XPULT EXERCISE – Business/Engineering Students

The Xpult is a device for launching table tennis balls or other light plastic balls. Most likely, you will have received the Xpult from an instructor in a course in engineering or business. 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. (Note: This exercise is intended for university/corporate students in business and engineering. You will find more basic instructions 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

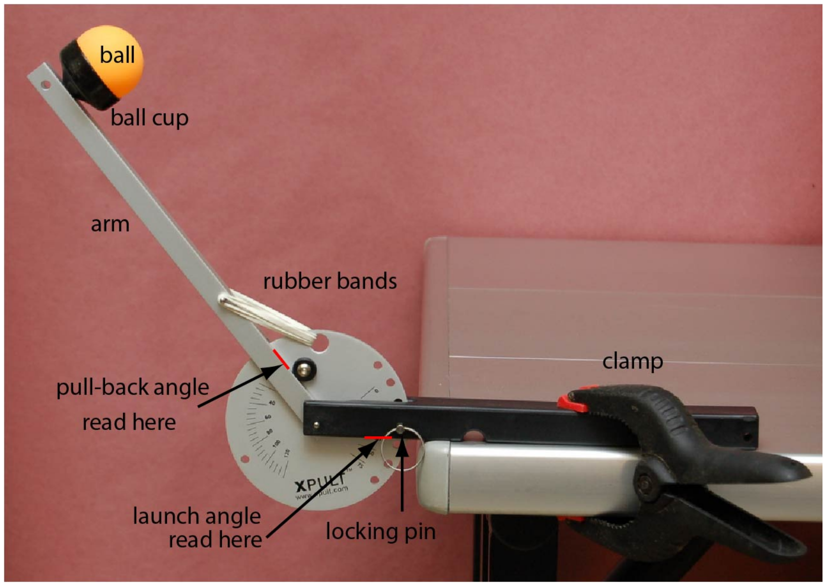

Figure 2: The Xpult in the deployed position

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).

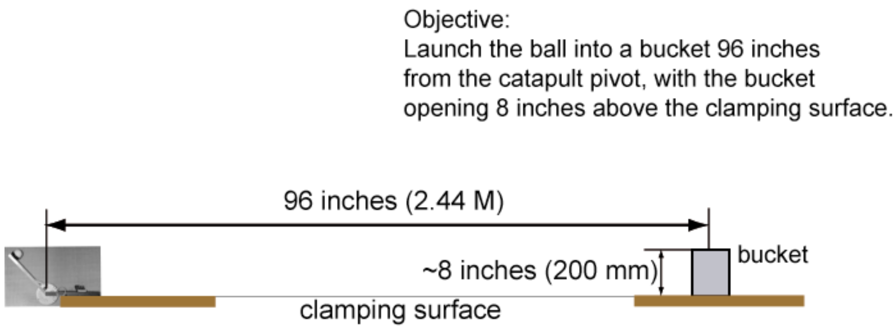

Figure 3: Setting up the target.

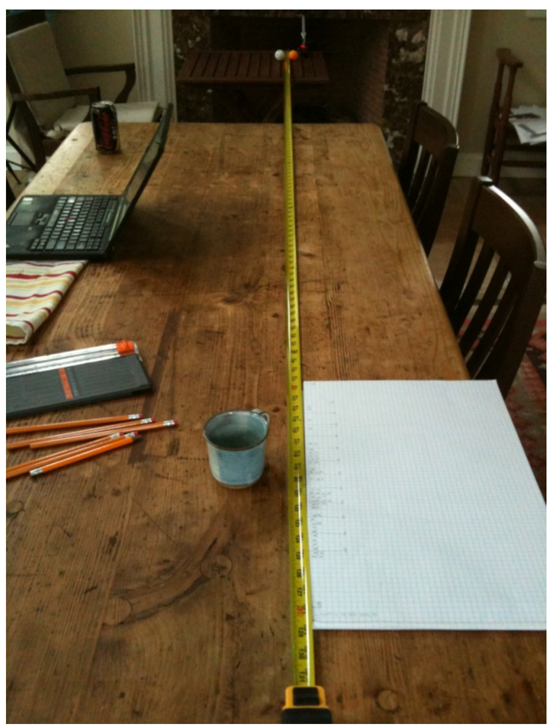

Figure 4: An example of the experimental set-up; note the computer next to the action to record data, the tape measure set-up, and the fact that the Xpult is not clamped to the antique furniture, but to another board/table.

Experiment: Measuring and improving consistency

Your objective for this exercise is to develop a model of the relationship between the catapult design variables and its launching performance. For this part of the exercise, you may approach this objective any way you please, although we do provide you with some suggestions. The end product of your efforts in this part of the exercise is a specification for four catapult design variables that will result in consistently launching a ball exactly 96 inches.

For this exercise, you will be setting four design variables:

1. Launch angle (e.g., flatter or steeper initial flight trajectory)
    a. Range of this variable is 0 degrees (horizontal trajectory) to 90 degrees (vertical trajectory), with discrete settings at 0, 15, 30, 45, 60, 75, and 90 degrees.
    b. You adjust this variable by changing the location of the locking pin with respect to the launch angle holes in the aluminum disc. When changing the launch angle, make sure the pin goes all the way through the base.
    c. **Note that you read the angle on the bottom edge of the black plastic base.**
2. Number of rubber bands (e.g., the force required for pull back)
    a. This variable can take on values of 1, 2, or 3 rubber bands.
    b. Watch out for the end of the launch lever. With three rubber bands, the lever moves very fast (and hurts if it hits you).
3. Pull-back angle (e.g., amount of energy accumulated in stretched rubber bands).
    a. The range of this variable is 0 degrees to 120 degrees, with tick marks at 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110, and 120 degrees.
    b. You may set this variable to any value, not necessarily the discrete values indicated by the tick marks.
    c. **Note that you read the pull-back angle on the bottom edge of the launch lever.**
4. Ball type.
    a. You have two choices: a table tennis ball or a perforated plastic ball.

NOTE: Not all combinations of variables work well together. For example, if you set the launch angle at 90 degrees, you won't be able to set the pull back angle at 120 degrees without the ball falling out of the ball cup.

The Objective

Your objective is to find a set of specifications of the four design variables that result in launching a ball exactly 96 inches (2.44 M) from the catapult pivot into a bucket **whose top edge is 8 inches (200mm) higher than the clamping surface**. (You will probably want to use a pretty big "bucket" to start with. A cardboard box or a trashcan works well.)

Figure 3 is an illustration of how we measure launch distance. Note that you must position the base of the "bucket" such that the top edge is about 8 inches above the catapult clamping surface or else the horizontal distance won't be quite right.

Suggestions

Here are some questions and thoughts to get you started:

1. Holding everything else constant, how do you expect the variables to influence distance?

    a. When I increase the number of rubber bands, the launch distance ________________.

    b. When I increase the launch angle, the launch distance__________________________.

    c. When I increase the pull back angle, the launch distance________________________.

    d. I expect the table tennis ball to go _____________ than the perforated plastic ball.

2. Is there exactly one set of values that will result in launching a ball 96 inches?

3. If more than one set of values will work, why might you prefer one set to another?

4. For the ambitious, you might try plotting launch distance as a function of each of the four variables. If you do this, you probably want to hold the other three variables constant at "reasonable" values.

Your Results

Enter the values for the design variables here.

Design Variable	Value
Number of Rubber Bands	
Launch Angle	
Pull-Back Angle	
Ball Type	

Using this exact set of specifications, launch 10 shots at the target. How many of these 10 shots were on target (i.e. in the bucket)?

Shots on target (out of 10)	

If your answer to the above question is “10 out of 10,” congratulations, you have completed this exercise. Consider moving to a smaller target and repeating the experiment. Independent on how many times you ran the experiments, reflect about the following questions:

1. Why were some of your shots on target, while others were not? Identify at least five factors that contributed to the ball missing the target.
2. How could you reduce the undesirable effect of the factors you identified above?
3. Could the values of your design variables be modified to allow you to hit the target more consistently?
4. Are there changes you could make to the catapult design or set-up to increase your percentage of good shots?