Module 3 – Nautical Science

Unit 5 – Physical Science

Chapter 19 - Buoyancy

Section 1 – Buoyancy

What You Will Learn to Do

Demonstrate understanding of Physical Science

Objectives

1. Describe Archimedes Law
2. Explain how objects float
3. Explain how a submarine floats and submerges
4. Explain stability in a ship and its importance

Key Terms

CPS Key Term
Questions 1 - 10

Key Terms

Buoyant force -	A force that opposes the weight of an object in fluid; this force, along with object shape and density, helps keep the object afloat, regardless of what the object is made of or whether the “fluid” is a liquid or a gas; the principle is described by Archimedes’ Law.

Key Terms

Archimedes' Law - A body immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced by the body

Apparent weight - The measured weight of an object immersed in a fluid; its true weight minus the weight of the displaced fluid

Key Terms

Freeboard - The distance between the waterline and the main deck or weather deck of a ship

Waterline - The point on the hull of a ship or boat to which the water rises; a line marked on the outside of a ship that corresponds with the water's surface when the ship is afloat on an even keel under specified conditions of loading

Key Terms

Density -	The quantity per unit volume, unit area, or unit length; the mass of a substance per unit volume
Center of gravity -	The center of mass of the ship, around which the ship seems to move
Center of buoyancy -	The geometric center of the portion of the ship's hull that is underwater

Key Terms

Ballast -	A heavy substance used to improve the stability and control the draft of a ship or the depth of a submarine
Ballast tanks -	Fillable water tanks used to provide additional weight to vessels In submarines, a space between the inner and outer hulls filled with water when submerged and with air when surfaced

Opening Question

Name three types of vessels that are designed to take advantage of the buoyancy force.

1.

2.

3.

(Use CPS "Pick a Student" for this question.)

Warm Up Questions

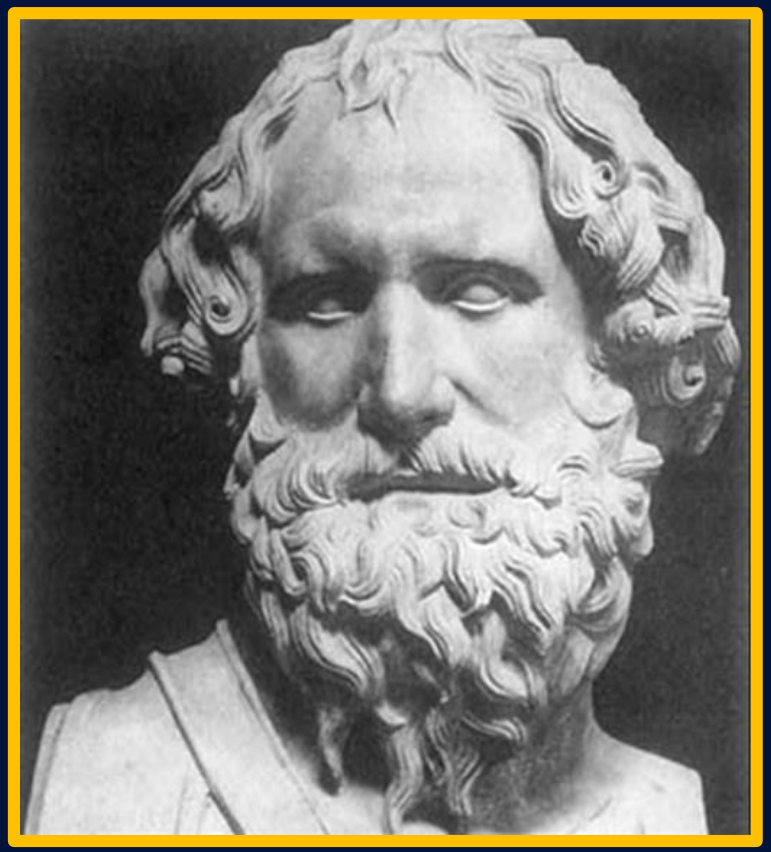
CPS Lesson
Questions 1 - 2

Introduction

Buoyant force enables metal ships to float and submarines to maintain a desired depth.

Greek scientist Archimedes described the force more than 2,000 years ago.

Introduction



Archimedes (287 - 212 B.C.)

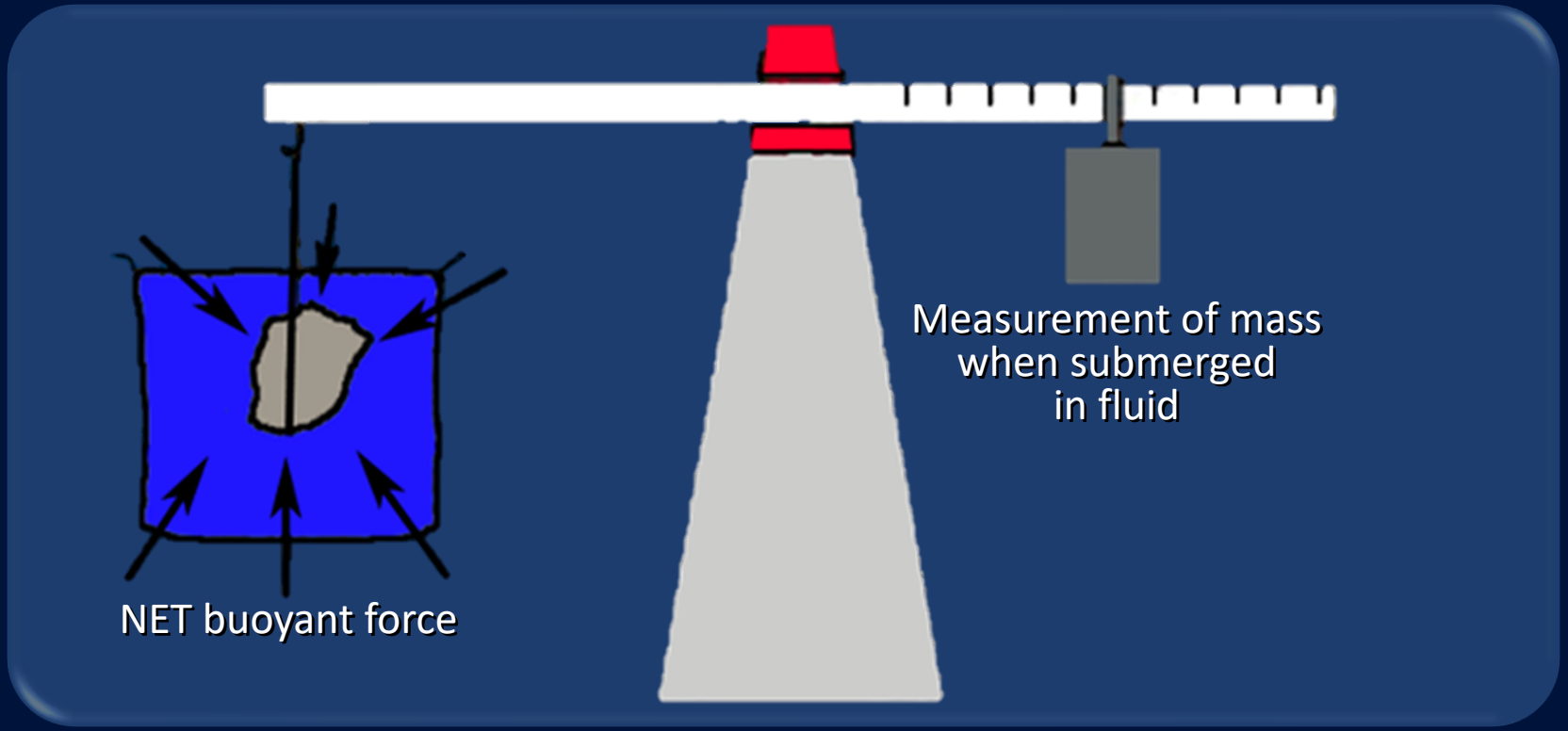
Archimedes' Law

An object immersed in fluid is pushed up with a force equal to the weight of the fluid it displaces.

The "fluid" can be liquid or gas.

Why Objects Float

Buoyant force equals the weight of fluid displaced.

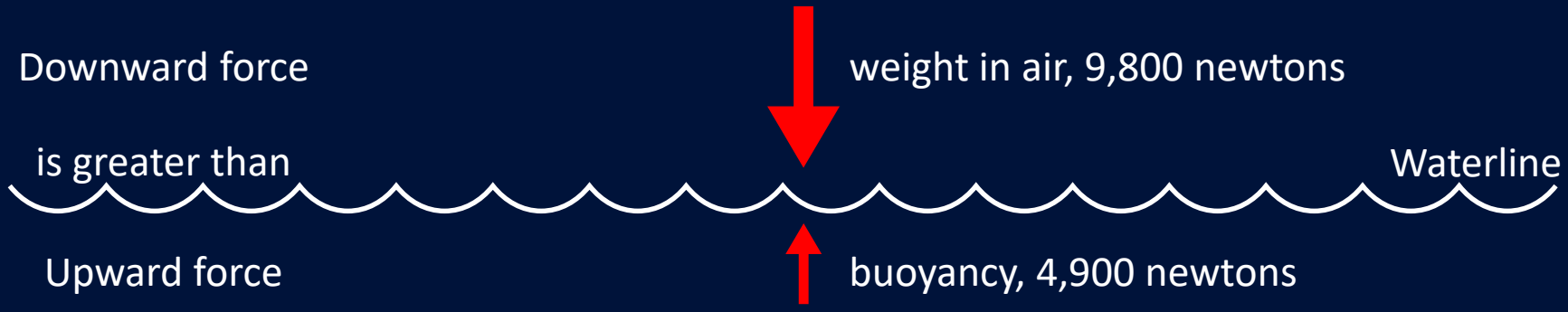


Why Objects Float

A stone is submerged in water. Its weight true weight is 9,800 newtons in air. Its volume is half a cubic meter.

The stone displaces 4,900 newtons of water, an amount equal to the stone's volume.

The stone sinks. Why?



Why Objects Float

The apparent weight of an object in water is:

- Its weight in air (true weight)
- minus the buoyant force (weight of the displaced fluid)

Why Objects Float

A hollow ship that weighs 9,800 newtons in air will begin to sink until it has displaced 9,800 newtons of water.

The upward force now equals the downward force. If there is still some part above water, the ship remains afloat.

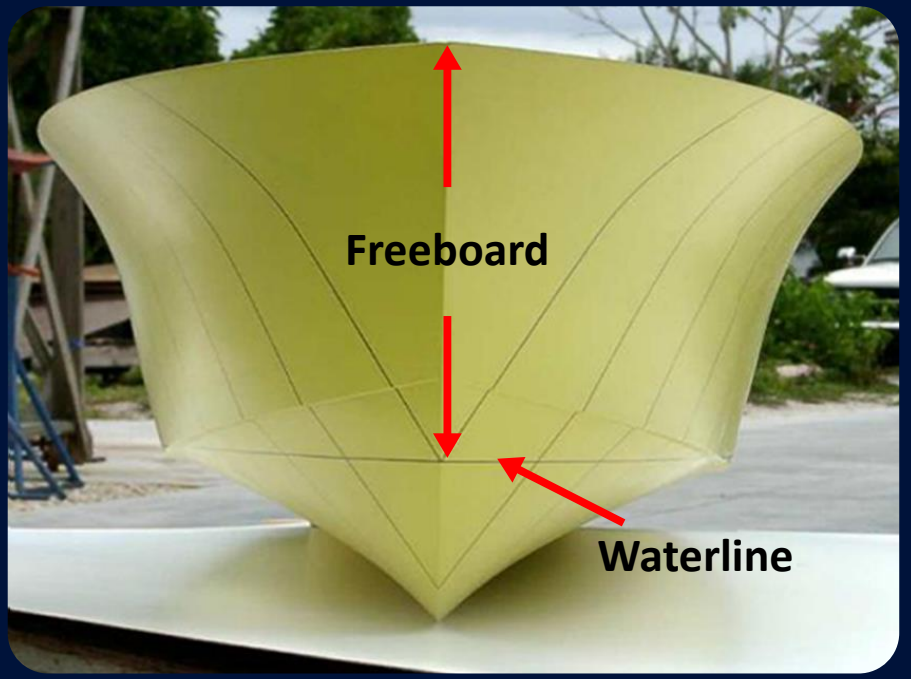
Why Objects Float

Remember Newton's first law: objects with no net force on them tend to remain at rest.

Why Objects Float

The point on the hull of a ship or boat to which the water rises is called the waterline.

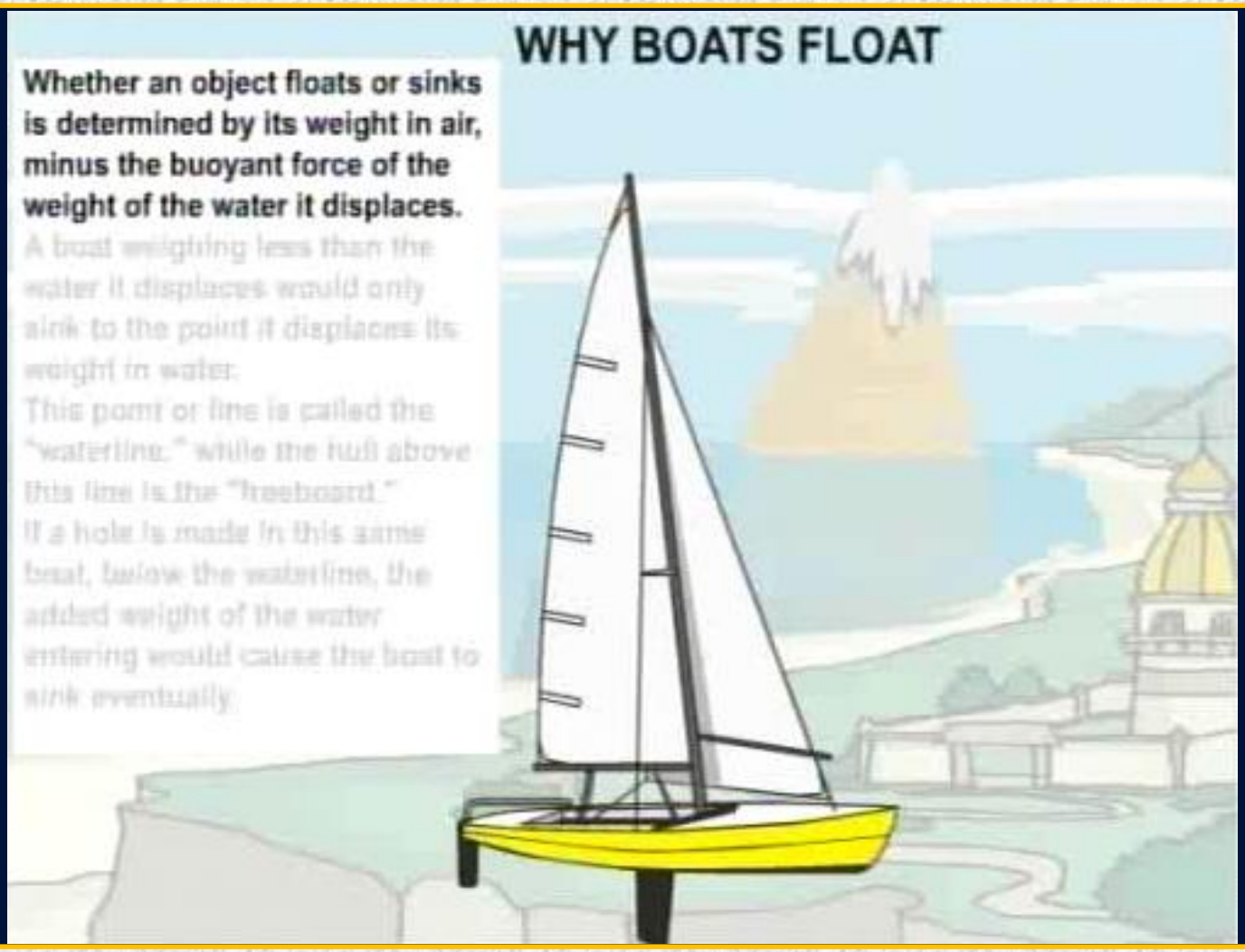
The part of the vessel between the waterline and the main deck or weather deck is called the freeboard.



Why Objects Float

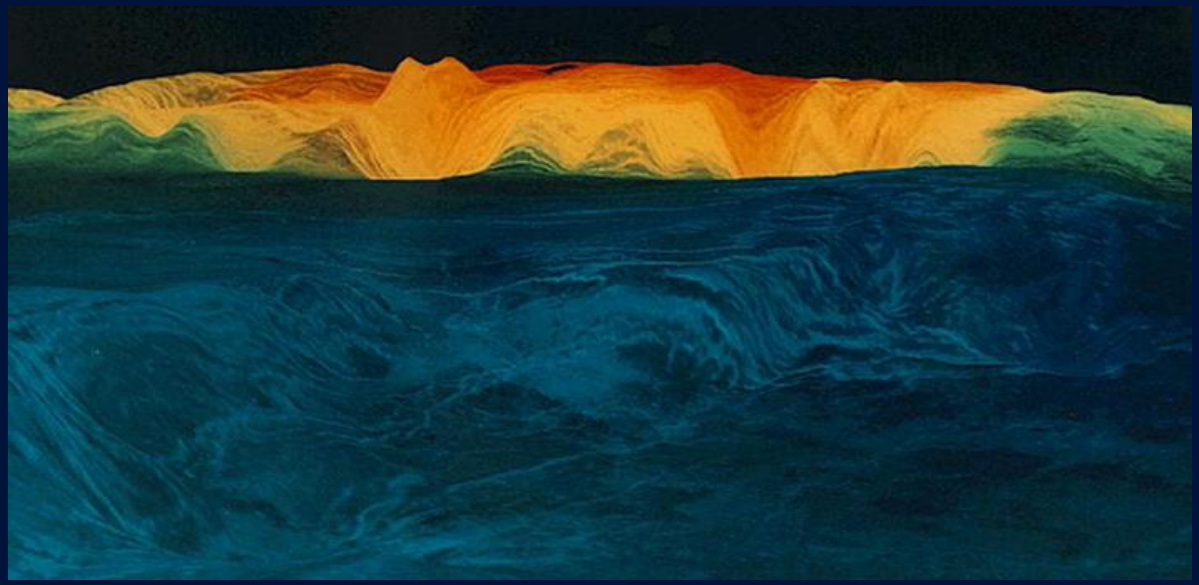
A ship will sink if the combined weight of water entering the ship and the ship's weight exceeds the weight of displaced water.

Why Objects Float



Why Objects Float

Density is a scientific term used to describe how much of a material is present per unit of its volume. By convention it is typically specified in kilograms per cubic meter, or smaller metric units (grams/centimeters).



Why Objects Float

Anything with a density less than water, such as wood, will always float, since it will achieve equality of upward buoyancy with downward weight before being totally submerged.

Solids with a density greater than water have a greater downward weight than upward buoyancy, and thus sink.

Check On Learning Questions

CPS Lesson
Questions 3 - 4

Why Objects Float

Gases, as well as liquids, exert upward buoyant forces.

A balloon filled with air that is at the same or lower temperature than the surrounding air will experience an upward force equal to the weight of the outside air being displaced.

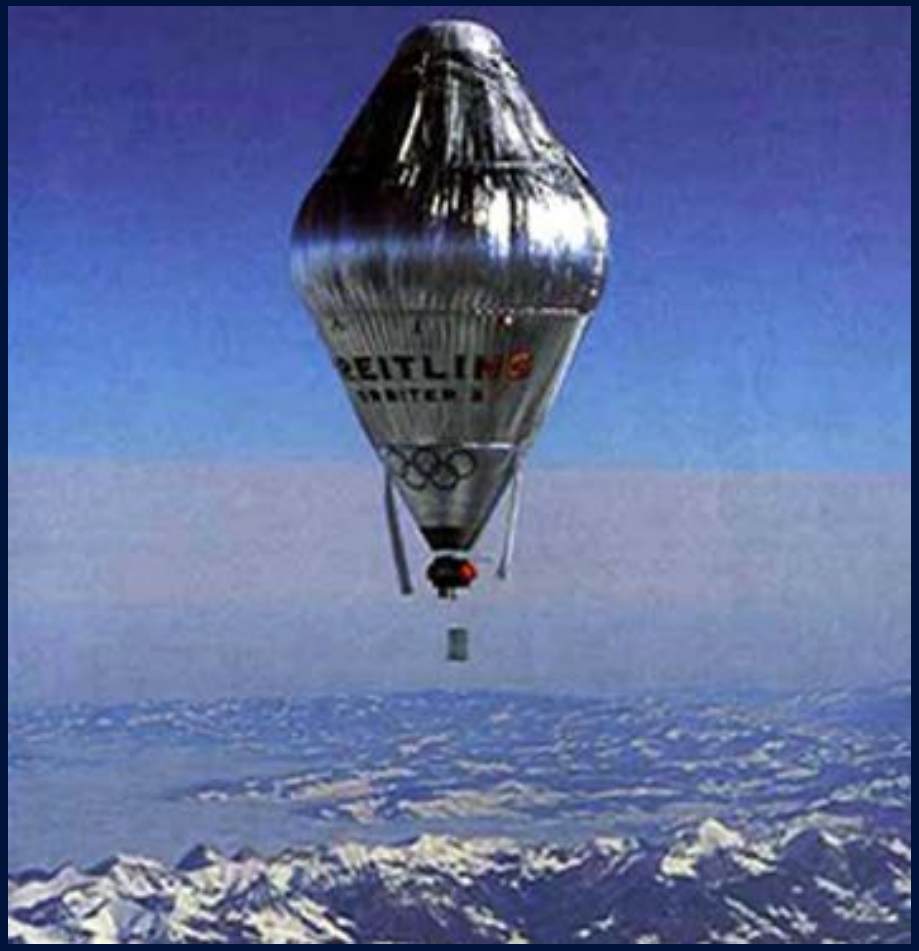
The weight of the balloon plus the air inside it, will eventually cause it to sink.

Why Objects Float

Hot air or light gases (helium) are less dense than regular air so they weigh less per unit volume.

A balloon filled with hot air or gas experiences less downward force, causing an unbalanced upward net force that allows it to rise.

Why Objects Float

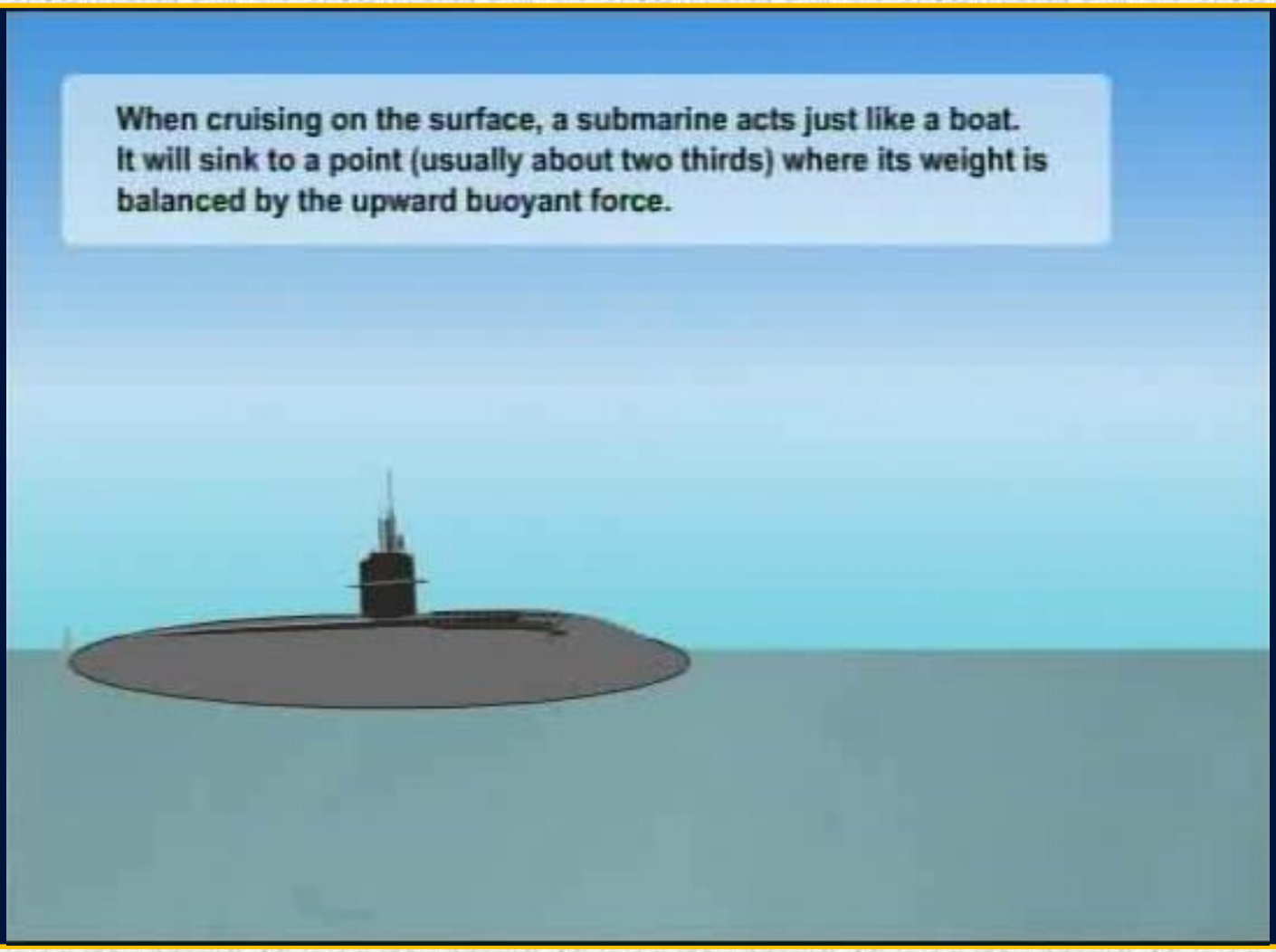


Large balloons can reach an altitude where the upward buoyant force equals the downward weight, allowing the balloon to maintain that altitude.

The Submarine

A surfaced submarine operates under the same buoyancy principles as a ship.

The Submarine

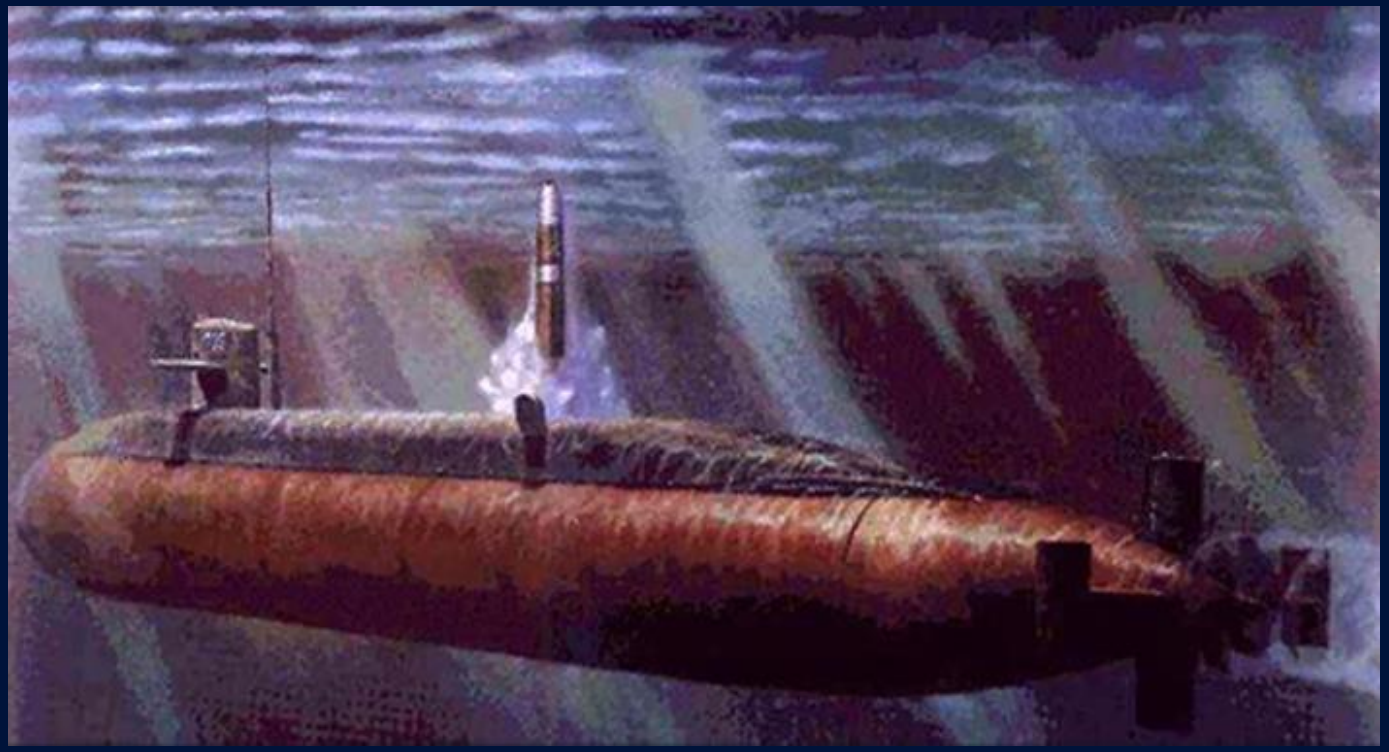


The Submarine

For most submarines, upward buoyancy and displacement weight equalizes with two-thirds of the hull submerged.

The Submarine

To submerge, a submarine needs more weight to overcome upward buoyant forces.

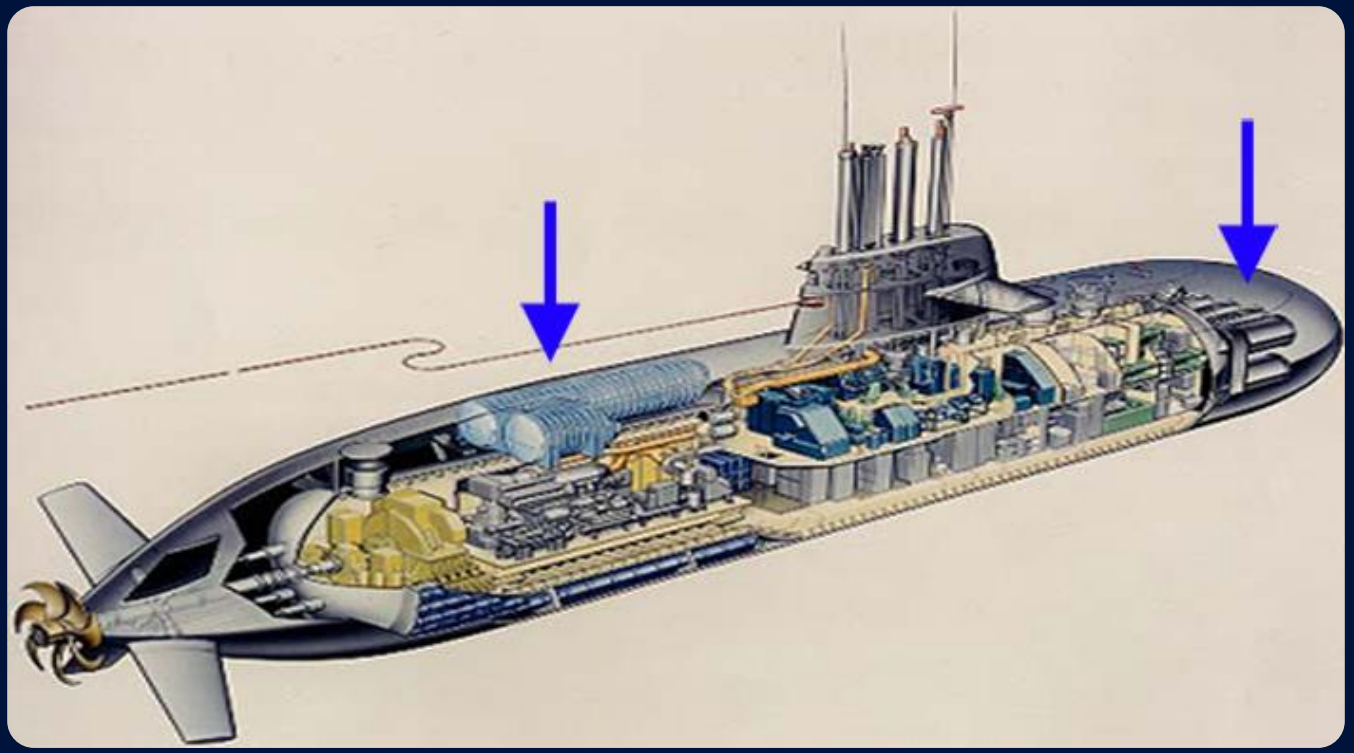


The Submarine

Submarines use fillable water tanks called ballast tanks in their hull to provide additional weight.

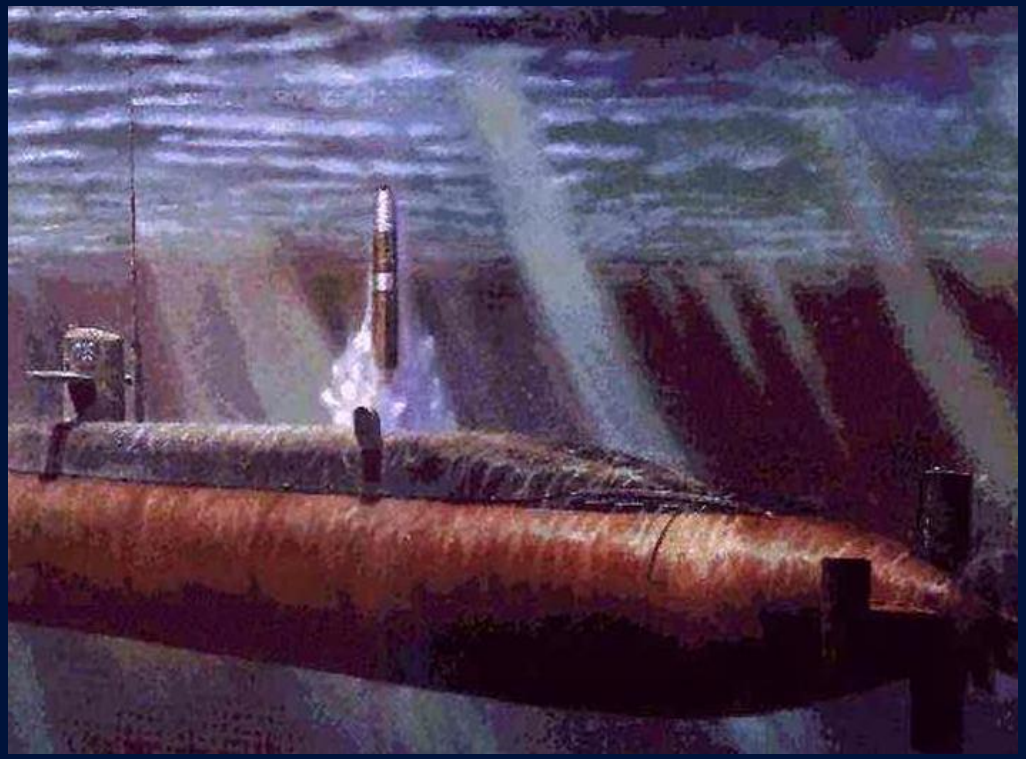
The Submarine

The water pumped into the ballast tanks provides the necessary weight for the submarine to dive.



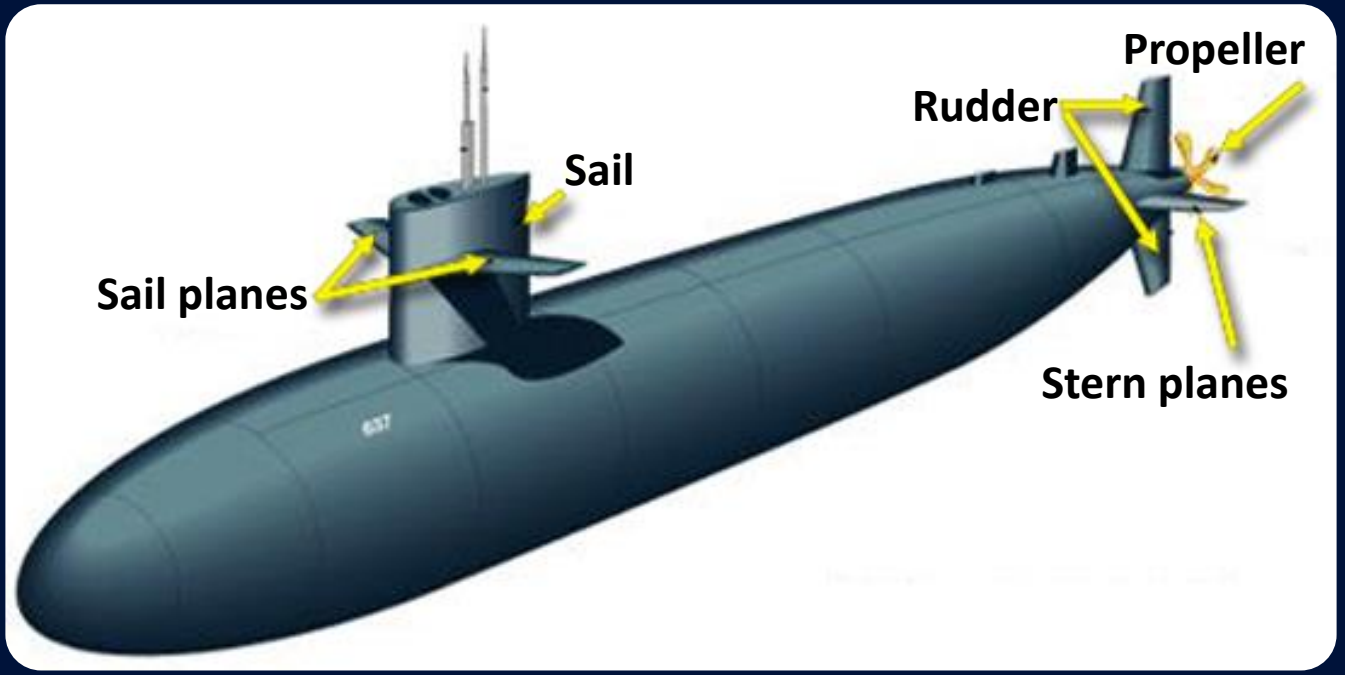
The Submarine

The submarine adjusts the amount of water in the ballast tanks to level off at a desired depth.



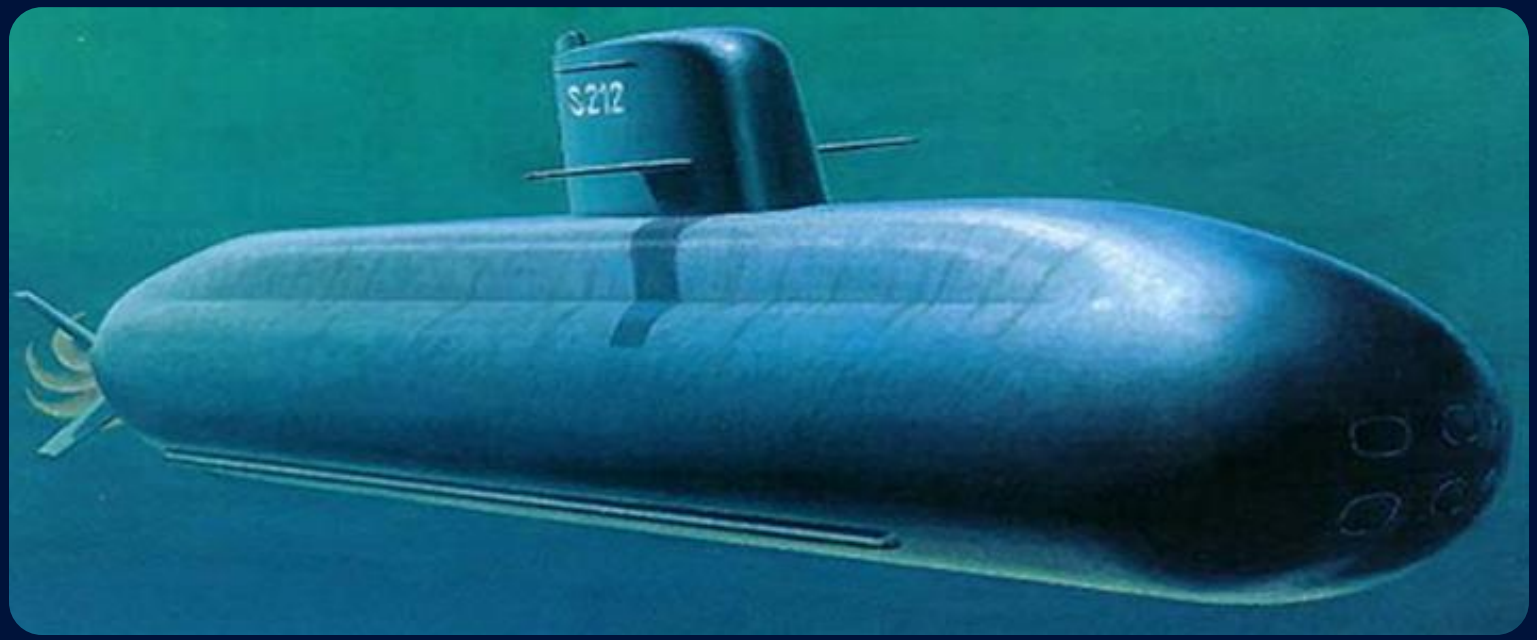
The Submarine

The propulsion system and diving planes can keep the submarine at the desired depth similar to an airplane flying.



The Submarine

Exactly matching the submarine's weight and buoyant force enables the submarine to maintain a desired depth without forward propulsion.



The Submarine

To surface, a submarine forces water from the ballast tanks with compressed air until the buoyant force is greater than the downward weight.

The Submarine

As the buoyant force exceeds downward weight the submarine will surface, aided by its propulsion plant.

The Submarine

Even though they operate in different media densities, a submarine in water acts much like a balloon in the air.

Check On Learning Questions

CPS Lesson
Questions 5 - 6

Ship Stability

A ship is designed to be stable in various sea conditions and when damaged.

Ship Stability

A ship's stability depends on the location of its center of gravity and center of buoyancy at various angles of inclination and roll.

Ship Stability

The center of gravity is the mass of the ship, around which the ship seems to move.

Ship Stability

The center of gravity remains constant as the ship moves.

Ship Stability

Center of buoyancy is the geometric center of the portion of the ship's hull that is underwater.

Ship Stability

The center of buoyancy tends to move in an arc as the ship rolls.

Ship Stability

A low center of gravity allows a greater distance between downward force and upward force through the center of buoyancy.

Ship Stability

Torque (force of rotation) generated through the center of buoyancy tends to right the ship as it rolls.

Ship Stability

Adding weight high in the ship raises the center of gravity and may cause the ship to capsize in a severe roll.

Ship Stability

A lightly loaded ship in heavy weather lowers its center of gravity and improves stability by filling ballast tanks near the keel with water. The additional water is called ballast.

Ship Stability

With the center of gravity lower, a ship is less likely to experience dangerous rolls in heavy seas.

Review Question

Name three precautionary measures to prevent a ship from sinking or capsizing.

1.

2.

3.

(Use CPS "Pick a Student" for this question.)

Closing Questions

CPS Lesson
Questions 7 - 8

Questions?