Journal of Physics Special Topics
An undergraduate physics journal

P6_1 The Lion King(dom)

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November 8, 2018

Abstract

In Walt Disney's film The Lion King, Mufasa tells his son Simba that everything he sees is their Kingdom. In this paper, we show that the area of their kingdom would depend on the height that they are at during this scene. At a height of 10 m, we found that Mufasa's kingdom has an upper limit of 493.4 km^2.

Introduction

"Look, Simba. Everything the light touches is our kingdom." [1]. In this article, we look into the implications of Mufasa's statement to his son Simba from the Disney production of The Lion King. For this we assume that when Mufasa says "Look", he means everything that Simba can see. The lion then goes on to clarify that this does not include the shadowy places. We will ignore these shadowy places for the purpose of this paper, so as to find an upper limit to the kingdom's size.

Since a lions eyesight is better than a humans [2], the horizon would be the boundary. We shall calculate the diststance between the lions and the horizon, hence showing the potential area of Mufasas' kingdom. We can then compare this with the typical size of an African lion's territory of about 100 mi^2 [3]. Our Calculations take into account atmospheric refraction, which is the bending of light rays as a result in the density gradient of the atmosphere [4].

Theory

If we ignore any atmospheric effects and assume a completely smooth terrain at sea level, the distance to the horizon can be calculated using Pythagoras' theorem. From figure (1), if d is the linear distance from the observer to the horizon, R is the radius of the Earth and h is the eye level height above the ground, we know that $d^2 = (R+h)^2 - R^2$. This can be expanded and simplified to give:

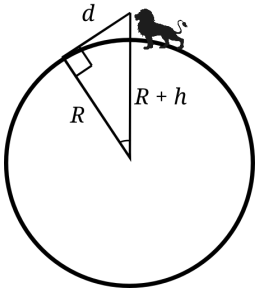

Figure 1: Using Pythagoras' theorem to find the distance to the horizon.

$$d = \sqrt{2Rh + h^2} \tag{1}$$

This, however, is not the distance of the visible horizon. We must also account for atmospheric refraction. The bending of light in the atmosphere means that the perceived horizon is actually further away than d, as shown in figure (2). The curved line of sight, d', has the curvature

of α times that of the Earth. We can amend Eq. (1) for a new radius $\frac{R}{1-\alpha}$ where α depends on the lapse rate, but at sea level is approximately $\frac{1}{7}$ [4]. Eq. (2) accounts for the atmospheric refraction.

$$d' = \sqrt{\frac{7Rh}{3} + h^2} \tag{2}$$

To calculate the area, A, of the lion's kingdom, we must multiply d'^2 by π

$$A = \left(\frac{7Rh}{3} + h^2\right)\pi \tag{3}$$

Since d' is small in comparison to R, we find d' a good approximation to the distance measured along the curvature of the Earth's surface.

Results

At ground level, the eye level of a lion is approximately 1 m. Taking this as our value of h and the radius of the Earth to be 6,371 km, the size of Mufasa's kingdom is approximately 46.7 km^2.

Figure 2: Atmospheric refraction lengthens line of sight.

The scene takes place on top of the fictional "Pride Rock", whose height is not specified. Plotting a range of heights up to 10 m, figure (3) shows us that increasing the viewing height has a significant effect on the size of the lion's kingdom.

h is small in comparison to R, meaning the kingdom area increases approximately linearly with the height. At a height of 10 m, the lions would lay claim to 493.4 km^2.

Conclusion

To conclude, the size of a Mufasa's kingdom depends on the height at which he and Simba are viewing it during the scene. We have shown the area of the kingdom to increase almost linearly with the height of viewing.

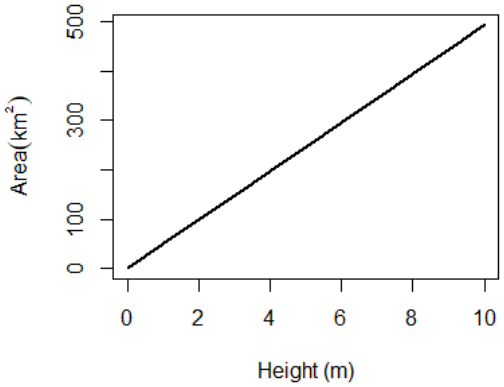

Figure 3: Relationship between the height of the lion and the area of his perceived kingdom.

The National Geographic has an African lion's territory at 100 mi^2, or 259 km^2. This would make the ground level calculation of 46.7 km^2 kingdom rather modest and the 493.4 km^2 sized kingdom at a view point of 10 m above sea level more impressive. To get a more accurate figure, the height of "Pride Rock" must be known.

References

[1] `http://lionking.org/scripts/Script.html` [Accessed 30 September 2018]

[2] Shea, T. (2013) Lions. New York: Gareth Stevens Pub, p. 5.

[3] `https://www.nationalgeographic.com/animals/mammals/a/african-lion/` [Accessed 30 September 2018]

[4] Young, A. (2018). Dip of the Horizon. [online] Aty.sdsu.edu. Available at: `https://aty.sdsu.edu/explain/atmos_refr/dip.html` [Accessed 30 Sep. 2018].