LAB 9, WEEK 1 ERROR ANALYSIS

There has been some confusion about the treatment of different measurement errors in Lab 9. The lengthy discussions advising that we measure errors as fractional errors (a.k.a. percent errors) led many people to compute the uncertainty in the torque improperly. To clear this up, we must first express the measurement we’re making as a differential measurement,

\[ \delta \tau_{\nu} = \delta \tau_{\text{coil}}, \]
\[ F_{\nu} (x_{\nu,B} - x_{\nu,A}) = (F_{\text{coil},B} - F_{\text{coil},A}) x_{\text{coil}}, \]

where A and B represent the system before and after the current is turned on, \( \delta \) represents the difference between A and B, \( F_{\nu} \) is the weight of the small nut, \( F_{\text{coil}} \) is the magnetic force between the coils, and \( x_{\nu} \) and \( x_{\text{coil}} \) are measured to the fulcrum. The convenience of the differential measurement is that we do not care about many of the absolute quantities involved in the torques, like the weight of the large nuts, the initial distance to the small nut, the weight of the top coil, etc. This equation is further simplified by noting that \( F_{\text{coil}} \) is zero when the current is off \( (F_{\text{coil},A} = 0) \).

In step 4 of the Lab 9 Procedure, the instructions ask us to make an estimate of the error in our measurement of \( x_{\nu} \), which we will call \( \Delta x_{\nu} \), using any method of estimation. However, the fractional error \( \Delta x_{\nu}/x_{\nu} \) is not appropriate for any analysis here, because we do not analyze any quantities that are proportional to \( x_{\nu} \), but rather to \( x_{\nu,B} - x_{\nu,A} \). \( x_{\nu} \) does not have any intrinsic significance, while \( \delta x_{\nu} = x_{\nu,B} - x_{\nu,A} \) does. The fractional error that is interesting is \( \Delta x_{\nu}/\delta x_{\nu} \). However, in step 4, we have not yet made an estimate of \( \delta x_{\nu} \), so we are not prepared to talk about the fractional error. It is easy to confuse the fact that we measured \( x_{\nu,A} \) several times, and measured different values each time, with measuring \( \delta x_{\nu} = x_{\nu,B} - x_{\nu,A} \), which we do not do until week 2.

The proper way to approach this question is not to use fractional errors in \( x_{\nu} \), but rather to compare \( \tau_{\text{coil}} \) to \( \Delta \tau_{\nu} \). This assumes that \( \Delta \tau_{\nu} = \Delta \tau_{\text{coil}} \), which is appropriate if we measure \( \delta x_{\nu} \) in order to estimate \( F_{\text{coil}} \). All of the other quantities involved in this experiment enter proportionally in the equations, so fractional errors should be used throughout the rest of the lab. It is important, however, not to use fractional errors in a variable that does not enter linearly into the equations \( (x_{\nu,A} \) does not).

To summarize, step 4 of Lab 9 asks us to compare \( \Delta \tau_{\nu} = F_{\nu} \Delta x_{\nu} \) to our estimate of \( \delta \tau_{\text{coil}} = F_{\text{coil},B} x_{\text{coil}} \).