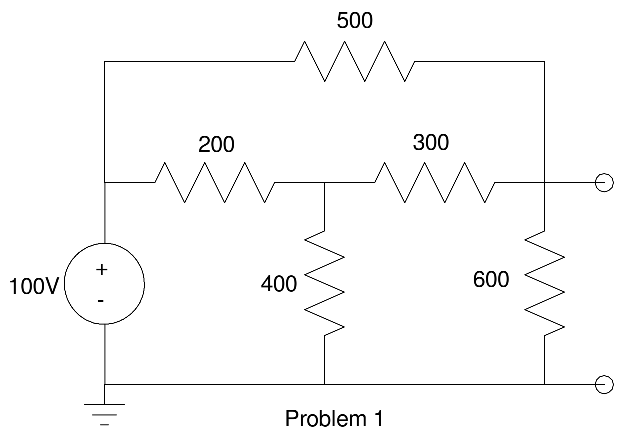
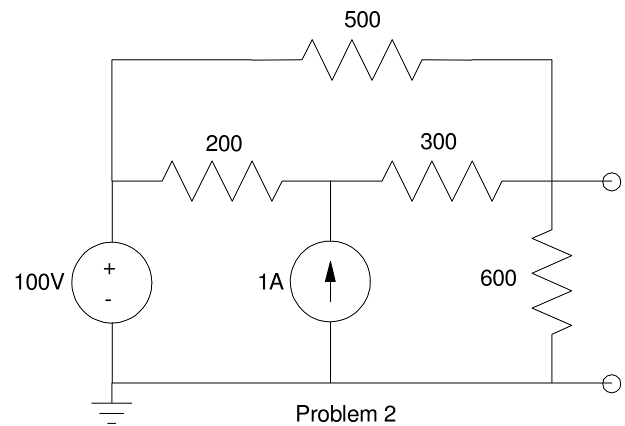
Thevenin Equivalents (Harder problems)

EE 206 Practice Problems

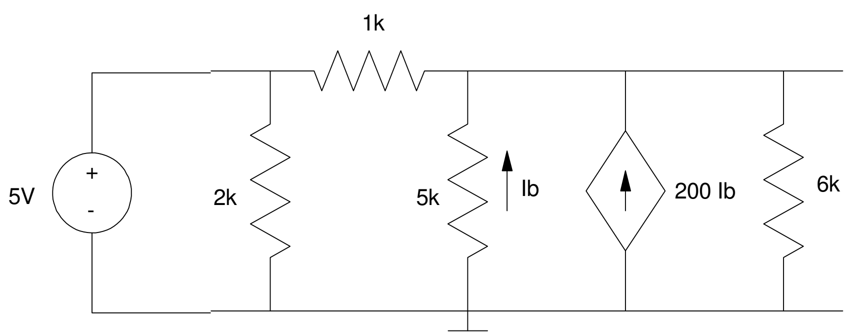
Find the Thevenin equivalent for the following circuits



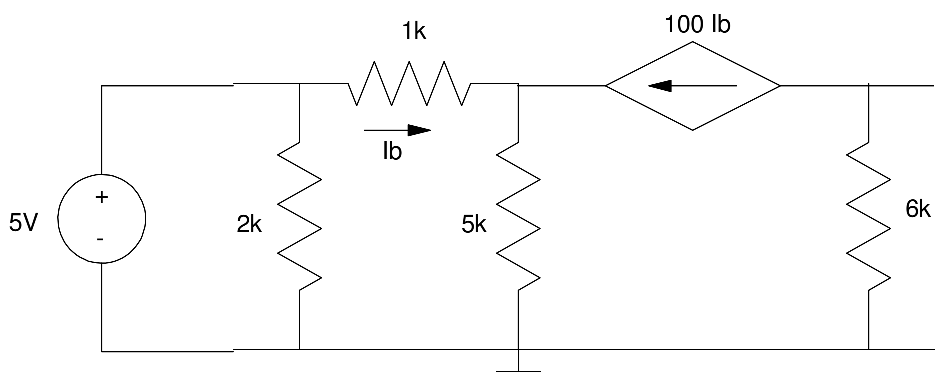
Problem 1



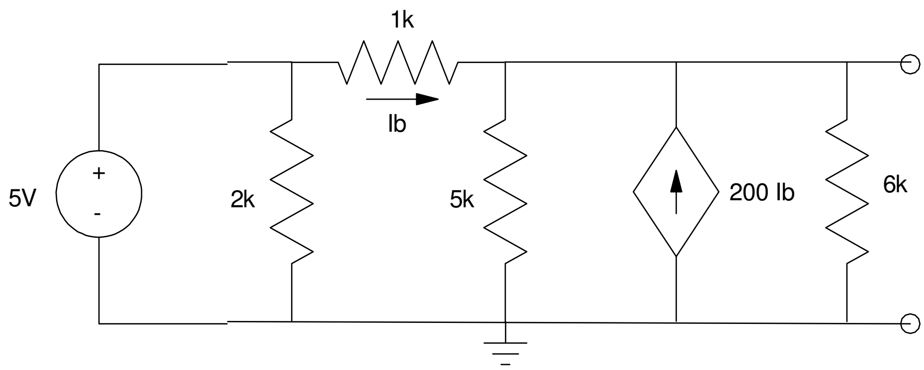
Problem 2



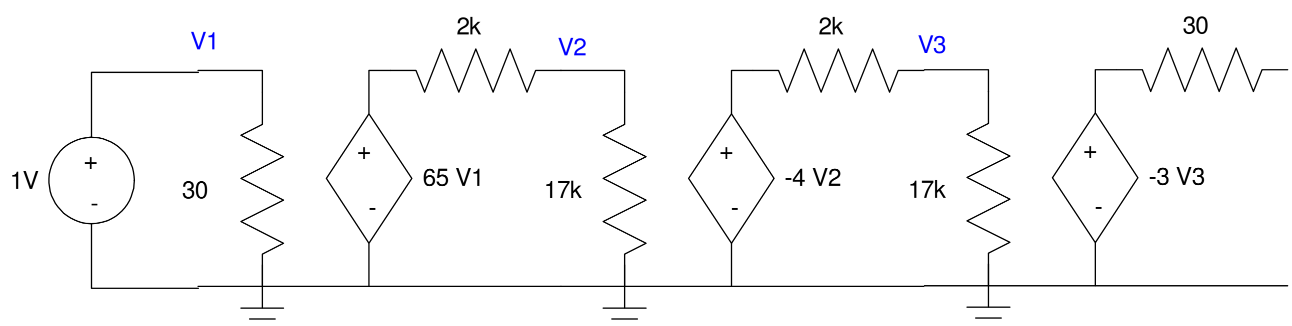
Problem 3: Assume Vin is connected to a +1.00V source



Problem 4: Assume Vin is connected to a +1.00V source

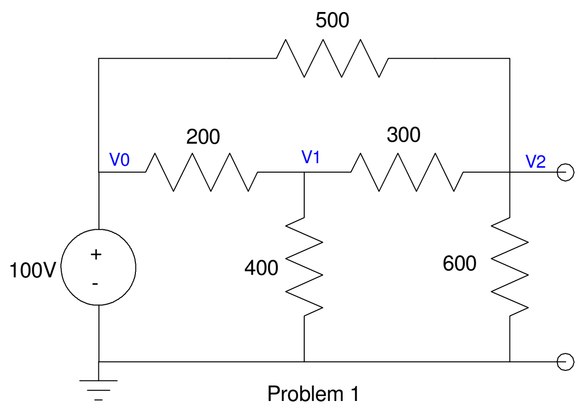


Problem 5: Assume Vin is connected to a +1.00V source



Problem 6

Solution - Problem 1:



Open Circuit Voltage: Write the voltage node equations

$$V_0 = 10V$$

$$\left(\frac{V_1 - V_0}{200}\right) + \left(\frac{V_1}{400}\right) + \left(\frac{V_1 - V_2}{300}\right) = 0$$

$$\left(\frac{V_2 - V_0}{500}\right) + \left(\frac{V_2 - V_1}{300}\right) + \left(\frac{V_2}{600}\right) = 0$$

Solve

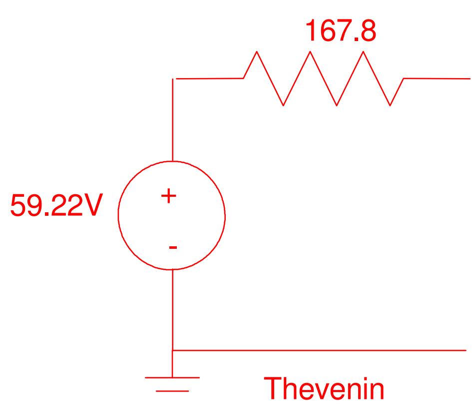
- V0 = 10
- V1 = 64.377682
- V2 = Vth = 59.227468 V

Thevenin Resistance: Turn off the power supply. Compute the resistance looking in:

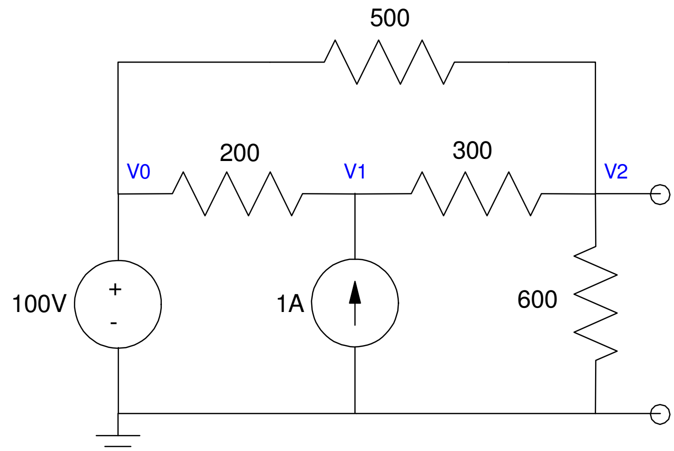
$$R = ((200||400) + 300)||600||500$$

$$R_{th} = (133.333 + 300)||600||500$$

$$R_{th} = 167.38$$



Solution - Problem 2:



Open Circuit Voltage: Write the voltage node equations

$$V_0 = 10V$$

$$\left(\frac{V_1 - V_0}{200}\right) - 1 + \left(\frac{V_1 - V_2}{300}\right) = 0$$

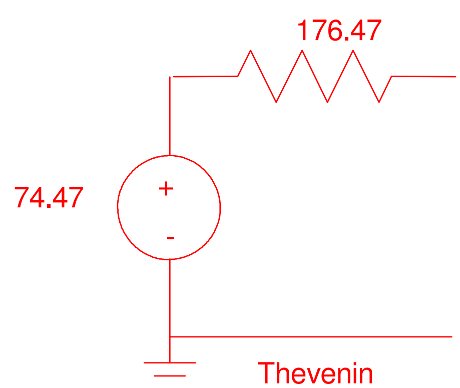
$$\left(\frac{V_2 - V_0}{500}\right) + \left(\frac{V_2 - V_1}{300}\right) + \left(\frac{V_2}{600}\right) = 0$$

Solve

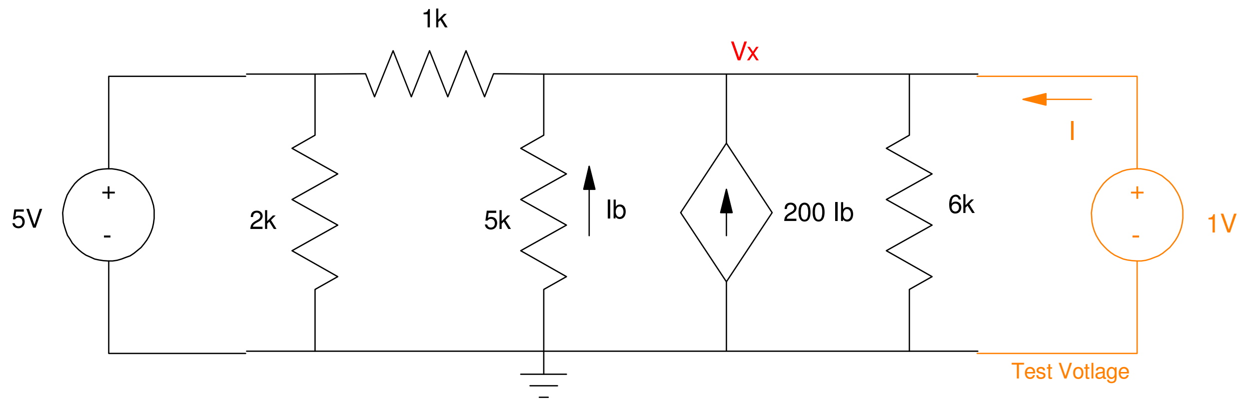
- V0 = 10V
- V1 = 155.78824
- V2 = Vth = 74.470588

Rth: Turn off the sources (V = 0V = short, I = 0A = open). Compute the resistance looking in

$$R_{th} = 600||500||500 = 176.47\Omega$$



Solution - Problem 3



Vth: Compute the open circuit voltage. To do this, write the voltage node equation at Vx

$$I_b = \left(\frac{0-V_x}{5k}\right)$$

$$\left(\frac{V_x-5}{1k}\right) + \left(\frac{V_x}{5k}\right) - 200I_b + \left(\frac{V_x}{6k}\right) = 0$$

Solving

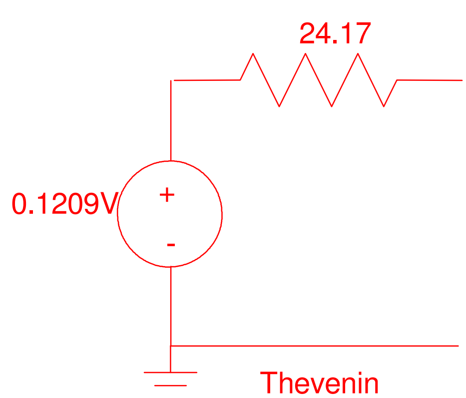
$$V_{th} = V_x = 0.1209V$$

Rth: Turn off the power supplies (5V becomes 0V or a short). Compute Rin.

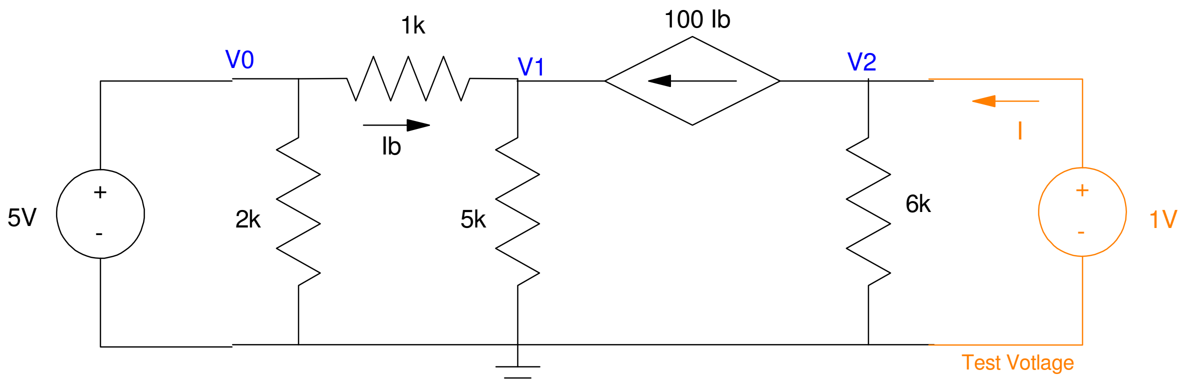
This isn't obvious, so apply a 1V test voltage and compute the current

$$I = \left(\frac{1V}{6k\Omega}\right) + \left(\frac{1V}{1k\Omega}\right) + \left(\frac{1V}{5k\Omega}\right) + 200\left(\frac{1V}{5k\Omega}\right) = 41.367mA$$

$$R_{th} = \left(\frac{1V}{41.37mA}\right) = 24.17\Omega$$



Solution - Problem 4



Vth: Compute the open-circuit voltage. To do this, compute V1

$$I_b = \left(\frac{5-V_1}{1k}\right)$$

$$\left(\frac{V_1-5}{1k}\right) + \left(\frac{V_1}{5k}\right) - 100I_b = 0$$

Solve

$$V_1 = 4.9901V$$

$$I_b = \left(\frac{5-V_1}{1k}\right) = 9.881\mu A$$

$$V_{th} = V_2 = -6000 \cdot 100I_b = -5.929V$$

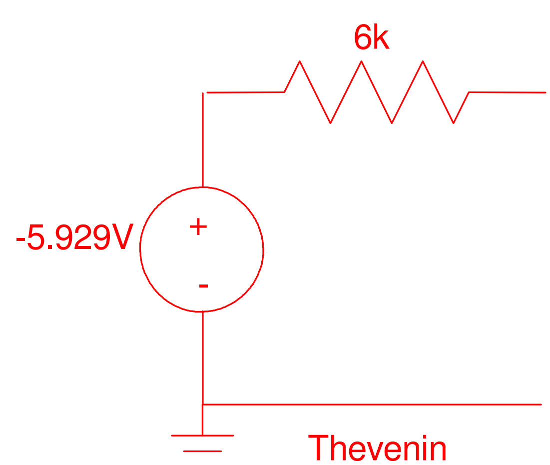
Rth: Turn off the source (5V becomes 0V or a short). Apply a 1V test voltage and compute the current. To do that, solve for V1 (with V0 = 0V)

$$\left(\frac{V_1-0}{1k}\right) + \left(\frac{V_1}{5k}\right) - 100\left(\frac{0-V_1}{1k}\right) = 0$$

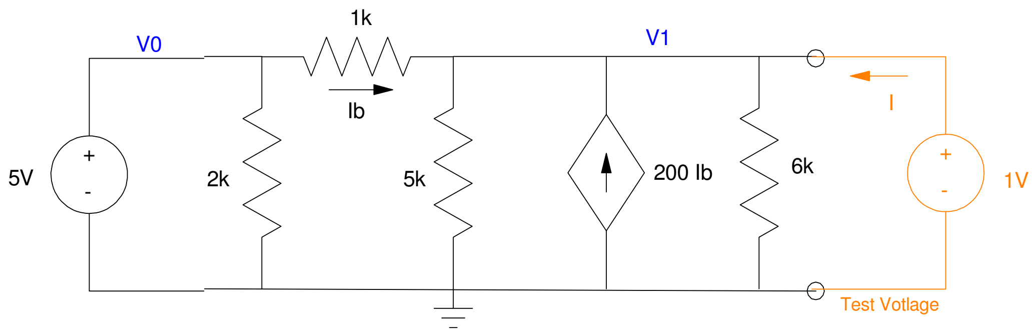
$$V_1 = 0, \qquad I_b = 0$$

$$I = \frac{1V}{6k} = 166.7\mu A$$

$$R_{th} = \frac{1V}{166.7\mu A} = 6k\Omega$$



Solution - Problem 5



Vth: Measure the open-circuit voltage. To do this, write the voltage node equation at V1

$$I_b = \left(\frac{5-V_1}{1k}\right)$$

$$-I_b + \left(\frac{V_1}{5k}\right) - 200I_b + \left(\frac{V_1}{6k}\right) = 0$$

Solving

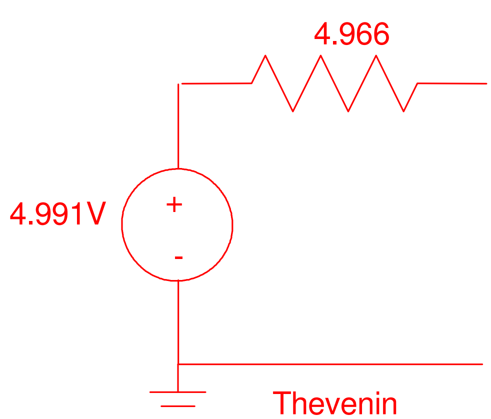
$$V_{th} = V_1 = 4.991V$$

Rth: Turn of the sources (V0 = 0V = short). Apply a 1V test voltage and compute the resulting current

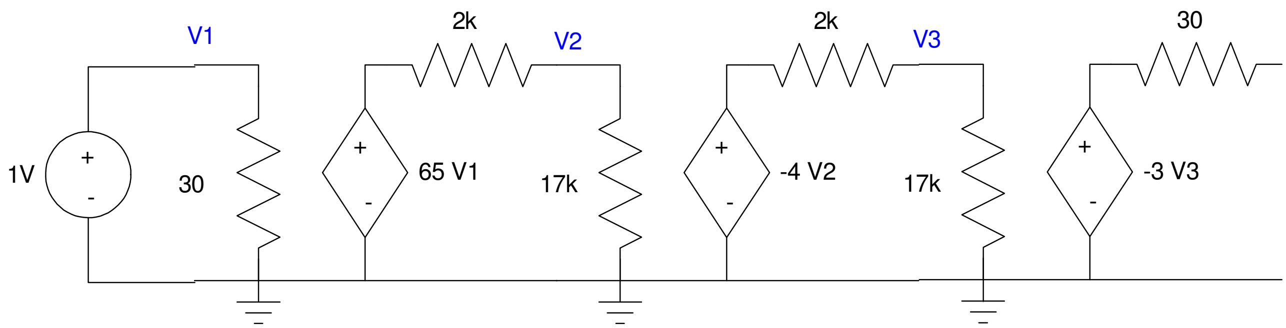
$$I_b = -\frac{1V}{1k} = -1mA$$

$$I = -I_b + \left(\frac{1}{5k}\right) - 200I_b + \left(\frac{1}{6k}\right) = 201.4mA$$

$$R_{th} = \frac{1V}{201.4mA} = 4.966\Omega$$



Solution - Problem 6



Rth: Set the sources to zero (1V becomes 0V or a short). This results in

- V1 = 0 65 V1 = 0
- V2 = 0 -4V2 = 0
- V3 = 0 -3V3 = 0

Rth = 30 Ohms

Vth: Compute the open-circuit voltage

V1 = 1V

65V1 = 65V

$$V_2 = \left(\frac{17k}{17k+2k}\right) \cdot 65V = 56.16V$$

$$-4V_2 = -232.632V$$

$$V_3 = \left(\frac{17k}{17k+2k}\right) \cdot (-232.632V) = -208.144V$$

$$V_{th} = -3V_3 = 624.432$$