Physics 8.01X   Fall Term 2001

Problem: EXPERIMENT AM: ANGULAR MOMENTUM

Handed out: November 14. Due: November 30 at 5 pm in 4-339B. The Experiment must be checked off in the lab.

Lab hours: Monday Nov 26 3-5 pm, Tuesday Nov 27 7:30-9:30 pm, Wednesday Nov 28 7:30-9:30 pm, Thursday November 29 3-5 pm, Friday November 30 11am-noon

1) In Experiment AM, a 1" US Standard Washer has inner radius r_i and an outer radius r_o. Show that **the moment of inertia about the center of mass of the washer I is given by** $I = \frac{1}{2}M(r_i^2 + r_o^2)$ where M is the mass of the washer. Use this expression to calculate the moments of inertia about the center of mass of each washer I_1 and I_2.

2) The voltage V generated by the motor is linearly proportional to the angular velocity of the motor, $\omega = \beta V$, where β is the constant of proportionality. Recall that the angular frequency $\omega = 2\pi f$; where f is the frequency. Do not confuse the two quantities or their units: ω [rad/sec] and f [Hz]. **Calculate your value for β** from your stroboscopic measurement of voltage generated by the motor when it is spinning at 30 Hz.

3) **Experiment 1:** Plot the voltage readings versus time for the three runs on different sheets of linear graph paper, arranging to have the first reading always at the zero of time. Select the most representative run and draw the best-fit straight line through the combined points. Use the slope of the line to deduce the frictional torque that slows the washer. Here's how to do that. Convert the measured slope of your best-fit line, $\frac{dV}{dt}$ to a value for $\frac{d\omega}{dt}$ using the calibration you made for voltage and angular frequency. Recall that the angular acceleration is $\alpha = \frac{d\omega}{dt}$, hence the frictional torque about the center of mass is given by $\tau = I_1\alpha$. **Calculate the frictional torque of the motor for Expt. 1.**

4) **Experiment 2:** Here we will calculate the angular momentum just before and after the inelastic rotational collision as a check on the near conservation of angular momentum. **Plot the voltage readings versus time for each of the three runs. Select the most representative graph;** the graph should have at least three or four data points for the slowing down of the first washer, and three or four data points for the slowing down of the two washers. The collision time is on the order of 0.5 seconds so it is unlikely that you have more than at most one data point for the collision. Draw a 'best-fit' straight line through the data points preceding the time the washer was dropped. Draw a second bet-fit

straight line for the data points after the collision. Extend both lines into the time where the collision occurred. Try to estimate when the collision occurred. Calculate the voltage just before the collision occurred using your first straight line. Then calculate the voltage 0.5 seconds after the collision occurred using your second straight line. Again convert your voltages to angular frequencies using your calibration. **Calculate the frictional torque of the motor for both of your best-fit straight lines. Recall that for your data after the collision $\tau = (I_1 + I_2)\alpha$. Does the frictional torque of the motor change when there are two washers on it?**

5) Compute the angular momentum $L_b = I_1\omega_b$, (where I_1 is the moment of inertia of washer #1) of the single washer just before the inelastic rotational collision. Use SI units.

6) Calculate the angular momentum of the two-washer system just after the collision, $L_a = (I_1 + I_2)\omega_a$, where I_2 is the moment of inertia of washer #2.

7) Calculate the change $\Delta L = L_a - L_b$ in angular momentum during the rotational collision.

8) Calculate the fractional change in angular momentum $f_L = \dfrac{\Delta L}{L_b}$. This is a measure of how closely angular momentum is conserved in the collision.

9) Based on your calculation in part 4), calculate the external frictional torque (due to the motor) during the rotational collision. Do you need to average your results from part 4)?

10) Calculate the torque times the collision time, **rotational impulse**, *Rotational impulse* $= \tau \Delta t_{collision}$. How does this compare to your calculation for the change in angular momentum during the rotational collision in part 7)?