

CIRCUS PHYSICS ACTIVITY GUIDE

# Linear Momentum

Platform trapeze requires athleticism, good timing, and a strong understanding of the principle of conservation of linear momentum. An object's momentum is its mass times its velocity. The momentum of a system is the sum of the momenta of all the objects in it. No matter how many times objects collide or change direction, their total momentum must stay the same. Like energy, the momentum of a closed system is always conserved. In this unit, students will learn how platform trapeze artists use this fact to soar beneath the big top.

## How to Incorporate the Video Into Instruction

---

This video can be used to motivate the study of linear momentum and its conservation. It can also serve as extra illustration to reinforce previous lessons on these topics. If you watch the video in class, ask students to pause the video at different points in the routine and describe how the momentum of the two swingers on the trapeze platform is distributed.

### Questions to Ask Students Before Watching the Video

1. How is the jumper able to jump so far?
2. Where does her momentum come from?
3. What happens to the momentum of the person who stays on the platform?

### Watch the Video: Linear Momentum

<http://www.pbs.org/opb/circus/classroom/circus-physics/linear-momentum/>

### Questions to Kick-Start Class Discussion After the Video

1. Why use the swing in the act?

*The swing couples the momentums of the two people on the forward stroke and provides a way for the flyer to jump off, thus capturing all of the forward momentum of the system.*

2. How is the jumper able to go so far?

*She captures the forward momentum of the entire system, plus the momentum required to push the platform backwards.*

3. How would this act change if different people were on the swing? What if the launcher was heavier? What would happen with a light launcher and a heavy jumper?

*A heavy launcher would allow the jumper to go further. A heavier jumper would not go as far. A heavy launcher and heavy jumper would have the same outcome as the original scenario.*

4. If the jumper's momentum is increased in the launch, where is the corresponding decrease?

*The swing's backward momentum.*

5. What happens when a heavy object collides with a light object?

*The small object goes flying off.*

### **Connections to Everyday Life**

Most students will have played billiards before. Momentum conservation is key to predicting the outcome of the various collisions involved. The kickback produced when firing a gun during target practice will be familiar to some students. Getting hit by anything.

### **Suggested Classroom Activities**

---

#### **Activity 1: Skateboard Trapeze**

With careful supervision and safety equipment, you can have students re-create the momentum transfer involved in the platform trapeze act. On smooth, flat ground, have two students stand on the same skateboard (wearing helmets and safety equipment). Have a third student push the two until they are moving at a good pace. Then ask the student in the rear to jump off of the back of the skateboard. The student on the skateboard will then be given a slight push forward. If you have a video camera, you can record this experiment, then have students calculate the various momentums involved before and after.

#### **Activity 2: Rulers and Marbles**

Using a grooved ruler and marbles of different weights and densities, students can verify the conservation of momentum in one dimension. Lean the ruler against a short stack of books so that it becomes a ramp. The low end of the ramp should be about a centimeter from the edge of a desk or table.

Have students put either carbon paper or regular paper on the ground beneath the ramp's edge, this will be used to mark the landing location of the marbles used in the experiment.

First have students run one of the marbles down the ramp and off the table, marking where it lands. By using the height of the table, and the distance the marble traveled, students can work out how fast it was going at the moment it left the table. From this, they can calculate its momentum.

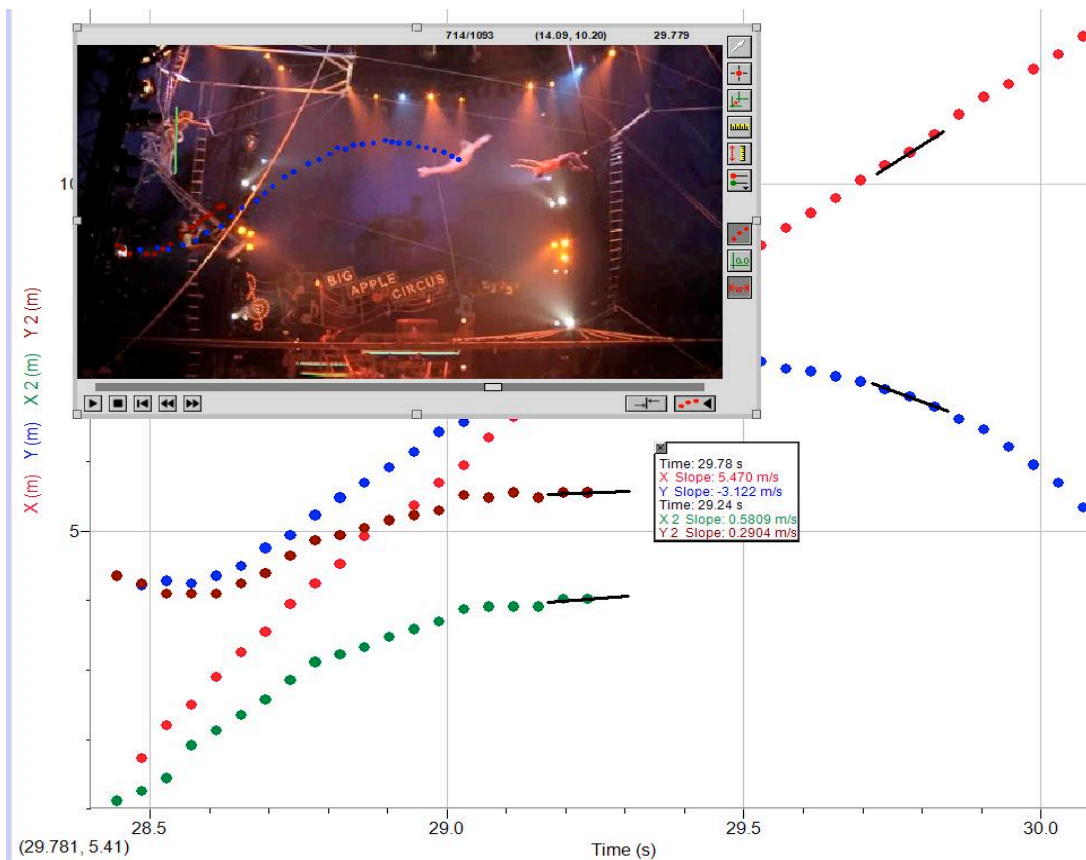
Now have students place another marble at rest at the base of the ruler and repeat the rolling experiment. Have them mark the landing positions of both marbles. They should now be able to calculate how much momentum was transferred to the stationary marble during the collision at the end of the ruler-ramp. Have them run this multiple times and use average values to come up with more accurate results. They can also verify that momentum is conserved in two-dimensions by constructing a vector triangle using the landing positions of each marble, it should add up to the momentum of a single marble rolling without colliding

Source adapted from: [http://dev.physicslab.org/Document.aspx?doctype=2&filename=Momentum\\_ConservationMomentum.xml](http://dev.physicslab.org/Document.aspx?doctype=2&filename=Momentum_ConservationMomentum.xml)

### Activity 3: Linear Momentum Video Analysis

To do this activity you will need to download the “Video Analysis: Linear Momentum” video from the CIRCUS web site (<http://www.pbs.org/circus/classroom/circus-physics/>). Use VideoPoint (<http://www.lsw.com/videopoint/>) or similar software for graphing and analysis.

This is a very challenging exercise for your students to capture. Horizontal momentum is conserved at the moment the performer leaps from the platform. She is gaining speed at the expense of the other performer who is slowing down on the platform. The difference is very subtle, making it a challenge to see. It is possible to see this qualitatively using VideoPoint. The screen shot below captures the moment.



Notice that the position of the performer leaping and the one on the platform are both marked. Have students use the slope to determine the speeds of the performers. Then make each have a mass of one and consider the platform to have a mass of half a person, or 0.5. With these numbers a rough calculation can show that the momentum is conserved.

Before  $(1 + 1 + \frac{1}{2}) * 6 =$  After  $(1 + \frac{1}{2}) * 4 + (1) * 8$ , it isn't exact! So be prepared for discussion!