Journal of Physics Special Topics
An undergraduate physics journal

P5_11 Saving Tom Cruise

D. Molloy, B. Rayson, G. Knott, M. Sharman

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

December 13, 2022

Abstract

We calculate the atmospheric density required to save Tom Cruise from a fall from the Burj Khalifa. We consider the actor's terminal velocity at different atmospheric densities and compare this to a survivable velocity obtained during a short fall of 10 m. By doing this we obtain an atmospheric density value of 13.6 $kgms^{-3}$ that would save Mr. Cruise from his otherwise deadly fall.

Introduction

In 2011 during the filming of Mission Impossible a picture of famous actor Tom Cruise was taken. The daredevil actor was pictured sitting on top of the Burj Khalifa. The Burj Khalifa is 830 m tall [1] and if the Golden Globe winner fell off the building he would have certainly met a mission to survive that even he could not make possible. However, if Earth's atmosphere were denser could the Academy Award nominee survive such a fall?

Terminal Velocity

Terminal velocity is defined as the maximum velocity an object can attain while falling through a fluid. This maximum velocity occurs when the drag force equals the force due to gravity.

$$\frac{1}{2}\rho v^2 C_d A = mg, \tag{1}$$

Rearranging these equations gives an expression for the terminal velocity of an object falling through a fluid:

$$v = \sqrt{\frac{2mg}{C_d \rho A}}, \tag{2}$$

C_d is the coefficient of drag of the object (in this case Tom). ρ represents the density of the fluid. A represents the cross-sectional area. Tom Cruise weighs 68 kg and is 1.7 m tall [2]. The average human has a drag coefficient of 1 falling belly first [3], which is a position we assume the actor can adopt with his extensive stunt experience. Therefore, we calculated a surface area of around 0.5 m^2. This value was obtained by assuming the actor had an average width of around 0.3 m. The atmospheric density, at the heights and relatively high temperatures of U.A.E., is approximately 1.1455 kgm^{-3} [4]. Using these values, we calculated the actor to have a terminal velocity of 48.26 ms^{-1}.

Surviving the Fall

The average person usually survive falls of around 6-8 m [5], but allowing for Tom Cruise's impressive robustness, we have assumed he could survive a fall from 10 m above the ground.

$$v = \sqrt{u^2 + 2as}, \tag{3}$$

Therefore, from a stationary initial position, we calculated that Mr. Cruise can survive falling at velocities no greater than 14 ms^{-1}. We can use this maximum velocity value to calculate the required atmospheric density to protect the Hollywood Walk of Famer from his fall of 830 m from the top of the Burj Khalifa.

$$\rho = \frac{2mg}{v^2 C_d A}, \tag{4}$$

We calculated that the atmosphere would need to have a density of 13.6 kgm^{-3} in order to save the Scientologist.

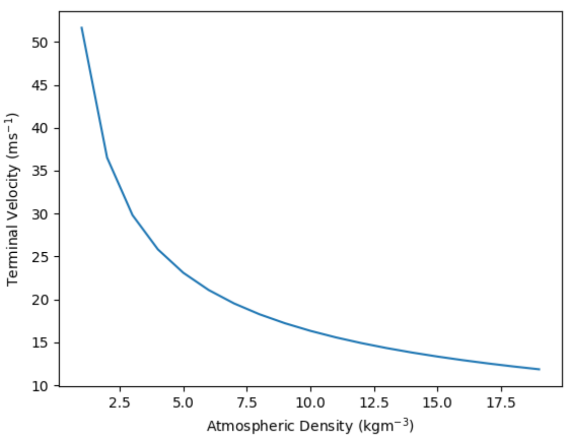

Figure 1: A graph showing the varying terminal velocities of Tom Cruise in different atmospheric densities plotted in Python.

Figure 1 shows that atmospheric densities above 13.6 kgm^{-3} result in survivable falls even from heights as large as the Burj Khalifa.

Atmospheric Pressure

Assuming the composition of Earth's atmosphere and the planet's gravitational field strength remain constant. We assume the increase in atmospheric density is due to an increase in the number of moles of atmosphere. We can then calculate the resultant increase in atmospheric pressure.

$$\frac{P}{n} = \frac{V}{RT} = constant, \tag{5}$$

Temperature is assumed to remain constant. Although probably not the case, this simplifies the problem.

$$\rho = \frac{m}{V} = \frac{nM_r}{V}, \tag{6}$$

M_r represents the relative molecular mass which remains constant, as the atmospheric composition is constant. V remains constant, as the volume of Earth's atmosphere is assumed to remain constant.

$$\frac{P_1}{n_1} = \frac{P_2}{n_2}, \tag{7}$$

$$\frac{n_2}{n_1} = \frac{P_2}{P_1}, \tag{8}$$

We calculated that this increase in atmospheric density required to save the actor would result in a 11.87 times increase in the atmospheric pressure. This would mean a pressure of 11.87 atm which is equivalent to the pressure around 115 m below the ocean's surface [6].

Conclusion

We have determined that by increasing the atmospheric density to 13.6 kgm^{-3} we would save Tom Cruise. However, the resulting increase in atmospheric pressure to 11.87 atm would mean that the actor would require a breathing apparatus like a scuba tank.

References

[1] https://missionimpossible.fandom.com/wiki/Burj_Khalifa [Accessed 7 November 2022]

[2] https://starsunfolded.com/tom-cruise/[Accessed 7 November 2022]

[3] https://openoregon.pressbooks.pub/bodyphysics/chapter/drag-force/[Accessed 7 November 2022]

[4] https://www.engineeringtoolbox.com/air-density-specific-weight-d_600.html[Accessed 7 November 2022]

[5] Lapostolle F, Gere C, Borron SW, Pétrovic T, Dallemagne F, Beruben A, Lapandry C, Adnet F. Prognostic factors in victims of falls from height. Crit Care Med. 2005.

[6] https://bluerobotics.com/learn/pressure-depth-calculator/[Accessed 7 November 2022]