Ex. 2.4 Solution Plan: We need to find the different behaviors of the OPAMP under varying conditions of input resistance. This can be done by taking each case separately and applying KCL & KVL to each case.

**Case 1: Switch Open**

\[ R_1 = R_2 = R_3 = R. \]

\[ V_s = R_2 i_2 + V_{in}. \]

But \( i_2 = 0 \) by summing constraint.

\[ V_{s} = V_{in}. \]

\[ i_1 = \frac{V_{in} - V_s}{R_1} = 0, \]

\[ i_3 = i_1 = 0 \]

\[ V_o = -R_3 i_3 + V_s \]

\[ = 0 + V_s \]

\[ = V_{in}. \]

Thus \( V_o = V_{in} \) and gain \( A_v = \frac{V_o}{V_{in}} \)

\[ A_v = 1 \]

\[ \Rightarrow R_{in} = \infty \]

**Case 2: Switch Closed**

The above problem discusses important applications of OPAMPs. This is the case of voltage followers. In this case, we manipulate the input resistance by adding a resistor. The OPAMP in this problem is used in the non-inverting configuration to amplify the input signal. Further analysis of this circuit for voltage gain is required.
\( i_1 = \frac{V_{in}}{R_1} \)
\( V_o = -R_3 i_3 \)
\( V_o = -\frac{R_3}{R_1} V_{in} \)

\[ A_v = -1 \]

\[ R_{in} = \frac{V_{in}}{i_{in}} = \frac{V_{in}}{i_1 + i_2} \]
\[ = \frac{V_{in}}{\frac{V_{in}}{R_1} + \frac{V_{in}}{R_2}} \]
\[ = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}} \]

But \( R_1 = R_2 = R_3 = R \)

\[ R_{in} = \frac{R}{2} \]

**Inference:** The above problem discusses important applications of OPAMP. In case 1, we saw that \( V_o = V_{in} \). This is the case of voltage follower. In the 2nd case, we can manipulate the input resistance by adding a switch. The OPAMP was used in the inverting configuration here.

**Ex2.6 Solution Plan:** The OPAMP in this problem is used in the non-inverting configuration. We need to analyze this circuit for voltage gain.
a) \[ V_i = V\text{in} \]
\[ i_1 = \frac{V\text{in}}{R_1} \]
\[ V_2 = V_1 + R_2 i_1 \]

\[ V_2 = V\text{in} + \frac{R_2}{R_1} V\text{in} \]
\[ = V\text{in} \left( \frac{R_1 + R_2}{R_1} \right) \]
\[ i_2 = \frac{V_2}{R_1} = V\text{in} \left( \frac{R_1 + R_2}{R_1} \right) \]

\[ i_3 = i_1 + i_2 = \frac{V\text{in}}{R_1} + V\text{in} \left( \frac{R_1 + R_2}{R_1^2} \right) \]

\[ i_3 = V\text{in} \left( \frac{2R_1 + R_2}{R_1^2} \right) \]

\[ V_o = R_2 i_3 + V_2 = V\text{in} \left( \frac{R_1^2 + R_2^2 + 3R_1R_2}{R_1^2} \right) \]

\[ V_o = V\text{in} \left( 1 + \left( \frac{R_2}{R_1} \right)^2 + \frac{3R_2}{R_1} \right) \]

\[ AV = \frac{V_o}{V\text{in}} = 1 + 3 \frac{R_2}{R_1} + \left( \frac{R_2}{R_1} \right)^2 \]

b) \[ AV \text{ for } R_1 = 1\,\text{K}\Omega \text{ and } R_2 = 10\,\text{K}\Omega \]
\[ AV = 131 \]

c) \[ R_{in} = \frac{V\text{in}}{V\text{in}} \]
\[ R_{in} = \infty \]

d) \( V_o \) is independent of \( R_o \). Therefore \( R_o = \infty \).
Solution Plan: Here we will study clipper circuits.

The circuit is shown in Fig 2.29 in the text. The OPAMP limits at output voltages of ±12V and currents of ±25mA. The gain of the circuit is 4. The O/P current of OPAMP is

\[ i_0 = \frac{V_o}{R_1 + R_2} + \frac{V_o}{R_L} - 1 \]

a) For a load resistance of 1kΩ, clipping occurs for \( V_o = 12V \). The current for a 12V output is 15mA, which is less than current limit of OPAMP.

b) For \( R_L = 200Ω \), \( i_0 = 25mA \)

\[ 25mA = V_o \left( \frac{1}{1kΩ + 3kΩ} + \frac{1}{200} \right) \]

\[ 25mA = V_o \left( 525 \times 10^{-3} \right) \]

\[ V_o = 4.76V \]

Clipping occurs at \( i_0 = 25mA \).

Inference: We study the behaviour of clipper circuits and the dependence of O/P voltages on resistances used in design.

Solution Plan: We need to find the operating point of the diode for various specifications. This can be done by calculating the intersection point of the diode curve with the load line.

Load line equation:

\[ V_{SS} = R_i i_0 + V_o \]
At the intersection points of load line with diode characteristics, we have:

a) $V_0 \approx 1.08 \text{V} \quad i_0 = 9.2 \text{mA}$

b) $V_0 = 1.18 \text{V} \quad i_0 = 13.8 \text{mA}$

c) $V_0 = 0.91 \text{V} \quad i_0 \approx 4.5 \text{mA}$

Ex:3.3 Solution Plan: We need to analyse the circuits to show that the condition given in the problem is not valid. This is done by assuming various cases for 'on' & 'off' conditions of diodes.

Assuming that diodes are 'on', the equivalent circuit is:

```
\[ \begin{array}{c}
10\text{V} \\
\downarrow \\
\| \\
4\text{K} \quad 6\text{K} \quad -3\text{V} \\
\\| \\
\uparrow \\
-10\text{V} \\
\end{array} \]
```

Solving for currents, we determine that $i_{01} = 1.75 \text{mA}$ and $i_{02} = -1.25 \text{mA}$.

The condition that $i_{02} < 0$ is inconsistent with the assumption that $D_2$ is 'on'.

Inference: This problem helps us to understand the state of the diode in a circuit. By judging the value of current and state of a diode, we can conclude if our assumption was right or wrong.
Ex. 3.4 Solution Plan: This problem is similar to the previous one.

a)

Assume $D_1$, solve for $V_0 / i_0$

- **ON**
  - $i_0 = 2 \text{mA}$
  - $V_0 = +2 \text{V}$

$V_0 = +2 \text{V}$ is inconsistent with assumption that $D_1$ is off. On the other hand $i_0 = 2 \text{mA}$ is consistent with assumption that $D_1$ is on. Thus we conclude $D_1$ is on $\Rightarrow i_0 = 2 \text{mA}$.

b)

Assume $D_2$, solve for $V_0 / i_0$

- **ON**
  - $i_0 = -1.5 \text{mA}$
  - $V_0 = -3 \text{V}$

Here the results are consistent for both cases.

c)

Assume $D_3$ $D_4$, impossible, no closed path for 5mA

- **OFF OFF**
  - $i_{04} = 5 \text{mA}$, $V_{03} = -5 \text{V}$

- **OFF ON**
  - $i_{03} = 5 \text{mA}$, $V_{04} = 20 \text{V}$

- **ON OFF**
  - $i_{03} = -1.67 \text{mA}$, $i_{04} = 6.67 \text{mA}$

Thus $D_3$ is off & $D_4$ is on.