HOW THE MOTION OF A SOUND SOURCE AFFECTS THE PITCH OF THE SOUND HEARD BY AN OBSERVER

TOPIC:

The Doppler Effect

SCIENTIST:

Christian Doppler 1803–1853

INTRODUCTION:

By the nineteenth century, scientists had described many of the characteristics of sound. Robert Boyle (see 1.009) showed in the seventeenth century that sound would not travel through a vacuum. Later it was shown that sound travels through air, water, and solids in the form of a longitudinal wave. Between the seventeenth and nineteenth centuries the speed of sound in both air and water was measured. By the beginning of the nineteenth century, however, there was a strange phenomenon concerning sound waves that remained unexplained. If a sound is moving toward a stationary observer the pitch of the sound apparently gets higher as it approaches the observer; as soon as it passes the observer, the sound apparently becomes more deeply pitched. A modern example of this effect happens when you are standing by the side of the street and a police car goes past with its siren on. Christian Doppler became fascinated by this problem. In 1842 he wrote a paper explaining the phenomenon in the following way. Sound waves that are close together have a higher pitch (frequency) than sound waves that are spread out. The sound waves from an approaching source of sound become "squashed together," so raising their pitch as heard by an observer. When the sound source passes by and then departs, its sound waves stretch out, thus lowering the pitch heard by the observer. Doppler showed mathematically the relationship between sound and the relative movement of source and observer. He arranged to have his theory put to the test in 1845 in a bizarre experiment organized by Dutch meteorologist Christophorus Buys Ballot (1817–1890). Musicians with perfect pitch—they could identify the pitch of musical notes precisely—were positioned next to a railroad track. A number of trumpeters placed in an open railroad truck played specific notes as they were driven past the musicians at different speeds. The musicians, meanwhile, recorded the notes they heard as the train approached or went past. The experiment, which took two days, confirmed Doppler's theory.

TIME NEEDED:

30 minutes

MATERIALS:

doorway with a wooden frame
thumbtack (or short nail and hammer)
1.5 m string
small sound source that produces a continuous, high-pitched sound (*e.g.*, electronic watch, kitchen timer, small electronic alarm clock, compact camera with battery sound tester switched on)
chair
safety goggles
optional: thick foam mat to place underneath experiment in case the sound source falls to the ground

Original Materials:

As stated in the Introduction, Doppler used a team of trumpeters and musicians and a railroad truck and locomotive.

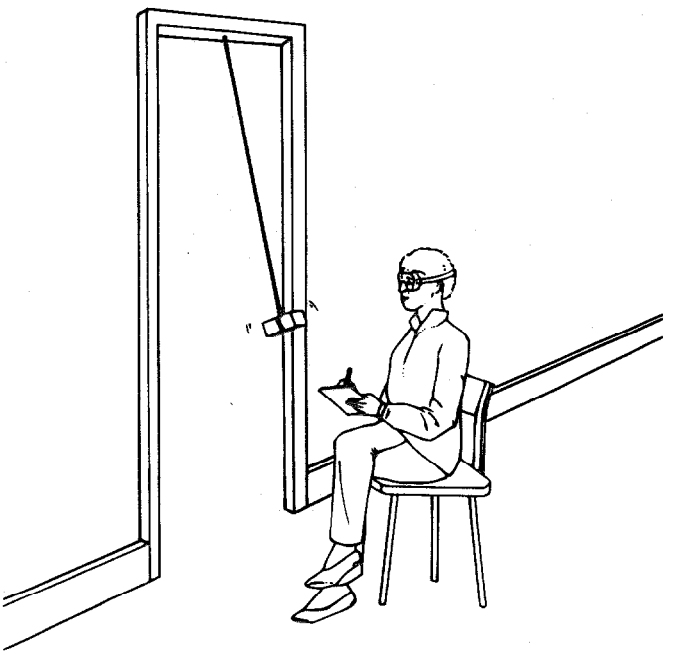
Safety Precautions

Please read and copy the safety precautions at the beginning of this book. Wear safety goggles in case the thumbtack or nail comes loose.

PROCEDURE:

1. Tie one end of the string around the thumbtack or short nail.
2. Push the thumbtack, or hammer the nail, into the center of the underside of the top of the door frame.
3. Tie the other end of the string carefully and securely to the sound source, so making a pendulum with a drop of about 1 m. Put the foam mat, if you use one, under the pendulum.
4. Practice using the pendulum. Pull back the pendulum by approximately 0.5 m and release it as smoothly as possible so that it does not wobble while swinging.
5. Position the chair facing the doorway so that when you repeat step 4 the sound source pendulum swings toward and away from you (see figure 1).

Figure 1



6. Switch on the sound source. Repeat step 4, listening carefully to the sound. Position your head just beyond the limit of the pendulum's backswing. Keep still while you listen. Carefully note any changes in the pitch and volume of the sound as the sound source swings toward then away from you.
7. Repeat the experiment as often as you need to make clear observations.

ANALYSIS:

1. Describe what happened to the pitch of the sound when the sound source pendulum was swinging.
2. Did any other sound characteristic change when the pendulum was swinging, and how did it affect your interpretation of the Doppler effect?

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