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A2_8 A Girl and her Horse

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Abstract

Horse-girls and their horses are inseparable in real life, but how strong is the actual gravitational bond between them? Using Newtonian gravity, we investigate by approximating both girl and horse as cylinders, and find they have a gravitational force between them of 4.9×10^{-6} N. We also investigate the size of the force exerted between the girl and the horse in free space if they were 100 m apart, and find that it would take them 194 days to drift back together under the influence of their own gravity alone.

Introduction

Tumblr user @gothicprep, who agreed to be credited, made a post on 29.10.2021 talking about a nightmare physics exam question they had in a dream: how strong is the bond between a girl and her horse? Here, we attempt to do the impossible, and quantify the bond between an average 11 year old girl and her Shire horse, which she is riding, by approximating them both to be cylinders and using this to find the distance between their centres of mass. For this, we assume that the legs and head of the horse have no impact on the centre of mass, and we assume that the legs of the girl do not impact the position of the centre of mass. In reality, there would be an impact on the positions, but it is beyond the scope of this paper to model an entire horse and girl.

Theory

This paper needs only one physical equation to solve it, which is the Newtonian equation of gravity:

$$F = \frac{GMm}{r^2}, \tag{1}$$

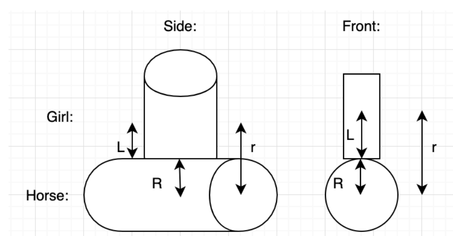

Figure 1: The girl and her horse's centres of mass separation if she were riding her horse.

where G is the gravitational constant, which we will take to be $G = 6.67 \times 10^{-11}$ Nm^{2}kg^{-2}[1]. The other parts of this equation are the masses of the girl and the horse (m and M respectively) and the exact distance between their centres of mass, r.

The average mass of a horse depends heavily on breed, with the heaviest horses being a Shire horse (between $850 - 1100$ kg)[3] and the Falabella being the smallest, lightest horse ($60 - 80$ kg). For the purposes of this paper, we will consider a Shire horse with a weight exactly in the mid range, at 975 kg. This provides us with the M value for the equation. To find m, we just need the average mass of an 11 year old girl, which is 36.9 kg[5]. To find the distance r between the centres of mass, we only need the radius of the horse's cylinder and the length of the girl's cylinder. A horse's "girth" is the circumference around its body between its shoulders and its stomach, which for a Shire horse, is around 213 cm [3]. We will assume this is the circumference of the cylinder representing the horse. The circumference of the circle is given by:

$$c = 2\pi R. \tag{2}$$

This gives us a radius of $R = 34$ cm. The last thing we need to know in order to have our r value is the length of the torso and head of an average 11 year old girl. The average height of an 11 year old girl is 144 cm [5], and around half of the height of a human is legs, so we only need half of this height, which is 72 cm. Of this, to find our radius r we need L, which is half of this again, 36 cm. Finally, we can find r using:

$$r = R + L, \tag{3}$$

which results in a value of 70 cm, or 0.7 m. We now have all of the components of our equation (1), which we can now use to calculate the gravitational bond between a girl and her horse.

Results and Discussion

Using equation (1), we calculated a gravitational force between the girl and her horse of 4.9×10^{-6} N. If the girl and the horse were tragically floating in free space, with a distance of $r = 100$ m between their centres of mass, this force would fall to 2.4×10^{-10} N. However, in an absence of other forces acting upon the horse and the girl, they should be drawn to one another with a force:

$$F = \frac{dP}{dt} = \frac{dv}{dt}(M+m) = \frac{GMm}{r^2}. \tag{4}$$

If we integrate (4) with respect to time, and then since $v = \frac{dr}{dt}$, we can integrate it again with respect to time and rearrange for t to find the time it takes for them to reunite:

$$\frac{t^2}{2} = \frac{M+m}{GMm}\left[\frac{1}{3}r^3\right]_0^{100}, \tag{5}$$

$$t = \sqrt{r_i^3 \frac{2(M+m)}{3GMm}}. \tag{6}$$

Using this equation and substituting in $r_i = 100$, we find that the time taken for the horse and girl to come together under only the influence of gravity is $t = 1.68 \times 10^7$ seconds, or 194 days. This time is likely to be longer than both of their lifetimes in this environment, so unfortunately their bond is not quite strong enough.

References

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