ARCHIMEDES' PRINCIPLE LAB

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Purpose:

To show that the buoyant force acting on an object submerged in a liquid is equal to the weight of the liquid displaced.

Equipment:

Metal sample, triple beam balance, vernier caliper, beaker, and liquids

Discussion:

Archimedes' Principle states that the buoyant force acting on a body submerged in a liquid is equal to the weight of the liquid displaced:

$$\mathbf{B = \rho_l V g} \qquad \textbf{where } \boldsymbol{\rho_l} = \text{ density of liquid}$$

The buoyant force is also equal to the difference between the actual and the apparent (or effective) weight of the sample:

$$\mathbf{B = W_{actual} - W_{apparent}}$$

Procedure:

Part A:
(a) Measure the mass of the metal sample
(b) Calculate its weight (the actual weight)
(c) Measure the mass of the sample submerged in water
(d) Calculate the apparent weight of the sample in water
(e) Calculate the buoyant force acting on the sample

Part B:
(a) Measure the dimensions of the cylindrical sample
(b) Calculate the volume of the cylinder
(c) Calculate the mass of an equal volume of water
(d) Calculate the weight of the displaced water

Part C: Find the percent difference between the buoyant forces found in part A and the weight of the displaced water found in part B.

$$\textbf{\% difference} = \left[\frac{Difference\ \ between\ \ the\ \ two\ \ \exp erimental\ \ values}{Average\ \ \exp erimental\ \ value} \right] \times 100$$

Part D: Repeat the above procedure using another metal sample and antifreeze.

Data:

Metal's Mass (M_C)	30.16 g	.03016 kg
M_C submerged in water (M_{Water})	19.71 g	.01971 kg
Density of water (ρ_{water})	1 $^{g}/_{cm^3}$	1×10^3 $^{kg}/_{m^3}$
M_C submerged in antifreeze ($M_{antifreeze}$)	18.69 g	.01869 kg
Density of antifreeze ($\rho_{antifreeze}$)	1.115 $^{g}/_{cm^3}$	1,115 $^{kg}/_{m^3}$
Metal's Height (h_1)	3.8 cm	
Metal's Diameter (d_1)	1.9 cm	
Metal's Radius (r_1)	.95 cm	
Metal's height of hole (h_2)	1.9 cm	
Metal's Diameter of hole (d_2)	.3 cm	
Metal's Radius of hole (r_2)	.15 cm	

Calculations:

Actual weight of metal sample: $(M_C)(g) = (.03016\ kg)(9.81\ ^{m}/s^2)$

$= .296\ N$

Volume of cylinder: $V_C = (\pi)(r_1)^2(h_1)$

$V_C = (\pi)(.95\ cm)^2(3.8\ cm)$

$V_C = 10.77\ cm^3$

Volume of cylinder hole: $V_H = (\pi)(r_2)^2(h_2)$

$V_H = (\pi)(.15\ cm)^2(1.9\ cm)$

$V_H = .13\ cm^3$

Cylinder's total volume: $V_T = V_C - V_H$

$V_T = 10.77\ cm^3 - .13\ cm^3$

$V_T = 10.64\ cm^3$

$V_T = .000011m^3$

For water procedure:

Apparent weight of metal: $(M_{water})(g) = (.01971\ kg)(9.81\ ^{m}/s^2)$

$= .193\ N$

Buoyant force acting on metal: $B = W_{actual} - W_{apparent}$

$B = .296\ N - .193\ N$

$B = .103\ N$

Mass of an equal amount of water (M_W): $M_W = \rho_{water}V_T$

$M_W = (1\times103\ ^{kg}/m^3)(.000011m^3)$

$M_W = .011$ kg

Weight of displaced water: $B = (M_W)(g)$

$B = (.011\ kg)(9.81\ ^m/s^2)$

$B = .108$ N

% difference = [(.108 N - .103 N)/(.106 N)] × 100

= 4.75 % difference

For antifreeze procedure:

Apparent weight of metal: $(M_{antifreeze})(g) = (.01869\ kg)(9.81\ ^m/s^2)$

= .183 N

Buoyant force acting on metal: $B = W_{actual} - W_{apparent}$

B = .296 N - .183 N

B = .113 N

Mass of an equal amount of antifreeze ($M_{antifreeze}$): $M_{antifreeze} = \rho_{antifreeze}V_T$

$M_{antifreeze} = (1{,}115\ ^{kg}/m^3)(.000011m^3)$

$M_{antifreeze} = .012$ kg

Weight of displaced antifreeze: $B = (M_{antifreeze})(g)$

$B = (.012\ kg)(9.81\ ^m/s^2)$

B = .118 N

% difference = [(.118 N - .113 N)/(.116 N)] × 100

= 4.31 % difference

Error analysis:

From the % difference equation, it was determined that some error occurred during the procedure of the lab. This error could be a result due to the improper use of the vernier caliper and the chance that the balance beam was not correctly zeroed at the start of the experiment. These errors would cause inaccurate values of the measured weight and a false value for the volume of the metal sample. Having these errors would be enough to offset the correct results, to a point where the experimental data is incorrect.

Conclusions:

As stated before, the purpose of the lab was to prove that the buoyant force acting on the metal sample is equivalent to the liquid displaced. This was made possible by using Archimedes' Principle. Though the metal sample was tested in two different fluids, water and antifreeze, the principle was proven correct. The difference between the actual and apparent weight was small showing the accuracy of Archimedes' Principle.