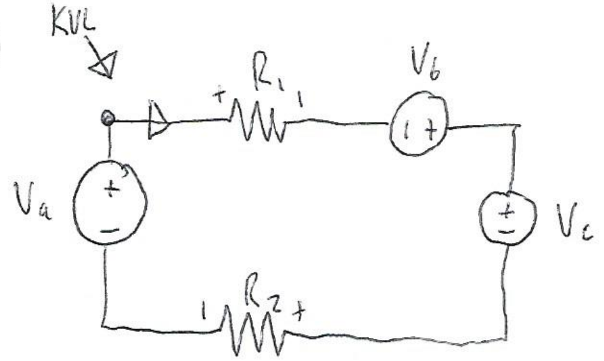
① a)



* Assume entering +ve end of component is +ve in equation

Find Veq   KVL:

$$0 = V_1 - V_b + V_c + V_2 - V_a$$

Move voltage sources to other side of equation

$$\underbrace{V_a + V_b - V_c}_{V_{eq}} = V_1 + V_2 \quad \text{or} \quad V_{eq} = V_1 + V_2$$

* V_{eq} is the summation of the 3 voltage sources:

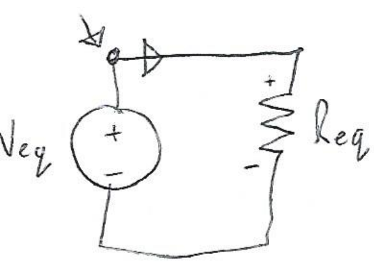
$V_{eq} = V_a + V_b - V_c$

Find Req

* R_1 and R_2 are in series

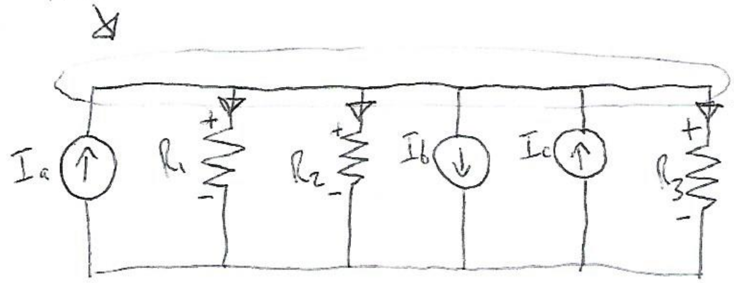
$\therefore R_{eq} = R_1 + R_2$

New Circuit:



New KVL: $0 = V_{R_{eq}} - V_{eq}$

① b) KCL



★ According to PSC assume currents are entering +ve end of each resistor

★ Assume current entering the node is +ve

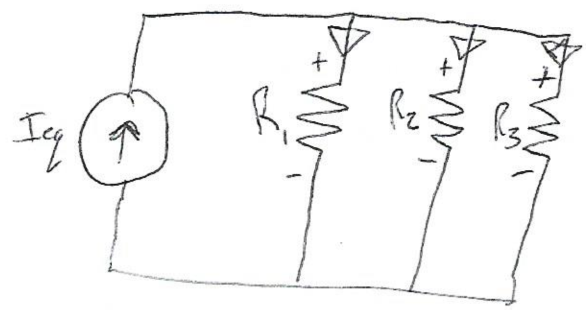
Find I_{eq} KCL:

$$0 = I_q - I_1 - I_2 - I_b + I_c - I_3$$

Isolate current source terms:

$$0 = \underbrace{(I_q - I_b + I_c)}_{I_{eq}} - I_1 - I_2 - I_3$$

$$0 = I_{eq} - I_1 - I_2 - I_3 \quad \Rightarrow$$



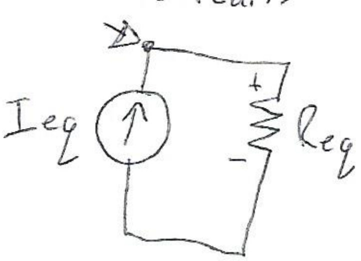
Find R_{eq}

$R_{eq} = R_1 \| R_2 \| R_3$ (all 3 in parallel)

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

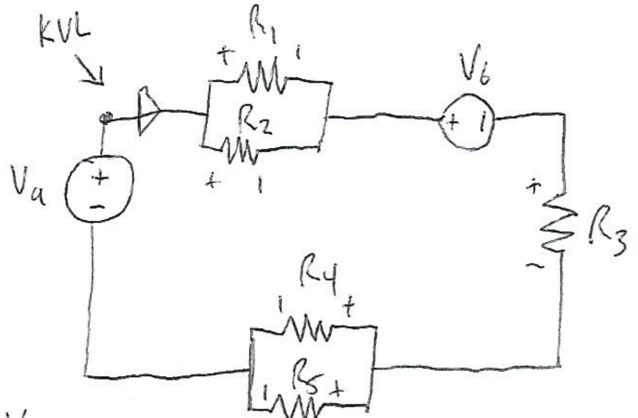
$$R_{eq} = \frac{1}{\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)}$$

New Circuit:



New KCL: $0 = I_{eq} - I_{R_{eq}}$

(1c)



* Assume entering the +ve end of the component is +ve in the equation

Find V_{eq}

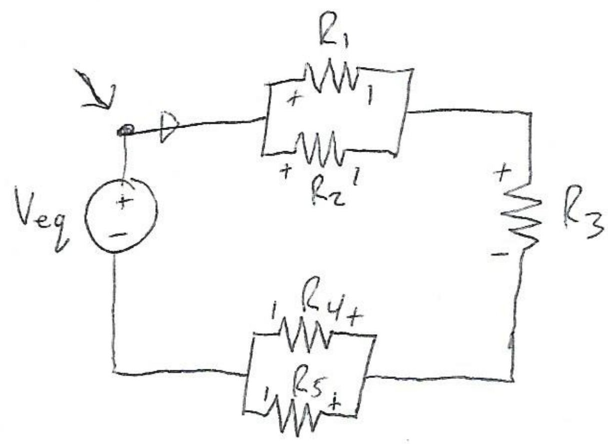
* We know $V_1 = V_2$ and $V_4 = V_5$ (the resistor pairs are in parallel)

KVL:

$$0 = V_1 + V_6 + V_3 + V_4 - V_a$$

$$\underbrace{V_a - V_6}_{V_{eq}} = V_1 + V_3 + V_4$$

$\Rightarrow$



$$V_{eq} = V_1 + V_3 + V_4$$

or

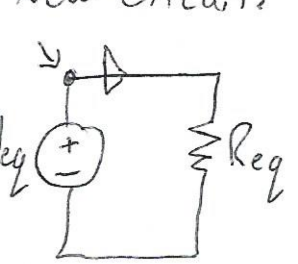
$$0 = V_1 + V_3 + V_4 - V_{eq}$$

Find R_{eq}

$$R_{eq} = (R_1 || R_2) + R_3 + (R_4 || R_5)$$

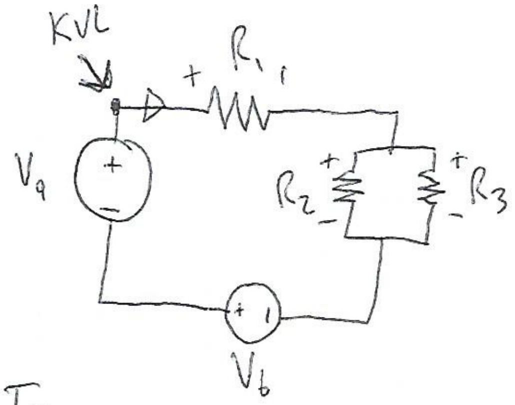
$$R_{eq} = \left[\frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}\right] + R_3 + \left[\frac{1}{\frac{1}{R_4} + \frac{1}{R_5}}\right]$$

New Circuit:



New KVL: $0 = V_{R_{eq}} - V_{eq}$

② a)



* Assume entering the +ve end of the component is +ve in the equation

* We know $V_1 = I_x \times R_1$ ①

and $V_2 = V_3 = I_x \times (R_2 || R_3)$ ②

Find I_x

KVL:

③ $0 = V_1 + V_2 - V_b - V_a$

sub in equation ① and ② into ③

$$0 = I_x R_1 + I_x (R_2 || R_3) - V_b - V_a$$

$$0 = I_x R_1 + I_x \left[\frac{1}{\frac{1}{R_2} + \frac{1}{R_3}} \right] - V_b - V_a$$

sub in values

$$0 = I_x (5k\Omega) + I_x \left[\frac{1}{\frac{1}{12k\Omega} + \frac{1}{4k\Omega}} \right] - 3V - 1V$$

$$0 = I_x (5k\Omega) + I_x (3k\Omega) - 4V$$

$$I_x = \frac{4V}{8k\Omega} = 0.5mA$$

Find V_1, V_2, V_3

$V_1 = (0.5mA)(5k\Omega)$

$= 2.5\ V$

From ③ (KVL)

$0 = V_1 + V_2 - V_b - V_a$

$\rightarrow V_2 = V_a + V_b - V_1$

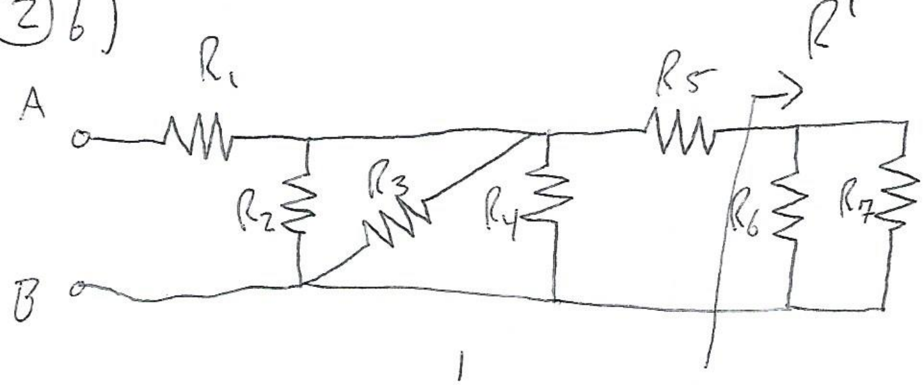
$= 3V + 1V - 2.5V$

$= 1.5V$

From ②

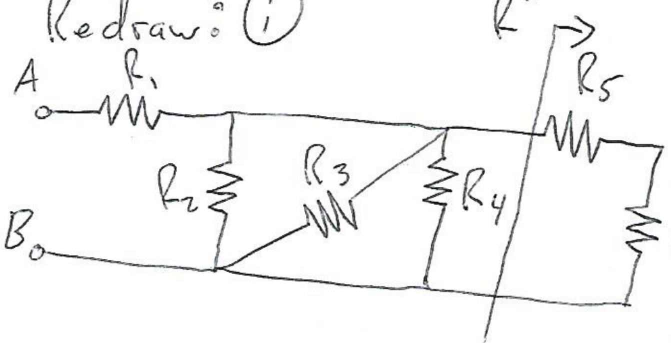
$V_2 = V_3 = 1.5V$

(2) b)



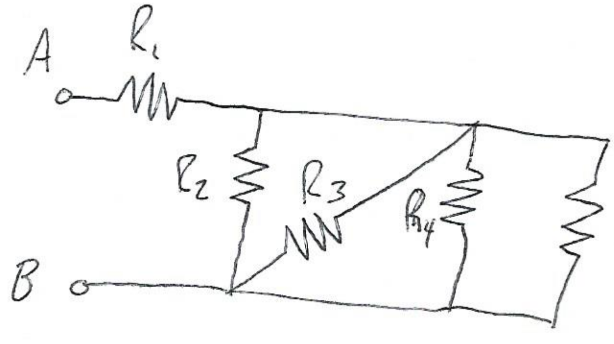
$$R' = R_6 \| R_7 = \frac{1}{\frac{1}{8k\Omega} + \frac{1}{8k\Omega}} = 4k\Omega$$

Redraw: (i)



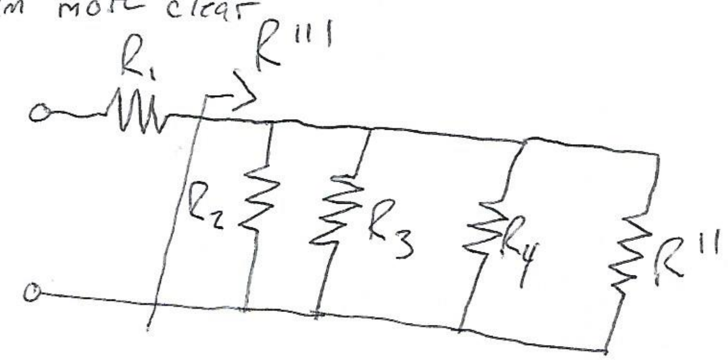
$$R'' = R_5 + R'$$
$$= 8k\Omega + 4k\Omega$$
$$= 12k\Omega$$

Redraw: (ii)



$\Rightarrow$

We can redraw again to make the diagram more clear

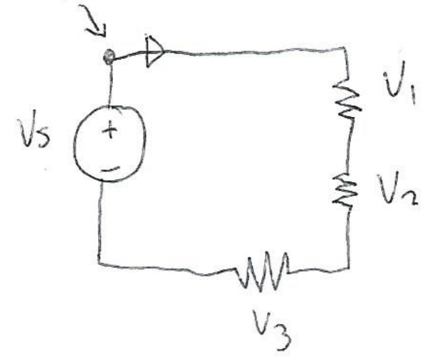


$$R''' = R_2 \| R_3 \| R_4 \| R''$$

$$R''' = \frac{1}{\left[\frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R''}\right]} = 1k\Omega$$

Lastly: $R_{AB} = R_1 + R''' = 6k\Omega$

③ a)



$$V_1 = V_S\left(\frac{R_1}{R_1+R_2+R_3}\right) = (25V)\left(\frac{2k\Omega}{2k\Omega+3k\Omega+6k\Omega}\right)$$

$$\approx 4.54V$$

$$V_2 = V_S\left(\frac{R_2}{R_1+R_2+R_3}\right) = (25V)\left(\frac{3k\Omega}{2k\Omega+3k\Omega+6k\Omega}\right)$$

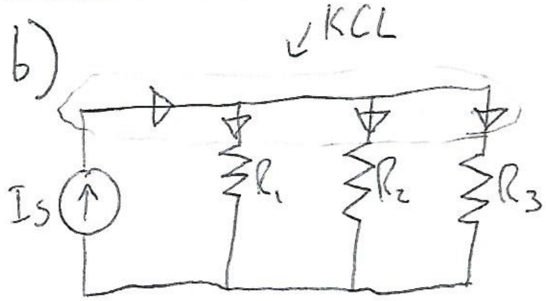
$$\approx 6.82V$$

$$V_3 = \left(\frac{6k\Omega}{2k\Omega+3k\Omega+6k\Omega}\right)(25V) \approx 13.64V$$

Check with KVL:

$$0 = V_1 + V_2 + V_3 - V_S \Rightarrow 0 = 4.54V + 6.82V + 13.64V - 25V = 0 \quad \therefore LHS = RHS$$

b)



Find R_p

$$R_p = R_1 \| R_2 \| R_3$$

$$= \frac{1}{\left(\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}\right)} = 1.69k\Omega$$

$$☆ \boxed{I_K = I_S \frac{R_p}{R_K}}$$

$$I_1 = I_S\left(\frac{1.69k\Omega}{5k\Omega}\right) \doteq 1.69mA$$

$$I_2 = I_S\left(\frac{1.69k\Omega}{4k\Omega}\right) \approx 2.11mA$$

$$I_3 = I_S\left(\frac{1.69k\Omega}{7k\Omega}\right) \approx 1.21mA$$

⇓

Check with KCL:

$$0 = I_S - I_1 - I_2 - I_3$$

$$0 = 5mA - 1.21mA - 2.11mA - 1.69mA$$
$$= -0.01mA$$

→ ☆ small error of 0.01mA due to rounding

$$\frac{0.01mA}{5mA}(100\%) = 0.2\% \text{ error}$$

(very small)