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P3_5 Phaser Recoil

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Abstract

The paper looks at the recoil which would be felt by a 5×10^9kg ship when firing a 5.1MW LASER beam. It is found that the recoil of the ship is very small, approximately 3.5×10^{-12}ms^{-1}.

Introduction

The primary weapon systems aboard most of the human star ships in the fictional television series "Star Trek" are phaser banks also known as phaser arrays. The phaser banks work is a similar way to a LASER/MASER, only they produce a beam of concentrated, highly collimated, fictional "Nadion" particles. Throughout the paper it will be assumed that phasers work in exactly the same manner as a conventional LASER, treating the fictional "Nadion" particles as photons. This paper will consider the recoil that might be experienced by one of the larger and more powerful human ships in the "Star Trek" universe.

Theory

In order to deduce the recoil of a ship due to firing its phaser array we must first make some assumptions about the ship itself and the beam of photons it will be firing. Let us consider a "Galaxy Class" ship, a human ship type in the "Star Trek" Universe. The phasers onboard have a maximum power output of 5.1MW and the ship is equipped with 12 of these arrays[1]. The first problem we encounter when considering this weapon is the fact that in the "Star Trek" Universe it is usual for ships to deliberately change wavelength and frequency due to reasons that are irrelevant, so this will not be discussed in this paper. However because we only wish to know the total momentum change we don't need to know the frequency, as they cancel out. In order to deduce the recoil of a ship we must also know the mass of the ship, for a "Galaxy Class" ship this is approximately 5Mtonnes [2].

The equation to calculate the energy of an individual photon is given by [3],

$$E_{photon} = hf, \qquad (1)$$

where h is Planck's constant and f is the frequency of the photons in the beam. The number of photons in the beam is equal to the total energy of the beam (E_{total}) divided by the energy of an individual photon (E_{photon}),

$$N_{photons} = \frac{E_{total}}{E_{photon}}. \qquad (2)$$

Combining equations 1 and 2 gives,

$$N_{photons} = \frac{E_{total}}{hf}. \qquad (4)$$

The momentum of an individual photon is given by [4],

$$p_{photon} = \frac{hf}{c}, \qquad (5)$$

where c is the speed of light in a vacuum. In order to find the total change in momentum of the beam (p_{beam}), we must multiply the momentum change of an individual photon by the total number of photons. So from equations 4 and 5,

$$p_{beam} = \frac{E_{total}}{c}. \qquad (6)$$

We find the total change in momentum of the beam to be 0.017kg ms^{-1}.

As momentum must be conserved [5], the change in momentum of the beam is equal to the change in momentum of the ship that fires the beam,

$$p_{beam} = p_{ship}. \qquad (7)$$

The momentum of the ship is defined as [6],

$$p_{ship} = m_{ship} \times v_{ship}, \qquad (8)$$

where m_{ship} is the mass of the ship and v_{ship} is the velocity of the ship.

If we consider the mass of a “Galaxy Class” ship, approximately $5x10^9$kg, firing a phaser shot lasting one second, we find that the ship will move with a velocity of the order $3.5x10^{-12}ms^{-1}$ in the opposite direction to the direction of phaser fire.

Conclusion

It would seem that the creators of “Star Trek” are correct in omitting any noticeable change in velocity of a $5x10^9$kg ship when it fires phasers, if the phasers are assumed to be LASERs with a total power of 5.1MW. Even if the ship were to fire 12 laser banks in the same direction simultaneously, the ship would only move with a velocity of approximately $4.2x10^{-11}ms^{-1}$ for a one second phaser burst i.e. not noticeable. It should noted that this paper only considers the hypothetical situation where a “Star Trek” like ship fires a LASER of energy similar to that of a phaser in the “Star Trek Universe”.

References

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[3] P.A. Tipler and G. Mosca, *Physics for Scientists and Engineers: Sixth Edition* (W.H. Freeman and Company, 2008) p. 1176

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[5] P.A. Tipler and G. Mosca, *Physics for Scientists and Engineers: Sixth Edition* (W.H. Freeman and Company, 2008) p. 249

[6] P.A. Tipler and G. Mosca, *Physics for Scientists and Engineers: Sixth Edition* (W.H. Freeman and Company, 2008) p. 248