

Pressure in Fluids

Mark Scheme



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1. Pressure in fluids explores how liquids and gases exert forces at right angles to surfaces, and how this pressure changes with depth, density, and altitude.

- a) A cylindrical barrel contains a chemical liquid with a mass of 45 kg.
The area of the base of the barrel is 0.15 m^2 . Gravitational field strength (g) = 9.8 N/kg

What is the pressure exerted by the liquid on the base of the barrel?

B – is the only correct answer.	1 mark
	Total: 1 mark

- b) The diagrams show three different containers, A, B, and C.

Which statement about the water pressure acting on the inside base of the containers is correct?

D – is the only correct answer.	1 mark
	Total: 1 mark

- c) A diver is swimming in the ocean at a depth of 15 m.

What is the fluid pressure acting on the diver?

C – is the only correct answer.	1 mark
	Total: 1 mark

- d) An object is at a depth h below the surface of a liquid.

The gravitational field strength is g . What is the density (ρ) of the liquid?

D – is the only correct answer.	1 mark
	Total: 1 mark

- e) The density of liquid gallium is 6100 kg/m^3 . Gravitational field strength (g) = 9.8 N/kg .

What is the pressure at the bottom of a column of liquid gallium that has a height of 85.0 cm ?

B – is the only correct answer.	1 mark
	Total: 1 mark

(Total for Question 1 is 5 marks)

2. For each of the scenarios below, use the equation $p = h \times \rho \times g$ to calculate the missing value.
Gravitational field strength (g) = 9.8 N/kg.

- a) A swimming pool is filled with water. The water has a density of 1000 kg/m³.

Calculate the pressure at a depth of 2.5 m.

Pressure = height $\times$ density $\times$ gravity	1 mark
$P = 2.5 \times 1000 \times 9.8$ $P = 24,500$	1 mark
Unit: Pa (or N/m²)	1 mark
	Total: 3 marks

- b) A deep vat of cooking oil has a density of 920 kg/m³.

Calculate the pressure at the bottom of the vat, which has a depth of 1.8 m.

Pressure = height $\times$ density $\times$ gravity	1 mark
$P = 1.8 \times 920 \times 9.8$ $P = 16,228.8$	1 mark
Unit: Pa (or N/m²)	1 mark
	Total: 3 marks

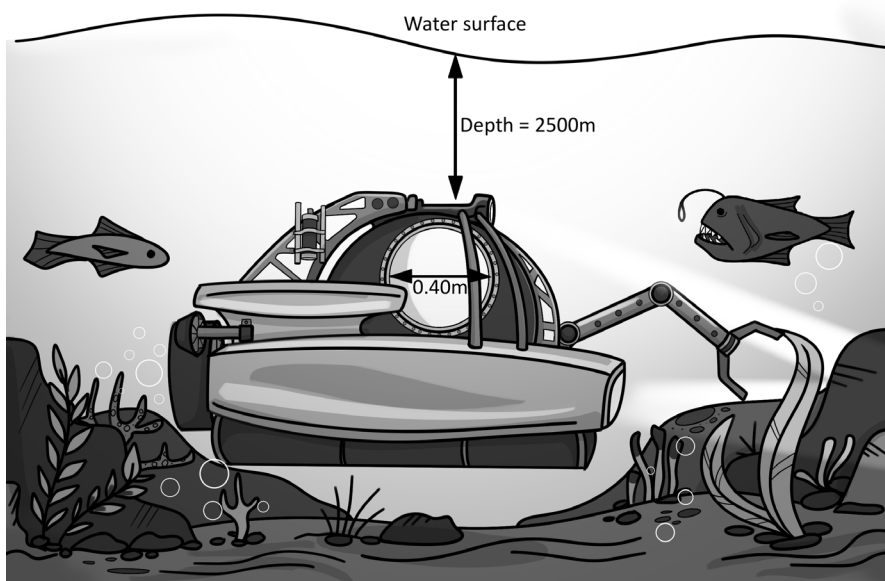
- c) A submarine dives into the ocean. The density of the seawater is 1030 kg/m³.
At its cruising depth, the submarine experiences a fluid pressure of 454,230 Pa.

Calculate the depth of the submarine.

height = pressure $\div$ (density $\times$ gravity)	1 mark
$h = 454,230 \div (1030 \times 9.8)$ $h = 45$	1 mark
Unit: m	1 mark
	Total: 3 marks

(Total for Question 2 is 9 marks)

3. A team of marine biologists is using a deep-sea submarine to explore the ocean floor at a depth of 2500 m. The figure below shows the submarine.



- a) State the equation that links pressure (p), force (F), and area (A).

pressure = force $\div$ area	1 mark
	Total: 1 mark

- b) The submersible has a flat, circular observation window with a diameter of 0.40 m. Calculate the **force** exerted by the water on the outside of the observation window.

- The density of the seawater is 1030 kg/m^3 .
- Gravitational field strength (g) = 9.8 N/kg .

You must show all of your working.

Calculate the area of the window: Radius = $0.40 \div 2 = 0.20 \text{ m}$ Area = $\pi \times r^2$ Area = $\pi \times 0.20^2$ Area = 0.1257 m^2	1 mark
Calculate the fluid pressure: $p = h \times \rho \times g$ $p = 2500 \times 1030 \times 9.8$ Pressure = $25,235,000 \text{ Pa}$	1 mark
Calculate the force: $F = p \times A$ $F = 25,235,000 \times 0.1257$ Force = $3,172,040 \text{ (N)}$	1 mark
	Total: 6 marks

- c) The walls of the submarine are made of thick titanium, but the observation window is made of glass. Explain, in terms of particles, why the water exerts a massive pressure on the window.

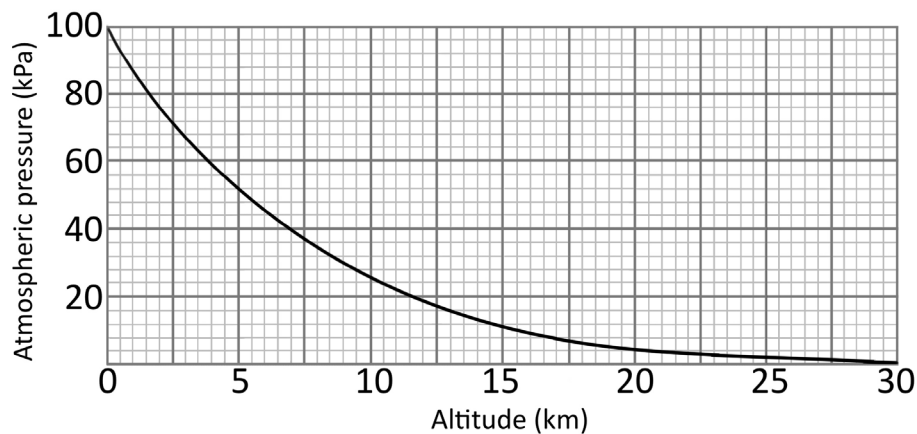
An explanation to include the following:	
Water particles are constantly moving and colliding with the surface of the window.	1 mark
Allow 1 mark for stating that particles collide with the window/surface.	
Each collision exerts a small force. Because there are many collisions per second this creates a large total force over the area of the window.	1 mark
Allow 1 mark for linking these collisions to creating a force over an area	
	Total: 2 marks

- d) The observation window on the submersible is perfectly flat and vertical. However, the main body of the submersible is built as a perfect sphere. Explain why a spherical shape is best for withstanding the fluid pressure at a depth of 2500 m.

An explanation to include the following:	
Pressure in a fluid acts equally in all directions.	1 mark
Allow 1 mark for stating that pressure in a fluid acts in all directions.	
The pressure exerts a force at exactly right angles (normal) to any surface it touches.	1 mark
Allow 1 mark for stating that the force acts at right angles / normal to the surface.	
A spherical shape distributes these inward forces evenly across the entire structure, preventing weak points or corners from crushing/imploding.	1 mark
Allow 1 mark for explaining that a sphere distributes this force evenly / prevents stress concentrations at corners.	
	Total: 3 marks

(Total for Question 3 is 12 marks)

4. The graph below shows how atmospheric pressure changes as altitude increases.



- a) State the atmospheric pressure at sea level.

100 kPa	1 mark
	Total: 1 mark

- b) A student looks at the graph and states:

"Atmospheric pressure decreases linearly as altitude increases."

State why the student is incorrect.

A statement that mentions that the graph is a curve or not a straight line.	1 mark
	Total: 1 mark

- c) Explain, in terms of particles and density, exactly why the atmospheric pressure drops so rapidly as altitude increases.

An explanation to include the following:	
As altitude increases, the atmosphere becomes less dense / there are fewer air particles in a given volume.	1 mark
Allow 1 mark for stating the atmosphere becomes less dense / fewer particles at high altitudes.	
This means there are fewer air particles resting above a given point to create weight.	1 mark
Allow 1 mark for linking less density to less weight pressing down.	
Furthermore, fewer particles mean there are fewer collisions with surfaces, resulting in a lower pressure.	1 mark
Allow 1 mark for linking fewer particles to fewer collisions.	
	Total: 3 marks

(Total for Question 4 is 5 marks)

5. A mechanic uses a hydraulic lift to raise a car. The hydraulic system contains oil.

The mechanic pushes down on Piston X with an input force of 450 N.

The figure below shows the hydraulic system.

- a) Calculate the pressure exerted on the oil by Piston X.

pressure = force ÷ area	1 mark
pressure = $450 \div 0.015$	1 mark
pressure = 30,000	1 mark
Unit: Pa or N/m²	1 mark
	Total: 4 marks

- b) State the pressure of the oil acting upwards on Piston Y.

30,000 Pa or N/m²	1 mark
	Total: 1 mark

- c) Calculate the maximum upward force that Piston Y can exert on the car.

$F = p \times A$	1 mark
$F = 30,000 \times 0.60$	1 mark
Force = 18,000 (N)	1 mark
	Total: 3 marks

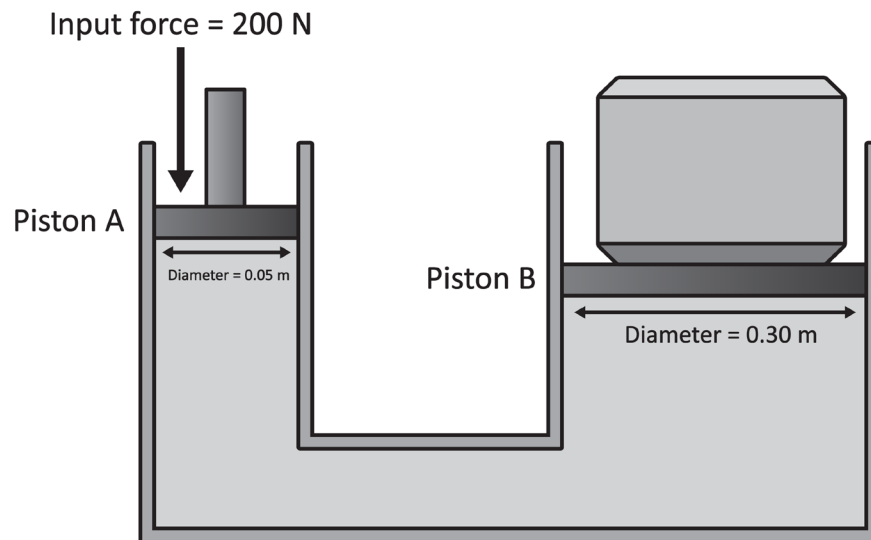
- d) The actual mass of the car is 1200 kg. Gravitational field strength (g) = 9.8 N/kg.
Will the mechanic's input force of 450 N be enough to lift the car?

You **must** show a calculation to justify your answer

Calculate weight of car: $W = m \times g$ $W = 1200 \times 9.8$ $W = 11,760 \text{ N}$	1 mark
Compare and conclude: The upward force from the piston (18,000 N) is greater than the weight of the car (11,760 N). <u>Yes</u> , the mechanic can lift it.	1 mark
	Total: 2 marks

(Total for Question 5 is 10 marks)

6. A factory uses a hydraulic press to lift heavy metal blocks. The figure below shows the press.



The hydraulic system uses two circular pistons, **A** and **B**.

- Piston A has a **diameter** of 0.05 m.
- Piston B has a **diameter** of 0.30 m.

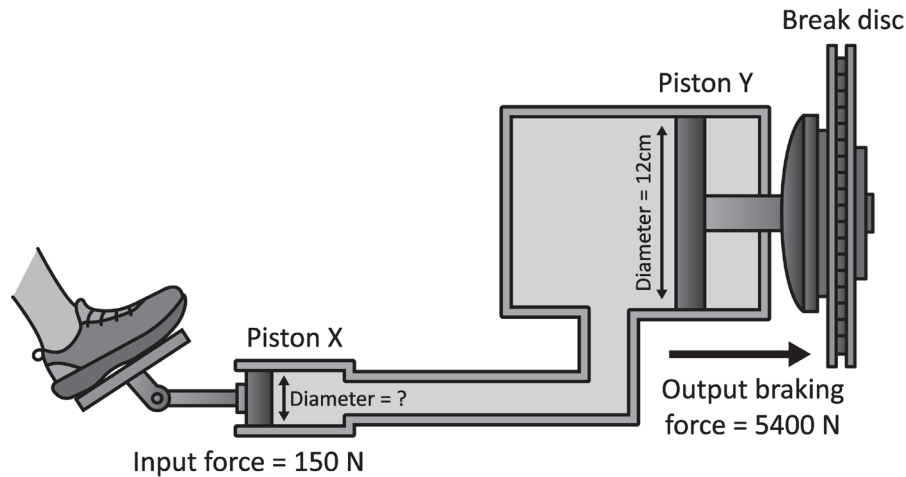
A motor applies a downward input force of 200 N on Piston A.

Calculate the force that Piston B can exert on the metal block.

Calculate the area of piston: Radius = $0.05 \div 2 = 0.025 \text{ m}$ Area = $\pi \times r^2$ Area = $\pi \times 0.025^2$ Area = 0.00196 m^2	1 mark
Calculate the pressure in the liquid: pressure = $200 \div 0.00196$ pressure = 101,859 Pa	1 mark
Calculate the area of piston B: Radius = $0.30 \div 2 = 0.15 \text{ m}$ Area = $\pi \times 0.15^2 = 0.07068 \text{ m}^2$	1 mark
Calculate output force on piston B: $F = P \times A$ $F = 101,859 \times 0.07068$ Force = 7200 N	1 mark
Total: 4 marks	

(Total for Question 6 is 6 marks)

7. A car uses a hydraulic brake system to multiply the force applied by the driver's foot.



- The driver presses the brake pedal, applying an input force of 150 N to the master cylinder.
- This must produce an output braking force of 5400 N at the slave cylinder.
- The slave cylinder has a diameter of 12 cm.

Calculate the **diameter** of the master cylinder to achieve this braking force.

Calculate area of slave cylinder: Radius = $12 \div 2 = 6 \text{ cm}$ Area = $\pi \times 6^2$ Area = 113.1 cm^2	1 mark
Calculate the fluid pressure: pressure = $5400 \div 113.1$ pressure = $47.75 \text{ (N/cm}^2\text{)}$	1 mark
Calculate required area of master cylinder: area = force $\div$ pressure Area = $150 \div 47.75$ Area = 3.14 cm²	1 mark
Work backwards to find the radius: Area = $\pi \times r^2$ $3.14 = \pi \times r^2$ $r^2 = 3.14 \div \pi = 1$ $r = 1 \text{ cm}$	1 mark
Diameter = $1 \times 2 = 2 \text{ cm}$	1 mark
	Total: 6 marks

(Total for Question 7 is 6 marks)