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A3_6 To Power a Miracle

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Abstract

Miracles and other extraordinary events are often conceived as implausible in an age where facts challenge beliefs. In this article we calculate the power required to part the Red Sea and the force needed to sustain this miracle for the length of time necessary for the Israelites to cross: a feat Moses is believed to have accomplished in the Bible. Our calculated values for the power and force are 5.73×10^{13}W and 8.63×10^{12}N respectively.

Introduction

The Book of Exodus in The Old Testament narates the Israelites' liberation from slavery in Egypt. During their journey to the 'promised land', they hit a bump in the road upon their arrival at the Red Sea and realising it needed to be crossed. The solution: God summoned a wind that parted the waters and allowed the Israelites to cross to freedom, escaping the Egyptian army who were in hot persuit. We calculate the power required for the wind to lift the water, and go on to determine the force needed to hold it in place.

The Exodus Route

The exact route taken by the Hebrews is disputed to this day. One theory proposes the best candidate for the crossing point to be the Straits of Tiran, in the Gulf of Aqaba[1]; we assume this to be the event location for our theoretical scenario. Constructing this route across the water on Google Earth, the total crossing distance was found to be 19.03km; this path follows natural land bridges across the straits[1]. The water depth varies over the crossing and was subsequently split into two average depths; one stretch of 70m and two of 205m [1]. Fig.(1) shows the separation of the route into three segments; AB and CD cover the stretch of water at a depth of 205m and BC covers the stretch of water at a depth of 70m. The width of the path created is assumed to be equal to the average width of the natural land bridge, 800m[1], also shown in Fig.(1). From this, the volumes of water needed to be displaced along each stretch was calculated; 1.14×10^{9}m^3 for AB, 565.6×10^{6}m^3 for BC, 336.2×10^{6}m^3 for CD, giving a total volume of 2.04×10^{9}m^3.

Parting the Red Sea

To calculate the power needed to produce two walls of water either side of the path, a model of the processes occurring in this scenario must be determined. We assume that the winds lift the water that is flooding the path and split it evenly between both walls. This water is moved on top of the sea on either side of the path, creating effective walls 0.4km wide and of height twice the depth of the original stretch (shown in Fig.(1).) To calculate the power necessary to do this, we calculated the gravitational potential energy (GPE) gained when lifting the water to the necessary heights by multiplying each mass by the acceleration due to gravity on Earth (9.81ms^{-2}) and the height to which the water is lifted. These values are then summed to give a total GPE of 3.44×10^{15}J. We then divided this by an estimate of the time taken for the wind to part the waters, 60s. Realistically it could have taken any length of time but, due to a lack of information on how long it actually

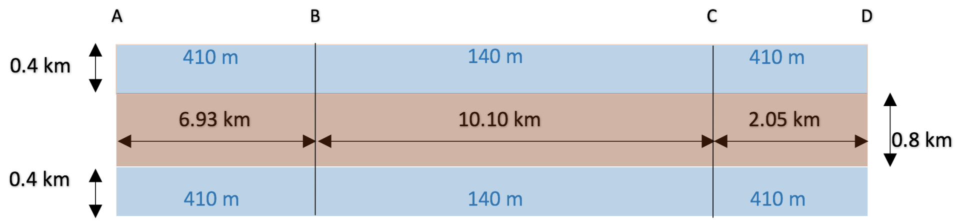

Figure 1: The route, split into three stretches of varying initial depth; land bridge and water walls are represented by brown and blue areas respectively. Widths and distances are also shown. Wall heights are depicted in blue text.

took, we use 60s based on the assumption that any longer will have stopped the Israelites from escaping in time. Dividing the GPE by 60s gives a value of 5.73×10^{13}W for the power.

Next we calculated how long the force holding the wall up would need to be maintained, ie. the time taken for everyone to cross over. Moses freed roughly 2.4 million people[2]; taking a crossing distance of 19.03km, a path width of 800m, an average human width (shoulder to shoulder) of 0.4m and an average human depth of 0.25m[3] , we calculate that 2.4 million Hebrews would need to make their way across in 1200 rows of 2000 people. Assuming an average speed of 3kmh^{-1} to allow for the elderly and children, it would have taken 6.46 hours for everyone to cross over.

Calculating the force needed to maintain these walls for 6.46 hours involves using a form of the hydrostatic equilibrium equation[5]

$$F = \rho g L \frac{1}{2} H^2, \tag{1}$$

where F is force, ρ is salt water density (1.03×10^3kgm^{-3}[4]), L is the length of the stretch and H is the height of the water wall at any point. Applying Eq.(1) to each stretch of water and summing the results gives a total Force of 8.63×10^{12}N.

Discussion and Conclusion

Our values for the power and force needed to perform this miracle are both incredibly large, which makes sense given the magnitude of this miracle. However, assumptions made in calculations inevitably lead to uncertainty in results. To start with, the exact location of the crossing is still debated; results would change depending on the location of the crossing, as volume and mass calculations revolve around this. We use one of many well debated locations for our model. Also, we assumed the time taken to shift the water; the exact time alleged is impossible to know, but our estimate uses the miraculous quality of this event to its advantage.

We also assume that waters around the event stay unaffected. Integrating these effects into calculations would require a more in depth analysis. However, as our event location is such that the water on one side of the path connects to the ocean, we can assume that the impact on surrounding waters is dispersed over the entire ocean, rendering them negligable.

To conclude, achieving this miracle would have taken a power of 5.73×10^{13}W and a force of 8.63×10^{12}N, to be maintained for 6.64 hours. Our results' accuracy could be improved with a better knowledge of the proceedings. However, such values are understandable given the circumstance of our scenario.

References

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