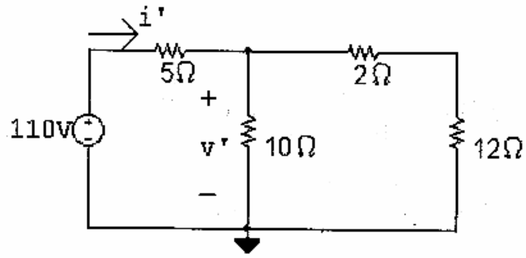
ENSC 220 – Assignment #3 Solutions

P 4.87 **[a]** 110 V source acting alone:

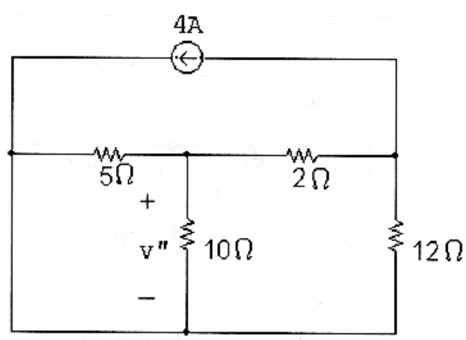


$$R_e = \frac{10(14)}{24} = \frac{35}{6}\,\Omega$$

$$i' = \frac{110}{5 + 35/6} = \frac{132}{13}\text{ A}$$

$$v' = \left(\frac{35}{6}\right)\left(\frac{132}{13}\right) = \frac{770}{13}\text{ V}$$

4 A source acting alone:

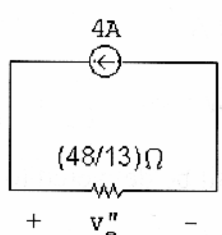


$$5\,\Omega \| 10\,\Omega = 50/15 = 10/3\,\Omega$$

$$10/3 + 2 = 16/3\,\Omega$$

$$16/3 \| 12 = 48/13\,\Omega$$

Hence our circuit reduces to:



It follows that

$$v_a'' = 4(48/13) = (192/13)\text{ V}$$

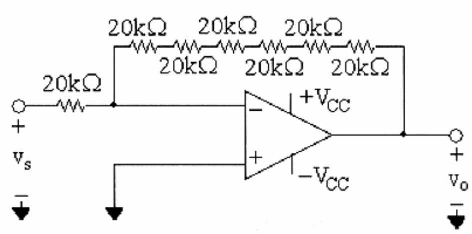
and

$$v'' = \frac{-v_a''}{(16/3)}(10/3) = -\frac{5}{8}v_a'' = -(120/13)\text{ V}$$

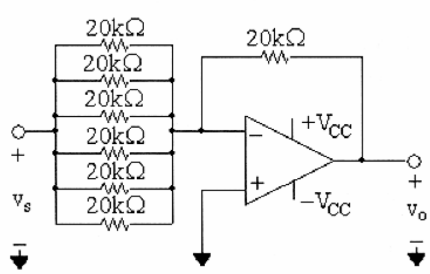
$$\therefore \quad v = v' + v'' = \frac{770}{13} - \frac{120}{13} = 50\text{ V}$$

[b] $p = \frac{v_o^2}{10} = 250\text{ W}$

P 5.6 **[a]** The gain of an inverting amplifier is the ratio of the feedback resistor to the input resistor. If the gain of the inverting amplifier is to be 6, the feedback resistor must be 6 times as large as the input resistor. There are many possible designs that use only 20 kΩ resistors. We present two here. Use a single 20 kΩ resistor as the input resistor, and use six 20 kΩ resistors in series as the feedback resistor to give a total of 120 kΩ.



Alternately, Use a single 20 kΩ resistor as the feedback resistor and use six 20 kΩ resistors in parallel as the input resistor to give a total of 3.33 kΩ.



[b] To amplify a 3 V signal without saturating the op amp, the power supply voltages must be greater than or equal to the product of the input voltage and the amplifier gain. Thus, the power supplies should have a magnitude of $(3)(6) = 18$ V.

P 5.8 $v_p = \frac{18}{24}(12) = 9\ \text{V} = v_n$

$$\frac{v_n - 24}{30} + \frac{v_n - v_o}{20} = 0$$

$$v_o = (45 - 48)/3 = -1.0\ \text{V}$$

$$i_L = \frac{v_o}{5} \times 10^{-3} = -\frac{1}{5} \times 10^{-3} = -200 \times 10^{-6}$$

$$i_L = -200\,\mu\text{A}$$

P 5.10 **[a]** Let v_Δ be the voltage from the potentiometer contact to ground. Then

$$\frac{0 - v_g}{2000} + \frac{0 - v_\Delta}{50{,}000} = 0$$

$$-25v_g - v_\Delta = 0, \qquad \therefore\ v_\Delta = -25(40 \times 10^{-3}) = -1\ \text{V}$$

$$\frac{v_\Delta}{\alpha R_\Delta} + \frac{v_\Delta - 0}{50{,}000} + \frac{v_\Delta - v_o}{(1-\alpha)R_\Delta} = 0$$

$$\frac{v_\Delta}{\alpha} + 2v_\Delta + \frac{v_\Delta - v_o}{1 - \alpha} = 0$$

$$v_\Delta \left(\frac{1}{\alpha} + 2 + \frac{1}{1-\alpha}\right) = \frac{v_o}{1-\alpha}$$

$$\therefore\ v_o = -1\left[1 + 2(1-\alpha) + \frac{(1-\alpha)}{\alpha}\right]$$

When $\alpha = 0.2, \qquad v_o = -1(1 + 1.6 + 4) = -6.6\ \text{V}$

When $\alpha = 1, \qquad v_o = -1(1 + 0 + 0) = -1\ \text{V}$

$$\therefore\ -6.6\ \text{V} \le v_o \le -1\ \text{V}$$

[b] $-1\left[1 + 2(1-\alpha) + \frac{(1-\alpha)}{\alpha}\right] = -7$

$$\alpha + 2\alpha(1-\alpha) + (1-\alpha) = 7\alpha$$

$$\alpha + 2\alpha - 2\alpha^2 + 1 - \alpha = 7\alpha$$

$\therefore\ 2\alpha^2 + 5\alpha - 1 = 0$ so $\alpha \cong 0.186$

P 5.13 **[a]** Assume the op-amp is operating within its linear range, then

$$i_L = \frac{8}{4000} = 2\,\text{mA}$$

For $R_L = 4\,\text{k}\Omega \qquad v_o = (4+4)(2) = 16\ \text{V}$

Now since $v_o < 20\ \text{V}$ our assumption of linear operation is correct, therefore

$i_L = 2\,\text{mA}$

[b] $20 = 2(4 + R_L); \qquad R_L = 6\,\text{k}\Omega$

[c] As long as the op-amp is operating in its linear region i_L is independent of R_L. From (b) we found the op-amp is operating in its linear region as long as $R_L \leq 6\,\text{k}\Omega$. Therefore when $R_L = 16\,\text{k}\Omega$ the op-amp is saturated. We can estimate the value of i_L by assuming $i_p = i_n \ll i_L$. Then $i_L = 20/(4{,}000 \ + 16{,}000) = 1\,\text{mA}$. To justify neglecting the current into the op-amp assume the drop across the 50 kΩ resistor is negligible, and the input resistance to the op-amp is at least $500\,\text{k}\Omega$. Then $i_p = i_n = (8-4)/(500 \times 10^3) = 8\,\mu\text{A}$. But $8\,\mu\text{A} \ll 1\,\text{mA}$, hence our assumption is reasonable.

[d]