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P4_8 The Coldest Shoulder

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Abstract

In this paper, we investigate the claim that a person would freeze in the presence of the pokémon Regice. We determined that a room with arbitrary dimensions 5m×5m×3m containing a Regice would reach a temperature of 134 K, plus if a person were to be placed into this room, they would completley freeze after 2.86 hours.

Introduction

The pokémon Regice is claimed to be able to control air as cold as -328°F [1], which is equivalent to about 73.2 K. In addition to this, things will freeze solid just by going near this Pokémon [1]. In this paper, we investigate these claims by calculating how long it would take a person in a room with Regice to become completly frozen.

Theory

To investigate how long it would take a human to freeze in a room with Regice, we considered what the temperature of a room with the arbitrary dimensions of 5m×5m×3m would be if it reached thermal equilibrium with Regice. For these calculations, we will be assuming that Regice has a temperature equal to the frigid winds it can control (73.2 K).

As the energy in the room can only flow between the air and Regice, the energy lost by the air must be the same as the energy gained by Regice. This energy can be found by using:

$$Q = -m_a c_a \Delta T_a = m_R c_R \Delta T_R, \tag{1}$$

where Q is the energy required, m is the mass of the object, c is the specific heat capacity of the object and ΔT is the change in temperature of the object, with the subscripts a and R representing the air and Regice respectively. Equation (1) can then be rearranged for ΔT_R:

$$\Delta T_R = \frac{-m_a c_a \Delta T_a}{m_R c_R}. \tag{2}$$

The total change in the temperature needed to reach thermal equilibrium will be the difference between the initial temperature of the air (T_a), the initial temperature of Regice (T_R) and the total change in temperature (which must be equal to the sum of ΔT_a and ΔT_R), which means:

$$T_a - T_R = \Delta T_a + \Delta T_R. \tag{3}$$

By substituting Equation (2) into Equation (3) and rearranging for ΔT_a, we find that:

$$T_a - T_R = \left(1 - \frac{m_a c_a}{m_R c_R}\right) \Delta T_a. \tag{4}$$

T_a was taken to be 300 K, as this is a reasonable temperature for a room, T_R was taken to be 73.2 K, m_a was found by multiplying the volume of the room (75 m^3) by the density of air (1.3 kgm^{-3}) [2], which was found to be 97.5 kg,

m_R was 175 kg [1], c_a was 1005 $Jkg^{-1}K^{-1}$ [3] and c_R was taken to equal to the specific heat capacity of ice which is 2090 $Jkg^{-1}K^{-1}$ [3], as Regice is also claimed to be made of ice [4]. Using these values and by rearranging Equation (4), we found that ΔT_a was equal to 166 K. This value for ΔT_a was then subtracted from T_a to find a value for the final temperature of the air in the room to be 134 K.

If a person were to be placed into this room, they would begin to lose heat to the cold air in the room. The time taken for a person to lose a given amount of heat can be found using [5]:

$$\frac{dQ}{dt} = -kA\frac{dT_P}{dx}, \qquad (5)$$

where k is the thermal conductivity, A is the surface area of the person, dT_P is the temperature difference between the person and the air and dx is the distance between the surface of the person and the centre of the person. To simplifiy calculations, we assumed that the person was entirley composed of water. As we were calculating the amount of energy needed to freeze a person we needed to find how much energy would need to be lost to reduce the person's core temperature from about 310 K to the freezing point of water (273 K). This was done using the equation:

$$Q = m_P c_P \Delta T_P, \qquad (6)$$

where the subscript P denotes a value related to the person and by taking the values of $m_P = 62$ kg [6], $c_P = 4180$ $Jkg^{-1}K^{-1}$ [3] and $\Delta T_P = 37$ K. This gave us a value for Q of 9.59×10^6 J. We then took values of 0.592 $Js^{-1}m^{-1}K^{-1}$ for k [7], 1.79 m^2 for A [8] and we used half of the average shoulder to shoulder distance, which is 0.205 m [9], for dx. Using these values, and by rearranging Equation (5), we found the time needed to freeze a person as being around 2.86 hours.

Results

While our results show that a person will freeze in these conditions, they also show that a person will not freeze just by going near Regice. A substantial amount of time is needed to completley freeze a person under these conditions.

In our calculations, we ignored the energy required to change the state of a substance. There were a number of places where this would have affected our results, for instance at temperatures as low as 134 K, it is possible that some of the gases that make up the air would have changed state to a liquid, and there would have been additional energy required to change the state of the person from liquid water to ice.

Conclusion

We found that a human would become completly frozen in 2.86 hours if they were to enter a room that had reached thermal equilibrium with Regice. This goes against the statement that things will freeze just by going near Regice, as a person would have to stay near Regice for nearly 3 hours to become frozen.

References

[1] Pokémon Sapphire, Game Freak, 2002

[2] https://www.engineeringtoolbox.com/density-specific-weight-gravity-d_290.html

[3] https://www.engineeringtoolbox.com/specific-heat-capacity-d_391.html

[4] Pokémon Emerald, Game Freak, 2004

[5] https://www.physicsclassroom.com/class/thermalP/\\Lesson-1/Rates-of-Heat-Transfer

[6] https://bmcpublichealth.biomedcentral.com/articles/10.1186/1471-2458-12-439

[7] https://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

[8] http://europepmc.org/articles/PMC2812484/reload=0;jsessionid=VMxGfFGKF2er3zi0XF6N.4

[9] https://www.cdc.gov/nchs/data/series/sr_11/sr11_249.pdf