



*Drexel-SDP GK-12 LESSON*

## Lesson: Pressure

**Subject Area(s)** Data Analysis & Probability, Measurement, Number & Operations, Physical Science, Science and Technology

**Associated Unit** Vital Mechanics

**Lesson Title** Pressure



**Many different forms of pressure used in a single activity.**

**Grade Level** 7 (6-12)

**Lesson #** 2 of 3

**Lesson Dependency**

**Time Required** 20 minutes

### Summary

Various types and applications of pressure are covered in the accompanying Powerpoint slides. This lesson is designed to enumerate the implications of pressure and how it is used. The associated activity relates blood pressure waveforms with sugar consumption, but the theme can be versatile and can be extended to other applications of pressure – hydraulics and sound, for example.

## Engineering Connection

Pressure governs many biological and environmental processes, and engineers in particular have used the concepts to their advantage for many years. Similar to the previous lesson, **Collisions**, the energy of particles on the molecular level can be changed dramatically with pressure (gas laws). On a larger scale, pressure influences particle movement due to gravity (water tower), chemical reactions (engine pistons), and even weather patterns (areas of high and low pressure). Earthquakes, tsunamis, and sound are all caused by pressure waves that propagate through solids, liquids, and gases, respectively.

The good news is that, besides acts of nature, we can control pressure and use it to generate electricity (hydroelectricity, wind power), water and septic systems, and create mechanical motion (engines). Among these uses, pressure occurs naturally in our body's circulatory system. When we have our blood pressure taken, the doctor or nurse reads our systolic and diastolic pressure as a ratio, like "120 over 80." This is measure of the pressure in the cuff (around our arm) necessary to close our brachial artery. Under normal conditions, our vasculature is a closed system and responds to stimuli just as temperature has an effect on an ideal gas in a container.

## Keywords

pressure, gas law, heart rate, exercise, hydrostatic, hydraulic, pulmonary, cardiovascular

## Educational Standards

- PA Science:
  - 3.1.7 – Unifying themes
  - 3.2.7.B – Apply process knowledge to make and interpret observations
- PA Math:
  - 2.1.8.D – Apply ratio and proportion to mathematical problem situations involving distance, rate, time, and similar triangles
  - 2.4.5.B – Use models, number facts, properties, and relationships to check and verify predictions and explain reasoning
  - 2.5.8.B – Verify and interpret results using precise mathematical language, notation and representations, including numerical tables and equations, simple algebraic equations and formulas, charts, graphs, and diagrams
  - 2.7.8.D – Compare and contrast results from observations and mathematical models
  - 2.8.8.B – Discover, describe, and generalize patterns, including linear, exponential, and simple quadratic relationships

## Pre-Requisite Knowledge

### Learning Objectives

After this lesson, students should be able to:

- Identify applications that rely on pressure
- Discuss the effects of temperature on pressure
- Describe the effect of negative pressure (vacuum) on liquids and solids with trapped air spaces
- Predict the outcome of pressure effects on a material

### Introduction / Motivation [refer to Powerpoint slides]

Ask students what they think of when they hear the word “pressure.” (Not necessarily how they would define “pressure”). How have they heard it used – what contexts? (*Peer pressure, tire pressure, water pressure, etc.*). How have they used pressure already today? (*Shower, brush teeth, tire pressure in bus and car wheels, other ordinary events*). Describe engineering definition of pressure and give examples of real-world applications (from **Engineering Connection**).

Show slides on example applications (water tower, post-mix fountain soda dispenser, hydraulics, SCUBA and nose/ear airspaces under hydrostatic pressure, cardiovascular system) and ask students to point out where pressure exists.

Several media clips can be played or demonstrated – boiling water at room temperature under a vacuum, hard-boiled egg in the Erlenmeyer flask, candle in the inverted Erlenmeyer flask, quenching aluminum can with steam in ice-cold water bath. Other demonstrations can be done with a laboratory vacuum (consumer models and shop-vacs don’t have the pull). Puffed marshmallows or marshmallow Peeps under vacuum will explode if the pressure drops quickly enough. Otherwise, marshmallows will enlarge as the relative pressure between air pockets and the chamber increases, after which they collapse then the air is sucked out of the pockets. Balloons under vacuum may enlarge or burst.

### Vocabulary / Definitions

Word	Definition
Pressure	(Engineering): Force per unit area (stress), acting perpendicular to a surface.
Vacuum	Negative pressure. Atmospheric pressure is 14.7 psi (pounds per square inch)
Blood Pressure	The amount of pressure necessary to close a blood vessel (usually the brachial artery), measured by a <i>sphygmomanometer</i> .

### Lesson Background & Concepts for Teachers

Pressure is transferred in different ways, so there are several methods to analyze pressure changes. Let’s start with the Ideal Gas Law definition from Chemistry:

$$PV = nRT$$

where  $P$  is pressure,  $V$  is volume,  $T$  is temperature, and  $n$  is the number of moles of the gas (a measure of quantity) and  $R$  is the universal gas constant. Assuming that our initial amount of gas and the universal gas constant do not change, the relation simplifies to

$$PV = T.$$

This can be re-written to show a change between two states,

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}.$$

Consider the “egg in the flask” and “candle in the flask” clips. The “egg in the flask” demonstration involved heated air  $T_1$  due to the match, and for the short time duration  $V_1 = V_2$ . After the match went out, the air temperature decreased ( $T_2$ ). Rearranging the last equation,

$$\frac{P_2}{P_1} = \frac{T_2 V_1}{T_1 V_2} = \frac{T_2}{T_1}$$

Since the pressure ratio is equal to the temperature ratio, it is clear that the temperature drop created the pressure drop that caused the egg to be pulled into the bottle.

Likewise, the “candle in the flask” clip shows a candle burning for an extended amount of time in an inverted flask. Here the end result is a reduction in pressure that pulls fluid up the neck of the flask. If we use the same equations and logic, the candle heats the air ( $T_2 > T_1$ ), and consequently  $P_2 < P_1$  (pressure increases) if no volume effects are considered. In order to get the condition of  $P_2 > P_1$  (a reduction in pressure), the volume decrease ( $V_1 < V_2$ ) must be greater than temperature increase. So while the candle is burning the oxygen, it is decreasing the amount of gas volume at a rate greater than it is increasing the temperature, resulting in the pressure drop that pulls fluid up the neck of the flask.

Another common usage of pressure besides gases applies to fluids. Cheap pressure gauges (pitot tubes) act on the basis of the hydrostatic pressure of the fluid. Concealed air pockets in submarines and on SCUBA divers are subject to hydrostatic pressures of water, which scales with density and height of a vertical water column,

$$p = \rho gh = \left(1000 \frac{\text{kg}}{\text{m}^3}\right) \left(9.81 \frac{\text{m}}{\text{s}^2}\right) (1\text{m}) = 9810 \cdot l \frac{\text{kg} \cdot \text{m}^2}{\text{m}^3 \cdot \text{s}^2} = 9810 \cdot l \frac{\text{kg}}{\text{m} \cdot \text{s}^2}.$$

By the definition of pressure,  $1 \frac{\text{N}}{\text{m}^2} = 1 \frac{\text{kg} \cdot \text{m}}{\text{m}^2 \cdot \text{s}^2} = 1 \frac{\text{kg}}{\text{m} \cdot \text{s}^2}$  so the units check out. Please note that pressure is always compressive, so it would carry a negative sign in an equation.

One great example of a structure designed to withstand hydrostatic pressure at great depths is the Hoover Dam. While the top span is 1244 feet long and 45 feet wide, the base of the dam is 660 feet wide (2 football fields) extending into Lake Mead. More information on the engineering of the Hoover Dam can be found [here](#).

### Associated Activities

Amp'd Up

## Lesson Closure

After the associated activity, **Pump'd Up**, mention that heart rate is a physiological health factor – if it is abnormal, it may be a sign of a health condition. At the same time, even if a heart rate is in the normal range, exposure to abnormal amounts of exercise might cause health complications. This is why gym equipment such as ellipticals, treadmills, and stationary bikes feature a heart rate monitor. Every person has a target heart rate for cardiovascular training – a point that exercises the heart without causing too much stress (demand). A maximum heart rate is figured as

$$HR_{\text{target}} = 220 - \text{age}$$

and a target heart rate for exercise is factored as 50-85% of the maximum heart rate ([AHA](#)).

Overuse injuries are the most common for athletes, which is why it is important to exercise in moderation and *train* or *condition* our bodies before participating in athletically demanding events. Failure to use a training regimen may not only cause cardiovascular complications, but it could also fatigue our joints and subject our bones, muscles, and ligaments to abnormal loadings (shin splints).

## Additional Multimedia Support

vital\_mechanics\_2\_lesson\_pressure\_multimedia.zip

## Owner

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