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Cinematic or Scientific: Defying Impact

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Abstract
In *Wicked*, Elphaba claims that no one in all of Oz can "bring her down". This paper investigates if this claim can be physically justified by modelling all residents of Oz as a single point mass tackling Elphaba simultaneously. Using classical mechanics, the total mass and momentum of Ozites are calculated and the minimum velocity Elphaba would need to achieve to withstand this tackle is estimated. The results show that such a velocity is far more than what is achievable with modern technology and if it were to be achievable the g-force experienced would be fatal.

Keywords: *Musical; Physics; Mechanics; Biomechanics; Wicked*

Introduction

In the popular musical now also movie, *Wicked* [1], the protagonist Elphaba claims that "nobody in all of Oz. No wizard that there is or was, is ever gonna bring me down". But to what extent could that be true? In this paper, I will explore the mechanics behind every current resident of Oz tackling Elphaba all at once, assuming their total mass as single point mass [2]. I will aim to answer the question "How much velocity would Elphaba have to generate in order to withstand a tackle from all of Oz?"

It is stated that the population of Oz is around half a million people (500,000) [3], for the sake of simplicity we will assume this number to be completely accurate. The general term for a resident of Oz is an "Ozite", though there are different groups of Ozites that live within Oz such as: Winkies, Munchkins, Quadlings and Gilikins [3]. It is never specified if these are sub-species of *Homo Sapiens* or if they in fact just different ethnic groups. Therefore, it will be assumed that these are different ethnic groups and thus have the same average mass.

Total mass of Oz

The average mass of a human is 62kg [4], since there is no mention of masses of Ozites, we will assume this is also the average mass of the Ozites. To find the total point mass of all of the Ozites we will use the equation [2]:

$$M = nm_{avg}, \quad (Eq^n\ 1)$$
$$M = 500{,}000 \times 62kg = 3.1 \times 10^7\ kg,$$

where M is the total point mass of all of Ozites in Oz, n is the total population of Oz and m_{avg} is the average mass of a person.

Momentum

Assuming that the average running speed of a person is 5ms^{-1} [5], then the total momentum that Elphaba would need to stop in order to withstand the tackle is [3]:

$$p = Mv, \quad (Eq^n\ 2)$$
$$3.1 \times 10^7 \times 5 = 1.55 \times 10^8\ kg \cdot ms^{-1},$$

where p is momentum, M is the total mass of all of Ozites, and v is the average running speed. Momentum is conserved in collisions [2] and determines the impulse needed to bring a moving mass to rest.

In order for Elphaba to not get knocked over, she doesn't necessarily need to have a higher mass than the Ozites, but she must have a greater momentum. She can do this by being significantly faster than the Ozites despite her mass being much less. Thus, we can say that we can find the velocity that Elphaba needs to be travelling using [2]:

$$v_e \geq \left(\frac{M}{m_e}\right) v_o, \quad (Eq^n\ 3)$$

where v_e is the velocity that Elphaba must reach, M is the total mass of all Ozites as a point mass, m_e is the mass of Elphaba and v_o is the velocity of the Ozite point mass. The condition of equation 3 represents that Elphaba will have a momentum either greater than or equal that that of the Ozites, ensuring that she is not reversed or bought to rest upon collision.

Since there is no data on Elphaba's mass we will be using the same number of 62kg as her assumed mass (m_e):

$$v_e \geq \left(\frac{3.1 \times 10^7}{62}\right) 5 = 2.5 \times 10^6\ ms^{-1}$$

This means that in order for Elphaba to withstand a tackle from all of Oz she must be travelling at 0.83% of the speed of light, not something achievable with modern technology.

G-force

To assess whether or not this velocity would be survivable (assuming it was achievable), the acceleration that Elphaba would need to achieve a velocity of 2.5×10^6 ms^{-1} is considered.

To give her the best chances, we will assume that she begins to accelerate just as the Ozites become visible in the horizon, assuming the curvature of Oz to be the same as that of Earth. To find the distance away that they would be, we will use the equation [6]:

$$d \approx \sqrt{2Rh}, \quad (Eq^n\ 4)$$

where, d is the minimum distance that the Ozites will need to be for Elphaba to see them on flat ground, R is the curvature of Earth (6.37×10^6 m) [7] and h is the height of Elphaba (1.54m).

$$d \approx \sqrt{2 \times (6.37 \times 10^6) \times 1.54} = 4429.4\ m$$
$$d \approx 4.4\ km$$

This means we can assume that Elphaba can begin acceleration at 4.4km separation. For simplicity we will assume that this is not changed by the velocity of the Ozites also running towards Elphaba [8]:

$$a = \frac{v_e^2}{2s}, \quad (Eq^n\ 5)$$
$$a = \frac{(2.5 \times 10^6)^2}{2 \times (4.4 \times 10^3)} = 7.1 \times 10^8\ ms^{-2},$$

where a is the average acceleration, v_e is Elphaba's final velocity and s is the distance between Elphaba and the Ozites.

To convert this to g-force we will divide by the Earth's gravitational constant, 9.81ms^{-2} [2, 7]:

$$g\text{-}force = \frac{a}{g}, \quad (Eq^n\ 6)$$
$$g - force = \frac{7.1 \times 10^8}{9.81} = 7.2 \times 10^7\ g,$$

where a is acceleration of Elphaba and g is the Earth's gravitational constant.

This value is 3.3×10^5 times more than the highest g-force ever experience and survived (214 g) [9].

Conclusion

Overall, in order for Elphaba to withstand a tackle from all of Oz, she would need to reach speeds that are far greater than those achievable with modern technology [2]. However, if this limitation is ignored due to the presence of "magic" within the narrative, the g-forces needed to achieve such velocity would be fatal [9]. Meaning that in preventing Oz from bringing her down, Elphaba would ultimately bring herself down instead, but maybe "magic" will protect her from that too [2,9].

References

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