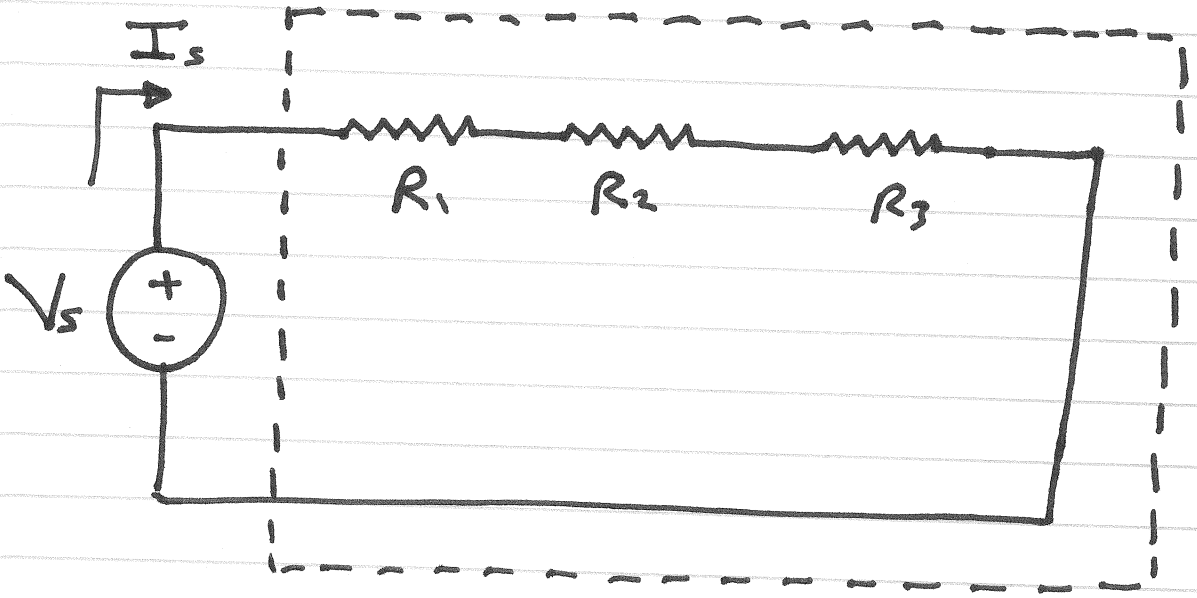
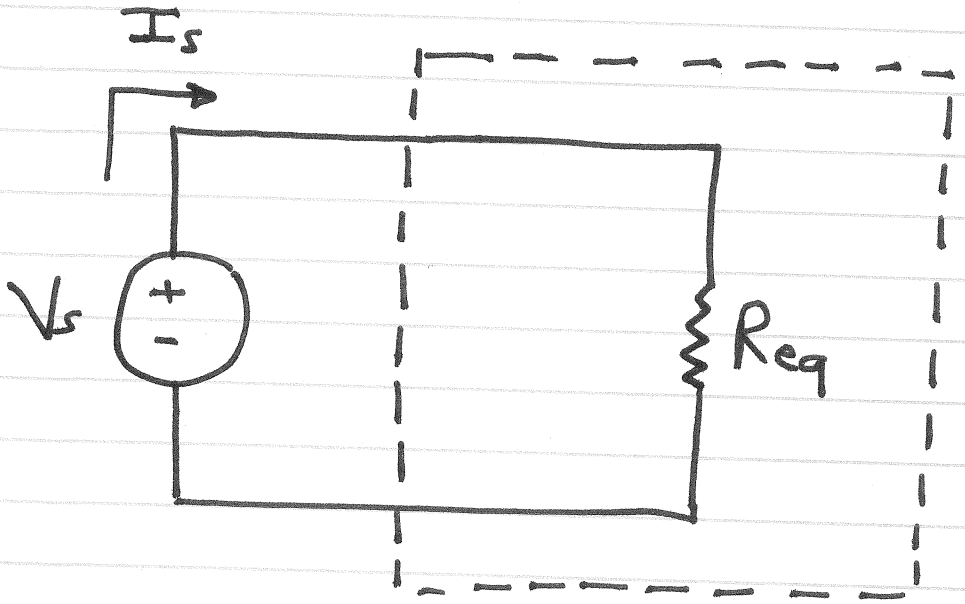
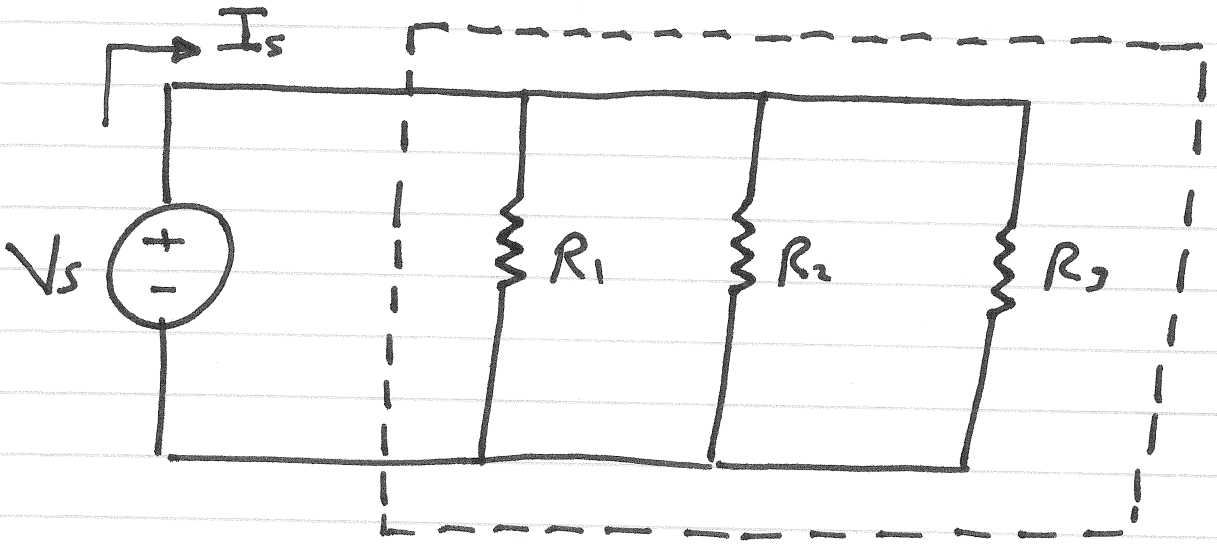
Resistors in Series

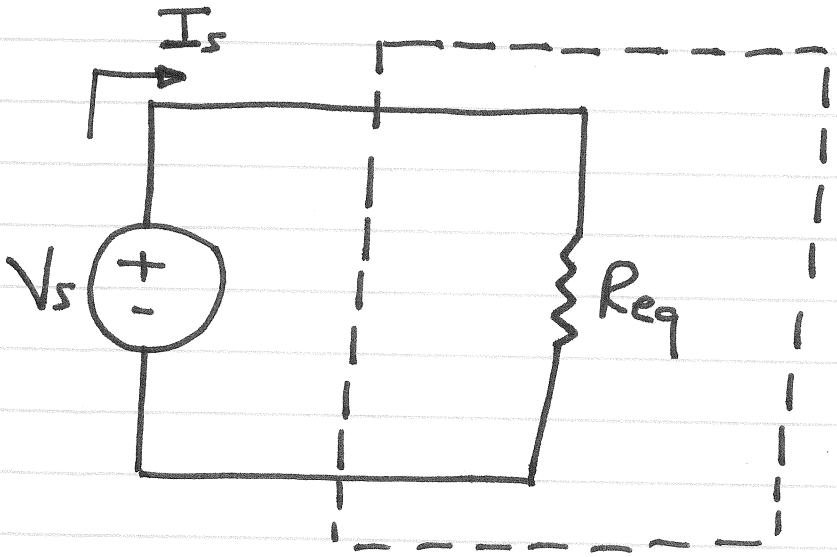




$$R_{eq} = R_1 + R_2 + R_3$$

Resistors in Parallel





$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

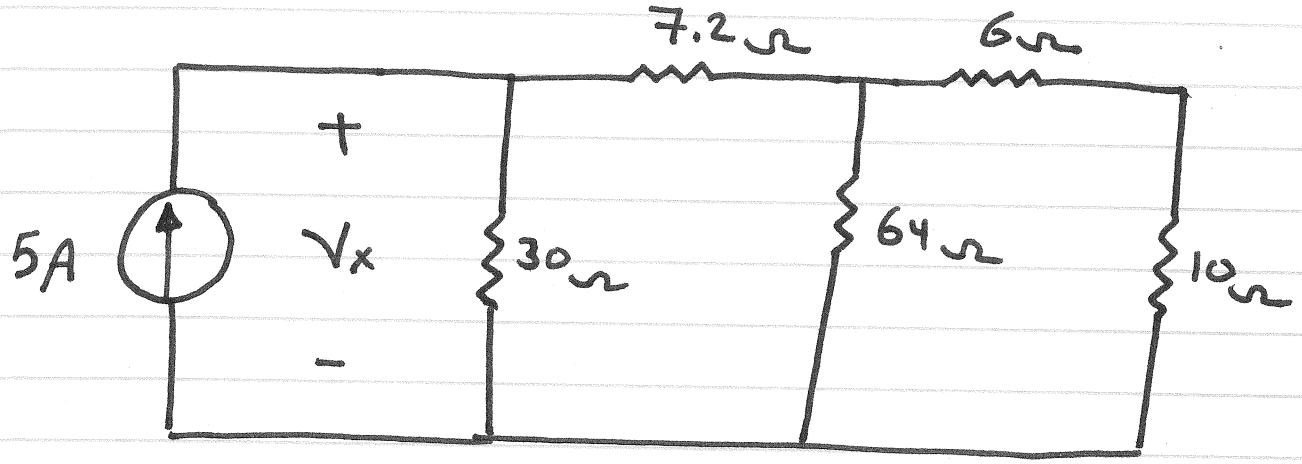
Two Resistors in Parallel

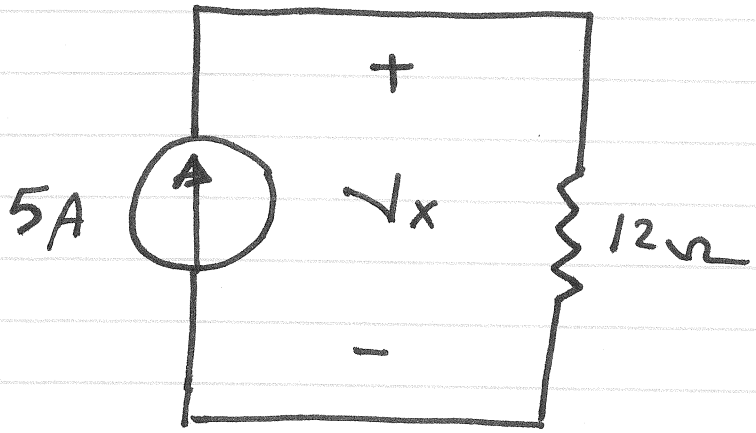
$$R_{eq} = R_1 \| R_2$$

$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$0.5 \min(R_1, R_2) < R_1 \| R_2 < \min(R_1, R_2)$$

Find V_x



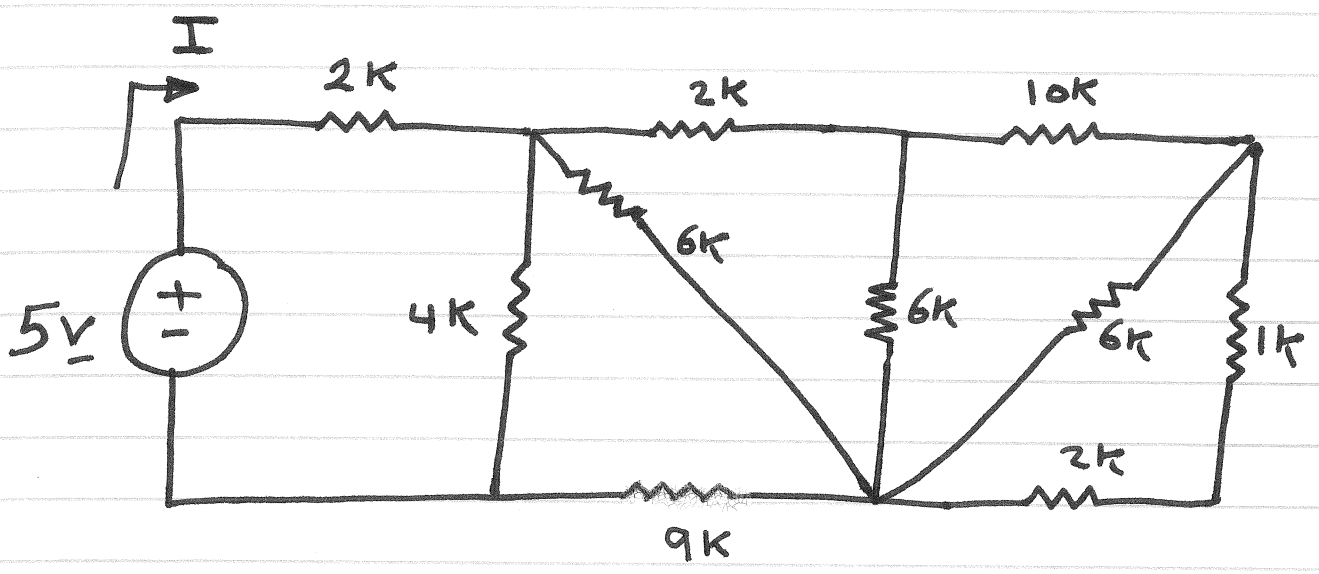


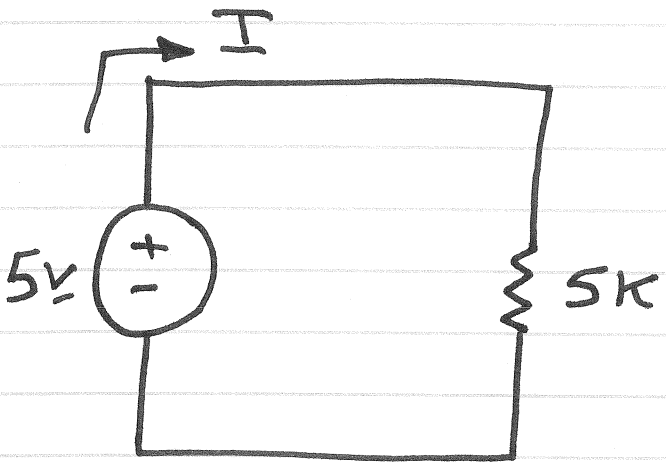
$$V_x = (5)(12) = 60V$$

$16\Omega \| 64 = 12.8\Omega$

$20\Omega \| 30\Omega = 12\Omega$

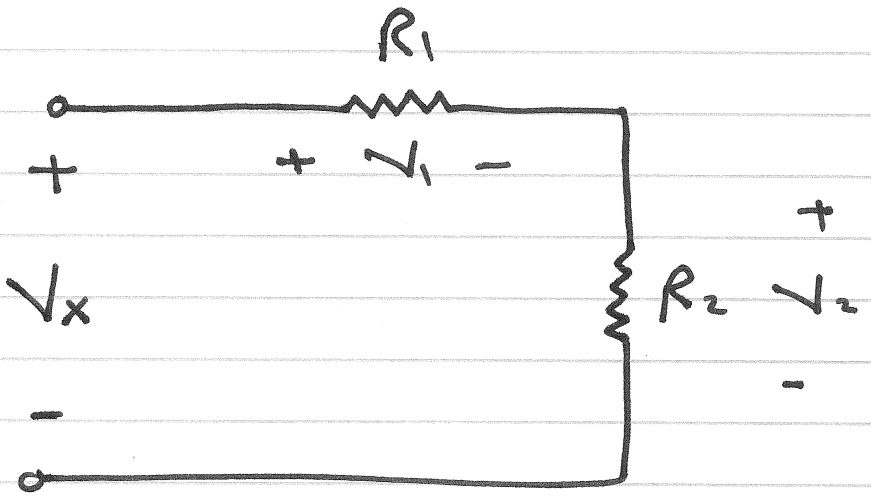
Find I





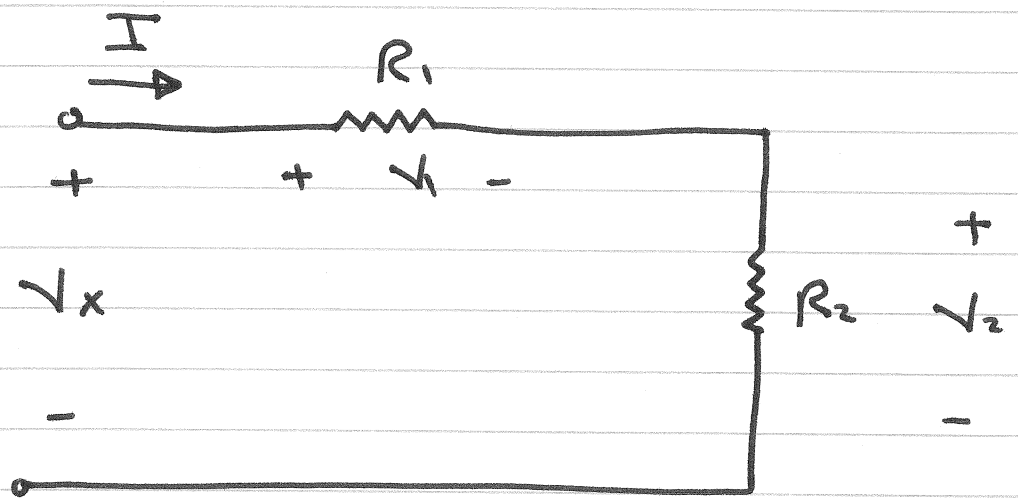
$$I = \frac{5v}{5k} = 1mA$$

Voltage Divider Rule



$$V_1 = \frac{R_1}{R_1 + R_2} V_x$$

$$V_2 = \frac{R_2}{R_1 + R_2} V_x$$



KVL :

$$V_x = V_1 + V_2$$

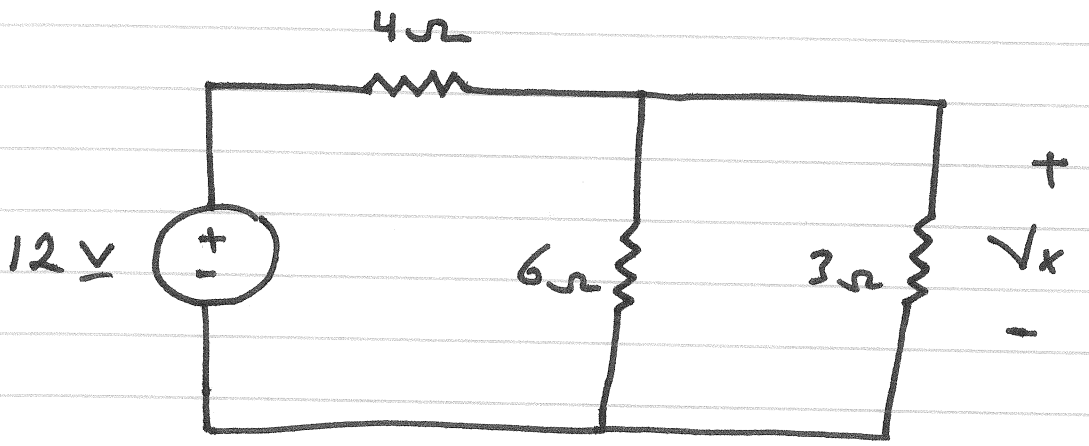
$$V_x = R_1 I + R_2 I$$

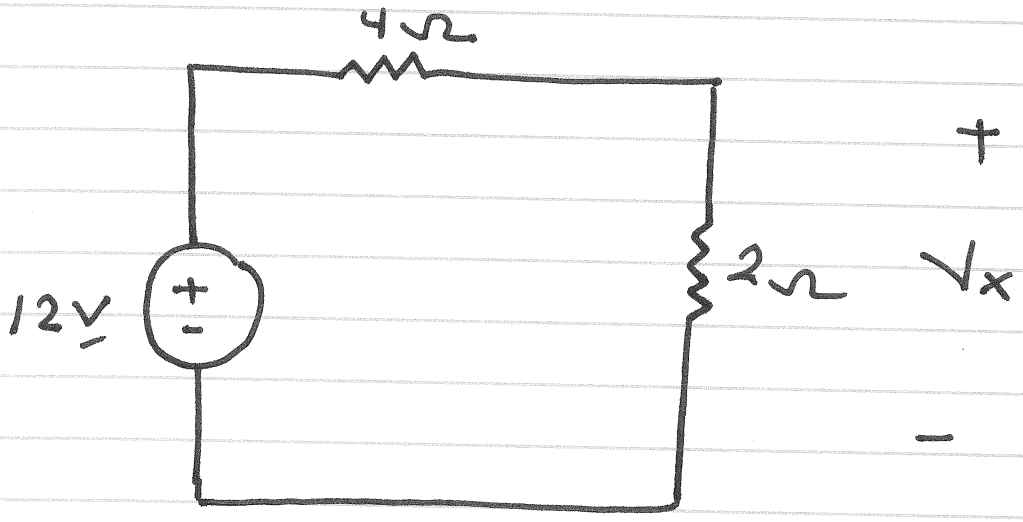
$$\therefore I = \frac{V_x}{R_1 + R_2}$$

$$V_1 = R_1 I = \frac{R_1}{R_1 + R_2} V_x$$

$$V_2 = R_2 I = \frac{R_2}{R_1 + R_2} V_x$$

Find V_x

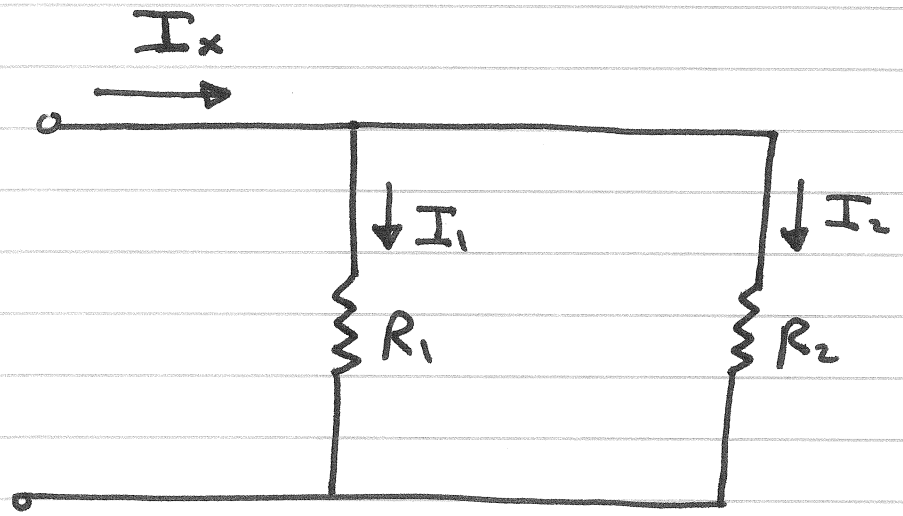




$$V_x = \frac{2}{4+2} \; 12$$

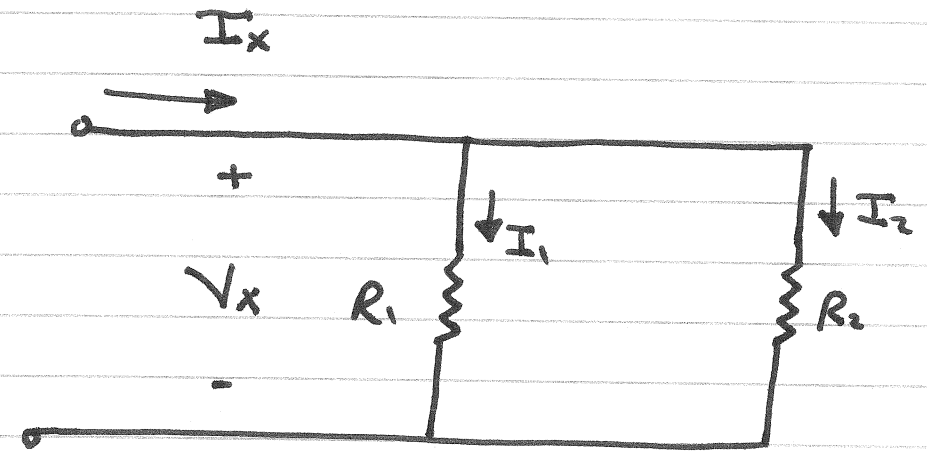
$$V_x = 4 \text{ V}$$

Current Divider Rule



$$I_1 = \frac{R_2}{R_1 + R_2} I_x$$

$$I_2 = \frac{R_1}{R_1 + R_2} I_x$$



KCL :

$$I_x = I_1 + I_2$$

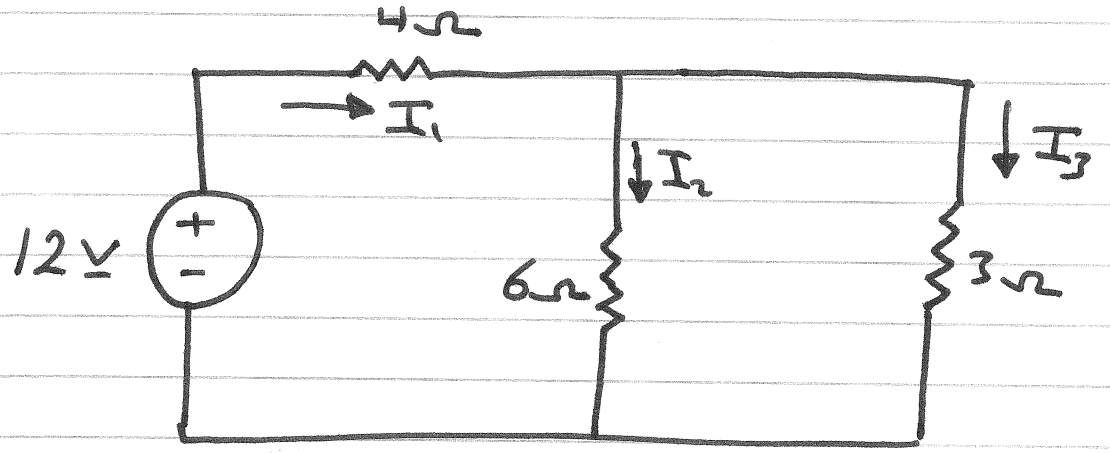
$$I_x = \frac{V_x}{R_1} + \frac{V_x}{R_2}$$

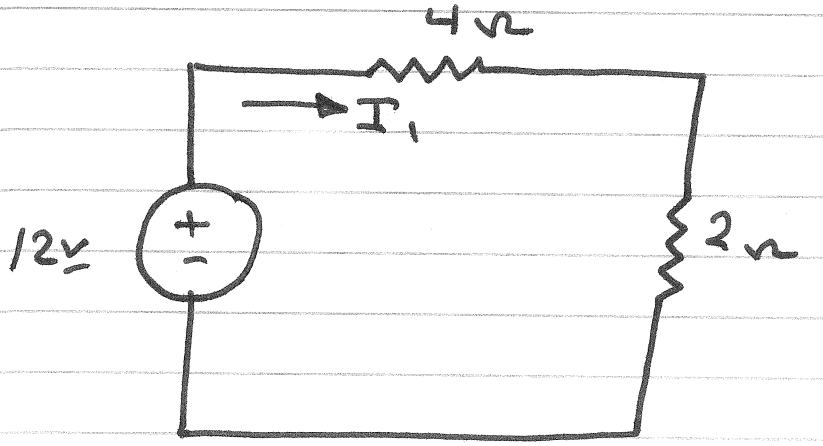
$$\therefore V_x = \frac{R_1 R_2}{R_1 + R_2} I_x$$

$$I_1 = \frac{V_x}{R_1} = \frac{R_2}{R_1 + R_2} I_x$$

$$I_2 = \frac{V_x}{R_2} = \frac{R_1}{R_1 + R_2} I_x$$

Find I_3



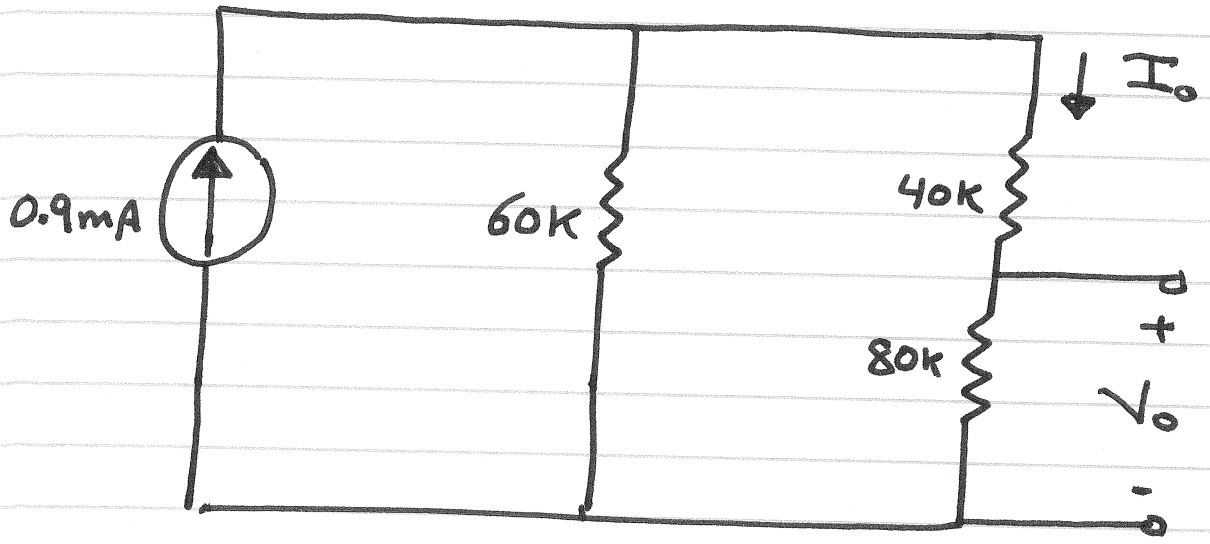


$$I_1 = \frac{12}{4+2} = 2A$$

$$I_3 = \frac{6}{6+3} I_1$$

$$I_3 = \frac{6}{9} \cdot 2 = 1.33A$$

Find V_o



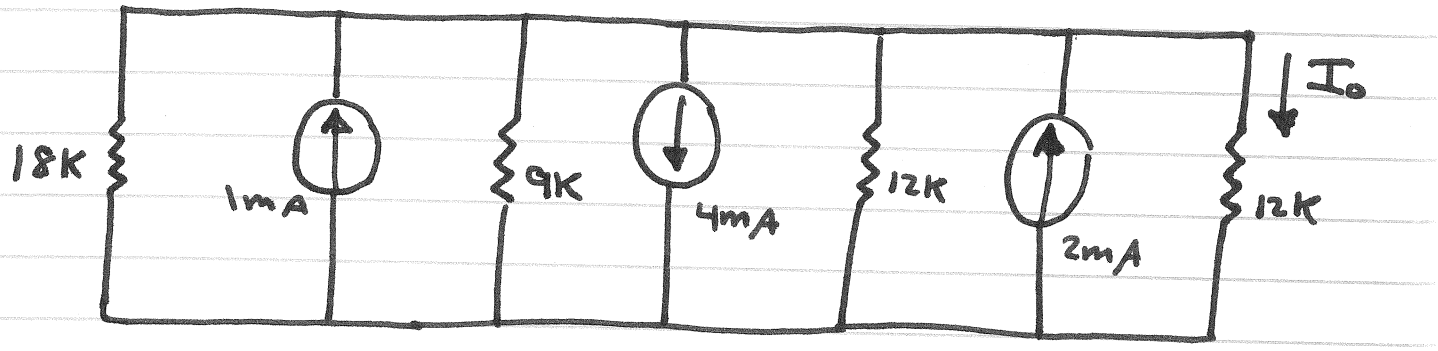
$$I_o = \frac{60k}{60k + (40k + 80k)} \, 0.9 \, mA$$

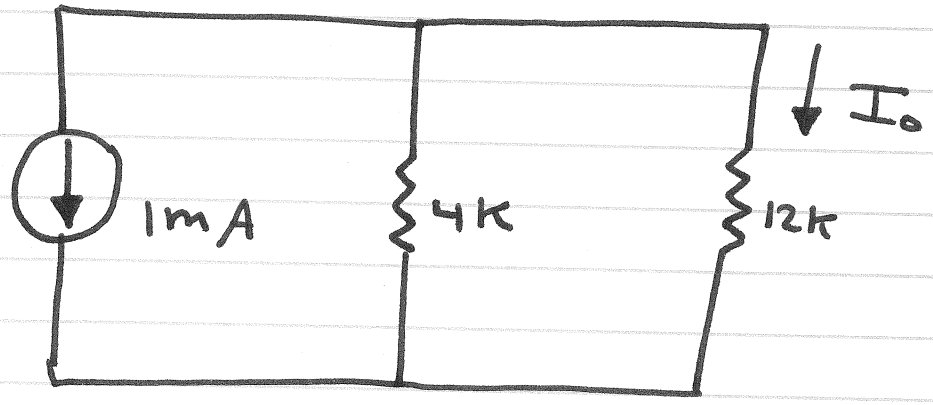
$$I_o = 0.3 \, mA$$

$$V_o = 80k \, I_o$$

$$V_o = 24 \, V$$

Find I_o



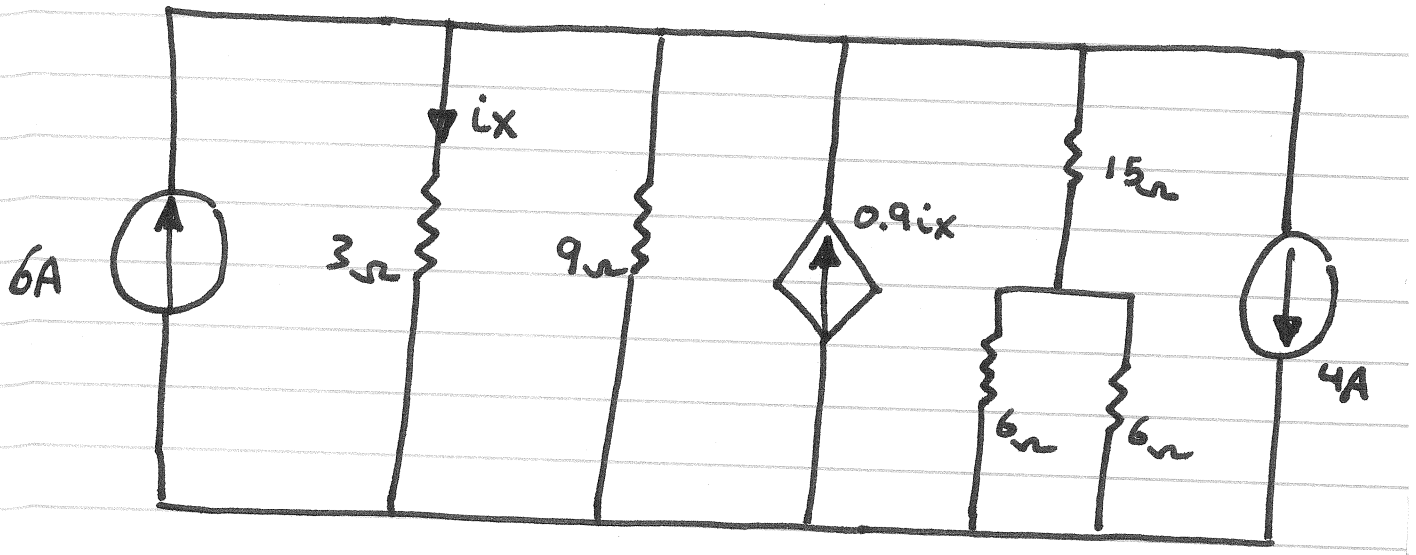


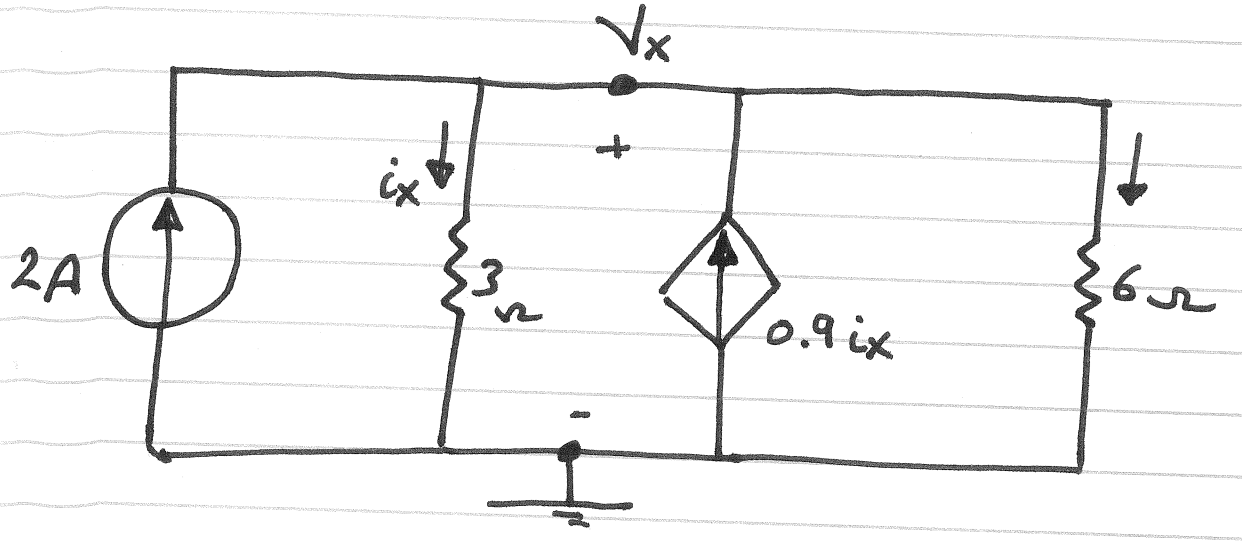
$18K \| 9K \| 12K = 4K$

$$I_o = - \frac{4K}{4K+12K} \; 1mA$$

$$I_o = - 0.25 mA$$

Find the power supplied by the 0.9ix source





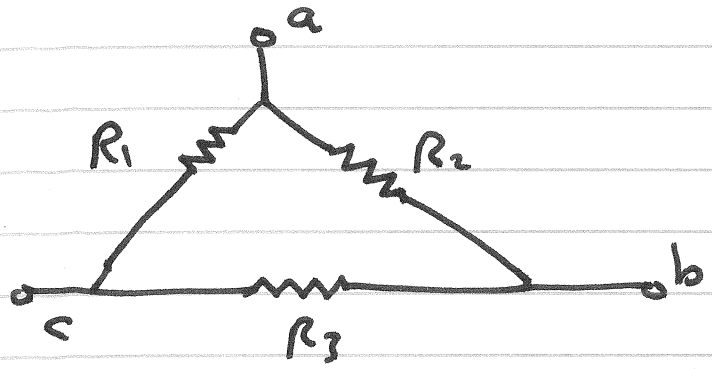
$$2 + 0.9\,i_x = i_x + \frac{V_x}{6}$$

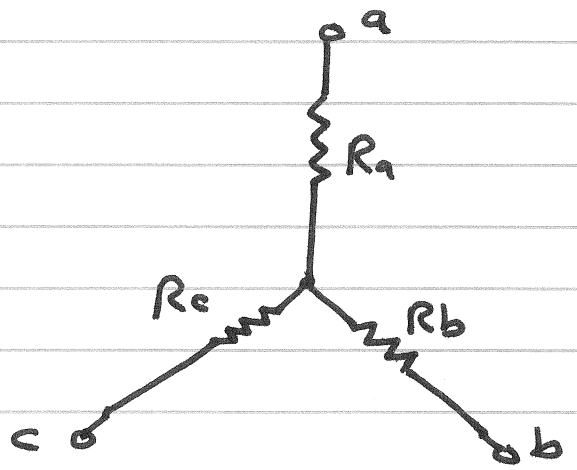
$$i_x = \frac{V_x}{3}$$

$$\therefore V_x = 10V \quad ; \quad i_x = \frac{10}{3}A$$

$$P_{0.9i_x} = -(0.9i_x)V_x = -30W \text{ Supplying}$$

Delta $\rightleftharpoons$ Wye Transformation





$$R_{ab} = R_a + R_b = \frac{R_2(R_1+R_3)}{R_1+R_2+R_3}$$

$$R_{bc} = R_b + R_c = \frac{R_3(R_1+R_2)}{R_1+R_2+R_3}$$

$$R_{ca} = R_c + R_a = \frac{R_1(R_2+R_3)}{R_1+R_2+R_3}$$

Solving this set of equations

$$R_a = \frac{R_1 R_2}{R_1+R_2+R_3}$$

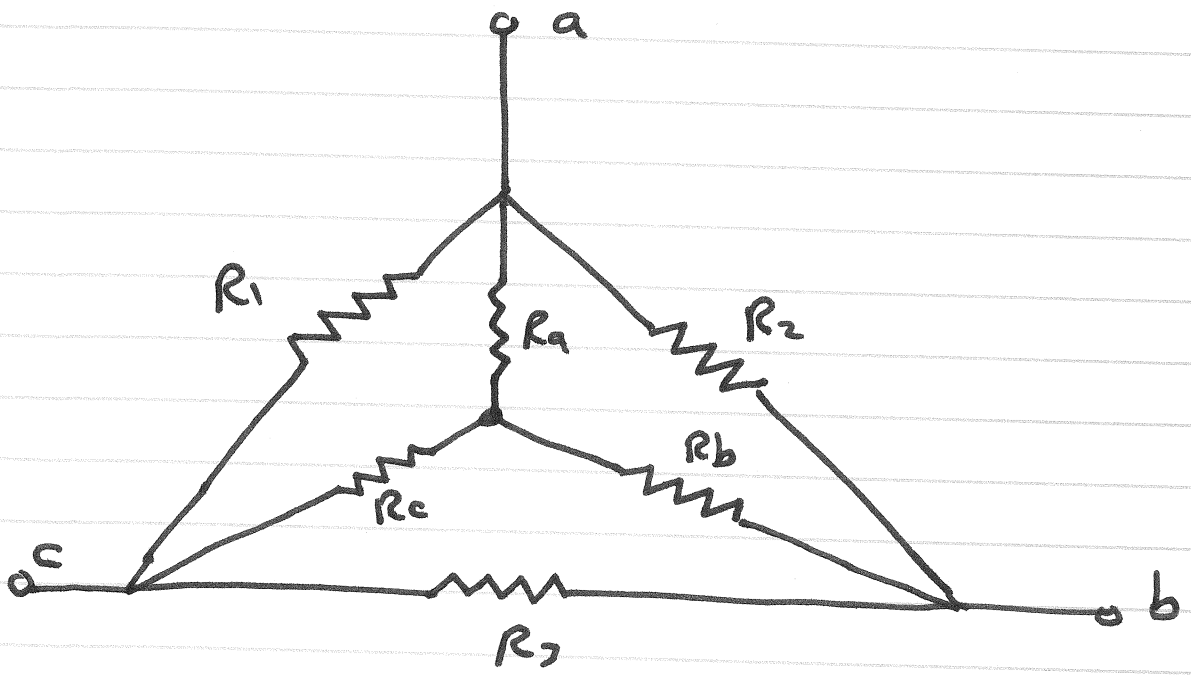
$$R_b = \frac{R_2 R_3}{R_1+R_2+R_3}$$

$$R_c = \frac{R_3 R_1}{R_1+R_2+R_3}$$

$$R_1 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$$

$$R_2 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$$

$$R_3 = \frac{R_a R_b + R_b R_c + R_c R_a}{R_a}$$



For the balanced case where

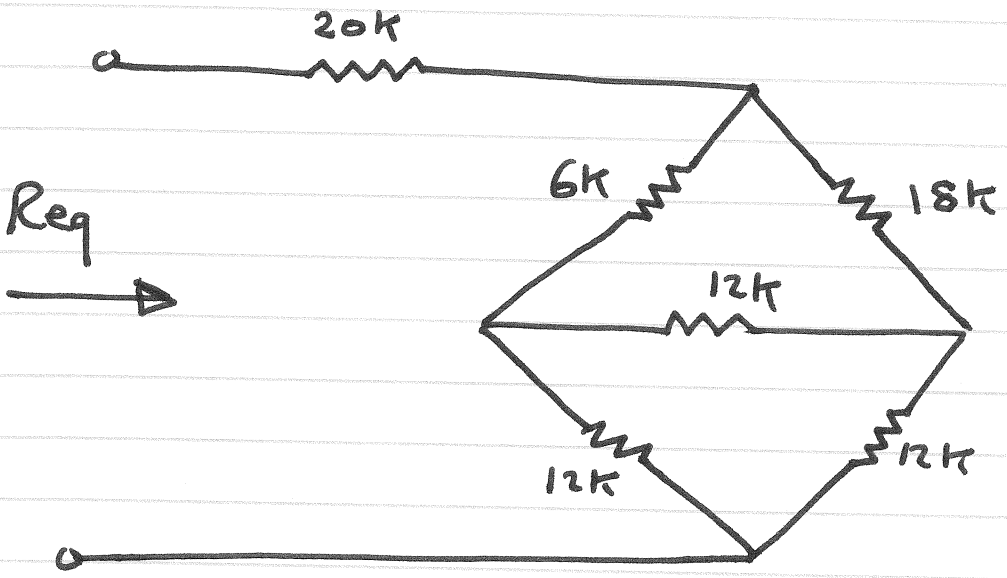
$$R_a = R_b = R_c = R_y$$

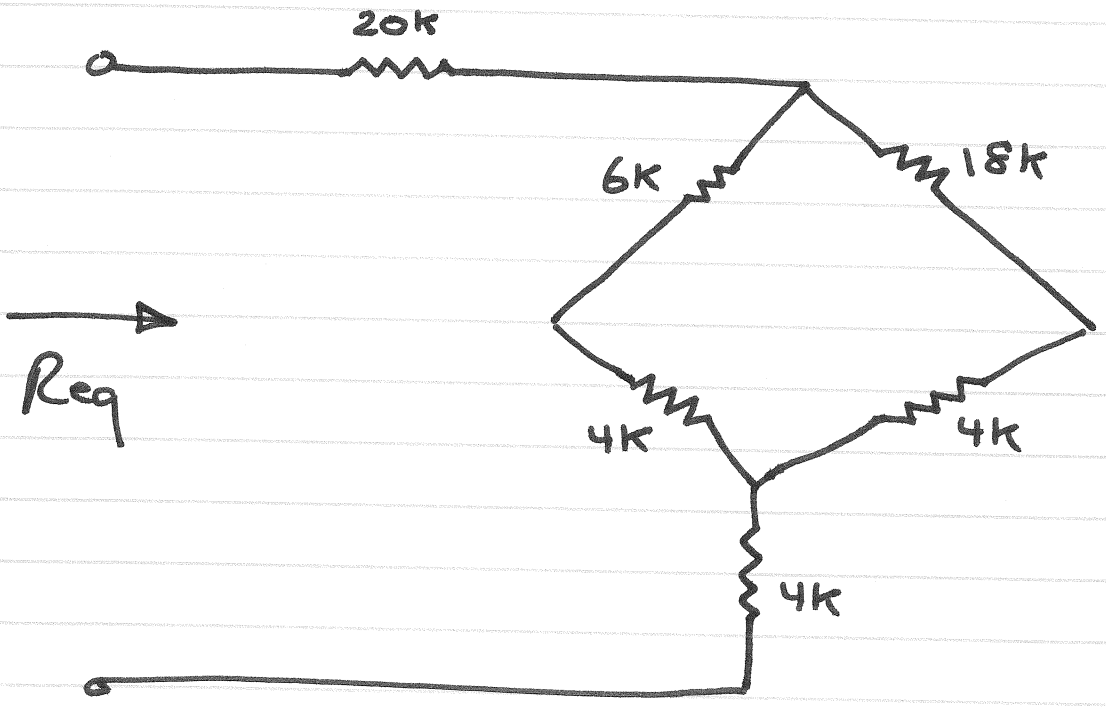
$$R_1 = R_2 = R_3 = R_\Delta$$

$$R_\Delta = 3R_y$$

$$R_y = \frac{1}{3} R_\Delta$$

Find Req



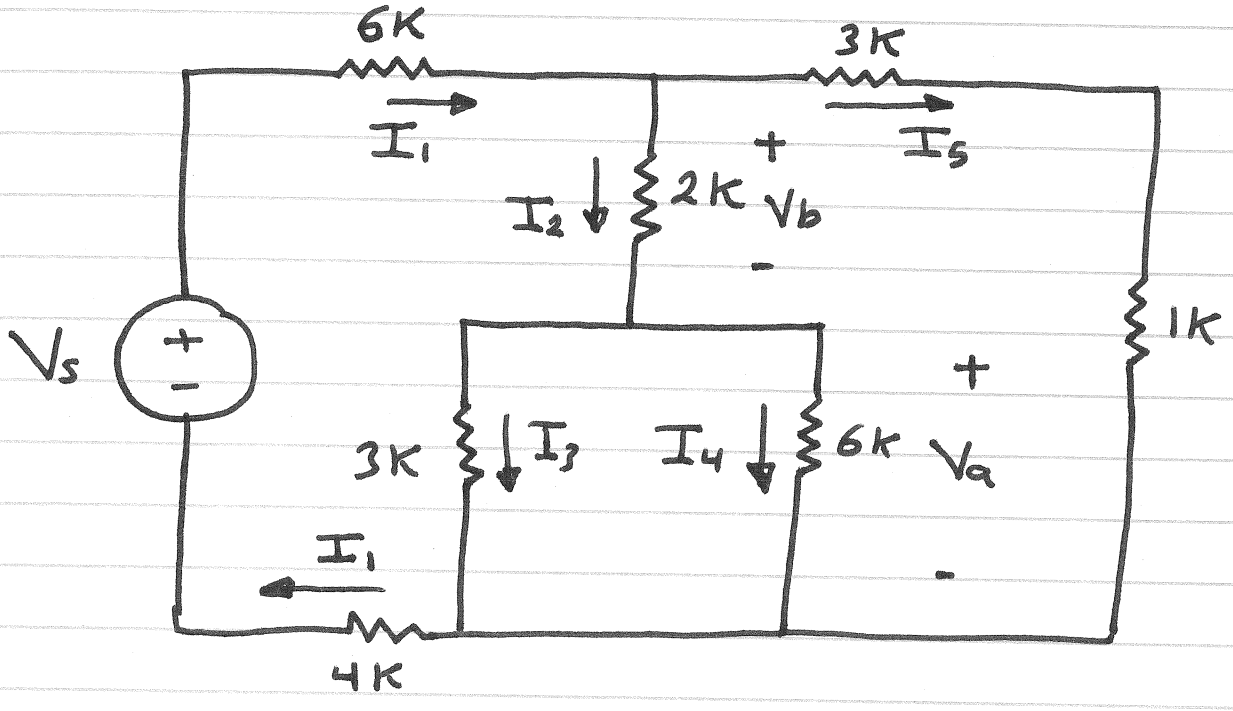


$$Req = 20K + 4K + (6K+4K) \| (18K+4K)$$

$$Req = 30.88K$$

Design :

Given $I_4 = 0.5\,mA$, Find V_s



$$V_a = (6K\Omega)(0.5\,mA) = 3\,V$$

$$I_3 = \frac{V_a}{3K} = 1\,mA$$

$$I_2 = I_3 + I_4 = 1.5\,mA$$

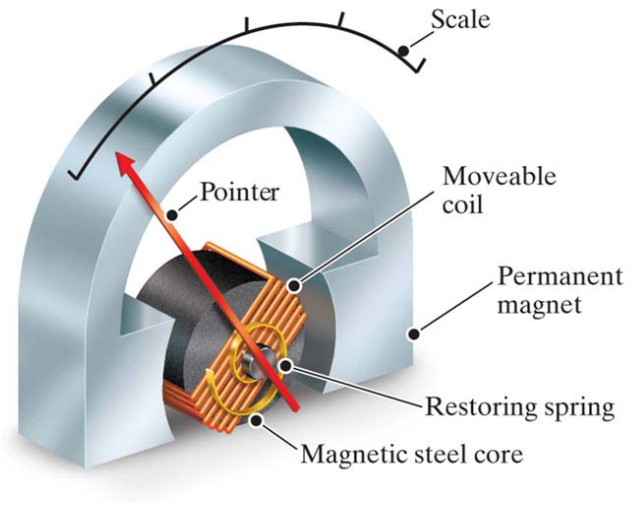
$$V_b = (2K\Omega)(1.5\,mA) = 3\,V$$

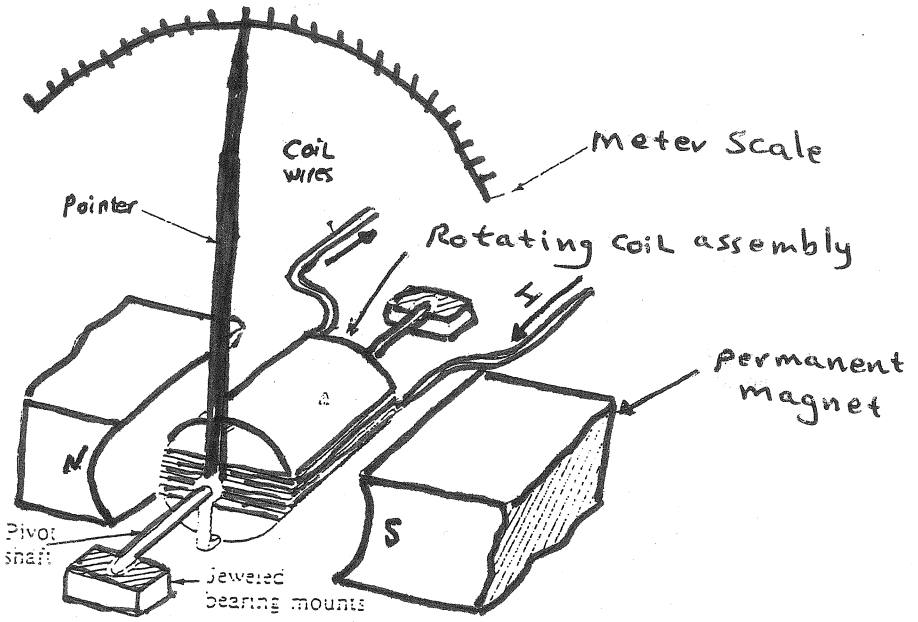
$$I_5 = \frac{V_a + V_b}{4K} = 1.5\,mA$$

$$I_1 = I_2 + I_5 = 3\,mA$$

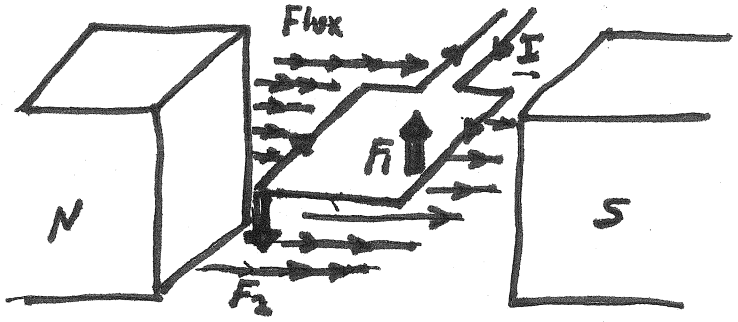
$$V_s = (10K\Omega)\,I_1 + V_b + V_a = 36\,V$$

Figure 3.23 A schematic diagram of a d'Arsonval meter movement.





Basic components of a D'Arsonval movement



$$F_1 = F_2 = IlB$$

$$T = IlBd$$

If the coil has N turns

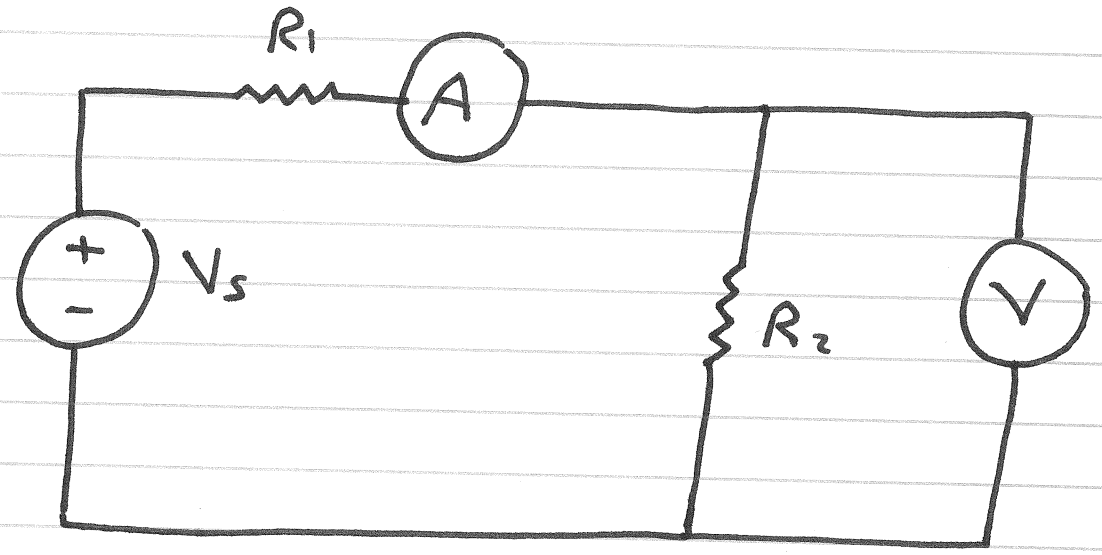
$$T = IlBNd$$

The D'Arsonval meter movement

- If a current is passed through the movable coil, the resulting magnetic field reacts with the magnetic field of the permanent magnet producing a torque which is counterbalanced by a restoring spring.

- The deflection of the pointer attached to the coil is proportional to the current produced by the quantity being measured.

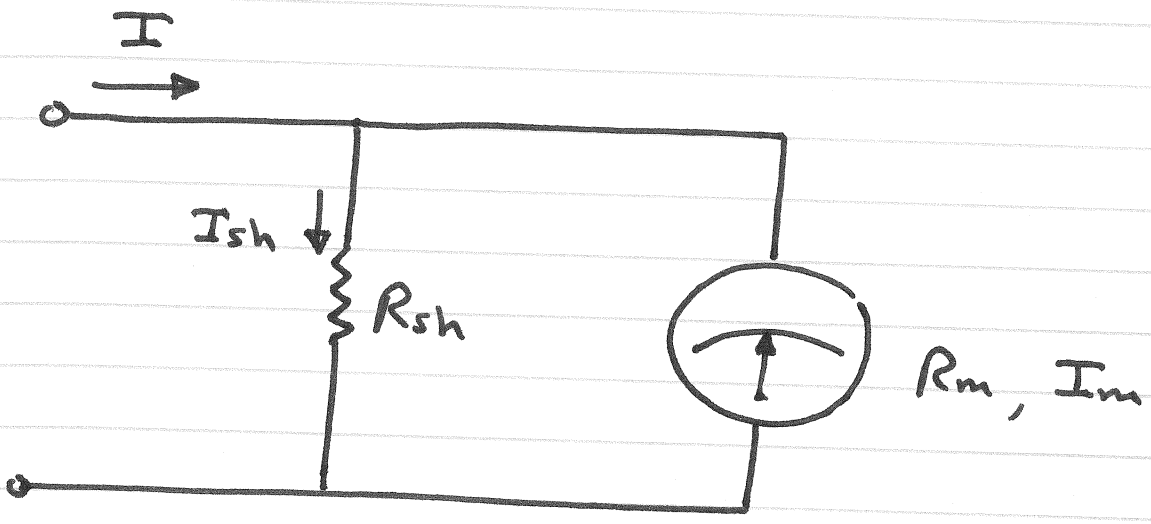
Measuring Voltage and Current



Ammeter : designed to measure current

Voltmeter : designed to measure voltage

Dc Ammeter



$$R_{sh}\ I_{sh} = R_m\ I_m$$

$$R_{sh} = \frac{R_m I_m}{I_{sh}} = \frac{R_m I_m}{I - I_m}$$

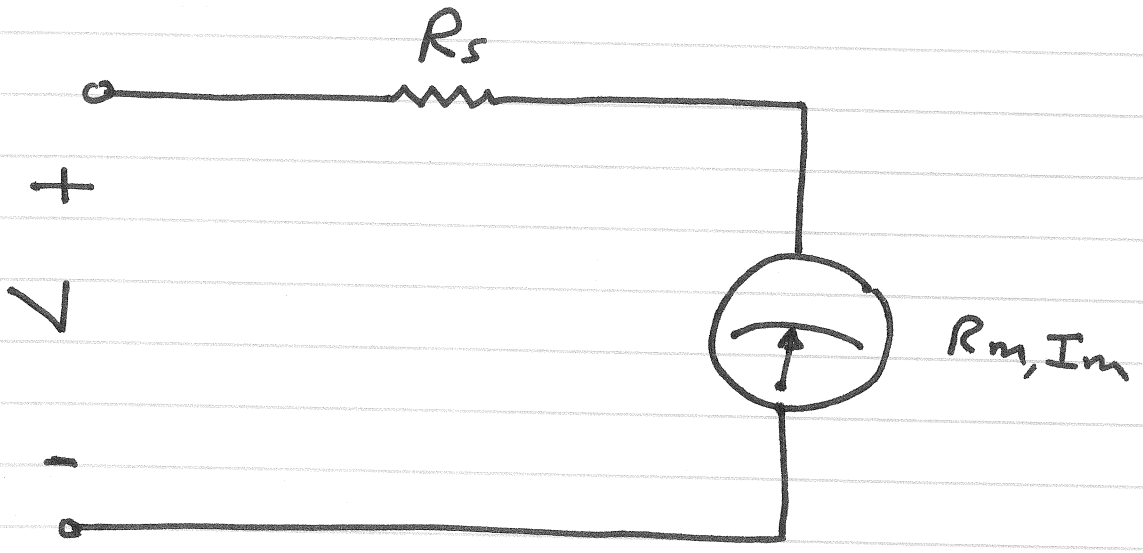
A 0-1mA meter movement with an internal resistance of 100Ω is to be Converted to a 0-100mA Ammeter.

$I_m = 1mA$
$R_m = 100\Omega$

$I = 100mA$
$I_{sh} = 99mA$

$$R_{sh} = \frac{I_m R_m}{I - I_m} = 1.01\Omega$$

Dc Voltmeter



$$V = R_s I_m + R_m I_m$$

$$R_s = \frac{V - R_m I_m}{I_m}$$

A basic D'Arsonval movement with $I_m = 1mA$ and $R_m = 100\,\Omega$ is to be converted into a dc voltmeter with the range $0 - 10\,V$

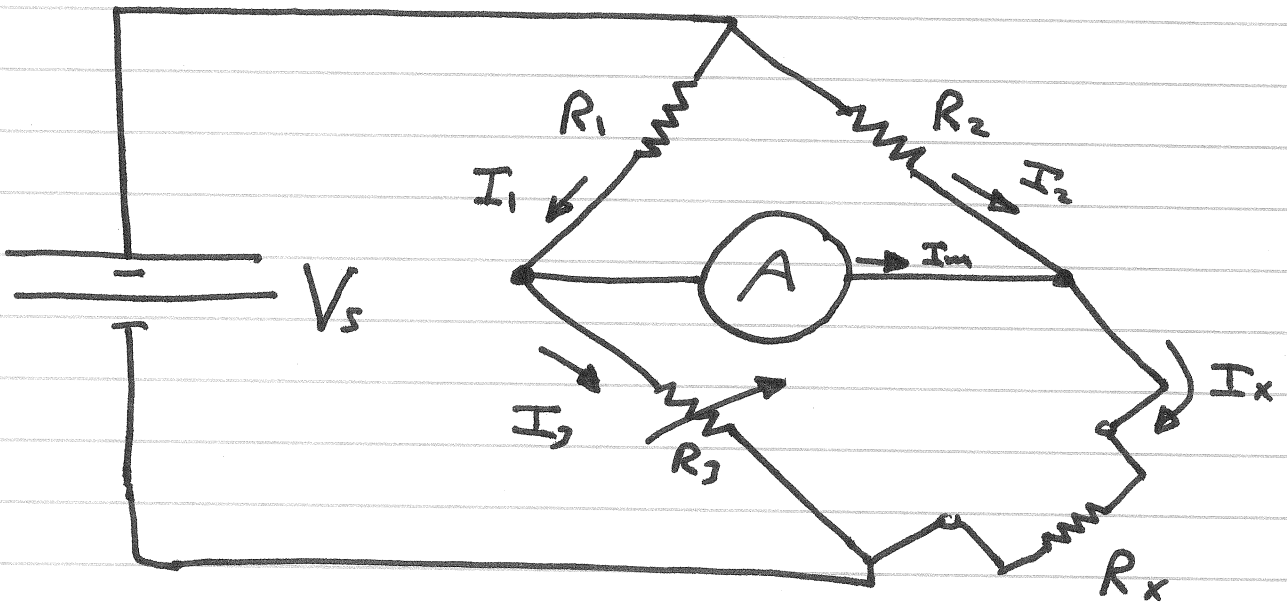
$$R_S = \frac{V - R_m I_m}{I_m}$$

$$= \frac{10 - (100)(1 \times 10^{-3})}{1 \times 10^{-3}}$$

$$R_S = 9900\,\Omega$$

Measuring Resistance

Wheatstone Bridge



R_3 is adjusted until $I_m = 0$

Bridge is balanced : $I_1 = I_3$

$I_2 = I_x$

$V_m = 0$

$$R_1 I_1 = R_2 I_2$$

$$R_3 I_3 = R_x I_x$$

$$\frac{R_1 I_1}{R_3 I_3} = \frac{R_2 I_2}{R_x I_x}$$

$$\frac{R_1}{R_3} = \frac{R_2}{R_x} \longrightarrow R_x = \frac{R_2 R_3}{R_1}$$