



# AS Level Physics

Chapter 3 – Forces and Motions

3.6.1 Density and Pressure

Notes

## DENSITY

The density of a substance is the mass per unit volume:

$$\rho = \frac{m}{V}$$

Where:

- $\rho$  = density measured in  $\text{kgm}^{-3}$
- $m$  = mass measured in kg
- $V$  = volume measured in  $\text{m}^3$

Density has a symbol,  $\rho$  (rho).

The more mass in a given volume, the greater the density.

## DENSITY

### Example 1:

A rectangular block of steel measures 10 cm x 7.5 cm x 5 cm and has a mass of 9 kg. Calculate the density of the steel.

1) Calculate the volume of the rectangular block:

$$V = 0.1 \text{ m} \times 0.075 \text{ m} \times 0.05 \text{ m}$$

$$V = 3.75 \times 10^{-4} \text{ m}^3$$

2) We know the mass to be 9 kg so use:

$$\rho = \frac{m}{V}$$

$$\rho = \frac{9 \text{ kg}}{3.75 \times 10^{-4} \text{ m}^3}$$

$$\rho = 24000 \text{ kgm}^{-3}$$



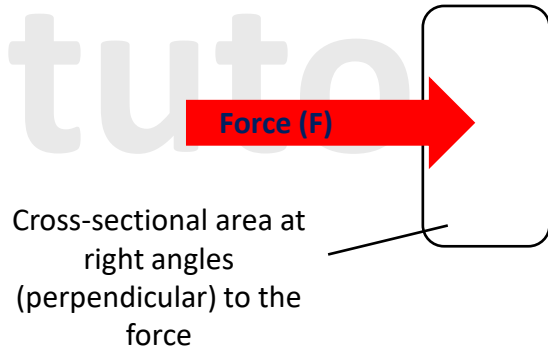
## PRESSURE

The pressure is defined as the perpendicular force per unit area.

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

Where:

- $P$  = pressure measured in Pascals (Pa)
- $F$  = perpendicular force measured in Newtons (N)
- $A$  = cross – sectional area measured in metres squared ( $m^2$ )



The unit of pressure is the Pascal (Pa).

Alternative units for pressure are *Newton per metre<sup>2</sup>*:

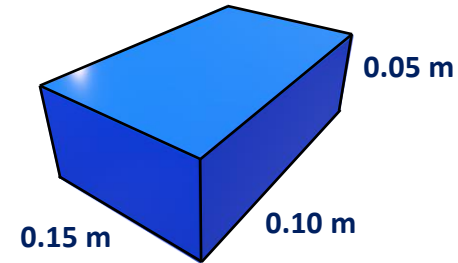
$$1 \text{ Pa} = 1 \text{ Nm}^{-2}$$

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## PRESSURE

### Example 1:

A 5 kg block has dimensions  $0.15 \text{ m} \times 0.10 \text{ m} \times 0.05 \text{ m}$ . Calculate the pressure the block exerts on the surface of a desk.



- 1) The only force that is being exerted on the surface of the desk is caused by the weight of the block. The weight force is acting perpendicularly to the desk:

$$\begin{aligned} W &= mg \\ W &= 5 \text{ kg} \times 9.81 \text{ ms}^{-2} \\ W &= 49.05 \text{ N} \end{aligned}$$

- 2) Calculate the cross-sectional area. The only area you should calculate and use is the one that is in contact with the desk. In this case its:

$$\begin{aligned} A &= 0.15 \text{ m} \times 0.10 \text{ m} \\ A &= 0.015 \text{ m}^2 \end{aligned}$$

- 3) Calculate the pressure:

$$\begin{aligned} P &= \frac{49.05 \text{ N}}{0.015 \text{ m}^2} \\ P &= 3270 \text{ Pa} \end{aligned}$$

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## ATMOSPHERIC PRESSURE

Pressure is exerted in all directions at the Earth's surface due to air. This is due to air molecules travelling in rapid random motion. When these air molecules collide with the surfaces they exert a force.

The force exerted by the atmosphere is known as the atmospheric pressure with a value of:

$$1.01 \times 10^5 \text{ Pa}$$

At higher altitudes atmospheric pressure decreases as there are fewer air molecules present and less weight is pushing them down from above.

## PRESSURE IN LIQUIDS

At the surface of a liquid the pressure is the same as atmospheric pressure.

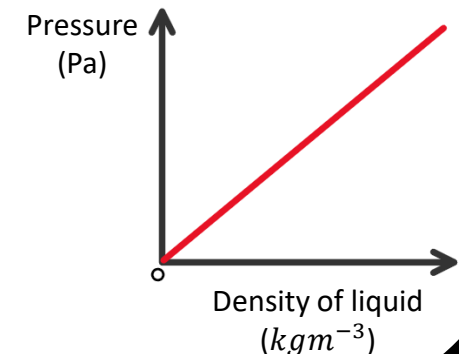
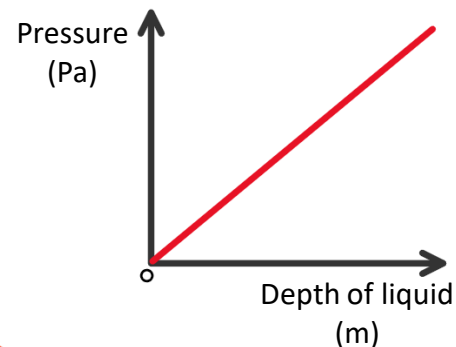
However, below the surface of a liquid, the pressure varies according to the depth and density of the liquid. This can be shown using the formula below:

$$P = h\rho g$$

Where:

- $P$  = pressure measured in Pa
- $h$  = depth measured in m
- $\rho$  = density measured in  $\text{kgm}^{-3}$
- $g$  = gravitational field strength measured in  $\text{Nkg}^{-1}$

As the depth increases. So does the pressure this is due to the weight of all the water above pushing down on the water below. The graphs below show this relationship:



## PRESSURE IN LIQUIDS

### Example 1:

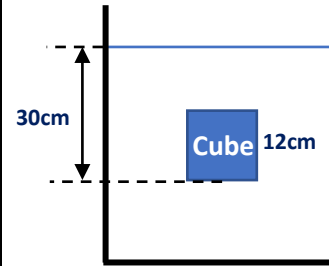
An object at 7 m is placed in a liquid with a density of  $900 \text{ kgm}^{-3}$ . Calculate the pressure due to liquid.

$$P = h\rho g$$
$$P = (7 \text{ m})(900 \text{ kgm}^{-3})(9.81 \text{ ms}^{-2})$$
$$P = 61803 \text{ Pa}$$

## PRESSURE IN LIQUIDS

### Example 2:

A cube with sides 12 cm is submerged in water to a depth of 30cm.



The density of fresh water is  $1 \times 10^3 \text{ kgm}^{-3}$

(a) Calculate the pressure at the bottom surface of the cube due to the water.

Use:  $P = h\rho g$

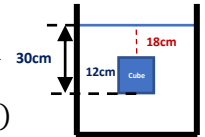
$$P = (0.3\text{m})(1 \times 10^3 \text{ kgm}^{-3})(9.81 \text{ ms}^{-2})$$
$$P = 2940 \text{ Pa}$$

(b) Calculate the pressure at the top surface of the cube due to the water.

Calculate the depth first:  $h = 30 - 12 = 18\text{cm} = 0.18\text{m}$

Use:  $P = h\rho g$

$$P = (0.18\text{m})(1 \times 10^3 \text{ kgm}^{-3})(9.81 \text{ ms}^{-2})$$
$$P = 1764 \text{ Pa}$$



(c) Calculate the force acting on the bottom surface of the cube.

Use:  $\text{Force} = \text{Pressure} \times \text{Area}$

$$\text{Force} = (2940 \text{ Pa})(0.12 \times 0.12)$$
$$\text{Force} = 42.3 \text{ N}$$

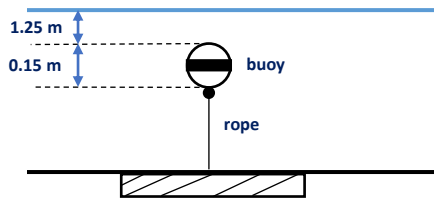
The area of a cube is length x width =  $0.12 \text{ m} \times 0.12 \text{ m}$



## PRESSURE IN LIQUIDS

### Example 3:

A mooring buoy is tethered to the bottom of a sea water loch by a vertical cable as shown:



The density of fresh water is  $1.02 \times 10^3 \text{ kgm}^{-3}$

a) Calculate the total pressure on the top of the buoy:

$$\begin{aligned} \text{Use: } P &= h\rho g \\ P &= (1.25\text{m})(1.02 \times 10^3 \text{ kgm}^{-3})(9.81 \text{ ms}^{-2}) \\ P &= \mathbf{12507.75 \text{ Pa}} \end{aligned}$$

This pressure is only due to the sea water.

To find the total pressure, we need to add the atmospheric pressure from the air above.

$$\begin{aligned} P_{\text{total}} &= 12507.75 \text{ Pa} + (1.01 \times 10^5 \text{ Pa}) \\ P_{\text{total}} &= 113507.75 \text{ Pa} \\ P_{\text{total}} &= \mathbf{1.14 \times 10^5 \text{ Pa}} \end{aligned}$$

## PRESSURE IN LIQUIDS

### Example 3:

b) Calculate the total pressure on the bottom of the buoy:

$$\begin{aligned} \text{The depth} \\ h &= 1.25\text{m} + 0.15\text{m} = 1.4\text{m} \end{aligned}$$

$$\begin{aligned} \text{Use: } P &= h\rho g \\ P &= (1.4\text{m})(1.02 \times 10^3 \text{ kgm}^{-3})(9.81 \text{ ms}^{-2}) \\ P &= \mathbf{14008.68 \text{ Pa}} \end{aligned}$$

This pressure is only due to the sea water.

To find the total pressure, we need to add the atmospheric pressure from the air above.

$$\begin{aligned} P_{\text{total}} &= 14008.68 + (1.01 \times 10^5) \\ P_{\text{total}} &= 115,008.68 \text{ Pa} \\ P_{\text{total}} &= \mathbf{1.15 \times 10^5 \text{ Pa}} \end{aligned}$$



Please see '**3.6.2 Density and Pressure Worked Examples**' pack for exam style questions.

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