THE UNIVERSITY OF HONG KONG

Department of Physics

PHYS2261 Introductory heat and thermodynamics

Laboratory manual 2261-2:

Heat Engine

* Remember to bring your USB to save down the raw data. You will need to them do plotting at home after the laboratory session. Print or attach the plots to your laboratory report before submission.

Part A.   Charles' Law

Equipment Required:
Heat Engine/Gas Law Apparatus, Temperature Sensor, SPARKlink, Container of hot water, Ice

Purpose:
To observe the Charles' law $V = cT$ at constant pressure.

Theory:
Charles' Law is an experimental gas law which results from gas expansion under heat. It states that at a constant pressure, the volume V of a fixed mass or quantity of gas is directly proportional to the absolute temperature T :

$$V = cT \qquad\qquad\qquad\qquad (1)$$

where T is measured in Kelvin (K) and c is a constant.

Setup:
1. Using the one-holed stopper and plain tubing, connect the base apparatus and the air chamber.
(Figure 1) Connect the temperature sensor to SPARKlink (Figure 2) through temperature port. Connect SPARKlink to computer.
2. Close the shut-off valve (Figure 3) on the tubing from the unused port.
3. Turn the base apparatus on its side. (In this position, the force acting on the apparatus is the atmospheric pressure and is equal throughout the range of operation of the piston.)

Software:
1. Open Capstone on computer. In the *Hardware Setup*, click *Add Sensor/Instrument* and select "PASPORT Sensors" in *Sensor or Instrument Type* and select "Temperature Sensor" in *Sensor/Instrument List*.
2. Drag-and-drop the *Graph* icon from the *Displays* menu onto the page. On the y-axis, select measurement to be Temperature that is under the SPARKlink Temperature Sensor label. Select Time(s) for the x-axis.
3. Drag-and-drop the *Table* icon from the *Displays* menu onto the page. In the header of the first column, click *Select Measurement* and create *User-Entered Data.* Give the name *Height* and appropriate unit. For the second column, select measurement to be Temperature under the SPARKlink Temperature Sensor label.
4. Drag-and-drop the *Graph* icon from the *Displays* menu onto the page. On the y-axis, select measurement to be Height. Select Temperature for the x-axis.
5. Adjust the common *Sample Rate* to 2s or 5s.

Procedure:
1. Place the air chamber and temperature sensor in a container of hot water (Figure 1). After the chamber equilibrates to the temperature, record the height of the piston in the table next to the latest temperature recorded.
2. Add ice to the container and record the temperature and the height of piston at regular time intervals.
3. Calculate the gas volumes at the various piston positions you measured and make a graph of temperature vs volume. (Hint: The diameter of the piston is 32.5 mm.)
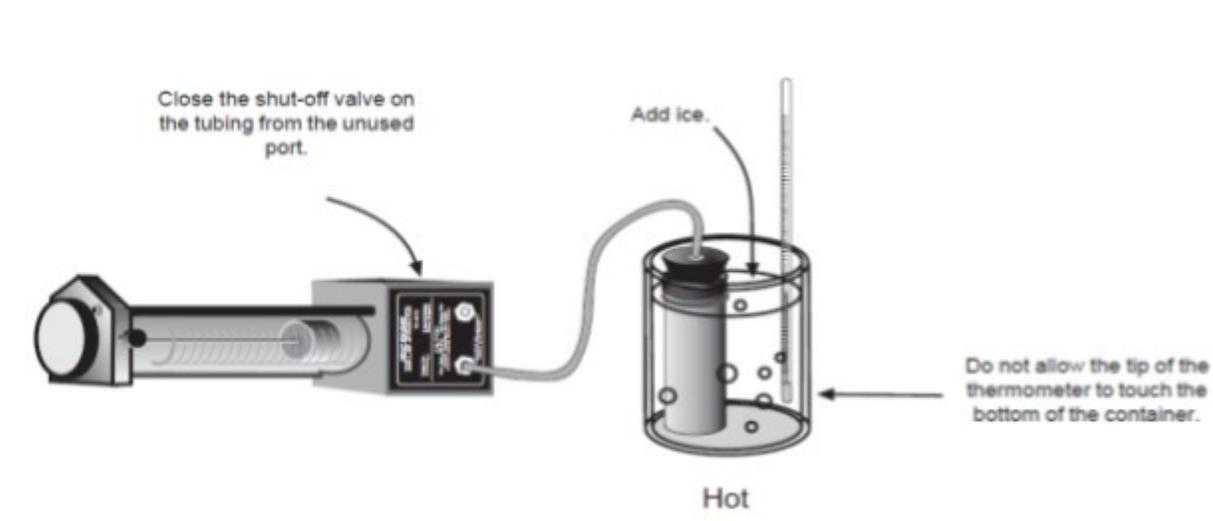
is experiment)

Figure 1 – Setup of Charles' Law experiment
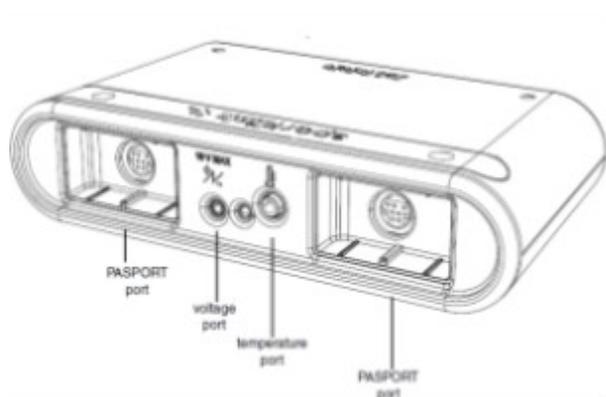
Figure 2 – SPARKlink

Figure 3 – Shut-off valve on tubing

Part B.   Gay-Lussac's Law

Equipment Required:
Air Chamber, SPARKlink, Dual Pressure Sensor, Temperature Sensor, Hot Plate, Beaker with water

Purpose:

To observe the Gay-Lussac's Law $\dfrac{P}{T}=k$ at constant volume.

Theory:

Gay-Lussac's Law states that the pressure P of a gas of fixed mass and fixed volume is directly proportional to the gas's absolute temperature T :

$$P \propto T \tag{2}$$

Setup:

1. Use a short piece of tubing to connect the Dual Pressure Sensor to the air chamber fitted with the 2-hole stopper.

2. Insert the Temperature Sensor into the other hole of the rubber stopper.

3. Connect the Dual Pressure Sensor and the Temperature Sensor to the computer.

4. Place the air chamber in the water container and turn on the hot plate. (Figure 4)

Figure 4a – Setup of Gay-Lussac's Law experiment

Figure 4b – Temperature sensor and pressure sensor fitting with the two-holed stopper

Figure 4c – Air chamber with temperature sensor and pressure sensor on the hot plate

Software:

1. Open Capstone on computer. In the *Hardware Setup*, click *Add Sensor/Instrument* and select "PASPORT Sensors" in *Sensor or Instrument Type* and select "Temperature Sensor" in *Sensor/Instrument List*.

2. Click *Add Sensor/Instrument* and select "PASPORT Sensors" in *Sensor or Instrument Type* and select "Pressure Sensor, Dual" in *Sensor/Instrument List*.

3. Drag-and-drop the *Graph* icon from the *Displays* menu onto the page. On the y-axis, select measurement to be Temperature that is under the SPARKlink Temperature Sensor label. Select Time(s) for the x-axis.

4. Drag-and-drop the *Graph* icon from the *Displays* menu onto the page. On the y-axis,

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select measurement to be Absolute Pressure 1/2 (Note which channel of the pressure sensor you connected and choose the correct channel) that is under the Dual Pressure Sensor label. Select Time(s) for the x-axis.

5. Adjust the common *Sample Rate* to 2s or 5s.

Procedure:

1. Record the temperature and pressure as the water heats.

2. CAUTION: To avoid over pressure, please ensure that the temperature inside the Air-chamber does not exceed 35 ° C. This is to prevent the stopper from blowing out thereby causing injury.

3. Make a graph of temperature versus pressure.

Part C.   Operation of a Heat Engine

Equipment Required:

Heat Engine/Gas Law Apparatus, 100 – 200 g mass, container of hot water, container of ice water

Purpose:

To observe and understand the operation of a mass lifting heat engine.

Setup:

1. Using the one-holed stopper, connect the tubing with the one-way valves to the air chamber and to a connecting port on the base assembly. (Figure 5)

2. Close the shut-off valve on the tubing from the unused port.

3. Set a mass of 100 to 200 g on the mass platform.

Note: Use a maximum mass of 200 grams in the experiment. A larger mass will cause the valve seals to leak.

Procedure:

1. Move the air chamber from an ice water bath to a hot water bath. You will note that the air in the chamber quickly expands through the tubing and moves the piston up. Note also that the one-way check valve in the tubing connecting the base apparatus and the air chamber permits air to enter the cylinder, while the other one-way check valve prevents air from leaving through the branched tube.

2. Move the air chamber back to the cold bath and note that external air is sucked into the air chamber through the one-way valve located at the end of the branched tube. Note also that the one-way valve in the connecting tube prevents the air from escaping from the piston, so the height of the piston remains the same.

3. Repeat steps 1 and 2 until the mass has been completely lifted.

Note: The greater the temperature differential between the hot and cold water baths, the greater the lift achieved through each cycle through them.

Close the shut-off valve on the tubing from the unused port.

one-way check valves

direction of air flow
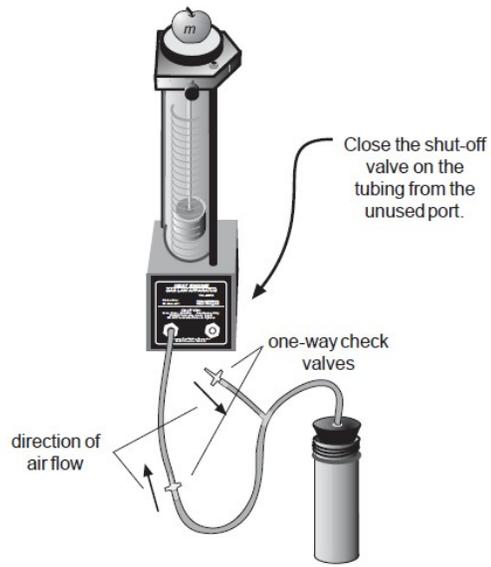
Figure 5 – Setup of Heat Engine