Roanoke Pinball Museum • Key Concepts

What are Pinball Machines Made of?

SOL 3.3

Many different materials are used to make a pinball machine:

1. Steel: The pinball is made of steel, so it has a lot of mass.
2. Rubber: The bumpers are made of rubber, so the steel ball will bounce.
3. Wood and plastic: The colorful cabinet of the machine and many of the little parts are made of wood and plastic.
4. Glass: The playfield cover is made of glass. This cover keeps the ball in the machine allows the player to see what the ball is doing as it travels around the playfield.
5. Wiring: Wires serve as a highway do that the machine is provided with the electricity needed to power the lights, music, flippers, and other components.

Simple pinball machines consist of components that are often studied in physics: inclined planes, pulleys, levers, wedges, and wheels.

How Do Pinball Machines Work?

SOL 4.2, 4.3, Ph.5

Key Terms: mass, speed, acceleration, force, kinetic energy, potential energy

We can understand the operation of a pinball machine using the laws of physics. Physical concepts like mass, speed, acceleration, force, and energy are important to the understanding of pinball.

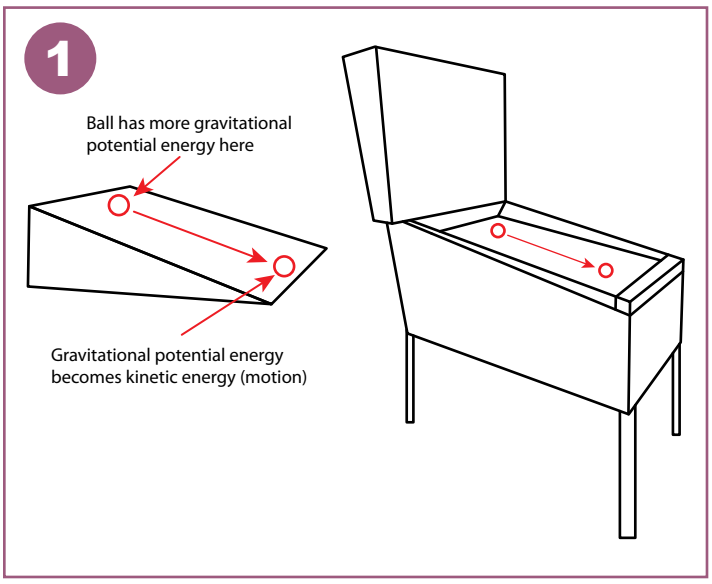
Pinball uses a steel ball. Even though the ball is pretty small, it has a lot of mass, so it is heavy. During play, the ball is in motion, that is, it has a speed in a particular direction. Pinballs can go very fast - up to 90 miles/hr (145 km/hr)!

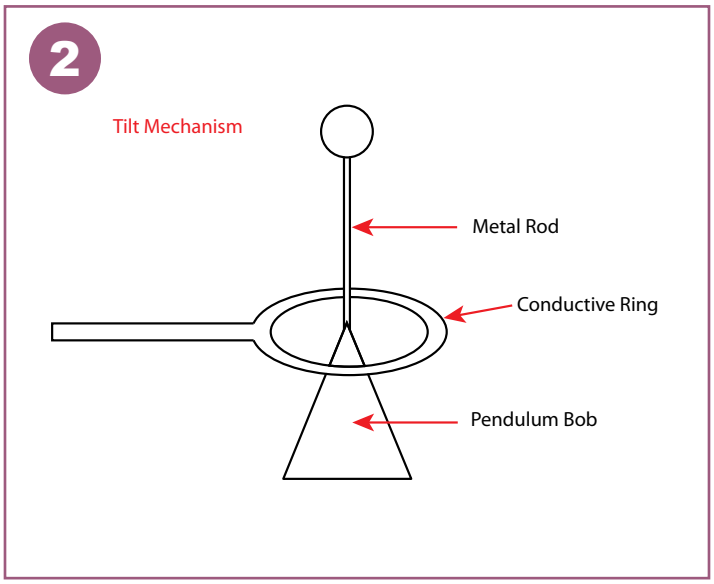
Newton's first law of motion tells us that any object that is in motion will stay in motion moving in a straight line, unless acted on by a force. A pinball machine works by using forces to change the motion of the ball. For example, we use the flippers to hit the ball, producing a force on the ball that makes it accelerate. Acceleration makes the ball speed up, slow down, or change direction. Other components like bumpers also hit the ball and produce forces, changing the direction or speed of the ball. When the ball is at the top of the sloped playfield, gravity exerts a force on it that makes it accelerate or speed up down the playfield toward the player (and the drain - watch out!). Because the ball has a lot of mass, we have to use a lot of force to make it accelerate.

Pinball also utilizes the physical concept of energy. To make the game more fun and challenging, the playfield is tilted at a 6-7 degree angle toward the player. This means that the playfield is sloped, with the back of the playfield higher than at the front of the machine. First, we give the ball energy by putting a force on it (hitting it) with the plunger, making it travel up the playfield. When the ball is at the top, it has more gravitational potential energy because it is higher above the surface of the earth. This potential energy from gravity is converted into the kinetic energy of the ball as it rolls down the sloped playfield.

The total amount of energy is conserved - that means it is neither created nor destroyed, but only converted from one form to another. The energy you put into the ball by hitting it with the plunger is converted to the kinetic energy of the ball's motion and gravitational potential energy at the top of the slope. Then the gravitational energy is converted into kinetic energy at the bottom. The bumpers add additional energy by applying forces to the ball. Of course, some of the energy is converted to heat by friction, so it is not available for potential or kinetic energy of the ball. The playfields are made smooth to keep friction to a minimum. Think about it…it is easier to ride your bicycle on smooth pavement than a gravel road (Diagram 1).

An interesting use of electromechanical energy and electrical circuits is the tilt mechanism of pinball machines. This keeps players from excessively shaking the machine. It consists of a pendulum bob that hangs inside a conductive metal ring from a metal rod. If the rod touches the conductive ring, a current is created and a circuit is activated. The machine gives the player a warning, or immediately disables the flippers (Diagram 2).





Vocabulary

1. Mass: The amount of material an object contains. It can be thought of as the number of atoms in an object. In physics, mass is a measure of inertia, or something's resistance to being moved. Mass is what causes things to have weight in a gravitational field.
2. Speed: The rate at which something moves, defined in physics as the distance something moves in a given interval of time.
3. Acceleration: A change in an object's speed – speeding up or slowing down.
4. Force: An influence on an object that causes it to accelerate, such as a push or pull.
5. Kinetic Energy: The energy associated with an object's motion.
6. Potential Energy: The energy associated with an object's position.

Questions & Answers

1. Question: If you flick the ball straight uphill towards the top of the tilted playfield, it gradually slows to a stop and then begins to roll downhill. Which way is the ball accelerating as it rolls uphill? downhill? Answer: As it rolls on the surface, it always accelerates downhill - first slowing down, then speeding up.
2. Question: If a ball is rolling downhill on the playfield and friction between the ball and the surface is slowing it down, in which direction is the force of friction pointing? Answer: The friction force is pointing uphill.

Science & History of Pinball

Pinball evolved out of a combination of billiards and bowling around 1700 in France. Table top ball games knocked down pins much like bowling. Forces were imparted to the balls, which, in turn, imparted their forces to the pins in order to knock them down.

Soon, the pins became fixed so players would not have to pick them up and holes were created for scoring instead. Then, in the mid-1700s, the spring launcher was introduced. This used the stored potential energy of a spring to apply a force to the ball and launch it up an inclined playfield. About 100 years later, modern pinball was born using the same concepts, but with marbles and metal pins instead of billiard balls and pins. The game now fit on a small table and had a glass top.

In the 1930s, the game became electrified. Electricity was used for lights and bells, making the game much more exciting. Solenoids were added to launch the ball. A solenoid is a wire wrapped around a metal bar. When a current is run through the wire, a magnetic field is produced. This field causes the spring in the plunger to contract. When it is released, the plunger puts a force on the ball which launches it up the ramp.

In 1947 flippers were introduced. These allowed the players to interact with the game more by hitting the ball and keeping it in play much longer. Now players could exert forces on the ball and move it where they wanted it to go.

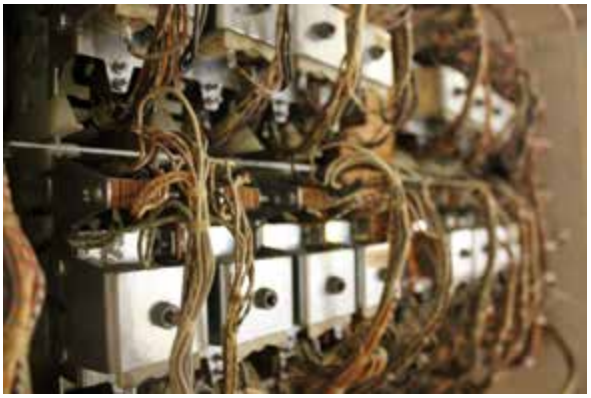
In the 1970s, solid state electronics were introduced. Many of the simple electrical circuits were replaced with digital electronic components called microprocessors. These devices function as mini-computers and produce the recorded sounds and complicated flashing lights in pinball machines.

Ramp

Flippers

Bumpers

Score Reel (internal)



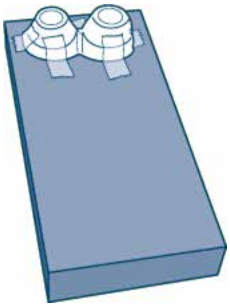
Make a Pinball Machine

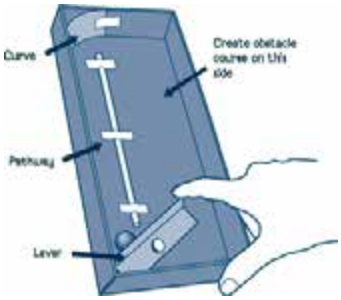
Supplies

1. Shoe box top
2. Scissors
3. 2 egg carton cups
4. Tape
5. Brass fasteners
6. Straws
7. Marble
8. Pencil

Instructions

1. Tape the two egg carton cups to the bottom of the box, this creates an incline
2. Make a lever by folding a 2 inch long piece of cardboard in half and attach it with a brass fastener, this will launch the marble
3. Make a channel along one side of the box top by taping down straws. This is where the ball will be launched.
4. In the top left-hand corner, tape a small piece of paper to create a curve for the marble
5. Consider making obstacles out of pipe cleaners, straws, or cups. Holes can be placed in the box for scoring. Bumpers can be made from rubber stoppers used in sinks.





Learning Objectives:
Simple levers can be explained using the pinball machine. Explain how the force on one end of the lever makes it pivot around the fulcrum, and that mechanical advantage is obtained, amplifying the input force.

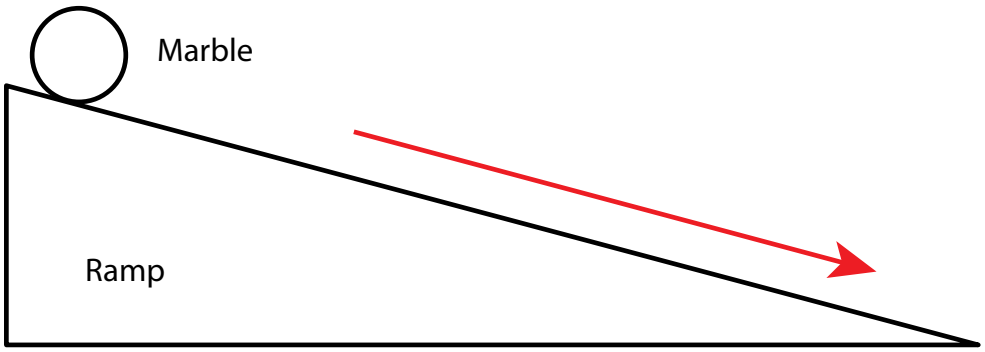
Balls & Ramps

Supplies

1. Marbles of varying sizes
2. Ramp
3. Deflectors (cardboard and rubberbands)

Instructions

Start a ball from rest at the top of a ramp. Show how the gravitational potential energy is converted into kinetic energy. Raise and lower the ramp to show that different heights give different final velocities.



Friction can be studied different surfaces and sliding objects down them. Examples include a slick plastic surface that allows a small block to easily slide. The friction of the surface can be changed by taping on a piece of paper.

Energy can be studied by building deflectors. These objects are made in the shape of an X using wood or stiff cardboard. Rubber bands are wrapped around the Xs and placed at the bottom of the ramps. Conservation of energy can be discussed - the rubber bands do not absorb all of the energy and it is redirected back to the ball.

Learning Objectives:
Friction and energy (conservation, transformation)