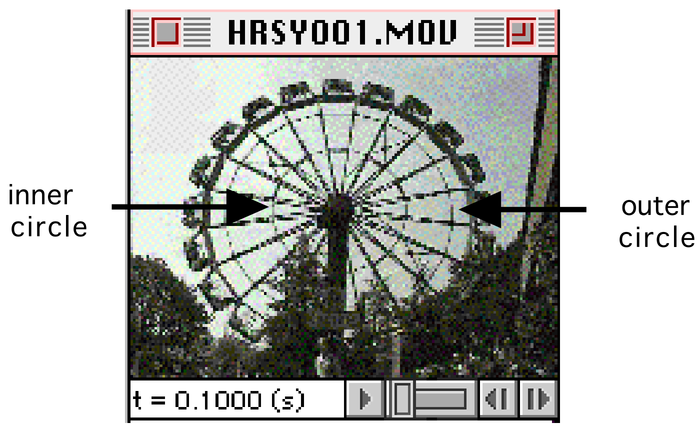
Unit 12 *Homework Problems*

To get credit for the homework problems, you must include all of the following:

1. All equations must be solved in symbol form before substituting in any numbers.
2. All numbers substituted into the equations must have the correct units and number of significant figures, and the correct vector notation (where appropriate).
3. All final numerical answers must have the correct units, correct number of significant figures, and correct vector notation (where appropriate),

UNIT 12 HOMEWORK AFTER SESSION ONE

12-1) **Cyclops Rotation:** You can use the Logger Pro software to find the rotational speed in radians/second of the Cyclops Ferris wheel at Hershey Park. This motion is shown in the digital movie HRSY001. A sample frame is shown below.



There are a couple of ways to find the rotational speed: a simple way that you can figure out for yourself or a more complicated way. The more complicated method involves: (1) Moving the origin of the default coordinate system to the center of the wheel; (2) locating a point on the wheel in each frame; (3) creating a graph of rotational position vs. time; (4) figuring out how to determine the rotational speed from the rotational position vs. time graph. If you decide to choose this method, I have already collected data for the first three frames of the movie.

(a) First play the movie. What is the nature of the rotational speed of the Ferris wheel as a function of time? Is it increasing, decreasing or remaining constant? Cite the evidence for your answer.

(b) At $t = 0.1000$ s, what is the linear speed of a point on the inner circle? Explain how you found your answer.

(c) At $t = 0.1000$ s, what is the linear speed of a point on the outer circle? Explain how you found your answer.

(d) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?

12-2) **Disk Rotation:** In this problem, you will be analyzing the motion of a rotating aluminum disk. This motion is shown in the digital movie DSON014.mov. A small spool is connected to the aluminum disk by an axle that is free to rotate in an almost frictionless manner inside of a bearing. A string is wrapped around the spool and a weight, which is attached to the string, is allowed to fall.

(a) Use the Logger Pro software to gather data for the rotational position of some recognizable point on the disk as a function of time. Create a graph of rotational position (*i.e.*, angle) vs. time. Is the rotational velocity constant or changing? Is the rotational acceleration constant or changing? What about the rotational position vs. time graph allows you to answer this question.

(b) If you concluded that the rotational acceleration is constant, then determine what its value is in rad/s/s. Explain how you arrived at your conclusions, showing relevant data and graphs.

(c) What is the equation that describes the angle through which the disk has moved as a function of time? Explain how you determined this equation.

(d) What is the equation that describes the rotational velocity of the disk as a function of time? Explain how you derived this equation.

(e) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?

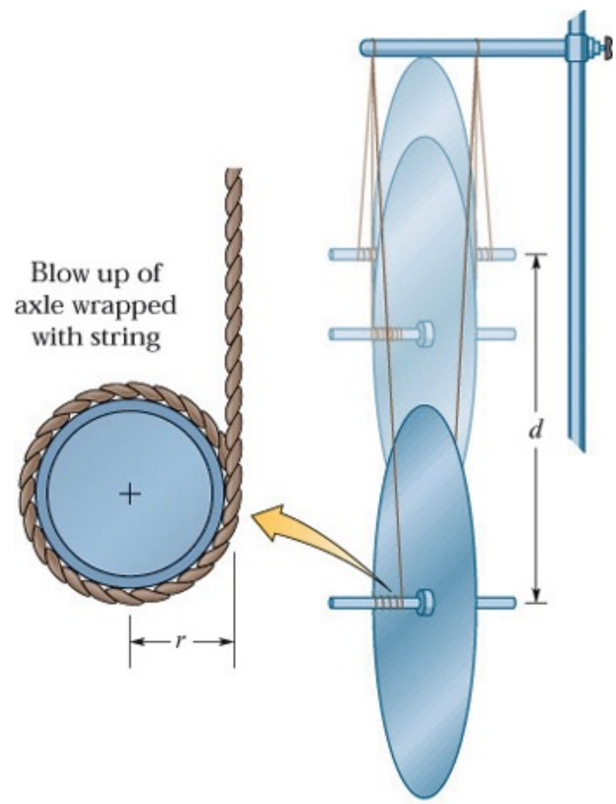
12-3) **The YO-YO:** A quantitative yo-yo consists of a disk (or other shape) fixed to an axle that has two strings wrapped around it. As the axle rolls off the strings, the disk and the axle fall as shown in the diagram on the right.

(a) If the disk has fallen through a vertical distance of $\Delta y = d = 30$ cm and the radius of the string and axle is given by r =5.0 mm, how many revolutions has the disk gone through?

(b) If the disk is rotating faster and faster with a constant rotational acceleration and takes 25 s to fall through the distance d from rest, what is the magnitude of its rotational acceleration α?

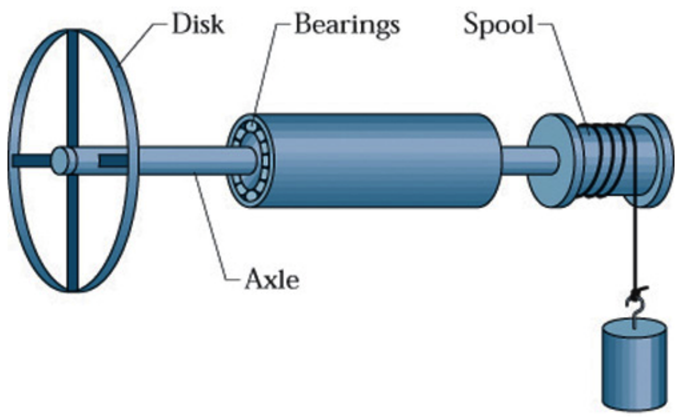
(c) What is the magnitude of its rotational velocity ω after the 25 seconds have elapsed? **Hint**: Use the rotational kinematic equations.

(d) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?



UNIT 12 HOMEWORK AFTER SESSION TWO

12-4) Rotational Inertia And Rotational Acceleration: A small spool of radius r_s and a large Lucite disk of radius r_d are connected by an axle that is free to rotate in an almost frictionless manner inside of a bearing as shown in the diagram below.



A string is wrapped around the spool and a weight with mass, *m*, which is attached to the string, is allowed to fall.

Note: This problem is a warm up for Activity 12.12*, which we are doing in session three. It is meant to be straightforward – essentially just a review of Newton's second law (linear and rotational) and the definitions of torque and rotational inertia.*

(a) Draw a free body diagram showing the forces acting on the falling weight. Label the magnitudes of the forces, where appropriate, in terms of the mass m, the gravitational constant g, and the tension force in the string F^{tens}.

(b) If the magnitude of the linear acceleration of the weight is measured to be a, what is the equation that should be used to calculate the tension force in the string F^{tens}? In other words, what equation relates F^{tens} to m, g, and a?

(c) A tension force from the string is also acting on the spool-axle-disk system. What is the torque, τ, on the spool-axle-disk system due to this force in terms of r_s and F^{tens}?

(d) What is the magnitude of the rotational acceleration, α, of the rotating system as a function of the linear acceleration, a, of the falling mass and the radius, r_s, of the spool?

(e) The rotational inertias of the axle and the spool are so small compared to the rotational inertia of the disk that they can be neglected. If only the rotational inertia, I_d, of the large disk of radius r_d is considered, what is the equation that can be used to predict the magnitude of the rotational acceleration, α, of the disk as a function of the torque on the system, τ, and the rotational inertia, I_d, of the disk?

(f) What is the theoretical value of the rotational inertia, I_d of a disk of mass M_d and radius r_d in terms of M_d and r_d?

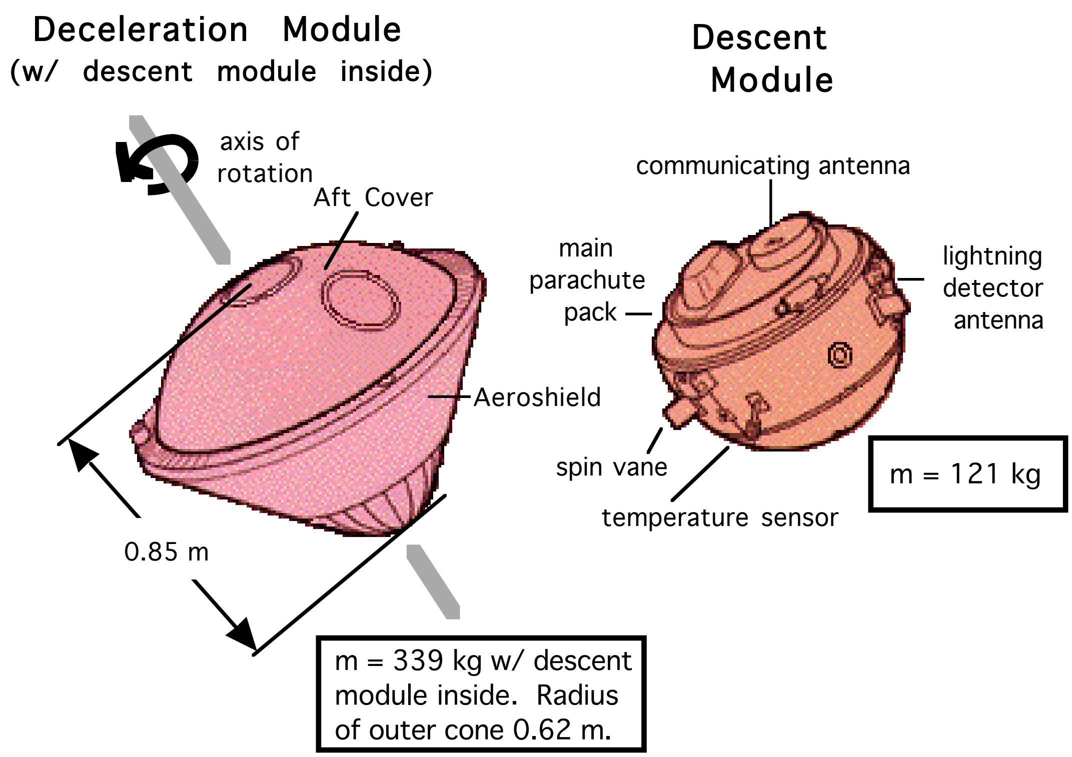
(g) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?

12-5) Exploring Jupiter: The Galileo Mission, which launched on October 18, 1989, reached its culmination on December 7, 1995 when the Galileo probe made a dramatic 60 minute journey into Jupiter's atmosphere. NASA scientists and engineers in the design and execution of this important planetary research mission used virtually all of the physics topics you studied during this semester. In the exercises that follow you will have a chance to think about a few of the many physics problems that had to be solved by project personnel. The last page of this assignment contains more information about the probe's journey and some of the major events it experienced. Data on the parts of the probe are included on the next page.

On July 13, 1995 the Galileo Deceleration Module was ejected from the larger orbiter to make its final 81 million kilometer trip to Jupiter. As part of the ejection process it was spun up to a rotational speed of $\omega = 1.1$ rad/s for stability. It moved toward Jupiter at a speed of 20.4×10^3 km/hr. This spin axis was carefully lined up with the Deceleration module's trajectory. The Deceleration module is actually rather small. It has a mass of 339 kg and is shaped more or less like a cone with a maximum radius, R, at the bottom of the cone of 0.62 m and a height, h, of 0.85 m. The equation for the rotational inertia of a cone is given by

$$I_{cone} = \frac{3}{10} MR^2$$

If you like, check out a QuickTime movie (orb_sep.mov) showing an artist's concept of the spin up and release of the Deceleration Module from the orbiter.



(a) Examine the rotational inertia equation. Is the rotational inertia of a cone smaller or larger that of a disk of the same radius and mass? Is this what you expect? Why? **Hint**: Explain this in terms of the distance of mass elements in an object from the axis of rotation.

(b) Calculate the approximate rotational inertia of the Deceleration Module assuming that it is shaped like a cone and has uniform density.

(c) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?

GALILEO PROBE TO LOOK FOR SECRETS OF JUPITER

Information adapted from NASA news releases obtained from the Internet on 12.14.95

The Galileo Probe--like a flaming meteor--made history's first entry into the atmosphere of Jupiter, a giant outer planet, on December 7, 1995. The Probe craft plunged into Jupiter's brilliantly-colored, swirling cloud tops at approximately 106,000 mph, and then descended 400 miles through turbulence, violent winds and three cloud layers into the hot, dense atmosphere below. Wrenching forces on the craft during its deceleration phase (from 106,000 mph to 100 mph in just four minutes) were up to 300 times those of Earth's gravity. The Probe is making the first-ever on-the-spot measurements of Jupiter or any outer planet. It is expected to identify the components of Jupiter's atmosphere and find clues to Jupiter's history, and the origin of the solar system. When the data are analyzed the Probe descent is expected provide our first true understanding of Jupiter as a planet.

Although the probe descent through Jupiter's atmosphere took only 60 minutes, it was the culmination of a six-year journey from Earth. The Shuttle Atlantis launched the Galileo Orbiter and Probe in October 1989. When the Probe separated from the Orbiter last July 13 it was still about 50 million miles from Jupiter. To enhance its stability the Galileo probe was accelerated (or "spun up") to a rotational velocity of 1.10 rad/s at the time of its separation from the Orbiter. Its spin axis was precisely aligned with its trajectory. (See the NASA QuickTime movie entitled orb_set.mov for an artist's rendering of the spin-up and probe separation from the orbiter.).

The Galileo probe that separated from the orbiter was composed of two sections. The Deceleration module is an outer shell that surrounded the capsule through entry and then dropped away. The outer shell included thick heat shields and their supporting structures, the thermal control hardware for mission phases up through entry, and a pilot parachute. Nested inside of this outer shell is the inner capsule, or descent module, that carried the payload of scientific instruments. This descent module moved down through Jupiter's lower atmosphere alone. It carried the main parachute along with the scientific instruments needed to transmit data back to the overflying Orbiter for relay to Earth.

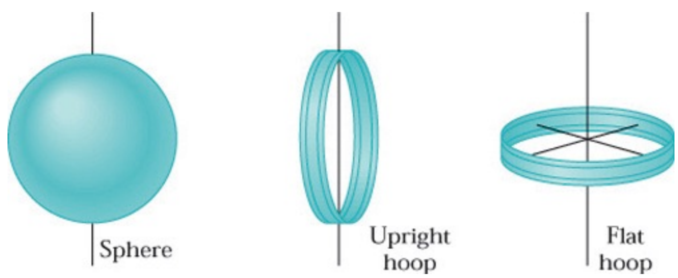
The probe entered the upper atmosphere 450 km above Jupiter at a speed relative to Jupiter of 17.1×10^4 km/h. In the next 112 seconds it slowed down to a speed of 9.9×10^5 km/h at an altitude of 50 km. Next the protective heat shields of the Deceleration Module were shed by first deploying a small pilot parachute and then a large main chute, exposing the Descent Module to the hydrogen/helium atmosphere at a pressure of about one-tenth of an Earth atmosphere.

UNIT 12 HOMEWORK AFTER SESSION THREE

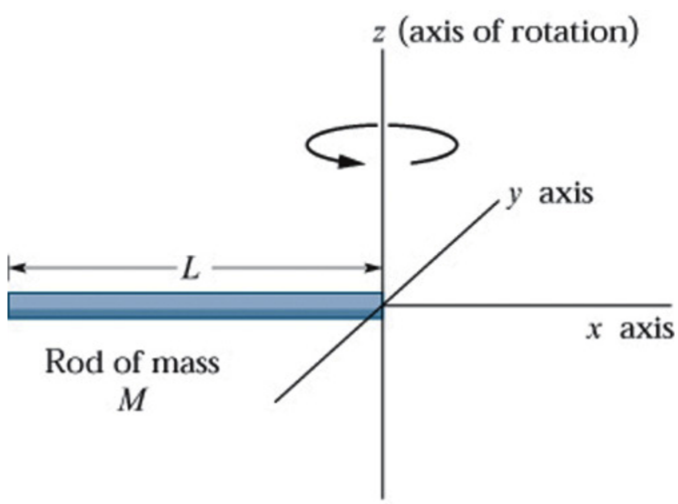
12-6) **Using A Torque To Stop A Motion:** Carman pulls on a rod mounted on a frictionless pivot with a force of 78.2 N at a distance of 49 cm from the pivot. Carlos is trying to stop the rod from undergoing a rotational acceleration by exerting a force in the opposite direction to the one Carman exerts. Carlos' force is applied 85 cm from the pivot and is perpendicular to the rod. What is the magnitude of his "balancing" force?
What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?

12-7) **Comparing Rotational Inertias**: If all three of the objects shown on the next page have the same radius and mass, which one has the most rotational inertia about its indicated axis of rotation? Which one has the least rotational inertia? Explain the reasons for your answer. **Hint**: Consider which one has its mass distributed farthest from the axis of rotation.

What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?



12-8) **Summing Up To Estimate Rotational Inertia:** By performing an integration it can be shown that the general equation for the rotational inertia of a thin rod of length L and mass M about an axis through one end of the rod which is perpendicular to its length is given by $I = \frac{1}{3}ML^2$. Consider a rod of length 0.50 m that has a mass of 1.2 kg.



(a) Calculate the theoretical value of the rotational inertia.

(b) Estimate the rotational inertia of the rod by breaking it into 50 small point objects, each having a mass of $M/50$, with the first point object being 0.005m from the axis of rotation, the second point object being 0.015 m from the axis of rotation, and so on. Use a spreadsheet to do your estimated calculations of the rotational inertia of the rod.

(c) Compare the theoretically calculated value with the estimated value. Are they similar?

(d) What activity or activities from the Activity Guide are related to this problem, how is the activity related, and what concepts were learned in the activity?