Class :2nd stage
Subject: thermodynamics
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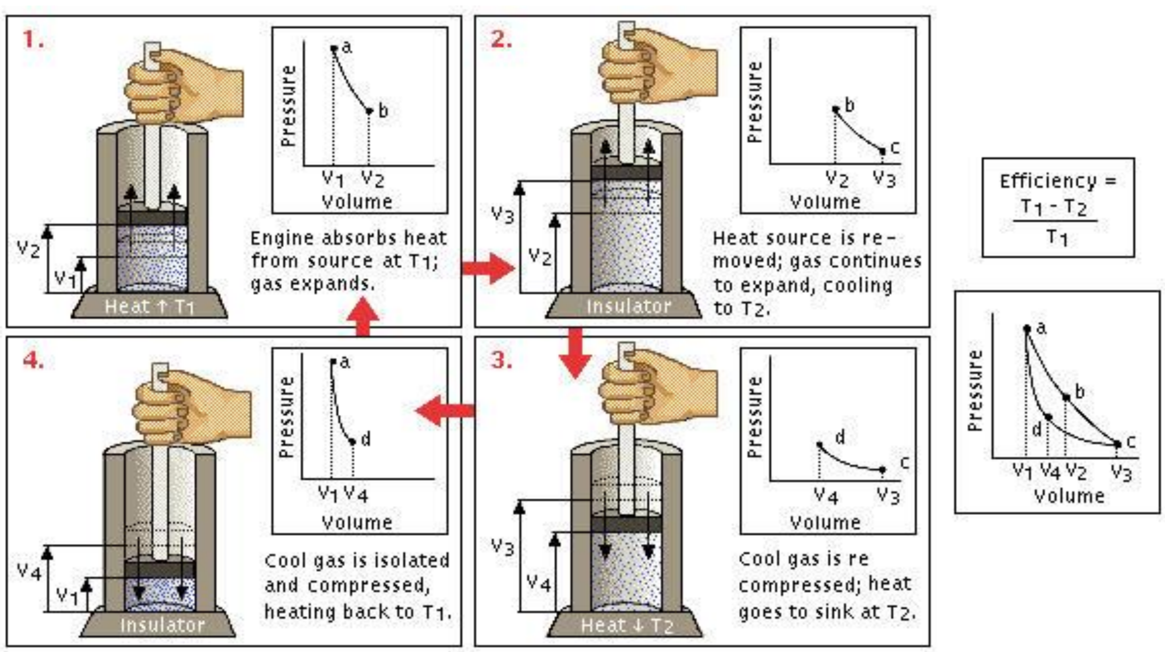
Experiment No (10): Heat engine (Carnot cycle)

The purpose of the experiment: Convert heat energy to work using the piston and mass.

Theory:

Stage 1: In the first stage, the piston moves downward while the engine absorbs heat from a source and gas begins to expand. Below, the portion of the graphic from point a to point b represents this behavior. Because the temperature of the gas does not change, this kind of expansion is called isothermic.

Stage 2: In the second stage, the heat source is removed; the piston continues to move downward and the gas continues to expand while cooling (lowering in temperature). This stage is presented by the graphic from point b to point c. This stage is called an adiabatic expansion (i.e., energy stays)



Figure(10-1): diagram of Carnot cycle.

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Stage 3: In the third stage, the piston begins to move upward and the cool gas is recompressed. The heat begins to fall. Points c and d represent this decrease in volume and increase in pressure. The engine gives energy to the environment. This stage is called isothermal compression.

Stage 4: In the final stage, the piston continues to move upward and the cool gas is secluded and compressed. Its temperature rises to its original state. Point c to point d illustrates this behavior: a continuing increase in pressure and decrease in volume until they return to their initial position. Because energy stays, it's an adiabatic compression.

An ideal cycle would be the cycle that a perfectly efficient heat engine performs — that is, all the heat would be converted to mechanical work. Such an ideal engine cannot exist. Any heat engine must expend some fraction of its heat input as exhaust. The second law of thermodynamics places an upper limit on the efficiency of engines, and implies that that upper limit will be less than 100 percent. The limiting case is now known as a Carnot cycle. The efficiency of the Carnot cycle is important because it is the highest possible efficiency that any engine can reach, if the highest possible temperature the working substance of an engine can reach is TH, and the lowest possible temperature the working substance of the engine can reach is TC.

Procedures:

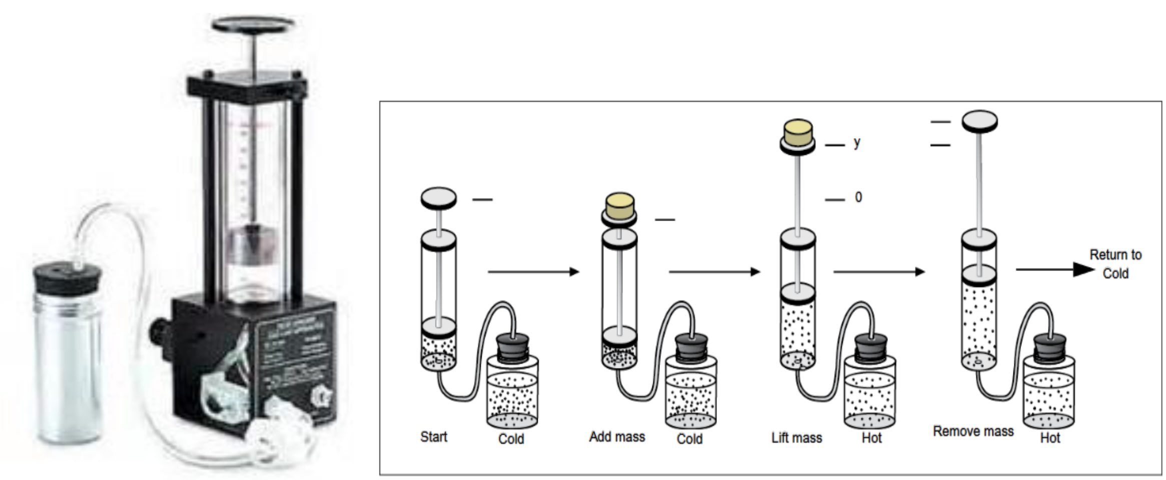

Figure (10-2): heat engine.

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The PASCO TD-8572 Heat Engine/Gas Law Apparatus is used to obtain the data. The heart of this apparatus is a nearly friction-free piston-cylinder system. The graphite piston fits snugly into a precision-ground Pyrex cylinder so that the system produces almost friction-free motion and negligible leakage. The Heat Engine/Gas Law Apparatus is designed with two pressure ports with quick-connect fittings for connecting to an air chamber and a pressure sensor with tubing.

In this exercise you will analyze data obtained with is a "real" thermal engine that can be taken through a four-stage expansion and compression cycle and that can do useful mechanical work by lifting small masses from one height to another. You will determine the useful mechanical work done by the engine by measuring the vertical distance y a mass m is lifted. You will compare this mechanical work $W_{mech} = mgy$ to the net thermodynamic work done during a cycle. The pressure as a function of volume is recorded for one cycle, and the net thermodynamic work done by the engine equals the enclosed area on the PV diagram.
$W = \sum_j P_j \Delta V_j$. We sum the work done during a large number of small changes of the volume.

1. The air chamber is placed into ice water.
2. A 100 g mass is placed on the platform. The weight of the mass increases the pressure at constant temperature, and the volume and therefore the height of the piston decrease by some amount.
3. The air chamber is placed into hot water. The temperature rises and the gas expands. The volume and therefore the height of the piston increase.
4. When the volume is no longer increasing, the mass is removed from the platform. Removing the weight decreases the pressure at constant temperature, and the volume and therefore the height of the piston increase by some amount.
5. The air chamber is placed back into the ice water. The temperature decreases and the gas contracts. The volume and therefore the height of the piston decrease.

6.When the piston has returned to the original position data acquisition stops.

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Calculations:

You must first calculate the total volume of air 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 $V = \pi r^2 L$.

1. What is the interior volume of air in the metal canister inm^3? ☐

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

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

After you have practiced running the cycle several times - the canister transfers, reading the probe values for temperature and pressure, the height at the base of the piston (mm), and carefully adding/removing the 100-gram mass from the top of the piston - you are ready to record the values for a complete cycle. Remember to move as quickly as possible after each step stabilizes.

position	Pressure (Pa)	Temperature (K)	Heigh of piston (m)	total volume of air piston chamber + metal cylinder + tubing (m^3)		
prepration						
B						
C						
D						
The end						

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Analysis and conclusion:

Construct a scaled P-V diagram of your entire cycle - plot all "five" data points: preparation, B, C, D, A. Your axes do not need to start at the origin since you will only be examining the interior of the cycle. Next decide whether to use the "preparation" position or the final position as "A." Calculate the area of your cycle. You may assume that the area is a quadrilateral.