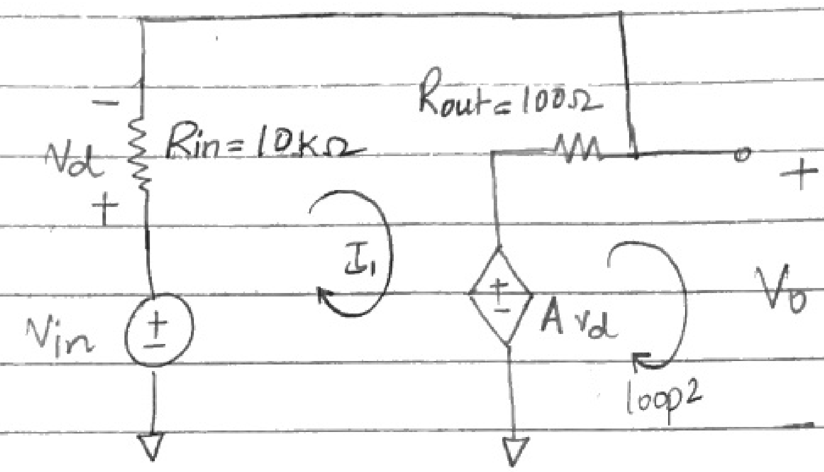
HW 5

SOLUTIONS

* 5.5
* 5.18
* 5.21
* 5.39
* 5.47
* 5.66

5.5



Applying KVL around loop 1:

1

$$-V_{in} + R_{in} \cdot I + R_{out} I + A V_d = 0 \quad \text{— (1)}$$

By Inspection:

$$V_d = I R_{in} \quad \text{— (2)}$$

From (1) and (2):

1/2

$$I = \frac{V_{in}}{(R_{in} + A R_{in} + R_{out})} \quad \text{— (3)}$$

Applying KVL around loop 2:

1

$$-A V_d - I R_{out} + V_o = 0$$

$$\Rightarrow V_o - \frac{A V_{in} R_{in}}{(R_{in} + A R_{in} + R_{out})} - \frac{R_{out} V_{in}}{(R_{in} + A R_{in} + R_{out})} = 0$$

(From (3))

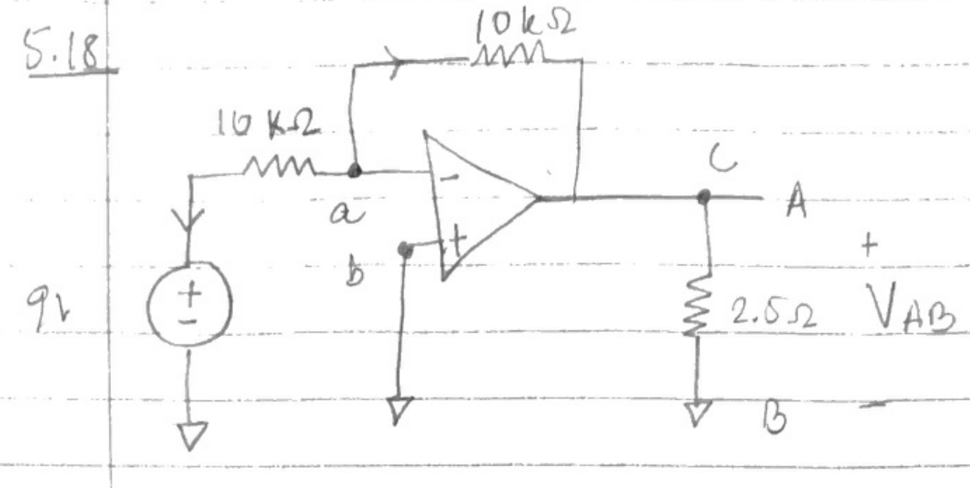
1/2 $\dfrac{V_o}{V_{in}} = \dfrac{A R_{in} + R_{out}}{(R_{in} + A R_{in} + R_{out})}$

(Dividing throughout by Vin)

Now subsituting $R_{in} = 10 k\Omega$, $R_{out} \Rightarrow 100\Omega$
and $A = 10^5$

1/2 $\boxed{\therefore \dfrac{V_o}{V_{in}} = 0.99}$

5.18



To find the thevenin equivalent, we find the open ckt voltage, V_{AB} and short ckt current, I_{sc}. ∴ $R_{Th} = \frac{V_{AB}}{I_{sc}}$

Applying KCL at node a:

(1) $\frac{V_a - 9}{10k} + \frac{V_a - V_c}{10k} = 0$ (Assuming ideal op-amp) — (1)

Now, for an ideal op-amp:

(1/2) $V_a = V_b = 0V$ — (2)

From (1) + (2) :

(1/2) $\boxed{V_c = -9V}$

$\Rightarrow V_c = V_{AB} = -9V.$

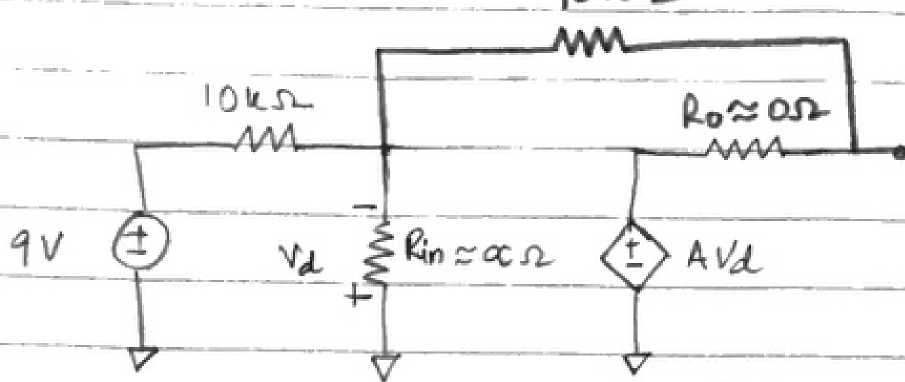
Approach I for R_{Th}

Now, if there's a short ckt between A & B,

1 $I_{sc} = \infty$. $\therefore R_{Th} = \frac{V_{AB}}{I_{sc}} = 0\Omega$

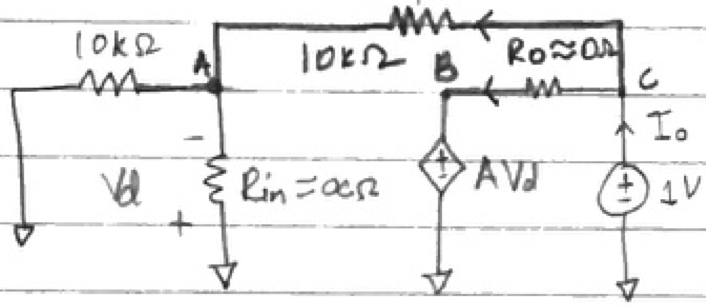
Approach II for R_{Th}:

Equivalent ckt for op-amp:



Ideal values
$R_{in} \approx \infty\,\Omega$
$R_o \approx 0\,\Omega$

⇓ Short the 9V source but not the dependent source.

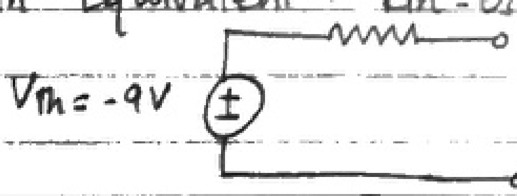


Applying KCL at node C: $I_o = \frac{1-AV_d}{R_o} + \frac{1+V_d}{10k\Omega}$

$\because R_o \approx 0$, $\frac{1-AV_d}{R_o} \approx \infty$ $\therefore I_o \approx \infty$

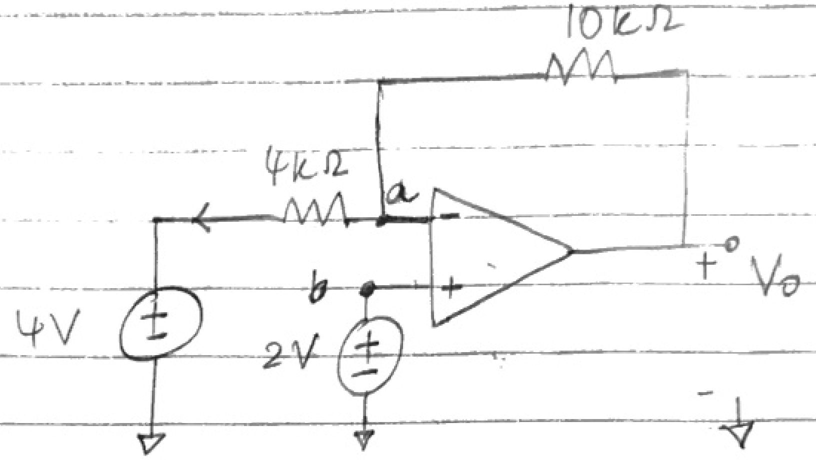
$\therefore R_{Th} = 1V/I_o \approx 0\Omega$

$\therefore$ Thevenin Equivalent: $R_{Th} = 0\Omega$



1/2

5.21



Applying KCL at node a :

1 $$\frac{V_a - 4}{4k} + \frac{V_a - V_o}{10k} = 0 \quad \text{— (1)}$$

(Assuming Ideal op-Amp)

Now, for an ideal op-Amp:

1 $$V_a = V_b = 2V \quad \text{— (2)}$$

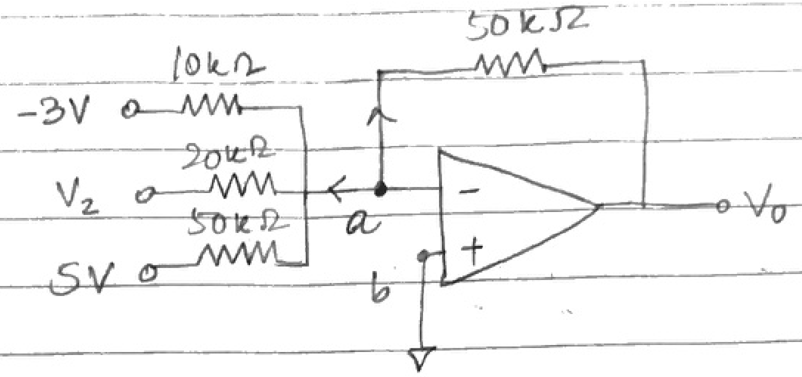
From (1) & (2) :

$$\frac{-2}{4} + \frac{2 - V_o}{10} = 0$$

$$10 \times (-0.5 + 0.2) = V_o$$

1 $$\Rightarrow \boxed{V_o = -3V}$$

5.39



Applying KCL at node a :

1

$$\frac{V_a + 3V}{10k} + \frac{V_a - V_2}{20k} + \frac{V_a - 5V}{50k} + \frac{V_a - V_o}{50k} = 0$$

(Assuming Ideal Op-Amp) — (1)

Now for an ideal Op-Amp:

1

$$V_a = V_b = 0V. \quad — (2)$$

From (1) & (2) :

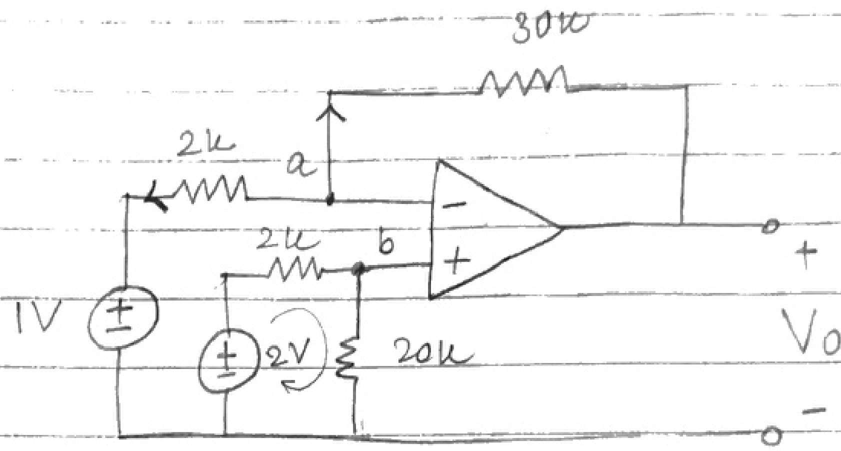
$$\frac{3}{10} - \frac{V_2}{20} - \frac{5}{50} + \frac{16.5}{50} = 0$$

$$\Rightarrow \frac{30 - 10 + 33}{5} = V_2$$

1

$$\boxed{V_2 = 10.6V}$$

5.47



At node b, V_b = voltage across 20k resistor.

Applying voltage divider rule:

1 $$V_b = \frac{20}{\cancel{22}\,11} \times 2V = \frac{20}{11} V.$$

Now, for an ideal op-amp:

½ $$V_a = V_b = \frac{20}{11} V. \quad — \ 1$$

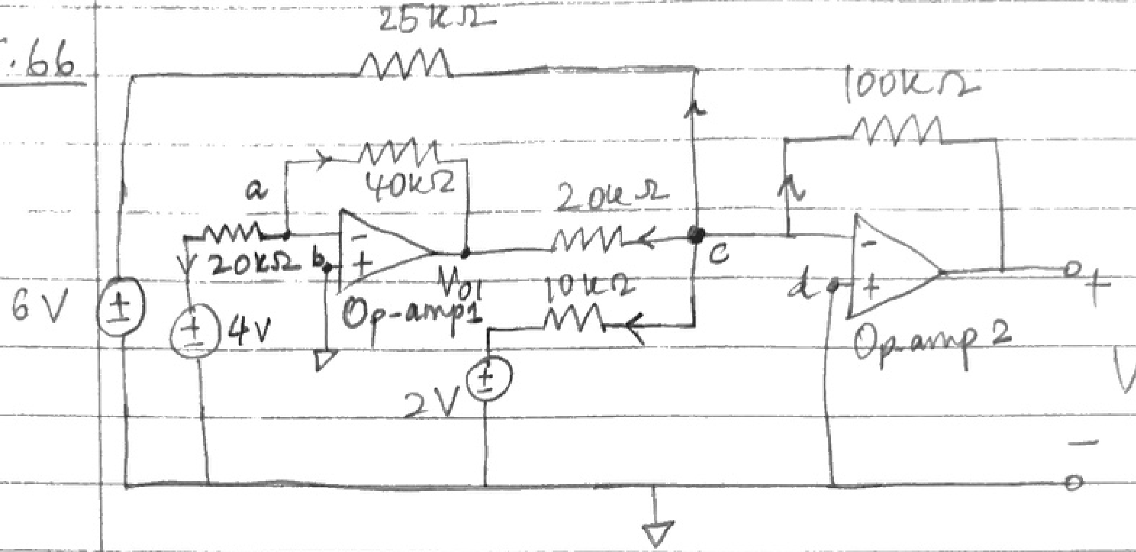
Applying KCL at a:

1 $$\frac{V_a - 1}{2k} + \frac{V_a - V_o}{30k} = 0$$

$$V_o = 30k \left(\frac{0.818}{2k} + \frac{1.818}{30k} \right).$$

½ $$\therefore \boxed{V_o = 14.09 V}$$

5.66



For an ideal op-Amp 1:

(1) $$V_a = V_b = 0. \quad — (1)$$

Applying KCL at a:

(1/2) $$\frac{V_a - 4V}{20k} + \frac{V_a - V_{01}}{40k} = 0$$

$$\cancel{40k}^{2} \times \left(-\frac{4}{\cancel{20k}} \right) = V_{01} \quad (\text{From } (1))$$

(1/2) $$V_{01} = -8V \quad — (2)$$

For an ideal op-Amp 2:

(1/2) $$V_c = V_d = 0V \quad — (3)$$

Thus, applying KCL at node C:

(1) $$\frac{V_c - 2V}{10k\Omega} + \frac{V_c - V_{01}}{20k} + \frac{V_c - 6V}{25k} + \frac{V_c - V_o}{100k} = 0$$

$$\therefore V_o = -2\left(\frac{100}{10}\right) + 8\left(\frac{100}{20}\right) - 6\left(\frac{100}{25}\right)$$

1/2

$\therefore$ $\boxed{V_0 = -4V}$