Lesson Title:	**Marshmallow Launcher Design**
Subject Area:	IB Physics
Grade Level:	10-12
Duration:	Two Weeks
Format (#students/group):	28 students in groups of 3-4
Overview:	Students will use materials to build a marshmallow catapult to launch it at a target 10 meters away. Students will be assigned the roles of team leader, technical writer, operator, and designer in each group. Each group will be given a $200 budget to purchase materials from supplies in the classroom (use fake money for sales).
Educational Standards:	HS-PS2-1 Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. HS-ETS1-2 Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering. ** Based on Michigan K-12 Science Standards - August 2015 CCR Standards - Technology & Tools: Use mathematics, information and computer technology, and computational thinking. Develop and use models. Argument & Reasoning: Analyze and interpret data. Communication & Collaboration: Obtain, evaluate, and communicate information Problem Solving: Ask questions (science) and define problems (engineering) Plan and carry out investigations. Construct explanations (science) and design solutions (engineering) CCSS: RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media (e.g., quantitative data, video, multimedia) in order to address a question or solve a problem. RST.11-12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information. RST.11-12.9: Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible.

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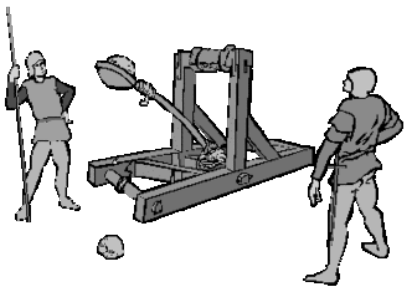
	WHST.11-12.7: Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. WHST.11-12.9: Draw evidence from informational texts to support analysis, reflection, and research.
Unit Question:	What are the elements of projectile motion?
Focus Question/ Purpose:	What factors (angle, tension, force, etc..) can affect the projectile motion of a marshmallow?
Desired Outcomes:	Students will design and build a working catapult that will launch a marshmallow 10 meters on the center of a bullseye target. Students will be graded based on budget, design, instructions to make design, accuracy and precision of launcher, force measurements, and lab report.
Activity Details/ Instructions:	Provide students with concepts of projectile motion. Allow students time to research designs and discuss construction of the launcher. During construction students should balance a budget of supplies used/purchased. Allow time to practice launching marshmallows from the device created. A bullseye will need to be made for students to have a target. To record the launch and analyze the components of projectile motion, create a reference poster behind the launch area that marks displacement in the x and y coordinates. A slow motion app is recommended to film and review launches (Video Physics). Analyze the launches for the components of projectile motion.
Safety:	No marshmallows will be harmed in the making of the devices. The materials being used are common household items. Caution should be used with the hot glue gun to prevent burns in skin.
Potential Cost:	$20-$40 per class of 28
Supplies (sources):	Popsicle sticks, rubber bands, marshmallows, tape, paper clips, plastic spoons, construction paper, fake money, cardboard, paper cups, paper plates, pencils, scissors, Elmer's glue, hot glue, Video Physics app PhET Projectile Motion Simulation, Laptops
Developed by:	Melanie Galonska
Date:	Fall 2015
Key Words:	STEM, SOP (Standard operating procedures), projectile motion, force, velocity, accuracy, precision, displacement, design, motion diagram
Other Resources:	Video Physics app, laptops for research and typed lab report

Catapult Design Lab

Team Leader:_____ Technical Writer: _____

Designer: _____ Operator: _____

In this activity, your group (3-4 students) will be responsible for designing, building and testing a catapult. The catapult will launch a marshmallow at a target 5 meters away. (100 points)

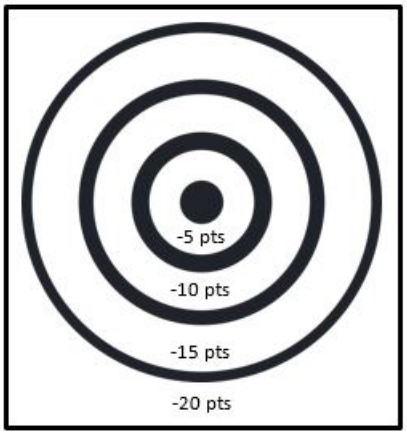


Day One: Research designs and draw a diagram of what your team plans to build. Look at material costs and determine what materials your team will need to buy from the supply store. The team will start with a balance of $200.

Day Two: Build and test the design created by the team. Write procedures to build the catapult. Trials at the target have a launch fee of $5.

Day Three: Last day to build and modify designs. Continue writing Lab Reports.

Day Four: Experiment Day! Launch your catapult for a grade at the target. Teams will get 3 trials to hit the target for points. Accuracy is needed; grades will be reduced if not able to hit center of the target. Additional launches will cost $20. Collect data from the motion video and complete calculations on projectile motion.



Lab Report DUE Date:

<Insert due date> electronic copy to Turnitin.com

Formal Laboratory Report

NO PERSONAL PRONOUNS

Team Names (5 pts)

Design and Research (15 pts)

- Hand drawn or computer generated
- (Final draft must include digital version – photo of hand drawn or computer generated)

(Research)

- Explain why the design was chosen using scientific reasoning
- Include scientific knowledge from research that leads to the design
- Include introductory information that will be helpful for the reader

Materials (15 pts)

- List all materials used and needed including equipment and consumable items
- Include a budget of how money was spent. It must include material costs, fines and extra launches purchased

Procedure (15 pts)

- Write a complete method (very detailed) for construction of the catapult
- Write steps to explain how to launch the catapult

- Include how the design was modified after testing

Data (30 pts)

- Complete the data table provided
- Complete all needed calculations using KUES
- Complete a motion diagram based on the video provided from one of the launches
- All calculations should be included in the final draft (a photo can be put in as an image)

Explanation of Data (5 pts)

- Explain any trends or patterns in the data collected during the multiple trials using correct scientific reasoning
- Describe any unreliable results (outliers, etc)

Conclusion/Evaluation (15 pts)

- Comment on the success of the catapult design
- Evaluate procedure for validity (Would another team be able to build the exact catapult made by the procedure provided?)
- Suggest improvements to the procedure/launch process to reduce sources of error
- Include ideas for further testing related to the topic

Work Cited (Must have – failure to include will result in a ZERO score for the entire lab)

- MLA or APA works cited format required

Lab Report Outline

Use the following outline as the guide to type the team paper. This will be turned in on the due date.

Team Names and Roles:

Design including Research:

Materials / Budget:

Item	Quantity	Cost	Balance Budget Starting Balance $200

Procedure (numbered format):

Data Collection: (Include a motion diagram of the video)

Data During Launch

Trial #	Release Angle	Time	Horizontal Distance (x)
1			
2			
3			
4			
5			

Data Calculations After Launch (show your work!)

Trial #	Vertical Distance (y)	Horizontal Velocity	Vertical Velocity	Resultant Velocity
1				
2				
3				
4				
5				
Equations to Use $\Rightarrow$ **a = -9.8 ms^{-2}**	$s_y = u_y t + \frac{1}{2} a_y t^2$ **Hint**: divide time by 2	$u_x = \frac{s_x}{t}$	$u_x \tan \Theta = u_y$	$u_r^2 = u_y^2 + u_x^2$

Explanation of Data:

Conclusion / Evaluation:

Works Cited from Research (Must be included!):

- Use Easybib.com to create a works cited page for your research done in the hypothesis section.

Team Initials: _____

Catapult Design Lab Teacher Evaluation

Tasks / Indicators	Teacher Comments	Points Received	Point Value
Team Names			5 points
Design and Research			15 points
Materials			5 points
Budget			10 points
Procedure			15 points
Data Table			10 points
Data Calculations			10 points
Motion Diagram			10 points
Explanation of Data			5 points
Conclusions / Evaluations			15 points
Works Cited	Must be included – lab will receive a ZERO if not included!		
	Total Points		**100 pts**

Note Card	$2
Marshmallow	$10
Craft Stick	$5
Dowel Rod	$5
Paper Clip	$1
Clear Tape (30cm)	$5
Masking Take (30 cm)	$10
Hot Glue (5 min)	$20
Mini Wood Stick	$1
Yarn (1 m)	$10
Spoon	$10
Cup	$10
Rubber Band	$5
Glue (1/2 cup)	$20

Name: _____ Hour: _____

Team Members Participation Evaluation

Circle the number that best represents your teammates and yourself for each area. (1 = lowest, 5 = highest)

Team Leader: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Technical Writer: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Designer: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Operator: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Other: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Other: _____

Attitude	1	2	3	4	5
Participation	1	2	3	4	5
Motivation	1	2	3	4	5

Team Leader: Responsible for time management, keeping focus, and communication with instructor. Responsible to check that tables are cleared and calculators/clickers returned everyday. Will cover any role of absent members.

Technical Writer: Responsible to record written portions. (procedures, descriptions, etc…) Responsible to have all members initial bottom of every project/activity.

Designer: Responsible to draw diagrams and illustrations. Responsible to create graphs and data tables (hand drawn and on computer).

Operator: Responsible to get/return supplies and setup experiments/projects. Will cover role of Team Leader if absent.