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How far could Elastigirl launch Jack-Jack?

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Abstract
Elastigirl from 'The Incredibles' has superhuman elasticity, amongst other special powers. This elasticity could enable her to act as a catapult and launch different objects considerable distances. This paper determines that Elastigirl's elastic potential energy, when fully stretched, is 17000 J. When acting as a catapult to launch her son, Jack-Jack, this is converted to kinetic energy and transferred to him. This could result in the super-baby travelling 255 m in the air before landing, if launched at a 45° angle.

Keywords: *Film; Physics; Mechanics; Projectile motion; The Incredibles; Elastigirl; Jack-Jack*

Introduction

Disney Pixar's 'The Incredibles' depicts the life of a family of 'Supers', all of whom possess special powers. Helen Parr, also known as Elastigirl, and her husband Mr Incredible have three children, Violet, Dash, and baby Jack-Jack. Elastigirl's powers include superhuman elasticity, agility, and durability [1], which could make her a suitable catapult. The extent of these catapulting abilities will be assessed in this paper, which calculates her elastic potential energy and uses this to determine how far she could launch her son, Jack-Jack.

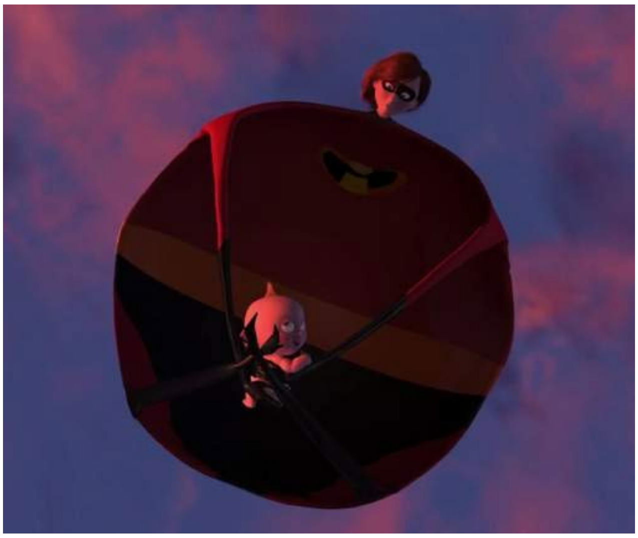

Figure 1 – Elastigirl demonstrating her powers to transform into a parachute for her son, Jack-Jack [2].

Elastic Potential Energy

The elastic potential energy, U, stored in an object can be calculated using the formula:

$$U = \frac{1}{2}k\Delta x^2, \quad (eqn. 1.0)$$

where Δx is the change in position, or length in this case, and k is the spring constant, where, according to Hooke's law:

$$F = k\Delta x. \quad (eqn. 1.1)$$

Substituting $eqn. 1.1$ into $eqn. 1.2$, it is possible to obtain an expression for U that does not require the spring constant:

$$U = \frac{1}{2}F\Delta x. \quad (eqn. 1.2)$$

The following formulae for force, F, tensile stress, σ, and tensile strain, ε, can be substituted into $eqn. 1.2$:

$$F = \sigma A, \quad (eqn. 1.3)$$
$$\sigma = E\varepsilon, \quad (eqn. 1.4)$$
$$\varepsilon = \frac{\Delta L}{L}. \quad (eqn. 1.6)$$

This is rearranged to give:

$$U = \frac{1}{2}E\left(\frac{\Delta L}{L}\right)A\,\Delta x, \quad (eqn. 1.7)$$

where E is the Young's Modulus, L is the length, and A is the cross-sectional area.

Since Elastigirl has shown the ability to shape-shift by means of her elasticity [1], in this investigation she will be modelled as a cuboid with a thickness of 1 mm and a length of 30 m, as this is the reported limit to her elasticity [3]. The width of the model is based upon the width of her shoulders. Assuming that Elastigirl's shoulders are of average width for an American woman, the width of the model is 36.7 cm [4]. From this, the cross-sectional area, A, can be calculated:

$$A = 0.367 \times (1 \times 10^{-3}) = 3.67 \times 10^{-4} m^2$$

A previous paper in the Journal of Interdisciplinary Science Topics, which calculated the force required to stretch Elastigirl's arm [5], suggested that the Young's Modulus of 'normal' dermis skin, 200 kPa [6], would be a good enough approximation of the Young's Modulus of Elastigirl, so that same approximation has been applied here. Elastigirl is also 1.73 m tall [1], so that would make:

$$\Delta L = 30 - 1.73 = 28.27m$$

Substituting these values into $eqn. 1.7$ above would give the elastic potential energy:

$$U = \frac{1}{2} \times (200 \times 10^3) \times \left(\frac{28.27}{1.73}\right) \times (3.67 \times 10^{-4}) \times 28.27 = 16953.97655\, J$$

$$U = 17000\, J$$

Jack-Jack's velocity

In this model, it is assumed that all of Elastigirl's elastic potential energy is converted to kinetic energy the moment the catapult is released. Therefore, Jack-Jack would have 17000 J of kinetic energy. From this, and Jack-Jack's reported mass of 13.6 kg [7], it is possible to calculate his initial velocity, v_0:

$$E_K = \frac{1}{2} m v^2$$

$$v_0 = \sqrt{\left(\frac{2E_K}{m}\right)}$$

$$v_0 = \sqrt{\left(\frac{2 \times 17000}{13.6}\right)} = 50\, ms^{-1}$$

Distance launched

It is assumed that Jack-Jack is launched from ground level at a 45° angle, as this angle maximises the distance launched from a catapult [8]. Jack-Jack can be treated as a projectile and his path of flight can be modelled as a parabola. Calculating the horizontal component of the initial velocity, v_{0x}, and vertical component of the initial velocity, v_{0y}:

$$v_{0x} = 50 \cos(45) = 25\sqrt{2} = 35.35533906\, ms^{-1}$$

$$v_{0y} = 50 \sin(45) = 25\sqrt{2} = 35.35533906\, ms^{-1}$$

At the maximum height of the parabola, the vertical component of velocity will be zero. This can be used to calculate the time, t, at this maximum height:

$$t = \frac{v_y - v_{0y}}{a}$$

$$v_y = 0\, ms^{-1}, v_{0y} = 25\sqrt{2}\, ms^{-1}, a = -9.81\, ms^{-2}$$

$$t = \frac{0 - 25\sqrt{2}}{-9.81} = 3.604010098\, s$$

From this, the horizontal distance at the highest point can be found:

$$d = vt$$

$$d = 25\sqrt{2} \times 3.604010098 = 127.420999\, m$$

Since parabolas are symmetrical, this value can be multiplied by 2 to give the total distance:

$$S = 2d = 2 \times 127.420999$$

$$S = 254.841998\, m = 255\, m$$

Conclusion

Using this simplified model, if Elastigirl were to be stretched out fully, she would have an elastic potential energy of 17000 J. Using her as a catapult, this energy would be transferred to Jack-Jack in the form of kinetic energy, resulting in an initial velocity of 50 ms^{-1}. This means that he would reach 255 m before landing. However, this paper makes many assumptions, including neglecting air resistance, which could result in a difference in the observed distance launched.

References

[1] The Incredibles Wiki (2021) *Elastigirl.* Available at: https://the-incredibles.fandom.com/wiki/Elastigirl [Accessed: 7th February 2023].

[2] Bird, B. (2004) *The Incredibles.* [Film] Directed by Brad Bird. Walt Disney Pictures. First released 26th November 2004.

[3] Pixar Wiki (2022) *Helen Parr.* Available at: https://pixar.fandom.com/wiki/Helen_Parr [Accessed: 7th February 2023].

[4] Healthline (2018) *What's an Average Shoulder Width?* Available at: https://www.healthline.com/health/average-shoulder-width [Accessed: 15th February 2023].

[5] Tobin, K. (2017) *The Force Required to Stretch Elastigirl's Arm,* Journal of Interdisciplinary Science Topics, vol.6. Available at: https://journals.le.ac.uk/ojs1/index.php/jist/article/view/726/

[6] Li, C., Guan, G, Reif, R., Huang, Z & Wang, R.K. (2011) *Determining elastic properties of skin by measuring surface waves from an impulse mechanical stimulus using phase-sensitive optical coherence tomography*, Journal of the Royal Society Interface, vol.9. DOI: 10.1098/rsif.2011.0583

[7] The Incredibles Wiki (2021) *Jack-Jack Parr.* Available at: https://the-incredibles.fandom.com/wiki/Jack-Jack_Parr [Accessed: 15th February 2023].

[8] Montoya, D. (2018) *How to Make a Catapult Launch Farther.* Available at: https://sciencing.com/make-catapult-launch-farther-7784454.html [Accessed: 8th March 2023].