Lab Handout

Lab 10. Rotational Motion: How Do the Mass and the Distribution of Mass in an Object Affect Its Rotation?

Introduction

The wheel and axle are arguably among the most important inventions of all time. When a wheel turns around an axle, every point on the wheel moves in a circle about an axis of rotation. The motion around an axis of rotation is called rotational motion. We can describe the motion of a rotating object just like we can describe the motion of objects moving in a straight line. There are many similarities between rotational motion and linear motion. Rotating objects also have inertia and are influenced by the net force acting on them just like an object undergoing linear motion. A force that causes an object to rotate is called a torque.

FIGURE L10.1

An ice-skater changes her body position to change the speed of her spin

There are also several important differences between rotational motion and linear motion. One big difference is how the distribution of mass within a rotating object affects how fast that object rotates around an axis of rotation. Take ice-skaters, gymnasts, and high divers as an example. These athletes often need to spin during a routine or a dive. As they spin, they can position their bodies in a way that will make them rotate faster or slower, which means they can change their angular velocity. Angular velocity is measured in radians per second (rad/s) and describes how much of a circle is completed by a rotating object in 1 second. A complete circle is equal to 360° or 2π radians (360° = 2π rad, therefore 1 radian ≈ 57.3°). An object with an angular velocity of 19 rad/s would complete approximately 3 rotations per second. Similar to linear motion, the mass of a rotating object influences how its velocity changes when a force acts on it. However, unlike linear motion, the angular velocity of a rotating object will also change when the position or distribution of the mass within that object is changed. Athletes, as a result, can change how far their body parts are away from the axis of rotation, which changes the distribution of their mass (their total mass stays constant, they do not gain or lose mass during the spin), in order to spin faster or slower during a routine or a dive (see Figure L10.1).

Understanding rotational motion is important in science and has implications for aspects of our everyday lives. One implication related to rotational motion is the behavior of automobile wheels. The early inventors of the wheel were not concerned with traveling

at the speeds we do today. Understanding how torque, mass, angular velocity, and angular acceleration influence the behavior of a wheel is important for ensuring that vehicles operate efficiently and are safe to drive. Putting too large a wheel on a car will cause the engine to become overworked and use more gas than necessary; additionally, if a wheel is too large or too massive, the brakes on the vehicle may not be strong enough to stop the wheel's rotation.

Your Task

Use what you know about rotational motion, patterns, and structure and function to design and conduct an investigation to determine how the mass and distribution of mass affect the rotation of an object.

The guiding question of this investigation is, ***How do mass and the distribution of mass in an object affect its rotation?***

Materials

You may use any of the following materials during your investigation:

Consumable
- Tape

Equipment
- Safety glasses or goggles (required)
- Records
- Wood dowels
- Stopwatch
- Slotted masses, washers, or coins
- Ramp (made from metersticks and a block)
- Electronic or triple beam balance

If you have access to the following equipment, you may also consider using a video camera and a computer or tablet with video analysis software.

Safety Precautions

Follow all normal lab safety rules. In addition, take the following safety precautions:

1. Wear sanitized safety glasses or goggles during lab setup, hands-on activity, and takedown.
2. Keep fingers and toes out of the way of moving objects.
3. Wash hands with soap and water after completing the lab.

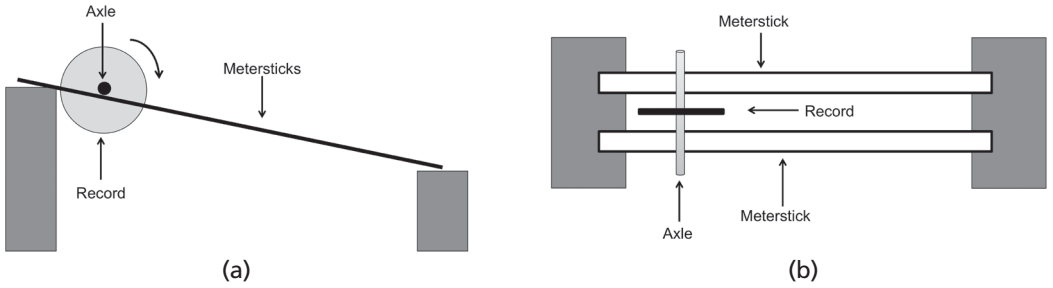
Investigation Proposal Required? ☐ Yes ☐ No

Getting Started

To answer the guiding question, you will need to design and carry out an experiment to determine how changes in mass and the distribution of mass affect the rotational motion of a record. The equipment setup shown in Figure L10.2 illustrates how you can use

FIGURE L10.2

Sample equipment setup using metersticks, a block, a wood dowel, and several records as shown from the side (a) and from the top (b)



metersticks and blocks (or a stack of books) to build a ramp for a rolling record. You can use a wooden dowel rod that has the same diameter as the center hole of a record for the axle (add tape to the rod if it is too thin). You can then change the total mass of the rotating system by adding additional records to the axle or by adding masses to the record. You can tape washers or coins to the sides of the records at different spots on the record (e.g., close to the outer perimeter or close to the center axle) to change the distribution of mass in the rotating system. Before you begin designing your experiment using this equipment, however, you must first determine what type of data you need to collect, how you will collect it, and how you will analyze it.

To determine *what type of data you need to collect,* think about the following questions:

- What are the boundaries and components of the system you are studying?
- How do the components of the system interact with each other?
- How might changes to the structure of what you are studying change how it functions?
- How could you keep track of changes in this system quantitatively?
- What variables do you need to compare?
- What is the outcome variable for your investigation?

To determine *how you will collect the data,* think about the following questions:

- What measurement scale or scales should you use to collect data?
- What other variables will you need to control during your investigation?
- How will you make sure that your data are of high quality (i.e., how will you reduce error)?
- How will you keep track of and organize the data you collect?

To determine *how you will analyze the data,* think about the following questions:

- What types of patterns might you look for as you analyze your data?
- What type of calculations will you need to make?
- How could you use mathematics to describe a relationship between variables?
- What type of table or graph could you create to help make sense of your data?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

As you work through your investigation, you may want to consider

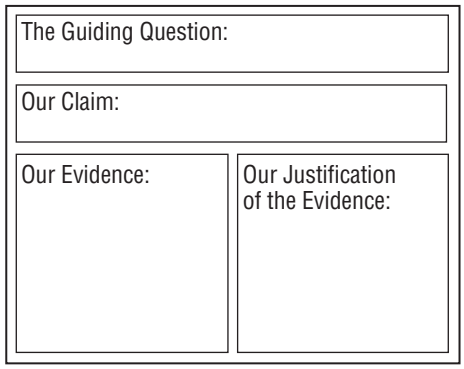
- the difference between observations and inferences in science, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument must include a claim, evidence to support your claim, and a justification of the evidence. The *claim* is your group's answer to the guiding question. The *evidence* is an analysis and interpretation of your data. Finally, the *justification* of the evidence is why your group thinks the evidence matters. The justification of the evidence is important because scientists can use different kinds of evidence to support their claims. Your group will create your initial argument on a whiteboard. Your whiteboard should include all the information shown in Figure L10.3.

FIGURE L10.3

Argument presentation on a whiteboard



Argumentation Session

The argumentation session allows all of the groups to share their arguments. One or two members of each group will stay at the lab station to share that group's argument, while the other members of the group go to the other lab stations to listen to and critique the other arguments. This is similar to what scientists do when they propose, support, evaluate, and refine new ideas during a poster session at a conference. If you are presenting your group's argument, your goal is to share your ideas and answer questions. You should also keep a record of the critiques and suggestions made by your classmates so you can use this

feedback to make your initial argument stronger. You can keep track of specific critiques and suggestions for improvement that your classmates mention in the space below.

Critiques about our initial argument and suggestions for improvement:

If you are critiquing your classmates' arguments, your goal is to look for mistakes in their arguments and offer suggestions for improvement so these mistakes can be fixed. You should look for ways to make your initial argument stronger by looking for things that the other groups did well. You can keep track of interesting ideas that you see and hear during the argumentation in the space below. You can also use this space to keep track of any questions that you will need to discuss with your team.

Interesting ideas from other groups or questions to take back to my group:

Once the argumentation session is complete, you will have a chance to meet with your group and revise your initial argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the best argument possible.

Report

Once you have completed your research, you will need to prepare an investigation report that consists of three sections. Each section should provide an answer to the following questions:

1. What question were you trying to answer and why?
2. What did you do to answer your question and why?
3. What is your argument?

Your report should answer these questions in two pages or less. This report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!