# Amusement Park Swing Ride

Ron DeFronzo and Barbara Wolff

## Topic

Circular motion; centripetal force

## Time

1½ hours

## Safety

Please click on the safety icon to view the safety precautions. Be careful using the matte knife and when poking holes with the compass or scissors.

## Materials

- drawing compass
- corrugated cardboard box with side dimensions at least 40 cm 2 50 cm
- string
- black sewing thread
- record player (with 78 rpm, if possible)
- four different colored marking pens
- two mailing tubes 30 to 45 cm (1 to 1½ ft) in length
- meterstick
- glue
- paper clips
- scissors or matte knife
- masking or duct tape
- eight pennies
- trigonometric table or calculator function
- stopwatch

## Procedure

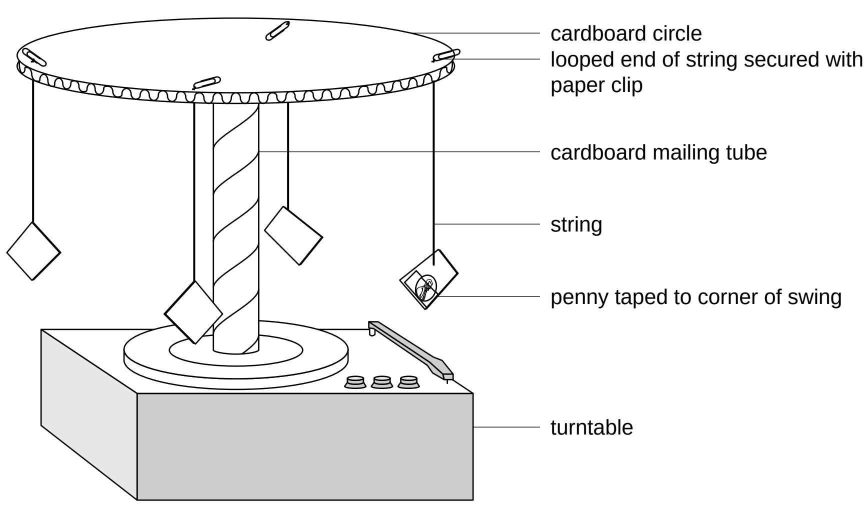
Ask the owner of the record player for permission to use the equipment.

### Part A: Constructing the Swing Ride

1. Cut up the box so that you separate the sides and are left with five separate pieces of cardboard. Put the bottom aside and use the four sides.
2. Using the meterstick, draw a diagonal line from one corner of a side to the other. Repeat this for the opposite corners. Where these lines cross is the center of the side. Do this for each side.
3. Use the compass to find the circumference of the mailing tube as follows: Place the point of the pencil and the needle on opposite sides of one end of the tube. Now, close down the compass legs to one half this distance. On a piece of paper, scribe this circle and see if the tube will fit right inside it. If the tube does not fit, adjust the compass legs to a larger or smaller radius until the tube fits just inside the lines.
4. Being careful to keep the compass at its present radius setting, place the needle of the compass on the center point of one of the pieces of cardboard, and scribe this circle on the cardboard.

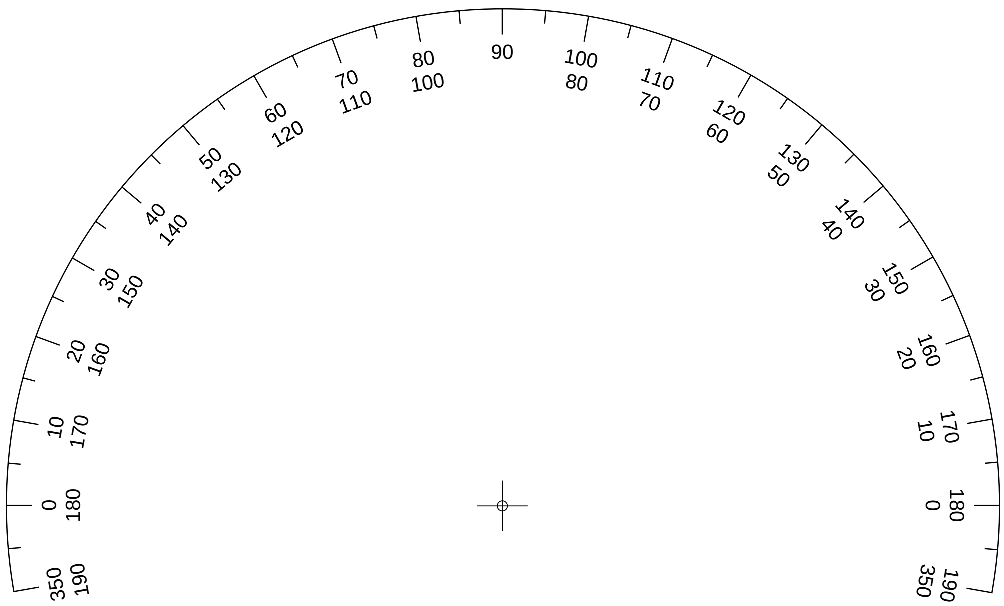
5. Repeat steps 2 and 4 on the other pieces of cardboard until you have a circle of the circumference of the mailing tubes drawn on the center of each piece.
6. On one piece of the cardboard, place the compass needle in the center and open the compass legs as wide as possible. Draw the largest circle you can around the smaller circle on this piece of cardboard. (If you use a long pencil, you should be able to draw a circle with a radius of about 16 cm.)
7. Carefully cut out this large circle, using either the scissors or the matte knife. Push the needle of the compass through the hole it has already made in the center of the circle so that it is visible on both sides of the cardboard.
8. Note the radius measurement on the compass, and close the legs to draw a circle with half the radius of the one that you just cut out.
9. Draw this circle on the other three pieces of cardboard as you did in step 6, and then repeat the directions in step 7 for each circle. Take two of the smaller circles, and, using the point of a pair of scissors, carefully enlarge the hole in the center of each circle until it fits over the spindle on your turntable. Be careful that the hole remains centered.
10. Glue one of the circles with the enlarged holes on the bottom of each mailing tube. Make sure that each tube is centered on the small, drawn circle before gluing.
11. Take the two remaining cardboard circles and poke four holes approximately .5 cm from the edge, one each on the points where the lines bisecting the circle reach the edge.
12. Glue the circles to the tops of the mailing tubes, making sure that they are centered.
13. Out of the bottom of the box, cut eight rectangles 4 cm 2 5 cm. These will be the “swings.” Punch a hole in the center of each one. Use the marking pens to color each of the swings a different color, covering both sides.
14. Cut eight pieces of string 48 cm long. Fold the strings in half, and push one through the hole in the center of each swing. Leave .5 cm of the loose ends coming through the holes, and tape these to the bottom of the swings. Make sure that the lengths of all the strings are even when taped.
15. Push the strings through the holes in the top circles, and secure each one by passing a paper clip through the loop coming through the top of the circle. Pull the strings taut. Tape a penny to the corner of each swing on one of the rides, as shown in figure 1.

**Figure 1**



16. Glue the copy of the protractor in figure 2 onto the remaining cardboard. Use the compass needle to poke a hole in the center near the straight edge. Cut off a piece of thread about 15 cm long. Tie one end through the hole. Tie the other end around four paper clips for weight.
17. Place one of the swing rides on the turntable. You are now ready to begin.

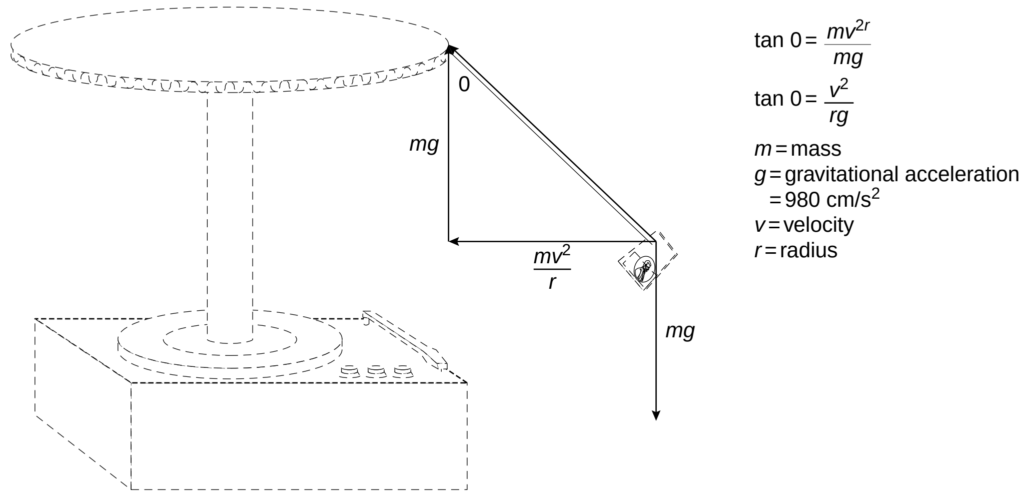
**Figure 2**




PART B: INVESTIGATING CENTRIPETAL FORCE

1. Set the turntable speed to 33 rpm and turn it on. Observe the action of the swing ride.
2. Note the angle of the strings. What do you think would happen to this angle if more weight were added to the swings? Stop the turntable. Tape two more pennies each to two of the swings on opposite sides of the ride. Write a hypothesis about what will happen to the angle when you start the ride again. Start the turntable; observe and record the results.
3. Figure 3 shows the forces operating on the swing ride. The vertical force is gravity, mass 2 gravitational acceleration *(mg)*. The horizontal force is the centripetal force that keeps the circling object from flying in a straight line. Note that the tension of the string is the resultant of these two forces. Since the forces are perpendicular to each other they form a right triangle, and we can determine the tangent of the angle of the string (U) by dividing the side opposite ($mv^2/r$) by the side adjacent *(mg)*. As the figure shows, this allows you to cancel the mass from the equation. How does this relate to the results you observed in step 2?

**Figure 3**

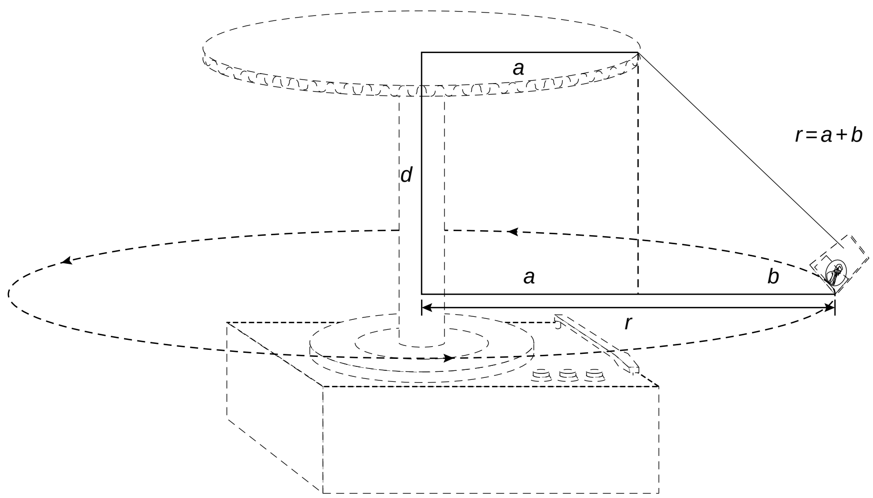



4. Look at the final equation: tan U = $v^2/rg$. Given that the larger an angle is, the larger its tangent, what should be the effects on the string's angle of increasing or decreasing the quantity *v* (velocity of the ride)? Write a hypothesis of what you think will happen if you increase the ride velocity to 45 rpm. Then try it and see. If your turntable will rotate at 78 rpm, test your ride at this speed, too.
5. To find out the effect of increasing *r* (the ride's radius), you will need to further analyze the quantities *v* and *r*. The radius of the ride *(r)* is the radius of the circle described by the swing. This is somewhat larger than the radius of the cardboard circle, as you have seen. Figure 4 shows how the radius of the swing's circle *(r)* is equal to the radius of the cardboard circle *(a)* plus the horizontal distance between the swing and the cardboard *(b)*. The velocity of the swing can be expressed in terms of (cm/sec), in order to conform to the other units in the equation. First you will need to know the *period* of swing—how long it takes to make the complete trip around the circle. The speed of the turntable is set to 45 rpm, but you might want to measure this directly to be sure that you have an accurate figure. To do this, choose one of the swings to watch as it passes a point on the wall behind the ride. Start the stopwatch as the swing goes by this point and count the number of times it passes in 1 min. Write the number here: ___________ rpm. Then, since there are 60 sec in a minute, divide 60 by this number to get the time in seconds of a single rotation. Write this number here as the swing's period *t*:___________ . Since velocity = distance/time, we need to know how far the swing travels in one rotation. The swing is always traveling in a fixed circle, so in each rotation it covers the distance of the circle's circumference.

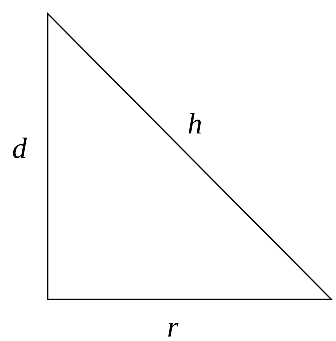
The formula for a circle's circumference *(c)* is $c = 2\pi r$, where π is the constant 3.14. In this case, as shown above, $r = a + b$.

So $v = 2\pi r/t$ and you could rewrite the formula tan U = $v^2/rg$ as tan U = $2\pi r/t^2/rg$ or tan U = $2\pi(a+b)/t)^2/(a+b)g$. Now what do you think the effect on the string's angle will be if you increase *r* by using the ride with the larger cardboard circle?

**Figure 4**



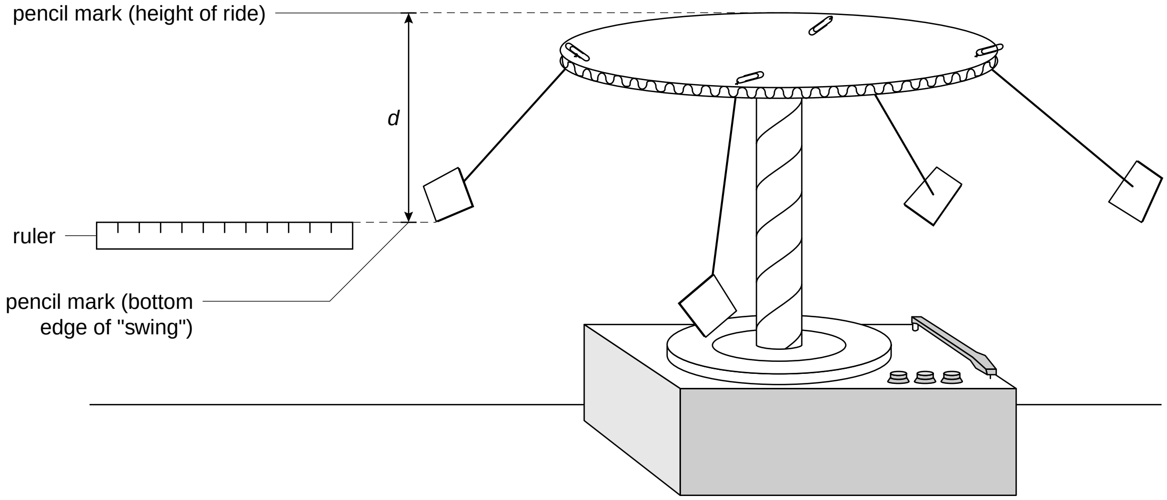

6. Before you switch to the larger ride to find out, test whether the formula accurately predicts the angle of the strings on your ride. First, use your protractor to directly measure the angle U. Stand or squat directly in front of the ride in motion, and hold up the protractor so that its edge lines up with the swings on the ride. Do this *very* carefully, because accuracy is of the utmost importance and it is easy to lose it here. Read the protractor where the thread crosses it. This will be the same angle as the ride, U. To solve the equation for U you will need to determine the value of *r*. You could measure directly, but this would be difficult. There is another way, by using the Pythagorean theorem, which states that for any right triangle:




$h^2$ 4 $r^2$ ʻ $d^2$

Applying this to your setup, *h* = length of string, *d* = the vertical distance between the swing and the top of the ride when the swing is in motion, and *r* = the radius that you are trying to find. You can measure *d* fairly easily by placing the ride near the wall and holding a ruler horizontally against the wall and adjusting its height until it appears even with the bottom edge of the swing as it passes, as shown in figure 5. Put a *small* pencil mark on the wall at this point. Then use the ruler to mark the height of the ride, and measure the vertical distance. This gives you the value of *d*. Measure the length of the string to get *h*, and plug these values into the formula just shown to solve for *r*. Using this value, solve for tan U, and find its value in your trig table or on your calculator. How closely does the answer you obtained from the formula match the angle you measured using the protractor?

**Figure 5**




7. Now, remove the ride from the turntable, and replace it with the larger ride. Measure the new value of *d*, using the procedure in step 6. Plug this new value into the formula, and again solve for tan U, and find U. Then use your protractor to see if the formula accurately predicted the angle of the strings on the larger ride.

## What's Going On

Results will vary depending on the size of the rides used. At 45 rpm, the period *t* equals 1.33 sec. Changing the mass *(m)* on the swings does not affect the string's angle. Increasing the velocity *(v)* of the ride increases the string's angle. Angles will depend on ride size. For a top circle radius of 8.7 cm at 45 rpm we got an angle of 29 degrees.

## Connections

If you tie a stone to the end of a string and swing it around your head, you will notice that its motion describes a circle. You will also notice that you must keep applying an inward pull to the string to keep the stone from flying off in a straight line (tangential to the circle). This inward pull is an example of *centripetal force*, the force necessary to keep an object moving in a circular path. In this experiment you constructed a model of an amusement-park swing ride that uses centripetal force. Then you analyzed the forces acting when your model is in motion.

# 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