Journal of Physics Special Topics
An undergraduate physics journal

P1_2 Cooked Snake Anyone?

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November 24, 2016

Abstract

In the video game Metal Gear Solid 4, Solid Snake, the human protagonist, traverses a corridor with walls which are constantly emitting deadly high energy microwaves. We estimate the power of the microwaves required to become a lethal hazard to be 2423 W.

Introduction

Towards the end of Metal Gear Solid 4 , Snake is required to go through a corridor that has been designed to constantly fire microwaves at whoever enters it. The intense heat from the microwaves puts Snake's life in serious danger. We calculated the power of the microwaves required to kill Snake, taking into account the effects of his Basal metabolic rate and heat loss from perspiration and conduction. We also compared this with the power of a microwave oven.

Theory

We assume that the microwaves being fired at Snake would be at a constant frequency of 2.45 GHz [1], similar to that of a microwave oven. We use this frequency for two reasons, first being that we will be comparing the power we calculate to the power of an oven. The second reason is that 2.45 GHz is lower than the resonant frequency of water, this allows the microwaves to penetrate sufficiently into the body, and not being absorbed at the surface.

First we calculate Snake's power input and output to deal with the heat. Snake has two main methods of losing heat: direct conduction to the air, and perspiring. He is constantly giving himself heat via his Basal metabolic rate (BMR). Since Snake must remain at a constant (hot) temperature, all power on Snake must equal zero, thus:

$$P_{rad} = P_c + P_p - P_{BMR} \tag{1}$$

P_{rad} is the power provided by microwave radiation, P_c is power loss by conduction, P_p is power loss by perspiration, and P_{BMR} is power gained by Snake's BMR.

Snake will be constantly producing energy due to his metabolism, P_{BMR}, which can be found by using the Harris-Benedict equation [2], $P_{BMR} = 10m + 625h - 5a + 5$ where his mass $m = 63.5$ kg, height $h = 1.8$ m and his age in years $a = 42$ [3].

Power lost by conduction can be found using $P_c = \frac{kA(T_{hot} - T_{cold})}{d}$ [4] where $k = 0.0257$ $\mathrm{Wm^{-1}K^{-1}}$ is the thermal conductivity of air [5], $A = 2.86$ m^2 is the surface area of Snake, who we modelled as a cylinder and used the equation $A = w\pi + 8\pi w^2$ to find his surface area, where width $w = 0.45$ m, assuming he is Vitruvian. For T_{hot}, we used the temperature of enzyme denaturing, as enzyme inactivity would cause a human to start dying, $T_{hot} = 40°$C [6].

T_{cold} is the standard room temperature, as the microwave radiation wouldn't heat up the corridor's atmosphere significantly, $T_{cold} = 21°\text{C}$ [7], and d is the distance from the skin where the ambient temperature of air would fall to room temperature, $d = 5 \times 10^{-2}$ m [4].

To find the power output via perspiration, we had to find the mass of sweat that is produced every second by a human who is subjected to high temperatures. We modelled the sweat as water, due to sweat mainly consisting of water. A human in a sauna sweats 4 litres an hour [8], and using the density of water, $\rho = 1000$ kgm^{-3} [9], we found the rate of perspiration is 1.11×10^{-3} kgs^{-1}. We then calculated the power required to heat this production of water up to 100°C and then evaporate it using the equation $P_p = Mc\Delta T + ML$, where $M = 1.11 \times 10^{-3}$ kgs^{-1}, the rate of perspiration, c is the specific heat capacity $c = 4.2$ kJkg^{-1}K^{-1} [9], ΔT is the temperature difference between room temperature and the temperature of evaporation, $\Delta T = 79°\text{C}$, and L is the specific latent heat of water, $L = 2257$ kJkg^{-1} [9]. We then calculated an overall power output by summing the individual outputs using equation (1).

We then calculated the power of the radiation absorbed by Snake by using $P_{micro}R = P_{rad}$ where R is the efficiency of a microwave oven $R = 55.6\%$ [10].

Our final equation for electric power for microwave emitters is:

$$P_{micro} = \frac{P_c + P_p - P_{BMR}}{R} \tag{2}$$

Results

Using the equation (1), we calculate the power of the radiation needed to maintain Snake's high temperature at $P_{rad} = 1347$ W. Then using equation (2) we find the power of the microwave needed to provide this radiation power, $P_{micro} = 2423$ W.

Discussion

The value calculated shows that the minimum required power to kill a human is very high. We compared this with the power of a microwave oven, which is 1000 W [11]. You would need 3 microwave ovens to produce the same amount of power required. Snake just barely survived this corridor, mainly due to his octocamo armour protecting him with an advanced fictional technology, and nano machines in his blood stream constantly repairing internal damage.

Conclusion

We found the power required in order to maintain a dangerous internal human temperature was $P_{rad} = 1347$ W. In order to provide this kind of radiative power, one would need to provide $P_{micro} = 2423$ W of power to microwave emitters, assuming that they have a similar cooking efficiency as a microwave oven. Future investigations into this topic may include a likely duration that Snake could survive in the corridor, and the effects of microwaves with different frequencies.

References

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