ENGINEERING GATORTRAX MATH EXCELLENCE PROJECT
ENGINEER-FOR-A-DAY LABORATORY MODULES

MECHANICAL ENGINEERING
ADVANCED LEVEL - LABORATORY ACTIVITY
HIGH SCHOOL
USE OF A PISTON PUMP FOR VOLUME MEASUREMENTS

1.0 INTRODUCTION

A pump is a hydraulic machine which is used by engineers for a variety of purposes. In its narrowest sense, a hydraulic machine interchanges energy between the moving parts of the equipment and the liquid flowing through it. The hydraulic machine is an energy converter transforming hydraulic energy into mechanical energy, or mechanical energy into hydraulic energy. Note the following:

i) If ***hydraulic energy*** is converted into ***mechanical energy***, then the machines are known as **hydraulic turbines** or **hydraulic motors**;
ii) If ***mechanical energy*** is converted into ***hydraulic energy*** then the machines are usually known as **pumps**

Hydraulic turbines or motors are typically used for power generation, such as in hydro-electric power plant, in which water at a high elevation is passed through the turbine. As the water passes through the turbine the energy due to its elevation is used to turn the blades of the turbine and generate electricity.

One of the primary uses of pumps is to move fluids (liquids or gases). The liquid to be pumped could be water, oil, spirit, milk. However, pumps are also used for moving solids. Indeed, anything that can be moved along a pipe can be pumped.

There are many different types of pumps, all of which utilize the same basic principle of transferring energy from some external source to the substance being moved through a conduit (pipe).

Pumps usually fall into the category of either
a) Positive-displacement pumps, or of
b) Dynamic-pressure, or rotodynamic pumps

Positive pumps usually have one or more chambers which are alternately filled with the liquid to be pumped, and then emptied again. Positive-displacement pumps may be further subdivided into
a) Reciprocating or piston pumps, and
b) Rotary pumps.

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In today=s laboratory activity our focus is on the use of piston pumps.

2.0 OBJECTIVES

i. Use basic geometric skills to determine the volume of a pump barrel and relate this to the total volume of the pumping apparatus.
ii. Conduct various procedures using a hand-operated piston pump to demonstrate the physical determination of volume of a liquid.

3.0 GOAL

Demonstrate the connection between classroom computational activities and real world applications.

4.0 APPARATUS

a) Hand-operated piston pump
b) Graduated beakers
c) Graduated cylinders
d) Measuring rule

5.0 PRINCIPAL COMPONENTS OF PUMP

The PVC pump comprises:

i) A pump barrel of nominal inside diameter of 3.44 cm, and 22.4 cm inside length
ii) A cap for the barrel
iii) Aluminum piston of nominal diameter 3.40 cm, 3.81 cm long, with two O-rings
iv) A graduated piston rod with handle
v) Two check valves - note direction of arrows for intake and discharge
vi} Intake and discharge tubes
vii) PVC connectors

6.0 PROCEDURE

i. Check the apparatus
ii. Remove the cap and check the piston and O-rings
iii. Re-assemble pump, **ensuring that the cap is in correct position**
iv. Calculate the volume of the pump barrel
v. Calculate the volume of the piston
vi. Deduct the volume of the piston from the volume of the barrel and record the result
vii. Place a known amount of water in a large beaker and place intake hose into beaker
viii. Place discharge hose into empty outlet connection beaker

ix. Prime the pump by drawing and pushing on the piston several times to expel the air.
x Pull the piston all the way up and determine the total amount of water in the apparatus
x. Empty the discharge beaker
xi. Push piston all the way down to the bottom of barrel
xii. Measure the volume discharged and record the results

7.0 LABORATORY ACTIVITIES

Activity 1 - Introductory

To determine the percentage of the total volume of space in the pump unit which is occupied by the pump barrel

Total volume of water in unit cc
Volume of water in barrel cc

$$\text{\% Space occupied by barrel} = \frac{\text{Volume of water in barrel}}{\text{Total volume of water in unit}} \times 100$$

= %

Activity 2 - Introductory

To determine the average net (displacement) volume of the pump barrel.

i. Slowly pull piston up to charge the pump barrel
ii. Slowly push piston down and discharge water into outlet collection beaker
iii Transfer volume to appropriate measuring cylinder and read
iv. Repeat activity a total of three times and record your results in your lab book
v. Compare your results to the calculated or predicted volume
vi. Comment on your results

Volume 1 cc
Volume 2 cc
Volume 3 cc
Total cc

$$\text{Average volume} = \frac{\text{Total Volume}}{3}$$

= cc

Activity 3 - Introductory

To make a plot of volume vs incremental linear movement of piston rod

1. Charge the pump barrel
ii. Discharge a volume by pushing the piston rod down 2-cm
iii Record the volume resulting from piston displacement
iv. Move the piston rod down another 2-cm and record the total volume for 4-cm
v. Continue moving at 2-cm increments until the volume is fully discharged
vi. Record all your results
vii Plot a graph by placing volume on the y-axis and piston movement on the x-axis.
viii Comment on your results

Activity 4 - Intermediate

Combining geometry and algebra concepts.

i. Draw the pump to x cm and pump into a beaker. Repeat n times.
ii. Measure the volume of water in the beaker and compare to predicted results
iii. Write functions for total volume pumped if one or more pumps are used simultaneously
iv If the first n_1 strokes are done with pump 1, and the next n_2 strokes are done with pump 2, what is the total volume as a function of the total number of strokes?
v. Verify experimentally.
vi. Determine percent error

Activity 5 - Advanced

Instead of using a cylindrical beaker to receive the pump outflow, use a shape with an area (a) which varies as a function of height (h). A cone is a good example of this. Write differential relations between the height of the water level in the cone and the distance traveled by the piston.

i. Given a = f(h) write a relation between differential height and area
ii. Find the volume of the pump as a function of differential displacement
iii. Equate the two differential volumes
iv. Predict the height of water level change for a given piston displacements
v. Verify experimentally.
vi. Experiment with various initial water levels and piston displacements.
vii. Log all results in your lab notebook.
viii Comment on results