Torque of Photon by Particle Nature

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ABSTRACT

According to Einstein (1905)[1], the concept of light quanta is essential for understanding the emission and transformation of light, which forms the basis for analysing photon behaviour in various media. Photon means energy packet in electromagnetic radiation. We have done a lot of research over this most tiny packet of energy but still I have one question. What's about its shape? And the answer to this question gives me multiple new questions and new answers. I started working over the answer and developed new research over the photon.

Let's start from one phenomenon of light known as refraction of light. We have seen that light bends and there is explanation of it by refractive index and angle of incidence, refraction, u = sin(i)/sin(r). But I believe this is incomplete. We have studied and focused only on motion or path of photon. But something happened to the energy packet there. Light consists of energy packets of photons.

If we assume that light coming from vacuum has spherical shape photon but after passing a transparent layer having refractive index and shape changes due to torque and force acting over the photons. This can lead to breakthrough in understanding of photon size and behavior.

1. Proposed Work

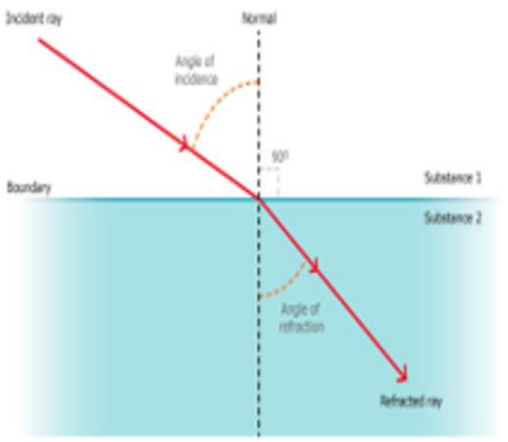

Figure 1: Refraction of Light

1.1. Refraction of Light

So, there is light that undergoes refraction of light from rarer to denser medium as shown in figure 1. Let's take a photon when it reaches medium boundary goes to other. We take its shape of sphere. So, a photon in sphere radius let say R rotate by an angle of w such that center remain fixed or rotate around its center axis. It is illustrated in figure 2.

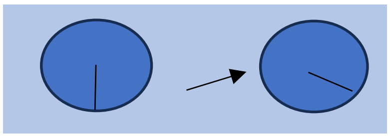

Figure 2: w angle it rotates by

In this torque=radius*force = rf sinw

Radius = R

W= angle it rotates by = final angle(refracted angle) – initial angle(incident angle)

Now,

Force = ma

$E = mc^2$

$E = hv = mc^2$

So, $m = hv/ c^2$

Here, h = Planck's constant and v = frequency of light

Before going forward, let's go to acceleration.

Here both speed and direction both changes.

Net acceleration = $a = a_t + a_c$

a_t = tangential acceleration due to speed change

a_c = centripetal acceleration due to direction change

Net force = $(F_t^2 + F_c^2)^{1/2}$

$F = m(a_t^2 + a_c^2)^{1/2} = m(a)^{1/2}$

Net force = $hv(a)^{1/2}/c^2$

Torque = R * (Net Force)

Now, torque = $(Rhv(a)^{1/2}/c^2)\sin w$ (here sin w varies)

Torque = $(ER(a_t^2 + a_c^2)^{1/2}/c^2)\sin w$

Also, torque = $(Rh(a)^{1/2}/cl)\sin w$ (where I = wavelength and v=c/l)

This is the formula of refractional torque of photon.

1.2. Physical Proof

1) Dimensional proof - on checking its dimension I conclude that its dimension matches.

2) Torque is proportional to frequency and inversely proportional to wavelength. We see in dispersion of light in prism that more is wavelength of light i.e. red less its deviation. But here we can see that if I take it to torque, high wavelength led to less torque to less change in its path of travelling and vice versa.

3) Now when light goes from rarer to denser its refracted angle is less than incident angle. This led to w = net angle difference by which it rotates by = negative which means torque is

negative. So instead of going torque outside, it bends inward (opposite direction) when it goes from rarer to denser and vice versa.

4) When light travels along the normal, i=r=0, so, sinw = sin0 = 0, Torque = 0. No refraction. Speed changes but path remains straight. This means here only tangential force acts not centripetal force.

5) It is said that there is instantaneous change when light travel from one medium to other medium, but according to me at such a small size, this process occurs gradually at its own level, such that we think it is instantaneous from our size view or even microscopic view.

1.3. Some more points

1) Here mass of photon of light by $m = hv/c^2$ be calculated. Let red color to have frequency of $430*10^{12}$hz, which led to m nearly to $3.15*10^{-36}$kg. Light photon taken as a massless particle but according to me, energy at micro level occupies some space and has mass. In other words, if energy of photon is fully converted to mass, its mass value can be calculated.
2) See if we see all this process, it is a natural process. But what if we use some benefit from it? It will be same as nuclear fission reaction. We humans make it possible to control nuclear fission by absorbing one neutron per breakdown which leads to controlled energy. Same here if we light photon comes, do its action of torque and deviation but somehow, we control it and take out some amount of energy. And, that amount of energy is very high.
3) This is too clear that I take light photon as a particle. But still today we are taking light as both particle and waves. According to me, now there is a need for a third term to be considered known as 'wavicle' means having some properties of both particle and waves.

1.4. Photon Shape

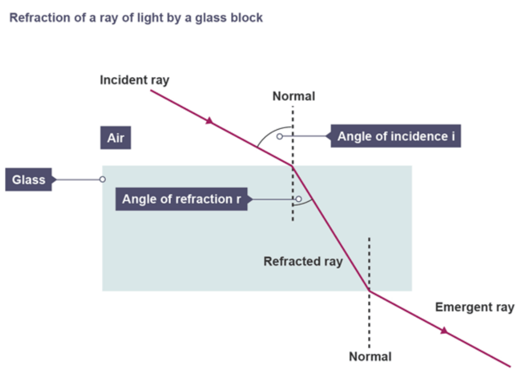

Figure 3: Refraction of light from air to glass to air medium

In figure 3, we have a case where light got refracted from air to glass then glass to air. As incident ray is parallel to emergent ray, we have two refractional torque both are which will be equal in magnitude.

So, here we know that, incident angle = emergent angle

And,

As, tangential acceleration = v_2-v_1/t and centripetal acceleration = v_2^2/R

Where, v_2 = final speed and v_1 = initial speed

So, Refractional Torque = $(ER(a_t^2 + a_c^2)^{1/2}/c^2)\sin w = (ER((v_2-v_1/t)^2 + (v_2^2/R)^2)^{1/2}/c^2)\sin w$

Now, in T_1 = Torque 1 = Air to Glass,

$v_1 = c$ (air medium), $v_2 = v$ (glass medium)

$T_1 = (ER((v-c/t)^2 + (v^2/R)^2)^{1/2}/c^2)\sin w$

Now, in T_2 = Torque 2 = Glass to Air,

$v_1 = v$ (glass medium), $v_2 = c$ (air medium)

$T_2 = (ER((c-v/t)^2 + (c^2/R)^2)^{1/2}/c^2)\sin w$

Both T_1 and T_2 are same in magnitude but opposite in sign as one torque is inwards and other is outwards.

So, $T_1 = - T_2$

$(ER((v-c/t)^2 + (v^2/R)^2)^{1/2}/c^2)\sin w = -(ER((c-v/t)^2 + (c^2/R)^2)^{1/2}/c^2)\sin w$

On simplifying, eliminating common terms and considering that time taken for speed change whether v to c or c to v is same, then,

$((v-c/t)^2 + (v^2/R)^2)^{1/2} = -((c-v/t)^2 + (c^2/R)^2)^{1/2}$

Squaring both sides,

$(v-c/t)^2 + (v^2/R)^2 = (c-v/t)^2 + (c^2/R)^2$

$(v^2/R)^2 = (c^2/R)^2$

$v^2/R = c^2/R$

Now, we find an important point from here that if we further solve it, v will be equal to c that is not possible as we know that speed of light change when it enters into glass medium.

So, let’s take case that radius of spherical photon got changed when it enters into glass.

Now, there is two radius R_1 and R_2,

R_1 = Radius in air medium

R_2 = Radius in glass medium

Now, $T_1 = - T_2$

$(ER_1((v-c/t)^2 + (v^2/R_1)^2)^{1/2}/c^2)\sin w = -(ER_2((c-v/t)^2 + (c^2/R_2)^2)^{1/2}/c^2)\sin w$

Simplify, eliminate and take $(v-c/t) = x$

$(R_1((x)^2 + (v^2/R_1)^2)^{1/2}) = -(R_2((x)^2 + (c^2/R_2)^2)^{½})$

Square both sides,

$(R_1^2(x^2 + (v^2/R_1)^2)) = (R_2^2(x^2 + (c^2/R_2)^2))$

Further solving,

$(xR_1)^2 + v^4 = (xR_2)^2 + c^4$

Now, $(R_1)^2 – (R_2)^2 = c^4 - v^4/x^2$

Taking $x = (v-c/t)$

$(R_1)^2 – (R_2)^2 = c^4 - v^4/(v-c/t)^2$

If we take Snell law, $u = c/v$, $v = c/u$ (u is refractive index of glass)

$(R_1)^2 – (R_2)^2 = c^4 – (c/u)^4/((c/u)-c/t)^2$

$(R_1)^2 – (R_2)^2 = c^4(1 – (1/u)^4)t^2/(c(1 – (1/u))^2$

$(R_1)^2 – (R_2)^2 = c^2(1 – (1/u)^4)t^2/(1 – (1/u))^2$

$(R_1)^2 – (R_2)^2 = c^2(u^4 - 1)t^2/(u^2)(u - 1)^2$

$R_2 = ((R_1)^2 – (c^2(u^4 - 1)t^2/(u^2)(u - 1)^2))^{1/2}$

This show that radius of photon changes when it enters into another medium.

Let's take another case

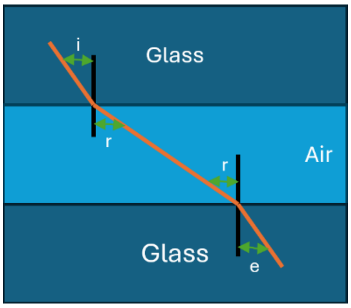

Figure 4: Refraction of light from glass to air to glass medium

In figure 4, there are two dense mediums and one rarer medium. Light from glass refracted to air then air to glass. Here we have two torque equal in magnitude, opposite in sign as one torque is inwards and other is outwards.

i = incident angle = emergent angle = e,

Two radius R_1 (glass medium) and R_2 (air medium),

Refractional Torque = $(ER((v_2-v_1/t)^2 + (v_2^2/R)^2)^{1/2}/c^2)\sin w$

In Torque 1,

$v_1 = v$ (glass medium), $v_2 = c$ (air medium)

$T_1 = (ER_1((c\text{-}v/t)^2 + (c^2/R_1)^2)^{1/2}/c^2)\sin w$

In Torque 2,

$v_1 = c$ (air medium), $v_2 = v$ (glass medium)

$T_2 = (ER_2((v\text{-}c/t)^2 + (v^2/R_2)^2)^{1/2}/c^2)\sin w$

$T_1 = -T_2$

$(ER_1((c\text{-}v/t)^2 + (c^2/R_1)^2)^{1/2}/c^2)\sin w = -(ER_2((v\text{-}c/t)^2 + (v^2/R_2)^2)^{1/2}/c^2)\sin w$

$R_1((c\text{-}v/t)^2 + (c^2/R_1)^2)^{½} = -R_2((v\text{-}c/t)^2 + (v^2/R_2)^2)^{½}$

Take $c\text{-}v/t = x$,

$R_1((x)^2 + (c^2/R_1)^2)^{½} = -R_2((x)^2 + (v^2/R_2)^2)^{½}$

Square both sides,

$R_1^2((x)^2 + (c^2/R_1)^2) = R_2^2((x)^2 + (v^2/R_2)^2)$

$(xR_1)^2 + c^4 = (xR_2)^2 + v^4$

$R_1^2 - R_2^2 = v^4 - c^4/x^2$

$R_1^2 - R_2^2 = v^4 - c^4/(c\text{-}v/t)^2$

$R_1^2 - R_2^2 = -(c^4 - v^4/(c\text{-}v/t)^2)$

On further solving,

$(R_1)^2 - (R_2)^2 = -(c^2(u^4 - 1)t^2/(u^2)(u - 1)^2)$

$R_2 = ((R_1)^2 + (c^2(u^4 - 1)t^2/(u^2)(u - 1)^2))^{1/2}$

Result:

So, we take two cases where we have light refraction from air to glass to air and other case where we have light refraction from glass to air to glass.

In case 1,

$R_2 = ((R_1)^2 - (c^2(u^4 - 1)t^2/(u^2)(u - 1)^2))^{1/2}$

We show that new radius of photon when it enters glass medium from air, its radius decreases.

In case 2,

$R_2 = ((R_1)^2 + (c^2(u^4 - 1)t^2/(u^2)(u - 1)^2))^{1/2}$

We show that new radius of photon when it enters air medium from glass, its radius increases.

Overall, this shows that photon got compressed when it entered into a dense medium and photon got expanded when it entered into rarer medium.

1.5. Further Research

Here I want to find a way such that we can find some value of t for further simplicity of formulas.

See, as centripetal and tangential force act together what we visualize a theoretical model of it illustrated in figure 5, understand it and manipulate it.

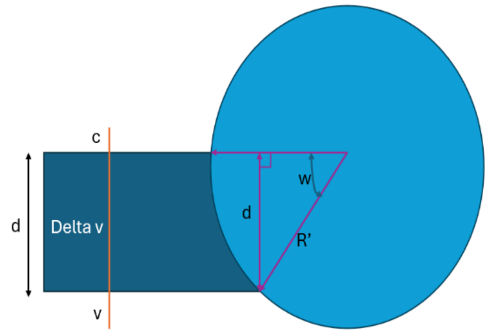

Figure 5: Theoretical Model

In this model, when photon experiences tangential acceleration from c to v, it will have change in speed or delta v. Now the distance covered during this acceleration is taken as d. During this time, centripetal acceleration is going on, which will rotate the photon with its center. Also, radius of photon got changed as either it got compressed or it got expanded. So, we have taken new radius as R'.

Now, if we make everything at one platform,

Sin w = d/R'

Where, w = angle it rotates by

See before we move forward, I analyze two possibilities or case happening during the refraction of light,

Case 1,

See if photon is getting experiencing both tangential and centripetal acceleration, there can lead to a case where photon center is not fixed. This means that photon is moving, center is also moving, during that time, it will face tangential and centripetal. But photon center got moved from initial position to different position. This model implies a more complex motion where the photon's centre and the photon itself are both in motion. This would involve:

$d_{Total} = d_{Tangential} + d_{Center}$

However, this case is less likely possible as it will lead to complications in defining a clear path and acceleration. This model is illustrated in figure 6.

Case 2,

What if photon center got fixed. This means it will experience a breaking effect at the boundary between the two mediums. Photon just enter different media, experiences break leading to experience of both tangential and centripetal acceleration. Here we have only d(tangential). This case is more possible. The fixed centre model aligns better with the idea of a photon experiencing a sudden change in speed and direction at the boundary, without involving complex motions of the centre. This model is illustrated in figure 7.

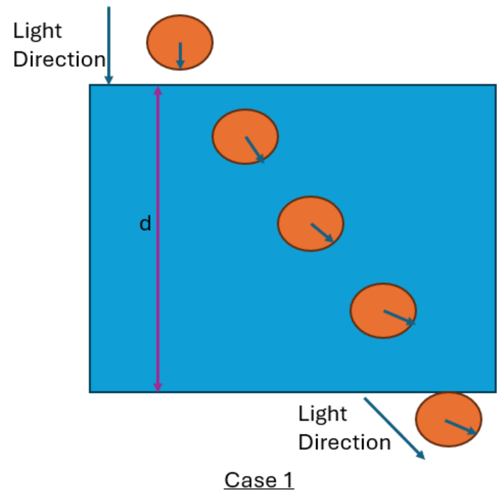

Figure 6: Case 1 theoretical model

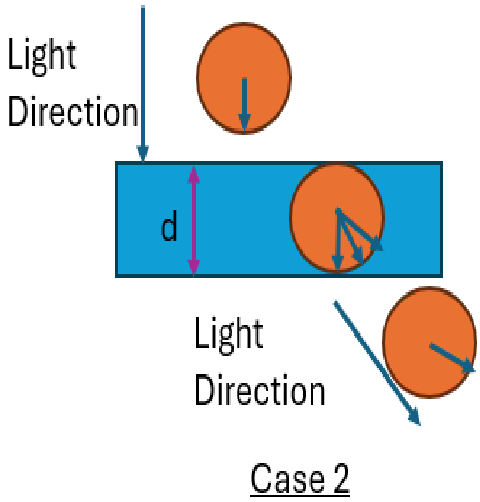

Figure 7: Case 2 theoretical model

If we go with this model, we have explanation of partial refraction and reflection phenomenon.

See, one by one photon coming, undergoing change and move ahead. Let's one photon will undergo break, but the previous photon is coming at different speed. So, between these two photons there will be speed and distance lag. Now if we see at the junction, incoming photons will start causing traffic there. All the photons will start collecting there. But in practical, this does not happen.

To maintain stability and prevent traffic at junction, photon will start experiencing repulsion force. Let's take reflected to refracted ratio is 1:4. This means out of 5 photons, 4 get refracted and one got reflected. Does photon experience any force between each other? Yes. Let's go for gravitational force.

$F = Gm^2/s^2$ (s is distance between two photons)

$M = E/c^2$

$F = GE^2/c^2s^2 = G(hv/cs)^2 = Kv^2/s^2$ (where $K = G(h/c)^2$, v is the frequency of phot)

So, at junction one photon comes, then second, then third, fourth and when it comes to fifth, it experiences such repulsion force from four in front photons such that it went for reflection.

Now coming back to Sin w = d/R'

We have one formula,

$v^2 – u^2 = 2as$

$a = v^2 – u^2/2d = v^2 – u^2/2R'sinw$

$a = v-u/t = v^2 – u^2/2R'sinw$

$2R'sinw = (v + u)t$

$t = 2R'sinw/(v + u)$

Applying this t in Radius calculation,

$(R_1)^2 – (R_2)^2 = c^2(u^4 - 1)t^2/(u^2)(u - 1)^2$ (Compressed when it goes into dense medium)

$(R_1)^2 – (R_2)^2 = c^2(u^4 - 1)(2R_2sinw/(v + c))^2/(u^2)(u - 1)^2$

$v = c/u$

$(R_1)^2 – (R_2)^2 = 4R_2{}^2c^2(u^4 - 1)(sinw/c(1 + (1/u))^2/(u^2)(u - 1)^2$

$(R_1)^2 – (R_2)^2 = 4R_2{}^2(u^4 - 1)(sinw)^2/(u^2)(u - 1)^2((u+1)^2/u^2)$

$(R_1)^2 – (R_2)^2 = 4R_2{}^2(u^2 - 1)(u^2 + 1)(sinw)^2/(u^2 - 1)^2$

$(R_1)^2 – (R_2)^2 = 4R_2{}^2(u^2 + 1)(sinw)^2/(u^2 - 1)$

$(R_1)^2/(R_2)^2 - 1 = 4(u^2 + 1)(sinw)^2/(u^2 - 1)$

$(R_1)^2/(R_2)^2 = (4(u^2 + 1)(sinw)^2/(u^2 - 1)) + 1$

$R_2 = R_1/((4(u^2 + 1)(sinw)^2/(u^2 - 1)) + 1)^{1/2}$

Simplified form of radius of photon when it got compressed under dense medium.

Similarly, we can find for those photons who go into rarer medium

$(R_1)^2 – (R_2)^2 = -(c^2(u^4 - 1)t^2/(u^2)(u - 1)^2)$

On further solving,

$(R_1)^2 – (R_2)^2 = -(4R_2{}^2(u^2 + 1)(sinw)^2/(u^2 - 1))$

$(R_2)^2 - (R_1)^2 = 4R_2{}^2(u^2 + 1)(sinw)^2/(u^2 - 1)$

$1 – (R_1)^2/(R_2)^2 = 4(u^2 + 1)(sinw)^2/(u^2 - 1)$

$(R_1)^2/(R_2)^2 = 1 – (4(u^2 + 1)(sinw)^2/(u^2 - 1))$

$R_2 = R_1/(1 – (4(u^2 + 1)(sinw)^2/(u^2 - 1)))^{1/2}$

Simplified form of radius of photon when it got expanded under rarer medium.

Overall, $4(u^2 + 1)(sinw)^2/(u^2 - 1)$ is a special factor by which radius of photon will matter.

Also, $(4(u^2 + 1)(sinw)^2/(u^2 - 1)) < 1$. This factor will also always be less than 1.

This factor depends on two things only

i. Refractive index of medium in which photon will enter
ii. Incident angle(i)

During the research I notice one point. Torque of photon not only happens in refraction of light but in reflection of light also. This is because light also deviates from incident path to a different path or reflected path.

1.6. Reflection of light

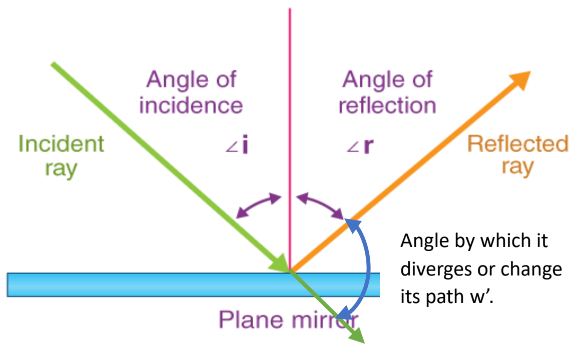

Figure 8: Reflection of light

Let's take a condition that light in air medium strike the mirror and reflected in another direction shown in figure 8.

Refractional Torque = $(ER(a)^{1/2}/c^2)\sin w$

Reflectional Torque = $(ERa/c^2)\sin w'$

Here, w' is the angle by which the incident light on a mirror changes its angle.

Here, a is centripetal acceleration as speed stays constant but direction changes.

a = centripetal acceleration = v^2/r

v = speed in the medium

Now, Reflectional Torque = $(Erv^2/rc^2)\sin w'$

Reflectional Torque = $(Ev^2/c^2)\sin w'$ (radius eliminated)

Incident angle = Reflected angle

$i + r + w' = 180$

$w' = 180 - 2i$

So, Reflectional Torque = $(Ev^2/c^2)\sin(180 - 2i) = (Ev^2/c^2)\sin(2i)$

If v = speed of light = c (air medium)

Then, Reflectional Torque = $E\sin(2i) = hv\sin(2i)$

Here I want to concluded my paper and with more research I will do further exploration of research.

2. Conclusion

In this study, we have explored the intricate behaviours and characteristics of photons as they encounter various media boundaries. Our theoretical model addresses both the tangential and centripetal accelerations experienced by photons, shedding light on the mechanisms behind refraction and reflection. The phenomena observed support the notion that photon interactions are influenced by complex forces at the media interface, resulting in changes in speed and trajectory (Einstein, 1905[1]; Crespi et al., 2012[2]).

The analysis of photon dynamics through quantum simulations and novel optical techniques has provided deeper insights into these interactions, highlighting their relevance in practical applications and advanced research (Rakher et al., 2011[3]; Polino et al., 2024[4]). Furthermore, our findings contribute to the broader understanding of light behaviour in varying refractive indices, which is critical for the development of future photonic technologies (Hannaford & Sacha, 2024[5]; McCutcheon, Ostermann, & Yelin, 2024[6]).

This work sets the stage for further research into the precise manipulation of photons, paving the way for advancements in quantum optics and photonics (Zhou et al., 2024[7]; Gordon & Beichman, 2024[8]). Future studies could delve deeper into the role of photon shape and the potential of photonic quantum simulators to unravel new dimensions of light-matter interactions. The exploration of these phenomena not only enhances our theoretical understanding but also opens new avenues for technological innovations.

3. Future Work

In future work, we aim to further explore the behaviour of photons in various mediums, including more complex scenarios involving multiple boundaries and different refractive indices. We also plan to investigate the practical applications of our findings in optical devices and technologies. Additionally, experimental verification of the theoretical models proposed in this paper will be a key focus, allowing us to refine our understanding and improve the accuracy of our predictions.

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