Journal of Physics Special Topics

P1_9 Can You Get Into Space for Peanuts?

B. Hall, A. Back, G. Brown, S. Turner

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

December 6, 2011

Abstract

Developing low cost space travel is a key issue since the retirement of the Shuttle. This paper looks at the feasibility of a mixture of toffee and peanuts in a low cost solid fuel rocket. It is found that this fuel mixture would lead to a mass ratio of about 322 which corresponds to a rocket consisting of 99.7% fuel and 0.3% remaining for the rocket structure and payload.

Fuel Costs Peanuts…

With the retiring of the space shuttle program and thus near-future human spaceflight by NASA earlier this year, the race to affordable space flight has entered the private sector with commercial journeys into orbit around Earth already available [1]. But at the current moment in time, the idea of orbiting the Earth is just as far away as our nearest star when put in terms of costs for the average person. This is when alternative methods of getting into space need to be considered if such space tourism is going to be able to reach the masses.

One of the most expensive components of space travel is also one of the most important. The propulsion system, or more correctly so, fuel. To minimize the costs of fuel alternate fuels need to be considered, hence, here we consider whether it is possible to utilize the high-energy content of toffee and peanuts as a fuel source for rocket propulsion into orbit around the Earth.

Toffee-Peanut Fuel? It's Hardly Rocket Science!

To determine whether a toffee/peanut fuel mix would be suitable for launching into a low Earth orbit (LEO), consider the energy requirement of such an action. Using the conservation of kinetic energy, as it is converted into gravitational potential energy, the total energy requirement of the transition between the Earth's surface and LEO is ΔE.

This energy requirement can be considered in terms of the equivalent velocity, which is a hypothetical initial velocity that would provide the total energy required to launch the spacecraft into LEO. The equivalent velocity v_{eq}, can be expressed as:

$$\frac{1}{2}v_{eq}^2 = \frac{\Delta E}{m} \sim \frac{GM_E}{r_E}, \quad (1)$$

where the fact that for LEO $r/r_E \sim 1.05$ has been used. Re-arranging for v_{eq} and substituting in the standard values of the constants gives the required equivalent velocity of 7.9 $\mathrm{kms^{-1}}$.

Assuming the toffee-peanut fuel system is utilized in a similar way to a solid fuel rocket [2], in which the pyrotechnic oxidiser Nitrous Oxide (N_20) is used, the chemical reaction occurring in the rocket can be analysed and energy requirement for LEO determined. By considering the energy provided by standard packets of peanuts and toffee, the energy provided per kilogram can be estimated as 25.12 $\mathrm{MJkg^{-1}}$ and 17.10 $\mathrm{MJkg^{-1}}$, respectively [3] [4]. Assuming first that the solid fuel is a mixture of equal parts peanuts and toffee, leading to an energy per kilogram of ~20 MJ. Then assuming, for the purpose of analysing the energy yield per kilogram, that the useful part of the solid fuel is glucose, which accounts for about 50% of the solid fuel mixture, so the energy per kilogram is about 10 MJ. The chemical reaction for the oxidation of glucose is [5];

$$C_6H_{12}O_6(aq) + 6\,O_2(g) \rightarrow 6\,CO_2(g) + 6\,H_2O(l). \quad (2)$$

Recall that the oxidiser in the case of a solid fuel mechanism is N_2O, and assuming the same molar ratio for glucose to oxygen as given in Eq. 2, it can be seen that 12 moles of N_2O oxidiser are required to burn each mole of glucose. Then, by determining the mass of a mole of each of the reactants, it is deduced that for every 4 kg of fuel $\sim$10 MJ of energy is produced (or in other words 2.5 MJ for every 1 kg of fuel). From Eq. 1, the equivalent velocity is calculated as 1.6 kms^{-1}, this is less than the required equivalent velocity of 7.9 kms^{-1}, so it seems unlikely that a toffee and peanut fuelled rocket would be capable of attaining LEO, but before dismissing it as a fuel consider the dynamics of rocket propulsion.

Better Check the Luggage Mass Restrictions.

Now considering the Rocket Equation (or Tsiolkovsky's Equation) [6], which considers the conservation of linear momentum as the fuel is expelled from the rocket;

$$v_s = v_e lnR, \quad (3)$$

where, v_s is the velocity of the rocket, v_e is the exhaust velocity, and $R = {}^{m_0}/_{m_f}$ is the mass ratio between initial mass, m_0, and final mass, m_f. The effective exhaust velocity is estimated from the efficiency ε of the propulsion system. An appropriate estimate for the efficiency of the propulsion system is determined by taking the ratio of $\frac{1}{2}v_e^2$ over the energy produced by the toffee and peanut solid fuel v_{eq}^2. Assuming a typical efficiency for rocket propulsion systems is 60%, since they use liquid H_2 and O_2 propellants producing 13.3 $MJkg^{-1}$ and yield typical exhaust velocities of 4 kms^{-1}. The same losses (heating of exhaust gasses and overcoming atmospheric pressure) are applicable in the case of the toffee and peanut fuelled rocket. Thus the exhaust velocity can be estimated using

$$v_e \approx \sqrt{2\varepsilon v_{eq}^2}$$

This gives an estimate for the exhaust velocity for a toffee-peanut solid fuel system as 1.7 kms^{-1}. In Eq. 3, the value for v_s is the required effective velocity for LEO. This value does not take into account any losses due to atmospheric drag or extra fuel required to perform manoeuvres and orbital corrections once in orbit which amounts to about an extra 2 kms^{-1}. Thus the best value to use for v_s is the characteristic velocity v_{char} which is taken as 10 kms^{-1}. Rearranging Eq. 3 for R and then substituting in the calculated exhaust velocity and appropriate characteristic velocity, R is calculated as 322. This value of R corresponds to a rocket that consists of 99.7% fuel and 0.3% mass for structure and payload, based directly on the kinematic properties of a peanut and toffee powered rocket.

Space for Peanuts?

In conclusion, 0.3% of the mass is far too small a portion of the rocket to be utilized for effective space travel (especially in space tourism when transporting people) when considering the mass of all the flight hardware and rocket structure itself. Given a large enough rocket it would be possible to transport a useful payload into space. Nevertheless further research is required before toffee and peanuts can be considered a viable option for rocket fuel; perhaps into a multi-stage rocket system, which might improve the percentage of mass available for the payload. If these weight limitations were to be overcome, the possibility of reaching LEO for the cost of peanuts is not out of the realm of possibility.

References

[1] http://www.virgingalactic.com/overview/space-tickets/
[Accessed: 22/11/11]

[2] "Bang Goes the Theory: Series 1, Episode 10", British Broadcasting Corporation, 2009. First broadcast October 5, 2009.

[3] ASDA Jumbo Roasted & Salted Peanuts (1000g)

[4] ASDA Smart Price Dairy Toffee (175g)

[5] http://www.rsc.org/Education/Teachers/Resources/cfb/respiration.htm
[Accessed: 22/11/11]

[6] http://www.braeunig.us/space/propuls.htm
[Accessed: 22/11/11]