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Mass of a System of Material Particles Including Photons

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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ABSTRACT

Aims/ Objectives: Using the standard momentum-energy relation in special theory of relativity, we try to show that massless moving particle with velocity of light can contribute energy and momentum to the system of objects.
Study Design: Relativistic mass energy relation.
Place and Duration of Study: Retired Professor of Mathematics, Megna Apartment , Krishnapur, between June 2020 and July 2021.
Methodology: We have considered here the mass of a system of non-interacting particles and computation of $M_{systerm}$ is in terms of unit mass m. Moreover we have considered here photon having no mass. But the presence of more than one of photon contribute energy because of increment of its mass in the system. And those photons considered here are non-interacting. The $M_{systerm}$ of photon is also expressed in unit mass m.

Keywords: Photon; energy; mass.

2010 Mathematics Subject Classification: 53C25; 83C05; 57N16.

1 INTRODUCTION

We know, the four momentum vector p_μ is obtained similar to Newtonian mechanics, by multiplying the four velocity vector by a mass m. Using the standard momentum-energy relation in special theory of relativity, we try to show that massless moving particle with velocity of light can contribute energy and momentum to the system of objects. First, the mass system is shown of non-interacting particles in the unit mass in excluding the photon. Secondly, the mass system is expressed only counting photons that are non-interacting. Photon having no mass may increase the mass of the system. And in both the cases the Mass-system is shown in term of unit mass m.

2 BASIC EQUATIONS

$E_{systerm}$ includes rest energy of particles and kinetic energy of moving particles. And squared momentum of the system equals to that of moving particles and which is $P_{systerm}$. And finally the square of the mass of the system is [1-3].

$$M^2_{systerm} = E^2_{systerm} - P^2_{systerm}. \tag{2.1}$$

Let us now give the problems below for non-intersecting particles (see Fig. 1). Eq. 1 is actually the momentum-energy relation [see ref. 4].

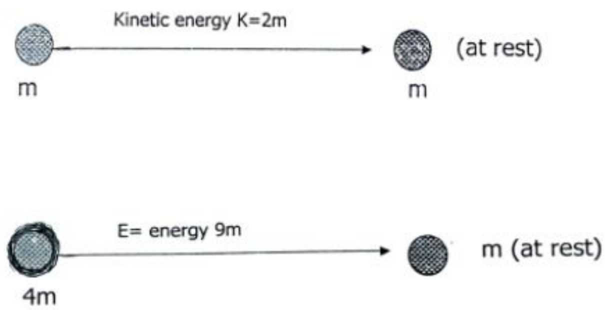

Fig. 1. Collision of two non-intersecting massive particles

3 SOLUTIONS

[1] For the first case, the system energy, i.e. $E_{systerm}$ becomes from the given problem, sum of the rest energy of two particles plus the Kinetic energy of the moving particle.

Thus

$$E_{systerm} = (m + m) + 2m = 4m. \tag{3.1}$$

We use mass-energy relation, $E = mc^2$. In this first system,

$$E = E_1 + E_2 + E_3 = mc^2 + mc^2 + 2mc^2 = 4mc^2 = 4m$$

(here we choose, $c = 1.$)

Now, $P_{systerm}$ i.e. squared momentum of the system which is equal to that of moving particle i.e. Thus

$$P^2_{systerm} = E^2 - m^2 = (3m)^2 - m^2 = 8m^2, \quad (3.2)$$

$$M^2_{systerm} = [(4m)^2 - 8m^2] = 8m^2. \quad (3.3)$$

Therefore,

$$M_{systerm} 2\sqrt{2}m \approx 2.828m. \quad (3.4)$$

[2] For the second case, the system energy is equal to $9m + m = 10m$.

Now,

$$P^2_{systerm} = (9m)^2 - (4m)^2 == 65m^2. \quad (3.5)$$

Now,

$$M^2_{systerm} = [(10m)^2 - 65m^2] = 35m^2. \quad (3.6)$$

Therefore,

$$M_{systerm} = \sqrt{35}m \approx 5.916m. \quad (3.7)$$

Let us now give problems below for non-interacting photon particles. Here we should remember that momentum of photon is equal to its energy (see Fig. 2) [5-6].

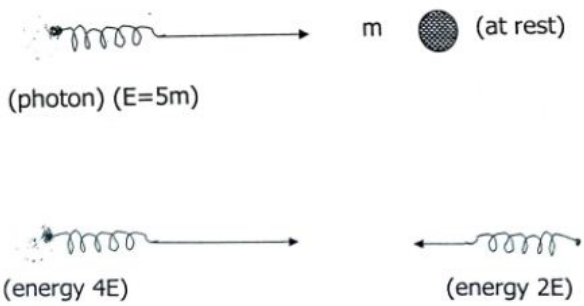

Fig. 2. Collision of two non-intersecting massive particles

[3] For the third case, system energy equals to sum of rest energy and Energy 5m of photon.

$$E_{systerm} = 5m + m = 6m. \quad (3.8)$$

The momentum of the system is equal to momentum of photon which is equal to its energy. Hence

$$P_{systerm} = 5m. \quad (3.9)$$

Therefore,

$$M^2_{systerm} = E^2_{systerm} - P^2_{systerm} = (6m)^2 - (5m)^2 = 11m^2. \quad (3.10)$$

Thus

$$M_{systerm} = \sqrt{11}m \approx 3.317m. \quad (3.11)$$

[4] For the last case, the total system energy = $4E + 2E = 6E$.

Regarding system momentum we will have to consider the difference between right momentum of the first particle and left momentum of the second particle $= 4E - 2E = 2E$. Therefore, the mass-system

$$M_{systerm} = [(6E)^2 - (2E)^2] = 32E^2, \quad (3.12)$$

Thus

$$M_{systerm} = \sqrt{32}E \approx 5.657m. \quad (3.13)$$

4 CONCLUSION

In the early of twentieth century, it is argued by Max Planck argued that light and other electromagnetic radiation comprised of distinct packets of energy which is known as quanta. He suggested that the energy of every quanta is proportional to its frequency. Problems relating photons are interesting because of the fact that it is massless moving with velocity of light and can contribute energy and momentum to the system of objects [7]. Therefore presence of more photons in a system must increase the mass of that system and photons are also used to create mass [8].

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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