Race Gear: Sensors and Barriers

Testing barriers in the real world offers many challenges: For example, how do you get a car going really fast and hit a target at a specific angle without anyone in the car? Testing barriers in the classroom also poses some challenges. This document shows you how to prepare a force sensor for testing barriers.

Materials Needed (for one track set up)

- Base
  - One 6”x 10” board, approximately 1” nominal thickness (pine is fine);
  - ¾” square pine moulding (approx 8” total length);
  - Small (3”x 3”) piece of scrap wood and long screw (optional);
- Track
  - One piece of foam core or plywood 6” x 30” (for ramp);
  - One piece of plywood 6”x13”, nominal 1” thick (for base of track)
  - 42” of “Hot Wheels”-type track for 1:64 scale cars;
  - ½” long small flat-head screw (to hold track to base);
- Wall
  - One piece of 6” x 2.5”about ½” thick plywood;
  - 1– 6-32 flat-head screw (1” long) with nut and washers (if needed);
  - 1 – 6/32 nut;
  - Washers for the 6-32 screw (optional);
- Books, table or other way of holding on end of the track anywhere from 15-20” off the ground;
- One force sensor (50 N max measurement);
- Clamps to hold down the base;
- Computer or calculator with data acquisition software and interface;
- Duct tape
- Scissors
- Drill (optional)

 The development of these materials was funded by the National Science Foundation through grant PHY-0839180. The opinions and conclusions expressed here do not necessarily represent those of the National Science Foundation. More information is available at www.buildingspeed.org.

Making the Wall

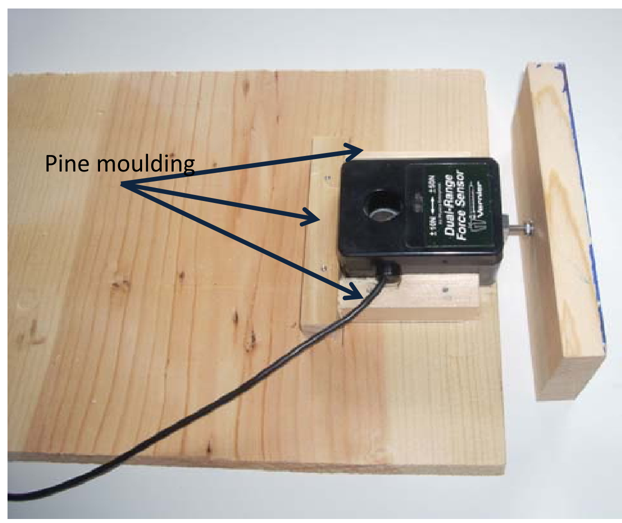
Vernier force sensors have a 6-32 screw thread to which the wall can be attached. We used a 2.5 cm (1" inch)-long 6-32 flat-head screw with a washer and nut to attach a 1.3 cm (½") thick piece of plywood to form the outer wall. The wall is 15.25 cm wide by 6.35 cm high (6.0" x 2.5"). You can use a thinner material for the wall, but it has to be thick enough to countersink the screw.

From left to right: The force sensor, a 6-32 nut, the washer for the 6-32 screw, a ½" thick piece of plywood with a hole drilled through it, and the 1" long 6-32 screw.

The 6-32 nut and washers (if needed) are tightened behind the wall with the washer(s) closest to the wall. You may need more than one washer to stabilize the assembly. You can use a shorter screw; however, make sure you have enough space to attach the screw to the sensor and tighten the nut properly.

The Base

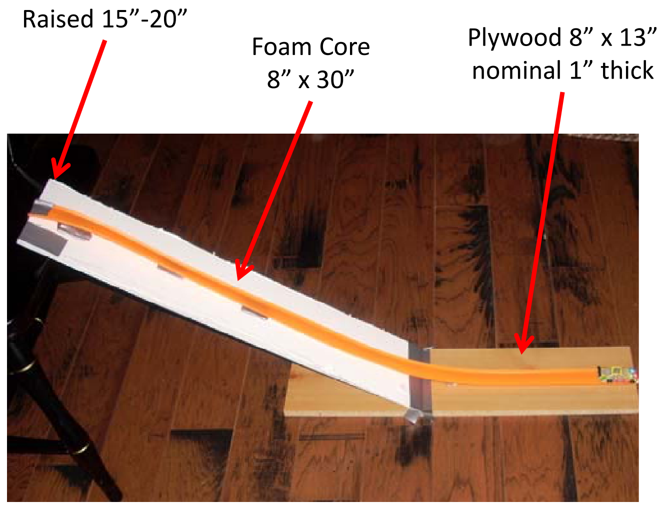
One of the most important things is mounting the sensor so that it doesn't move during the impact. If you have a ring-stand setup in your classroom, you can use the hole in the sensor and some clamps to mount it to a table. In lieu of that, we made a wood base and used some scrap moulding to fix the force sensor in place. It is important that the sensor is prevented from rotating when the wall is hit. The wall should be mounted so that it isn't dragging against the floor.



The base and wall mounted on the sensor. We used scrap wood pieces to form a base that ensures the sensor doesn't move when the wall is hit. A clamp holds the sensor and the base to a table.

The Track

The car should be going the same speed each time it hits the wall. The best way to assure this is to use a ramp. As long as you release the car from the same height on the ramp, conservation of energy tells you that the car should have the same speed when it hits the wall. We used a piece of plywood for the bottom of the ramp because it raises the car to the right height. Foam core was used for the rest of the ramp, but it could also be made of plywood.



A side view of the track. The bottom part is about 1” thick or so, which brings the car up to the right level so that it hits the wall squarely.

The track is standard “Hot Wheels track”. We used duct tape to fix it in place on the foam core and used a small screw to attach the track to the bottom piece of plywood so that the car is aimed directly at the wall. Mount the track so that the track runs all the way to the edge of the bottom piece of ply wood. That way, the wheels will remain on the track during the entire collision.

The car should hit the wall so that the nose of the car is at the same height as the force sensor. You’ll get the most accurate readings when the car hits the sensor squarely, as shown in the picture to the right.

This is how the car should hit the wall. The part of the car that hits first should hit at approximately the center of the wall.

We used a small screw to hold the end of the track down near the end of the base. This ensures that the track doesn’t move before the car hits the wall or if the car rebounds

A screw holds the track to the plywood base at the end of the track.

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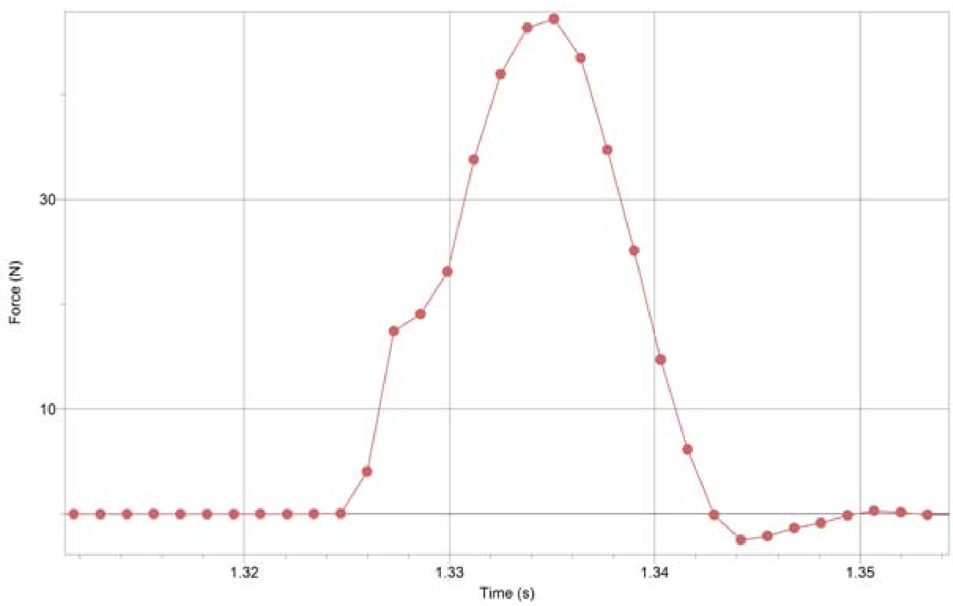
Taking Data

Set up the test stations ahead of time so that the force sensor reads between 40 N and 50 N when the car hits the plywood wall. A height around 38 cm (15 inches) works well. If you start with too low a value for the force on the bare wall, the forces will be too small to compare when you start modifying the wall.

A typical hit on a bare wood wall lasts from about 2-4 tenths of a second. Taking 750-1000 points/second will ensure enough data points to define the peak clearly enough. The figure below shows a typical force vs. time curve for a car hitting the bare wood wall.

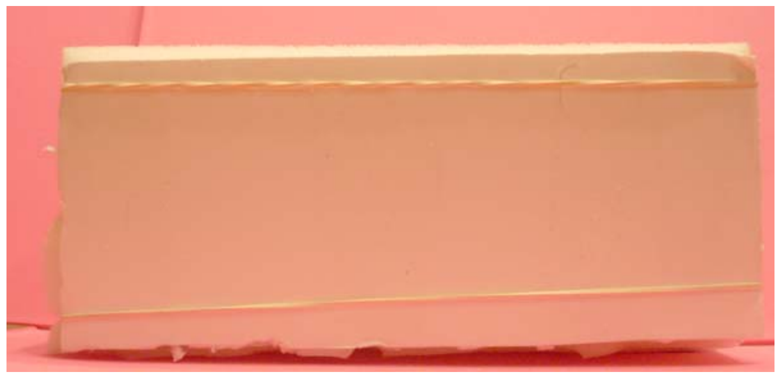


Force vs. time plot for a car hitting a bare wall. The total time of the collision is less than 2/10 of a second.

Modifying the Wall

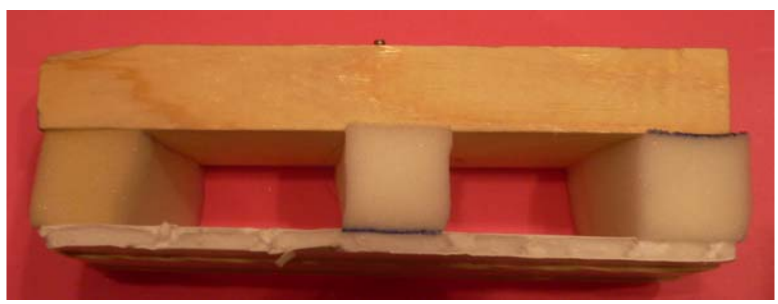
The wall can be modified in many ways. Thin pieces of foam core, luan (a type of thin plywood) or foam rubber can be used as an outer wall and a variety of foam (as described in the Building Barriers module) can be used as the lining. Hold the pieces together with rubber bands that run lengthwise around the assembly, as shown in the picture at right. If you're testing materials, you don't want the rubberbands to be in the area where the car hits; however, students might want to purposely incorporate rubber bands into their designs,

Most wall designs use foam and, in the case of two-material walls, an outer wall in addition to the inner wall.



Use rubberbands to hold the wall together.

Students' first impulse often is to put the largest piece of foam in front of the wall, which does soften the impact; however, the foam springs the car back up the track, which would send the car back into traffic to get hit by other cars.



A wall that uses

If you use, for example, foam core on top of the wall, you still have a pretty hard hit, but the car doesn't spring back very much. The optimal design requires the use of multiple components. One possibility is shown at right. Students might start out with a piece of foam and an outer wall of foam core; however, they will find that using strips of foam decreases the bounceback while still softening the impact.