Journal of Physics Special Topics
An undergraduate physics journal

A4_8 How To Float

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December 12, 2018

Abstract

In this paper, we resolve the vertical forces acting on a 70 kg person to determine that if their lungs are entirely full of helium gas they would feel between 5.24 - 8.73 grams lighter; this is asssuming that their surroundings are at a temperature of 20 °C and at a pressure of 1 atm. Taking the density of a human body to be 1010 kgm^{-3} [1], we also calculate that in order to be lifted upwards in air, they must inhale a volume of 129 m^3 of helium gas. Finally, we discuss the feasibility of inhaling helium gas as a means to acheive the ability to reach suspension in air.

Introduction

Helium gas is commonly used to make objects such as balloons and blimps float in air; this is possible because the density of helium gas is lower than that of air. Many people inhale helium gas to temporarily change the pitch of their voice but due to its comparatively low density, inhaling helium gas may also increase the buoyant force acting on a person's lungs. Potentially inhaling a high enough volume of helium gas can produce a great enough change in the buoyant force to overcome the force of gravity on a person. In this paper we calculate the reduction in the efffective weight experienced by a person with their lungs full of helium and the volume of helium that they would need to inhale in order to lift them.

Theory

Figure 1 is a force diagram displaying the vertical forces that would act on a person floating in a fluid; the forces labelled are due to the weight and buoyancy of the person's body and the gas in their lungs, respectively. The net downwards force acting on a person whose lungs are full of air is

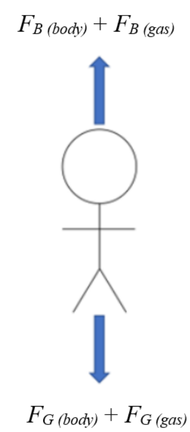

Figure 1: Vertical forces acting on a person in air.

$$F_{net(1)} = (m_{body} + m_{air})g - V_{body}\rho_{air}g, \quad (1)$$

where m_{body} is the mass of the persons body excluding the gas in their lungs, m_{air} is the mass of the air in their lungs, V_{body} is the volume of the person's body, ρ_{air} is the density of air and g is the gravitational field strength, 9.81 ms^{-2}.

When the total lung capacity of a person (i.e. the volume of gas contained in the lungs at the end of a maximum inspiration [2]), consists only of helium, the net downwards force becomes

$$F_{net(2)} = (m_{body}+m_{He})g-(V_{body}\rho_{air}+V_{lung}\rho_{air})g, \tag{2}$$

where m_{He} is the mass of helium in the person's lungs and V_{lung} is the volume of their lungs.

The difference between these two net forces is equal to the change in the normal reaction force, and is given by:

$$F_{net(1)} - F_{net(2)} = gV_{lung}(2\rho_{air} - \rho_{He}). \tag{3}$$

We can also consider how much helium gas a person would be required to inhale in order to lift them off the ground. An object will accelerate upwards in air if the buoyant force acting on the object is greater than the force it experiences downwards due to gravity i.e. $F_B > F_G$, therefore the condition that must be met for the person to float away from the ground is

$$V_{body}\rho_{air}g + V_{lung}\rho_{air}g > m_{body}g + V_{lung}\rho_{He}g. \tag{4}$$

Rearranging this for V_{lung} gives

$$V_{lung} > \frac{m_{body} - V_{body}\rho_{air}}{\rho_{air} - \rho_{He}}. \tag{5}$$

In our calculations we will use the values of the densities of air and helium gas, $\rho_{air} = 1.205$ kgm^{-3} and $\rho_{He} = 0.664$ kgm^{-3}; these are the values for the gases at a temperature of 20 °C and at a pressure of 1 atm [3].

Results

The total lung capacity of a 70 kg adult averages 3 - 5 L [4]. If the total lung capacity of a 70 kg adult is fully replaced with helium gas and assuming that they are standing on the surface of Earth where $g = 9.81$ ms^{-2}, we calculate that they will experience feeling between 69.991 kg and 69.995 kg, or 5.24 - 8.73 grams lighter than normal, from equation (3).

We also calculate that a 70 kg person must inhale a minimum volume of 129 m^3 of helium gas in order for the condition in equation (3) to be met so that they are lifted away from the ground. We have taken the density of a human body to be 1010 kgm^3 [1] in order to calculate the volume of the person.

Conclusion

The results show that a 70 kg person will feel lighter by only a negligible amount even if helium gas fully makes up the maximum capacity of their lungs. Therefore in order to lift off the ground, they must inhale a much larger volume of helium. We calculate that the volume required is at least of the magnitude 10^4 times greater than their maximum lung capacity. We can conclude that a person is not likely to be able to float by inhaling a large amount of helium gas; using helium to lift a person may only be made possible by attaching them to an object of considerable size and low mass that contains a volume of more than 129 m^3 of helium gas, for example a very large helium-filled balloon.

References

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[3] `https://www.engineeringtoolbox.com/gas-density-d_158.html/` [Accessed 20 November 2018]

[4] `https://www.aic.cuhk.edu.hk/web8/lung_function_tests.htm/` [Accessed 20 November 2018]