Journal of Physics Special Topics

An undergraduate physics journal

P6_5 Pedalling Power

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November 8, 2018

Abstract

Since the devastating effects of burning fossil fuels has been brought to light, the urgency to find reliable, sustainable energy sources has become ever more prevalent. This article explores whether or not it would be possible to power Leicester for 24 hours by human pedal power alone. We found that this would be theoretically possible, but unrealistic in reality as it requires each citizen in Leicester to pedal for 7.7 hours at a constant velocity of 8.30 ms^{-1}. Also, we find that a human of mass 70 kg performing this task would burn 7890 kilocalories.

Introduction

Leicester is a city located in central England. By considering homes and businesses, we are going to investigate how many hours a day each member of the population would be required to pedal on a stationary bike to power the city for 24 hours. Energy loss due to friction is negated as it is negligible. Also, we will calculate how many calories an average human would burn during this task.

Theory

The average UK household is occupied by 2.4 people [1]. By dividing the total population of Leicester, $342,000$ [2], by this, we find the approximate number of households in Leicester to be 1.43×10^5.

It is estimated that each household in the UK has an average annual energy output of 3940 kWh [3]. In 24 hours, a household's energy output will be this figure divided by 365; 10.8 kWh. Hence, the total energy consumed by homes in Leicester in 24 hours is 1.54×10^6 kWh.

The average annual energy usage for a business in the UK is approximately 5.00×10^4 kWh [4]. To find the amount of energy used in 24 hours, we will divide this figure by 365. This gives 137 kWh. We can now multiply this result by the number of businesses in Leicester, $12,000$ [5], to arrive at a value for the total energy used in 24 hours; 1.64×10^6 kWh.

To find the total combined energy used in Leicester by businesses and households, we can sum the total energy used by each in 24 hours and convert to Joules. This is found to be 1.10×10^{13} J.

Now we can calculate how many hours it would take a human to produce this much energy by pedalling on a stationary bike. We will assume the human has a mass of 70 kg, is pedalling at a constant velocity of 30 kmh^{-1} (8.30 ms^{-1}) [6] and the bike is on a resistance setting of 20 kg, hence a force of approximately 200 N is applied to the pedals.

The power produced by the human pedalling is given by:

$$P = F\,v \tag{1}$$

Where F is the force applied to the pedals and v

is the velocity. By substituting in the numerical values, the power is found to be 1660 W. Therefore, the energy produced in 1 hour in Joules is given by multiplying 1660 W by 3600 s. This is found to be 4.18×10^6 J.

To find out how many hours this human would be required to pedal for to produce the necessary energy, we will divide Leicester's combined total energy usage (1.10×10^{13} J) by the total energy produced per hour (4.18×10^6 J). Hence, we find that they would have to pedal for 2.63×10^6 hours.

Therefore, to find how long each member of Leicester's population would be required to pedal for, we will divide 2.63×10^6 hours by the the population of Leicester. This results in 7.7 hours per person.

Next, we will consider the energy lost through the pedaller's increase in body temperature. The equation for the heat lost (Q) is given by:

$$Q = m\, c\, \Delta T \tag{2}$$

Where m is the mass of the human, c is the specific heat of water (4181 J °C^{-1} kg^{-1}), used because the majority of the human body is composed of water [7], and ΔT is the change in body temperature. The human body is effective at regulating temperature, even during exercise, so ΔT is estimated to be 0.5 °C [8] . By substituting these values into the equation above, we find Q to be 1.46×10^5 J.

Finally, we are going to find out how many calories this human burnt during that time by multiplying 7.7 hours by the total energy used by the human in one hour and adding our value of Q. We obtain a value of 7890 kilocalories.

Conclusion

We can conclude that it would be possible, in theory, for Leicester to be powered for 24 hours by its population given that each person cycles for 7.7 hours at a constant velocity of 8.30 ms^{-1}. However, this not possible in practice. The value used for the population of Leicester includes all ages, ranging from children to the elderly. These parties make up a large portion of the population and would most likely be unable to pedal for 7.7 hours a day. Not to mention other adults of average athletic ability would also be unable to fulfil this pedalling quota and each person would be required to significantly increase their kilocalorie intake for the day.

References

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