THE FIRST SCIENTIFIC STUDY OF MUSICAL SOUNDS

TOPIC:

Relationship among Sound Pitch, String Length, and Tension

SCIENTIST:

Pythagoras c.580–c.500 BC

INTRODUCTION:

Unfortunately, none of the writings of the great Greek thinker Pythagoras of Samos have survived, but we know of his work because his pupils wrote down what he taught them. Pythagoras was especially interested in mathematics and believed that everything could be explained by numbers. Everyone knew that when you plucked the string of a bow it gave off a musical note. One day Pythagoras decided to try to find out what happened when strings of different lengths were plucked. He knew that a tight string produced a higher pitch than a slacker string, so he decided to work with a single string of constant tension and to see what happened when parts of the string were plucked. He also decided to see how the pitch of the note was related to the tension on the string. The simple apparatus Pythagoras made is called a "monochord"; after you have made one very similar to the one he made, you will carry out the same experiments he did and find out what he discovered.

TIME NEEDED:

1 hour

MATERIALS:

- strong lumber plank 110 cm x 5 cm x 3 cm
- 2 pieces of triangular section hardwood molding 5 cm long and 3 cm high at the apex
- 2-in. nail
- wooden meter ruler, calibrated in cm
- 2 m length of fine steel wire, about 25 awg
- upright bullet block (small metal pulley-wheel mounted in bracket with two screw holes)*
- 2 1-in. screws
- 4 lb., 9 lb., and 16 lb. weights (fishing weights are recommended because they have holes to string the wire through)
- 3 m length of picture cord (strong cord used for hanging pictures and mirrors)
- Krazy Glue® or other contact adhesive
- hammer
- screwdriver
- awl
- pliers
- safety goggles
- duct tape
- pencil
- pen
- small metal hook (*e.g.*, an S-hook)

*Available from a marine supply store.

Original Materials:

There is no record of the materials Pythagoras used for his monochord. The experiment is more impressive if a hollow box with a thin top is used, as the top acts as a sounding board and gives louder tones. Pythagoras, who was familiar with plucked musical instruments of the day, may have used a hollow box, but this is unnecessary and his experiment can be followed without it.

Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Be careful to use good-quality flexible wire on your monochord as breaking wire might be dangerous. Use caution near the weights; if the wire breaks, the falling weights could cause injury. Wear safety goggles when carrying out the experiment to protect your face in case the wire breaks.

PROCEDURE:

1. Mark a point 5 cm from one end of the plank, in the center, using the pencil. Hammer in the nail at this point, leaving about 2 cm of the nail protruding.
2. Stick one of the triangular section pieces of wood (the first bridge) across the plank about 3 cm from the nail (see figure 1) using contact adhesive such as Krazy Glue®.
3. Draw a line down the middle of the plank, from one end to the other, using the meter ruler and a pencil. Make marks 50 cm, 66 cm, 75 cm, and 100 cm from the top of the first bridge.
4. Attach the pulley to the edge of the other end of the plank using two screws and a screwdriver as shown in figure 2 so that the pulley wheel movement is parallel to the long axis of the plank.
5. Set the other triangular piece of wood (the second bridge) across the end of the plank with the pulley so that the tops of the two bridges are exactly 1 m apart. DO NOT GLUE this second bridge to the plank.
6. Twist one end of the wire two or three times round the nail, just below the head, making sure you leave approximately 4 cm of wire protruding at the free end. Then twist the free end a dozen times around the long piece of wire next to the nail, using the pliers to tighten it (see figure 3).
7. Position the plank so that the pulley end overhangs the edge of a table. Secure it to the table using duct tape (so that it does not slip during the experiment).
8. Stretch the wire over the first bridge, along the line in the middle of the plank, over the second bridge, and over the pulley.
9. Attach the metal hook to the end of the wire about 30 cm beyond the pulley, twisting the wire as you did with the nail.
10. Tie some picture cord around or through the 4 lb., 9 lb., and 16 lb. weights so that they can be suspended from the hook.
11. Put on the safety goggles. Attach the 4 lb. weight to the hook. Let the weight sit for about 10 minutes to let the wire tense up.

Figure 1

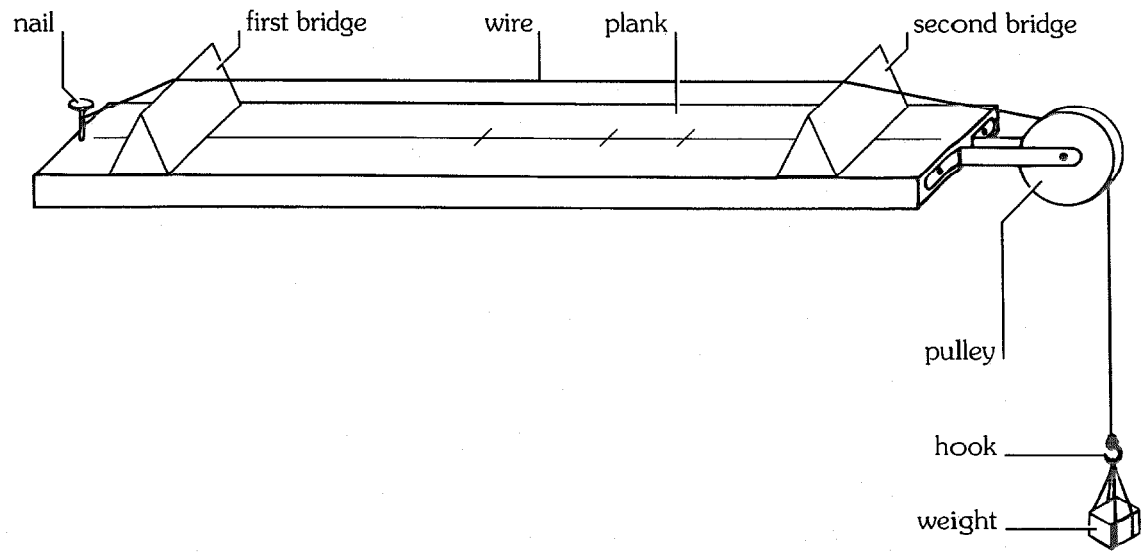


Figure 2

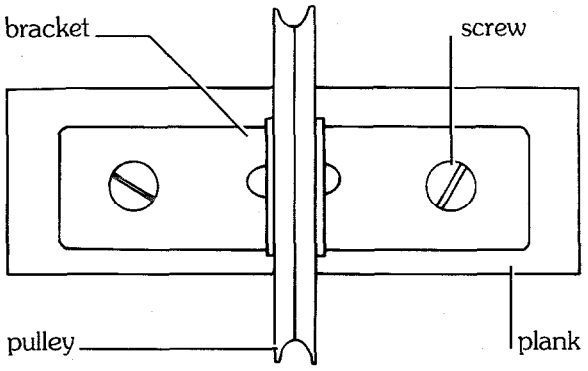
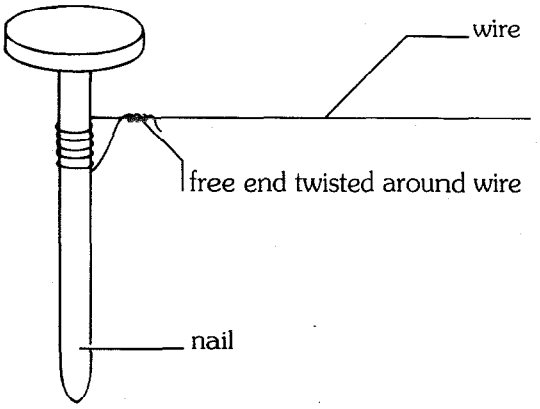


Figure 3



12. Pluck the string, or tap it with a pen (whichever produces the better sound), and listen carefully to the pitch of the sound of the 100-cm length wire.
13. Move the second bridge along to the 50-cm mark and pluck the wire again. Compare the pitch of the 100-cm wire with that of the 50-cm wire using the "do, re, me, fa, so, la, te, do" scale. Record your findings (note that 50 cm is ½ of 100). Repeat this several times with both lengths until you are sure of your comparison.
14. Repeat step 13, comparing the pitch of the 100-cm wire with the pitch of a 66-cm length of wire (*i.e.*, move the second bridge to the 66-cm mark). Record your findings (note that 66 cm is ⅔ of 100).
15. Repeat step 13 comparing the pitch of the 100-cm wire with the pitch of a 75-cm length of wire. Record your findings (note that 75 cm is ¾ of 100).
16. Return the second bridge to the 100-cm position and listen to the pitch of the note. Remove the 4 lb. weight and add the 16 lb. weight. Compare the pitch produced by the two weights using the method described in step 13. Record your findings.
17. Repeat steps 12 to 15 using the 16 lb. weight.
18. Repeat step 16, comparing the 4 lb. weight to the 9 lb. weight.
19. Repeat steps 12 to 15 using the 9 lb. weight.

ANALYSIS:

1. What did you notice about the change in the pitch of the note between steps 12 and 13?
2. What did you notice about the change in the pitch of the note when the length of the wire was adjusted from 100 cm to 66 cm in step 14?
3. What did you notice about the change in the pitch of the note when the length of the wire was adjusted from 100 cm to 75 cm in step 15?
4. How did the pitch of the 100-cm wire change when you altered the tension of the wire by a) replacing the 4 lb. weight with the 16 lb. weight, and b) replacing the 4 lb. weight with the 9 lb. weight?

OUR FINDINGS:

Click on above link to see what we found.

SPECIAL SAFETY NOTE TO EXPERIMENTERS

Each experiment includes any special safety precautions that are relevant to that particular project. These do not include all of the basic safety precautions that are necessary whenever you are working on a scientific experiment. For this reason, it is absolutely necessary that you read, copy, and remain mindful of the General Safety Precautions that follow this note.

Experimental science can be dangerous, and good laboratory procedure always includes carefully following basic safety rules. Things can happen very quickly while you are performing an experiment. Things can spill, break, even catch fire. There will be no time after the fact to protect yourself. Always prepare for unexpected dangers by following basic safety guidelines the *entire* time you are performing the experiment, whether or not something seems dangerous to you at a given moment.

We have been quite sparing in prescribing safety precautions for the individual experiments. We made this choice for one reason: We want you to take very seriously every safety precaution that is printed in this book. If you see it written here, you can be sure that it is here because it is absolutely critical to your safety.

One further note: The book assumes that you will read the safety precautions that follow, as well as those in the box within each experiment you are preparing to perform, and that you will *remember* them. Except in rare instances, these precautions will not be repeated in the procedure itself. It is up to you to use your good judgment and pay attention when performing potentially dangerous parts of the procedure. Just because the book does not say BE CAREFUL WITH HOT LIQUIDS or DON'T CUT YOURSELF WITH THE KNIFE does not mean that you should be careless when simmering water or stripping an electrical wire. It does mean that when you see a special note to be careful, it is extremely important that you pay attention to it.

If you ever have a question about whether a procedure or material is dangerous, wait to perform it until you find out for sure that it is safe.

GENERAL SAFETY PRECAUTIONS

Accidents caused by carelessness, haste, insufficient knowledge, or taking unnecessary risks can be avoided by practicing safety procedures and being alert while conducting experiments. Be sure to check the experiments in this book for additional safety regulations and adult supervision requirements. If you will be working in a lab, do not work alone.

PREPARING:
—Clear all surfaces before beginning experiments
—Read the instructions before you start
—Know the hazards of the experiments and anticipate dangers

PROTECTING YOURSELF:
—Follow the directions step-by-step; do only one experiment at a time
—Locate exits, fire blanket and extinguisher, master gas and electricity shut-offs, eye wash, and first-aid kit
—Make sure there is adequate ventilation
—Do not horseplay
—Wear an apron and goggles
—Do not wear contact lenses, open shoes, loose clothing, or loose hair
—Keep floor and work space neat, clean, and dry
—Clean up spills immediately
—Never eat, drink, or smoke in laboratory or work space
—Do not eat or drink any substances tested unless expressly permitted to do so by a knowledgeable adult

USING EQUIPMENT WITH CARE:
—Set up apparatus far from the edge of the desk
—Use knives and other sharp or pointed instruments with caution
—Pull plugs, not cords, when removing electrical plugs
—Don't use your mouth to pipette; use a suction bulb
—Clean glassware before and after use
—Check glassware for scratches, cracks, and sharp edges
—Clean up broken glassware immediately
—Do not use reflected sunlight to illuminate your microscope
—Do not touch metal conductors
—Use only low voltage and current materials such as lantern batteries
—Be careful when using stepstools, chairs, and ladders

USING CHEMICALS:
—Never taste or inhale chemicals
—Label all bottles and apparatus containing chemicals
—Read labels carefully
—Avoid chemical contact with skin and eyes (wear goggles, apron, and gloves)
—Do not touch chemical solutions
—Wash hands before and after using solutions
—Wipe up spills thoroughly

HEATING SUBSTANCES:
—Use goggles, apron, and gloves when boiling water
—Keep your face away from test tubes and beakers
—Never leave apparatus unattended
—Use safety tongs and heat-resistant mittens
—Turn off hot plates, bunsen burners, and gas when you are done
—Keep flammable substances away from heat
—Have fire extinguisher on hand

FINISHING UP:
—Thoroughly clean your work area and glassware
—Be careful not to return chemicals or contaminated reagents to the wrong containers
—Don't dispose of materials in the sink unless instructed to do so
—Wash your hands
—Clean up all residue and put in proper containers for disposal
—Dispose of all chemicals according to all local, state, and federal laws

BE SAFETY CONSCIOUS AT ALL TIMES