

**The University of Hong Kong**  
**Department of Physics**  
**Experimental Physics Laboratory**

**PHYS2260 Heat and Waves**  
**2260-2 LABORATORY MANUAL**  
**Experiment 2: Heat Engine**

**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  $T$ :

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

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.)

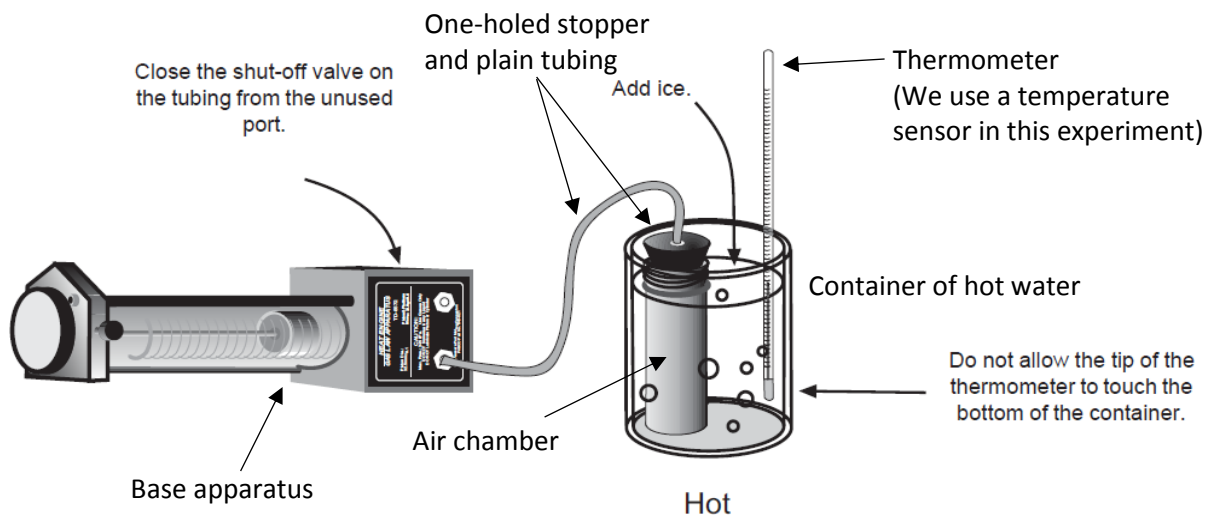


Figure 1 – Setup of Charles' Law experiment

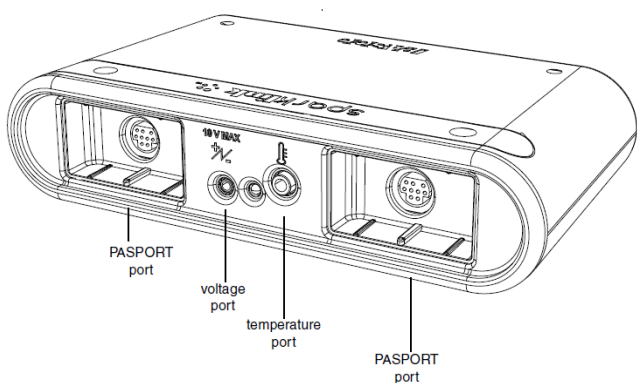


Figure 2 – SPARKlink



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  $\frac{P}{T} = k$  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  $T$ :

$$P \propto T \quad (2)$$

or

$$\frac{P}{T} = k \quad (3)$$

where  $k$  is a constant.

**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, 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.

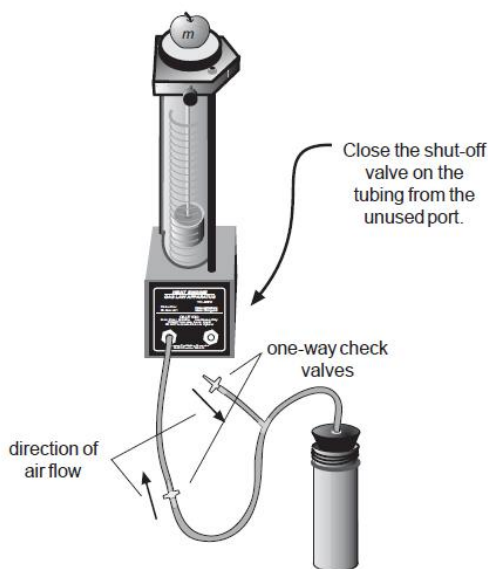


Figure 5 – Setup of Heat Engine