Outcome 1
LESSON 1
Basic Principles

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BASIC PRINCIPLES

The ***density*** of any given substance is it's ***mass per unit volume***.

This can be expressed as:

$$\textbf{DENSITY} = \frac{\textbf{MASS}}{\textbf{VOLUME}}$$

For ship stability purposes the units commonly used are:

Mass: ***tonnes (t)***
Volume: ***cubic metres (m^3)***
Density: ***tonnes per cubic metre (t/m^3)***

Rearranging the above formula gives:

$$\textbf{VOLUME} = \frac{\textbf{MASS}}{\textbf{DENSITY}}$$

and:

$$\textbf{MASS} = \textbf{VOLUME} \times \textbf{DENSITY}$$

Density of water in which a ship typically floats

A ship is presumed to always float in water which lies in the following density range:

FRESH WATER (FW): 1.000 t/m^3 to
SALT WATER (SW): 1.025 t/m^3

Water that lies between these two extremes is termed ***DOCK WATER (DW).***

The laws governing flotation

Two laws need to be considered:

- * *Archimedes' principle;*
- * *The law of flotation.*

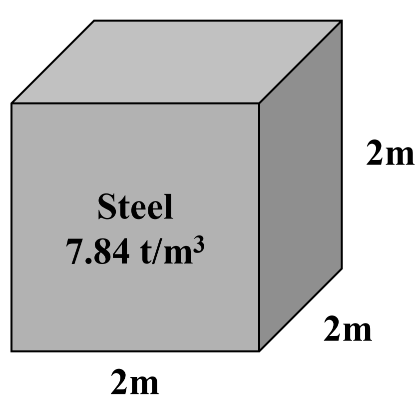
1. **Archimede's principle**

States that when a body is wholly or partially immersed in a liquid, it experiences an upthrust (apparent loss of mass - termed Buoyancy force (Bf)) equal to the mass of liquid displaced.

Consider a block of steel measuring 2m × 2m × 2m that has a density of 7.84 t/m^3.

SAQ

If this block was to be suspended by a ship's crane that has a very accurate load gauge, what load (mass) would register on the gauge if the block was suspended over the ship's side in air?



Answer

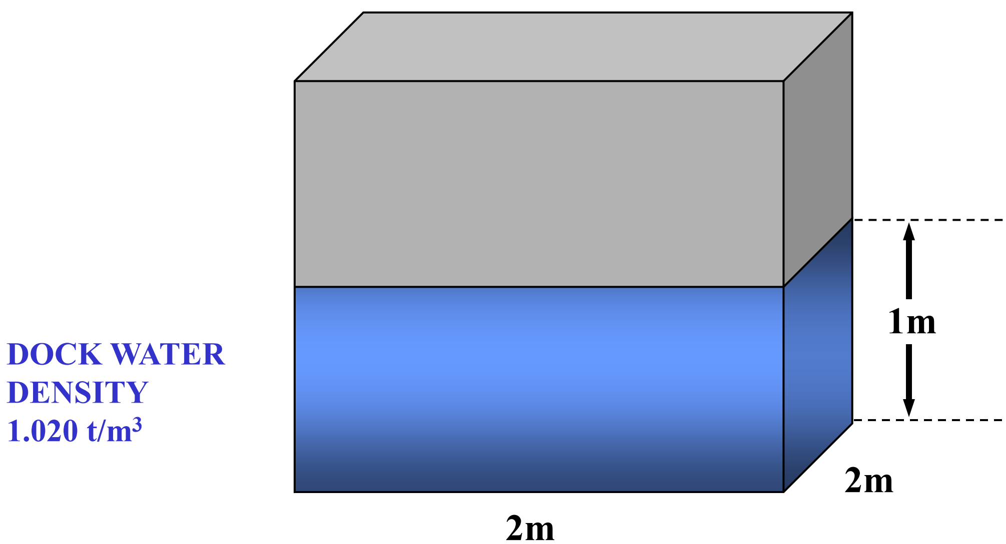
The block is suspended in air!

Since: $$\textit{Mass} = \textit{Volume} \times \textit{Density};$$

$$\textit{Mass of the block} = (2m \times 2m \times 2m) \times 7.84\ t/m^3$$

$$= \underline{62.72\ t}$$

The crane driver now lowers the block so that it becomes ***half submerged*** in the dock water which has a density of 1.020 t/m^3.



SAQ

What load (mass) will the gauge now indicate?

Answer

The block is now displacing a volume of water where:

Volume of water displaced = (2m × 2m × 1m)

$$= 4\ m^3$$

Mass of water displaced = Volume × Density of the dock water;

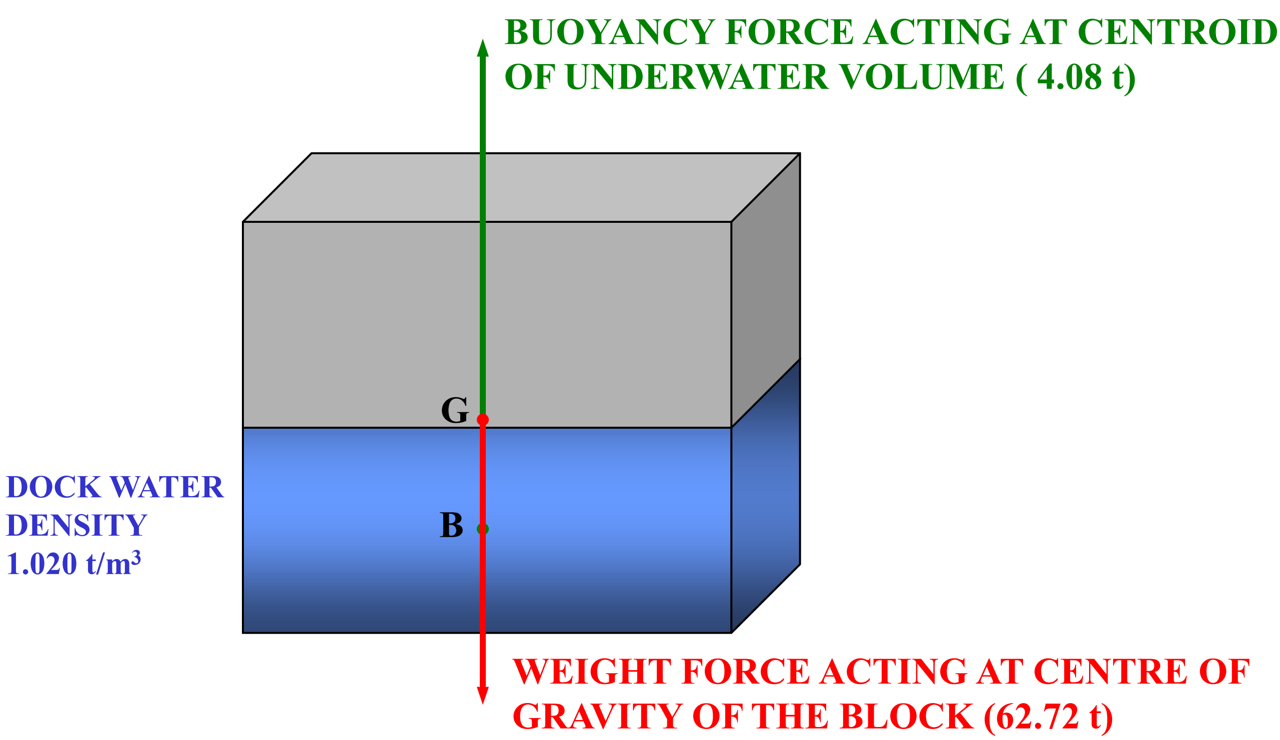
$$= 4\ m^3 \times 1.020\ t/m^3$$

$= \underline{4.08\ t}$ ***which represents the upthrust of the buoyancy force (Bf) created by the displaced water.***

Therefore: ***Mass of block = 62.72 t***

Upthrust due to Bf = 4.08 t

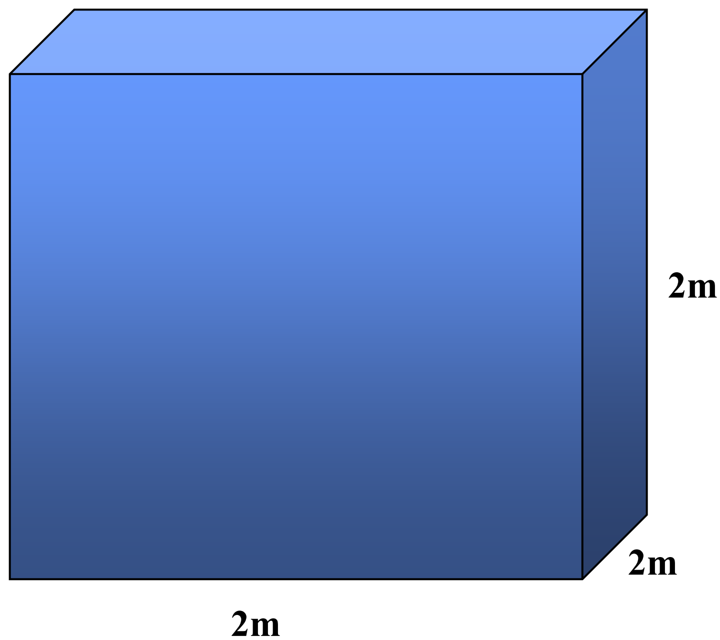
Gauge reading = 58.64 t



<u>SAQ</u>

What load (mass) will the gauge indicate if the crane driver now lowers the block so that it is completely submerged in the dock water?

DOCK WATER DENSITY $1.020\ t/m^3$



Answer

The block is now displacing a volume of water where:

Volume of water displaced = (2m × 2m × 2m)

$= 8\ m^3$

Mass of water displaced = Volume × Density of the dock water;

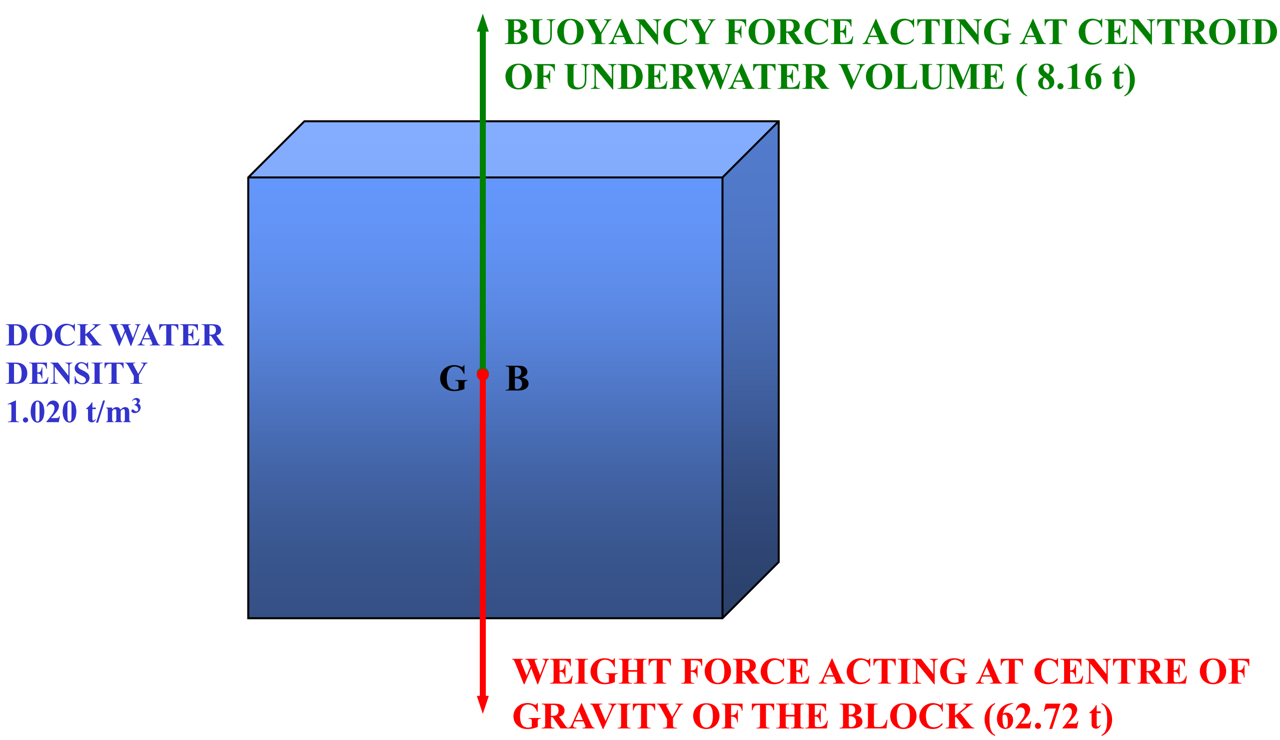
$= 8\ m^3 \times 1.020\ t/m^3$

= ***8.16 t*** ***which represents the upthrust of the buoyancy force (Bf) created by the displaced water.***

Therefore: ***Mass of block = 62.72 t***

Upthrust due to Bf = 8.16 t

Gauge reading = 54.56 t



2. **<u>Law of flotation</u>**

States that every floating body displaces it's own mass of the liquid in which it floats.

The ***displacement*** of a ship (or any floating object) is defined as ***the number of tonnes of water it displaces***. It is usual to consider a ship displacing salt water of density 1.025 t/m^3, however, fresh water values of displacement (1.000 t/m^3) are often quoted in ship's hydrostatic data.

The ***volume of displacement*** is the ***underwater volume of a ship*** afloat i.e. the volume ***below*** the waterline.

To calculate the displacement (W) of a ship the following needs to be known:

The volume of displacement (V)
The density of the water in which it floats (ρ)

Since: **MASS = VOLUME × DENSITY**

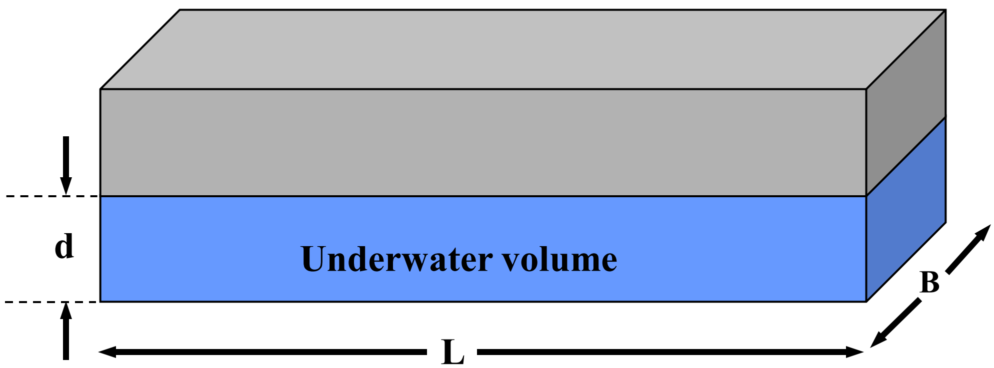
the mass, or ***displacement***, of a ship is calculated by:

DISPLACEMENT = VOL. OF DISPL. × WATER DENSITY

i.e. $W = V \times \rho$

To calculate the displacement of a box-shaped vessel

Consider the vessel shown.



VOLUME OF DISPL. = LENGTH × BREADTH × DRAUGHT

$$V_{BOX} = L \times B \times d$$

Therefore:

DISPLACEMENT = VOL. OF DISPL. × WATER DENSITY

$$\boxed{W_{BOX} = (L \times B \times d) \times \rho}$$

SAQ
Calculate the displacement of a box-shaped vessel that has a length of 80 m, breadth of 16 m and floats at a draught of 4.2 m in salt water (density 1.025 t/m³).

Answer

$$W_{BOX} = (L \times B \times d) \times \rho$$

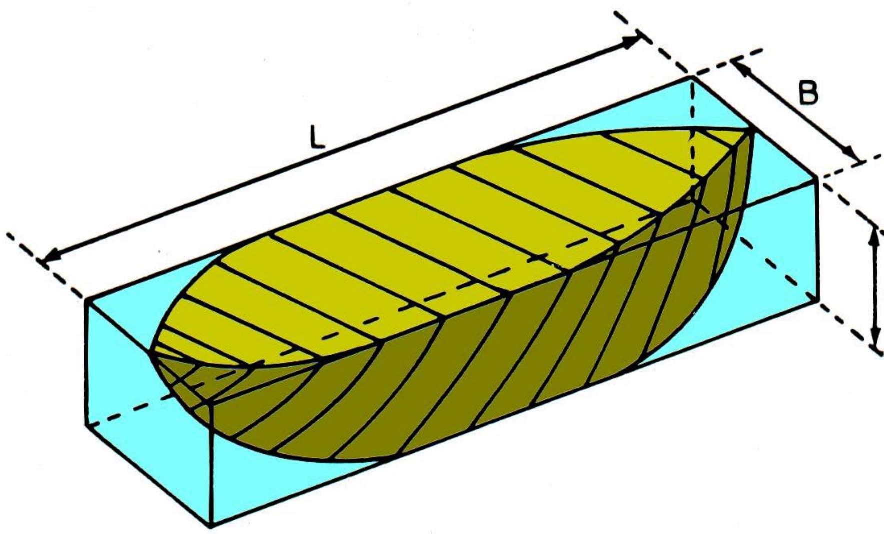
$$\therefore \quad W_{BOX} = (80 \times 16 \times 4.2) \times 1.025$$

$$\therefore \quad W_{BOX} = \underline{5510.4\ t}$$

To calculate the displacement of a ship

Since a ship is not box-shaped, a factor known as the ***block coefficient*** ***(C_B)*** **needs to be considered**.

The block coefficient (C_B) of a ship is the ratio of the underwater volume to the volume of the circumscribing block.



$$C_B = \frac{V}{L \times B \times d}$$

Therefore: $$W_{SHIP} = (L \times B \times d \times C_B) \times \rho$$

SAQ

A ship displaces 11400 tonnes and floats at a draught of 5.60 m in salt water. If the waterline length and breadth are 140 m and 18 m respectively calculate the block coefficient of the ship.

Answer

$$Mass = Volume \times Density$$

$$Displacement = Vol.\ of\ displ. \times Water\ density$$

$$\therefore \quad 11400 = Vol.\ of\ displ. \times 1.025$$

$$\therefore \quad Vol.\ of\ displ. = \frac{11400}{1.025} = 1112.951\ m^3$$

$$C_B = \frac{Vol.\ of\ displ.}{L \times B \times d}$$

$$\therefore \quad C_B = \frac{1112.951}{140 \times 18 \times 5.60}$$

$$\therefore \quad C_B = \underline{0.788}$$

REMEMBER THAT C_B HAS NO UNITS, IT IS A RATIO!

An alternative solution might be as follows:

Alternatively

$$W_{SHIP} = (L \times B \times d \times C_B) \times \rho$$

$$11400 = 140 \times 18 \times 5.60 \times C_B \times 1.025$$

$$\therefore \quad C_B = \frac{11400}{140 \times 18 \times 5.60 \times 1.025}$$

$$\therefore \quad C_B = \underline{0.788}$$