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Abstract

Films are a great place to look for physical inaccuracies and impossibilities. One such film is Disney's 'Pirates of the Caribbean', where they walk underwater within a capsized row boat. From resolving the buoyancy and weight forces, the resultant force is 13200 N opposing the force of weight, which will act to push the boat up to the surface. From this we conclude that it is not possible for them to be able to traverse underwater in this fashion.

Introduction

One of Disney's film franchises is 'Pirates of the Caribbean'. The realm of pirates is one that has potential for lots of physics problems and inaccuracies. In this paper we test the scene from the first film of the franchise, where Captain Jack Sparrow and Will Turner walk underwater within an air pocket of a capsized row boat, in order to approach a ship undetected. How plausible is it that they could walk underwater with the boat without the buoyancy force sending them back to the surface? In this paper we will look into the buoyancy and weight forces of the system to calculate the end result.

Buoyancy

The force that is opposing the weight of the system is buoyancy, and hence this force will act in a way as to make them return to the surface. This can be calculated by [1]

$$F_B = \rho_f V_s g, \tag{1}$$

where F_B is the buoyancy force, ρ_f is the density of the fluid, V_s is the volume of the system that is submerged, and g is the acceleration due to gravity. To be able to calculate this force we first need to find the volume occupied by the whole system. The shape of the boat has been approximated to be a prolate spheroid with total length of 3 m, total width of 1 m, depth of 0.5 m and the thickness of the wood as 0.05 m. Using the formula for the volume of a prolate spheroid [2]

$$V_{ps} = \frac{4}{3}\pi a^2 c, \tag{2}$$

where V_{ps} is the volume of a prolate spheroid, a is the depth of the boat and c is half the total length. Using the values specified earlier for a and c, the full volume of the boat (both the wood and air) is

$$V_b = \frac{4}{3}\pi \times 0.25^2 \times 1.5 = 1.57\,\mathrm{m}^3. \tag{3}$$

The volume of the wood is simply the whole volume minus the volume of the air; this air volume can be calculated with the values stated earlier but with the thickness of the wood subtracted, giving the total volume of wood to be

$$V_w = 1.57 - (\frac{4}{3}\pi \times 0.2^2 \times 1.45) = 0.340\,\mathrm{m}^3. \tag{4}$$

This gives the volume of air inside the boat to be 1.23 m^3. It should be noted that the heads of both characters are inside the boat, and also the compressibility of the air at depth have both not been accounted for in this value. These would realistically subtract from the total volume of the system. The last volume needed is of the two pirates; the volume of a 70 kg man is approximately 0.0665 m^3 [3] and so the total volume of the system is

$$V_s = 1.57 + (0.0665 \times 2) = 1.70\,\mathrm{m}^3. \tag{5}$$

Using this value in Eq. (1), and a value for the density of salt water of 1025 kgm^{-3} [1], we get the buoyancy force to be 17100 N.

Weight

In our scenario we assume the only other force acting on the system will be the weight; any attempt to try and pull the boat downwards would be the same as you pulling yourself up towards the boat, resulting in no contribution to the overall system. To be able to calculate the weight of the individual components we took the volume of each and multiplied it by its density. The wood that was used for the construction of the row boat was assumed to be oak, with a density of 750 kgm^{-3} [1]. Air at sea level has a density of 1.293 kgm^{-3} [1]. Taking these values, multiplying them by their respective volumes and then taking the pirates' mass to be 70 kg each, the total mass of the system is

$$\begin{aligned} M_s = (750 \times 0.34) + (1.293 \times 1.23) \\ +(70 \times 2) = 394\,\mathrm{kg}. \end{aligned} \tag{6}$$

This then gives the force of the systems weight acting against buoyancy to be 3860 N.

Resolving the forces

Now that we have both of the forces acting on the system, we can resolve it in the vertical direction. This is a simple subtraction and gives a resultant force of 13200 N. The only way that the buoyancy force can be countered is by having additional weight. By converting this resultant force into a mass, we find that 1350 kg needs to be added in order for this system to remain on the sea floor, as it does in the film.

Conclusion

To conclude, while it may be portrayed as a great way to sneak onto a ship underwater, just getting the boat to stay under is realistically a challenge in itself. It would not be possible for two pirates to do this with only their bodyweight. There would need to be a significant amount of additional weight added to the system in order to keep the boat submerged. This outcome comes as a bit of a relief as the whole purpose of a boat is to float and carry cargo across water, not to sink as soon as it touches the surface.

References

[1] Tipler, P. and Mosca, G. (2008). Physics for scientists and engineers. New York: W. H. Freeman. Sixth Edition

[2] `http://mathworld.wolfram.com/Volume.html` [Accessed 05 November 2017]

[3] Krzywicki, H et al (1966). Human body density and fat of an adult male population as measured by water displacement.