Date: _____

Your Name: _____

New England Common Assessment Program

Released Science Inquiry Task

The Throwing Contest

2014

Grade 11

Science

Directions:

You will be analyzing the results of an investigation described in a short story called "The Throwing Contest" and applying what you learn to answer a set of questions. Thoroughly explain all of your answers. You may include labeled drawings or diagrams to help you answer the questions.

This inquiry task presents information and data found by students doing field research. You will form a hypothesis based on their research question; organize, analyze, and present data; and evaluate your hypothesis and the research results.

The Word Bank below provides the definitions that apply to some words used in the investigation. You may refer back to this page throughout the session.

Word Bank

Arm ratio	The ratio of the length of a sling arm to the length of a counterweight arm
Counterweight	A weight placed on the opposite end of a lever from the load (projectile) end; the applied force on a trebuchet beam
Projectile	An object launched toward a distant target
Sling	A small pouch used to hold a projectile
Trebuchet	A machine that launches objects long distances with precision

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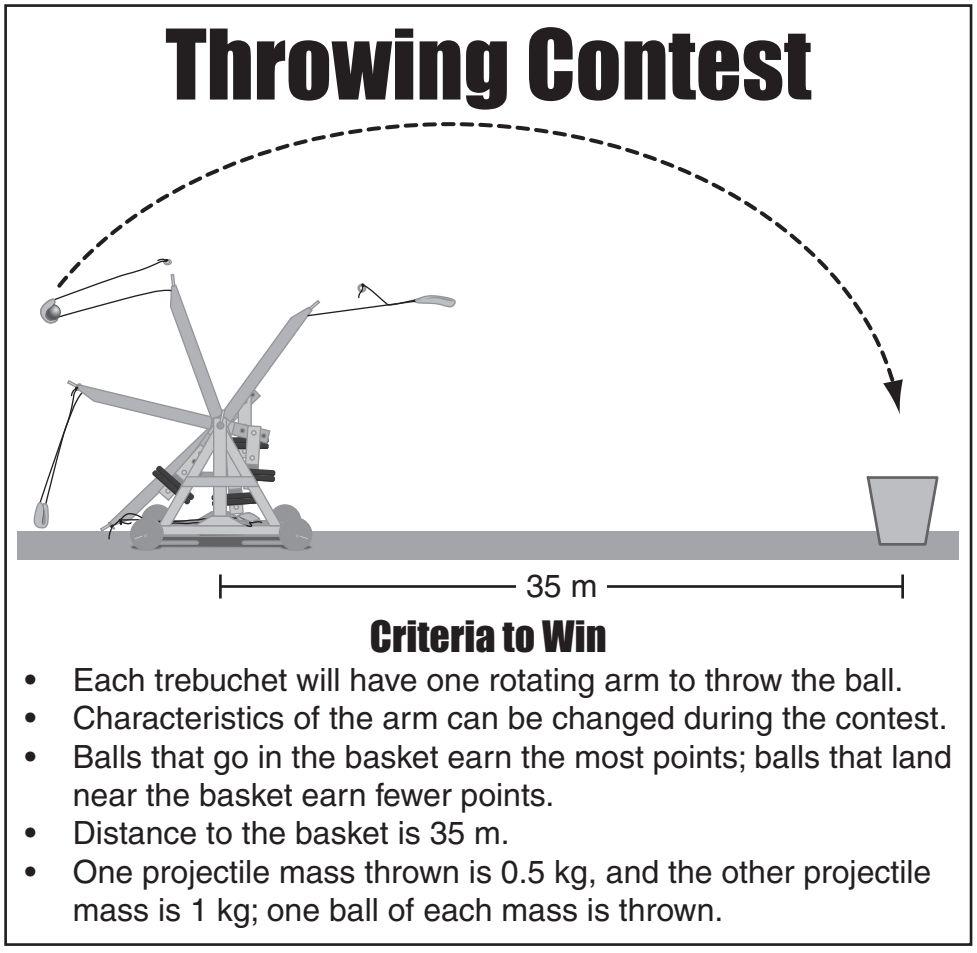
The Throwing Contest

Mr. Nelson's physics class finished a unit about forces and motion. Mr. Nelson wanted the students to participate in a fun project to demonstrate everything they learned. He asked the class for some ideas.

"How about the throwing contest?" Brian asked. "I have a poster for it. It says that this year each team is designing a trebuchet that can throw a ball into a basket. Some points are awarded for the balls that come close to the basket and more points are awarded when the balls go in the basket. The team with the most points wins."

Brian showed his classmates this poster.



"Have you ever seen a trebuchet?" Marla asked. "Trebuchets are huge machines that were first built back in the Middle Ages. They were used all over Europe and even in Asia. One or two good trebuchets and a supply of boulders could turn a castle into rubble from a long distance away. Trebuchets changed the technology of combat."

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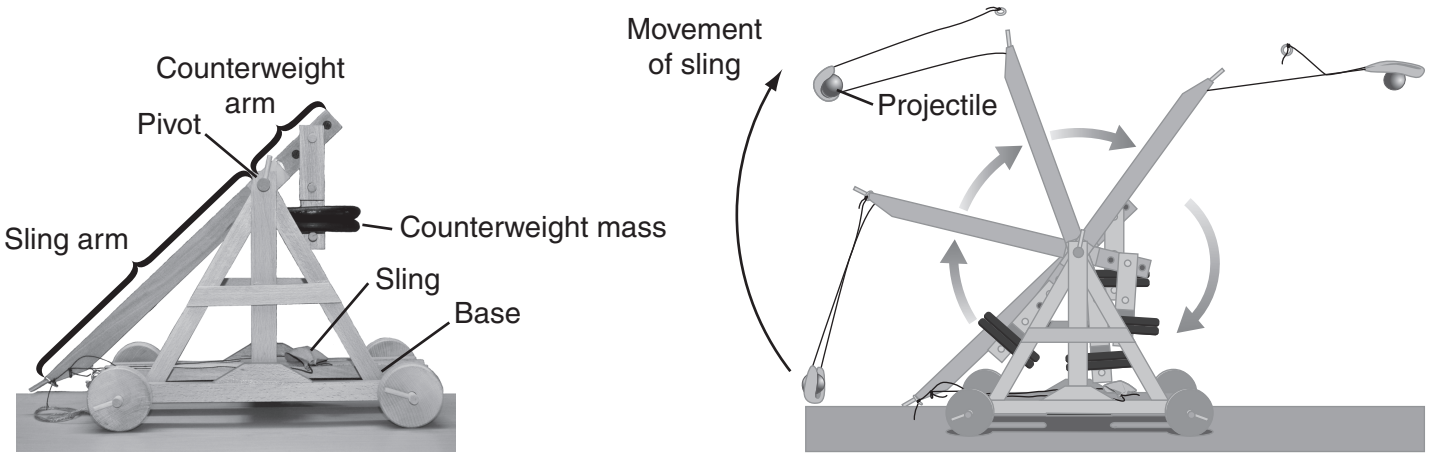
"Model trebuchets are smaller than the ones used for combat," Marla continued. "They are only about four feet tall. I've seen model trebuchets that were accurate enough to put oranges inside a small cardboard model of a castle from a long distance away. I observed that large trebuchets can throw large objects farther than small trebuchets."

"Let's enter a model trebuchet in the throwing contest!" Brian exclaimed. The class all agreed.

"Okay, while I come up with the materials you can use, you do some research that relates the trebuchet to force and motion of objects," Mr. Nelson responded.

Through their research, the students learned that a trebuchet is basically a lever. The lever applies mechanical advantage to allow a large weight to launch a lighter weight a great distance. A typical trebuchet design and how it works is shown in Diagram 1 below.

Diagram 1: Trebuchet Design and How It Works



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The class decided on the following research question.

Research Question:

How does the design of the model trebuchet affect the launching of a projectile?

After watching a video of trebuchet models in action, the class divided into four groups. The students in each group built their own model trebuchet from the same set of materials. The overall arm length and sling design of the trebuchets all had to have the same measurements.

The students determined that arm ratio, counterweight mass, and projectile mass would most affect the performance of the model trebuchets. Mr. Nelson set limits for all three of these variables, as shown in Table 1 below.

Table 1: Limits for Model Trebuchet Variables

Variable	Range
Arm ratio	2.5:1 to 4.0:1
Counterweight mass	10 kg to 60 kg
Projectile mass	0.5 kg or 1.0 kg
All other variables remain constant.	

Mr. Nelson allowed the students in each group one practice session to test their model trebuchets. Each group made a hypothesis about the answer to their research question.

Defining the Problem and Making Predictions

Answer question 1 on page 1 in your Student Answer Booklet.

1 Based on **Table 1** and **Diagram 1**, write a hypothesis about how a change in one of the variables might affect the throwing contest results. Explain the reasoning for your hypothesis.

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Each group wanted to increase the distance their projectile went during the practice session. They experimented with different ways to do this. Then they used their data to compare their results with the other trials. The data from one group is shown in Tables 2a and 2b below.

Table 2a: Design Test Launches (0.5 kg projectile)

Trial	Counterweight Mass (kg)	Arm Ratio	Flight Distance (m)
1	50	4:1	58.7
2	40	4:1	49.3
3	50	3:1	61.8

Table 2b: Design Test Launches (1.0 kg projectile)

Trial	Counterweight Mass (kg)	Arm Ratio	Flight Distance (m)
1	50	4:1	41.4
2	40	4:1	37.7
3	50	3:1	43.1

Answer question 2 on page 2 in your Student Answer Booklet.

❷ Based on the data in **Tables 2a** and **2b**, identify one change to the trebuchet design that will increase the distance the projectile travels. Be sure to include evidence from the tables that supports your answer.

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After conducting an initial test, the groups conducted three more tests to measure the effect of using different arm ratios. Table 3 shows the class's results.

Table 3: Projectile Flight Distance with Controlled Counterweight Mass of 50 kg (1 kg projectile mass)

Group	Test 1		Test 2		Test 3	
	Arm Ratio	Flight Distance (m)	Arm Ratio	Flight Distance (m)	Arm Ratio	Flight Distance (m)
1	4.0:1	42.0	3.5:1	46.2	3.5:1	46.5
2	3.0:1	53.2	3.0:1	54.0	3.0:1	52.9
3	3.0:1	46.7	2.5:1	43.8	3.0:1	46.1
4	4.0:1	50.0	3.5:1	53.2	3.0:1	53.0

Answer question 3 on page 2 in your Student Answer Booklet.

3 Explain how the use of multiple tests helped the students achieve the maximum flight distance during the investigation. Identify data from **Table 3** that supports your explanation.

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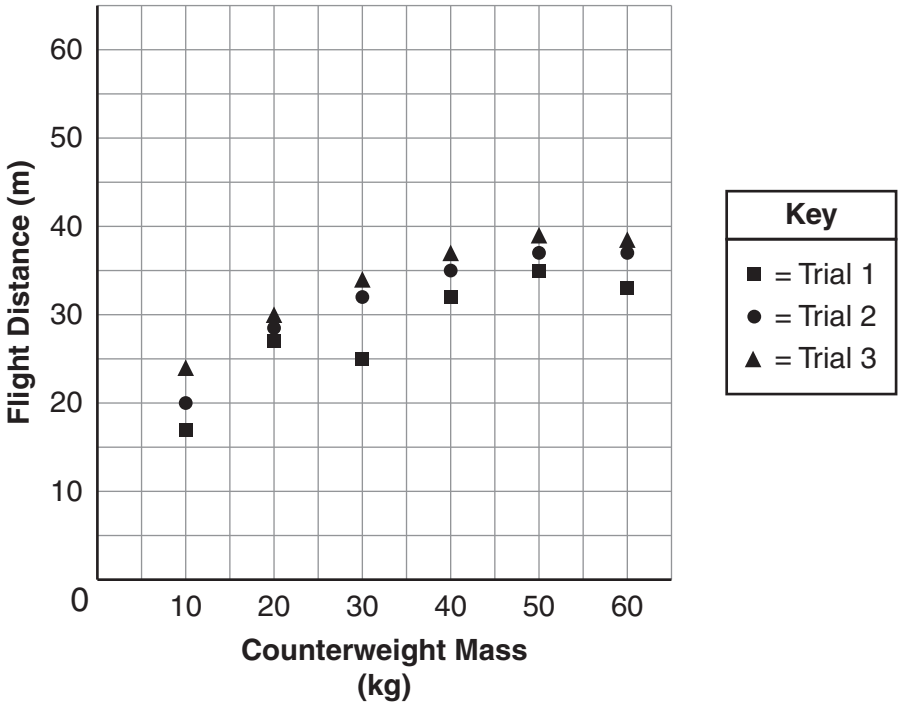
In another test, the students kept the arm ratios and projectile mass constant. They used six different counterweight masses and performed three trials for each one and measured the flight distance. Then the students from each group made a graph of the data from their practice session to help them make adjustments. The graph below shows one group's data.

Graph 1: The Effect of Counterweight Mass on Flight Distance



Answer question 4 on page 3 in your Student Answer Booklet.

4 Use the trend shown in **Graph 1** to determine which counterweight mass to use to make a projectile land in a basket 35 meters away. Explain how the data pattern supports your choice.

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For the next part of the investigation, Mr. Nelson let each group have three tests to get the 1 kg mass into the basket 35 meters away. He explained that the projectile could land in the basket or a distance from the basket. If the projectile did not land in the basket, the students were to measure the number of meters the projectile landed before, after, or next to the basket during each test. The table below shows the four groups' results.

Table 4: Projectile Accuracy: Distance from Basket (3:1 Arm Ratio)

Group	Test 1		Test 2		Test 3	
	Counter-weight Mass (kg)	Distance from Basket (m)	Counter-weight Mass (kg)	Distance from Basket (m)	Counter-weight Mass (kg)	Distance from Basket (m)
1	33	1.8	38	0.7	37	1.2
2	30	3.3	35	1.1	38	0.2
3	30	1.2	28	1.3	25	0.3
4	25	5.6	33	0.5	32	1.4

Answer question 5 on page 3 in your Student Answer Booklet.

5 Based on Table 4, identify whether the students should change the independent or dependent variable. Explain what effect the change will have on the results.

Answer question 6 on page 4 in your Student Answer Booklet.

6 Explain how the data from this investigation **support** or **refute** your hypothesis from question 1. Cite evidence from this investigation.

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Developing and Evaluating Explanations

Mr. Nelson asked each group to study the results of their investigations and to find sources of possible error in the procedures or data collection. He also asked the groups to identify factors that were not controlled during their investigations that might have affected the results.

Answer question 7 on page 4 in your Student Answer Booklet.

7 Identify an example of data from **Table 4** that does not seem to agree with the other data in the table. Explain what may have caused the difference in data sets.

During the throwing contest, the trebuchet the students will build will need to throw one projectile that is 0.5 kg and one projectile that is 1.0 kg. The projectiles that land close to the basket earn points.

Answer question 8 on page 5 in your Student Answer Booklet.

8 Identify one variable based on all the data from the trebuchet investigation that will **best** help the students win the throwing contest. Use evidence from this investigation to support your reasoning.