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# A4_4 Jack-Jack Keeps Falling On My Head

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**Abstract**

In The Incredibles, the antagonist, Syndrome, kidnaps the super human baby, Jack-Jack, by flying up towards a plane by using rocket-propelled boots. Jack-Jack attempts to escape him by turning his entire body into metal, causing Syndrome to drop rapidly due to the sudden change in mass. In this paper, we chose the metal platinum, and focus on the forces Syndrome will experience after Jack-Jack changes into platinum. We find that they would hit the ground with a velocity of around $38.7ms^{-1}$ and an impact force of $268MN$, which is 500x to that of a car crash.

## Introduction

The Incredibles is a film based around a family of superheroes who each have their own special abilities, such as super-human strength, or the ability to turn invisible. This paper focuses on one power in particular that the baby of the family, Jack-Jack, exhibits, where he is able to turn his entire body into solid metal.

We examine what force of Jack-Jack changing into metal would induce, namely in the scenario where he is being kidnapped by the film's antagonist, Syndrome, who is holding Jack-Jack while flying upwards. We then calculate the result of this force, if they were allowed to fall with a constant acceleration and hit the ground from a low-flying height. In the film, Syndrome manages to overcome the force change by increasing his thrust, but this paper assumes he was already at maximum thrust prior to this.

## Theory

In order to calculate the force for a baby made of metal, the volume of Jack-Jack must be known. This is found using Eq.(1),

$$V = \frac{M}{\rho} \tag{1}$$

where $V$ and $M$ are the volume and mass of Jack-Jack respectively, and $\rho$ is the density of a human. Once the volume is known, Eq.(1) can then be rearranged for M in order to calculate his mass once he is made of metal. $\rho$ is now not the density of a human, but the density of platinum.

The velocity that Jack-Jack and Syndrome are initially travelling (with an assumed height) is,

$$u = \frac{h}{t} \tag{2}$$

where $u$ is the velocity, $h$ is height travelled and $t$ is time taken to reach said height.

The difference in force of the pair before and after he turns into metal is then found using,

$$\Delta F = \Delta M a = m_2 a - m_1 a \tag{3}$$

where $\Delta F$ is the difference in force, $m_2$ is the combined masses of Syndrome with metal Jack-Jack, and $m_1$ is the combined mass of Syndrome

with normal Jack-Jack, and $a$ is gravitational acceleration. After the transformation, Newton's 2nd law is rearranged for $a$, where $F$ is $\Delta F$, and $m$ is $m_2$, to find the new, constant acceleration due to the change in force.

After he turns into metal, the distance travelled until peak height, where vertical velocity is zero, is reached is found using,

$$s = \frac{(v^2 - u^2)}{2a} \tag{4}$$

where $s$ is the distance and $v$ is the final velocity. This is combined with an assumed height to find the total distance the pair will fall once Jack-Jack turns into metal. Eq.(4) is then rearranged for $v^2$, in order to find the velocity that they will hit the ground with.

Finally, the impact force that Syndrome and Jack-Jack hit the ground can be found using,

$$F = \frac{\frac{1}{2}mv^2}{d} \tag{5}$$

where $F$ is the impact force and $d$ is the compression that the ground sinks by upon impact.

**Results**

Using a mass of $13kg$ [1] and density of $1010kgm^{-3}$ [2], the volume of Jack-Jack is found using Eq.(1) to be $0.0129m^3$. Assuming the metal is platinum with a density of $21,450kgm^{-3}$ [3], the new mass, of Jack-Jack as a metal is found to be $\approx 276kg$.

The velocity of the pair at time of transformation is found through Eq.(2) to be around a constant $7.7ms^{-1}$, assuming a height travelled of $100m$ and travel time of $13s$ [4].

The combined masses of Jack-Jack and Syndrome [5], $m_1$ and $m_2$, are found to be $96kg$ and $359kg$ respectively. Substituting into Eq.(3), $\Delta F$ is found to be $2580N$, with the assumption net force prior to transformation is $0N$. Using Newton's 2nd law rearranged for $a$, we find that the pair will begin to accelerate towards the Earth at around $7.18ms^{-2}$.

With an assumed initial height of 100m and a further height found using Eq.(4) of $4.12m$ for transition of Jack-Jack to peak height, the total height is found to be $\approx 104m$. The final velocity from falling to the ground is then found using a rearranged Eq.(4) to be $38.7ms^{-1}$.

Finally, the impact force with which the pair hit the ground with is found to be around $268MN$ using Eq.(5). We assume a small compression of 0.1cm as they are in a suburban neighbourhood so therefore they will likely land on concrete which does not compress easily.

**Conclusion**

In this paper, we assume no wind resistance upon falling. This is done as the calculations are beyond the scope of the paper. However, if it had been considered, the force calculated would be reduced due to the contesting drag force. The metal that Jack-Jack transforms into was assumed as it was not documented anywhere, so using different metals could vary the result significantly. Our value of $268MN$ is around 500 times that of a car crash. This is high, but due to the assumptions we've made, we consider it to be a reasonable conclusion.

**References**


[1] `https://www.writeups.org/jack-jack-the-incredibles-baby/` [Accessed November 19, 2021]

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[3] `https://hypertextbook.com/facts/2004/OliviaTai.shtml` [Accessed November 19, 2021]

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