Physics 238—Intermediate Physics Lab
Homework Assignment #2
Due Wednesday, February 26, 2025, 1:15 p.m.

In the torsional oscillator experiment, you can either measure the angle directly from the visual scale, or indirectly, by recording an output voltage. The goal of this assignment is to develop a calibration function to convert voltages into angle. In future dynamic experiments, you will record the voltage and use that calibration function to convert those voltage readings into angular displacements.

1. Linear Fits and Residuals

(30 pts.) Import your data for raw angle *vs.* voltage into *Mathematica*. Subtract your relaxed angle θ_R off each of the angles to give a table of angular displacement θ *vs.* voltage.

a. (10 pts.) Use the full range of data to make a graph of θ *vs.* voltage. (That is, the angular displacement goes on the vertical axis, and the voltage goes on the horizontal axis. We pick this orientation because the voltage measurements are typically more precise than the angle measurements.) Make a linear fit to the data and include that fit on the same graph. Record the slope and intercept.

b. (10 pts.) Make a plot of the residual angle *vs.* voltage. That is, plot $\theta - \theta_{fit}$ *vs.* voltage.

c. (10 pts.) Discuss the quality of the fit. What is the root mean square error? (Recall you can get this with `Sqrt[fit["EstimatedVariance"]]`.) Are there any noteworthy qualitative trends?

2. Voltage Calibration

(30 pts.) You likely found that the fit works well only over a somewhat smaller range of angles. In this problem, you will explore that issue further.

a. (20 pts.) Try restricting your fit to use just a subset of your data and make two new plots: θ *vs.* voltage for all your data along with the new fit, and residual angle *vs.* voltage. Adjust the range of data included in the fit until you find a reasonable range that is described by a linear fit. Note that there is no single unique recipe for "reasonable" here, but you do want to come up with a fit that describes your data well over a range of useful angles.

   Include both graphs along with a brief discussion of your reasoning for picking that specific range. Include any other quantitative measures you think appropriate.

b. (10 pts.) Voltage calibration: Record an equation that will permit you to convert voltage readings into angular displacement. Include the uncertainties as well. Be sure to be explicit about the units. You will use that equation in the next experiment. (The intercept may drift a bit, especially if anyone turns the "Zero Adjust" knob, but the slope should remain fixed.)