Name: Solutions

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EE 40

Midterm 2

October 17, 2002

PLEASE WRITE YOUR NAME ON EACH ATTACHED PAGE

PLEASE SHOW YOUR WORK TO RECEIVE PARTIAL CREDIT

Problem 1: 10 Points Possible ________

Problem 2: 5 Points Possible ________

Problem 3: 15 Points Possible ________

Problem 4: 10 Points Possible ________

Problem 5: 10 Points Possible ________

Problem 6: 15 Points Possible ________

Problem 7: 15 Points Possible ________

Problem 8: 5 Points Possible ________

Problem 9: 15 Points Possible ________

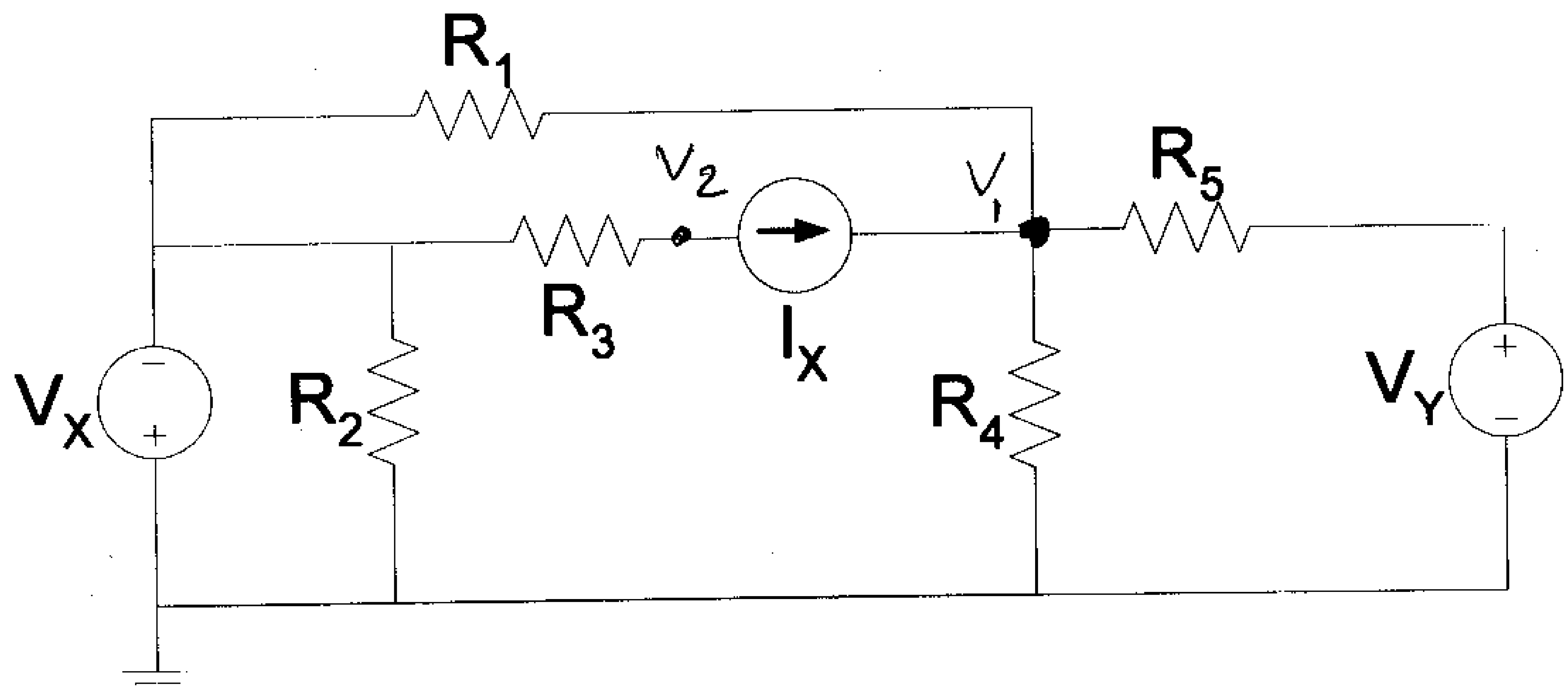
Problem 10: 10 Points Possible ________

TOTAL: 110 Points Possible ________

Name: Solutions

Problem 1: 10 Points Possible

Perform nodal analysis on the circuit below. This means write a KCL equation for each node with unknown voltage. DO NOT SIMPLIFY the circuit. DO NOT SOLVE the KCL equations.



Required: KVL @ V_1:

$$\frac{V_1 - -V_x}{R_1} - I_x + \frac{V_1}{R_4} + \frac{V_1 - V_y}{R_5} = 0$$

Optional: KVL @ V_2:

$$\frac{V_2 - -V_x}{R_3} + I_x = 0$$

Problem 2: 5 Points Possible

In nodal analysis, when is a supernode needed? Why is a supernode needed?

A supernode is needed when there is a "floating" voltage source (neither terminal of the source is at ground). The source makes it difficult to write KCL equations at its terminal nodes because it has no V-I relationship (current is unknown). KCL is possible after enclosing the source in a supernode.

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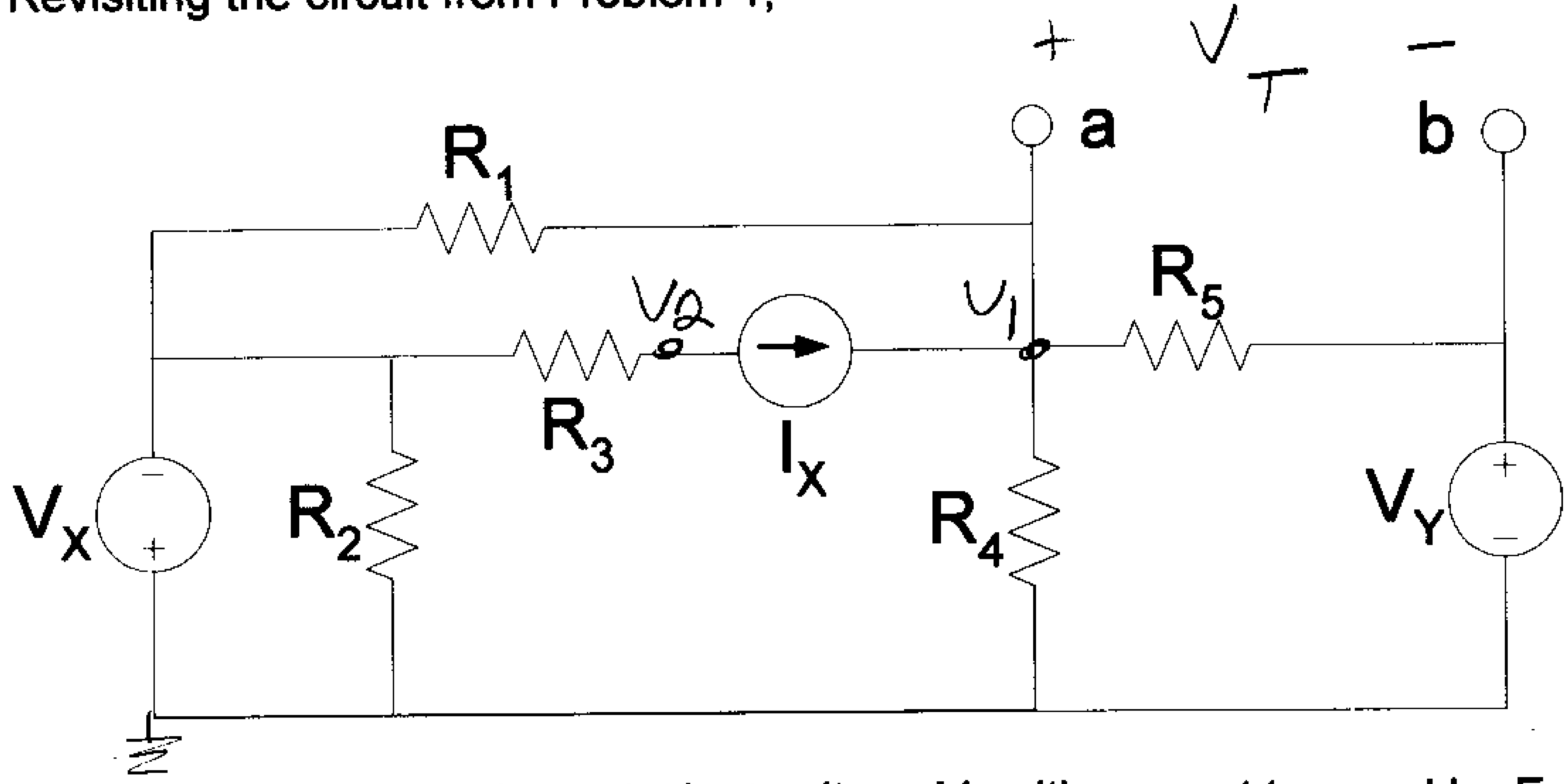
Problem 3: 15 Points Possible

Revisiting the circuit from Problem 1,

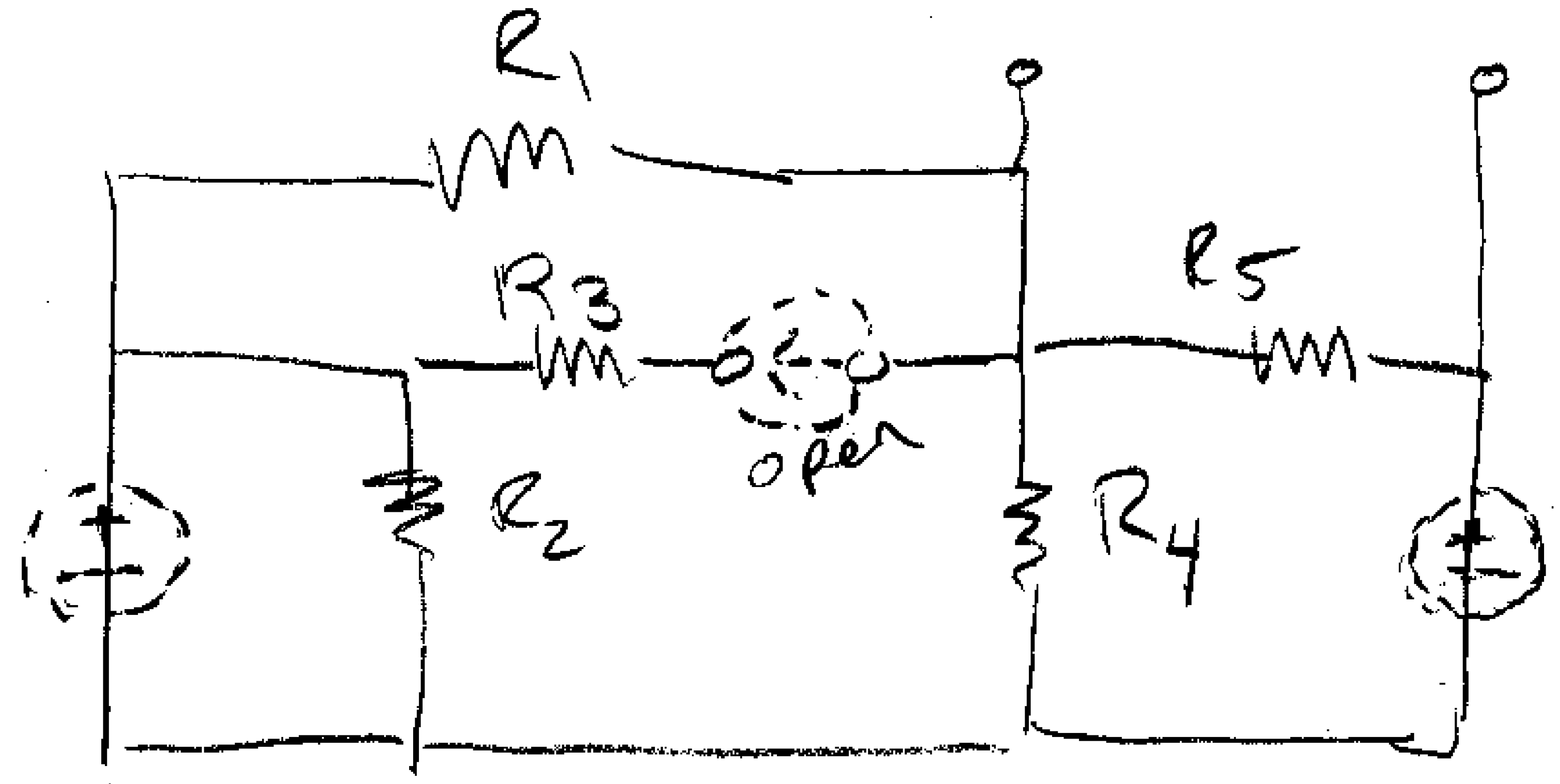


a) Find the Thevenin equivalent voltage V_T with respect to a and b. Express V_T in terms of node voltages. (5 Points Possible)

b) Find the Thevenin equivalent resistance R_T. DO NOT INCLUDE || symbol in final answer; write the full mathematical expression. (10 Points Possible)

a) $V_T = V_{ab} = V_1 - V_Y$

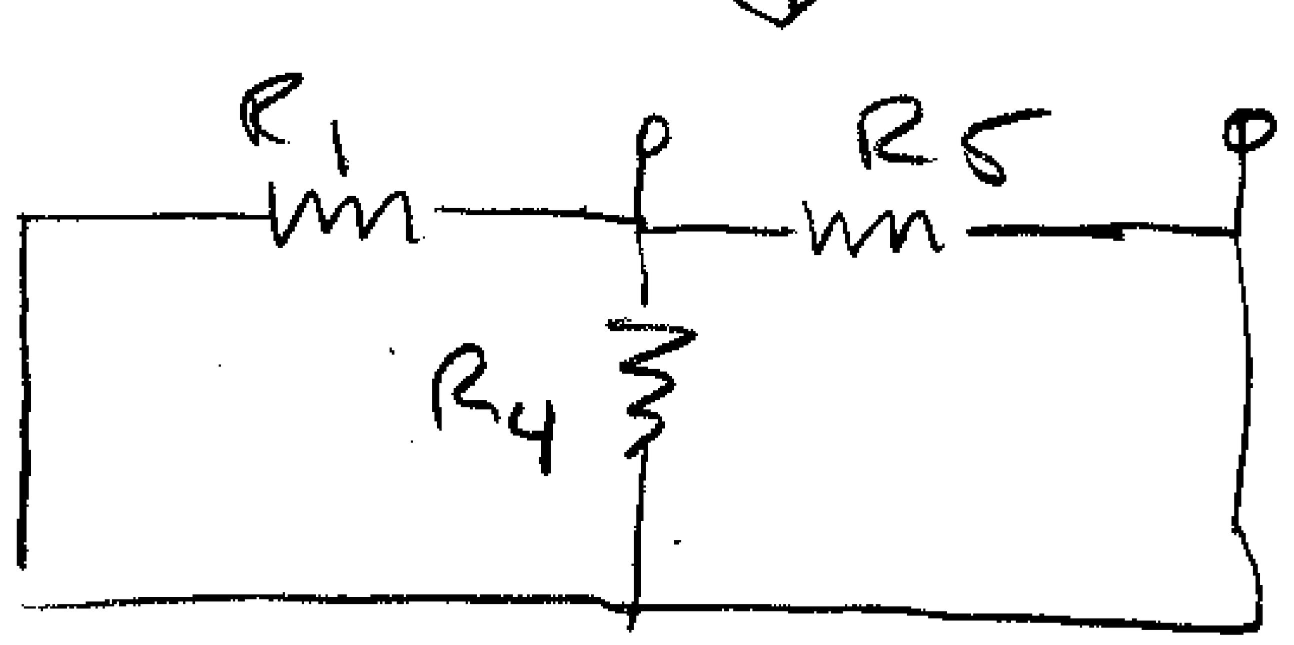
b) Deactivate independent sources:



R_3 carries no current (series w/ open circuit)

R_2 carries no current (shorted out) parallel w/ wire

⇓



$$R_T = R_1 \| R_4 \| R_5$$

$$= \left(R_1^{-1} + R_4^{-1} + R_5^{-1}\right)^{-1}$$

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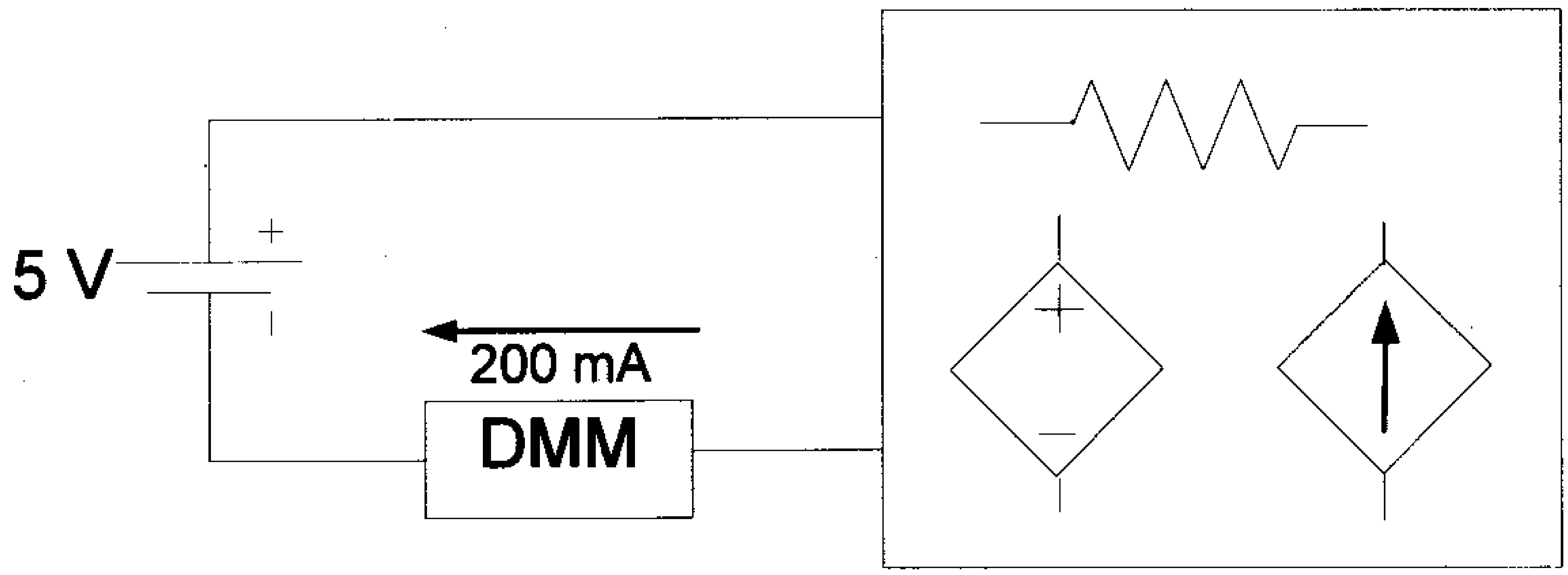
Problem 4: 10 Points Possible

Suppose I have a black-box circuit (I can't see exactly what's inside) but I know it only contains resistors and linear dependent sources. The controlling voltages and currents for the dependent sources are also in the box.

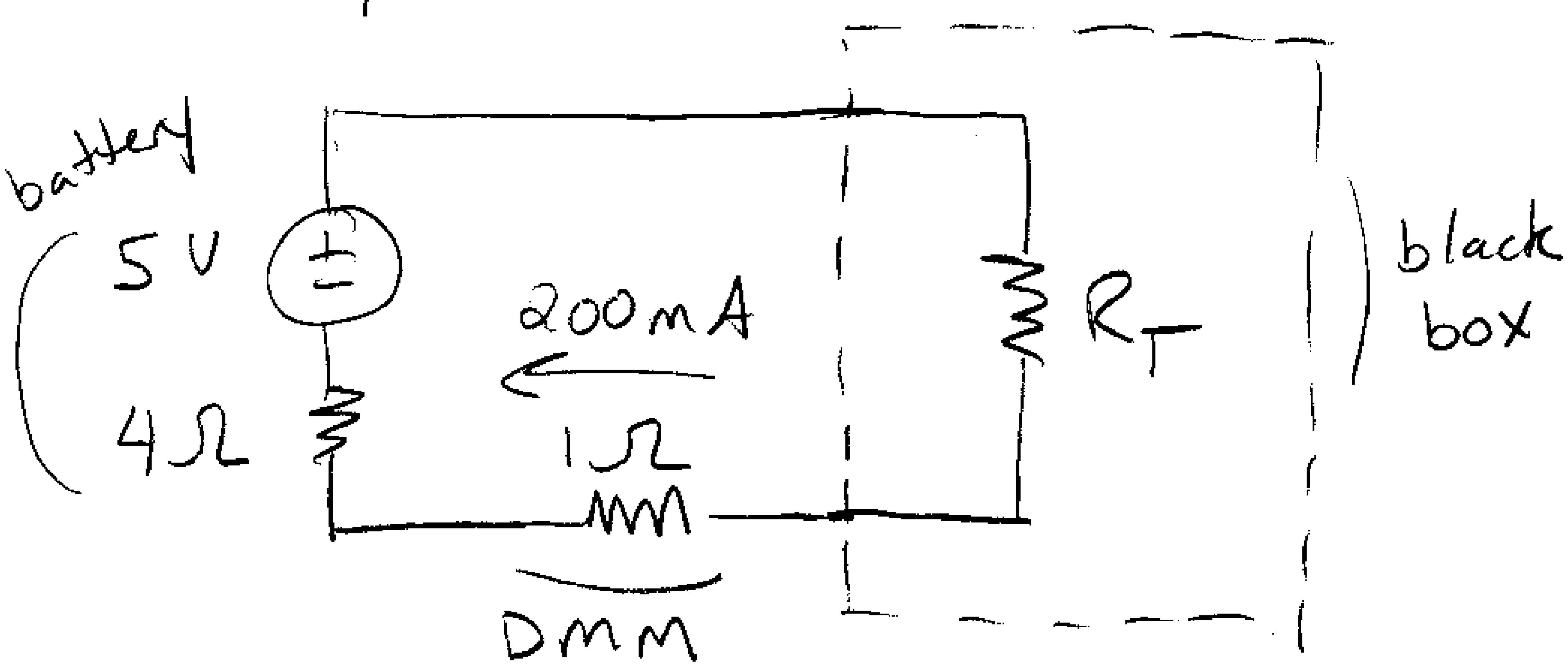
I perform one experiment: When I attach a 5 V battery as shown, I measure a 200 mA current in the direction shown. The internal resistance of the battery is 4 Ω and the internal resistance of the DMM is 1 Ω.



Can I find the Thevenin equivalent of the black-box circuit with this information? If yes, find the Thevenin equivalent. If no, explain why not.

Since there are only dependent sources & resistors, No independent sources,

$V_T = 0$



$$\frac{5\,V}{200\,mA} = 4\Omega + 1\Omega + R_T$$

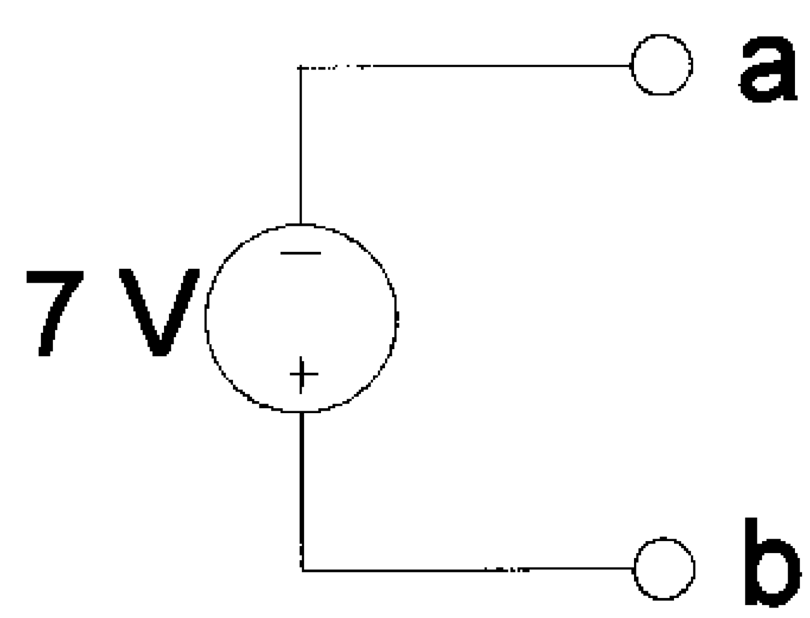
$$25\Omega = 5\Omega + R_T$$

$$R_T = 20\Omega$$

Name: Solutions

Problem 5: 10 Points Possible

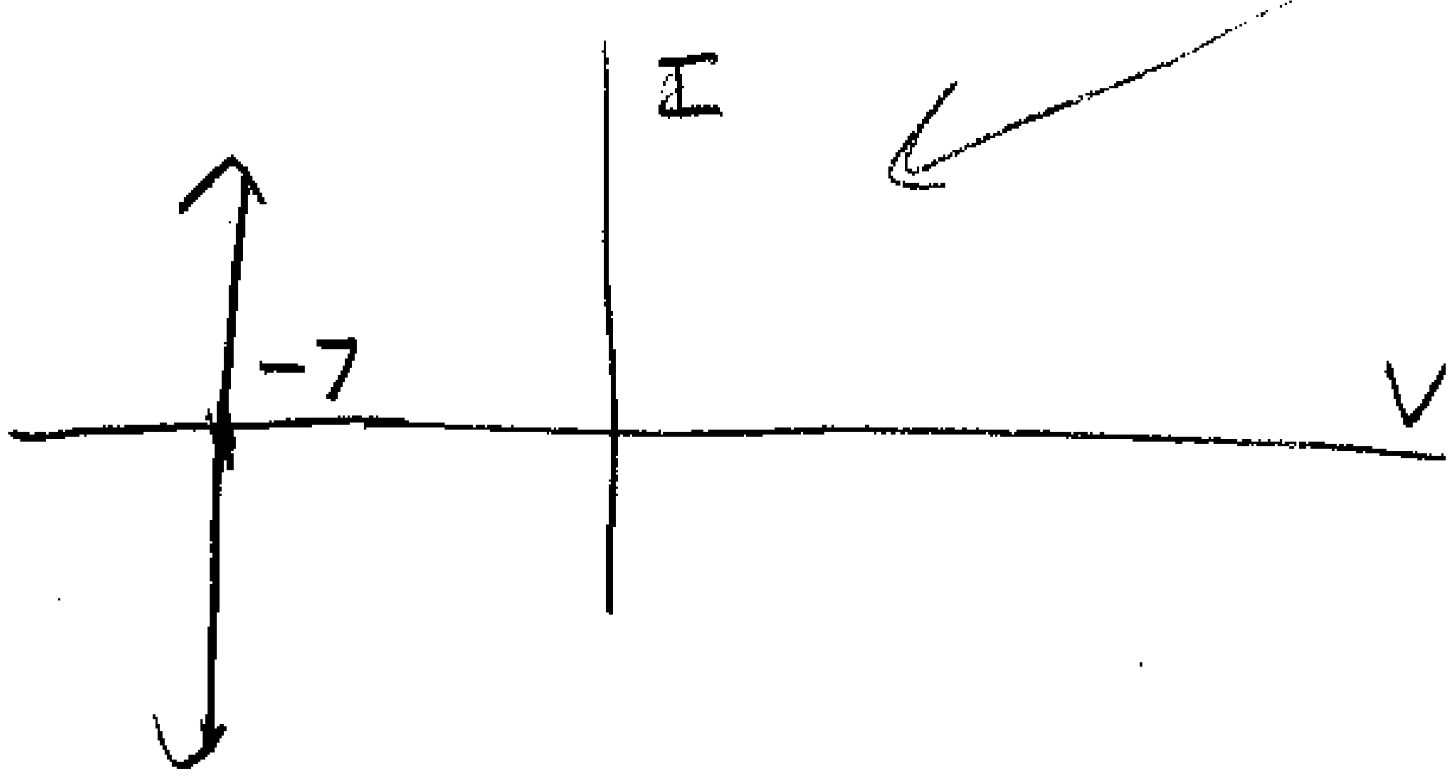
Find the Thevenin and Norton equivalents (if possible) for the following circuits:
(3 Points Possible for each Thevenin, 2 Points Possible for each Norton)



This is the Thevenin equiv.

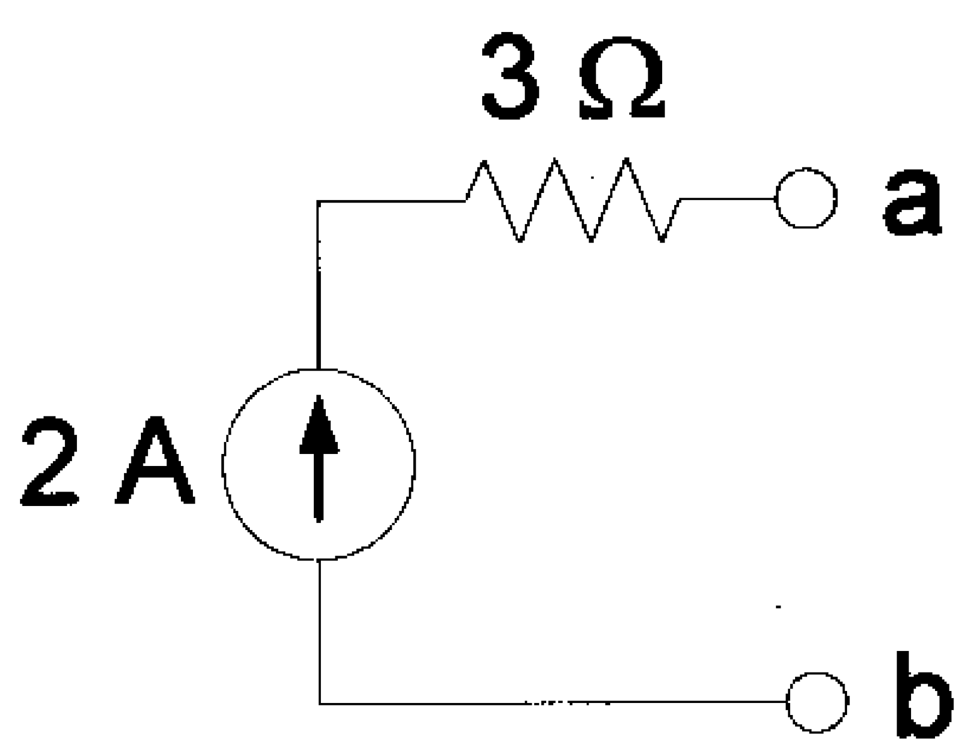
$V_T = -7\ V \quad R_T = 0\,\Omega$

I-V graph



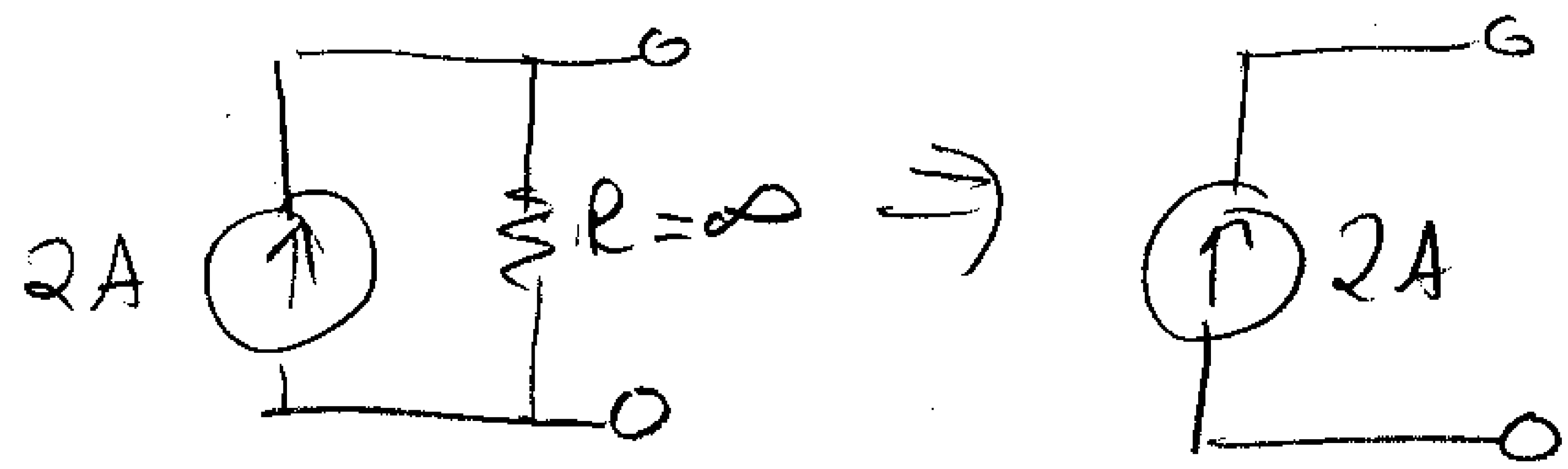
No Y-intercept ⇒ I_N does not exist

Norton equiv does not exist!

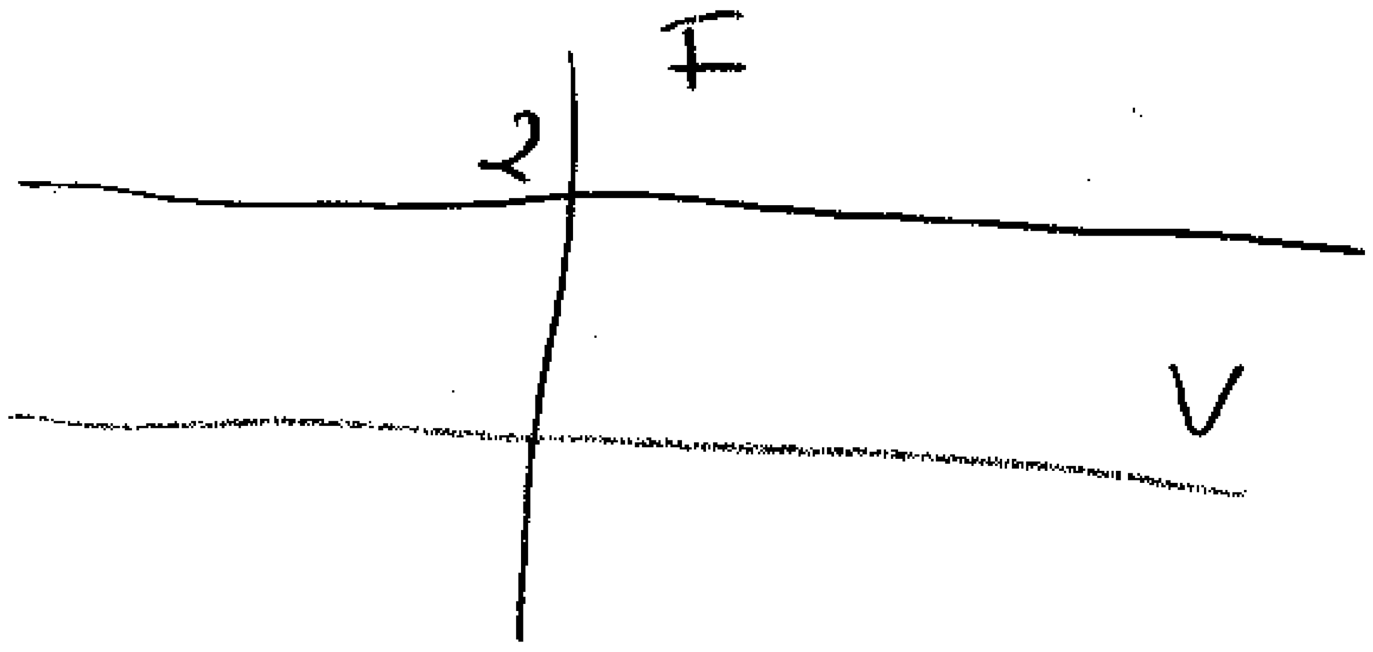


I-V graph same as 2A source alone without resistor

Norton equivalent:



I-V graph



No X-intercept ⇒ V_T does not exist

Thevenin equivalent does not exist!

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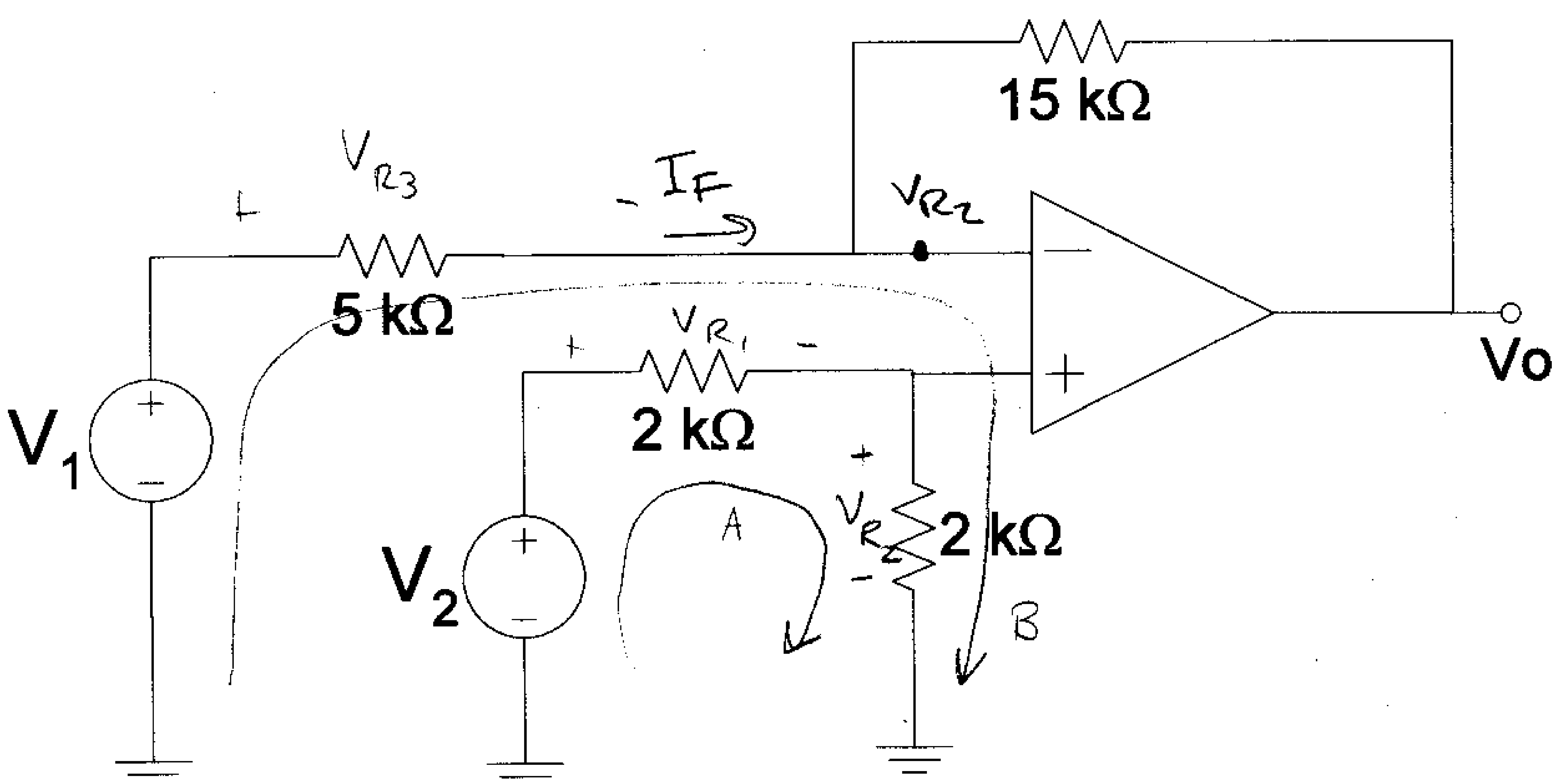
Problem 6: 15 Points Possible

For the ideal operational amplifier circuit below, find V_O in terms of V_1 and V_2. Assume that the operational amplifier is operating linearly (ignore the rails).



KVL on input loops:

A: $-V_2 + V_{R_1} + V_{R_2} = 0$

but since same resistance and same current (no current into op-amp input),

$-V_2 + 2V_{R_2} = 0$

$V_{R_2} = V_2/2$

B: $-V_1 + V_{R3} + V_{R_2} = 0$

$V_{R3} = V_1 - V_{R2} = V_1 - V_2/2$

Feedback current:

$I_F = \frac{V_{R3}}{5k} = \frac{V_1}{5k} - \frac{V_2}{10k}$

KVL on output loop:

$-V_O - 15k I_F + V_{R2} = 0$

$V_O = V_{R_2} - 15k I_F$

$= \frac{V_2}{2} - 15k\left(\frac{V_1}{5k} - \frac{V_2}{10k}\right)$

$= \frac{V_2}{2} - 3V_1 + 1.5V_2$

$= \boxed{2V_2 - 3V_1}$

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Problem 7: 15 Points Possible

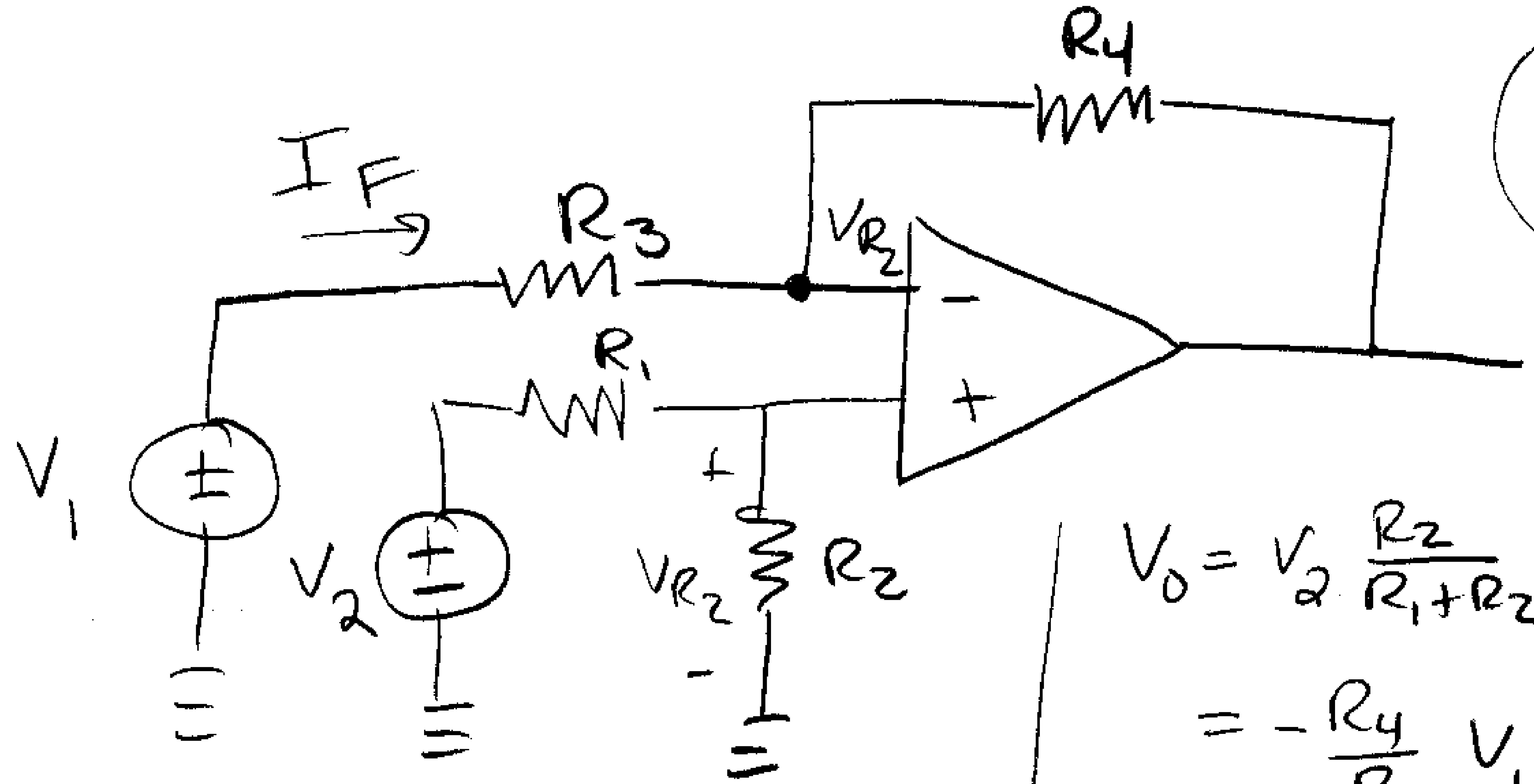
Design an operational amplifier circuit that has an output voltage $V_O = 3\,V_2 - 5\,V_1$. The input voltage sources V_1 and V_2 cannot be detached from ground, and each have their negative terminals at ground. Assume that your amplifier is operating linearly.

You will lose 5 points if you use more than one differential amplifier. If you are desperate, the instructor will "sell" you a hint for points.

$3V_2 - 5V_1$ has same form as Problem 6

(V_2 on non-inverting, V_1 on inverting terminal)

Use same circuit, change values:



Many possible answers!

$$V_0 = V_2 \frac{R_2}{R_1+R_2} - \frac{R_4}{R_3}\left(V_1 - V_2 \frac{R_2}{R_1+R_2}\right)$$

$$= -\frac{R_4}{R_3} V_1 + \left(1 + \frac{R_4}{R_3}\right)\left(\frac{R_2}{R_1+R_2}\right) V_2$$

$$R_4/R_3 = 5 \Rightarrow (1+5)\left(\frac{R_2}{R_1+R_2}\right) = 3$$

$$\Rightarrow \frac{R_2}{R_1+R_2} = 1/2$$

$R_4 = 5\,k\Omega$
$R_1 = R_2 = R_3 = 1\,k\Omega$

Same analysis:

$$V_{R_2} = V_2 \cdot \frac{R_2}{R_1+R_2}$$

$$I_F = \frac{V_1 - V_{R_2}}{R_3} = \frac{V_1 - V_2 \frac{R_2}{R_1+R_2}}{R_3}$$

$$-V_0 - R_4 I_F + V_{R_2} = 0 \Rightarrow V_0 = V_{R_2} - R_4 I_F$$

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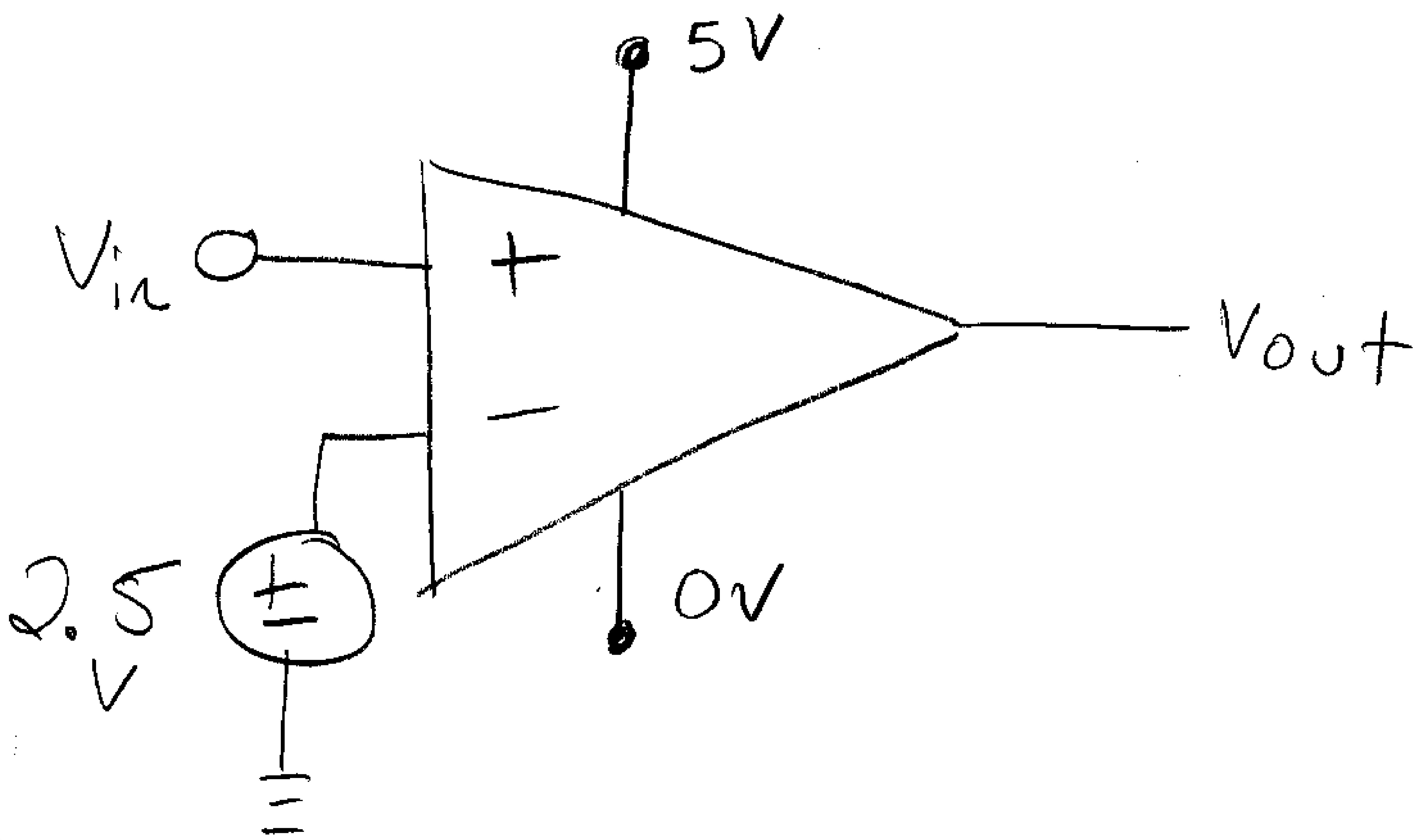
Problem 8: 5 Points Possible

Suppose that we want to "clean up" a logic signal by transforming input voltages over 2.5 V (the threshold voltage) to 5 V (logic 1) as output and voltages under 2.5 V to logic 0. Design a differential amplifier circuit that will perform this function. You may use one ideal differential amplifier; $R_i=\infty$, $R_O = 0\ \Omega$ and gain $A=\infty$. You must specify the rail voltages for this amplifier.



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Problem 9: 15 Points Possible

Now suppose that your differential amplifier circuit from Problem 8 has a finite gain A = 10,000. For the input $v_i(t)$ defined below, determine the propagation delay t_p, where t_p= time output reaches 50% of final value - time input reaches 50% of final value.

$$v_i(t) = \begin{cases} 0 & \text{for } t < 0 \\ t & \text{for } 0 \le t \le 5 \\ 5 & \text{for } t > 5 \end{cases}$$

t in seconds, v_i in volts

time input reaches 50% of f.v. is

time $V_i(t) = 2.5\ V$

$t = 2.5\ s$ (from above definition)

During transition, Vout has equation

$V_{out}(t) = A(V_p - V_n) = 10^4(V_i(t) - 2.5\ V)$

$= 10^4 V_i(t) - 2.5 \cdot 10^4$

Want $V_{out}(t) = 2.5$

$2.5 = 10^4 V_i(t) - 2.5 \cdot 10^4$

$10^4 V_i(t) = 2.5 + 2.5 \cdot 10^4$

$V_i(t) = 2.5 + 2.5 \cdot 10^{-4}$

this occurs when $t = 2.5 + 2.5 \cdot 10^{-4}$

difference in times: $2.5 + 2.5 \cdot 10^{-4} - 2.5 = 250\,\mu s$

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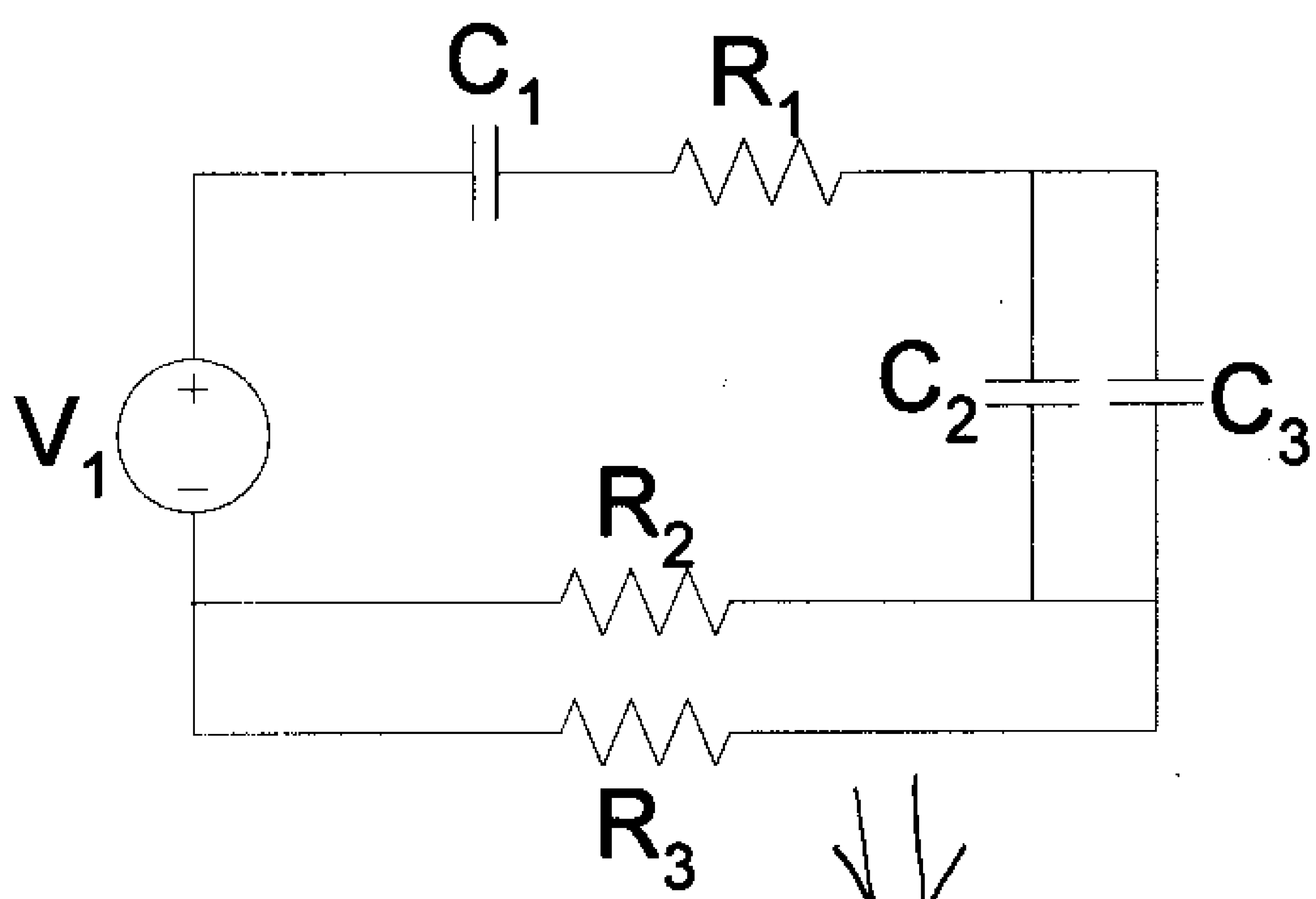
Problem 10: 10 Points Possible

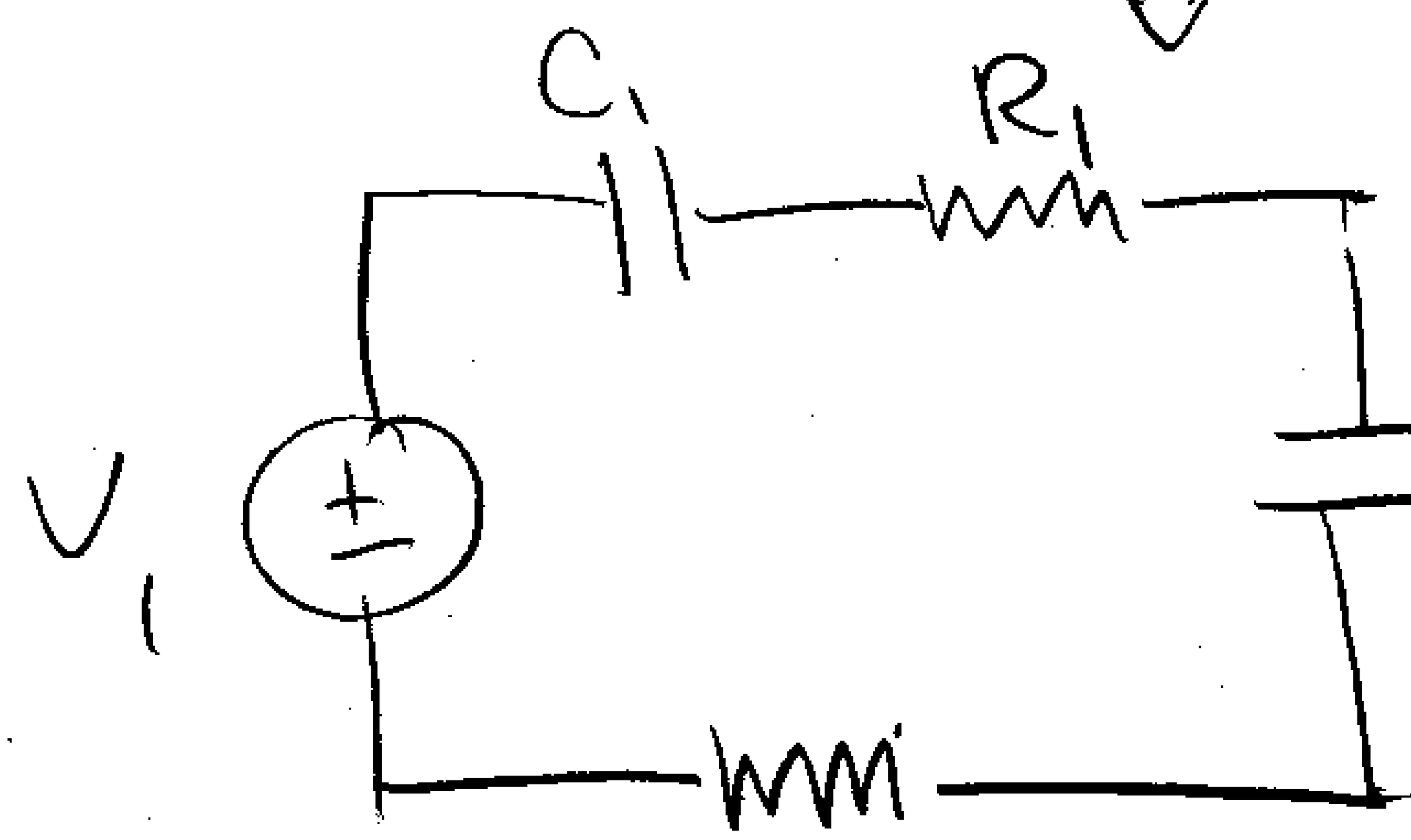
Find the time constant for the RC circuit below. DO NOT INCLUDE || symbol in final answer; write the full mathematical expression.



$$\tau = R_{eq} C_{eq}$$

$$= \left(R_1 + \frac{R_2 R_3}{R_2 + R_3}\right)\left(\frac{C_1(C_2+C_3)}{C_1+C_2+C_3}\right)$$

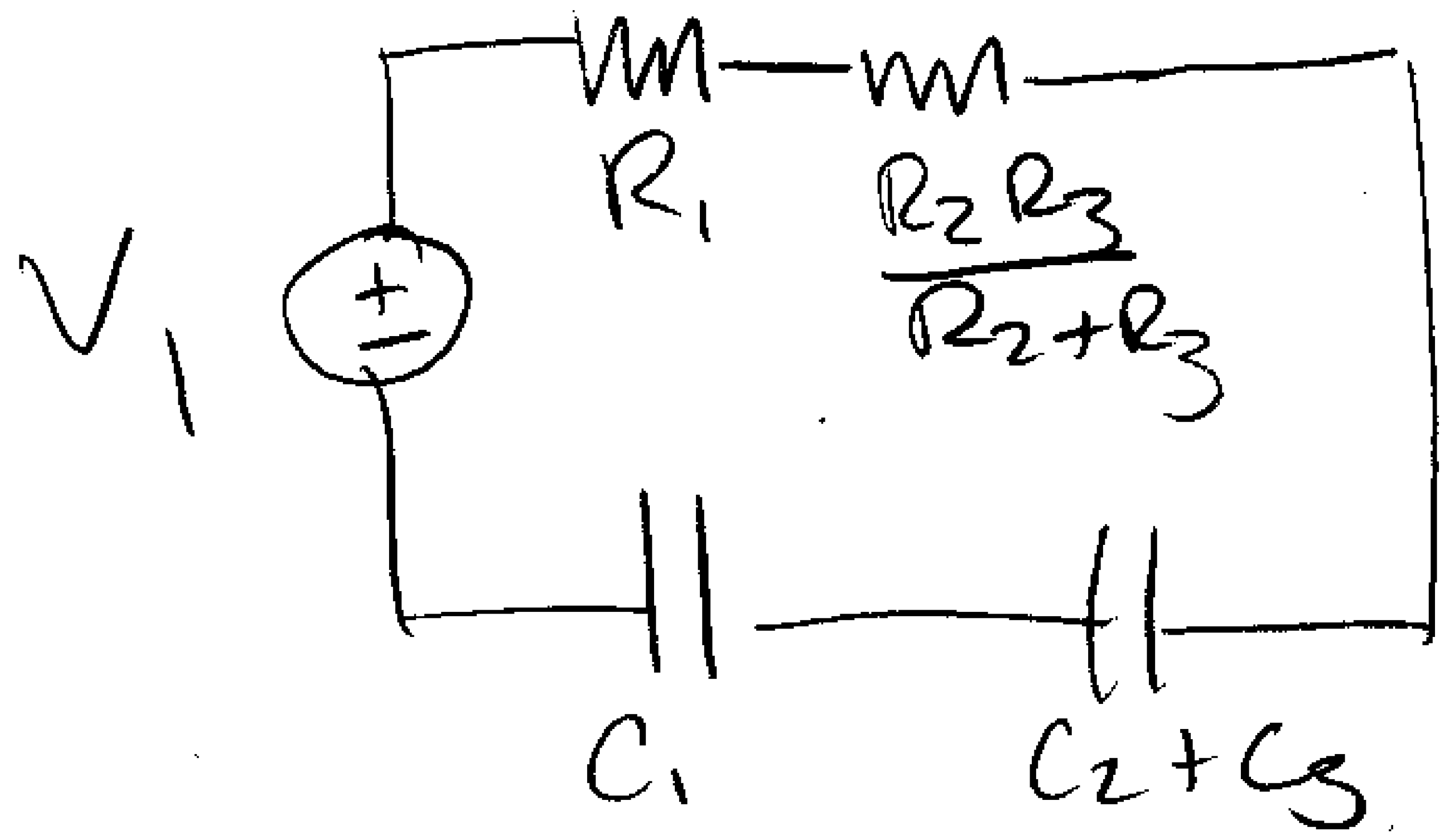
$\Downarrow$



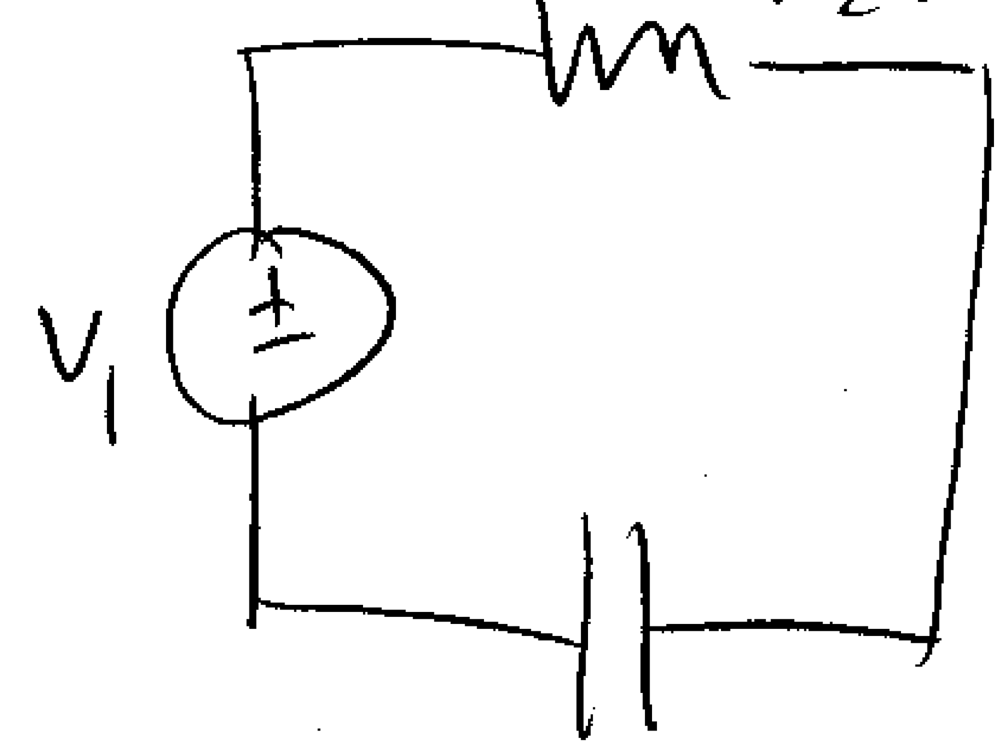
$C_2 \| C_3 = C_2 + C_3$

$R_2 \| R_3 = \frac{R_2 R_3}{R_2 + R_3}$

$\Downarrow$



$\Rightarrow$



$$\frac{C_1(C_2+C_3)}{C_1+C_2+C_3}$$