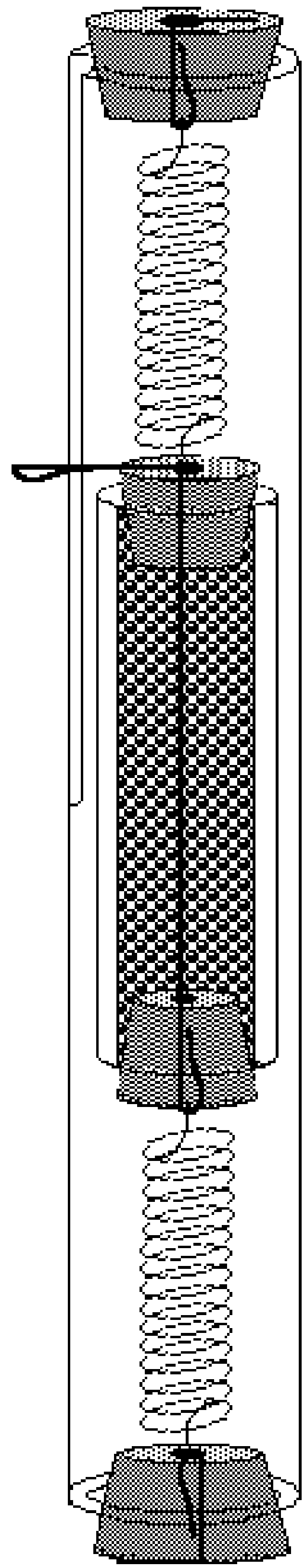
Dual Spring Accelerometer

Horizontal and vertical mass-spring accelerometers are simple and inexpensive to use. If the conditions of the ride aren't too extreme they give reasonably good results. They do have their limitations however, and these can sometimes be great enough to render them nearly useless.

Horizontal accelerometers made by hanging a small mass from the center of a protractor are great for measuring side-to-side accelerations and are very useful for measuring angles of inclination to determine the heights of objects and structures. This second use makes them an indispensable tool for physics day at the amusement park. They are, however, very susceptible to the wind and on all but the slowest rides are blown around so badly that getting any useful measurements is problematic, at best.

Vertical mass-spring accelerometers aren't disturbed as much by the wind since the suspended mass and spring tend to be enclosed in a clear plastic tube. They can, however, be difficult to read while riding a fast roller coaster and can oscillate out of control. Another drawback is that they can really only measure accelerations up (positive accelerations). Once zero g is reached the accelerometer (and rider) is in free fall and the mass is "weightless", exerting no force on the spring. If, say at the top of a hill on a roller coaster track, the train dives down faster than gravity would pull it, a negative g situation is encountered. The normal mass-spring accelerometer cannot measure this negative acceleration.

The Dual Spring accelerometers helps to overcome these limitations. Essentially it is a piston with springs attached to both ends which slides inside of a cylinder. The ends of the cylinder are plugged with rubber stoppers and the other ends of the springs are attached to the stoppers. The piston is made from 3/4 inch outside diameter PVC pipe of the kind used for household water pipes and the cylinder is made from 3/4 inside diameter PVC pipe. The piston is filled with lead shot to increase it’s inertia. The result is the the piston assembly slides inside the cylinder with some friction. This friction helps keep the piston-spring assembly from oscillating out of control. Here a little friction is a good thing.



Because it has springs of equal stiffness and size pulling it towards both ends of the cylinder, the piston has an equilibrium position at about the middle of the cylinder. If the device is accelerated in the direction of either end the piston will deflected in the opposite direction. The amount of deflection is proportional to the magnitude of the acceleration. If there is no acceleration there is no movement of the piston. A groove is cut in the side of the cylinder from one end to just past the mid point so that a pointer can be added to show the position of the piston. If the device is held horizontally the pointer indicates the equilibrium, or zero position. This is what the device would read in a non-accelerated, zero g environment. If it is then held vertically the pointer moves down to a new position. This corresponds to a one g acceleration, the same as we experience in our normal every day life. If the device accelerates upward, like at the bottom of a roller coaster dip, the pointer moves down more. This device can be calibrated to measure up to five g’s.

If the device accelerates down faster than gravity would cause it to fall, like at the top of some roller coaster hills, the pointer will move above the zero mark. Thus, this accelerometer is capable of measuring negative g forces up to about 5 g's. It should be noted that it would be rare to encounter one or more negative g's on any amusement park ride.

Because this accelerometer can measure accelerations in both directions, it can be used to measure horizontal accelerations as well. If a rider holds the device so that it's length is parallel to the floor it will measure side to side or horizontal accelerations. If the ride is moving in a straight line the piston and pointer will return to the zero mark. This accelerometer is not just limited to measuring change of direction accelerations. If it is held parallel to the floor and with one end pointing towards the front of the car, it can measure accelerations associated with speeding up or slowing down.

Because of the versatility of this device it is the only accelerometer you will need at the amusement park. It is also very useful in class for doing experiments. It is relatively easy to construct and should take one to two class periods, depending on how much preparation is done ahead of time. I recommend cutting the PVC pipe and the groove in the cylinder ahead of class. These can be disassembled at the end of the school year and be reused year after year. The cost of making these is about $5.00 each.

Procedures for construction and calibration start on the next page.

Material for each accelerometer:

Rubber Stoppers
    2 - #4 one-hole stoppers
    2 - #2 one hole stoppers
Springs
    2 - Century spring Co. part # C-185 length: 7 cm,
3/4 inch inside diameter PVC pipe cut into 46 cm length
3/4 inch outside diameter PVC pipe cut into 12 cm length
wire coat hanger, approximately 24 cm total wire
1 large paper clip
1 mechanical pencil eraser
Duct Tape
Lead shot, approximately 150-180 grams

Also needed for Construction and Calibration:

Hack Saw.
Electric Drill.
Large drill bit (1/4 inch).
Small grinding wheel that can be attached to an electric drill.
2 large c-clamps or a table mounted vise.
Heavy duty wire cutters.
Chisel.
File.
Sand paper.
Pliers.
Permanent marking pen.
Equal arm balance.

Procedure:

1. Cut the PVC pipe into the following lengths:
   cylinder = 46 cm; piston = 12 cm.

2. Clamp the cylinder piece to a table or in the vise. Measure 25 cm from one end of the cylinder and mark.

3. Using the grinding wheel and electric drill, grind out a 1/4 inch groove from the end measured from to the mark at 25 cm. Drill a hole through the opposite end of the cylinder, about 1 inch from the end.

4. Use the chisel, file and sand paper, as needed, to smooth out the edges of the groove. Place the cylinder aside when complete.

5. Cut a piece of coat hanger about 18 cm long with the wire cutters. Bend 1.5 cm of one end of the wire back so that a narrow loop is formed.

6. Push the wire loop just made through the hole in the narrow end of one of the #2 stoppers so that about 2-3 mm of the loop sticks out of the wide end of the stopper.

7. Slide the wire through the piston tube and secure the rubber stopper in the tube so that one end of the tube is closed and the wire goes through the tube and has about 4-5 cm sticking out the open end of the piston.

8. Place the assembly on the balance with the Styrofoam cup and the other #2 stopper. Add lead shot to the cup until the mass of the shot and piston is about 150 - 180 grams. You will need to experiment to find the optimum mass for the piston. Pour the shot into the piston.

9. Slide the second #2 stopper over the wire so that it plugs the open end of the piston. Using the pliers, bend the wire 90 degrees so that it is flush against the stopper and holds it in place. This should be a fairly snug fit. Check to see that there is still 2-3 mm of loop showing at the opposite end of the piston. Bend the last 1.5 cm of the wire back to form another narrow loop.

10. Connect the springs to the ends of the piston. The loop of one spring should go through the narrow loop of wire at one end of the piston. The other spring fits over the wire bent at a right angle to the piston.

11. Slide the piston assembly into the cylinder so that the wire slides in the groove. This is the pointer. Make sure the assembly slide smoothly, with only a little friction. <u>Remember, some friction is desirable.</u>

12. Cut two pieces from the remaining wire about 2.5 cm longer than the #4 rubber stoppers. Bend about 1.5 cm of one end into a narrow loop, as before. Push the loop through the <u>wide</u> ends of the stopper so that 2-3 mm shows through the narrow end. Bend the other end of the wire 90 degrees as before, making sure of a snug fit.

13. Pull the end of the spring attached to the piston out the un-grooved end of the cylinder. Attach it to the loop sticking through the #4 stopper. Place the stopper snugly in the end of the cylinder. Attach the other spring to the other stopper in a similar fashion. Place that stopper in the other end of the cylinder.

14. Thread the string through the holes drilled in the cylinder and tie the ends together to form a loop. This is a safety wrist strap to wear while carrying the accelerometer on an amusement park ride. Use the duct tape to double secure the rubber stopper in the ends of the cylinder. The device is now ready to calibrate and use.

Calibrating the Accelerometer:

1. Lay the device on a table so that it is parallel to the floor. Place a mark at the location of the pointer. Label this "0 g".

2. Tip the device up so that it is perpendicular to the floor. Mark the location of the pointer. Label this "1 g".

3. Turn the device around so that the end that was pointing down is now pointing up. Make sure that the device is perpendicular to the floor. Mark the position of the pointer. Label this "-1 g".

4. Measure the distances from the "0" mark to the "+1" and "-1" g marks. Extend these distances out in both directions. Mark each distance and label 2g, 3g, 4g, 5g. and -2g, -3g, -4g, -5g.

The device is now calibrated and ready for use.