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A5_2 Falling into Jupiter

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Abstract

We investigate the cause of death from falling into the atmosphere of a gas giant, as happened in the novel *Hidden Empire* by Kevin J. Anderson. Using a computer model of terminal velocity in Jupiter's atmosphere, we determine the man will begin to die from extreme heat after 11 minutes.

Introduction

In the science fiction novel *Hidden Empire*, the first book in the *Saga of Seven Suns* series, a scene is described where a man is on a large spacecraft in a gas giant's atmosphere. While the craft is collecting hydrogen, the man goes onto an observation platform. At this point the spacecraft is attacked by a mysterious vessel, and is destroyed. The man is thrown off and falls into the gas giant. In this article we determine how long this fall is and how the unfortunate man meets his eventual demise.

Theory

This problem contains many unknown factors. For example, we do not know the size or position of the gas giant in its solar system. Therefore, we will make a few assumptions to make the problem solvable. Firstly, we assume the gas giant is Jupiter. Secondly, we assume the craft is at an altitude where air pressure is equal to Earth's atmospheric pressure. Finally, we assume the man is wearing a mask providing breathable air. Jupiter's atmosphere is well studied, but there is no simple expression for how pressure and temperature change with altitude. These properties can, however, be approximated at high altitudes to follow a set of simple relationships; produced from atmospheric data and the assumption that temperature and pressure change linearly and exponentially respectively with depth.

$$T = 165 + 2(10^{-3})D \quad (1)$$

$$P = exp(1.91(10^{-5})D) \quad (2)$$

Where D is depth from the radius r at which pressure $P = 10^5$ Pa (at $r = 71,500$ km) and T is temperature [1].

Using the ideal gas law, these can be used to find an equation for density at a given depth.

$$PV = NkT \quad (3)$$

$$\frac{Nm_h}{V} = \frac{Pm_h}{kT} \quad (4)$$

$$\rho = \frac{Pm_h}{kT} \quad (5)$$

Where ρ is density, N is number of particles, m_h is mass of hydrogen, V is volume and k is the Boltzmann constant. We then substituted (1), (2) and (5) into (6) to give an equation for terminal velocity with depth [4].

$$v_{max} = \sqrt{\frac{2mg}{\rho AC}} \qquad (6)$$

$$v_{max} = \sqrt{\frac{2mg}{AC\frac{m_h exp(1.91(10^{-5})D)}{k(165+2(10^{-3})D)}}} \qquad (7)$$

Where v_{max} is terminal velocity, m is mass of the person and g is acceleration due to gravity ($25.4\ \mathrm{ms}^{-2}$) [1]. This is assumed to be constant due to the very small effective change in radius taking place; $\Delta r < 500$ km, the distance fallen in 15 minutes, compared to a radius of $r = 71,500$ km [1]. $A = 1\ \mathrm{m}^2$ is the projected area (estimated for a human male) and $C = 0.5$ is the drag coefficient (for a sphere in hydrogen) [4].

These assumptions will cause a small error; however, this will be negligible compared to the error caused by approximating pressure P, which is accurate to within 20% of atmospheric data between $D = 0$ km and $D = 500$ km [1], which will in turn cause an error in v_{max}.

Analysis

In order to find how long the man survives, we will need to determine how and when he will die. The possible ways are: freezing to death; being killed by rapidly changing or immense pressure; dying from heat as the temperature increases. We approached this problem by calculating the time, depth, pressure and temperature every second to see how the conditions change. Figure 1 shows that the pressure increases to 18 bar which is roughly 18 times the air pressure at sea level. This rate of pressure change is survivable as the freediving world record is 122 m, reaching 12 times atmospheric pressure in 4.4 minutes [2] [5]. Freezing is also unlikely as, even though the initial temperature is 160K, the temperature reaches survivable levels in 4 minutes; this level of exposure is unlikely to kill the man as, generally speaking, hypothermia takes a long period of time to kill a human. After this point the temperature increases to lethal levels. A human can survive an air temperature of up to about 400 K for very short periods, as competitive sauna competitions have lead to deaths at 383 K in 6 minutes [3].

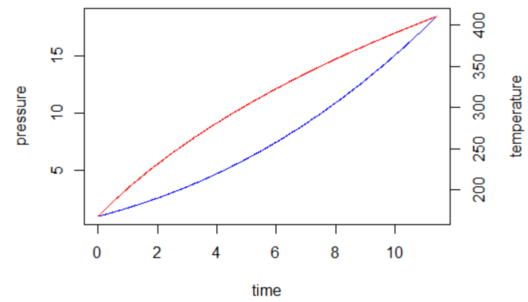

Figure 1: Graph of pressure (bar) and temperature (K) vs time (minutes) during fall. Red and blue lines are temperature and pressure respectively.

Conclusion

The man will start to die from the heat of the gas giants atmosphere after about 11 minutes. This will change for different gas giants; however, unless the conditions are drastically different, heat will be the cause of death as longer exposure to extreme cold or a much higher rate of pressure change would be needed to be fatal.

References

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