

A3_10 Fancy a cuppa?

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Abstract

This paper discusses how much cooler blowing air over a hot object will become using the Bernoulli equation and the perfect gas law. The conclusion is that assuming the aperture created by the lips is 1cm^2 and the person is blowing as hard as they can, then the temperature in the air expelled is 16K less than the ambient temperature.

Introduction

Instinctively we know that blowing on hot food and drinks will cool them down. This paper will investigate why this works and how great the temperature change is.

Well blow me down...

The peak flow from the lungs of a 20 year old male of height 5ft 9ins is 570 L min^{-1} [1]. This can be expressed in SI units as $9.5 \times 10^{-3}\text{ m}^3\text{ s}^{-1}$. This is how much air can flow from the lungs when blowing as hard as possible. When blowing on things to cool them down we purse our lips. This is to create as small an aperture for the air to flow through as possible.

If we assume that the lips create an aperture of 1cm^2 ($1 \times 10^{-4}\text{m}^2$) then the speed of the air out of the mouth is 95 ms^{-1} , since

$$v_{\text{air}} = \text{flow rate} / \text{aperture}, \quad (1)$$

where v_{air} is the velocity of the air expelled from the mouth. This velocity can be used in the Bernoulli equation [2], the full form of which is given in equation 2.

$$P + \rho g y + \frac{1}{2} \rho v^2 = \text{constant}, \quad (2)$$

where P is pressure, ρ is density, g is the acceleration due to gravity, y is the vertical height and v is the velocity of the fluid.

In this case we can set up two regions which satisfy equation 2. The first is through the aperture of the mouth and the second is the stationary air which is unaffected by the blow. Since this case has no vertical differences the $\rho g y$ term is zero, also since the air in the second region is stationary then the velocity term for this region is also zero. This results in equation 3.

$$\frac{v_{\text{air}}^2}{2} + \frac{p_1}{\rho} = \frac{p_{\text{atm}}}{\rho}, \quad (3)$$

where p_{atm} is the atmospheric pressure and p_1 is the pressure through the mouth. Making p_1 the subject of the equation we find equation 4.

$$p_1 = p_{\text{atm}} - (\rho v_1^2) / 2. \quad (4)$$

Using $\rho = 1.223$ and $p_{\text{atm}} = 101.3\text{kPa}$ [3], this equation provides us with a value of 95.8kPa for p_1 .

Some like it hot

This pressure drop in the air above the food or drink leads to a decrease in temperature, which is why food and drink gets cooler as you blow on it. This temperature difference can be calculated using the perfect gas law

$$p V = n R T, \quad (5)$$

which, assuming that the volume and the number of moles of the gas does not change, can be rearranged to make

$$\frac{p_1}{T_1} = \frac{p_{atm}}{T_{ambient}} \quad (6)$$

Rearranging to make T_1 the subject of this equation and assuming the ambient temperature of the room ($T_{ambient}$) to be 297K (24°C) it can be calculated that,

$$T_1 = 281K, \quad (7)$$

meaning that there is a temperature drop of 16K.

Conclusions

The fact that in the best case scenario blowing on hot objects causes a temperature drop of 16K explains why it is a common way of trying to cool things down. This creates a larger temperature difference between the object and the surrounding air than were it to be just in the surrounding ambient air.

It must be noted that this is a best case scenario and that in reality it is not possible to maintain this temperature as the flow rate used is the maximum possible for an average height male and, of course, this can only be maintained for an extremely short amount of time.

Also the temperature drop is reduced by the probable increase in volume of the air as it exits the mouth.

A possible extension to this paper could be to investigate how much quicker an object will cool down when being blown on but the authors thought that this would be more suitable for a separate paper

References

[1] Nunn, A. J., and I. Gregg. 1989. New regression equations for predicting peak expiratory flow in adults. *Br. Med. J.* 298: 1068-1070

[2] Tipler, P (1999) *Physics for scientists and engineers*, WH Freeman and company, p386

[3] <http://www.grc.nasa.gov/WWW/k-12/airplane/airprop.html> [accessed 06/12/11]