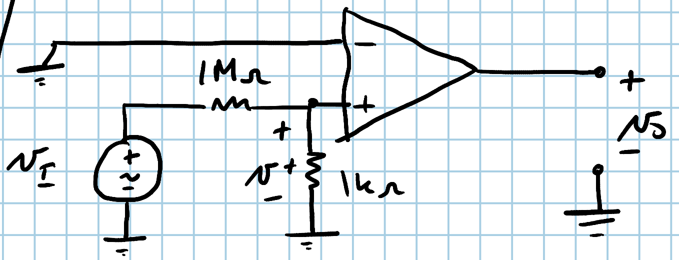
2.2



IDEAL OP-AMP EXCEPT

$A_{OL} \neq \infty$

$v_O = 4\,V$ WHEN $v_I = 2V$

$$v^- = \phi V$$

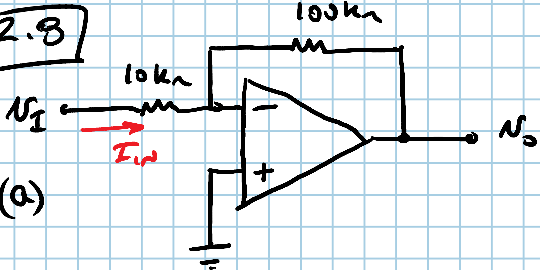
$$v^+ = \left(\frac{1k\Omega}{1000k\Omega + 1k\Omega}\right) v_I = \left(\frac{1}{1001}\right) 2V = 0.001998\,V$$

$$v_O = A_{OL}(v_2 - v_1) = A_{OL}(v^+ - v^-)$$

$$A_{OL} = \frac{v_O}{v^+ - v^-} = \frac{4}{0.001998 - 0} = \boxed{2002\ V/V}$$

2.8

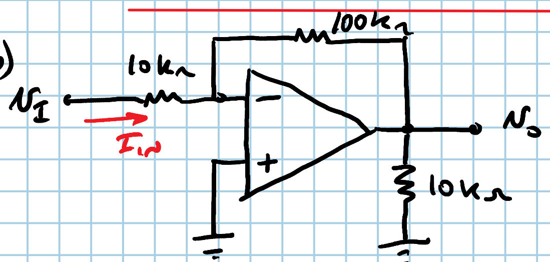
(a)



$$A_{CL} = \frac{v_O}{v_I} = -\frac{R_2}{R_1} = -\frac{100k\Omega}{10k\Omega} = \boxed{-10\,V/V}$$

$$R_{in} = \frac{V_{in}}{I_{in}} = \frac{V_{in}}{\frac{V_{in} - 0}{10k\Omega}} = \frac{V_{in}}{V_{in}/10k\Omega} = \boxed{10k\Omega}$$

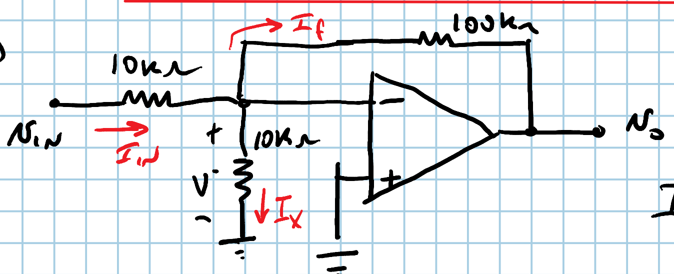
(b)



10kΩ LOAD RESISTOR CHANGED NOTHING.

$$\boxed{A_{CL} = -10,\quad R_{in} = 10k\Omega}$$

(c)

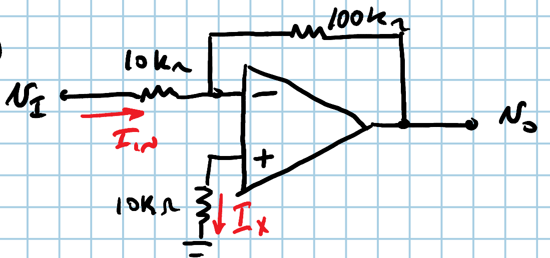


$V^+ = \phi V \Rightarrow V^- = \phi V$

$$I_{IN} = \frac{v_{IN}}{10k\Omega},\quad R_{in} = \frac{v_{IN}}{I_{IN}} = \frac{v_{IN}}{\frac{v_{IN}}{10k\Omega}} = \boxed{10k\Omega}$$

$$I_X = \frac{\phi V - \phi V}{10k\Omega} = \phi A \Rightarrow I_{in} = I_f \Rightarrow \boxed{A_{CL} = -10}$$

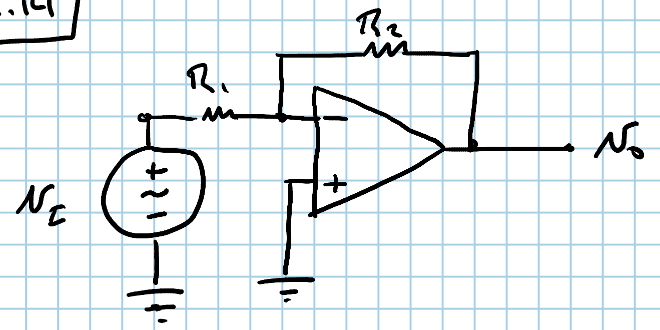
(d)



$$I_X = \phi A \Rightarrow \boxed{A_{CL} = -10}$$

$$\boxed{R_{in} = 10k\Omega}$$

2.14



IDEAL OP-AMP, MAX RESISTANCE: 1 MΩ

$$A_{CL_{dB}} = 26\ dB = 20\log\left[\left|\frac{v_O}{v_I}\right|\right]$$

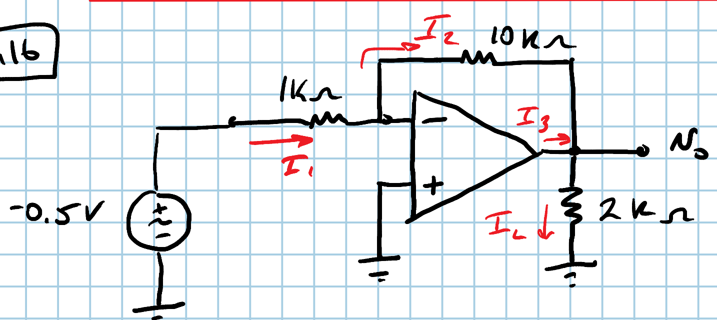
$$\Rightarrow \left|\frac{v_O}{v_I}\right| = 19.95$$

$$\therefore \frac{v_O}{v_I} = -19.95 \quad \text{(INV. AMP)}$$

ALSO, $\frac{R_2}{R_1} = 19.95$, $R_{IN} = R_1$

IF $\boxed{R_2 = 1\ M\Omega}$, $R_1 = \frac{1M\Omega}{19.95} = \boxed{50.12k\Omega}$

2.16



$$I_1 = \frac{-0.5V-0}{1k\Omega} = \boxed{-0.5\ mA}$$

$$I_2 = I_1 = \boxed{-0.5mA}$$

$$\boxed{V^+ = 0V}$$

$$V^- = V^+ = \boxed{0V}$$

$$v_O = -\left(\frac{10k\Omega}{1k\Omega}\right)v_I = -(10)(-0.5V) = \boxed{+5V}$$

$$I_L = \frac{v_O}{R_L} = \frac{+5V}{2k\Omega} = \boxed{2.5\ mA}$$

$$I_3 = I_L - I_2 = 2.5mA - (-0.5mA)$$

$$\boxed{I_3 = 3mA}$$

2.20

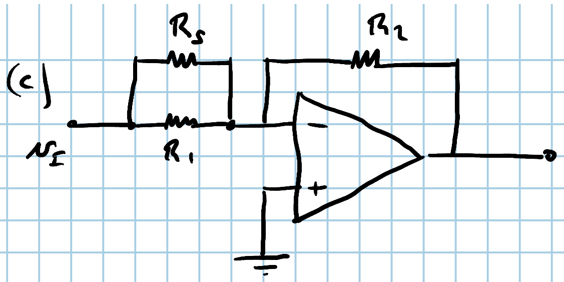
(a) $A_{CL} = -100\ V/V$, $R_{IN} = 1k\Omega \Rightarrow \boxed{R_1 = 1k\Omega}$

$$A_{CL} = -100 = \frac{-R_2}{R_1} \Rightarrow \boxed{R_2 = 100k\Omega}$$

(b) $A_{OL} = 2000$, $A_{CL} = \frac{-R_2}{R_1 + \left(\frac{R_1+R_2}{A_{OL}}\right)} = \frac{-100}{1+\left(\frac{1+100}{2000}\right)} = \boxed{-95.2}$

PART (c) →

$\boxed{2.20}$ (c)



$R_1^* = R_1 // R_S$

$$A_{CL} = \frac{-R_2}{R_1^* + \left(\frac{R_1^* + R_2}{A_{OL}}\right)} = -100 \left(\text{IDEAL } A_{CL}\right)$$

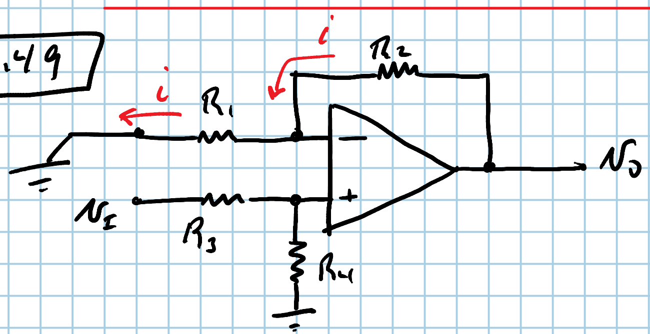
$$\cancel{-100} = \frac{-1\cancel{00}}{R_1^* + \frac{R_1^* + R_2}{2000}}$$

$$1 = \frac{1}{R_1^* + \frac{R_1^* + 100}{2000}} \Rightarrow R_1^* + \frac{R_1^* + 100}{2000} = 1 \Rightarrow R_1^* = 0.9495\,k\Omega$$

$$R_1^* = R_1 // R_S = 1k\Omega // R_S = 0.9495\,k\Omega$$

$$\frac{1}{1k\Omega} + \frac{1}{R_S} = \frac{1}{0.9495\,k\Omega} \Rightarrow \boxed{R_S = 18.8\,k\Omega}$$

$\boxed{2.49}$



CLOSED-LOOP NEGATIVE FEEDBACK

$\therefore\ V^- = V^+$

$$V^+ = \left(\frac{R_4}{R_3 + R_4}\right) v_I \Rightarrow v_I = \left(\frac{R_3 + R_4}{R_4}\right) V^+$$

ALSO, $$v_I = \left(\frac{R_3 + R_4}{R_4}\right) V^-$$

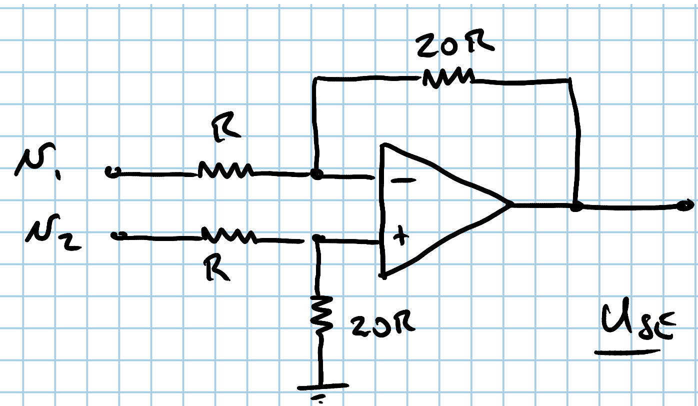
$$v_I = \left(1 + \frac{R_3}{R_4}\right) V^-$$

$$i = \frac{V^-}{R_1} = \frac{v_O - V^-}{R_2} \Rightarrow \frac{R_2}{R_1} V^- + V^- = v_O$$

$$v_O = \left(1 + \frac{R_2}{R_1}\right) V^-$$

$$\frac{v_O}{v_I} = \frac{\left(1 + \frac{R_2}{R_1}\right) V^-}{\left(1 + \frac{R_3}{R_4}\right) V^-} = \boxed{\frac{1 + \frac{R_2}{R_1}}{1 + \frac{R_3}{R_4}} = A_{CL} = \frac{v_O}{v_I}}$$

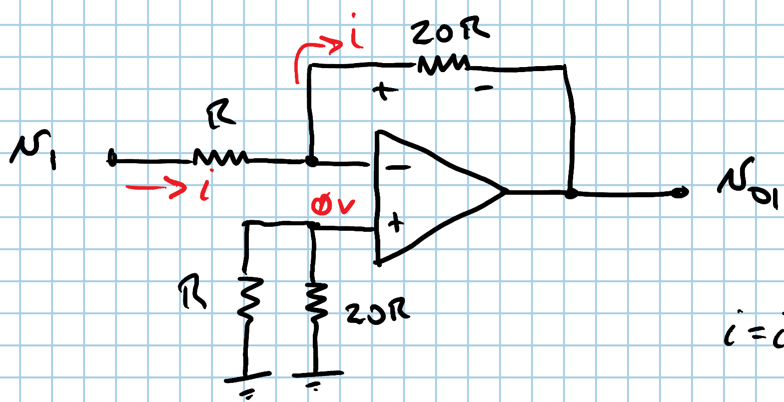
$\boxed{2.50}$



$v_o = f(v_1, v_2)$

USE SUPERPOSITION

① GROUND v_2



$i = \frac{v_1 - 0}{R} = \frac{v_1}{R}$

$i = \frac{0 - v_o}{20R} = \frac{-v_o}{20R}$

$i = i \Rightarrow \frac{v_1}{R} = \frac{-v_o}{20R}$

$\underline{\underline{v_{o1} = -20\, v_1}}$

② GROUND v_1, UN-GROUND v_2

IN GENERAL, $v_o = \left(\frac{R_2}{R_1} + 1\right) v_I$

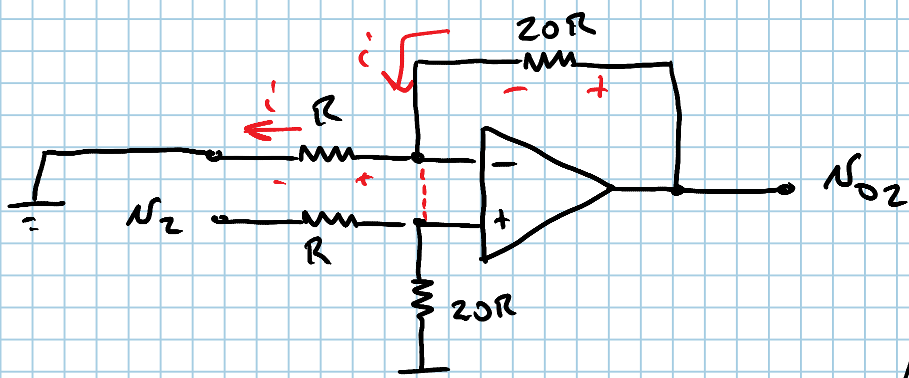
$v_I = V^+ = \left(\frac{20R}{R + 20R}\right) v_2$

$R_2 = 20R$

$R_1 = R$

$v_{o2} = \left(\frac{20R}{R} + 1\right)\left(\frac{20R}{21R}\right) v_2$

$v_{o2} = (21)\left(\frac{20}{21}\right) v_2 = \underline{\underline{20\, v_2}}$

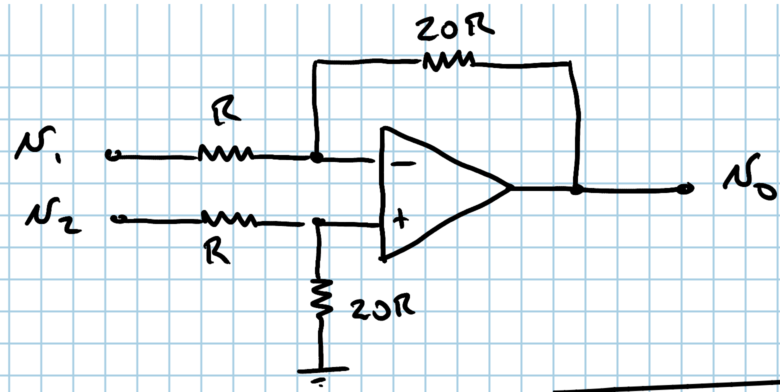


$V^+ = \left(\frac{20R}{21R}\right) v_2 = \frac{20}{21} v_2$, $V^- = V^+ = \frac{20}{21} v_2$

$i = \frac{V^-}{R} = \frac{20}{21}\frac{v_2}{R}$, $i = \frac{v_{o2} - \frac{20}{21} v_2}{20R}$

$i = i \Rightarrow \underline{\underline{v_{o2} = 20\, v_2}}$

$\boxed{2.50}$ (CONT.)



$$v_o = v_{o1} + v_{o2} = -20 v_1 + 20 v_2 = \boxed{20 (v_2 - v_1) = v_o}$$

IF $v_1 = 10 \sin(2\pi \times 60t) - 0.1 \sin(2\pi \times 1000t)$ V

$v_2 = 10 \sin(2\pi \times 60t) + 0.1 \sin(2\pi \times 1000t)$ V

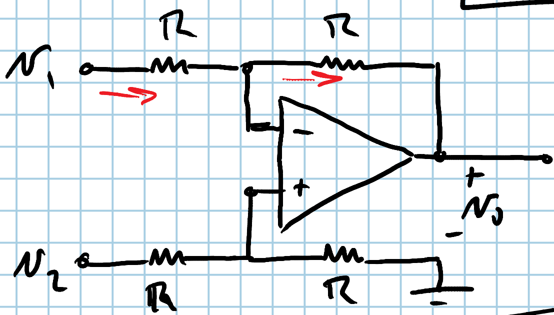
$$v_o = 20 (v_2 - v_1),$$

$$v_2 - v_1 = \left[\cancel{10 \sin(2\pi \times 60t)} + 0.1 \sin(2\pi \times 1000t)\right] - \left[\cancel{10 \sin(2\pi \times 60t)} - 0.1 \sin(2\pi \times 1000t)\right]$$

$$v_2 - v_1 = 0.2 \sin(2\pi \cdot 1000t)$$

$$v_o = 20 \; v_2 - v_1 = 4 \sin(2\pi \times 1000t) \text{ V}$$

$\boxed{2\text{-}62}$

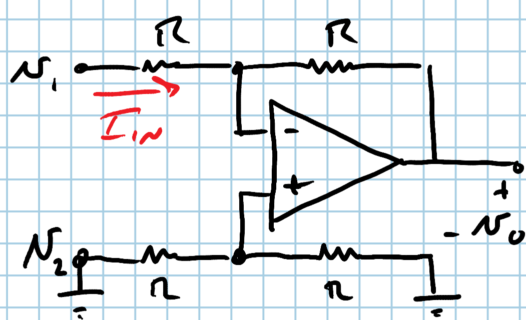


$$v^+ = \left(\frac{R}{R+R}\right) v_2 = \frac{1}{2} v_2 = v^-$$

$$\frac{v_1 - v^-}{R} = \frac{v^- - v_o}{R} \Rightarrow v_1 - \frac{1}{2} v_2 = \frac{1}{2} v_2 - v_o$$

$$\therefore \boxed{v_o = v_2 - v_1}$$

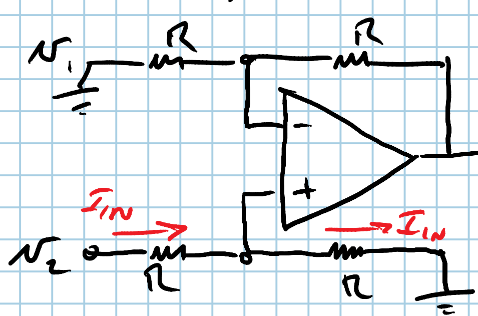
FIND R_{IN} SEEN BY v_1 ALONE



$$R_{IN} = \frac{v_1 - \cancelto{0}{v^-}}{I_{IN}} \qquad (v^+ = v^- = \phi V)$$

$$R_{IN} = \frac{v_1}{I_{IN}} = \boxed{R}$$

FIND R_{IN} SEEN BY v_2 ALONE



$$R_{IN} = \frac{v_2}{I_{IN}} = 2R$$

$$I_{IN} = \frac{v_2}{2R} \Rightarrow R_{IN} = 2R$$