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Lean on Me – Can Bill Withers stay true to his word?

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Abstract

This paper aims to calculate the amount of force that Bill Withers would have to exert in order to support the people that have listened, or are listening to his song, *Lean on Me,* based upon the analytics from YouTube and Spotify. This will consider two scenarios: one in which everyone who has ever listened to his song leaned at him all at once, and another where all the concurrent listeners are leaning on him at any given time. These will be modelled through the use of component forces. The force that Bill Withers would have to exert when everyone leans on him at once, is calculated to equal 2.27×10^{10} N. The total force for the listeners at any given time is determined to be 19560 N.

Introduction

The song *Lean on Me* was released in April 1972, by the American singer songwriter Bill Withers [1]. In the song Bill Withers sings "lean on me, when you're not strong". This raises the question; what if everyone that has listened, or is currently listening to the song took him up on his promise? This paper will investigate the force Bill Withers would have to exert in order to support all the people who need "someone to lean on".

As of the time this paper was written, the most viewed version of the song on YouTube, uploaded on the 19th August 2008, has accumulated a total of 89,802,468 views [2], and 59,688,923 plays [3] on Spotify. This paper will base its investigation from these figures.

The model

Bill Withers will be modelled as uniform, smooth and vertical, and the people that are leaning on him will be assumed to act as a single mass, with the shape of a rectangle, as seen in figure 1. The single mass will have a uniform weight distribution and a centre of mass at the centre of the object. This paper will not consider the issues associated with such a high mass density.

In order for Bill Withers to offer maximum support and comfort to his listeners, he will be modelled to support the single mass of people on his shoulder. It will be assumed that no sliding takes place. Bill Withers is 1.87 m tall [4], and the average person's height, representative of the constituents of the single mass being modelled, is 1.7 m tall [5]. If the average head height, 23.9 cm [6] and neck length, 11 cm [7], for men, are taken away from Bill Withers' height, the height that his shoulders are off the ground is found to be 1.52 m.

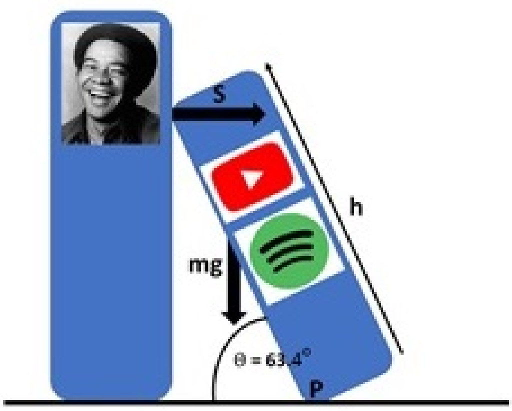

Figure 1 – Component force diagram, highlighting Bill Withers, and the single mass of people leaning on him, based on YouTube and Spotify records. The forces acting around the pivot point P are also shown, along with the height and angle of the single mass. [2, 3, 8]

Using this information and trigonometry, the angle that the single mass of people must be leaning at to lean on his shoulder can be calculated to equal 63.4°, as per equation 1.

$$\theta = \sin^{-1}\left(\frac{Height\ of\ Shoulder\ from\ ground}{Height\ of\ average\ person}\right) \quad (1)$$

In order to calculate the force that Bill Withers has to exert to hold the single mass of people, the torque around the pivot point, P has to be considered. The only two forces that influence the torque around this point are; the weight of the object, mg, and the reaction force from Bill Withers to the single mass, S. The mass of the single mass is acting in an anti-clockwise direction and the reaction force is acting in a clockwise direction. If anti-clockwise is said to be positive equation 2 can be established [9]:

$$mg \times \left(\frac{h}{2}\right) \times cos\theta - S \times h \times sin\theta = 0 \quad (2)$$

Where m is the mass of the single mass, g is the gravitational constant, θ is the angle of the single mass leaning against Bill Withers, h is the height of an average person, and S, is the reaction force between Bill Withers and the single mass. The system will be in equilibrium, hence why the total torque is equal to zero in equation 2.

This equation can be rearranged in order to work out S, equation 3.

$$S = \frac{mg \times \left(\frac{h}{2}\right) \times cos\theta}{h \times sin\theta} \quad (3)$$

The total number of listens/views with YouTube and Spotify combined is equal to 149,491,391. Since the mass of the average person is equal to 62 kg [10] the total mass, m, is equal to 9.27×10^{9} kg. The gravitational constant is equal to 9.81 ms^{-2}, and the average height of a person, h, that will be used is 1.7 m.

Using these values, as well as the angle, 63.5° the amount of force that Bill Withers would have to exert to support all the people who have listened to his song is equal to 2.27×10^{10} N . This amount of force is 680 times the launch thrust of a Saturn V rocket [11].

To estimate the number of concurrent listeners at any given time, it is assumed that each YouTube view is an individual listening to the entire duration of the song. Dividing the number of minutes the song has been uploaded for (5018400 [2]), by the duration of the song (4:19 [2]) will give the total number of times the song could have been played in this timeframe:

$$possible\ plays = \frac{t_{total}}{t_{song}} \quad (4)$$

This gives a value of 1162564 plays. It is assumed that the number of concurrent listeners is spread out evenly over the total time. Dividing the total number of views by the number of possible plays will give the number of concurrent listeners. This results in a value of 77 concurrent listeners on YouTube. Applying this ratio of total plays to concurrent plays for Spotify gives 52 concurrent listeners. In total for YouTube and Spotify combined, this is 129 listeners at any given time.

If equation 3 is applied to this number of people, the total force that Bill Withers must exert at any given time is equal to 19560 N. This would be the equivalent of supporting the entire weight of approximately 1 and a half Black Rhinos at all times [12].

Conclusion

In conclusion, if Bill Withers was to hold up the total weight of all the people who have ever listened to his song on YouTube and Spotify, he would have to exert a force equal to 2.27×10^{10} N, enough to launch the Saturn V rocket into orbit 680 times. The force that would have to be exerted at any given time, for concurrent listeners, was found to equal 19560 N, which is the same as constantly supporting approximately 1.5 black rhinos. The likelihood of either of these scenarios in reality is, unsurprisingly, very unlikely.

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