CENCO Physics
Selective Experiments In Physics
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BOYLE'S LAW

OBJECT: To investigate the relationship between the pressure and the volume of a confined mass of gas at Constant temperature.

METHOD: Amass of dry air is trapped above a column of mercury in a closed tube which forms one arm of a mercury manometer. The pressure upon the confined air can be regulated by means of a plunger which controls the height of the mercury columns, and its value is determined from the difference between the mercury levels in the open and closed arms. The volume of the confined air is measured by the length of the closed tube above the mercury level. From a series of determinations of pressure and volume, curves are plotted showing the relation between pressure and volume.

THEORY: In 1661 the British scientist Robert Boyle made an exhaustive experimental study of the variation of the pressure and volume of a given mass of gas under constant temperature. As a result of his experiments he concluded that: *Temperature remaining constant, the volume of a confined gas varies inversely as the pressure to which it is subjected*. This relationship, discovered experimentally by Boyle and since shown to be true from theoretical considerations, is known as Boyle's law. Mathematically the law may be written

$$V = k\frac{1}{P} \qquad \text{(t constant)} \qquad (1)$$

or

$$PV = k \qquad \text{(t constant)} \qquad (2)$$

Thus Boyle's law may be stated as follows: *At constant temperature the product of the pressure and volume of a given mass of gas is constant*. The numerical value of the constant *k* depends upon the mass of the gas used and the temperature of the gas.

APPARATUS: The Boyle's law apparatus represented diagrammatically in Fig. 1 and illustrated in Fig. 2 consists of three vertical tubes A, C and D connected together at their lower ends. The tubes A and Care open at the top while the upper end of D is closed. The large tube A serves as a reservoir for mercury, and the mercury levels in the tubes C and D can be controlled by means of a wooden plunger E inserted in the reservoir. When mercury is poured into A some air is trapped in the closed arm D. The volume *V* of the confined air is proportional to the length of the air column (since the cross section is uniform) and the pressure is measured by the difference in height *h* of the mercury columns in C and D (Fig. 1). The values of *V* and *h* are measured by a scale S mounted beside the tubes. The pressure on the surface of the mercury in the open tube C is atmospheric and can be determined merely by reading a barometer. The pressure on the air confined in the closed tube D differs from atmospheric pressure by an amount equal to the pressure exerted by the column of mercury *h* (Fig. 1); it is greater or less than atmospheric pressure depending upon whether the level in C is above or below that in D. Thus, if B represents the barometric reading

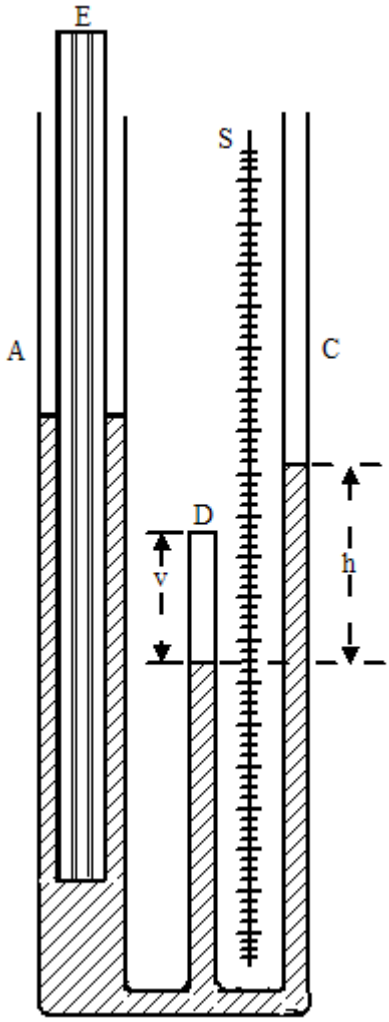

Fig. 1. Diagram of Boyle's Law Apparatus.

expressed in centimeters of mercury, the pressure P of the confined air is

$$P = B \pm h \tag{3}$$

The necessary auxiliary apparatus consists of a mercury barometer, a series of drying tubes, and an aspirator pump.

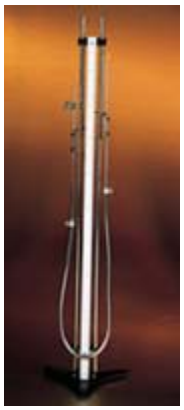

Fig. 2. Boyle's Law Apparatus

PROCEDURE:

Experimental: Before undertaking to perform the experiment the apparatus must be filled with dry air, since Boyle's law applies to a gas but not to a vapor near its condensation point. A convenient way of introducing dry air is illustrated in Fig. 3. *The drying process should be carried out only under the direct supervision of the instructor*.

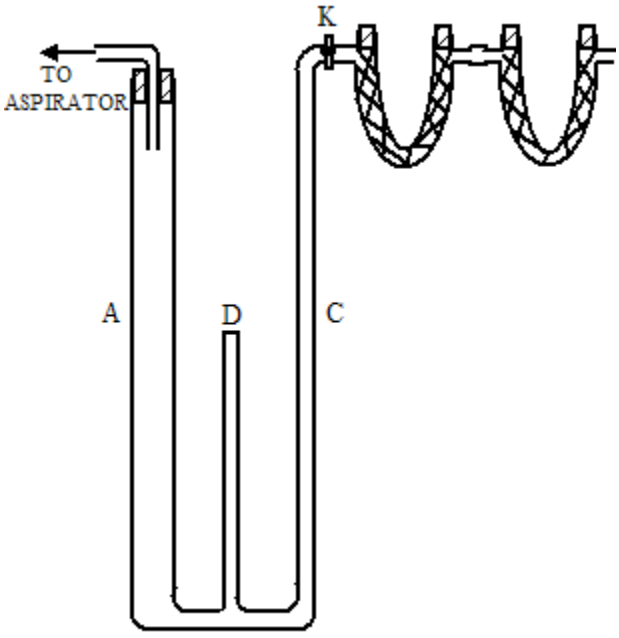

Fig. 3. Method of introducing dry air.

A series of drying tubes containing calcium chloride, or other drying agent, is connected to the open tube C. The air is exhausted from the apparatus by means of an aspirator pump connected to the tube A. Close the pinchcock K and start the pump. After pumping a minute or two, open the pinchcock and permit air to be drawn in through the drying tubes. In this manner flush the apparatus with dry air two or three times before beginning the experiment.

Read the laboratory barometer. Pour about 25cc of clean mercury into the reservoir A. Insert the plunger E and note the rise of the mercury in the tubes C and D as the plunger is depressed. The quantity of mercury should be such that the level in C is near the top of the tube when the plunger is pushed to the bottom of the reservoir. Under these conditions it will be noted that the level in D is below that in C, indicating that the confined air is under pressure somewhat above atmospheric. Tilt the apparatus and manipulate the plunger so as to permit some of the trapped air to escape, leaving the mercury level in D a few centimeters above the level in C. With the plunger withdrawn, take initial readings of the levels in C and D. Push the plunger into the reservoir until the mercury rises four or five centimeters in the open tube C and again read the levels in C and D while holding the plunger in position; Continuing in this manner take a series of eight or ten readings up to the maximum attainable pressure. Record the data as shown in Table I. Take a second reading of the laboratory barometer and record the average value over the duration of the experiment.

Interpretation of Data: By means of Eq. (3) compute the values of the pressure P and enter in column V of the table. Compute the products of corresponding values of P and *V* and enter in column VI. Plot Curve 1 of pressure versus volume with P as the ordinate and *V* as the abscissa. On the same sheet of graph paper plot Curve 2 of pressure versus reciprocal volume with P as the ordinate and 1/*V* as the abscissa.

QUESTIONS: 1. Show how Curve 1 conforms with Boyle's law. What type of geometrical figure is it?

2. Describe the appearance of Curve 1 at extremely large and at extremely small values of the pressure.

3. What does Curve 2 indicate about the consistency of the results? Explain.

4. Does the diameter of tube C have to be uniform? Explain.

5. What would the value of *h* have to be in order to subject the confined air to a pressure of three atmospheres?

6. Show how the apparatus may be used to measure the barometric pressure by applying Boyle's law to any two different settings.

TABLE I

I	II	III	IV	V	VI
Level in C	Level in D	Volume V	Pressure Difference h	Pressure P	Product PV