DISCOVERY
SCIENCE CENTER

8^{th} – 12^{th} GRADES

8^{th} Grade Science Content Standards: Physical Science

Motion

1. The velocity of an object is the rate of change of its position.

   b. The average speed is the total distance traveled divided by the total time elapsed; the speed of an object along the path traveled can vary.

   e. Changes in velocity may be due to changes in speed, direction, or both.

9^{th} - 12^{th} Grade Science Content Standards

Motion and Forces

1. Newton's laws predict the motion of most objects.

   b. When forces are balanced, no acceleration occurs; thus an object continues to move at a constant speed or stays at rest (Newton's First Law).

   d. When one object exerts a force on a second object, the second object always exerts a force of equal magnitude and in the opposite direction (Newton's Third Law).

   e. The relationship between the universal law of gravitation and the effect of gravity on an object at the surface of Earth.

   f. Applying a force to an object perpendicular to the direction of its motion causes the object to change direction, but not speed (e.g. Earth's gravitational force causes a satellite in a circular orbit to change direction, but not speed.).

   g. Circular motion requires the application of a constant force directed toward the center of the circle.

8^{th} – 12^{th} GRADES
Physics

Motion

Isaac Newton proposed his three Laws of Motion dealing with inertia, the connection of a net force to acceleration, and the concept that forces come in pairs (action - reaction). Some of these Laws can be seen in action at home, at school, and in some of the exhibits at the science center, if you know how to look for them. In addition, some of the science center exhibits have strobe lights or other means to limit our view of the objects; that is, it controls *when* we can see where the object is located. Since motion relies on detecting changes in the position at successive clock readings, the motion that our eye-brain system perceives can be very different from the natural movement of objects. Animation is one technique that allows artificial movements to appear as real motion.

Exhibit Study One: Video Animation

In this exhibit, you are the director, the editor, and the sound mixer. You control the placement of objects. You control when the images are captured by the digital camera and transferred to the computer memory. You control the sound track that provides viewers of your animation with auditory clues while they see the object move on the screen during playback. In other words, you control the impressions that your animation sequence makes on people that see your short movie.

If you have several objects in the camera's view, some of them can remain stationary to provide a reference frame for the ones that will appear to be moving. The effect of the completed animation on the human mind depends upon many factors. Our first impression is seeing the movement on the video screen with the realization that some of the movement is (1) acceptable because that part of the sequence may appear natural. Some of the movement will seem (2) unnatural because another part of the sequence may produce jerky changes in direction or in speed or include movements that defy the natural laws of the universe.

This exhibit utilizes persistence of vision which is a relationship between the information (images) that the eye is capable of receiving and how the brain is interpreting that information. The human eye is capable of capturing one image at a time, which it transfers to the brain. The brain interprets the individual images and puts them together in such a way that the world around us appears seamless when moving from one step to another or changing our focus from one thing to the next. This process can also facilitate optical illusions, such as attributing movement to an object that has no true movement, such as is seen in the animated playback of your short movie.

Questions

1. Why is the frame rate, i.e., the number of frames per second, a fixed value instead of having different time intervals between frames?
2. How would you determine the speed of an object on the screen?

Exhibit Study Two: Strobe Fan

The strobe light emits a flash of whitish light and within a few nanoseconds some of the light reflects from a rotating disk into your eyes. The next flash results in another reflection and its additional information is absorbed by the eyes and transmitted to your brain. The numerous periodic glimpses create images that either exist on top of each other (persistence of vision) or appear rotated with respect to each other. If the flashes occur rapidly enough, the movement appears to be continuous, but if the flashes are too seldom, the images appear to jump from one to the other. What you see depends upon several factors: the time length of each light flash, the time interval between the flashes, the rotation rate of the image disk on the strobe fan, and the speed and quality of your eye-brain system response.

People have learned to sequentially replace one image with another to produce moving images. Before the 1800's, moving images were created with flipbooks. In the early 1800's, people used rotating cylinders containing sequential images to produce the illusion of motion. When motion pictures appeared on the social scene in the late 1800's, these sequential images were recorded on one piece of film to be played in a light projector over and over in commercial theaters. Today, more than 100 years after the first movies, motion pictures shape the ways in which people view the world.

At this exhibit, you can experiment with the disks provided or create unique disks at school and bring them to view at the science center.

Questions

1. The strobe flash lasts approximately one microsecond. If the fan turns at 1200 rpm, how far does the image move during the flash?

2. Why is difficult to make a strobe with an ordinary light bulb? How might one do it?

Activity

Use the template and examples of Strobe Fan disks to design a series of disks that can be placed on the Strobe Fan at the science center. It is best if you can run the template on cardstock for sturdiness.

Waves
Waves of all kinds transport energy from the source to its surroundings, at all times obeying the Law of Conservation of Energy. One might say that they propagate from a region of higher energy density to a region of lower energy density. The appropriate type of receiver can detect the presence of the waves. All waves except for electromagnetic waves require a medium, a material through which the wave propagates. Sound waves require a solid or a liquid or a gas because sound involves the organized motion of adjacent atoms or molecules to help transfer the energy from the source. There are also elastic waves in materials. And there are seismic waves, water waves, and plasma waves. All these wave types originate with a vibration of some material at the source, and they cause vibrations at the receiver end. For example, in response to sound waves, our receivers are our ear drums, which will vibrate and transfer this vibration inward to the inner ear and eventually be perceived by the brain as sound.

Electromagnetic waves do *not* require a medium for energy transport. The vacuum of empty space works extremely well for the various kinds of electromagnetic waves: gamma rays, x-rays, ultraviolet, visible light, infrared, radar, and radio waves. Electromagnetic waves originate with the acceleration of an electric charge, and as they propagate into materials, they display a whole range of phenomena such as refraction, reflection, absorption, diffraction, transmission, etc.

Waves are characterized in many ways, not only by the type of waves but also by the wavelength and frequency, the speed of the wave, the intensity, etc. In the exhibits, these characteristics place limitations on the phenomena to be observed and on the parameters that can be varied. In each exhibit, one should decide which characteristics are emphasized.

Exhibit Study Three: Strobe String
The strobe string exhibit shows the behavior of an elastic wave on a string. The strobe light flashes to allow a glimpse of the reflected light off the string so that its position at that moment can be seen. If the strobe flash is just right, the string will appear to be stationary, i.e., confined to a plane and not rotating along its long axis, and the nodes and antinodes are clearly visible. When viewed this way, the strobe string displays a standing wave. A standing wave occurs when a continuous set of waves reflect off a surface and overlap each other. Sections of the wave that appear to stay still are called nodes and sections between the nodes that have maximum movement are called antinodes.

In all cases, though, the string continues to be rotated. If you put your finger into the wave display at most locations, you can disrupt the behavior of the string, but the system soon recovers to once again show the original pattern. However, if the fingers are spread and carefully placed around a node, the string will remain undisrupted. In this manner, one can determine where the string really is at times other than when the strobe is flashing.

Essentially, one end of the string is being driven periodically by the rotating disk because that end of the string is slightly off center. You can move the opposite end forward or backward to alter the tautness of the string. You can also change the rotation speed of the string and change the flash frequency of the strobe light.

Certain patterns can be established that are stable. Each stable pattern, also called a mode, either has an antinode in the center or a node there. Of course, the apparatus forces a node at the far end, and the rotating disk end is practically a node, but not quite. If one knew the frequency of the wave motion and the wavelength along the string, the product of these two parameters equals the wave velocity. Then one might know how fast the energy is being transported by the waves.

Questions

1. What are the three variables you can adjust in this exhibit?

2. How does changing the tautness of the string affect the number of nodes?

3. How do you need to adjust the exhibit to show the greatest number of wavelengths?

4. How would you describe the concept of “pitch” using the strobe string as a model?

<u>Exhibit Study Four: Lariat Chain</u>

This exhibit has a continuously moving chain that is actually designed to encourage you to grab or at least touch it momentarily. A clutch mechanism at the top near the bicycle wheel will disconnect the drive motor whenever a small force hindering its movement is sensed, thereby releasing the chain.

The nature of this exhibit is quite interesting because stable patterns in the moving chain geometry are obvious, and they can be changed with a light tap of the hand. From the initial disturbance place, you can watch the displacement travel both directions up and down the chain to reflect on the other side. The speed of this displacement is different in the two directions because the impulse along the chain moves with the moving chain in one direction and opposite to the moving chain in the other. An analogous example is the movement of a surface wave produced by a pebble on the top of a moving stream of water. The downstream speed is greater than the upstream speed. (Note that this behavior is not the Doppler effect, a phenomenon which has to do with a moving source of vibration or a moving receiver but not a moving medium.)

You might also want to experiment to determine what kinds of stable patterns can be established in this moving chain. Must all segments of the chain bow outward, or are there stable patterns for which part of the chain can bend inward, such as a stable kink in the chain that maintains a fixed position above the floor as the chain continues to cycle through it? You may need to use the brush on the floor to help you investigate. In addition, can you measure the speed of the chain? Is the speed the same all the way around?

Questions

1. After experiencing the lariat chain, which direction is the chain moving, clockwise or counter clockwise?

2. While at the science center, give a light tap on the right side of the chain and observe what happens. Give a light tap on the left side of the chain and observe what happens. What difference do you notice in the chain's response to your taps?

Newton's First Law of Motion ~ Inertia

A. An object will stay at rest unless something comes along and moves (exerts a force on) it. Demonstrate this by setting an object on the table. Ask for an explanation of how to get the object to move. Explain that any of these ways of making the object move is exerting a force on it.

B. An object will stay in motion unless something interferes with it. (gravity, friction, etc) Demonstrate this by rolling a ball across the table. Ask for ways that would cause the ball to stop. Explain that any of these ways of making the object stop is exerting a force on it.

C. A ball will roll along in a straight line unless something changes its direction. (centripetal force, shear force, etc) Demonstrate how you can change the direction of a rolling object using the ball. Explain that centripetal force is a force which makes rotating bodies move toward the center of rotation; the force which holds objects in an orbit.

Newton's Third Law of Motion

For every action, there is an equal and opposite reaction. Explain what this means using an example which the people can visualize or participate in. For example: when you row a boat, the water is pushed forward with the oars while the boat responds by moving backward with equal force.

Centripetal Force

Use a lightweight object attached to a string. Hold one end of the string while spinning the object in a circular motion. The inward pull you are exerting by holding onto the string is an example of centripetal force. If you let go of the end of the string, the object would fly in a straight line away from the center until the force of gravity causes the object to curve toward the ground (Newton's First Law of Motion).

According to Newton's Third Law, for every action there is an equal and opposite reaction. The centripetal force (the action) is balanced by a reactive force, the centrifugal ("center-fleeing") force. The two forces are equal in magnitude and opposite in direction. The centrifugal force does not act on the body in motion; the only force acting on the body in motion is the centripetal force. The centrifugal force acts on the source of the centripetal force to displace it radially from the center of the path. Therefore, in twirling an object on a string, the centripetal force transmitted by the string pulls in on the object to keep it in its circular path, while the centrifugal force transmitted by the string pulls outward on its point of attachment at the center of the path. The centrifugal force is often mistakenly thought to cause a body to fly out of its circular path when it is released; rather, it is the removal of the centripetal force that allows the body to travel in a straight line as required by Newton's First Law.

Exhibit Study Five: Gravity Well

The Gravity Well demonstrates the principles of gravity and centripetal force. Drop the ball from the side of the well to observe the force of **gravity** (*the force which pulls everything toward the center of the Earth*). Roll the ball along the wall of the well to observe centripetal force. How can you make the ball stay in orbit longer? *(Answer: the ball will stay in orbit longer if it is moving faster.)* How does this apply to planets orbiting the Sun? *(Answer: the planets must progress quickly around the Sun ~ the closer they are to the Sun, the faster they travel.)* What causes the ball to eventually go down the hole? *(Answer: friction, air resistance, and gravity slow the ball, reducing the centripetal force.)* Why do planets not get pulled into the Sun? *(Answer: without atmosphere, space is, for all practical purposes, frictionless and objects don't experience air resistance.)*