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P5_5 Cloudy With a Chance of Meatballs

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Abstract

In Sony Picture's 'Cloudy with a Chance of Meatballs', a sentient machine rains down meatballs upon unsuspecting people causing havoc. We investigate, in this paper, the effect such meatballs would have on people, and show that smaller meatballs could cause bodily harm, and larger meatballs could destroy objects as large as cars. However it is still unknown whether a meatball would be able to withstand falling through the atmosphere.

Introduction

We investigate in this paper how harmful it would be to have meatballs falling from the sky instead of rain by calculating terminal velocities and kinetic energies of the respective meatballs, we also investigate how different sized meatballs would have different effects.

Theory and Results

For the purpose of modelling meatballs as raindrops we shall assume they are falling from a height of 2 km which is where low level clouds are found [1]. We shall also assume that the meatball is the same size as a tennis ball, and experiences the same drag forces as a tennis ball. In order to calculate the kinetic energy of the meatball we need to first calculate how fast it is moving. We are including the resistances of air so the meatball will reach a terminal velocity where it is being accelerated by gravity at the same rate the drag force is decelerating it. This is given by the following equation,

$$v_t = \sqrt{2mg/p_a A C_d}, \quad (1)$$

Where v_t is the terminal velocity, m is the

mass of meatball, g is the acceleration due to gravity, p_a is the density of air, A is the projected area of the meatball, and C_d is the drag coefficient of the meatball [2].

We are assuming our meatball is the same size as a regulation use tennis ball, which has a radius of $r = 3.43$ cm [3], and a drag coefficient of $C_d = 0.7$ [4]. We will also be assuming the density of the meatball to be the same as the density of lean beef $p_b = 1033$ kgm⁻³ [5]. For the density of air we shall assume it is a constant value of $p_a = 1$ kgm⁻³, even though in reality it will increase by approximately 20% [6] as the meatball travels towards the earth's surface. The mass of the meatball is given by $m = p_b V$, where the volume is $V = (4/3)\pi r^3$, substituting our radius r and density p_b gives a mass of $m = 0.175$ kg.

The projected area of the meatball is equivalent to the area of a circle with the same radius, given by $A = \pi r^2$, using our radius of $r = 3.43$ cm gives an area of $A = 0.00370$ m²

We can now substitute all these values into Equation 1 to calculate a terminal velocity of $v_t = 36.4$ ms⁻¹. The kinetic energy of the meatball can be obtained using $E_k = (1/2)mv_t^2$,

substituting our values of $m = 0.175$ kg and $v_t = 36.4$ ms⁻¹ gives $E_k = 116$ J.

Using the same method we can also look at meatballs of different size, for example if we use the exact same method but use a radius of $r = 1$ m, the meatball would achieve a terminal velocity of $v_t = 196$ ms⁻¹, and therefore have a kinetic energy of $E_k = 83$ MJ

Discussion

For the tennis ball sized meatball, its effects would definitely be noticeable compared to regular rainfall, as for example a raindrop of radius 0.5 mm would have a terminal velocity of approximately 10 ms⁻¹ [7] and therefore a kinetic energy of only 26 μ J [9]. This means that our tennis ball sized meatball is the equivalent of approximately 1 million drops of rain. Comparatively a small calibre .22lr bullet has approximately 170 J of energy when it is fired [8], which is approximately 1.5 times greater than the energy of the tennis ball sized meatball, making being hit by one quite unpleasant.

However for our larger meatball that has a radius of $r = 1$ m, its effects would be catastrophic, as 83 MJ of energy is the equivalent of 2 kg of TNT [10] being dropped down onto you, which is easily enough to destroy a car [11], and if multiple of these monster meatballs were raining down, then it is safe to say that serious damage would be inflicted on any city unfortunate enough to be under them.

It is unknown whether a meatball would be able to withstand the previously calculated speed of 10 ms⁻¹ and stay intact, as the drag force experienced may be enough to tear it apart into smaller chunks, this requires further research. If it can not stay intact then our assumption of the meatball staying as a sphere for the whole duration of the fall is incorrect.

Conclusion

We conclude, that a tennis size meatball would certainly be dangerous to people if it could stay intact during its whole descent down from the sky, however it is unknown whether this is pos-

sible or not. If it does disintegrate, its energy would be spread out instead of concentrated on a point of impact. Also, if the meatball was significantly larger, and could stay intact, it would have the destructive power of several kilograms of TNT, which would most definitely pose a threat to people.

References

- [1] [http://ww2010.atmos.uiuc.edu/\(Gh\)/guides/mtr/cld/cldtyp/home.rxml](http://ww2010.atmos.uiuc.edu/(Gh)/guides/mtr/cld/cldtyp/home.rxml)
- [2] <https://www.grc.nasa.gov/WWW/K-12/airplane/termv.html>
- [3] ITF approved tennis balls, classified surfaces - a guide to products and test methods, 2019
- [4] Review of tennis ball aerodynamics, Rabinindra Mehta¹, Firoz Alam² and Aleksandar Subic, 2008
- [5] Physical and Thermal Properties of Ground Beef During Cooking, Z.Pan, R.Paul, 2001
- [6] https://www.engineeringtoolbox.com/standard-atmosphere-d_604.html
- [7] <https://hypertextbook.com/facts/1999/MichaelKodransky.shtml>
- [8] <https://www.mcarbo.com/22LR-Ballistics-Chart>
- [9] <https://wxguys.ssec.wisc.edu/2013/09/10/how-fast-do-raindrops-fall/>
- [10] <http://www.unitconversion.org/energy/tons-explosives-to-gigajoules-conversion.html>
- [11] Blast effects of external explosions, Isabelle Sochet, Sep 2010