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P2_8 Charybdis Vs. The Argonauts

J. Mooney, K. Hinchcliffe, H. Biddle, K. Golsby

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

The Greek Hero Jason, while sailing on the Argo to fetch the Golden Fleece, encounters a sea creature which sucks in the ocean, creating a huge whirlpool. This paper finds the intital buoyancy force of the Argo and compares this to the centripetal force exerted on the Argo by the whirlpool, which were found to be 5.69 million N and 157 million N respectively. We also calculated the pressure gradient throughout the radius of the whirlpool to be 12100 Pa, and its rotational velocity to be 0.61 rad s^{-1}.

Introduction

In the Greek myth of Jason and the Argonauts, the heroes encounter a terrible sea creature, Charybdis. Charybdis sits in the Strait of Messina, and three times a day it opens its mouth and sucks in as much of the sea as it can, creating a dangerous whirlpool capable of sucking in numerous ships within its path. This whirlpool is visualised as a vortex with a downdraft.

Speed of the Whirlpool

Initally, we calculated the buoyancy force that the boat would feel under normal conditions when sailing through the Strait of Messina. This force is given by Equation 1,

$$F_B = \rho_{sea} V g \tag{1}$$

, where ρ_{sea} is the density of the saltwater ocean $\rho_{sea} = 1020$ kg m^{-3} [1], V is the volume of water displaced and g is the gravitational constant, 9.81 m s^{-2}.

We equate the volume of water displaced by the Argo to the volume of the ship. To find the ship's volume, we use Equation 2,

$$V = \frac{m_{ship}}{\rho_{ship}}, \tag{2}$$

where m_{ship} is the mass of the ship and ρ_{ship} is the density of the ships wood.

We have assumed the Argo to have been constructed using 20 Silverfir trees [2] (Silverfir being a construction material in Ancient Greece) [3], and can therefore take the density of the ship (Silverfir) as $\rho_{ship} = 480$ kg m^{-3} [4].

As the density of an individual tree is $\rho_{tree} =$ 480 kg m^{-3} [4], which, when using the volume of one cylindrical tree as 29.06 m^3 as $V = \pi r^2 h$ (using a Silverfir tree height of 37 m and radius of 0.5 m [4]), we find the mass of one dried tree to be $m_{tree} = 13900$ kg. This can then be multiplied by 20 to give us a total mass of the ship, $m_{ship} =$ 278000 kg. This mass, along with the density of wood, can be placed into Equation 2 to find the volume of the ship and hence the volume of water displaced as $V = 579$ m^3.

This displaced volume can then be inserted into Equation 1 to find a buoyancy force of 5.79 million N.

We have approximated the surface of a whirlpool to the surface of a bucket of water, as described by Newton's bucket argument [5]. We can hence describe the centrifugal force, F_{cfgl} acting on any object in the surface of the water with Equation 3,

$$F_{cfgl} = mv^2r \tag{3}$$

where $m = 278000$ kg is the mass of the ship, $v = 25.2$ km h^{-1} is the waters average velocity [6], and $r = 11.5$ m is the radius of the whirlpool [7]. Using these values in Equation 3, we find F_{cfgl} to be 157 million N. To find the minimum rotational velocity of the whirlpool that the Argo could not escape, we equate the centripetal force to the force of the 20 rowers (1600 N) [2][8], $m\omega^2 r = 20 \times 1600$ where ω is the waters rotational velocity, presuming they are rowing directly away from the vortex axis. Using our previous value of r and m, we can find the minimum rotational velocity $\omega_{min} = 0.10$ rad s^{-1}.

The water that Charbydis spits out is likely to form a large wave, which could sink the ship. Waves with a height 55% of the boats length will cause it to capsize [10]. Galley ships such as the Argo were thought to be 35 m long [2], hence needing a wave height of 19 m to capsize.

Finally, we can calculate the pressure gradient of the whirlpool itself. A whirlpool dips in the centre due to a change in pressure between the centre of the vortex and the outside edge. This gradient, dp, can be calculated using the Equation 4,

$$p = \rho_{sea}\Omega \int_0^d \frac{d^2}{d} dr \tag{4}$$

where d is the distance from the vortex axis (radius r). By integrating, we find $dp = \frac{1}{2}\rho_{sea}\Omega d^2$. We can find the real value of ω using $\omega = \frac{v}{d}$, giving us a value of $\omega = 0.61$ rad s^{-1} for the whirlpool. Using this value of ω in Equation 4 gives us $dp = 41100$ Pa. Using the minimum value of ω_{min} calculated earlier, this gives a minimum pressure gradient of 6740 Pa.

Assumptions

For this paper, we have neglected air resistance and other external forces. We have assumed the ships mass to solely be 20 silverfir trees, and have ignored any exponential effects as the boat is pulled further into the whirlpool. Further consideration could be done into the Coriolis Effect and how this could influence the scenario.

Conclusion

We found that Charybdis creates a pressure gradient of 41100 Pa and centripetal force of 157 million N, causing a galley ship such as the Argo to be sucked in when the whirlpools angular velocity is 0.61 rad s^{-1}. Perhaps wisely, Jason and the Argonauts chose to turn away from Charybdis and the ship-destroyed whirlpool.

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