Ships and Submarines

Name: _____ **Class:** _____ **Date:** _____

Quick Review

Ships and submarines use **buoyancy** to float, sink, or remain underwater.

- **Buoyant force (upthrust):** The upward force exerted by water on an object.
- **Archimedes' Principle:** Buoyant force equals the weight of the water displaced by an object.
- **Floating:** A ship floats at rest when its weight equals the buoyant force.
- **Average density:** A hollow metal ship can float because its overall average density, including the air-filled spaces, is lower than the density of water.
- **Ballast tanks:** Compartments in a submarine that can contain water or air. Adjusting the amount of water changes the submarine's mass and overall average density.
- **Neutral buoyancy:** A fully submerged submarine can remain at a constant depth when its buoyant force balances its weight.

Useful formulas

Buoyant force = Density of water × g × Volume displaced

$F_\beta = \rho \times g \times V$

Net vertical force = Buoyant force − Weight

For calculations, use:

- Density of water = 1000 kg/m³
- g = 10 N/kg

Part A — Multiple Choice

Circle the correct answer.

1. Why can a large steel ship float?

A. Steel becomes lighter in water
B. The ship displaces enough water to balance its weight
C. Gravity does not act on ships
D. Ships contain no metal

2. What is the main purpose of ballast tanks in submarines?

A. To store food
B. To produce electricity
C. To control buoyancy and depth
D. To increase the speed of the propeller

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3. What usually happens when a submarine takes water into its ballast tanks?

A. Its overall average density increases
B. Its mass decreases
C. Its buoyant force becomes zero
D. Its volume doubles

4. What condition allows a fully submerged submarine to remain stationary at a constant depth?

A. Weight is greater than buoyant force
B. Buoyant force is greater than weight
C. Gravity disappears
D. Buoyant force equals weight

5. Which design feature helps a large ship remain stable in rough water?

A. Placing all heavy equipment as high as possible
B. Keeping the centre of gravity suitably low
C. Making the hull as narrow as possible in every situation
D. Removing all internal compartments

Part B — Matching

Match each term with its correct description.

Term	Answer	Descriptions
1. Buoyant force	_____	A. The main watertight body of a ship or submarine
2. Ballast tank	_____	B. A compartment used to take in or release water to adjust buoyancy
3. Displacement	_____	C. The upward force exerted by a fluid
4. Neutral buoyancy	_____	D. The amount of water moved aside by an object
5. Hull	_____	E. A condition in which upward and downward forces balance while fully submerged

Part C — Understanding Submarines

Complete the table. Assume the submarine's external volume remains approximately constant.

Situation	What happens to the submarine's mass?	Expected movement
1. Water enters the ballast tanks	_____	_____
2. Compressed air pushes water out of the ballast tanks	_____	_____
3. Buoyant force equals weight while fully submerged	_____	_____

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4. Why does taking water into the ballast tanks help a submarine sink?

5. Why does pumping water out of the ballast tanks help a submarine rise?

Part D — Buoyancy Calculations

Show your working.

1. A ship displaces 500 m^3 of freshwater.

Calculate the buoyant force.

2. A small submarine weighs 80,000 N and experiences a buoyant force of 75,000 N.

a) Calculate the net vertical force.

b) Will the submarine initially rise or sink if released from rest?

3. A submarine weighs 120,000 N and experiences a buoyant force of 120,000 N.

a) Calculate the net force.

b) What type of buoyancy does this represent if the submarine is fully submerged?

4. A floating boat has a total weight of 20,000 N.

What buoyant force acts on it while it floats at rest?

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Part E — Engineering and Design

1. Why is a hollow steel ship more likely to float than a solid steel block of the same mass?

2. Explain why ships have limits on the amount of cargo they can carry.

3. Why are watertight compartments important in large ships?

4. Engineers are designing a submarine to operate at great depths. Identify two important design considerations and explain why each matters.

Consideration 1: _____

Explanation: _____

Consideration 2: _____

Explanation: _____

Part F — Design Challenge

Scenario: You are designing a small model boat that must carry as many metal washers as possible without sinking.

You have:

- Aluminium foil
- A container of water
- Metal washers
- A ruler

1. Describe the shape you would give your boat and explain why.

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2. How would you arrange the washers to help keep the boat stable?

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3. Identify one change you could make if the boat begins to sink too deeply.

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4. How could you test and improve your boat design fairly?

Exit Ticket

1. Why can a steel ship float?

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2. What happens when water enters a submarine's ballast tanks?

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3. What must be true about weight and buoyant force for a submarine to remain neutrally buoyant?

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4. Why are watertight compartments useful?

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5. Name one engineering challenge involved in designing ships or submarines.

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Ships and Submarines — Answer Key

Part A — Multiple Choice

1. B — The ship displaces enough water to balance its weight.
2. C — To control buoyancy and depth.
3. A — Its overall average density increases.
4. D — Buoyant force equals weight.
5. B — Keeping the centre of gravity suitably low.

Part B — Matching

Term	Answer	Description
1. Buoyant force	C	The upward force exerted by a fluid
2. Ballast tank	B	A compartment used to take in or release water to adjust buoyancy
3. Displacement	D	The amount of water moved aside by an object
4. Neutral buoyancy	E	A condition in which upward and downward forces balance while fully submerged
5. Hull	A	The main watertight body of a ship or submarine

Part C — Understanding Submarines

Situation	Change in mass	Expected movement
1. Water enters the ballast tanks	Increases	Tends to sink
2. Compressed air pushes water out	Decreases	Tends to rise
3. Buoyant force equals weight while fully submerged	No change required once balanced	Remains at a constant depth if initially stationary

4. Why does taking water into the ballast tanks help a submarine sink?

Water entering the ballast tanks increases the submarine's mass and overall average density.

Because its external volume remains approximately constant, the buoyant force changes very little. The increased weight can exceed the buoyant force, producing a downward net force.

5. Why does pumping water out of the ballast tanks help a submarine rise?

Compressed air pushes water out of the ballast tanks, reducing the submarine's mass and overall average density.

Its weight decreases while the buoyant force remains approximately constant. If buoyant force becomes greater than weight, the submarine accelerates upward.

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Part D — Buoyancy Calculations

Use:

$F_\beta = \rho \times g \times V$

Net vertical force = Buoyant force − Weight

1. A ship displaces 500 m³ of freshwater. Calculate the buoyant force.

Given:

- $\rho = 1000$ kg/m³
- $g = 10$ N/kg
- $V = 500$ m³

$F_\beta = 1000 \times 10 \times 500$

Answer: 5,000,000 N upward

2. A small submarine weighs 80,000 N and experiences a buoyant force of 75,000 N.

a) Calculate the net vertical force.

Net force = 75,000 − 80,000

Answer: −5000 N, or 5000 N downward

b) Will the submarine initially rise or sink if released from rest?

Sink. Its weight exceeds the buoyant force, so the resultant force acts downward.

3. A submarine weighs 120,000 N and experiences a buoyant force of 120,000 N.

a) Calculate the net force.

Net force = 120,000 − 120,000

Answer: 0 N

b) What type of buoyancy does this represent if the submarine is fully submerged?

Neutral buoyancy. The upward and downward forces are balanced.

4. A floating boat has a total weight of 20,000 N. What buoyant force acts on it while it floats at rest?

Answer: 20,000 N upward

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The buoyant force must balance the boat's weight.

Part E — Engineering and Design

1. Why is a hollow steel ship more likely to float than a solid steel block of the same mass?

A hollow ship has a larger external volume than a compact solid block of the same mass.

Its hull encloses air-filled spaces, allowing it to displace more water and achieve a lower overall average density.

The ship can therefore displace enough water for the buoyant force to balance its weight before becoming completely submerged.

2. Explain why ships have limits on the amount of cargo they can carry.

Adding cargo increases the ship's total weight.

The ship must sink deeper to displace additional water and produce enough buoyant force.

If overloaded, the ship may lose necessary freeboard (the distance between the waterline and the deck), become unstable, take on water, or sink.

3. Why are watertight compartments important in large ships?

Watertight compartments divide the hull into separate sealed sections.

If one compartment is damaged and floods, other compartments can remain dry, limiting the amount of water entering the ship.

This helps preserve buoyancy, stability, and safety.

4. Engineers are designing a submarine to operate at great depths. Identify two important design considerations and explain why each matters.

Accept any two well-explained answers, including:

Design consideration	Explanation
Strong pressure hull	Must withstand very high external water pressure without collapsing
Ballast control system	Must reliably adjust buoyancy to dive, rise, and maintain depth
Watertight seals	Prevent water from entering the submarine
Corrosion-resistant materials	Reduce damage from seawater
Emergency buoyancy systems	Help the submarine surface during emergencies
Reliable oxygen and life-support systems	Keep the crew safe underwater
Stable design and weight distribution	Help maintain balance and controlled movement

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Part F — Design Challenge

1. Describe the shape you would give your boat and explain why.

A good design would be a wide, shallow, tray-shaped boat with raised sides.

This allows the boat to displace a large volume of water while supporting its load and helps reduce the risk of tipping or water entering.

2. How would you arrange the washers to help keep the boat stable?

Place the washers evenly across the bottom of the boat.

Keep the load low and centred to reduce tipping and improve stability.

3. Identify one change you could make if the boat begins to sink too deeply.

Acceptable answers include:

- Make the boat wider or increase its usable hull volume.
- Raise the sides to reduce the risk of flooding.
- Reduce the number of washers.
- Redistribute the washers to keep the boat level.
- Strengthen the foil to prevent leaks or deformation.

4. How could you test and improve your boat design fairly?

Students should:

1. Build a boat using a fixed amount of aluminium foil.
2. Place it in the same container of water.
3. Add identical washers one at a time.
4. Record the maximum number supported before the boat sinks or floods.
5. Change one design feature, such as hull width.
6. Repeat the test and compare results.

A fair test keeps the amount of foil, type of washers, and testing conditions the same.

Exit Ticket

1. Why can a steel ship float?

Its hollow hull allows it to displace enough water for the buoyant force to balance its weight.

2. What happens when water enters a submarine's ballast tanks?

Its mass and average density increase, helping it sink.

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3. What must be true about weight and buoyant force for a submarine to remain neutrally buoyant?

Buoyant force = Weight

The net vertical force is zero.

4. Why are watertight compartments useful?

They limit flooding if part of the hull is damaged, helping the ship remain afloat and stable.

5. Name one engineering challenge involved in designing ships or submarines.

Acceptable answers include maintaining stability, preventing leaks, resisting corrosion, supporting heavy cargo, controlling buoyancy, or withstanding high water pressure.

Teaching Notes

- Ships float because of displacement, not because steel is less dense than water. The ship's overall average density is sufficiently low.
- Submarine ballast tanks change mass and average density. They do not normally change the submarine's external volume significantly.
- Neutral buoyancy means balanced vertical forces. A submarine that is already moving may continue moving at constant velocity if the net force is zero.
- Stability and buoyancy are different. A ship can have enough buoyancy to float but still be unstable and capsize.
- Watertight compartments improve safety but do not guarantee that a damaged ship cannot sink.

Assessment suggestion: For Parts E and F, award credit for scientifically correct explanations even when students use different wording or propose alternative practical designs.

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