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A2_4 Batman's Really Big Microwave

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Abstract

In the film Batman Begins (2005) an evil organisation (the League of Shadows) successfully retrieve an experimental microwave emitter from Wayne Enterprises. This emitter is said to be used to vaporise large bodies of water using only microwaves, and the League of Shadows plan on vaporising Gotham's water supply. Here we discuss the energy and power required to achieve this; 1.18 petajoules and 13.7 gigawatts respectively, as well as the isotropic electric and magnetic fields produced; 3.24×10^7 NC^{-1} and 0.108 T respectively.

Introduction

Within the film Batman Begins (2005) the League of Shadows, an organisation that seeks to destroy the fictional city Gotham, captures a prototype weapon made by Wayne Enterprises. This weapon is known as the Microwave Emitter and is used to focus microwaves to vaporise large quantities of water. In the film the League of Shadows are attempting to use it to vaporise Gotham's water supply, releasing a toxin on the population. In this paper we study the energy required to vaporise the water supply of a city that size, the strength a microwave emitter required to do so, and the electromagnetic field strengths produced from such a weapon. This investigation assumes certain details such as isotropic microwave radiation throughout Gotham, the water supply is pure water, some other minor assumptions stated, and that Batman lost.

Theory

We will take New York City (NYC) as representative of Gotham city as they share some important statistics such as population per km^2 (Gotham: 9945 [1], NYC: 11000 [2]) and size (km^2) (Gotham: 846.9, NYC: 783.8 In 2017 NYC's daily water consumption was 990.2 million gallons (450,200 m^3) [3], we will therefore assume the emitter will be running for a day to vaporise the Gotham's water. Equation 1 below is used to calculate the energy required to raise a materials temperature, equation 2 is used to calculate mass of the water.

$$Q = cm\delta T \tag{1}$$

$$m = \rho V \tag{2}$$

Q is the energy transferred, c is the specific heat capacity, m is the mass, δT is the change in temperature, ρ is the density and V is the volume. We also need to calculate the energy required for a phase change, from liquid to gas. This can be done by using the latent heat equation below.

$$Q' = mL \tag{3}$$

Where m is the mass, Q' is the energy and L is the latent heat of a material. Summing the two energies gives us total energy required. To find the power, equation 4 below is used.

$$P = \frac{Q_{tot}}{t} \tag{4}$$

Where P is power and t is time.

To find the electric and magnetic field strength produced by the microwave emitter, we assume the energy density is uniform across Gotham. The volume taken for energy density will be Gotham's area multiplied by the depth of its deepest water pipe (150 m) [7].

$$B = \frac{E}{c} \tag{5}$$

$$w = \epsilon_0 E^2 \tag{6}$$

ϵ_0 is permittivity of free space, E is electric field strength, B is magnetic field strength, μ_0 is permeability of free space and c is the speed of light.

Results

Starting with equation 1, we took the density of water $\rho = 997$ kgm^{-3}, volume of water $V = 450,200$ m^3, specific heat capacity of water $c = 4186$ Jkg^{-1}K^{-1} and change in temperature $\delta T = 87$ K (373 K − 286 K, 286 K being the yearly average temperature of NYC's sea temperature [4]). This gives us a mass of water $m = 4.488 \times 10^8$ kg and energy required to bring to boil $Q = 1.634 \times 10^{14}$ J.

For a liquid to gas phase shift, L is the latent heat of vaporisation for water $= 2.265 \times 10^6$ Jkg^{-1}. This gave us an energy of $Q = 1.017 \times 10^{15}$ J, summing both Q values gives a total energy required to vaporise water from 286 K is $Q_{tot} = 1.180 \times 10^{15}$ J. Since the microwave emitter is running for 24 hours, its power will need to be 1.37×10^{10} W. To put this in perspective NYC's daily average source power consumption in 2011 was 59 times larger [5], meaning the microwave emitter would produce 1/60th of Gotham's power.

Using Q_{tot} and the volume of water related to Gotham's area to give an energy density $w = 9290$ Jm^{-3}. Rearrangement of equation 8 gives us an electric field strength $E = 3.24 \times 10^7$ NC^{-1}, and using equation 5 we find the magnetic field strength $B = 0.108$ T.

These are fairly large numbers for what could be found within a city environment. The local magnetic field strength of the average sunspot on the surface of our sun [6] is of the same order of magnitude as what the microwave emitter can produce.

Conclusion

Leaving such a microwave emitter on for a day would require extreme levels of energy to fulfil the organisation's plans. The level of isotropic microwave radiation and strength of electromagnetic fields produced would surely influence the electrical appliances of the city negatively, which would be an interesting avenue of investigation to see what extent the damage would cause to the city and its people.

References

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