Physics 5BL Lab 2* Manual: Ideal Gas Laws
Fall 2024, UCLA Department of Physics & Astronomy

<u>Directions:</u> As you read through the lab manual, follow along and complete the Google Slides lab assignment submission template to submit your responses to prompts on each slide as indicated. Refer to your pre-lab for theoretical background, including key equations and definitions as needed.

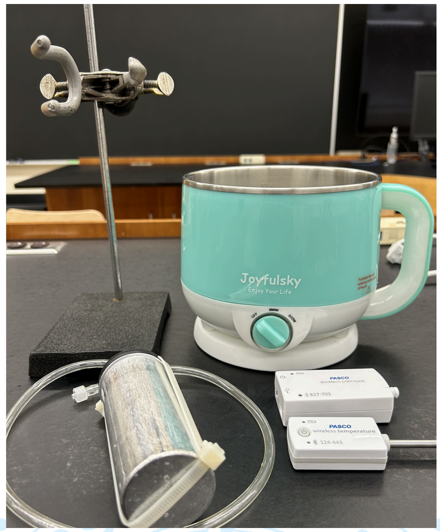

Figure 1: inventory of equipment for Activity 1.

<u>Lab Procedure - Activity 1</u>

Your goal for today's experiments is to quantify absolute zero on the Celsius temperature scale using the ideal gas law.

1. First set up the experiment software by opening the PASCO Capstone program on the computer from the start menu. Click on the "Hardware Setup" button on the left, to connect your sensors. Keep the pressure sensor plugged into the computer. Since the temperature sensor is wireless, make sure that you **correctly set up the device in the "Hardware Setup" by clicking on the temperature sensor to make sure the 6-digit code matches your device**. Failure to do so may result in measuring someone else's temperature data (since wireless Bluetooth can range across the entire room).

2. **Click on "common rate"** at the bottom of your screen to take pressure and temperature data **around 10Hz**. Click and drag the "graph" icon into the main window four times, consecutively. Click on the "Select Measurement" buttons on the vertical and horizontal axes to simultaneously show graphs of **T(t), P(t), T(P), and P(T)**.

3. A group member can fill up the water kettle with the tap water at the sink. Do not take the gas canister out of the ice bath and plug in the electric kettle but do not turn the kettle on.

4. **When you are ready to begin taking data, place the gas canister into the kettle**. Turn the screw that connects the stand to the clamp. You can move and rotate the clamp holding the gas canister up and down on the stand rod. You do not need to touch the gas canister at any point during the lab. **If you are unsure of how to adjust the clamp or stand, ask your instructor for help.**

5. Make sure the bottom of the gas canister does not touch the bottom of the kettle, or else heat will transfer differently from the heating element to the metal container without allowing for

the inside air to equilibrate to the same temperature. **Only adjust the height of the gas canister in the filled kettle, reducing any metal-to-metal contact**. Make sure not to get water into the canister (Do not fully submerge!).

6. **Take a preliminary control measurement immediately after placing your gas canister in the kettle** to make sure that your temperature sensor and pressure sensor are correctly measuring the physical parameters. Click **Record** to start recording, and click the same button to stop. It will automatically be saved in the “Data Summary” Tab, accessed either by the far left tab, or the upper menu that appears when you hover the mouse over the top of a specific graph.

7. After your baseline recording, take your data recording. Start recording in PASCO and turn on the electric kettle to the **“200 Watt”** setting. You can review your data at any time after by clicking the black arrow next to the “Rainbow Triangle Data Summer” button above the graph. Be sure to remember which trials correspond to which particular setups/experiments you performed.

8. Once you reach 50°C end data-taking and turn off the kettle, note that the kettle may keep going to higher temperatures, but **you MUST turn off and unplug the kettle at 50°C and end your run after unplugging the kettle**. Failure to do so may irreversibly melt parts of the kettle and ruin the experiment for your future attempts or the students taking the lab after you.

9. **DO NOT TOUCH THE GAS CANISTER IT WILL BE HOT**, carefully adjust the clamp on the stand, and put it back into the ice bath **at the end of the lab**. If there is no ice or water in the ice bath let the instructor know.

10. Empty your kettle when you are done with Activity 1. **Carefully** pour out the water in your kettle at either the sink or outside the room at the drinking fountain station. If you would like to make another attempt, you must consult your TA because you will probably need help to reset your station so that everything starts equilibrated again.

11. **For PASCO highlighting analysis**: Click the “Yellow Highlighter Tool” button directly to the right of the “Rainbow Triangle Data Summary” menu button, to select a portion of your data for further analysis. Only select the linear portion of your data, around 10 degrees after your control measurement.

12. **For PASCO best-fit line analysis**: Click the “Red Line on Blue Dots Trend Line” button to the right of the “Yellow Highlighter Tool” button. Select the simplest fit option that will provide both slope and y-intercept best-fit parameters.

Lab Procedure - Activity 2

The goal of this activity is to experiment with measuring your heart rate and blood pressure(s) to understand applications of the physics of pressure & volume changes in a fluid to medicine.

Figure 2: human wrist blood pressure sensor for Activity 2.

1. **Take** your own blood pressure and heart rate by putting the heart rate monitor on your wrist, staying still, and holding your wrist at your heart. You can search online for standard human blood pressure ranges to see if your device is working.

2. If the device is stating "error" try tightening the velcro around the wrist, or moving the device so that it is higher up on the arm and makes better contact with the skin. *(Note: you must stay still and keep the device level with the heart or you will experience an error. You will explore next week how pressure depends on potential energy (height), so it is important to measure your blood pressure at the height of your heart, which is the "zero" relative height to which the machine is calibrated.)*

Lab Procedure - Activity 3

The goal of this activity is to experiment with creating pressure changes using a simplified apparatus to understand the physics of pressure & volume changes produced by the heart in the human vascular system.

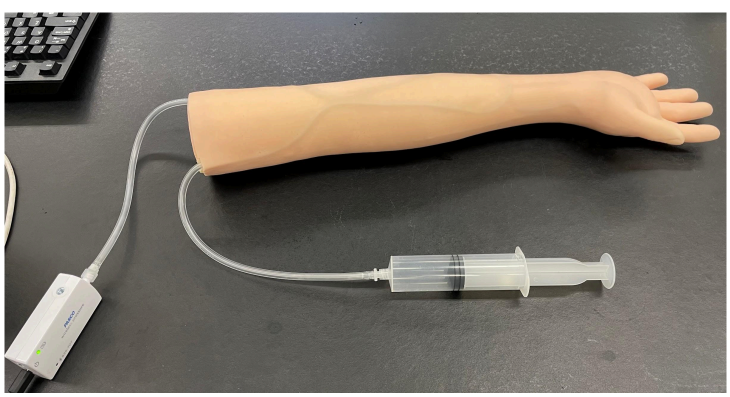

Figure 3: Syringe-Heart Arm Model for Activity 3.

1. Pull the syringe out approximately **halfway** before connecting to the arm model. Connect the pressure sensor and syringe to the arm model.
2. Remove the pressure sensor from the gas canister setup. Once connected to the arm model setup on PASCO Capstone **zero the pressure sensor** in the hardware settings.
3. Drag a graph icon onto the page and a digits icon **to** set the selected measurements to Pressure (mmHg) versus Time (s).
4. **Start** recording, push, and pull the syringe to observe the change in volume and pressure.
5. When you are done **remove the zero offset** for the pressure sensor in the hardware settings, and reconnect it back to the gas canister system. **Now you can place the gas canister setup into the ice bath.**

Lab Submission

Slide 2: Activity 1 Scientific Question, Experimental Setup & Prediction:

a) **Describe the** experimental setup that will let you test the ideal gas relationship.

b) **State** your prediction about how temperature and pressure are related if the system is behaving like an ideal gas.

c) **Explain** how to find the Celsius temperature that corresponds to absolute zero from the portion of your pressure and temperature results that support the ideal gas relationship.

Slide 3: Activity 1 Raw Data:

Show plots of P(t) and T(t) made in Excel or other software from the raw data, or import a copy of your plots from Capstone (tutorial here). **Label** the initial temperature and pressure at the start of the trial and the final temperature and pressure at the end of the trial, using quantitative units and values. Make sure that axis labels and numerical scales are legible.

Slide 4: Activity 1 Analysis:

a) **Show a** plot of P(T) as the first step in your analysis from the raw data, with suitable data chosen & best-fit line that provides information about calculating Absolute Zero from extrapolating pressure and temperature measurements.

b) **State** your final result of Absolute Zero (zero degrees Kelvin) in units of Celsius, and compare it to the actual value (from your class, textbook, or Google).

Slide 5: Activity 2 Analysis:

a) **State** the blood pressure values (max/min) and heart rates for each member of your lab, after having tested with the human blood pressure wrist sensor (being sure to stay still and hold the sensor over the heart for the entire duration of the measurement!) **Determine** whether these health device blood pressure readings are absolute pressure or gauge pressure that is relative to absolute pressure. (Be mindful of units and be prepared to google information about converting between Pa, Atm, pounds per square inch (psi), and mm Hg units of pressure).

b) **Predict** whether an ideal gas model (a plunger changing the "heart" volume) will overestimate or underestimate the realistic pressure changes in your vasculature from your heart's pumping and artery compression.

Slide 6: Activity 2 Conclusions:

Justify reasoning (sense-making) for how this model emulates aspects of blood pressure in the human body. Also, **discuss** one way that real-world human vasculature and blood pressure are more complicated than a simple ideal gas relationship between pressure and volume. Articulate something that you learned through this lab and something that you will take forward and possibly apply in your own life or future career that you can connect back to this laboratory.

Slide 7: Activity 3 Analysis:

Show plots of P(t) made in PASCO Capstone of your syringe-heart model. **Describe** what you observed as you changed the volume of the syringe, how was the pressure in the system affected? **Show** your results for the maximum and minimum pressures observed. **Compare** the pressure differences between your systolic and diastolic blood pressures.