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Photon and Electron Interactions from Moving Photon Sources in an Inertial and non-Inertial Frames of Reference

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ABSTRACT

In 2016, for the first time to the author's knowledge, the conservation of energy and momentum was balanced for an emission and absorption of a photon that results in motion of an atom or molecule [1]. This balancing was performed by reasoning and algebra. In this paper a formal balancing of the conservation laws is presented. This includes a new operator that allows a photon to be separated between an observed value of the photon, and a value that is the difference between the observed and the emitted value of the photon at the source, for a single atom in space and a single photon source. A new method for applying the conservation of momentum to an absorption and emission of a photon is also presented, where the coordinate system, for the emitted photon, is shifted so the emitted photon is moving in the same direction as the absorbed photon.

***Keywords*:** Conservation, Energy, Momentum, Photon, Electron, Coordinate

1. INTRODUCTION

When a photon interacts with an atom or molecule in its ground state, where both the photons source and atom or molecule are in the same inertial frame of reference, and the photon has the same energy as the first energy state of the atom or molecule, the atom or molecule will

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absorb the photon, and after a time the photon will be emitted in a random direction. In a previous publication, it was shown that if the conservation of momentum and conservation of energy were conserved there would be no motion of the atom or molecule caused by the interaction of the photon, despite the direction of the emitted photon [1]. However, in the previous publication it was shown that if the source was moving there would be a possibility of motion for the atom or molecule, where the direction of the moving source determined the possibility of motion. This was determined by reasoning and simple algebra. In this paper, mathematics will be introduced, including a new operator and a new method of applying the conservation of momentum, which will produce the equivalent of what was reasoned in the previous paper. Also, this paper will show examples of what this mathematics can produce that is not in current physics theory, to the author's knowledge.

2. SINGLE PHOTON AND A SINGLE ATOM OR TWO IN EMPTY SPACE

The concepts and mathematics that will be introduced in this paper, to the author's knowledge, is new. Because of this reason, the photon and electron interactions will be limited to a single photon from a single photon source and a single atom, or two atoms.

3. MOMENTUM AND ENERGY EQUATIONS OF A PHOTON FROM A MOVING SOURCE

When a photon is emitted from a moving source, in an inertial frame of reference relative to an atom, there is a change to the observed wavelength by the atom due to the Relativistic Doppler Shift [2], where the observed energy is equal to the first energy state of the atom.

However, for motion to occur after an atom in the ground state absorbs and emits the photon, when the source is moving away from the atom, the momentum and energy of the photon at the source is used as the actual momentum and energy that interacts with the atom [1].

For the momentum and energy to be conserved, the kinetic energy and momentum of the atom, after the interaction with the photon, is equal to the difference between the energy and momentum of the photon at the sources frame of reference and the energy and momentum of the emitted photon from the atoms frame of reference before the atom moves.

As the energy and momentum of the photon from the source is used in the interaction with the atom, and the atom absorbs and emits the photon it observes, where the kinetic energy and momentum of the atom, after interaction with the photon, is the difference between the energy and momentum of the sources photon and the emitted photon, then the following equations can be used for the photons momentum and energy:

(1) $$\overrightarrow{P_T} = \overrightarrow{P_O} + \overrightarrow{P_S}ⅆ$$

and

(2) $$E_T = E_O + E_Sⅆ$$

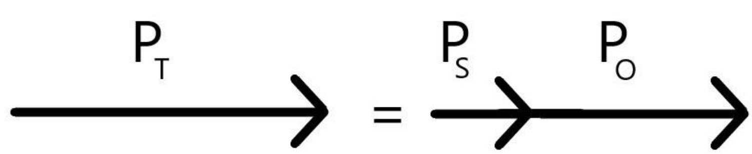
where:

$\overrightarrow{P_T}$ and E_T are the photons momentum and energy, from the sources perspective, prior to the interaction with the atom, respectively. $\overrightarrow{P_O}$ and E_O are the photons momentum and energy that is observed by the atom, respectively. $\overrightarrow{P_S}$ and E_S are the momentum and energy difference between the sources photon, from the sources perspective, and the emitted photon, from the atoms perspective, respectively. ȡ is the new operator that will allow the momentum and energy of the photon to be divided, and interact with the atom independently.

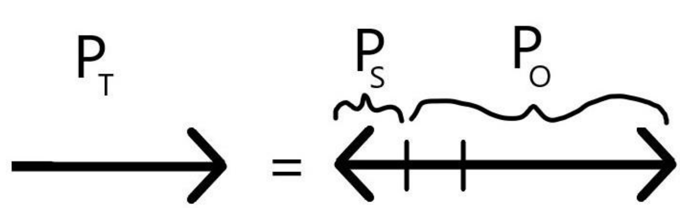
The equations above imply that the photons momentum and energy, from the sources frame of reference, is constant in every frame of reference, and it is only the observed momentum and energy that differs per frame of reference. Further, the equation was introduced with regards to the photon source moving away from the atom. This would cause the sign of the momentum and energy, attached to the operator, to be positive, as the observed photon's momentum and energy is smaller than the photon's momentum and energy from the moving source, per Relativistic Doppler Effect [2].

For sources moving toward the atom, the sign of the momentum and energy of the photon, in front of the operator, would be negative. This is because the observed photon's momentum and energy is larger than the photon's momentum and energy from the moving source, per Relativistic Doppler Effect [2], where the sources photon's momentum and energy, from the sources frame of reference, remains constant. This new operator is designed to allow for this sign change, as this operator is designed to work with photons from sources moving toward an atom and away from an atom.

As momentum is a vector, and the new operator allows for a split of the momentum, then the new vector representation is as follows for a photon source moving away from an atom:



For a photon source moving toward an atom, the new vector representation is as follows:



4. VECTOR REPRESENTATION OF A PHOTON WITHIN AN ATOM

After an atom, in the ground state, absorbs a photon, where the photons energy, from a source in the same inertial frame of reference as the atom, is equal to the first energy state of the atom, the atom maintains the energy for a time, τ, or the decay time. Further, it does not matter what direction the photon is coming in, the atom will absorb the photon and maintain the new energy state for about the same amount of time. And, for the conservation of energy to be maintained there would be no motion caused by the absorption, as the photons energy would equal to the energy inside the atom, leaving no extra energy for motion.

In this same situation, the momentum of the photon is also absorbed into the atom, and though the direction of the momentum can be different, the momentum inside the atom will increase by the same amount every time. Classically, if an electron is orbiting around a nucleus, an increase of momentum would imply an electron is moving faster around the nucleus in a larger orbit, but the nucleus's attraction prevents the electron from flying off.

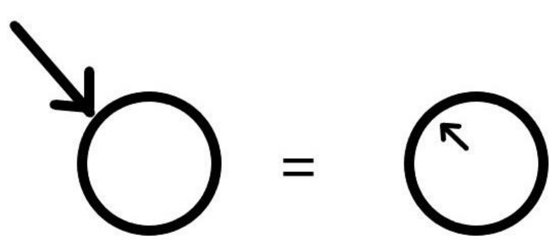
Further, in this classical example, the location of the electron would be more difficult to determine due to the increased speed of the electron around the atom, as compared to before the atom absorbing the photon. As a result, the momentum vector of any photon that is absorbed inside the atom can be represented inside the atom the same way every time, despite the initial direction from the incoming photon.

For simplification, the momentum vector inside the atom, after an absorption, can be represented by a radial vector pointing in no particular angular direction, away from the atom, with a value equal to the magnitude of the momentum of the photon. With this transformation, momentum of a photon can be represented inside an atom, despite direction. The following are mathematical examples, in two dimensions, of how this transformation occurs.

$$a\hat{\imath} + b\hat{\jmath} = |c|\hat{p}$$

$$|c| = \sqrt{a^2 + b^2}$$

a and b are the scalar values of the vector, and $\hat{\imath}$ and $\hat{\jmath}$ are unit vectors associated with the direction, representing the photon that is to be absorbed inside the atom. $|c|$ is the magnitude of the photon vector, and $\hat{p}$ is the unit vector pointing away from the atom, where both the magnitude and direction represent the vector inside the atom due to the absorbed photon. This transformation can be represented graphically as the following.



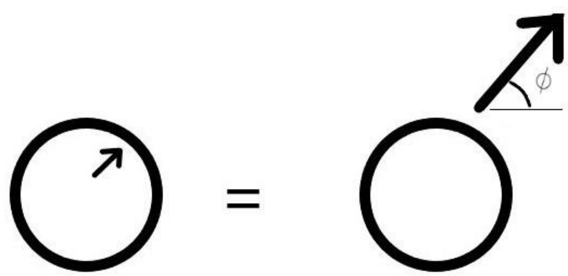
The graph, to the left of the equals sign, represents the photon to be absorbed, where the arrow represents the momentum vector of the photon. The graph, to the right of the equals sign, represents the momentum inside the atom due to absorbed photon, where the arrow represents the momentum vector. The circles on both sides of the equals sign represent the atom.

The atoms natural state is the ground state, where the atom, after absorbing a photon, will move towards. After absorption, the atom will be excited until after about the decay time, and emit a photon.

This implies that the momentum inside the atom must reduce for the emission of the photon to occur. This can be done by subtracting the momentum inside the atom with the following:

$$-|c|\hat{p}$$

During the time when the atom is in its excited state the position of the electron varies greater compared to the ground state. As a result, the direction of the photon can vary greatly when the photon is emitted. However, despite this direction, the atoms position in space will not be effected by the emission of the photon, as energy is conserved. For momentum to be conserved, the magnitude of the emitted photon must equal to the momentum that was inside the atom. Using the diagram below the momentum of the photon can be calculated.



So

$$p_x\hat{\imath} + p_y\hat{\jmath}$$

$$p_x = |c|\cos\emptyset$$

$$p_y = |c|\sin\emptyset$$

That is, the momentum of the atom is represented as a two dimensional vector outside of the atom. However, as there is no impact to the atom caused by the emitted photon, and there is only one direction of the emitted photon from the perspective of the atom, the photon will always have the same value and direction from the perspective of the atom. To maintain the idea of no impact to the atom, the emitted atom must be equal to the photon that was absorbed, despite direction, from the observer's perspective.

So, as the direction of the photon changes with respect to the observer, and there is no impact to the atom, for the conservation of momentum to be maintained the coordinate system of the emitted photon must shift or rotate so the direction of the emitted photon can be equal to that of the photon that was absorbed.

This will allow for the mathematics for the conservation of energy to uphold, where the atom and photon source are in the same inertial frame of reference.

To verify the use of this coordinate shift when calculating the conservation of momentum, the coordinate shift after an absorption and emission of a photon will be applied to an inertial frame of reference where the photon source is moving, and where the introduced momentum and energy equations of the photon of a moving source will be used.

5. CONSERVATION OF MOMENTUM AND ENERGY BALANCING USING THE COORDINATE SHIFT AND THE INTRODUCED PHOTON EQUATIONS IN AN INERTIAL FRAME OF REFERENCE

For the following discussion, the photon source is moving away from an atom in the ground state, where the observed energy of the photon, E_O, is equal to the energy needed to bring the atom from its ground state to its first excited state, and where the energy difference between the sources photon, from the photon sources perspective, and the emitted photon from the atom, from the atoms perspective, E_S, is equal to the energy needed to bring the atom from its first excited state to its second excited state. From the sources perspective, the value of the emitted photon energy is E_T. Equations (1) and (2) will be used as the momentum and energy of the photon.

After the photon is emitted from the source, from the atoms perspective, there will be an absorption of the E_O part of the photon. However, as the photon, from the photon sources perspective, is a single photon, the E_S value would need to be represented or the conservation laws will not uphold. There are two possibilities for the representation of the E_S value, where one possibility is that the electron absorbs the E_S value and the electron is in the second energy state. The second possibility is the energy is represented as translational motion of the atom, at value E_S. As E_O and E_S are part of the same photon, then the absorption of E_S, or translational motion at E_S, must occur at the same time E_O is absorbed.

There are two possibilities of emission if the E_S value is absorbed, and there is only an E_O emission if E_S is represented as translational motion.

The table below summarizes the emissions.

E_S Possibilities While E_O is Absorbed	Emission Possibilities
Photon portion of E_S is absorbed into the Atom	A single photon at value E_T
Photon portion of E_S is absorbed into the Atom	Two photons at values of E_O and E_S
Photon portion of E_S is represented as translational motion of the Atom	A photon at value of E_O

For the first two rows, the conservation of energy is balanced as the value of the energy of the photon from the photon source is equal to the energy of the photon(s) emitted from the atom, for both possibilities. If the coordinate system shifted for every emitted photon, for both rows, the conservation of momentum will be balanced, as the incident photons momentum is equal to the emitted photons momentum for the first row, and the incident photons momentum is equal to the addition of the momentum of both photons for the second row. The coordinate system was shifted for each photon emitted for the second row. If there is a part of or an entire photon absorbed by the atom, for each photon emitted the coordinate system must shift so each emitted photon is in the same direction as the incident photon.

For the third row, the conservation of energy balances as the energy of the translational motion and the energy of the emitted photon equals to the energy of the incident photon. As the momentum represented as translational motion was from the portion of the photon that was not absorbed in the atom, the coordinate system will not shift for the direction of the translational motion. However, the direct transfer of momentum to the atom from the $\overrightarrow{P_S}$ portion of the photon will include the direction. Also, the coordinate system of the emitted photon would shift to be in the same direction as the incident photon. This would balance the conservation of momentum.

There can be several types of interactions of photons from moving photons sources with an atom or atoms in the ground state and/or in excited states. To further clarify the use of the photon equations and the coordinate shift, some examples of an atom or atoms will be presented.

6. FURTHER EXAMPLES OF CONSERVATION OF MOMENTUM AND ENERGY BALANCING USING THE COORDINATE SHIFT AND THE INTRODUCED PHOTON EQUATIONS IN AN INERTIAL FRAME OF REFERENCE

6. 1. Photon Interacting with an Atom in the Ground State with Source Moving Away

For the following discussion, the photon source is moving away from an atom in the ground state, where the observed energy of the photon, E_O, is equal to the energy needed to bring the atom from its ground state to its first excited state, and where the energy difference between the sources photon, from the photon sources perspective, and the emitted photon, from the atoms perspective, E_S, is equal to the energy needed to bring the atom from its first excited state to its second excited state.

From the sources perspective, the value of the emitted photon energy is E_T. Equations (1) and (2) will be used as the momentum and energy of the photon.

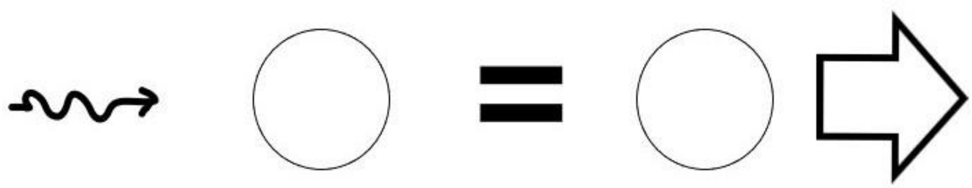
Considering translational motion as an option and the photon is a single photon at a value of E_T, from the perspective of the photon source, then translational motion of the atom at E_T can be a possibility. That is, an interaction can be possible as long as the conservation laws are upheld. The total interactions, before and after the interaction, of the photon with the atom are as follows:

Before Interaction	After Interaction
Photon value of E_T and Atom in Ground State	Translational motion of atom at value E_T
Photon value of E_T and Atom in Ground State	No translational motion of atom and Photon at Value E_T
Photon value of E_T and Atom in Ground State	No translational motion and two photons at values of E_O and E_S
Photon value of E_T and Atom in Ground State	Translational motion at value E_S, and a photon at value of E_O

From the table above, the second and third possibility are based on the electrons behavior: where the second possibility is caused by the drop of the electron in the second excited energy state to the ground state; and the third possibility are two drops, where the photon value of E_S is caused by the drop of the electron in the second excited energy state to the first excited energy state, and the photon value of E_O is caused by the drop of the electron in the first excited energy state to the ground state. In the third possibility, the photon of value E_S will be emitted prior to the photon of value E_O.

Mathematics, in lieu of the conservation laws, will be applied to each possibility to verify the possibility of the interaction. As energy has been discussed, only momentum will be considered, to simplify the discussion.

The first possibility is a simple transition of momentum of the photon to translational momentum of the atom. As there is no direct interaction with the electron, and only the atom, there is no need to transform the momentum of the photon to momentum inside an atom.



On the left side of the figure above a photon is about to interact with the atom. On the right side of the figure is the atom moving via translational motion, where the momentum of the photon is equal to the momentum of the moving atom.

As there is no absorption into the atom, the coordinate system does not need to be rotated. Therefore, the momentum equation before and after the photon interacts with the atom is $\overrightarrow{P_T} = \overrightarrow{P_T}$. The direction of the atom is moving in the direction the photon was moving in.

The second possibility requires the momentum of the photon to be transformed into the momentum within the atom.

The photon contains the following momentum equation.

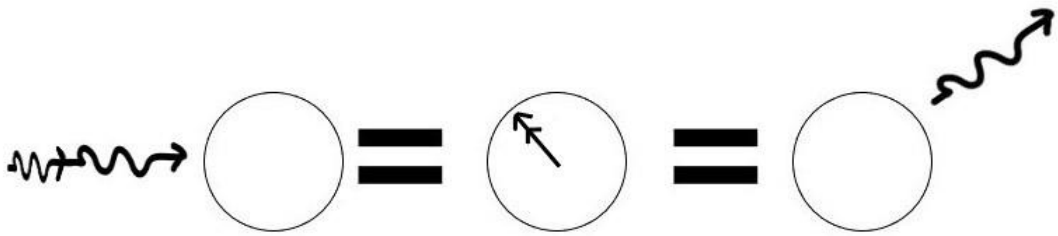
$$\overrightarrow{P_T} = \overrightarrow{P_O} + \overrightarrow{P_S}$$

when the photon is absorbed, both $\overrightarrow{P_O}$ and $\overrightarrow{P_S}$ are transformed into the atom to get the following equation:

$$\overrightarrow{P_O} + \overrightarrow{P_S} = \left|\overrightarrow{P_O}\right|\hat{p} + \left|\overrightarrow{P_S}\right|\hat{p} = \left(\left|\overrightarrow{P_O}\right| + \left|\overrightarrow{P_S}\right|\right)\hat{p}$$

The right most side of the equation was written to emphasize that both momentum values will combine, where both values will be used to create a single magnitude of a photon when emitted from the atom.

After rotating the coordinate system so the emitted photon will be identical to the absorbed photon, the momentum of the emitted photon will be $\overrightarrow{P_T}$. Graphically this becomes:

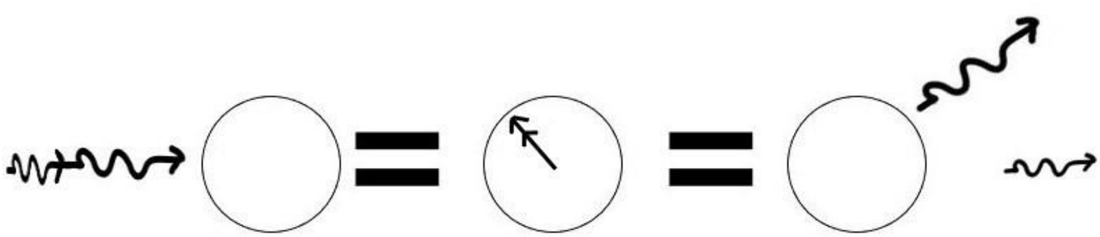


The left is the photon split into $\overrightarrow{P_O}$ and $\overrightarrow{P_S}$, the center is the momentum inside the photon $(|\overrightarrow{P_O}| + |\overrightarrow{P_S}|)\hat{p}$, and the right side is the emitted photon $\overrightarrow{P_T}$. As the momentum of the emitted photons coordinate system is rotated so the emitted photon is equal to the absorbed photon, the difference between these two vectors will be zero, where the conservation of momentum is upheld.

The third possibility requires the momentum of the photon to be transformed into the momentum within the atom as in the previous possibility, and using the same momentum equation. After absorption the momentum can be kept as:

$$|\overrightarrow{P_O}|\hat{p} + |\overrightarrow{P_S}|\hat{p}$$

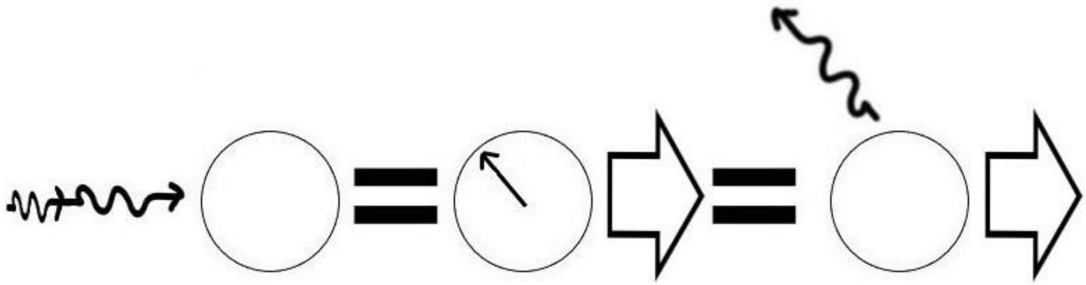
The first photon that will be emitted will have a magnitude equal to $|\overrightarrow{P_S}|$, and after rotating the coordinate system, the momentum will be $\overrightarrow{P_S}$. The second photon will also require the coordinate system to be rotated, where the momentum will be equal to $\overrightarrow{P_O}$. Graphically this becomes:



The fourth possibility was discussed in a previous paper [1], and will be calculated similar to the previous possibilities. The same momentum equation of a photon will be used.

$$\overrightarrow{P_T} = \overrightarrow{P_O} + \overrightarrow{P_S}$$

The observed photon will be absorbed into the atom, so the internal momentum of the atom will increase by $|\overrightarrow{P_O}|\hat{p}$. Further, the second part of the photon equation needs to be satisfied concurrently, as both parts of the photons momentum in the equation above are a single momentum from the perspective of the photon source. As a result, as $\overrightarrow{P_O}$ is being absorbed into the atom, the momentum $\overrightarrow{P_S}$ will be transferred to translational motion of the atom. Also, as the momentum $\overrightarrow{P_S}$ is not absorbed into the atom, there is no need to rotate the coordinate system, where the original coordinate system is maintained for the translational momentum. After $\overrightarrow{P_O}$ is absorbed, and after the decay time, a photon is emitted with a magnitude of $|\overrightarrow{P_O}|$, where the coordinate system will be rotated so the emitted photon momentum will be $\overrightarrow{P_O}$. Graphically, this will be:



From the perspective of the photon source, if the emitted photon from the atom was sent back to the photon source, then the difference between the photons momentum at the source and the total photon's momentum that is returned, and not the observed momentum, would be equal to $\overrightarrow{P_S}$. That is,

$$\overrightarrow{P_T} - \overrightarrow{P_O} = \overrightarrow{P_S}$$

$\overrightarrow{P_S}$ is equal to the momentum of the moving atom. This implies the conservation of momentum is upheld.

6. 2. Photon Interacting with an Atom in the Ground State with Source Moving Toward

If a photon source is moving toward an atom in the ground state, where the observed energy of the photon, E_O, is equal to the energy needed to bring the atom from its ground state to its first excited state, E_S would be a negative value if the following equation was used for the photon.

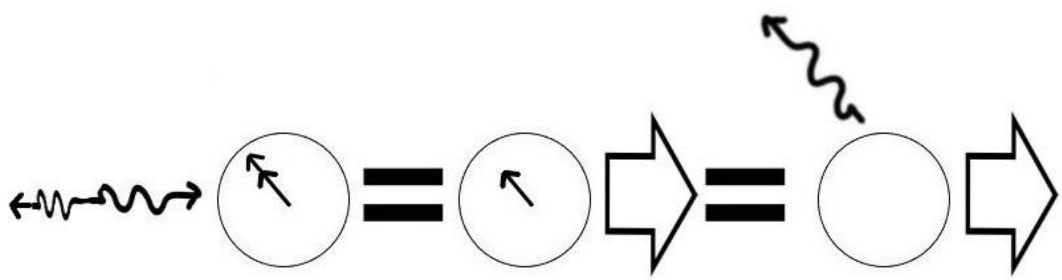
$$E_T = E_O + E_S$$

The total energy of the photon, E_T, would be smaller than E_O. No absorption would occur as there is no energy within the atom that will cause the negative value to become zero, due to the atom being in the ground state. As mentioned, both sides of the equation need to be satisfied, because the photon is a single photon, as observed from the photons sources perspective. An atom in the ground state does not provide this satisfaction. However, there is a possibility that the total energy, E_T, and total momentum, $\overrightarrow{P_T}$, of the photon can change directly to translational motion of the atom, as there is no absorption of the photon. The discussion for this change of energy and momentum is similar to the first possibility above.

6. 3. Photon Interacting with an Atom in the Excited State with Source Moving Toward

For the following discussion there will be a single atom in its second excited energy state. The photon source is moving toward the atom, where the E_S is negative and equal to the magnitude of the energy it takes to bring the atom from its first energy state to its second energy state. The E_O is not equal to the magnitude to any combination of electron energy states of the atom.

The E_S portion of the photon equation can cause the electron in the atom to drop to its first electron energy state, as the energy E_S is negative. If this occurred the E_O value would need to be satisfied, via translational motion in the direction of the initial photon. Using momentum, a photon will be emitted from the atom at a value of P_O, where the coordinate system would shift so the photon would move in the direction of the incoming photon, as there is an interaction of the photon with the atom. Graphically, this would be:



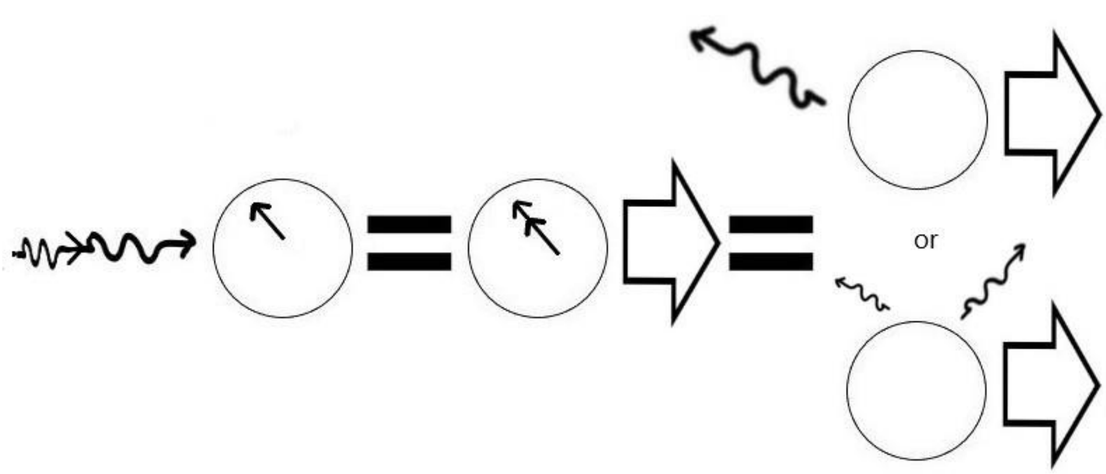
6. 4. Photon Interacting with an Atom in the Excited State with Source Moving Away

For the following discussion there will be a single atom in its first excited energy state. The photon source is moving away from the atom, where the E_S is equal to the magnitude of the energy it takes to bring the atom from its first energy state to its second energy state.

The E_O is not equal to the magnitude to any combination of electron energy states of the atom.

The E_S portion of the photon equation can cause the electron in the atom to increase to the second electron energy state. If this occurred the E_O value would need to be satisfied, via translational motion in the direction of the initial photon. Using momentum, either a single photon with a momentum of magnitude equal to the first plus the second electron momentum state or two photons with one with a momentum of a magnitude equal to the first electron momentum state and a second with a momentum of magnitude equal to P_S.

There will be a coordinate system shift for all photons. Graphically, this would be:

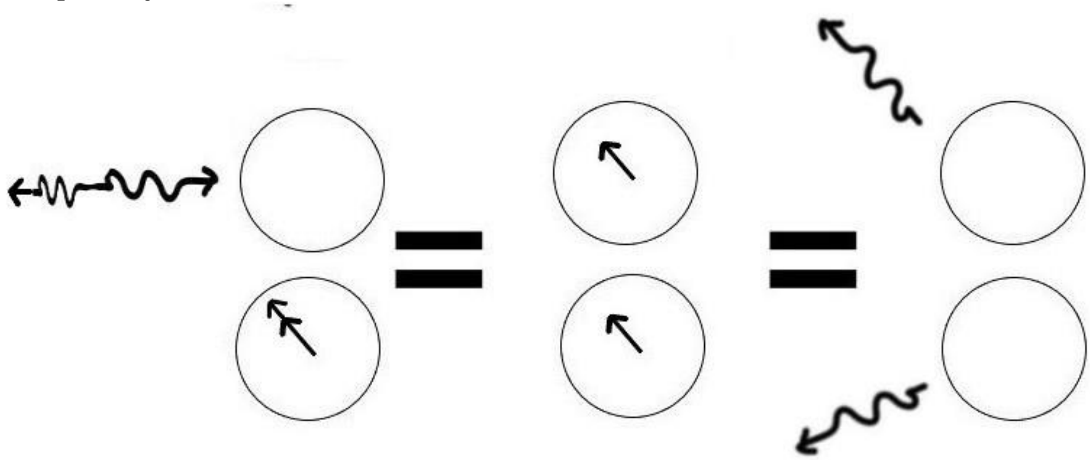


6. 5. Photon Interacting with Atoms in Excited States with Source Moving Toward

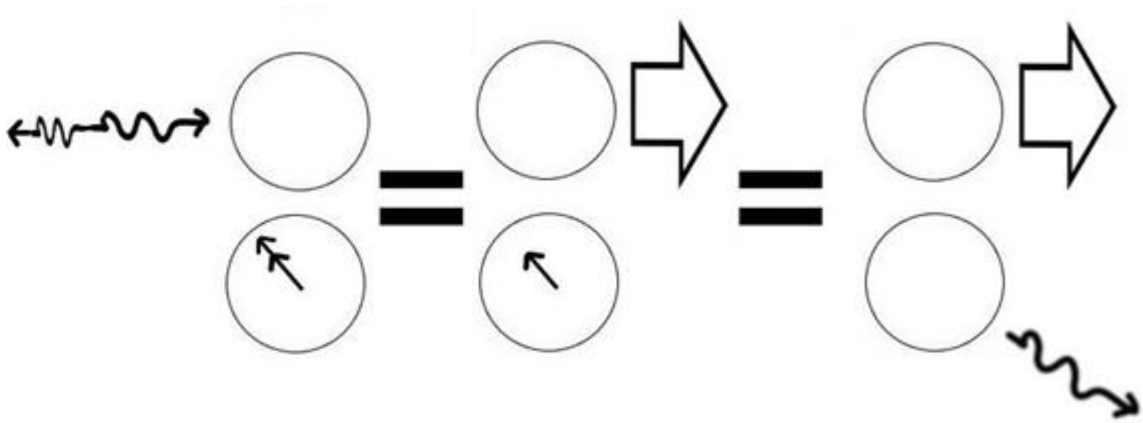
For the following discussion there will be two atoms very close to each other, where one atom is excited in its second energy state, and the second atom is in its ground state. The photon source is moving toward the two atoms where its photon will strike the second atom. The E_O of the photon is the same energy necessary to bring the second atom to its first excited energy state, and the E_S is negative, were its magnitude is equal to the energy it takes to bring the atom from its first energy state to its second energy state.

The electron cloud of the first and second atoms can vary greatly and possibly overlap. Because of this, there is a possibility the E_S can affect the first atom despite the photon striking the second atom. If this occurred there are a few possible results. The first is where each atom will emit a photon of value E_O; the second is where the first atom emits a photon of value E_O, and translational motion would occur for the second atom with a kinetic energy of E_O; third is where the first atom undergoes translational motion at a kinetic energy of E_O and emits a photon at a value of E_O. Though the third does not seem likely, the laws of conservation would still uphold. When considering momentum, all translational motion would occur in the direction of the incoming photon, and there will be coordinate system shift for all emitted photons.

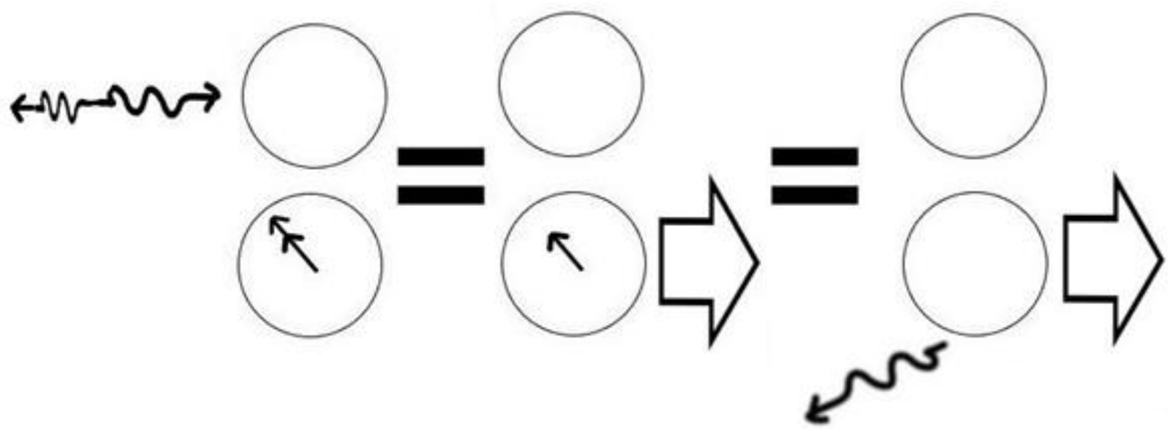
Graphically this would be:



First Probability, of Source Moving Toward



Second Probability, of Source Moving Toward



Third Probability, of Source Moving Toward

6. 6. Photon Interacting with Atoms in Excited States with Source Moving Away

For the following discussion there will be two atoms very close to each other, where one atom is excited in its first energy state, and the second atom is in its ground state. The photon source is moving away from the two atoms where its photon will strike the second atom.

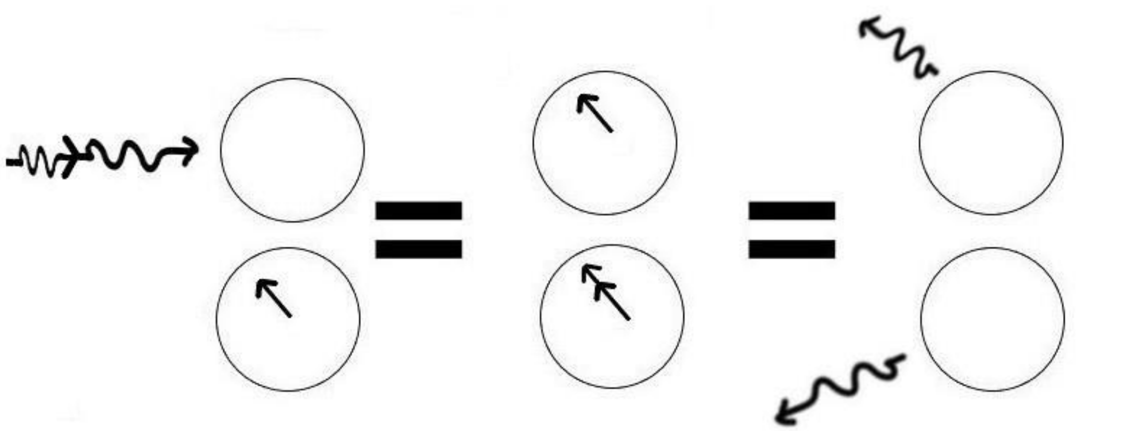
The E_O of the photon is the same energy necessary to bring the second atom to its first excited energy state, and the E_S is positive, were its magnitude is equal to the energy it takes to bring the atom from its first energy state to its second energy state.

Using the same reasoning as in the previous discussion, an electron cloud of the first and second atoms may overlap. So it may be possible that E_S can affect the first atom despite the photon striking the second atom. The possibilities are tabled below.

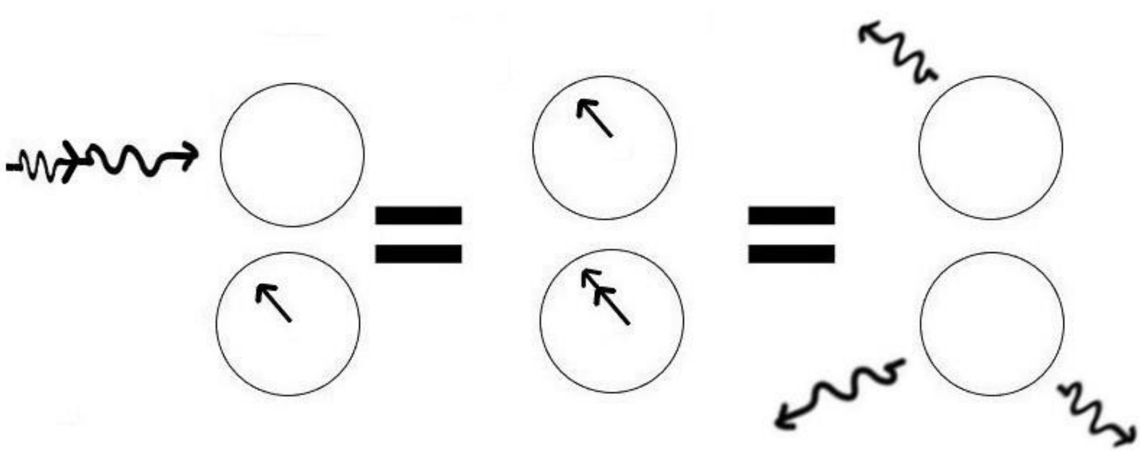
Before Interaction	After Interaction
One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	One photon from the First Atom at a value E_O+E_S. One photon from the Second Atom at a value of E_O
One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	Two photons from the First Atom at a values of E_O and E_S. One photon from the Second Atom at a value E_O.
One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	One photon from the First Atom at a value E_O+E_S. Translational motion of Second Atom at value E_O.
One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	Two photons from the First Atom at a values of E_O and E_S. Translational motion of Second Atom at value E_O.

One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	Translational motion and one photon from the First Atom at values of E_O and E_O+E_S, respectively.
One Atom in its First Energy State, Second Atom in its Ground State, and a Photon at a value of E_T Striking the Second Atom	Translational motion and two photons from the First Atom at values of E_O for translational motion, and E_O and E_S for the photons.

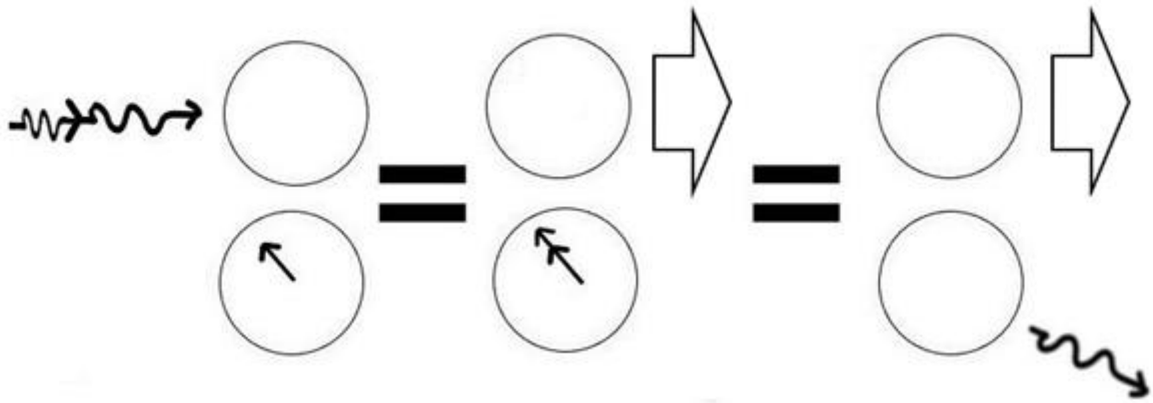
When considering momentum, the translational motion is in the same coordinate system of the incoming photon. The coordinate system for all emitted photons must be rotated so the emitted photons can be parallel to the incoming photon. Graphically these becomes:



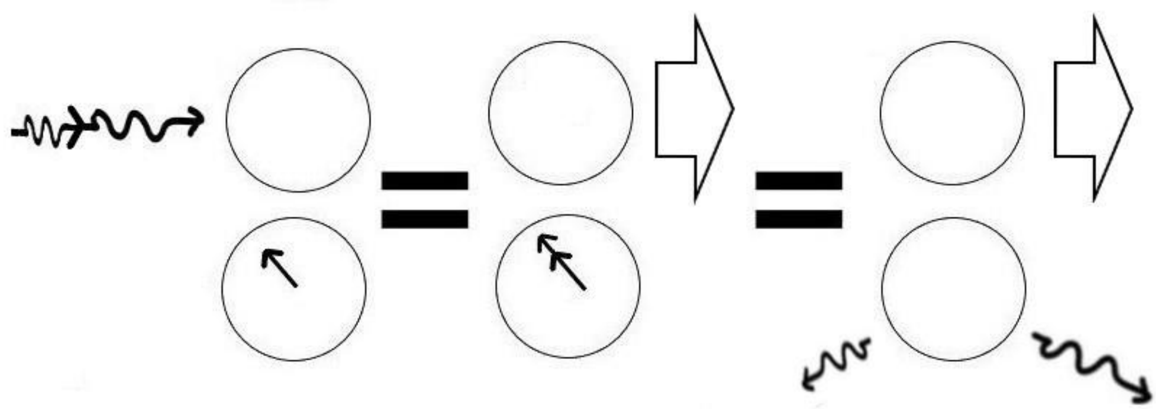
First Probability, of Source Moving Away



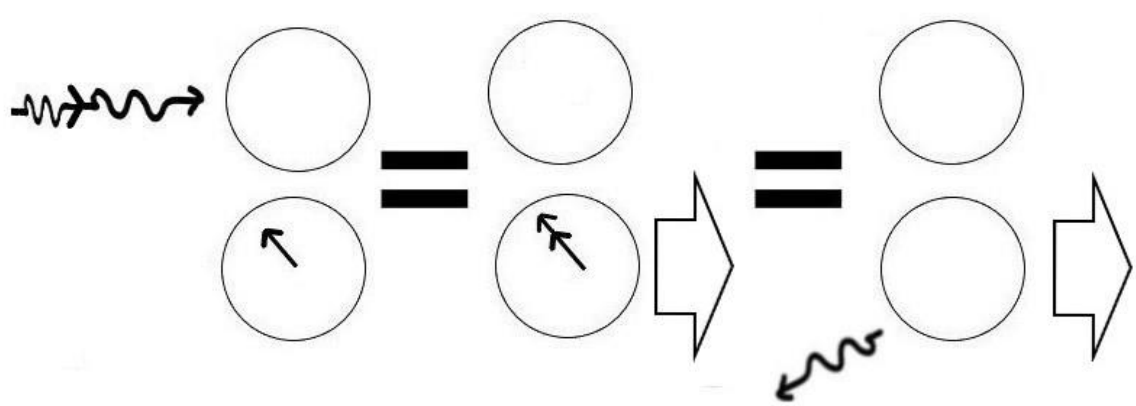
Second Probability, of Source Moving Away



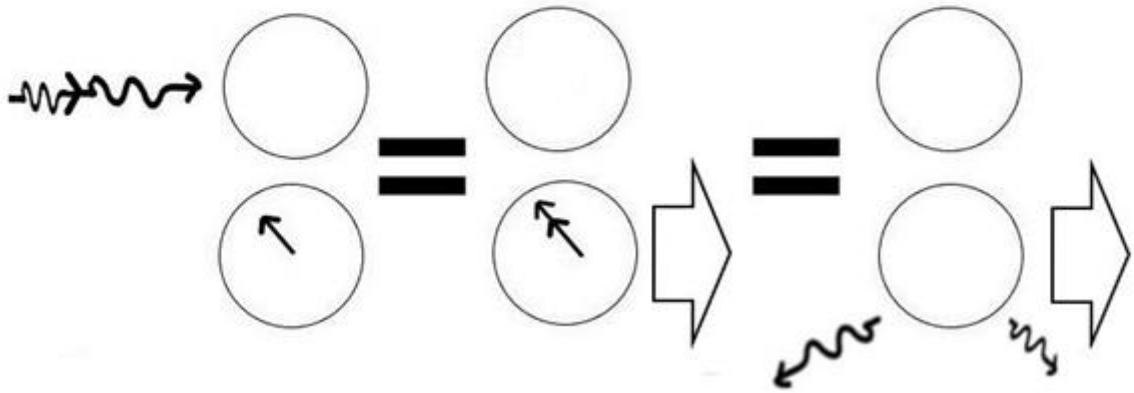
Third Probability, of Source Moving Away



Fourth Probability, of Source Moving Away



Fifth Probability, of Source Moving Away



Sixth Probability, of Source Moving Away

7. PHOTON SOURCE FROM A NON-INERTIAL FRAME OF REFERENCE

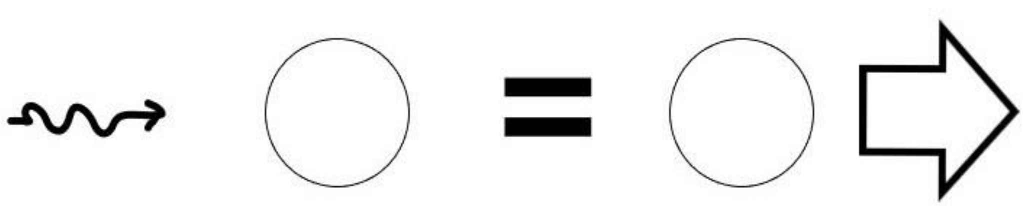
7. 1. Non-Inertial Source Moving Away from an Atom

If a photon source moving away from an atom is accelerating and the wavelengths emitted from the source, relative to the photon source, is constant, the atom observing the photon source may only absorb and emit photons when the photon source is at specific energies, relative to the atom. That is, blips of wavelengths from the source that are equal to the electron energy states of the atom occur only at specific wavelengths of the changing wavelengths, relative to the atom. When the source is accelerating away from the atom, the energy of the E_O decreases [3], and the E_S increases, though the addition of the two energies is equal to E_T.

This is from

$$E_T = E_O + E_S$$

If E_n are the energy states of the atom, then the blips would occur at the following energies from the photon source: $E_n = E_O$ and $E_n = E_S$. Further, as the emitted energy is constant, a complete transfer of energy, would result in the following:



The photon and the translational motion have a value of E_T with a momentum of $\overrightarrow{P_T}$. As the value from the source is constant, the derivative of $\overrightarrow{P_T}$ would be zero, which would result in the following.

$$\frac{d\overrightarrow{P_T}}{dt} = \frac{d\overrightarrow{P_O}}{dt} + \frac{d\overrightarrow{P_S}}{dt} = 0$$

$$\frac{d\overrightarrow{P_O}}{dt} = -\frac{d\overrightarrow{P_S}}{dt}$$

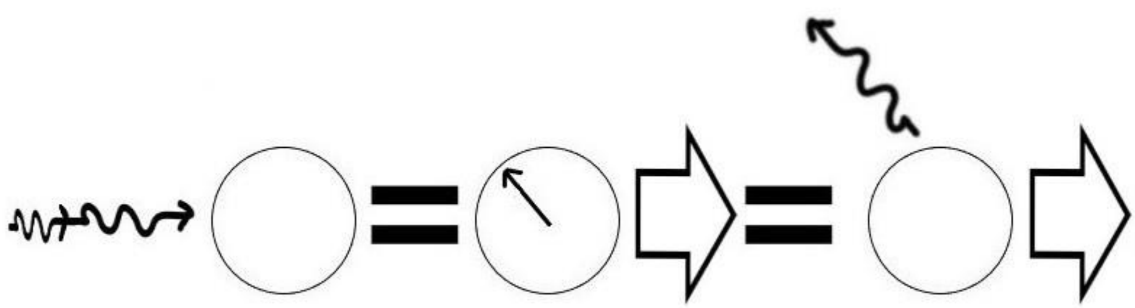
The values of $\frac{d\overrightarrow{P_O}}{dt}$ and $\frac{d\overrightarrow{P_S}}{dt}$ may not be zero as the observed wavelength changes due to the acceleration of the photon source. So as $\overrightarrow{P_O}$ changes, $\overrightarrow{P_S}$ changes also so the value of $\overrightarrow{P_T}$ would remain a constant. Further, if the source is accelerating linearly away from the atom, the wavelength of $\overrightarrow{P_O}$ will increase over time. This implies $\overrightarrow{P_O}$ will decrease over time due to the relation $P = h/\lambda$, where P is momentum, h is planks constant, and λ is the wavelength. So the slope of the momentum, the derivative, would be negative. Conversely, $\overrightarrow{P_S}$ increases over time as the wavelength decreases over time, where the slope of the momentum would be positive. This would change the equation above to:

$$-\frac{d\overrightarrow{P_O}}{dt} = -\frac{d\overrightarrow{P_S}}{dt}$$

or

$$\frac{d\overrightarrow{P_O}}{dt} = \frac{d\overrightarrow{P_S}}{dt}$$

However, the derivatives can be separated under the following condition, where E_O is equal to the first energy state of the atom and $E_n \neq E_S$, where E_n are the energy states of the atom. Graphically, using momentum, this becomes:



That is, the derivatives can be separated if the incoming photon was separated between absorption of the photon within the atom and translational motion of the atom. The portion of the photon that is absorbed into the atom would not be affected by the negative value derivative, as there would be no excess energy or momentum for motion or an emission. For the portion of the photon that changes to translational motion of the atom, the force is instantaneous and a positive value.

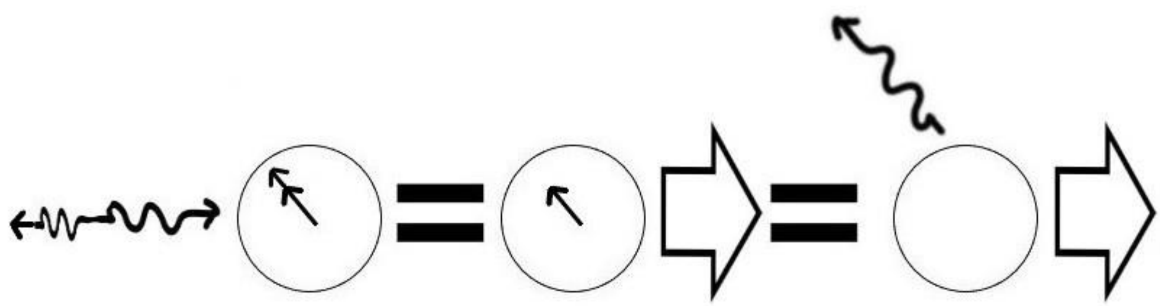
However, if there was a similar photon about to impact the atom, the atom can undergo the same instantaneous force after the decay time, where the atom will be ready for absorption and translational motion.To maintain the force of the photon on the atom after each decay time, the portion of the photon that is used for translational motion cannot be absorbed into the atom.

So therefore, $E_n \neq E_S$, as is the reason this condition was introduced for this example

7. 2. Non-Inertial Source Moving Toward an Atom

For the following discussion there will be a single atom in its second excited energy state. The photon source is accelerating toward the atom and the wavelengths emitted from the source, relative to the photon source, is constant. For every emitted photon E_S is negative and equal to the magnitude of the energy it takes to bring the atom from its first energy state to its second energy state. The E_O is not equal to the magnitude to any combination of electron energy states of the atom, $E_n \neq E_O$.

Graphically, using momentum, this becomes:



As the wavelength is decreasing when the source is accelerating toward the atom [3], $\overrightarrow{P_O}$ will increase over time. So the slope of the momentum, the derivative, would be positive. As $\overrightarrow{P_O}$ is greater than $\overrightarrow{P_T}$, $\overrightarrow{P_S}$, a negative value, would need to decrease over time so $\overrightarrow{P_O}$+$\overrightarrow{P_S}$ would equal to $\overrightarrow{P_T}$.

This implies the slope of the momentum would be negative. This would change the derivative of $\overrightarrow{P_T}$ to be the following:

$$\frac{d\overrightarrow{P_T}}{dt} = \frac{d\overrightarrow{P_O}}{dt} - \frac{d\overrightarrow{P_S}}{dt}\mathbb{d} = 0$$

So

$$\frac{d\overrightarrow{P_O}}{dt} = \frac{d\overrightarrow{P_S}}{dt}\mathbb{d}$$

The derivatives can be separated because the magnitude of E_S is equal to the energy it takes to bring the atom from its first energy state to its second energy state and $E_n \neq E_O$, where E_n are the energy states of the atom. As in the previous discussion, the portion of the photon that is absorbed into the atom also has a negative derivative.

Further, though the situation of the photon being in its second excited energy state is possible, this situation is less likely to occur compared to an atom being in the ground state. And to maintain the force on the atom, whatever energy it takes to bring the atom to its second excited energy state, would need to occur immediately after the decay time.

Therefore, an instantaneous acceleration is less likely to occur, compared to the previous discussion, when the photon sources are moving toward the atom.

8. DISCUSSION

The examples presented for inertial frames and non-inertial frames of reference does not include every example for an atom or molecule absorbing and emitting a photon. However, the application of the equations presented, and the shift of the coordinate system for emitted photons, can apply to many more examples. It was the intent of the author to not bombard the reader with examples, as any further examples may be redundant. It was the intent of the author to present the new equations and the new method of applying the conservation of momentum in the simplest way possibly, as this is only an introduction to what was presented.

Though the examples presented included single, or two atoms, and single photon sources, the ideas presented in this paper can apply to molecules and multiple photon sources. However, if photons in space become dense there is a possibility the photons can effect each other due the possible effect on space-time, where the E_S and E_O of a single incident photon must account for the photon field the photon encountered. This examination is not within the scope of this paper, as this paper served as the introduction to the ideas presented.

For a non-Inertial frame of reference, the instantaneous force, which is caused by the accelerating photon source, applies to any example presented in this paper, and not in this paper, where a photons energy is separated between absorption into the atom and translational motion.

Further, it does not matter if $\overrightarrow{P_O}$ or $\overrightarrow{P_S}$ is absorbed into the atom or used for translational motion, as long as they are separated. So therefore, $E_n \neq E_O$ if E_O is used for translational motion or $E_n \neq E_S$ if E_S is used for translational motion, where E_n are the energy states of the atom.

9. CONCLUSIONS

In this paper new equations of energy and momentum of a photon from a moving source was introduced, where the energy and momentum from the source was maintained despite the energy and momentum observed by the source. Also in this paper, a new method of applying the conservation of momentum for an atom or molecule that absorbs and emits a photon was introduced, where the coordinate system of the emitted photon was shifted so the emitted photon was moving in the same direction of the absorbed photon. Introducing the equations and the method of applying the conservation of momentum resulted in the conservation of energy and conservation of momentum being balanced for any absorption and emission of a photon from an atom or molecule, whether the atom or molecule results in motion or non-motion due to the absorption and emission of the photon. The equations and method applies to inertial and non-inertial frames of reference. However, the translational motion for a non-inertial frame of reference will have an instantaneous force if the photon is separated between translational motion and absorption and emission.

References

[1] Gabriel James Tambunga, General Relativity, quantum behavior and Doppler factor basics in laser driven light-sailing and solar sailing. *BIBECHANA* 14 (2016) 9-15

[2] Herbert E. Ives and G. R. Stilwell, An Experimental Study of the Rate of a Moving Atomic Clock. *Journal of the Optical Society of America* 28(7) (1938) 215-226

[3] Walter Kundig, Measurement of the Transverse Doppler Effect in an Accelerated System. *The Physical Review* 129(6) (1963) 2371-2375

[4] M. Moriconi, Special Theory of Relativity Through the Doppler Effect. *European Journal of Physics* 27(2006) 1409-1423

[5] W. Cochran, Some Results on the Relativistic Doppler Effect for Accelerated Motion. *American Journal of Physics* 57(11) (1989) 1039-1041

[6] Christian Corda, Interpretation of Mossabauer Experiment in a Rotating System: A New Proof for General Relativity. *Annals of Physics* 355 (2015) 360-366

[7] Christian Corda, New proof of general relativity through the correct physical interpretation of Mossabauer rotor experiment. *International Journal of Modern Physics D* 27(14) (2018) 360-366

[8] Gabriel James Tambunga, The Doppler Factor and Quantum Electrodynamics Basics in Laser-Driven Light Sailing. *International Letters of Chemistry, Physics and Astronomy* 14 (2013) 10-14

[9] Gabriel James Tambunga, Source's and Sinks in Phases of Matter. *World Scientific News* 70(2) (2017) 189-200

[10] Gabriel James Tambunga, Expansion of the Universe and Cosmic Microwave Background Correlation and Detecting Deficient Energy Photons. *World Scientific News* 98 (2018) 115-126

[11] J. C. Hauck, B. Mashhoon, Electromagnetic waves in a rotating frame of reference. *Annalen der Physik* 12 (2003) 275-288

[12] Zhong-Yue Wang, Non-Doppler frequency shift of Newton waves. *Optik* 174 (2018) 676-683

[13] Xuan-Lin Chen, Limin An, Xing-Bin Huang, Chang-Bin Yu and Liang Xu, Comment on 'Correct interpretation of two experiments on the transverse Doppler shift'. *Physica Scripta* 89(6) (2014) 067004

[14] Jeffrey S. Lee, Gerald B. Cleaver, The relativistic blackbody spectrum in inertial and non-inertial reference frames. *New Astronomy* 52 (2017) 20-28

[15] Grzegorz Lach, Maarten DeKieviet, Ulrich D. Jentschura, Einstein-Hopf drag, Doppler shift of thermal radiation and blackbody drag: Three perspectives on quantum friction. *Central European Journal of Physics* 10(4) (2012) 763-767

[16] Oyvind Gron, Oystein Elgaroy, Is space expanding in the Friedmann universe models? *American Journal of Physics* 75(2) (2007) 151-157

[17] Elmo Benedetto, Antonio Briscione, Gerardo Lovane, Underlying possible effects of Coriolis acceleration in experiments with a Mossbauer source. *Europhysics Letters* 132 (4) (2020) 49001

[18] Joao Magueijo, Lee Smolin, Lorentz Invariance with an Invariant Energy Scale. *Physical Review Letters* 88 (2002).

[19] Stephan J. G. Gift, The Invalidation of a Sacred Principle of Modern Physics. *Physics Essays* 17(3) (2004) 338-342

[20] Zhe Chang, Qing-Hua Zhu, Redshift drift in uniformly accelerated reference frame. *Chinese Physics C* 44(7) (2020) 075103