3.1.3 Purchasing or Otherwise Acquiring Bow Drill Sets

If you don't have the time or desire to make your own bow drill set, they are available for purchase from various sources. Prices are about $15 - $30 per set. Listed below are a few sources to get you started.

1. Ricardo Sierra at Hawk Circle Programs, PO Box 506, Cherry Valley, NY 13320, 607-264-3396, www.hawkcircle.com, ricardo@hawkcircle.com. This is where I received my first formal training in wilderness skills and I've returned periodically for various programs. I trust Ricardo to provide a good product for a reasonable price. He's also someone who would answer questions and provide advice.

The next two sources were found on the Internet, just to show that there are people supplying this product. I have had no dealings with the organizations listed below, so please exercise the same caution you would when purchasing anything from an unknown dealer on the Internet.

2. Granny's Country Store, Silver Star Montana
http://www.grannysstore.com/Wilderness_Survival/Bowdrill_Fire_Kit.htm

3. EBay has several bow drill sets for sale.

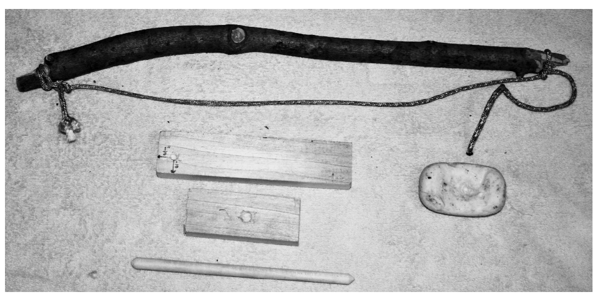
Lastly, there are probably organizations or individuals who would be happy to help you make bow drill sets for your classroom. Boy Scout troops, Girl Scout troops or other organizations may be interested in helping as a service project. Some students may agree to stay after school in exchange for extra credit or food. Sometimes parents may be interested in becoming involved. Of course, if you can spare the time in one of your classes, most students enjoy a craft project like this once in a while.

3.2 TECHNIQUE

This section describes in detail how to assemble and operate a bow drill. The instructions are for a right-handed person and assume you have all the components described in Section 3.1. The first set of instructions, 3.2.1, will introduce you to the posture and technique required to operate your bow drill. If you're using a beginner bow drill and will not be producing an ember, this is all you need. In either case, the process described in Section 3.2.1 is called "burning in". The fireboard and spindle are mated together so the fit is at its best before the notch is cut. Section 3.2.2 describes how to cut the notch and some additional tips for using your bow drill to make fire.

3.2.1 "Burning In"

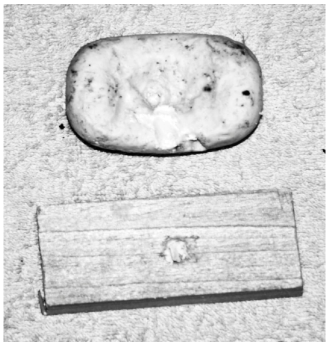
Gather all your bow drill components (bow, fireboard, handhold, spindle, and lubricant).



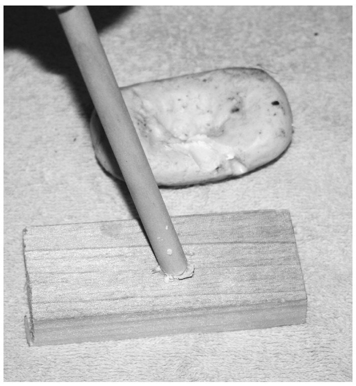
As you read the following instructions, keep in mind that maintaining proper form is key to success with the bow drill. Instructions are given for the right-handed person.

Place the fireboard on a level part of the ground or floor so that the hole you started is to your right.

Place some of your lubricant in the handhold.

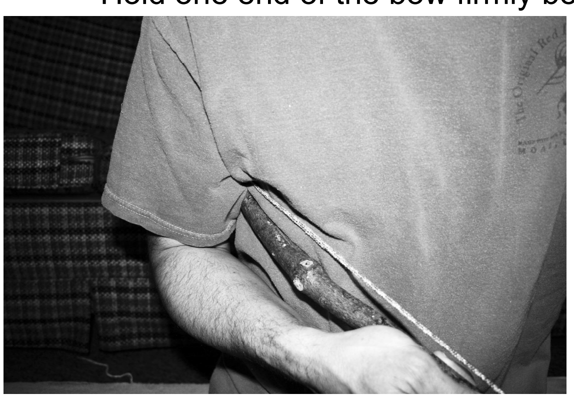


Place one end of the spindle into the handhold and twist to coat both surfaces with the lubricant.



<u>NOTE:</u> Whenever you use this bow drill, the end of the spindle you just lubricated must ALWAYS be in the handhold. DO NOT switch ends, i.e. use the end you just lubricated in the fireboard. This will reduce friction at the fireboard interface and make creating an ember difficult or impossible. The exception to this is if you need to avoid producing any smoke in the lab environment. You can then lubricate both ends. No dust will be produced, but students will be able to learn most of the techniques and concepts.

Hold one end of the bow firmly between your left arm and your body.

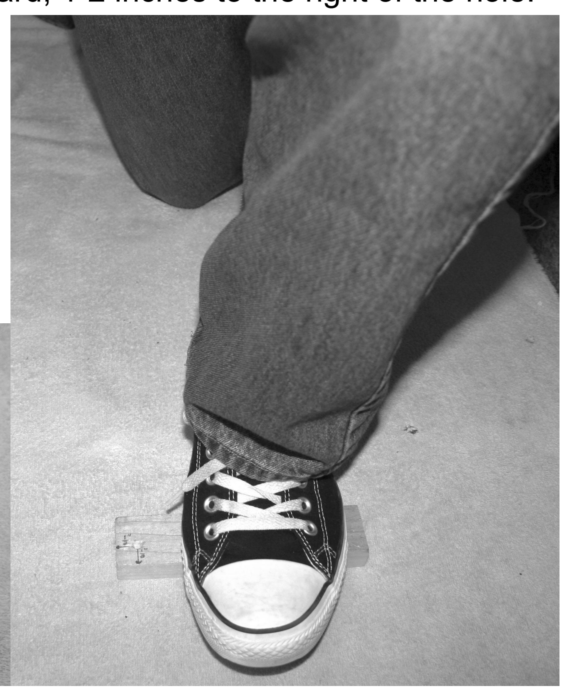


Twist the spindle onto outside of the bowstring with your right hand.



The spindle should feel like it wants to fly off. If it is too tight or too loose, adjust the bowstring accordingly. Hold the spindle and bow firmly in your right hand so the spindle does not fly off the bow.

Place your left foot on the fireboard, 1-2 inches to the right of the hole.

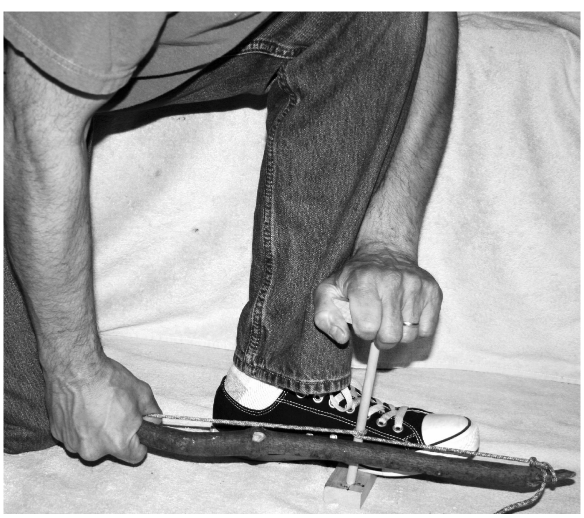



Kneel on your right knee.

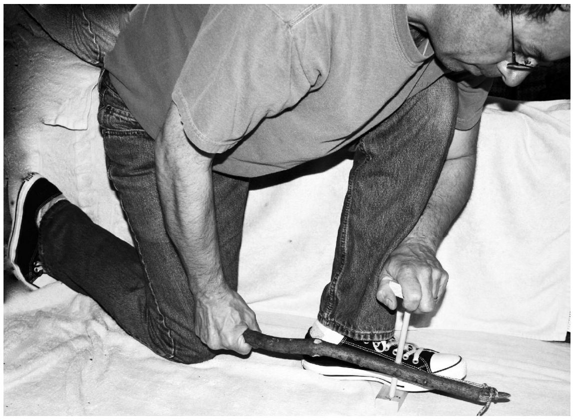
Place the proper end of the spindle into the hole in the fireboard.

At this point, you will still need to hold onto the spindle and bow with your right hand.

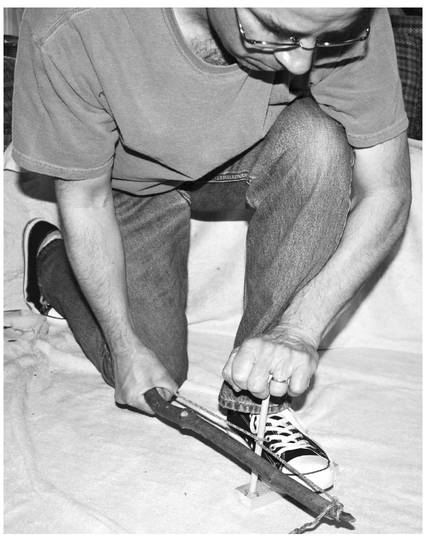
Grab your handhold with your left hand. Firmly brace your left forearm against your left shin.



Place the handhold onto the upper part of the spindle and apply moderate pressure. You should now be able to let go of the spindle and hold only the bow with your right arm.



Your left elbow should be to the outside of your left knee.



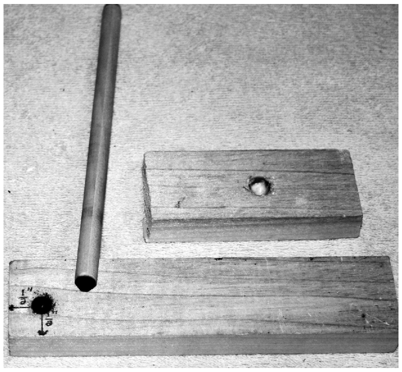
Check your alignment. The spindle should be perpendicular to the fireboard. Your right hand should be grasping the bow toward the back and the bow should be parallel to the ground. Your upper body should be bent at the waist so that your chest is near or touching your left knee. In addition to being the optimum alignment for operating the bow drill, this body position protects the apparatus from weather.

Once the apparatus is assembled and aligned, begin moving the bow back and forth while maintaining downward pressure with your left hand. Keep the bow level with the ground and use the whole bow, front to back. Avoid rapid back and forth movements over just a short portion of the bowstring.

Your first goal is to be able to maintain this motion for one minute without the spindle coming out of the apparatus. This is an art and requires attention to detail. Keep the left lower leg straight with the shin and lower left arm pushing gently against one another. This stabilizes the spindle vertically. Meanwhile, adjust the pressure exerted on the handhold and note the changes in how the apparatus operates. All the while, practice long, smooth strokes with the bow.

Learning this technique takes some patience. If the spindle falls out easily, you probably need to make the holes in the handhold and fireboard deeper. Also, if your bow stroke is not level, the bowstring will move up and down and can come off the spindle.

Once you've "gotten the hang" of the technique, you should notice the hole in the fireboard getting deeper and rounder.

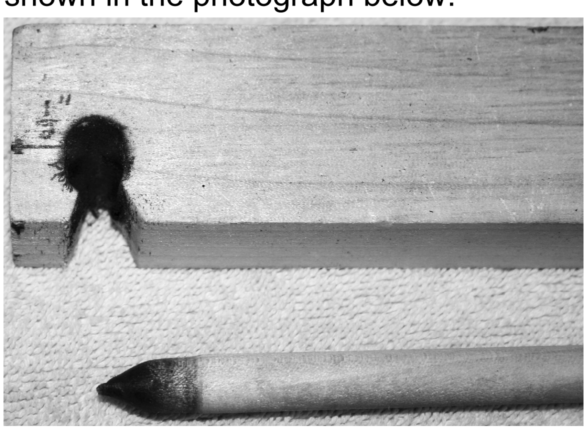


If you've applied sufficient downward force and rapid enough bow strokes, you may even see smoke. Once a good, round impression matching the spindle is formed, the fireboard is considered "burned in".

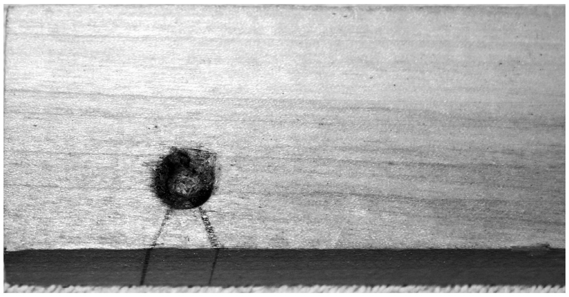
Congratulations! You now can use your skill with the bow drill in your classroom! Read and modify the labs based on your skill level, environmental constraints (is it ok to produce some smoke or not etc.), and goals. The first time you try this in a classroom, you may want to do a simplified version of the lab, "Introduction to Bow Drill Fire Making". If you wish to continue your training to the point where you can use the bow drill to make a fire, go on to Section 3.2.2 "Producing an Ember".

3.2.2 Producing an Ember

While practicing the technique described in the previous section, you probably noticed a fine brown or black dust produced. This dust, when properly collected, compressed and heated, produces an ember. The key to this process is cutting a notch, as shown in the photograph below.



Once the fireboard is burned in, mark a triangle on your fireboard from the edge until just before the center of the hole.



It should be about 1/5 to 1/8 of a circle and must be cut through the entire thickness of the fireboard. If the notch is too big, the spindle will “pop put” of the fireboard when the bow is moved forward. If the notch is too small, too little dust will gather to create an ember. A knife or small saw is needed for this.

It is important that the sides of the notch are smooth.

The dust created by the friction between the spindle and fireboard collects here, is compressed and heated. If the notch is not cleanly cut, the ember will have wood fibers from the walls of the notch embedded in it. When you attempt to remove the ember to place it into the tinder bundle, these fibers will pull out and break the ember apart.

You’re now ready to make fire! Gather your tinder bundle (described in Section 3.1 and in the teachers’ edition of the lab, “The Science of Bow Drill Fire Making: Physical Science) along with a small piece of bark, cardboard, paper etc. that will act as a “coalcatcher” (the word “coal” is more typically used among bow drill aficionados than “ember”). Before beginning, work your tinder bundle into the shape of a bird’s nest. The ember will be placed in the central depression and the tinder fed to it by pushing from the outside with your fingers.

Examine your work surface. If it is moist, place a piece of dry bark or similar substance on the ground to create a dry work area. Place the coalcatcher under the notch in the fireboard. Assemble the bow drill as you did during the “burn-in”. Begin moving the bow with long steady strokes, pushing on the handhold with light pressure. Gradually increase the pressure and speed. This motion heats up the fireboard and drives off moisture in the wood. Smoke should start rising along with the formation of a dark powder in the notch. Increase pressure and speed more. The board should smoke even more and dust should pour into the notch. As you continue, the notch will fill and the dust will pour out of the notch. The dust in the notch is being compressed and heated. You should notice a steady thin stream of smoke rising from the dust in the notch. At this point, take ten more strokes then stop.

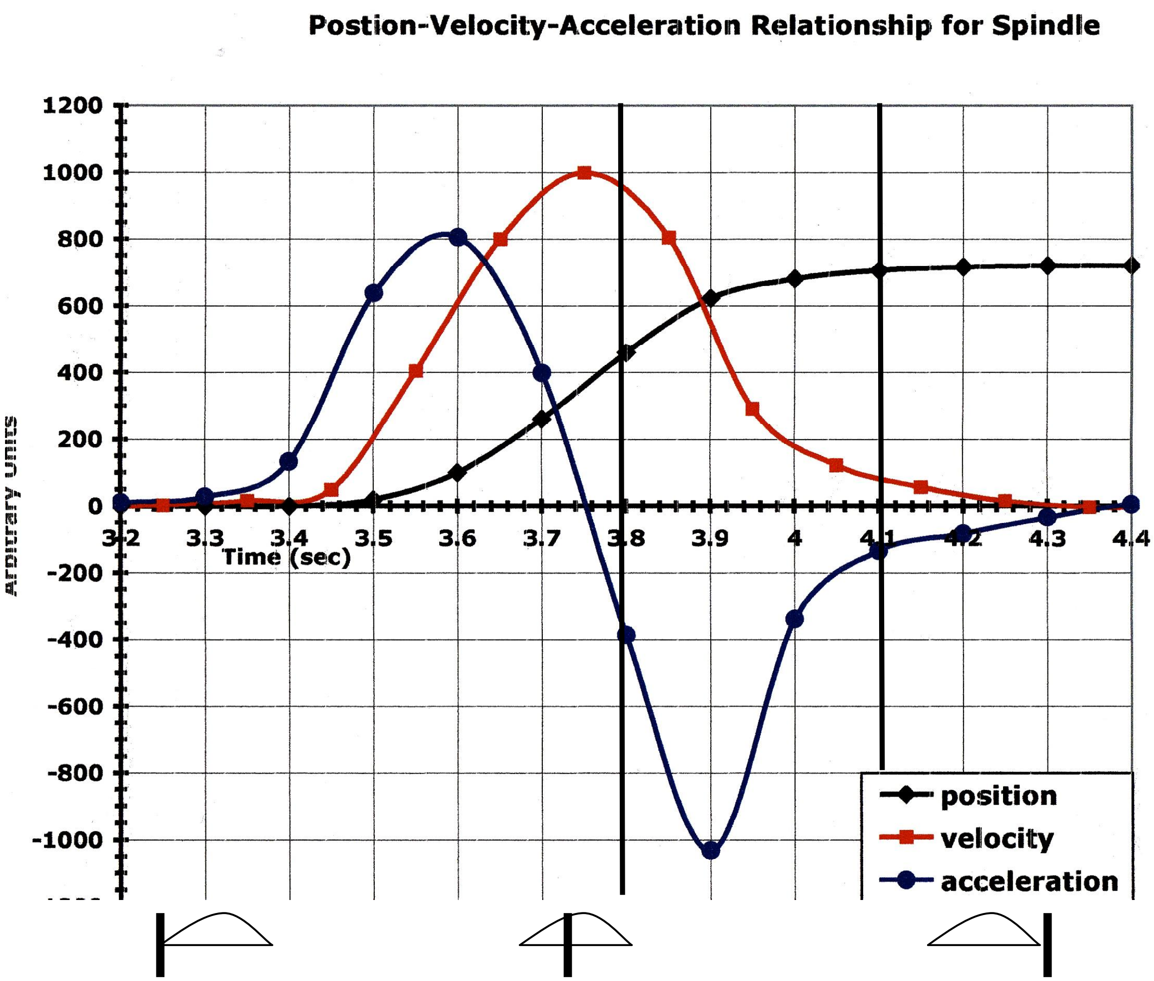
A thin wisp of smoke should continue to rise from the notch, confirming that an ember has formed and is burning. CAREFULLY lift the spindle from the fireboard. Work very carefully and gently. You can GENTLY blow on the ember to encourage its growth. You do not need to rush – the ember will burn for a few minutes without more fuel.

GENTLY lift the fireboard while placing a stick or knife tip on the top of the ember. The goal is to have the ember standing alone on the coalcatcher. You can gently blow on the ember during this process to encourage its growth. Gently transfer the ember from the coalcatcher into the central depression of your tinder bundle.

With the ember in the tinder bundle, gently blow onto the ember. You are trying to get the material around the ember to glow, effectively increasing the size of the ember. This is an art and depends on the material the tinder bundle is made of in addition to its moisture content. Use pressure from your fingers to adjust how densely the tinder fibers are packed. The fibers need to be rather closely packed, yet have enough room for air to circulate. The ember should expand and the amount of smoke should dramatically increase. Increase the airflow and adjust the tinder around the ember as seems appropriate. (Since one’s fingers can get very hot during this process, some people like to wrap a thin, flexible piece of bark around the tinder bundle. This provides the fingers with some insulation from the heat.) At some point, the bundle will burst into flames. If in a classroom you can throw the burning bundle into the fume hood or a sink. Outdoors, be sure to completely stomp the fire out. In an outdoor situation, a teepee fire would already be set up. When the tinder bundle bursts into flames, it is placed into the teepee to ignite the tinder and wood there.

4 Velocity Profile

To the measure the actual change of the spindle's position, velocity and acceleration, a rotational motion sensor was attached to the spindle of a bow drill set. The figure below illustrates the position, velocity and acceleration profile for the spindle (and also for the bow as they are related by a constant) during a single bowstroke. The three diagrams on the bottom illustrate the relative position of the spindle on the bow at the beginning, middle and end of a bowstroke.



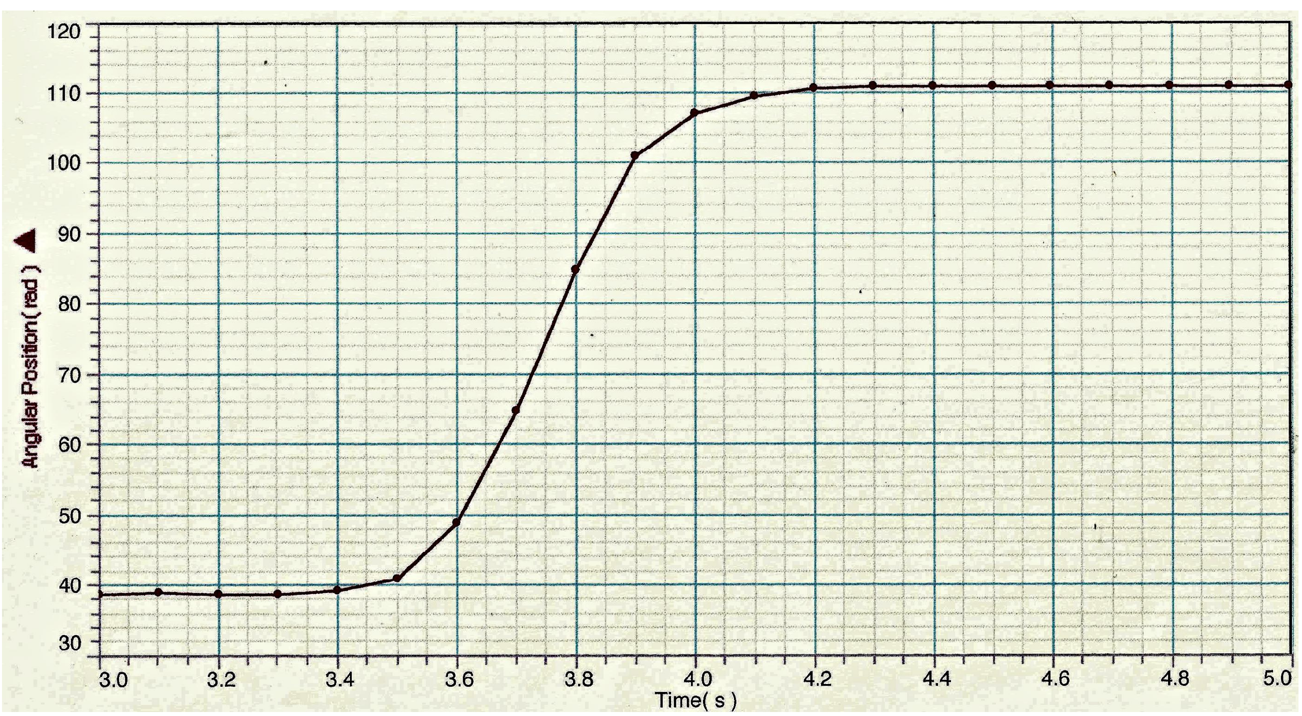
Time, which is proportional to the location of the spindle on the bow, is labeled on the x-axis. The y-axis provides a relative measure of the magnitude of position, velocity and acceleration of the spindle as it is rotated by the bow.

First examine the position curve, marked in black ovals. The position of the spindle changes little from 3.3 to 3.5 seconds. At 3.5s, the slope increases and becomes a maximum around 3.75s. The slope remains constant until 3.85s when it begins to decrease. By 4.3s, the position of the spindle is barely changing.

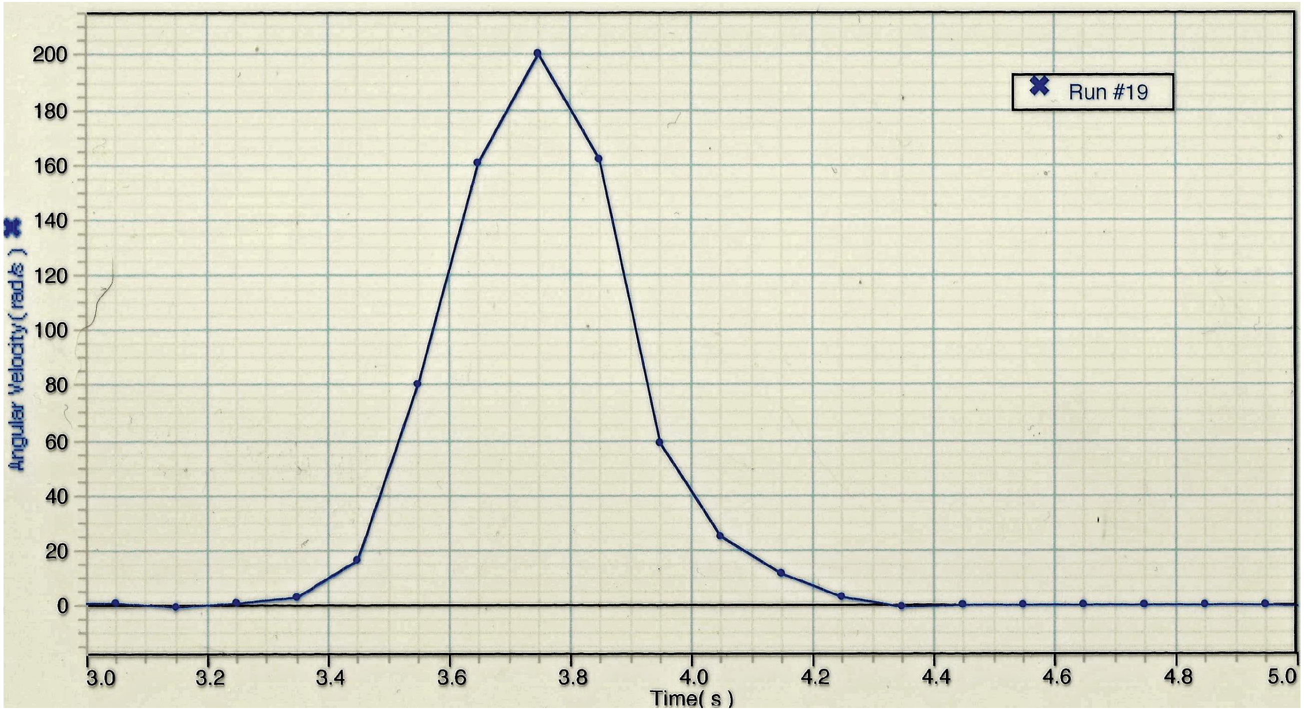
The velocity profile is shown in red squares. Note that the velocity is increasing as long as the slope of the position curve is increasing. When the slope of the profile curve reaches its maximum at 3.75s, the velocity curve is at its peak. As the slope of the position curve deceases, the velocity curve shows a negative slope. This graphically shows the relationship between the position versus time curve and its first derivative, velocity versus time. Note also that the velocity curve has the same shape as that deduced in the bow drill lab, THE SCIENCE OF BOW DRILL FIRE-MAKING: PHYSICAL SCIENCE.

The acceleration behavior of the spindle is shown by the blue circles in the diagram. The acceleration curve reaches a maximum where the velocity curve has its maximum slope, about 3.8s. As the spindle approaches the middle of its travel on the bow, the spindle continues to accelerate, but at a decreasing rate. At 3.75s, the spindle reaches its maximum velocity, then begins to slow. The acceleration crosses 0 at this point, corresponding to the change from acceleration to deceleration. As the spindle is now slowing, the velocity is decreasing and positive, but the acceleration is negative.

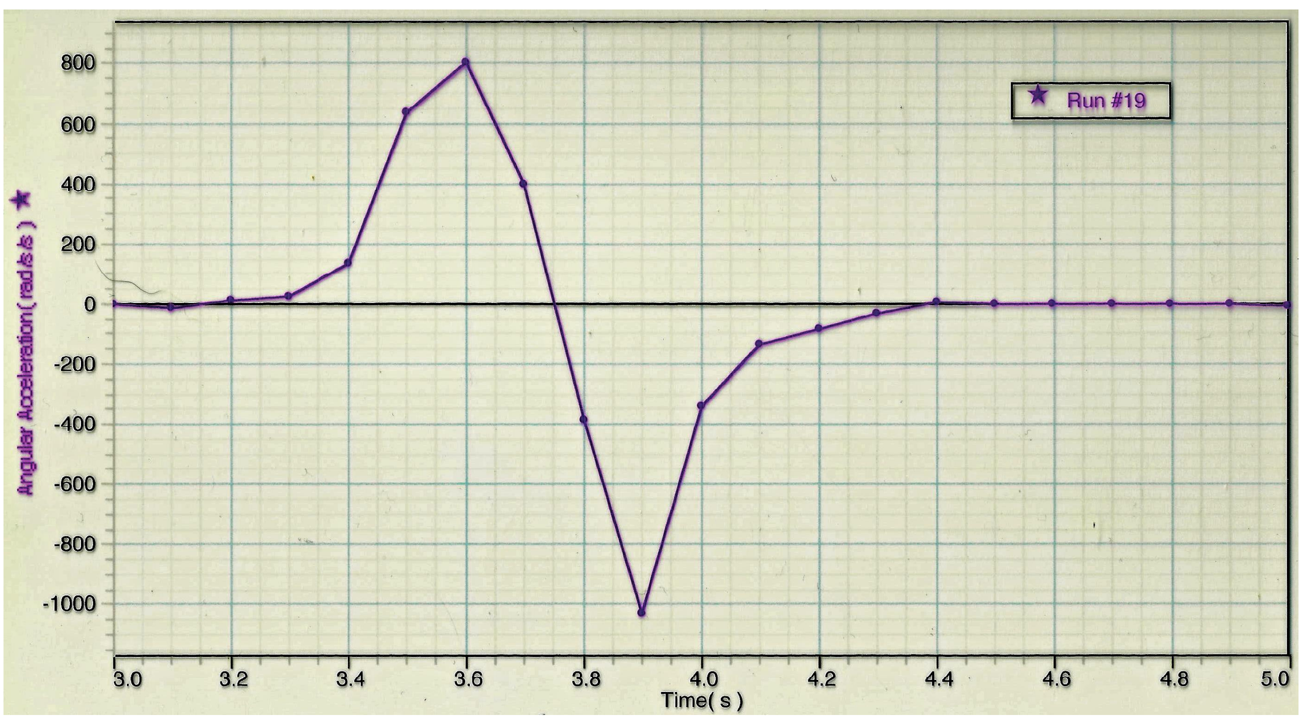
Below are the three individual graphs of raw data from which the graph above was created.



Graph showing the change in position of the spindle with time, during a single bowstroke.



Graph showing the change in velocity of the spindle with time, during a single bowstroke.



Graph showing the change in acceleration of the spindle with time, during a single bowstroke.

5 Glossary

Acceleration- In general, the change in velocity divided by time. Instantaneous acceleration is the change in velocity at any instant in time.

Atom- The smallest identifiable part of an element

ATP- Chemical compound that stores energy in cells in a readily usable form.

Average speed- Total distance traveled divided by the time it took to travel that distance

Bow- Device used to transform linear motion into rotational motion. Allows spindle to be rotated much faster than could be done by hand

Cattail down- Fluffy white material that makes up the brown cigar shape portion of the top of the cattail plant. When dry, this material can be added to a tinder bundle to help enlarge the ember.

Chemical bonds- Any rearrangement of electrons in two atoms that generates a force, causing the atoms to be bound to each other, forming a molecule.

Circumference- distance around a circle

Coal- a piece of glowing, charred, or burned wood or other combustible substance. Another name for an ember.

Coalcatcher- Any thin, relatively stiff material that can be placed under the fireboard to "catch" the ember (or coal) when it is pushed out of the notch. The coalcatcher is used to transfer the ember to the tinder bundle.

Coefficient of friction- Measurement of the roughness between two surfaces. Used to calculate the frictional force.

Combustion- The act or process of burning.

Compound- Two or more elements, chemically combined in definite proportions. **Conifer (coniferous tree)-** Trees that produce their seeds in cones and have needle shaped leaves.

Deceleration- Negative acceleration or slowing down.

Density- A measurement of the amount of mass contained in a particular volume of a substance; mass divided by volume.

Deciduous- Trees that lose their leaves every year. Usually, but not always, broad leaf trees.

Diameter- Distance across a circle, through the center

Dowel- A round piece of wood, usually long compared to its diameter.

Dust- Fine material created by abrasion between the surfaces of the fireboard and spindle, collecting in the notch to form an ember. Also called "char".

Ember- A small piece of burning wood. Also called a "coal".

Endothermic- A chemical reaction in which heat is absorbed.

Energy- the capacity to do work

Exothermic- A chemical reaction that releases heat.

Fireboard- Portion of the bow drill apparatus into which a spindle is inserted and spun. The notch cut into the fireboard collects, compresses and heats the dust created to form an ember.

Force- Any influence that tends to accelerate and object.

Friction- Force that opposes motion between two surfaces in contact.

Handhold- Part of the bow drill apparatus used to keep the spindle upright and apply a normal force to the spindle-fireboard interface.

Heat- The energy of the motion of the molecules making up a substance. Energy transferred from a higher to a lower temperature object.

Hydrocarbon- A class of compounds containing hydrogen and carbon, typically useful as fuels.

Inference- A conclusion reached by evidence and reasoning. (As opposed to an observation, which is a statement of fact, without reasoning or drawing conclusions)

Instantaneous speed- Speed of an object at a given moment

Interface- A common boundary or interconnection between components of a system. (For example, the spindle-fireboard interface in the bow drill.)

Inversely- In science and math, when one variable increases, the other decreases. On a typical graph, this relationship is a line from the upper right to lower left. (negative slope)

Jute twine- Cord made from long, soft, shiny vegetable fiber sold for gardening but useful for tinder.

Linear velocity- Velocity in a straight-line motion

Lubricant- A substance that smooths surfaces in contact, reducing the friction between them.

Mass- The amount of matter making up an object

Maximum- The greatest quantity or amount possible. The largest y value on a graph.

Minimum- The least quantity or amount possible. The smallest y value on a graph.

Molecule- A group of atoms bonded together. The smallest physical unit of a compound

Normal force- Force perpendicular to two surfaces in contact. Used to calculate the frictional force.

Notch- V-shaped cut in the fireboard to catch, compress and heat the dust to produce an ember.

Observation- Recording a fact or occurrence.

Photosynthesis- The synthesis by plants of organic compounds from carbon dioxide and water (with the release of oxygen) using light energy absorbed by chlorophyll.

Pressure- Force divided by the area over which it is exerted.

Qualitative- A descriptive observation.

Quantitative- An observation that can by noted numerically; answers questions like "How much?" or "How many?"

Radius- distance from the center of a circle to the outside

Reaction- Action in response to some influence

Respiration- The process in living organisms of taking in oxygen from the surroundings and giving out carbon dioxide in order to release energy for life processes.

Rotational velocity- Number of times an object rotates during a certain period of time

Scalar- Quantity that has magnitude but no direction, i.e. speed

Simple machine- A basic device for altering the magnitude or direction of a force.

Spindle- A round piece of wood that is inserted into, and spins in the fireboard of a bow drill.

Theory- A system of rules or ideas to explain something.

Tinder- Very thin, dry material that catches fire easily

Vector- A quantity that has both magnitude and direction, i.e. Velocity

Volume- The amount of space an object occupies

Work- The product of the force applied to an object and the distance the object is moved.

6 References

Brown, Tom, and Brandt Morgan. *Tom Brown's Field Guide to Wilderness Survival*. New York, NY: The Berkley Publishing Group, 1983. 59-78.

Frank, David V, John G Little, and Steve Miller. *Science Explorer: Chemical Building Blocks*. Upper Saddle River, New Jersey: Prentice Hall, 2000.

Hewitt, Paul. *Conceptual Physics*. Boston: Pearson Prentice Hall, 2006.

Hewitt, Paul. *Touch this! Conceptual Physics for Everyone*. San Francisco: Addison Wesley, 2002.

Holtzclaw, Fred, Linda Cronin Jones, and Steve Miller. *Science Explorer: Environmental Science*. Upper Saddle River, New Jersey: Prentice Hall, 2000.

Moc, Peter. "Basic Bow-Drill." Wildwood Survival. Walter Muma, 17Mar2011. http://www.wildwoodsurvival.com/survival/fire/bowdrill/pmoc/basicbowdrill.html

Muma, Walter. "Bowdrill: Introduction." Wildwood Survival. Walter Muma, 17Mar2011. http://www.wildwoodsurvival.com/survival/fire/bowdrill/index.html.

Sierra, Ricardo, Hawk Circle Wilderness Education Earth Mentoring Institute P.O. Box 506, 3496 State Highway 166 Cherry Valley, NY 13320 (607)264-3396 (Main Office) (607)264-3256 (Fax), HawkCircleOffice@gmail.com (Main Office) Ricardo.J.Sierra@gmail.com (Director), http://www.hawkcircle.com

Watts, Steven M. *Practicing Primitive: A Handbook of Aboriginal Skills*, Gibbs Smith, Layton, Utah, 2004

7 Appendix

7.1 Alternative Introductions and Folklore

7.1.1 Lost in the Woods: "The Law of Threes"

Imagine you are at a picnic with friends in the middle of a big beautiful park. The weather is sunny and in the mid 60's. It's just after lunch and everyone is just sitting around but you want to go for a walk. You head out on one of the many trails that lead from the picnic area into the forest surrounding it. You've been walking for a while when you realize the sky is getting dark and the wind is picking up. You decide you should turn around and go back. As you walk back down the path, the trail looks different because of the darkening sky. The air is getting noticeable cooler. The wind is picking up and its direction seems to be shifting. (A cold front is passing through.)

Soon you come to a place where the path splits. The problem is that you didn't notice this junction on your way in. You're getting nervous as you realize you're not sure of the way back. You need to make a choice: left, right or stay put and wait for someone to come looking for you. The wind is getting stronger and colder. The sky is darkening and a few drops of rain land on your head.

You decide to make a run for it and choose the path to the left. Unfortunately, that path leads deeper into the woods and not the picnic area. Nothing looks familiar and before long you are gripped by that panicky feeling of being lost. You fight off the urge to continue running blindly. You sit down and pull your cotton hoody tight around you.

You admit to yourself that you are lost and need to make a plan.

You are lost in the woods with only the clothes you're wearing: jeans, t-shirt, hoody and sneakers. A good plan recognizes the risks you face, ranks the risks according to their real danger to you and has options for dealing with the most severe risks. In the spaces below list 5 dangers to life or safety that a person faces when lost in the woods. Write them in order of severity with number 1 the greatest risk to your life.

1

2

3

4

5

TEACHER NOTES

At this point, ask for volunteers to share their list with the class. You can even make a list on the board and tally everyone's responses to come up with a class list, if you wish to spend the time. After you have a feel for the class's response, it's time to introduce the law of 3's.

The first and greatest risk when lost is hypothermia. A person can succumb in as little as 3 hours even in relatively mild temperatures if their clothes are wet. Death by dehydration takes about 3 days though weakness, headaches and chills will make you pretty uncomfortable long before that. Students are often concerned with starvation, but on average it takes about 3 weeks to starve. You will be ill and weak well before that but when first lost, starvation is not a real concern.

This is known as the "Law of Threes". It's an easy way to keep the relative threat of these issues in mind.

Hypothermia – 3 hours, Dehydration – 3 days, Starvation – 3 weeks

Therefore, the first priority is shelter. Natural shelters such as under trees or rock overhangs or constructing a simple shelter from natural materials is one option. Clothing is your first shelter. Stuffing clothes with leaves increases their dead air space like a down jacket. Avoid getting wet as this draws heat from the body more quickly. This is especially true of cotton fabrics.

In the survival scenario presented here, finding shelter is the clear priority. The person is relatively close to civilization and others will soon realize he/she is missing. A more remote location with the possibility of being lost for an extended time requires assessing more variables. For example, safe drinking water requires some form of filtration or treatment. This is all difficult without a container. Water filtration and treatment is an entire are of study in itself. But, if there is no sign of rescue after 1-2 days, it may be best to drink water even if it is not treated as the risk of dehydration begins to outweigh the risk of the water.

Also, if a person is allergic to bee stings, this needs to be at the top of the threat list. Moving carefully to avoid injury is important, as simple injuries

can be life threatening in a survival situation. Awareness of the area is helpful. Are there venomous snakes or insects in the area and where do they reside? Are there poisonous plants? Settling down in a patch of poison ivy would be very unpleasant and potentially life threatening.

Students often list animal attack as a major threat in the wild. In our area, this is very rare compared to the other risks. This can lead to a discussion of animal behaviors etc.

Fire can be a helpful element to all aspects of survival. It lends heat to stave off hypothermia, can purify drinking water and cook food. In addition fire provides light and is a huge psychological advantage for someone alone in the wilderness. Animals are less likely to come around and searchers can see the smoke.

Following are some statistics concerning the survival of lost people.

Of the 398 lost people Tom Brown (wilderness survival and tracking expert) tracked up to the year 2000, 200 were found alive. Most of the children survived, presumably because they were more closely in touch with their natural instincts and they are used to adults coming to their aid. They tended to find a sheltered area and stay there. Of the 198 people Tom found dead, 194 died of exposure. Many of these had stopped at good shelter locations but continued on and subsequently perished. Three drank contaminated water and one ate a poison mushroom. The clear message in most situations is to find a safe, sheltered area and wait for help.

Also of interest: A poll of 6th graders in California taken around the year 2000 found that 1 out of 20 had been lost for more than 3 hours at some point in their life.

7.1.2 The Elephant and the Blind Men

(A traditional folktale from several Asian countries)

Once upon a time, a prince and his son were riding to town on an elephant. Along the way the son, being a rather deep thinking lad asked, “Father, what is reality?” The prince was stunned by the enormity of the question and his mind raced for words to explain his rather meager understanding of this question. As he looked up, the prince saw that they were about to pass a group of blind men begging on the roadside. An idea came into his quiet, confused mind. The prince stopped the elephant in front of the beggars and had them stand around the elephant, in different places. He did not tell them there was an elephant before them and gave his son strict instructions to say nothing. The prince then instructed the blind men to step forward, touch the object in front of them and try to guess what it was. The result was exactly as the prince had hoped. The blind man touching the elephant’s leg described it as a column that must be supporting a structure while the man at the elephant’s rear had the tail and insisted that the object was a rope. Another man, touching the elephant’s massive side believed that they were in front of a wall. The blind man touching the elephant’s tusk insisted they were in the presence of a fine sculpture while next to him yet another man, holding the elephant’s trunk declared the object to be some sort of large tube. As they made their observations and shouted their conclusions, the men became rather annoyed with one another. Each felt he understood the object in front of him and the others were fools. In the midst of this scene the prince hopped back on the elephant with his son and continued their journey. After allowing his son a few moments of stunned silence, the prince said, “You see, my son, Reality is an elephant and we are all blind men.”