Experiment 3
RATIO OF SPECIFIC HEATS OF AIR

1.0 OBJECTIVE

- The purpose of the experiment is to determine the ratio of the specific heats of air $(K = \frac{C_P}{C_V})$ of a diatomic gas (air) by method of adiabatic expansion.
- The results obtained are compared with the theoretical value.

2.0 INTRODUCTION & THEORETICAL BACKGROUND

This method was devised by Clement and Desormes in 1819. It is based upon the adiabatic expansion of a gas in a large container; the experimental process is shown in Figure 1. A laboratory version of their apparatus is shown in Figure 2.

As we know $(K = \frac{C_P}{C_V})$, where:

Cp: means specific heat of air at constant pressure $(\frac{kJ}{kg.k})$

Cv: means specific heat of air at constant volume $(\frac{kJ}{kg.k})$

Also $H = Cp \times T \quad and \quad U = Cv \times T$

So, $K = H / U = Cp / Cv$

Further $Cp - Cv = R \ then \quad Cp = \frac{K}{K-1} R \quad and \quad Cv = \frac{R}{K-1}$

For diatomic gas (air) $K = 1.4 \ldots\ldots\ldots\ldots\ldots \frac{f+2}{f} \ldots\ldots\ldots f = 5$

For monoatomic gas $K = 1.67 \ldots\ldots\ldots\ldots \frac{f+2}{f} \ldots\ldots\ldots f = 3$

A PV diagram of the experiment is shown in Figure 1

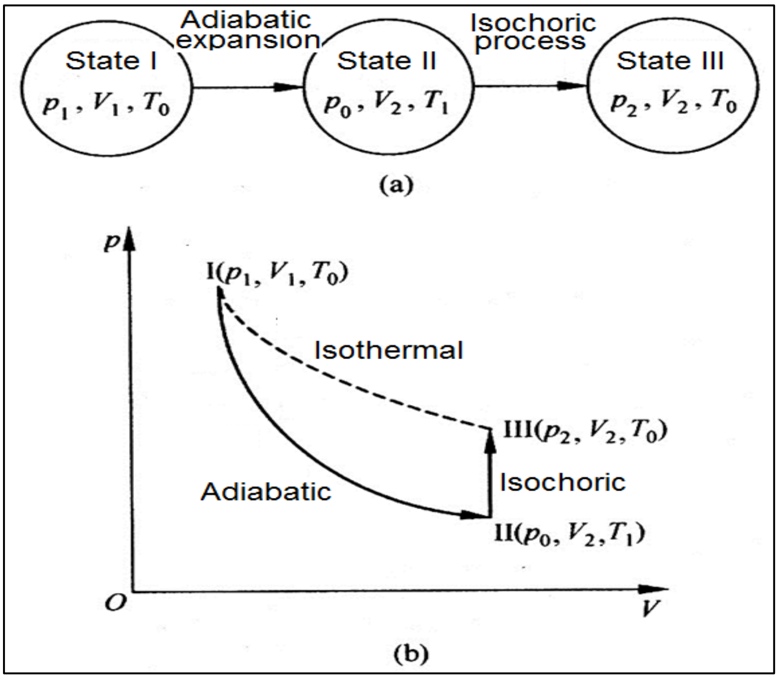

Fig. 1: Experimental process

Stage One: Adiabatic Expansion Process (State I- State II)

$$\frac{P^{K-1}}{T^K} = C$$

$$\left(\frac{P_1}{P_o}\right)^{K-1} = \left(\frac{T_o}{T_1}\right)^{K} \tag{1}$$

Stage Two: Constant volume Expansion Process

(Isochoric Process) (State II- State III) **till** ($T_{air} = T_o$)

$$\frac{P}{T} = C$$

$$\frac{P_o}{T_1} = \frac{P_2}{T_o}, \qquad and \qquad \frac{T_o}{T_1} = \frac{P_2}{P_o}$$

$$\frac{P_2}{P_o} = \frac{T_o}{T_1} \tag{2}$$

Combining these two equations (1) & (2) we get:

$$\left(\frac{P_1}{P_o}\right)^{K-1} = \left(\frac{P_2}{P_o}\right)^{K}$$

With $P_o = P_{\text{atm}}$ $\qquad P_1 = \gamma H_1 + P_{atm}$ $\qquad P_2 = \gamma H_2 + P_{atm}$ $\qquad \gamma = \rho g$

Take $(K-1)\, ln\left(\frac{P_1}{P_o}\right) = (K) ln\left(\frac{P_2}{P_o}\right)$, Then

$$K == \frac{ln\left(\frac{P_1}{P_o}\right)}{ln\left(\frac{P_1}{P_2}\right)} \tag{3}$$

3.0 APPARATUS

A large container of at least 10 liters (0.01 m3) capacity contains air at atmospheric pressure. The container is connected with a bicycle tire pump, a large valve and a tube connecting the container to a manometer filled with mercury.

The container is usually surrounded by insulation although this is really unnecessary since the air is a bad conductor of heat and the resulting expansion is rapid. A little concentrated sulphuric acid may be placed in the container to dry the air. (See Figure 2)

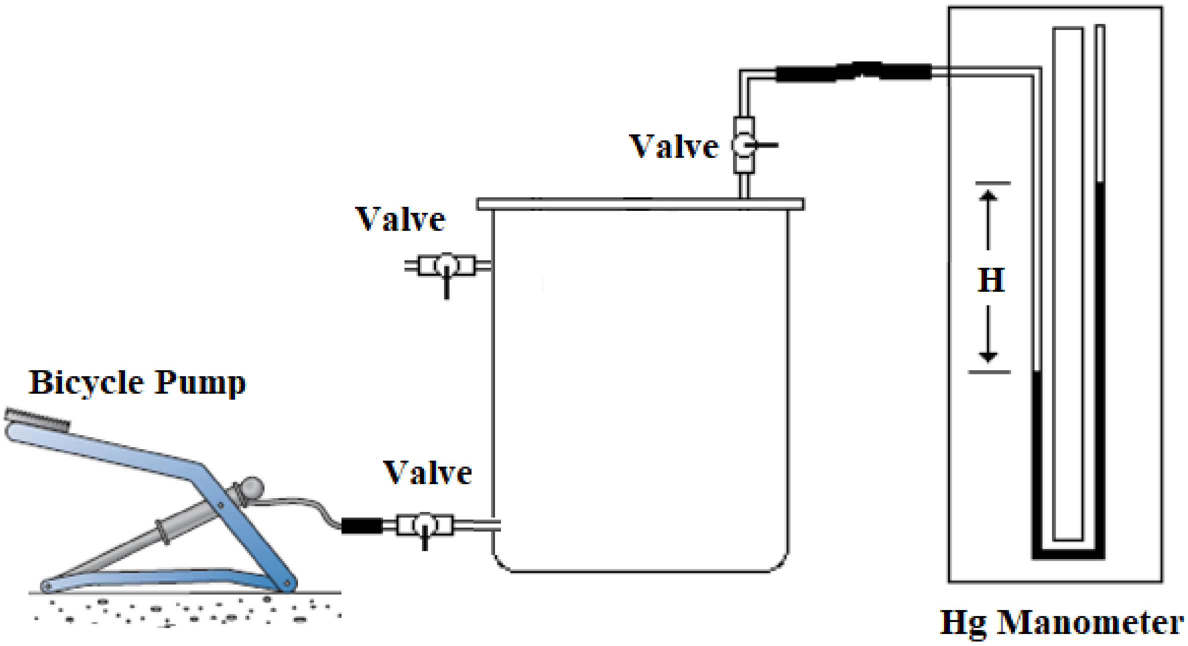

Fig. 2: Apparatus - Schematic Layout

4.0 PROCEDURE

1. The vessel is filled with air at pressure P_1 using the bicycle pump until the manometer reads a pressure **H_1** mm of mercury slightly greater than atmospheric.
2. The vessel is then put in communication with the free air at pressure P_o by opening stopcock valve, so as to equalize the pressures in the sudden, nearly adiabatic expansion.
3. The stopcock is then rapidly closed.
4. The air in the vessel allowed to regain its initial temperature, and the pressure P_2 is then determined from **H_2** .
5. One source of error in this method is the exchange of heat between the air and the walls of the vessel during the expansion.

OBSERVATIONS

Table 1: DATA OBSERVED

Atmospheric Pressure $P_o = P_{atm}$:____________ kP_a			
Trial #		**H_1** **mmHg**	**H_2** **mmHg**
1			
2			
3			
4			
5			

*** All pressures must be in absolute values**

5.0 DATA ANALYSIS

$P_o = P_{atm}$ *All in* kP_a

$P_1 = \rho_{Hg} \times g \times H_1 + P_{atm}$

$P_2 = \rho_{Hg} \times g \times H_2 + P_{atm}$

$$\boldsymbol{K} == \frac{\boldsymbol{ln}\left(\frac{\boldsymbol{P_1}}{\boldsymbol{P_o}}\right)}{\boldsymbol{ln}\left(\frac{\boldsymbol{P_1}}{\boldsymbol{P_2}}\right)}$$

6.0 RESULTS & DISCUSSION

Table 2: SUMMARY OF RESULTS

Trial #	P_o	P_1	P_2	$\ln\left(\frac{P_1}{P_o}\right)$	$\ln\left(\frac{P_1}{P_2}\right)$	K	Error %
	kPa	kPa	kPa				
1							
2							
3							
4							
5							

$$\% \ \mathbf{Error} = \frac{|\mathbf{Theoretical} - \mathbf{Measured}|}{\mathbf{Theoretical}} \times \mathbf{100}\%$$

The Theoretical value for adiabatic index (K) is equal to 1.4.

$$\mathbf{Kair = 1.4}$$

1. Plot the graph of $ln\left(\frac{P_1}{P_o}\right)$ versus $ln\left(\frac{P_1}{P_2}\right)$ and using the basic fitting linear, find the slope of the line which = K-value.
2. All the results were recorded and tabulated under the results table.
3. Compare (K-value) from results to that of standard value.
4. Discuss any discrepancy and sources of the possible causes of errors.
5. Write your own opinions about the results. What might be? Discuss about whether the results are acceptable or not?

NOTE: This page is intentionally left blank to identify your important notes