Journal of Special Topics

P1_9 Powering Nanobots with Body Heat

A. S. Dulay, R. A. Boadle, E. Wigfield

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

November 27, 2009

Abstract

This article discusses the feasibility of using variations in the human body temperature to power a medical nanobot. It is found that thermal energy gained from a Carnot cycle process is not sufficient to power a typical nanobot. A typical medical nanobot requires 1×10^{-9}W, the model outlined here finds that the maximum power a nanobot can gain is 5.7×10^{-17}W. Under normal circumstances the power gain is only 9.8×10^{-19}W. Thus it is concluded that this process is not sufficient to act as the sole power source for such a nanobot.

Introduction

Nanorobotics refers to the mainly hypothetical discipline of building robots on the nanometre scale. Nanobots are still very much in a research and development phase [1], for example, a sensor only 1.5nm across has been developed capable of counting individual molecules in a chemical sample. One of the first uses for nanobots is likely to be for medical applications where they may be used to find and destroy cancer cells [2].

How the nanobots produce the energy required to function is one of the key areas of development in nanobot design. This article discusses an idea for generating power by utilising internal body heat.

The Human Power Source

The example nanobot considered in this model has a volume of $2.7 \times 10^{-17} m^3$, this diameter is an approximation based on a published medical nanobot design [3].

As a nanobot travels in the bloodstream it will experience temperature changes of several Kelvin as it moves from the body core to the extremities. Temperature differences such as this are utilised in Carnot-cycle heat engines which extract work from temperature gradients. In a reversible Carnot-cycle, changes in temperature cause gas to expand or contract in a closed chamber driving a piston to do work on its surroundings.

A Carnot-engine's efficiency, η, where T_1 is the maximum temperature and T_2 is the minimum temperature, is,

$$\eta = 1 - \frac{T_2}{T_1}. \qquad (1)$$

The power output of an ideal Carnot engine is given by

$$P = \frac{\Delta T C_{Vol} V \eta}{t} \qquad (2)$$

where V is the volume of the nanobot's thermal sink, C_{Vol} is the volumetric heat capacity of the substance used as a thermal sink, in this case water , ΔT is the temperature difference experienced, where $\Delta T = T_1 - T_2$ and t is the duration of the temperature change. For this model, it is assumed that the nanobot will not lose any heat through radiation to its surroundings.

When the nanobot is at the core of the body, starting its cycle at the heart, the temperature is generally agreed to be 310K (37^{o}C) [4]. As a nanobot circulates around the body, a journey taking approximately 60s [5], it will undergo temperature changes depending on the various organs it passes through. The largest temperature gradient would be for a nanobot passing through a male's testes where T_1=310K and T_2=307K [5]. Where C_{Vol}=4.186kJ.kg^{-1}.K^{-1}[6], the volume as stated earlier, V=2.7x10^{-17}m^3 , ΔT=3K and t=60s, η =0.01 calculated from (1). Using (2), the maximum power output for the nanobot under these circumstances is 5.7x10^{-17}W.

Typically, nanobots such as the example robot would be used for arterial work close to the core of the body, and therefore would only undergo slight temperature changes of 0.4K[7], using previous values for V and C_{vol} and η =0.0013, in this case the maximum power output given by (2) is 9.8x10^{-19}W.

In a very extreme case such as hyperthermia where the human body undergoes heat stroke, the core body temperature rises to 315K within a period of 10minutes. Where T_1=315, T_2=310K, V=2.7x10^{-17}m^3, C_{Vol}=4.186kJ.kg^{-1}.K^{-1}, ΔT=5K and t=600s, η=0.016 (2) giving a maximum power output of 1.5x10^{-17}W. This produces less power than the

Nanobot Power Requirements

A medical nanobot would contain a number of nanobiosensors to allow for target cell identification, drug delivery and propulsion systems. A typical nanobot designed for medical application is theorised to use around 1x10^{-9}W[8].

Conclusion

It can be seen that even in the case of hyperthermia when 1.5x10^{-17}W can be generated, it is theoretically impossible to produce the power output of 1x10^{-9}W which is required for the example nanobot to function. The 5.7x10^{-17}W produced from the temperature changes undergone whilst circulating nanobot to a male's testes falls 10^{-8} short of the requirement. Further to this, in the typical case where arterial work is conducted, only 9.8x10^{-19}W is produced. Heat energy from the human body utilised in this manner provides neither a realistic nor reliable energy source for powering medical nanobots which will often require constant energy to power transmitters and propeller motors. The theorised power outputs also disregard power loss via radiative transfer into the surroundings and hence the above demonstrates a best case scenario.

Much research is being conducted in the field of 'nanopower' with researchers at the Georgia Institute of Technology currently working on piezoelectric nanowire technology. This technology is expected to one day lead to mobile phones powered purely by thermal energy radiated from the human body [9], and could also be employed to power medical nanobots.

References

[1] Wang, J. (2009). "Can Man-Made Nanomachines Compete with Nature Biomotors?".
[2] http://nano.cancer.gov/resource_center/sci_biblio_enabled-therapeutics_abstracts.asp
[3] A Cavalcanti et. al. "Nanobot architecture for medical target identification."
[4] http://hypertextbook.com/facts/LenaWong.shtml
[5] H. Prech et. Al. (1973). "Temperature and Life"
[6] http://www.yourhome.gov.au/technical/fs49.html
[7] E Rubenstein, et al (1960). "Common carotid blood temperature."
[8] http://www.nanobotdesign.com/papers/nanoboticTutorial.pdf
[9]http://www.intomobile.com/...you-powered-cellphones-made-possible-with-piezoelectric-nanowires.html