

Lecture 8

The first topic that we will discuss this evening is the wave-particle duality of elementary particles. It was first Einstein who postulated that light, which at that time was considered to be a wave phenomenon, possessed a particle expression called a photon. A photon has no mass, it is not like an electron that has mass. It travels at the maximal speed of light, c , which for Einstein in his theory of relativity is considered to be the absolutely fastest speed physically possible in this world.

Later, another scientist discovered that particles, like electrons, also exhibit wave properties. In a certain sense, this was a greater innovation, but since Einstein had already said that a wave is also particle, this is usually seen as just the other side of one duality. This is an example of symmetry (in this case a duality). If what seems to behave like a wave also exhibits particle-like behavior, it is simply the next step to say that what seems to behave like a particle also has wave behavior.

The wave function is a probability function, which measures the probability that a particle can be found in a particular position (or state) in the universe. Now it is agreed that all elementary particles, whether they are fermions or bosons, all of the particles exhibit this duality, which is a paradoxical phenomenon. It only depends on the observer, whether he is concentrating on observing the wave or the particle-like characteristics.

Let us explain what this duality means in terms of Chassidic teachings. What does it mean to be a wave and a particle at the same time?

We wrote on the board an important model in Kabbalah, which is an example of the principle of a **חותם המתהפך**, the reversing seal (a principle of symmetry) which applies to every Kabbalistic model that makes use of the essential Name of God, *Havayah*. Whether it be the four letters as they correspond to wisdom, understanding, the emotive faculties, and kingdom, or whether it be the model of how they correspond to the four Worlds, the model always exhibits this property. Between them, the four letters of God's essential Name exhibit the phenomenon of a reversing seal, where whatever corresponds to the first two letters, is duplicated in reverse in relation to the two last letters. The best example to illustrate

this is how the four letters of God's essential Name correspond to love and fear:

Yud - higher awe
Hei - higher love
Vav - lower love
Hei - lower awe

The metaphor for this is that when you have an embossed seal (the stamp sticks out) then when you push down on hot wax for instance, it will engrave an inverted image of itself.

In respect to elementary particles, let us first say that we can relate their particle and wave properties to two concepts that appear clearly in Kabbalah: matter and form. That the particle properties correspond to matter is clear, and here we are adding that the wave properties correspond to form. Now, the example here of how the reversing seal is used in a model relies on us recognizing that in our revealed reality form informs matter and therefore is considered higher than matter. Revealed reality corresponds to the two lower/last letters of the Tetragrammaton, *vav* (ו) and *hei* (ה). In almost all discussion of these two concepts we find that form is like the soul of matter. So in our revealed reality, form is higher than matter. Form is like the male aspect and matter is the female aspect. But, in respect to their origins the reverse is true: the origin of matter is higher than the origin of form.⁶⁴ The origins correspond to the two first/higher letters, *yud* (י) and *hei* (ה) of God's essential Name, *Havayah*. These two levels are also called the father and mother principles. So the origin of matter, which is called by the sages *hiyuli*⁶⁵ matter, or primordial, ethereal matter, is like the father and the hidden origin of form is like the mother.⁶⁶

So our complete model, which exhibits the reversing seal, looks like this:

⁶⁴. In Kabbalistic terminology this is known as "the source of the vessels is higher than the source of the lights."

⁶⁵. This word originally comes from the ancient Greek *hyle*, however its meaning in Jewish philosophy is markedly different. One of the most important early discussions in Jewish philosophy of the *hiyuli* matter appears in Nachmanides' commentary to the second verse of Genesis. Interestingly, today *Hyle* is the name of the International Journal for the Philosophy of Chemistry.

⁶⁶. It may be noted in passing that the word "matter" in English stems from the root form of "mother," indicating that it refers to the revealed aspect of matter, which is feminine (referred to in Kabbalah as the lower mother).

Letter of Tetragrammaton	
<i>yud</i> (י)	(origin of) matter
<i>hei</i> (ה)	(origin of) form
<i>vav</i> (ו)	form
<i>hei</i> (ה)	matter

Further we are taught that the subjective experience of matter arouses awe and fear, whereas the experience of form arouses love and attraction. Meaning, if we experience light as a wave, it ignites in our heart in some way love. This is exactly what is said that in the two higher levels, the *yud* is called the higher fear, which is nullification of reality connecting it with the primordial matter, whereas, the *hei* (mother) is called higher love, which corresponds to the origin of form.

But in the revealed levels, form is the masculine, while matter is considered the feminine. So in direct experience, the masculine induces love, while the feminine awakens fear, or awe.

The sages say that innately a child fears and has awe of his father and loves his mother. But this needs to be balanced, so that he should also fear his mother and love his father. To this end, when the Torah commands us to fear our parents, it first mentions the mother: "A man should fear his mother and father." But, when it commands us to honor our parents, and honor is considered to be an expression of love, then it first mentions the father: "Honor your father and mother..." Once more we see that the father represents awe and the mother represents love (these correspond to the two initial letters of the Tetragrammaton). But, in respect to the husband and wife relationship (corresponding to the two last letters of the Tetragrammaton), the husband becomes love and the wife represents awe (as in Proverbs, where the good wife, is called a God-fearing woman⁶⁷—because she assumes the simple duty of raising her children in accordance with the Torah). So, this is a very general principle throughout the entire Torah. The phrase most often used to describe this principle of the inverted seal is in Aramaic and it reads: "fear and love, love and fear."⁶⁸ Often before commandments that we perform we say, or have in mind, that we are performing this commandment "with fear and love, with love and fear." This is just like saying: "matter and form, form and matter," or "particle and wave, wave and particle."

⁶⁷. אשה יראת הוי'. Proverbs ???

⁶⁸. דחילו ורחימו, רחימו ודחילו.

According to Kabbalah if there is a true state of unification, it must have both manifestations, both aspects. If it is the higher unification, then the particle comes before the wave. If it is the lower unification, then the wave is above the particle. But, each unification has to have both aspects to it. Especially, if it is a total consummate unification, it has to have all four aspects to it. Meaning that this would be an objective of science to try and distinguish between the concealed wave property, vs. the revealed wave property. And even harder: to distinguish between the concealed particle property vs. the revealed particle manifestation. The clue to understanding these distinctions is that the concealed property is "non-local" whereas the revealed property is "local." And therefore, the concealed wave/particle property envisions each wave/particle as relating to and interacting with all others across the span of the entire universe simultaneously, while the revealed property does not. Locality vs. non-locality is a most important topic that we leave for later.

Albert Einstein in the Torah?

In this context, let us mention that James Gleick, the author of *Chaos*, claims that the three most brilliant physicists of all time lived in the previous century. They were all Jewish and they all suffered from anti-Semitism in one way or another: Einstein, Lev Landau, and Richard Feynman. Lev Landau was a Russian physicist. In addition to being a physicist he was an educator. He mentions that when Lev Landau taught physics he created a system to rank the genius of a physicist. It was like a quantum system and went in increments of $\frac{1}{2}$. The greater the physicist, the lower was his number. So Planck, Bohr, and Dirac received a rank of 1 (as did Feynman). Lev Landau ranked himself initially as 2.5, but at the end of his life he ranked himself as a 2. According to him, in all of history, only Einstein had a rank of $\frac{1}{2}$. This conceptualization of rank for physicists goes very well with what we discussed in an earlier lecture, that the smaller you are, the greater you are.

Apropos, let us say another thing. If Einstein is at a different level altogether than all the other physicists, so he too must be alluded to in the Torah. What we are trying to say is that everything is alluded to in the Torah. Nowadays, people look for celebrities and events in the Torah using letter skipping and the like. All those so-called Torah codes, which there is a lot to say about, but not right now, are not as significant or as serious as finding some explicit source in the Torah: a literal source in the Torah for a person or a concept. For Einstein there

is a very explicit and beautiful such source. We mentioned earlier the prophecy of Zachariah and his vision of the Divine chariot. There is another important prophecy of Zachariah who lived in the time of the construction of the second Temple after the Babylonian exile. In his prophecy, he sees the cornerstone of the Temple and the Menorah. About the cornerstone he writes: "On one stone are seven eyes."⁶⁹ This one stone that he is referring to is the cornerstone (or headstone) of the Temple. The end of the prophecy reads: "The headstone, grace and grace to it."⁷⁰ As we have already mentioned, the word חן, which here is translated as "grace" means symmetry. Since here it says "grace and grace," this even means double symmetry. Now, the name "Einstein," in German and Yiddish literally means "one stone." This idiom appears actually five times in the Bible. If we would like to give a lecture on Einstein we would have to go through all five times that the Bible speaks of "one stone." But now we will only mention the first and the last.

The first time is found in the Book of Joshua where it mentions that when the Jewish people were passing over the Jordan river, to enter the Land of Israel, each of the princes of the 12 tribes took one stone on their shoulder from the Jordan river and carried it to the west bank of the Jordan.

The last time that this phrase "one stone" appears in the Bible is here in this prophecy of Zachariah. What does it mean here that the "one stone" has "seven eyes." There are some commentaries who say that the seven eyes are a symbol for the guarding force watching over the "one stone." But, in our opinion there is a much better explanation.

In another place in the Bible, we find that the phrase "seven eyes" symbolizes God's Providence over every single aspect of creation (what we know as personal and individual Providence). So, what the verse is saying is that all of God's Providence over the entire world is concentrated through the cornerstone of the Temple. It is like the "one stone" is the focusing lens of Divine Providence. This concept also appears in two other verses in the Torah. The first is a verse in Deuteronomy, which states that the eyes of God are on the Land of Israel, from the beginning of the year to the end of the year. So here, the Land of Israel is like the lens through which God sees the entire world. First his "gaze" is focused on the Land of Israel, and from there it spreads out to the rest of the world.⁷¹ The second verse is said

⁶⁹. על אבן אחת שבעה עינים. Zachariah 3:9.

⁷⁰. האבן הראשה תשאות חן חן לה. Zachariah 4:7.

⁷¹. This concept is discussed in many places in Kabbalah. The consummate work on this subject remains to date Rav Natan Shapira's

as part of the bringing of the first fruit to the Temple: "Gaze down from Your holy abode in the heavens and bless Your people, Israel." In that case, it is explained that "the heavens" are a metaphor for the Torah, thus the Torah acts like the lens through which all of Divine Providence passes.

In any case, what this means then is that God's Providence is first concentrated on the "one stone" of the Temple, and then spread out to every minute detail of creation.

Seven space-time directions

But now, what do "seven eyes" have to do with Einstein. We mentioned earlier that Einstein united space and time. Normally, we consider space and time to be 4 dimensional: 3 dimensions of space and one dimension of time. But, the dimension of time is not the same as the 3 dimensions of space. What is the difference between them? When represented mathematically, as a complex field, the time dimension is described as the imaginary component (in terms of i , the $\sqrt{-1}$) in this complex plane, while the spatial dimensions make up the real component. But, more simply put, the difference between the time dimension and the space dimensions is obviously that in each spatial dimension you can go in two directions—to two different extremities (קצוות). I can go east and I can go west. I can go up and I can go down. There is no preference or dictation in which direction to go. But time is uni-directional. I cannot go in both directions. This is the arrow of time, which we have explained already as the law of entropy.

Another way to understand direction is to say vector, which is like the direction of sight. So each of the seven eyes is symbolic of sight in a given direction, like a vantage point from which something is being looked at. So in 4-dimensional space-time you can only go in seven directions.

In Kabbalah we always speak of the 6 extremities of space, not of 3 dimensions of space. But, time only has one direction. These seven directions correspond to the seven attributes of the heart and to the seven days of the week. The Midrash tells us that each day of the week is paired with one another, just like the three spatial dimensions have two directions each. But, Shabbat complained to God that it was lacking a partner (exhibiting its uni-directional character). So, the Midrash says that the Almighty paired the Shabbat with the Jewish people. The six days, which correspond to the six extremities of space relative to

Toov Ha'aretz. For a pdf version of this work, see: <http://www.hebrewbooks.org/5921>.

Shabbat, are paired. But, Shabbat, which is the essence of time, does not have a pair, so that is why God paired it with the Jewish people. What does this mean? It means that there is something about the congregation of Israel that can go backwards in time. Because if they are really going to be the Shabbat's soul mate so, even though Shabbat is uni-directional, nonetheless, the Jewish people represent movement in the opposite time direction. How is this? Because the Jewish people exhibit the secret of *Teshuvah*, they can go back in time. Indeed, in Kabbalah the word Shabbat in Hebrew is also read as the word that means "[you shall] return" (שָׁבַת). *Teshuvah* is capable of converting a transgression into a merit. But to do that you have to be able to go back in time. So *teshuvah* is like a time machine.

Shabbat: time travel and teleportation

In Hebrew, "time machine" is written מְכוּנַת זְמַן, and has the numerical value of 613!, the number of commandments in the Torah. If a person is complete in all 613 commandments then he has a time machine. There is a related concept called teleportation, which is the short form of tele-transportation. This is a phenomenon of quantum tunneling. The way to think of a teleporter is as a "space machine," just as there is a time machine. In Hebrew teleporter, a space machine is written מְכוּנַת מְקוֹם = שָׁבַת, Shabbat.

So here we have an example of inter-inclusion of space and time within Shabbat. On the one hand the Shabbat complained to God that it has no pair, indicating that it is uni-directional, like time. On the other hand, we see here that Shabbat is also a space-machine.

This reminds us that the sages say that if the Jewish people would keep but two Shabbatot, they would be immediately redeemed. Sometimes it is explained that the two Shabbatot are the two Shabbatot before Pesach, Shabbat Parshat Hachodesh and Shabbat Hagadol, because Pesach is the time of redemption. But, in Kabbalah and Chassidut, it is explained that these two Shabbatot occur together on the same Shabbat, meaning that every Shabbat has two aspects to it. This corresponds to our description of Shabbat having a potential of moving us freely both forward and backward in time. Shabbat is the seventh eye on the one stone that represents the uni-directional arrow of time. But, in order to be redeemed we have to pair it too through *teshuvah*, specifically *teshuvah* out of love. Redemption is freedom. The ultimate prison that the world is in right now is time. The best you can do is to maximize your time. But to get out of the uni-

directional prison of time, to free yourself from aging, that is the ultimate form of redemption. Only the Jewish people can achieve this freedom and redemption through the power of *teshuvah*. Because the Jewish soul is the partner of Shabbat, it is like the second extreme of the dimension of time.

So all of this came out of our searching in the Torah for an allusion to Einstein. The "one stone" is the lens through which all the personal Divine Providence goes through.

Now what is the gematria of the word "stone" once and the word "eye" 7 times? The model here is 1:7 and the word that reflects this ratio is אַז ($\aleph = 1, \beth = 7$), which means "then."

אבן עין עין עין עין עין עין עין = 963

But, 963 is also the value of the phrase found in the beginning of creation: "And God saw that the light was good" (וַיֵּרָא אֱלֹהִים אֶת הָאוֹר כִּי טוֹב = 963).

The first time that there is a phrase whose numerical value is 613 in the Torah is in the words: "[And God saw] the light" (אֵת הָאוֹר = 613). So, light is a "time machine," as above.

So, all that was in praise of Einstein. We hope that he appreciates it.

How do you say "wave-particle duality" in Hebrew?

Our motivation for going into this discussion about the allusion to Einstein in the Torah is that every concept in science must have an origin that can be identified in the Torah. One might think that a sophisticated idea like light being both a wave and a particle simultaneously would be beyond the mind-set of the Torah, that there could be no simple word to describe this. But, *chas veshalom* that this should be the case. This is a false thought. There must be a word in the Torah that expresses the wave-particle duality inherent in a photon. Why are we so sure of this? Because we are taught that God creates the world continuously through the letters of the holy language of the Torah, so if there is such a phenomenon it must be possible to find it in the Torah.

One of the foundations of teaching science in a 100% Torah context is that we need to rename many of the concepts and terminology that science uses today.

So now we are looking for a word in the Bible that unites the concepts of wave and particle. And we would like this word to be directly related to light, which is the way that Einstein originally came upon this duality. So we turn to the Book of Job once more. Job is about a man who is afflicted with terrible suffering. He has three very good friends who come to console him but fail. Then a young man, who was listening quietly to the

conversation, interjects. His name is Elihu ben Brachel (אליהוא בן ברנאל), which in Hebrew has the numerical value of 358, the same as "Mashiach" (משיח = 358). After Elihu speaks, God himself addresses Job with 50 rhetorical questions dealing with the secrets of creation: "Do you know this?" "Do you know that?" Thus, teaching him that if you do not know the secrets of creation you cannot understand the Divine Providence that governs your fate. In the introduction to his commentary on Sefer Yetzirah, the Ra'avad explains that these 50 questions correspond to the 50 Gates of Understanding. One of those 50 questions is: "Who gave birth to the drops of dew?"

(הַיֵּשׁ לְמִטְרָא אֵב אוּ) מִי הוֹלִיד אֶגְלֵי טָל

This is one of the most beautiful of these questions. Drops of dew are very special because they do not fall from the sky like rain or snow. Instead, we wake up every morning to find these drops on the grass. Where did they come from? From our perception they came out of nothing. Earlier, we talked about virtual particles that just appear out of nowhere. Our experience of drops of dew is that they just come out of nothing.

To continue we have to note that every word in Hebrew has both a 3 letter root, and an essential root, which is a two letter sub-root. Now, the first experience that we have of light is as a wave. "Wave" in Hebrew is גל (pronounced "gal"), so these two letters make up the essence of the word we will be looking at. There is a rule in Hebrew grammar that there are seven letters (האמנותיו) that do not change the essence of the essential two-letter root; they are either vowels (אהוי) or the three letters מנת, which tend to fall from the two letter essential sub-root.⁷² So definitely א is an added letter to this two letter sub-root גל. Nonetheless, if you look in the Radak's book of Hebrew roots you will find that אגל is a unique root. What does it mean? It means a drop of dew. It is never used in any other context. It is not a drop of rain, or a drop of oil, or a drop of anything else. Only a drop of dew. What is special about this is that the sub-root by itself means wave, but as soon as you add an א to it you get a "drop." Now a drop of dew as we just said is special because it just appears out of nowhere. But more importantly, dew is a symbol in the Bible for light, as in the verse טל אורות טליך. Not only is this any light, this is the dew, the light that resurrects the dead. This is a very special type of light called טל תורה, the dew of Torah, the mysteries of the mysteries of the Torah, the deepest secrets of the Torah, that bring the dead back

⁷². This is one of the principles of Hebrew grammar discussed by the Malbim in the introduction to his commentary on the Book of Vayikra (Leviticus).

to life. So God is asking Job, do you know who gave birth to these drops of dew?

So we have here a most beautiful origin for the fact that photons have a dual property, a dual representation of a wave (גל) and particle (אגל). Some of the commentaries explain why drops of dew are named after a wave, because when you look at the entire field full of grasses and all the drops of dew on it, it looks like waves of dew.

For which reason, we can say that the best choice for a word for "photon" in the language of the Bible, is אגל (*egal*). This is not to be confused with the word עגל, which is pronounced the same (*egal*), but is written with an *ayin* (ע), not with an *alef* (א) and means "calf," like the golden calf.⁷³

Let's return to a story we did not tell before about Richard Feynman. As a child he did not speak until he was three years old. Sometimes the greatest geniuses start speaking at a very late age, so do not worry if your child talks late. Sometime in grade school Feynman taught himself trigonometry. He saw that trigonometry uses all these strange notations like sin(e), cos(ine), tan(gent), etc, which take three letters to write. At a very early age he came up with a much better notation. He decided to use his completely different and simpler notation. Much later in life he came up with diagrams to describe some of the most complex ideas in quantum mechanics. But, at this early age he was very frustrated that nobody adopted his notation, which he considered to be much better. At a certain point he matured enough to understand that he cannot change the world. Even though I could have done it much better, it is a lost cause.

So the question we have to ask is: should we too despair of changing the word used by all of science today to fit the Torah? We don't think we should! One of our objectives in teaching science is to change words. It's a very difficult objective. Feynman tried and failed. If it is already engraved in the psyche of the world it is difficult to change it. But, here we are saying something else. We are looking for the correct Torah terminology for describing something that science has discovered. So we want to change "photon" into "*egal*," and "electron" into "*ofan*," and there are numerous other such examples. Now, the moment that science adopts the Torah word for these terms it itself will be resurrected. Scientific thinking will be given new life, like the dry bones we were talking about earlier. To resurrect science, it has to use the proper Torah terminology.

⁷³. On the other hand, one should know that there is a principle in Kabbalah that every word that is written with an *ayin* has as its inner essence the same word written with an *alef*.

More waves

Now, the sub-root that means wave is גל. We explained that there are seven letters that you can add to the sub-root which do not significantly change its essential meaning. For example, we mentioned the word that means "calf" and is written with an *ayin* (ע) added to it. But, since *ayin* is not one of these seven letters, it significantly changes the essence of the sub-root. In our case, there is another letter, except for *alef* (א) that most easily fits in phonetically to this sub-root: the letter *mem* (מ). The *mem* can be added either before the two-letter root, in between the two letters, or after them. In each case, we have a new word that has meaning. They are

- מגל, which means "sickle"; if we have our high grass with the drops of dew on the top, then we take a sickle, it is a symbol for many things in the Torah.
- If you put the *mem* in the middle of the wave it turns into גמל, which means "camel."
- And if you put it at the end of the wave, you get גלם, which means "golem."

So all three of these words are variations of "wave" (גל) with a letter *mem*.

In the next lecture we will see that camels are also symbols of photons.