True/false questions:

1. Low pass filters cause a measurable phase shift at input frequencies above the break frequency.
2. With normally distributed data, less than 80% of the data will fall between the mean value and the mean value $\pm 2\sigma$.
3. Passive filters always reduce the amplitude of the output signal compared to the input signal.
4. Low input impedance is desirable in measuring devices, since they will draw very little current from the measured system.
5. The minimum gain for an inverting op-amp circuit is 1.
6. Error bars are placed on plots of experimental data to indicate the uncertainty associated with each measurement.
7. Range is the difference between the minimum and maximum inputs that produces a valid output.
8. Accuracy is the difference between “true” and measured values.
9. Resolution is the difference among repeated measurements of the same quantity.
10. Precision is the change in output per change in input (slope of output vs. input line).
Part 2: Closed book, closed notes, one 8.5x11 inch hand-written formula sheet allowed.

12. The input, \( E_i(t) \) to each of the 5 circuits below is a 2.0 \( V_{pp} \) sine wave at 100 Hz.
   - Describe (in words and/or equations) what each circuit "does" to the input signal.
   - Accurately sketch the output waveform \( E_o(t) \) on the "scope" for each of the circuits.
   - Note that the input waveform \( E_i(t) \) is already provided on each "scope" figure.

![Figure 12-A](image_url)

\[ 20k\Omega \]

\[ + \]

\[ - \]

\[ 10k\Omega \]

\[ E_i(t) \]

\[ + \]

\[ - \]

\[ E_o(t) \]

![Figure 12-B](image_url)

\[ 0.047\mu F \]

\[ + \]

\[ - \]

\[ E_i(t) \]

\[ + \]

\[ - \]

\[ E_o(t) \]

![Figure 12-C](image_url)

\[ +1.0 \text{ volt} \]

\[ + \]

\[ - \]

\[ E_i(t) \]

\[ + \]

\[ - \]

\[ + \]

\[ - \]

\[ E_o(t) \]

![Figure 12-D](image_url)

\[ + \]

\[ - \]

\[ 20k\Omega \]

\[ 30k\Omega \]

\[ - \]

\[ + \]

\[ 20k\Omega \]

\[ 30k\Omega \]

\[ + \]

\[ - \]

\[ E_o(t) \]
13. Six different measurements of the same DC voltage are listed in the table below.

|---------|--------|--------|--------|--------|--------|--------|

The mean value for the voltage readings is 3.528 volts.

a. Determine the standard deviation of the sample for the voltages.
b. Estimate the 95% confidence interval for the mean value.
c. If each of the voltage measurements given in the table above were subject to ±0.3% + 2 digit accuracy (due to the DMM), what would be your estimate of the total uncertainty for the mean voltage value?

![Diagram of the op-amp circuit](image)

14. The op-amp circuit shown above creates an output voltage \( E_o = 4.567 \) volts with an input of \( E_i = 1.234 \) volts. Each voltage measurement is subject to ±1% + 2 digit accuracy.

The tolerance on each resistor value is ±3% (no measurement of the resistors is available).

a. What is the experimental gain?
b. What is the uncertainty in the experimental gain?
c. What is the theoretical gain?
d. What is the uncertainty in the theoretical gain?
e. Do the experimental and theoretical values “overlap?”

![Figure 6.6](image)

15. You have been given a breadboard with a 741 op-amp, a selection of 10kΩ, 22kΩ, and 47kΩ resistors, as well as several short pieces of wire.

Design and completely wire a multiple input, summing amplifier with a gain of -2.59.

- input \( E_1 \) uses a blue/black wire pair,
- input \( E_2 \) uses an orange/black wire pair,
- output \( E_{out} \) uses a yellow/black wire combination.

Resistor color codes:
- 10kΩ – Brown / Black / Orange
- 22kΩ – Red / Red / Orange
- 47kΩ – Yellow / Violet / Orange