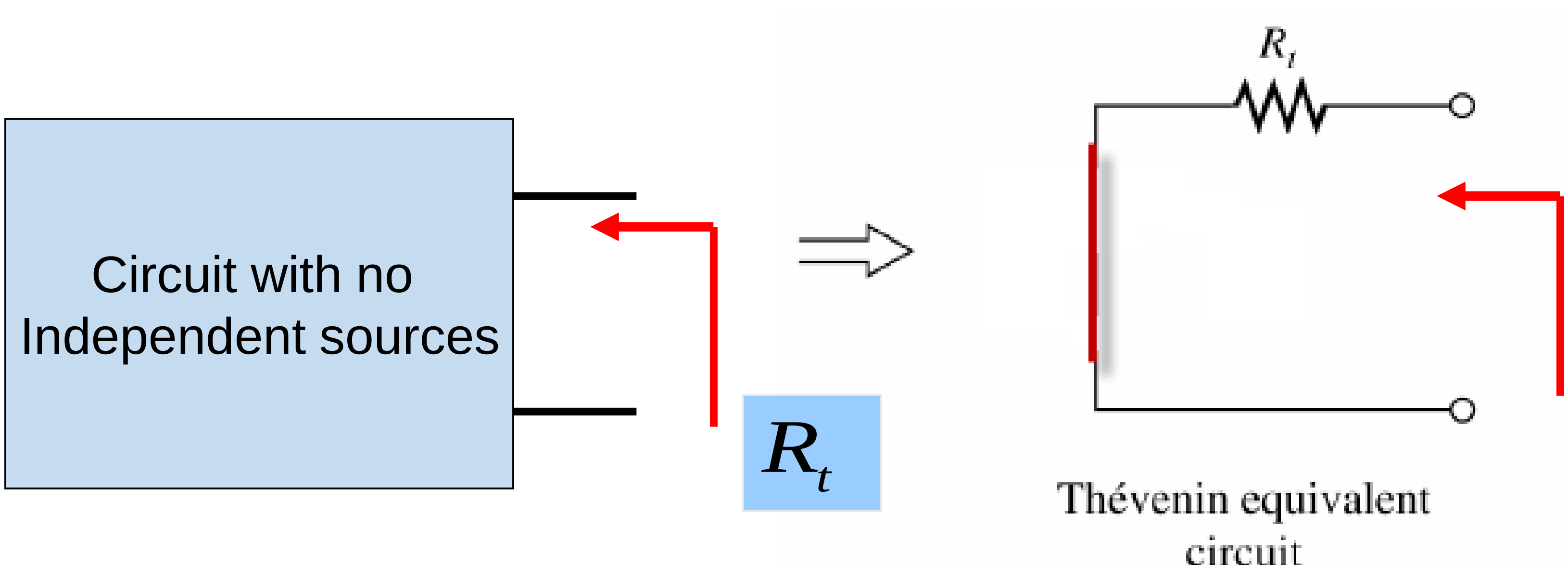


$$R_t = 33.3\Omega$$

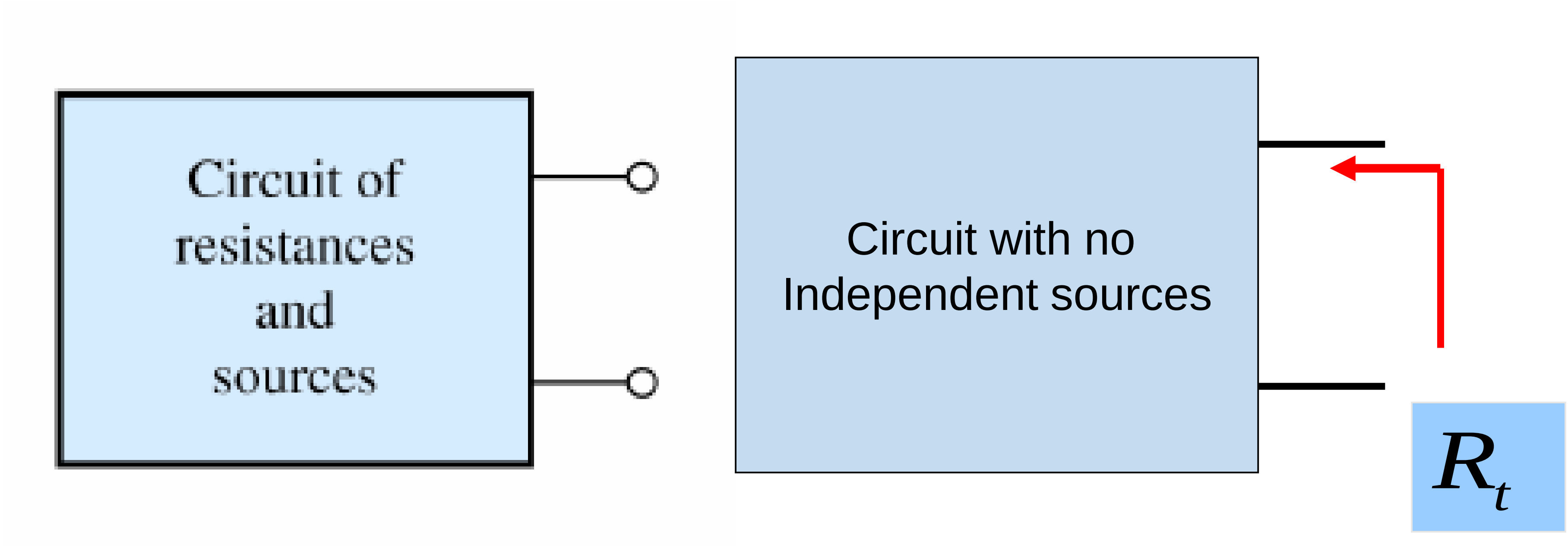
Finding the Thévenin Resistance Directly



Suppose we turnoff all independent sources in the circuit



Finding the Thévenin Resistance Directly

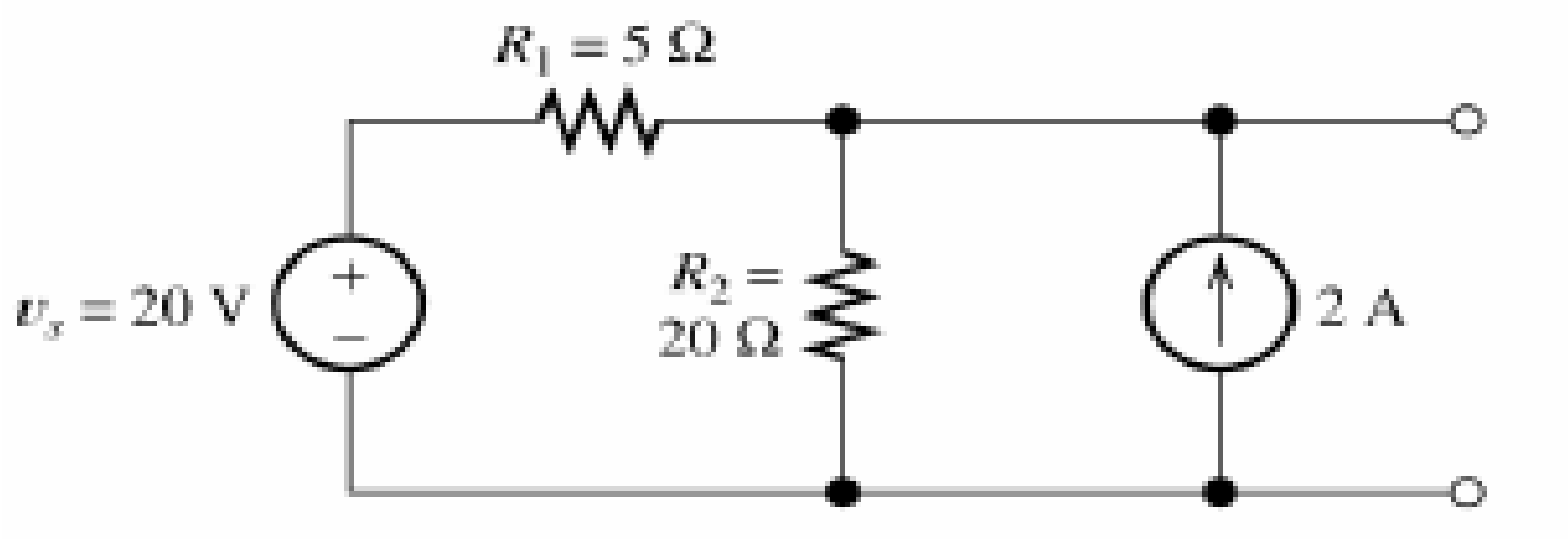


1.Turn off independent sources in the original network:

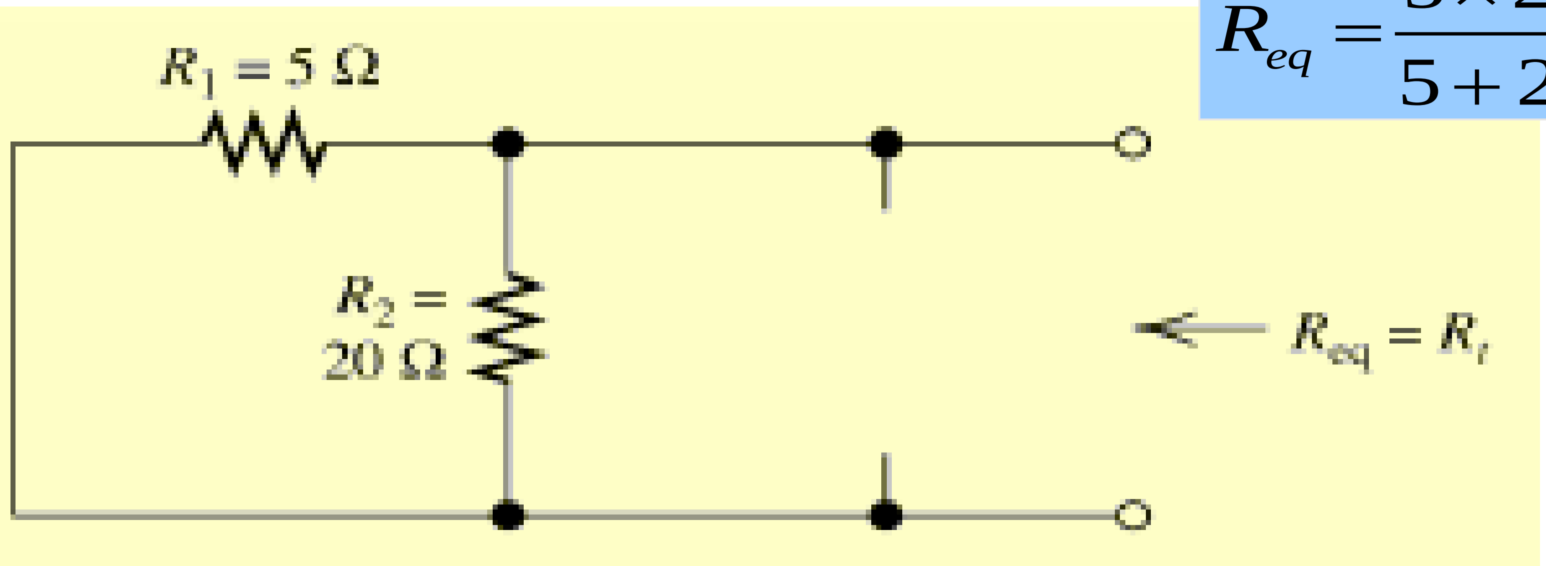
-A voltage source becomes a short circuit

-A current source becomes an open circuit

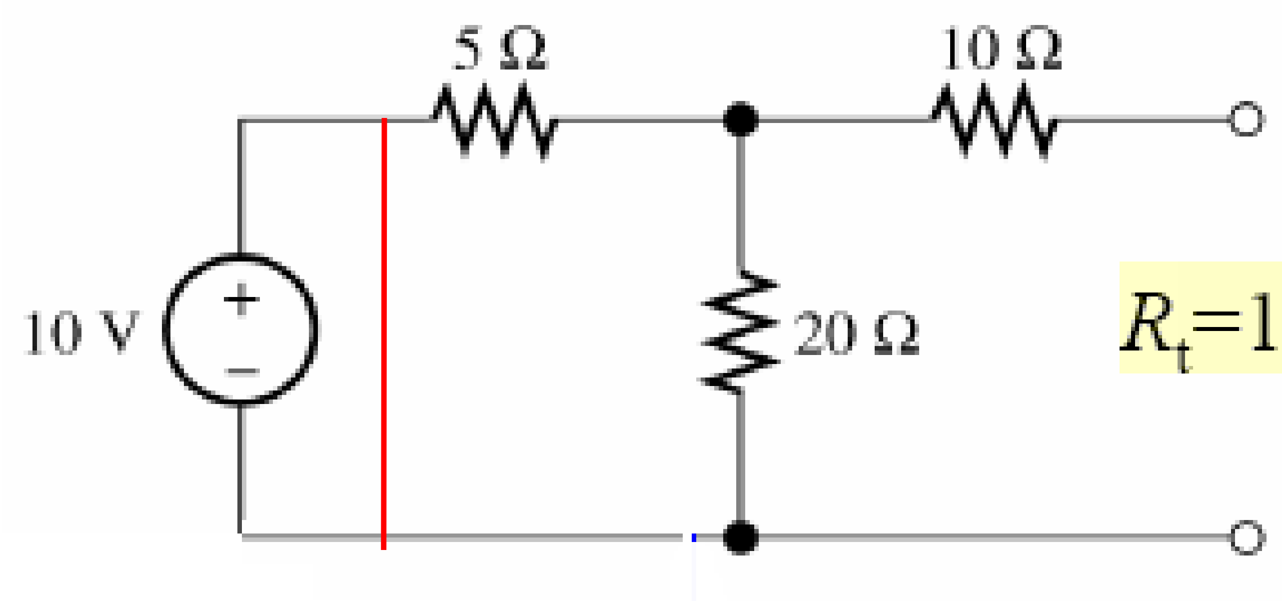
2. Compute the resistance between the terminals



$$R_{eq} = \frac{5 \times 20}{5 + 20} = 4\Omega$$

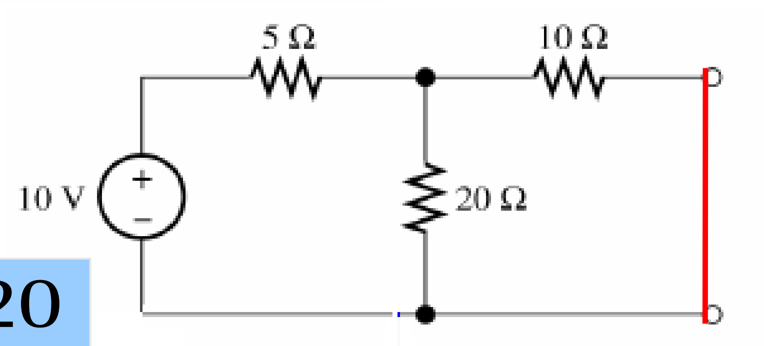


Find Thevenin resistance for each of the circuits shown below



R_t=10+(5||20)=14

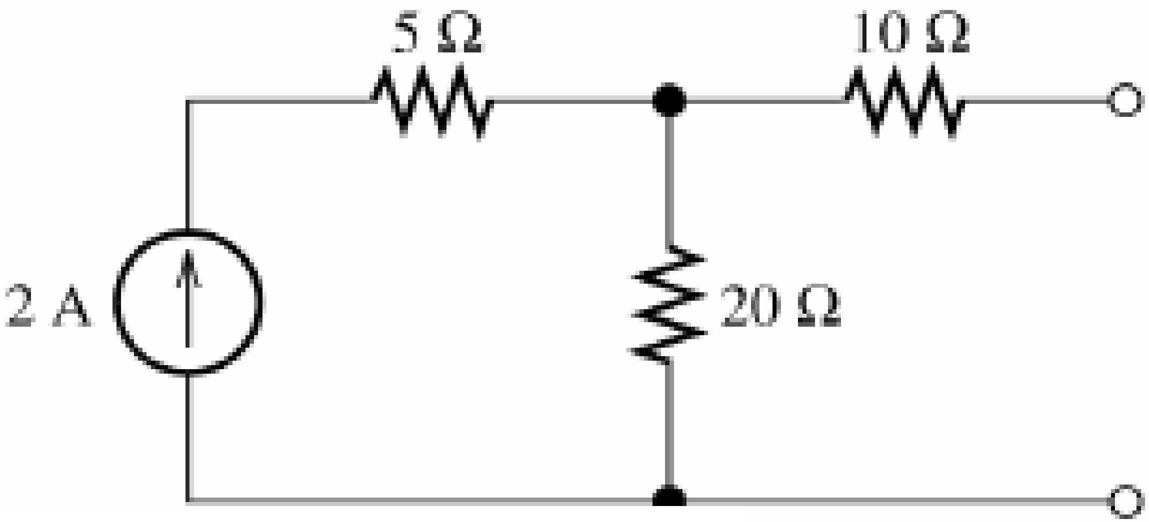
$$V_{OC} = V_t = \frac{20}{20+5} \times 10 = 8$$

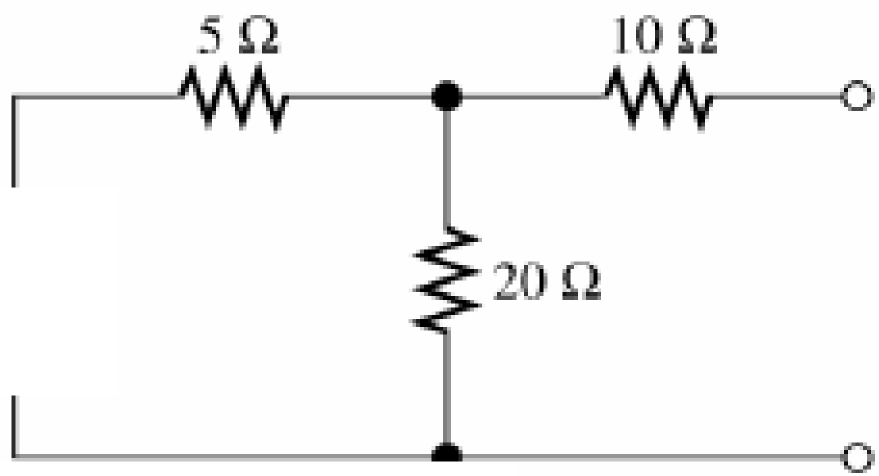


$$i_{sc} = \frac{10}{5+(10\,||\,20)} \cdot \frac{20}{20+10} = \frac{20}{35}$$

$$R_t = \frac{v_{oc}}{i_{sc}} = \frac{8 \times 35}{20} = 14$$

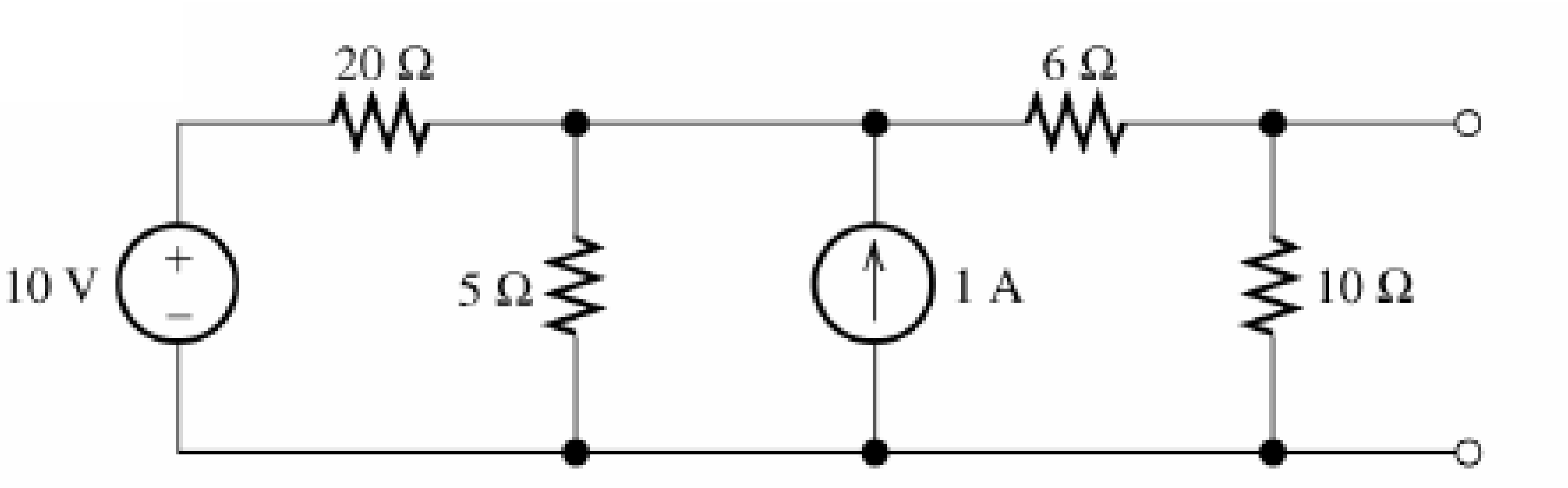
Find Thevenin resistance for each of the circuits shown below





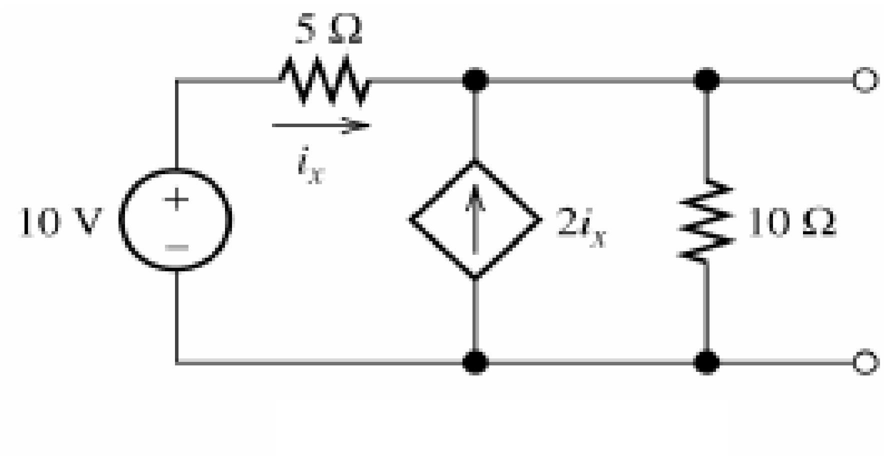
$R_t = 10 + 20 = 30$

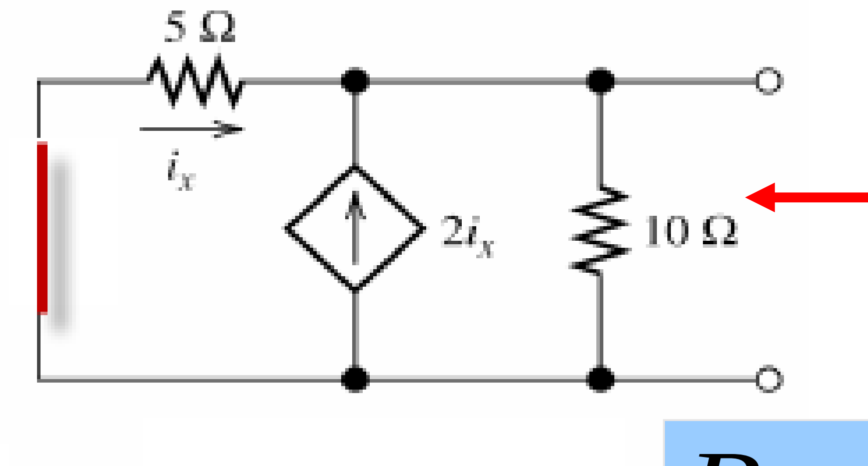
Find Thevenin resistance for each of the circuits shown below



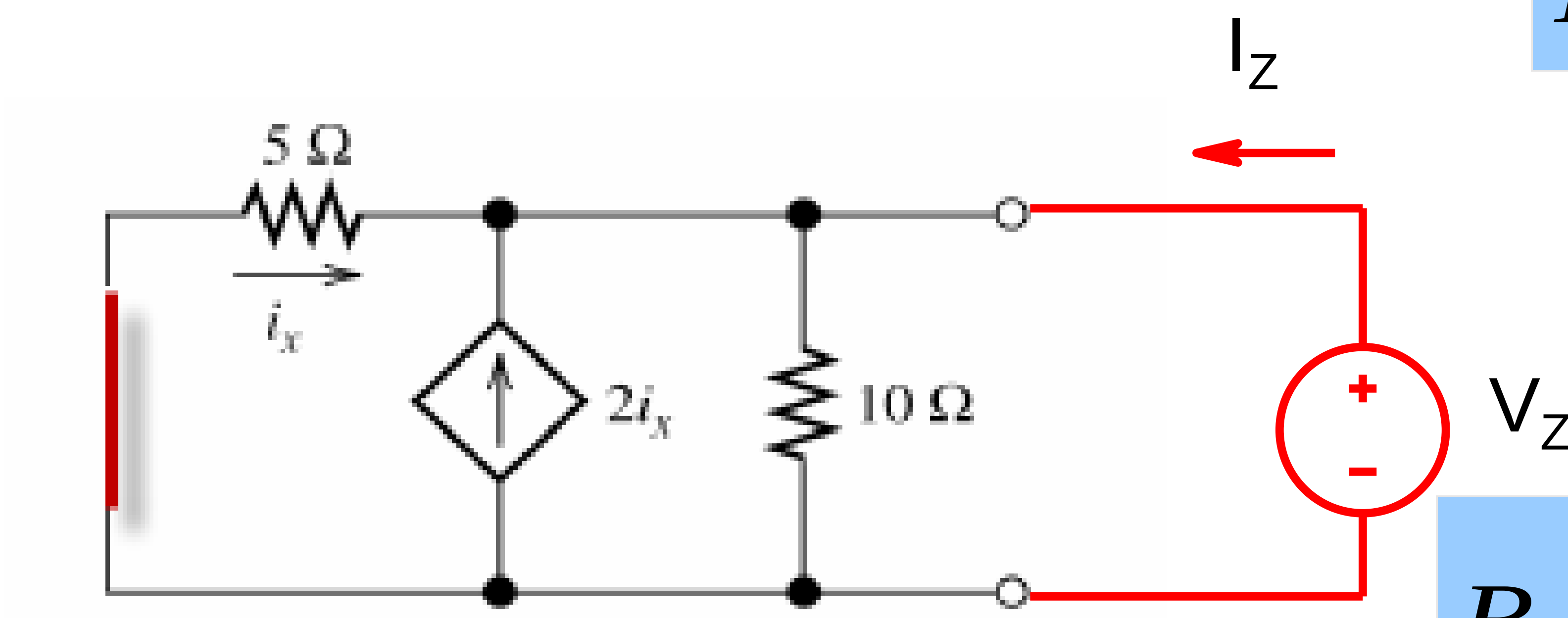
$$R_t = ((20 \| 5) + 6) \| 10) = 5$$

Circuit with dependent Sources



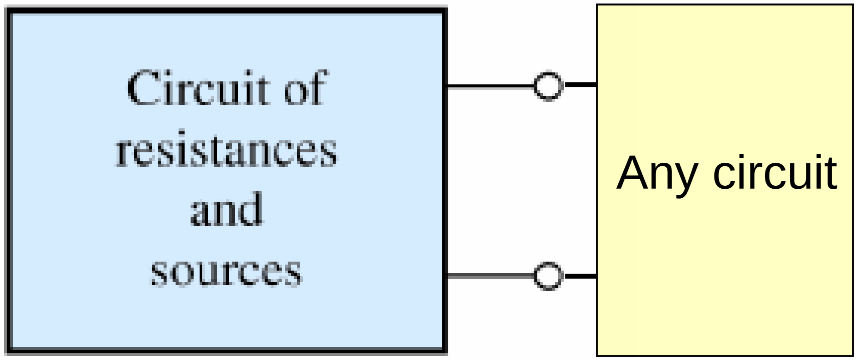


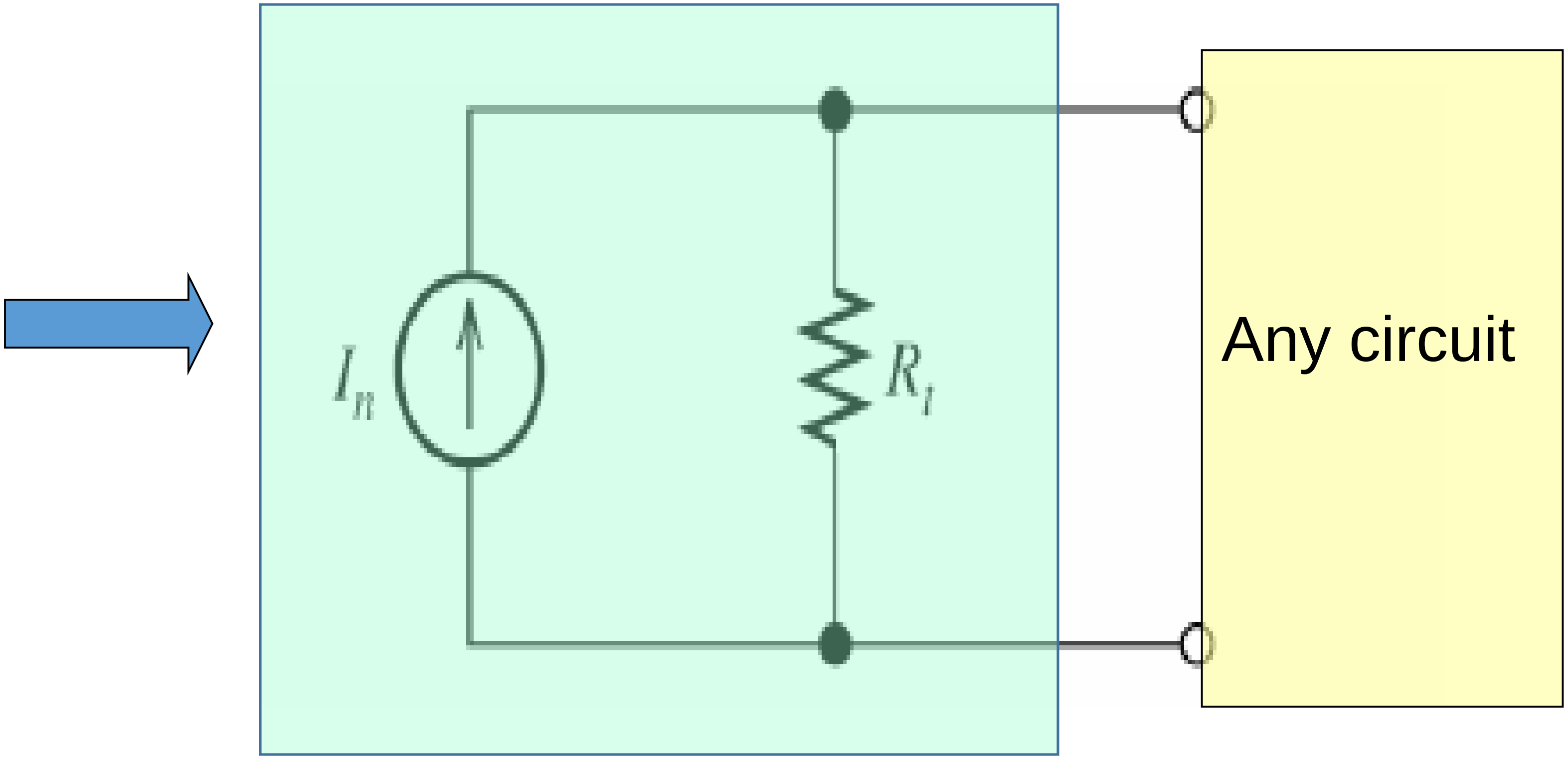
$$R_t = ?$$



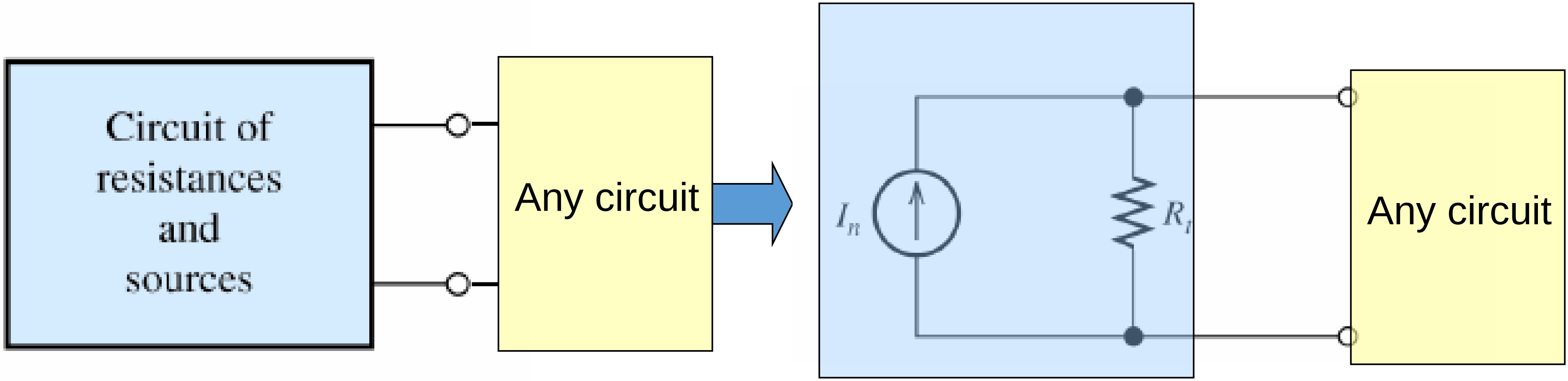
$$R_t = \frac{V_Z}{I_Z}$$

Norton’s equivalent

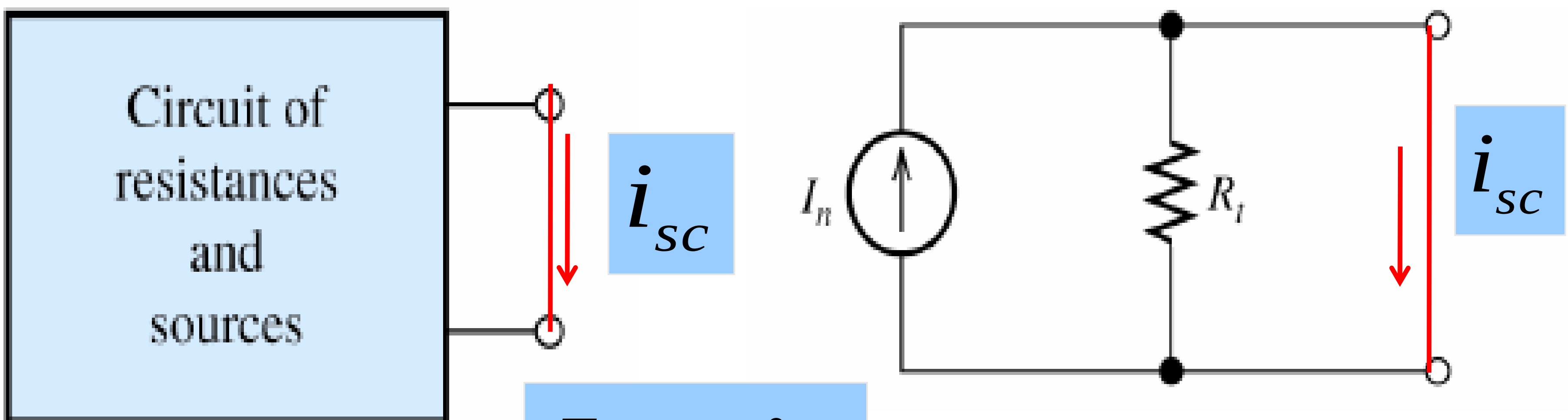




Norton's equivalent

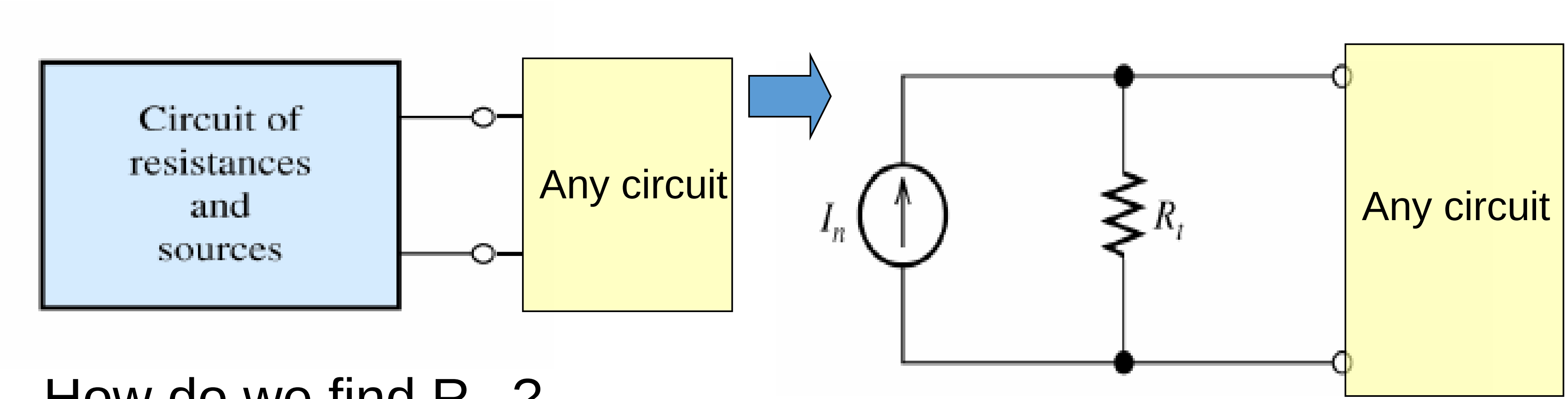


How do we find I_N ?

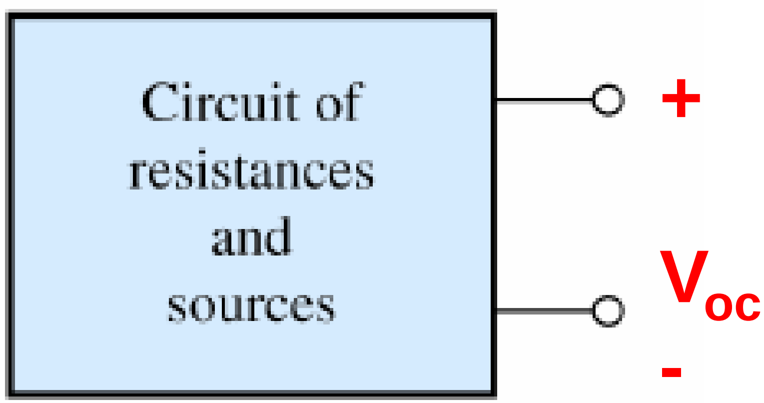


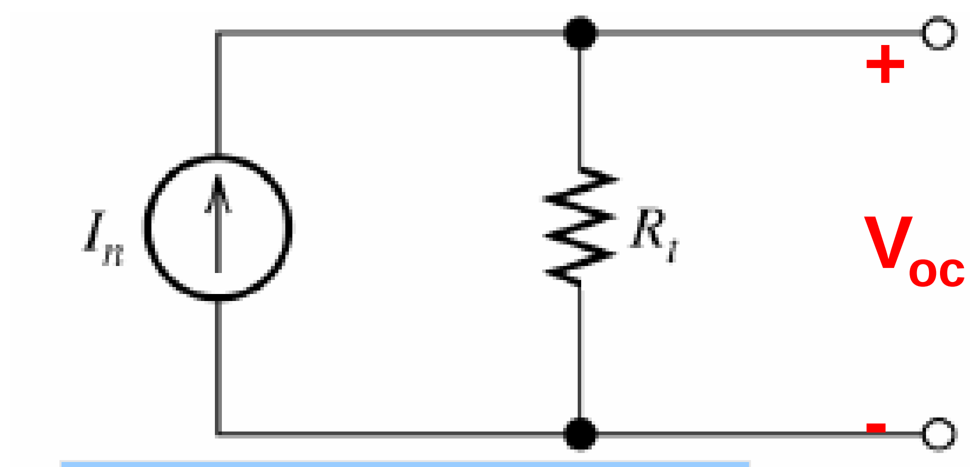
$$I_n = i_{sc}$$

Norton's equivalent



How do we find R_N ?

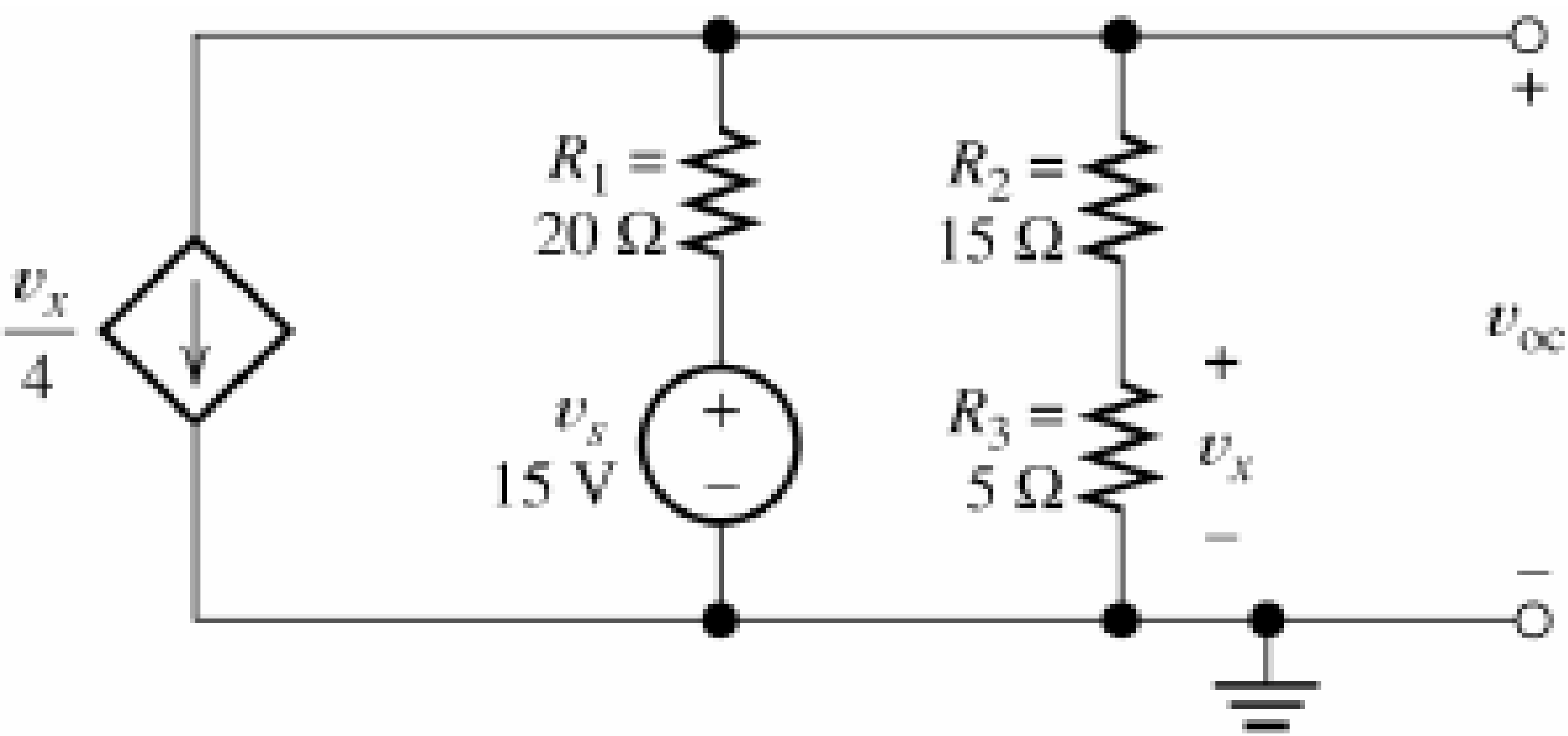


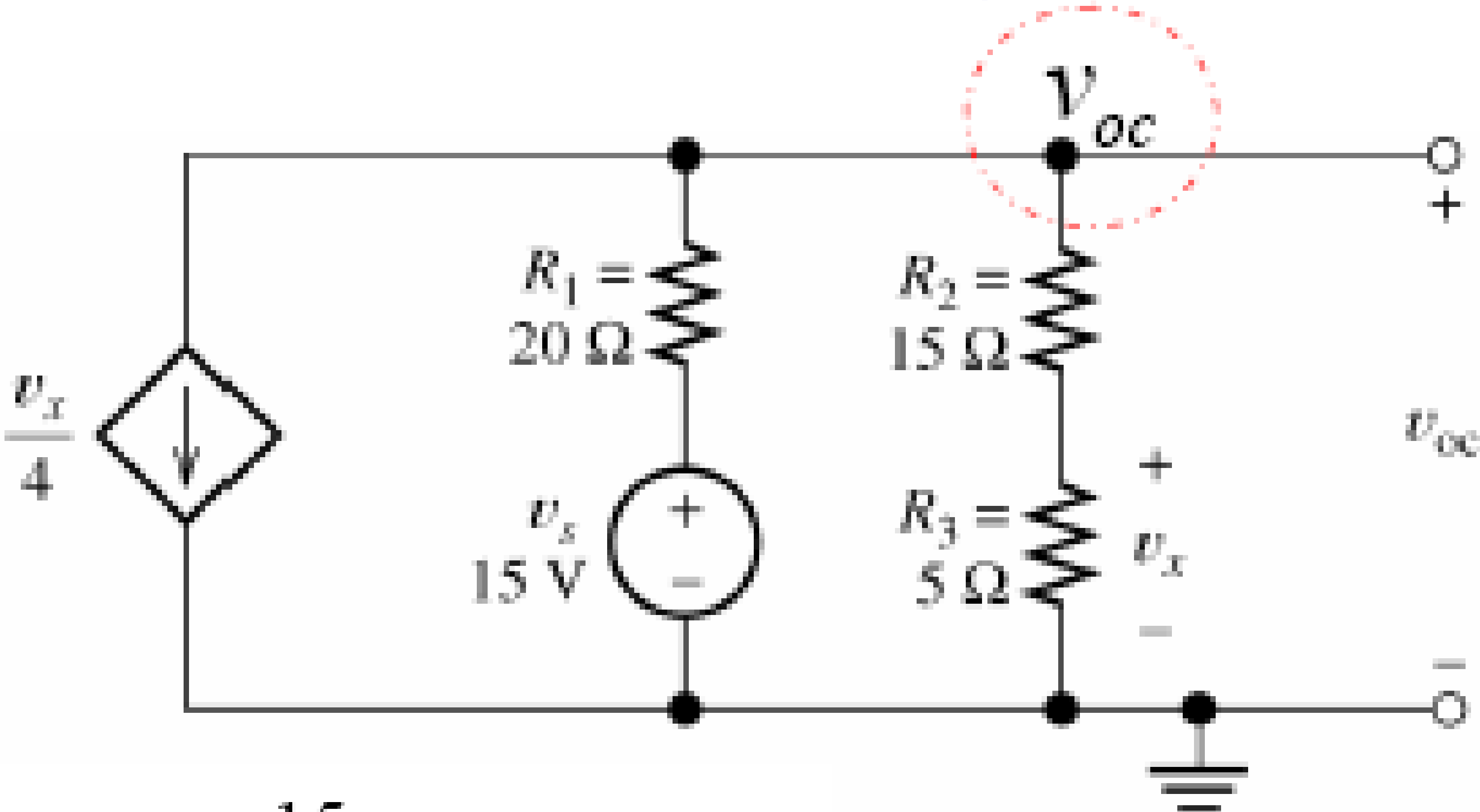


$$R_t = \frac{v_{oc}}{i_{sc}}$$

$$v_{oc} = I_n \times R_t$$

Example: Find the Norton equivalent for the following circuit

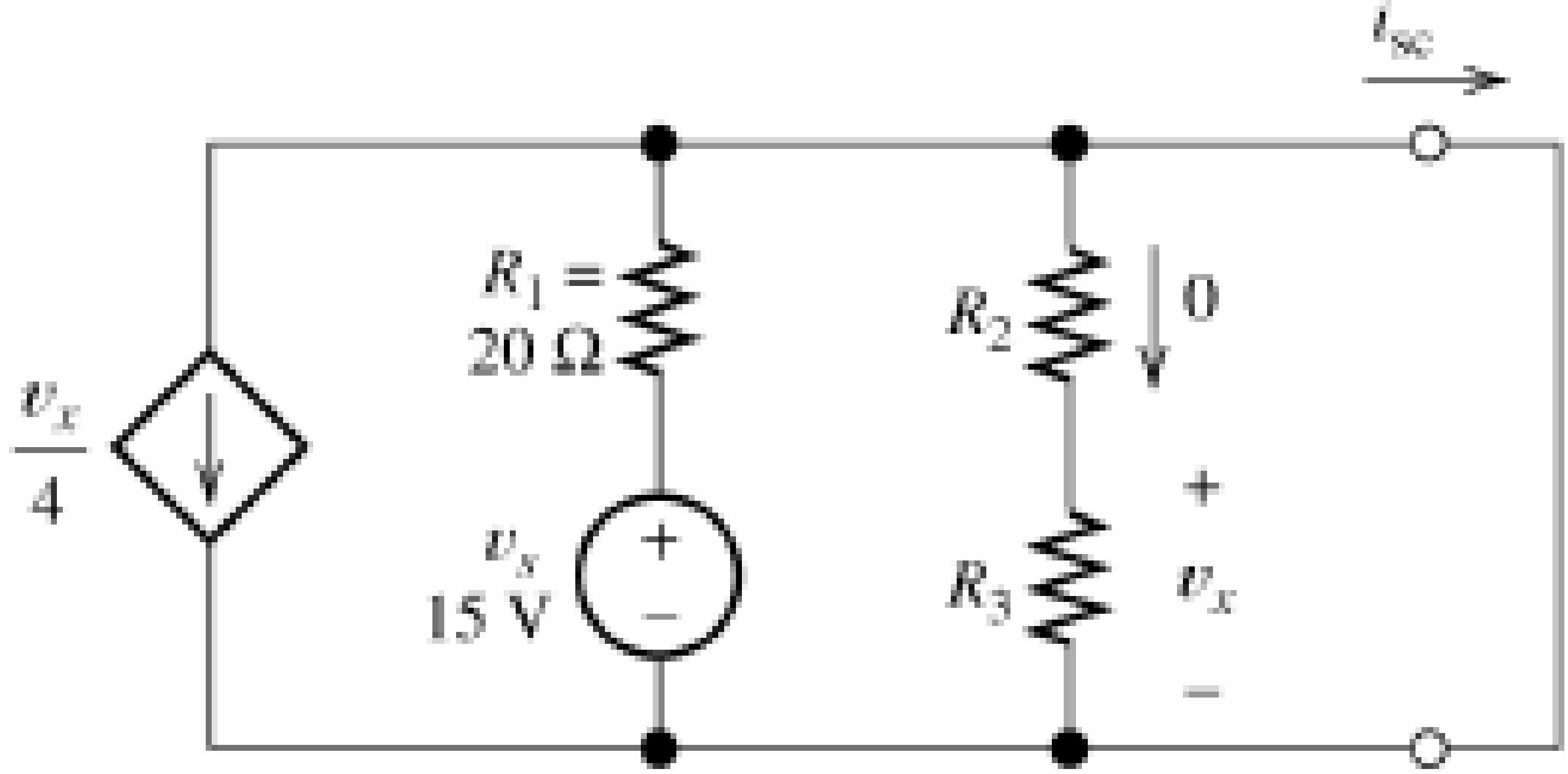




$$\frac{v_x}{4} + \frac{v_{oc} - 15}{R_1} + \frac{v_{oc}}{R_2 + R_3} = 0$$

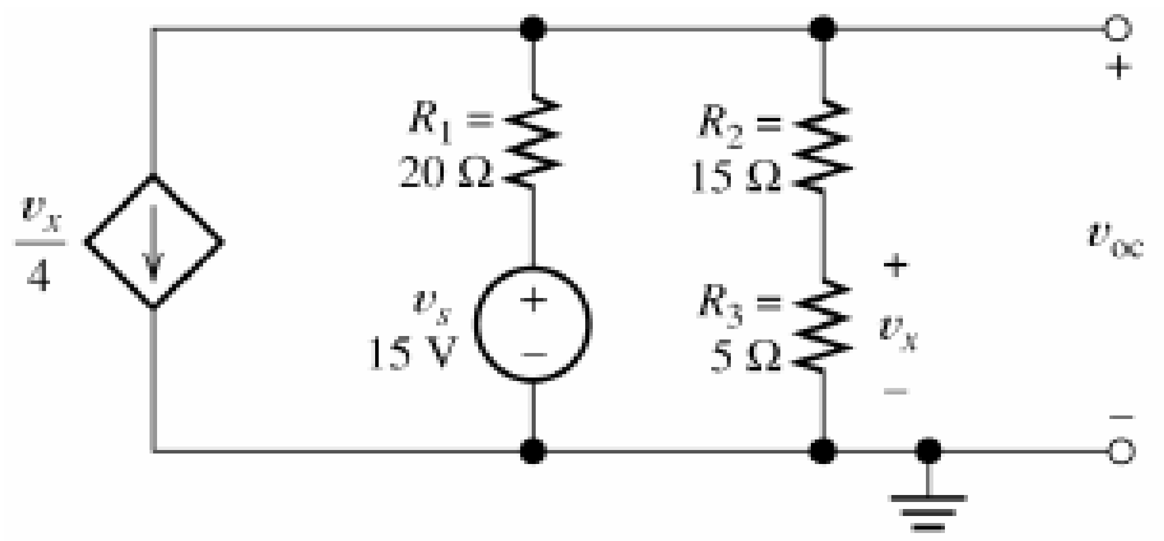
$$v_x = \frac{R_3}{R_2 + R_3} v_{oc} = 0.25 v_{oc}$$

$$\boxed{v_{oc} = 4.62\text{V}}$$



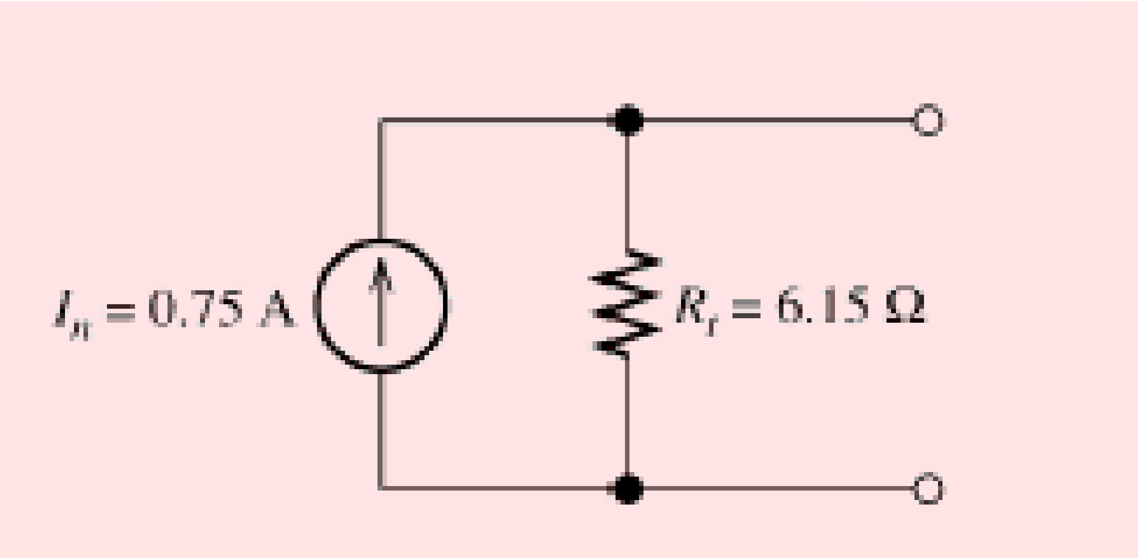
$$i_{sc} = \frac{v_s}{R_1} = \frac{15\text{V}}{20\Omega} = 0.75\text{A}$$

$$R_t = \frac{v_{oc}}{i_{sc}} = \frac{4.62\text{V}}{0.75\text{A}} = 6.15\Omega$$



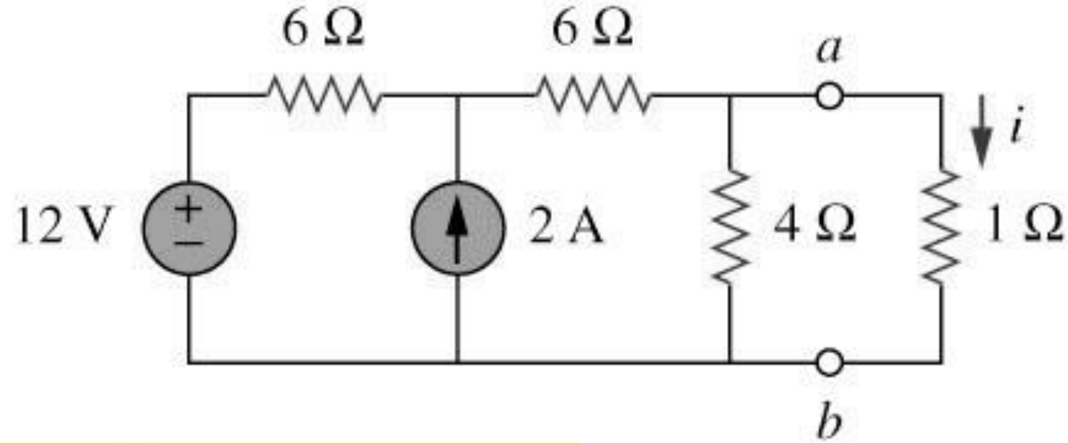
Norton's equivalent

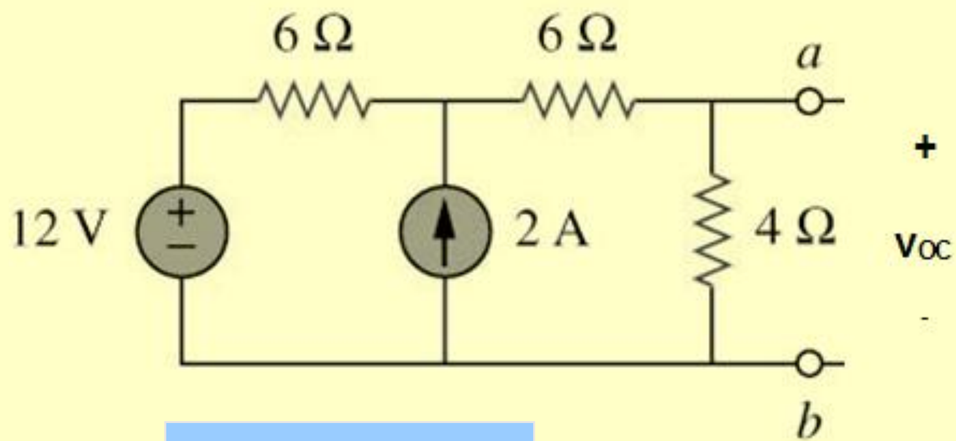
$$\boxed{v_{oc} = 4.62\text{V}}$$



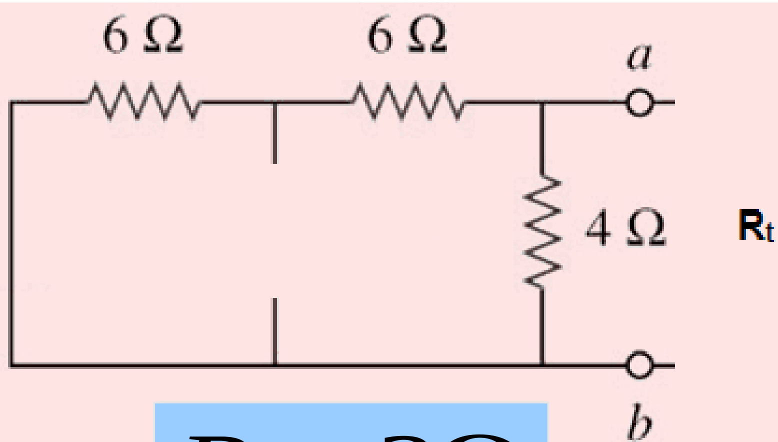
$R_t = 6.15\ \Omega$

Using Thevenin's theorem, find the equivalent circuit to the left of the terminals in the circuit shown below. Hence find i.

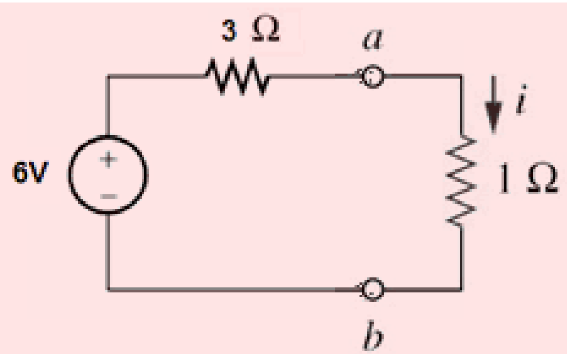




$$v_{oc} = 6V$$



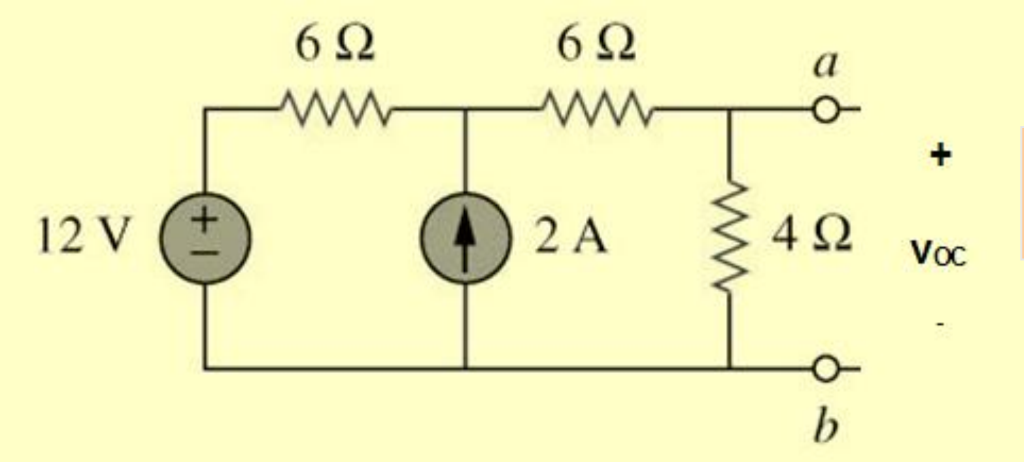
$$R_t = 3\Omega$$



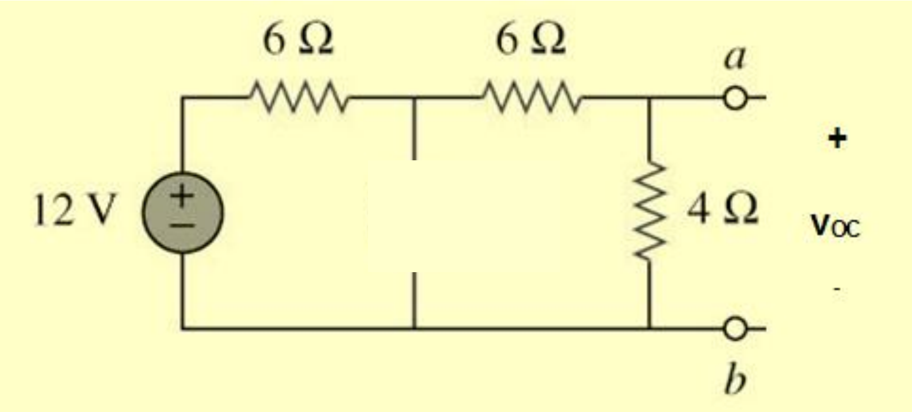
$$i = 1.5A$$

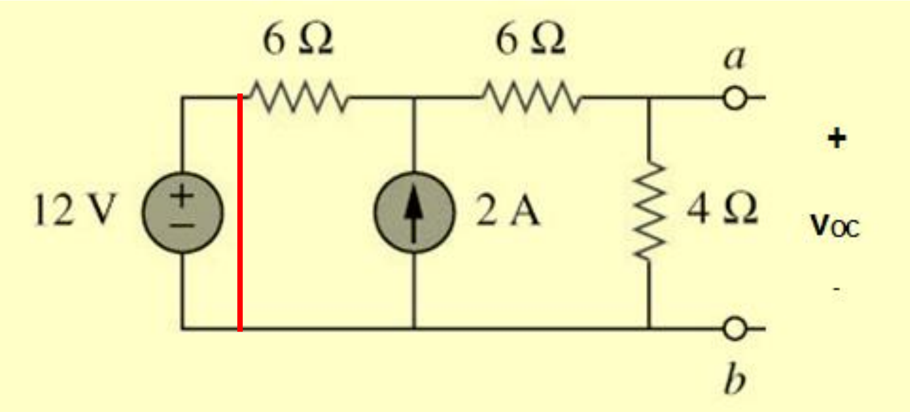
Use Superposition

$$v_{oc} = 6V$$



$$V_{oc} = V_{oc1} + V_{oc2} = 6$$

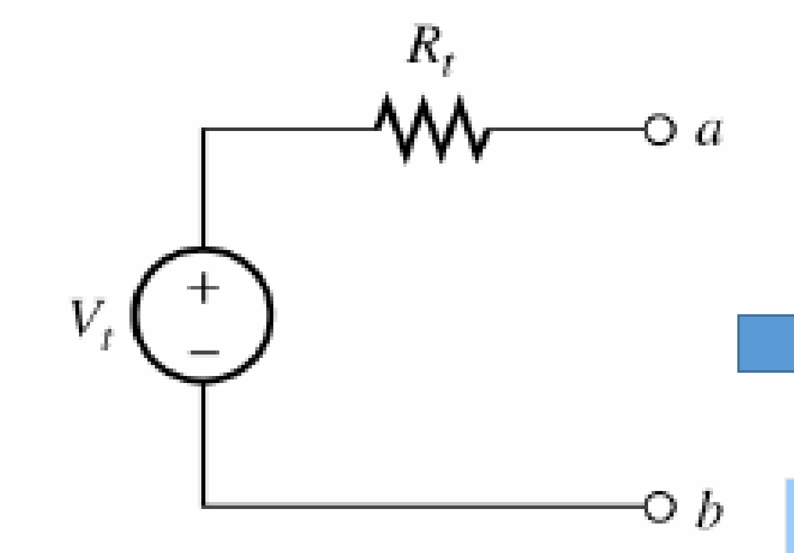


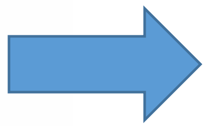


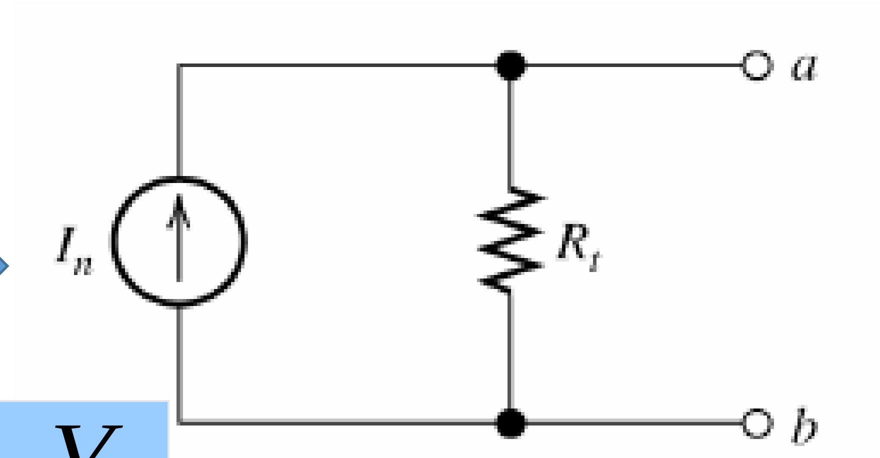
$$V_{oc1} = \frac{4}{4+12} \times 12 = 3$$

$$V_{oc2} = 4 \times \left(2 \times \frac{6}{6+10} \right) = 3$$

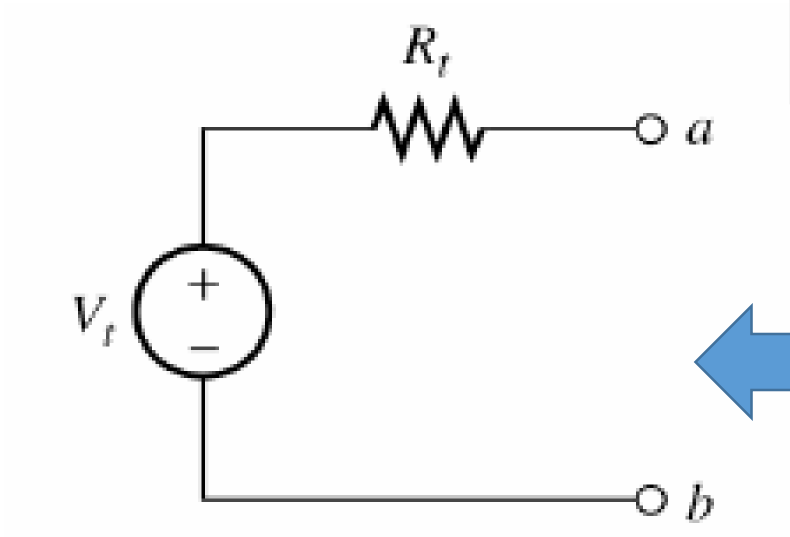
Source Transformation

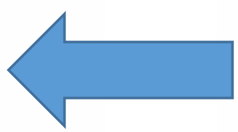


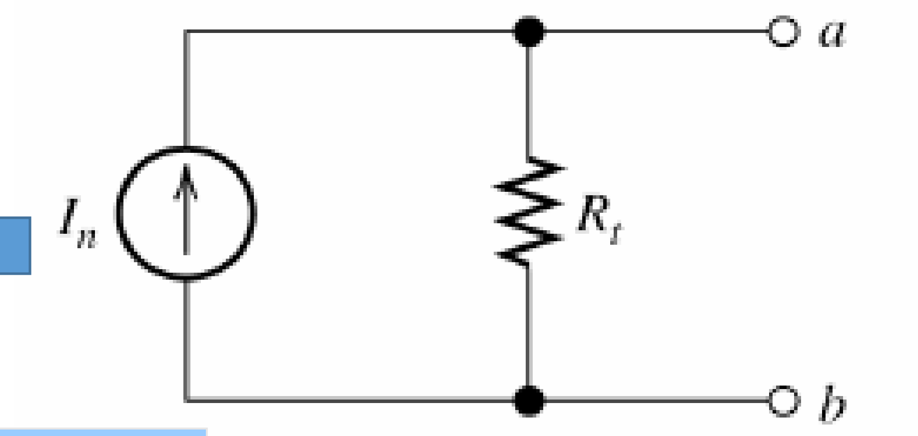




$$I_n = \frac{V_t}{R_t}$$

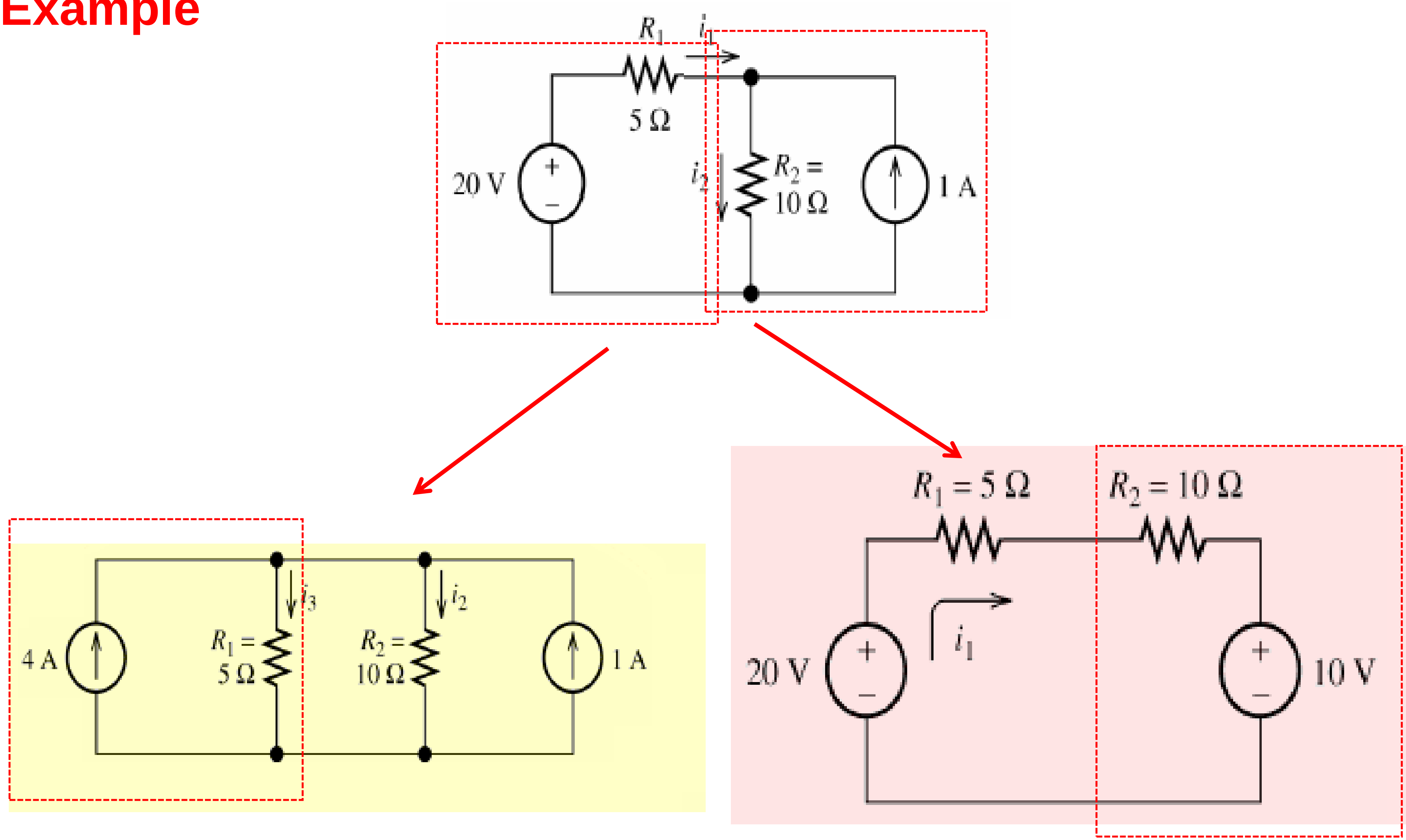






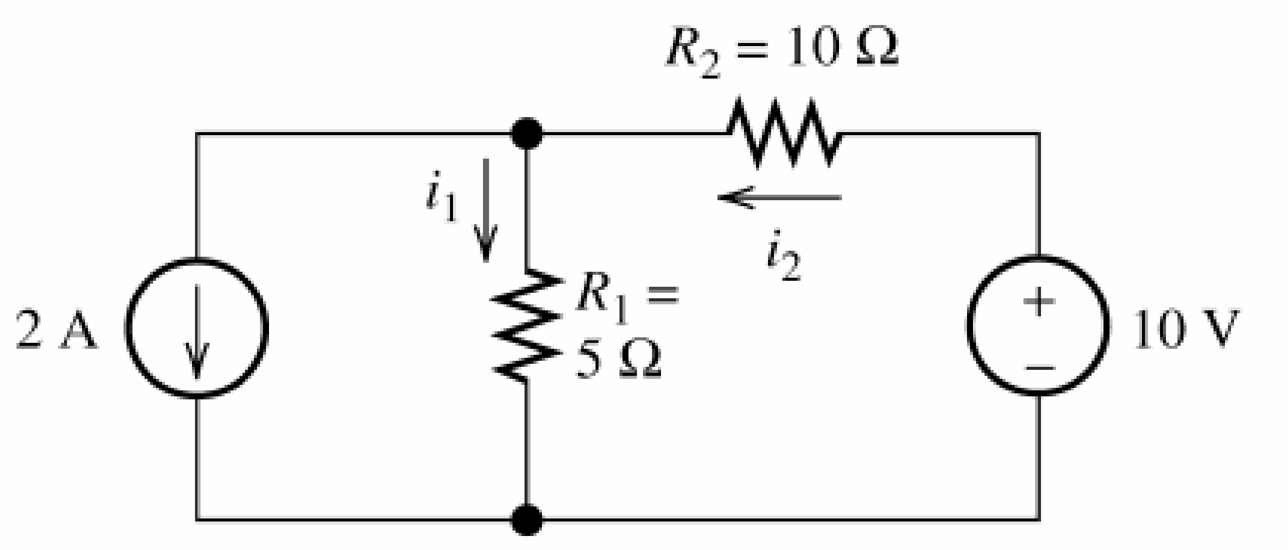
$$V_t = I_n \times R_t$$

Example

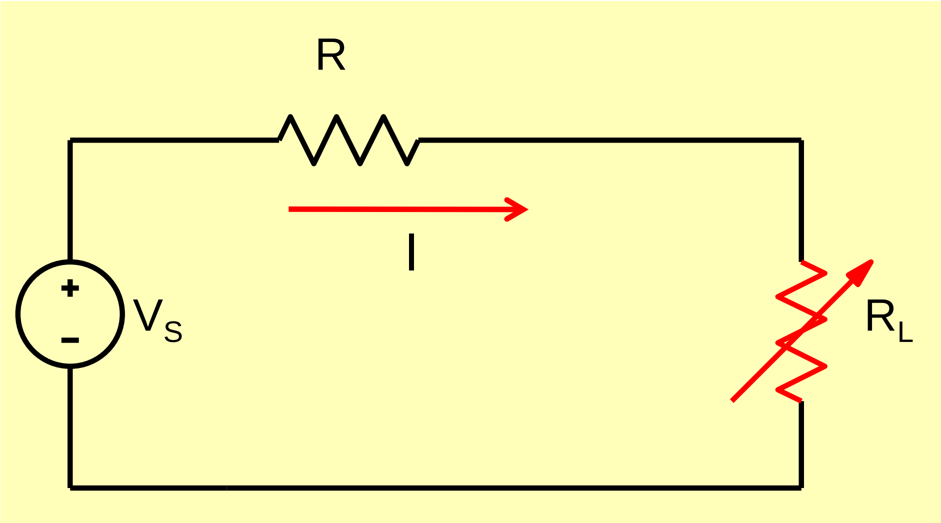


R1
i1
5 Ω
20 V
i2
R2 =
10 Ω
1 A
4 A
i3
R1 =
5 Ω
i2
R2 =
10 Ω
1 A
R1 = 5 Ω
R2 = 10 Ω
20 V
i1
10 V

Use source transformation to solve for the indicated currents



Maximum Power Transfer for dc circuits



What value of R_L will give rise to maximum load power ?

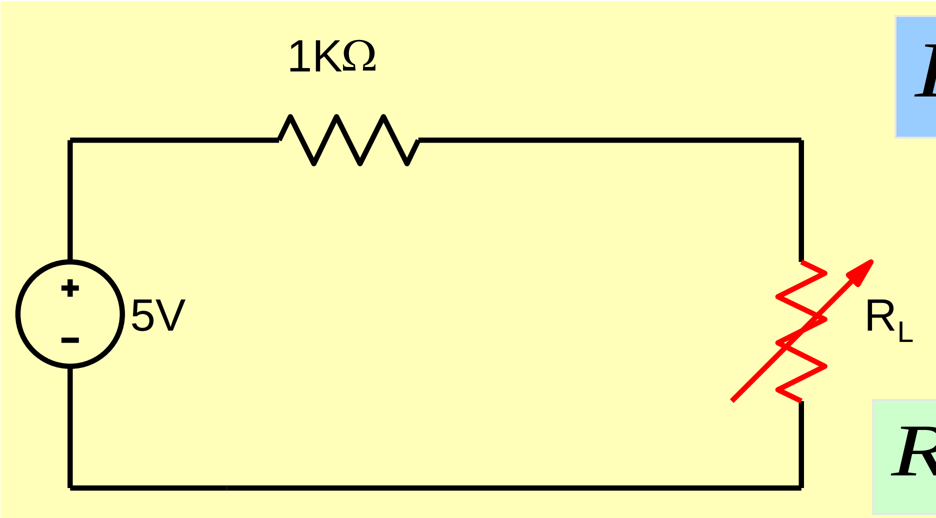
$$I = \frac{V_S}{R + R_L}$$

$$P_L = I^2 R_L = V_S^2 \times \frac{R_L}{(R + R_L)^2}$$

$$\frac{\partial P_L}{\partial R_L} = 0$$

$$R_L = R$$

$$P_{L\max} = \frac{V_S^2}{4R_L}$$

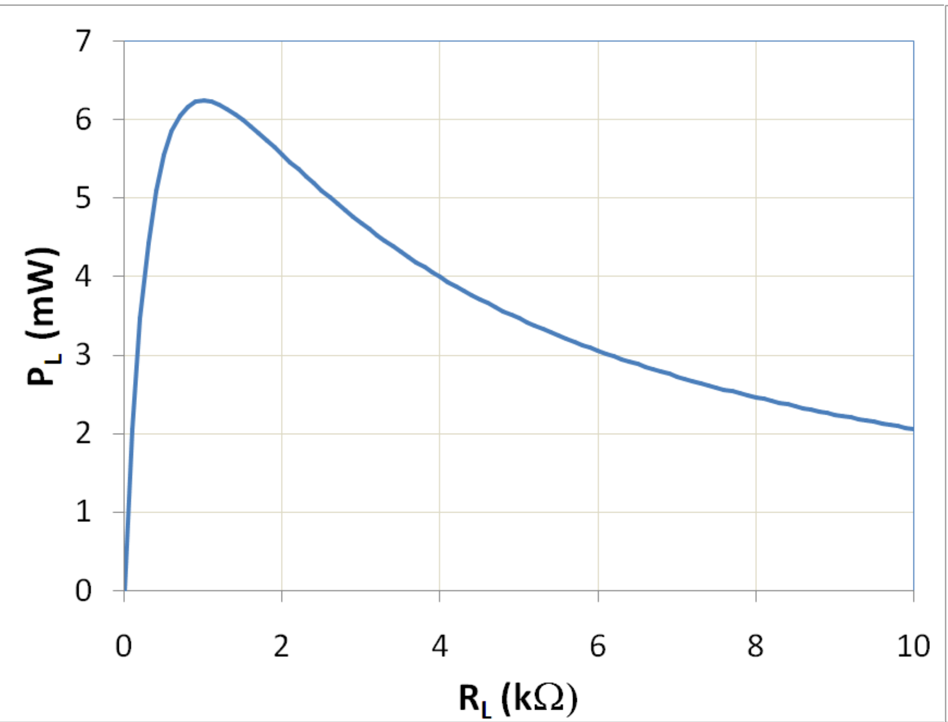


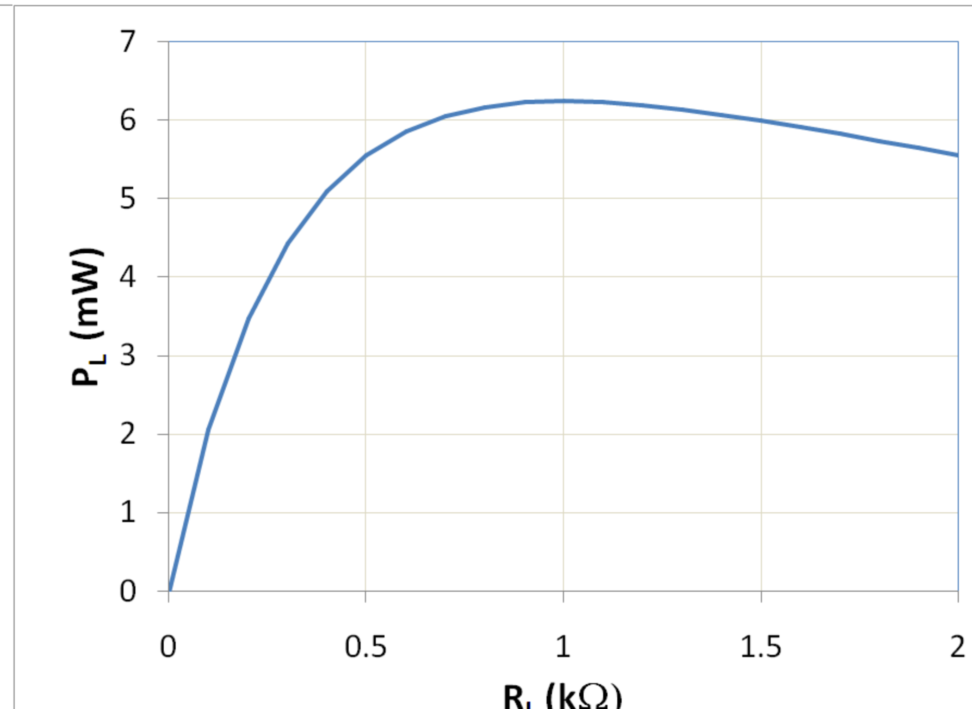
$$R_L = 1K \Rightarrow P_L = 6.25mW$$

$$R_L = 10K \Rightarrow P_L = 2mW$$

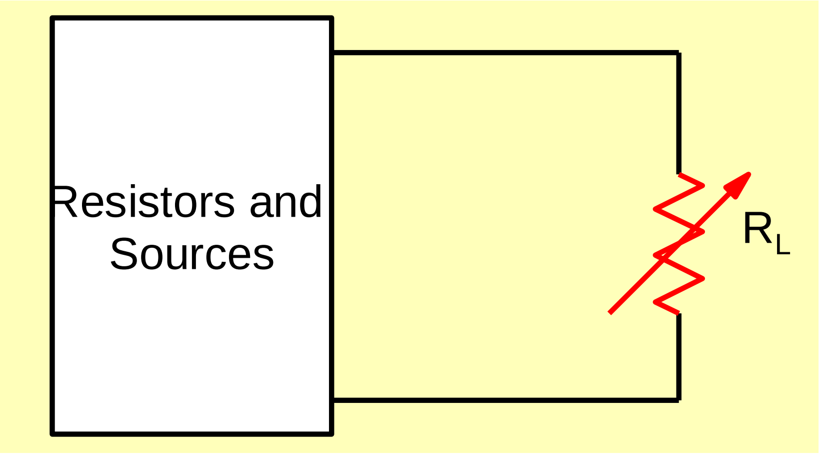
$$R_L = 0.2K \Rightarrow P_L = 3.47mW$$

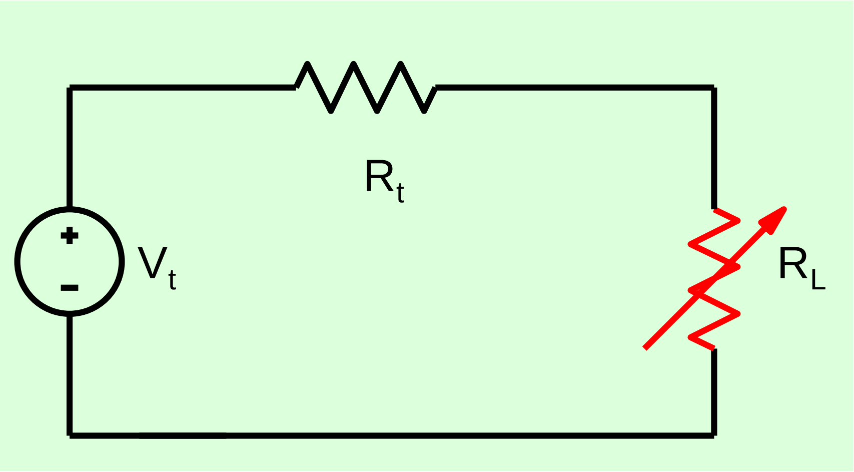
Maximum power is delivered to the load when **R_L = R**





General Case

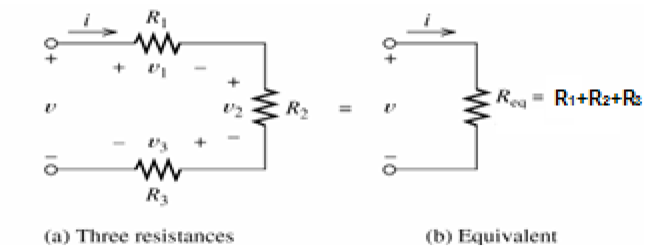


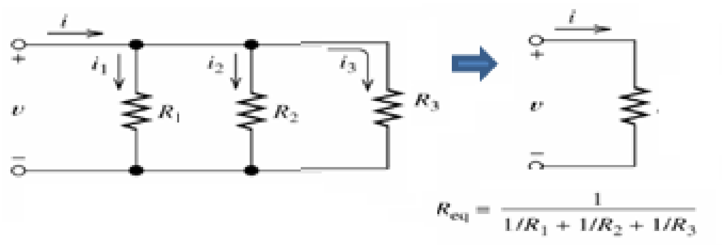


Maximum power is delivered to the load when $\mathbf{R_L = R_t}$

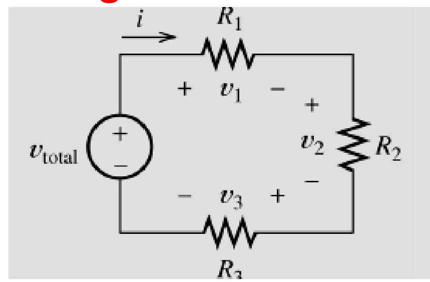
Summary

Series/Parallel resistances





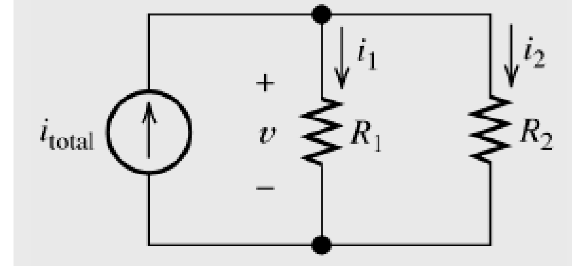
Voltage division



$$v_2 = R_2 i = \frac{R_2}{R_1 + R_2 + R_3} v_{total}$$

$$i_2 = \frac{v}{R_2} = \frac{R_1}{R_1 + R_2} i_{total}$$

Current division



Mesh Analysis

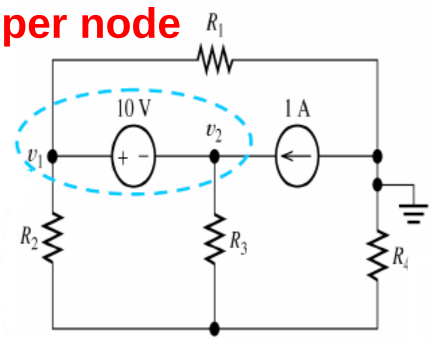
1. Assign mesh currents i_1, i_2, …, in to the n meshes.
2. Apply KVL to each of the n meshes. Use Ohm's law to express the voltages in terms of the mesh currents.
3. Solve the resulting n simultaneous equations to get the mesh currents.

Nodal Analysis:

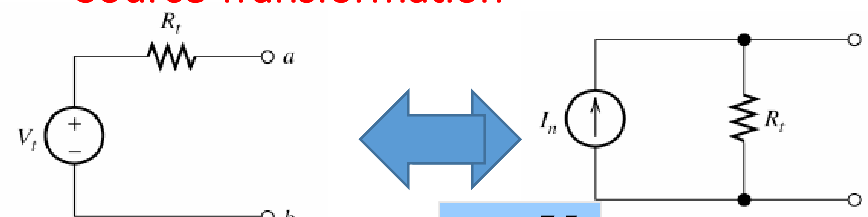
1. Identify and number the nodes
2. Choose a reference node
3. Write KCL for each node such that

Sum of currents leaving a node is zero.

Super node



Source Transformation



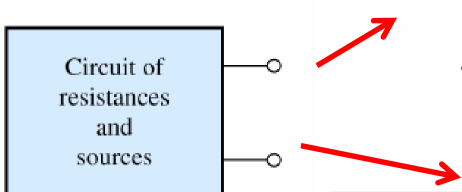
$$V_t = I_n \times R_t$$

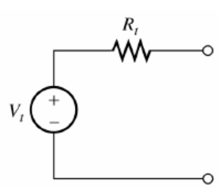
$$I_n = \frac{V_t}{R_t}$$

The **superposition principle** states that the total response is the sum of the responses to each of the independent sources acting individually.

Thevenin & Norton

$$V_t = v_{oc}$$

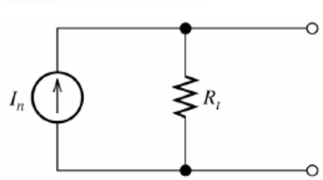




Thévenin equivalent circuit

$$R_t = \frac{v_{oc}}{i_{sc}}$$

$$I_n = i_{sc}$$



Labs

Link for Handouts:

https://iitk-my.sharepoint.com/:f:/g/personal/mnisha_iitk_ac_in/EmZwnMY48-NGmHlMZ7ZmXyEBhKhAR4qfJhuSYm03pHGDlA?e=W8AXrz

Weekly Schedule:

Week	Monday M1 - M4	Tuesday Tu1 - Tu4	Wednesday W1 - W4	Thursday Th1 - Th4	Friday F1 - F4	Saturday
00: A01-A05						
01: A08-A12	E1	Moharram	E1	E1	E1	E1 (Tu)
02: A15-A19	Indep. Day	E2	E2	E2	Janmashtami	E2 (M)
03: A22-A26	E3	E3	E3	E3	E2	E3 (F)
04: A29-S02	E4	E4	E4	E4	E4	
05: S05-S09	E5	E5	E5	E5	E5	
06: S12-S16	Make Up					
07: S19-S23	Mid Semester Exam					
08: S26-S30	E6	E6	E6	E6	E6	
09: O03-O07	Mid Semester Recess					
10: O10-O14	E7	E7	E7	E7	E7	
11: O17-O21	E8	E8	E8	E8	E8	
12: O24-O28	Diwali	E9	E9	E9	E9	E9 (M)
13: O31-N04	Makeup					
14: N07-N11	Lab Examination					
15: N14-N18	End Semester Exam					
16: N21-N25	End Semester Exam					

Link to youtube videos for labs have also been provided in resources document