Ex:

Rail voltage = ±9 V

a) The above circuit operates in linear mode. Derive a symbolic expression for \( v_o \).
The expression must contain not more than the parameters \( i_s, v_s, R_1, R_2, \) and \( R_3 \).

b) If \( v_s = 0 \) V, find the value of \( R_2 \) that will yield an output voltage of \( v_o = 1 \) V when \( i_s = 1 \) mA.

c) Using the value of \( R_2 \) from part (a), find the value of \( v_s \) that will yield \( v_o = 1 \) V when \( i_s = 0 \) A.

d) Using the value of \( R_2 \) from part (a), calculate the input resistance, \( R_{in} = v_1/i_s \), seen by the \( i_s \) source.

\[ \text{sol'n: a) } \]
First, we find the voltage, \( v_1 \), at the + input of the op-amp.

\[ v_1 = i_s \cdot R_{1||R_2} \]

Second, we assume the voltage, \( v_n \), at the - input of the op-amp = \( v_i \).
\[ V_n = i_d \cdot R_1 \parallel R_2 \]

Third, we find the value of \( V_0 \) that yields the above value of \( V_n \).

Since no current flows into the op-amp inputs, no current flows in \( R_3 \), and \( R_3 \) has no voltage drop.

\[ \therefore V_0 = V_n - V_g \]

or \[ V_0 = i_d \cdot R_1 \parallel R_2 - V_g \]

b) Given \( V_g = 0V \) and \( i_d = 1mA \) we are to find the value of \( R_2 \) that yields \( V_0 = 1V \).

Using the expression in (a) for \( V_0 \) we have

\[ 1V = 1mA \cdot 2k\Omega \parallel R_2 - 0V \]

or \[ 2k\Omega \parallel R_2 = 1k\Omega \]

or \[ R_2 = 2k\Omega \]

\[ \text{or} \]

\[ V_g = -1V \]

\[ \text{or} \]

\[ V_g = -1V \]

\[ \text{or} \]

\[ V_g = -1V \]
d) From part (a), we have the following:

\[ v_1 = i_s \cdot R_1 \parallel R_2 \]

\[ R_{in} = \frac{v_1}{i_s} = R_1 \parallel R_2 = 1k\Omega \]