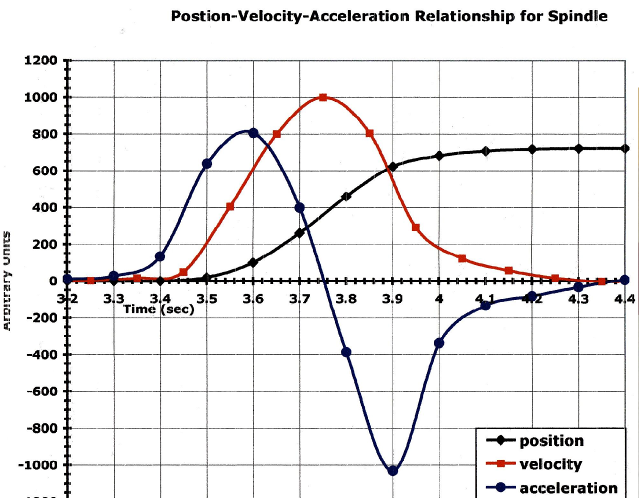
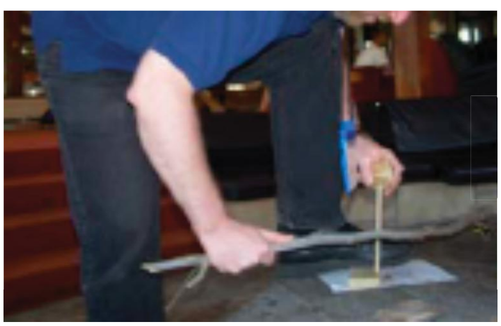
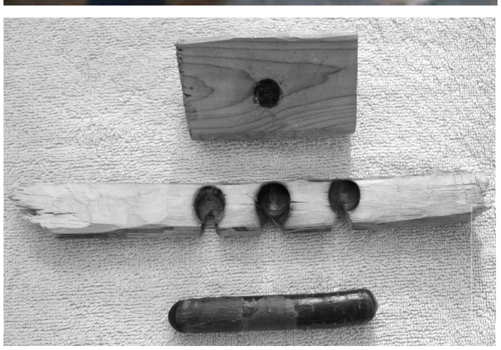
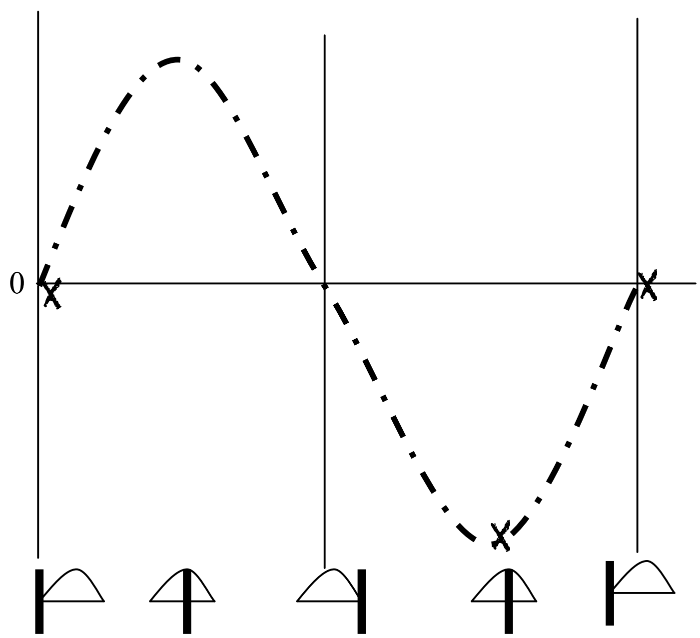
Teaching Science Through Primitive Fire Making Technology: A Lab Manual and Primer

Tony Carbone









This manual contains information about scientific concepts, primitive technologies, educational strategies and folklore that are accurate to the best of the author's knowledge and experience.

The author has also attempted to describe any foreseeable hazard that may arise as the result of activities described in this book. Hundreds of people, from young children to senior citizens have participated in these activities with no ill effects. This however is no guarantee and any individual performing activities described in this manual or leading others in such activities must provide a safe work area and be vigilant during activities to prevent situations that cause injury, especially if tools or sharp implements are in use. If using tools or knives always begin with a review of safe use. In the hundreds of times the author has made and used primitive fire making tools, the only time he sustained an injury occurred in the early morning hours while making last minute preparations for a morning workshop. For a brief moment the "never cut towards yourself" rule was ignored in the interest of saving time. This led to a trip to the emergency room for stitches (including a bit of tendon repair). Misuse of tools and techniques or a lack of vigilance and safe practice can cause serious injury for which the author disclaims any liability.

Comments and questions welcomed by the author at tonyc@nycap.rr.com. Please include the book title on the subject line.

Acknowledgements

Thanks to Dr. Bruce Tulloch of Union Graduate College for his patience, guidance and support as we transformed a collection of documents, data and ideas into this manual. Thanks to Dr. Michael Tucker and the faculty and students of the Charlton School for supporting the incubation and development of this work. Most important of all is the constant love and support of my family, especially my loving wife and daughters. Without a positive, nurturing atmosphere at home, nothing of substance can be accomplished. My heartfelt thanks to the many teachers and mentors (including Tom Brown, Jon Young, Riccardo Sierra and Mark Elbroch) who have shared their love of the natural world with me and so many others. Lastly, thanks to fire, stones, trees, water, animals and all the other entities of the natural world. During quiet moments, they have provided the most insightful lessons of all.

There is no freedom that compares
To the ability to walk into the wilderness
With nothing
And return a year later
Healthier, stronger, happier and wiser
Having suffered no true deprivation
But having had all your needs provided for
By a combination of Earth’s gifts
And your knowledge of how to use them.
This is freedom.
This is our birthright.

Source unknown

Sunlight is at the heart of it all.
Sunlight is love. Love is a sacrifice,
especially when given to those who do
not understand…

Joseph Bruchac

It my be that some little root of the
sacred tree still lives. Nourish it then, that it may
leaf and bloom and fill with singing birds.

Black Elk

Foreword

On the morning of August 30, 1996 I started my first fire by friction using a bow drill I carved myself. As a participant at one of my later workshops put it, "I felt like a cave man!" The feeling that comes from the experience is very deep, joyful and primal. The experience was compounded as I had been working for 5 days for this fire. My wife, twin daughters and I spent that last week before school at Hawk Circle, an outdoor skills camp in Cherry Valley, New York. The week was a combination of adult skills classes, kids activities and activities that brought everyone together. The adults had been taught the bow drill technique Monday morning. In between the various other classes and activities, I spent several hours a day working for that fire and failing in so many ways. Little did I know that was part of the plan. The instructors let me try things that didn't work so I could make as many mistakes and learn as much as possible while I had support. As with other things in life, all success teaches you is that what you did worked. Failure requires you to think about all the possible causes, prioritize them and formulate a strategy. By the time I left, though still a very green neophyte, I acquired enough skill to teach myself.

Beyond the shear excitement of "rubbing two sticks together" and making a fire, I saw vast potential in this technique as a teaching tool on many levels. I began to teach the technique as a "lab" at the school where I work and also at my children's elementary schools. Everyone always wants to handle the apparatus and guess what it's for. Breaking classes into groups provided an opportunity to explore group dynamics and teambuilding. With my 8th, 9th and 10th graders, I used the bow drill to introduce a variety of science concepts in addition to measurement and math skills.

For the last 15 years I've worked to refine the bow drill as a teaching tool. I've presented my methods and results at the Science Teachers Association of New York State (STANYS) and New York State Outdoor Educators Association (NYSOEA) conferences several times. What follows is a distillation of my experience and feedback from my students and colleagues. While it took me a week to get my first fire and weeks to come up with my first "lab", I believe the reader needs to invest much less time to add this technique to their collection of classroom activities. To begin, all you need is one bow drill set and about a half hour. In that time you can learn the mechanics well enough to use the labs. You won't yet have the skill to make a fire, but as a teacher you don't need it. If you choose to practice more, you can acquire whatever skill level you desire.

My most important reason for adding this to my teaching repertoire is that I can fulfill some of my curricular responsibilities while increasing student awareness of, and connection to the natural environment. No one can look at a tree the same after they've seen fire made from its branches or cordage from its bark. So, look through the following pages and consider adding bow drill fire-making to your skill set. Everything you need to get started from scratch is described here.

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1 Introduction

1.1 WHAT'S IN THIS BOOK?

This manual is divided into seven Chapters, which are outlined below.

Chapter 1: Introduction

Introductory remarks and instructions for using this manual.

Chapter 2: Laboratories

Copy-ready versions of classroom-tested labs are presented in three sections. Each section begins with suggested approaches to the lab along with safety tips and ideas for extensions. Following this is an annotated teachers' edition (TE) of the lab. The annotations and answers to lab exercises are in red italics. The student edition of the lab is the third part of each section.

Keep in mind that these labs are summaries of exercises I've used with students. I modify them every time to suit the students' abilities and attitudes, time constraints and concepts I'm trying to address. Please do the same.

Section 2.1 (Chapter 2, Section 1) introduces (or reviews) the concepts of observation and inference and uses sketching as an aid to memory and focus. This lab can also be used as an introduction to the bow drill technique and followed up at a later date with one of the labs that requires more analysis from the students. No significant prior science knowledge is required of students.

Section 2.2 seeks to highlight and explore some of the physics concepts at work while using a bow drill apparatus such as velocity, acceleration and friction. After the introduction and teachers' edition of the lab, two student versions are provided. One is written for the case where the teacher will be using the bow drill technique as a demonstration only. The other lab is written for the teacher who, after a brief demonstration, breaks the students into groups to try the technique himself or herself.

Section 2.3 uses the bow drill to explore energy and ecological relationships in Biology.

Chapter 3: Acquiring and Using a Bow Drill Set

Section 3.1: This section includes instructions for acquiring or building your own bow drill sets for personal or classroom use. The time and energy required depends on your ultimate goals and your classroom plan. For example, making a set capable of starting a fire requires more time and energy than a set that simply demonstrates the technique. Also, if you're planning to do the lab as a demonstration, you only need one set. If you plan to break your students into groups, you'll obviously need one set per group.

Section 3.2: A very brief description of the technique of operating a bow drill is given in each lab. This section expands on this, providing more detail and a few hints to minimize your learning time.

Chapter 4: Velocity Profile

A rotational motion sensor was attached to the spindle of a bow drill set. The resulting displacement, velocity and acceleration profiles are presented and discussed.

Chapter 5: Glossary

Definitions of bow drill terms and science terms used in this manual.

Chapter 6: References

Chapter 7: Appendix

2 Laboratories

2.1 INTRODUCTION TO BOW DRILL FIRE MAKING

2.1.1 TEACHING TIPS

Suggested Approach

The lab titled “Introduction to Bow Drill Fire Making” uses this fire by friction technique to introduce basic science concepts like observation and inference. The lab can easily be completed in a 45-minute period. It is designed to be interactive between the instructor and the students. A very brief introduction is followed by a sketching exercise to keep the students engaged and sharpen their observation skills.

As written, the fire making technique is demonstrated by the teacher and observed by the students. Actually demonstrating the technique can take as little as 5-10 minutes. If time is available, the teacher can provide the students with an opportunity to try the technique. This can be done in several ways with different levels of structure built into the activity. In one case, the students are divided into lab groups with each group receiving its own bow drill set. Each student in the group is given an opportunity to try the bow drill individually while the other group members offer suggestions to maintain proper form. This approach has the students emulate the technique demonstrated by the teacher, but a less structured alterative is often used. Instead of one student operating the bow drill with the others watching and supporting, the students are told that as many members of the group as possible (or the entire group) are to be directly involved. This creates an open-ended problem, as they have been shown no technique for performing this task as a group. Students tend to come up with very creative solutions but the possibility of frustration is greater since they have less guidance. Both approaches require multiple bow drill sets. If the teacher has only one bow drill set, student volunteers can be allowed to try the technique in front of the class, individually or as a group.

After addressing the concepts of observation and inference, students are asked to perform various measurements, practicing basic lab skills. Any of these activities can be deleted from the lab. Just be sure to delete any corresponding questions in the “Analysis and Conclusion” section.

If time allows, another possible introduction provided in Section 7.1.1 involves having students imagine being lost in the woods and needing to stay overnight. They then brainstorm what their biggest threats to survival are. Through discussion and questioning, the teacher leads students to an understanding of the "Law of Threes" (Section 7.1.1). This provides a “public service” to students by giving critical information that can help them survive should they get lost in the future.

Before beginning, you also need to decide whether you and your students will use a “beginner’s bow drill” or a fully functioning bow drill set in an attempt to produce an ember.

Options for acquiring the apparatus suited to your purpose are discussed in Section 3. It's important to set the students' expectations realistically. If you do use the beginners' set, tell them there are a few more steps to actually produce an ember, but they will be learning the key techniques and concepts.

Safety Suggestions

-Schools may not want smoke generated in a classroom, even in a small amount. The technique can be demonstrated with virtually no smoke, but obviously no ember would be produced. (See Sections 3.1 and 3.2 for more information on this.) An outdoor location is ideal. Also, some students may be sensitive to smoke or have asthma or allergies. Appropriate precautions must be taken.

-If you desire to show students the entire process and blow an ember into a flame, be sure to have a fume hood, sink or similar fireproof site immediately available and at no risk to students. Again, an outdoor location is ideal.

- Whenever working with sticks ensure that you and your students have sufficient space to avoid injuring one another.

- While the bowstring is wrapped around the spindle, it is under considerable tension. During this time, the spindle can fly off the bowstring if not sufficiently restrained. This most commonly happens 1) while attempting to wind the bowstring around the spindle and 2) while spinning the spindle with the bow. Use appropriate caution. As with any activity where objects may fly through the air, safety glasses are indicated when students are operating the apparatus or near someone else who is operating the apparatus.

- Even if there is no smoke, the surfaces of the spindle, fireboard and handhold that are in contact get hot. Warn students not to touch them.

Extensions

This lab can act a brief introduction to fire by friction, without going into the science principles at work. After completing this lab, the teacher could do the Physical Science version of the lab. As the students would now be familiar with the apparatus and technique, it would be easier for them to focus on and understand the science concepts and analysis included in that lab.

NAME___________________________________DATE_________________

INSTRUCTOR_______________ PERIOD _______PARTNERS___________

INTRODUCTION TO BOW DRILL FIRE MAKING (TEACHERS' EDITION)

The suggestions offered to the teacher in this Teachers' Edition are written in the font currently being used, Comic Sans MS, and are not present in the student edition. The portions of the labs (both student and teacher editions) providing information to the student are in *Arial Italics font*. **Where the student is to compete a task or answer a question,** Arial regular font **is used.**

INTRODUCTION

Nearly everyone has heard of making fire by "rubbing two sticks together". Making fire by friction is challenging but has been performed by people all over the world for thousands of years. Today you're going to see how an apparatus called the bow drill is use to make fire by friction.

PROCEDURE

The parts that make up a bow drill are listed below. Look carefully at each piece as your instructor shows them to you and sketch them in the space below. The sketch should show the important features of each part. It doesn't need to look exactly the same. **Sketching is being used here as another way to learn information. Instruct the students to look at the object for a few seconds then look away and sketch, repeating the process until complete. Limit their time for each and let them know their time limit. Keep it short, no more than 1 minute per item. Emphasize that their sketch should capture the important aspects of each piece but will not resemble them in detail. We're trying to train their brains to see and remember the key elements of a situation.**

A. bow

B. spindle

C. fireboard

D. handhold

Below are 2 other important components of the bow drill fire making apparatus. Listen as your instructor describes them. Write their function next to the term below.

E. lubricant

Show the lubricant and how to use it in the bow drill as you explain the following. Lubricants reduce friction. In the bow drill apparatus, friction between the fireboard and spindle is required to produce an ember. A lubricant is placed between the spindle and fireboard because friction here is a waste of energy. It slows the spindle and can make the handhold uncomfortably hot. Soap is a good lubricant for practice. In the natural world, the resin in conifer needles smashed between the spindle and handhold works well. Even skin oil, such as from the side of the nose, can work well. Water and water-based substances don't work well.

F. tinder bundle

Show an example of a tinder bundle as you describe the following. Tinder is any very dry, fine easily combustible material. Jute twine works great for practice. In the natural world grasses and inner bark of trees are among many possibilities. The material must be very dry and very thin. If using the just twine, unravel and separate the threads to make a ball of very fine, randomly arranged fibers. With dried grasses and bark, rubbing rapidly between the palms helps separate out individual fibers. A baseball size tinder bundle formed into a bird nest shape provides a place for the glowing ember to be blown into a flame.

Technique: *The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 1-3 during the following description).*

The bowstring is wrapped around the cylindrical spindle. (Figure 1)

Figure 1

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 2)

Figure 2

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 3)

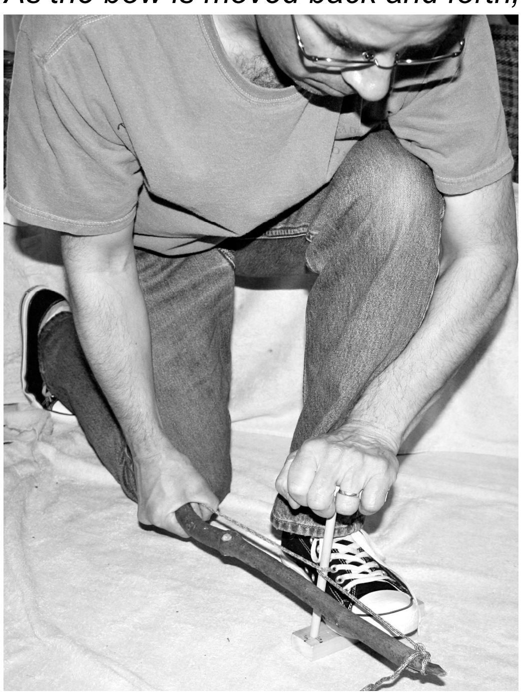


Figure 3

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then be transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.

The proper technique will be demonstrated for you now.

As you demonstrate, talk through your actions, or ask students to describe what you're doing and hypothesize the reasons. As you're demonstrating you can prompt students with ideas for observations. This is also a good place to inform students if you will not be attempting to produce an ember, for example because smoke cannot be produced in the school or there is no notch in your fireboard. Reassure them that the technique they will watch – and maybe try- is the same used to start a fire. The technique or apparatus just needed alteration for use in the classroom. You can also have a video of someone (even you) igniting a tinder bundle with an ember to show that it can be done.

1. Make at least 10 observations using sight, sound and smell. List them in Table 1. After the demonstration, your instructor will ask you to share your observations with the class.

This is a good place to discuss why different people have different observations even though they are observing the same event. Each person has a different viewing angle and sees the scene slightly differently. In addition, each individual has a tendency to notice some things more than others based on their experience and the way their nervous system is tuned. If you wish, a short version of a story such as "The Elephant and the Blind Men" (Section 7.1.2) can help to make this point. Also encourage students to make their observations as descriptive and free of judgmental language as possible. For example, students frequently write, "It smelled nasty". While they clearly noticed a smell, the only information is that they didn't like it. Instead, encourage a more descriptive statement such as " It smelled like something was burning". This statement provides information that anyone can use unlike words like "nasty" which can be used to describe a very wide variety of smells.

2. Did everyone have the same observations?

Not exactly but there will be several in common.

3. What was the most common visual observation?
This varies, but observations of the movement of the bow, spindle and the body of the operator are most common along with formation of dust and smoke.

4. Did everyone describe what he or she saw in the same way?
See comments under question #1.

Observations can be divided into 2 types, qualitative and quantitative. A qualitative observation is a description. A quantitative observation describes "how much or how many". An example of a qualitative observation is:

"John is wearing a blue sweatshirt".

An example of a quantitative observation is:

" Four people in the classroom are wearing sweatshirts".

5. In the third column of Table 1, label each of your observations as qualitative or quantitative.

Table 1

	Observation: **Below are common examples. Many others observations are possible.**	Qualitative or Quantitative
1	**The spindle moved when the bow moved**	**qualitative**
2	**The string moved up and down the spindle**	**qualitative**
3	**It made a squeaky sound.**	**qualitative**
4	**Dark brown and black dust started coming out of the notch**	**qualitative**
5	**I smelled smoke**	**qualitative**
6	**The spindle stayed straight up and down**	**qualitative**
7	**I saw smoke**	**qualitative**

8	**It took 4 attempts to get a fire**	**quantitative**
9	**Teacher was sweating**	**qualitative**
10	**It looked hard to do. – This is actually an inference. I would ask what made them think that. What they actually saw or heard to make them think, "It looks hard" is the observation.**	**qualitative**

An inference is a conclusion reached using observations as evidence. Recall our example of a qualitative observation:

"John is wearing a blue sweatshirt"

An inference based on this observation is:

" John likes the color blue."

We have assumed that since John is wearing the color blue, he likes blue. But we don't know if this is true. We have some evidence that supports the inference but to verify it we'd need to do more research, like asking John.

6. In the space below, write inferences based on any 2 of your observations from Table 1. Include the number of the observation with your inference.

Possible inferences from observation 5, " I smell smoke", include:

The fireboard and spindle are hot.

Some part of the apparatus is burning.

Possible inferences from observation 8, "It took 4 attempts to get a fire", include:

The technique is difficult.

The teacher is inexperienced with this technique.

The apparatus was faulty.

At this point, you can have your students practice measurement and deduction skills. First, they can measure the length and circumference of the spindle. The circumference is used to calculate diameter. The students can also find the mass of the spindle using a balance. The teacher can continue the lab as a demonstration and ask a few students to help with the measurements and calculations. The other option is to break the students into groups, give each a bow drill set and some time to practice. After the practice time, each group makes their own measurements.

The bow drill is going to be used again, but first you need to take some measurements.

7. Write the length of the spindle before using the bow drill in centimeters (cm) in Table 2.

8. Measure the circumference of your spindle before using the bow drill. You can do this by wrapping a piece of paper or string around the spindle and marking the circumference. Use a ruler to measure the distance you marked on the paper or string. **(Students will need this demonstrated for them as they attempt to do it.)**
Write the circumference of the spindle before using the bow drill in centimeters (cm) in Table 2.

9. Find the diameter of the spindle before using the bow drill by dividing the circumference by π (π is about 3.14). Write your answer for diameter in Table 2.

10. Use a balance to find the mass of the spindle, in grams, BEFORE using the bow drill. Record this number in Table 2.

Table 2

	Spindle Length (cm)	Spindle Circumference (cm)	Spindle Diameter (cm)	Spindle Mass (g)
Before Using Bow Drill	**13.6**	**3.0**	**.95**	**7.8**
After Using Bow Drill	**12.9**	**3.0**	**.95**	**7.4**

It's time to put together the bow drill and use it. Follow your teacher's instructions for this.
Demonstrate again or give the students some time to use their bow drill sets in their groups. After the allotted time, tell them to stop (or stop your demonstration) and complete the following measurements and calculations.

11. Write the length of the spindle after using the bow drill in centimeters (cm) in Table 2.

12. Write the circumference of the spindle after using the bow drill in centimeters (cm) in Table 2.

13. Find the diameter of the spindle after using the bow drill by dividing the circumference by π (π is about 3.14). Write your answer for diameter in Table 2.

14. Use a balance to find the mass of the spindle, in grams, after using the bow drill. Record this number in Table 2.

15. Measure the diameter of the hole in the fireboard in centimeters (cm) and write it in the space below.

This value should be a little larger than the diameter of the spindle.

ANALYSIS AND CONCLUSIONS

1. Did the length of the spindle change after using it in the bow drill? If it changed, did it get longer or shorter? By how many centimeters did it change?

Shorter by 13.6-12.9 = .7 cm

2. Think about your answer to question #1. Would you expect this to happen? Explain your answer.

This is expected because as the spindle rubs against the fireboard both are abraded away, creating dust. If the bow drill was not worked hard enough to produce dust, there should be no difference in length.

3. Did the circumference of the spindle change after using it in the bow drill? If it changed, did it get larger or smaller? By how many centimeters did it change?

No change is expected. However, sometimes the middle of the spindle shows a decrease in diameter because it is squeezed by the bowstring.

4. Think about your answer to question #3. Would you expect this to happen? Explain your answer.

The spindle is only being abraded at the bottom, not the sides. Therefore the circumference would not be expected to change. Note the exception described in #3.

5. Did the mass of the spindle change after using it in the bow drill? If it changed, did it get larger or smaller? By how many grams did it change?

Smaller, change of .4g

6. Think about your answer to question #5. Would you expect this to happen? Explain your answer.

Since the spindle became shorter, it must have lost mass.

7. Compare the spindle diameters you calculated in Table 2 to the diameter of the fireboard you measured in Procedure question 13. Are they the same? If not, which is bigger, the spindle or the hole? Does this make sense to you? Explain why or why not.

It is expected that the diameter of the hole in the fireboard would be a little

larger than the diameter of the spindle. The first reason is that since the spindle must fit inside the fireboard hole, the spindle must be slightly smaller. Students may notice the fireboard hole is larger than necessary to fit the spindle. Encourage them to think about this. If the spindle is not held perfectly straight (which is virtually impossible), it will wear the fireboard hole more in the direction toward which it is leaning. Also, if the spindle is not perfectly round, the wider dimension will determine the diameter of the hole that is drilled in the fireboard.

The following questions only make sense if the students observed a significant change in the length of the spindle. If no dust was produced, the spindle did not abrade a measurable amount.

8. We're going to calculate the volume of material that was worn away from the spindle by rubbing against the fireboard. First, write the change in the length of the spindle from question #1 in the space below.
Change in length of spindle = **.7 cm**.

Second, write the diameter of the spindle before using the bow drill from Table 2 in the space below.
Diameter of spindle = **.95 cm**.

The volume of an object is the amount of space it takes up. The spindle is in the shape of a cylinder. The equation used to calculate the volume of a cylinder is:

$$v = \frac{\pi}{4} d^2 l$$

v is the volume you're calculating, d is the diameter of the spindle and l is the change in length of the spindle.

Use your values for d and l to calculate v. Write your values for v, to the nearest .1 cm, in the space below.
v = **.5** cm^3

9. Density is a measure of the amount of matter that makes up a volume of a material. It is calculated using the equation:

$$D = \frac{m}{v}$$

D is density, m is mass and v is volume. So, if you have 2 objects that are the same size (same volume) the one with the larger mass is denser. For example, a bowling ball and a soccer ball both have a diameter of about 22 cm. This means they have the same volume. But a typical bowling ball has a mass of about 6,800 g while a soccer ball's mass is only about 430 g. The bowling ball packs much more matter in the same amount of space as the soccer ball, making it denser.

Calculate the density of the wood that makes up the spindle by dividing the change in mass, m from question 5 by the change in volume from question 8. Write your answer in the space below.

D= **.4/.5 = .8 g/cm^3**

10. Water has a density of 1 g/cm^3. If you place the spindle in a bucket of water, will it sink or float? Explain your answer by comparing the density of the spindle to the density of water.

Since the spindle has a lower density than water, it will float.

11. See if your teacher has a sink or container filled with water. Place the spindle in the water and note whether or not it floats. Does your observation confirm or refute your answer to question #10? Explain.

The spindle should float, assuming the wood has a density less than 1 (as most do). The student's answer will depend on their answer to question 10.

NAME_________________________________ DATE__________________
INSTRUCTOR________________ PERIOD _______ PARTNERS___________

INTRODUCTION TO BOW DRILL FIRE MAKING

INTRODUCTION

Nearly everyone has heard of making fire by "rubbing two sticks together". Making fire by friction is challenging but has been performed by people all over the world for thousands of years. Today you're going to see how an apparatus called the bow drill is use to make fire by friction.

PROCEDURE

The parts required for a bow drill are listed below. Look carefully at each piece as your instructor shows them to you and sketch them in the space below. The sketch should show the important features of each part. It doesn't need to look exactly the same.

A. bow

B. spindle

C. fireboard

D. handhold

Below are 2 other important components of the bow drill fire making apparatus. Listen as your instructor describes them. Write their function next to the term below.

E. lubricant

F. tinder bundle

<u>Technique:</u> The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 1-3 during the following description).

The bowstring is wrapped around the cylindrical spindle. (Figure 1)

Figure 1

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 2)

Figure 2

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 3)

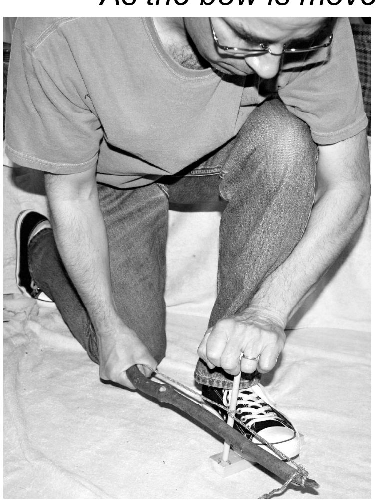


Figure 3

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.

The proper technique will be demonstrated for you now.

1. Make at least 10 observations using sight, sound and smell. List them in the "Observations" column of Table 1. After the demonstration, your instructor will ask you to share your observations with the class.

2. Did everyone have the same observations?

3. What was the most common visual observation?

4. Did everyone describe what he or she saw in the same way?

Observations can be divided into 2 types, qualitative and quantitative. A qualitative observation is a description. A quantitative observation describes "how much or how many". An example of a qualitative observation is:

"John is wearing a blue sweatshirt".

An example of a quantitative observation is:

" Four people in the classroom are wearing sweatshirts".

5. In the third column of Table 1, label each of your observations as qualitative or quantitative.

Table 1

	Observation	Qualitative or Quantitative
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

An inference is a conclusion reached using observations as evidence. Recall our example of a qualitative observation:

"John is wearing a blue sweatshirt"

An inference based on this observation is:

" John likes the color blue."

We have assumed that since John is wearing the color blue, he likes blue. But we don't know if this is true. We have some evidence that supports the inference but to verify it we'd need to do more research, like ask John.

6. In the space below, write inferences based on any 2 of your observations from Table 1. Include the number of the observation with your inference.

The bow drill is going to be used again, but first you need to take some measurements.

7. Write the length of the spindle <u>before</u> using the bow drill in centimeters (cm) in Table 2.

8. Measure the circumference of your spindle <u>before</u> using the bow drill. You can do this by wrapping a piece of paper or string around the spindle and marking the circumference. Use a ruler to measure the distance you marked on the paper or string.
Write the circumference of the spindle <u>before</u> using the bow drill in centimeters (cm) in Table 2.

9. Find the diameter of the spindle <u>before</u> using the bow drill by dividing the circumference by π (π is about 3.14). Write your answer for diameter in Table 2.

10. Use a balance to find the mass of the spindle, in grams, <u>before</u> using the bow drill. Record this number in Table 2.

Table 2

	Spindle Length (cm)	Spindle Circumference (cm)	Spindle Diameter (cm)	Spindle Mass (g)
Before Using Bow Drill				
After Using Bow Drill				

It's time to put together the bow drill and use it. Follow your teacher's instructions for this.

11. Write the length of the spindle after using the bow drill in centimeters (cm) in Table 2.

12. Write the circumference of the spindle after using the bow drill in centimeters (cm) in Table 2.

13. Find the diameter of the spindle after using the bow drill by dividing the circumference by π (π is about 3.14). Write your answer for diameter in Table 2.

14. Use a balance to find the mass of the spindle, in grams, after using the bow drill. Record this number in Table 2.

15. Measure the diameter of the hole in the fireboard in centimeters (cm) and write it in the space below.

____

ANALYSIS AND CONCLUSIONS

1. Did the length of the spindle change after using it in the bow drill? If it changed, did it get longer or shorter? By how many centimeters did it change?

2. Think about your answer to question #1. Would you expect this to happen? Explain your answer.

3. Did the circumference of the spindle change after using it in the bow drill? If it changed, did it get larger or smaller? By how many centimeters did it change?

4. Think about your answer to question #3. Would you expect this to happen? Explain your answer.

5. Did the mass of the spindle change after using it in the bow drill? If it changed, did it get larger or smaller? By how many grams did it change?

6. Think about your answer to question #5. Would you expect this to happen? Explain your answer.

7. Compare the spindle diameters you calculated in Table 2 to the diameter of the fireboard you measured in Procedure question 13. Are they the same? If not, which is bigger, the spindle or the hole? Does this make sense to you? Explain why or why not.

8. We're going to calculate the volume of material that was worn away from the spindle by rubbing against the fireboard. First, write the change in the length of the spindle from question #1 in the space below.

Change in length of spindle = ________________________________ cm.

Second, write the diameter of the spindle before using the bow drill from Table 2 in the space below.

Diameter of spindle = _______________________________ cm.

The volume of an object is the amount of space it takes up. The spindle is in the shape of a cylinder. The equation used to calculate the volume of a cylinder is:

$$v = \frac{\pi}{4} d^2 l$$

v is the volume you're calculating, d is the diameter of the spindle and l is the change in length of the spindle.

Use your values for d and l to calculate v. Write your values for v in the space below.

v = ______________________ cm^3

9. Density is a measure of the amount of matter that makes up a volume of a material. It is calculated using the equation:

$$D = \frac{m}{v}$$

D is density, m is mass and v is volume. If you have 2 objects that are the same size (same volume) the one with the larger mass is denser. For example, a bowling ball and a soccer ball both have a diameter of about 22 cm. This means they have the same volume. But a typical bowling ball has a mass of about 6,800 g while a soccer ball's mass is only about 430 g. The bowling ball packs much more matter into the same amount of space as the soccer ball, making it denser.

Calculate the density of the wood that makes up the spindle by dividing the change in mass, m from question 5 by the change in volume from question 8. Write your answer in the space below.

D= __________________________ g/cm^3

10. Water has a density of 1 g/cm^3. If you place the spindle in a bucket of water, will it sink or float? Explain your answer by comparing the density of the spindle to the density of water.

11. See if your teacher has a sink or container filled with water. Place the spindle in the water and note whether or not it floats. Does your observation confirm or refute your answer to question #10? Explain.

2.2 THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL SCIENCE

2.2.1 TEACHING TIPS

Suggested Approach

The two labs included in "The Science of Bow Drill Fire making: Physical Science" section use the bow drill technique to illustrate basic physical science concepts. As written, the labs take about 2 - 45 minute periods. Suggestions are made below to produce a shorter lab. Also presented are ideas to extend the experience.

The Introduction and Pre-Lab Questions attempt to illuminate the role of fire in our lives and the lives of our ancestors. I complete the Pre-Lab Questions with my students as a group discussion. Sample answers are provided in the Teachers' Edition to guide such a discussion. Alternately, to save time, the Pre-Lab Questions can be skipped without affecting the rest of the lab.

The Vocabulary section introduces terms used in the lab. It is important that the students have some understanding of these terms before beginning the lab. Definitions are provided in the Glossary, Chapter 5.

The Procedure section introduces the materials, techniques and concepts used in the bow drill method of producing fire by friction. Simply introducing the materials and not requiring the students to write a description of the components can save time. In fact, throughout the lab, exercises can be eliminated to save time, if desired.

If time allows, an alternate introduction provided in Section 7.1.1 involves having students imagine being lost in the woods and needing to stay overnight. They then brainstorm what their biggest threats to survival are. Through discussion and questioning, the teacher leads students to an understanding of the "Law of Threes" (Section 7.1.1). This provides a "public service" to students by giving critical information that can help them survive should they get lost in the future.

Before beginning, you also need to decide whether you and your students will use a "beginner's bow drill" or a fully functioning bow drill set in an attempt to produce an ember. Options for acquiring the apparatus suited to your purpose are discussed in Section 3. It's important to set the students' expectations realistically. If you do the basic technique, tell them there are a few more steps to actually produce an ember, but they will learn most of the process.

The section of the lab entitled, "Simple Machines and Velocity" includes procedure questions 25-31. It provides a hands-on exercise in taking measurements and calculating quantities from these measurements. This usually takes at least 20 minutes and can be eliminated without affecting the rest of the lab, except for skipping Analysis and Conclusion questions 7 and 8.

The first lab (titled: THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL

SCIENCE - DEMONSTRATION) is designed as a demonstration, with the teacher leading the students through the "Procedure" section. Actually demonstrating the technique can take as little as 5-10 minutes.

The second lab (titled: THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL SCIENCE) provides an opportunity for the students to try the technique themselves. In this case, several bow drill sets will be required, one for each group of students. Different levels of structure can be built into the activity depending on the class and the teacher's goals. One group member can be designated to operate the bow drill while the other members of the group help the student maintain proper form. If time permits, everyone in the group can have an opportunity to try.

While the approach taken in the above paragraph has the students emulate the technique demonstrated by the teacher, a less structured alterative is often used. Instead of one student operating the bow drill with the others watching and supporting, the students are told that as many members of the group as possible (or the entire group) are to be directly involved. This creates an open-ended problem, as they have been shown no technique for performing this task as a group. Students tend to come up with very creative solutions but the possibility of frustration is greater since they have less guidance. This lab requires more time than the demonstration lab due to the student participation. The teacher needs to decide how much time to allot for students to practice their technique.

Also keep in mind that to complete the “Simple Machines and Velocity” section of the lab, the students will again need time with their bow drills to collect data. During this time, they may not succeed in maintaining the motion of the bow for 1 minute as directed. In this case there are 2 choices. They can use someone else's data or students can extrapolate their data if they did not last a full minute. For example, if they counted 53 strokes in 30 seconds, they can assume 106 strokes for a full minute. This can be done for any amount of time and is an opportunity to work on fractions and proportions.

Questions 17-20 help the student to draw a velocity profile of the spindle based on their observations. An actual velocity profile, recorded from a spindle using a rotational motion sensor and computer is provided in Chapter 4. The graph simultaneously plots the position, velocity and acceleration of a spindle over the course of a single bowstroke. After the students draw their profile, the instructor can provide this graph for comparison. These profiles also provide an opportunity to discuss the relationship between position, velocity and acceleration.

Safety Suggestions

-Schools may not want smoke generated in a classroom, even in a small amount. The technique can be demonstrated with virtually no smoke to illustrate the science concepts involved, but obviously no ember would be produced. An outdoor location is ideal. Also, some students may be sensitive to smoke, or have asthma or allergies. Appropriate precautions must be taken.

-If you desire to show students the entire process and blow an ember into a flame, be sure to have a fume hood, sink or similar fireproof site immediately available and at no risk to students. Again, an outdoor location is ideal.

- Whenever working with sticks, be sure that you and your students have sufficient space to avoid injuring one another.

- While the bowstring is wrapped around the spindle, it is under considerable tension. During this time, the spindle can fly off the bowstring if not sufficiently restrained. This most commonly happens 1) while attempting to wind the bowstring around the spindle and 2) while spinning the spindle with the bow. Use appropriate caution. As with any activity where objects may fly through the air, safety glasses are indicated when students are operating the apparatus or near someone else who is operating the apparatus.

- Even if there is no smoke, the surfaces of the spindle and fireboard that are in contact get hot. Warn students not to touch them.

Extensions

- Investigate how changing different parts of the apparatus affects the result. For example, experiment with different length bows or spindles with different diameters. Only change one parameter at a time. Note how the change affects the speed or the effort required to move the spindle.

NAME_____________________________________DATE______________
INSTRUCTOR________________ PERIOD _____PARTNERS____________

THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL SCIENCE (TEACHERS' EDITION)

The suggestions offered to the teacher in this Teachers' Edition are written in the font currently being used, Comic Sans MS, and are not present in the student edition. The portions of the labs (both student and teacher editions) providing information to the student are in *Arial Italics font*. **Where the student is to compete a task or answer a question,** Arial regular font **is used.**

INTRODUCTION

Nearly everyone has heard of making fire by "rubbing two sticks together". To those who have tried without coaching, it often seems impossible. As reliable matches and lighters were only developed within the last 300 years, our ancestors had 3 choices for obtaining fire. The most convenient choice, once fire was harvested from a natural source, was to never allow the home or community fire to go out. In this case, no one needed to "make" fire. Without access to fire, people created it either by striking objects together to create a spark (for example, flint and steel) or rubbing two sticks together to create an ember by friction.

There are probably over one hundred different methods used by people around the world to create fire by friction. In this lab, you will learn the bow drill method of fire making. Though this technique requires more components and preparation than some other methods, it is among the most reliable techniques and, with practice, can be used successfully under virtually any conditions.

Before embarking on your quest for fire, take a few minutes to reflect on the role of fire in the lives of humans by answering the pre-lab questions below.

OBJECTIVE

To understand the science behind making fire by friction.

VOCABULARY

linear velocity

rotational velocity

acceleration

deceleration

friction

coefficient of friction

normal force

PRE-LAB QUESTIONS

1. For what purposes did “primitive” peoples use fire?

Most common answers: heat, light, cooking, making tools, protection, and ceremony

2. For what purposes do we use fire in our modern world?

Same as above, but not as obvious. For example, we have electric lights, heating and cooking but the electricity needs to be generated, often by burning fossil fuel. We still have open flames in many places such as furnaces, gas appliances, barbeques and candles.

3. Some modern conveniences are listed below. See if you can figure out how each one is related to fire.

A. radiator in a building used for heat

Hot water runs through the radiator. The water is heater by the burning of fossil fuels in the furnace. This is an opportunity to note that radiators heat a room mostly through convection, not radiation. If you talk about these two concepts you may also want to bring in conduction so students are introduced to all three heat transfer concepts.

B. electric light

Most power plants generate electricity by burning fossil fuels. Fuel is burned to boil water to create steam, which turns generators that produce the electricity. This can be an opportunity to discuss nuclear and hydroelectric power. For example, hydro uses the kinetic energy of flowing water to turn the generators. Since nuclear power plants generate heat to create steam, this is an opportunity to discuss the difference between combustion and a nuclear reaction.

C. air conditioner

Same as the above, burning produces electricity that runs the air conditioner.

4. How did “primitive” people obtain fire?

Like the modern day lighter, two materials that produced a spark were struck together. While butane or other combustible gases are ignited with the spark in today's lighter, the ancients needed a very fine, very dry material to catch a spark and coax it into life.

Friction - ex bow drill, hand drill, fire plough, pump drill. All these

techniques rub wood against wood to create a hot ember that is then used to set a tinder bundle ablaze.

Storage - Fire was "harvested" from naturally occurring fire. A person or group was in charge of maintaining the fire and transporting it when moving.

5. How do we obtain fire?
Matches and lighters

PROCEDURE

As with most skills, the knowledge required for success with the bow drill can be divided into three types: materials, methods and theory. We'll start with materials.

Materials: *The parts required for a bow drill are listed below. Figure 1 illustrates components A through D. Use Figure 1 and information from your instructor to write a brief description of the following components of a bow drill fire making apparatus. Information provided later in the lab is also helpful.*

A. bow
Relatively rigid, approximately arm length with a good curvature. Allows you to rotate the spindle much more rapidly than can be done with the hands alone. You can have the students compare spinning the spindle with their hands versus with the bow, or you can demonstrate for them.

B. spindle
A little less than thumb thickness and length from end of thumb to outstretched pinky finger. Spins rapidly in the fireboard. Friction between the spindle and fireboard generates the heat and dust required to produce an ember.

C. fireboard
A little less than thumb thickness, length of your forearm, width of arm or hand. Creates heat and "dust" by friction with the spindle. This hot dust is compacted and further heated in the notch of the fireboard to form an ignited ember.

D. handhold
Sized to fit comfortably in your hand. Holds the spindle straight in place. Allows you to control the normal force applied to the spindle/fireboard interface.

E. lubricant
Any material that reduces friction between surfaces. I usually wait until later in

the lab to give the following details, and I have the students figure it out using a series of questions. We do not want lubrication at the fireboard/spindle interface because the friction produces the heat and dust necessary for the ember. But friction at the handhold is a waste of energy (effort) and should be minimized through the use of a lubricant. Water and water-based products are not effective lubricants. Soap works well as do conifer needles. Skin oil, easily obtained from the side of the nose or scalp, also works.

F. tinder bundle

Tinder is any very dry, fine, easily combustible material. For practice, jute twine (from garden or hardware shops) works great. Unravel the twine (or whatever you're using) and make a baseball-softball size mass. You want a lot of material but also adequate air circulation. This is a bit of an art. Birch bark does not catch fire until there is an open flame, but it can be useful in extremely thin pieces mixed throughout to help when the ember ignites. Cattail down does not ignite easily, but some people use it as an "ember extender" - that is, although it does not ignite, it smolders and produces heat and hot mass that effectively increases the size of the ember and the chance of ignition.

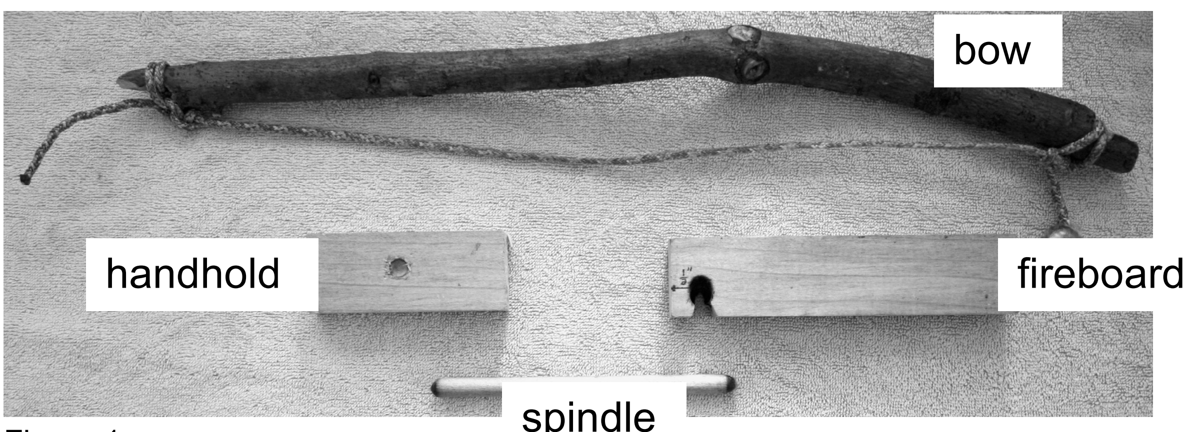


Figure 1

<u>*Technique:*</u> *The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 2-4 during the following description).*

The bowstring is wrapped around the cylindrical spindle. (Figure 2)

Figure 2

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 3)

Figure 3

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 4)

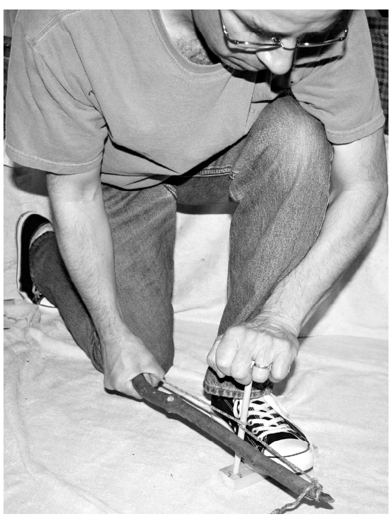


Figure 4

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this hot dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.
The proper technique will be demonstrated for you now.

At this point you can inform students that they could be left with the material and, if they were persistent, they could probably figure out how to get a fire - but it would take a long time. Learning proper technique speeds up the process tremendously and makes results more reliable.

6. First, write the length of the spindle before the demonstration: ___________________
(Be sure to include units)

7. During this demonstration, use the space below to record as many observations as possible. Remember, observations are made with all of your senses. Try to list at least 10 observations. List your observations in the space below then answer the following questions.

Depending on your age group and focus, you may want to review the five senses here. This is also an opportunity to distinguish between observation and inference.

There are many visual observations - the person's body position and motion, the position and motion of the bow drill etc. Many sounds are also audible. Soon after, someone usually detects a burning smell - often before smoke is actually seen. One reason I like to use cedar is that the aroma is pleasant to most people.

8. What is the length of the spindle after the demonstration? _________________

9. What was the change in length of the spindle during the demonstration? __________

10. Describe changes to the hole in the fireboard during the demonstration.

The hole should be deeper after the demonstration. It may have a more charred appearance and may be a little wider.

11. Is the spindle always moving?

No

12. If it stops, when does this happen?

The spindle must stop each time it reaches an end of the bow.

13. When is the spindle going fastest?

Since it stops at each end of the bow, the spindle must be spinning most rapidly near the center of the bow.

Theory: *Understanding the science behind fire by friction allows you to become much more effective, much more quickly. Friction and velocity are 2 key concepts involved in producing fire by friction.*

If you understand the theory, you will be able to figure out good technique and good materials for yourself - you can effectively teach yourself. Understanding the theory - the science - allows you to be a much more effective troubleshooter.

Friction *is defined as a force that resists the relative motion of objects in contact. The frictional force, F_f, is the product of the coefficient of friction, μ (a measure of the "stickiness" of the surfaces), and the normal force, N.*

In equation form, $F_f = \mu N$

14. Reread the description of the bow drill technique in the Procedure section to figure out the two important tasks performed by friction between the spindle and fireboard. Describe them below. (hint: Friction between the fireboard and spindle generates a type of energy and a type of matter. What are they?)

1. Produces heat, i.e. converts mechanical energy provided by your muscles into heat energy

2. Produces dust - Tiny, hot bits of wood break off the spindle and fireboard and collect in the notch. There, they are compacted and further heated.

15. Describe as many ways as you can think of to increase the friction between the spindle and fireboard in the bow drill apparatus. (Use the definition of friction above and your knowledge of the bow drill to find them!

1. Increase the surface areas in contact - A larger spindle gives more contact area and can thus form an ember more quickly. But, the larger the spindle, the more energy required to spin it.

2. Increase the "stickiness" of the surfaces (i.e., the coefficient of friction) - In general, rougher surfaces produce more friction than smooth surfaces. This can be demonstrated by having a block side down a smooth ramp then a rough ramp. A larger angle will be necessary to begin the slide down the rough ramp.

3. Increase the normal force - The force of friction is directly proportional to the normal force. So, the harder one pushes down on the handhold, the higher the frictional force. Knowing the ideal amount of pressure in any given situation is an art.

Also, the faster the spindle moves, the more heat and dust will be produced per unit time.

16. The bow drill also requires the proper amount of friction between the bowstring and spindle. What do you think are the consequences of too little friction here? What are the consequences of too much friction here?

Too little friction between the bowstring and the spindle causes the string to simply slip around the spindle without turning it. If there is too much friction, the spindle will be too difficult to spin.

Velocity is a measure of how fast and in what direction an object is moving.

While learning to use the bow drill, you should have noted the spindle rotated at different speeds at different points in the bow stroke. There are three points for which we have information about the spindle's velocity. At the beginning of the stroke, velocity is zero. The x-axis on the graph below corresponds to the position of the spindle on the bowstring. The first half is on the outstroke (defined here as positive motion) and the second half is on the return stroke (defined as negative). The y-axis is a measure of velocity in arbitrary units. Positive velocities correspond to the outstroke and negative velocities to the return stroke.

For answers to questions 17-20, see diagram on next page

17. Make an X on the graph showing the velocity of the spindle is zero at the beginning of the bow stroke.

As the bow is pushed forward, the spindle accelerates to a maximum velocity until it must decelerate as you reach the other end of the bow. The velocity must again be zero at the end of the bow.

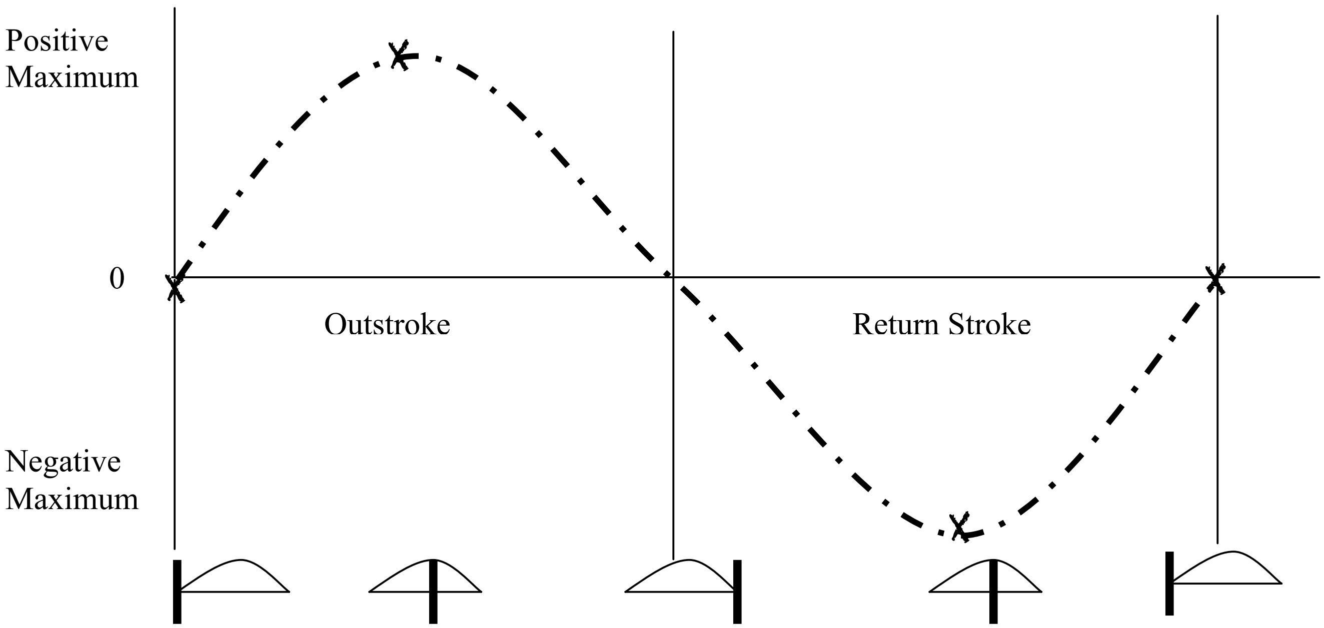
18. First, make an X corresponding to zero on the graph below at the end of the bow stroke.

Also, the spindle must obtain a maximum velocity between these 2 points, probably near the middle of the bow.

19. Now make an X corresponding to maximum velocity at the middle of the bow. Connect the points with a smooth freehand pencil line.

At the end of the outstroke, the spindle not only stops, but also changes direction. The return stroke now begins and has the same velocity profile as the outstroke except the velocities are in the opposite direction and defined here as negative.

20. Using the above information, plot the velocity of the spindle at the beginning, middle and end of the return bow stroke on the graph below. Connect the points with a smooth freehand pencil line.



NOTE: Questions 17-20 help the student to draw a velocity profile of the spindle based on their observations. An actual velocity profile, recorded from a spindle using a rotational motion sensor and computer is provided in Chapter 4. The graph simultaneously plots the position, velocity and acceleration of a spindle over the course of a single bowstroke. After the students draw their profile, the instructor can provide this graph for comparison. These profiles also provide an opportunity to discuss the relationship between position, velocity and acceleration.

21. Using your graph and experience with the bow drill, briefly describe the change in velocity of the spindle during a complete out and back cycle.

At the beginning of the cycle, the velocity is zero. As the bow is moved, the spindle accelerates until reaching maximum velocity in the middle region of the bow. The bow then decelerates, slowing to a velocity of zero at the other end of the bow. As the return stroke begins the spindle accelerates in the opposite direction to a maximum velocity at the middle region of the bow. The spindle then decelerates until it returns to zero velocity at the front of the bow.

22. Imagine you had a longer bow. How might this affect the maximum velocity of the spindle?

A longer bow could have one or both of the following effects. 1. With the longer

travel, it may allow the spindle to reach a higher maximum velocity before decelerating. 2. If the bow does not travel faster, it may allow the spindle to rotate at its maximum for a longer period of time before decelerating. Some students may speculate that a much longer bow would be heavier and could actually slow the spindle since it would be more difficult to accelerate.

23. Imagine you had a shorter bow. How might this affect the maximum velocity of the spindle?
This is the opposite of question 22 and student answers should reflect that.

24. Recall that heat is generated by friction between the spindle and fireboard. The faster the rotation, the more heat and dust generated. Whenever the spindle stops moving, it is cooling. Keeping this in mind along with your answers to questions 21-23 above, would a longer or a shorter bow generate more heat in the same amount of time? Explain your answer.
When using a long bow, the spindle is in motion for a longer time before stopping than when using a short bow. So, in any given time period, the spindle stops fewer times and thus has less time to cool down when using a long bow compared to a short bow. Keep in mind that there are practical limits to the size of bows. As they get larger bows become more massive, harder to move (as mentioned above) and more difficult to control.

Simple Machines and Velocity: *The bow and spindle act as a simple machine, transforming the linear motion imparted to the bow to the rotational motion of the spindle. Following is an exercise to quantify this transfer.*
Measurements made will vary with the materials used and students involved. A set of measurements made by one of my classes is given below as an example.

Make the following measurements to the nearest 0.1 cm.

25. Measure the length of your bowstring, l = **64.1 cm**

26. Measure the circumference of your spindle, c = **5.5 cm**
(Note that this is most easily done by wrapping a piece of paper or string around the spindle, marking the circumference and then measuring the paper on a ruler.)

27. r is the radius of the spindle. Calculate the radius of the spindle with the equation

$r = \frac{c}{2 \times \pi}$. Assume $\pi = 3.14$

r = **0.9 cm**

28. Diameter = $2 \times r$. Calculate the diameter of the spindle.
d = **1.8 cm**

Assemble your bow drill set and use the technique you developed to get long, smooth bow strokes. Then do the following:

29. Use the stopwatch to count the number of bow strokes in one minute, n.
    n = **102**

Linear velocity is the speed of an object moving in a straight line and is measured in units like miles per hour or centimeters per second. To find the linear velocity of the spindle, multiply the number of bow strokes per minute times the length of the bowstring. This gives the number of centimeters the spindle traveled in one minute. Mathematically;

30. linear velocity, V_l = n x l = **6528 cm/min**

(If you want a challenge, try to figure out how fast is this in miles per hour. Hint: 2.54 cm = 1 inch, 2 inches = 1 foot, 5280 feet = 1 mile, 60 minutes = 1 hour)

Rotational velocity, v_r, is a measure of how many times an object rotates during a certain period of time. The rotational velocity of the spindle is obtained by dividing the linear velocity by the circumference of the spindle. The answer is in units of revolutions per minute, also know as rpm.

31. rotational velocity, $V_r = \frac{n \times l}{c}$ = **1187 rev/min**

ANALYSIS AND CONCLUSION

Answer the following questions on a separate piece of paper.

1. Are the linear and rotational velocities you calculated in the Procedure section instantaneous or average values? How do you know? Explain the difference.

Average. The plot of velocity vs. position from #17-20 shows that the velocity changes as a function of position. Because we are measuring how far the bow (or spindle) has traveled in one minute we are calculating an average. The instantaneous velocity is the velocity at a particular instant of time. The plot from #17-20 shows the change in instantaneous velocity with position on the bow (which, for the bow stroke, is equivalent to time).

2. Why is a lubricant used between the spindle and the handhold and not between the spindle and the fireboard?

The purpose of the handhold is to apply pressure to the spindle-fireboard interface and to keep the spindle properly aligned. Any friction at the spindle-handhold interface is wasted energy. Applying a lubricant minimizes this waste. Friction is critical to the spindle-fireboard interface as this is how heat and dust are generated and transformed into a burning ember.

3. Describe one way in which friction aids in creating an ember.

Generating heat or dust in the fireboard. Friction between the bowstring and the spindle is required for the back and forth movements of the bow to be translated into the rotation of the spindle.

4. Describe one way in which friction wastes energy, making it more difficult to create an ember.

Friction between the handhold and spindle slows the spindle and wastes energy. Too much friction between the bowstring and the spindle can make the bow very hard to move.

5. Describe the change in length of the spindle (Review your answer to Procedure question 8). Where did the wood go? How is this related to creating an ember?

The spindle should have shortened. The thinner the spindle used, the more pronounced this effect in the same amount of time. Most of the wood abraded away into tiny particles of dust that collect in the notch (some is scattered) and heat up. Note that the fireboard is abraded away at the same time and this dust also collects in the notch. This dust is compacted and heated in the notch

until is begins to burn.

6. Look at your answer to question 31 in the Procedure section. Do you think you could spin the spindle with the same velocity using only your hands? Explain your answer.
The bow allows the spindle to be rotated much faster than one could by hand. The bow provides a much longer stroke and stronger connection with the spindle than can be obtained with hands alone. The hand drill is an effective fire making technique but is much more difficult to learn and is much more sensitive to materials and weather conditions.

7. Describe 2 potential sources of error in your measurements
Following are a few of many possibilities. While taking measurements, the ruler could be aligned or read improperly. One student may measure to the nearest centimeter while another may measure to the nearest tenth of a centimeter. Data can be recorded incorrectly. Errors can be made in timing or counting the bow strokes. Numbers can be incorrectly entered into the calculator and the final result misread. If the entire bowstring is not used on each stroke, the length of the bowstring is essentially shortened. This means that the measured bowstring length used in the calculations is too large.

8. Fill in the table below with data from each group in your class.
Skip this question if you are only demonstrating the technique. Data will vary with the class. Also, questions 8A and 8B only make sense if you provided a variety of different bow and spindle sizes to the class.

Group Number	Length of Bowstring (cm)	Circumference of Spindle (cm)	Rotational Velocity (revolutions/minute)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

A. Does your data show a relationship between the length of the bowstring and rotational velocity? If so, describe the relationship.

A longer bowstring would be expected to correlate with a higher velocity. A long bow required less stopping and changing direction and has the potential to have the spindle reach a higher maximum velocity. The data however, do not often reflect this because other factors are at work. For example, a longer bow is more massive and difficult to control, especially for a beginner. Thus the student cannot move it nearly as quickly as a shorter bow without practice.

B. Does your data show a relationship between the circumference of the spindle and rotational velocity? If so, describe the relationship.

A spindle with a larger circumference is expected to have a lower rotational velocity. The larger the circumference, the more bowstring required to produce one rotation. Therefore, the larger the spindle the fewer rotations produced by each bow stroke. As with question 8A, because other variables are involved, the data do not always support this.

FOR FURTHER INVESTIGATION

1. Describe an assumption made in the calculation of rotational velocity.

2. What is the purpose of the notch in the fireboard?

3. Describe other methods used by people to make fire by friction?

4. What other techniques besides the bow drill did people use to make fire?

5. Why do you think different cultures used different techniques? Support your answer with at least one example.

5. Instead of making fire, some people harvested fire and stored it. How was this done?

6. Is fire making a uniquely human activity in the animal world? Support your opinion.

NAME____DATE_____________
INSTRUCTOR__________________ PERIOD ____PARTNERS_____________

THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL SCIENCE DEMONSTRATION

INTRODUCTION

Nearly everyone has heard of making fire by "rubbing two sticks together. To those who have tried without coaching, it often seems impossible. As reliable matches and lighters were only developed within the last 300 years, our ancestors had 3 choices for obtaining fire. The most convenient choice, once fire was harvested from a natural source, was to never allow the home or community fire to go out. In this case, no one needed to "make" fire. Without access to fire, people created it either by striking objects together to create a spark (for example, flint and steel) or rubbing two sticks together to create an ember by friction.

There are probably over one hundred different methods used by people around the world to create fire by friction. In this lab, you will learn the bow drill method of fire making. Though this technique requires more components and preparation than some other methods, it is among the most reliable techniques and, with practice, can be used successfully under virtually any conditions.

Before embarking on your quest for fire, take a few minutes to reflect on the role of fire in the lives of humans by answering the pre-lab questions below.

OBJECTIVE

To understand the science behind making fire by friction.

VOCABULARY

linear velocity	*rotational velocity*
acceleration	*deceleration*
friction	*coefficient of friction*
normal force	

PRE-LAB QUESTIONS

1. For what purposes did “primitive” peoples use fire?

2. For what purposes do we use fire in our modern world?

3. Some modern conveniences are listed below. See if you can figure out how each one is related to fire?

A. radiator in a building used for heat

B. electric light

C. air conditioner

4. How did "primitive" people obtain fire?

5. How do we obtain fire?

PROCEDURE

As with most skills, the knowledge required for success with the bow drill can be divided into three types: materials, methods and theory. We'll start with materials.

Materials*: The parts required for a bow drill are listed below. Figure 1 illustrates components A through D.* Use Figure 1 and information from your instructor to write a brief description of the following components of a bow drill fire making apparatus. Information provided later in this lab is also helpful.

A. bow

B. spindle

C. fireboard

D. handhold

E. lubricant

F. tinder bundle

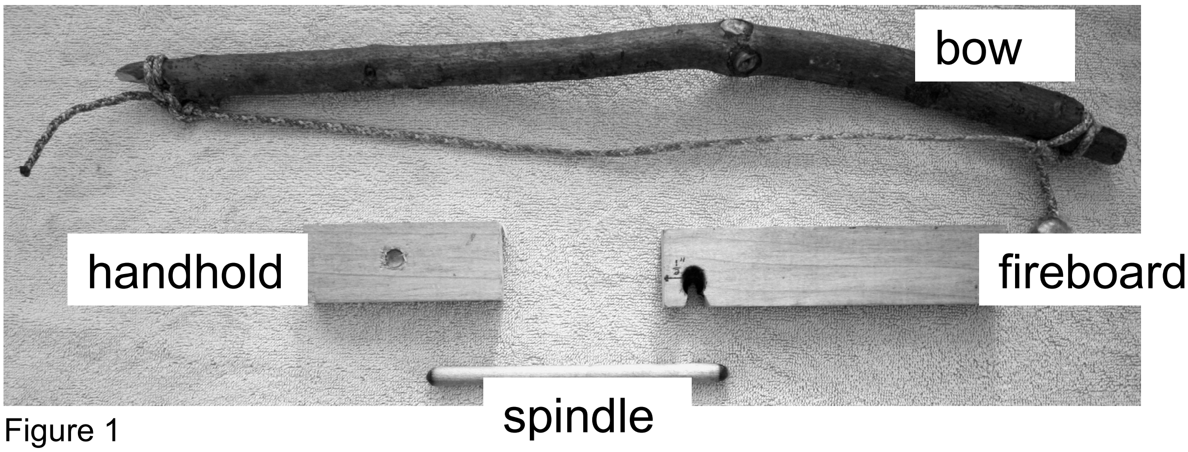


Figure 1

Technique: *The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 2-4 during the following description).*

The bowstring is wrapped around the cylindrical spindle. (Figure 2)

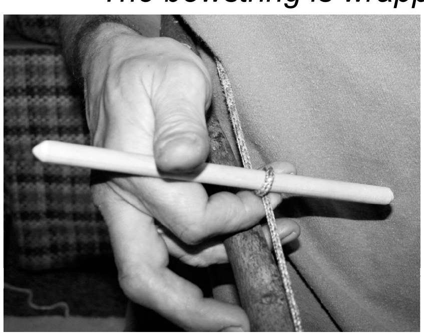


Figure 2

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 3)

Figure 3

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 4)

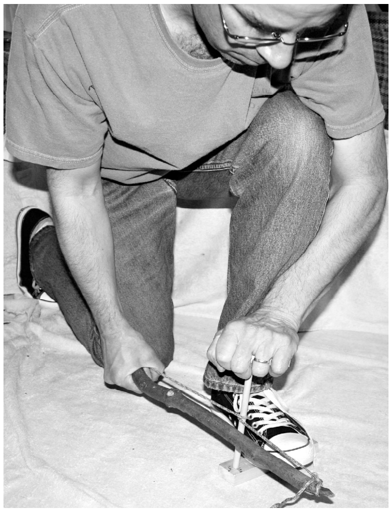


Figure 4

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this hot dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.

The proper technique will be demonstrated for you now.

6. First, write the length of the spindle before the demonstration: ___________________
(Be sure to include units)

7. During the demonstration, use the space below to record as many observations as possible. Remember, observations are made with all of your senses. Try to list at least 10 observations. List your observations in the space below then answer the following questions.

8. What is the length of the spindle AFTER the demonstration? _________________

9. What was the change in length of the spindle during the demonstration? __________

10. Describe changes to the hole in the fireboard during the demonstration.

11. Is the spindle always moving?

12. If it stops, when does this happen?

13. When is the spindle going fastest?

Theory: *Understanding the science behind fire by friction allows you to become much more effective, much more quickly.* **Friction and velocity** *are 2 key concepts involved in producing fire by friction.*

Friction *is defined as a force that resists the relative motion of objects in contact. The frictional force, F_f, is the product of the coefficient of friction, μ (a measure of the "stickiness" of the surfaces), and the normal force, N.*

In equation form, $F_f = \mu N$

14. Reread the description of the bow drill technique in the procedure section to figure out the two important tasks performed by friction between the spindle and fireboard. Describe them below. (Hint: Friction between the fireboard and spindle generates a type of energy and a type of matter. What are they?)

15. Describe as many ways as you can think of to increase the friction between the spindle and fireboard in the bow drill apparatus. (Use the definition of friction above and your knowledge of the bow drill to find them.)

16. The bow drill also requires the proper amount of friction between the bowstring and spindle. What do you think are the consequences of too little friction here? What are the consequences of too much friction here?

Velocity *is a measure of how fast and in what direction an object is moving.*

While learning to use the bow drill, you should have noted the spindle rotated at different speeds at different points in the bow stroke. There are three points at which we have information about the spindle's velocity. At the beginning of the stroke, velocity is zero. The x-axis on the graph below corresponds to the position of the spindle on the bowstring. The first half is on the outstroke (defined here as positive motion) and the second half is on the return stroke (defined as negative). The y-axis is a measure of velocity in arbitrary units. Positive velocities correspond to the outstroke and negative to the return stroke.

17. Make an X on the graph showing the velocity of the spindle is zero at the beginning of the bow stroke.

As the bow is pushed forward, the spindle accelerates to a maximum velocity until it must decelerate as you reach the other end of the bow. The velocity must again be zero at the end of the bow.

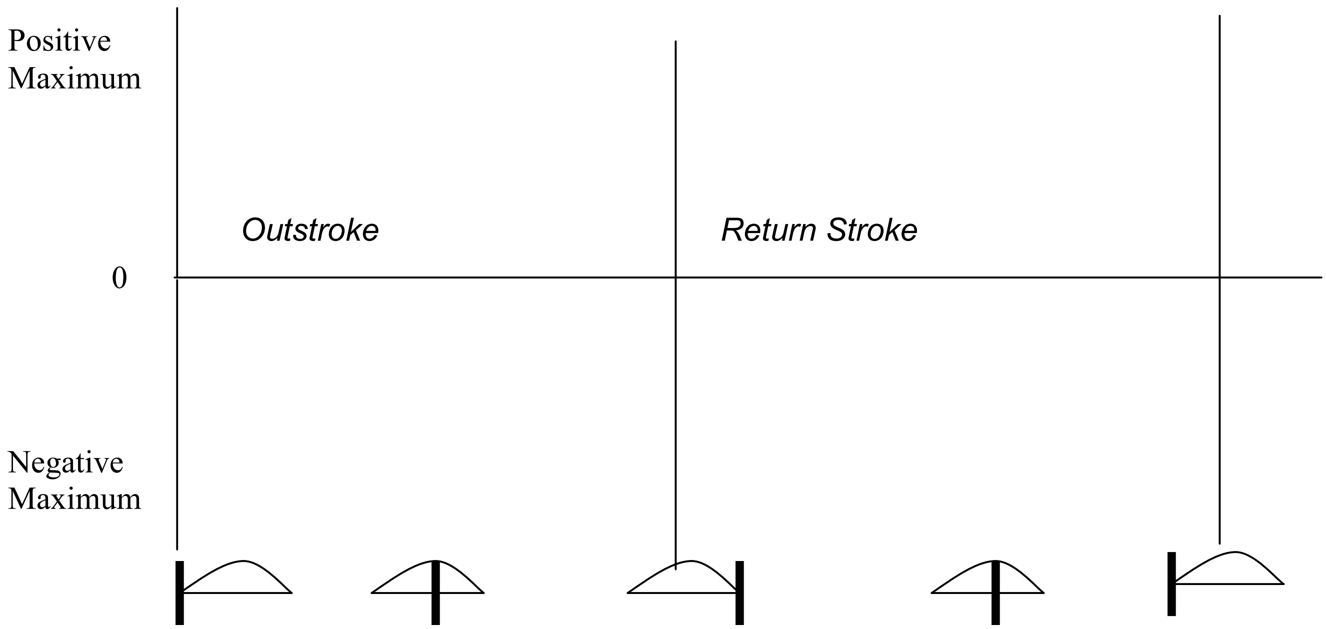
18. Make an X corresponding to zero on the graph below at the end of the bow stroke.

Also, the spindle must obtain a maximum velocity between these 2 points, probably near the middle of the bow.

19. Make an X corresponding to maximum velocity at the middle of the bow. Connect the points with a smooth freehand pencil line.

At the end of the outstroke, the spindle not only stops, but also changes direction. The return stroke now begins and has the same velocity profile as the outstroke except the velocities are in the opposite direction and defined here as negative.

20. Using the above information, plot the velocity of the spindle at the beginning, middle and end of the return bow stroke on the graph below. Connect the points with a smooth freehand pencil line.



21. Using your graph and experience with the bow drill, briefly describe the change in velocity of the spindle during a complete out and back cycle.

22. Imagine you had a longer bow. How might this affect the maximum velocity of the spindle?

23. Imagine you had a shorter bow. How might this affect the maximum velocity of the spindle?

24. Heat is generated by friction between the spindle and fireboard. The faster the rotation, the more heat and dust generated. Whenever the spindle stops moving, it is cooling. Keeping this in mind along with your answers to questions 21-23 above, would a longer or a shorter bow generate more heat in the same amount of time? Explain your answer.

Simple Machines and Velocity: *The bow and spindle act as a simple machine, transforming the linear motion imparted to the bow, to the rotational motion of the spindle. Following is an exercise to quantify this transfer.*

Make the following measurements to the nearest 0.1 cm.

25. Measure the length of your bowstring, l = _______________________

26. Measure the circumference of your spindle, c = _______________________
(Note that this is most easily done by wrapping a piece of paper or string around the spindle, marking the circumference and then measuring the paper on a ruler.)

27. r is the radius of the spindle. Calculate the radius of the spindle using the equation

$$r = \frac{c}{2 \times \pi}.$$ Assume $\pi = 3.14$

r = ________________________

28. Diameter = $2 \times r$. Calculate the diameter of the spindle.
d = ____________________

Assemble your bow drill set and use the technique you developed to get long, smooth bow strokes. Then do the following:

29. Use the stopwatch to count the number of bow strokes in one minute, n.
n = ____________________

Linear velocity *is the speed of an object moving in a straight line and is measured in units like miles per hour or centimeters per second. To find the linear velocity of the spindle, multiply the number of bow strokes per minute times the length of the bowstring. This gives the number of cm the spindle traveled in one minute. Mathematically;*
30. linear velocity, V_l = n x l = ______________________________________

(If you want a challenge, try to figure out how fast this is in miles per hour. Hint: 2.54 cm = 1 inch, 12 inches = 1 foot, 5280 feet = 1 mile, 60 minutes = 1 hour)

Rotational velocity, V_r, *is a measure of how many times an object rotates during a certain period of time. The rotational velocity of the spindle is obtained by dividing the linear velocity by the circumference of the spindle. The answer is in units of revolutions per minute, also know as rpm.*

31. rotational velocity, $V_r = \frac{n \times l}{c}$ = ________________________________

ANALYSIS AND CONCLUSION

Answer the following questions on a separate piece of paper.

1. Are the linear and rotational velocities you calculated in the last section instantaneous or average values? How do you know? What 's the difference?

2. Why is a lubricant used between the spindle and the handhold and not between the spindle and the fireboard?

3. Describe one way in which friction aids in creating an ember.

4. Describe one way in which friction wastes energy, making it more difficult to create an ember.

5. Describe the change in length of the spindle (Review your answer to Procedure question 8). Where did the wood go? How is this related to creating an ember?

6. Look at your answer to question 31 in the Procedure section. Do you think you could spin the spindle with the same velocity using only your hands? Explain your answer.

7. Describe 2 potential sources of error in your measurements

FOR FURTHER INVESTIGATION

1. Describe an assumption made in the calculation of rotational velocity.

2. What is the purpose of the notch in the fireboard?

3. Describe other methods used by people to make fire by friction?

4. What other techniques besides the bow drill did people use to make fire?

5. Why do you think different cultures used different techniques? Support your answer with at least one example.

5. Instead of making fire, some people harvested fire and stored it. How was this done?

6. Is fire making a uniquely human activity in the animal world? Support your opinion.

NAME____DATE_____________
INSTRUCTOR__________________ PERIOD ____PARTNERS_____________

THE SCIENCE OF BOW DRILL FIRE MAKING: PHYSICAL SCIENCE

INTRODUCTION

Nearly everyone has heard of making fire by "rubbing two sticks together. To those who have tried it without coaching, it often seems impossible. As reliable matches and lighters were only developed within the last 300 years, our ancestors had 3 choices for obtaining fire. The most convenient choice, once fire was harvested from a natural source, was to never allow the home or community fire to go out. In this case, no one needed to "make" fire. Without access to fire, people created it either by striking objects together to create a spark (for example, flint and steel) or rubbing two sticks together to create an ember by friction.

There are probably over one hundred different methods used by people around the world to create fire by friction. In this lab, you will learn the bow drill method of fire making. Though this technique requires more components and preparation than some other methods, it is among the most reliable techniques and, with practice, can be used successfully under virtually any conditions.

Before embarking on your quest for fire, take a few minutes to reflect on the role of fire in the lives of humans by answering the pre-lab questions below.

OBJECTIVE

To understand the science behind making fire by friction.

VOCABULARY

linear velocity

rotational velocity

acceleration

deceleration

friction

coefficient of friction

normal force

PRE-LAB QUESTIONS

1. For what purposes did “primitive” peoples use fire?

2. For what purposes do we use fire in our modern world?

3. Some modern conveniences are listed below. See if you can figure out how each one is related to fire.

A. radiator in a building used for heat

B. electric light

C. air conditioner

4. How did "primitive" people obtain fire?

5. How do we obtain fire?

PROCEDURE

As with most skills, the knowledge required for success with the bow drill can be divided into three types: materials, methods and theory. We'll start with materials.

Materials*: The parts required for a bow drill are listed below. Figure 1 illustrates components A through D.* Use Figure 1 and information from your instructor to write a brief description of the following components of a bow drill fire making apparatus. Information provided later in this lab is also helpful.

A. bow

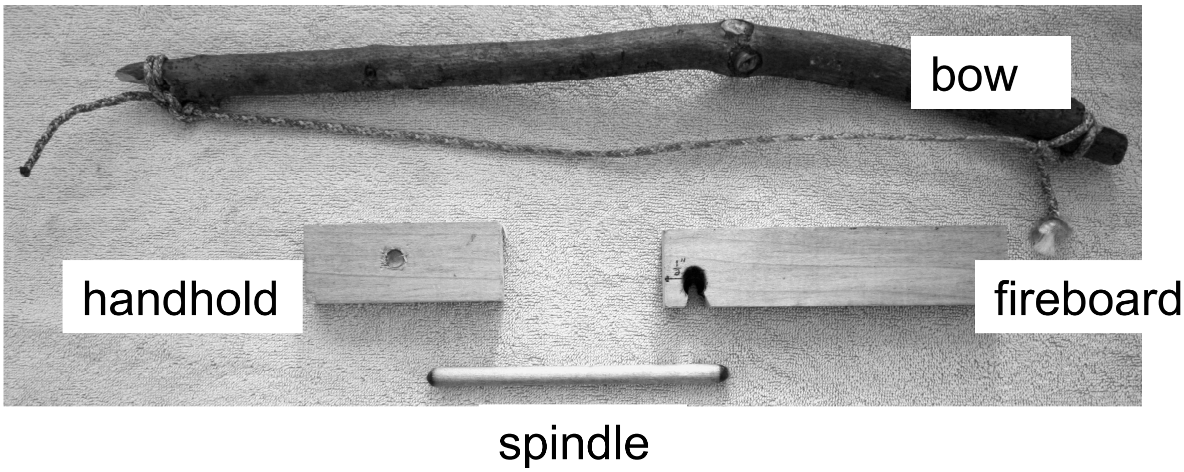
B. spindle

C. fireboard

D. handhold

E. lubricant

F. tinder bundle



Technique: *The basic idea of the bow drill is pretty simple, though challenging to master. (Refer to Figures 2-4 during the following description).*

The bowstring is wrapped around the cylindrical spindle. (Figure 2)

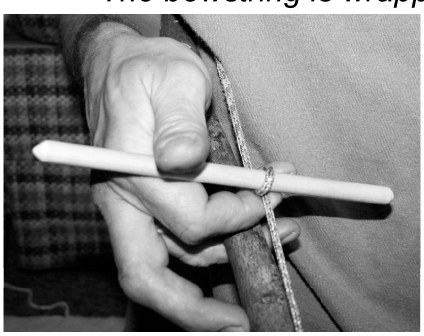


Figure 2

The spindle is then sandwiched vertically between the fireboard at the bottom and the handhold on top. (Figure 3)

Figure 3

As the bow is moved back and forth, the spindle rapidly rotates. (Figure 4)

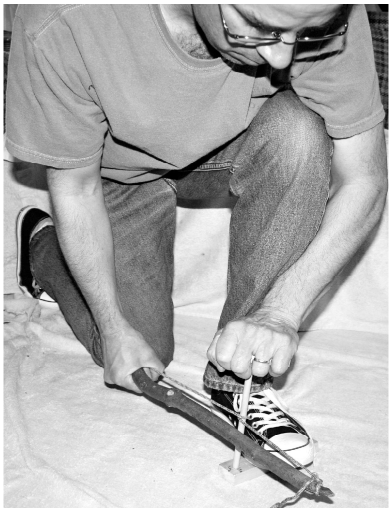


Figure 4

Downward pressure exerted on the handhold combined with the spinning motion causes wood to be worn off the mating surfaces of the spindle and fireboard. A notch cut into the fireboard collects this dust, causing it to compress and increase in temperature. With sufficient heat and pressure, the mass of dust becomes a glowing ember that can then transferred to a tinder bundle and blown into a flame. No dust or heat should be created at the spindle-handhold interface, as this would be a waste of energy. A lubricant, such as soap or pinesap, is used here to allow the spindle to spin as freely as possible.
The proper technique will be demonstrated for you now.

6. First, write the length of the spindle before the demonstration: ___________________
(Measure to the nearest 0.1 cm)

7. During this demonstration, use the space below to record as many observations as possible. Remember, observations are made with all of your senses. Try to list at least 10 observations. List your observations in the space below then answer the following questions.

8. What is the length of the spindle AFTER the demonstration? _________________
(Measure to the nearest 0.1 cm)

9. What was the change in length of the spindle during the demonstration? __________
(Measure to the nearest 0.1 cm)

10. Describe changes to the hole in the fireboard during the demonstration.

After carefully watching the demonstration, take about 10 minutes and work with your group to develop your own technique. **<u>As a group, your goal is to be able to move the bow continuously in smooth, long strokes for one minute.</u>** *While you are working on this, watch closely and try to answer the following questions:*

11. Is the spindle always moving?

12. If it stops, when does this happen?

13. When is the spindle going fastest?

List any other observations you made during your work.

<u>Theory:</u> *Understanding the science behind fire by friction allows you to become much more effective, much more quickly*. **Friction and velocity** *are 2 key concepts involved in producing fire by friction.*

Friction *is defined as a force that resists the relative motion of objects in contact. The frictional force, F_f, is the product of the coefficient of friction, μ (a measure of the "stickiness" of the surfaces), and the normal force, N.*

In equation form, $F_f = \mu N$

14. Reread the description of the bow drill technique in the Procedure section to figure out the two important tasks performed by friction between the spindle and fireboard. Describe them below. (Hint: Friction between the fireboard and spindle generates a type of energy and a type of matter. What are they?)

15. Describe as many ways as you can think of to increase the friction between the spindle and fireboard in the bow drill apparatus.

16. The bow drill also requires the proper amount of friction between the bowstring and spindle. What do you think are the consequences of too little friction here? What are the consequences of too much friction here? (You may have experienced one or both of these effects when you practiced with the apparatus.)

Velocity *is a measure of how fast and in what direction an object is moving.*

While learning to use the bow drill, you should have noted that the spindle rotated at different speeds at different points in the bow stroke. There are three points for which we have information about the spindle's velocity. At the beginning of the stroke, velocity is zero. The x-axis on the graph below corresponds to the position of the spindle on the bowstring. The first half of the x-axis corresponds to the outstroke (defined here as positive motion) and the second half corresponds to the return stroke (defined as negative). The y-axis is a measure of velocity in arbitrary units. Positive velocities correspond to the outstroke and negative velocity to the return stroke.

17. Make an X on the graph showing that the velocity of the spindle is zero at the beginning of the bow stroke.

As the bow is pushed forward, the spindle accelerates to a maximum velocity until it must decelerate as the spindle reaches the other end of the bow. This allows us to plot another point because the velocity must again be zero at the end of the bow.

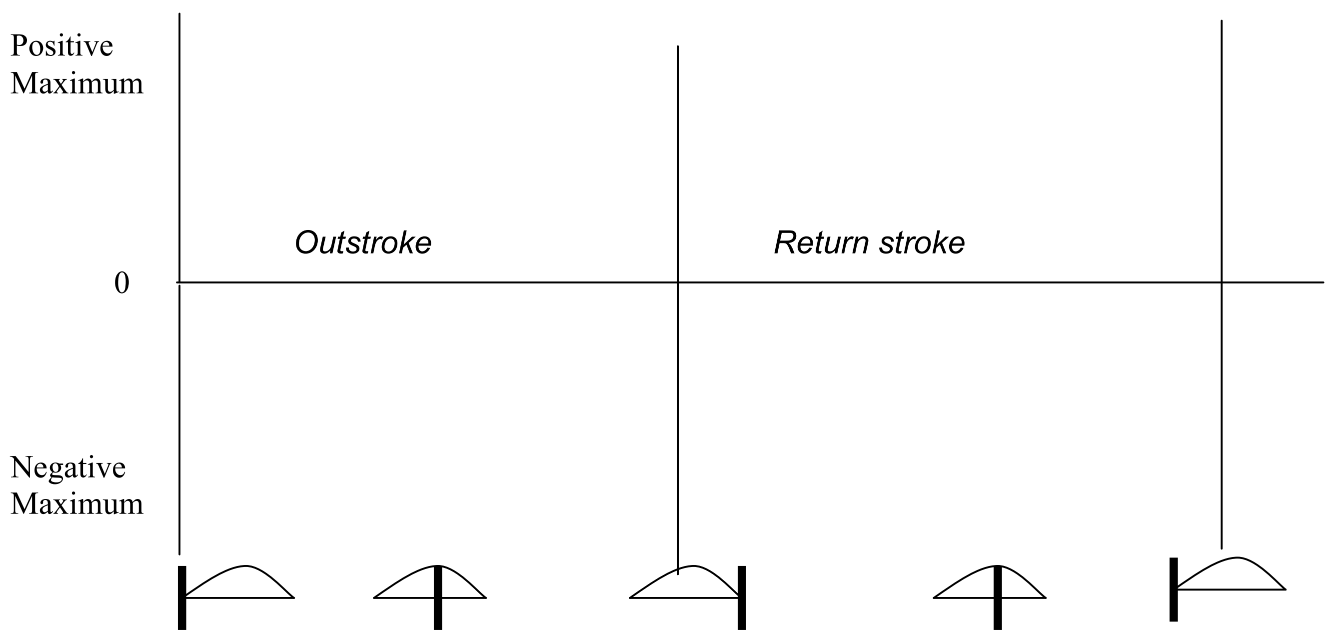
18. Make an X corresponding to zero on the graph below at the end of the bow stroke.

Also, the spindle must obtain a maximum velocity between these 2 points, probably near the middle of the bow.

19. Make an X corresponding to maximum velocity at the middle of the bow.
Connect the points with a smooth freehand pencil line.

At the end of the outstroke, the spindle stops. As the return stroke begins, the spindle reverses direction. It has the same velocity profile as the outstroke except the velocities are in the opposite direction and defined here as negative.

20. Using the above information, plot the velocity of the spindle at the beginning, middle and end of the return bow stroke on the graph below.
Connect the points with a smooth freehand pencil line.



21. Using your graph and experience with the bow drill, briefly describe the change in velocity of the spindle during a complete out and back cycle.

22. Imagine you had a longer bow. How might this affect the maximum velocity of the spindle?

23. Imagine you had a shorter bow. How might this affect the maximum velocity of the spindle?

24. The spinning of the spindle in the fireboard generates heat. The faster the rotation, the more heat and dust generated. Whenever the spindle stops moving, it is cooling. Keeping this in mind along with your answers to questions 21-23 above, would a longer or a shorter bow generate more heat in the same amount of time? Explain your answer.

Simple Machines and Velocity: *The bow and spindle act as a simple machine, transforming the linear motion imparted to the bow, to the rotational motion of the spindle. Following is an exercise to quantify this transfer.*

Make the following measurements to the nearest 0.1 cm.
25. Measure the length of your bowstring, l = ______________________

Next, assemble your bow drill set and use the technique you developed to get long, smooth bow strokes. Then:

26. Use the stopwatch to count the number of bow strokes in one minute, n.
n = ___________________

Linear velocity *is the speed of an object moving in a straight line and is measured in units like miles per hour or centimeters per second. To find the linear velocity of the spindle, multiply the number of bow strokes per minute times the length of the bowstring. This gives the number of centimeters the spindle traveled in one minute. Mathematically;*

27. linear velocity, $v_l = s \times l$ = ____________________________________

(If you want a challenge, try to figure out how fast this is in miles per hour. Hint: 2.54 cm = 1 inch, 12 inches = 1 foot, 5280 feet = 1 mile, 60 minutes = 1 hour)

Next, the linear velocity along with a few other measurements will be used to calculate the rotational speed of the spindle.

28. Measure the circumference of your spindle, c = _______________________
(Note that this is most easily done by wrapping a piece of paper or string around the spindle, marking the circumference and then measuring the paper on a ruler.)

Rotational velocity, v_r, *is a measure of how many times an object rotates during a certain period of time. Rotational velocity of the spindle is obtained by dividing the linear velocity by the circumference of the spindle. The answer will have units of revolutions per minute, also know as rpm.*

29. rotational velocity, $V_r = \frac{n \times l}{c}$ = ______________________________

ANALYSIS AND CONCLUSION

1. Are the linear and rotational velocities you calculated in the last section instantaneous or average values? How do you know? What 's the difference?

2. Why is a lubricant used between the spindle and the handhold and not between the spindle and the fireboard?

3. Describe one way in which friction aids in creating an ember.

4. Describe one way in which friction wastes energy, making it more difficult to create an ember.

5. Describe the change in length of the spindle (Review your answer to Procedure question 8). Where did the wood go? How is this related to creating an ember?

6. Look at your answer to question 31 in the previous section. Do you think you could spin the spindle with the same velocity using only your hands? Explain your answer.

7. Describe 2 potential sources of error in your measurements

8. Fill in the table below with data from each group in your class.

Group Number	Length of Bowstring (cm)	Circumference of Spindle (cm)	Rotational Velocity (revolutions/minute)
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			

A. Does your data show a relationship between the length of the bowstring and rotational velocity? If so, describe the relationship.

B. Does your data show a relationship between the circumference of the spindle and rotational velocity? If so, describe the relationship.

FOR FURTHER INVESTIGATION

1. Describe an assumption made in the calculation of rotational velocity.

2. What is the purpose of the notch in the fireboard?

3. Describe other methods used by people to make fire by friction?

4. What other techniques besides the bow drill did people use to make fire?

5. Why do you think different cultures used different techniques? Support your answer with at least one example.

5. Instead of making fire, some people harvested fire and stored it. How was this done?

6. Is fire making a uniquely human activity in the animal world? Support your opinion.