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A1_11 The Mexican Wave

J. Harrison, N. Carr, A. McCulloch, J. Whitaker

Department of Physics and Astronomy, University of Leicester, Leicester, LE1 7RH

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Abstract

In this paper a Mexican Wave is compared to and assumed to be similar to a wave on a string. The maximum energy able to be transferred along the 'Mexican Wave' is calculated to be 52 MW. This energy is compared to how much money could be saved for the stadium per hour, of £760, if the wave would be generated in the Leicester Tigers Stadium.

Introduction

On the off-chance in a stadium during a sports match, fans will group together and perform a Mexican Wave. Waves on a string act in a similar way due to factoring in the mass per unit length of the string to find out the power transmitted. This paper looks into how much power could be transmitted along a Mexican Wave if it were to be compared to a wave on a string and if the Leicester Tigers stadium could be powered by just the theoretical maximum power of the 'Mexican Wave' alone.

Theory and Assumptions

For the type of Mexican Wave used, it was assumed that every person involved simply throws their arms into the air and back down again within 1 s (T) this will be used as the time for one wavelength to occur. The average length of the arm (68 cm) [1] is used as the amplitude (A) for the wave and an assumption of one motion of arms is equivalent of a single full wavelength (λ) has been made. The wave equation is a negative cos function to incorporate the start of the wave being at the lowest point of the arms:

$$y(x,t) = -Acos(x - wt) \tag{1}$$

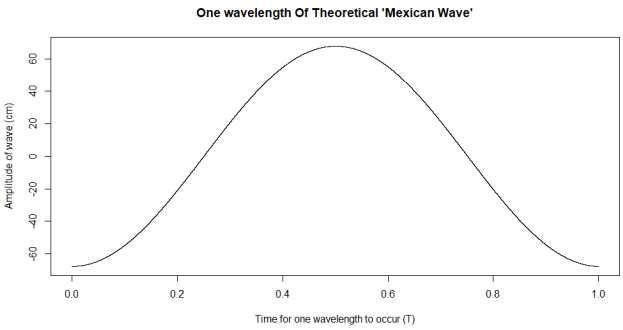

Figure 1: This figure shows an example of one full wave pattern for a single person throwing their arms into the air over 1 second.

Figure 1 shows that kinetic energy is generated from the person involved to move their arms to the maximum height and potential energy is used to bring their arms down. Therefore the energy in total is the sum of the kinetic and potential energy. The mass of both arms (8 kg) is used alongside the average male biacromial measurement (42 cm) [1] to give a mass per unit length of one person (μ) and an angular frequency (ω) can be calculated using 2π/T. The overall wave speed of this Mexican Wave is assumed to be the

same as the speed in which an average Mexican Wave travels around a stadium which is equal to approximately 12 m s^{-1} (ν) [2]. The maximum number of people (n) that could be seated in the Leicester Tigers stadium is also used to calculate the maximum power. All of the above values can be used in the power transmitted of a string equation stated:

$$P = 0.5n\mu\omega^2 A^2 \nu \tag{2}$$

This power equation is derived from P=E/T with energy being equal to the potential and kinetic sections of the waves summed after being integrated from a small section of wave. The total energy is therefore equal to E=$0.5\mu\omega^2 A^2 \lambda$ [3]. To be able to quantify how much energy is needed to operate the stadium the average electricity costs as of November 24th 2022 of 38p per kWh is used to calculate money saved [4].

Results and Discussion

The values used for evaluating a power for equation (2) are all values derived from an average human and a realistic scenario of a Mexican Wave. The values for mass and biacromial distance of the arms can be used to give a mass per unit length (μ) of 19 kg m^{-1}. An angular frequency (ω) of 2π is calculated and the maximum number of people able to fit inside the Leicester Tigers stadium is approximately 26,000 [5]. Values stated above can all be used in equation (2) to give a total power transmitted of 52 MW. This is the energy generated per second of Mexican Wave which could power a sports stadium for up to 25 hours given that 10 MW is used per 5 hours [6]. This total power transferred through the Mexican Wave would save upwards of £760 per hour.

Conclusion

If a Mexican Wave was considered to be a wave on a string and this energy could be harnessed by a stadium, Leicester Tigers fans would be reducing electricity costs for their local stadium and be supporting their team in more than just cheering. The assumption of a Mexican wave being an actual wave is a large assumption as the people performing it are not linked and energy is not transferred across, however, this may change in the future if we can invent a device capable of harnessing this energy or linking people in a efficient way. Moving this more into a realistic scenario energy could be generated by fans in many other ways, for example kinetic floors or using the heat produced.

References

[1] https://exrx.net/Kinesiology/Segments Accessed December 15, 2022

[2] https://www.exploratorium.edu/blogs/tangents/stadium-waves Accessed December 15, 2022

[3] http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/powstr.html Accessed December 15, 2022

[4] https://www.gov.uk/government/publications/energy-bills-support/energy-bills-support-factsheet-8-september-2022 Accessed December 15, 2022

[5] https://www.leicestertigers.com/mattioli-woods/mattioli-woods-welford-road Accessed December 15, 2022

[6] https://sportsmanist.com/how-much-electricity-do-stadiums-use Accessed December 15, 2022