XPULT INSTRUCTIONS – BASIC VERSION

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. 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 to you how to set up the Xpult. We also provide you with instructions for a specific experiment in which you will have to predict the flight distance of the ball. A second, more advanced experiment, can be found 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

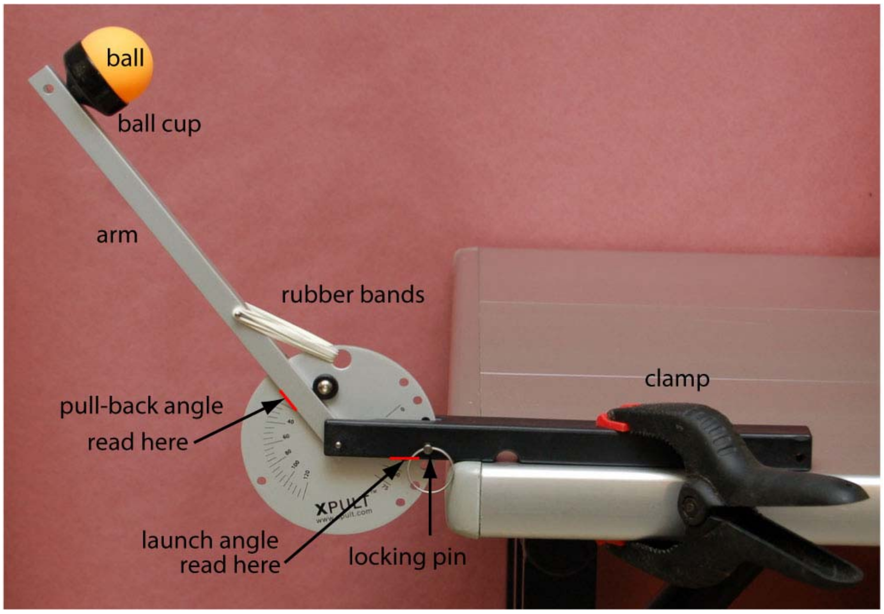


Figure 2: The Xpult in the deployed position

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).

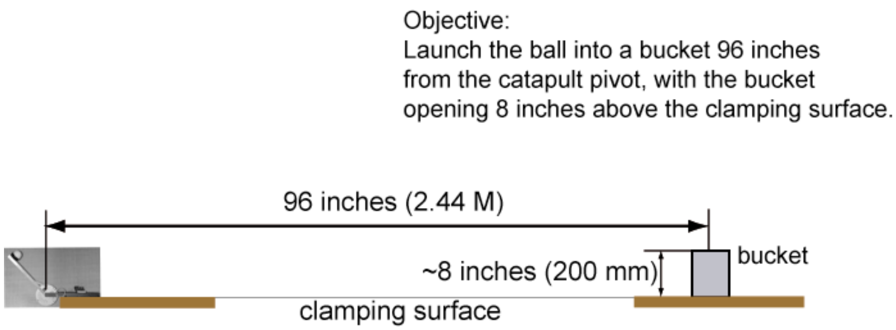


Figure 3: Setting up the target.

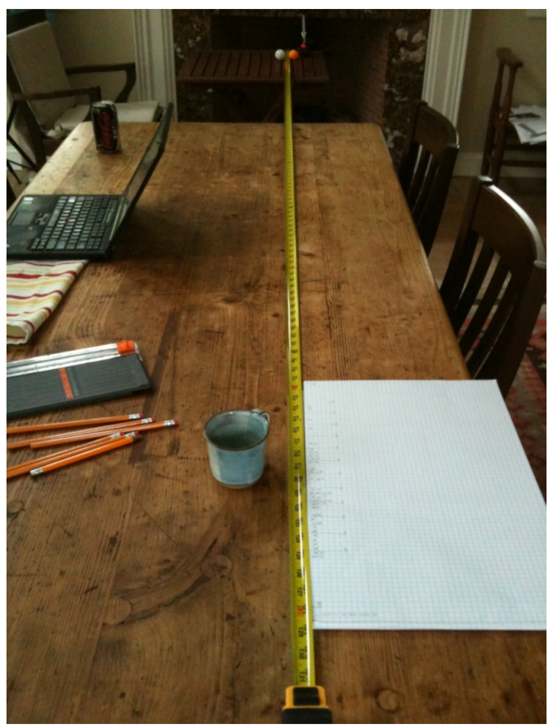


Figure 4: An example of the experimental set-up; note the computer next to the action to record data, the tape measure set-up, and the fact that the Xpult is not clamped to the antique furniture, but to another board/table.

Experiment: Predict How Far the Ball will Fly

Catapults have been used as weapons for centuries. You might be surprised, but catapults are even used by the military in present times, mostly to launch unmanned aerial vehicles (small remote controlled aircraft).

Now, when medieval armies were firing with their catapults, predicting how far the catapult would shoot was of essential importance. (A shot too short might have knocked out your own soldiers while a shot too long might have been a bigger threat to the birds than to the opposing army.) Moreover, finding out the right settings of the catapult to hit the target by trial-and-error (i.e., by trying all kinds of settings until finally one works) would also be a poor strategy. The better the ability to predict distance, the more valuable of a weapon the catapult becomes.

To understand the relationship between the catapult settings, in particular the launch angle and the pull back angle, we want you to conduct a set of experiments. We want you to do this carefully and scientifically, so please stick to the following instructions.

To start, set up the Xpult with one rubber band and a launch angle of 45 degrees. Note that you read the launch angle at the bottom edge of the black plastic base. You can experiment with other settings, but we found this to be a good way to get going. Next, roll out a tape measure with the tip of the tape at the catapult. Take another look at the photo in Figure 4 to get a sense of the experimental set-up.

You will now perform a battery of shots increasing the pull back angle. As you are doing this, mark where the ball lands and then measure the distance to the Xpult. If you are working in a team, have one person operate the Xpult, one spot the exact landing location of the ball, and one enter the data into the computer (or in the empty work sheets provided at the end of this document):

- Start with a pull-back angle of 30 degrees and the (white) perforated ball. The ball will only fly some 30'' or so, but that is fine. Do this THREE times and then find the **median** of the distances (not the smallest, not the largest, the middle one). Note that you read the pull-back angle at the bottom of the launch arm. (Set the ball on the cup; do not push it into the cup, as this will cause it to stick and reduce the launch distance.)

- For each catapult setting, also measure the range of your three shots. The range is defined as the difference between the largest number (the furthest shot) and the smallest number. You often find that the range increases as you pull back the arm further (which has to do with the ball moving its position in the cup at high pull back angles). Think about this – this could be the beginning of another round of experiments.

- Now move up the pull-back angle by 10 degrees and do the same thing (i.e. three shots) over again.

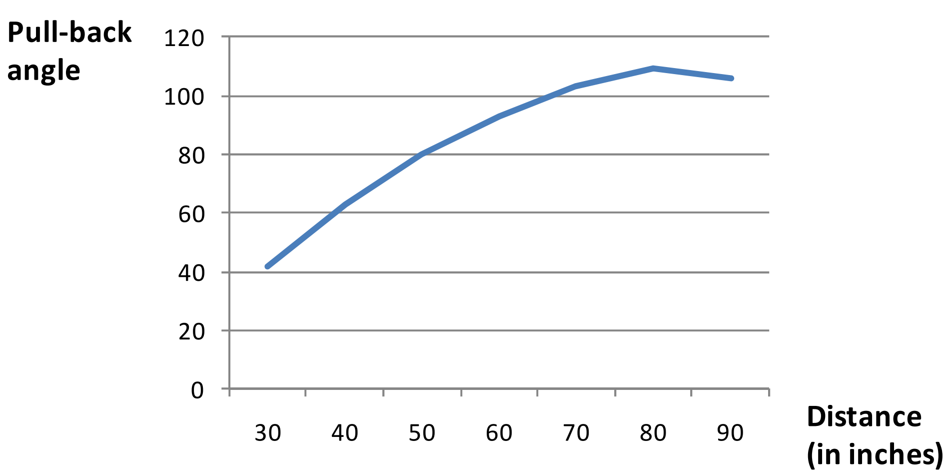
- Continue to increase the pull-back angle in increments of 10 degrees. For each setting, record the pull-back angle and the median distance as well as the range of distances. Do this until you have reached a pull-back angle of 90 degrees or higher. You will notice that the ball has a tendency to fall out of the cup if you pull the arm of the catapult too far back.

- Draw a graph with the pull-back angle on the x-axis (horizontal axis) and the distance of the median shot at this setting on the y-axis (vertical axis). You will find an example of an excel file with this data in Exhibit 1 followed by an example analysis of these data in graphical format (Analysis 1). You can generate the excel file yourself or download it from our web-site (www.Xpult.com).

This set of experiments will establish how distance depends on the pull-back angle for a *given* launch angle. You can repeat the first set of experiments (changing the pull back angle) for other launch angles. Recall that you read the launch angle at the bottom edge of the black plastic base. Again, do three shots at each setting and record the median distance for each launch angle. (You can use the work sheets at the end of this document.)

Experiment 1		*One rubber band; 45 degree*			
pull-back	**Shot 1**	**Shot 2**	**Shot 3**	**median**	**range**
10					
20					
30	43	38	42	42	5
40	63	64	62	63	2
50	80	77	81	80	4
60	93	94	90	93	4
70	100	104	103	103	4
80	90	109	111	109	21
90	106	117	89	106	28
100					

Exhibit 1: Example data for a catapult set up with one rubber band and a launch angle of 45 degrees. Three shots are recorded for each pull-back angle and the median distance and the range are computed.



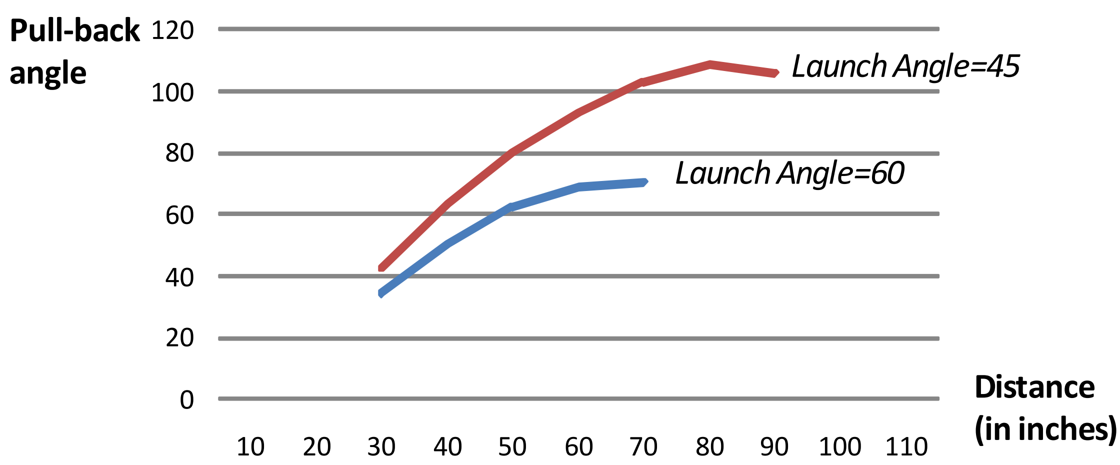
Analysis 1: Example analysis of the data displayed in Exhibit 1.

Whether or not you continue is up to you (and, maybe, up to your teacher or parent…). If you stop experimenting now, you will be able to shoot a certain distance so to hit a target. If you keep on going, you will be able to shoot a certain distance AND be able to overcome an obstacle (like a castle wall).

If you decide to carry on, start changing the launch angle. Move it up or down, up to you. This creates more data and additional graphs (see Exhibit 2 and Analysis 2 as an example).

		Distance (at 45 degree launch angle; one rubber band)						
Pull back angle	**Launch**	0	15	30	45	60	75	90
10		0						0
20		0						0
30		0			42	34		0
40		0			63	50		0
50		0			80	62		0
60		0			93	69		0
70		0			103	70		0
80		0			109			0
90		0			106			0
100		0						0
110		0						0

Exhibit 2: Example, partially completed, data for a catapult set up with one rubber band and launch angels of 45 degrees and 60. Three shots are conducted for each pull-back angle and the median distance is recorded for each setting



Analysis 2: Example analysis for the data shown in Exhibit 2; note that we now have a family of curves that relate pull-back angle to distance for various launch angles

Once you are done experimenting, you are ready for the Xpult challenge. Have somebody position the target anywhere between 2 and 10 feet away from you. They choose the distance. Your job is to hit the target with the first shot.

To do this, leverage the experiments that you have done before. In particular, notice that when you plotted the graph showing launch angle and distance, you have created a mathematical function linking these two variables. Using these graphs, find the catapult setting that corresponds to hitting the target.

If you have some experience in algebra, you can even attempt to write a mathematical equation for finding the pull-back angle given a certain distance. And, if you have done the experiments for multiple launch angles, you can be smart about which launch angle to pick. (Would you pick one where you found a high range or a low range in distance across the three shots?)

Launch angle:
# of rubber bands:

pull-back	Shot 1	Shot 2	Shot 3	median	range
10					
20					
30					
40					
50					
60					
70					
80					
90					
100					
110					
120					

	Median distance across three shots							
Pull back angle	**Launch**	0	15	30	45	60	75	90
10								
20								
30								
40								
50								
60								
70								
80								
90								
100								
110								

