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P1_3 Spinning a Deuteron to Pieces

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Abstract

In this paper we calculate the angular velocity needed to overcome the binding energy holding the nucleus of deuterium, or a deuteron, together. Thus, inducing nuclear fission by spinning the nucleus. We find that the angular velocity we would need to induce in the nucleons would be 9.65×10^{21} rads^{-1}, around 3.5% the speed of light.

Introduction

In nuclear physics, the binding energy of a nucleus is the energy required to overcome the bonds between all the nucleons in the nucleus of the atom [1]. If energy equal to this value is imparted onto the particles in the nucleus, the bonds will break and the nucleons will fly apart, releasing the energy bound up in said bonds. Typically, as in nuclear power plants, this is done by firing neutrons at high speed towards naturally unstable nuclei. However, we wanted to calculate the feasibility of breaking down a nucleus by spinning it, imparting rotational kinetic energy, in order to overcome the binding energy of the nucleus.

We chose the nucleus of deuterium, or hydrogen-2, as the isotope we would model, since its nucleus contains only a proton and a neutron and thus there are no opposing charges generating repulsive forces that would otherwise complicate our model [2]. We also decided to use Newtonian physics to model this system, as a simple way to test the feasibility of the technique. To find the actual angular velocity required, quantum mechanics must be taken into account. That is beyond the scope of this paper.

Theory

In order to break down the deuteron, the rotational kinetic energy of the particles therein must equal the total binding energy of the deuteron. The binding energy of the deuteron E_b has been measured to be 2.23 MeV [2]. The equation for total rotational kinetic energy of a system [3] is

$$K = \frac{1}{2}\Sigma m_i r_i^2 \omega^2 \qquad (1)$$

in which K is the total kinetic energy of the system in joules, m_i is the mass of each component of the system in kilograms, r_i is the radial distance of each corresponding mass from the centre of rotation in m, and ω is the angular velocity of the system in radians per second. We can equate the kinetic energy of the system to the binding energy of the deuteron.

The mass of the deuteron M is $2.014u$ [2], or 3.344×10^{-27} kg. The radius of the spherical deuteron R has been measured to be 2.141×10^{-15} m [2]. In order to model the system, we defined the proton and the neutron that make up the deuteron as being point masses of mass $\frac{M}{2}$ each, and being at a distance of $\frac{R}{2}$ away from the centre of rotation, denoted as r_d equal to

1.0705×10^{-15} m, as illustrated in figure 1. By

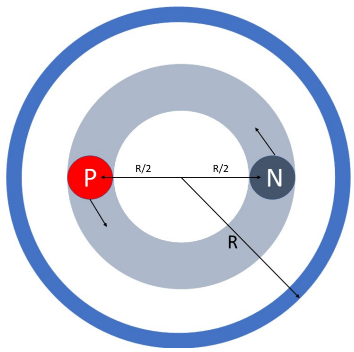

Figure 1: Our simplified model for the layout of the interior of the deuteron, showing the proton P and the neutron N as two masses equidistant from the centre of rotation, at distance $\frac{R}{2}$ from the centre of rotation of the system.

substituting in the values for mass, radius, and binding energy calculated above, and multiplying by 2 to account for the two masses involved, we can rearrange equation 1 to give the equation for the angular velocity of the system

$$\omega = \sqrt{\frac{E_b}{M \times r_d^2}}. \tag{2}$$

Results

By substituting our stated values for M, r_d, and E_b, we calculated that an angular velocity of 9.65×10^{21} radians per second, or 1.54×10^{21} revolutions per second, to induce fission of the nucleus by rotational kinetic energy alone. By calculating the circumference C of the circle each particle would trace using

$$C = 2\pi r_d \tag{3}$$

we found C to be 6.73×10^{-15} m. Tracing this path 1.54×10^{21} times per second means that each particle must be travelling at 1.03×10^7 ms^{-1}, about 3.5% the speed of light.

Conclusion

While we did manage to calculate a value for the angular velocity of the spinning particle which would cause the nucleus of deuterium to undergo fission, given that the angular velocity of the particles enters relativistic magnitudes, and the quantum nature of the actual deuteron system, these results only show that spinning a deuteron apart is theoretically possible. A quantum and relativistic approach should be taken when modelling and observing actual spinning binary particle systems[4].

References

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[3] A.Tipler, *Physics for Scientists and Engineers, Sixth Edition*, p.289-293.

[4] `https://newatlas.com/fastest-spinning-object/55564/` [Last Accessed 29 Nov 2018]