Research Note

Salvaging Newton's 313 Year Old Corpuscular Theory of Light

G. G. Nyambuya†[1], A. Dube† and G. Musosi†
†National University of Science and Technology,
Faculty of Applied Sciences – Department of Applied Physics,
Fundamental Theoretical and Astro-Physics Group,
P. O. Box 939, Ascot, Bulawayo,
Republic of Zimbabwe.

Abstract

As is well known – Newton's corpuscular model of light can explain the Law of Reflection and Snell's Law of Refraction. Sadly and regrettably – its predictions about the speed of light in different mediums runs contrary to experience. Because of this, Newton's theory of light was abandoned in favour of Huygens' wave theory. It [Newton's corpuscular model of light] predicts that the speed of light is larger in higher density mediums. This prediction was shown to be wrong by Foucault's 1850 landmarking experiment that brought down this theory of Newton. The major assumption of Newton's corpuscular model of light is that the corpuscles of light have an attraction with the particles of the medium. When the converse is assumed, *i.e.*, the corpuscles of light are assumed to not have an attraction-effect, but a repulsion-effect with the particles of the medium, one obtains the correct predictions of the speed of light in denser mediums. This new assumption [of Newton's corpuscles repelling with the particles of the medium] might explain why light has the maximum speed in any given medium.

1 Introduction

Seventeen years after his great touchstone masterpiece which is probably the greatest synthesis ever by a single human mind – *Philosophiae Naturalis Principia Mathematica* (popularity known as the *Principia*); the great Sir Isaac Newton published yet another great masterpiece – his treatise, *Opticks* (Newton 1704). Sir Isaac Newton could have published this work much earlier and the reason for the delay is he 'had to wait' until the death of one of his greatest critics and intellectual nemesis – Robert Hooke (1635 – 1703). That is – despite his influence, great stature and standing as a towering figure of human history and his unparalleled giant intellect, Sir Isaac Newton faced criticism on his theories and Hooke was one of them and he – Newton – had become so sensitive to criticism, especially from Hooke (1667) who was a strong advocate of the wave theory of light (Descartes 1637) which was latter put into its present final form (Huygens 1667) by the great Dutch mathematician and scientist, Christiaan Huygens (1629 – 1695). So it would appear that, to avoid further quarrels with Hooke, Newton saw it 'fit and wise to wait' until the death[2] of Robert Hooke.

[1]Correspondence: E-mail: physicist.ggn@gmail.com

[2]One wonders what would have happened had Hooke outlived Newton? Had Newton prepared a posthumous publication of his treatise *Opticks*?

Unlike in his *Principia*, the treatise *Opticks* was written in *English* and not in *Latin* which at the time in Europe was the dominate language for intellectual discourse. It obviously was much easier to read for the English audience – because of this, it was very popular. Newton would revise *Opticks* three times (Newton 1706, 1717/8, 1730). In this landmarking work – *Opticks* – which was inspired by the works of the great French philosopher, priest, astronomer, and mathematician – Pierre Gassendi $(1592 - 1655)$; Newton propounded on Gassendi's ideas, that light consists of tiny spherical *billiard-ball-like* particles that he called corpuscles: the word corpuscle means 'a tiny piece of anything (something)'. Newton's corpuscles could easily account for the reflection and refraction of light. The case of reflection – where the angle of the incident ray relative to the normal is equal to the angle of the reflected ray relative to the normal; this can neatly be explained from the viewpoint of how an elastic and frictionless ball bounces off a smooth surface. Newton's corpuscular theory of light would dominate Western philosophical thinking for at least 100 years before it was brought down by Foucault's single measurement of 1850.

In his theory, the great Sir Isaac Newton imagined that when a light corpuscle is in the immersion of a given medium – such as water or glass *etc*, it is surrounded by equal numbers of particles of the given medium. In such a scenario, Newton imagined there being an attractive force between the light corpuscle and the surrounding particles of the medium. Deep within this medium, these forces would naturally cancel each other out thus resulting in no net force on the light particle – the corpuscle would, in accordance with Newton's first law of motion, proceed in a uniform motion in a straight line inside this medium.

As already stated, reflection of light is straight forwardly explained in Newton's corpuscular theory from the viewpoint of how an elastic and frictionless ball bouncing off a smooth surface. A key property of Newton's corpuscular theory is how it accounts for refraction. Near an interface – such as the boundary between air and water or air and glass, the situation is different from that obtaining deep inside the medium. At the boundary, the light corpuscle would experience more attracting matter particles on one side than the other – in which event, the corpuscle will experience a non-zero net force. Newton imagined that in this brief moment when the corpuscle leaves one medium as it enters another, it would experience an net attractive force towards the medium with more matter particles. In-accordance to Figure (1), this net attractive force would increase the vertical component of the corpuscle's velocity (hence momentum), thus resulting in the 'deflection' in its velocity towards the surface's normal.

Because the vertical forces would speed up the corpuscles, it means the speed of these corpuscles would have to be much larger in a denser medium and this is all Newton needed to do – *i.e.*, to claim that the speed of light is different in different transparent materials. He was right on the prediction that "the speed of light is different in different transparent materials" but was wrong on the prediction that "the speed of these corpuscles was much larger in a denser medium than in a less dense one". It was the French physicist – Jean Léon Foucault $(1819 - 1868)$, who in 1850, demonstrated with his small steam turbine-mirror experiment, that this prediction of Newton (that the speed of these corpuscles was much larger in a denser medium than in a less dense one) runs contrary to experimental evidence. This wrong prediction of Newton's corpuscular theory coupled with its failure to adequately explain the diffraction, interference and polarization of light lead to it to be abandoned in favour of Huygens' wave theory which would explain all these issues.

On the more positive side of things, since the corpuscle does not experience any net horizontal force, its horizontal velocity (hence momentum) remains the same (*i.e.*, $p_i \sin\theta_i = p_t \sin\theta_t$) and it is this that leads to Snell's[3] Law (also known as Snell-Descartes Law). Newton regarded the explanation of Snell's

[3] Willebrord Snellius $(1580 - 1626)$, after whom the law of refraction is named was a Dutch astronomer.

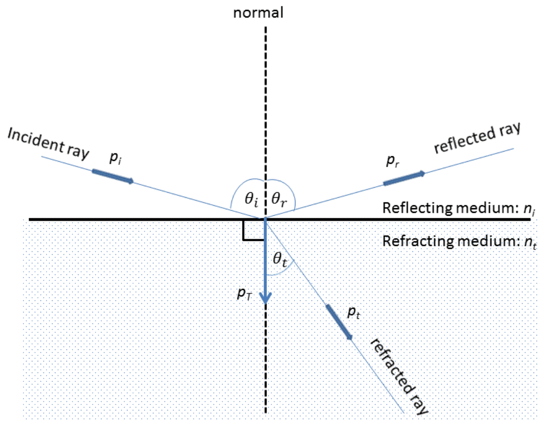

Figure (1): **Incident, Reflected and Refracted Light Ray Diagram:** *Specular reflection of light at a smooth interface separating mediums of refractive indices n_i and n_t respectively. According to the well established empirical Laws of Optics, the normal, incident, reflected and refracted ray all lie on the same plane – and, the incident (θ_i) and reflected (θ_r) angles are identical i.e. $(\theta_i = \theta_i)$ while the incident and refracted (θ_t) angles are related by Snell's Law, i.e.: $n_i \sin\theta_i = n_t \sin\theta_t$. The momenta p_i, p_r and p_t are the momenta of the photon (corpuscle) of the incident, reflected and refracted rays respectively, while p_T is the momentum that is transmitted (along the normal) to the refracting medium. No energy is transferred to the refracting medium.*

Law $(p_i \sin\theta_i = p_t \sin\theta_t)$ as one of the triumphs of his corpuscular theory. He feverishly concluded his discussion of this in his book Opticks with the words: "*I take this to be a very convincing argument of the full truth of this proposition.*" Newton never lived to witness his prediction being monumentally crushed. Once his prediction was crushed, advocates of the corpuscular theory succumbed under the weight of Foucault's all-important experimental result. Such is science's clearest demonstration of the superiority of measurements over authority.

2 Critic

In-order to improve on Newton's Corpuscular Theory, we shall criticize two areas of it, and this critic is so designed so that if one where to overcome it (critic), they would – *with greater insight* – bring Newton's Corpuscular Theory into tandem with evidence from experimental philosophy. Below we present our tripartite critic:

1. **Law of Conservation of Energy:** The Law of Conservation of Energy (LCE) is not applied in the equations of motion of the corpuscles. However, without any mention of it – Newton, somehow assumes this sacrosanct law is upheld. The reason for him [Newton] not applying it – is because, it is not necessary. As we shall demonstrate in a short-while [*i.e.*, in §(3)], an application of the law of conservation of energy to the corpuscles will bring in new insight and clarity in the dynamics of the corpuscles.

2. **Interaction of Newton's Corpuscles with Matter (Medium):** Newton assumes that his corpuscles interact with matter (and the medium in which they travel) *via* attraction with all the particles of the medium that

surround them. This assumption leads to Newton's corpuscles to have a greater speed in air than in water: as demonstrated by the French physicist – Jean Léon Foucault $(1819 - 1868)$, with his small steam turbine-mirror experiment, this prediction of Newton is contrary to experimental evidence. Equally – instead of attraction, one can assume repulsion which leads to the same prediction insofar as the 'straight line trajectory of the corpuscles' and in addition to this, repulsion of the corpuscles with matter and the medium leads to the correct prediction of the light travelling faster in air than in water.

According to prevailing wisdom, the energy E of a photon is related to its momentum p by the formula:

$$E = pc, \tag{2.1}$$

where c is the speed of light in *vacuo*. This photon energy-momentum was not known to Newton nor to anyone in his day, thus, the Law of Conservation of Energy (LCE) was not used as a constraint to the equations of motion in Newton's corpuscular theory. The photon energy-momentum relation $(E = pc)$ is both a theoretical (Maxwell 1873, Bartoli 1876) and experimental (cf., Nichols & Hull 1903*a*,*b*, Lebedew 1902) fact which is derived indirectly from the relationship between radiation pressure (P_{rad}) and radiation intensity (I_{rad}): $P_{\mathrm{rad}} = I_{\mathrm{rad}}/c$, and this is in the case of complete absorption of the radiating by the illuminated body. Maxwell (1873) derived the photon energy-momentum relation $(E = pc)$ from his celebrated electromagnetic theory while (Bartoli 1876) derived a modified form of this relation from the *Second Law of Thermodynamics* and this result of (Bartoli 1876) would reduce to Maxwell (1873)'s result in the case of a perfectly reflecting body. Bartoli contrived elaborate experiments to verify the relation $(E = pc)$, and like all before him, he was balked in the search by the complicated character of the gas action which he found no way of eliminating from his experiments and after Bartoli's work, the subject was dealt with theoretically by Boltzmann (1884), Galitzine (1892), Heaviside (1893, 1894), Guillaume (1894) and Goldhammer (1901).

3 Modification

When a corpuscle of light approaches the boundary surface, one of the following three things will happen, either:

(a) The corpuscle will – on arriving at the boundary, *as a whole* – be reflected.

(b) The corpuscle will – on arriving at the boundary, *as a whole* – be transmitted.

(c) The corpuscle will – on arriving at the boundary, *decompose* into two parts with one part being reflected and the other being refracted.

In treating the corpuscle as a ordinary particle, the laws of conservations of momentum and energy will hold true. We will consider these scenarios. However, we shall not consider scenario (c) as this scenario is contrary to all-known experience. In this scenario, the LCE renders this scenario un-physical as one will fail to explain how the reflected and transmitted photon will have the same frequency as the incident photon without violating the LCE. It is a perdurable and unassailable observational fact that the reflected and transmitted photons do have the same frequency as the incident photon.

(a) In this scenario, the corpuscle will – *as a whole* – be reflected. The LCE demands that the energy $(E_i = p_i c)$ of the incident photon (corpuscle) must equal the energy $(E_r = p_r c)$ of the reflected photon (corpuscle), *i.e.* $(E_i = E_r)$, hence:

$$p_i = p_r. \tag{3.1}$$

While momentum is transmitted, no energy is transmitted to the refracting medium. The LCM demands that the x-components of momenta be such that:

$$p_i \sin\theta_i = p_r \sin\theta_r, \tag{3.2}$$

hence:

$$\theta_i = \theta_r. \tag{3.3}$$

For the y-components of momenta, the LCM demands that:

$$p_i \cos\theta_i = p_T - p_r \cos\theta_r. \tag{3.4}$$

From (3.6) and (3.4), it follows that:

$$p_T = 2p_i \cos\theta_i = 2p_r \cos\theta_r. \tag{3.5}$$

For so long as the reflected photon is able to impart some momentum (p_T) to the refracting medium, the corpuscle will be reflected as a whole.

(b) In this scenario, the corpuscle will – *as a whole* – be refracted. The LCE demands that the energy $(E_i = p_i c)$ of the incident photon (corpuscle) must equal the energy $(E_t = p_t c)$ of the refracted (transmitted) photon (corpuscle) plus that transmitted to the medium (E_T), *i.e.* $(E_i = E_t + E_T)$, hence:

$$p_i = p_t + \frac{E_T}{c}. \tag{3.6}$$

The LCM demands that the x-components of momenta be such that: $(p_i \sin\theta_i = p_t \sin\theta_t)$, hence:

$$\frac{\sin\theta_i}{\sin\theta_t} = 1 - \frac{E_T}{E_i} = \frac{n_t}{n_i} \quad \Rightarrow \quad \frac{E_T}{E_i} = 1 - \frac{n_t}{n_i}. \tag{3.7}$$

Equation (3.7) is Snell's Law of Refraction. From this, it is seen that the ratio of the refractive indices of the two medium are a measure of the fraction of the energy transmitted to to the refracting medium.

When the corpuscle moves from a less dense medium to a more dense medium, we will have for this setting that $(n_t/n_i > 1)$; from this – it follows from (3.7) that: $(E_T < 0)$. That is to say, as the corpuscle accelerates as it increases its speed, it acquires some energy from this medium. Conversely, when the corpuscle moves from a more dense medium to a less dense medium, we will have for this setting that $(n_t/n_i < 1)$; from this – it follows from (3.7) that: $(E_T > 0)$. That is to say, as the corpuscle decelerates as it decreases its speed, it will cede some of its energy to the less dense medium.

4 General Discussion

Within the realm and confines of logic and intuition, we have argued that Newton's corpuscular theory of light can be salvaged if the contrary hypothesis is assumed, *i.e.*, if the corpuscles and the particles of the medium are to repel each other. An advantage of this hypothesis is that it may allow one to explain why photons have the maximum speed in any given medium – because, if the photon and the particles of the medium where to repel each other, the photon will travel with no '*friction*' within the medium in which it is propagating. In the case where the photon and the particles of the medium are to attract each other, the photon will have to traverse in the medium a some '*friction*' to it – this 'friction' should somehow slow down the photon, the meaning of which is that the photon should be short-ranged.

On the other hand, we have the issue of inertia. Could this '*friction*' of the corpuscles with the media have anything to do with inertia mass? Photons appear to have no inertia properties – hence their been assigned a zero rest mass. Could it be that, matter particles and the particles of the medium through which matter traverses ('*empty*' space/*vacuo*) attract each other in the same manner as Newton's corpuscles so that this attraction leads to this 'friction' which in-turn results in the inertia properties of matter? These are just some of the exciting questions that come to mind. With this idea of photons and the particles of the medium repelling each other, it seems one may reap two benefits (1) : of correctly predicting that light is slower in a higher density medium than in a lower density medium, and (2) : of possibly explain the origins of inertia. At this point, we should say that it is not in our scope to go deeper than we already have done on the polemical issue of the origins of inertia properties of photons and matter. Ours was just to '*stir inside a hornet's nest*' and '*flee*'.

At this point, we must address the issue of what the particle theory can explain. After Newton's corpuscular theory of light was short-down by Foucault's 1850 experiment, other issues such as the failure of the corpuscular theory of light to explain, polarization, diffraction and interference pattens observed in the Young's Double Slit Experiment, these where brought up to bury the theory once and for altime.

As is well known, it was Albert Einstein $(1879 - 1955)$ in one of his five landmarking papers of 1905, that the particle theory of light was resurrected. Einstein did not resurrect Netwon's concept of light – as comprising tiny particles – in the same sense as it was champion by Newton. Einstein's photon concept was taken-up by the illustrious French Prince and physicist – Louis Victor Pierre Raymond *de* Broglie $(1892 - 1987)$ and finally by the towering Austrian physicist – Erwin Rudolf Josef Alexander Schrödinger $(1887 - 1961)$. Today we talk of the wave-particle duality of matter and light. Both matter and energy have the dual properties of waves and particle. There are some aspects of matter and light that are best explained by the particle-model and not the wave-model and on the same pedestal, there are some aspects of matter and energy that can be explained using the wave-model and not the particle-model.

For example, the photo-electric effect and the Compton effect can only be explained using the particle-model and not the wave-model, yet on the other hand, the diffraction and observed interference pattern seen in both matter and light can be explained using the wave-model and not the particle-model. In simple terms, we should not expect the particle-model to explain all expects of light and on the same footing we should not expect the wave-model to explain all of the behaviour of light.

On the podium and level of understanding - we shall close this reading by saying that, we have shown that Newton's particle-model can be salvaged. Be that as it may, we do not expect the particle-model of Newton in its present modified form to explain diffraction, interference and polarization. We believe it is sufficient that this model can – under the new hypothesis, explain both reflection and refraction without contradicting experience. This new hypothesis not only fixes the bug in Newton's theory, it opens up hope in probing the origins of inertia.

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