XPULT INSTRUCTIONS – ADVANCED VERSION (11th Grade – College)

The Xpult is a device for launching table tennis balls or other light plastic balls. Most likely, you will have received the Xpult from your teacher or somebody else who wants to help you learn about science or math. Before you start, please read carefully the following safety warning.

WARNING: The Xpult is designed to be safe. However, it does store and release energy and therefore could cause injury. Never launch a ball at other people and don't launch balls or objects that are heavier than the balls included with the Xpult. **Pay particular attention to the end of the launch lever and make sure your eyes and other body parts are clear before releasing it.**

In this document, we explain how to set up the Xpult. We also provide you with instructions for an experiments that helps you become a better target shooter by analyzing and reducing the statistical deviations that occur across a sequence of shots. If you find this experiment to be too advanced for your grade level, you will find an easier experiment on our web-site www.xpult.com.

What's in the Box?

Make sure that you have everything that you need for setting up the Xpult. The Xpult is shipped along with the following items (see Figure 1):

- The catapult itself, including a locking pin.
- Three rubber bands (size: 3 inches x 1/8 inch).
- A table tennis ball and a light plastic ball with small holes.
- A clamp for attaching the catapult to the edge of a table.

Figure 1: Items that are shipped with the Xpult

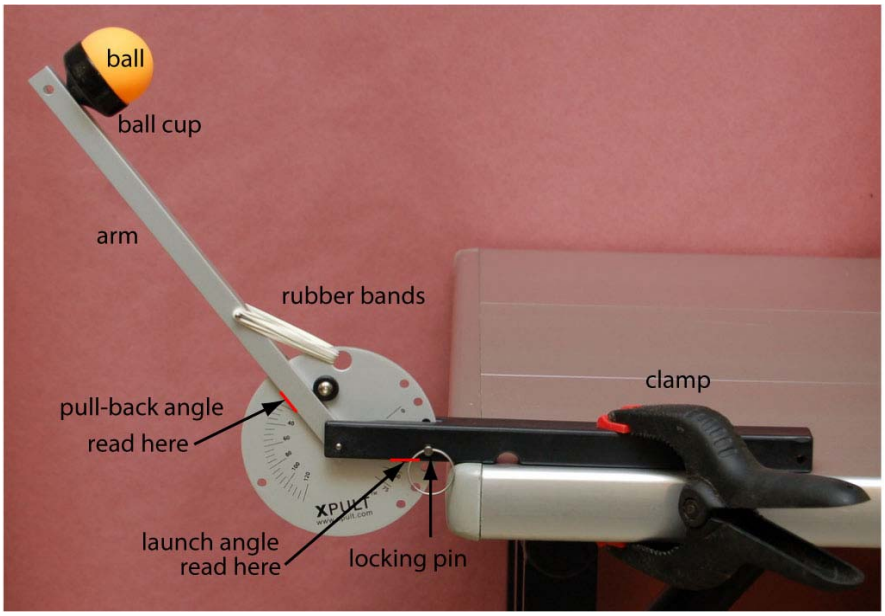


Figure 2: The Xpult in the deployed position

Setting up the Xpult

The catapult is shown in the deployed position in Figure 2. To unfold the catapult, remove the locking pin from the end of the folded assembly.

If your catapult is not yet equipped with one or more rubber bands, thread a rubber band through the large hole in the aluminum disc. Hook one end of the rubber band on one side of the pin inserted through the launch lever. Hook the other end of the rubber band to the other end of the pin. (See Figure 2.) Several rubber bands can be attached this way, though for safety reasons you should never attempt to attach more than three rubber bands at the same time. To get started, just put one rubber band on the Xpult.

Once the pin is removed (and rubber band attached), swing the aluminum launch lever all the way around to the other side of the black plastic base and re-insert the pin in one of the holes that specifies the launch angle. For now, set the launch angle anywhere between 30 and 60 degrees.

Clamp the black plastic base of the catapult to the edge of a table. Note that you will need to read the indicators on the side of the aluminum disc, so you will probably want to position it on the left side of a table as you face it. Position the table so that you have 10-12 ft (3-4 meters) of free space in the launch direction. You probably want to set up indoors, as wind has a large effect on the flight of table tennis balls.

Note: the edges of the catapult base could leave scratch marks on furniture. Depending on the furniture, you may wish to use a piece of cardboard to protect the surface underneath the catapult

Finally, you need to set up a target. If your teacher has provided you with a target, use that one. Alternatively, you can make your own target by using a box or a trash can. As you

become better at using the Xpult, you might even want to use something small like a cereal bowl or a coffee mug as a target.

Independent of what target you use, position it at a set distance (e.g., 96 inches or 120 inches) from where you have clamped the Xpult. Use a tape measure – don't just eyeball the distance. Remember, 96 inches is the same as 8 feet or 2.44 meters. A picture of this set-up is shown in Figures 3 and 4.

Once you have completed the set-up, take 10 shots at the target to familiarize yourself with the mechanics of the Xpult. Make sure that you try different pull back angles (i.e. vary how far you pull the arm of the Xpult backwards) and different launch angles (this requires taking out and reinserting the locking pin – see above). If you work as a team, make sure everybody takes a turn. You can also assign different roles to team members, including a spotter (who determines the exact landing location of the ball), a shooter (who operates the Xpult), and an analyst (who enters the data onto a work sheet or directly into a computer).

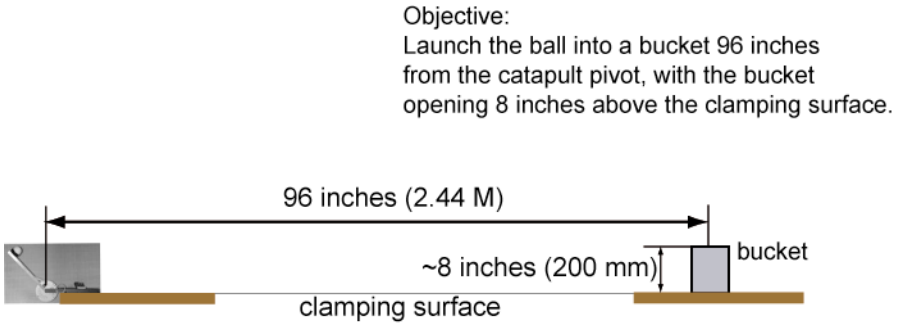


Figure 3: Setting up the target.

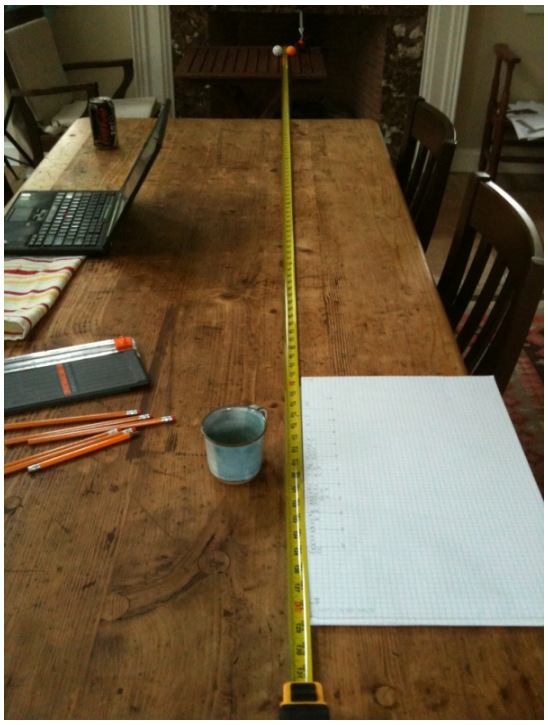


Figure 4: An example of the experimental set-up; note the computer next to the action to record data, the tape measure set-up, and the fact that the Xpult is not clamped to the antique furniture, but to another board/table.

Experiment: Hitting the Target – Over and Over Again

Imagine two catapult operators, both of whom are aiming at a target 96 inches away from them. One of them is consistently shooting the ball 95 inches (with only tiny variations). The other one has half of the shots at 90 inches and the other half at 102 inches (but shoots, on average, 96 inches). Who do you think is the better target shooter? Well, this experiment will answer this question and many others.

You'll need a target made from a sheet of paper and a tape measure (figure 5). The target is positioned next to the tape measure (at the target distance, in this case from 120'' to 124'')

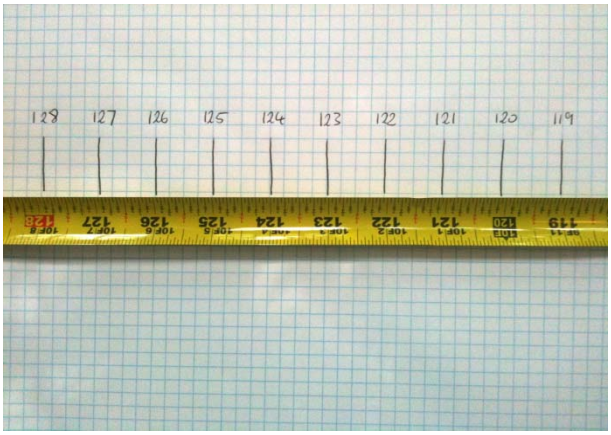


Figure 5: Making your own experimentation kit using graph paper

Once you have set up everything, find a catapult setting that gets you one shot on the target. You can do this by playing around with the catapult. Write down the settings (launch angle, number of rubber bands, pull-back angle).

Now, we want to find out if you were a lucky target shooter (and hit the target by accident) or if you are able to be consistent in your shots. Towards that goal, repeat multiple shots with the same catapult settings. Are all of them hitting the target (do all of them fly the same exact distance?). Most likely, the answer is NO. So let's find out how much variation is in your shots and what we can do to reduce it. To get motivated, go onto YouTube and type in "Xpult Indian School of Business" or go to the Xpult web-site (www.Xpult.com). The video shows one of the best (most consistent) target shooters we have seen so far.

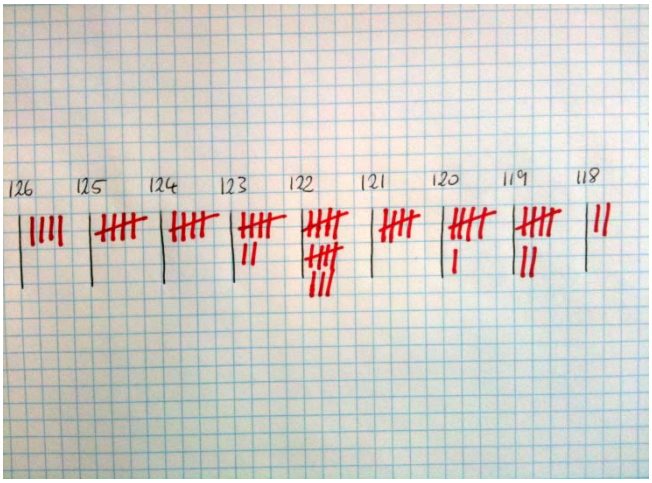
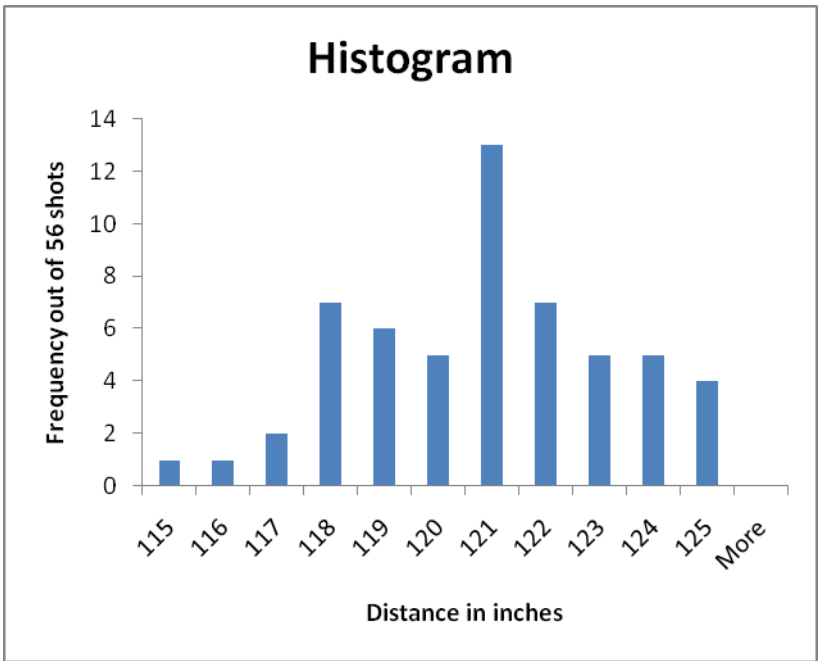


Figure 6: Example of a marked-up target after a set of shots.

To become a better target shooter, we want you to conduct some experiments. First, we need to measure how much variation you have between shots. To do this, conduct at least 50 shots with the exact same catapult settings. This can best be done with a team of three. One team member operates the Xpult, one carefully marks the landing position of the ball, and one records the data. To mark the landing position of the ball, you can either use a sticker or pin or you can mark the landing position directly on the target. Once all 50 shots have been conducted, look at the pattern of the stickers or marks. Most likely, your data looks something like that shown in Figure 6.

Next, enter the exact distances into an Excel file. (You can download the excel file used below from our website, www.xpult.com). We leave it up to you to determine how accurately you want to measure. In the beginning, you do not have to worry about fractions of an inch, just record the nearest integer number by counting the ball landings within a one inch interval. (See Figure 6 for an example.)



Analysis 1: A histogram consisting of 56 shots with the same catapult settings (to be precise, we should say "the same *intended* catapult settings"…)

Based on these data, you can compute the following statistical measures:

- The average distance.
- The standard deviation of your distance. This measure is mathematically defined as follows:
  (1) Compute the average distance
  (2) for each of your shots, compute the difference between the distance and the average distance; this defines the deviation of each shot. (Note: this number can be positive or negative.)
  (3) square this deviation for every shot (i.e., multiply this number by itself).
  (4) sum up the squared deviations.
  (5) divide the resulting sum by the number of shots minus one (in this case by 56-1=55).
  (6) take the square-root of this.

  Again, you can download an Excel file from our web-site, so do not be intimidated by this process. Also the Excel function "=stdev(A1:A56)" does these steps for you, in this case calculating the standard deviation for values A1 to A56.

You can also create a histogram, similar to what is shown in Analysis 1.

With this data at hand, try to answer the following questions:

- What measures would you use to determine how good a target shooter a person is?
- Why were some shots on target and others not (although you used the same catapult settings)? Identify at least three factors.
- What can you do to reduce the effect of the three factors that you have identified in the previous question?

If you still have energy, do another battery of 50 experimental shots. But, this time, do this after having eliminated some of the effects that you have identified above. Have you become a better target shooter? Has the standard deviation gone down? Keep on iterating between experimentation and data analysis. This is at the heart of the scientific method.

Hint: you will find that there are many catapult settings that lead to the same average distance of the ball. Given that you have many ways to launch the ball say 120 inches, which catapult setting do you think would be best to consistently hit the target?

