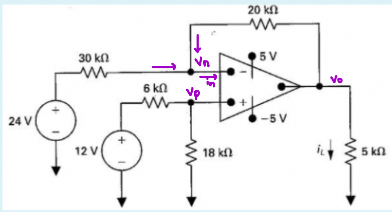
1.

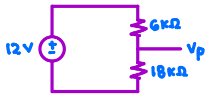


P5.02_6ed

Assume the op amp is ideal.

Determine the current i_L.

i_L = -200 μA (micro Amp)



USE VOLTAGE DIVISION

$V_p = \frac{(12V)(18k\Omega)}{18k\Omega + 6k\Omega} = 9V$

$V_n = V_p = 9V$ $\quad i_n = 0$

@ NODE V_n: $\left[\frac{V_n - 24V}{30k\Omega} + \frac{V_n - V_o}{20k\Omega} - i_n = 0\right]$ 60K

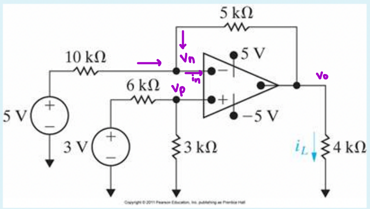
$2V_n - 48V + 3V_n - 3V_o = 0$

$5V_n - 48V = 3V_o$

$V_o = \frac{45V - 48V}{3} = -1V$

$i_L = V/R = {}^{-1V}/_{5k\Omega} = -2\times10^{-4}A \approx \boxed{-200\ \mu A}$

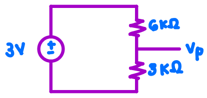
2.



P5.04_9ed

Assume the op amp is ideal.

Find i_L in this circuit. i_L = -250 μA (micro Amps)



USE VOLTAGE DIVISION

$V_p = \frac{(3V)(3k\Omega)}{3k\Omega + 6k\Omega} = 1V$

$V_n = V_p = 1V$ $\quad i_n = 0$

@ NODE V_n: $\left[\frac{V_n - 5V}{10\ k\Omega} + \frac{V_n - V_o}{5\ k\Omega} - \cancel{i_n}^{0} = 0\right]$ 10K

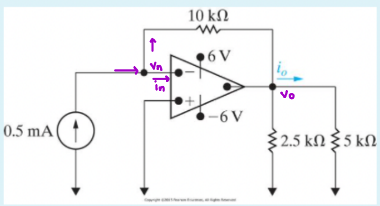
$V_n - 5V + 2V_n - 2V_o = 0$

$3(1V) - 5V = 2V_o$

$V_o = \frac{3V - 5V}{2} = -1V$

$i_L = V/R = {}^{-1V}/_{4k\Omega} = -2.5\times10^{-4}A \approx \boxed{-250\ \mu A}$

3.



P5.05_10ed

Assume the op amp is ideal.

Find current i_0 which flows through the 5k W (Ohm) resistor.

i_0 = -1 mA (milli Amp)

$V_n = V_p = 0$ $\quad i_n = 0$

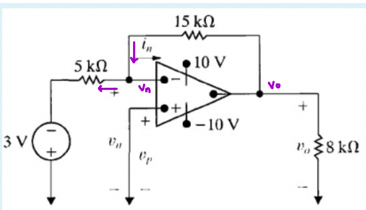
@ NODE V_n: $0.5mA - \frac{\cancel{V_n}^{0} - V_o}{10k\Omega} - \cancel{i_n}^{0} = 0$

$0.5 + \frac{V_o}{10k\Omega} = 0$

$V_o = -5V$

$i_o = \frac{V_o}{R} = \frac{-5V}{5k\Omega} = -1mA$

4.



P5.01_9ed

Assume the op amp is ideal.

a) What is the value of the current i_n? i_n = 0 A

b) What is the value of v_n? v_n = 0 V

c) Calculate v_0 in this circuit. v_0 = 9 V

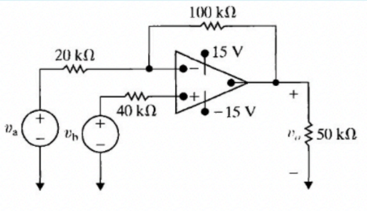
@ NODE V_n: $\left[\frac{V_n - 3V}{5k\Omega} - \frac{V_n - V_o}{15k\Omega} + i_n = 0\right]$ 15K

$3V_n - 9V - V_n + V_o = 0$

$2V_n - 9V + V_o = 0$

$V_o = 9V$

(5)



P5.03_9ed

Assume the op amp is ideal.

a) Calculate v_O if v_a = 4 V and v_b = 0 V. v_O = -15 ✔ V

b) Calculate v_O if v_a = 2 V and v_b = 0 V. v_O = -10 ✔ V

c) Calculate v_O if v_a = 2 V and v_b = 1 V. v_O = -4 ✔ V

d) Calculate v_O if v_a = 1 V and v_b = 2 V. v_O = 7 ✔ V

e) Calculate v_O if v_a = 1.5 V and v_b = 4 V. v_O = 15 ✔ V

f) If v_b = 1.6 V, specify the range of v_a such that the amplifier does not saturate.

-1.08 $\le v_a \le$ 4.92 V ✔

(a) $V_a = 4V$ $V_b = 0V$

@ NODE V_n: $\left[\frac{V_n - V_a}{20k\Omega} + \frac{V_n - V_o}{100k\Omega} = 0\right]100k$

$5V_n - 5V_a + V_n - V_o = 0$

$V_o = 6V_b - 5V_a = -5(4V) = -20V$

$-15 \le V_o \le 15$

$V_o = -15V$

(b) $V_a = 2V$ $V_b = 0V$

$V_o = V_b\left[1 + \frac{R_f}{R_{in}}\right] + V_a\left[-\frac{R_f}{R_{in}}\right]$

$V_o = 0 + 2\left[-\frac{100k}{20k}\right] = -10V$

(c) $V_a = 2V$ $V_b = 1V$

$V_o = 1\left[1 + \frac{100k}{20k}\right] + 2\left[-\frac{100k}{20k}\right]$

$= -4V$

(d) $V_a = 1V$ $V_b = 2V$

$V_o = 2\left[1 + \frac{100k}{20k}\right] + 1\left[-\frac{100k}{20k}\right]$

$= 7V$

(e) $V_a = 1.5V$ $V_b = 4V$

$V_o = 4\left[1 + \frac{100k}{20k}\right] + 1.5\left[-\frac{100k}{20k}\right]$

$= 16.5V$

$V_o \le 15V$

$V_o = 15V$

(d) $V_a = ?$ $V_b = 1.6V$

@ NODE V_n: $\left[\frac{V_n - V_a}{20k\Omega} + \frac{V_n - V_o}{100k\Omega} = 0\right]100k$

$5V_n - 5V_a + V_n - V_o = 0$

$V_o = 6V_b - 5V_a = 6(1.6) - 5V_a = 9.6 - 5V_a$

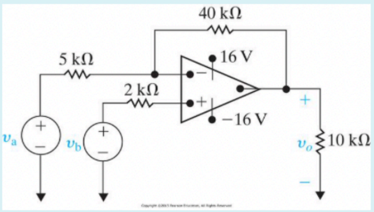
$-15V \le V_o \le +15V$

$-15V \le 9.6 - 5V_a \le +15V$

$-24.6V \le -5V_a \le 5.4V$

$4.92 \ge V_a \ge -1.08 \longrightarrow -1.08 \le V_a \le 4.92$

(6)



P5.04_10ed

Assume the op amp is ideal.

a) Calculate v_O if v_a = 1.5 V and v_b = 0 V. v_O = -12 ✔ V

b) Calculate v_O if v_a = -0.5 V and v_b = 0 V. v_O = 4 ✔ V

c) Calculate v_O if v_a = 1 V and v_b = 2.5 V. v_O = 14.5 ✔ V

d) Calculate v_O if v_a = 2.5 V and v_b = 1 V. v_O = -11 ✔ V

e) Calculate v_O if v_a = 2.5 V and v_b = 0 V. v_O = -16 ✔ V

f) If v_b = 2 V, specify the range of v_a such that the amplifier does not saturate.

0.25 $\le v_a \le$ 4.25 V ✔

(a) $\longrightarrow$ (e) $V_o = V_b\left[1 + \frac{R_f}{R_{in}}\right] + V_a\left[-\frac{R_f}{R_{in}}\right]$

(d) $V_a = ?$ $V_b = 2V$

@ NODE V_n: $\left[\frac{V_n - V_a}{5k\Omega} + \frac{V_n - V_o}{40k\Omega} = 0\right]40k$

$8V_n - 8V_a + V_n - V_o = 0$

$V_o = 9V_b - 8V_a = 9(2) - 8V_a = 18 - 8V_a$

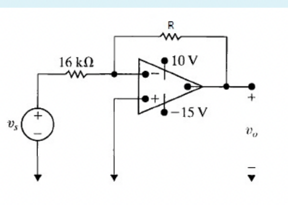
$-16V \le V_o \le +16V$

$-16V \le 18 - 8V_a \le +16V$

$-34V \le -8V_a \le -2$

$4.25 \ge V_a \ge 0.25 \longrightarrow 0.25 \le V_a \le 4.25$

(7)



AP5.02_9ed

The source voltage v_S in this circuit is -640 mV.

What range of R allows the inverting amplifier to operate in its linear region?

0 ✔ kΩ < R < 250 ✔ kΩ (kilo Ohms)

NODE V_n: $\frac{V_n - V_s}{16k\Omega} + \frac{V_n - V_o}{R} = 0$

$R(V_n - V_s) + 16k(V_n - V_o) = 0$

$\cancel{V_n}(R + 16k) - V_s R - 16k V_o = 0$

$V_o = \frac{-V_s R}{16k} = \frac{-(-640m)R}{16k}$

$= 4\times10^{-5} R$

$-15V \le V_o \le 10V$

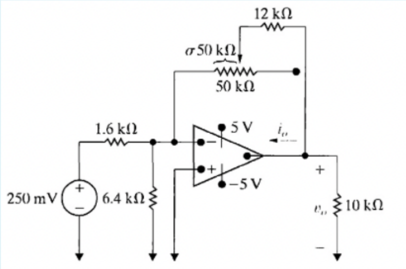
$-15 \le 4\times10^{-5}R \le 10$

$-375k \le R \le 250k$

$0 \le R \le 250k$

NO (-) R

8



P5.09_9ed

Find the range of values for σ in which the op amp does not saturate. Assume the op amp is ideal

0 ✔ ≤ σ ≤ 0.4 ✔

NODE V_n: $\frac{\overset{0}{\cancel{V_n}} - 250mV}{1.6k\Omega} + \frac{\overset{0}{\cancel{V_n}}}{6.4k\Omega} + \frac{\overset{0}{\cancel{V_n}} - V_o}{12k\Omega + \sigma 50k\Omega} = 0$

$-1.5625\times10^{-4} = \frac{V_o}{12k + \sigma 50k}$

$-1.875 - 7.8125\sigma = V_o$

$-5 \le V_o \le 5$

$-5 \le -1.875 - 7.8125\sigma \le 5$

$-3.125 \le -7.8125\sigma \le 6.875$

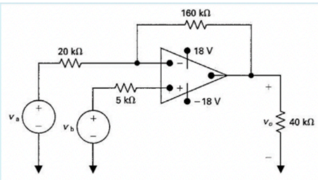
$0.4 \ge \sigma \ge -0.88$

$-0.88 \le \sigma \le 0.4$

-R is not possible

$0 \le \sigma \le 0.4$

9



P5.03_6ed

Assume the op amp is ideal

a) Find v_O for $v_a = 1.5$V and $v_b = 0$ (zero) V.

$v_O =$ -12 ✔ V

b) Find v_O for $v_a = 3.0$V and $v_b = 0$ (zero) V.

$v_O =$ -18 ✔ V

c) Find v_O for $v_a = 1.0$V and $v_b = 2$V.

$v_O =$ 10 ✔ V

d) Find v_O for $v_a = 4$V and $v_b = 2$V.

$v_O =$ -14 ✔ V

e) Find v_O for $v_a = 6$V and $v_b = 8$V.

$v_O =$ 18 ✔ V

f) Given v_a = ?? V and $v_b = 4.5$V. Find the voltage range for v_a that keeps the opamp in the linear region.

2.8125 ✔ $\le v_a \le$ 7.3125 ✔ V

(a) ⟶ (e) $V_o = V_b\left[1 + \frac{R_f}{R_{in}}\right] + V_a\left[-\frac{R_f}{R_{in}}\right]$

(d) $V_a = ?$ $V_b = 4.5V$

@ NODE V_n: $\left[\frac{V_n - V_a}{20k\Omega} + \frac{V_n - V_o}{160k\Omega} = 0\right]$ 160K

$8V_n - 8V_a + V_n - V_o = 0$

$V_o = 9V_b - 8V_a = 9(4.5) - 8V_a = 40.5 - 8V_a$

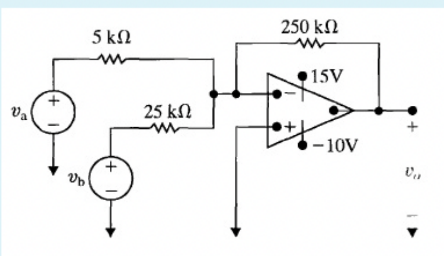
$-18\,V \le V_o \le 18V$

$-18 \le 40.5 - 8V_a \le 18$

$-58.5 \le -8V_a \le -22.5$

$7.3125 \ge V_a \ge 2.8125 \longrightarrow 2.8125 \le V_a \le 7.8125$

10.



AP5.03_9ed

Assume the op amp is ideal.

a) Find v_O in the circuit shown if $v_a = 0.1$ V and $v_b = 0.25$ V.

$v_O =$ -7.5 ✔ V

b) If $v_b = 0.25$ V, how large can v_a be before the op amp saturates?

$v_a =$ 0.15 ✔ V

$V_o = V_a\left[-\frac{R_f}{R_a}\right] + V_b\left[-\frac{R_f}{R_b}\right] + V_c\left[-\frac{R_f}{R_c}\right] + \ldots + V_n\left[-\frac{R_f}{R_n}\right]$

(a) $V_o = 0.1\left[-\frac{250K}{5k}\right] + 0.25\left[-\frac{250K}{25K}\right]$

$V_o = -7.5V$

(b) $V_o = V_a\left[-\frac{250K}{5k}\right] + 0.25\left[-\frac{250K}{25K}\right]$

$V_o = -50V_a - 2.5$

$-10V \le V_o \le 15V$

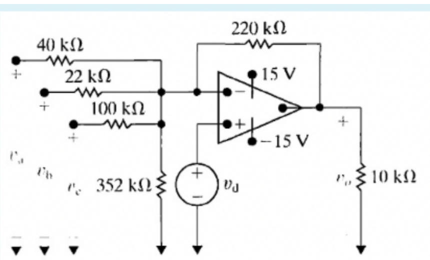
$-10 \le -50V_a - 2.5 \le 15$

$-7.5 \le -50V_a \le 17.5$

largest

$0.15 \ge V_a \ge -0.35 \longrightarrow -0.35 \le V_a \le \boxed{0.15}$

11



P5.14_9ed

Assume the op amp is ideal.

Find v_o if $v_a = 4$ V, $v_b = 9$ V, $v_c = 13$ V, and $v_d = 8$ V.

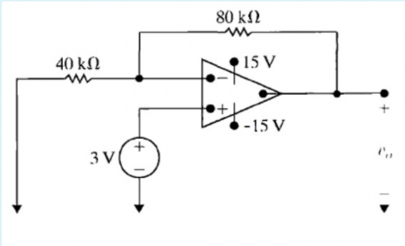
$v_o =$ 14 ✔ V

$\frac{V_n - V_a}{40K} + \frac{V_n - V_b}{22K} + \frac{V_n - V_c}{100K} + \frac{V_n}{352K} + \frac{V_n - V_o}{220K} = 0$

$\frac{8-4}{40K} + \frac{8-9}{22K} + \frac{8-13}{100K} + \frac{8}{352K} + \frac{8 - V_o}{220K} = 0$

$V_o = 14\,V$

12



P5.16_9ed

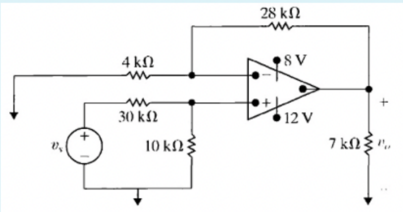
Calculate v_0 for this circuit.

v_0 = 9 V

$$V_o = V_g\left[1 + \frac{R_f}{R_s}\right]$$

$$V_o = 3V\left[1 + \frac{80k\Omega}{40k\Omega}\right] = 9V$$

13

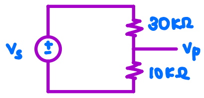


P5.17_9ed

Find v_0 in terms of v_s.

v_o/v_s = 2

Note: The figure has an error. The power supply voltages are: V^- = -12V and V^+ = 8V.



USE VOLTAGE DIVISION

$$V_p = \frac{V_s\ (10k\Omega)}{10k\Omega + 30k\Omega} = 0.25\ V_s$$

$V_n = V_p = 0.25V_s$

@ NODE V_n: $\left[\frac{V_n}{4k\Omega} + \frac{V_n - V_o}{28k\Omega} = 0\right]28$

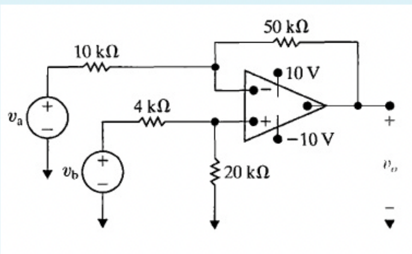
$7V_n + V_n - V_o = 0$

$V_o = 8V_n = 8(0.25V_s)$

$V_o = 2V_s$

$V_o/V_s = 2$

14

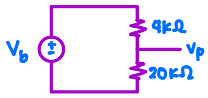


AP5.05_9ed

In the difference amplifier shown, v_b = 4.0 V.

What range of values for v_a will result in linear operation?

2 $\leq v_a \leq$ 6 V



USE VOLTAGE DIVISION

$$V_p = \frac{4.0V\ (20k\Omega)}{20k\Omega + 4k\Omega} = \frac{10}{3}$$

$V_n = V_p = \frac{10}{3}$

@ NODE V_n: $\left[\frac{V_n - V_a}{10K} + \frac{V_n - V_o}{50K} = 0\right]50K$

$5V_n - 5V_a + V_n - V_o = 0$

$V_o = 6V_n - 5V_a = 6(10/3) - 5V_a$

$V_o = 20 - 5V_a$

$-10V \leq V_o \leq 10V$

$-10 \leq 20 - 5V_a \leq 10$

$-30 \leq -5V_a \leq -10$

$6 \geq V_a \geq 2 \longrightarrow 2 \leq V_a \leq 6$