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| Lesson Title | 19. Physics of Fluid and Pressure |
| Lesson Designer | Nicole Granucci |
| Standards | ☐ CCSS ☑ NGSS ☐ ASCA ☐ Other<br>HS-PS3-2 Energy. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). |
| Learning Objectives | Students will define and use blood pressure to describe percent changes and change over time. |

| Timeline | Duration |
|---|---|
| Day 1 - Students do the activity on determining the frequency of the tuning forks.<br>Day 2 - Students can take a hearing test<br>Day 3 - Students can learn about intensity and loudness and then do an activity to organize the loudness of objects. | 90 minutes |

| Teaching Strategies/Student Actions | Monitoring |
|---|---|
| • Lab Activity - See attached below for delivery | • Teacher will model and explain expectations - task oriented and behavioral.<br>• Teacher will move around the room to observe student progress.<br>• Teacher will provide feedback and suggestions for students.<br>• Teacher will remind students of time remaining for each portion of the activity (i.e., You have five minutes remaining to collect data). |

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| Product Description | Lab Data sheet at the end of this activity. |
| Evaluation | Lab Data sheet at the end of this activity. |

| Resources and Materials | Additional Notes |
|---|---|
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# Physics of Liquid Pressure: Blood Pressure

Blood pressure is the force exerted by the blood on the walls of the arteries. To measure this, a sphygmomanometer is used. The arterial blood flow in the arm is blocked by the cuff and a stethoscope is placed inside the cuff. The air that is pumped into the arm cuff is then released. As the air is released, the stethoscope is used to listen to the Korotkoff sounds, or the K sounds. The K sounds are the result of vibrations from the turbulent flow caused by the blood squirting back into the arteries. When the sound is first detected, the pressure measurement is taken as the systolic pressure. As the sounds becomes fainter and disappears, the diastolic pressure is taken. The blood pressure of someone with a systolic pressure of 120 and a diastolic pressure of 80 would be expressed as 120 / 80 mm Hg (16 kPa / 10.5 kPa).

The human body can be treated like a column of blood and the liquid pressure can be measured. The pressure exerted by a liquid at any point in the liquid, due to the weight of the liquid above, follows the relationship

$$P = \rho g h$$

Where ρ = density of the liquid in (kg/m$^3$), g is the acceleration due to gravity, 9.81m/s$^2$, and h is the height of the liquid at the point of pressure measurement. P represents the liquid pressure in Pascals (Pa) or sometimes referred to as the gauge pressure. Figure 1 depicted the variables needed to measure the pressure at the bottom of a container. Pressure also has units of mm Hg because it was traditionally measured the height difference with a column of Mercury. 1 mm Hg = 133.322 Pa.

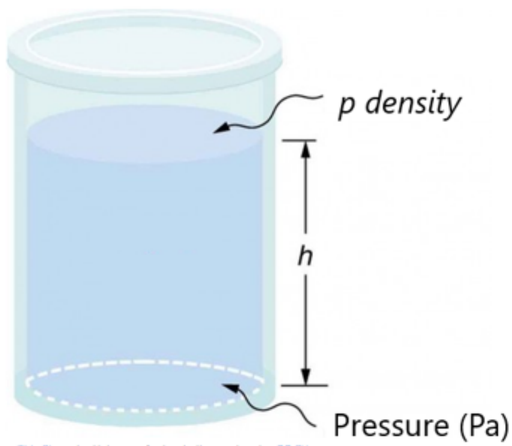




*Figure 1 – Liquid pressure measured on a column of water*

The liquid pressure is only based on the height of the liquid. Its is not based on the volume of the liquid nor the shape of the container. This is an important feature as the blood pressure can be measured on any shape/volume of a person. Only the depth or location of the measurement is needed to measure the blood pressure

In this lab, you are going to treat the body like a column of liquid and measure the pressure at different depths. Figure 2 shows a person standing and the different locations that are going to measured as well as a comparison of pressure between two points. Location A is the wrist resting on the lap. Location B is the wrist at heart level and location C is lifted to the head level. Location A has more depth, therefore will measure more pressure than location B, and C. In lab, you will see the pressure increase as you lower your wrist. Also, note the importance of measuring the pressure at the heart level. This allows the nurse or doctor to record the blood pressure at the heart. Measuring the pressure at any other point would not be accurate at determining the blood pressure.

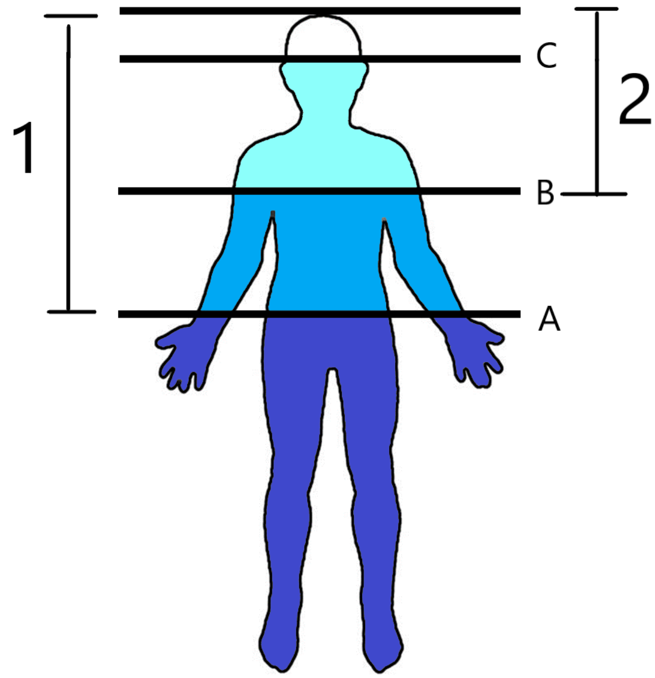


*Figure 2 – Body like a column of liquid*

The lab will be using a blood pressure cuff instead of the traditional sphygmomanometer as it is easier and cheaper to use. Figure 3 shows the display for a blood pressure cuff. The cuff is placed on the wrist. When it is turned on, the cuff will inflate, blocking artery of the arm. The blood flow is stopped. Then the cuff is gradually deflated until the pulsations are perceived by the device. The measurement is the systolic pressure. Please note that this lab is for recreation and does not pertain medical advice.


*Figure 3 - Blood Pressure Cuff from Amazon. There are different varieties however for this lab, a basic one like this is sufficient. A blood pressure cuff can be purchased on Amazon for as little as $20.*

## Procedure

1. It is recommended that the measurements are taken within 30 minutes of eating, smoking or exercise. Taking the measurement under any of those conditions will not reflect a true blood pressure reading.
2. Select one person to be measured for each position.
3. Put the cuff on your left hand, wrist facing up so that the screen of the pressure sensor is facing upward. Be sure that the cuff is about ½ inch from the wrist. Fasten the cuff so that there is no space between the cuff and the wrist.
4. If possible, do not support your own arm. Rest it on the table or have a partner hold the arm. If the person holds their own arm, the readings will be higher due to isometric activity.
5. Do not move, chat or strain your arm during the measurement. Try to relax and a take a few deep breaths before measuring.
6. Position your arm and hold it still. Have another person measure the height of the cuff in centimeters and in meters. Record on Data Table 1.
7. Turn on the power button. The apparatus will start to inflate. Record the measurement after the measurements are displayed on the screen.
8. Repeat for three trials. It is recommended that you wait 5 minutes between measurements.
9. Repeat the entire experiment. Choose one of the options to investigate
   A. Have same experimenter stand for measurements
   B. Do the experiment with a different person
   C. Do the experiment with a person who had eaten/exercised/smoked in the last 30 minutes

# Physics of Blood Pressure Data Sheet

## Data Set 1 – Measuring Pressure While Seated

| Placement of Cuff | Height (cm) | Systolic Trial 1 (mm Hg) | Systolic Trial 2 (mm Hg) | Systolic Trial 3 (mm Hg) | Average Systolic (mm Hg) |
|---|---|---|---|---|---|
| A. Resting on lap | | | | | |
| B. Heart level | | | | | |
| C. Elbow raised to head height | | | | | |
| | Height (m) | Diastolic Trial 1 (mm Hg) | Diastolic Trial 2 (mm Hg) | Diastolic Trial 3 (mm Hg) | Average Diastolic (mm Hg) |
| A. Resting on lap | | | | | |
| B. Heart level | | | | | |
| C. Elbow raised to head height | | | | | |

## Calculations Table 1 - Pressure while Seated Between A & B

| Δh between positions A and B in (m) | $P = \rho\ g\ \Delta h$ (Pa)<br>ρ of blood ~ 1,040 $kg/m^3$ | Convert P to mm Hg |
|---|---|---|
| | | |

| Change in Systolic Pressure A & B | % Difference Calculation<br>ΔSystolic & Pressure in mmHg |
|---|---|
| | |

## Calculations Table 2 - Pressure while Seated Between A & C

| $\Delta$h between positions A and C in (m) | $P = \rho\ g\ \Delta h$ (Pa)<br>$\rho$ of blood ~ 1,040 $kg/m^3$ | Convert P to mm Hg |
|---|---|---|
| | | |

| Change in Systolic Pressure A & C | % Difference Calculation<br>$\Delta$Systolic & Pressure in mmHg |
|---|---|
| | |

## Data Set 2 – Measuring Pressure ______________________________

| Placement of Cuff | Height (cm) | Systolic Trial 1 (mm Hg) | Systolic Trial 2 (mm Hg) | Systolic Trial 3 (mm Hg) | Average Systolic (mm Hg) |
|---|---|---|---|---|---|
| D. Resting on lap | | | | | |
| E. Heart level | | | | | |
| F. Elbow raised to head height | | | | | |
| | Height (m) | Diastolic Trial 1 (mm Hg) | Diastolic Trial 2 (mm Hg) | Diastolic Trial 3 (mm Hg) | Average Diastolic (mm Hg) |
| C. Resting on lap | | | | | |
| D. Heart level | | | | | |
| C. Elbow raised to head height | | | | | |

## Calculations Table 1 - Pressure Between A & B

| Δh between positions A and B in (m) | $P = \rho\ g\ \Delta h$ (Pa)<br>$\rho$ of blood ~ 1,040 $kg/m^3$ | Convert P to mm Hg |
|---|---|---|
| | | |

| Change in Systolic Pressure A & B | % Difference Calculation ΔSystolic & Pressure in mmHg |
|---|---|
| | |

## Calculations Table 2 - Pressure Between A & C

| $\Delta h$ between positions A and C in (m) | $P = \rho\ g\ \Delta h$ (Pa) $\rho$ of blood ~ 1,040 $kg/m^3$ | Convert P to mm Hg |
|---|---|---|
| | | |

| Change in Systolic Pressure A & C | % Difference Calculation $\Delta$Systolic & Pressure in mmHg |
|---|---|
| | |

## Analysis Questions

1. Analyze the systolic blood pressure. What positions had the highest systolic value? The lowest value? Does your data support the liquid pressure equation?

2. What were the percent differences for each position change? Which position was more accurate? What could account for the discrepancies in measurements?

3. For a seated person, would there be a difference in the measurement in the ankle verses the measurement at heart level?

4. If a person was lying flat, would there be a difference in measurement in the ankle verse the measurement at heart level?