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A1_10 Constructing the Pokébomb

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Abstract

In this paper we have discovered that under certain circumstances, a Pokéball from the Pokémon franchise in fact becomes a lethal weapon. We considered the structural integrity of the device when a Gastly is forced inside and found that the pressure exerted on the Pokéball from the Pokémon would destroy it, sending shards of shrapnel outwards at a velocity of 1.45 km s^{-1}.

Introduction

The world of the Pokémon franchise is inhabited by an abundance of creatures known as Pokémon. Players can catch these creatures using a Pokéball - a device that houses Pokémon. Fans may speculate that the Pokémon shrinks in order to fit inside this small device, but we think otherwise. We seek the consequences of squeezing down one such creature - Gastly, a living ball of gas.

Theory

According to its Pokédex entry (an in-game encyclopedia for Pokémon), Gastly has a height of 1.3 m [1]. Meanwhile a Pokéball is similar in size to a baseball with a diameter of 7.5 cm [3]. We will arbitrarily assume the thickness of the device to be 1 cm.

Since Gastly is 95% gas [2], we can model it as an ideal gas. In order to accommodate Gastly's body in the Pokéball, the gas molecules that make up its body must be compressed to a volume equal to the volume inside the Pokéball. This increases the pressure P exerted on the container according to the ideal gas law:

$$PV = nRT \tag{1}$$

where n is the number of moles, R is the ideal gas constant (8.31 J K^{-1} mol^{-1}), and T is the temperature (293 K assuming room temperature).

Assuming Gastly is spherical and that we know its height (and therefore diameter) we know its volume is 1.15 m^3. Upon being caught in a Pokéball, we can find the increase in pressure since isothermal compression occurs.

Work has to be done on Gastly's body in order for compression to occur, given by equation (2):

$$W = -nRTln(\frac{V_f}{V_i}) \tag{2}$$

where W is the work done in J, and V_f and V_i are the final and initial volumes respectively. W is then stored as potential energy inside the Pokéball.

If P from equation (1) is great enough to fracture the Pokéball, elastic potential energy stored during the compression of Gastly is released, accelerating fragments creating high-velocity shrapnel. Since Pokéballs have a hinge mechanism to open, this is the most likely point of fracture, creating two equal mass hemispheres that fly off in opposite directions with equal magnitude in velocities. This is the premise of the Pokébomb. Assuming that the potential energy is 100% converted into kinetic energy, equally distributed between the two fragments, the speed v can be found by equation (3):

$$v = \sqrt{\frac{2E}{m}} \tag{3}$$

where E is the kinetic energy and m is the mass of the shrapnel.

Equations (4) and (5) below provide the steps necessary to find m:

$$m = \rho V_s \tag{4}$$

$$V_s = \frac{4}{3}\pi(r_1^3 - r_2^3) \tag{5}$$

where V_s is the volume of the shell of the Pokéball, r_1 is the radius of the Pokéball, r_2 is the radius of the empty space inside the device, and ρ is the density of the shrapnel pieces.

Since there are 2 fragments, the mass must be divided by 2 to find the velocity of each component.

Results and Discussion

At atmospheric pressure (101 kPa [4]), we can use equation (1) to find the number of moles that make up Gastly's body. This value is 47.7 moles.

We have assumed the thickness is 1 cm, therefore the radius of the empty region is 2.75 cm. This gives a volume of 87.1×10^{-6} m^3, as it is a sphere. Rearranging equation (1) for P as Gastly is compressed to this minuscule volume we find the compressed pressure to be 1.33 GPa.

There is no literature regarding the composition of a Pokéball, so we assume it is a readily available metal since they are manufactured in large quantities within the in-game universe. Therefore we assume stainless steel.

Stainless steel has a tensile strength of 505 MPa [5]. This is the point at which tension on the material is so high that it breaks. Since the pressure inside the Pokéball is much greater than the tensile strength of stainless steel, the device will experience a mechanical failure and violently fracture.

Equation (2) can now be used to find the work done on Gastly to compress it. This gives a value for W to be 1.10 MJ. This is the energy that is converted into kinetic energy of the shrapnel.

We can sub equation (5) into (4) and then equation (4) into (3) to find v. Stainless steel has a density of 7850 kg m^{-3} [6]. Using 1 cm as the thickness of the shell of the Pokéball gives a volume V_s as 134×10^{-6} m^3, with a mass of 1.05 kg. To account for the energy being distributed equally, we divide this by 2, as well as the total energy. Each hemisphere has a mass of 0.525 kg with kinetic energy of 0.55 MJ. Finally, subbing these values into equation 3 gives a velocity of each fragment to be 1.45 km s^{-1}.

Conclusion

We have discovered that applying the laws of thermodynamics to Pokémon results in a very hazardous situation, with potentially lethal shrapnel hurtling at speeds of 1.45 km s^{-1}, far greater than the speed of sound. Since Gastly does not spontaneously explode out of its Pokéball in-game, we conclude that it does not get physically compressed, and there must be another mechanism behind the capture of Pokémon. This is a possible avenue for further study.

References

[1] https://bit.ly/2OSIkG8 [Accessed 28/11/19]

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