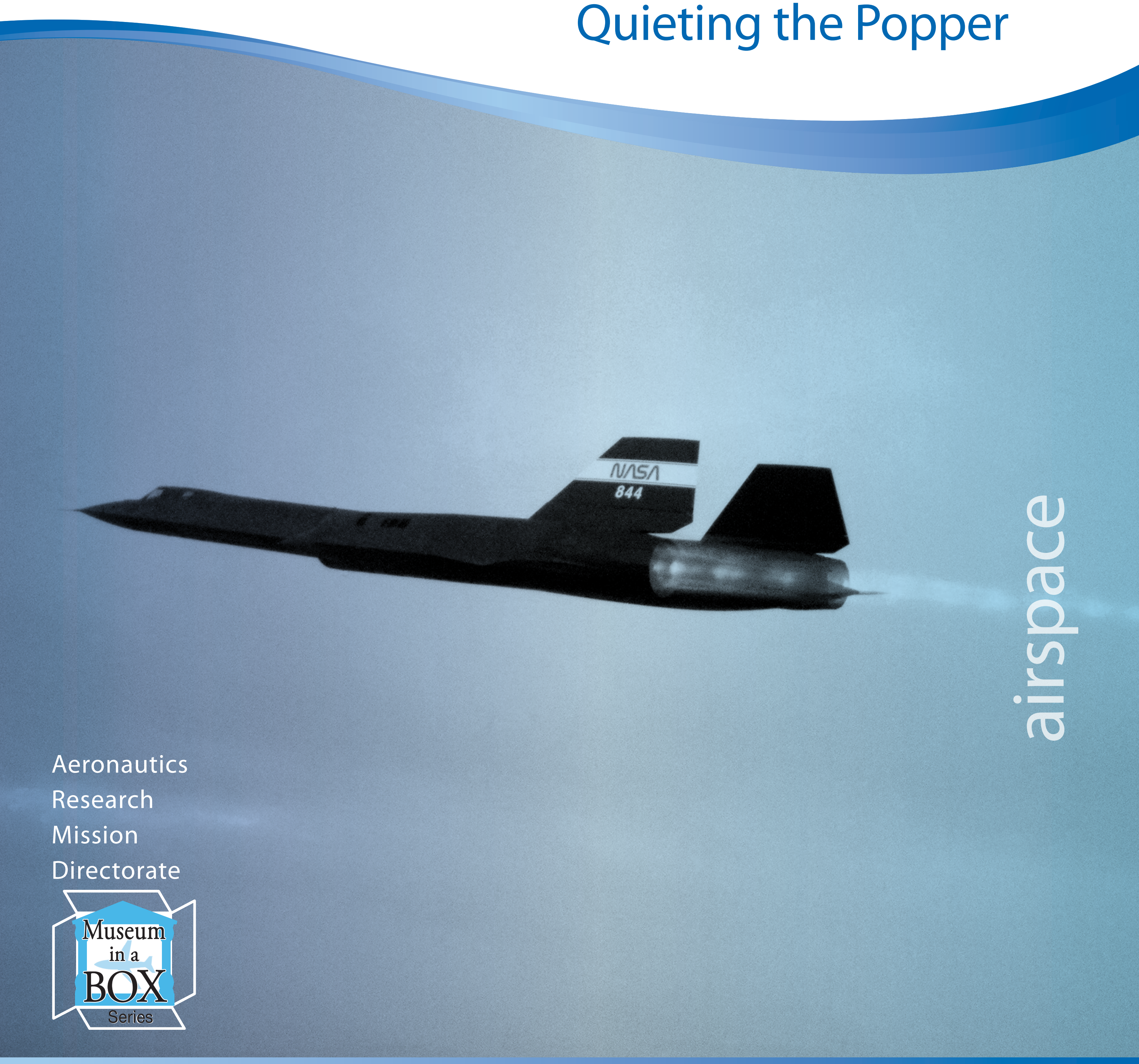
National Aeronautics and Space Administration

GRADES 5-12

Quieting the Popper



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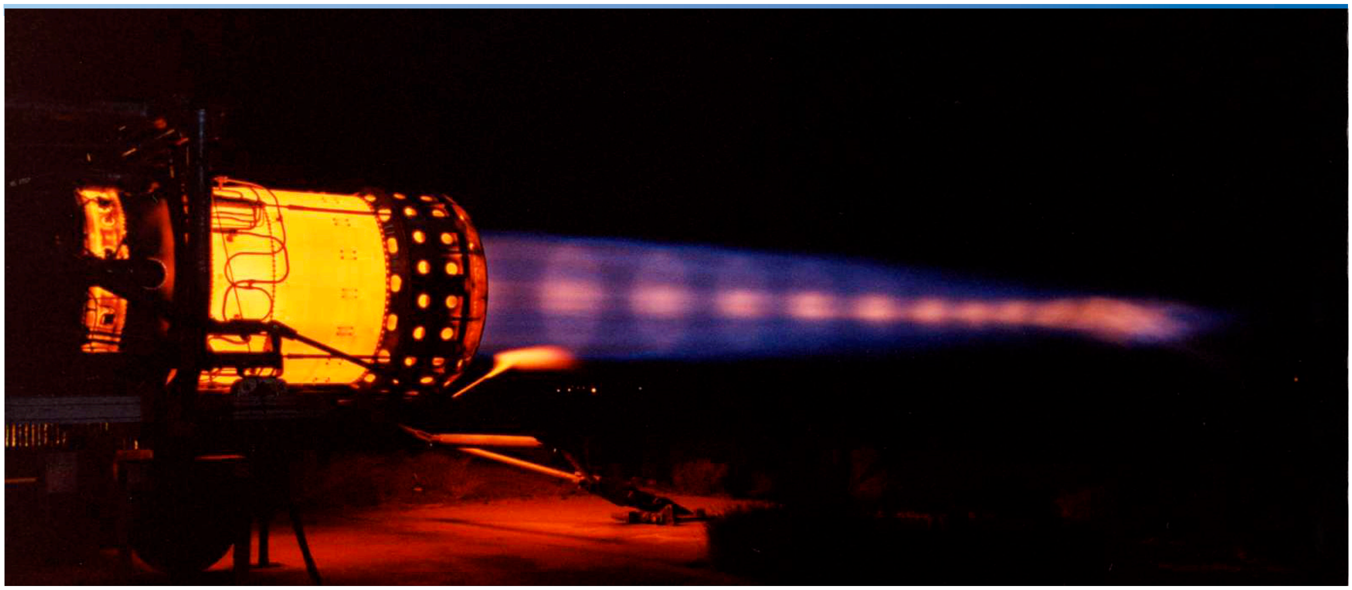


Quieting the Popper

Lesson Overview

In this lesson, students will learn about motions and forces, transfer of energy, and the abilities of technological design as they attempt to silence the noise created by a piezoelectric "Popper". This activity will teach students how sound waves travel and what methods can be employed to suppress them.

Objectives

Students will:

1. Use a variety of materials and methods to reduce or eliminate the noise created by a piezoelectric "Popper."

Materials:

In the Box

Piezoelectric "Popper"

Pipette

Ear protection (2)

Decibel meter

Goggles (2)

Provided by User

Combustible fluid
(see warning box in Activity 1 for details)

Sound dampening materials such as:
- Blankets
- Pillows
- Towels
- Heavy coats

Cardboard boxes/tubes

Scissors

Tape

Metric ruler

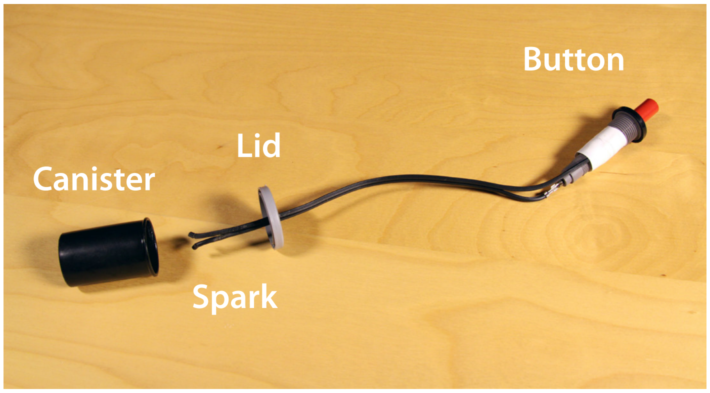
Hairdryer (optional)

GRADES 5-12 **Time Requirements:** 2 hours

Background

The Mechanics of the Popper

The "Popper" is a piezoelectric device used to create a spark, which ignites the vapor released by a combustible fluid. (Piezo is derived from the Greek word meaning to squeeze or press.) The spark itself is simply an electrical spark, no different to that produced by a faulty electrical cable or used in certain types of welding. It is created by applying pressure to a special crystal, typically quartz, which, due to its molecular properties, produces electricity. That electricity is then transmitted along a copper wire where normally it would be used to power a circuit. In this case though, the electricity is allowed to spark by "jumping" between two copper wires.



In addition to the spark, the device also needs a combustible substance to make the explosion. The vapor ignited by the "Popper" is produced by allowing a small amount of combustible liquid with a low flash point, such as ethanol, to evaporate.

The Science of Sound

Sound is something most of us take for granted and rarely do we consider the physics involved. It can come from many sources – a voice, machinery, musical instruments, computers – but all are transmitted the same way: through vibration.

In the most basic sense, when a sound is created it causes the molecule nearest the source to vibrate. Since this molecule is touching another molecule, it causes that molecule to vibrate too. This continues, from molecule to molecule, passing the energy on as it goes. This is also why at a rock concert, or even being near a car with a large subwoofer, you can feel the bass notes vibrating inside you. The molecules of your body are vibrating, allowing you to physically feel the music.

As with any energy transfer, each time a molecule vibrates or causes another molecule to vibrate, a little energy is transferred to the atoms and molecules the wave touches, which is why sound gets quieter with distance (Fig. 1) and why louder sounds, which cause the molecules to vibrate more, travel farther. The loudness of a sound is measured in decibels, or dB, with sounds above 120dB having the ability to cause permanent hearing loss to humans.

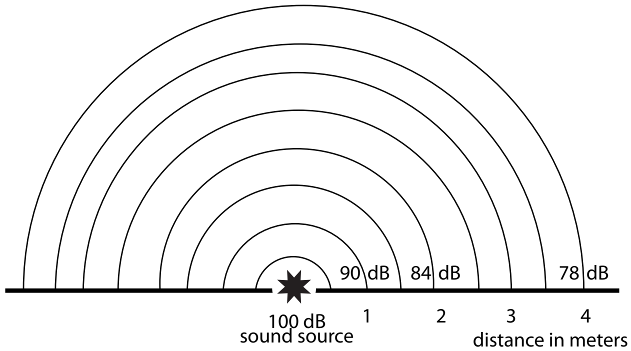


Fig. 1 Sound vs Distance

The loudness of a sound is more of a human perception and interpretation than a scientific quantity or property. However, volume can be measured in terms of the amount of energy that travels over a specified distance within a specific period time. This is measured in watts per square meter, where a watt is energy/time (joules/sec). Another important point of note is that it takes ten times as much energy to produce a noise that sounds only twice as loud as another. Correspondingly, in order to halve the noise something produces, we have to reduce its energy by a factor of 10.

Jet plane at takeoff	110-140dB
Loud rock music	110-130dB
Chain saw	110-120dB
Thunderstorm	40-110dB
Vacuum cleaner	60-80dB
Normal voices	50-70dB
Whisper	20-50dB
Purring cat	20-30dB
Falling leaves	10dB
Silence	0dB

Sound Suppression

Sometimes loud sounds are desirable and in some cases, can even be beneficial. Burglar alarms, police sirens or the loud "ping" of a piece of medical equipment are necessary to signal that assistance is required. Other times however, loud noise is potentially hazardous to health, or simply unwelcome, as in the case of the engine noise of an aircraft.

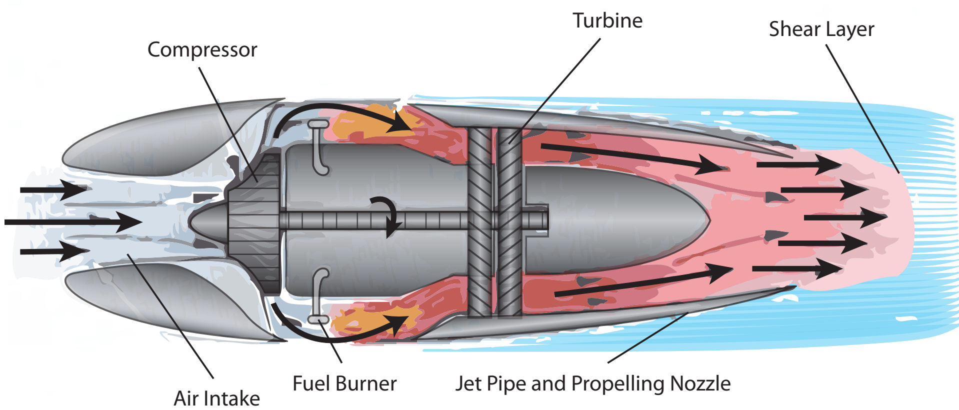


Fig. 2 Turbo-jet engine

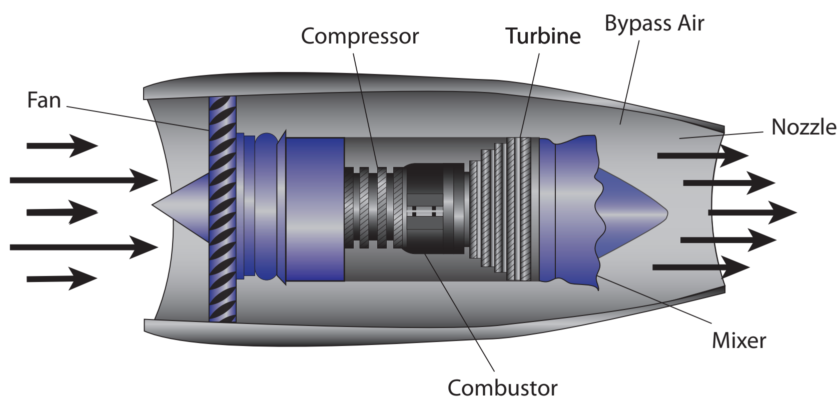


Fig. 3 Turbo-fan engine with mixer

Over the years, manufacturers have had to make significant changes to the design of aircraft engines in order to reduce the noise they produce. In the 1950s and '60s, the raw thrust of a jet engine could be heard from almost a mile away, yet today their noise levels are tolerable from very short distances. With most older jet-powered engines, called turbo-jet engines, the noise predominately came from the exhaust, where the extremely hot gasses mixed with the ambient air, creating a shearing effect, where the fast moving exhaust gasses rub against the slower moving ambient air (Fig. 2). This in turn produced a very loud, hissing noise. In modern turbo-fan engines however, cold bypass air is mixed with the exhaust gasses, cooling it in a controlled way and greatly reducing the noise produced (Fig. 3).

The Boeing 787 Dreamliner, Boeing's latest passenger aircraft, takes this approach one step further with the introduction of chevrons on the exhaust nozzle. This further reduced engine noise by four decibels.

Fig. 4 The Boeing 787 Dreamliner

For decades, NASA has been studying aircraft noise in order to reduce the impact jet aircraft have on the world. In 1992, NASA initiated the Advanced Subsonic Technology (AST) program, a partnership between NASA, the U.S. aviation industry, and the Federal Aviation Administration. The goal of the AST program was to develop technologies that enabled a safe, highly productive global air transportation system, without increasing the manufacturing or operating costs of the aircraft.

The simplest way of reducing noise is to reduce the number of molecules available to vibrate. In a vacuum for example, there are no air molecules to vibrate and as such, sound cannot travel away from the origin of the noise, regardless of how loud the original sound may be. Another method is to reduce its energy in a controlled way so that by the time it reaches our ears, its level is safe. The muffler of a car's exhaust (Fig. 5), for example, uses baffles to increase the distance the gases have to travel, as well as constantly changing its direction, with each turn further reducing the energy available for noise production. The down side to this method is that this muffler style is fairly large, so cannot be used on smaller vehicles such as motorcycles. With motorcycles, the muffler uses a combination of tubes with holes and fiberglass padding (Fig. 6), similar to that used in insulating a home. The tubes make it harder for the sound to escape and when it eventually does, it is predominately absorbed by the padding before being released into the atmosphere.

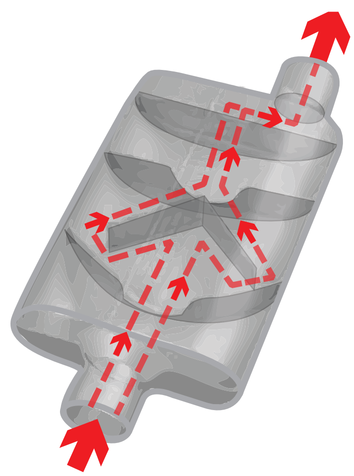


Fig. 5 Car muffler

New techniques for reducing noise emissions from engines are constantly being developed. For more information on the science of sound, please refer to the Museum in a Box lessons "Good Vibrations" and "Seeing Sound".

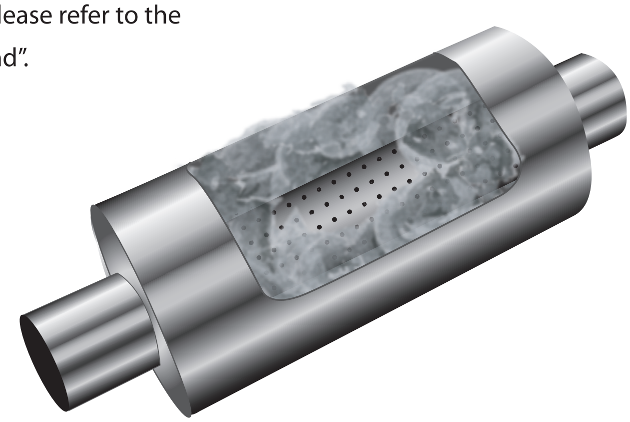


Fig. 6 Motorcycle muffler

Activity 1 Quieting the Popper

GRADES 5-12

Time Requirements: 2 hours

Materials:

In the Box

Piezoelectric "Popper"
Pipette
Ear protection (2)
Decibel meter
Goggles (2)

Provided by User

Combustible fluid (see warning box)
Sound dampening materials such as:
Blankets
Pillows
Towels
Heavy coats
Cardboard boxes/tubes
Scissors
Tape
Metric ruler
Hairdryer (optional)

Worksheets

Sound Supression Experiments (Worksheet 1)

Reference Materials

Decibel Meter Instructions

Objective:

In this activity, students will learn about motions and forces, transfer of energy, and the abilities of technological design as they use a variety of materials and methods to reduce or eliminate the noise created by a piezoelectric "Popper."

Activity Overview:

Students will use a piezoelectric "Popper", a device that ignites a small amount of flammable vapor in order to generate a loud bang. Then, by using simple household materials, they will try to reduce or eliminate that noise as much as possible.

WARNING: This activity uses a small amount of flammable liquid and explosive vapor. It is imperative that the students are properly briefed on the safety measures described below while performing this activity. While the chances of fire are very low if the instructions below are followed correctly, you may want to consider having a fire extinguisher readily available, if only to visually reinforce the inherent dangers of working with combustible fluids.

The lesson requires the use of a combustible liquid that vaporizes at a low temperature. As such, only perfume, nail polish remover, ethanol or rubbing alcohol should be used.

1. **Explain to the students that this activity uses a device that creates a loud bang, similar in sound and volume to a gunshot.** Ask if anyone is sensitive to loud noises or has a medical condition which may preclude them from taking part in the experiment.
   While most students will have no issues with loud noises, there might occasionally be a student with a medical or psychological condition that would preclude them from participating. If you are working near other classrooms or groups, you should alert them of the loud noises you are about to produce as well.

Key Terms:

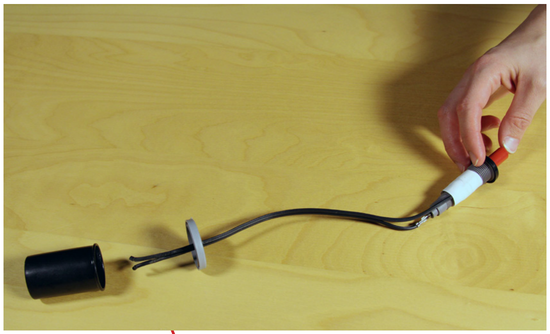
Attenuation
Decibel
Muffler
Piezoelectricity
Turbo-jet engine
Turbo-fan engine
Vacuum
Vaporize

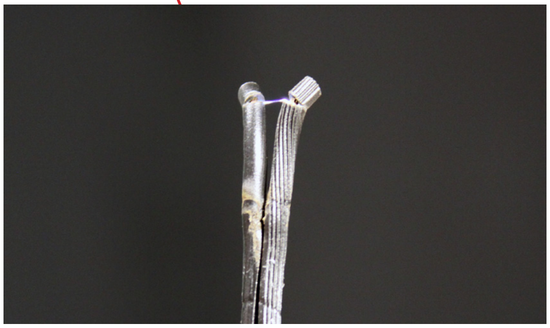
Correct Way

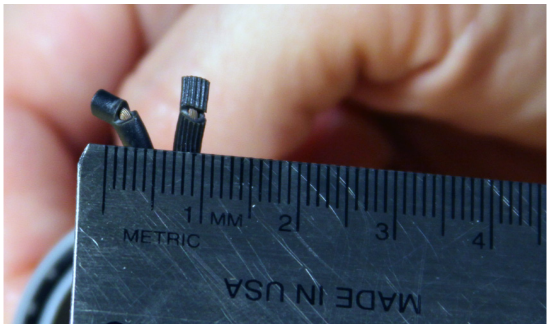
Incorrect Way

WARNING: Do not hold "Popper" as pictured above right. Use caution not to touch the exposed metal at the base of the popper.

2. **Begin by explaining how a piezoelectric device works using the Background information provided.** You can also demonstrate this by removing the cap from the "Popper" and pressing the igniter button. Ensure that the students see the spark jumping between the two copper wires. *If the gap between the two wires is excessive, the piezoelectric element will be unable to produce a sufficient charge to create the spark. Ensure that the gap between the two wires is no greater than 1cm (3/8").*







3. **Give each student a copy of the Sound Suppression Experiments worksheet.**

MUSEUM IN A BOX

4. **Using the pipette, place two drops of fuel into the "Popper's" combustion chamber and reattach the lid.** Explain to the students that the liquid is slowly evaporating, turning into a vapor (or a gas) which can be ignited.
   It may be necessary to hold the combustion chamber snugly in order to allow heat from your body to accelerate the process. If faster results are desired, a hairdryer can be used instead. Tests have shown that isopropyl alcohol will take approximately 5 minutes to reach a combustible state if left unattended in a room with an air temperature of 22ºC (72ºF).

WARNING: Under no circumstances should more than 2 drops of liquid be placed into the combustion chamber. It will not produce a louder bang, but WILL GREATLY increase the chance of fire!

5. **Explain that the purpose of this activity is to try, as much as possible, to stop the sound produced by the "Popper" from reaching the decibel meter.**

6. **Set up a control shot.** Continue to explain that before any experiments can be made, a control firing is needed to determine how loud the "Popper" is without any attenuation (sound dampening).

7. **Select a volunteer student.** Give the student (Student A) a pair of ear protectors, goggles and the decibel meter. Next, have Student A stand at "the listening point", approximately 2 meters (6 feet) away from where the "Popper" will be fired (the firing point). Note the points where you and the student stand so that each test can be performed from the same places. You may want to put pieces of tape on the floor to make placement more accurate.
   Instructions on using the decibel meter can be found in the Reference Materials section.

8. **Ask the other students to stand at least 5 meters (15 feet) behind Student A while the "Popper" is fired.** Their role is to find where the "Popper" lands and retrieve it.

9. **Warn everyone within earshot that you are about to fire the "Popper".** Ensure that Student A is ready, with the decibel meter set correctly (90db) and pointed towards the "Popper". When ready, put on your ear protection and goggles. Hold the "Popper" correctly and press the igniter button.
   The igniter may require more than one press before the spark is produced. If after a few presses it fails to ignite, remove the igniter cap completely from the "Popper" and move it a safe distance from the combustion chamber. Check to see if a spark is being produced by pressing the igniter button. If it is sparking correctly, then the liquid did not vaporize sufficiently. Reset the experiment and consider using a hairdryer to warm the combustion chamber and speed up the process. If the igniter failed to spark, try moving the two wires closer to each other and retest.

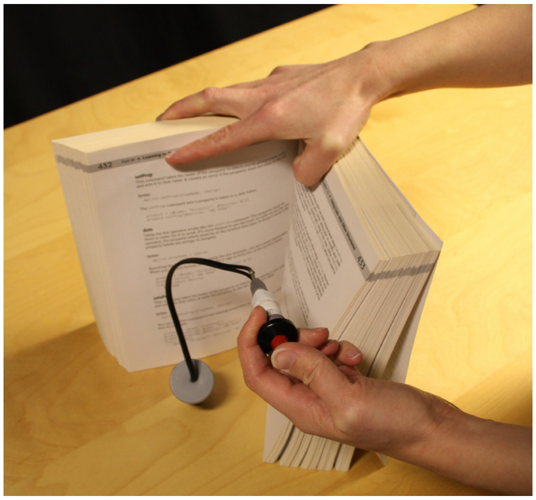
10. **Have the students record the decibel reading of the control test on their worksheets for later reference.**

11. **Using the Background information, explain how sound is produced and how it can be reduced or eliminated.**

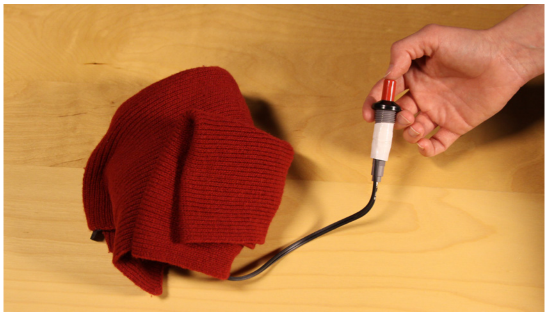
12. **Next, divide the students into pairs.** Assign each pair the task of producing a device which will attempt to reduce the noise produced by the "Popper". The winning design will be the one that obtains the largest reduction in noise in relation to its size. Students can use any items around the classroom, including those in the Materials list.
If necessary, you can inspire the students by suggesting various ideas for them to try. Examples might include:

Filling a box with pillows and placing the "Popper" in the center.

Placing a large book between the "Popper" and the decibel meter.



Wrapping the "Popper" in a scarf.



Caution: Remove flamable materials immediately after firing the "Popper" to reduce fire hazard.

For the contest, the size of the suppressor is taken into consideration to prevent students from grabbing handfuls of items and silencing the "Popper" by simply suffocating it.

13. **After each team has constructed their device, have them predict the level of reduction it will achieve.** This encourages students to use good estimating practices in order to select the appropriate decibel range setting on the decibel meter.
When estimating the reduction, remind students that they have to reduce the energy by a factor of 10 to reduce the number of decibels by half.

14. **Re-arm the "Popper" with two more drops of fluid, reattach the cap and warm if necessary.**

15. **Have one member of the team place their silencing device at the firing point while the other team member sets the decibel meter to the proposed level and stands at the listening point.** Then, place the "Popper" assembly into the noise attenuating device. Ensure that both students are wearing hearing and eye protection.

16. **Ensure the area is clear and then have one student activate the "Popper" while the other records the decibel reading onto the worksheet.**

    - If the decibel meter reads LO, then the selected range was too high, meaning the students underestimated the ability of their silencing device. Set the meter to a lower threshold and try again.
    - If the number on the decibel meter flashes, the selected range was too low, meaning the students overestimated the ability of their silencing device. Set the meter to a higher threshold and try again.

17. **Repeat steps 14 through 16 for each pair of students until all students have a successful test.** If desired and time permits, afford the students an opportunity to modify their devices based upon what was witnessed during testing. Use a fresh worksheet to record the results of the modified device.

18. **Have the students complete the math portion of the worksheet.** Here they will calculate the level of sound reduction in relation to the size of the device constructed. The winner is the team with the highest effectiveness rating.

Discussion Points:

1. **Based upon what was demonstrated today, what materials made the most efficient sound reducer?**
   Answers will vary depending on the materials and methods used, but in general, less dense materials such as furnishings and fabrics will perform better than denser ones such as wood, metal or paper.

2. **Why do you think that was?**
   Again, answers will vary depending on the materials and methods used but typically speaking, the molecules in the softer items are farther apart, meaning that it takes more energy to make them vibrate, as opposed to dense objects whose tightly packed molecules can vibrate and transfer energy easily and efficiently.

3. **Apart from the ones we discussed earlier (planes, cars and motorcycles), what other objects use a device to reduce noise?**
   Answers will vary by student, but may include:
   - *Some computers use soundproofing to reduce the noise of the fan*
   - *Helicopters*
   - *Lawn mowers*
   - *Headphones/ear plugs*

4. **Are there any other benefits to reducing noise other than for comfort?**
   Yes. In the case of a car for example, a gallon of gasoline will always produce a fixed amount of energy. In an ideal world 100% of it would be converted to motion energy by the engine and sent to the wheels but in actuality, a lot of it is wasted as heat and noise. By reducing the unwanted forms of energy, such as sound, we can increase the amount of kinetic motion produced, thereby increasing the fuel efficiency (miles per gallon) for that vehicle.

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Properties and changes of properties in matter
- Transfer of energy

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

NATIONAL SCIENCE STANDARDS 9-12

SCIENCE AS INQUIRY

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

PHYSICAL SCIENCE

- Structure and properties of matter
- Interactions of energy and matter
- Conservation of energy and increase in disorder
- Interactions of energy and matter

SCIENCE AND TECHNOLOGY

- Abilities of technological design
- Understanding about science and technology

Reference Materials

Glossary

Attenuation:
A decrease in a property, usually energy, that occurs as a result of absorption or displacement

Decibel:
A unit of the intensity of sound

Muffler:
A device designed to reduce the level of noise produced by an engine

Piezoelectricity:
Electric charge produced by a crystal or other material through a means of compression

Turbo-jet engine:
An aircraft engine whose primary means of producing thrust is through pressurized exhaust gas

Turbo-fan engine:
An aircraft engine whose primary means of producing thrust is through a ducted fan attached to the front of the engine

Vacuum:
An enclosed space in which air has been either partially or fully removed

Vaporize:
To convert a solid or liquid into a vapor

Decibel Meter Instructions

- If the decibel meter reads LO, then the selected range was too high, meaning the students underestimated the ability of their silencing device. Set the meter to a lower threshold and try again.
- If the number on the decibel meter flashes, the selected range was too low, meaning the students overestimated the ability of their silencing device. Set the meter to a higher threshold and try again.

Fig. 1 Sound vs Distance

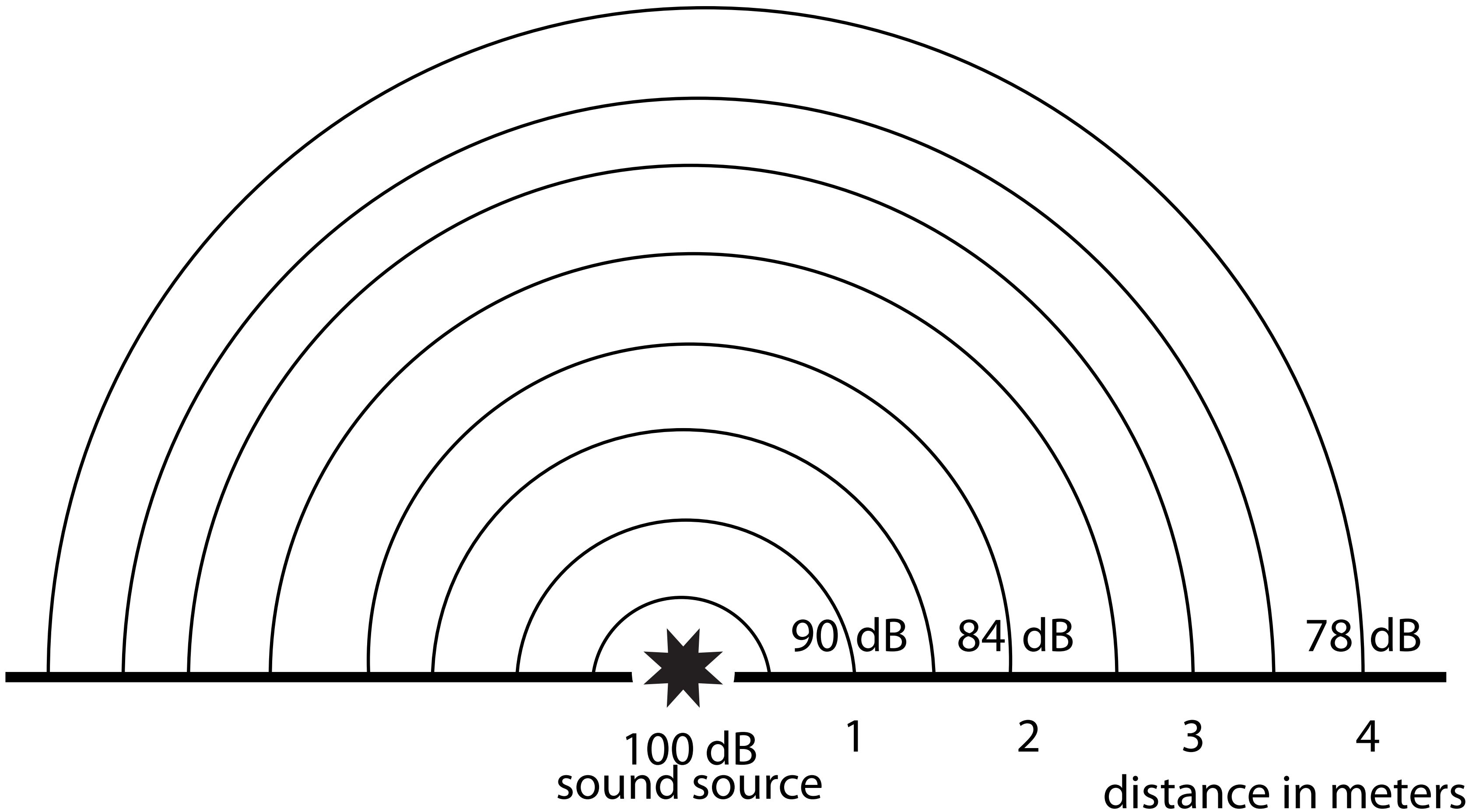


Fig. 2 Turbo-jet engine

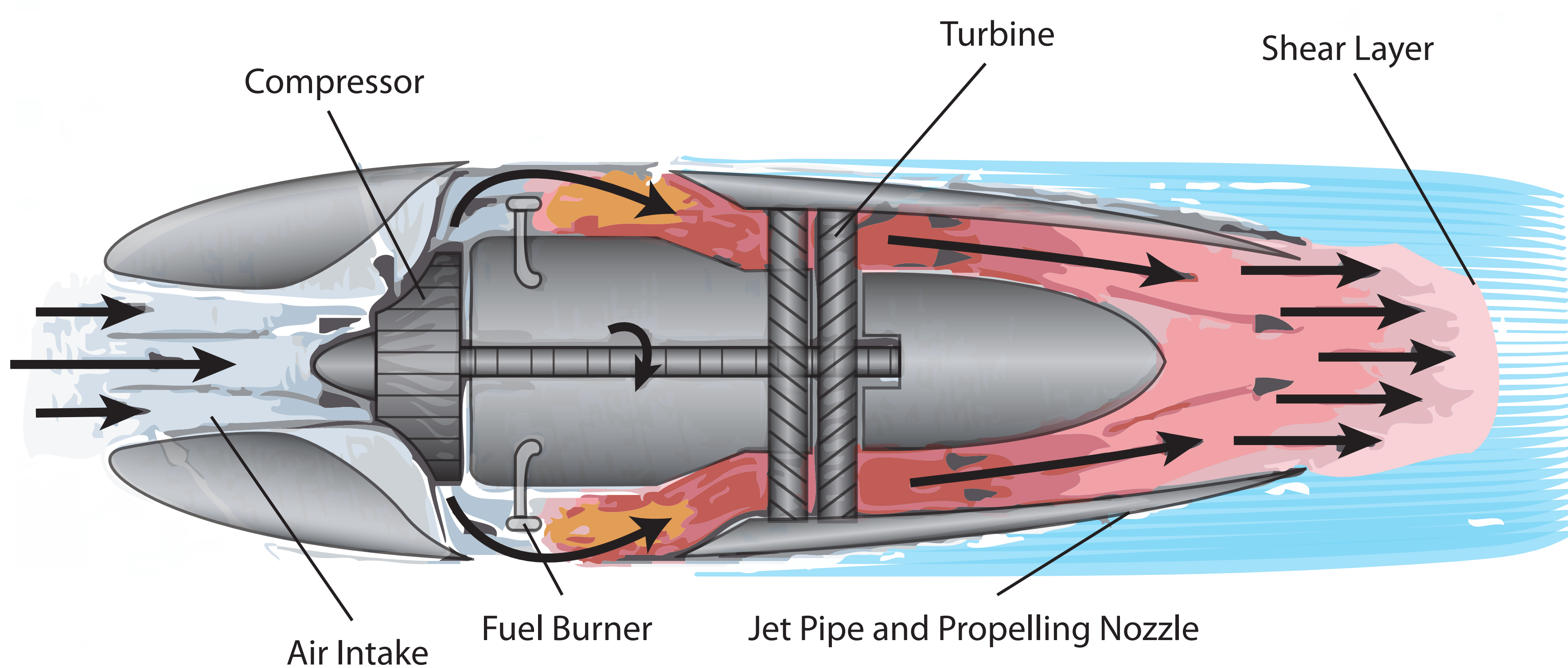


Fig. 3 Turbo-fan engine with mixer

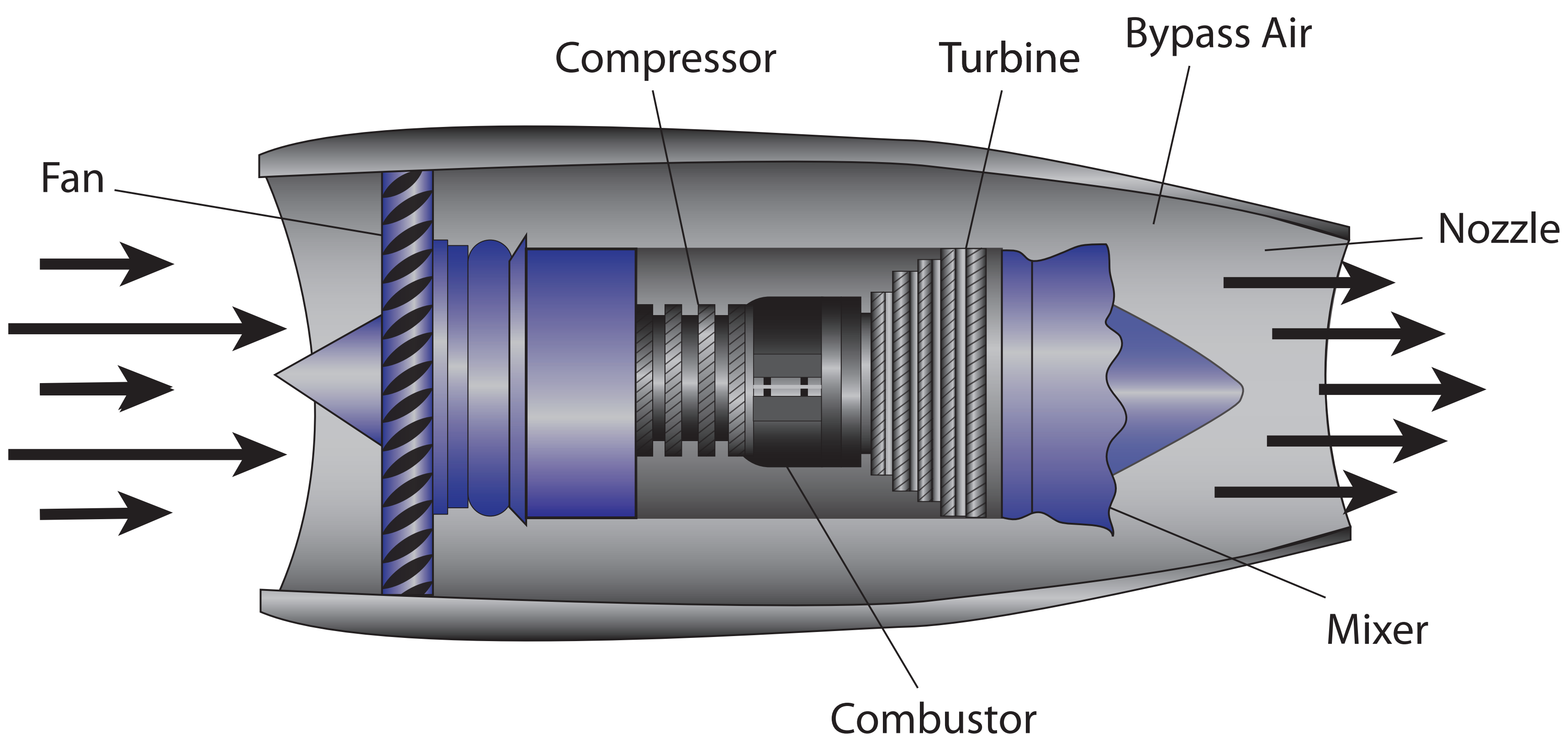


Fig. 5 Car muffler

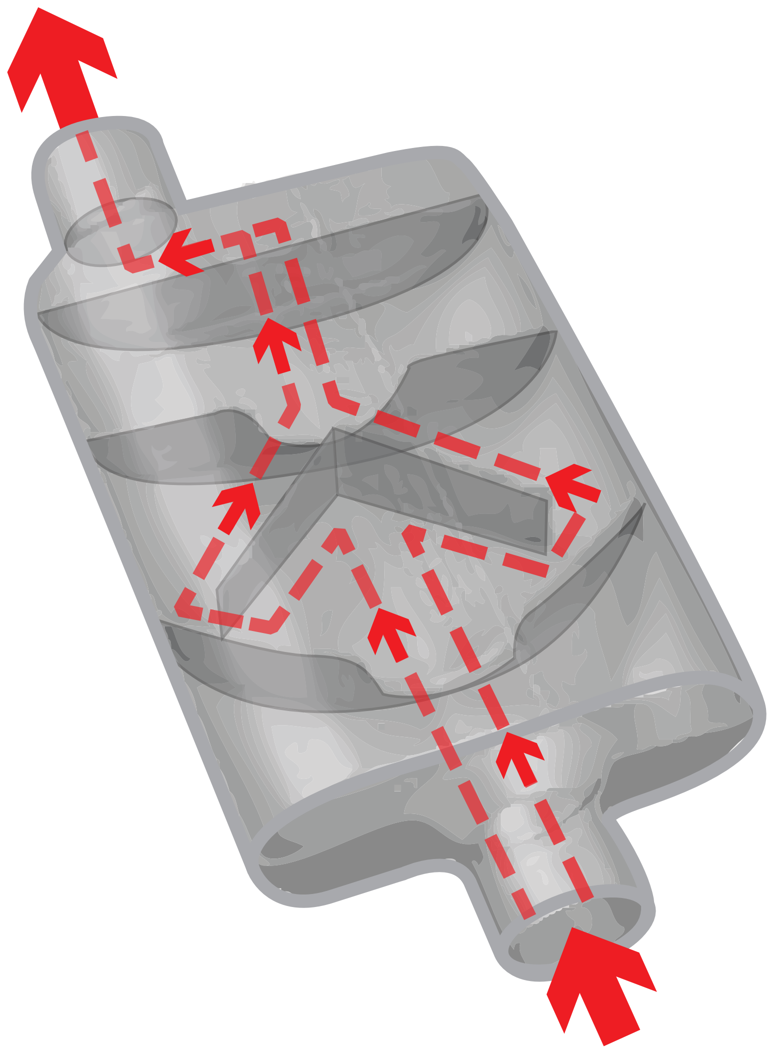
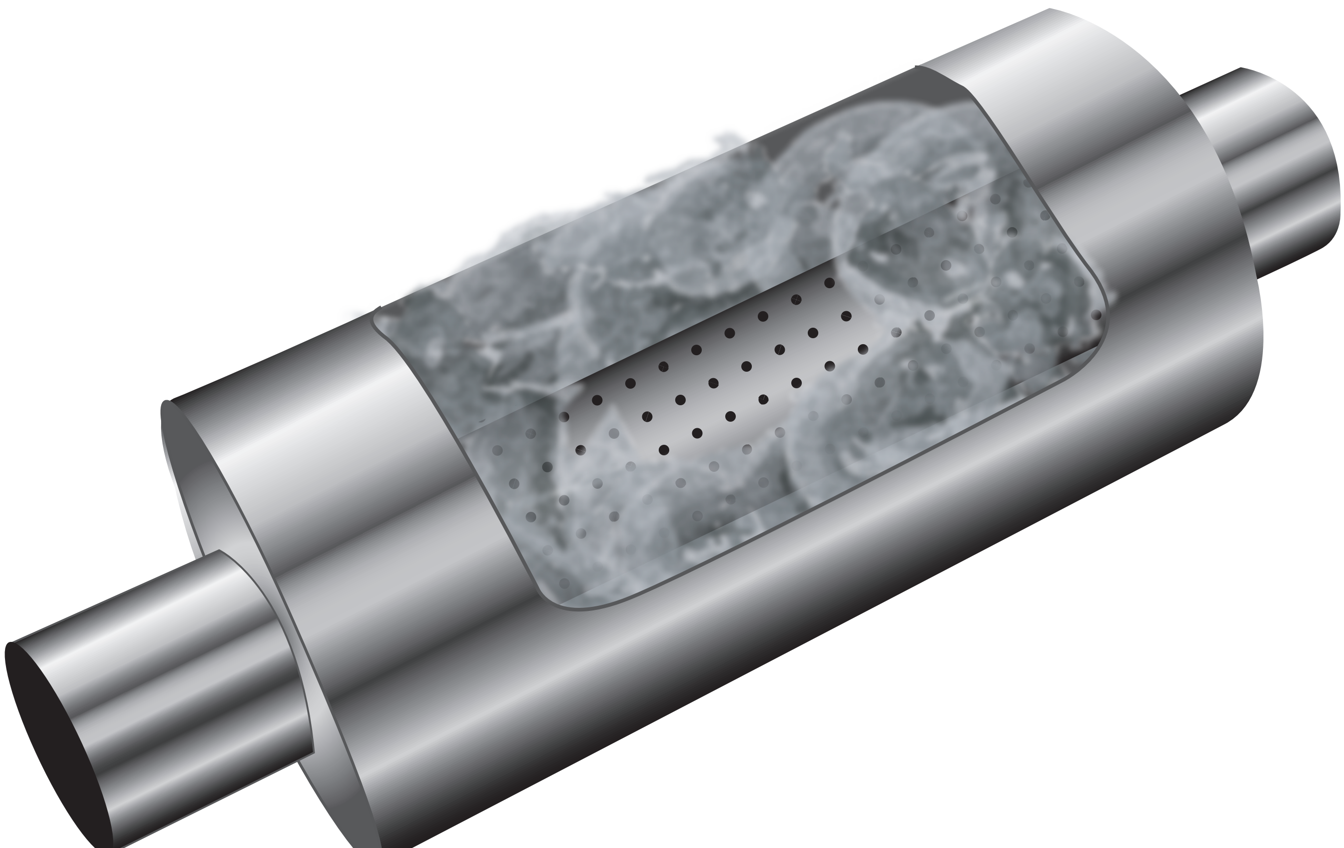


Fig. 6 Motorcycle muffler



Student Worksheets

Worksheet 1 Sound Supression Experiments

Name______________________________

1. Name description of device ____

2. Control Test - Decibel Level ________________________db

3. Device Used - Decibel Level

Your Results	Other Students' Results			
db	db	db	db	db

4. Decibel Difference:

Your Results	Other Students' Results			
db	db	db	db	db

5. Size of the Device:

Your Results	Other Students' Results			
Width	Width	Width	Width	Width
Height	Height	Height	Height	Height
Depth	Depth	Depth	Depth	Depth

6. Cubic Feet: (Width x Height x Depth)

Your Results	Other Students' Results			
m^3	m^3	m^3	m^3	m^3

7. Device Effectiveness Rating = Decibel Difference ÷ Size (Volume) of Device

	Your Results	Other Students' Results			
Device Effectiveness Rating=	db ÷ m^3	db ÷ m^3	db ÷ m^3	db ÷ m^3	db ÷ m^3
Device Effectiveness Rating=	db/m^3	db/m^3	db/m^3	db/m^3	db/m^3

8. What were the weaknesses of this design?

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9. How could you improve the performance of this design?

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