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A2_6 Tubular Travel

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Abstract

This paper looks at whether it would be possible to use pneumatic tubes as a transport system for humans, similar to that shown in the cartoon series Futurama. We looked at the pressure required to push a human through a tube horizontally, assuming the only force resisting their movement was air resistance. The pressure required was found to be ~90.1 kPa (0.89 Atm).

Introduction

The cartoon series Futurama is set in the year 3000, and one of the most intriguing devices used on the show are pneumatic tubes. On the show, not only are they used to transport mail, they are also used to transport individuals to wherever they desire. Currently, pneumatic tubes are used to transport items quickly over short distances, such as in hospitals [1], but would it be possible to transport human beings using this method?

Investigation

For the purposes of this investigation, we have assumed the mass, *m* of a typical person to be 75 kg, the effective area to be 0.135 m^2, and the drag coefficient, C_d to be 1.2 [2] (similar to that of a ski jumper as they would adopt a similar position). A diagram showing the way these tubes work in the show is shown below in Fig. 1.

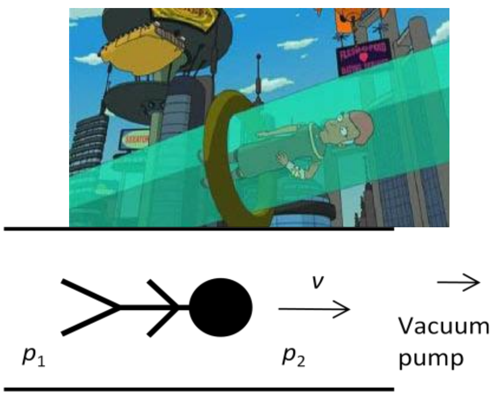

Fig. 1. Top: Screen from the cartoon showing the tubes in action, Bottom: Diagram showing how the pneumatic tubes might work

The person would be pushed along due to the pressure difference in the tube, created by the vacuum pump. The force exerted on the body, *F* due to this pressure difference is given below in Eq. 1,

$$F = ma = (p_1 - p_2)A - \frac{1}{2}\rho A C_d v^2, \quad (1)$$

where *a* is the acceleration, p_1 and p_2 are the pressures on either side of the body ($p_1 > p_2$), *A* is the effective area of the body as it moves through the tube, ρ is the density of air (1.225 kgm^{-3} [3]) and *v* is the velocity that the body moves at (here it is assumed that the person would move horizontally as to not introduce gravity to the situation). The last term in this equation is the drag force [4]. As can be seem in Fig. 1 (Top), the person does not touch the tubes, so we have neglected any friction with the tube in Eq. 1.

As the only thing resisting the travel is air resistance, we can work out the terminal velocity of a human by equating the drag force with the force acting due to gravity and rearrange for the velocity (shown in Eq. 2),

$$v = \sqrt{\frac{2mg}{\rho A C_d}}, \quad (2)$$

where *g* is the acceleration due to gravity (9.81 ms^{-2}). This velocity can be substituted into Eq. 1 to find the pressure p_2 required to force the body through the tube. For safety purposes, we will assume that the acceleration, *a* will be equal to *g*. We can rearrange Eq. 1 and substitute Eq. 2 to form Eq. 3 below,

$$p_2 = p_1 - \frac{2mg}{A}. \qquad (3)$$

As the entrance to the tube will be open to the atmosphere, p_1 is just atmospheric pressure (101 kPa). This gives a value of ~90.1 kPa (0.89 Atm) for p_2.

Discussion

The value for p_2 of 0.89 Atm is a very easily attainable pressure, which would allow humans to travel at speeds close to their terminal velocity (assuming there is no friction with the tube, as previously stated), provided enough distance was given. To slow down on arrival, the airflow would have to be controlled, as to match the pressure with that of the atmosphere to bring the person to a complete stop. This value would have to be decreased if someone were to travel up, as gravity would act against them also. One issue could arise if tubes were crossed, or connected in different places. In this situation, the 'traffic' would need to be constantly monitored and the pressure would need to vary quickly and frequently as to not cause harm to anyone using the system.

Conclusion

It would appear to be possible to transport humans using pneumatic tubes, in a similar manner to that depicted in the cartoon series Futurama. The pressure required to force a human through such a tube has been found to be ~90.1 kPa (0.89 Atm). This is assuming that the person does not touch the tube, so that the only other force acting to slow them is air resistance. If they were to travel in a vertical direction, the pressure would have to be altered accordingly, i.e. decrease the pressure if travelling up. One problem has presented itself and that is of intersections in the tube network. However, as computer systems become more advanced, this should become less of a problem.

References

[1] http://med.stanford.edu/ism/2010/january/tubes-0111.html#.html (21/02/2011)

[2] http://www.engineeringtoolbox.com/drag-coefficient-d_627.html (20/02/2011)

[3] http://wahiduddin.net/calc/density_altitude.htm

[4] http://www.grc.nasa.gov/WWW/K-12/airplane/drageq.html