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P5_6 Yo Ho, Yo Ho, It's A Buoyant Life For Me!

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Abstract

In this paper, we have calculated whether the crew of the Black Pearl would have been able to walk along the sea bed while in skeleton and human form. We find that while in skeleton form they would be able to walk along the bottom, however when they lose the moonlight and turn back to human form they would start to rise to the surface due to their added buoyancy. This means that the journey along the sea bed would only be possible on a clear night, with the moonlight unobscured.

Introduction

In *The Pirates of the Caribbean: The Curse of the Black Pearl*, the crew of the Black Pearl are under a curse which turns them into skeletons when they step into moonlight, which also makes them invulnerable. At the climax of the film, Barbossa and the pirate crew are planning a surprise attack on a Royal Navy ship. Barbossa then orders his crew to "take a walk" underwater in the moonlight so that they can reach HMS Dauntless without being spotted [1].

We want to calculate whether it would be possible for the crew to do this, in both their skeleton and fleshy forms, by calculating the buoyant force they would experience and comparing this against the force due to gravity.

Method

During the scene, the pirates begin in the moonlight as they walk out from Isla de Muerta along the sea bed. The curse that makes the crew live forever only turns them into skeletons when they are in the moonlight. This means that when they reach the English HMS Dauntless they are shaded from the moonlight by the ship and so they turn back into their normal form. We will consider these two cases separately and compare between them.

First, we must define the conditions that determine whether an object or material will float when submerged in a liquid. The first of these is that the buoyant force has to be greater than or equal to the force due to gravity:

$$F_{Buoyant} \geq F_{Down}, \tag{1}$$

If this condition isn't met the pirates will sink to the bottom of the sea bed. On top of this, the weight of displaced fluid also has to be equal to the weight of the body which is being submerged. For the sake of this test, we will be assuming that human bodies and bones are completely non-porous resulting in a volume displacement of water equal to that of the body. Finally, the density of the body must be less than the density of the fluid. With these three conditions the following equation can be formed using Archimedes' principle:

$$\rho g V_f \geq mg, \tag{2}$$

Where $g = 9.81$ ms^{-1}, ρ is the fluid density, V_f is the volume of the displaced fluid and m is the mass of the submerged object. If this inequality is satisfied the object will, therefore, be able to float.

Since we previously established that the volume of water displaced, in this case, can be assumed to equal the volume of the submerged body, and that the volume is equal to the mass divided by the density of the body ($V = m/\rho$), the equation becomes:

$$\frac{\rho_f g m_b}{\rho_b} \geq mg, \tag{3}$$

Where the subscript 'f' relates to the fluid variables and the subscript 'b' relates to those of the body being submerged.

Before calculating whether the crew would be able to float, we must assign values to our variables. For instance, seawater density varies throughout the day, this is because density increases with a reduction in temperature. Since the scene takes place at night we can assume the density is at its highest and is, therefore, 1029 kgm^{-3} at the surface [2]. The water is at maximum 10 m deep, so we will ignore any density gradients. We have also taken the mass of each pirate as 80 kg as this is the average for an adult male in North America [3]. We, therefore, neglect the added mass of any of their "effects".

For the phase where they are in skeleton form, we also need to consider bone mass and density. Bones are estimated to contribute to 15% of a human body's mass [4]. They are also also a lot more dense than human flesh. The average bone density of a human is approximately 1175 kgm^{-3} compared to the overall density of human flesh, 1000 kgm^{-3} [5]. We have used this information to find that the skeletons would weigh 12 kg.

Results and Discussion

Using the equations above we arrived at a buoyant force of 807.6 N and a down force due to gravity of 784.8 N for the fleshy pirates case. We can clearly see that this agrees with the inequality in Equation 1. Conversely, we find that the skeleton pirates have a buoyant force of 103.1 N and a down force of 117.7 N, evidently breaching the requirements for an object to float. Therefore, we can conclude the pirates would definitely sink to the bottom when they are in their skeleton form. However, they would raise to the surface when out of the moonlight, in conflict with the scene in the film. This would have, consequently, meant that they would not have been able to hide under the boat.

Their curse could actually be used as an advantage as they could use the additional buoyancy they gain in the shade of the ship to float to the surface quickly. Combining this with swimming could give them enough speed to jump onto the boat.

References

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