Edexcel GCSE Physics

Your notes

Pressure & Pressure Differences in Fluids

Contents

Pressure in Fluids

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Pressure in a Fluid

- A **fluid** is either a **liquid** or a **gas**
- When an object on the Earth's surface is immersed in a liquid, the liquid exerts a pressure upon the object
  - This pressure is in addition to the pressure already exerted by the atmosphere
- For example, an object at sea level (on the surface of the sea) experiences a pressure of 101 kPa due to the atmosphere
- If this object is now immersed to a depth of 10 metres underwater, it experiences an extra pressure of 100 kPa due to the water
- This means that the object will experience a total pressure of

101 kPa + 100 kPa = 201 kPa

- This fluid pressure arises due to both:
  - The water (liquid) pressure
  - Atmospheric (gas) pressure

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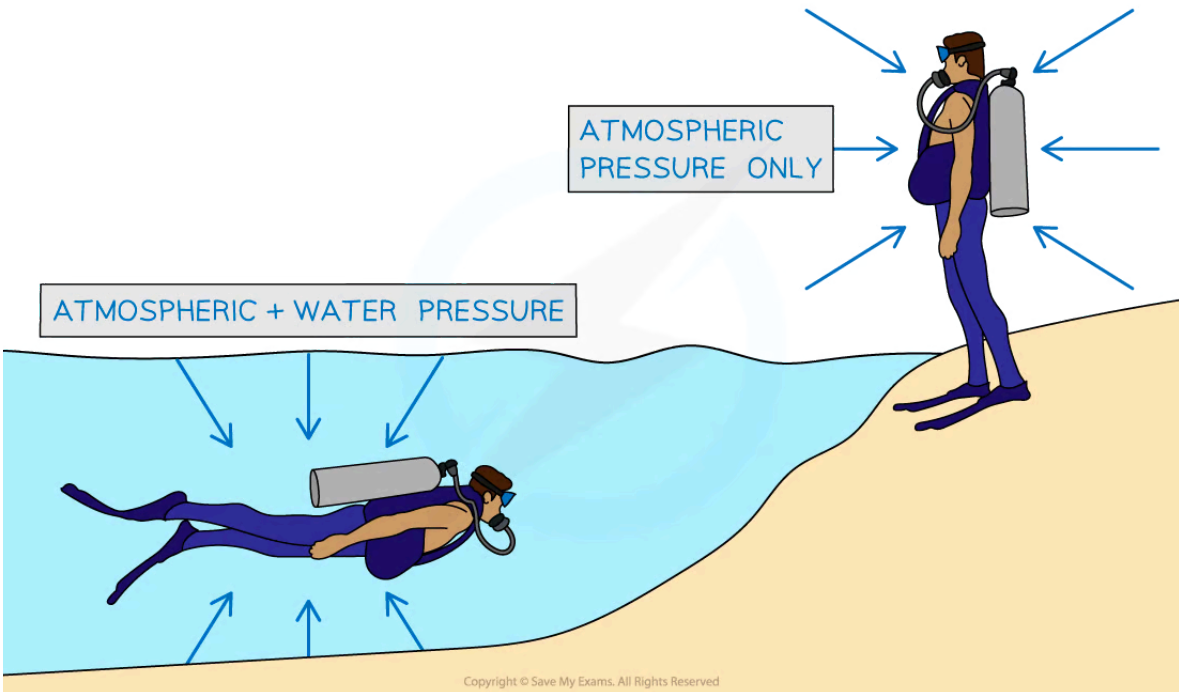

When an object is immersed in a liquid, it experiences pressure due to both the liquid and the atmosphere

The Force Exerted by a Fluid

- When an object is immersed in a fluid, the fluid will exert pressure, squeezing the object
  - This pressure is exerted evenly across the whole surface of the fluid and in **all directions**
  - The pressure exerted on objects in fluids creates **forces** against surfaces
  - These forces act at **90 degrees** (at right angles or 'normal') to the surface

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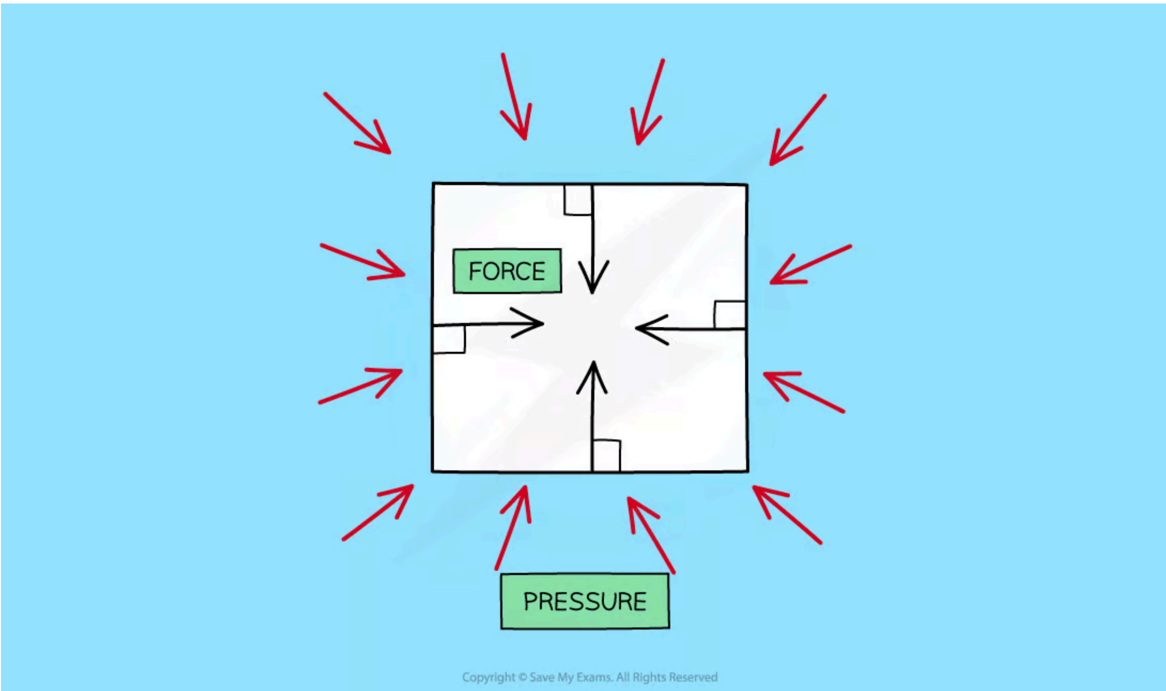

The pressure of a fluid on an object creates a force normal (at right angles) to the surface

Atmospheric Pressure

- The Earth's atmosphere is a thin layer (relative to the size of the Earth) of air around it
  - It exerts a pressure of about 101 kPa at sea level

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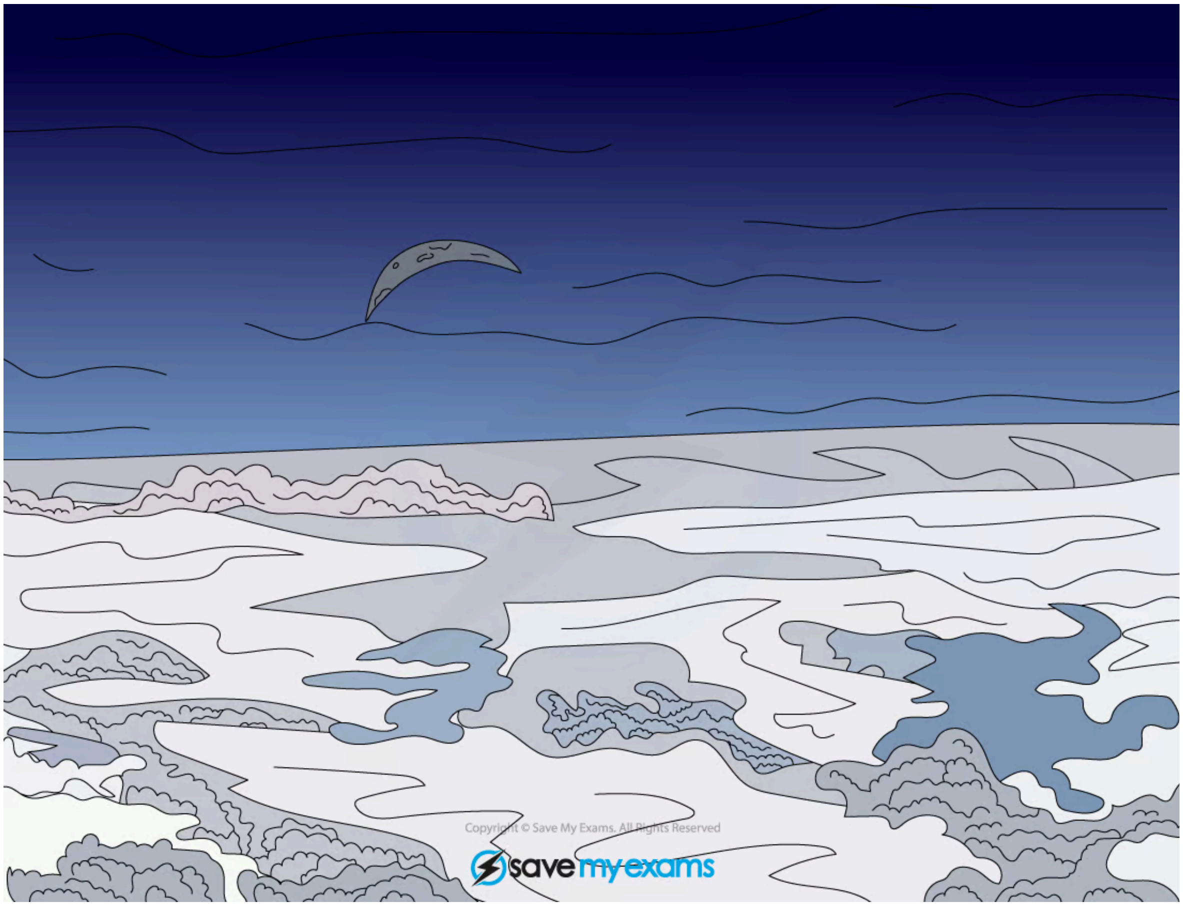

The Earth's atmosphere

- The atmosphere extends more than 100 km into space and becomes **less** dense with **increasing** altitude (height above sea level)
  - This means that the **pressure** becomes less too
- Atmospheric pressure various slightly from day to day, depending on the weather, and fine clear weather is usually associated with high pressure
- The graph below shows how the pressure varies with altitude:

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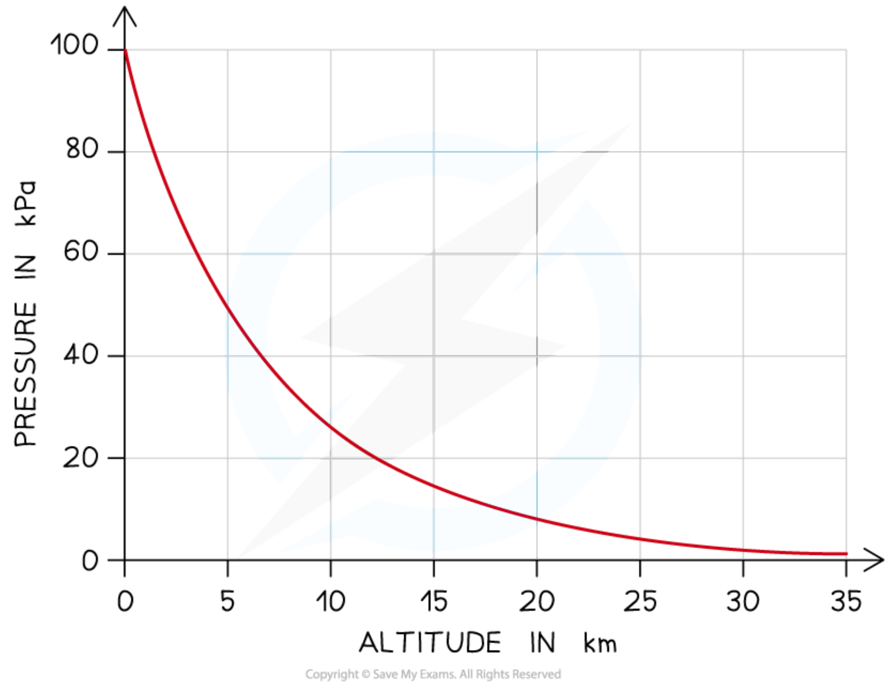

Graph of atmospheric pressure against altitude

- Atmospheric pressure varies with height above a surface, for example, at sea level
- This is due to **air molecules** colliding with a surface creating **atmospheric pressure**
  - These molecules create a **force** per area of the surface which creates the pressure
- The number of air molecules (and so the weight of air) above a surface **decreases** as the **height** of the surface above ground level **increases**
  - This is also known as the **density** of the air
- Therefore, as height increases, there is always **less** air above a surface than there is at a lower height and the atmospheric pressure **decreases** with an increase in height

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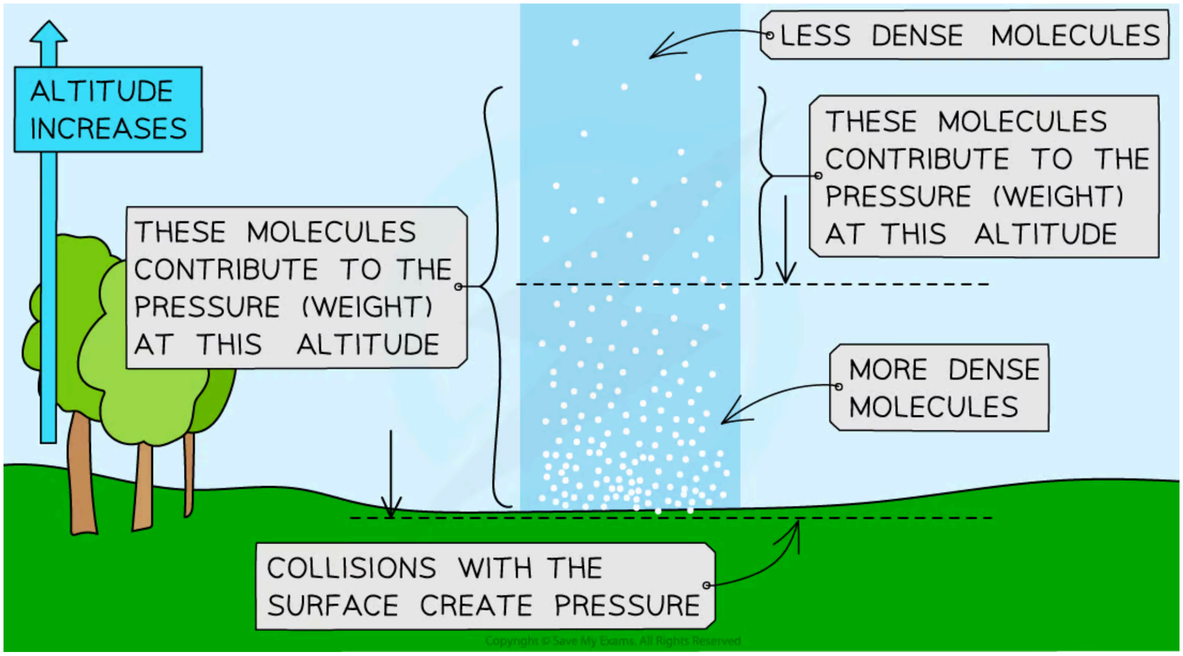

Atmospheric pressure decreases as the density of the molecules decreases

Pressure & Forces

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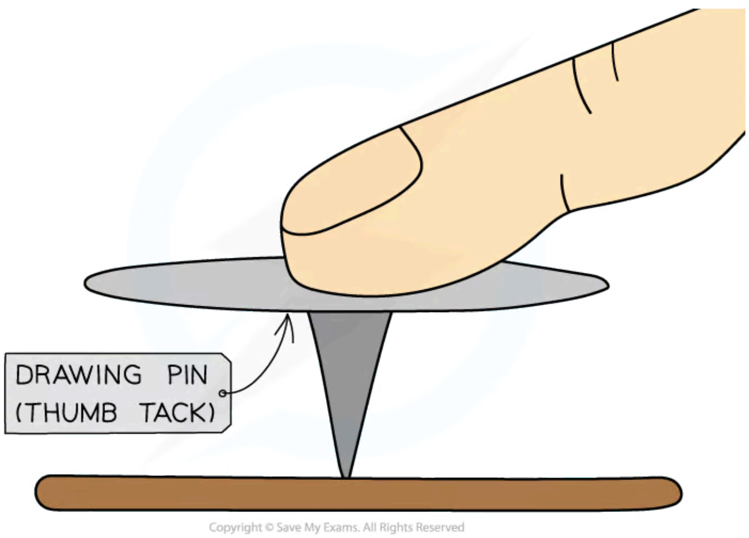
Force & Area

- **Pressure** is defined as

  The concentration of a force or the force per unit area

- For example, when a drawing pin is pushed downwards:
  - It is pushed into the surface, rather than up towards the finger
  - This is because the sharp point is more **concentrated** (a small area) creating a **larger** pressure



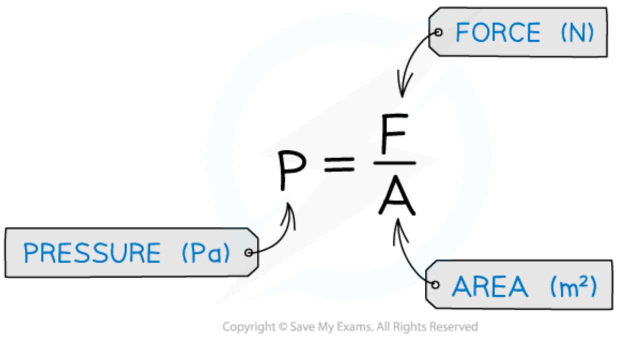
When you push a drawing pin, it goes into the surface (rather than your finger)

- **Example 1:** Tractors
  - Tractors have **large tyres**
  - This spreads the weight (force) of the tractor over a large area
  - This reduces the pressure which prevents the heavy tractor from sinking into the mud
- **Example 2:** Nails
  - Nails have **sharp pointed ends** with a very small area
  - This concentrates the force, creating a large pressure over a small area

- This allows the nail to be hammered into a wall

Calculating Pressure

- The pressure at the surface of a fluid can be calculated using the equation:



- Pressure is measured in the units **Pascals (Pa)**
- The area should always be the **cross-sectional area** of the object
  - This means the area where the force is at right angles to it
- This equation can be rearranged with the help of a formula triangle:

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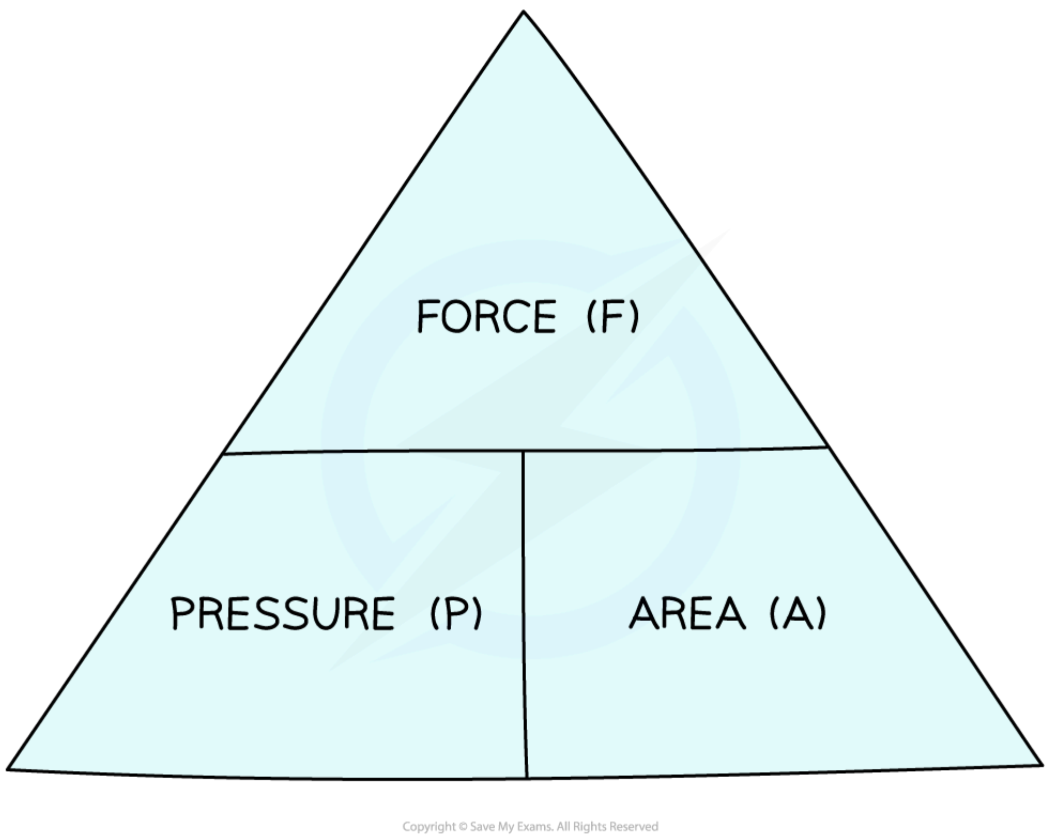

Force, pressure, area formula triangle

- This equation tells us that:
  - If a force is spread over a **large** area it will result in a **small** pressure
  - If it is spread over a **small** area it will result in a **large** pressure

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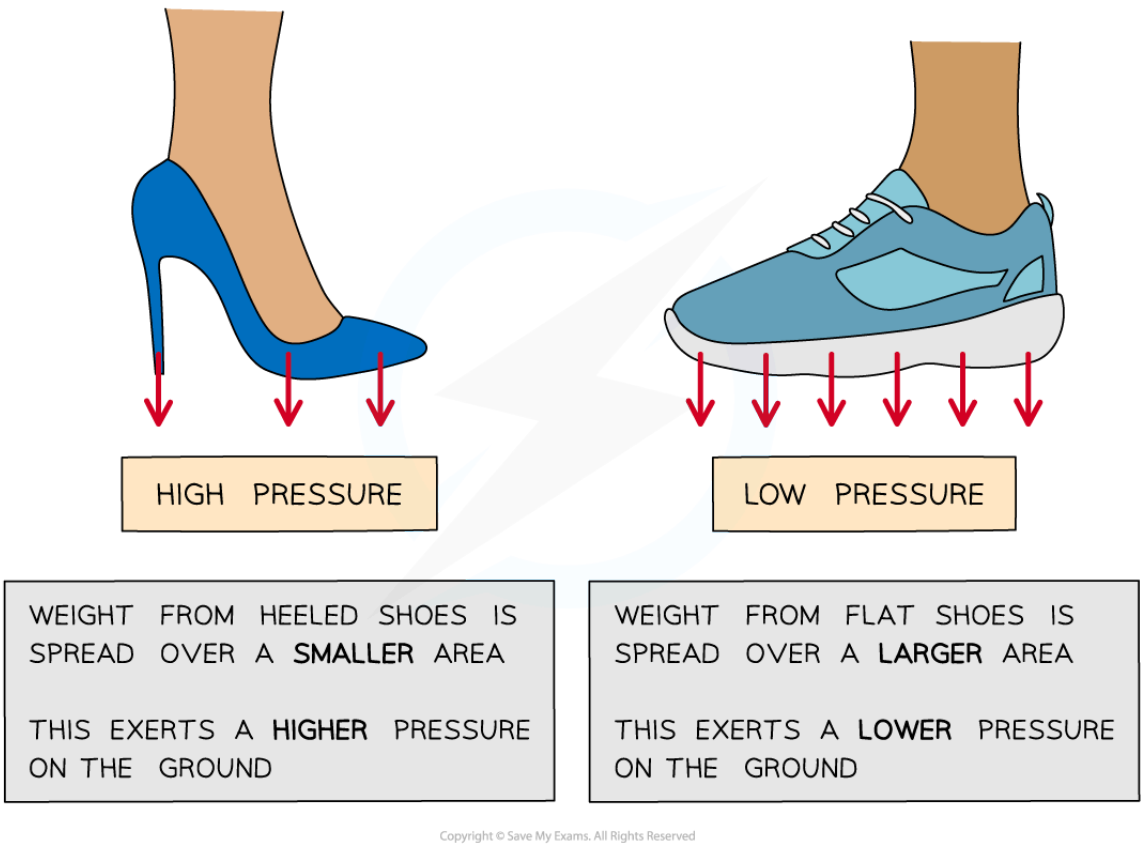

High heels produce a higher pressure on the ground because of their smaller area, compared to flat shoes

Worked Example

The diagram below shows the parts of the lifting machine used to move the platform up and down.

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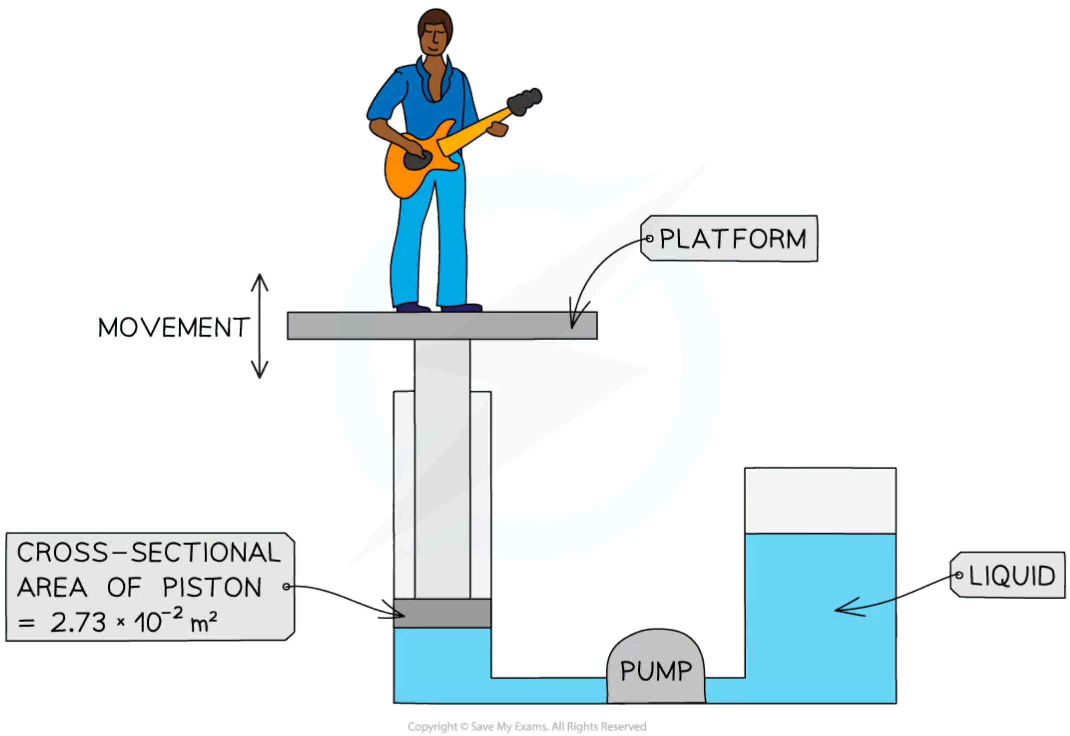

The pump creates pressure in the liquid of 5.28×10^5 Pa to move the platform upwards. Calculate the force that the liquid applies to the piston.

Answer:

Step 1: List the known quantities

- Cross-sectional area = 2.73×10^{-2} m^2
- Pressure = 5.28×10^5 Pa

Step 2: Write down the relevant equation

$$p = \frac{F}{A}$$

Step 3: Rearrange for the force, *F*

$$F = p \times A$$

Step 4: Substitute the values into the equation

$$F = (5.28 \times 10^5) \times (2.73 \times 10^{-2}) = 14\,414.4$$

Step 5: Round to the appropriate number of significant figures and quote the correct unit

$$F = 14\,400 \text{ N} = 14.4 \text{ kN (3 s.f)}$$

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Examiner Tips and Tricks

Look out for the units for the force! **Large pressures** produce **large forces** - this is sometimes in kN! (1 kN = 1000 N)

Pressure in a Liquid

Your notes

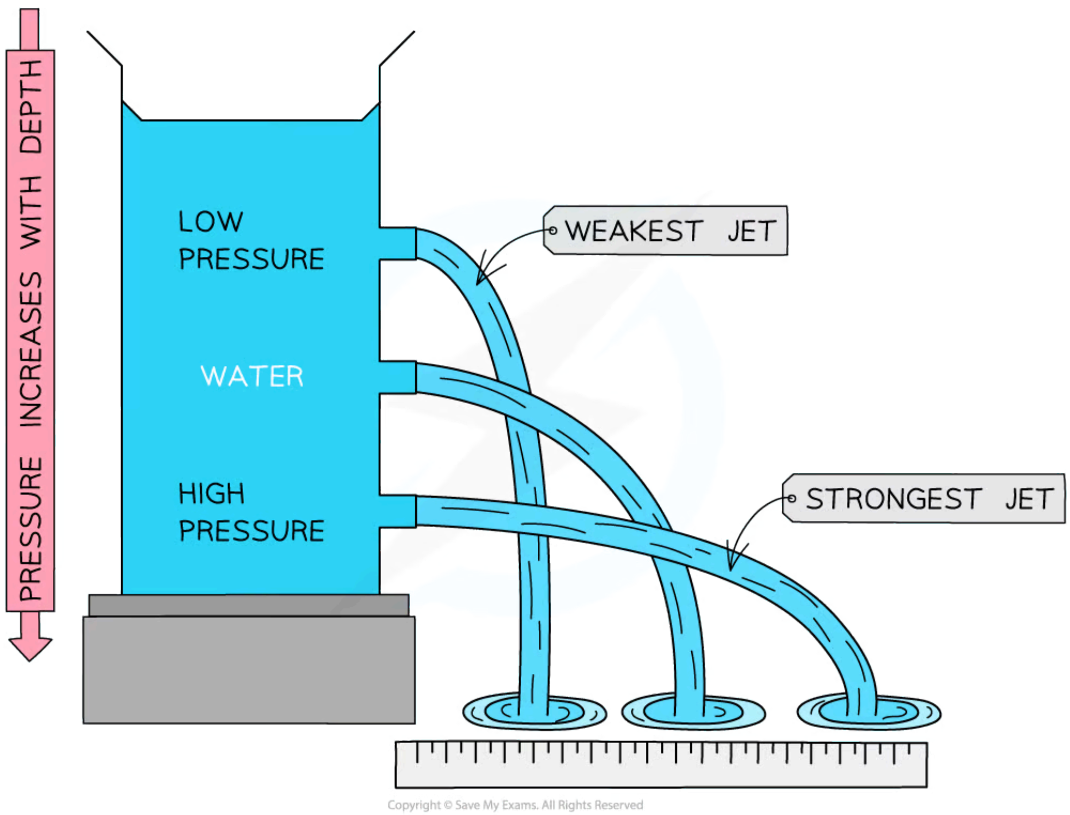
Pressure & Depth

- When an object is immersed in a liquid, the liquid will exert a pressure, squeezing the object
- This pressure is exerted evenly across the whole surface of the liquid and in all directions
  - The greater the **depth** of the liquid, the greater the pressure
  - The greater the **density** of the liquid, the greater the pressure

Understanding Pressure

Higher Tier Only

- In a liquid, the pressure at a point **increases** with the **height** of the column of liquid about that point
  - If there is more liquid above that point, then the pressure is more
- This is because the pressure in a liquid is caused by the **weight** of the liquid pushing against objects immersed in the liquid
  - As the liquid becomes deeper, the amount of liquid (and hence the weight) increases which causes the pressure to increase
- This is why, for example, the pressure increases with the depth of the ocean
  - The pressure on the seabed is far higher than that on the surface of the ocean
- The weight of the liquid also depends on its **density**
  - A more dense liquid has a greater weight and therefore will exert a **higher** pressure



Pressure in a column of water increases with depth, shown by the strong and weak jet of water

- In a column of water, the **highest pressure** would be at the **bottom**
  - If a hole is made at the bottom of the column, the water will pour out with a **large** force
  - If a hole was made at the top of the column, the water will pour out with a **small** force
  - This is because of the **difference in pressure** in the column caused by the weight of the water

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Calculating Pressure in a Liquid

Your notes

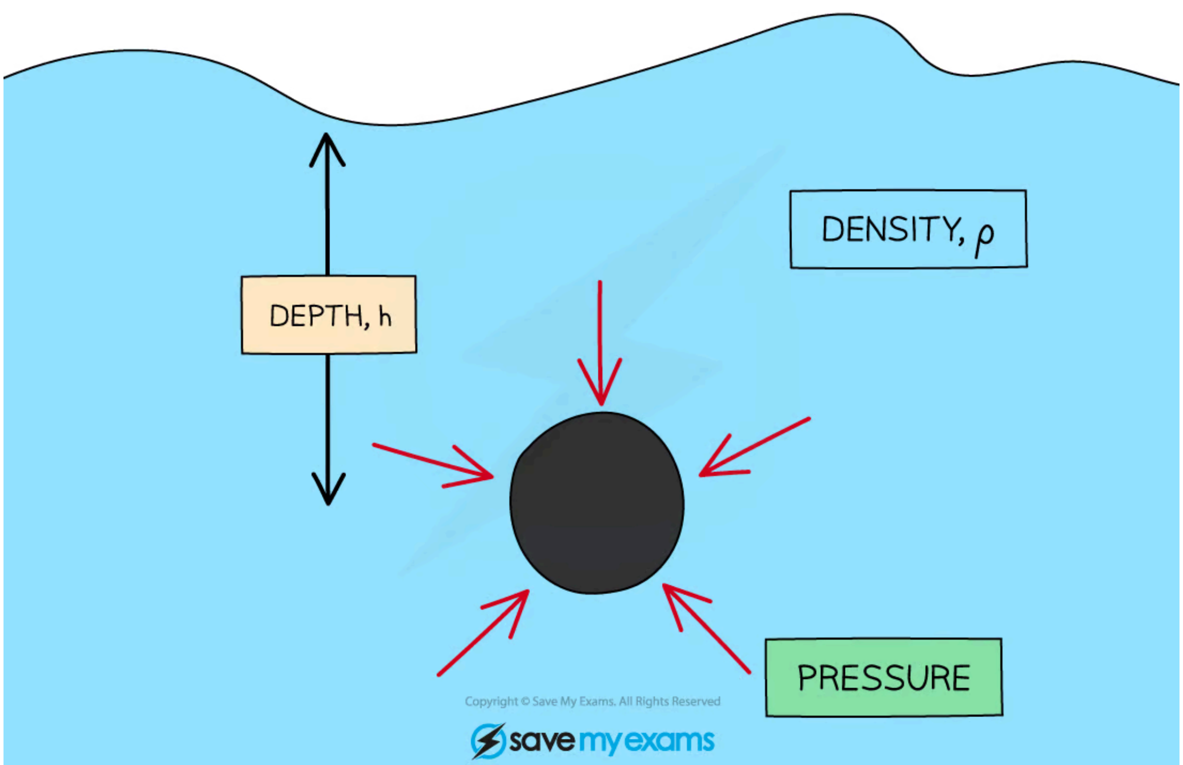
Calculating Pressure in a Liquid

Higher Tier Only

- The pressure due to a column of liquid can be calculated using the equation

$$p = h \times \rho \times g$$

- Where:
  - p = pressure in pascals (Pa)
  - h = height of the column in metres (m)
  - ρ = density of the liquid in kilograms per metre cubed (kg/m^3)
  - g = gravitational field strength on Earth in newtons per kilogram (N/kg)
- The force from the pressure is exerted evenly across the whole surface of an object in a liquid, and in **all** directions



The force from the pressure of objects in a liquid is exerted evenly across its whole surface

- The pressure is more accurately the **difference** in pressure at different depths *h* in a liquid, since the pressure changes with the depth

Your notes

Worked Example

Calculate the depth of water in a swimming pool where a pressure of 20 kPa is exerted.

The density of water is 1000 kg/m^3 and the gravitational field strength on Earth is 9.8 N/kg.

Answer:

Step 1: List the known quantities

- Pressure, p = 20 kPa
- Density of water, ρ = 1000 kg/m^3
- Gravitational field strength, g = 9.8 N/kg

Step 2: List the relevant equation

$$p = h\rho g$$

Step 3: Rearrange for the height, *h*

$$h = \frac{p}{\rho g}$$

Step 4: Convert any units

$$20 \text{ kPa} = 20\ 000 \text{ Pa}$$

Step 4: Substitute in the values

$$h = \frac{20\ 000}{1000 \times 9.8} = 2.0408 = 2.0 \text{ m}$$

Examiner Tips and Tricks

This pressure equation will be given on your formula sheet, however, make sure you are comfortable with rearranging it for the variable required in the question!

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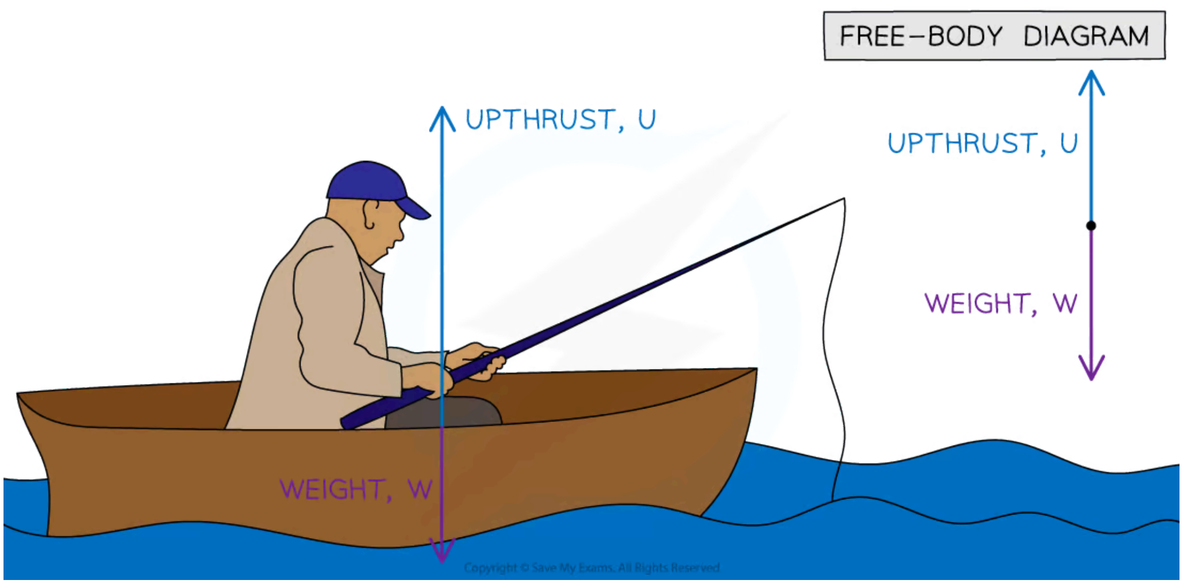
Upthrust

Your notes

Upthrust

Higher Tier Only

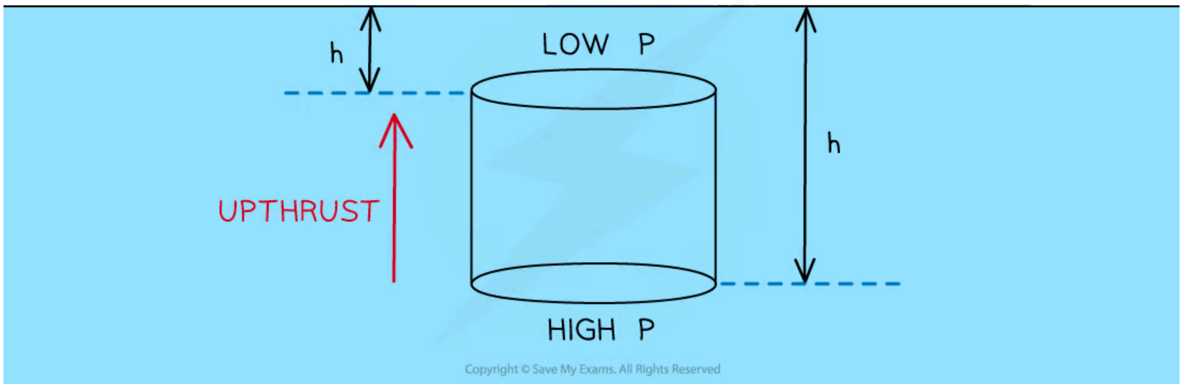
- Upthrust is a force that pushes upwards on an object submerged in a fluid i.e. liquids and gases
- It is always in the opposite direction to the object's weight
  - This is why boats, and objects that are less dense than water, float
- The size of the upthrust depends on the **density** of the fluid as well as the **volume** of fluid that is displaced (which is equal to the volume of the object)
  - The **denser** the liquid, the **greater** the upthrust it will exert on an object



Upthrust is in the opposite direction to the weight of the boat and the fisherman

- Upthrust is due to the **difference in pressure** between the top and the bottom of the submerged object
- A partially (or totally) submerged object experiences a **greater** pressure on the **bottom** surface than on the top surface
  - This is because the pressure *p* is proportional to the depth *h* of the object

- The difference in pressure creates a resultant force **upwards** (upthrust)
- Upthrust is why objects appear to weigh less when immersed in a liquid



Upthrust is due to the different pressure at the top and bottom of this cylinder

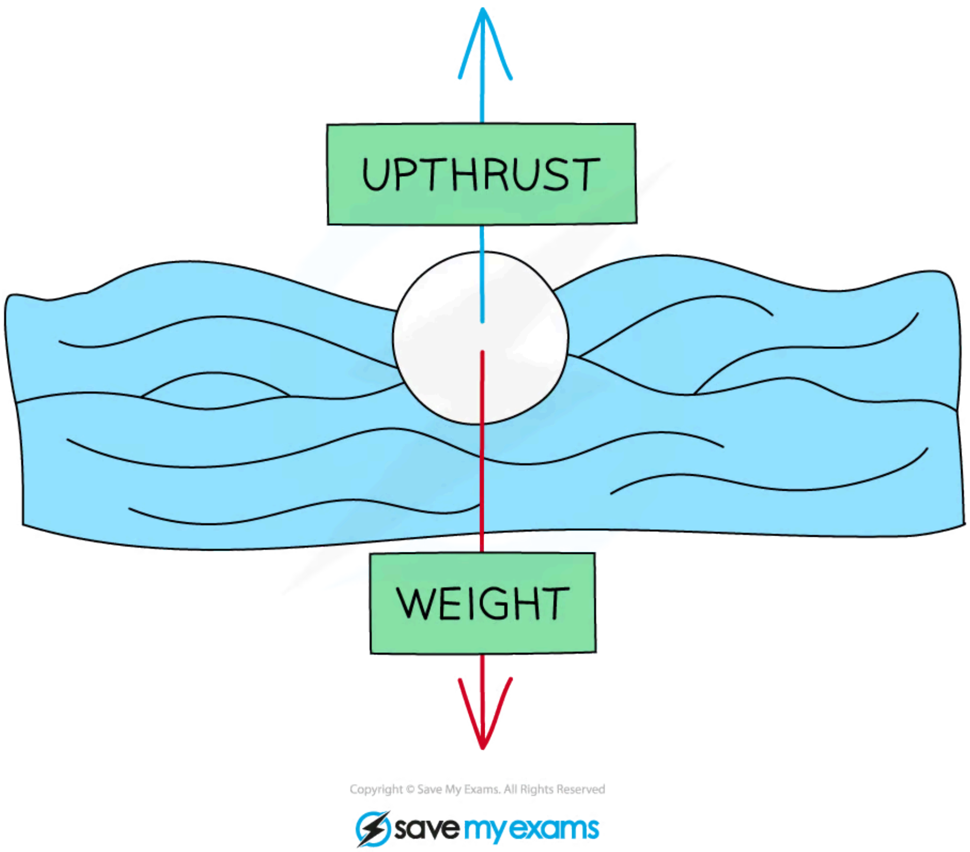
Upthrust & Displacement

Higher Tier Only

- The amount of upthrust on an object depends on the weight of the fluid that the object displaces
  - Upthrust is **equal** to the weight of fluid displaced

Your notes

Your notes



Liquids exert an upwards force (upthrust) on objects immersed in them equal to the weight of the fluid displaced

- Upthrust can be found by:
  - Calculating the volume of the object that is immersed in the fluid
  - Then using this volume to calculate the weight of the liquid that would occupy that volume

Worked Example

A cube of length 40 cm is partially submerged up to 20 cm in water.

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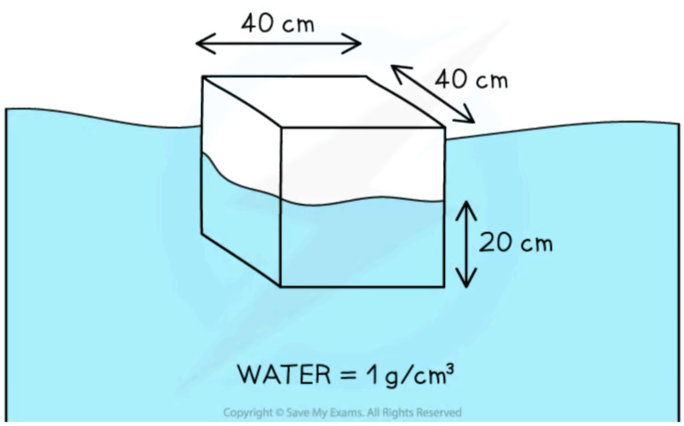


Water has a density of 1 g/cm^3. Take gravitational field strength to be 10 N/kg. Calculate the upthrust on the cube.

Answer:

Step 1: Calculate the volume of the cube submerged in the water

$$\text{Volume, } V = 40 \text{ cm} \times 40 \text{ cm} \times 20 \text{ cm} = 32\,000 \text{ cm}^3$$

Step 2: Write down the equation for density, mass and volume

$$\text{mass} = \text{density} \times \text{volume}$$

$$m = \rho V$$

Step 3: Calculate the mass of displaced water

- Since water has a density of 1 g/cm^3, the mass of displaced water will be:
$$m = 1 \text{ g/cm}^3 \times 32\,000 \text{ cm}^3 = 32\,000 \text{ g} = 32 \text{ kg}$$

Step 4: Write down the equation for weight

$$\text{Weight} = \text{mass} \times \text{gravitational field strength}$$

$$W = mg$$

Step 5: Calculate the weight of displaced water

$$W = mg = 32 \text{ kg} \times 10 \text{ N/kg} = 320 \text{ N}$$

Step 6: State the value of upthrust

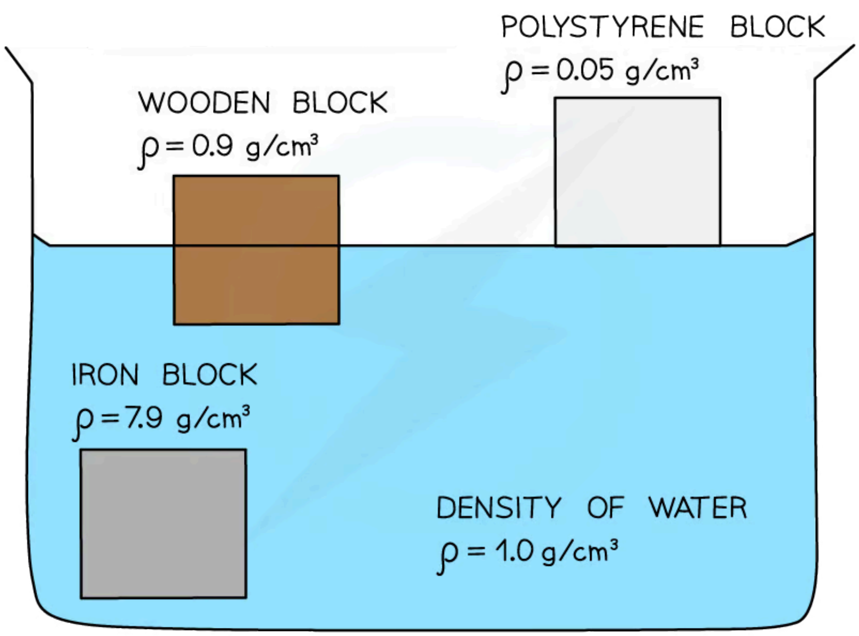
- The upthrust on an object is equal to the weight of fluid displaced

- Hence the upthrust on the object will be **320 N**

Factors Affecting Upthrust

Higher Tier Only

- Whether an object sinks or floats depends on the **upthrust**:
  - If the upthrust on an object is **equal** to (or **greater** than) the object's weight, then the object will **float**
  - If the upthrust is **smaller** than the weight then the object will sink
- The outcome also depends on the object's **density**:
  - If it has a density **less** than the density of the fluid it is immersed in, the object will **float**
  - If it has a density **more** than the density of the fluid it is immersed in, the object will **sink**
- This is because if the density of the object is greater than the density of the fluid, the object can never displace enough fluid to create an upthrust that will hold its weight up (and therefore sinks)



Objects which are less dense than water will float and which are more dense will sink

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- A polystyrene block will **float** in water
  - This is because polystyrene has a density of 0.05 g/cm^3 which is **much less** than the density of water (1.0 g/cm^3)
- A wooden block will be partially submerged but will still **float**
  - This is because the density of a wooden block (0.9 g/cm^3) is **slightly less** than the density of water
- An iron block will **sink**
  - This is because iron has a density (7.9 g/cm^3) that is **much higher** than water