



Projectiles and Gravity

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Topic

Projectile motion



Time

2 hours



Safety

Please click on the safety icon to view the safety precautions.

Materials

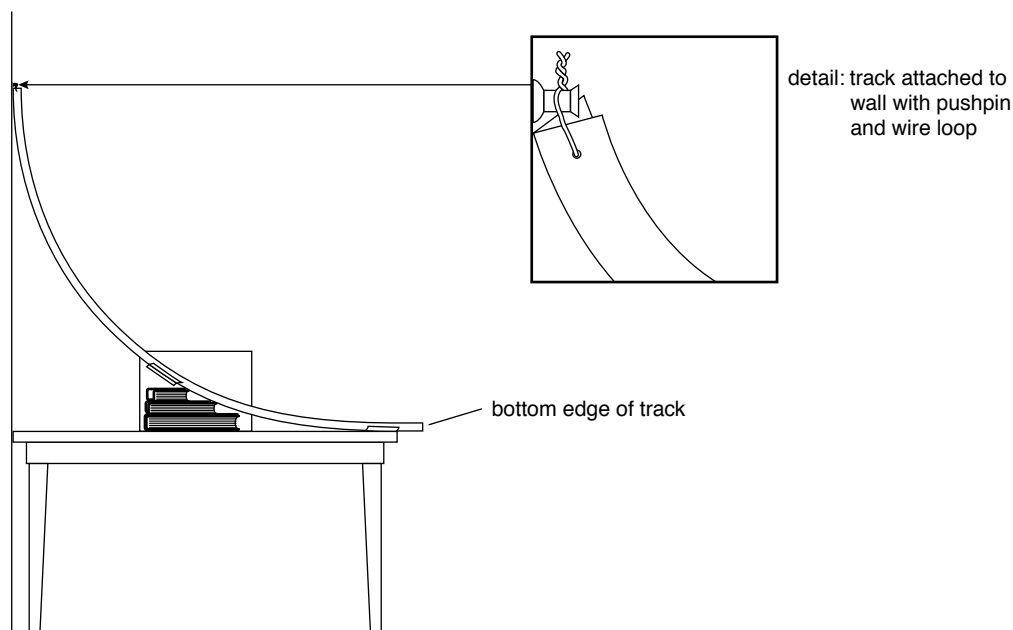
steel or glass ball about 1.5 cm in diameter (a marble will work)
one sheet carbon paper
one sheet typing paper
ring stand with 3-in. ring
flat table or countertop on which to mount track
carpenter's level
metric ruler

flexible U-shaped corner plastic molding (not rigid V-shaped)—available in 8-ft lengths at lumber yards and home improvement stores
masking tape
plastic pushpins
picture wire
plumb bob

Procedure

1. Set up the track as shown in figure 1. Puncture one end of the track, and attach a loop of wire through it. Stick a pushpin in the wall about 5 ft above the tabletop, and hook the wire loop over it so that the track is flush with the wall (see detail of figure 1). Attach the other end of the track to the table edge with double masking tape beneath it and pieces of supporting tape on the sides. The bottom edge of the track should be right at the table's edge or projecting over it slightly. Use the carpenter's level to make sure that the track is completely horizontal at the point where the ball leaves it. Place a box or a stack of books under the middle of the track and attach with the tape if necessary. The entire track must be securely mounted so that it does not wobble when the ball rolls down.
2. With tape, mark a point near the top of the track from which to start all trials. Practice releasing the ball to avoid "backspin." It is crucial to start from the same spot every time, since it will affect the velocity of the ball at the bottom of the track. Notice where the ball lands on the floor, and after you are through practicing, tape a piece of white typing paper over the area and then tape a piece of carbon paper face down over it.

Figure 1. Track setup



3. Use the plumb bob to mark a spot on the floor directly underneath the end of the bottom of the track. You will use this for later measurements.
4. Roll the ball down the track from the starting position so that it hits the floor on the carbon paper–white paper combination to make a spot where it lands. After some practice, you should be able to get these spots very close together, which indicates good technique and no track wobble.
5. Now you are ready to calculate the trajectory of the ball after it is launched from the track until it hits the floor. Projectile motion consists of two independent vertical and horizontal components that occur over the same time. If air resistance, is ignored—which is negligible for the smooth, dense ball—the vertical component of the projectile's motion is identical to the motion of an object in free-fall, subject to the constant acceleration of gravity. The horizontal component is uniform; it has constant velocity.

The following equations express this mathematically:

vertical component

$$dv = \frac{1}{2}gt^2$$

where dv = vertical distance traveled by the ball

g = constant acceleration due to gravity = 980 cm/sec²

t = time it takes for the ball's flight

horizontal component

$$dh = vht$$

where dh = horizontal distance traveled by the ball

vh = constant velocity at which the ball travels horizontally

t = time it takes for the ball's flight

Note that though the value of dv will be independent of the values for dh and vh , t will have the same value in both equations.

6. First obtain values for dv and dh by direct measurement:
 - a. Measure the distance in centimeters from the center of the spots on the paper to the plumb bob spot. This is dh , the horizontal distance traveled by the ball from the end of the track to landing.

- b. Measure the height (in centimeters) from the point where the ball leaves the track to the plumb bob spot on the floor. This is dv , the vertical distance traveled by the ball from the end of the track to landing.
7. Since g is a constant (980 cm/sec^2), you now have values for two of the three unknown terms in the equation for vertical motion, and you can solve for t as follows:

vertical motion:

$$dv = \frac{1}{2}gt^2$$

Multiply both sides by 2:

$$2dv = gt^2$$

Divide both sides by g to isolate t :

$$\frac{2dv}{g} = t^2$$

Take the square root to remove the square:

$$= \sqrt{\frac{2dv}{g}} = t$$

Substitute known values of dv and g , and solve for t .

8. Because the horizontal component of projectile motion takes place over the same time as the vertical component, you can use the value of t obtained in the step above to solve for vh as follows:

horizontal motion:

$$dh = vht$$

Divide both sides by t to isolate vh

$$vh = \frac{dh}{t}$$

Substitute known values of dh and t and solve for vh .

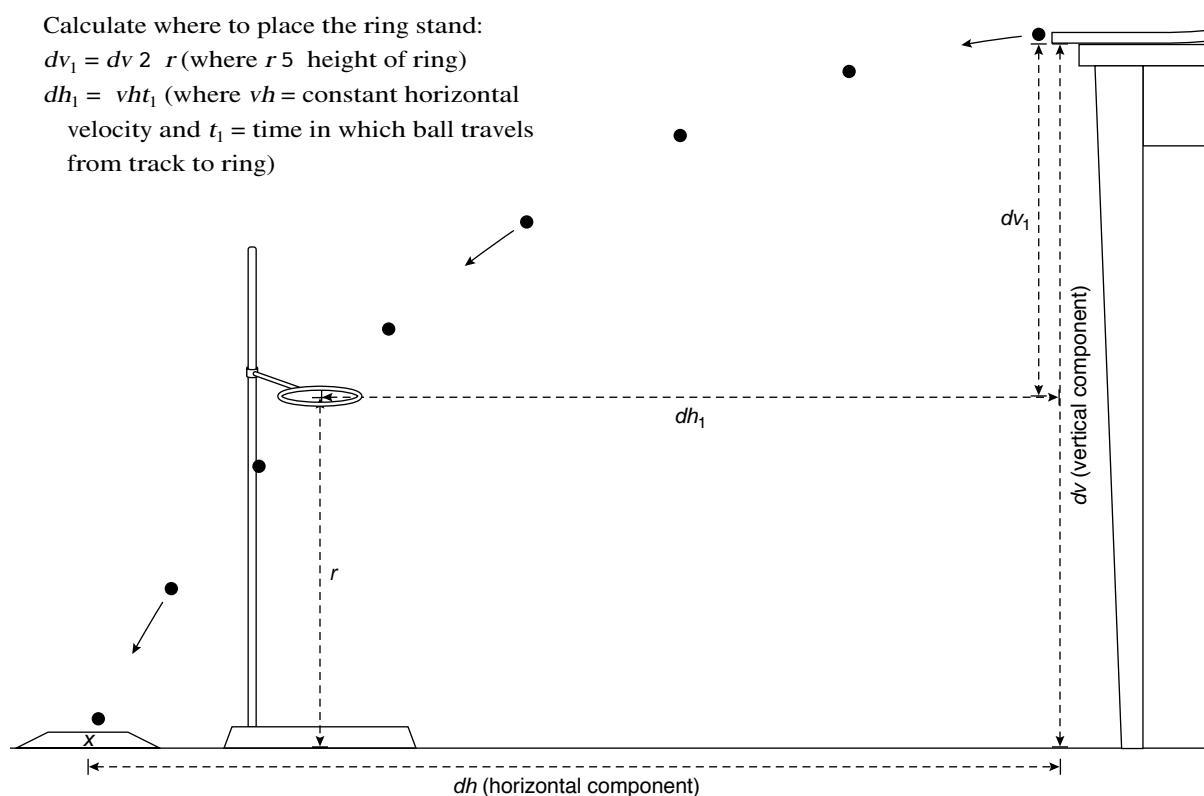
You now know the values of all the terms in the equations describing the projectile motion of the ball launched from the track. To make sure that your calculations really do accurately describe the ball's motion when it leaves the track, perform the following verification procedure:

9. Set the height of the ring on the ring stand so that its distance from the floor is less than the value of dv (the height of the track from the floor).
10. Using your solutions to the equations for vertical and horizontal motion, you can now determine where to set the ring stand so that the ball will drop through the ring on its path from the track to the ground.
11. To set the ring stand correctly, you will need to know the vertical and horizontal distances traveled by the ball from the end of the track to the center of the ring. Look at figure 2 for an illustration of the relationships of these values to the values of dv and dh you have already obtained.
12. To obtain the vertical distance traveled by the ball from the track to the ring (dv_1), subtract the height of the ring from the height of the track (dv).
13. Substitute this new vertical distance value (d_1) in the equation for vertical motion $dv_1 = \frac{1}{2}gt_1^2$ to find the new value for t_1 , that is, how much time it will take the ball to go from the end of the track to the ring. Now, substitute this new

value for t_1 in the equation for horizontal motion: $dh_1 = v_h t_1$, along with the value for v_h you obtained in your initial calculations (remember, v_h is constant) and solve for dh_1 . This is the distance from the plumb bob spot to the place where you should place the center of the ring.

14. Try it to see if it works. *No practice!* If it doesn't work, don't shift the ring around. Go back over your calculations, starting with your original measurements of dv and dh . Check your arithmetic for errors. Remeasure the height of the ring and check to see that you correctly figured dv . Double-check your calculation of v_h . Make any needed adjustments to the position of the rim according to your revised calculations. Make sure you are still starting the ball from exactly the same spot on the track. If all the measurements and calculations are in order, this verification procedure will work.

Figure 2



What's Going On

Results will vary according to particular experimental conditions.

Connections

An object thrown into motion in any direction other than straight up or down is called a *projectile*. Baseballs, rockets, slingshots, and frisbees all commonly move as projectiles. The curved path traveled by a projectile is called its *trajectory*. The trajectory can be analyzed into separate horizontal and vertical components, which have independent distance and velocity but which act over the same time. In this project, you employed this characteristic of projectile motion to calculate the trajectory of a ball launched from a track.

Safety Precautions

READ AND COPY BEFORE STARTING ANY EXPERIMENT

Experimental science can be dangerous. Events can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. Basic safety procedures help prevent serious accidents. Be sure to follow additional safety precautions and adult supervision requirements for each experiment. If you are working in a lab or in the field, do not work alone.

This book assumes that you will read the safety precautions that follow, as well as those at the start of each experiment you perform, and that you will *remember* them. These precautions will not always be repeated in the instructions for the procedures. It is up to you to use good judgment and pay attention when performing potentially dangerous procedures. Just because the book does not always say “be careful with hot liquids” or “don’t cut yourself with the knife” does not mean that you should be careless when simmering water or stripping an electrical wire. It *does* mean that when you see a special note to be careful, it is extremely important that you pay attention to it. If you ever have a question about whether a procedure or material is dangerous, stop to find out for sure that it is safe before continuing the experiment. To avoid accidents, always pay close attention to your work, take your time, and practice the general safety procedures listed below.

PREPARE

- Clear all surfaces before beginning work.
- Read through the whole experiment before you start.
- Identify hazardous procedures and anticipate dangers.

PROTECT YOURSELF

- Follow all directions step by step; do only one procedure at a time.
- Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eyewash, and first-aid kit.
- Make sure that there is adequate ventilation.
- Do not horseplay.
- Wear an apron and goggles.
- Do not wear contact lenses, open shoes, and loose clothing; do not wear your hair loose.
- Keep floor and work space neat, clean, and dry.
- Clean up spills immediately.
- Never eat, drink, or smoke in the laboratory or near the work space.
- Do not taste any substances tested unless expressly permitted to do so by a science teacher in charge.

USE EQUIPMENT WITH CARE

- Set up apparatus far from the edge of the desk.
- Use knives and other sharp or pointed instruments with caution; always cut away from yourself and others.
- Pull plugs, not cords, when inserting and removing electrical plugs.
- Don’t use your mouth to pipette; use a suction bulb.
- Clean glassware before and after use.
- Check glassware for scratches, cracks, and sharp edges.
- Clean up broken glassware immediately.

- Do not use reflected sunlight to illuminate your microscope.
- Do not touch metal conductors.
- Use only low-voltage and low-current materials.
- Be careful when using stepstools, chairs, and ladders.

USING CHEMICALS

- Never taste or inhale chemicals.
- Label all bottles and apparatus containing chemicals.
- Read all labels carefully.
- Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves).
- Do not touch chemical solutions.
- Wash hands before and after using solutions.
- Wipe up spills thoroughly.

HEATING INSTRUCTIONS

- Use goggles, apron, and gloves when boiling liquids.
- Keep your face away from test tubes and beakers.
- Never leave heating apparatus unattended.
- Use safety tongs and heat-resistant mittens.
- Turn off hot plates, bunsen burners, and gas when you are done.
- Keep flammable substances away from heat.
- Have a fire extinguisher on hand.

WORKING WITH MICROORGANISMS

- Assume that all microorganisms are infectious; handle them with care.
- Sterilize all equipment being used to handle microorganisms.

GOING ON FIELD TRIPS

- Do not go on a field trip by yourself.
- Tell a responsible adult where you are going, and maintain that route.
- Know the area and its potential hazards, such as poisonous plants, deep water, and rapids.
- Dress for terrain and weather conditions (prepare for exposure to sun as well as to cold).
- Bring along a first-aid kit.
- Do not drink water or eat plants found in the wild.
- Use the buddy system; do not experiment outdoors alone.

FINISHING UP

- Thoroughly clean your work area and glassware.
- Be careful not to return chemicals or contaminated reagents to the wrong containers.
- Don't dispose of materials in the sink unless instructed to do so.
- Wash your hands thoroughly.
- Clean up all residue, and containerize it for proper disposal.
- Dispose of all chemicals according to local, state, and federal laws.

BE SAFETY-CONSCIOUS AT ALL TIMES