While you explore Fort Ticonderoga, you will see many examples of artillery, and their history, and statistics. Use the information on this sheet, and around Fort Ticonderoga to solve the physics problems below. A formula sheet is included. Because the metric system was not introduced until the French Revolution in 1799, and SI Units were not established until 1960, you will need to convert most of the measurements into SI Units before doing calculations.

Mortars:

On lower level of the Mars Education Center there is a picture of a Sea Service Mortar which fires a 13 inch shell at a 45° angle. Use the statistics to answer this series of questions. Ignore air resistance and the height of the mortar for these questions. (Bonus: Answer all of these questions for the 10 inch mortar on display next to it.

1. What is the horizontal velocity of the mortar shell ?

2. What is the initial vertical velocity of the mortar shell?

3. What is the initial velocity of the mortar shell?

4. What is the maximum height reached by the mortar shell?

5. If this mortar were set at a 40°angle relative to the ground, what would the total distance travelled be?

6. If this mortar were set at a 50°angle relative to the ground, what would the total distance travelled be?
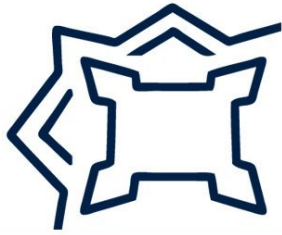
Cannons Atop Mount Defiance:

In July of 1777, Arthur St. Clair's American Troops abandoned Fort Ticonderoga, partly because of the two 12 pound cannons that General Burgoyne's forces hauled to the top of Mount Defiance. The summit of Mount Defiance is 200 meters higher than the walls of Fort Ticonderoga, and the horizontal distance between the summit of Mount Defiance and Fort Ticonderoga is 1835 meters.

 1. What is the minimum velocity needed by those 12 pounders, if a shot fired horizontally from a cannon on Mount Defiance is to hit the walls of Fort Ticonderoga? Is this possible?

Aiming at Mount Defiance:

In 1776, Johnathan Trumbull, Adjutant General to General Gates warned of the danger of artillery on Mount Defiance. He ordered a 12 pound cannon on Mount Independence to be fired at Mount Defiance. Trumbull wrote in his memoirs"

   General (then Major Stevens) was busy at the north point of Mount Independence in examining and proving cannon; I desired him to elevate this gun so that it should point at the summit of Mount Defiance, he looked surprised and gave his opinion that the shot would not cross the lake. "That is what I wish to ascertain, Major," was my answer; "I believe they will and you will direct your men to look sharp and we too will keep a good look-out; if the shot drop in the lake their splash will easily be seen; if, as I expect, they reach the hill, we shall know it by the dust of the impression which they will make upon its rocky face." The gun was fired, and the shot were plainly seen to strike at more than half the height of the hill.

The north point of Mount Independence is 61 meters above Lake Champlain and Mount Defiance is 225 meters above Lake Champlain. The horizontal distance between Mount Independence and Mount Defiance is 1963 meters.

2. The initial velocity of a 12 lb ball leaving a cannon is 1486 feet per second, If Major Stevens elevated the gun to an angle of 45°, ignoring air resistance, how far should the cannonball have travelled?

3. How much was the horizontal distance reduced by air resistance? (Assume the cannonball had already reached maximum height and was beginning to descend when it hit Mount Defiance, approximately 115 meters above Lake Champlain.

Physics of Artillery:

Projectile Motion in Two Dimensions

FORT TICONDEROGA

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Cannons Atop Mount Defiance:

 After hitting halfway up Mount Defiance from Mount Independence, Trumbull decided to make another experiment.

 "I returned to head-quarters and made my triumphant report, and after dinner requested the general and officers who were with him to walk out upon the glacis of the old French fort, where I had ordered a common six pound field gun to be placed in readiness. This was, in their presence, loaded with the ordinary charge pointed at the top of the hill, and when fired, it was seen that the shot struck near the summit."

The horizontal distance between Mount Defiance and the glacis of Fort Ticonderoga is 1770m. The peak of Mount Defiance is 195 meters higher than the glacis at Fort Ticonderoga. The initial velocity from a 6 pound cannon ball is 1437 feet/sec.

If you like, you can stand where Trumbull stood as you solve this problem. Near the Log House Welcome Center is a group of picnic tables. Beyond the picnic tables is a set of stairs leading down to the lower field. The six pounder in this account was likely placed near the top of those stairs. Look out on Mount Defiance and imagine calculating the amount of powder and the elevation needed to hit the summit of Mount Defiance.

4. Ignoring air resistance, what is the maximum height and distance a cannon ball could travel when fired at this velocity?

5. How much was the horizontal distance reduced by air resistance?

6. Did air resistance have more of an impact on an heavier or lighter projectile?

Note: The velocities used in this document come from calculations done by Benjamin Robbins, published in his 1742 book, *New Principles of Gunnery.* Robbins was one of the first artillerists to produce formulas and tables to calculate air resistance. *New Principles of Gunnery* is available for free on Google Books.