Archaeo-Tech: Atlatl Physics

Cultural Resources Education

Created by Jacob Hamill, SCDNR Heritage Trust Public Information Coordinator (2019). Adapted from "Atlatl Antics" by Cassandra Rae Harper, Florida Public Archaeology Network, and "Investigating the Physics of the Atlatl" by Lauri Davis, Mississippi Valley Archaeology Center.

Grade Levels

5th – 8th, High School Physics

Estimated Time

1 - 2 class periods. Approximately 1 - 2 hours. Time will vary depending on the materials used for the lesson.

Goal

Students will learn how before the bow and arrow, prehistoric people used a spear-throwing device for hunting called an atlatl. Students will learn what an atlatl is, the basic parts of an atlatl, and how an atlatl works. In the lesson activity, students will compare throwing a projectile freehand to throwing a projectile with an atlatl (or alternative device). Students will use data collected from the activity to study the physics behind the atlatl, learning how the atlatl magnifies the user's throwing distance and power.

Objectives

After viewing the *Archaeo-Tech: The Atlatl* video and completing the activity, students will be able to:

1. *Explain* what an atlatl is and how it works.
2. *Discuss* how the atlatl predates the bow and arrow and was used by prehistoric hunters in North America for thousands of years.
3. *Explain* how an atlatl is a simple machine and *relate* the scientific concepts of simple machines to the mechanics of the atlatl. Understand how energy is transferred from the user to the atlatl to the dart.
4. *Observe* and *practice* how to properly use an atlatl.
5. *Construct* and *test* their own replica atlatls or *relate* the dynamics of an atlatl to a modern dog toy used to throw balls longer distances.
6. *Compare* throwing a projectile freehand to throwing a projectile with an atlatl.
7. Work in teams to *record* and *collect* data on the time and distance traveled by a projectile.
8. *Apply* kinematic formulas to the data collected in the activity to find various measurements, such as velocity, kinetic energy, momentum, acceleration, force, and work.
9. *Analyze* and *explain* what these measurements tell us about a projectile thrown with an atlatl compared to a projectile thrown freehand.
10. *Explore* the motion of a projectile in two dimensions and the effect of gravity on a projectile.
11. *Consider* the reality that atlatls are rarely found complete in an archaeological setting and *discuss* the value of experimental archaeology, a subfield of archaeology that studies past material culture through reproduction and testing.

South Carolina Academic Standards

Science

5.P.5 The student will demonstrate an understanding of the factors that affect the motion of an object.

- **5.P.5A.4** Analyze and interpret data to describe how a change of force, a change in mass, or friction affects the motion of an object.

6.P.3 The student will demonstrate an understanding of the properties of energy, the transfer and conservation of energy and the relationship between energy and forces.

- 6.P.3B.1 Plan and conduct controlled scientific investigations to provide evidence for how the design of simple machines (including levers, pulleys, inclined planes) helps transfer mechanical energy by reducing the amount of force required to do work.

8.P.2 The student will demonstrate an understanding of the effects of forces on the motion and stability of an object.

- **8.P.2A.1** Plan and conduct controlled scientific investigations to test how varying the amount of force or mass of an object affects the motion (speed and direction), shape, or orientation of an object.
- **8.P.2A.3** Construct explanations for the relationship between the mass of an object and the concept of inertia (Newton's First Law of Motion).
- **8.P.2A.5** Analyze and interpret data to describe and predict the effects of forces (including gravitational and friction) on the speed and direction of an object.
- **8.P.2A.7** Use mathematical and computational thinking to describe the relationship between speed and velocity (including positive and negative expression of direction) of an object in determining average speed (v=d/t).

H.P.2 The student will demonstrate an understanding of how the interactions among objects and their subsequent motion can be explained and predicted using the concept of forces.

- **H.P.2A.3** Use mathematical and computational thinking to apply formulas related to an object's displacement, constant velocity, average velocity and constant acceleration. Interpret the meaning of the sign of displacement, velocity, and acceleration.
- **H.P.2A.5** Construct explanations for what is meant by "constant" velocity and "constant" acceleration (including writing descriptions of the object's motion and calculating the sign and magnitude of the slope of the line on a position-time and velocity-time graph).
- **H.P.2B.1** Plan and conduct controlled scientific investigations involving the motion of an object to determine the relationships among the net force on the object, its mass, and its acceleration (Newton's second law of motion, $F_{net} = ma$) and analyze collected data to construct an explanation of the object's motion using Newton's second law of motion.
- **H.P.2B.2** Use a free-body diagram to represent the forces on an object.
- **H.P.2B.4** Use mathematical and computational thinking to derive the relationship between impulse and Newton's Second Law of Motion.
- **H.P.2D.6** Use a free-body diagram to represent the gravitational force on an object.

H.P.3 The student will demonstrate an understanding of how the interactions among objects can be explained and predicted using the concept of the conservation of energy.

- **H.P.3A.1** Use mathematical and computational thinking to determine the work done by a constant force (W=Fd).
- **H.P.3A.2** Use mathematical and computational thinking to analyze problems dealing with the work done on or by an object and its change in energy.

- **H.P.3B.2** Use mathematical and computational thinking to argue the validity of the conservation of mechanical energy in simple systems and those with periodic motion and on which only conservative forces act ($KE = \frac{1}{2} mv^2$, $PE_g = mgh$, $PE_e = \frac{1}{2} kx^2$).

Social Studies

4-1.2 Compare the everyday life, physical environment, and culture of the major Native American cultural groupings, including the Eastern Woodlands, the Plains, the Southwest, the Great Basin, and the Pacific Northwest.

6-1.1 Explain the characteristics of hunter-gatherer groups and their relationship to the natural environment.

8-1.1 Summarize the collective and individual aspects of the Native American culture of the Eastern Woodlands tribal group, including the Catawba, Cherokee, and Yemassee.

Activity Type: In-Class

This lesson is to be done as an in-class activity. The teacher will provide the required materials and necessary instructions. Two class periods may be needed for the completion of the lesson, depending on the materials used. The activity for this lesson requires a large outdoor space, which should be set up in advance.

Materials

- Activity Handout (1 per student)
- Clipboards (1 per student)
- Measuring tapes (1 per group)
- Stopwatches (1 per group)
- Calculators
- Electronic Scale (1 per group)
- Orange safety cones
- Pin Flags
- Replica atlatls & darts (1 atlatl and at least one dart per group of students. It is recommended to have several darts per group)
    - There are many resources available online on how to make and throw an atlatl. For this lesson, the atlatl does not need to look authentic or have a high level of craftmanship.
    - Atlatl & Dart Materials (From "Making an Atlatl" by the Montana Historical Society, instructions available online at https://mhs.mt.gov/Portals/11/education/Textbook/Chapter2/Atlatl_LessonPlan.pdf)
        - 5/8" diameter, 48" long wooden dowel
        - Duct Tape (preferably in a color that is not gray)
        - Scissors
        - 1" diameter, 48" long piece of scrap wood
        - Hammer
        - 1" Nail
        - 80 grit sandpaper
    - Another good but slightly more complicated atlatl guide is "How to Make an Atlatl and a Dart" by the Florida Public Archaeology Network, available online at http://fpan.us/resources/Beyond%20Artifacts_2011%20v3.pdf

- **Alternatively**, a dog ball launcher with extra tennis balls can be used in place of a replica atlatl. The ball launcher works on the same principle as the atlatl. While making atlatls and darts would be a better experience for students, in many schools that is not feasible and a ball launcher like the ChuckIt!© Ball Launcher is a good alternative. The ChuckIt!© Ball Launcher can be found online (https://www.amazon.com/Chuckit-Classic-Launcher-Thrower-Assorted/dp/B00006IX59) or at local pet stores.
- Markers or other supplies to decorate the atlatls and darts.

Atlatl Background Information

- Before the bow and arrow, prehistoric hunters relied on a device called an **atlatl**, or spear-thrower, to hunt game.
- The atlatl was used throughout the world and varied in size, shape, and complexity. In North America, the atlatl was used for thousands of years until around 1,600 years ago, when the bow and arrow replaced it. However, this timeline varies by region, and in some parts of North America, the atlatl was still in use by the time of European contact.
- The word atlatl comes from the Aztecs, who used atlatls against Spanish conquistadors because of the weapon's penetrating power over the bow and arrow. In the 1700s, Russian traders reported hunters using atlatls off the coast of Alaska.
- The atlatl works like a **lever** to magnify the user's throwing power. The atlatl is a stick that is held at one end with a hook on the other end. The atlatl is used to propel a long, flexible dart with a hollowed out back end. The dart resembles a spear in shape and length but is lighter in weight. The dart lays on the atlatl with the back end of the dart fitted into the hook.
- To throw, the user pinches the dart with their thumb and index finger, and wraps their middle, ring, and pinky fingers around the atlatl. Using a motion similar to casting a fishing rod, the user releases the dart at just the right moment, allowing the dart to rotate relative to the atlatl with the end of the dart still in contact with the hook. Through this point of contact, force generated by the thrower is transferred to the dart, resulting in a projectile that is more powerful, accurate, and can travel longer distances than a projectile thrown by hand. For an experienced thrower, the mechanical advantage of throwing with an atlatl compared to throwing freehand is around 6:1.
- Atlatls are made of wood, an organic material, meaning that outside of a few exceptional **sites**, like bogs or dry caves, complete atlatls are not preserved in the archaeological record. What archaeologists typically find are the stone points from darts. Atlatl darts were larger and heavier than arrows and needed to be tipped with a larger and heavier stone point. When the bow and arrow replaced the atlatl and dart, stone **projectile points** gradually reduced in size since arrows needed smaller and lighter points to accurately fly.
- Archaeologists also find atlatl hooks (also called spurs) and dart tips made from deer bone. Archaeologists have also found stone and bone atlatl weights. These weights would have been attached to the center of the atlatl. One theory is that the weight would have helped the hunter throw with a greater velocity and accuracy.

Pockoy Shell Ring Background Information

- **Pockoy Island** (pronounced Pock-ee) is a remote South Carolina sea island and a part of the SC Department of Natural Resource's Botany Bay Heritage Preserve and Wildlife Management Area. The property is located on the northeastern corner of Edisto Island in Charleston County.
- Botany Bay is one of the largest relatively undeveloped wetland ecosystems on the Atlantic Coast, providing a critical habitat for numerous wildlife species.
- The **cultural resources** of Botany Bay are equally important, with sites dating from approximately 4,000 years ago to the nineteenth century. Several sites are listed on the National Register of Historic Places, including the outbuildings from Bleak Hall Plantation, granite markers from the 1850 Alexander Bache U.S. Coast Survey, and the Fig Island Shell Rings.
- The shell ring on Pockoy Island was first identified in early 2017 by analysts studying Hurricane Matthew's effect on South Carolina's coastline. When studying maps produced by aerial light detection and ranging, or **LiDAR**, analysts noticed strange circular features on the coast of Pockoy Island, indicating the presence of a shell ring. **Shovel testing** began in the summer of 2017, which confirmed the ring's existence. **Radiocarbon dating** conducted on recovered animal bone revealed that the site was approximately 4,300 years old, making it the oldest known shell ring in South Carolina.
- Testing continued in late 2017, and large-scale **excavations** were conducted in May and December of 2018, and May of 2019.
- **Shell rings** are structures found along the coasts of South Carolina, Georgia, Florida, and Mississippi, dating to the **Late Archaic** period (roughly 5,000 – 3,000 years ago). Dating suggests that the shell ring on Pockoy Island was built over a relatively short period of time, around 20 – 30 years.
- As the name indicates, shell rings are large circular or semi-circular structures made from piled shell. Some are C-shaped and U-shaped, while others are irregularly shaped or made up of multiple shapes. Pockoy's shell ring is doughnut-shaped. Shell rings are primarily composed of oyster shell, but cockles, periwinkles, clams, and whelk shells are also commonly found. Shell rings range in size from 30 to 250 meters in diameter and are between 1 and 6 meters high. The Pockoy shell ring is approximately 60 meters in diameter.
- Another key feature of a shell ring is a central area called a **plaza**, which is devoid of shell. Archaeologists speculate that this area was maintained for ceremonial purposes or contained some sort of structure.
- Archaeologists have been studying shell rings for decades but there is still a lot we do not know about them.
- Archaeologists are unsure if shell rings were intentionally built or not. Some argue that shell rings were inadvertently created from piles of discarded shell following meals over a long period of time. Others believe shell rings were planned structures built from leftover shells from ceremonial feasts and other quarried shell.
- Archaeologists are also unsure what shell rings were used for. Some believe shell rings were sites of general human occupation, while others theorize shell rings were ceremonial structures only used for specific purposes at specific times.
- Archaeologists have recovered thousands of **artifacts** from Pockoy and other shell ring sites. The most common artifacts are pottery, shell, and animal bone.
    - The pottery found at Pockoy belongs to the earliest types of ceramics found in South Carolina. Many of the potsherds found at Pockoy are decorated with

punctations, incised lines, or stamped designs. The people who created this pottery used shells, reeds, and other natural materials to produce these effects.
    - Shells were not only used to build the ring, they were also used as tools and for decoration. The Late Archaic inhabitants of Pockoy modified whelk shells and other shells to create hammers, awls, adzes, hoes, and other necessary tools for everyday life. They also turned shells into jewelry by shaping them into beads.
    - Animal bone is normally not well preserved because of the acidity of South Carolina's soil. However, bone is plentiful at Pockoy because the calcium from the shell raises the soil's pH level, preserving the bone. Worked bone is frequently found at Pockoy and archaeologists have recovered numerous finely decorated bone pins.
- What archaeologists do not find at a site can also tell them a lot about the people that lived there. Very little stone has been found at Pockoy, telling archaeologists that the people that once lived there did not rely primarily on stone tools. Some archaeologists interpret this as evidence that the shell ring was not a site of general human occupation, but others propose that this is reflective of the environment; good stone is hard to find on the coast so people living there relied on tools made out of shell and bone.
- Due to Pockoy's location on the coast, the site is vulnerable to coastal erosion and rising sea levels. With a rate of 9.5 meters of coastline lost per year, Pockoy is expected to be completely engulfed by the ocean by 2024.
- Climate change, or "heritage at risk", poses a serious challenge to archaeologists, and Pockoy is not the only site facing destruction. According to a report by DINAA (The Digital Index of North American Archaeology), a one-meter rise in sea level would result in the loss of 13,583 archaeological sites across the Southeastern United States. It is imperative to salvage, protect, and study these vulnerable sites before they are gone.

Vocabulary

- **Anthropology:** The study of humans, past and present. In the United States, the study of Anthropology is divided into four subfields (Sociocultural Anthropology, Biological or Physical Anthropology, Archaeology, and Linguistic Anthropology).
- **Archaeological Site:** A place where human activity occurred and material remains were deposited.
- **Archaeologist:** An Anthropologist (social scientist) who studies the material remains of past human activity.
- **Archaeology:** The scientific study of past human cultures by analyzing the material remains (sites and artifacts) that people left behind.
- **Artifact:** Any object made, modified, or used by people.
- **Atlatl:** A device used to achieve greater leverage and velocity for throwing a spear or dart. Atlatls typically consist of a board with a hook at the end to hold the spear or dart in place until released.
- **Dart:** The object propelled by an atlatl that resembles a spear in size and shape but is much lighter in weight.
- **Experimental Archaeology:** A branch of archaeology that studies past technology by reproducing it or by recreating a type of site to study the processes of site formation.
- **Function:** The way in which something was used; its purpose.
- **Hafting:** Stone points were attached or hafted with cord or sinew to a shaft to make a spear.
- **Lever:** a type of simple machine. A rigid bar resting on a pivot, used to help move a heavy or firmly fixed load with one end when pressure is applied to the other.

- **Material Culture:** Items that people make and use.
- **Organic Material:** Bones, wood and leather are examples of organic material. These items typically do not survive in the archaeological record.
- **Prehistoric:** The period of time before written records. Dates vary in different geographical areas.
- **Projectile:** An object upon which the only force is gravity. Gravity acts to influence the vertical motion of a projectile, thus causing vertical acceleration. The horizontal motion of a projectile is the result of the tendency of an object in motion to remain in motion at constant velocity.
- **Projectile Point:** A general term for stone points that were hafted to darts, spears, or arrows.
- **Shell Ring:** Large circular or semi-circular structures made from piled shell. In the southeastern United States these structures date to the Late Archaic period (5,000 – 3,000 years ago) and are found along the coasts of South Carolina, Georgia, and Florida.
- **Simple Machine:** A mechanical device that changes the magnitude or direction of the force. There are six types of simple machines.

Lesson

** The physics behind the atlatl is beyond what a classroom studying elementary physics would normally cover. Instructors should amend this lesson plan as necessary and tailor it for their specific class. For instructors teaching advanced physics, the concepts in this lesson can easily be expanded to cover more complex concepts.*

1. Begin the lesson with a quick definition and discussion on simple machines. Ask your students if they can name the six basic types of simple machines (lever, wheel and axle, wedge, inclined plane, pulley, and screw). Tell your students that humans have used simple machines to make work easier for a long time, even as far back as the stone age. In prehistoric times, humans used natural materials, like wood, stone, bone, shell, and other materials to create tools that aided in everyday life.

2. Show your students the *Archaeo-Tech: Atlatl* video.

3. Discuss the video with your students. Ask your students what kind of simple machine an atlatl is (it is a lever, specifically a third-class lever).

4. Next, tell your students that they will be building and testing their own replica atlatls. Divide your class into groups (six to eight students per group) and distribute the atlatl supplies. Print off and distribute the building instructions for the atlatl design you decided to use for this activity or post the instructions on the board. You may also want to demonstrate to your students how to build an atlatl before they attempt building one for themselves.
    a. **Alternatively,** for younger grades and/or to save time, you can build the atlatls and darts yourself before starting the lesson.
    b. **Or,** if using a dog ball thrower for the activity instead of a replica atlatl, explain to your students how throwing a ball with the thrower is similar to throwing a dart with an atlatl.

5. Have your students create their atlatls and darts. Students may need to wear safety goggles and lab aprons, depending on the materials and construction methods used. Assist students in the construction process when necessary. Allow groups to personally decorate their atlatls and darts using markers or other art materials when finished (this will help

students quickly identify their darts when conducting the activity in the field). It is likely that this step will take the remaining class time.

If using ball throwers or if you created the atlatls and darts before the lesson, skip this step.

6. Create the test range for the atlatl activity. It is recommended to do this step before class. The range should be set up in a location where there is zero chance of injuring bystanders. Use orange safety cones to denote the range's baseline. Then, using a tape measure and pin flags, mark the range in meter intervals, up to 40 meters. Write the distance from the baseline on the pin flags. You can adjust the size of your range, interval between pin flags, or system of measurement, but it is important that your students can accurately measure the distances the darts (or tennis balls) are thrown.

7. In the classroom, distribute to each student a clip board with the activity handout. Have your students read the introduction and activity procedure before beginning the activity.

8. Distribute the activity materials. Have your students find the mass of their atlatl dart or tennis ball and record the information on their handout.

9. Take your class to the test range. Tell your students that they will first record the distances thrown by hand. Space the groups out and have each group form a single file line a safe distance from the baseline (the orange cones).
    a. When everyone is ready, have each group send the first person in line to the base line to throw their dart (or tennis ball) by hand. The second student in line will be the timer. The timer will watch the thrower and start the stopwatch as soon as the dart or ball leaves the thrower's hand and stop the watch as soon as the object hits the ground. The timer will give the thrower their time to record on their handout.
    b. When the range is safe, have the thrower measure and record the approximate distance thrown and collect the dart. The thrower will move to the back of the line and the second student (the timer) will become the new thrower. The third student in line will become the new timer. Cycle through this process until every member of the group has had a chance to throw the dart or ball by hand.
    c. Repeat this process two more times so everyone has had three freehand throws.

10. When everyone is finished collecting their data, instruct your students that they will repeat the same process but this time using an atlatl. Demonstrate to your students how to throw a dart using an atlatl and stress the importance of safety when using the atlatl. It is recommended to give everyone a practice round before recording any data.

11. Repeat Step 9 with the atlatl (or ball launcher). When everyone is finished throwing and recording, collect your materials and return to the classroom.

12. Back in the classroom, have your students find their individual and group averages for time and distance thrown for both tables. Compare the group averages for time and distance thrown by freehand to the group averages for time and distance thrown by atlatl. What is the difference between these averages? Which average is higher? Why? If students had a hard time throwing with the atlatl, stress that properly using an atlatl takes practice. Using their collected data and observations, have your students answer the "Questions & Calculations" section on their handout.

13. When students are finished with their calculations, discuss the "Questions for Discussion" on the handout together as a class. Have your students write their answers in the space provided on the handout.

14. For advanced physics classes, the activity can be expanded to discuss the motion of a two-dimensional projectile. Additional formulas, background information, and data will need to be provided by the teacher.

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Archaeo-Tech: Atlatl Activity Handout

Introduction

Before the bow and arrow, prehistoric hunters relied on a device called an **atlatl**, or spear-thrower. The atlatl was used throughout the world and varied in size, shape, and complexity. In North America, the atlatl was used for thousands of years until around 1,600 years ago, when it was replaced by the bow.

The atlatl works like a **lever** to magnify the user's throwing power. The atlatl is a stick that is held at one end with a hook (also called a spur) on the other end. The atlatl is used to propel a long, flexible **dart** with a hollowed out back end. The dart resembles a spear in shape and length but is lighter in weight. The dart lays on the atlatl with the back end of the dart fitted into the hook.

To throw, the user pinches the dart with their thumb and index finger, and wraps their middle, ring, and pinky fingers around the atlatl. Using a motion similar to casting a fishing rod, the user releases the dart at just the right moment, allowing the dart to rotate relative to the atlatl with the end of the dart still in contact with the hook. Through this point of contact, force generated by the thrower is transferred to the dart, resulting in a projectile that is more powerful, accurate, and can travel longer distances than a projectile thrown by hand.

Materials

Each should group have the following materials:

- Atlatl and Dart (or ChuckIt!© Ball Launcher and tennis balls)
- Clipboards
- Measuring Tape
- Stopwatch
- Pen or Pencil
- Calculator (for use in the classroom)
- Electronic Scale (for use in the classroom)

Procedure

1. Form a group for the lesson activity (six to eight students per group).
2. Gather your materials for the activity. Use the electronic scale to find the mass of your projectile.
3. After finding the object's mass, collect your activity materials, except for the calculator and electronic scale, and follow your instructor to the test range.
4. At the test range, stay in your group and form a line a safe distance from the baseline.
5. Using **Table 1** on page 3, record the time and distance thrown by hand. The first person in line will be the first to throw and the second person in line will be the timer. The timer will watch the thrower and start the stopwatch as soon as the dart or ball leaves the thrower's hand and stop the watch as soon as the object hits the ground. The timer will give the thrower their time to record on their handout.
6. When the range is safe (i.e. every group has thrown and the teacher has given approval to walk on the range), the thrower will measure and record the approximate distance thrown and collect the dart or ball. The thrower will move to the back of the line and the second student (the timer) will become the new thrower. The next student in line will become the new timer. Cycle through this process until every member of the group has had a chance to throw the dart or ball by hand.
7. Repeat this process two more times so everyone has had three freehand throws (three trials).
8. Now you will record the time and distance thrown with an atlatl (or ball launcher). Repeat steps 5-7 using the atlatl or ball launcher and record your data in **Table 2** on page 3.
9. When everyone is finished throwing and recording data, collect your materials and return to the classroom.
10. In the classroom, calculate your freehand individual and group averages for time and distance thrown. Then calculate your individual and group averages for time and distance thrown using the atlatl (or ball launcher). Compare these averages.
11. Use the data in Table 1 and Table 2 to answer the questions in the "Questions & Calculations" section of the handout. You can work together as a group to find your answers.
12. Using what you learned from the activity, answer the questions in the "Questions for Discussion" section of the handout. Discuss your answers as a class.

Archaeo-Tech: Atlatl Activity Handout

Group Number:

Mass of projectile (in kilograms): _____

Record your data in the following charts.

Table 1 - Thrown by Hand

	Time (seconds)	Distance (meters)
Trial 1		
Trial 2		
Trial 3		
Individual Average		
Group Average		

Table 2 - Thrown by Atlatl (or Ball Launcher)

	Time (seconds)	Distance (meters)
Trail 1		
Trial 2		
Trial 3		
Individual Average		
Group Average		

Questions & Calculations

1. Compare the individual averages in Table 1 to the individual averages in Table 2. Which averages are higher? Explain your results.

2. Compare the group averages in Table 1 to the group averages in Table 2. Are the results similar or different compared to the individual averages? Explain your results.

3. Look at both your group and individual averages. How does throwing a projectile with an atlatl effect time and distance traveled?

4. Using your group averages, calculate the freehand average velocity and the atlatl average velocity of your projectile. Remember the formula for average velocity is v = d/t. Which had a higher velocity?

5. Find the momentum of the object when thrown by freehand and when thrown by the atlatl. The formula for momentum is p = mv. Which had more momentum?

6. Now find the kinetic energy of the projectile when thrown by hand and when thrown by the atlatl. The formula for kinetic energy is $E_k = ½ mv^2$. Which had more kinetic energy?

7. An atlatl is a device used to launch a projectile. A projectile is defined as an object upon which the only force acting is gravity. How does Newton's Second Law of Motion relate to the trajectory of a projectile?

8. In the space below, draw a free body diagram representing the forces acting on the atlatl as it launches a projectile and draw a free body diagram representing the forces acting on the dart after launch.

9. Find acceleration, force, and work using the two group average velocities (if applicable).

10. Compare your results. What do these values tell us about throwing a projectile with an atlatl compared to throwing a projectile by hand?

Questions for Discussion

1. How easy or difficult did you find using the atlatl? Did throwing feel natural or do you think you needed more practice to adequately use the atlatl?

2. Why do you think the atlatl and dart was replaced by the bow and arrow in most parts of the world? What advantages does the bow have over the atlatl? What advantages does the atlatl have over the bow?

3. How would a heavier dart effect the atlatl's range? How would it effect the force of the dart's impact?

4. Archaeologists have found stone and bone weights that would have been attached to the center of the atlatl. What effect do you think these weights had on the user's throw?

5. Atlatls are wooden tools. Wood is an organic material, which decays over time. Except for a few special locations, like dry caves or bogs, atlatls are not well preserved in the archaeological record. What archaeologists usually find are stone projectile points. How do you think archaeologist distinguish between earlier points used for atlatl darts and later points used for arrowheads?

6. Experimental archaeologists, like Scott Jones from the *Archaeo-Tech: The Atlatl* video, specialize in recreating and testing technology from the past, like atlatls. Why is replicating and testing the material culture of the past important? What information does experimental archaeology yield that other forms of archaeology might not?