LAB 4

Lab Handout

Lab 4. The Coriolis Effect: How Do the Direction and Rate of Rotation of a Spinning Surface Affect the Path of an Object Moving Across That Surface?

Introduction

When studying the motion of objects, one of the assumptions that we often make is that the ground underneath the object being studied is stationary. That is, the frame of reference being used to study the object is not moving. It turns out, however, that very few reference frames are perfectly stationary (or, more formally, inertial). For example, imagine that a person is standing on a flatbed train car. The train is moving on a track to the east with a constant velocity. Both the person and train, as a result, have the same velocity in the horizontal direction. Now imagine that the person standing on the flatbed train car were to drop a ball while the train was moving. The person who dropped the ball would see the ball fall straight down to the ground because that person has the same reference frame as the train. A second person that is watching the train go by, however, would see something different. That person would see the same ball fall to the ground following a curved path. This is because the ball has both a vertical and horizontal component to its velocity as viewed from the reference frame of the person standing on the ground watching the train pass.

FIGURE L4.1

A point on the solid circle travels a farther distance in one day than a point on the dashed circle. The tangential velocity is therefore greater on the solid circle than on the dashed circle.

A French mathematician and physicist, Gaspard-Gustave de Coriolis, conducted numerous investigations in the 1800s to understand the movement of various bodies when the frame of reference was rotating. Initially, his studies were conducted against a rotating disc. Subsequent work by other scientists has applied his findings, known as the Coriolis effect, to the rotation of spheres, such as Earth. One of the interesting things that scientists have found is that while the rate of rotation is the same at all points on the globe, the tangential velocity is different depending on the latitude. Although every point makes one full rotation in one day, the radius of the disk traced by a point on the globe differs based on the latitude. Points near to the poles travel a smaller circle than points near the equator. Figure L4.1 illustrates this fact. What this means is that when an airplane travels with a north-south component, the place it takes off from will have a different east-west velocity than the place it intends to land. It is therefore important to take into account the Earth's rotation when planning a flight path between two airports.

In this investigation you will have an opportunity to explore the motion of a marble as it moves across a rotating surface. Your goal will be to determine the path the marble will take when it is rolled in the y direction across a surface that is rotating in either a clockwise or counterclockwise direction. Much like the example of the person standing on a train that is moving, the rotation of the surface on which movement takes place can lead different observers to see different paths of motion based on their frame of reference. An observer on the rotating surface (formally, a non-inertial reference frame) will see the marble take a different path than a stationary person watching from outside the rotating surface (formally, an inertial reference frame). This is because, relative to each observer, the marble has different velocity vectors. To the stationary person, the marble has two velocity components, one in the y direction and one in the x direction that is due to the rotation of the surface. To the observer on the rotating platform, however, the marble only has a velocity component in the y direction.

Your Task

Use what you know about vector quantities, measurement and scale, and systems and system models to design several experiments to determine how the motion of a rotating platform affects the movement of a marble rolled across the platform as viewed from different frames of reference.

The guiding question of this investigation is, ***How do the direction and rate of rotation of a spinning surface affect the path of an object moving across that surface?***

Materials

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

- Safety glasses or goggles (required)
- Video camera
- Computer or tablet with video analysis software
- Rotating "Coriolis" platform
- Marble
- Stopwatch
- Ruler

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. Do not throw marbles.

4. Pick up marbles or other materials on the floor immediately to avoid a trip, slip, or fall hazard.
5. 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 at least two different experiments because a rotating platform can move in different directions (clockwise or counterclockwise) and at different rates. You will need to examine how both of these factors affect the movement of a marble rolled across the platform as viewed from different frames of reference. As you design your two experiments, you must decide 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 can you describe the components of the system quantitatively?
- What will be the independent variable and the dependent variable for each experiment?
- How will you quantify a change in the independent variable?
- Which variables are vector quantities, and which variables are scalar quantities?

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

- How will you define the two reference frames?
- How will you vary the rotation rate of the platform?
- How will you measure the dependent variable?
- How will you measure the magnitude and direction of any vector quantities?
- What equipment will you need to take your measurements?
- 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 could you look for in your data?
- How could you use mathematics to describe a relationship between variables?
- What type of calculations will you need to make?

- How will you determine whether the movement of a marble rolled across the platform as viewed from different frames of reference is the same or different?
- How will you model the motion of the marble as it moves across the rotating platform?

Connections to the Nature of Scientific Knowledge and Scientific Inquiry

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

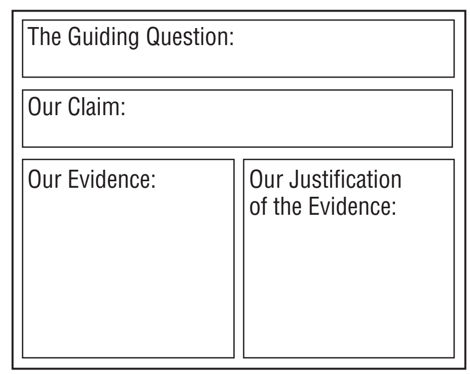
- the difference between data and evidence in science, and
- the role of imagination and creativity in science.

Initial Argument

Once your group has finished collecting and analyzing your data, your group will need to develop an initial argument. Your argument needs to 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 L4.2.

FIGURE L4.2

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!