

Science: Physics

Archimedes' Principle

Objectives

Students will be able to:

- Identify the relationship between buoyancy and density.
 - Use Archimedes' principle to calculate buoyant force.
 - Determine what fraction of a floating object will submerge in a fluid.
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Warm-Up

Ask students whether wood floats or sinks in water. The question may elicit a variety of responses. Some students may have seen sticks or fallen branches sink to the bottom of a pond, while the very existence of wooden rafts implies that wood floats. Can students explain this difference?


Lesson

- Explain the story of Archimedes, his melodramatic discovery of the principle of fluid displacement, and this principle's relation to buoyancy. Use W|A to show students the formula for finding the submerged fraction of a solid object in a fluid.

The screenshot shows the WolframAlpha interface. At the top, the search bar contains 'Archimedes' principle'. Below the search bar, a message states: 'Assuming "Archimedes' principle" refers to a formula | Use as a word instead'. The 'Calculate' section shows 'effective gravity' selected, with input fields for 'volume of body: 1 L', 'mass density of body: 1 g/cm^3', and 'fluid density: 1 g/cm^3'. The 'Input Interpretation' section shows 'Archimedes' principle'. The 'Equation' section displays the formulas $F_{net} = m_b g - B$ and $B = \rho V_f g$, along with $R = \frac{V_f}{V_b}$. Below these are several rows of variables and their definitions:

F_{net}	effective gravity
m_b	mass of body
g	acceleration due to gravity ($\approx 9.807 \text{ m/s}^2$)
B	buoyancy force in fluid
ρ	fluid density
V_f	volume of replaced fluid
R	fraction of body submerged
V_b	volume of body

- Now ask students to test their guesses regarding whether or not wood will float in water. Use W|A to find a volume and density for a wooden object (for example, an 8-foot log with a 12-inch diameter) and the fluid in which it is submerged (water in this example).

 computational knowledge engine

volume of a cylinder diameter 12in, height 8ft

Assuming the input refers to a formula | Use "a cylinder" as a [geometric object](#) instead

Assuming diameter | Use [radius](#) instead

Input Information:

volume of a cylinder	
diameter	12 inches
height	8 feet

Result: [More](#)

volume	0.1779 m ³ (cubic meters)
	177920 cm ³ (cubic centimeters)
	177.9 L (liters)

Equation:


$$V = \frac{1}{4} \pi d^2 h$$

V	volume
d	diameter
h	height

(volume of a solid right circular cylinder of finite height)

Computed by: [Wolfram Mathematica](#) Download as: [PDF](#) | [Live Mathematica](#)

- Next, find the density of water.

 computational knowledge engine

Density of water

Assuming "water" is a chemical compound | Use as a [food](#) instead


Input Interpretation: [Mathematica form](#)

water density

Result:

1 g/cm³ (gram per cubic centimeter)

- Next, find the density of wood.


 computational knowledge engine

Density of wood

Assuming "wood" is a class of materials | Use as a general material instead

Input Interpretation:
wood density

Summary: Show details

median	0.57 g/cm ³
highest	1.09 g/cm ³ (lignum vitae wood)
lowest	0.0897 g/cm ³ (DIAE Inc. ProBalsa LD7)
distribution	

(based on 245 values; 12 unavailable) Units

Density rankings: More | Reverse

1	lignum vitae wood	1.090
2	African azobe wood	1.070
3	greenheart wood	1.040
4	Asian balau wood	0.980
5	wallaba wood	0.910
⋮		
241	European grecian fir wood	0.220
242	tropical balsa wood	0.160
243	American balsa wood	0.160
244	DIAE Inc. ProBalsa PB	0.155
245	DIAE Inc. ProBalsa LD7	0.090

(in grams per cubic centimeter)

- In the previous step, students discovered that different types of wood have very different densities. Now, ask students to select one dense and one light type of wood and input the relevant information into the Archimedes' principle calculator on W|A, indicating which types of wood will float (submerged fraction < 1.0) or sink (submerged fraction = 1.0).
- Lignum vitae, the densest known wood, will sink.

WolframAlpha computational knowledge engine

Fraction of body submerged Archimedes' principle 0.1779m^3 1.090g/cm^3

Calculate: fraction of body submerged

fluid density: 1g/cm^3


Input information:

Archimedes' principle	
volume of body	0.1779 m^3 (cubic meters)
mass density of body	1.09 g/cm^3 (grams per cubic centimeter)
fluid density	1 g/cm^3 (gram per cubic centimeter)

Result:

fraction of body submerged	1
buoyancy force in fluid	1.745 kN (kilonewtons) 1745 N (newtons) 392.2 lbf (pounds-force)
effective gravity	157 N (newtons) 0.157 kN (kilonewtons) 35.3 lbf (pounds-force)
mass of body	193.9 kg (kilograms) 427.5 lb (pounds) 0.2138 short tons
volume of replaced fluid	0.1779 m^3 (cubic meters) 177900 cm^3 (cubic centimeters) 177.9 L (liters)

- American balsa wood, one of the lightest known woods, will float with only 16% of its volume submerged.

 computational knowledge engine

Fraction of body submerged Archimedes principle 0.1779m³ 0.16g/cm³

Calculate fraction of body submerged

fluid density: 1 g/cm³

Input information:

Archimedes' principle	
volume of body	0.1779 m ³ (cubic meters)
mass density of body	0.16 g/cm ³ (grams per cubic centimeter)
fluid density	1 g/cm ³ (gram per cubic centimeter)

Result: More

fraction of body submerged	0.16
buoyancy force in fluid	279.1 N (newtons) 0.2791 kN (kilonewtons) 62.75 lbf (pounds-force)
effective gravity	0 N (newtons)
mass of body	28.46 kg (kilograms) 62.75 lb (pounds) 28464 grams
volume of replaced fluid	28464 cm ³ (cubic centimeters) 0.02846 m ³ (cubic meters) 28.46 L (liters)

Closing

- Ask students to make predictions about whether an apple, a piece of plastic, or a chunk of bituminous coal will sink or float. Then have them research and test these predictions using W|A.

Demonstrations

The Principle of Archimedes

Forces Exerted on an Immersed Object