Tutorial Answers

1. A crane is used to lower weights into the sea (density = 1025 kg/m^3) for an underwater construction project. Determine the tension in the rope of the crane due to a rectangular 0.4 m x 0.4 m x 3 m concrete block (density = 2300 kg/m^3) when it is (a) suspended in the air and (b) completely immersed in water.

   Reference Cengel soft copy-PP 100

2. A 200 kg granite rock (ρ= 2700 kg/m^3) is dropped into a lake. A man dives in and tries to lift the rock. Determine how much force the man needs to apply to lift it from the bottom of the lake. Do you think he can do it?

Determine the force required to lift a rock from the bottom of a lake.

Assumptions
- buoyancy force is negligible in air
- the body is completely submerged
- the fluid is pure

Properties / Data

$\rho_{water} = 1000 kg/m^3$

$M_{rock} = 200 kg$

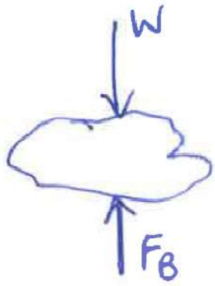
$\rho_{rock} = 2700 kg/m^3$

Analysis

volume of rock, $V = \frac{m}{\rho} = \frac{200}{2700} = 0.07407\, m^3$

weight of rock, $W = mg = 200 \times 9.81 = 1962 N$

buoyant force $F_B = \rho_f g V_f = 1000 \times 9.81 \times 0.07407$
$= 726.67 N$



Net force acting on the rock, $F_{net} = W - F_b$
$= 1962 - 726.67$
$= 1235.33$
$F_{net} = \underline{1240 N \quad (3 s.f.)}$

corresponding mass, $m_{net} = \frac{F_{net}}{g} = \frac{1235.33}{9.81}$
$= 125.9 = \underline{126 kg \ (3 s.f.)}$

Discussion
The force required to lift the rock from the bottom of the lake is 1240N. This corresponds to a mass of 126kg. If the man can lift 126kg on land, he can also lift the rock in water.

3. The volume and the average density of an irregularly shaped body are to be determined by using a spring scale. The body weighs 7200 N in air and 4790 N in water. Determine the volume and the density of the body. State your assumptions.

find the volume and average density of the body

Assumptions

- buoyancy force is negligible in air
- the body is completely submerged

Properties

$\rho_{H_2O} = 1000\ kg/m^3$

Analysis

Determine the mass of the body in air

$$m = \frac{W}{g} = \frac{7200}{9.81} = 733.945\ kg$$

The buoyancy force in water causes the change in weights of the body in air and water

$$F_B = \Delta W = 7200 - 4790$$
$$= 2410\ N$$

$$F_B = \rho_f g V$$

$$2410 = 1000 \times 9.81\ V$$
$$\underline{V = 0.246\ m^3} \quad (3\ \text{sig. fig})$$

$$\rho = \frac{m}{V} = \frac{733.945}{0.246}$$

$$\underline{\rho = 2990\ kg/m^3} \quad (3\ \text{sig. fig.})$$

Discussion

The volume of the body is 0.246 m^3 and the density is 2990 kg/m^3. The buoyancy force does not depend on shape, only the submerged volume and density of fluid.

4. Find the volume of the water displaced and position of centre of buoyancy for a wooden block of width 2.5 m and of depth 1.5 m, when it floats horizontally in water. The density of wooden block is 650 kg/m3 and its length 6.0 m.

Solution. Given :

Width $= 2.5$ m

Depth $= 1.5$ m

Length $= 6.0$ m

Volume of the block $= 2.5 \times 1.5 \times 6.0 = 22.50 \text{ m}^3$

Density of wood, $\rho = 650 \text{ kg/m}^3$

$\therefore$ Weight of block $= \rho \times g \times \text{Volume}$

$= 650 \times 9.81 \times 22.50 \text{ N} = 143471 \text{ N}$

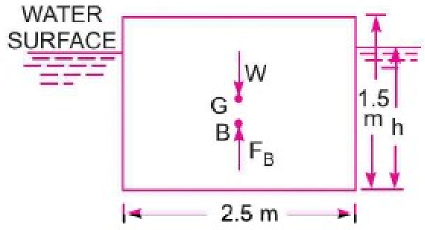


Fig. 4.1

For equilibrium the weight of water displaced = Weight of wooden block

$= 143471$ N

$\therefore$ Volume of water displaced

$$= \frac{\text{Weight of water displaced}}{\text{Weight density of water}} = \frac{143471}{1000 \times 9.81} = \mathbf{14.625 \text{ m}^3}. \textbf{ Ans.}$$

($\because$ Weight density of water $= 1000 \times 9.81 \text{ N/m}^3$)

Position of Centre of Buoyancy. Volume of wooden block in water

= Volume of water displaced

or $2.5 \times h \times 6.0 = 14.625 \text{ m}^3$, where h is depth of wooden block in water

$$\therefore \quad h = \frac{14.625}{2.5 \times 6.0} = 0.975 \text{ m}$$

$$\therefore \quad \text{Centre of Buoyancy} = \frac{0.975}{2} = \mathbf{0.4875 \text{ m from base.}} \textbf{ Ans.}$$