In order to measure the voltage across a resistor in a circuit, a voltmeter is used. Although we assume an ideal voltmeter in most cases, a real voltmeter has a finite resistance (R₃) which can have an effect on your circuit. Consider the following measurement on a voltage divider.

In the circuit, \( V_{\text{in}} \), \( R_1 \), and \( R_2 \) are just the standard elements of a voltage divider.

1a. How many nodes are there in the circuit?
1b. How many meshes are there in the circuit?

2. Write a KCL equation at node A. Convert the currents into voltages.

3. Solve the equation for \( V_{\text{out}} \), so that you have an equation for \( V_{\text{out}} \) based on \( V_{\text{in}}, R_1, R_2, \) and \( R_3 \).

4. Show that as \( R_3 \) approaches infinity (i.e. \( R_3 \rightarrow \infty \)), you get the standard equation for a voltage divider.
For problems 5 through 11, consider the following circuit:

\[ \text{4 \, \Omega} \]
\[ \text{10 V} \]
\[ \text{i_x} \]
\[ \text{2 \, \Omega} \]
\[ 4i_x \]

Find the Norton equivalent circuit, as follows:

5. Short circuit the two terminals and redraw the circuit without the 2 \( \Omega \) resistor. Explain why the 2 \( \Omega \) resistor can be dropped from the circuit.

6. Use node analysis to find \( I_{sc} \). (You will need to come up with one additional equation to eliminate \( i_x \) and get a numerical answer)

7. Now consider the circuit when the two terminals are open circuited. Using mesh analysis, find \( i_x \) under these conditions.

8. Using your results from #7 (or using node analysis, which will take more time), find \( V_{oc} \), the voltage across the two terminals in an open circuit condition.

9. Confirm that power is conserved in the circuit under open-circuit conditions. Find the power dissipated in each resistor. Find the power generated (or dissipated in each source). Be clear in your answers whether power is being generated or dissipated in each circuit element.

10a. Draw the Norton equivalent circuit. Label values for all circuit elements.

10b. Draw the Thevenin equivalent circuit. (Note: you already have everything you need)

11a. Assume that a circuit element (that draws some current \( I \) and has some voltage drop \( V \)) is attached to the terminals of the Norton equivalent circuit. Using KCL, write an equation for \( I \) in terms of \( V \).

11b. Graph the IV relationship (i.e. the load line). Use \( I \) as the “y-axis” and \( V \) as the “x-axis”. Label all relevant points.
For problems 12-17, consider the following op-amp circuit:

12. Use KCL to find the voltage at node B

13. Find the currents (magnitude and direction) through all 4 resistors.

14. Find the gain of the circuit, i.e. $V_{out} / V_{in}$. Assume that the 11 v supply is the input voltage.

15a. Redraw the circuit and replace the op-amp with an equivalent circuit model. Label values for all circuit elements. Assume the op-amp has an input resistance of 100 kΩ, an output resistance of 30 Ω, and a differential gain of 10000.

15b. Find the voltage drop across the output resistance. (since $R_{in}$ is much larger than any of the resistors in our circuit, we can use the results from #13)

16. Test the validity of the summing point constraint and the assumption made in #15b. Using the results from #14 and #15b at the output portion of the op-amp equivalent circuit, find $V_-$ and the current flow through the input resistance. Comment on the results you get.

17. If all of the external resistors are reduced by 1000, i.e. we use 2 Ω, 4 Ω, 6 Ω, and 12 Ω resistors, the node voltages will remain the same. The resistances will also still be much lower than $R_{in}$. However, why is this not done in practice? (Hint: repeat #13 for the feedback resistor and #15b)