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A3 7 Super Mario's Super Muscle

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Abstract

Within this paper, the authors investigated the presumed strength of Super Mario's legs given the simple fact that he is capable of breaking bricks with his jumping power. Also accounting for known values of extreme gravity displayed in the Mario games, we found he should be capable of jumping 294 m within game or over 2.7 km on Earth!

Introduction

Previous studies have been done into the force of Mario's jumps given the gravitational model in the Mario games measuring the rate of acceleration due to gravity and the observed "standard" jump found using his supposed body height and pixel length [1]. In this paper we draw on these ideas but calculate Mario's possible jump strength via different methods to compare to previous findings.

We will investigate the force in Mario's jump in order to break stacks of bricks directly above him. The jump must carry enough kinetic energy at the point of contact to transfer this and break the block. Therefore, in this paper we investigate the implications of being able to perform this feat. The main focus investigated is the maximum height Mario should be capable of jumping if his trajectory was not impeded by the bricks, calculated given a sufficient amount of transferable energy at the point which he breaks the block.

Brick strength

Firstly, for an estimate as to the strength which Mario jumps with, we must know the minimum force required to be able to break the bricks. For simplicity we take an average level layout where the block is placed most commonly 20 pixels above Mario's head. Using accepted measurements of Mario's height [2], we find he is 155 cm tall and 89 kg in mass and therefore given he is 32 pixels tall, the bricks are 97 cm above him and 82 cm wide in all dimensions.

One could assume the block is a homogeneous, isotropic material as it is the smallest customisable scale in the game, however since you can see individual bricks, we assume it can be broken due to shear stress along the mortar lines. For solid brick, the force to break it would relate to the compressive strength, F_b, of the material which we take to be a relatively conservative estimate of 20 MPa [3]. The corresponding value for Mortar, F_m, would be 4 MPa [4]. Given the known compressive strengths of both materials, we can substitute values into equation (1) below [5] for breaking force F and with constants K, α and β corresponding to standard brick as in previous works (0.5, 0.7 and 0.3 accordingly).

$$F = K \cdot (F_\mathrm{b})^\alpha \cdot (F_\mathrm{m})^\beta, \quad (1)$$

By accounting for the weaker structural integrity caused by the mortar, we find a threshold breaking force of 6.2 x 10^6 N.

Jump strength

Given our calculated value for breaking force, we must now investigate the requirements for Mario to be able to carry that force while mid-jump at a height of 97 cm. This requires a combination of projectile motion and prior research into the gravity acting on Mario's planet.

Previous studies have found that Mario's standard jump with nothing restricting him overhead is roughly 5 times his height and using frame by frame analysis of his jumps, finds that he falls this distance in just 0.5 s. Therefore the gravity acting in Super Mario is 91.28 m s^{-2} [1].

This alone makes his standard jumps extremely impressive as that is over 9 x Earth's gravity. To investigate maximum height we predict Mario is physically capable of jumping however, we need to consider energy transfer from kinetic to gravitational potential as he carries out his jump. The kinetic energy at launch and later, transfer to potential energy, are given as below.

$$E_{\mathrm{k0}} = \frac{1}{2} \cdot m \cdot v_0^2, \tag{2}$$

$$E_{\mathrm{pot}} = m \cdot g \cdot h, \tag{3}$$

Therefore at a given height, the remaining kinetic energy is the initial kinetic energy - the potential. To convert between kinetic energy and force available to transfer to an object, we rearrange and substitute a derivation of momentum $F = mv/t$ and the equation for kinetic energy (2) thus finding,

$$F = \frac{(2m \cdot E_{\mathrm{k0}})^{1/2}}{\Delta t}, \tag{4}$$

Where Δt represents the time taken in the collision in which momentum transfer occurs, which is taken as $0.82/v_0$ as that is the time taken to pass that distance if the block was not there. We now have all our information, so substituting E_k at a given height, h, into equation (4), and rearranging for v_0, we can find the balance point where v_0 and Δt satisfy all equations. Performing these calculations, we find a launch velocity of 232 m s^{-1}.

Using basic projectile motion, we find Mario's maximum jump given this information on both his planet and if he was on earth. This is found via equation (5).

$$H_{\max} = \frac{v_0^2}{2g}, \tag{5}$$

So for his gravity of 91.28 m s^{-2}, we find a maximum jump of 294 m and if he was on Earth, Mario would be able to jump a whopping 2.7 km!

Conclusion

In conclusion, due to the overlooked nature of how difficult it is to break bricks by Mario's game developers, we find that he should be capable of jumping far higher than he ever displays within the game at roughly 294 m. Furthermore, due to inconsistencies with gravity acting in the games, we estimate if he was placed on Earth, he should be able to jump over 2.7 km.

References

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