Journal of Physics Special Topics
An undergraduate physics journal

A3_3 When Roasted Pigs Fly

T. Leversha, L. Flood, K. Holland, M. Manley

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

November 2, 2022

Abstract

This paper investigated the excess energy produced when propane is used to lift a hot air balloon by testing if you could roast a pig while the balloon is flying. We found that the balloon would be able to fly as the propane releases 24.0MW, which is more than enough to roast the pig and fly the balloon.

Introduction

Hot air balloons are able to fly due to the simple principle that hot air rises. Hot air balloon pilots have to heat air by burning fuel, and once the air has reached an appropriate temperature, the balloon will begin to rise. Not all of the heat ends up being used to help the balloon to fly; we propose that there can be a use for this wasted energy, such as cooking a pig.

Theory

We modelled the pig as a cuboid with height h, width w, length L, and one side that is at a constant temperature equal to the flame of a propane burner, 1200°C [1].

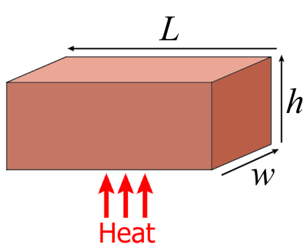

Figure 1: A pig modelled as a cuboid with a constant heat being applied to its downwards oriented face

To analyse if the propane burner could supply the hot air balloon with enough energy to fly when simultaneously cooking a pig, we first calculated the power losses from the balloon, P_{bal}, due to heat radiation into the adjacent environment. This was done by assuming the air inside the balloon could be modelled as a black-body.

$$P_{bal} = \sigma A_{bal}(T_{bal}^4 - T_{env}^4) \tag{1}$$

Where σ is the Stefan-Boltzmann constant, A_{bal} is the surface area of the balloon, T_{bal} is the temperature inside of the balloon, and T_{env} is the ambient temperature.

The power losses to the pig are equivalent to the heat flow into the pig, which can be described by Fourier's Law.

$$I = kA\frac{|\Delta T|}{|\Delta x|} \tag{2}$$

Where I is the heat current through the pig, k is the thermal conductivity of the pig, which we have assumed to be equal to water as a pig is mostly water, A is the cross sectional area of the pig facing the burner, ΔT is the temperature difference between the burner and the coldest point on the pig, and Δx is the length of the pig in the direction of heat flow, which we have denoted h.

Finally, to judge whether the propane could supply enough energy, we calculated the power generated as it burns.

$$P_{bur} = E_{1L} \times \frac{V_{trip}}{t_{trip}} \tag{3}$$

Where P_{bur} is the power produced by the burner, E_{1L} is the energy released when 1L of propane is burned, V_{trip} is the volume of propane consumed in one trip, and t_{trip} is the duration of one trip.

Results

T_{bal} is approximately 105°C [2] if we assume the ambient temperature T_{env} is 10.0°C at the balloon's travelling altitude. A_{bal} is 1510m^2 [3], and σ is $5.670{\times}10^{-8}\mathrm{Wm^{-2}K^{-4}}$. Using these values with Eq. 1 gives the power losses from the balloon to be 1.200 MW.

To calculate the heat flow into the pig, we plotted the thermal conductivity of water against its temperature. [4]

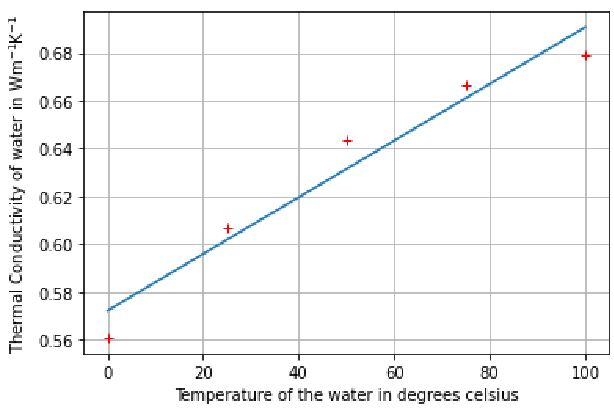

Figure 2: A plot of water's thermal conductivity against its temperature

Assuming the temperature of the pig increases linearly over time, we average the thermal conductivity between 10.0°C and 60.0°C (the temperature at which pork is safe to eat) to get $0.614\mathrm{Wm^{-1}K^{-1}}$. We then estimated the dimensions of a pig to be L = 1.250m, w = 0.350m, and h = 0.450m. Consequently, A = L×w = 0.440m^2. Using equation 2 we then calculate the thermal current in the pig to be 710W initially, and 680W when the pig has reached 60.0°C. The average is thus 695W.

We calculated the power of the propane using equation 3 with E_{1Litre}= 25.0MJ[5], V_{trip} = 3410L and t_{trip} = 1 hour[3] to get approximately $24.0\mathrm{MJs^{-1}}$

Discussion

The balloon will continue to fly if $P_{bur} > P_{bal} + I = 1.200\mathrm{MW}$. Since the burner provides much more energy than this, the balloon will fly without consequence. We could improve our model if we considered:

- If the pig would fully cook in 1 hour, or if the average thermal conductivity would be shifted lower.
- The heat losses from the burner to the ambient air.

Conclusion

It is possible to cook a pig using the burner of a hot air balloon whilst mid flight due to the massive energy release from combustion of propane compared to the energy required to keep the balloon buoyant.

References

[1] https://bullfinch-gas.co.uk/safety-and-technical/10-safety-technical/26-flame-temperatures [Accessed 12 October 2021]

[2] https://www.outbackballooning.com.au/balloons/ [Accessed 12 October 2021]

[3] https://skydrifters.com/faq/ [Accessed 12 October 2021]

[4] https://www.engineersedge.com/heat_transfer/thermal_conductivity_of_liquids_9921.htm [Accessed 12 October 2021]

[5] https://www.elgas.com.au/blog/2208-complete-incomplete-combustion-of-lpg-propane-equations/[Accessed 12 October 2021]