**Free fall Ping pong ball drop**

**Objective**

To calculate the altitude of a rocket by timing the fall of a ball it drops. This exercise will teach the relation of free fall time and ***altitude*** from ***velocity***.

**Materials**

Ping pong balls, possibly painted bright colors

A model rocket with a BT60 type body diameter (1.6)

Motors to launch the rocket to between 100 and 400 feet altitude, ‘B’ to ‘C’ size

Launch pad and firing system

Stopwatches

Masking tape

**Procedure**

Each student can have their own rocket or work in teams of three. In addition a launch pad operator and timekeeper are needed.

Prepare the rocket for flight as usual, but place the ping pong ball on top of the parachute before inserting the nose cone. Launch the rocket.

At apogee the ping pong ball will eject from the rocket and free fall to the ground. The rocket will descend normally on the parachute. Have a student use a stopwatch to time the ball’s fall from the ejection point where the ball separates from the rocket in the air to the moment of ground impact. Record the time measured on a data sheet. Use the time value to solve for the free fall distance which is from the presumed peak altitude of the rocket with a constant ball velocity of **30 ft/sec**. Repeat the experiment several times, or have students launch balls in identical rockets and motors and compare the measurements and calculations. Using two stopwatches and taking the average time will improve accuracy, and also helps assure to get a time reading if one of the watches fails during the event.

**Data sheet sample**

Flight time (t) **altitude = 30 ft/sec \* t = y**

Model #3 on B6-2 13.3 seconds x 30 ft/sec = 399 ft

As you launch have other students measure the altitude with the protractor altimeter. Compare these altitude values. If you have a rocket altitude simulation software program, how does the prediction compare to the calculated value for the rocket?

You can also launch the rockets with different size motors to measure the different altitudes to compare the motor performance effects. Or, have another student time the ascent of the rocket (liftoff to ejection) and compare it to the ball’s free fall time.

**Alternative Indicator**

The same experiment can be done with a streamer instead of a ping pong ball. From 1 mil thick plastic such as a shopping or garbage bag cut a streamer that is one inch wide and twelve inches long. Tape a penny to one end for a weight. Roll up the streamer and place it under the nose cone as was done for the ping pong ball. Follow the launch and timing procedure as was given for the ball. The streamer will fall at a rate of **18 ft/sec**.

**Questions**

What aspects of the ball are being ignored in the descent measurement? If a billiard ball or baseball were dropped instead of the golf ball, how much faster would they fall? If the ball separates from the rocket with a lot of sideways motion, how does that affect the descent time of the fall?

Rocket Parachute Flight Duration study

**Objective:**

To understand the flight time performance effects and trades and to relate ***time*** to ***velocity***, students will measure the flight time of rockets of various sizes and parachutes types, but using the same motor type in order to achieve the longest total flight time.

**Materials**:

Several identical and some assorted size rockets

Various standard size parachutes to test

Plastic shopping bags, thread or string for making custom size parachutes

B6-4 motors, or type A motors if needed for small fields

Stopwatches

Data sheet

**Procedure**

For this exercise a student is needed for each task to set up the pad, launch the rocket, time and record the data. Each student can have their own rocket or work in teams of three.

Tell the students to design a system (they will select a rocket and parachute) in order to achieve the longest total flight time on a B motor. All rockets must fly on the same type motor. Prepare and launch the rockets and record each flight time with the rocket information on the data sheet. The flight time for the stopwatch operation is from the moment of first motion by the rocket off the pad until any part of it touches the ground. Two timers are recommended for better accuracy.

After the first round of launches the students will review the data sheet of all flights. Discuss which rockets had the highest and lowest flight times and why. The students then experiment with their rocket selection and parachute types to determine how to improve and extend their flight time. They can design and make their own parachute. They can investigate packing techniques, shroud line length and other chute design parameters. Students will then launch another round of rockets with an adjusted and improved design following the same timing process and observe and record the results.

**Questions**

How much better was the flight times of the redesigned rockets? How does the flight time of a large rocket with a large parachute compare to a small rocket with a small parachute? What’s the main variable effecting descent time?

**Data sheet sample**

Rocket total weight body diameter chute diameter flight time

Starsquawk 4 oz. ¾ in 12 in 33 sec

Starsquawk 4.5 oz ¾ in 18 in 55 sec

Icarus 6 oz 1 in 24 in 56 sec

### Finding Model Rocket Descent Velocity from Para[chute Size Calculation](http://www.washingtonhighpower.com/Chute%20Calculator.htm)

**Objective**:

The size of the parachute and weight of the rocket determine how fast it will all come down. This equation shows the relation of all the rocket parameters to ***velocity***. Use it to select the right size parachute for a rocket.

**Materials**:

Several identical rockets with parachutes

B motors,

Stopwatches

Data sheet

## Procedure: Input the values for a rocket and the constants given into this equation and solve.

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Where

* D is the chute diameter in meters 18”=.4572 m
* m is the rocket mass in kilograms
* g is the acceleration of gravity = 9.8 m/s2
*  is 3.14159
*  is the density of air = 1.22 kg/m3
* C is the drag coefficient of the chute, which is 0.75 for a parasheet
* v is the velocity at landing (desired to be 3 m/s = 9.8 f/s or less)

The rocket mass m can be found from the manufacturer’s catalog if it is a standard kit, or you can weigh it on a scale. All the other values are constants in this case and given above.

Choose an elevated position to do your drop tests. To test your parachutes, you must drop each parachute from the exact same location each time. Measure the distance from the floor to that point. Use a 18” diameter chute.

Have one group member drop the parachute while another group member times the parachutes descent. They must time the drop from the moment the parachute is released to the time the payload hits the floor. The third group member can record the data on the data sheet.

Repeat this process for each students’ parachute. If time permits, drop each parachute twice.

Remove the 18” chute and replace it with a 14” chute. Repeat drop test.

Once you have collected all of your data, calculate the descent time of the chutes.

Time of the fall \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_seconds

Distance of the fall \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_meters  
At what speed did the capsule hit the ground: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_m/s?  
speed (m/s) = distance (m) / time (s)

Compare the measured descent velocity with the calculated velocity. How do they compare?

**Data sheet sample**

Student chute diameter flight time distance velocity

1 18 in 3 sec 3m 1 m/s

2 14 in 2 sec 3m 1.5 m/s

Optional-Create a graph comparing the diameter of the parachute to the drop time. On your graph, label the x-axis with the diameter of the parachute and the y-axis with the drop time.

Put the paracute in your model rocket and launch it. Time and record the descent. Calculate the descent velocity. Compare the flight performance times with the test drop times.

**Check for Understanding**

Explain how the equation is a good theory for predicting the descent of your measured flights. How does this equation apply to understanding parachute flight performance? What’s the most critical parameter in the equation? What’s the second most critical?

Predicting and measuring rocket parachute drift rate

**Objective**

Students will use vector ***velocity*** calculations to determine the vertical descent rate and horizontal drift distance of a rocket parachute. Predicted values will be compared to measured data. Students will learn to manage and interpret data and evaluate results.

**Materials**

Same as for the parachute duration experiment but including

Anemometer to measure wind speed

Scale to measure rocket weight

Hundred foot long tape measure

Data sheet

**Procedure**

This is similar to the previous parachute duration experiment. Referring to that basic procedure, launch the rocket but in this case measure the time of the flight from the moment when the parachute opens to the time of landing. Measure the wind speed with the anemometer near and about the same time as the flight. Use the tape or a long string to measure the distance from the launch pad to where the rocket lands. You can pace this off and approximate the distance if a straight line measurement isn’t possible. Weigh the landed rocket with its burned out motor. Record all these data on the sheet.

**Data sheet**

Rocket weight, chute diameter, flight time, landing distance, wind speed

Icarus 6.2 oz 24 in 56 sec 356 feet 6 ft/sec

**Calculations**

Use the equation below to calculate the descent velocity from the known rocket weight and parachute diameter. From the measured wind speed and flight time, calculate the horizontal drift of the parachute from the equation given in the section below. Compare this drift value to the measured drift distance.

Calculated predictions : Descent rate = , Drift rate =

**Questions**

What is the highest wind speed you can fly a rocket in before it will likely drift from your pad to outside the clear area of your field? What is the maximum altitude a rocket can have that will still land in the field? You will need to estimate your field dimensions to get an answer.

## Finding Parachute Descent Velocity

Given the parachute diameter is set, the descent velocity equation for the rocket can be determined by rearranging the above equation for parachute size to get velocity:



## Input the values for a rocket and the constants given above into this equation and solve.

**Calculating the Drift distance:**

Drift = Timehang x  Vwind

Where:

* Drift= How far the rocket will travel from the launch site
* Vwind= wind velocity
* Timehang= Hang Time in Seconds

Example

If you have a Vwind = 20 kilometer/hour wind blowing (and convert it to 5.6 m/s,) and the parachute flight was 33 sec, the drift distance

Drift distance = 33 s (5.6 m/s) = 185m.



Egg Launch and Lander

**Objective**

Students will create a rocket capsule to contain and successfully land unbroken a raw egg from a fall to the ground. Then the students will launch the capsule in a rocket. They will learn how ***velocity*** and ***acceleration*** from falling relate to a force on landing.

### Materials

Raw eggs

Packing material (foam, bubble wrap, etc.)

Meter stick or tape measure, Stopwatch

### Procedure

Each student will build a capsule. Select someone to be a timekeeper, distance measurer and data recorder.

Choose the packaging material you will use around the egg. Wrap your egg and assemble your capsule. Attach the parachute.

From the top of a high place drop your capsule.

Record the distance and time it takes for the egg lander to reach the ground.

Examine the capsule. A drop is successful if the egg does not crack.

### Data & Results

Describe the packaging material used. Which material and packing technique worked the best?  
  
Time of the fall \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_seconds

Distance of the fall \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_meters  
At what speed did the capsule hit the ground: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_m/s?

speed (m/s) = distance (m) / time (s)

**Launch**

From what you learned in packaging and protecting the egg in this drop test, prepare a capsule from a model rocket nosecone that can contain the egg. Launch the egg in the rocket and see how well the parachute brings it down.

Time the capsule from the moment the parachute opens to the moment it lands. Compare the descent time to the test drop to estimate a descent speed.

**Check for Understanding**

Explain why you chose the material you used to cushion the egg. Explain in terms of acceleration why the greatest force on the egg is at landing. Explain how the material absorbs the force and protects the egg.

**Investigating Parachute Area versus Drop Time**

**Objective**

Students will create parachutes and time them as they fall to the ground. Then the students will launch the parachute in a rocket. They will learn how parachute ***geometry and area*** effects the ***velocity*** of the falling object to create a soft landing.

**Materials**

Plastic shopping, dry cleaning or trash bag or tissue paper

String

Payload (plastic toy figure, large pencil eraser, metal key, etc.)

Graph paper

Ruler

Tape

Scissors

Stopwatch

Science journal

Rocket with which to test fly the parachutes

**Procedure**

Your group will be testing parachute shapes and sizes to determine the best combination to safely bring a payload to the ground.  Follow the steps below to complete the experiment.

To make your first three parachutes, cut out three differently-sized squares about 6 - 8 inches across from the plastic bag or tissue paper.   You may need to fold the squares into triangles and trim them to make them exact squares.

Using a pencil, label the parachutes A, B, and C.

Now, determine the area of each parachute. Measure the length of the sides of the parachute to be sure they are the same. Use the equation below to calculate the area of each parachute. Record the data in your science journal.

Area of square = length of side \* length of side

To complete the parachutes, cut twelve pieces of string. Each piece should be about 6 inches long. Tape the end of a piece of string to each corner of each parachute. If extra payload is available, tie the loose ends of the string to the payload. If necessary, wait until after square parachutes are tested, and use the same payloads for the triangle parachutes.

To make your next three parachutes, you will cut three differently-sized equilateral triangles from the plastic bag or tissue paper. You may need to fold the triangles to make sure each side is the same length.

Using a pencil, label the parachutes 1, 2, and 3.

Now, determine the area of each parachute. Measure the length of the sides of the parachute to be sure they are the same. Use the equation below to calculate the area of each parachute. Record the data in your science journal.

Area of equilateral triangle =side\*side\*

To complete the parachutes, cut nine pieces of string. Each piece should be about 6 inches long. Tape the end of a piece of string to each corner of each parachute. If extra payloads are available, tie the loose ends of the string to the payload. If necessary, wait until after square parachutes are tested, and use the same payloads for the triangle parachutes.

**Taking Data**

Choose an elevated position to carefully do your drop tests, like over a balcony. To test your parachutes, you must drop each parachute from the exact same location each time.

Have one group member drop the parachute while another group member times the parachutes descent. They must time the drop from the moment the parachute is released to the time the payload hits the floor. The third group member can record the data in their science journal.

Repeat this process for each parachute. Drop each parachute as many as five times to get consistent values. Once you have collected all of your data, create a graph comparing the area of the parachute to the drop time. On your graph, label the x-axis with the area of the parachute and the y-axis with the drop time.

If your students are extra inquisitive, try making parachutes in a hexagon shape and repeat the experiment. Directions for making them are on the internet. The six sided chute is harder to make, but performs much better.

**Questions**

Answer the following questions in your science journal.

Is there a definite relationship between the area of the parachute and the drop time?

Does more area equal more drop time? Why do you think this is so?

Were there any variables in this experiment that could have made your results invalid?

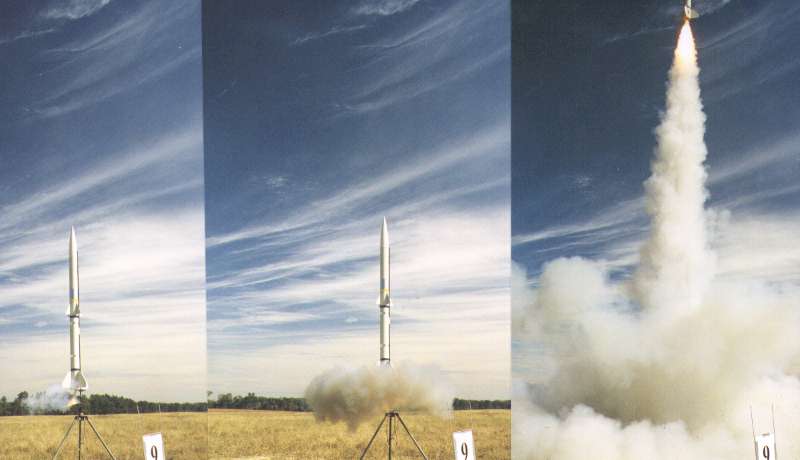
Does the shape of the parachute make a difference?

Which parachute performed the best? Worst? Why do you think so?

**Flight Test**

Put the first parachute in your model rocket and launch it. Be sure you pack the parachute carefully and use recovery wadding. Time and record the descent. Now switch out the parachutes with the second one and launch and time it with the same type motor. Repeat for the third parachute. Compare the flight performance times with the test drops to decide which parachute worked best. Answer the questions again.

Rocket Motion Video studies

**Objective:** Students will use a video camera to record ***motion***, measure ***velocity*** and compute ***acceleration*** of a model rocket at launch. This lesson will teach measurement methodology, data interpretation, and deriving acceleration from velocity.

**Materials**:

Model rocket launch pad and firing system

Small model rockets

Motors

Video camera on a tripod

Computer for video editing, or TV screen connected to camera

Video editing software or camera that can view frame by frame

Pole or PVC pipe about ten feet long, vinyl electrical tape, tape measure



**Procedure**

For this exercise a student is needed for each task to set up the pipe and pad, prep the rocket, launch the rocket, record the data and operate the camera.

Measure and mark the pipe off in foot long increments. Put a wrap of tape around the pole at each foot mark (black tape on a white pipe for contrast.) Number the marks so that the pipe becomes a giant ruler.

Set the pipe straight up in the launch field next to the launch pad. This can be done by driving a broom stick in the ground like a stake and setting the pipe on it. Set up the video camera so that the launcher and the entire pipe length is framed and focused within the viewfinder. The pipe should be directly behind the rocket.

Set up a small model on the pad to launch. Check the camera operation, and then set it to record. Launch the model. Stop the camera from recording. Repeat for several other launches and note which motors are flown in each scene. A data sheet will help listing flight order, motor type, camera settings, and display counter index.

Connect the camera to the computer to analyze your recording. Note in the video where the nose of the rocket or the fins are against the markings on the pipe. Step through the frames until you see the moment the rocket begins to move. Count the number of frames from that point to where the nose (or fin) crosses the next mark on the pipe. Count again from that point the frames for the nose to reach the next mark, and so on until the rocket is out of view. You might like to save and print the best frames and work from a hard copy.

Check the camera manual to find the video frame speed, which is likely 30 frames per second. This means each frame is 1/30 of a second. The rocket speed is v = y/t where y is the distance moved and t is time. Calculate the rocket velocity from the actual displacement in time.

For example, if the rocket takes 5 frames to move up one foot, then one foot divided by (5 x 1/30 sec) = 6 ft/sec.

If the rocket moves 3 foot marks between frames, then

3 feet/ (1/30sec) = 90 ft/sec.

To find the acceleration, first compute a final velocity for the last frames at the top of the pipe. Then count up the frames of the entire flight from first motion to the last view of the rocket to get a total time. Acceleration will be (a = v/t.)

If the final velocity is 90 ft/s over a total time of 1/3 second, then

a =90ft/s **/** (1/3s) = 270 ft/s/s.

Compare these values to the predicted values of the same rocket in a simulation program.

**Questions**:

How does the thrust given in the motor code affect the observed acceleration, that is, how does the take off of the same rocket with a B4-4 motor compare to its launch with a B6-4? What shutter speeds on the camera work best to freeze the motion of rocket flights? Does changing the contrast of the image during analysis help the resolution or clarity?

**Additional approach:**

Get a small strobe light that brightly flashes at a known constant rate that can be easily seen in daylight. This may be a bicycle hazard light or a toy blinker. Use a clear plastic nose section to contain the strobe in a rocket. Use an appropriate size rocket and motor to safely carry the weight of the strobe. Test the strobe with the video camera by moving the strobe through the field of view and then noting how the flashes appear in the image. Adjust the camera exposure to be sure the flashes appear bright enough to be clearly recorded. Set up the pipe again by the launch pad, but position the camera further back or zoom out so that it sees space of about five times the pipe length above the pad. Launch the rocket and record the flight with the strobe light flashing. On the video editor, find the frames where the flashes appear and use them as time markers. Count the frames between the peaks of the flashes. Approximate the distance moved by the rocket by referring to the pipe length. Using the known time of the flashes, find the velocity by dividing the approximated distance traveled by the rocket by the time. Note, there are some physics video applications available that will greatly assist in this motion analysis.

For another approach, back up the camera far enough to see the entire rocket flight in the viewfinder. The increasing spacing of the flashes along the flight path illustrates the rocket’s acceleration.