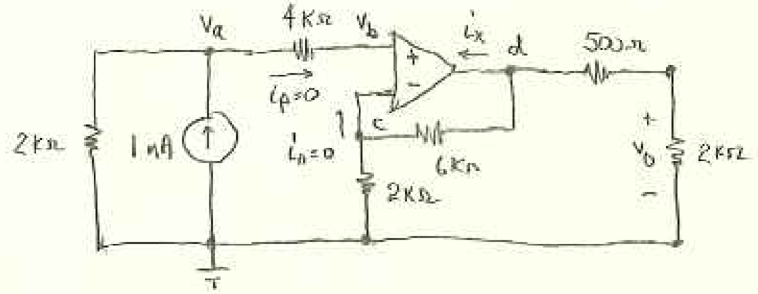
Question 1



At node a: $\frac{V_a}{2K} - 0.001 + \cancel{i_p}^{\to 0} = 0$

so $V_a = 2V$

This is also the voltage V_b and V_c: $V_a = V_b = V_c = 2$

At node c: $\frac{V_c}{2K} + \frac{V_c - V_d}{6K} + \cancel{i_n}^{\to 0} = 0$

$(\times 6K)$ $3V_c + V_c - V_d = 0$

so $V_d = 4V_c = 4(2) = 8\,v$

At V_o, we have a simple voltage divider

$$V_o = \frac{2K}{2K + 500} \times V_d = 0.8 \times 8$$

$$\boxed{V_0 = 6.4v}$$

Question 2

At node d in the diagram above,

$$\frac{V_d - V_c}{6K} + i_x + \frac{V_d - V_0}{500} = 0, \quad \text{where } V_d = 8v, \; V_c = 2V, \; V_0 = 6.4v$$

$\times(6K)$ $V_d - V_c + 6000 i_x + 12V_d - 12V_0 = 0$

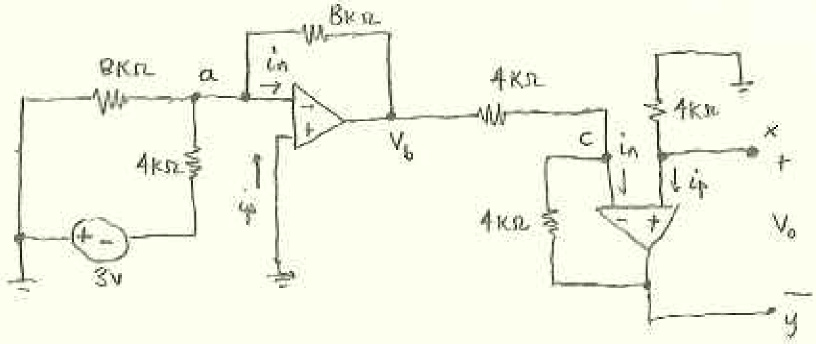
$8 - 2 + 6000 i_x + 96 - 76.8 = 0$

$6000 i_x = -25.2$

$$\boxed{i_x = -4.2 \text{ mA}}$$

Question 3

Zeroing all sources except the 3v source gives



We see that the voltage at node $V_a = 0$. Applying the node-voltage method, we may find V_b

$$\frac{V_a}{8K} + \frac{V_a - (-3)}{4K} + \cancel{i_n}^{0} + \frac{V_a - V_b}{8K} = 0$$

With $V_a = 0$,
$$\frac{3}{4K} - \frac{V_b}{8K} = 0$$

$(\times 8K)$
$$6 - V_b = 0$$

$$V_b = 6.$$

In the second op-amp, we see that $V_c = 0$ as well. Writing a node equation there will give us V_y

$$\frac{V_c - V_b}{4K} + \frac{V_c - V_y}{4K} + \cancel{i_n}^{0} = 0$$

or
$$-\frac{V_b}{4K} - \frac{V_y}{4K} = 0$$

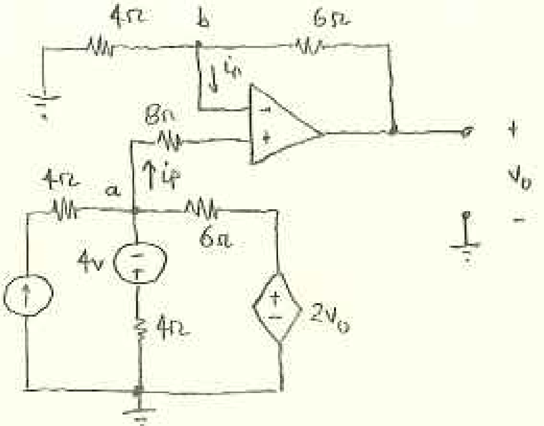
giving $V_y = -V_b = -6v.$

With V_x also at zero volts

$$V_o' = V_x - V_y = 0 - (-6)$$

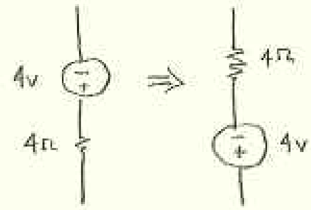
$$\boxed{V_o' = 6\text{ v}}$$

Question 4



Two node equations, one at a, the other at b, should do it.

Node a: Notice the middle branch. We could make a supernode there, but we could also make a slight modification



$$-2 + \frac{V_a - (-4)}{4} + \frac{V_a - 2V_o}{6} + \cancel{i_p}^{\,0} = 0$$

(x12) $$-24 + 3V_a + 12 + 2V_a - 4V_o = 0$$
$$5V_a - 4V_o = 12$$

$$\text{so} \quad V_a = \frac{12 + 4V_o}{5} \qquad (1)$$

Node b: $$\frac{V_b}{4} + \frac{V_b - V_o}{6} = 0$$

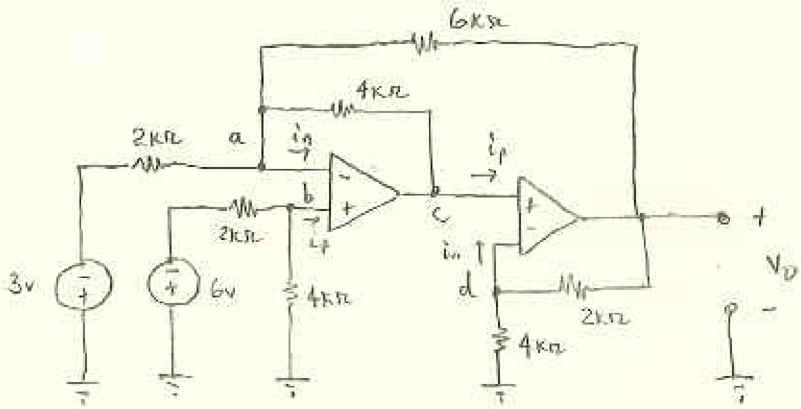
(x12) $$3V_b + 2V_b - 2V_o = 0$$
$$5V_b = 2V_o$$

Substituting equation (1) for V_o, and with $V_a = V_b$,

$$5V_a = 2V_o$$
$$5\left(\frac{12 + 4V_o}{5}\right) = 2V_o$$

$$12 + 4V_0 = 2V_0$$
$$-2V_0 = 12$$
$$\boxed{V_0 = -6\,v}$$

Question 5



Remember: op-amp input nodes are perfect for writing node-voltage equations.

Node a: $\frac{V_a - (-3)}{2K} + \frac{V_a - V_c}{4K} + \cancel{i_n}^{\,0} + \frac{V_a - V_0}{6K} = 0$

(x12) $\quad 6V_a + 18 + 3V_a - 3V_c + 2V_a - 2V_0 = 0$

$$11V_a - 3V_c - 2V_0 = -18 \qquad (1)$$

Node b: $\frac{V_b - (-6)}{2K} + \frac{V_b}{4K} + \cancel{i_p}^{\,0} = 0$

(x 4K) $\quad 2V_b + 12 + V_b = 0$

$$3V_b = -12$$

$$V_b = -4\,v$$

And since, $V_a = V_b$, equation (1) becomes

$$11(-4) - 3V_c - 2V_0 = -18$$
$$-3V_c - 2V_0 = 26 \qquad (2)$$

Node d: $\frac{V_d}{4K} + \frac{V_d - V_0}{2K} + \cancel{i_n}^{\,0} = 0$

(x 4K) $\quad V_d + 2V_d - 2V_0 = 0$

$$3V_d - 2V_0 = 0 \qquad (3)$$

And we see that $V_d = V_c$, so equation (3) becomes

$$3V_c - 2V_o = 0$$

$$\text{or} \quad V_c = \frac{2}{3} V_o$$

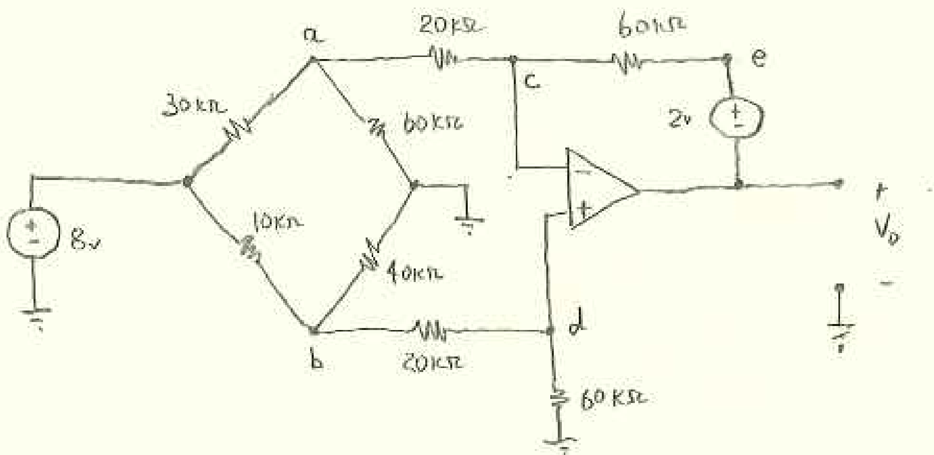
Substitute back into (2),

$$-3\left(\frac{2}{3}V_o\right) - 2V_o = 26$$

$$-2V_o - 2V_o = 26$$

$$\boxed{V_o = -6.5\text{ v}}$$

Question 6



Node-voltage method.

Node a: $$\frac{V_a - 8}{30K} + \frac{V_a}{60K} + \frac{V_a - V_c}{20K} = 0$$

(x 60k) $$2V_a - 16 + V_a + 3V_a - 3V_c = 0$$

$$6V_a - 3V_c = 16 \qquad (1)$$

Node b: $$\frac{V_b - 8}{10K} + \frac{V_b}{40K} + \frac{V_b - V_d}{20K} = 0$$

(x 40k) $$4V_b - 32 + V_b + 2V_b - 2V_d = 0$$

$$7V_b - 2V_d = 32 \qquad (2)$$

Node d: $\frac{V_d - V_b}{20k} + \frac{V_d}{60k} + \cancel{i_p}^{\,0} = 0$

(x 60k) $3V_d - 3V_b + V_d = 0$

$4V_d = 3V_b$

so $V_d = \frac{3}{4} V_b$ (3)

We see that $V_d = V_c$, so $V_c = \frac{3}{4} V_b$

Substitute this into equation (1)

$$6V_a - 3\left(\frac{3}{4}V_b\right) = 16$$

$$6V_a - \frac{9}{4}V_b = 16 \quad (4)$$

Same substitution into equation (2)

$$7V_b - 2\left(\frac{3}{4}V_b\right) = 32$$

$$5.5V_b = 32$$

so $V_b = 5.818$ v

From (1), $6V_a - 3V_c = 16$, so $V_a = \frac{16 + 3V_c}{6}$ (5)

With $V_b = 5.818$, then $V_d = \frac{3}{4}V_b = 4.3636$

$V_c = V_d = 4.3636$v

and $V_a = \frac{16 + 3V_c}{6} = 4.8485$

One more node!

Node c: $\frac{V_c - V_a}{20k} + \frac{V_c - V_e}{60k} + \cancel{i_n}^{\,0} = 0$

(x 60k) $3V_c - 3V_a + V_c - V_e = 0$

$$V_e = 4V_c - 3V_a$$
$$= 4(4.3636) - 3(4.8485) = 2.9091$$

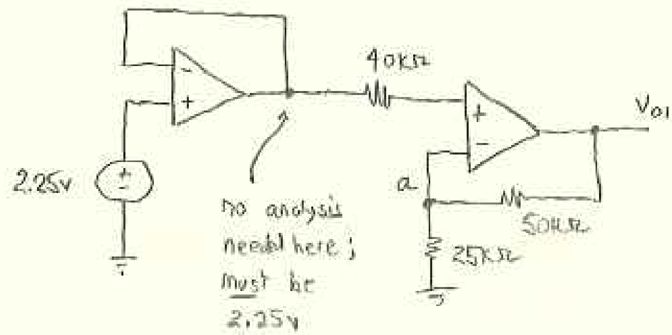
Finally, From node e to V_o, there is 2v drop through the voltage soure

$$V_o = V_e - 2v = \boxed{0.9091 \text{ v}}$$

Question 7

This is easiest to break into parts.

(a) lower-left part:



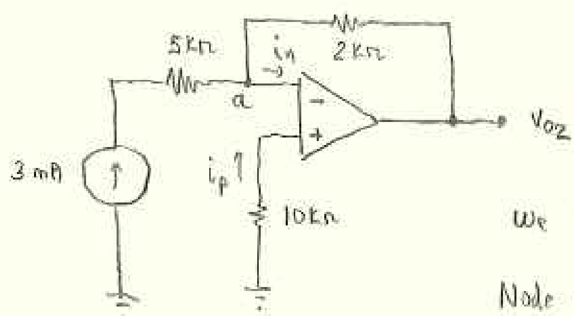
Node a: $\frac{V_a}{25k} + \frac{V_a - V_{o1}}{50k} + \cancel{i_n} = 0$

(×50k) $2V_a + V_a - V_{o1} = 0$

$V_{o1} = 3V_a$

And we know $V_a = 2.25$, so $\boxed{V_{o1} = 6.75v}$

(b) upper-left part



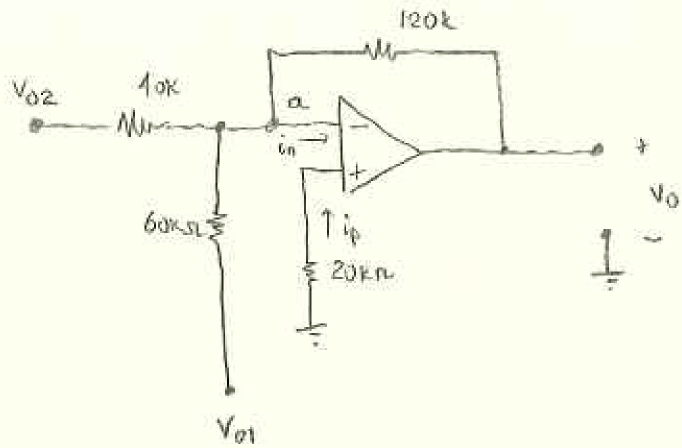
We know $V_a = 0$

Node a: $-0.003 + \frac{V_a - V_{o2}}{2K} + \cancel{i_n} = 0$

(×2k) $-6 - V_{o2} = 0$

$\boxed{V_{o2} = -6v}$

(c) top-right part



Once again, we see $V_a = 0$

Node a: $$\frac{V_a - V_{02}}{40k} + \frac{V_a - V_{01}}{60k\Omega} + \frac{V_a - V_0}{120k} + \cancel{i_n}^{\,0} = 0$$

(x 120k) $$3V_a - 3V_{02} + 2V_a - 2V_{01} + V_a - V_0 = 0$$
$$6V_a - 2V_{01} - 3V_{02} = V_0$$

$$V_0 = 6 \times 0 - 2(6.75) - 3(-6)$$
$$\boxed{V_0 = 4.5\,\mathrm{v}}$$