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P2_6 The Breakfast Club

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Abstract

This paper investigates the sonic boom generated by crunchy foods. Specifically, the force required to tip over an empty cereal box 0.1 m from a person's mouth is calculated to be 8.37 x 10^{-10} N. It would take the force of 29 million people crunching in unison to generate the required 2.45 x 10^{-2} N to tip over the box.

Introduction

The human jaw is a powerful muscle and when eating, in terms of pressure per single burst of activity, it is the strongest muscle in the body [1]. Crunchiness and crispiness differ as the former is quickly atomised while the latter provides a sustained resistance to chewing. The sound produced by chewing can be assessed and the threshold frequency between these two sensations occurs at 1.9 kHz where crunchiness takes place below this limit. Crunching breaks food at speeds of ~300 ms^{-1} which matches the speed of sound, creating a small sonic boom [2]. We aim to investigate the force exerted by these pressure waves on an empty cereal box at breakfast time.

Theory

Sound levels in decibels (β) can be converted to intensities with the following equation

$$\beta = 10log_{10}\left(\frac{I}{I_0}\right), \quad (1)$$

where I is the intensity of the sound and I_0 is the reference intensity at the threshold of human hearing at a value of 10^{-12} Wm^{-2} [3]. As a sound travels through space, the intensity decreases due to the inverse square law as shown by

$$I = \frac{P}{4\pi r^2}, \quad (2)$$

where P is the power and r is the distance from the source which is the mouth in this case. The force imparted at a given distance can then be calculated with

$$F = \frac{P}{v}, \quad (3)$$

where v is velocity (300 ms^{-1}). In order to calculate the force required to tip an object over, the torque due to the weight of the object and the torque due to the applied force can be equated giving

$$F = \frac{mgL}{2h}, \quad (4)$$

where m is the mass of the object, g is the gravitational constant, L is the vertical length of the object and h is the height at which the force is applied.

Results

A typical crunch generated by a person eating with their mouth open has a sound level value of 63 dB [4]. Using equation 1, the intensity of a crunch can be calculated as 2 x 10^{-6} Wm^{-2}. Assuming the cereal box is 0.1 m away from the source, the power at the box can be calculated using equation 2 and equals 2.51 x 10^{-7} W. The force imparted on the cereal box from a single crunch can then be calculated as 8.37 x 10^{-10} N. Equation 4 can be used to determine the required force to tip over a box of mass 20g and dimensions 40cm x 30cm x 5cm is 2.45 x 10^{-2} N assuming the force acts in the middle of the box (h = 20cm).

Discussion and Conclusion

The force imparted on an empty cereal box, 0.1 m away, by a sonic boom generated due to crunching was calculated to be 8.37×10^{-10} N. The required force to tip this box over was calculated to be 2.45×10^{-2} N, significantly greater than the force from the pressure wave. To simplify calculations, any attenuation or absorption that occurs when exiting the mouth or travelling through the air is neglected. The force of the sonic boom is therefore miniscule and it would take 29 million people, almost half the population of the UK [5], crunching in unison to impart enough force to tip the box over.

References

[1] http://www.stufftoblowyourmind.com/podcasts/nose-tail-mysteries-mouth/ (12/11/14)

[2] Joel Beckerman (2104), The Sonic Boom: How sound transforms the way we think, feel, and buy, Houghton Mifflin.

[3] http://hyperphysics.phy-astr.gsu.edu/hbase/sound/intens.html (12/11/14)

[4] http://www.randombio.com/foodsound.html (12/11/14)

[5] http://www.ons.gov.uk/ons/rel/pop-estimate/population-estimates-for-uk--england-and-wales--scotland-and-northern-ireland/2013/index.html (12/11/14)