**Learning Activities 4.2: Demonstrations of Various Physical Phenomena in Vacuum Systems**

**Summary of Learning Activities:**

* Qualitatively investigating the effects of reduced pressure on propagation of sound.
* Qualitatively investigating the effects of reduced pressure on performance of mechanical systems such as a fan.

# Student Learning Objectives:

1. Qualitatively explain how vacuum conditions affect the propagation of sound waves.
2. Qualitatively explain the observed behavior of a fan operating at different pressure levels.

**Suggested Pre-lab Assignment:** None

**Theoretical Background:**

In a sound wave traveling in a gas, gas molecules vibrate back and forth parallel to the direction of the sound wave’s travel. In places where molecules of gas momentarily move away from each other, low pressure areas are formed. And in places where molecules of gas move closer to each other, high pressure areas are formed. Such moving consecutive segments of high and low pressures form what we call a sound wave. The key point to understand is that a sound wave requires a medium (gas, liquid, or even solid) to be able to travel. If the medium is removed, a sound wave will cease to exist. This means that sound cannot travel in an ideal vacuum. In a practical vacuum, the amount of gas molecules is reduced to the point that the intensity of the sound wave can drop below the audible level.

Another application that requires the motion of gas molecules is the operation of an electric fan. When a fan is operating at standard atmospheric pressure, it can move a substantial volume of air and produce a noticeable air flow. However, when a fan operates in a space under vacuum where enough gas molecules are removed, the fan cannot produce a noticeable air flow.

# Equipment and Materials:

* Rough Vacuum Equipment Trainer (RVET) system
* Nitrile or Latex Gloves
* Small battery-powered radio.
* Small battery-powered electric fan.

**Procedure:**

**Learning Activity 4.2a: Demonstration with a Radio**   
  
This learning activity shows how pressure affects sound (pressure wave) propagation. You may want to discuss the physics behind the phenomena of sound and how it travels in a medium such as air. Sound is essentially a pressure wave which has areas of high and low pressure which need a medium to travel or propagate. Sound can travel in gas, liquid, and solid objects. Depending on the medium, the speed of sound can also change. For example, in helium sound can travel faster than in the air (you may use an example of helium from party balloons here and what happens if helium gas is inhaled). However, if the medium is removed, then sound waves cannot propagate anymore. So, when you place a radio receiver in the chamber, initially you should be able to hear the sound produced by the radio. But as air gets pumped out from the chamber (essentially removing the medium in which sound can travel), the sound intensity or loudness will gradually decrease until no sound can be heard outside of the chamber. Thus, sound does not travel in vacuum.   
  
For this learning activity, it is better to use a battery-operated device like a radio so that no feedthroughs are needed for a power cord. If a radio is not available, you can use another sound generating device like a battery-operated alarm clock.   
   
This activity can be done in class, or the following video can be used in place of performing this learning activity in class:  
<https://youtu.be/xMOp7UFb3mc>

1. Vent the chamber.
2. Place the radio (or other device) playing loud sound inside the chamber.
3. Do you hear sound from the radio inside of the chamber?
4. What is going to happen when we start pumping air out of the chamber?  
     
   As the pressure in the chamber decreases, the sound from the radio becomes noticeably quieter.
5. What is going to happen after a lot of air has been pumped out of the chamber?
6. Close the vent valve and roughing valve.
7. Start the roughing pump.
8. Open the roughing valve.
9. Pump the system down and record your observations.
10. Close the roughing valve.
11. Turn off the pump.
12. Can sound travel in a vacuum and why?
13. Vent the system slowly and record your observations.

**Learning Activity 4.2.b: Demonstration with an Electric Fan**   
  
This learning activity demonstrates how gas pressure affects operation of devices, such as electric fans. For this learning activity, it is better to use a battery-operated fan so that no feedthroughs are needed for a power cord. Attach cloth or plastic strips to the frame of the fan. When the fan is working at atmospheric pressure, the strips should move because the fan produces air motion. When air is evacuated from the chamber, the strips should move less (with decrease in pressure, there is less air moved by the fan blades). And eventually, as the pressure in the chamber is reduced, the strips will no longer move even when fan’s blades are moving.  
   
This activity can be done in class, or the following video can be used in place of performing this learning activity in class:  
<https://youtu.be/Kkk3wVT-IDc>

1. Vent the chamber.
2. Place a working battery-operated electric fan with loose material strips inside the chamber. Do the blades of the fan move? Do the hanging strips of cloth or plastic move? Explain why.
3. Pump the system down and observe the behavior of the fan and hanging strips.
4. After the pump-down process is just started, do the fan blades still move? Do the strips move? Explain why.
5. After running the pump-down process for a while, do the fan blades still move? Do the strips still move? Explain why.
6. Close the roughing valve and turn off the pump when pump-down process is completed.
7. Vent the chamber.

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