LAB MANUAL

PHYS102

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EASTERN MEDITERRANEAN UNIVERSITY
Department of Physics

Experiment 1: Specific Heat Capacity and Latent Heat of Fusion


Eastern Mediterranean University
"Virtue, Knowledge, Advancement"

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PURPOSE

To evaluate the specific heat capacity of iron and brass and the latent heat of fusion of water.

APPARATUS

Calorimetric cup, a saucepan, a heater, a thermometer, an electronic balance, metal blocks, ice cubes, and purified water.

THEORY

Once heat energy is provided to a system, this energy will lead to an increase in the average kinetic energy per molecule, which in turn implies that the temperature of the system will rise. At this point, it would be beneficial to introduce the quantity called *specific heat capacity*. Specific heat capacity, c, is the amount of heat required to raise the temperature of unit mass of a substance by one Celsius degree, which can be stated as

$$Q = mc\Delta T, \qquad 1.1$$

where Q is the heat lost or gained in Joules, m stands for mass in kg, and $\Delta T = T_f - T_i$. It is worthwhile to note that, the unit of specific heat capacity will be expressed as $J/(kg°C)$.

For the case when the heat energy is used for changing the state of a system, we require to define a new quantity, namely the latent heat, which can be expressed as

$$Q = mL, \qquad 1.2$$

where Q and L stand for the heat transferred (in $Joules$) and latent heat (in $Joules/kg$), respectively. As can be noticed from Eq. (1.2), there exists no temperature change for this case, since all the energy is used for breaking the existing chemical bonds among the molecules. Therefore, the average internal energy per molecule remains constant.

The latent heat can be classified into two; *the latent heat of fusion*,L_f , which is the heat energy released when 1 kg of a substance in liquid form solidifies (i.e. fuses) without changing its temperature, and *the latent heat of vaporization*,L_v , which is the heat energy needed to vaporize 1 kg of a liquid substance without changing its temperature. As a matter of fact, water has one of the highest values of the latent heat of fusion

$\left(L_f\right)_w = 333000\,J/kg$. It also has a high specific heat capacity value relative to other liquids; $c_w = 4186\,J/(kg°\text{C})$.

Transfer of heat energy occurs when substances having different temperatures are allowed to interact thermally. In any energy transformation for an isolated system, the total amount of energy remains constant. This is called *the law of conservation of energy*. Whenever two substances at different temperatures are allowed to be thermally exposed to each other, heat travels from the warmer substance to the colder one. The quantity of heat given off by the warmer substance is equal to the negative value of the quantity of heat energy gained by the colder one, provided that heat energy does not escape to the surroundings (an isolated system). The energy transfer will continue until both substances reach the same temperature (equilibrium temperature). This is called *the principle of heat exchange*; i.e.

$$heat\ energy\ lost + heat\ energy\ gained = 0:$$

$$Q_{lost} + Q_{gained} = 0 \qquad 1.3$$

Consider the case in which a metal block at a higher temperature is mixed up with purified water. In this case, one can write

$$Q_{lost} = Q_b = m_b c_b\left(T_f - T_b\right) \qquad 1.4$$

$$Q_{gained} = Q_w = m_w c_w\left(T_f - T_w\right)$$

where T_f , T_w , T_b , m_w , m_b , c_b and c_w represent the equilibrium temperature of the system, the initial temperature of water, the initial temperature of the metal block, mass of water, mass of the metal block, specific heat capacity of the metal block and specific heat capacity of water, respectively. Note that the specific heat capacity of the beaker is neglected throughout the calculations stated in Eq. (1.4). Substituting expressions in Eq. (1.4) into Eq. (1.3), one obtains

$$m_b c_b\left(T_f - T_b\right) + m_w c_w\left(T_f - T_w\right) = 0 \qquad 1.5$$

which in turn implies

$$c_b = \frac{-m_w c_w\left(T_f - T_w\right)}{m_b\left(T_f - T_b\right)}. \qquad 1.6$$

For latent heat of fusion

$$m_{ice}L_f + m_{ice}c_w(T_f - 0) + m_w c_w(T_f - T_w) = 0. \quad 1.7$$

Rearranging for L_f leads to

$$L_f = \frac{-m_{ice}c_w(T_f - 0) - m_w c_w(T_f - T_w)}{m_{ice}}. \quad 1.8$$

You may take specific heat capacity of water as $c_w = 4186\ \mathrm{J/(kg°C)}$.

EXPERIMENTAL PROCEDURE

For the Metal Blocks

1) Place the beaker on the digital balance and press the calibrate button.

2) Add some purified water into the beaker and measure the mass, m_w, and the initial temperature, T_w, of water.

3) Press the calibrate button of the digital balance again.

4) Heat a metal block in boiling water long enough for the block to reach $100°C$.

5) Transfer the hot metal block into the system.

6) Record the mass of the metal block as m_b.

7) Measure the final temperature of the water & block system once the heat transfer has taken place.

For the Ice

1) Place the beaker on the digital balance and press the calibrate button.

2) Add some purified water into the beaker and measure the mass, m_w, and the initial temperature, T_w, of the water.

3) Press the calibrate button of the digital balance again.

4) Add the ice cubes (held at the melting point) into the beaker and measure the mass of ice.

5) Measure the final temperature of the water & ice system once the heat transfer has taken place.

RAW DATA

a) For iron

m_w(kg)	m_{iron}(kg)	T_w (^{0}C)	T_{iron} (^{0}C)	T_f (^{0}C)

b) For brass

m_w(kg)	m_{brass}(kg)	T_w (^{0}C)	T_{brass} (^{0}C)	T_f (^{0}C)

c) For ice

m_w (kg)	m_{ice} (kg)	T_w (^{0}C)	T_{ice} (^{0}C)	T_f (^{0}C)
			0	

DATA ANALYSIS

1) The experimental value for specific heat of iron [Eq. (1.6)]: ……..

2) The experimental value of specific heat of brass [Eq. (1.6)]: ……..

3) The experimental value of latent heat of fusion of water [Eq. (1.8)]: ....

4) Since the standard values of the associated specific heats and the latent heat are as follows:

$$c_{iron} = 438\, J/(kg°\mathrm{C})$$

$$c_{brass} = 380\, J/(kg°\mathrm{C})$$

$$\left(L_f\right)_w = 333000\, J/kg$$

Percent error is used when comparing an experimental result E with a theoretical value T that is accepted as the "correct" value.

$$\Sigma = percent\ (relative)\ error\ = \frac{|T-E|}{T} \times 100\%$$

Fractional or relative uncertainty is used to quantitatively express <u>the precision of a measurement</u>.

$$\varepsilon = percent\ (relative)\ uncertainty = \frac{\Sigma}{E}$$

Measurement = (measured value ± uncertainty) unit of measurement

Find the **percent errors and uncertainties** for c_{iron}, c_{brass}, and $\left(L_f\right)_w$ by using the expressions provided below and **make comment on the possible sources (minimum two) of those errors**.

IRON	BRASS	LATENT HEAT OF FUSSION
$\Sigma_{IRON} =$	$\Sigma_{BRASS} =$	$\Sigma_{\left(L_f\right)_w} =$
$\varepsilon_{IRON} =$	$\varepsilon_{BRASS} =$	$\varepsilon_{\left(L_f\right)_w} =$

Experiment 2: Ideal Gas Law

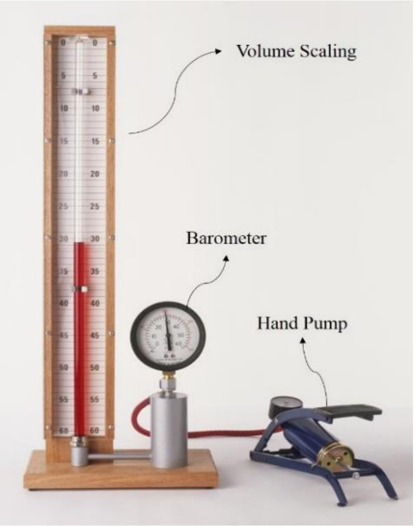

Figure 2.1

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PURPOSE

Utilizing the ideal gas law to measure the number of moles of a confined ideal gas.

APPARATUS

The gas law apparatus

THEORY

All macroscopic pieces of matter have in common some fundamental properties. For example, pressure (P), volume (V), temperature (T), internal energy (U) and entropy (S). These variables are not independent and for simple states of matter any of these variables can be expressed in terms of any two of the others. These expressions are called *equations of state*. The ideal gas law is the simplest equation of state:

$$PV = nRT \,, \qquad 2.1$$

where n is the number of moles, $R = 8.31\, J/(mole.K)$ is the gas constant in SI units and T is absolute temperature, $T\,(K) = 273 + T$ (°C). The first law is Boyle's law, which is expressed as

$PV = K_1$ (K_1 is a constant)

In the case when pressure is kept fixed, Charles' law is

$$\frac{V}{T} = K_2 \qquad (K_2 \text{ is another constant})$$

and the third law (Avagadro's law) reads

$$\frac{V}{n} = K_3 \qquad (K_3 \text{ is a third constant})$$

Throughout this experiment, we will be investigating the Boyle's law, i.e we can express V as a function of $1/P$ as follows.

$$V = nRT\,\frac{1}{P}, \tag{2.2}$$

where in this case the slope is equivalent to nRT.

EXPERIMENTAL PROCEDURE

1) The apparatus is already set up in the laboratory. A fixed amount of air is closed in a glass tube by a column of oil. The volume of the air above the oil is measured directly from the volume scale on the apparatus, in cm^3. The pressure of the gas is determined directly from the barometer in units of atmosphere. You should start the experiment by setting the gas on some initial pressure (e.g. $2.8\ atm$ is a good starting point).

2) Decrease the pressure (in steps of $0.3\ atm$) by opening the valve on the apparatus. For each specific pressure measurement, record the associated volume reading from the scale and write it down in the table provided in the Raw Data section.

RAW DATA[1]

P (atm)	V (cm^3)	P (Pa)	V (m^3)

[1] In order to complete the table in this section, you may need the following conversion factors.
$1cm^3=10^{-6}m^3$
$1atm=1.01x10^5Pa$

DATA ANALYSIS

You may use the following table and formula to find the equation of the least-square line of y versus x^2.

$X(=1/P)$ [Pa^{-1}]	$Y(=V)$ [m^3]	X^2 [Pa^{-2}]	XY [$Pa^{-1}m^3$]
$\sum X=$	$\sum Y=$	$\sum X^2=$	$\sum XY=$

The least-square line is given by

$$Y = mX + c \qquad (2.3)$$

in which

$$m = \frac{n\sum XY - \sum X \sum Y}{n\sum X^2 - (\sum X)^2} \qquad (2.4)$$

and

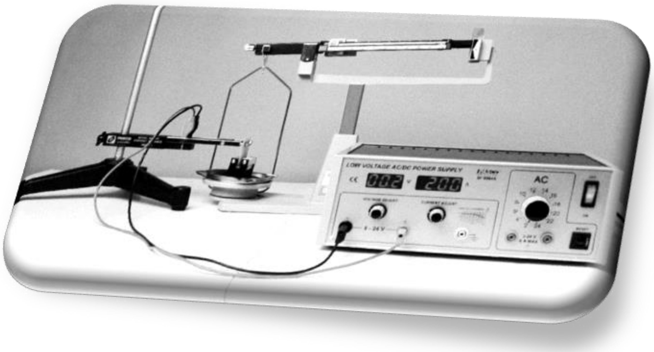
$$c = \frac{\sum Y \sum X^2 - \sum X \sum XY}{n\sum X^2 - (\sum X)^2} \qquad (2.5)$$

where n stands for the number of measurements (for this experiment, $n = 5$ by default).

Draw the least-squares line $Y = mX + c$, by substituting the m and c values you have already calculated. To this end, pick any two X-values from your raw data and plug into the equation of the least-squares line to obtain two corresponding Y-values. This will give you two points which can then be plotted onto the graph paper using a proper scaling.

Finally, knowing that the experiment has been made while the temperature of the gas is held at room temperature (about $27°C$ on average), determine the amount of air (in moles) enclosed in the glass tube of your apparatus by using Eq. (2.2).

Experiment 3: Magnetic Force on a Wire



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PURPOSE

To determine the strength of a constant magnetic field by investigating the relation between the magnetic force and current.

APPARATUS

A cent-o-gram balance, a magnet, a low voltage AC/DC power supply, plug cord sets, a current loop board, a tripod.

THEORY

A current carrying wire in a magnetic field experiences a force that is usually referred to as a magnetic force. The magnitude and direction of this force depend on four variables: The magnitude and direction of the current (I); the strength of the magnetic field ($\vec{B}$); the length of the wire ($\vec{L}$); and the angle between the field and the wire (θ). This magnetic force can be described mathematically by the vector cross product:

$$\vec{F}_m = I\vec{L} \times \vec{B} \quad 3.1$$

In scalar form, the above expression becomes

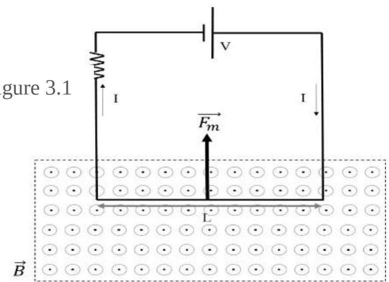
$$F_m = ILB \sin\theta \quad 3.2$$

In the special case of $\theta = 90°$, when the magnetic field and the current carrying wire are normal to each other, Eq. (3.2) turns into

$$F_m = ILB, \quad 3.3$$

which will be the case for the incoming experiment.

Figure 3.1



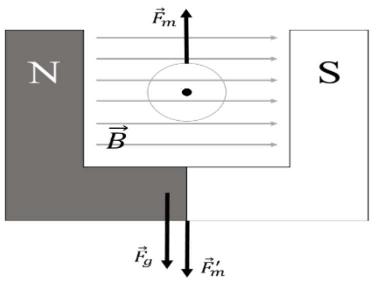


Figure 3.2

As in Figure 3.1, the lower part of a rectangular current loop is lying in a magnetic field. The magnetic field produced by a permanent magnet is constant, uniform, and directed outwards. Once the current flows through the wire, the magnet starts to exert a force upon the wire via its magnetic field. Direction of this force is upwards and in case if you need assistance regarding how to prove this, you may ask for your assistants' help. Figure 3.2 illustrates the same picture but from another point a view. In this rotated picture, the magnet itself together with the forces acting on it are shown. One of these forces is the so-called gravitational field $\vec{F_g}$, while the second one, $\vec{F}'_m$, is nothing but the <u>reaction force</u> exerted on the magnet by the wire. Based on Newton's third law, the magnitude of this force is equal to the magnitude of the original force $\vec{F}_m$, whereas its direction is opposite to it. Therefore, the magnitude of the net force exerted on the magnet (the magnitude of the apparent weight of the magnet: Mg) can be expressed as

$$F_{net} = F'_m + F_g = Mg = ILB + M_0 g \qquad 3.4$$

This implies that the changes of Mg with respect to I is linear, with its slope and y-intercept being equal to LB and $M_0 g$, respectively. (M_0: mass of the magnet when there is no current)

EXPERIMENTAL PROCEDURE

1) Set up the apparatus as shown in Figure 3.3 and make sure that the magnet and the current loop board are not in contact.

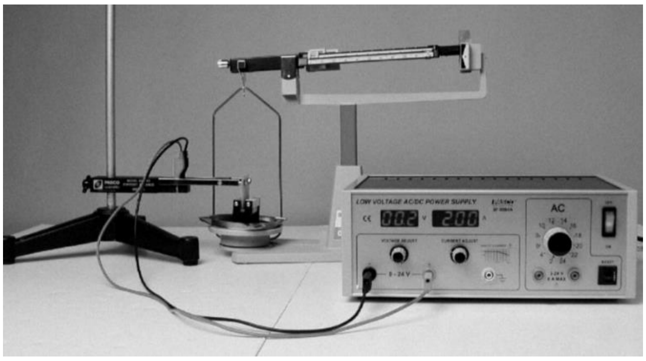


Figure 3.3

2)The magnet should be situated on the scale pan in such a way that the white side (south pole) of the magnet faces the tripod.
3) Determine M_0 of the magnet when there is no current in the wire. The procedure to be followed for this step is explained in Appendix.
4) Convert M_0 value into *kg* and record it into the table provided in the Data Table section. This number represents the true mass of our magnet.
5) Turn on the power supply and set <u>first the current to **1A**</u>. Once the current starts flowing, the measurement to be taken will be equal to the apparent mass of the magnet. Your aim now is to readjust the position of the center windows in a way to make the two indicators match again.
6) Having completed step 5, continue taking the measurements and record each value of apparent masses in your table.

DATA TABLE

$I\ (A)$	$M\ (kg)$
0	
1	
2	
3	
4	
5	
6	

The length of the wire under the influence of magnetic field is $L = 0.03(m)$
Take the magnitude of the gravitational acceleration of g as $g = 9.81\ m/s^2$

DATA ANALYSIS.
Plot M versus I graph and determine the least-squares line with its $y = mx + c$ by using **Excel program**. Comparing the obtained result with Eq. (3.4):

$$M = \frac{ILB}{g} + M_0 \qquad 3.5$$

Determine the experimental value of the magnitude of the magnetic field of the magnet:

$$B_{exp} = \ldots\ldots\ldots\ldots \text{(Tesla)} \qquad 3.6$$

If its theoretical value is $B_{th} = 0.12$T, calculate the percentage error made for the magnetic field.

$$\Delta = percent\ (relative) error\ = \frac{|th - exp|}{th} \times 100$$

List at least two possible reasons for that error:

(i)

(ii)

APPENDIX

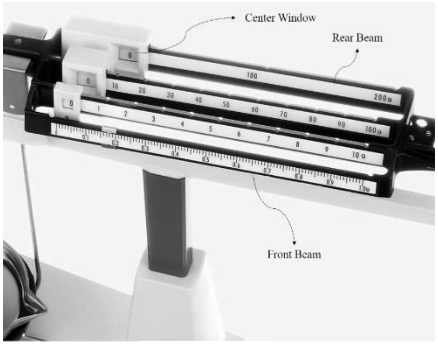
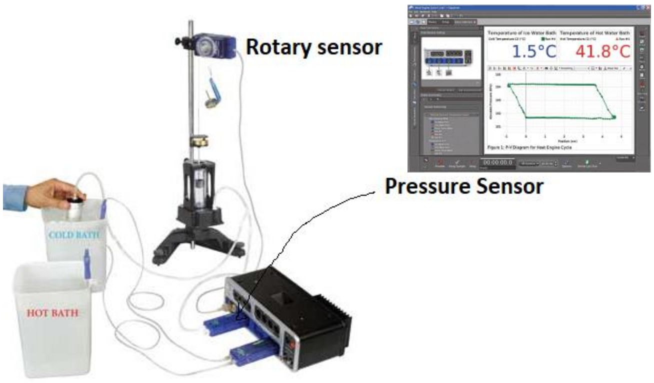


Figure 3.4

As can be observed from the apparatus, you will be able to determine the mass values via using the scaling provided on the **cent-o-gram balance**. The poise show weights through the center windows and the beams are stepped up from front to rear. Each poise will enable you to determine which number you shall quote for each digit. Adjust the position of the center window on the rear beam to ‘100’. Then, by trial and error, figure out which numbers shall be chosen for the second, third and front beams so that the indicator aligns with the reference point marked at the right side of the cent-o-gram balance. Once this is achieved, **your system is in equilibrium.**

Experiment 4: Heat Engine Cycle



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PASCO scientific

Equipment: PASCO Gas Law Apparatus, a ring stand, an ice-water bath, a hot water bath, a thermometer, a low gas-pressure sensor, LabPro interface, a 100-gram mass, and various tube couplings

Introduction

The PASCO heat engine apparatus is a closed system consisting of a nearly friction-free piston inside a cylinder. It has two air tubes leading from the cylinder: one going to a pressure sensor (which is measured using the Lab Pro) and the other leading to an air reservoir (*aluminum can or the so-called canister*) that we will immerse in water to change the temperature of the air in the system. There is also be a rotary sensor connected to the interface to record the height of each movement of the piston.

The manufacturer states that the piston has a diameter of $32.5 \pm 0.1\ mm$ and a mass of $35.0 \pm 0.06\ grams$.

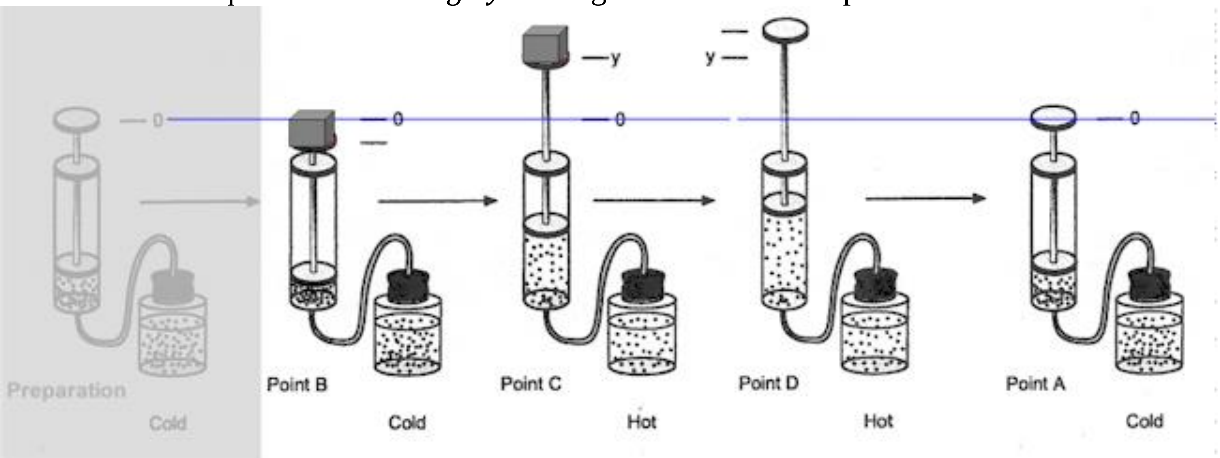
The platform on the top of the piston gives you the ability to add a mass that will change the pressure in the cylinder. The manufacturer recommends that this mass does not exceed $200\ grams$; we will use a $100-gram$ slotted mass. The pressure sensor measures the absolute pressure in the cylinder, P, in kPa.

As the piston moves, the volume of the air inside the cylinder changes. The total volume of the air in the system consists of the volume of the cylinder plus the volume of the canister and the two air hoses. The millimeter scale on the cylinder will also allow you to directly measure the cylinder's height.
When the piston undergoes transitions in which one or more of the system's properties (P, V, or T) change, the data can be potted on a $P-V$ diagram. Any work done by the system during a transition can be found as the area of the graph bounded by the x-axis (volume axis) and that process' graph. The processes that can be applicable to our heat engine's cycle are limited to isovolumetric, isothermal, isobaric, and adiabatic.

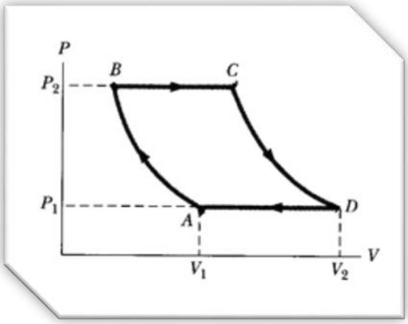
The total work done during a complete cycle is represented by the area of the closed cycle on the $P-V$ diagram.

It is important to take your measurements of pressure and piston height as quickly as possible after each transition stabilizes since the apparatus does leak air slightly and you want the completed cycle to return to its initial conditions providing you with a closed PV diagram to analyze.

This is a “**real**” 4-step heat engine that has expansion and compression processes in which the engine will do useful mechanical work by lifting a 100-gram mass (and the piston) from one height to another. During the expansion steps, the gas lifts the mass and piston increasing their potential energy; while during the compression steps their potential energy is reduced. Remember that potential energy is calculated with the equation $PE = mg\Delta y$. A diagram of the four steps is shown below:



When your experimental data has been plotted on a $P - V$ diagram, it will hopefully ressemble the diagram below where there is a close agreement between the state variables for Point A (P, V) and the values for the cycle's initial preparation conditions.



Notice that steps BC and DA are isobaric processes and steps AB (hopefully the conditions at the engine's preparation and those at the end of the cycle will be synonymous) and CD are isothermal processes.

Volume

You must first calculate the total volume of air (gas) in the system that does not change with the height of the piston. Remember that this volume includes the volume of the metal canister and the volume of the air in the tubing. The volume of a cylinder equals $V = \pi r^2 h$.

What is the interior volume of air in the metal canister in m^3?

What is the interior volume of air in the tubing in m^3 if it has an interior diameter of $0.4cm$?

What is the total volume that air can occupy in the metal canister and tubing during the experiment?

Experiment

After you run the cycle with CAPSTONE software {by reading the probe values for pressure (kPa) and the height from the base of the piston [position(mm)], and carefully adding/removing the 100-gram mass from the top of the piston}, the computer will record the values for a complete cycle. Remember to move as quickly as possible after each step stabilizes.
Based on your P-V diagram (copy the plot of Capstone and embed it into an Office Word or Excel page to get its printout) to be obtained, fill the following table:

Point or State	Pressure (kPa)	Position (height=h) of the Piston (m)	Total Volume of Air (piston chamber + metal cylinder + tubing) (m^3)
B			
C			
D			
A			

How much volume of air is leaked out of the system during the cycle?

Analysis

We can calculate work and heat separately for each portion of the process:

Isothermal

Temperature is constant, so $P = \frac{nRT}{V}$, where nRT is a constant. The work done by the gas is given by $W = \int PdV = nRTln(\frac{V_f}{V_i})$.

Since the added heat is not causing a change in temperature, all the heat must be contributing to the work done: $W = Q = nRTln(\frac{V_f}{V_i})$.

Also, the ideal gas equation of state tells us that $PV = nRT$. Since nRT is a constant, $P_iV_i = P_fV_f = nRT$ so we can express the work and heat in any of the following ways:

$$W = Q = P_iV_iln\left(\frac{V_f}{V_i}\right) = P_fV_fln\left(\frac{V_f}{V_i}\right) = nRTln(\frac{V_f}{V_i}).$$

Isobar

Pressure is constant, so $W = \int PdV = P(V_f - V_i)$ and $Q = nc_p(T_f - T_i)$ where c_p is the specific heat at constant pressure.

Analysis

1. Describe each leg of the cycle (isothermal, isobaric, etc.) on your PV-diagram.

2. For each leg of the cycle, calculate the following:

a. W (work done by the system)

b. Q (Heat added to the system)

3. Find the total work done by the system from your PV diagram.

4. Find the total mechanical work, $mg\Delta y$:

5. Compare the results of 3 and 4. Are they different? Why?

6. Calculate Q_H for the entire cycle.

7. Calculate the thermodynamic efficiency of your engine.

Experiment 5: Magnetic Induction

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PURPOSE

The purpose of this experiment is to

1- Verify Faraday's law of induction, and

2- Determine the value of $\frac{\mu_0}{4\pi}$.

APPARATUS

Function generator, two solenoids, ammeter and digital voltmeter.

THEORY

About 1820 the Danish physicist Oersted noticed that a wire carrying an electric current produced a magnetic field. It occurred to Michael Faraday to ask the converse question: Is a current produced by a magnetic field in the vicinity of a wire? The answer he found is yes, but only if the field is changing by time.

Faraday saw that when a closed conducting loop (see Fig. (5.1)), is in a region containing a static magnetic field (i.e., a magnetic field independent of time) the voltmeter will show zero volt. In other words, the current in the loop is zero and so is the potential difference between the ends of the loop.

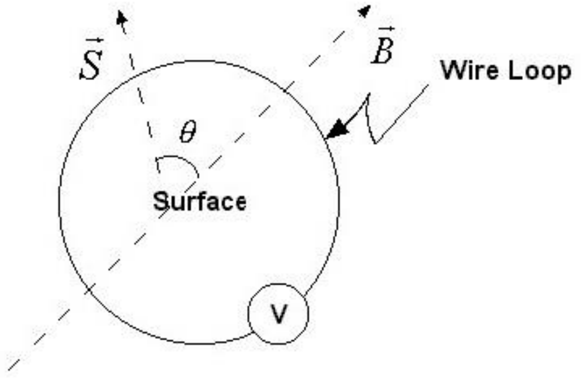

Figure 5.1

On the other hand, if the magnetic field is not static (i.e., its value depends on time) the voltmeter will show a non-zero voltage. The non-zero voltage shows that there exists a current flowing in the loop.

Namely, there is a potential difference between the ends of the loop, which is called *INDUCED* electromotive force, emf defined as

$$emf = -\frac{d\Phi_B}{dt}.$$

This is called the Faraday's law where Φ_B is the magnetic flux through the loop given by

$$\Phi_B = \oint \vec{B}.d\vec{A}. \qquad 5.2$$

To gain some intuition about the flux, consider a loop in a uniform magnetic field $\vec{B}$. Then the flux through the loop is given by

$$\Phi_B = BAcos(\theta) \qquad 5.3$$

where A is the area of the loop and θ is the angle between $\vec{B}$ and a perpendicular plane of the loop. In a sense, then, flux is the "amount" of magnetic field which goes straight through the loop. The direction of the perpendicular, which determines θ and the sign of the flux, is given by an arbitrary rule: Imagine standing on the surface and walking around the loop with the inside of the loop to your left. The perpendicular points from your feet toward your head. If the loop is part of a complete circuit, so that current flow, an additional magnetic flux will be produced by the induced current. The negative sign in Faraday's law tell us that the flux produced by the induced current opposes the change in the external flux. This result is called **Lenz's law**, and often provides an easy way to find the direction of the induced current or voltage.

The instrument that we will use in this experiment is given in Fig. (5.2) as:

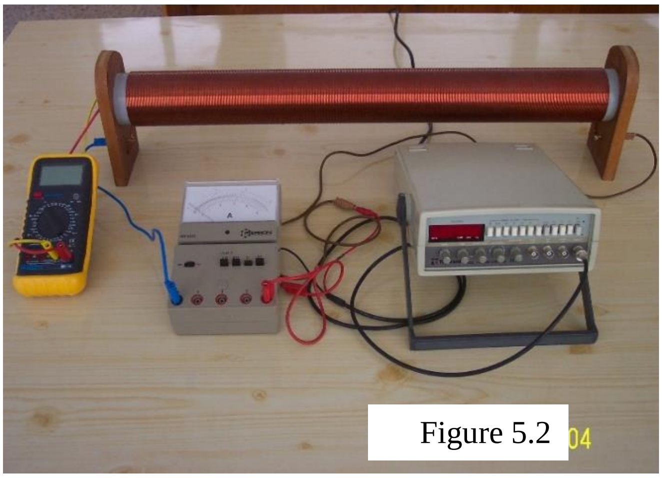

Figure 5.2

Inside a long solenoid, the magnetic field is calculated as

$$B = \mu_0 n_1 I_0 \sin(2\pi f t), \qquad 5.4$$

where I_0 is the amplitude of the current flowing through the windings, n_1 is the number of windings per unit length of the big solenoid and f is the frequency of the function generator. Therefore, when an induction coil (small solenoid) of n_2 windings, each of area A is put inside the solenoid, the induced emf in the coil is

$$emf = A\mu_0 n_1 n_2 I_0 2\pi f \cos(2\pi f t). \qquad 5.5$$

The relation between induced emf and output of the current ($I = I_0 \cos(2\pi f t)$) can be written as

$$emf = A\mu_0 n_1 n_2 2\pi f I. \qquad 5.6$$

EXPERIMENTAL PROCEDURE

The experimental set is already set up in the lab. First you should know that here you will apply AC current, which is a function of time, to the big solenoid. Using AC current always creates the magnetic flux through the loop. In a sense, the magnetic field goes straight through the big solenoid. So, when you insert the small solenoid (induction coil) into the big solenoid, a current is induced on the small solenoid. Consequently, you see that the digital voltmeter displays a non-zero value.

Your lab TA will show you how to use the function generator to fix the frequency of the AC current to $10.7 \times 10^3 s^{-1}$ and how to change the amplitude of the current. Then you will also learn to read the ammeter and the digital voltmeter for collecting the data.

Read the windings of n_1 and n_2 written on the big solenoid and the small solenoid, respectively.

On the small solenoid there is a $\emptyset$ symbol. Here, $\emptyset$ indicates the diameter, in millimeter, of the small solenoid. In order to find the cross-sectional area, A (in m^2), of the induction coil, you will use the following formula

$$A = \pi\left(\frac{\emptyset}{2} \times 10^{-3}\right)^2. \qquad 5.7$$

RAW DATA

You start to take data by setting the current on the initial value $10\,mA$, as given in the table below. Then you increase the current (in steps of $10mA$). At each value of the current, you read emf from the display of the digital voltmeter and write it down in the following table.

$\boldsymbol{I(mA)}$	**10**	**20**	**30**	**40**	**50**	**60**	**70**
$\boldsymbol{emf(V)}$							

DATA ANALYSIS

1) Find the least square line for your data having emf on the y-axis and I on the x-axis. You may use EXCEL program to find the equation of the least-square line $emf(V)$ versus the current $I(A)$. Note that you need to convert the unit of I to A for this plot.

2) Use the value of the slope with Eqs. (5.6) and (5.7) to determine the experimental value of $\frac{\mu_0}{4\pi}$. Call this $\left(\frac{\mu_0}{4\pi}\right)_{exp}$. Show your calculation!

3) Show % error calculation to compare $\left(\frac{\mu_0}{4\pi}\right)_{exp}$ and $\left(\frac{\mu_0}{4\pi}\right)_{th}$. Are they close? Recall that $\left(\frac{\mu_0}{4\pi}\right)_{th} = 10^{-7}\,\frac{T.m}{A}$.

4) List at least two sources of errors in your experiment.

QUESTIONS

A. Assume that you turn off the function generator during the experiment. Normally, you expect to read zero volts of the voltmeter, connected to the induction coil, both for the two cases: when the induction coil is outside and inside the big solenoid. However, it is possible to read non-zero volts for the outer case. What can be reasons of this?

B. A circular loop of wire of radius $3\ cm$ and 40 turns is perpendicular to a magnetic field whose magnitude decays in time according to $B = 0.5t^2 - 0.6$ in $Tesla$ and t in $seconds$. What is the induced emf as a function of time?

C. 120 turns flat circular loop of radius $10cm$ and total resistance $R = 80\ \Omega$ lie perpendicular to a magnetic field given by $B = 2 + t$ in $Tesla$ and t is in $seconds$. Find,

- **a.** the magnetic flux through the circular loop,
- **b.** the total induced emf, and
- **c.** the induced current.