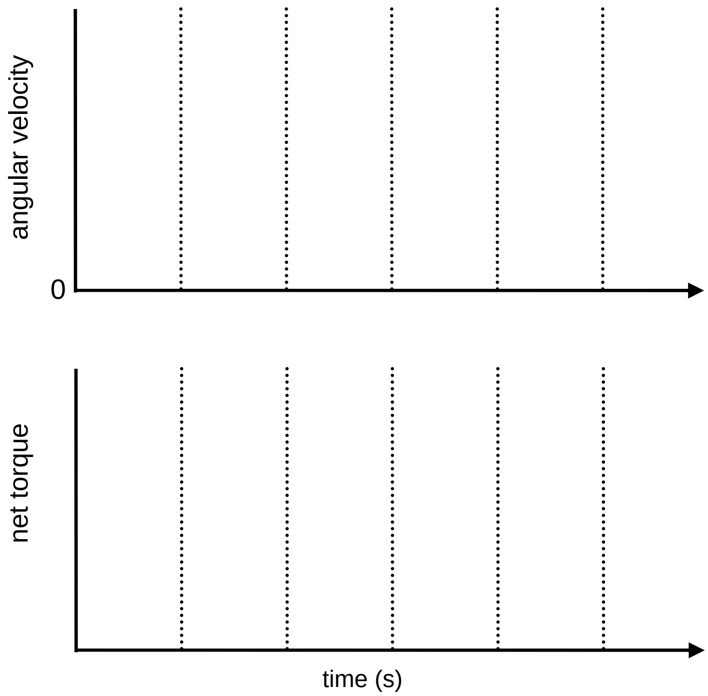
PRELAB: ROTATIONAL DYNAMICS

1. Sketch the graphs for Prediction 1-1 on the axes below. Explain your reasoning in the space beside the graph.



2. Predict what will happen in step 1 of Investigation 2. Explain your reasoning.

3. Write Prediction 3-1 here. Explain your reasoning.

4. Why is the tire on the bike wheel used in Investigation 2 replaced with heavy metal wire?

ROTATIONAL DYNAMICS

Topic: Moment of inertia, torque, angular momentum

Overview: This lab consists of three short activities that focus on the interconnections between the angular momentum and torque vectors

Writing it up: Throughout this handout, you will be asked to answer questions, sketch graphs and diagrams, and do calculations. Write these things in your lab notebook *as you go through the experiment*. Label each answer/graph/calculation/diagram so that you (or your lab TA) can find things quickly. If you have any computer printouts (such as graphs), remember to affix them to your lab notebook. After lab, write a short (<300 words) conclusion of the experiment that summarizes what you did and the major findings of the experiment.

Safety/Equipment Tips

Room setup notes (for TA's)

Throughout this lab, the words "torque" and "angular momentum" refer to the torque (or angular momentum) about the axis of rotation. (Remember that the magnitude and direction of many rotational vectors, including torque and angular momentum, depend on the position of the origin of the coordinate system).

Investigation 1: Spinning stool

Have you ever noticed how skater spinning in circles can control their spin rate by changing the position of their arms and legs? In this Investigation, you will simulate this situation with a person sitting on a rotating stool.

Prediction 1-1: Suppose a person sitting on the low friction stool with a mass in each hand with arms fully extended is given a push. Once the seated student has been spinning for a few revolutions, he/she pulls the masses (and his/her arms) in to toward his/her torso and holds them there for a few revolutions. Sketch prediction graphs for angular velocity vs. time, and net torque versus time, starting at the moment when the seated person is at rest. Arrange the two prediction graphs vertically, so that important events on the two graphs line up.

1. Check Prediction 1-1 qualitatively.

   Q1-1: During which time interval does the angular momentum of the system change the most? Explain.

   Q1-2: When is the person's moment of inertia larger: when the arms are extended, or when the arms are near the body? Explain two different ways to infer the answer.

2. Devise two different methods to estimate the ratio of the person's two different moments of inertia (arms extended vs. arms near body) using the equipment available. Describe each method in your notes. Execute the two methods and compare the results. (Hint: One method involves a stopwatch; the other involves estimating masses and positions).

Investigation 2: Spinning bike wheel

Changing the axis of rotation of a wheel can produce some surprising results. In this Investigation, you will explore the relationship between changes in angular momentum vector and the torque vector, using a bike wheel mounted on a handle. The tire has been replaced by several coils of massive wire.

1. Sit on the rotating stool. Hold the bike wheel with its axis oriented horizontally and pointed away from you. (You will be looking at the face of the wheel). Give the wheel a clockwise spin. (Its angular velocity vector now points away from you). Try to increase the vertical component of the angular velocity vector $\vec{\omega}$ slightly. Describe what you did to increase the vertical component of $\vec{\omega}$. Record what happens as a result.

   Q2-1: Did the wheel exert a torque on you? Explain how you can tell from your observations. Which direction does this torque vector point? Explain how you know.

   Q2-2: Did the wheel's angular momentum $\vec{L}$ change? If so, which direction in the change in angular momentum $\Delta\vec{L}$ point? Explain, using a diagram.

Investigation 3: Gyroscope

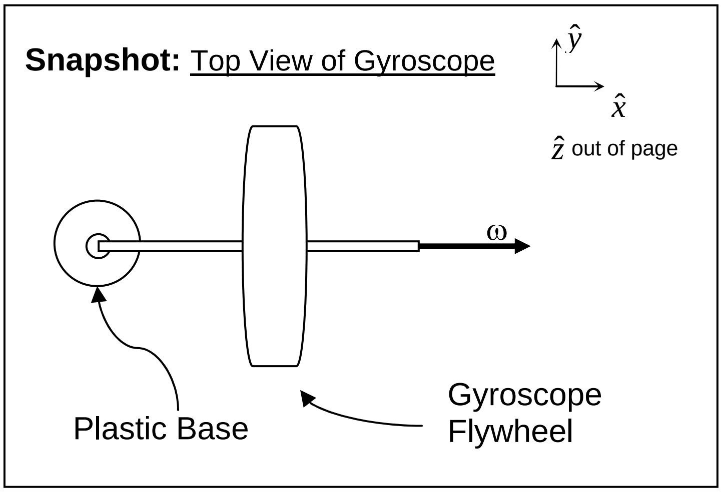
The gyroscope demonstrates how the net torque vector $\vec{\tau}$ leads to changes in the angular momentum vector $\vec{L}$.

1. Give the gyroscope a spin. Before you pull the string to get the gyroscope started, note which direction the angular velocity vector will point once the gyroscope is started. Hold on to the gyroscope's plastic base and place the tip of the gyroscope on the base so that the angular velocity vector points away from the plastic base. Describe how the angular momentum $\vec{L}$ of the gyroscope changes with time. Your description should answer the following questions: Which component of $\vec{L}$ is changing slowly? Which ones are changing more rapidly? If the motion is viewed from above, what shape does the tip of the $\vec{L}$ vector trace out (approximately)? Which direction does the tip of angular momentum vector travel?

Q3-1: Once the gyroscope is placed on its base, what forces act on it? Which of these forces contributes to the net torque? Explain.

Q3-2: Is the net torque on the gyroscope zero? Explain how you know.

The diagram below shows a snapshot of the top view of the gyroscope at some moment in time.



Q3-3: Using your observations of the gyroscope's motion, infer the direction of the angular acceleration $\vec{\alpha}$. (Use the coordinate system shown in the diagram). Explain how you inferred the direction from the motion of the gyroscope.

Q3-4: Use the equation $\vec{\tau} = \vec{r} \times \vec{F}$ to determine the direction of the torque exerted by the gravitational force the earth on the gyroscope at the time of the snapshot above. Does this direction match what you would expect from your answer to Q3-3?

Q3-5: Does the torque $\vec{\tau}_{grav}$ exerted by gravity remain constant? Does the magnitude of the gravitational torque remain constant? Explain.

Prediction 3-1: Suppose you set up the gyroscope so that the angular velocity vector always points toward the plastic base. How would the motion of the gyroscope change? Which vectors would change direction? Which would stay the same?

2. Check your predictions. Resolve any differences or inconsistencies.