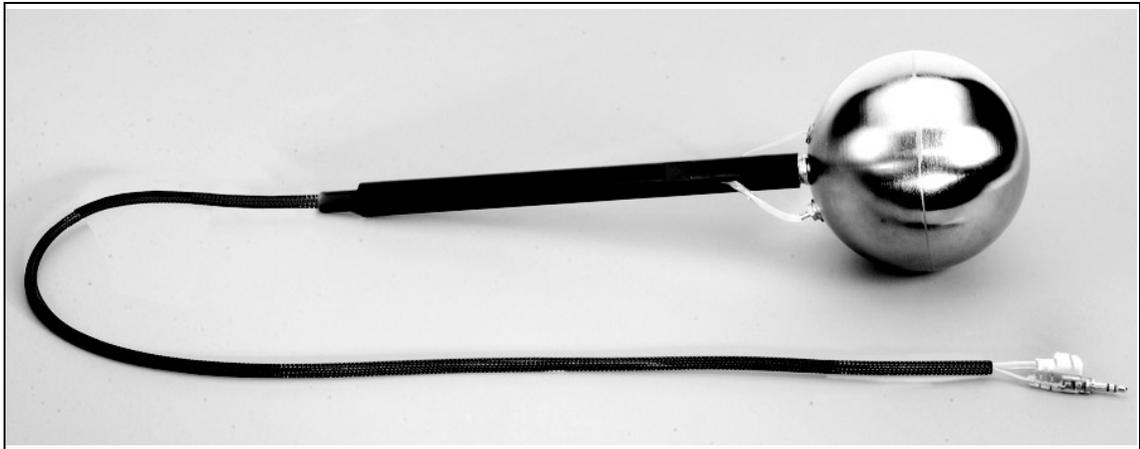




# Absolute Zero Apparatus

Model No. TD-8595





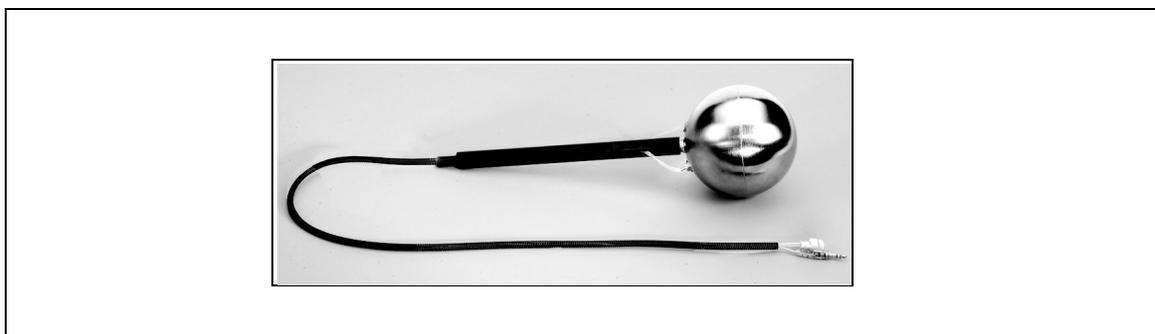
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# Absolute Zero Apparatus

Model No. TD-8595

## Equipment List



| Included Equipment         | Replacement Model Number* |
|----------------------------|---------------------------|
| 1. Absolute Zero Apparatus | TD-8595                   |

\*Use Replacement Model Numbers to expedite replacement orders.

| Additional Equipment Required                                       | Replacement Model Number*      |
|---|--------------------------------|
| A PASCO computer interface (PASPORT™ or <i>ScienceWorkshop</i> ®)*  | Various (See PASCO catalog.)   |
| DataStudio software (version 1.7 or later)                          | Various (See PASCO catalog.)   |
| Steam Generator or Hot Plate (or other means of heating water)      | TD-8556 or SE-8767             |
| Absolute Pressure Sensor or combination Pressure/Temperature Sensor | PS-2107 or CI-6532A or PS-2146 |
| Temperature Sensor or Thermistor Sensor*                            | PS-2125 or CI-6527A            |
| Ice (approximately 2 cups)  | N/A                            |
| A computer  | N/A                            |

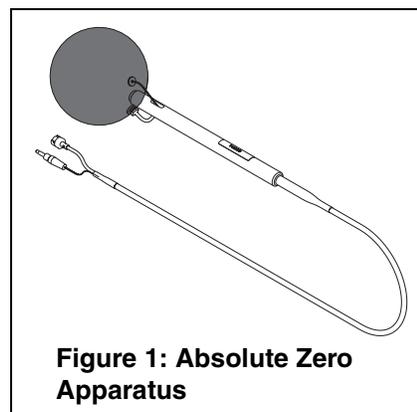
\*PASCO sensors require a PASPORT interface; *ScienceWorkshop* sensors require a *ScienceWorkshop* interface. A Fast Response Sensor is molded into the Absolute Zero Apparatus and works with any PASPORT interface. If you have a *ScienceWorkshop* interface, you will need a Thermistor Sensor (instead of a PS-2125 Temp. Sensor) to use the Absolute Zero Apparatus.

## Introduction

The Absolute Zero Apparatus consists of a Fast Response Temperature Sensor and plastic tubing (with pressure connector) mounted into a hollow copper sphere. When the sphere is submerged in a water bath and connected to a temperature sensor, pressure sensor, and a computer interface, DataStudio records and displays the temperature and pressure.

The Fast Response Temperature Sensor plugs into any PASPORT Temperature Sensor box or a *ScienceWorkshop* Thermistor Sensor, allowing the Absolute Zero Apparatus to be used with both PASCO's PASPORT and *ScienceWorkshop* interfaces.

The Absolute Zero Apparatus is used to experimentally determine the temperature of absolute zero (in degrees Celsius). Absolute zero, by definition, is the point at which a gas exerts zero pressure. With a computer, the Absolute Zero Apparatus can help students to observe the relationship between temperature and pressure and use DataStudio to mathematically extrapolate to find absolute zero.



**Figure 1: Absolute Zero Apparatus**

## Theory:

For an ideal gas, the absolute pressure is directly proportional to the absolute temperature of the gas.

$$T = \frac{V}{nR} P$$

Thus a plot of temperature vs. pressure will result in a straight line.

$$y = (\text{slope})x + b$$

$$T = \frac{V}{nR} P + 0$$

The slope of the line depends on the amount of gas in the thermometer, but regardless of the amount of gas, the intercept of the line with the temperature axis should be at absolute zero. If we instead plot the temperature in degrees Celsius, the intercept will not be zero, but rather the temperature of absolute zero in degrees Celsius.

## Equipment Setup (for use with DataStudio)

1. Plug the Fast Response Temperature stereo plug into a PASPORT Temperature Sensor box or into a *ScienceWorkshop* Thermistor Sensor.
2. PASPORT users: Plug the Temperature Sensor box into a PASPORT interface.  
  
Or  
*Science Workshop* users: Plug the Thermistor Sensor into a *ScienceWorkshop* interface.
3. Connect the Pressure port connector to a Pressure Sensor. Plug the Pressure Sensor into the computer interface.
4. Set up your experiment in DataStudio. In DataStudio, open a Graph display and plot temperature vs. pressure. Use manual sampling, with no keyboard input. (For detailed software setup instructions, See Appendix B of this manual.)
5. Submerge the sphere into a bucket of ice water.
6. In DataStudio software, click the **Start** button to begin collecting data. (For suggested experiments, see pages 6 to 9 of this manual.)

### Using the Absolute Zero Apparatus with a PASPORT Xplorer

The Absolute Zero Apparatus can be used with one or more Xplorers. If measuring both the pressure and the temperature with a combination Pressure/Temperature Sensor, you only need one Xplorer. If measuring both the pressure and temperature with two sensors, you will need at least two Xplorers.

1. Plug the stereo plug of the Fast Response Temperature Sensor into a PASPORT Temperature Sensor box.
2. Plug the Temperature Sensor into the first Xplorer.
3. (Optional): Connect the Pressure port connector to a Pressure Sensor. Then connect the Pressure Sensor to a PASPORT interface. Plug the Pressure Sensor into a second Xplorer.
4. Grasp the handle and submerge the sphere into the container of ice water.
5. In your Xplorer(s), press the **Start/Stop** button to begin collecting data.

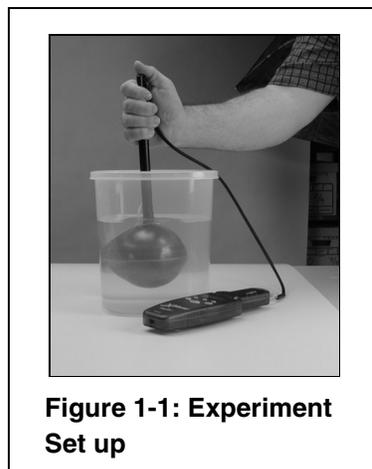
## Suggested Experiments

### Experiment I: Determining Absolute Zero while Keeping the Number of Gas Moles (n) Constant.

| Equipment required:  |  |
|--|--|
| Absolute Zero Sphere (TD-8595)                               | One bucket of hot water, one bucket of cold water, ice |
| Absolute Pressure Sensor (PS-2107) or (CI-6532A)             | DataStudio software (version 1.7 or later)             |
| Temperature Sensor (PS-2125) or Thermistor Sensor (CI-6527A) | Steam Generator (TD-8556) or Hot Plate (SE-8767)       |

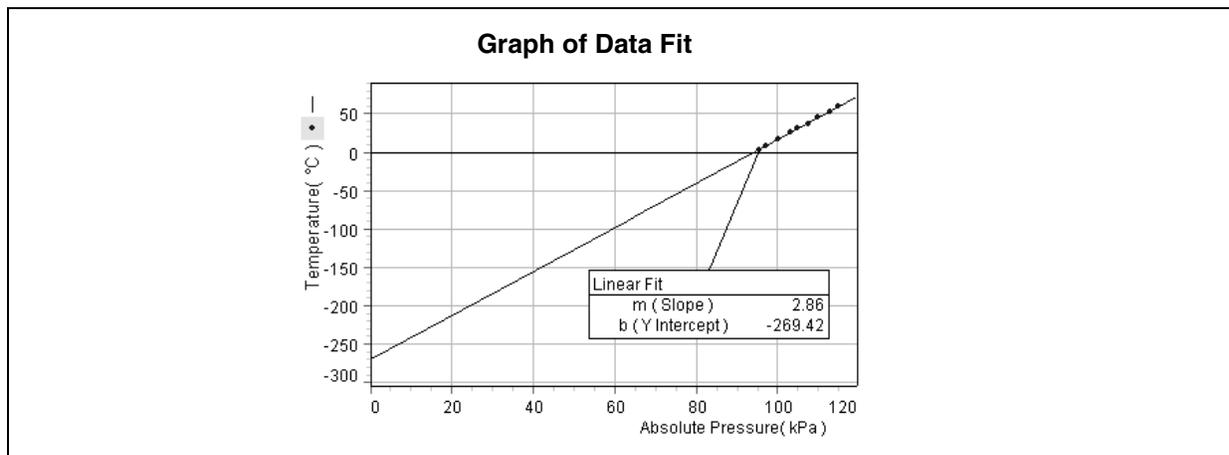
#### Procedure:

1. Start with the water as hot as possible.
2. Connect the hose fitting from the Absolute Zero Apparatus to the Pressure Sensor. Connect the stereo plug from the apparatus to the Temperature Sensor.
3. Set up your experiment in DataStudio (See Appendix B for setup instructions.) In DataStudio, open a Digits display and a temperature vs. pressure graph. Click the **Start** button.
4. Place the sphere of the apparatus in the water bath, and keep the sphere completely submerged.
5. Watch the Digits display of temperature. When the display stops changing (in the hundredths place), click on the **Keep** button. Do **not** stop recording.
6. Cool the water bath by adding cold water or some ice cubes. When the container becomes too full, dump out some of the water, but always have enough water to keep the apparatus completely submerged. Cool the bath by about  $10^{\circ}\text{C}$ , and repeat step (4).
7. Repeat steps 4 through 6, for temperatures down as low as you can go, and then click on the **Stop** button to end recording.
8. In the Graph display, click on the **Fit** button and select a linear curve fit. The y-intercept is your value for absolute zero.



**Figure 1-1: Experiment Set up**

## Sample Data (Experiment 1)



## Experiment II: Varying the Number of Moles of Gas (n)

|  |  |
|--|--|
| <b>Equipment required:</b>                                   |  |
| Absolute Zero Sphere (TD-8595)                               | One bucket of hot water, one bucket of cold water, ice, one bucket at room temperature |
| Absolute Pressure Sensor (PS-2107) or (CI-6532A)             | DataStudio software (version 1.7 or later)   |
| Temperature Sensor (PS-2125) or Thermistor Sensor (CI-6527A) | Steam Generator (TD-8556) or Hot Plate (SE-8767)                                       |

### Experiment Procedure:

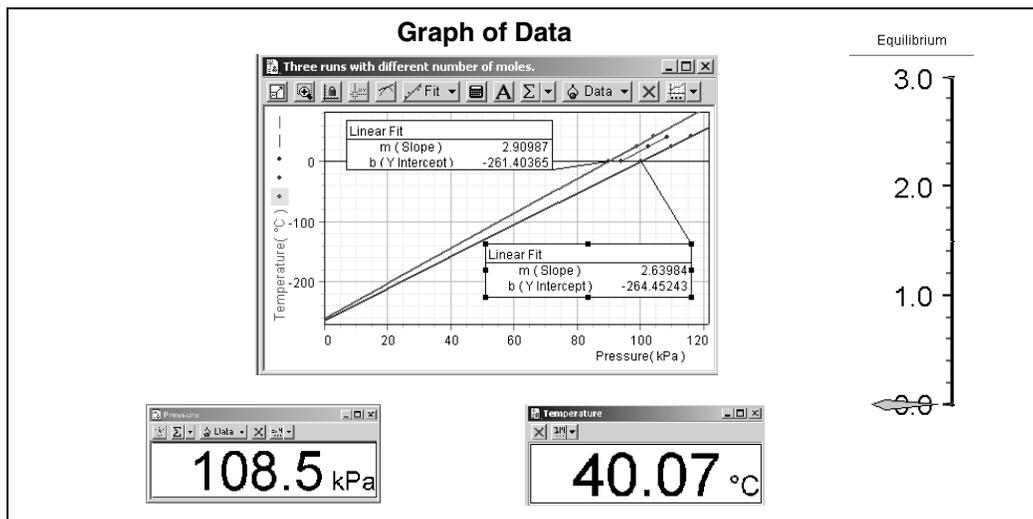
1. Prepare three different temperature water baths: A hot-water bath, room temperature bath, and a cold-water bath. Keep the hot-water bath as hot as possible, using a steam generator or hot plate, if available. Use ice for the cold water bath, if available. The room temperature bath needs to be somewhere in the temperature range between the other two baths.
2. Connect the stereo plug from the Absolute Zero Apparatus to the Temperature Sensor, but leave the hose fitting disconnected.
3. Set up your experiment in DataStudio. (For setup instructions, see Appendix B.)



**Figure 2-1: Experiment Setup**

4. Place the sphere of the apparatus in the ice-water bath, and connect the hose fitting to the Pressure Sensor. Keep the sphere completely submerged, click the **Start** button, and watch the Digits display of temperature.
5. When the temperature stops changing (in the hundredths place), click on the **Keep** button. Do **not** stop recording.
6. Place the sphere in the room temperature bath and repeat step 5.
7. Place the sphere in the hot-water bath and repeat step 5.
8. Click on the **Stop** button to end recording. Save this data to disk.
9. Click on the **Fit menu** button and select a linear curve fit. The y-intercept is your value for absolute zero.
10. Repeat the above procedure using a *different amount of gas (n)* in the sphere. This time, start with the room temperature bath. Disconnect the hose fitting from the Pressure Sensor. Place the sphere in the bath and re-connect the fitting. Take readings for all three baths as before. Plot this data on the same graph, click on the Fit menu button, and choose a linear curve fit. You will now have two lines with different slopes, but about the same intercept.
11. Repeat the above procedure again, starting this time with the hot-water bath. Take the readings in the other two baths, and plot this data on the same graph.
12. Average your three values, estimate the uncertainty, and round your answer to the appropriate number of significant figures. Compare the average of your three values for absolute zero with the accepted value of  $-273^{\circ}\text{C}$ .
13. Measure the volume of the sphere. Using the slope of each of the lines, determine the number of moles of gas in the container for each of the three runs.

## Sample Data (Exp.2) - Three Runs with Different Molar Amounts



## Appendix A: Specifications

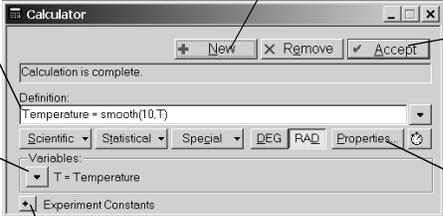
| Component                          | Description  |
|------------------------------------|--|
| Sphere:                            | Material: copper with hollow center<br>Radius: 2 inches<br>Volume: 32.66 inches<br>Surface area: 50.24 inches  |
| Temperature Probe (Fast Response): | Thermistor is 10,000 Kohms at 25°C,<br>Range: -35 to 135°C, -31 to 279°F,<br>238 to 408 K<br>Resolution: $\pm 0.01^\circ\text{C}$<br>Accuracy: $\pm 0.5^\circ\text{C}$ |
| Tubing:                            | Polyurethane, 3 feet in length   |
| Stereo plug:                       | 3.5 mm male plug   |

## Appendix B: DataStudio Setup Instructions

Follow the steps specific for the type of sensor and interface (i.e. PASPORT or ScienceWorkshop).

| Procedure   | Steps   |
|---|---|
| <b>PART I:</b> Plug the sensors into the interface:       | <p><b>PASPORT:</b> <b>a)</b> Plug the Temperature and Pressure Sensors into a PASPORT interface. <b>b)</b> Connect the PASPORT interface (i.e. USB Link, PowerLink, etc.) to a USB port on your USB-compatible computer. <b>c)</b> When the PASPORTAL window opens, select “Launch DataStudio.”</p> <p>OR</p> <p><b>ScienceWorkshop:</b> <b>a)</b> Plug the Temperature and Pressure Sensors into a <i>ScienceWorkshop</i> interface. <b>b)</b> Launch DataStudio.</p>  |
| <b>PART II:</b> Set up your experiment                    | <p><b>PASPORT:</b> <b>a)</b> In the Experiment Setup window, scroll to the Temperature Sensor, select “C” and set the sample rate to 10 Hz. <b>b)</b> Scroll to the Pressure Sensor, select “kPa” and set the sample rate 10 Hz. <b>c)</b> In the Experiment menu, select “ Set Sampling Options.” In the Sampling Options dialog, click on the Manual Sampling tab and click to place a check in the box next to “Keep data values only when commanded.” Click OK.</p> <p>OR</p> <p><b>ScienceWorkshop:</b> <b>a)</b> In the Welcome to DataStudio window, double click “Create Experiment.” <b>b)</b> In the Sensors list, click and drag the Temperature Sensor and Pressure Sensor icons to channels on the picture of the interface (i.e. to the same letters in which you have the sensors connected). <b>c)</b> In the Experiment Setup window, double click on the Temperature Sensor icon and ensure the sampling rate is set at 10 Hz. Repeat this step for the Pressure Sensor. Click OK to save any changes. <b>d)</b> In the Experiment menu, select “ Set Sampling Options.” In the Sampling Options dialog, click on the Manual Sampling tab and click to place a check in the box next to “Keep data values only when commanded”. Click OK.</p> |
| <b>PART III:</b> Create the equations for your experiment | <p><b>a)</b> Temperature equation: <math>\text{Temperature} = \text{smooth}(10, T)(^{\circ}\text{C})</math> where T= temperature in degrees Celsius <b>b)</b> Pressure equation: <math>\text{smooth}(10, P)</math> (kPa), where P= pressure in kPa [Select “data measurement” for the “T” and “P” variables. <b>c)</b> <math>\text{Change} = \text{abs}(100 * \text{derivative}(2, \text{smooth}(8, T/P))</math>. This equation can be transferred to a Meter display to show an equilibrium scale, which indicates how much the temperature deviates from absolute zero (where zero is no thermal motion of gas molecules). Drag this equation to a Meter display. In the Scale tab of the Meter display, set the minimum to 3.0, maximum to 0, start angle to 359.99, and end angle to 0.01. Select custom sweep and click <b>OK</b>. (For more instructions on creating equations, see Appendix C or the DataStudio online help.)]</p>   |
| <b>PART IV:</b> Collect Data                              | <p><b>a)</b> From the Data list, drag each of the parameters (i.e temperature, pressure, change) over a y-axis in a separate graph display. <b>b)</b> Drag the equilibrium parameter to a Meter display. <b>c)</b> Click the <b>Start</b> button on the main toolbar.</p>   |

## Appendix C: Creating Equations in DataStudio



**Step 1: Create a new equation.** On the main toolbar, click the **Calculate** button to open the Calculator dialog. In the Calculator dialog, click the **New** button.

**Step 2: Type in and/or build the equation.** (Use the Scientific, Statistical, and Special menus, and the trigonometric functions to build the equation.) Click the **Accept** button.

**Step 3: Define the dependent variables.** Under “Variables,” use the down arrow to select a variable or constant, etc. and click OK. (Example: For “T,” select “Data Measurement.” In the pop-up, select “Temperature,” and click OK.

**Step 4: Enter any experiment constants (optional).** Use the (+) button to create an experiment constant. Click **New**, then enter the name, value and units for the constant. Click the **Accept** button. Go back to the Variables menu and select “experiment constant”. Click OK.

**Step 5: Label the units.** Click on the **Properties** button to open the Data Properties dialog and enter the name and units. (Example: In the Data Properties dialog, type “temperature” in the name box and “C” in the units box.)

**Step 6: Save the equation.** Click the **Accept** button.

**Note:** Each time you build a new equation, click the **New** button. To edit a completed equation, double click on the equation in the Data list, make your changes, and click the **Accept** button to save your changes.

## Appendix D: Technical Support

For assistance with the TD-8595 Absolute Zero Apparatus or any other PASCO products, contact PASCO as follows:

Address: PASCO scientific

10101 Foothills Blvd.

Roseville, CA 95747-7100

Phone: (916) 786-3800

FAX: (916) 786-3292

Web: [www.pasco.com](http://www.pasco.com)

Email: [techsupp@pasco.com](mailto:techsupp@pasco.com)

## Appendix E: Copyright and Warranty Information

### Copyright Notice

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### Warranty

For a description of the product warranty, see the PASCO catalog.

