Instructions, notes, and hints:

You may make reasonable assumptions and approximations in order to compensate for missing information, if any. Provide the details of all solutions, including important intermediate steps. You will not receive credit if you do not show your work.

Prob. 4.27: The output voltage should be equal to \((v_1 + v_2 + \cdots + v_5)/5\). More than one op-amp may be used in the circuit, but all should operate from the same power supply(ies). There is a lot of flexibility in the design. You may specify resistor ratios instead of specific resistor values, if appropriate.

Probs. 4.29, 4.30, 4.31: The power supply label \(V_{CC} = 16\) V implies that a bipolar power supply set to \(\pm16\) V and that includes a common reference node is applied to the op-amp.

Probs. 4.29 and 4.30: You may assume that the op-amp is ideal and can produce output voltages all the way to the power supply “rails.” Note that fixed input voltage source \(V_0\) is different from the output voltage \(v_o\) (one is upper case).

Assignment:

Probs. 4.27, 4.29, 4.30, and 4.31 in the textbook plus the following additional problems:

1. Consider the difference amplifier (diff amp) circuit shown below. The resistor pairs \(R_1-R_3\) and \(R_2-R_4\) are not perfectly matched in value. Show that the total output voltage \(v_o\) as a function of the input voltages \(v_1\) and \(v_2\) is given by the expression below. You may analyze the circuit with both inputs active, or you may apply the superposition principle.

\[
v_o = \left(1 + \frac{R_2}{R_1}\right) \left(\frac{R_4}{R_3 + R_4}\right) v_2 - \frac{R_2}{R_1} v_1.
\]
2. Show that the output voltage expression given in Prob. 1 for the diff amp circuit reduces to
\[ v_o = \frac{R_2}{R_1} (v_2 - v_1) \] if \( \frac{R_4}{R_3} = \frac{R_2}{R_1} \) exactly.

3. The circuit shown below will be used to indicate on a voltmeter the number of spaces that are occupied in a parking lot. A sensor located at each of the 24 spaces produces a 2-V DC signal that appears at one of the 24 inputs labeled \( v_1 \) through \( v_{24} \). If no car is parked in the space, the sensor produces a 0-V signal. The labeled circles indicate that the input is connected to a sensor not shown; thus, current can flow in and out of the terminal. For example, current can flow through \( R_1 \) into/out of the sensor connected to the circle labeled \( v_1 \); the left end of \( R_1 \) does not end in an open circuit. Find the required values for \( R_f \) and \( R_1 \) through \( R_{24} \) to produce an output voltage \( v_o \) with a scale of 1 V/occupied space. For example, if 14 spaces were occupied then \( v_o \) should be 14 V. An additional constraint is that the output current \( i_{o1} \) of the first op-amp (\( IC_1 \)) must be less than 5 mA in magnitude at all times. (Don’t forget to include the current that flows into the circuit built around \( IC_2 \).)