JANUARY 2014

Learning Object 1

Buoyancy

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Fun Fact

The deep-sea organism pertaining to the mollusk family, the Nautilus has a spiral shell, split up into chambers. These chambers allow it to control its buoyancy underwater. It can control this by filling or ridding its chambers of gas and water. This quality allows it in turn to rise and lower itself effortlessly in the depths of the ocean.

Source:
http://www.asknature.org/strategy/7dc27a9235da264c043acad2dc56e04d



1.Fish Buoyancy

Fish control their buoyancy with a gas-filled organ called a swim bladder. The average density of the air located in the fish's swim bladder is 1.03 kg/m^3.

If the fish's mass is 8.2 kg, what volume of gas in its swim bladder will raise the fish off of the sea floor, at a depth where the density of the surrounding seawater is 1.03 x 10^3 kg/m^3 ?



http://www.keyfinanceuk.com/resources/FishBubblesShrunk.jpg



2. Bathysphere Application

A bathysphere is used for deep-sea exploration; it has a diameter of 3.08 meters, and a mass of 1.10×10^4 kg. In order to dive, the bathysphere takes on a mass in the form of seawater. Determine the amount of mass that the submarine must take on if it is to descend at a constant speed of 1.15 m/s, when there is a resistive force of 1100 N acting on it in the upward direction. The density of seawater is 1.03×10^3 kg/m^3.

Solutions

Solution 1.

When the fish's swim bladder is filled with air, the surrounding seawater exerts a buoyant force on the fish and the air inside the swim bladder. As air is added to the swim bladder, the volume of the bladder increases, therefore displacing more seawater and increasing the buoyant force. When the buoyant force becomes equal to the total weight of the fish including the air in the swim bladder, the fish will rise off of the sea floor.

The total weight of the fish is: W = weight of fish + weight of air filling swim bladder

$$W = 8.2 \text{ kg} + (V_{air}\, \rho_{air})g$$

where V_{air} is the volume of the air inside the swim bladder and ρ_{air} is the density of the air.

The buoyant force exerted by the seawater on the fish is:

$$F_B = \text{weight of seawater displaced by fish} \rightarrow F_B = (V_{air}\, \rho_{seawater})g$$

When lifting off the sea floor, the buoyant force is equal to the total weight of the fish, therefore,

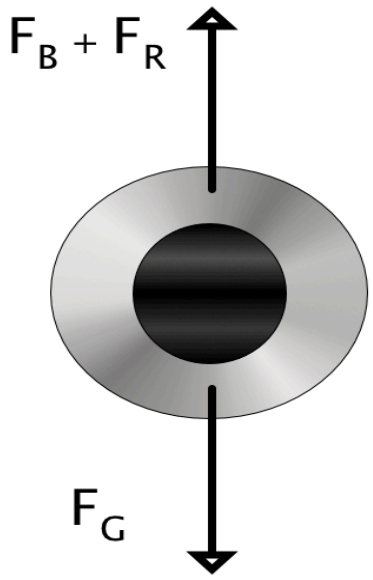
$$8.2 \text{ kg} + (V_{air}\, \rho_{air})g = (V_{air}\, \rho_{seawater})g$$

$$V_{air} = \frac{8.2kg}{(\rho sw - \rho air)kg/m\text{^}3} = \frac{8.2kg}{(1030-1.30)kg/m\text{^}3} = 7.97 \times 10^{-3} \text{ m}^3$$

Therefore, 7.97×10^{-3} m^3 of air will lift the fish off the sea floor.

Solution 2.

Step 1. Drawing a free body



Step 2. Determine variables

Let: F_G= force of gravity (mass x gravity)

F_B= buoyant force: ($\rho_f Vg$)

F_R= resistant force: 1100 N [upwards]

M=mass of bathysphere: 1.10×10^4 kg

m=mass of seawater

r = radius of bathysphere: 1.54 m

V = volume of bathysphere: $(4/3\text{pi}(r)^3)$

ρ_f = density of seawater: 1.03×10^3 kg/m^3

v = velocity: 1.15 m/s

Step 3. Work through question

Since the bathysphere is descending at a constant speed, this means that it is not accelerating, thus all forces must add to zero. Therefore,

$$F_G = F_B + F_R$$

Now we can sub-in each constituent equations and given information.

$$Mg = \rho_f Vg + F_R$$

$$Mg = \rho_f g((4/3)\text{pi}(r)^3) + F_R$$

Since the bathysphere takes on mass of seawater, it absorbs water to increase its mass in order to sink, therefore, its total mass is $M_{\text{bathysphere}} + m_{\text{seawater}}$.

$$(M+m)g = \rho_f g((4/3)\text{pi}(r)^3) + F_R$$

$$Mg + mg = \rho_f g((4/3)\text{pi}(r)^3) + F_R$$

$$mg = \rho_f g((4/3)\text{pi}(r)^3) + F_R - Mg$$

$$m = (\rho_f g((4/3)\text{pi}(r)^3) + F_R - Mg)/g$$

Substitute all of the given information.

$$m = (\rho_f g(4/3pi(r)^3) + F_R - Mg)/g$$

$$m = [((1.03 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s})((4/3)pi(1.54m)^3) + 1100 \text{ N} - (1.10x10^4 \text{ kg})(9.8 \text{ m/s}))/ (9.8 \text{ m/s})]$$

$$m = [((1.03 \times 10^3 \text{ kg/m}^3)(9.8 \text{ m/s })(15.30 \text{ m}^3) + 1100 \text{ N} - (1.10x10^4 \text{ kg})(9.8 \text{ m/s}))/ (9.8 \text{ m/s})]$$

$$m = 4871.24 \text{ kg}$$

Therefore, the bathysphere must take on 4871.24 kilograms of seawater in order to descend at a constant speed of 1.15 m/s.