Week 28

AP Physics 1

Homework bundle for this week

本周作业合集

exercises.lol

Contents 目录

AP Physics 1 Name: ____________ Score: ______

1. A block has mass 600 g and volume 200 cm^3. What is its density, in $\frac{\mathrm{g}}{\mathrm{cm}^3}$?

   ____________ $\mathrm{g/cm}^3$

2. A force of 200 N presses on an area of 0.5 m^2. What is the pressure, in Pa?

   ____________ Pa

3. A block of volume 0.002 m^3 is submerged in water ($\rho = 1000\ \frac{\mathrm{kg}}{\mathrm{m}^3}$, $g = 10\ \frac{\mathrm{m}}{\mathrm{s}^2}$). What is the buoyant force, in N?

   ____________ N

4. Water at 2 $\frac{\mathrm{m}}{\mathrm{s}}$ flows from a pipe of area 6 cm^2 into one of area 2 cm^2. What is the new speed, in $\frac{\mathrm{m}}{\mathrm{s}}$?

   ____________ m/s

5. Density is defined as:

   ☐ mass times volume

   ☐ mass per unit volume

   ☐ weight per unit area

   ☐ volume per unit mass

6. Find the water pressure 2 m deep ($\rho = 1000\ \frac{\mathrm{kg}}{\mathrm{m}^3}$, $g = 10\ \frac{\mathrm{m}}{\mathrm{s}^2}$), in Pa.

   ____________ Pa

7. Archimedes' principle says the buoyant force equals:

   ☐ the weight of the object

   ☐ the weight of the fluid displaced

   ☐ the volume of the object

   ☐ the density of the object

8. The continuity equation $A_1 v_1 = A_2 v_2$ is a statement of the conservation of:

   ☐ energy

   ☐ mass

   ☐ momentum

   ☐ charge

9. A large, heavy object always has a high density.

☐ True ☐ False

10. The same force on a **smaller** area produces:

- ☐ less pressure
- ☐ more pressure
- ☐ the same pressure
- ☐ zero pressure

AP Physics 1

1. **3 g/cm^3**

   $\rho = m/V = 600/200 = 3\ \frac{\text{g}}{\text{cm}^3}$.

2. **400 Pa**

   $P = F/A = 200/0.5 = 400$ Pa.

3. **20 N**

   $F_b = \rho V g = 1000 \times 0.002 \times 10 = 20$ N.

4. **6 m/s**

   $A_1 v_1 = A_2 v_2 \Rightarrow 6 \times 2 = 2 v_2 \Rightarrow v_2 = 6\ \frac{\text{m}}{\text{s}}$.

5. **mass per unit volume**

   $\rho = m/V$ — mass per unit volume.

6. **20000 Pa**

   $P = \rho g h = 1000 \times 10 \times 2 = 20\,000$ Pa.

7. **the weight of the fluid displaced**

   $F_b = \rho_{\text{fluid}} V g$ — the weight of the fluid the object pushes aside.

8. **mass**

   No fluid piles up or disappears — it is conservation of mass.

9. **False**

   Density is mass **per volume**. A large object can be low-density if its mass is spread over a big volume.

10. **more pressure**

    $P = F/A$: a smaller area gives a larger pressure — why knives and needles are sharp.

8.1 Internal Structure and Density

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS density 密度

Objective

Build the skills to answer exam questions on **internal structure and density**.

You must be able to:

- define **density** 密度 as mass per unit volume, $\rho = \dfrac{m}{V}$
- relate a substance's density to the **spacing** and mass of its particles
- compare the densities of solids, liquids, and gases

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Density

$\rho = \dfrac{m}{V}$, measured in kg m^{-3}. Rearranged: $m = \rho V$.

■ Particle picture

Closely packed, more massive particles give a higher density. Gases have widely spaced particles, so they are far less dense than solids or liquids.

■ Example

A 240 g block of volume 30 cm^3: $\rho = \dfrac{240}{30} = 8.0$ g cm^{-3}.

2 Practice

2.1 A 240 g block has a volume of 30 cm^3. Find its density. [2]

2.2 State which state of matter is usually the least dense. [1]

2.3 A liquid has density 800 kg m^{-3}. Find the mass of 2.0 m^3 of it. [2]

3 Exam-style questions

3.1 Density is defined as [1]

- **A** mass × volume
- **B** mass ÷ volume
- **C** volume ÷ mass
- **D** force ÷ area

3.2 Which state of matter is usually the densest? [1]

- **A** gas
- **B** liquid
- **C** solid
- **D** all are equal

3.3 A metal cube of side 0.10 m has a mass of 2.7 kg.

(a) Find its volume. [1]

(b) Find its density. [2]

Solutions

2.1 $\rho = \dfrac{m}{V} = \dfrac{240}{30} = 8.0\ \text{g cm}^{-3}$.

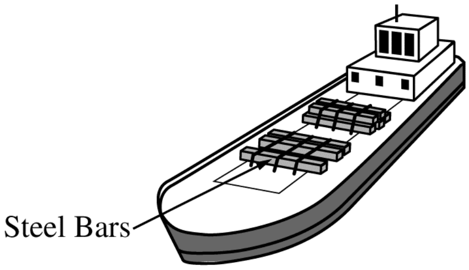
2.2 a gas.

2.3 $m = \rho V = 800 \times 2.0 = 1600$ kg.

3.1 **B**.

3.2 **C**.

3.3 (a) $V = (0.10)^3 = 1.0 \times 10^{-3}\ \text{m}^3$. (b) $\rho = \dfrac{2.7}{1.0 \times 10^{-3}} = 2700\ \text{kg m}^{-3}$.



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \mathrm{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

STOP

END OF EXAM

8.2 Pressure

Name: ____________ Class: ________ Date: __________ **Total: 9 marks**

KEY WORDS pressure 压强 • depth 深度 • fluid 流体 • density 密度

Objective

Build the skills to answer exam questions on **pressure**.

You must be able to:

- define **pressure** 压强 as force per unit area, $P = \dfrac{F}{A}$
- calculate the pressure due to a column of fluid, $P = \rho g h$
- explain how pressure increases with **depth** and acts in all directions

1 Worked examples

Study these first. Each one shows the method for a question type used later.

> **■ Pressure**
>
> $P = \dfrac{F}{A}$, measured in pascals ($1\ \text{Pa} = 1\ \text{N m}^{-2}$). The same force over a smaller area gives more pressure.
>
> **■ Pressure in a fluid**
>
> $P = \rho g h$ increases with **depth** h and acts equally in **all directions** at a given depth.
>
> **■ Example**
>
> At 2.0 m depth in water ($\rho = 1000$, $g = 10$): $P = 1000 \times 10 \times 2.0 = 2.0 \times 10^4$ Pa.

2 Practice

2.1 A force of 200 N acts on an area of 0.50 m^2. Find the pressure. [1]

2.2 Find the pressure 5.0 m below the surface of a lake ($\rho = 1000\ \text{kg m}^{-3}$, $g = 10\ \text{m s}^{-2}$). [2]

2.3 State how the pressure in a fluid changes with depth. [1]

3 Exam-style questions

3.1 Pressure is defined as [1]

- **A** force $\times$ area
- **B** force $\div$ area
- **C** mass $\div$ volume
- **D** density $\times$ depth only

3.2 The pressure due to a column of fluid depends on [1]

- **A** the shape of the container
- **B** the surface area
- **C** the depth and the fluid density
- **D** the total volume

3.3 A diver is 12 m below the sea surface ($\rho = 1030$ kg m^{-3}, $g = 10$ m s^{-2}).

(a) Find the pressure due to the water. [2]

(b) Find the total pressure if atmospheric pressure is 1.0×10^5 Pa. [1]

Solutions

2.1 $P = \dfrac{F}{A} = \dfrac{200}{0.50} = 400$ Pa.

2.2 $P = \rho g h = 1000 \times 10 \times 5.0 = 5.0 \times 10^4$ Pa.

2.3 it increases with depth.

3.1 **B**.

3.2 **C**.

3.3 (a) $P = \rho g h = 1030 \times 10 \times 12 = 1.24 \times 10^5$ Pa. (b) total $= 1.24 \times 10^5 + 1.0 \times 10^5 = 2.24 \times 10^5$ Pa.

(12 points, suggested time 25 minutes)

A group of students is investigating how the thickness of a plastic rod affects the maximum force F_{max} with which the rod can be pulled without breaking. Two students are discussing models to represent how F_{max} depends on rod thickness.
Student A claims that F_{max} is directly proportional to the radius of the rod.
Student B claims that F_{max} is directly proportional to the cross-sectional area of the rod—the area of the base of the cylinder, shaded gray in the figure above.

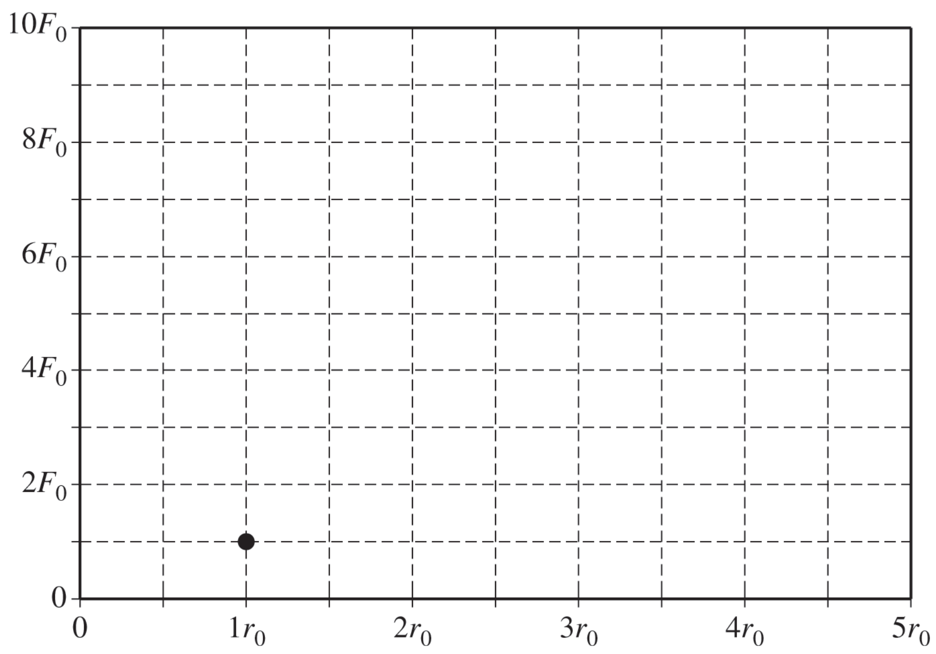
(a) The students have a collection of many rods of the same material. The rods are all the same length but come in a range of six different thicknesses. Design an experimental procedure to determine which student's model, if either, correctly represents how F_{max} depends on rod thickness.

In the table below, list the quantities that would be measured in your experiment. Define a symbol to represent each quantity, and also list the equipment that would be used to measure each quantity. You do not need to fill in every row. If you need additional rows, you may add them to the space just below the table.

Quantity to be Measured	Symbol for Quantity	Equipment for Measurement

Describe the overall procedure to be used, referring to the table. Provide enough detail so that another student could replicate the experiment, including any steps necessary to reduce experimental uncertainty. As needed, use the symbols defined in the table and/or include a simple diagram of the setup.

(b) For a rod of radius r_0, it is determined that F_{max} is F_0, as indicated by the dot on the grid below. On the grid, draw and label graphs corresponding to the two students' models of the dependence of F_{max} on rod radius. Clearly label each graph "A" or "B," corresponding to the appropriate model.



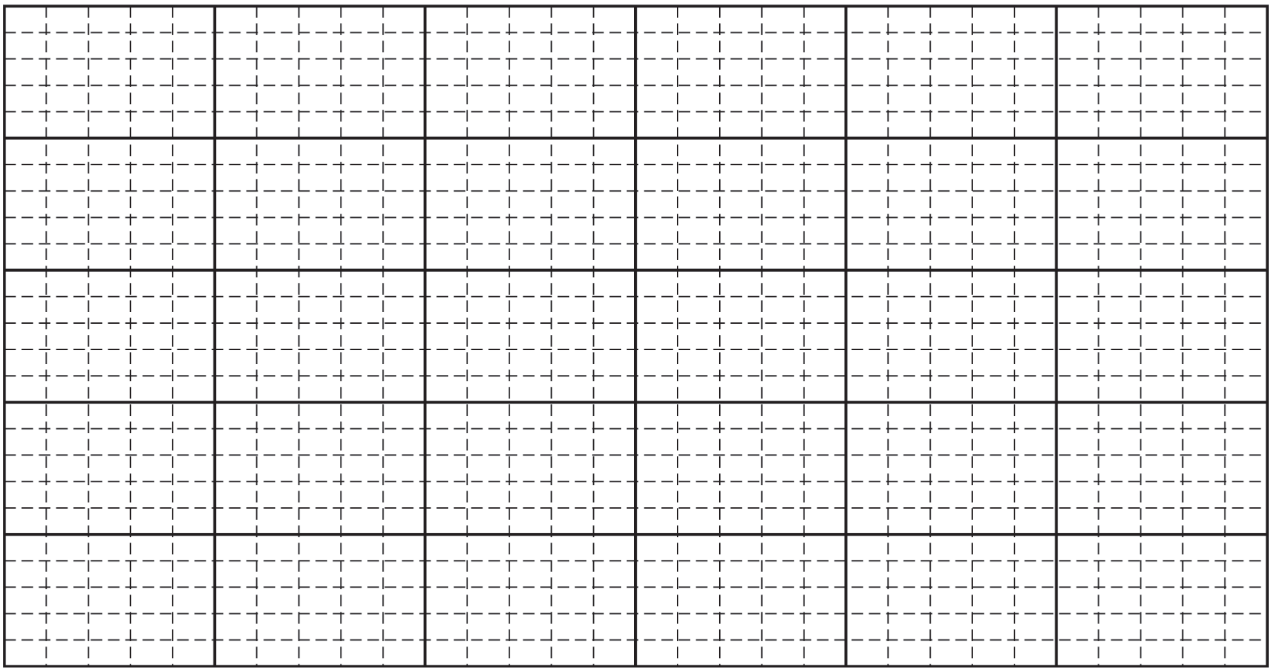
GO ON TO THE NEXT PAGE.

Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

The table below shows results of measurements taken by another group of students for rods of different thicknesses.

Rod radius (mm)	0.5	1.0	1.5	2.0	2.5
F_{max} (N)	40	120	320	520	900

(c) On the grid below, plot the data points from the table. Clearly scale and label all axes, including units. Draw either a straight line or a curve that best represents the data.



(d) Which student's model is more closely represented by the evidence shown in the graph you drew in part (c) ?

____ Student A's model: F_{max} is directly proportional to the radius of the rod.

____ Student B's model: F_{max} is directly proportional to the cross-sectional area of the rod.

Explain your reasoning.

GO ON TO THE NEXT PAGE.

8.3 Fluids and Newton's Laws

Name: ______________ Class: __________ Date: ____________ **Total: 10 marks**

KEY WORDS buoyant force 浮力 • archimedes' principle 阿基米德原理 • density 密度 • fluid 流体

Objective

Build the skills to answer exam questions on **fluids and Newton's laws**.

You must be able to:

- treat **buoyancy 浮力** as a net upward force from a fluid
- state **Archimedes' principle 阿基米德原理**: the buoyant force equals the weight of the displaced fluid
- explain floating and sinking by comparing an object's weight with the buoyant force

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Archimedes' principle

The **buoyant force** equals the weight of the fluid displaced: $F_b = \rho_{fluid}\, g\, V_{displaced}$.

■ Float or sink

Compare weight and buoyant force. Float if $F_b \geq$ weight — equivalently, if the object's density is less than the fluid's.

■ Example

An object of weight 10 N displacing fluid of weight 12 N feels a net upward force → it floats up.

2 Practice

2.1 State Archimedes' principle. [2]

2.2 An object weighs 8.0 N in air and displaces fluid weighing 5.0 N when submerged. Find the buoyant force on it. [1]

2.3 State the condition, in terms of density, for an object to float. [1]

3 Exam-style questions

3.1 The buoyant force on a submerged object equals the weight of the [1]

- **A** object
- **B** displaced fluid
- **C** container
- **D** air above it

3.2 An object floats when its density is [1]

- **A** greater than the fluid's
- **B** exactly equal to the fluid's
- **C** less than or equal to the fluid's
- **D** unrelated to the fluid's

3.3 A 2.0 kg block of volume 1.0×10^{-3} m^3 is fully submerged in water ($\rho = 1000$ kg m^{-3}, $g = 10$ m s^{-2}).

(a) Find the buoyant force on it. [2]

(b) State whether it sinks or rises, with a reason. [2]

Solutions

2.1 the buoyant force on an object equals the weight of the fluid it displaces.

2.2 5.0 N (equal to the weight of displaced fluid).

2.3 the object's density must be less than (or equal to) the fluid's density.

3.1 **B**.

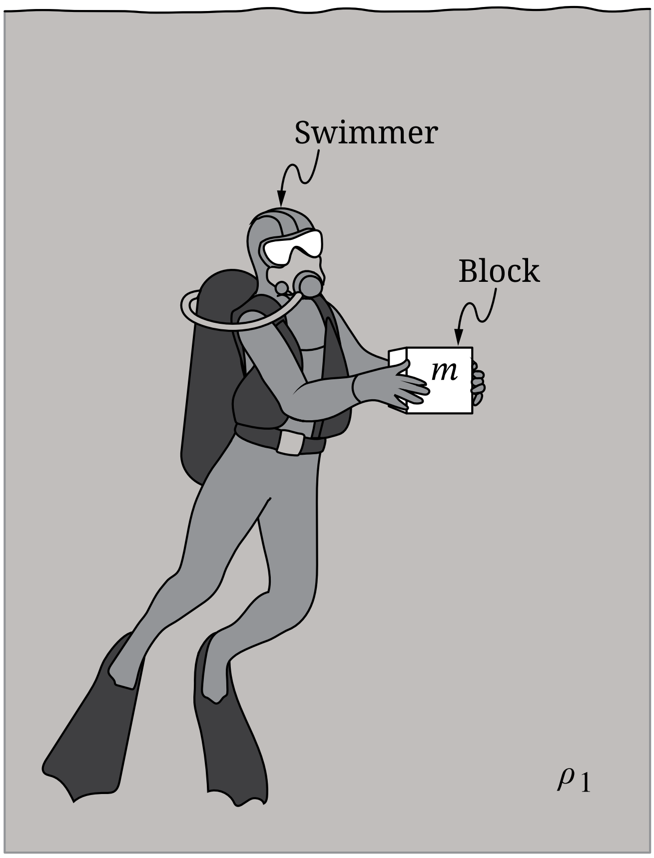
3.2 **C**.

3.3 (a) $F_b = \rho g V = 1000 \times 10 \times 1.0 \times 10^{-3} = 10$ N. (b) weight $= mg = 20$ N > 10 N, so it sinks — the buoyant force cannot support it.

Question 4

4. In Scenario 1, a swimmer holds a block of mass m at rest in a tank of freshwater with density ρ_1, as shown in Figure 1. The block is released from rest and accelerates upward with an initial acceleration a_1. All frictional forces are negligible.

Figure 1



In Scenario 2, the swimmer holds the same block at rest in a tank of salt water with density ρ_2, where $\rho_2 > \rho_1$. The swimmer again releases the block from rest, and the block accelerates upward with initial acceleration a_2. All frictional forces are negligible.

A. Indicate whether a_1 is greater than, less than, or equal to a_2 by writing one of the following in your answer booklet.

- $a_1 > a_2$
- $a_1 < a_2$
- $a_1 = a_2$

Justify your answer in terms of ALL forces exerted on the block in each scenario. Use qualitative reasoning beyond referencing equations.

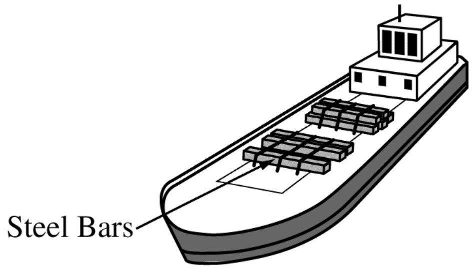
B. Consider the general case where a block of mass m and volume V is completely submerged in a fluid of density ρ.

Starting with Newton's second law, **derive** an expression for the initial upward acceleration a of the block when the block is released from rest. Express your answer in terms of m, V, ρ, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. Indicate whether the expression for the acceleration a you derived in part B is or is not consistent with the claim made in part A. Briefly **justify** your answer by referencing your derivation in part B.

STOP

END OF EXAM



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \mathrm{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

STOP

END OF EXAM

8.4 Fluids and Conservation Laws

Name: ______ Class: ______ Date: ______ **Total: 9 marks**

KEY WORDS continuity 连续性 • bernoulli's principle 伯努利原理 • continuity equation 连续性方程 • fluid 流体 • pressure 压强

Objective

Build the skills to answer exam questions on **fluids and conservation laws**.

You must be able to:

- apply **conservation of mass** with the **continuity equation** 连续性方程 $A_1v_1 = A_2v_2$
- apply **conservation of energy** with **Bernoulli's principle** 伯努利原理
- explain why a fluid speeds up through a narrow section and its pressure drops

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ Continuity (conservation of mass)

$A_1v_1 = A_2v_2$: a **narrower** pipe forces the fluid to flow **faster**.

■ Bernoulli (conservation of energy)

Where a fluid flows **faster**, its **pressure is lower**. This lift-and-spray effect explains aeroplane wings and perfume atomisers.

■ Example

Flow narrowing from 0.02 m^2 to 0.005 m^2 with $v_1 = 1.0$ m s^{-1}: $v_2 = \dfrac{0.02 \times 1.0}{0.005} = 4.0$ m s^{-1}.

2 Practice

2.1 Water flows through a pipe that narrows from 0.020 m^2 to 0.0050 m^2. If $v = 1.0$ m s^{-1} in the wide part, find the speed in the narrow part. [2]

2.2 State what happens to the fluid pressure where the flow speeds up. [1]

2.3 State the continuity equation. [1]

3 Exam-style questions

3.1 As a fluid flows into a narrower pipe, its speed [1]

- **A** decreases
- **B** increases
- **C** stays constant
- **D** drops to zero

3.2 Where a fluid flows faster, its pressure is [1]

- **A** higher
- **B** lower
- **C** unchanged
- **D** zero

3.3 Water (incompressible) flows at 2.0 m s^{-1} through a pipe of area 0.010 m^2 that narrows to 0.0040 m^2.

(a) Find the speed in the narrow section. [2]

(b) Explain what happens to the pressure there. [1]

Solutions

2.1 $v_2 = \dfrac{A_1 v_1}{A_2} = \dfrac{0.020 \times 1.0}{0.0050} = 4.0\ \text{m s}^{-1}$.

2.2 it drops (Bernoulli's principle).

2.3 $A_1 v_1 = A_2 v_2$.

3.1 **B**.

3.2 **B**.

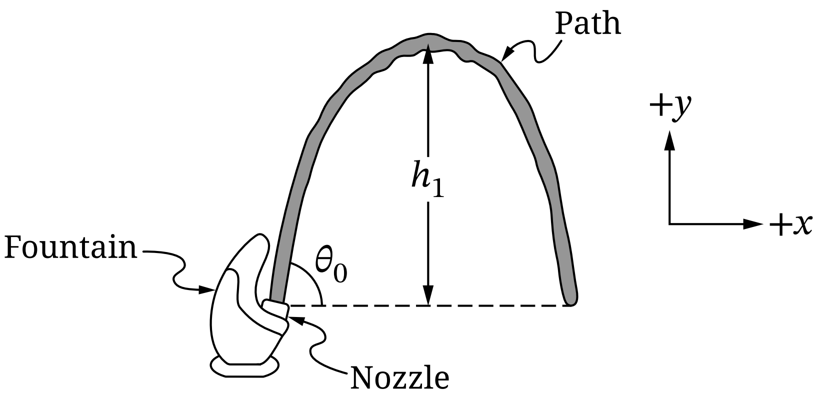
3.3 (a) $v_2 = \dfrac{0.010 \times 2.0}{0.0040} = 5.0\ \text{m s}^{-1}$. (b) the pressure drops, since the fluid moves faster there (Bernoulli).

Question 1: Version J

1. Water exits the nozzle of a fountain at an angle θ_0 above the horizontal.

At time $t = 0$, a droplet of water exits the nozzle and follows the path shown in Figure 1. The droplet reaches a maximum height h_1 above the nozzle.

Figure 1



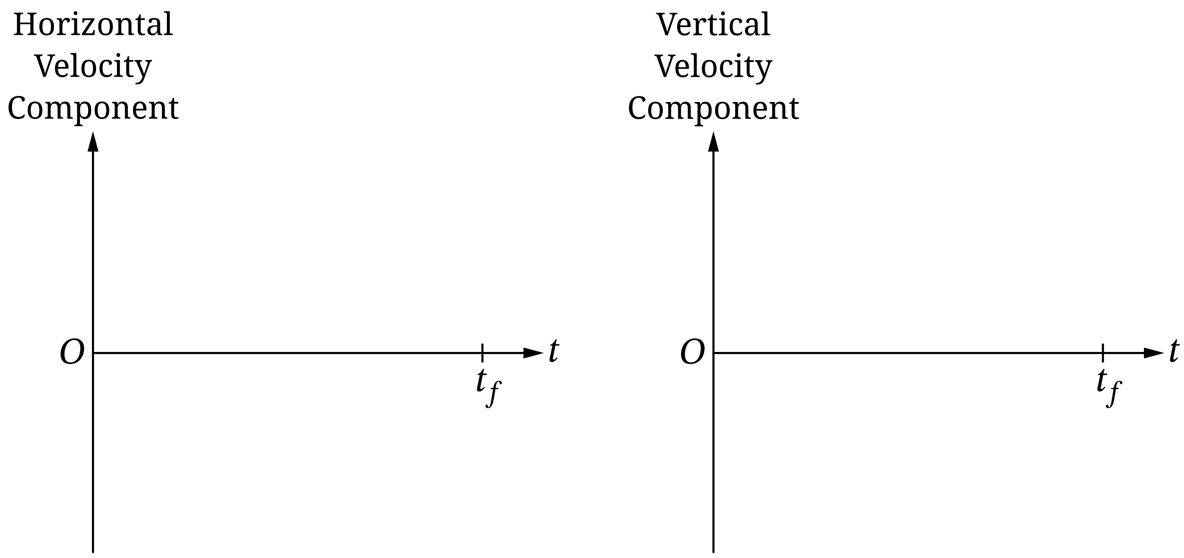
Note: Figure not drawn to scale.

At $t = t_f$, the droplet returns to the same height at which the droplet exited the nozzle.

Part A

i. On the axes shown in Figure 2, **sketch** graphs of the horizontal and vertical components of the velocity of the water droplet as functions of t from $t = 0$ to $t = t_f$.

Figure 2



ii. **Derive** an expression for the speed of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

iii. The nozzle has a circular cross-section with radius r_0. **Derive** an expression for the volume flow rate of the water exiting the nozzle. Express your final answer in terms of θ_0, h_1, r_0, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

Part B

The fountain nozzle is replaced with a new nozzle with a radius smaller than r_0. The water exits the new nozzle at the same angle θ_0 above the horizontal. The volume flow rate of the water exiting the new nozzle is equal to the volume flow rate of the water exiting the original nozzle. A water droplet exiting the new nozzle reaches a maximum height h_2 above the nozzle.

Indicate whether h_2 is greater than, less than, or equal to h_1 by writing one of the following.

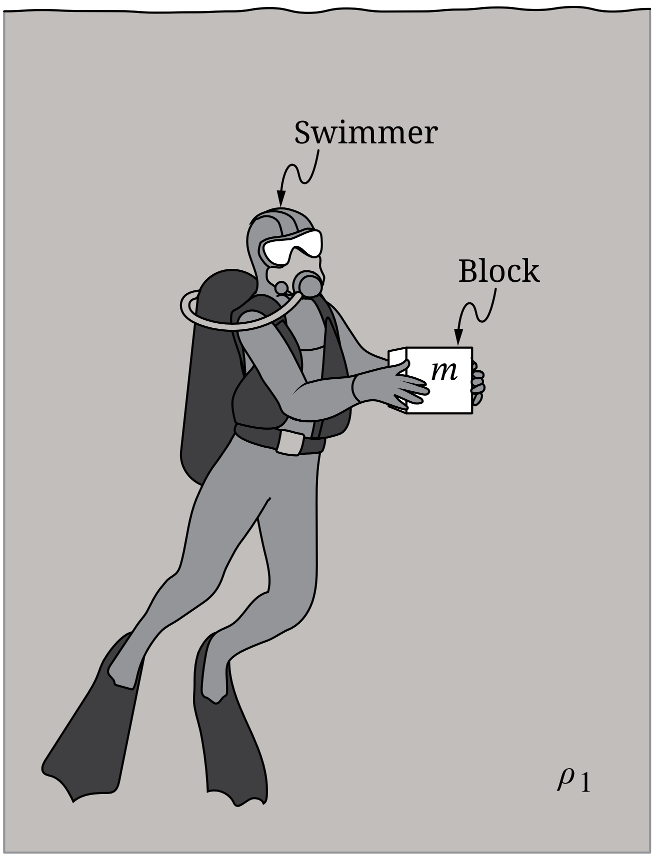
- $h_2 > h_1$
- $h_2 < h_1$
- $h_2 = h_1$

Justify your answer. In your justification, include qualitative reasoning beyond mathematical derivations or expressions.

Question 4

4. In Scenario 1, a swimmer holds a block of mass m at rest in a tank of freshwater with density ρ_1, as shown in Figure 1. The block is released from rest and accelerates upward with an initial acceleration a_1. All frictional forces are negligible.

Figure 1



In Scenario 2, the swimmer holds the same block at rest in a tank of salt water with density ρ_2, where $\rho_2 > \rho_1$. The swimmer again releases the block from rest, and the block accelerates upward with initial acceleration a_2. All frictional forces are negligible.

A. **Indicate** whether a_1 is greater than, less than, or equal to a_2 by writing one of the following in your answer booklet.

- $a_1 > a_2$
- $a_1 < a_2$
- $a_1 = a_2$

Justify your answer in terms of ALL forces exerted on the block in each scenario. Use qualitative reasoning beyond referencing equations.

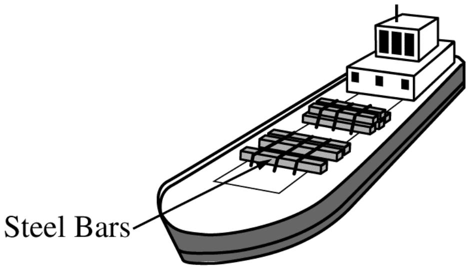
B. Consider the general case where a block of mass m and volume V is completely submerged in a fluid of density ρ.

Starting with Newton's second law, **derive** an expression for the initial upward acceleration a of the block when the block is released from rest. Express your answer in terms of m, V, ρ, and physical constants, as appropriate. Begin your derivation by writing a fundamental physics principle or an equation from the reference information.

C. **Indicate** whether the expression for the acceleration a you derived in part B is or is not consistent with the claim made in part A. Briefly **justify** your answer by referencing your derivation in part B.

STOP

END OF EXAM



4. (10 points, suggested time 20 minutes)

A large boat like the one shown above has a mass M_b and can displace a maximum volume V_b. The boat is floating in a river with water of density ρ_{water} and is being loaded with steel beams each of density ρ_{steel} and volume V_{steel}. The boat owners want to be able to carry as many beams as possible.

(a) Derive an expression for the maximum number N of steel beams that can be loaded on the boat without exceeding the maximum displaced volume, in terms of the given quantities and physical constants, as appropriate.

(b) The captain realizes that oil is leaking from the boat, creating a thin film of oil on the water surface. In one area of the oil film the surface looks mostly green. Explain in detail how constructive interference contributes to the green appearance. Assume the index of refraction of the oil is greater than the index of refraction of the water.

(c) Later the boat is floating down the river with the water current, heading for a town. The river has a width of 60 m and a constant depth and flows at a speed of $5\ \mathrm{km/hr}$. Partway to the town, the river narrows to a width of 30 m while its depth remains the same. Calculate the speed of the water in the narrow section.

STOP

END OF EXAM