Journal of Physics Special Topics

An undergraduate physics journal

P1_5 Would You Kindly Conserve EVE?

A. Hunter, R. R. Bosley, J. B. Galloway and J. Michalowska

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

November 24, 2016

Abstract

In this paper, we investigate the Electro Bolt, Insect Swarm and Incinerate! plasmids from the video game Bioshock. We calculate the energies required to execute these plasmids, their efficiency and also the minimum energy that would need to be contained in an EVE hypo, 2.98×10^{16} J.

Introduction

In the game Bioshock, the protagonist Jack has access to various serums called plasmids, that give him 'super powers', which are powered by a substance called EVE. Each use of a plasmid uses EVE and when Jack's EVE level is void, he injects himself with an 'EVE hypo' to continue using plasmids. In this paper, we calculate how much energy would be required to perform three of these plasmids, their efficiency and how much energy would need to be in an EVE hypo to enable Jack to utilise these powers.

Theory

Electro Bolt allows Jack to shoot electricity to stun opponents. From the game, we estimate a range of Electro Bolt, $l = 25$ m [1]. We assume that the current required to stun a person is equivalent to a stun gun, $I = 3$ mA [2] and the resistance of the enemy is negligible. The equation $R = \frac{\rho l}{A}$ is used to find the resistance of air, $\rho = 4 \times 10^{13}$ Ωm is the resistivity of air [3], l is the range and $A = 2.03 \times 10^{-3}$ m^2, the cross-sectional area of the bolt, calculated using the radius of a lightning bolt, $r = 0.0254$ m [4]. The resistance calculated is $R = 4.93 \times 10^{17}$ Ω, giving a voltage of $V = 1.48 \times 10^{15}$ V. Since this is very large, we calculate the breakdown voltage of air to attempt a dielectric breakdown model. Air requires a voltage of 30×10^6 Vm^{-1} [5] to break down and become a conducting plasma. The voltage calculated exceeds this, so this model can be used. Using the dielectric strength of air, $B = 30 \times 10^6$ Vm^{-1}, the range of the bolt, $l = 25$ m, and the equation $Bl = V$, a voltage of $V = 7.5 \times 10^7$ V is found. The energy required to execute Electro Bolt is found by

$$E_{Electro} = IVt \tag{1}$$

Where $t = 6$s, the time the enemy remains stunned in the game [1].

The Insect Swarm plasmid summons a swarm of hornets which attacks any enemies in Jack's vicinity. To find the energy we require the mass of hornets produced. From the game we estimated that 250 hornets were produced with the mass $m = 0.33$ g [6] per hornet. From this we could find the mass of the swarm, and hence the energy needed, from

$$E_{Insect} = mc^2 \tag{2}$$

The Incinerate! plasmid enables Jack to set an enemy on fire. Assuming the process by which this happens is the temperature of the enemy's clothes is heated to a sufficient temperature causing them to self-ignite. The temperature this would occur at is $T = 286°\text{C}$ [7], which covers cotton, linen and wool, ensuring that ignition happens, whatever the enemy is wearing. The energy required for this to happen comes from

$$E_{Incinerate} = mc\Delta T \tag{3}$$

To find the mass of air heated around the enemy in order to ignite their clothing, we observe in game that the amount of air that is initially heated is a cylinder of volume $v = 0.0335$ m^3. This is a small volume, however the fire spreads due to the flammability of cloth. Using the density of air $\rho = 1.205$ kgm^{-3} [8], the mass is found by $m = \rho v = 0.0404$ kg. ΔT is the difference between 286°C and room temperature, 20°C [9], and c is the specific heat capacity of air, 1.005×10^3 Jkg^{-1}K^{-1} [8].

After calculating the energies of each plasmid, the energy used per one EVE for each plasmid is found, followed by the efficiency. We assume that the Insect Swarm plasmid is 100% efficient as it involves a direct mass to energy conversion. Using these energies, and how many times each plasmid can be used per hypo, enables us to find how much energy is in an EVE hypo.

Results

Using equations (1), (2) and (3) we found $E_{Electro} = 37500$ J, $E_{Insect} = 7.43 \times 10^{15}$ J and $E_{Incinerate} = 9330$ J.

For each use of Electro Bolt, 95 EVE is used [10] and Insect Swarm and Incinerate! each use 48 EVE [11][12]. The energy per EVE for each of these plasmids are 394.74 J EVE^{-1}, 1.55×10^{14} J EVE^{-1} and 194.45 J EVE^{-1} respectively.

The efficiencies of the inefficient plasmids are 2.55×10^{-10}% for Electro Bolt and 1.25×10^{-12}% for Incinerate!.

Discussion

The energies above show that the EVE hypos contain a substantial amount of energy to allow the plasmids to be used multiple times before Jack has to replenish his EVE. Jack can use Insect Swarm five times before running out of EVE, with the last use consuming his remaining EVE, not the full allotment. Therefore, in a single hypo, a range of four and five uses of EVE is stored. Insect Swarm uses 48 EVE each time giving a range of between 192 and 240 EVE. Since the energy per EVE is 1.55×10^{14} J, we can find that the range of energy needed in a hypo is between 2.98×10^{16} J and 3.72×10^{16} J.

Conclusion

Electro Bolt and Incinerate! both use EVE very inefficiently, compared to Insect Swarm. The minimum amount of energy that is contained in one EVE hypo is 2.98×10^{16} J. Future investigations into this topic could involve looking at other plasmids or reducing the energy required for Insect Swarm.

References

[1] Bioshock, 2K (Developers), (2007)

[2] `goo.gl/ajcTv7` Accessed: 2/11/2016

[3] Mark W. Denny, *Air and Water*

[4] `goo.gl/GIslB6` Accessed: 2/11/2016

[5] `goo.gl/ETGHXv` Accessed: 2/11/2016

[6] S. J. Martin, *Weight changes in adult hornets*, 1993: 365

[7] S. H. Graf, *Ignition Temperatures of Various Papers, Woods, and Fabrics*, 1949

[8] `goo.gl/HhCiLm` Accessed: 2/11/2016

[9] `goo.gl/1Q9kKn` Accessed: 2/11/2016

[10] `goo.gl/YC4h87` Accessed: 2/11/2016

[11] `goo.gl/YqbyqJ` Accessed: 2/11/2016

[12] `goo.gl/VcFcoR` Accessed: 2/11/2016