1. A 1000 Hz, 2 volt (peak-to-peak) sine wave is applied to two different amplifier circuits
   a) a single input, inverting amplifier with a gain of -0.5
   b) a single input, non-inverting amplifier with a gain of +1.5
   Sketch the output waveform for each of these amplifiers in the scope screens below.

   ![Inverting amplifier waveform](image1)
   ![Non-inverting amplifier waveform](image2)

   inverting amplifier with a gain of -0.5
   non-inverting amplifier with a gain of +1.5

2. Define in terms a bright high school student would understand the following terms related to instrumentation:
   - uncertainty
   - ADC
   - repeatability

3. An ME professor’s son weighs 115 lbf. What is the professor’s son’s mass in both lbm and kg?
4. Measurements of the weight of 100 manhole covers give an average weight of 14.73 lb with a standard deviation of 0.26 lb. What is the uncertainty in the average weight at the 95% confidence level?

5. You are given two capacitors: \( C_A = 0.0022 \mu F \) and \( C_B = 470 \) pF. What are the series (\( C_S \)) and parallel (\( C_P \)) capacitances?

6. The first natural frequency of a vibrating beam is given by the formula, \( \omega = 3 \sqrt{\frac{E \pi d^4}{64 M L^2}} \). Write the simplified formula for calculating the uncertainty, \( u_\omega / \omega \).
Closed book, closed notes, one 8.5x11 inch hand-written formula sheet allowed. Work the problem in the space provided below each problem.

6a. Eight measurements of resistance (in kΩ) are listed below.
Determine the mean value and the precision uncertainty for the mean at a 95% confidence level.

<table>
<thead>
<tr>
<th>9.79</th>
<th>9.83</th>
<th>10.01</th>
<th>9.93</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.85</td>
<td>9.78</td>
<td>9.91</td>
<td>9.86</td>
</tr>
</tbody>
</table>

6b. A Fluke 75 DMM was used to measure the resistances. Data from the manufacturer’s spec sheet is given below. Determine the bias uncertainty in resistance for the mean or average resistance value.

**Fluke 75 Digital Multimeter (handheld)**

<table>
<thead>
<tr>
<th>Function</th>
<th>Range</th>
<th>Resolution</th>
<th>Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volts</td>
<td>0-3.2 V</td>
<td>0.001 V</td>
<td>± (0.5% of reading + 1 digit)</td>
</tr>
<tr>
<td>DC voltage</td>
<td>3.3-32 V</td>
<td>0.01 V</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>33-320 V</td>
<td>0.1 V</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>330-1000 V</td>
<td>1 V</td>
<td>± (0.6% of reading + 1 digit)</td>
</tr>
<tr>
<td></td>
<td>330-3200 Ω</td>
<td>0.1 Ω</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3 kΩ-32 kΩ</td>
<td>0.01 kΩ</td>
<td>± (0.7% of reading + 2 digits)</td>
</tr>
<tr>
<td>Resistance</td>
<td>33 kΩ-320 kΩ</td>
<td>0.1 kΩ</td>
<td>&quot;</td>
</tr>
<tr>
<td></td>
<td>330 kΩ-3.2 MΩ</td>
<td>0.001 MΩ</td>
<td>± (1.0% of reading + 3 digits)</td>
</tr>
<tr>
<td></td>
<td>3.3 MΩ-32 MΩ</td>
<td>0.01 MΩ</td>
<td>± (2.5% of reading + 1 digit)</td>
</tr>
</tbody>
</table>
7. A first order system is shown in the electrical schematic below. The time constant is given by the formula \[ \tau = (R_1 + R_2)C \]

Determine the time constant, \( \tau \), for the circuit. Given that each of the resistor values has an uncertainty of \( \pm 5\% \) and the capacitor value has an uncertainty of \( \pm 10\% \), find the uncertainty in the time constant, \( u_\tau \).
8. Design a two op-amp circuit that will convert the load cell output values \( (E_1) \) to the desired circuit output values \( (E_O) \) in the table on the right. Use standard ME 360 resistor values, i.e., 1kΩ, 2.2kΩ, 4.7kΩ, 10kΩ, 22kΩ, 47kΩ and 100kΩ resistors.

a) Draw a schematic diagram of your circuit, showing all power and input/output connections.

b) Draw your circuit on the breadboard below. Show all power and input/output connections to the circuit. Draw resistors like this.

\[ \text{Mass} \quad \text{Load Cell Output, } E_1 \quad \text{Circuit Output, } E_O \]

\[
\begin{array}{|c|c|c|}
\hline
\text{Mass} & \text{Load Cell Output, } E_1 & \text{Circuit Output, } E_O \\
\text{kg} & \text{volts} & \text{volts} \\
1.0 & 0.0 & 1.0 \\
3.2 & -1.0 & 3.2 \\
5.4 & -2.0 & 5.4 \\
7.6 & -3.0 & 7.6 \\
\hline
\end{array}
\]