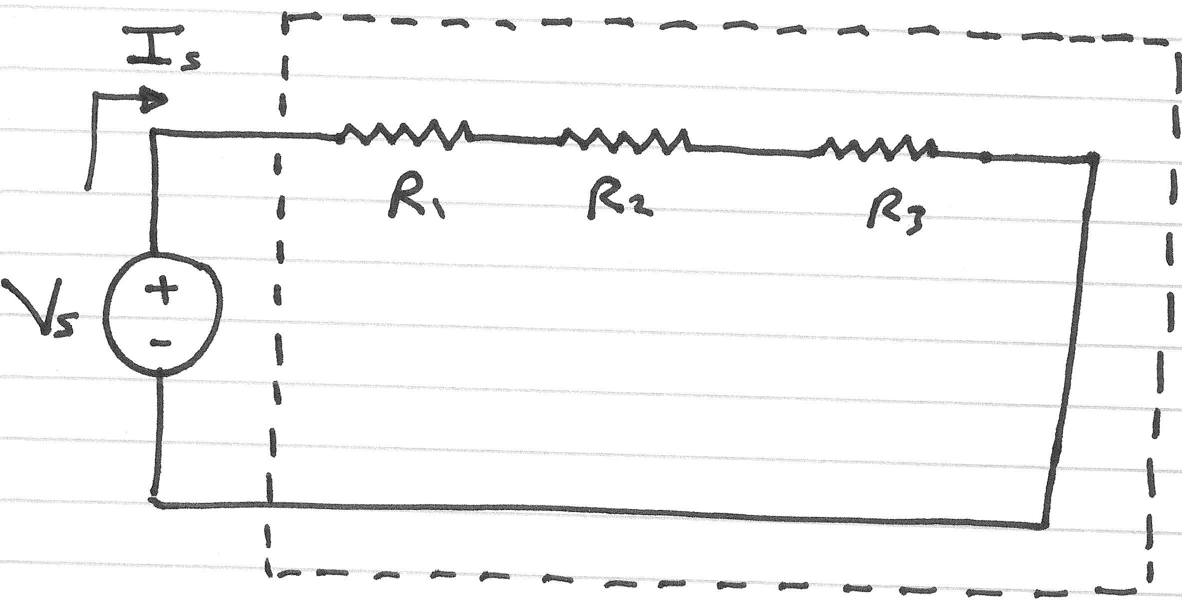
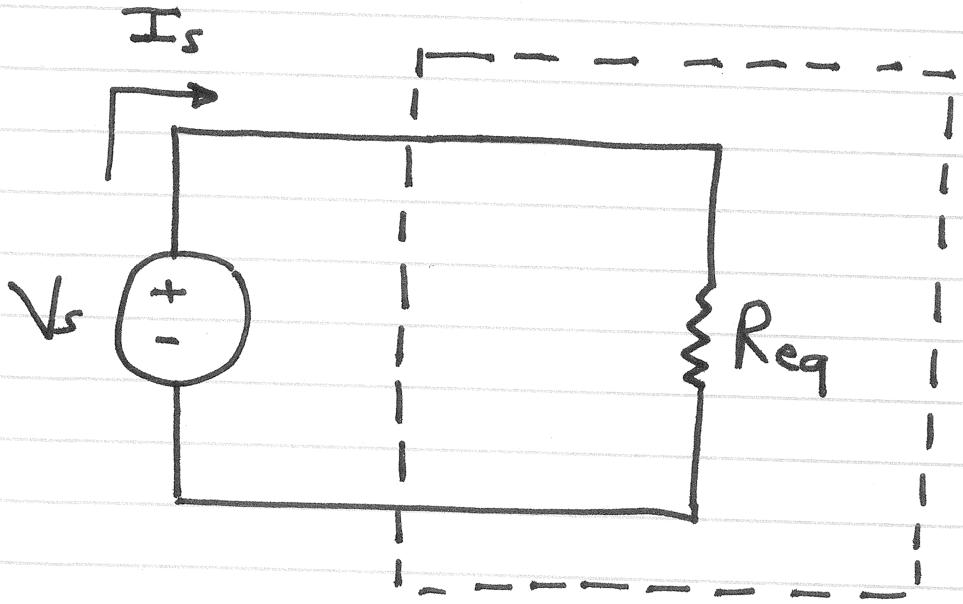
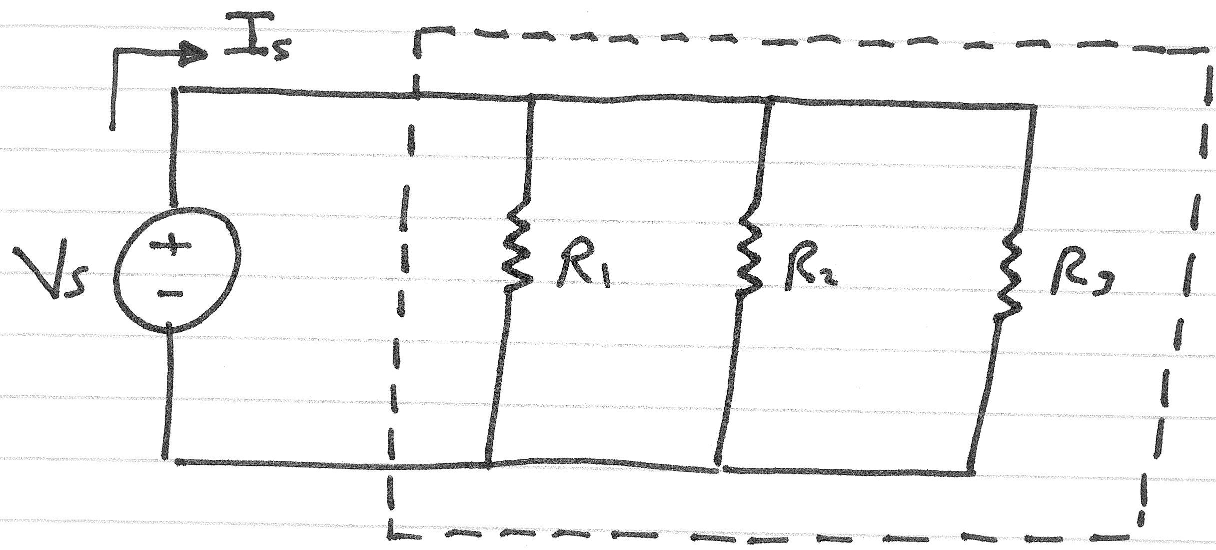
Resistors in Series

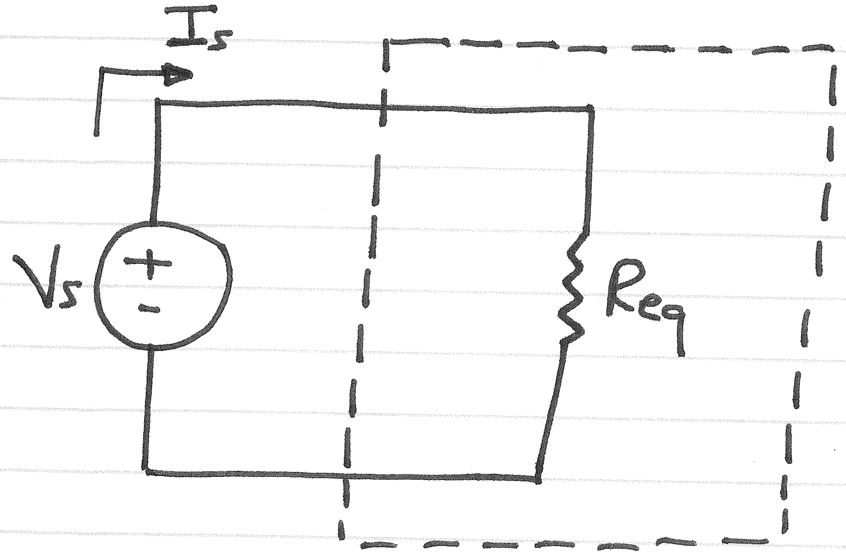




$$R_{eq} = R_1 + R_2 + R_3$$

Resistors in Parallel





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

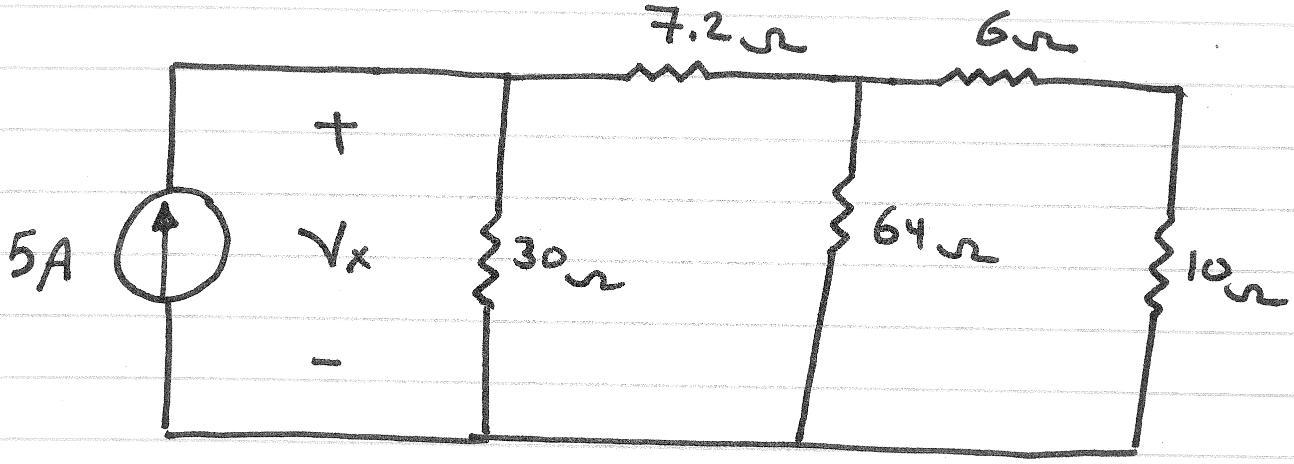
Two Resistors in Parallel

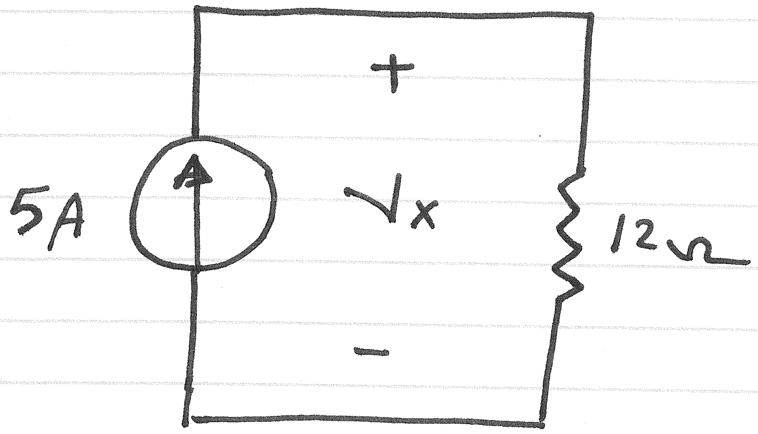
$$R_{eq} = R_1 \| R_2$$

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

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

Find V_x



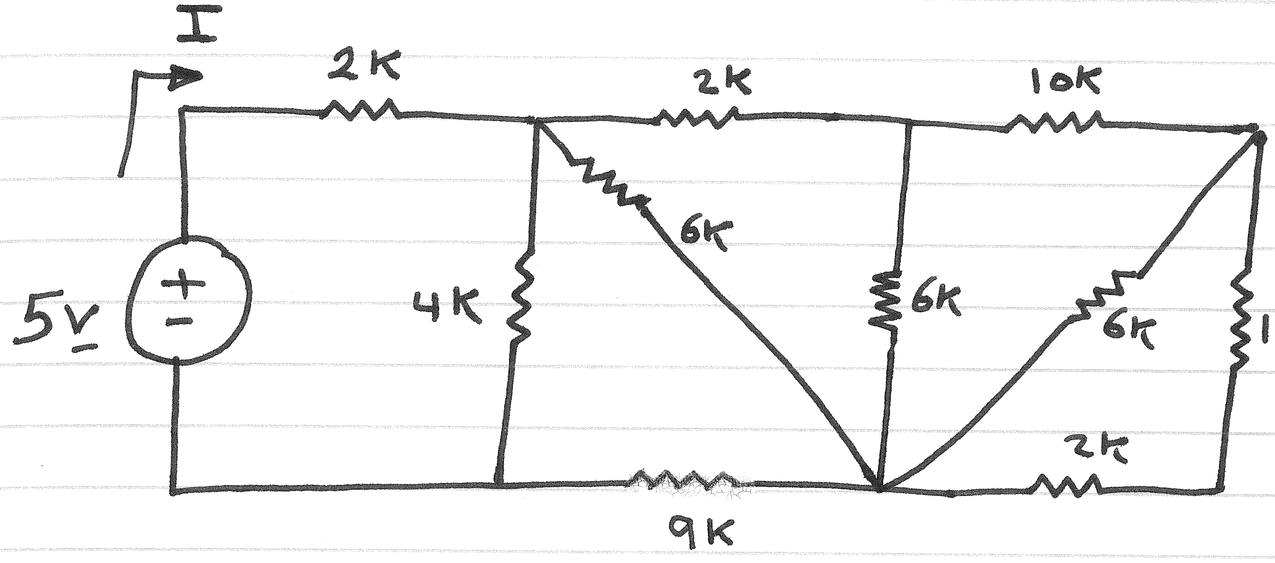


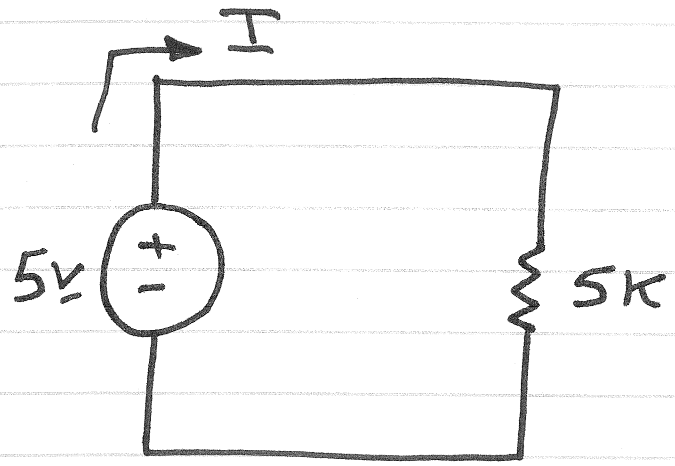
$$V_x = (5)(12) = 60\,V$$

$16\Omega \parallel 64 = 12.8\Omega$

$20\Omega \parallel 30\Omega = 12\Omega$

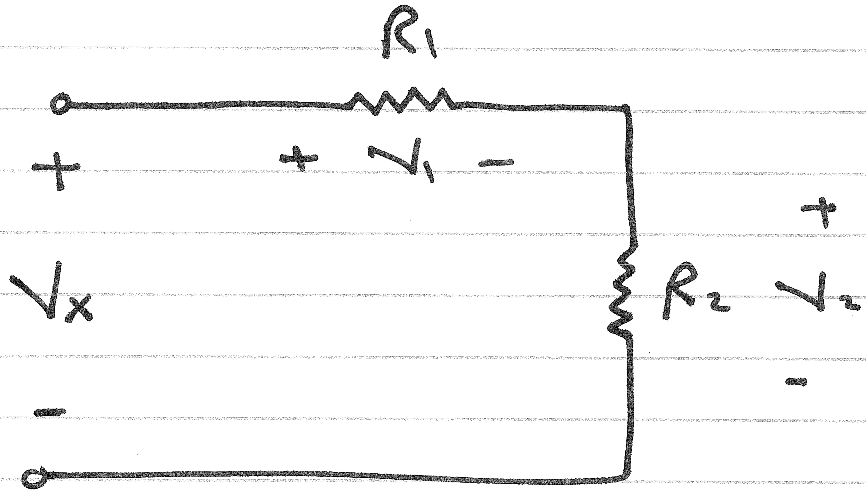
Find I





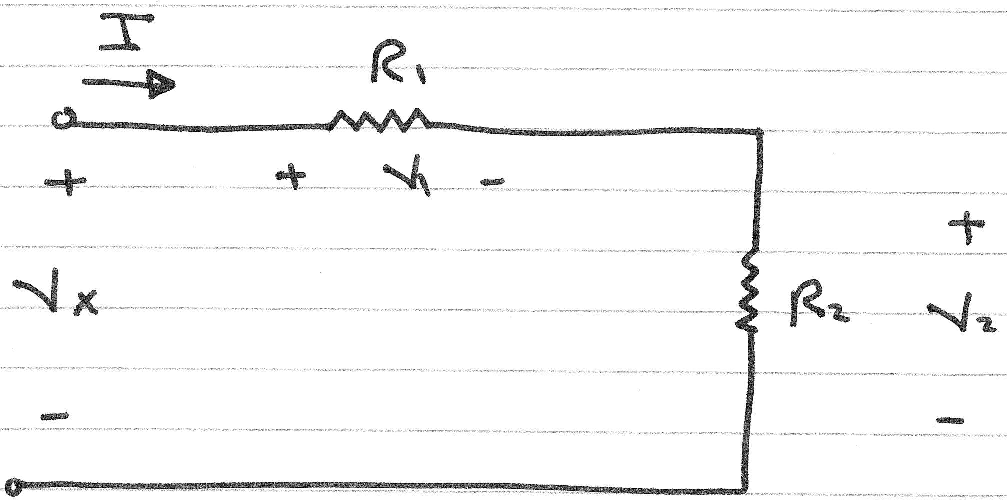
$$I = \frac{5v}{5K} = 1mA$$

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 :

$$V_x = V_1 + V_2$$

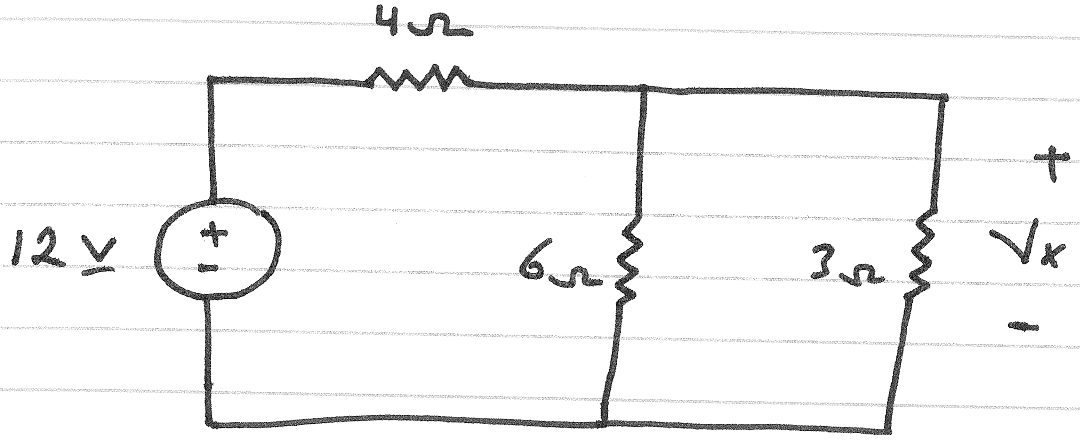
$$V_x = R_1 I + R_2 I$$

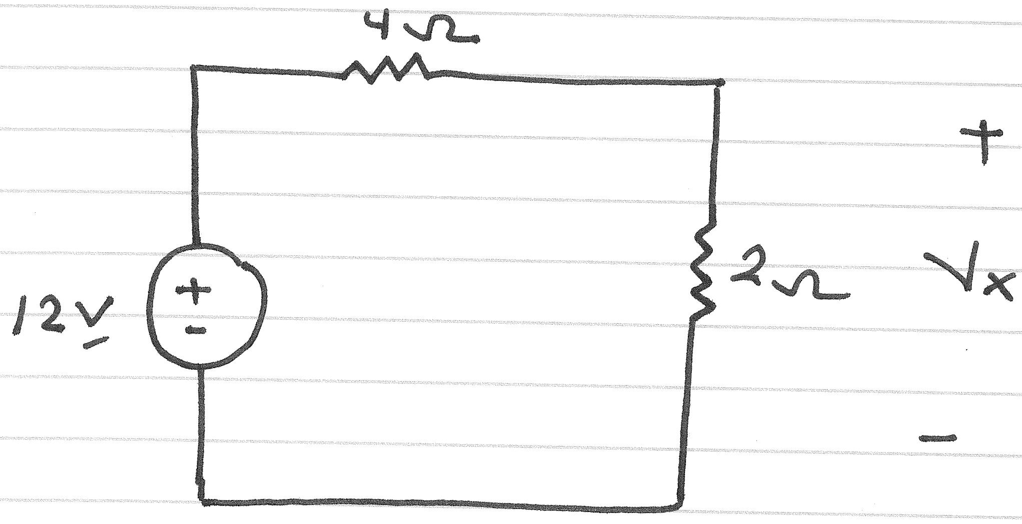
$$\therefore \quad I = \frac{V_x}{R_1 + R_2}$$

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

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

Find V_x

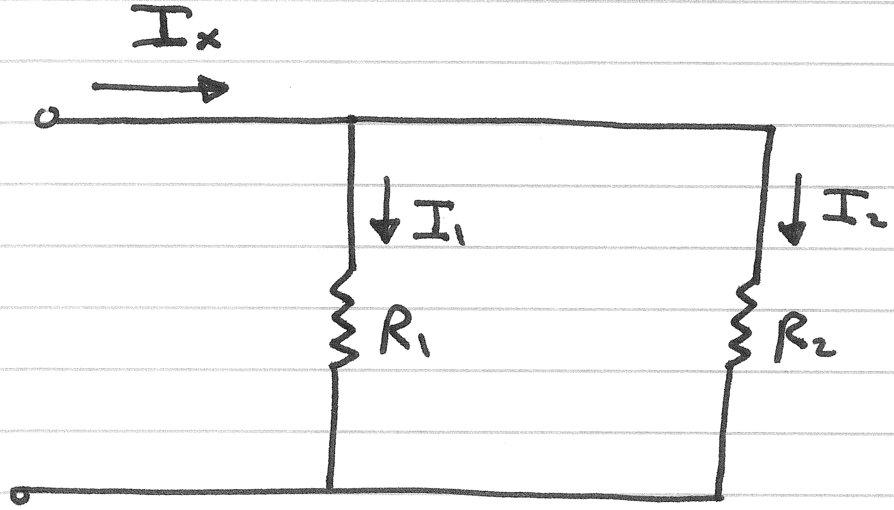




$$V_x = \frac{2}{4+2} \, 12$$

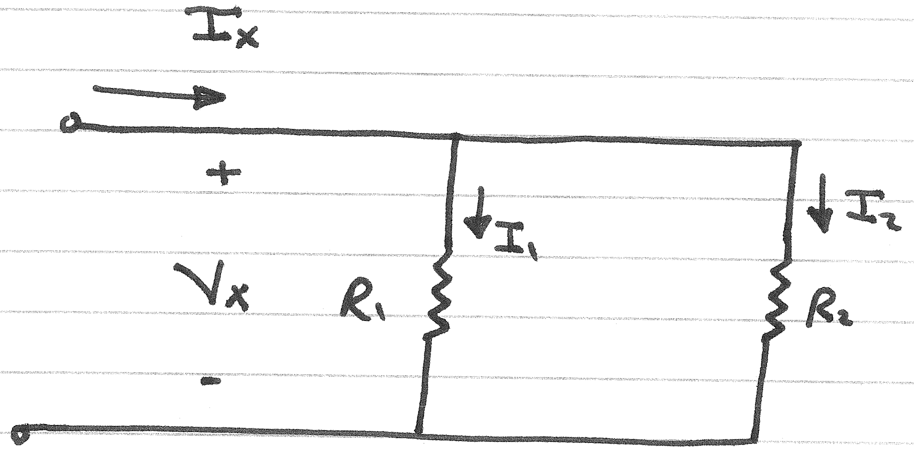
$$V_x = 4 \text{ V}$$

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 :

$$I_x = I_1 + I_2$$

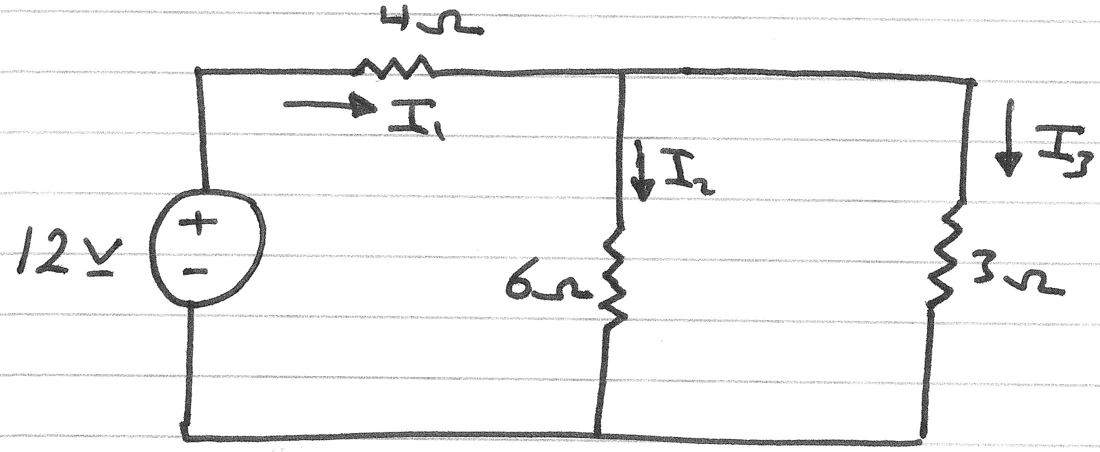
$$I_x = \frac{V_x}{R_1} + \frac{V_x}{R_2}$$

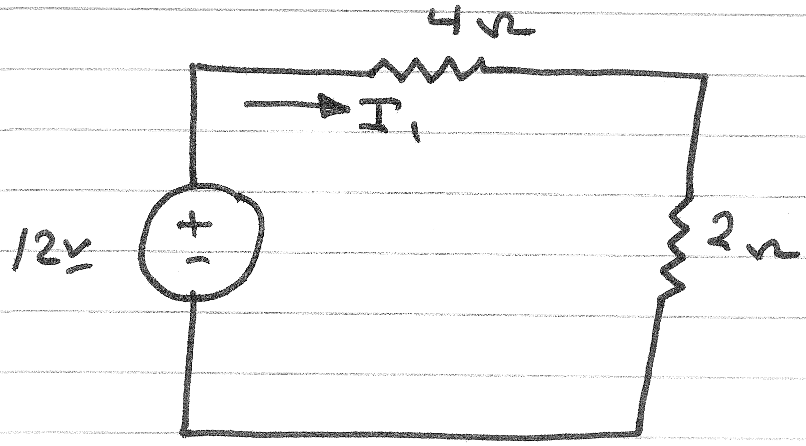
$$\therefore V_x = \frac{R_1 R_2}{R_1 + R_2} I_x$$

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

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

Find I_3



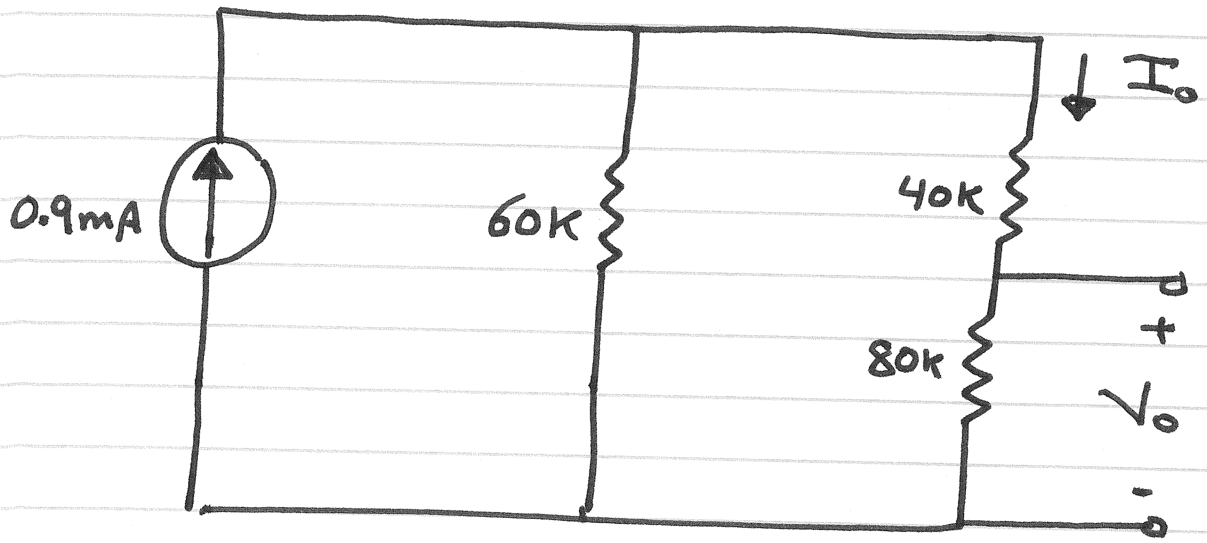


$$I_1 = \frac{12}{4+2} = 2A$$

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

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

Find V_o



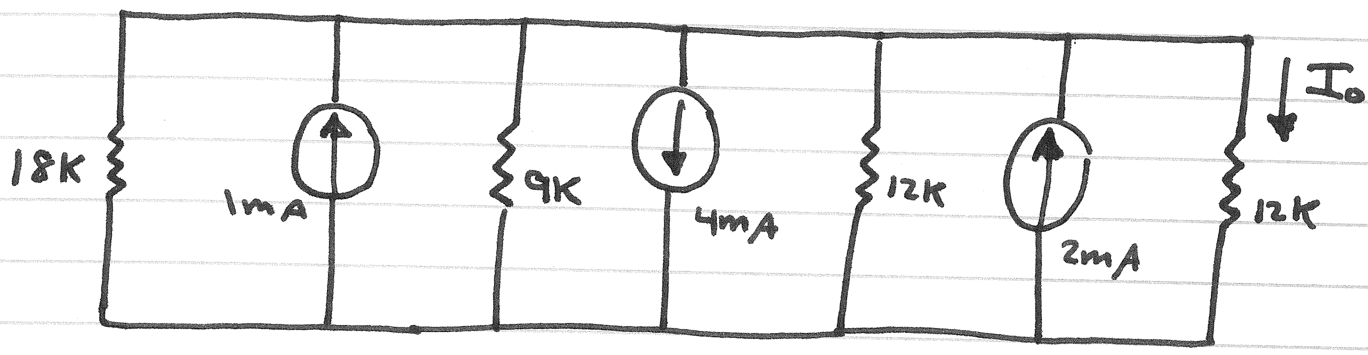
$$I_o = \frac{60K}{60K + (40K + 80K)} \, 0.9\,mA$$

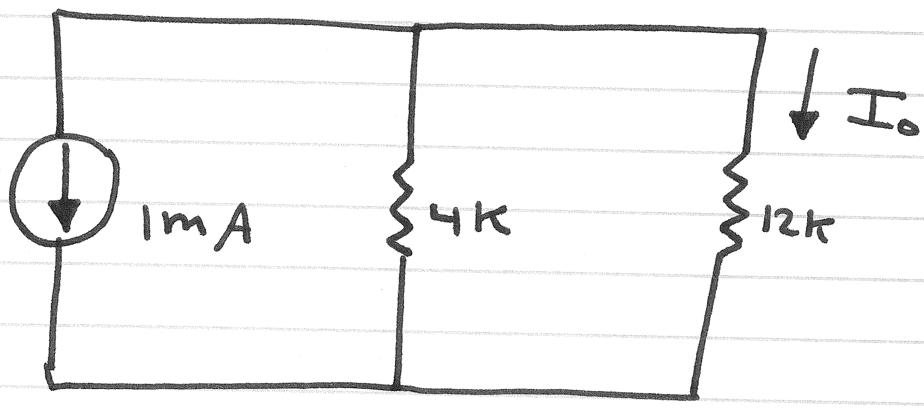
$$I_o = 0.3\,mA$$

$$V_o = 80K\,I_o$$

$$V_o = 24\,V$$

Find I_o



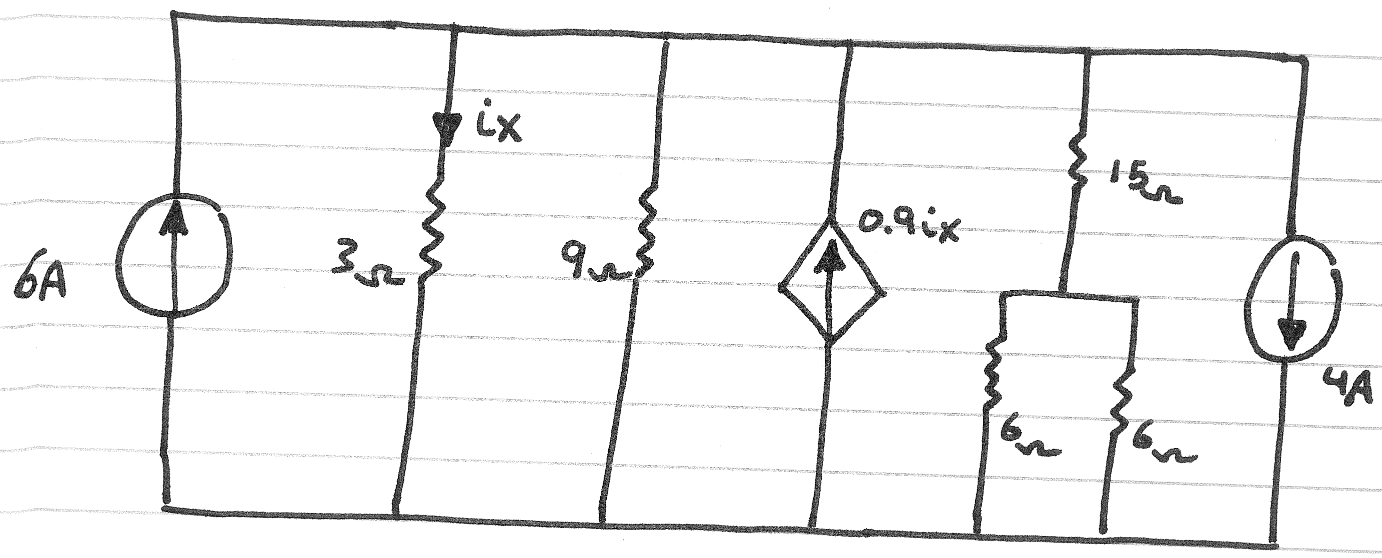


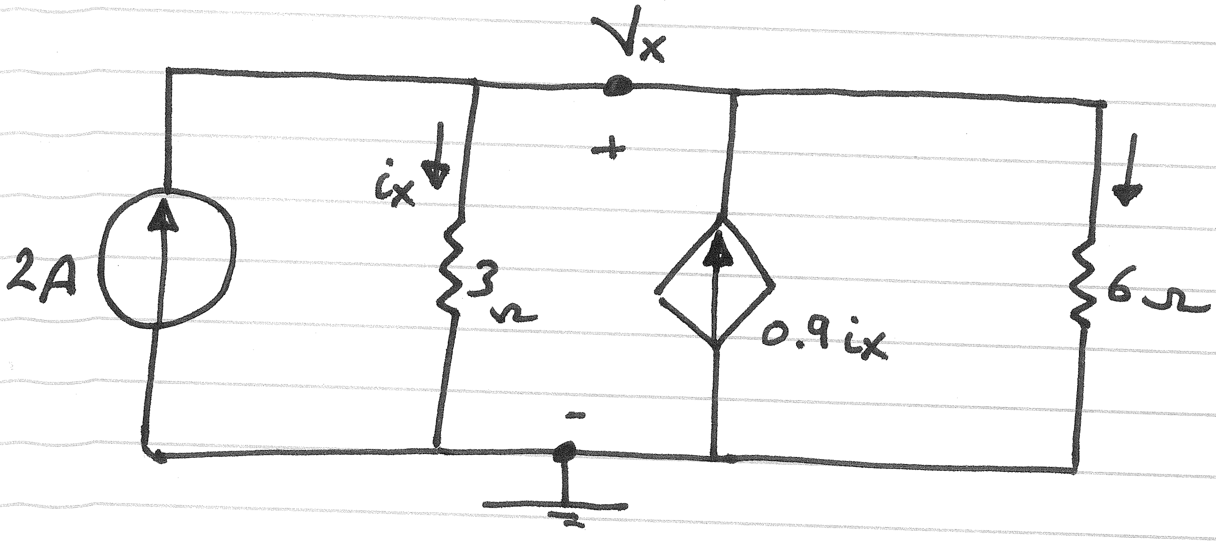
$$18K \| 9K \| 12K = 4K$$

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

$$I_o = -0.25 \, mA$$

Find the power supplied by the 0.9ix source





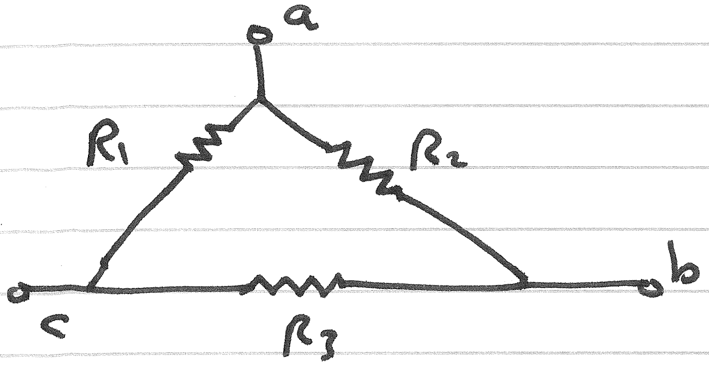
$$2 + 0.9\,i_x = i_x + \frac{V_x}{6}$$

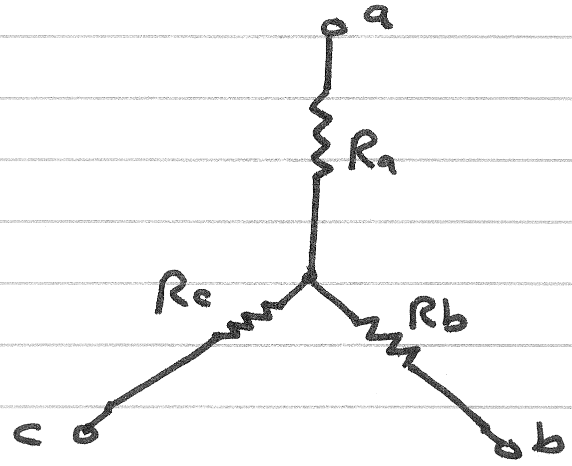
$$i_x = \frac{V_x}{3}$$

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

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

Delta ⇄ 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

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

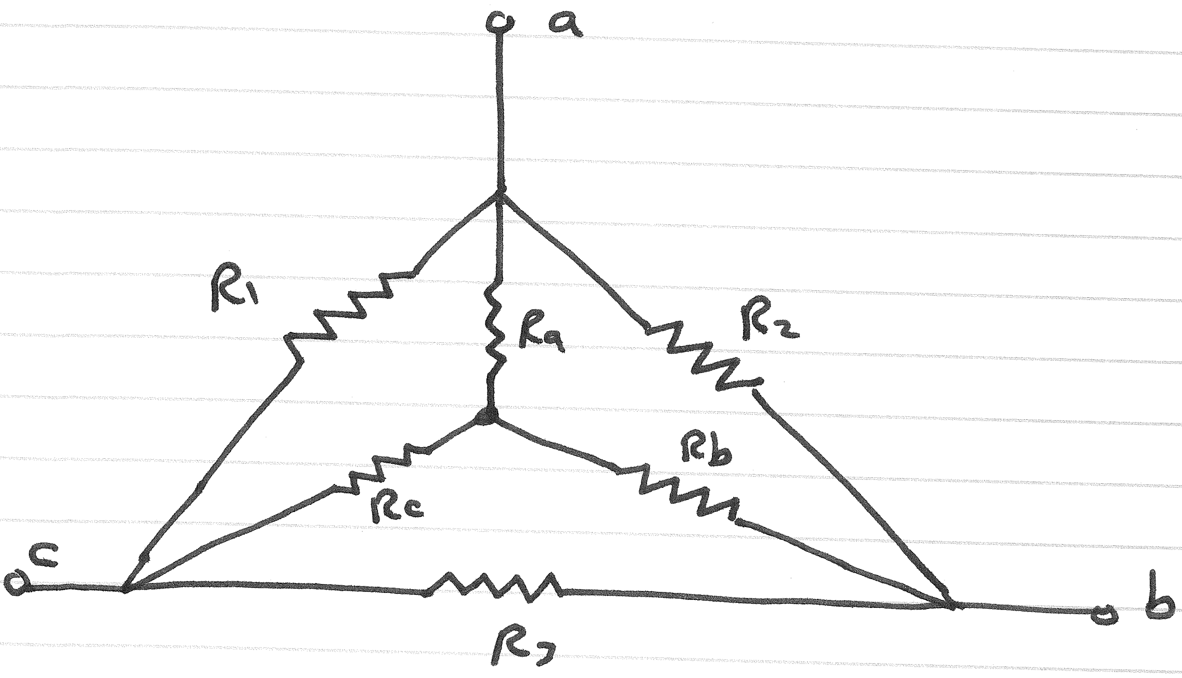
$$R_b = \frac{R_2 R_3}{R_1+R_2+R_3}$$

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

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

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

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



For the balanced case where

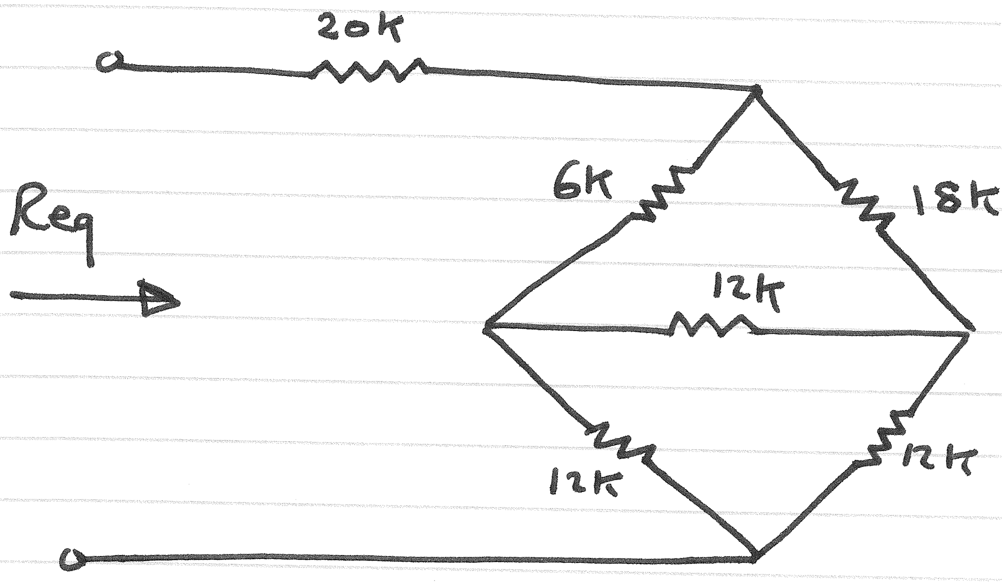
$$R_a = R_b = R_c = R_Y$$

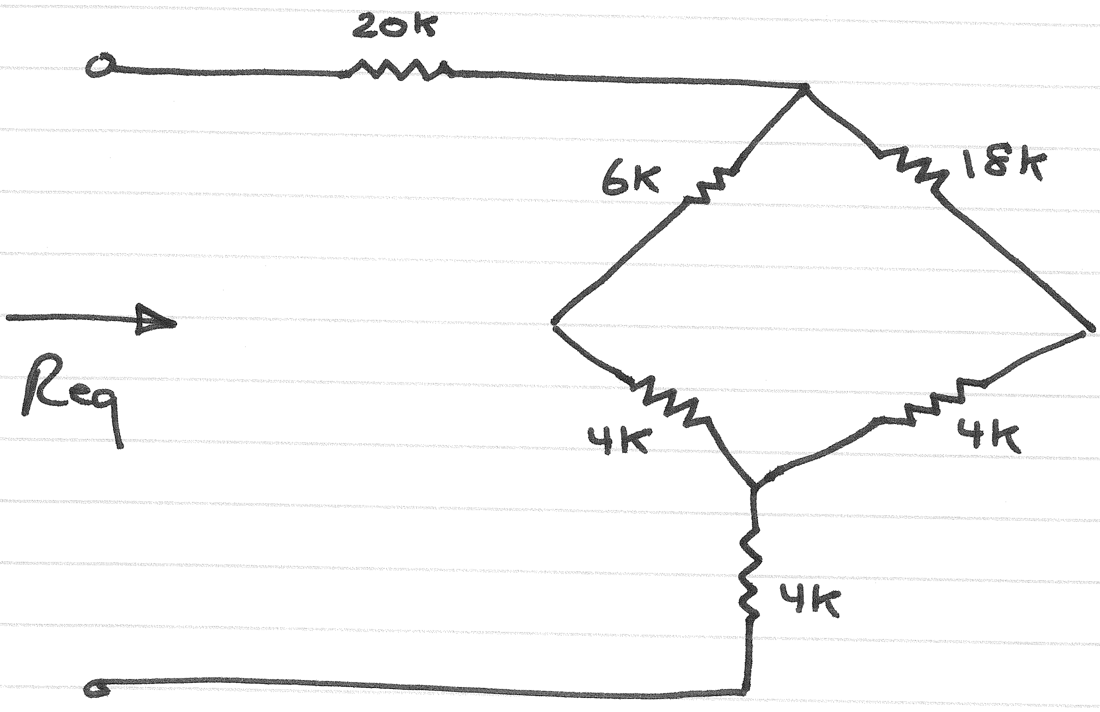
$$R_1 = R_2 = R_3 = R_\Delta$$

$$R_\Delta = 3 R_Y$$

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

Find Req



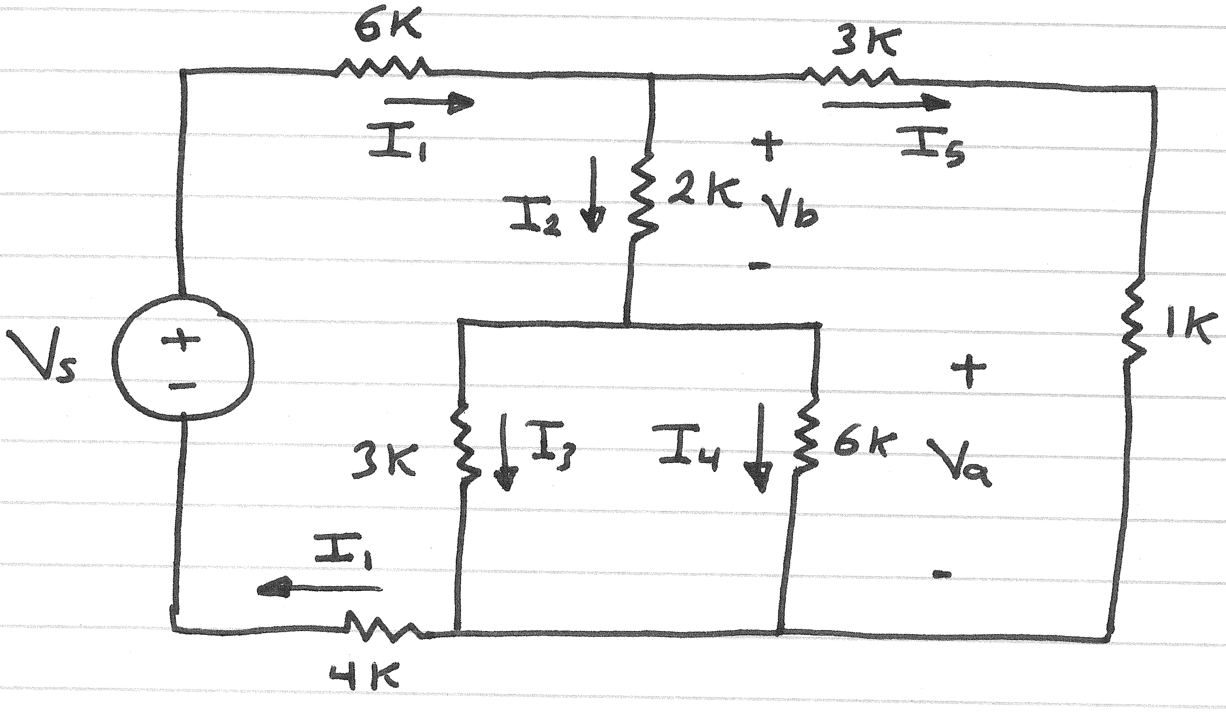


$$R_{eq} = 20k + 4k + (6k + 4k) \| (18k + 4k)$$

$$R_{eq} = 30.88k$$

Design :

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



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

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

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

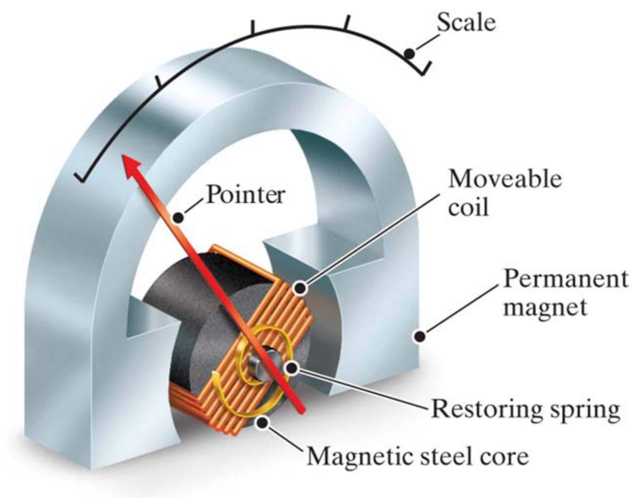
$V_b = (2K\Omega)(1.5\,mA) = 3\,V$

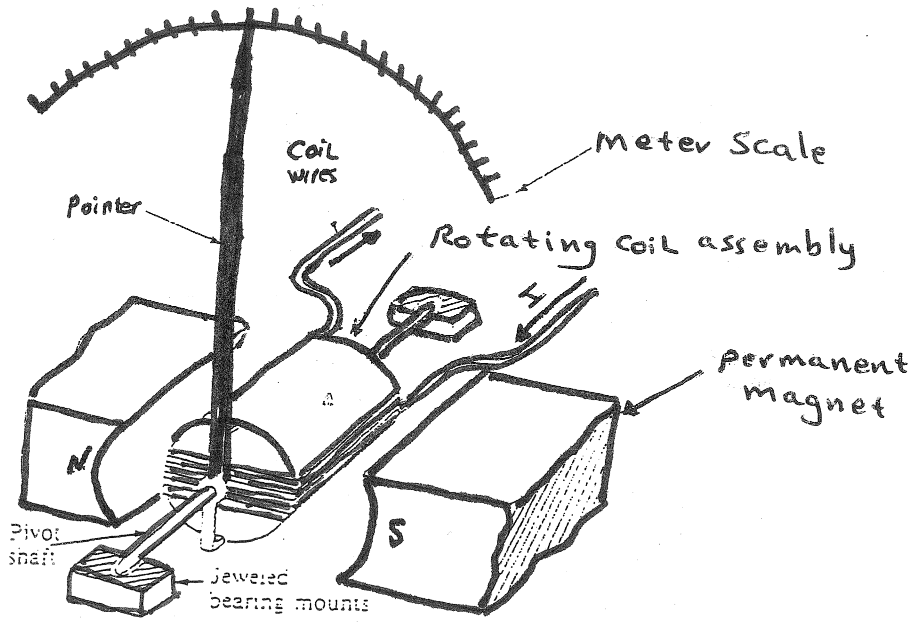
$I_5 = \frac{V_a + V_b}{4K} = 1.5\,mA$

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

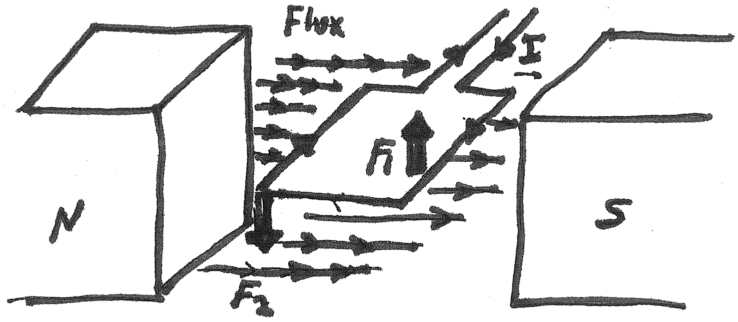
$V_s = (10K\Omega)\,I_1 + V_b + V_a = 36\,V$

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





Basic components of a D'Arsonval movement



$$F_1 = F_2 = I \ell B$$

$$\tau = I \ell B d$$

If the coil has N turns

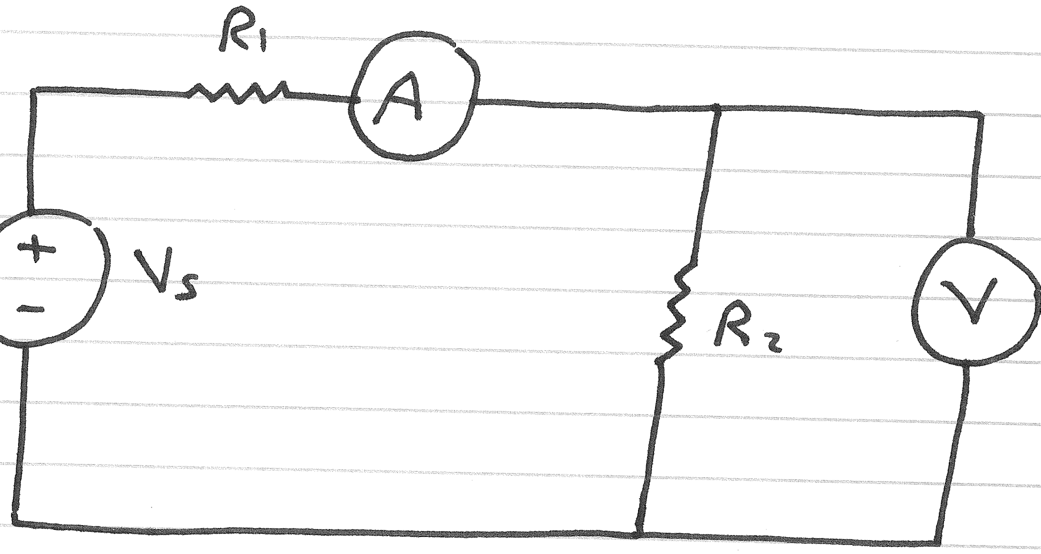
$$\tau = I \ell B N d$$

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.

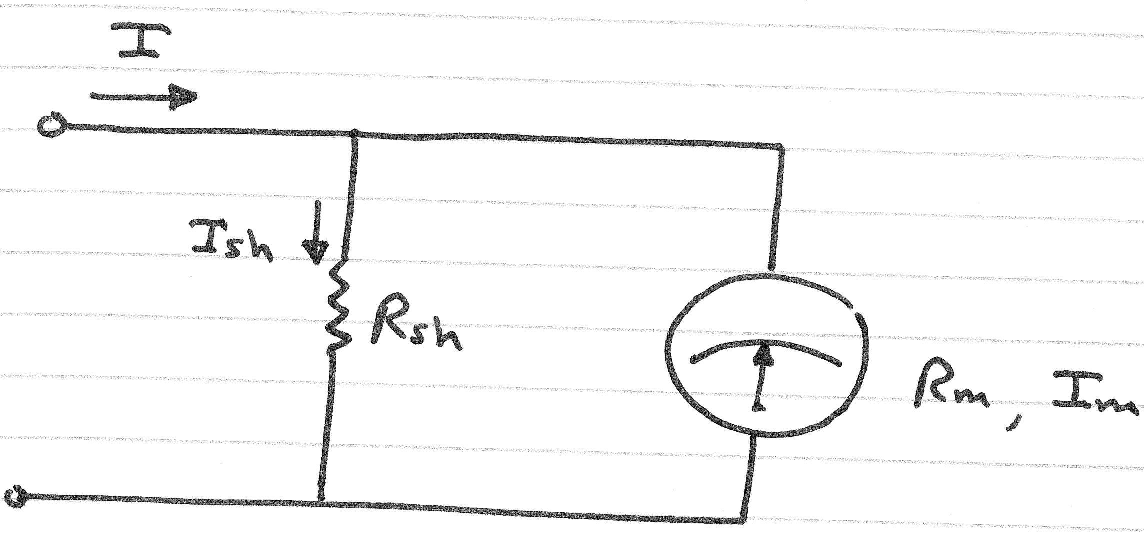
Measuring Voltage and Current



Ammeter : designed to measure current

Voltmeter : designed to measure voltage

Dc Ammeter



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

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

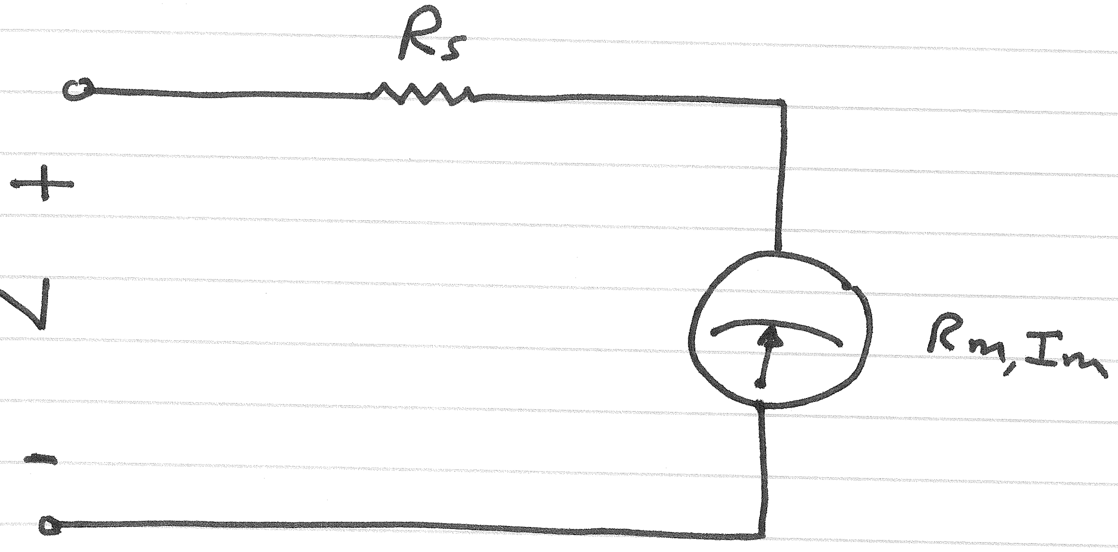
A 0-1mA meter movement with an internal resistance of 100 Ω is to be converted to a 0-100mA Ammeter.

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

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

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

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 $0 - 10\,V$

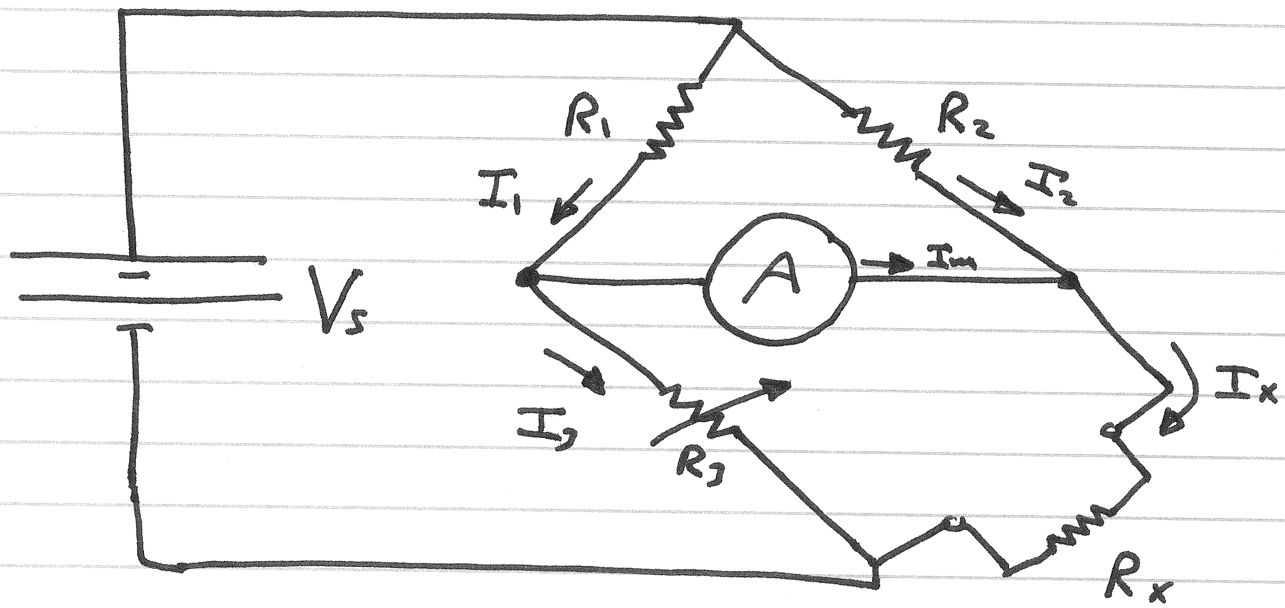
$$R_S = \frac{V - R_m I_m}{I_m}$$

$$= \frac{10 - (100)(1\times10^{-3})}{1\times10^{-3}}$$

$$R_S = 9900\,\Omega$$

Measuring Resistance

Wheatstore Bridge



R_3 is adjusted until $I_m = 0$

Bridge is balanced : $I_1 = I_3$

$I_2 = I_x$

$V_m = 0$

$$R_1 I_1 = R_2 I_2$$

$$R_3 I_3 = R_x I_x$$

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

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