

Rotational Energy

Instructional Objectives

After viewing the program and participating in the accompanying activities, the student will be able to:

1. compare and contrast rotation with revolution,
2. explain why the various positions on a solid sphere or globe move at different speeds in order to complete one revolution in the same amount of time, and
3. compare and contrast the rotations of planets and stars.

Synopsis

In "HST Data Stream," Dr. Eric Chaisson of the Space Telescope Science Institute shares some of the latest information received from the Hubble Space Telescope.

Using the movements of the earth as an example, the program begins by explaining the distinction between rotation and revolution. Students are shown geocentric and heliocentric models of the solar system. Active involvement in concept formation is encouraged as viewers are shown the axis line about which a basketball spins, and are then asked to identify the axes on other rotating objects. Their predictions are confirmed with an arrow indicating the axes' locations.

A spinning gyroscope is compared to the rotation of the earth. The gyroscope will stop rotating, but (as evidence of Newton's First Law of Motion) the earth could continue to rotate forever because there is almost no force in space to stop it.

Studio demonstration and animation explain why various points on rotating discs and spherical objects travel at different speeds in order to complete one revolution in the same amount of time. Points on the globe are marked to indicate that all parts of the earth travel at different speeds in order to complete one rotation in 24 hours. In contrast, the sun is an example of a rotating gaseous object, in which all parts do not rotate in the same amount of time.

In "The People Behind the HST," viewers will be introduced to Andy Lubenow, a Technical Assistant in the Science Planning Branch of the Space Telescope Science Institute. Andy is involved in the overall scheduling of the telescope, ensuring the most efficient use of viewing time. The end result of his work is a master plan of when observations will be carried out.

Vocabulary

Axis - An imaginary line about which an object rotates.

Equator - An imaginary circle around the earth, equal in distance from the north and the south poles.



Pendulum - An object that can swing freely. Jean Foucault used a pendulum to provide evidence that the earth was spherical and that it rotates.

Gyroscope - A wheel mounted in a ring, whose axis is free to turn in any direction, but keeps its original plane of rotation when spun rapidly.

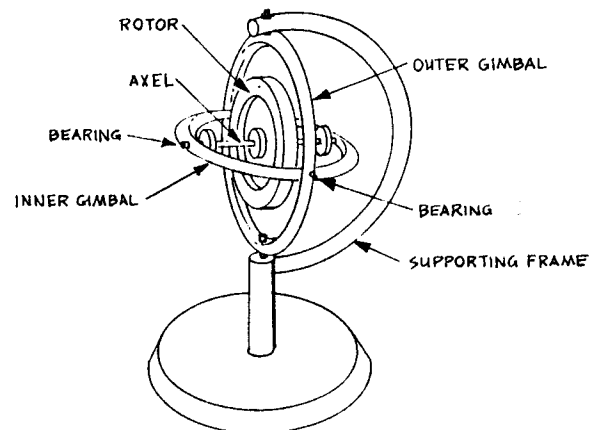
Revolve - To move in an orbit around an object.

Rotate - To spin about an axis.

Sunspots - Powerful magnetic disturbances which occur in the outermost layer of the sun, appearing as dark spots on the surface of the sun.

Previewing

Bring a gyroscope to class. Point out the axis and its tilt.



Discuss the fact that while the earth is rotating, people and objects on the surface of the earth are revolving about the axis. Set up a demonstration in which an object is rotating as it revolves around an object.

Have students create lists of things that rotate and revolve.

Find pictures of the early planetary models of the geocentric solar system. Compare and contrast these with the heliocentric model. Discuss with students whether they think the earth would have been believed to be rotating in a geocentric model.

Postviewing

Discuss the latest information from the Hubble Space Telescope.

Discuss the four movements of the earth. It not only rotates on its axis and revolves around the sun, it is part of the movement of the entire solar system through the galaxy and part of the galaxy's movement outward through the universe.

Ask students what would happen if all parts of the earth's surface traveled at the same speed. What role does gravity play in determining the shape of the earth?

Earth's axis is at a 23° angle. Discuss with students why this is the reason for the seasons. What would be different about our world if the earth's axis was perpendicular to its orbit?

Discuss the effect of earth's rotation upon weather patterns.

Display photographs of the earth from space in which the swirl of clouds exemplifies the movement of weather systems. Discuss the Coriolis Effect. To demonstrate this effect on a rotating globe, replace a free spinning globe on its stand with a sphere of equal size (one you do not mind getting stained). As you spin the new "globe," slowly pour a colored liquid on the upper half (northern hemisphere). Have students make note of the pattern of the liquid as the globe spins. Have them predict what pattern they would see if they could pour the liquid "up" on the lower half.

Try to find a gyrocompass. Due to the rotation of the earth, the axis of this device will always align itself along a north-south plane. Unlike a magnetic compass, a gyrocompass points to the true north pole, not the magnetic north pole.

Bring a phonograph to class. Place quarters on a record, then spin. Have students make note of the variance in speed of the quarters. Use the phonograph to discuss the term rpm (revolutions per minute).

Active Involvement

Let students become human gyroscopes by holding a bicycle wheel with a stick through the axle while sitting on a swivel chair or piano stool. The wheel should move freely on the axle. Have one student sit on the stool, holding the axle of the wheel straight out in front of him/her. Another student will be needed to spin the wheel as rapidly as possible. Have the seated student slowly turn the wheel, until it is on its left side. The class should make note of which way the student's stool turns. Now have him/her turn the wheel to the right and note the way the chair turns. Reverse the spin of the wheel and note what happens.

Use a ten speed bike to demonstrate the effects of the size of circular gears on speed and power. Have students investigate the ratio of gear size to bike speed.

Attach an accelerometer to a lazy susan or record turntable and note the direction of acceleration. Move the accelerometer closer to the center and compare speed and direction. For directions on how to make and use an accelerometer, see the Experiments/Projects section in the Teacher Guide for Program 5.

Draw three large concentric circles on a parking lot or gym floor. Ask three students to move around the circle at speeds such that they will each complete one revolution at the same time. Add new circles (and students) extending the outer edges as far as space permits. Discuss who had to travel the fastest.

Due to its rotation, the earth's shape is not spherical. It is slightly flattened at the poles and bulges slightly around the equator. The term for this is "oblate spheroid." Have students make a globe that is proportional to the shape of the earth.

One way to demonstrate what happens to a spherical shape when it rotates is to form a loop of paper, using a thin dowel or pencil as its axis. Take one strip of paper, about 3/4" by 8-10" and punch a hole in the middle, slightly larger than the diameter of the axis. Insert the axis through the hole and secure the two ends of the paper up to the top with tape or tack. Have one student quickly spin the axis. Have students note the shape. Spin the axis at different speeds. Ask if the shape of the loop changes differently at the faster and slower speeds.

Visit a museum with a Foucault Pendulum. Have several students report on Jean Foucault's experiment which provided evidence that the earth rotates.

Bibliography

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For middle school readers:

Adler, Irving. *The Sun and Its Family*. New York: The John Day Company, 1973.

Renner, Al G. *Experimental Fun with the Yo-Yo*. New York: Dodd, Mead and Company, 1979.

See for Yourself: Experiments/Projects (PART 1)

Working with Pendulums

I. A Simple Pendulum

The direction, or plane of swing, of a pendulum remains constant. In other words, once a pendulum begins its swing in one direction, it will continue along that same line of swing unless it encounters interference. One way to demonstrate this phenomenon is to make your own pendulum.

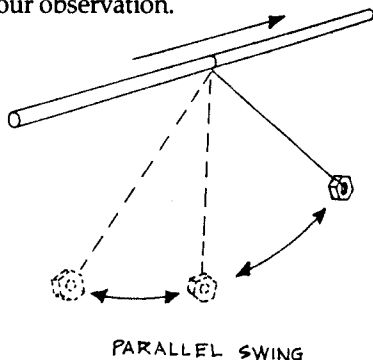
► MATERIALS:

- string, about 10-12"
- weight, such as a washer
- wooden dowel

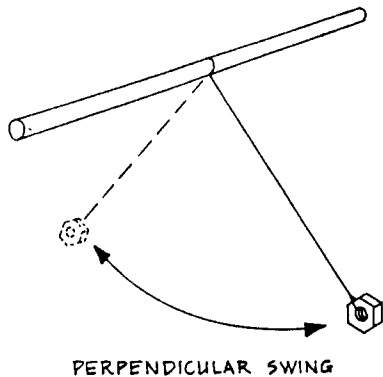
► DIRECTIONS:

To make your pendulum, attach one end of the string to the weight and tie the other end to the center of the wooden dowel.

1. While one student holds the dowel, the other student should swing the pendulum in a line parallel to the dowel. Observe what happens to the direction of swing. Record your observation.



2. Repeat step 1, but set the pendulum swinging in a line perpendicular to the dowel. Observe what happens to the direction of swing. Record your observation.



STARFINDER

PROGRAM 14

3. Choose a spot on the wall and point the dowel directly at it. Swing the pendulum in that direction. While the pendulum is swinging, slowly rotate the dowel away from the spot. Observe what happens to the direction of swing of the pendulum. Record your observation.
4. Write one or two sentences about what you think happens to the direction, or plane of swing, of the pendulum while it is on a rotating body.

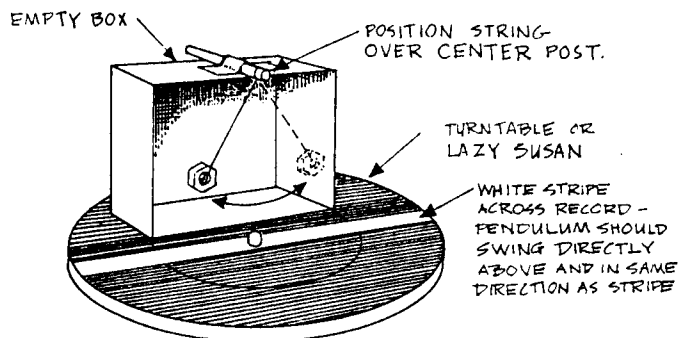
II. A Rotating pendulum

► MATERIALS:

- small pendulum made by tying a weight to a piece of string
- small dowel or pencil
- box, small enough to fit on one half of a record
- record player turntable or lazy susan
- old LP record with a white line directly across the middle (chalk line or tape), or circular piece of cardboard cut to a size that would fit on the turntable

► DIRECTIONS:

Assemble the pendulum by tying the weight to the string. Attach the other end of the string to a pencil on the top of the box, so that the pendulum swings down over the open side. The string needs to be short enough so that it can swing in any direction without bumping into the sides of the box. Place a piece of white tape across the diameter of the record. Secure the box onto an old record, in such a way that the swing of the pendulum will be directly above the white line (see diagram).



- Carefully swing the pendulum in the same direction as the line on the record. Does the plane of swing remain in line with the stripe on the record? Record your observation.
- Once again, swing the pendulum in the same direction as the line on the record. Rotate the turntable once and observe what happens to the plane of the pendulum's swing in relation to the white line. Record how many turns of the record it takes for the swing of the pendulum to return to a swing directly in line with the stripe on the record.
- Discuss with your partner what you might observe if you could shrink down to a size small enough to sit at the axis of the record and observe the pendulum swinging over your head. Write down your conclusions to the following questions.
 - Think about how the pendulum's swing would appear to you. Would it appear to turn?
 - If your world were turning counter clockwise (as the earth is at the north pole), in what direction would the pendulum appear to turn?
 - In what direction would the pendulum appear to swing if your world were turning clockwise (as the earth spins around the south pole)?
 - How many times would the pendulum turn for each complete rotation of your world?
 - If it took your world 24 hours to complete one rotation, how long would it take the swing of the pendulum to appear to turn a full circle (360°)?

III. Reproducing the Foucault Experiment

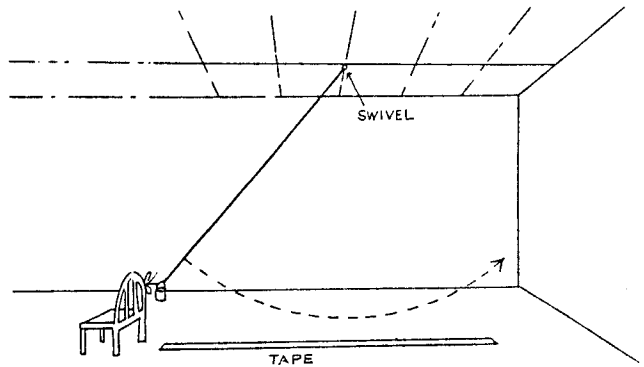
In 1851, Jean Foucault, a French scientist, used the motion of a pendulum to provide evidence that the earth rotates. He hung a heavy iron ball on a 200 foot wire from the ceiling of the Pantheon. Foucault knew that the direction, or plane, of swing of the pendulum would remain constant, but that if the earth were indeed rotating, the line of the pendulum's swing would rotate in a clockwise direction. In order to make his experiment as free from outside forces as possible, he tied the wire back with a piece of string and burned the string to release the wire. If you have a sturdy beam on the ceiling, you can try a similar experiment.

► MATERIALS:

- one swivel hook such as one used on fishing line
- length of wire long enough for the wire to swing freely from the ceiling
- string
- weight, such as a heavy fishing weight

► DIRECTIONS:

Attach the length of wire to the swivel hook and hang it from a string around a beam on the ceiling. Attach the weight to the other end of the wire. Place a length of tape on the floor. To replicate Foucault's experiment as closely as possible, tie the wire back with a string, attach to a chair at the end of the taped line, and release the pendulum by cutting the string with scissors after the pendulum is completely stationary.



- Because we are located on a rotating body (the earth), how would you expect the direction of swing to appear if you could swing a pendulum from a ceiling and allow it to swing freely for 24 hours? Record your prediction.
- When the pendulum is stationary, release it by cutting the string, making sure the plane of swing is directly above, and in the same direction as the line on the floor. Your pendulum will not swing indefinitely due to outside forces. It's swing will be very short, but you should be able to check if for at least one half hour.
 - Note the plane of swing one half hour later. Has it changed? Draw two lines indicating the original plane of swing (as shown by the tape on the floor) and the direction of swing one half hour later.
 - Does the plane of swing appear to be moving in a clockwise or counterclockwise direction?
 - Write your conclusions as to why this has occurred.

Foucault's pendulum was set over a railing covered with sand. This allowed him to track the locations of each swing, and indeed, the plane of swing moved in a clockwise direction. This confirmed his hypothesis that the earth rotated in a counterclockwise direction. But as he predicted, it did not complete one full rotation in 24 hours. His pendulum turned about 270° in one day. It took approximately 36 hours to rotate the full 360° . You may wish to go to the library and research why this fact provided evidence that the earth was spherical. Find out where on the earth the swing of the pendulum would have made one full rotation in 24 hours, and where on the earth it would not have rotated at all.

See for Yourself: Experiments/Projects (PART 2)

STARFINDER

PROGRAM 14

Tracking the Movement of Sunspots

Galileo used the movement of sunspots across the face of the sun as evidence that the sun does rotate. You also may be able to record and track sunspots.

CAUTION: LOOKING AT THE SUN CAN BLIND YOU. NEVER LOOK DIRECTLY AT THE SUN—WITH OR WITHOUT BINOCULARS.

► MATERIALS:

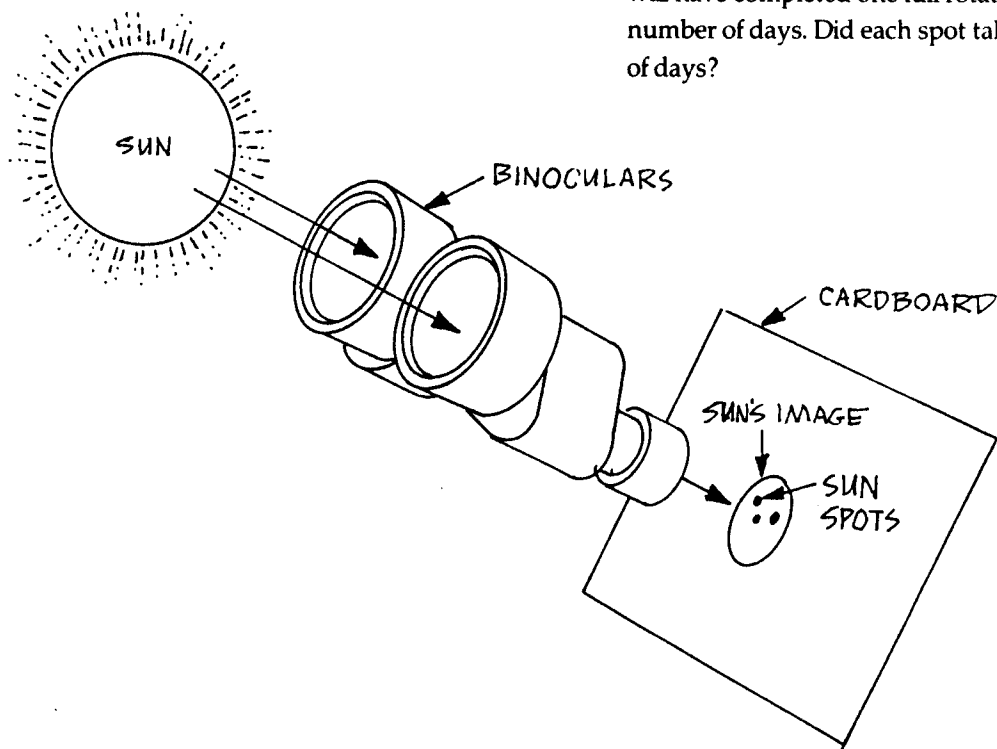
- binoculars
- posterboard (or stiff paper)

► DIRECTIONS:

Prop the posterboard up so that it is directly opposite the sun. Hold or prop the binoculars about two feet away, with eyepieces pointed towards the paper (see diagram).

Adjust the position of the binoculars until you get an image of the sun on the paper. Adjust the focus if necessary. Any dots you see on the sun's image are sunspots.

1. To record the sun's rotation, trace the outline of the sun's image on the posterboard. Circle the sunspots and mark with the date.
2. Repeat your setup each sunny day, so that the sun's image falls exactly inside the circle you drew on day #1. Circle the new positions of the sunspots and record the dates.
3. When the spots return to their original place, the sun will have completed one full rotation. Record the number of days. Did each spot take the same number of days?



Science Career Profile

ANDY LUBENOW

Technical Assistant

Space Telescope Science Institute

Education: B.S. Astrophysics

M.S. Astronomy



Chief Responsibilities

As a Technical Assistant for the Space Telescope Science Institute, Andy Lubenow assists in the long range planning and scheduling of scientific observing proposals. When writing an original proposal, a scientist describes what observation he or she wants the telescope to make. Andy then fills in all the details of how, and especially when, these observations can be made by the HST. Each proposal requires a great deal of work, much of it by computer, before it can actually be scheduled. Andy must keep tabs on the progress of up to twenty observing proposals. These could involve hundreds of actual observations.

Andy is particularly concerned with observations of solar system objects, such as planets, moons, comets, and asteroids. Unlike stars and galaxies, objects within our own solar system move in complicated ways, and the Hubble Space Telescope must be programmed to track these motions. This makes the timing of the observations of solar system targets quite complicated. If a scientist wants to observe a particular desert on Mars, the observations must be planned for times when that side of Mars is facing the telescope, and during daylight.

Andy has helped with the development, testing, and operation of a large set of computer programs that track the motions of solar system targets to very high accuracy and assisted in planning good times for observations. This is Andy's favorite part of his work at the Institute. He also operates other computers and software that are used for all scientific observing proposals. Each one must be scheduled for the best possible time in terms of its own needs, other observations being considered for the same time span, and the needs and restrictions of the telescope.

A Typical Day

On a typical day, Andy will look over the list of proposals assigned to him to see if any have been changed and what remains to be done for each one. He will try to fix any problems. For example, scientists may not want to have an observation interrupted, but may find that during the time the target is visible, the earth gets in the way. The observation might have to be shortened or interrupted, or perhaps a new observing time might need to be found. It is difficult for the scientists to predict these details. Andy helps by running sophisticated computer programs that take every detail into account. When difficult problems are found, he will often have to get advice from others at the Institute who are experts in whatever field the problem lies. Andy spends a lot of time in meetings discussing problems, solutions, and schedules.

When all the proposals seem to be in good shape, Andy will turn his attention to monitoring the moving target software and computers. He is personally responsible for keeping them running correctly, so that when software bugs are found, or the hardware breaks down, he must arrange for repairs.

Andy is also involved in improving the software, suggesting new features or better ways to handle the work, and testing these when they are written.

Because things do not always go exactly as planned, a quick fix may be needed to repair or work around whatever trouble has arisen. When a problem involves solar system targets, Andy is the one who is called in to run the software in a different way, or even write new software to address the problem.

Career Viewpoint

Andy has always been fascinated by space and astronomy, and has worked in a wide variety of projects, both in college and at the Space Telescope Science Institute. He likes to maintain a broad viewpoint, and always likes to be helping to create or perfect something new. Once a project becomes routine, he likes to move on to another one that needs work, often something quite different. In doing this, Andy keeps learning new things. Andy has always been curious about how things work, in nature, in machines, and even in people. That is why Andy chose a career in science; discovering how things work is what science is all about.

Andy has been fascinated by the universe since he was twelve and first looked up at the constellation Orion with his father's binoculars. He likes astronomy because it involves everything from what goes on inside an atom to how the entire universe works, and practically everything in between. There is always a wide variety of different projects to work on, interesting new things to learn, and lots of clever sophisticated gadgets like computers, telescopes, and spacecraft with which to "work."

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