ENGR/PHYS 216 Spring 2023
HW Assignment 2: Propagation of Error

1. In an experiment on the conservation of angular momentum, a student needs to find the angular momentum L of a uniform disk of mass M and radius R as it rotates with angular velocity ω. She makes the following measurements:

$$M = 2.50 \pm 0.020\ kg$$
$$R = 0.180 \pm 0.0030\ m$$
$$\omega = 17.5 \pm 0.250\ rad/s$$

and calculates L using $L = \frac{1}{2}MR^2\omega$ (you will learn where this formula comes from in PHYS 206.) What is her answer for L with its uncertainty? (You can consider the three original uncertainties independent.)

2. According to theory, the period T of a simple pendulum is $T = 2\pi\sqrt{\frac{L}{g}}$
   a. If L is measured as $L = 0.75 \pm 0.011\ m$; what is the predicted value of T?
   b. Would you say that a measured value of $T = 1.75 \pm 0.010\ s$ is consistent with the theoretical prediction of part (a)?

3. To find the acceleration of a baseball ball rolling down a ramp, you measure its velocity at two points (v_1 and v_2); and the time t it takes between them:

$$v_1 = 3.54 \pm 0.10\ m/s$$
$$v_2 = 8.16 \pm 0.10\ m/s$$
$$t = 2.79 \pm 0.10\ s$$

   a. Assuming all uncertainties are independent and random, and acceleration is calculated using $a = \frac{v_2 - v_1}{t}$, what should you report for a and its uncertainty?
   b. You calculate using a kinematics model that the acceleration should be $1.85 \pm 0.10\ m/s^2$. Does your measurement agree with this prediction?

4. You have a set of calipers that can measure the thicknesses of a few inches with an uncertainty of $\pm\ 0.0050$ inches. You measure the thickness of an old physics textbook (437 pages) and get 1.24 in:
   a. If you now calculate the thickness of 1 page, what is your answer, including its uncertainty?
   b. You can improve this result by measuring multiple textbooks together. If you want to know the thickness of 1 page with an uncertainty of only 5.0 x 10^{-6} in., what is the minimum number of (whole) textbooks that you need to measure together?

5. An Atwood machine consists of two masses m_1 and m_2 (with $m_1 > m_2$) attached to the ends of a light string that passes over a light, frictionless pulley. When the masses are released, the mass m_1 is easily shown to accelerate down with an acceleration

$$a = g\frac{m_1 - m_2}{m_1 + m_2}$$

Suppose that m_1 and m_2 are measured as $m_1 = 102 \pm 1.0\ grams$ and $m_2 = 86 \pm 0.90\ grams$. Derive an equation for the uncertainty in the expected acceleration in terms of the masses and their uncertainties, and then calculate $a \pm \delta a$ for the given numbers. You do not have to simplify your uncertainty equation. *Hint: is there hidden correlation?*