

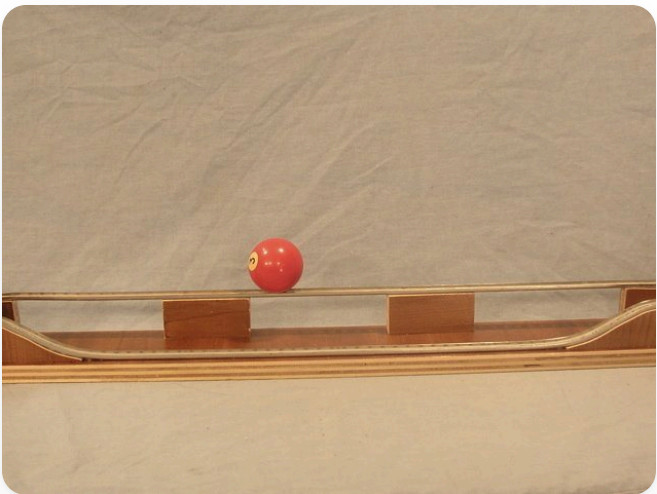
EQUIPMENT BUILD PLAN

ENERGY

High Road, Low Road Tracks

Two metal tracks start and end at the same height. One runs straight across; the other drops into a dip and climbs back out, making it about 5 percent longer. The ball on the low road always arrives first, a striking way to show how potential energy turns into speed.

Written from Bruce's original workshop handout. Bruce's final review of this plan is in progress.



<div>DIFFICULTY</div> <div>Intermediate</div>	<div>BUILD TIME</div> <div>4-6 hours (quick version: about 1 hour)</div>
<div>COST</div> <div>About \$20-30</div>	<div>SAFETY</div> <div>Adult build / supervision</div>
<div>GOOD FOR</div> <div>Teachers, Makers</div>	

What it shows

Two balls race across side-by-side tracks, and the one that takes the longer road through a dip wins every time.

Key ideas: potential and kinetic energy, conservation of energy, speed versus distance, rotational kinetic energy

Safety (Adult build / supervision).

Cutting the plywood supports with a jigsaw, band saw or coping saw, and cutting the metal track with a hacksaw, should be done by an adult with eye protection. Freshly cut metal edges are

sharp: sand or file them smooth before anyone handles the track. Clamp the track to the bench while cutting.

CONSTRUCTION

Build it

Materials

- ☐ **Two balls** · 2
Pool balls, steel balls or large glass marbles
- ☐ **Metal shelving track (shelf standard)** · Two 3 ft pieces
From any home improvement store
- ☐ **Plywood for the base** · 4 in wide x 3 ft long
- ☐ **Scrap plywood** · 3 pieces
For the four end supports, the two cross blocks and the middle supports
- ☐ **Wood screws, 1 in** · 14
- ☐ **Very small wood screws** · About 20
To fasten the track to the supports
- ☐ **Stain and varnish** · Optional

Tools

Jigsaw, small band saw or coping saw
Hacksaw
Drill with small bits for pilot holes
Screwdriver
Clamps, including a C-clamp
Sandpaper (medium and fine)
Masking tape and pencil

1

Draw the first end support

Put masking tape on a plywood block and draw the end support freehand: a raised slope at the end that curves down to a level run, then continues down into the dip. All four slopes must end up identical, so take care with this first one.

2

Cut and copy the support

Cut the first support with a jigsaw, band saw or coping saw and sand the curve smooth. Use it as the pattern to trace and cut the second one, then clamp the two together and sand the curves until they match exactly.

3

Make the two short supports

Trace the same pattern onto the third and fourth blocks, but stop at the point where the curve would start down into the dip. These carry the straight track. Clamp all four together and sand until the shared slopes match.

4

Space the tracks

Decide which balls you will use and set the supports far enough apart that the balls cannot touch as they roll side by side. Cut a plywood cross block that holds one long and one short support at that spacing.

5

Assemble the end units

Clamp a long and a short support to the cross block with the back and bottom edges flush, and fasten them with wood screws, two per side. Build the other end the same way, making sure each support faces its partner.

6

Attach the low-road track

Start at one end. Bend the track to the upper slope and screw it to the support with small screws; the screws pull the track to the curve as you tighten them. Keep bending and screwing down into the dip. Do the same at the other end.

7

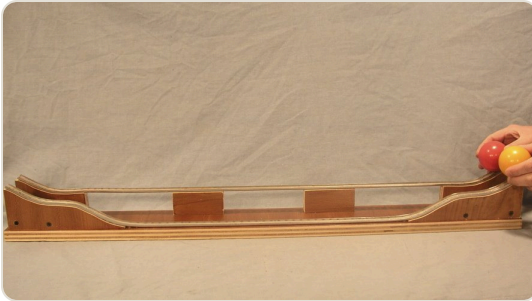
Mount on the base

Set the assembly on the plywood base. Drill pilot holes from underneath and drive wood screws up into the supports until the heads are flush with the bottom.

8

Attach the high-road track

Bend the second track to match the end slopes and screw it on. Cut two plywood blocks to hold its level run at a constant height in the middle and screw them to the base from underneath.



9

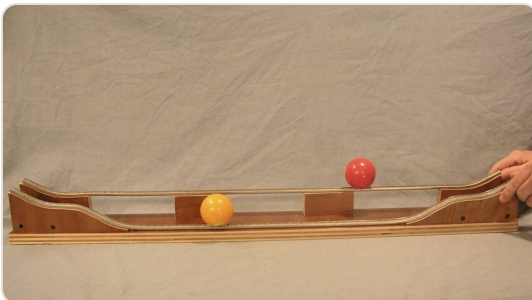
Trim and smooth

Cut off any track that hangs past the end supports with a hacksaw and sand the cut ends. Remove the tracks to sand, stain and varnish the wood if you like, then reattach them and run fine sandpaper along the track edges so the balls roll smoothly.

10

Race

Hold both balls at the top of one end and release them together. The ball on the low road pulls ahead in the dip and reaches the far end first.



THE PHYSICS

How it works

Both balls start with the same gravitational potential energy and finish at the same height, so in the end neither has gained an advantage in energy. What differs is what happens in between.

When the low-road ball drops into the dip, it converts extra potential energy into kinetic energy and speeds up. It stays faster than the

Using it

- Before releasing the balls, ask: which track is longer? Which ball will get to the other side first, and why? Have everyone commit to a prediction.

high-road ball for most of the trip, only slowing back down as it climbs out at the far end.

The low road is only about 5 percent longer, but the ball travels it much faster on average. Higher average speed more than makes up for the extra distance, so it arrives first.

The balls roll, so part of their energy goes into spinning. If a slope is so steep that a ball slips instead of rolling, it loses energy to friction and may not make it back up. Keep the climbs gentle enough for the balls to roll without slipping.

- Release the balls together several times so students can see the low-road ball pull ahead in the dip.
- Ask where each ball is moving fastest and slowest, and connect the answers to height.
- Switch the balls between tracks to show the result is not caused by the balls.
- Show the version with small hills in the low road and ask for predictions again.

GO FURTHER

Variations

- Quick version: cut a 2 ft piece of track for the high road and a piece about 4 in longer for the low road (don't cut it until it is bent). Cut a 2×4 into two end blocks: draw a line across the edge 2 1/4 in up, mark a point about 3/16 in lower on the other side, and cut the slight slope between them. Screw the straight track to both blocks with two small screws at each end. Bend the low-road track so it slopes down to the tabletop over about 5 1/2 in, runs along the table, and climbs back up over about 2 in at the far end. Trim and sand. Golf balls work well.
- Hilly low road: Bruce has made tracks with 1, 2, 3 and 4 humps in the lower road, each rising only to the height of the straight track. The hilly tracks still win, because wherever the ball is lower than the straight track it is moving faster. Draw a pattern for the hills, and use a C-clamp to help bend the track while screwing it down every few inches.
- Big drop: a version with a much deeper dip still gets to the other side first.
- Larger tracks: the design can be scaled up as long as the climbs stay gentle enough that the ball rolls without slipping.

IF IT DOESN'T WORK

Troubleshooting

IF THIS HAPPENS

The low-road ball doesn't make it back up.

TRY THIS

The climb is too steep and the ball is slipping.
Reshape the slope to be more gradual, and sand the track.

IF THIS HAPPENS

The balls bump into each other.

TRY THIS

Widen the spacing between the tracks for the size of balls you are using.

IF THIS HAPPENS

A ball rattles or slows at certain points.

TRY THIS

Add screws there so the track follows the wood closely, and smooth any burrs on the track edges.

IF THIS HAPPENS

The race is too close to call.

TRY THIS

Make the dip deeper, or check that both start slopes are identical so both balls launch at the same speed.