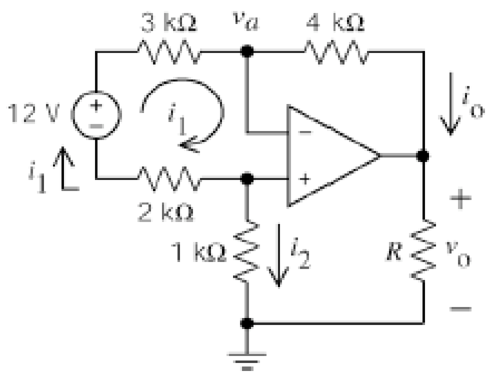
P6.4-2



Apply KVL to loop 1:

$$-12+3000\,i_1+0+2000\,i_1 = 0$$

$$\Rightarrow i_1 = \frac{12}{5000} = 2.4 \text{ mA}$$

The currents into the inputs of an ideal op amp are zero so

$$i_o = i_1 = 2.4 \text{ mA}$$

$$i_2 = -i_1 = -2.4 \text{ mA}$$

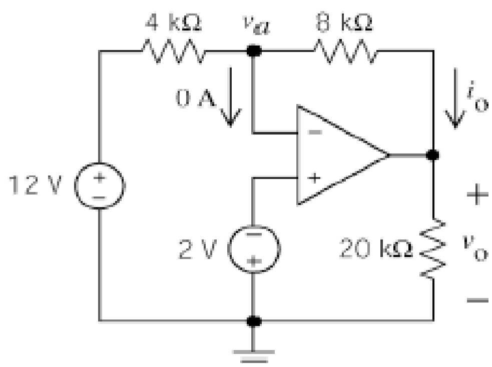
$$v_a = i_2(1000)+0 = -2.4 \text{ V}$$

Apply Ohm's law to the 4 kΩ resistor

$$v_o = v_a - i_o(4000)$$

$$= -2.4-(2.4\times10^{-3})(4000) = -12 \text{ V}$$

P6.4-3



The voltages at the input nodes of an ideal op amp are equal so $v_a = -2$ V.

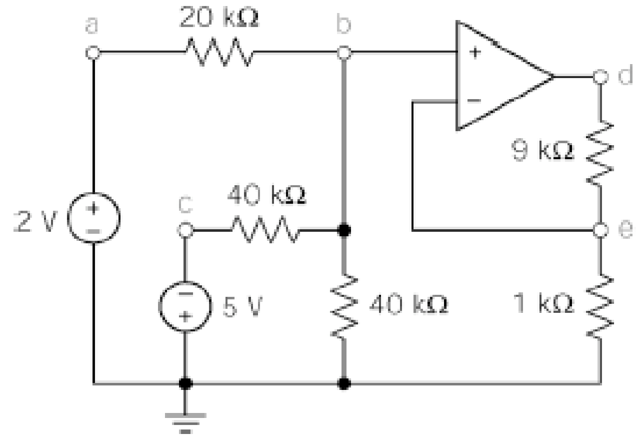
Apply KCL at node a:

$$\frac{v_o-(-2)}{8000}+\frac{12-(-2)}{4000}=0 \quad \Rightarrow v_o = -30 \text{ V}$$

Apply Ohm's law to the 8 kΩ resistor

$$i_o = \frac{-2-v_o}{8000} = 3.5 \text{ mA}$$

P6.5-1

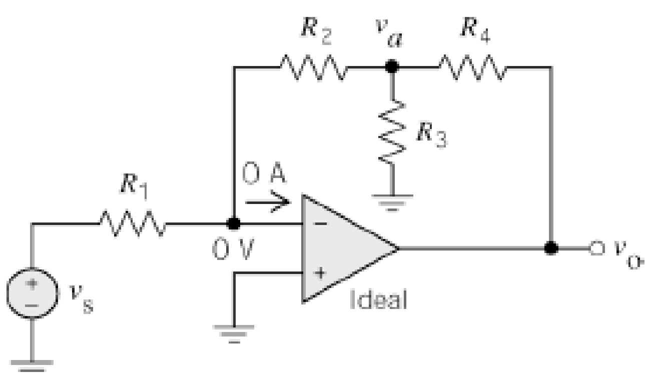


KCL at node b: $\dfrac{v_b - 2}{20000} + \dfrac{v_b}{40000} + \dfrac{v_b + 5}{40000} = 0 \Rightarrow v_b = -\dfrac{1}{4}$ V

The node voltages at the input nodes of an ideal op amp are equal so $v_e = v_b = -\dfrac{1}{4}$ V.

KCL at node e: $\dfrac{v_e}{1000} + \dfrac{v_e - v_d}{9000} = 0 \Rightarrow v_d = 10\,v_e = -\dfrac{10}{4}$ V

P6.5-3



Apply KCL at the inverting input of the op amp:

$$-\left(\frac{v_a - 0}{R_2}\right) - \left(\frac{v_s - 0}{R_1}\right) = 0$$

$$\Rightarrow v_a = -\frac{R_2}{R_1} v_s$$

Apply KCL at node a:

$$\frac{v_a - v_0}{R_4} + \frac{v_a}{R_3} + \frac{v_a - 0}{R_2} = 0 \Rightarrow v_0 = R_4\left(\frac{1}{R_4} + \frac{1}{R_3} + \frac{1}{R_2}\right) v_a = \frac{R_2R_3 + R_2R_4 + R_3R_4}{R_2R_3} v_a$$

$$= -\frac{R_2R_3 + R_2R_4 + R_3R_4}{R_1R_3} v_s$$

Plug in values $\Rightarrow$ yields $\dfrac{v_o}{v_s} = -\dfrac{30 + 900 + 30}{4.8} = -200$ V/V

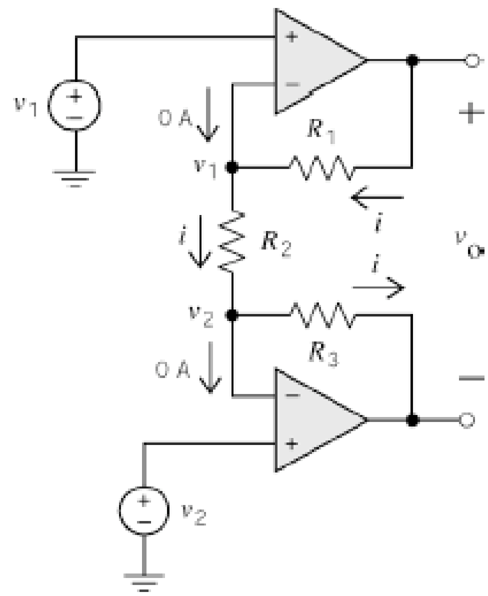
P6.5-4

Ohm's law:

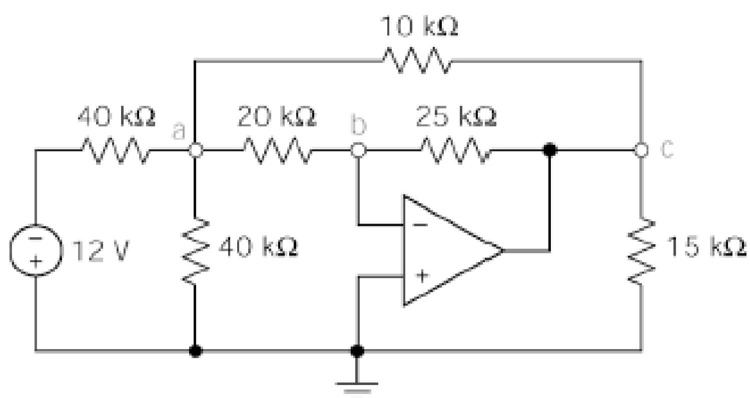
$$i = \frac{v_1 - v_2}{R_2}$$

KVL:

$$v_0 = (R_1 + R_2 + R_3)\, i = \frac{R_1 + R_2 + R_3}{R_2}(v_1 - v_2)$$



P6.5-6



KCL at node b: $$\frac{v_a}{20\times 10^3} + \frac{v_c}{25\times 10^3} = 0 \quad \Rightarrow \quad v_c = -\frac{5}{4} v_a$$

KCL at node a: $$\frac{v_a - (-12)}{40\times 10^3} + \frac{v_a}{10\times 10^3} + \frac{v_a + 0}{20\times 10^3} + \frac{v_a - \left(-\frac{5}{4} v_a\right)}{10\times 10^3} = 0 \quad \Rightarrow \quad v_a = -\frac{12}{13} \text{ V}$$

So $$v_c = -\frac{5}{4} v_a = -\frac{15}{13}.$$