Gas Laws

Purpose

To appreciate the Gas Laws and investigate how temperature affects the air pressure inside a sealed tube with fixed volume, followed by an estimation of absolute zero – the lowest possible temperature.

Theory

- By kinetic theory, temperature *T* represents the kinetic energy contained by the gas molecules. The SI unit is Kelvin (K). In this experiment, however, degree Celsius (°C) will be used for graph plotting in order to extrapolate absolute zero.
- Pressure *P* is defined by the force exerted on the container wall by the gas per unit area. The SI unit is Pascal (Pa) which is equivalent to kg m^{-1} s^{-1}. Since the air pressure at 25°C is about 101325Pa, we usually express pressure with kPa (1kPa = 1000Pa).
- Volume *V* is the effective volume of container. Number of mole *n* represents the number of molecules in terms of the multiple of 6.02×10^{23} which is called Avogadro's constant.
- The Ideal Gas Laws are constructed by 4 famous laws, namely Avogadro's Law, Boyle's Law, Charles' Law and Gay-Lussac's Law.
- **Avogadro's Law** states that the volume *V* occupied by an ideal gas is directly proportional to the number of gas molecules *n*.

$$\text{i.e. } \frac{V_1}{n_1} = \frac{V_2}{n_2}$$

- **Boyle's Law** states that volume *V* of a fixed amount of gas is inversely proportional to its pressure *P* given that its temperature *T* is kept constant.

$$\text{i.e. } V \propto \frac{1}{P} \text{ OR } P \propto \frac{1}{V}$$

- **Charles' Law** states that at constant pressure *P*, the volume of gas *V* is directly proportional to its temperature *T*.

$$\text{i.e. } V \propto T$$

- **Gay-Lussac's Law** states that with constant volume of gas *V*, the pressure exerted *P* is directly proportional to its temperature *T*.

$$\text{i.e. } P \propto T$$

- Summing up the above laws, the Ideal Gas Law is derived.

$$PV = nRT$$

  where *R* is the universal gas constant valued at 8.314 kPa m^3 mol^{-1} K^{-1}.
- Ideal gas refers to one that the gas molecules perform completely random motion in all directions, without interactions with each other except elastic collisions.

Apparatus

- A mobile device with "Lab in Your Pocket" app
- A power bank
- An air-filled sealed tube with temperature and pressure sensors inside (provided)
- A water bath

Experimental Set-up

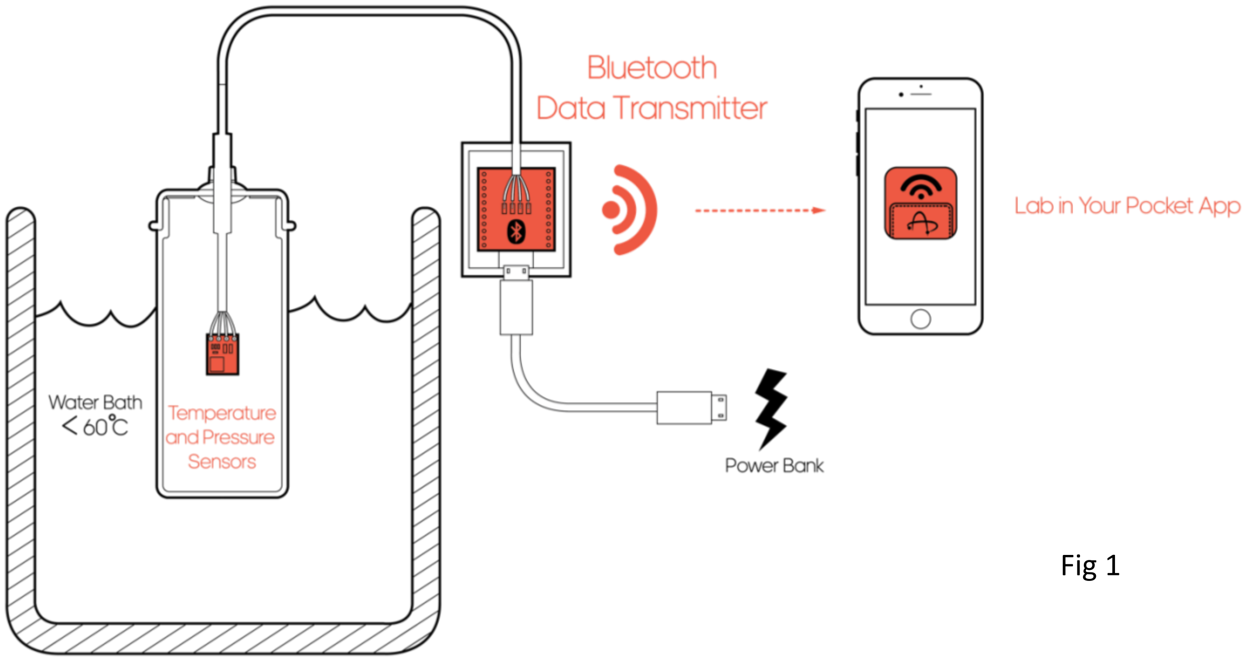

Fig 1

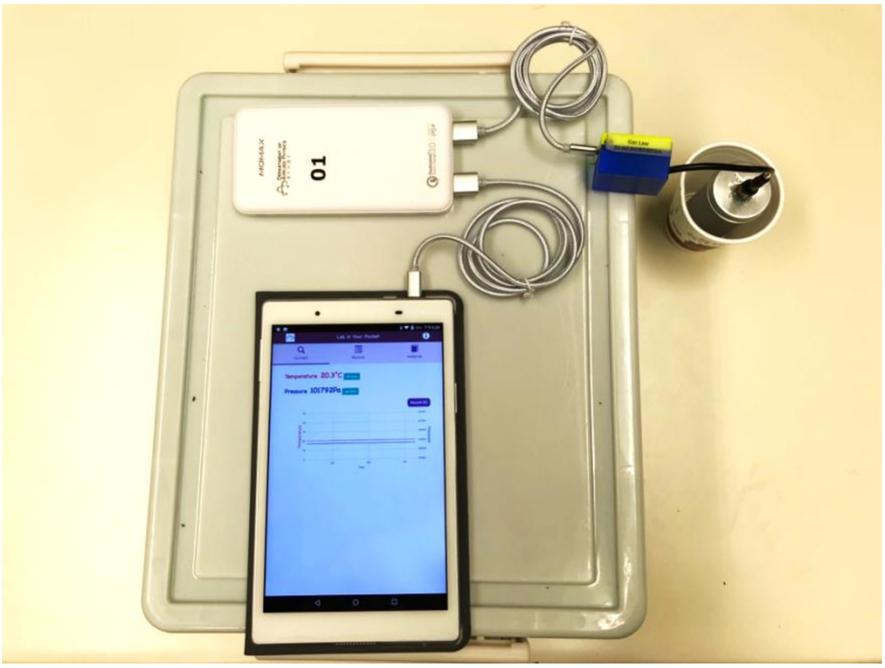

Fig 2

Precautions

1. Keep the water bath below 50°C to prevent injury or damage of sensors.
2. Avoid opening any part of the set-up as leakage of aluminium can may occur. If the pressure rapidly returns to initial level after warming up/cooling down, it implies that the aluminium can is not perfectly sealed. In this case, check the possible leakage at the conjunctions of set-up and tighten the cover of aluminium can. Contact the supporting team in case the problem persists.

Procedure

1. Turn on the temperature and pressure sensors by connecting the power cable.
2. Open the app "Lab in Your Pocket" and choose "Gas Law" (Fig 3).

Fig 3

Fig 4

3. Enter Bluetooth address of the sensors (Fig 4) and connect them to the app via Bluetooth by pressing "Connect".
4. Read the temperature and pressure data under room environment and record it by pressing the "Record" button at the bottom right corner (Fig 6). The number above the button shows the data points collected.
5. Prepare a water bath at about 40°C. Insert the tube into the water bath.

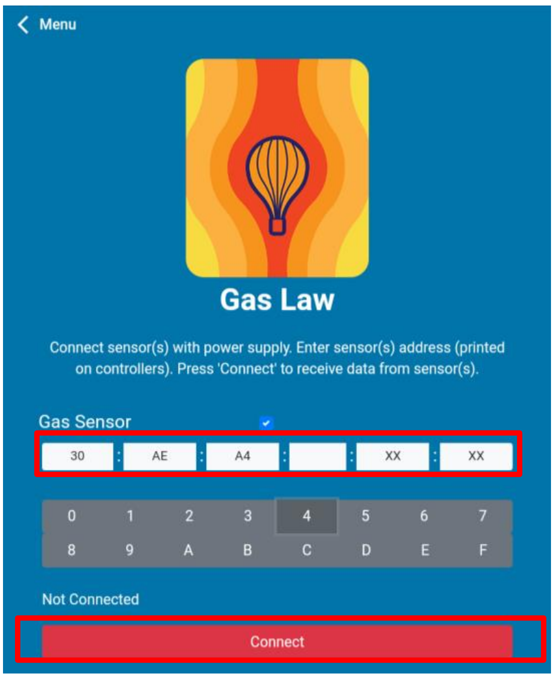

Fig 5

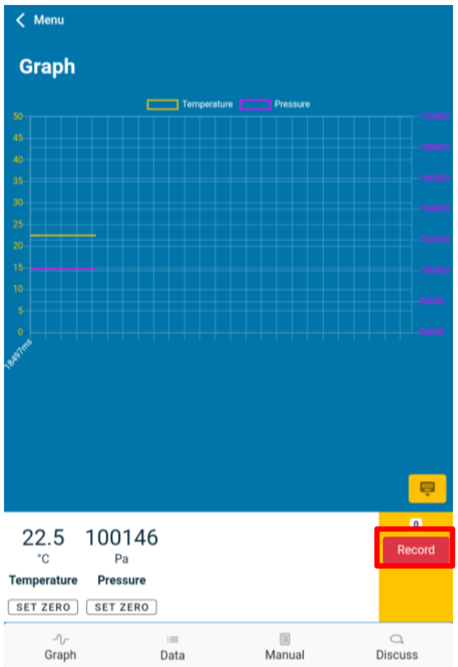

Fig 6

6. Read the data as the temperature of the air inside the tube rises. Note that the pressure sensor reacts faster than the temperature sensor. It is advised to wait for 5-10 minutes until both sensors give accurate data in the can.
7. When the temperature starts to flatten out or drop, i.e. the equilibrium temperature has been reached, press the “Record” button to record data.
8. As the water bath gradually loses heat to the surroundings, repeatedly take data with the “Record” button at 1-minute interval until the temperature is approaching room temperature. You may speed up the cooling process by adding tap water to the water bath.
9. Export the data in the “Record” tab and plot them on the graph paper (Fig 7).

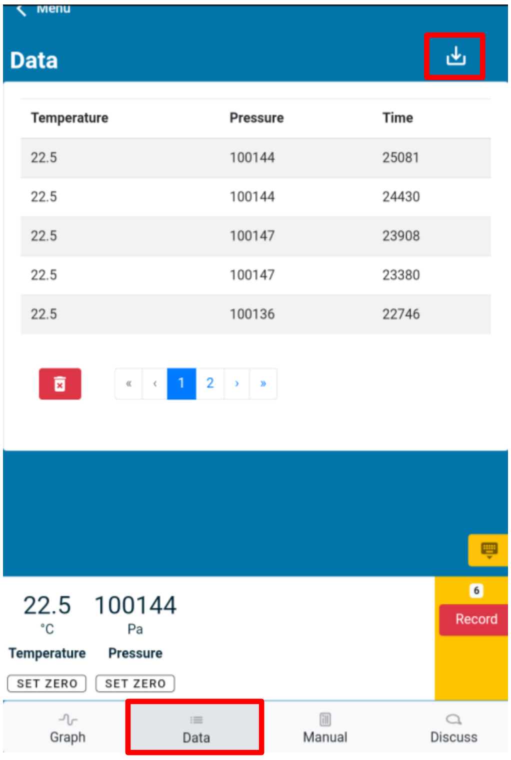

Fig 7

Data

Table:

Temperature (°C)	Pressure (kPa)

Graph:

Discussion

1. What is the relationship between absolute temperature and pressure? Does it align with the gas laws?
2. What is the slope and y-intercept of the graph? By y = mx + c, the “absolute zero” can be determined by dividing c with m. What is the experimental value of “absolute zero” in degree Celsius?
3. What are the possible reasons of the discrepancy between the experimental value and the literature value?