Simple Machines: Mechanical Advantage, Work & Efficiency in the Actual (Real) World (30 Point Lab)

Background: A catapult is, in essence, a simple lever. Its purpose is to launch objects a long distance. Our catapult is more appropriately called a trebuchet, which was a middle age siege engine used to smash castle walls or to throw projectiles over them. Our "counterweight trebuchet" is a catapult that uses a large mass as the input force to launch a smaller massed projectile.

Materials: Catapult, Paper Wad, 500g mass, Spring Scale, Meter Stick, Mass Scale

Part 1. Determine the Ideal Mechanical Advantage (IMA)

IMA = Input Distance/ Output Distance

Possible Procedures: Determine which side is the input arm and the output arm of your catapult and measure each of them from the fulcrum to the mass/projectile connection point.

Part 2. Determine Actual Mechanical Advantage (AMA) of your Catapult.

AMA = Output Force/ Input Force

Possible Procedures: Hang a known mass from the output arm of your catapult and balance that mass with another mass from the input arm (or use a spring scale).

Part 3. Determining Work Input and Work Output of a Catapult in Action

Work = Force * Distance
Force = Mass * Acceleration   Weight = Mass * Acceleration due to Gravity

Possible Procedures: We are going to simplify this by assuming the work output is the weight of the projectile multiplied by the distance it was thrown. Use a triple beam balance, acceleration due to gravity, and a meter stick to determine distance.
The input work will be the weight of the mass used to throw the projectile and the distance it moves in the catapult's operation. Use a scale or you can accept the known value on the mass and measure the distance traveled with a meter stick.

Part 4. Determining the Efficiency of your Catapult

Efficiency = Output Work / Energy Used (Think of this as Input Work)
Note: We were taught that Work In = Work Out, but more accurately it should be Net Work In = Net Work Out. We would need to be able to measure the work of every part of the machine and projectile interactions. Since we cannot in this lab, our efficiency will refer to the work in and the useful work out which ignores many of the variables. If our purpose is to throw a projectile, then this approach of determining efficiency is valid. In real world situations with machines, work in is almost never equal to the useful work out.

Data Tables and Calculations (15 Points Total)

Part 1

IMA (1 point)

Input Distance	Output Distance	Catapult IMA

Calculations: Plug in values with their units into the formulas and solve. (2 points)

IMA =

Part 2

AMA (1 point)

Input Force	Output Force	Catapult AMA

Calculations: Plug in values with their units into the formulas and solve. (2 points)

Force = AMA =

Part 3

Input Work or Energy Used (1 point)

Force of ______kg mass	Distance	Work In

Calculations: Plug in values with their units into the formulas and solve. (2 points)

Force = Work =

Output Work (1 point)

Force of ______kg mass	Distance	Work Out

Calculations: Plug in values with their units into the formulas and solve. (2 points)

Force = Work =

Part 4

Efficiency (1 point)

Output Work	Input Work	Catapult Efficiency

Calculations: Plug in values with their units into the formulas and solve. (2 points)

Efficiency =

Lab Questions Answer here, or on a separate sheet of paper. (15 Points Total)

1. Name the three classes of levers (research) and give 2 examples of each. (3 points)

2. Which class of lever is your catapult? (1 point)

3. On the back of this paper--Draw your catapult and label the input arm, output arm, and fulcrum. Identify the input force and the output force. (3 points)
4. Think of a different possible method to measure IMA (input and output distances) on your catapult for part 1. What would it be? (1 point)

5. If you were a siege engine builder, which piece of information would be more valuable to you, IMA or AMA? Explain why (for 1 point).

6. We did not measure Net Work In or Net Work Out. We just measured the work of the input force and the work on the launched output projectile. List 2 examples of work done (or caused) by the operation of this machine that we ignored in our calculations (1 for output, and 1 for input). (2 points)

7. An efficiency of 1 is 100% efficient (Work in = Work Out). What percent efficient is your catapult? (1 point)

8. Find someone in class that had at least a 10% different efficiency for their catapult results than yours. Evaluate their data and calculations to determine why theirs were more, or less, efficient. If they made a simple calculation mistake, show them their error and find someone else with a 10% difference if theirs is not when it is corrected.
   8a) What did you find in the data that could account for this difference? (1 point)

   8b) What specific <u>force</u> might be involved in this difference? Explain. (2 points)

Extra Credit: Design 3 improvements on your catapult that would improve its efficiency. Explain and show those improvements on you diagram from Question 3. (3 pts)