Determination of the Air Adiabatic Constant
Meteorology & Climatology

Environmental Science Degree

December 17, 2018

Date Performed:	____________
Partners:	____________
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Abstract

In this lab session the Rüchhardt method is used to measure the adiabatic coefficient, γ, of the air.

1 Introduction

Due to the low thermal conductivity of the air and the typical time of most meteorological processes, the buoyant convection and, in general, most vertical air parcels displacements can be considered as adiabatic processes. To do so, the following aaproximations are assumed:

- The air parcel does not mix appreciably with its surroundings.
- Mechanical equilibrium: the parcel pressure adjusts instaneously to pressure changes in the surrounding atmosphere.
- The parcel temperature does NOT adjust to temperature changes in the environment.
- Energy changes in the macroscopic motion of the parcel are small compared to total energy.

An adiabatic process is characterized by the lack of heat transfer. All temperature changes are associated with exchanges between internal energy and work, typically through expansion (gas temperature diminishes) or contraction (gas temperature increses) of the system. For ideal gases they are modeled by the Poisson equations

$$p\ V^{\gamma} = \text{Constant}, \quad (1)$$

$$T\ V^{\gamma-1} = \text{Constant}, \quad (2)$$

$$T\ p^{-\kappa} = \text{Constant}, \quad (3)$$

where $\kappa = 1 - \frac{1}{\gamma}$ and γ is the adiabatic coefficient of the ideal gas and it is equal to the ratio of the molar heat capacity for constant pressure and constant volume, $\gamma = \frac{C_p}{C_v}$. For diatomic ideal gases $\gamma = 7/5 = 1.4$ and $\kappa = 0.286$.

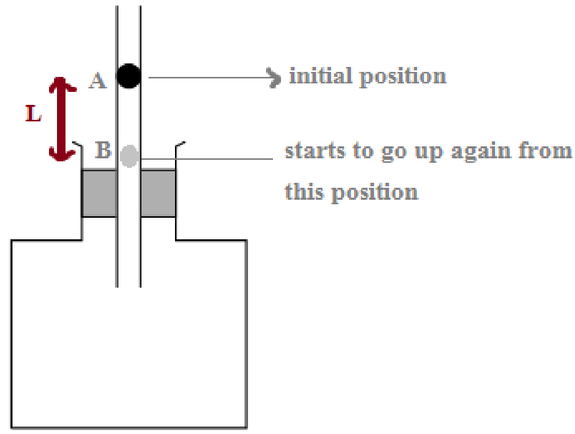

Figure 1: Scheme of the Rüchhardt method.

2 Objectives

The objective of this lab session is to *determine the adiabatic coefficient of the air* γ using the Rüchhardt method. This method is based on the displacement from equilibrium of a piston of mass m that is released to oscillate in damped simple harmonic motion (see figure 1). The frequency of oscillation is measured and this measurement is combined with the known physical parameters of the system to estimate γ. *The piston is a fragile piece of equipment that should be handled with care*.
As a bonus, a second objective of the lab session is to appropriately identify the *possible sources of errors and your result uncertainty*.

3 Theoretical Basis and Lab Procedures

The harmonic motion of the piston is modeled by the following equation

$$\frac{d^2 z}{dt^2} = -\frac{\pi^2 R^4 p\,\gamma}{mV}\,\Delta z\,, \tag{4}$$

where R and m are the piston radius and mass, p is the pressure on the vessel and V is the vessel volume.
From Eq. (4) we know that the period of the harmonic motion, T is

$$T = \frac{1}{2R^2}\sqrt{\frac{m\,V}{p\,\gamma}}\,, \tag{5}$$

and thus, once we measure the period of the vibrations we can compute γ as

$$\gamma \;=\; \frac{4\;m\;V}{T^2\;R^4\;p} \tag{6}$$

4 Experimental Data

Piston mass:

$m \pm E_m =$ ______________________

Piston diameter and radius:

D_1	D_2	D_3	D_4	D_5
R_1	R_2	R_3	R_4	R_5

$\overline{R} =$ ______________________ $\sigma_{\overline{R}} = \sqrt{\frac{\sum_i (R_i - \overline{R})^2}{N(N-1)}} =$ ______________________

$R \pm E_R =$ ______________________

Period of the harmonic motion:

Time for 500 oscillations:

t_1	t_2	t_3	t_4	t_5
$T_1 = t_1/500$	T_2	T_3	T_4	T_5

$\overline{T}$ **=** $\bar{t}$**/500 =** ______________________ $\sigma_{\overline{T}} =$ ______________________

$T \pm E_T \ =$ ______________________

Pressure in the vessel:

p_{atm} **=** ______________________ $\frac{m\ g}{\pi\ \overline{R}^2}$ **=** ______________________

$p \ = \ p_{atm} \ + \ \frac{m\ g}{\pi\ \overline{R}^2}$ **=** ______________________

$p \pm E_p \ =$ ______________________

Vessel volume:[1]

$V \pm E_V =$ ________________

5 Results and Conclusions

Air adiabatic coefficient:

γ **=** ________________ $\sigma_{\overline{\gamma}} =$ ________________

[1]The vessel volume measurement implies filling the vessel with water and weighing it.This is not going to be done during the lab session and we provide its value and error: $V = (1020 \pm 5)\ \mathrm{cm}^3$.

References

M.W., Z. and R.H., D. (November 1, 1996). *Heat and Thermodynamics*. McGraw-Hill, 7th edition.

Stull, R. (2015). *Practical Meteorology*. UBC.