

UNIVERSITY OF NOTRE DAME
DEPARTMENT OF ELECTRICAL ENGINEERING

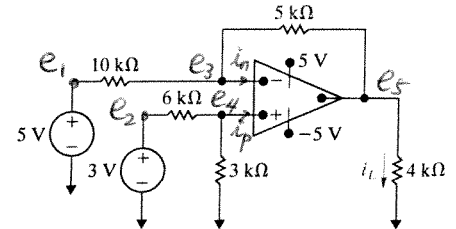
EE20224

QUIZ #5

10-7-2011

Student's Name: Solutions
(Please Print LAST, First, MI)

Problem 1 (5 pts) Assuming that the op-amp in the circuit shown is ideal, find i_L , i.e. the branch current through the 4 kΩ resistor branch. What is i_L if the load is changed to a 2 kΩ resistor.



$$\left\{ \begin{array}{l} e_1 = 5 \text{ volts} \\ e_2 = 3 \text{ volts} \\ \frac{e_1 - e_3}{10} - \frac{e_3 - e_5}{5} - i_n = 0 \\ \frac{e_2 - e_4}{6} - \frac{e_4}{3} - i_p = 0 \\ e_3 = e_4 \quad (\text{ideal op-amp, } v_n = v_p) \end{array} \right.$$

Assuming an ideal op-amp, $i_n = i_p = 0$

$$\therefore e_4 = 1 \text{ volt}^* = e_3 \Rightarrow e_5 = -1 \text{ volt}$$

$$\text{Thus } i_L = \frac{e_5}{4k\Omega} = -0.25 \text{ mA}$$

Note e_5 will remain the same when the 4kΩ resistor is changed to a 2kΩ resistor,

$$i_L = \frac{e_5}{2k\Omega} = -0.5 \text{ mA}$$

* e_4 can be obtained by simply recognizing that the input port to the non-inverting node forms a single loop ckt ($i_p = 0$). Thus $e_4 = 3 \times \frac{3}{6+3} = 1$ by voltage divider rule.

Answer: $i_L = \underline{-0.25 \times 10^{-3}}$ Amps; $i_L = \underline{-0.5 \times 10^{-3}}$ Amps

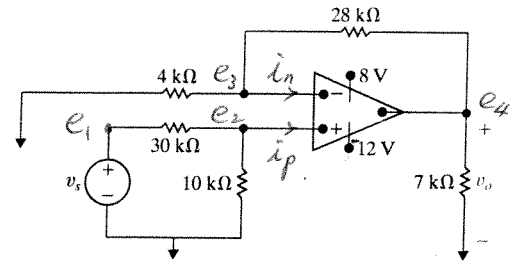
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Problem 2 (5 pts) The op-amp in the circuit shown is assumed to be ideal, and $v_s = 2$ Volts. (a) Find v_o ; (b) Now, replace the $28 \text{ k}\Omega$ resistor with a variable resistor with resistance R_f . What is the maximum value that R_f , denoted by $R_{f\max}$, can be before the op-amp gets into saturation?

Ideal Op-Amp: $i_n = i_p = 0$
 $v_n = v_p$ (hence $e_2 = e_3$)



(a) $e_1 = v_s$

$$\left. \begin{aligned} \frac{e_1 - e_2}{30} - \frac{e_2}{10} - i_p = 0 \\ -\frac{e_3}{4} - \frac{e_3 - e_4}{28} - i_n = 0 \end{aligned} \right\} e_2 = \frac{1}{4} v_s = e_3$$
 (A)

$\therefore e_4 = 8e_3 = 8 \cdot \frac{1}{4} v_s = 2v_s = 4 \text{ volts}$

i.e., $v_o = 4 \text{ volts}$

(b) When the $28 \text{ k}\Omega$ resistor is replaced by R_f , Eq. (A) becomes

$$-\frac{e_3}{4} - \frac{e_3 - e_4}{R_f} - i_n = 0$$

$\therefore v_o = e_4 = \left(1 + \frac{R_f}{4}\right) e_3 = \left(\frac{1}{2} + \frac{1}{8} R_f\right) \leq 8 \text{ volts}$

$\therefore R_{f\max} = 60 \text{ k}\Omega$

Answer: (a) $v_o = \underline{4}$ Volts; $R_{f\max} = \underline{60 \times 10^3}$ Ω