Calculating the force exerted by the photon on the elementary particle

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Abstract: - Photons, like all elementary particles, exhibit both wave –like and particle -like properties .The dual nature of photons can be visualized through their interaction with other objects. The photons possess momentum; carry mass during its motion. Hence they also exert force and pressure on other objects. The recent astronomical observations stated that the radiation pressure is strong enough to push an asteroid. This statement shocked the scientific comity and made them to gape in an astonished way, thinking that do radiation pressure really pushes an asteroid. The inherent goal of proposal of this mathematical model is to calculate the force exerted by the photon on the other elementary particles, in a simple and consistent way. The basic concepts of quantum mechanics and classical mechanics are incorporated together in a single frame work to lay the foundation for the emergence of the equation for the calculation of the force imparted by the photon on other elementary particles like proton, electron etc. [Nature and Science 2010;8(10):82-87]. (ISSN: 1545-0740).

Key words: - speed of light, scattering angle, photon, particle, energy, force and time.

Quantum mechanics is a well defined mathematical model that grew out of Planck's quantum theory, considered as one of the major revolutions of 12th century. It takes into account the dual nature of particles, Heisenberg uncertainty principle and quantum mechanical behavior of the microscopic particles. Let us consider a particle at rest with respect to the observer frame of reference. Total energy associated with the particle will be equal to [m_oc^2].Suppose a photon of quantum energy [hf] is incident on that particle. A part of the energy [hf''] is absorbed by the particle and rest of the energy [hf'] is scattered by the particle. The energy of the particle {after the absorption of energy [hf''] from the photon} will be equal to $m_oc^2+hf'' = mc^2$.Let [θ] be the scattering angle formed between the incident photon and scattered photon respectively.

Energy ∝ 1/stability

Higher the energy, lesser is the stability .In order to attain stability, absorbed energy is converted into motion of the particle. Hence the particle travels a distance [X] in time [t].

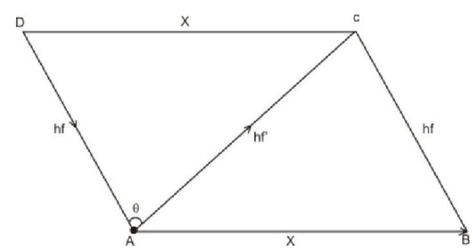

Figure: 1 –Schematic diagram of scattering of energy of the photon by the particle

X= Linear displacement of the particle

hf = Energy of incident photon

hf' = Energy of scattered photon

θ = scattering angle

Consider a parallelogram ABCD constructed as shown in the FIGURE:-1.

Let AB=CD=X, AD=BC=hf, AC=hf' [opposite sides in a parallelogram are always equal]

Law of cosine is mathematically represented by: -
$a^2=b^2+c^2-2bc \cos\theta$.

Let a =X, b=hf, c=hf', cos A = cosθ.

By applying the *law of cosine* to the triangle ADC

We get:-$X^2 = (hf)^2 + (hf')^2 - 2(hf)(hf')\cos\theta$
[1]

By the law of conservation of momentum of the photon

We get $\vec{p}_y = \vec{p}_{y''} + \vec{p}_{y'}$; where $\vec{p}_y, \vec{p}_{y''}, \vec{p}_{y'}$ is the momentum of the incident photon, absorbed momentum of the photon by the particle, momentum of the scattered photon. When the particle-photon collision takes place .A part of the motion of the photon is transferred to the particle, resulting in the motion of the particle. The Absorbed momentum of the photon equals the momentum of the particle.

$$\vec{p}_{y''} = \vec{p}$$

$$\vec{p}_y = \vec{p} + \vec{p}_{y'}$$

Where $\vec{p}$ = momentum of the particle

$$\vec{p} = \vec{p}_y - \vec{p}_{y'}$$

Squaring on the both sides; we get:

$$p^2 = \left(\vec{p}_y - \vec{p}_{y'}\right)^2$$

$$(a-b)^2 = a^2 + b^2 - 2ab$$

Thus the above equation becomes $p^2 = p_y^2 + p_{y'}^2 - 2\,|\vec{p}_y * \vec{p}_{y'}|$

According to dot product rule: - $|\vec{a} \bullet \vec{b}| = |a||b|\cos\theta$

$$|\vec{p}_y * \vec{p}_{y'}| = |p_y|\,|p_{y'}|\cos\theta$$

Then we get $p^2 = p_y^2 + p_{y'}^2 - 2|p_y|\,|p_{y'}|\cos\theta$

Let us multiply the above equation by c^2

We get: - $p^2 c^2 = p_y^2 c^2 + p_{y'} c^2 - 2|p_y|\,|p_{y'}|c^2\cos\theta$

Where c = speed of light in vacuum [3×10^8m /s]

The photons carry momentum proportional to their frequency

$$f \propto p$$

$$hf = pc$$

$p^2 c^2 = (hf)^2 + (hf')^2 - 2(hf)(hf')\cos\theta$
[2]

By comparison of [1] and [2]

We get: $X^2 = p^2 c^2$

$$X = pc \qquad [3]$$

Here X=linear displacement of the particle

p= amount of motion associated with the particle.

c= speed of light in vacuum [3×10^8m /s]

The linear displacement of the particle is defined as the function of the amount of motion associated with the particle. The displacement of the particle equals the momentum possessed by the particle times the speed of light in vacuum. The value of [X]is too large compared to that of [p].

$$X > p$$

Although $X \propto p$, displacement of the particle [X] is always greater than the momentum[p] possessed by the particle.

The mass of the particle before collision with the photon= m_o

The mass of the particle after collision with the photon= m

$$m = m_o + hf''$$

Here hf"=loss of energy from the photon

Loss of energy from the photon =energy absorbed by the particle after collision with the photon

The absorbed energy stored in the particle decreases with the distance travel of the particle.

If [hf”] = 0, then $m=m_o$

The amount of motion associated with the particle is given by: - p= m v

Here m= mass of the particle after collision

v= velocity of the particle

X= (m v) c

Velocity of the particle is defined as the displacement of the particle per unit time.

[v=X/t]

t=mc [4]

Here t=time of travel of the particle

m= mass of the particle after collision

c= speed of light in vacuum [3×10^8m /s]

The time of travel of the particle is defined as the function of the mass of the particle after collision. The time of travel of the particle equals the mass of the particle after collision times the speed of light in vacuum. The value of [t]is too large compared to that of [m].

t>m

Although $t \propto m$, time of travel of the particle [t] is always greater than the mass of the particle after collision[m].

The principle of relativity in conjunction with Maxwell equations explained, in a consistent way that mass is a direct measure of the energy content of the body. The photons carry mass proportional to their frequency .Let us imagine a trapped photon escapes from the gravitational field of the black hole, we observe difference in the frequency of photon i.e. frequency [f] of photon has been decreased. A Part of the energy of the trapped photon is utilized to do work against gravitational field of the black hole. Total energy content of the photon is a measure of mass known as relativistic mass. We also observe that the relativistic mass of the photon has been decreased followed by the decrease in the frequency of photon. Hence frequency[f] of the photon is directly proportional to its mass[m].

$$f \propto m$$

[Mass of the particle after collision – mass of the particle before collision]= loss of energy from the photon

When a particle –photon collision takes place, mass of the particle will be:-

$$m=m_o+ m_*$$

Here m= mass of the particle after collision

m_o= rest mass of the particle or mass of the particle before collision

m_*= mass of absorbed energy of the photon or loss of mass from the photon after collision with the particle

Multiplying by c^2, we get: $mc^2=m_oc^2+m_*c^2$

$$m_*c^2=hf”$$

$$m_* \propto f”$$

Conversion of energy into mass and its vice versa is beautifully explained by Einstein’s famous equation $E=mc^2$,here c is not just the velocity of a certain phenomenon—namely the propagation of electromagnetic radiation —but rather a fundamental feature of the way space and time are unified as space- time continuum. The equation implies conversion of energy into mass and it’s vice versa accounts the unification of space and time. In other words in presence of mass there is unification of space and time .In absence of mass, space and time behave as two separate factors. The space, time, mass are different concepts in physics and these concepts are incorporated in a single mathematical equation. Moreover the question arises in human mind, the need of unification of space and time in conversion of energy into mass and it’s vice versa.

$mc^2=m_oc^2+hf''$

From (3) we know: X=pc

Absorbed momentum of the photon equals the momentum of the particle

$p_{y''}= p$

$X= p_{y''}c$

The absorbed frequency of the photon is directly proportional to its momentum

$p_{y''} \propto f''$

$p_{y''}c= hf''$

$X= hf''$ [5]

Absorbed energy is completely utilized by the particle to travel a distance [X] from point [A] to point [B] in a time [t]. When a particle –photon collision takes place .A part of the energy of the photon is transferred to the particle, resulting in the decrease of energy of the photon and simultaneous increase of energy of the particle ;energy of the particle increases from [m_oc^2] to [mc^2].

$mc^2=m_oc^2+X$

$m=m_o + X /c^2$

Here m=mass of the particle after collision

m_o=rest mass of the particle or mass of the particle before collision

X=linear displacement of the particle

c= speed of light in vacuum [3×10^8m /s]

The position and time are undefined parameters, most fundamental assumptions in physics. For our convincible purpose of understanding, we assume [X] =zero, when the particle is at rest .Since we can measure no value for [X].

If [X] =0, then [$m=m_o$]

The [m_o] approaches[m] and [m]approaches [m_o] by the factor X/c^2.

From (4) we know t=mc

$m=m_o + X /c^2$

Time of travel of the particle [t] expressed in terms of the mass of the particle before collision [m_o] and linear displacement of the particle [X]:-

$t=m_o c + X/c$ [6]

The theory of general relativity points out that photons have no mass .Experimental value of mass of photon was found to be 4×10^{-48} grams. However if the mass of the photon is not considered to zero, then quantum mechanics would be in trouble .It also an uphill task to conduct a experiment which proves the photon mass to be exactly zero. If we apply the above equation to photons:-m_o= 0 [since photons can never be at rest in any frame of reference].

We get X=c t

c=X / t

The Particle only with a zero rest mass can travel with a velocity equal to that of light.

From (6), we know: - $t=m_o c + X/c$

X=pc

X/p=c

$t= m_o c + p$ [7]

The momentum possessed by the particle is given by: p=mv

Thus [7] becomes: $t= m_o c + mv$ [8]

Every particle continues in its state of rest with respect to observer frame of reference, unless compelled by an external force to change that state. When a particle –photon collision takes place, the photon exerts force [F] on the mass [m_o] and produces acceleration [a] in it.

$F=m_oa$

Here m_o=rest mass of the particle or mass of the particle before collision

a=acceleration produced in the particle

Acceleration is defined as velocity of the particle per unit time.

$$a=v/t$$

Here v= velocity of the particle

t= time of travel of the particle

$$Ft=m_o v$$

Impulse is the effect of force acting for short interval of time .It is measured as the product of the force and time.

$$I=Ft$$

$$I= m_o v \quad [9]$$

Here m_o=rest mass of the particle or mass of the particle before collision

v=velocity of the particle

I= impulse

$$v=I/m_o$$

Thus [8] becomes: - $t= m_o c + (mI /m_o)$ [10]

From [4], we know: - t=mc

$$t/c= m$$

Here t=time of travel of the particle

m= mass of the particle after collision

c= speed of light in vacuum [3×10^8m /s]

Thus [10] becomes: - $t= m_o c + (tI /m_o c)$

$$t - (tI /m_o c) = m_o c$$

$$t [1- (I /m_o c)] = m_o c$$

$$[1- (I /m_o c)] = m_o c /t$$

$$[1- (m_o c /t)] = I /m_o c$$

$$I= [m_o c- (m_o^2 c^2 /t)] \quad [11]$$

Impulse is measured as the product of the force and time: - I=Ft

Thus [11] becomes: - $F= [m_o c/t - (m_o^2 c^2 /t^2)]$ [12]

Here F=force exerted by the photon

m_o= rest mass of the particle

t= time of travel of the particle

c= speed of light in vacuum [3×10^8m /s]

Thus, we have the formula [12] for the calculation of the force exerted by the photon on the other elementary particles, which takes into consideration the time of travel of the particle and rest mass of the particle. The discovery of laws of motion by Sir Isaac Newton is one of the most remarkable events in the history of physics. The Newton laws of motion are being constantly tested by many physicists from past several centuries. So far these laws have with stood every test of experimentation. These laws of motion holds good for all practical purposes in an inertial frame of reference. The statement: *force applied on the body varies inversely with the time of travel of the body or time after which the body again comes to its initial state*, predicted by Newton laws of motion. The above statement has been experimentally verified by several scientists across the world.

$$F \propto [1/ t]$$

More the force applied on the particle, less will be time of travel of the particle. If the equation [12] obeys the above cited statement then the equation holds good for all practical purposes of experimentation. If the equation fails to satisfy the above condition then the equation brings about its own pitfall. We can't just accept the mathematically derived equations without testing them. The allowed orbits are those for which the orbital angular momentum of the electron about the nucleus is an integral multiple of $h/2\pi$.That is, angular momentum of the electron about the nucleus is $mvr = n [h/2\pi]$

Here m= mass of electron

v= orbital velocity of the particle

r=radius of electron orbit

h=Planck's constant [6.625×10^{-34} Js]

For the electron at a infinite distance from the nucleus

$$r = \infty$$

$$v \propto 1/r$$

$$v=0$$

The electron in the very distant orbit is assumed to be at rest since their orbital velocity is very negligible [approximately equal to zero].

Newly derived mathematical formula: -

$$F= [m_o c /t - (m_o^2 c^2 /t^2)] \qquad [12]$$

For electron: - $m_o=9.1\times10^{-31}$kg

The value of [F] is calculated for different values of [t] using the equation [12].The values are noted in the tabular column as shown below:

SLNO	Time of travel of the particle	Force exerted by the photon
1]	1s	2.73×10^{-22} N
2]	2s	1.365×10^{-22} N

From the above observations, we come to the final conclusion that the value of [F] decreases with increase in the value of [t]. Hence the newly framed mathematical equation [12] holds good for all practical purposes of examination.

References

1. en.wikipedia.org/wiki/Parallelogram - Cached – Similar
2. en.wikipedia.org/wiki/Law of cosines - Cached – Similar
3. en.wikipedia.org/wiki/Planck's law - Cached – Similar
4. en.wikipedia.org/wiki/Mass–energy equivalence - Cached – Similar
5. en.wikipedia.org/wiki/Momentum - Cached – Similar
6. en.wikipedia.org/wiki/Compton scattering - Cached – Similar
7. en.wikipedia.org/wiki/Force - Cached – Similar
8. en.wikipedia.org/wiki/Impulse_(physics) – Cached
9. en.wikipedia.org/wiki/Newton's_laws_of_motion - Cached – Similar
10. mathworld.wolfram.com › Algebra › Vector Algebra - Cached – Similar
11. en.wikipedia.org/wiki/Bohr_model - Cached – Similar
12. en.wikipedia.org/wiki/Photon - Cached – Similar
13. www.tomzap.com/notes/Physics/Modern2426.pdf - Similar

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