TABLE OF CONTENTS, CHAPTER V

Scientists' and Kabbalists' Thoughts on Light and Lamps

Exploring the scientific conception of physical light, the light of Creation, and Jewish understandings of the menorah

The Bezalel Art Institute's Menorahs. The new art institute in Jerusalem at the turn of the 20th century aimed to revive the visual arts in Jewish tradition. The Zionist national renaissance used art nouveau *to develop a new shape to the ancient seven-branched menorah as the emblem of Judea. The students' creations are displayed in the following pages.*

SOURCE
"A DIFFERENT LIGHT"
NOAM ZION

INTRODUCTION

LIGHT AND LAMPS

The weave of topics in this chapter is surprising, interdisciplinary and associative. In a playful, exploratory way we sought to view the major symbol of Hanukkah — light emanating from a candle placed in a menorah — in a broader perspective. For the light of the Hanukkah menorah can be understood as a subset of a larger field of associations:

(1) the use of light as a metaphor in Jewish tradition and of course other cultures;

(2) the conceptual understanding of the processes of producing and disseminating light both according to modern physics and traditional Kabbalah;

(3) the history of the particular lamp called a "menorah," both in the world of Jewish law and the history of lamps in countries where Jews have lived; and

(4) the use of the menorah of the Temple as a national emblem for Judaism and the Jewish people in contrast with the star of David.

Casting our net widely we hope to expand the meaning of the Hanukkah lamp beyond its historical memories to its spiritual and physical significance. Yet this chapter will provide only a taste of physics, of Kabbalah, of Jewish ceremonial art, and of Zionist history — to whet your appetite.

1.

Light and Language

Proverbs and Parables about Light and Lamps

Light glides easily from the realm of the physical to the symbolic in all languages and cultures. In the following proverbs and parables drawn mainly from Jewish tradition but also from other Western sources, you will find beautiful turns of phrase and delightful play of imagination. Find one that speaks to you and share it with others, perhaps as part of the candle lighting ceremony on Hanukkah.

Proverbs & Parables

When God began to create heaven and earth — while the earth was still unformed and void and darkness was spread over the surface of the deep — a Divine wind swept over the water. Then God said:"Let there be light," and there was light. God saw that the light was good, and God separated the light from the darkness.

— **Genesis 1:1-3**

The Holy One created light out of darkness.

— **Rabbi Berechia** (Leviticus Rabbah 31:8; 3rd century)

I form the light and create the darkness,
I make peace and create evil.

— **Isaiah the Prophet in the name of God**
(Isaiah 45:7, 6th century BCE)

Zohar: The Hidden Light[1]

God said, "Let there be light!" and there was light.
God saw how good the light was
and God separated the light from the darkness.[2]

Rabbi Isaac said,

"The light created by God in the act of Creation flared from one end of the universe to the other but then it was hidden away, reserved for the righteous in the world that is coming, as it is written: *'Light is sown for the righteous.'*[3] At that time the worlds will be fragrant, and all will be one. But until the world-to-come arrives, it is stored and hidden away."

Rabbi Judah responded,

"If the light were completely hidden, the world would not exist for even a moment! Rather, it is hidden and sown like a seed that gives birth to seeds and fruit. Thereby the world is sustained. Every single day, a ray of that light shines into the world, keeping everything alive; with that ray God feeds the world. And everywhere that Torah is studied at night, one thread-thin ray appears from that hidden light and flows down upon those absorbed in her. Since the first day, the light has never been fully revealed, but it is vital to the world, renewing each day the act of Creation."[4]

Before the world was created, an impulse arose in the Divine mind to create a great shining light. A light was created so bright that no creature could control it. When God saw that no one could bear it, He took one-seventh of the light and gave it to humans in its place. The rest He hid away for the righteous for the time that would come, saying, "If they prove worthy of this seventh and guard it, I will give them the rest [of the hidden light] in the final world."[5]

1. The parables from the Zohar (1:31b; 2:148b), Moshe Cordovero and Azriel of Gerona are translated by Daniel C. Matt and reprinted from *The Essential Kabbalah* (1995) p. 90, 38, 110, and 193 by permission of HarperCollins publishers.
2. *Genesis* 1:3-4 3. *Psalms* 97:11 4. *Zohar* 1:31b; 2:148b 5. *Sefer Bahir* 160

Light and shade go together in this world.

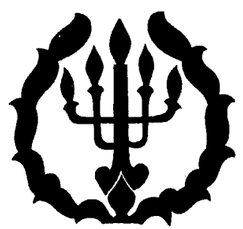
— **Mendele Mocher Seforim**
(Hebrew and Yiddish writer, 19th century, Eastern Europe)

I sense how meaningless is light,
without darkness,
How lauded righteousness
exists, only because of
wickedness . . .
What is the image of God
without Satan at His back?

— **Zalman Schneor**
(Hebrew poet, 1903)

Light that makes things seen,
makes things invisible. Were it
not for night and the shadow of
the earth, the noblest part of
creation had remained unseen
and the stars in heaven invisible.

— **Sir Thomas Browne**
(English poet)



Imagine that You are Light

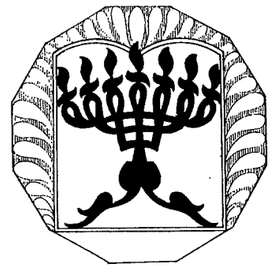
Whatever one implants firmly in the mind becomes the essential thing. So if you pray and offer a blessing to God, or if you wish your intention to be true, imagine that you are light. All around you — in every corner and on every side — is light. Turn to your right, and you will find shining light; to your left, splendor, a radiant light. Between them, up above, the light of the Presence. Surrounding that, the light of life. Above it all, a crown of light — crowning the aspirations of thought, illumining the paths of imagination, spreading the radiance of vision. This light is unfathomable and endless.[6]

The Ein Sof and the Colors of a Ray of Sunlight

In the beginning *Ein Sof*, the kabbalist Infinity of God, emanated ten *sefirot*, which are of its essence, united with it. It and they are entirely one.

To help you conceive this, imagine water flowing through vessels of different colors: red, green, and so forth. As the water spreads through those vessels, it appears to change into the colors of the vessels, although the water is devoid of all color. The change in color does not affect the water itself, just our perception of the water.

So it is with the *sefirot*. They are vessels, known, for example as *Hesed*, *Gevurah* and *Tiferet*, each colored according to its function, white, red, and green, respectively, while the light of the emanator — their essence — is water, having no color at all.



Better yet, imagine a ray of sunlight shining through a stained-glass window of ten different colors. The sunlight possesses no color at all but appears to change hue as it passes through the different colors of glass. Colored light radiates through the window.

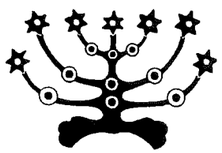
Just so the *sefirot*. The light that clothes itself in the vessels of the *sefirot* is the essence, like the ray of sunlight. That essence does not change color at all, neither judgment nor compassion. Yet by emanating through the *sefirot* — the variegated stained glass — judgment or compassion prevails.[7]

The Prophetic Spirit as a Candle

"God descended in a cloud and spoke to Moshe. In the process, the prophetic spirit that dwelt on Moshe emanated on the 70 elders and just as it poured out on them, they began to speak ecstatically, as prophets."[8]

How shall we explain this? It is like a human being lighting one candle from another. It is analogous to someone doing a favor for others, without suffering loss. One benefits but the other does not lose out.[9]

6. *Shaar Ha-kavannah*, attributed to Azriel of Gerona, 13th century Spain
7. Moshe Codovero, *The Light of the Candles*, 6:1-6, 16th century Eretz Yisrael
8. *Numbers* 11:2 9. *Midrash Bemidbar Rabbah* 13



The first creation of God, in the works of the days, was the **light of senses**; the last was the **light of reason**; and his Sabbath work, ever since, is the **illumination of the spirit**.

— **Francis Bacon**
(English philosopher, 16th century)

Your words are a lamp for my feet and a light on my path.

— **Psalms 119:105**

The mitzvah is a lamp and the Torah, a light.

— **Proverbs 6:23**

The life breath (the soul) of a human is the lamp of God. With it, God searches all the hidden chambers.

— **Proverbs 20:27**

Let us walk in the light of God.

— **Isaiah 2:5**

Light is sweet and it is good for the eyes to be able to see the sun.

— **Ecclesiastes 11:7**

Lord, may it be Your will to place us on the side of Light.

— **Rabbi Hamnuna** (Babylonian Talmud, Berachot 17a)

Light a Menorah for God?

"When you light the lamps, the seven lamps shall illuminate the menorah."[10]

Israel asks incredulously: "You light the whole world and tell us to light the menorah?"

"Let us see light in your light!" says the Holy One, "The little lights of your menorah are more precious to me than the lights of all the stars I have placed in the sky."[11]

This may be compared to a king who had a beloved friend and told him one day, "I intend to come to your home for a meal. Please make preparations."

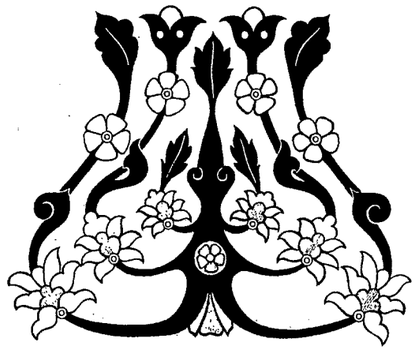
His friend hurried to set up the house, arranging his simple table and lamp. The king came to visit surrounded by his entourage, preceded by a servant bearing a lamp of gold. When the friend saw all the honor of the king, he became embarrassed, and hurriedly hid all he had prepared, for it was all so plain and common.

The king entered and said, "Didn't I tell you I was coming? Why is nothing prepared?" Said his beloved friend, "I saw all your honor and was embarrassed, for all I prepared for you was common and simple."

Said the king, "I swear to you! I reject everything I have. Out of love for you I want to share only your simple things."

So too — the Holy One is all Light, yet He tells Israel to light a menorah! And as soon as they light the menorah, the *Shechina* (the Divine presence) arrives.[12]

Does He then need our light? Rather, it is testimony to all on earth that the *Shechina* depends on the people of Israel.[13]



The Teacher: The Lamp of Israel

King David is called by his followers *"Ner Yisrael"* — the lamp of Israel — and so also is Rabbi Yochanan ben Zakai. When his students came to visit, they greeted him: "The lamp of Israel, the right hand pillar, the powerful hammer!"

10. *Numbers* 8:1
11. *Midrash Tanhuma Tizaveh* 2
12. *Bamidbar Rabbah* 15:8
13. *Talmud Bavli Shabbat* 22b

The light of a candle is serviceable, only when it precedes a human being on his/her way, but it is useless when it trails behind.

— **Bahya son of Asher**
(14th century Spain)

A lantern at night is as good as a companion, and moonlight is as good as two.

— **Rav**
(Babylonian Talmud, Berachot 43b)

A light for one is a light for a hundred.

— **Babylonian Talmud, Shabbat 122a**

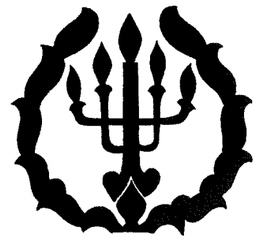
A little truth overcomes much falsehood, as a little light dispels much darkness.

— **Bahya Ibn Pakuda** (Spanish Jewish philosopher, 1040 CE)

How far that little candle throws his beams! So shines a good deed in a naughty world.

— **Shakespeare**
(The Merchant of Venice, 1597)

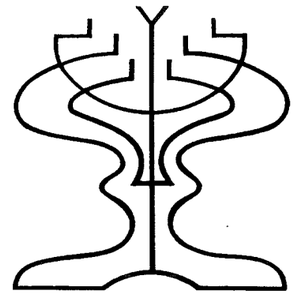
Sunrise is like Redemption



At dawn Rabbi Chiya and Rabbi Shimon ben Chalafta were walking in the valley beneath the Arbel Mountain (that rises above the Sea of Galilee / Kineret). They saw the morning star's light break through. "That," said Rabbi Chiya, "is like the process of redemption of Israel. First it emerges a little at a time, and the more it continues, the greater the light increases."[14]

The Borrowed Light and Your Own Light

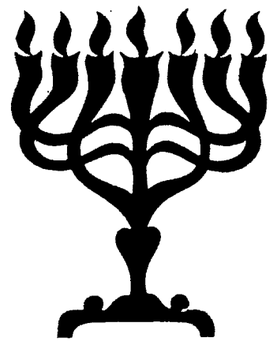
A rabbi once poured out his heart to the Rizhiner Rebbe (19th century) saying: "What shall I do? As long as I am studying Torah and commentaries, I feel myself encompassed by holy light. However as soon as I halt my studies, I feel chilled and surrounded by darkness. Can I ever make this light my own?"



The Rizhiner Rebbe replied, "Whenever you are not occupied with Torah, then occupy yourself with a mitzvah, then the light will not fail you." He explained, "The light you feel surrounding you as you study is a **light borrowed** from the souls of great scholars. However, a light derived from your performance of a mitzvah is **your own light** and it will never fail you."

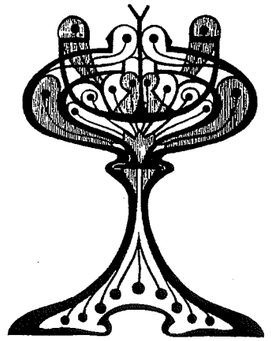
The Hidden Diamond

The Rizhiner Rebbe explained how in the midst of the plague of darkness in Egypt, *"All the children of Israel had light in their homes."*[15]



"Each one of us possesses a Holy Spark, but not everyone exhibits it to best advantage. It is like a diamond, which cannot cast its luster if buried in the earth. However when our Divine spark is disclosed in its appropriate setting, after being suitably cut and polished, there is light, as from a diamond, in each one of us."

14. *Jerusalem Talmud, Berachot* 1:1
15. *Exodus* 10:23



There is a palace of light that opens only to one who occupies himself with the light of Torah.

— TIKKUNEI ZOHAR
(13TH CENTURY SPAIN)

Instead of cursing the darkness, light a candle.

— ELEANOR ROOSEVELT
(AMERICAN FIRST LADY AND SOCIAL REFORMER)

May each page be a point of light
to illuminate the mind.
Or if not the light,
at least the wick
that holds the fire in line.
And if no wick, then may it be
the oil to anoint the eye.
But if no oil, then at least the
branch that brought the olive
to life.
And if no branch,
then a single seed to plant the
point of light.
Yes, let there be a single seed
within each page I write.

— CHAYA KAPLAN-GAFNI
(JERUSALEM POET)

The Lamp / Menorah of Imperfections

by Rabbi Nachman of Bratzlav (19th century Eastern Europe)

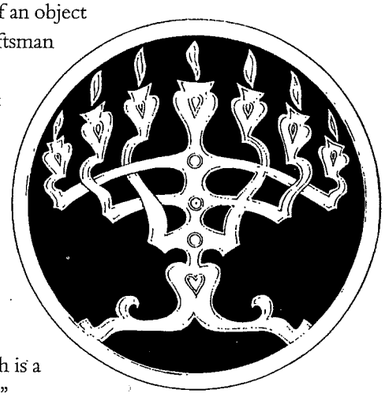
This is the tale of one who left his father's house and the land of his birth and went forth to distant parts to learn a craft. In time he returned to his land and to his father's house. His father asked: "What skill have you learned in distant lands, my son?"

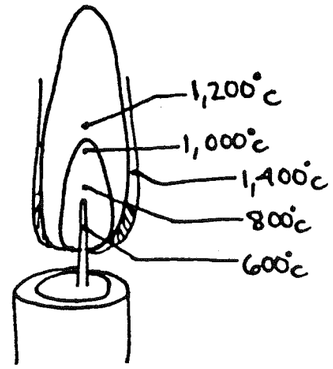
The son said: "I have learned to fashion a hanging lamp that is a wonderful piece of art. And if you please, my father, assemble all the masters of this art that live in the land and I will show them the lamp that I have fashioned by the skill of my hands."

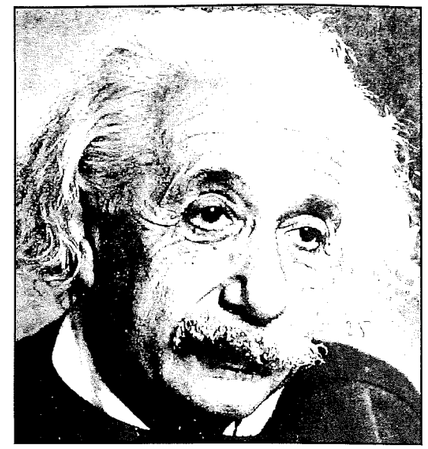
So the father assembled all the masters of that art living in the land to show them the great accomplishments his son had mastered in his years abroad. The son brought forth the wonder lamp and displayed it before the large gathering. They looked at it and it did not please them. And when the father asked them for their opinion of the lamp, they all answered as one, that it was extremely misshapen, for they did not wish to hide the truth from him.

As soon as the visitors left the house, the father said to his son: "Listen, my son, your fellow craftsmen all agreed as one that the lamp is misshapen. Wherein then lies its greatness?"

"This is its greatness, that in this lamp I have combined all the imperfections that are to be found in the work of my fellow craftsmen gathered in our house today. Look, father, the work of every craftsman has some imperfection of its own. One craftsman excels in making one part of an object while he fails in another; a second craftsman turns out one part of his work with exquisite beauty, whereas in another it is truly ugly. What is good with the one is faulty with his fellow, and just what is ill-made and ungainly with his fellow turns out graceful in his own hands. And I have a lamp that is a combination of all their imperfections, in order to inform and advise them all that they have not attained perfection. My lamp/menorah is a reminder to each of his imperfections."







Albert Einstein

2.

THE SCIENTIFIC MIRACLE OF LIGHT AND ITS JEWISH ANALOGIES

by Sherman Rosenfeld and Noam Zion

In this interdisciplinary section, we explore light as a paradigm for both science and the Jewish tradition. We set the stage with a brief biography of the Jewish hero of light — Albert Einstein — and then present the topic of candles and flames from several points of view: chemistry, biology and Jewish sources. Finally, we dip very lightly — and hopefully tantalizingly — into two extremely abstract worlds of system building — modern physics and Kabbalah. The dialogue between a science educator, Sherman Rosenfeld, and a Jewish educator, Noam Zion, in search of analogies between such disparate realms should serve as an initiation to those who wish more knowledge from scientists and from scholars of mysticism.

"The most incomprehensible fact about the universe is that it is comprehensible."

— ALBERT EINSTEIN

"God does not play dice with the world. God is subtle, but He is not malicious."

— ALBERT EINSTEIN

"In the time left to me to live, I just want to reflect on the essence of light."

— ALBERT EINSTEIN

2a.

Albert Einstein, Hero of Light

Physicist, Zionist, Humanist (1879-1955)

"What is a Jew? Judaism is interested primarily in the moral stance toward life. Therefore the life of the individual has meaning only insofar as the individual helps to make the life of every creature more noble, more beautiful.

"However Judaism includes an added element, something expressed in the Book of Psalms — a kind of intoxication and amazement with the beauty and magnitude of the universe. From this feeling true scientific research draws its spiritual nourishment, but it is also expressed in the songs of the birds. Therefore Judaism honors so greatly every intellectual aspiration and spiritual effort. ***The desire to know for its own sake, an almost fanatic love for justice and the passion for personal independence are the characteristics of Jewish tradition*** *which lead me to thank my destiny that I am connected to them.*

"Those in our world today [the Nazis] who rebel against the ideals of reason and freedom of the individual and who are trying to establish a slave state lacking in spirit, by the cruel use of force, see us absolutely justifiably as their uncompromising enemies."

— Albert Einstein

The first scientific superstar known by the person in the street all over the world was Albert Einstein, even though his theories were way over people's heads. His selection by Time Magazine as "Person of the Millennium" reinforces that status today. That status was well earned, for Albert Einstein as a theoretical physicist deserves to be called a "hero of light" in two ways. In his scientific research, his insights about the nature of light revolutionized modern physics and won him a Nobel Prize. His method, as well as his results, were extraordinary. Einstein "threw light" on the topic of light, by using a visualization technique, in which "thought experiments" preceded mathematical and verbal thinking. In other words, he "illuminated" difficult problems by non-verbal insights that only later were translated into equations and words. So by better understanding Einstein's life, one might better understand not only the nature of light but also the value of using visual thinking as a tool for "enlightenment."

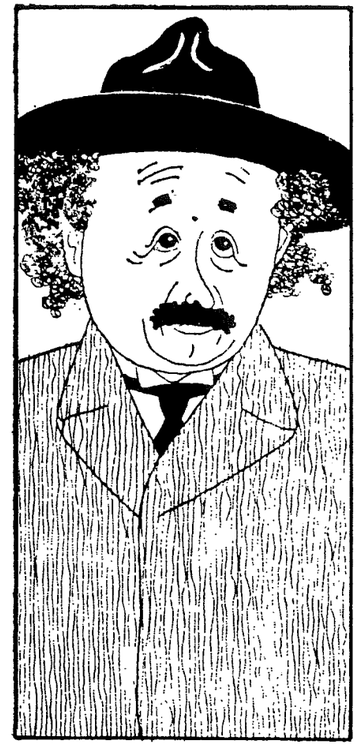
At the same time, it is important to go beyond his scientific life; Einstein was also a moral "source of light," particularly as a Zionist and as a humanist.

Albert Einstein was born in Ulm, Germany, on March 14, 1879. From an early age, he disliked school but enjoyed playing the violin and learning about physics and geometry, particularly in his spare time. Einstein rejected the Germanic school structure designed to "pour knowledge" into students' heads, and followed his own interests. Following the completion of his Ph.D. in physics, Einstein applied for a university position, but was rejected. Instead, in 1903, he accepted a position as patent official at a Swiss Patent office. While this was a low-ranking job, it gave him time to think and write about topics that interested him. Then, in 1905 at the age of 26, out of the clear blue (from the point of view of the scientific establishment), Einstein published four classic papers: on the size of sugar molecules, on Brownian motion, on the photoelectric effect, and on the special theory of relativity. This tremendous burst of intellectual energy signaled the beginning of a long career of scientific contributions about the nature of matter, energy and the fundamental physical forces of the universe.

Throughout his life, Einstein made a number of original insights into the nature of light, such as the following:

(1) When photons (the "packets of light" that constitute light waves) bump into metal atoms, they stimulate a discharge of electrons. This is called the **"photoelectric effect"** for which he won the Nobel Prize in 1922. One of the uses of this effect is the "electric eye," used to open and close some automatic doors. Imagine the entrance to a building. Parallel to the door, a beam of light from one side of the entrance hits a metal receiver on the other side. When a person's body blocks this beam of light, the "electric eye" sends an electrical signal to the door to open.

(2) At speeds close to the speed of light, the size of an object decreases and time slows down (as measured by an observer at rest). This insight is part of the special theory of relativity, which represents a major revolution over Newtonian physics. Einstein conceived of the world in four, rather than three, dimensions — the usual spatial dimensions — height, width and depth, and the fourth dimension, time.



Caricature of Professor Einstein visiting America in 1919

Einstein conceived of the world in four, rather than three, dimensions — the usual spatial dimensions — height, width and depth, and the fourth dimension, time.

One way Einstein arrived at this insight was through a visual "thought experiment." He imagined that he was "riding on a beam of light," flashlight in hand. How fast would the light from the flashlight travel? Twice the speed of light? No, if you assume that nothing can go faster than the speed of light. So Einstein reasoned that at speeds close to the speed of light, distance contracts and time expands. As experiments showed, Einstein was right. As an example of Einstein's general theory of relativity, imagine two twins, each with a clock. One stays on Earth while the other takes off on a space ship traveling very close to the speed of light. Two hours later (from the ship's perspective), the space traveler returns to find the other twin over 80 years older!

(3) Matter and energy are not distinct but in fact are related by the speed of light. More specifically, a tiny bit of matter can be converted into a huge amount of energy, and vice versa. Einstein's expression of this idea is his famous equation, $\mathbf{E=mc^2}$. To better understand this insight, consider that "c" equals the speed of light, which is a huge number, about 300,000 kilometers — or 186,000

miles — per second. Now multiply this number by itself and you get an even HUGER number (this is the c^2 in the equation). Multiply THIS number by a teeny tiny bit of matter (which is the **m** or mass in the equation) and this equals a HUGE amount of energy (which is the **E** in the equation.) In other words, every bit of matter in the universe contains in it the potential for releasing tremendous amounts of energy.

This insight led to the creation of atomic bombs, as well as electric power plants based on atomic energy. However, Einstein's relationship to atomic energy was ambivalent. On one hand, during World War II, he wrote an influential letter to President Roosevelt which resulted in the formation of the Manhattan Project, which in turn produced the atomic bombs used to win the war. On the other hand, after the war, he became chairman of the Emergency Committee of Atomic Scientists and lobbied for outlawing atomic and hydrogen bombs.

Einstein not only thought a great deal about light, but he did so in a visual manner. In fact, the "brilliance" of Einstein's intellect was largely due to the exceptional ability he had to think in non-verbal ways. He used many visual **"thought-experiments"** to investigate his questions (as illustrated above in the example of "riding on a light beam"). When asked to reflect about how he thought, Einstein claimed that he reasoned with a combination of mental images, which were of a "visual and muscular type." Later, to communicate his insights, Einstein would "translate" the content of these non-verbal images into words and mathematical equations. As he wrote:

> "The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The psychical entities which seem to serve as elements of thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined."

Recent brain research supports the notion that Einstein excelled in non-verbal thought. Neuroscientists have discovered that certain areas of the brain — the lower bulge of the inferior parietal lobes — are the "home" of spatial reasoning and abstract mathematical thought. A study of Einstein's brain showed that these areas were unusually large. (You may wonder, how could a recent development in the theory of the brain be tested on the long-dead Einstein. In fact, after his death a colleague removed his brain, the physical remains of the greatest scientific genius of this century, and preserved it for later scientific research).

The Public Conscience: Zionist and Humanist

In his lifetime, Albert Einstein not only contributed enormously to our understanding of light but also acted as a "beacon" on moral issues. He not only dedicated his efforts to solve the mysteries of the universe but also was actively involved in the social and political world around him. As a result of his superstar standing, Einstein's public pronouncements carried weight.

In particular, he was a proud member of his people who defended their right to be different, to be Jews even in a hostile world during the worst period of anti-semitism in history. Einstein repudiated the anti-semitism of Germany and left his native land in 1932. He revoked his own citizenship as well as his membership in the Prussian Academy of Sciences, an organization that led the way in persecuting Jewish scientists and in condemning the false "Jewish physics promoted by Einstein." As soon as Hitler came to power, Einstein's life was often threatened by German nationalists. One organization put a $5000 price on his head, encouraging assassins to murder him. In May, 1933, the Nazis staged a book burning at the end of a torch parade in which 20,000 volumes were soaked in kerosene. This is how the newspaper described the event:

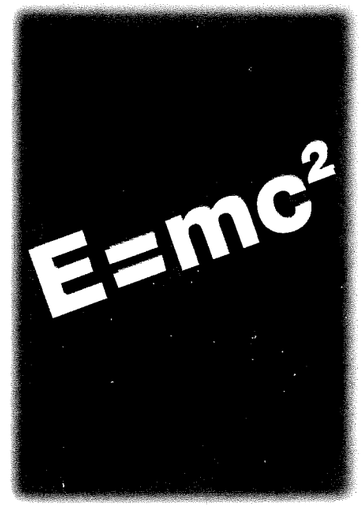
> "A tall, middle aged Nazi held a large picture of Einstein in his right hand and a burning torch in his left. Then he cast the picture on the pile and in an instant all 20,000 books were aflame as the crowd cried: 'Away with traitors!'"

Einstein never forgot that he was a refugee and extended his assistance to many people who asked for his help. He worked tirelessly to raise money, speak and write articles on behalf of refugees and other worthwhile causes. He became an active supporter of the unpopular Zionist cause for an independent Israel. In 1921 he took his first break from scientific research to go across America speaking and raising money for the nascent Hebrew University in Jerusalem. "I am doing this only for the Zionist cause to raise dollars for education in Jerusalem. For this occasion I must play the role of a minor god [the revered genius] and serve as a trap [for potential donors]."

In 1923 Einstein visited the future campus of the Hebrew University and spoke in his opening words in Hebrew on Mount Scopus:
"I am very happy to be able to lecture in this land from which emerged Torah and light to the whole enlightened world and before this building that will be a center of wisdom and science."

In 1923 Einstein visited the future campus of the Hebrew University and spoke in his opening words in Hebrew on Mount Scopus: "I am very happy to be able to lecture in this land from which emerged Torah and light to the whole enlightened world and before this building that will be a center of wisdom and science." Though he vigorously supported Zionism, he did so from a critical point of view. For example, he thought that Chaim Weizmann, also an eminent scientist in his own right — and later to become the first president of Israel — was too much of a *"Realpolitiker"* (Weizmann, of course, thought that Einstein was an impractical idealist!). Later, in 1952, Prime Minister David Ben-Gurion invited Einstein to be Israel's second president. However he declined, saying, "I know a little about nature but almost nothing about human beings."

As a humanist, he was a courageous believer in the moral imperative of international peace in a warring world. In fact, his scientific search for intellectual unity in physics parallels his search for international harmony. It is fitting to close on the note that the physicist who struggled for so long to develop a "unified field theory" (including all of the fundamental forces of the universe) was also very active in working for the cause of world peace. He believed that the only solution to this issue was on a supranational basis, as promoted by the World Federalist Movement. Although the achievement of world peace eluded Einstein and his colleagues — as did his attempt to develop a unified field theory — it focused a great deal of his own energies. One might conclude that part of Einstein's legacy — as physicist, Jew and humanist — is the commitment to achieve these two noteworthy goals.



2b.

Candles and Flames

A Scientific Perspective on Lighting the Menorah

On Hanukkah, we light wax candles or oil lamps for eight days. By doing so, we illuminate the darkness. But what exactly is a flame? A candle? How does a solid, cold mass of wax turn into a flame, giving off heat and light? And how does one burning candle — a *shamash* — ignite another?

On this holiday we also eat lots of fatty, oily foods, like potato pancakes ("latkas"). Then we need lots of exercise to "burn off the fat." Are our bodies somehow related to burning candles, and if so, how?

In order to investigate these questions, we will first look at the amazing process that turns fuels (like wax or oil) into light and heat. Then we will see how the cells in our body act as "slow-burning candles." We will explore the origin of the energy found in both the candle's fuel and our body's food. Finally, we will try to understand how the *shamash* can ignite the other candles, without diminishing its own flame.

1. What is the Chemical History of a Candle?

If you look at the flame of a candle, you will notice that it has three distinct regions, each with its own color. A black area surrounds the wick, a blue area surrounds the base of the flame, and both seem to give rise to a bright yellow area in the rest of the flame. What is the significance of these three areas of the flame? Moreover, why does a candle need a wick? What happens there?

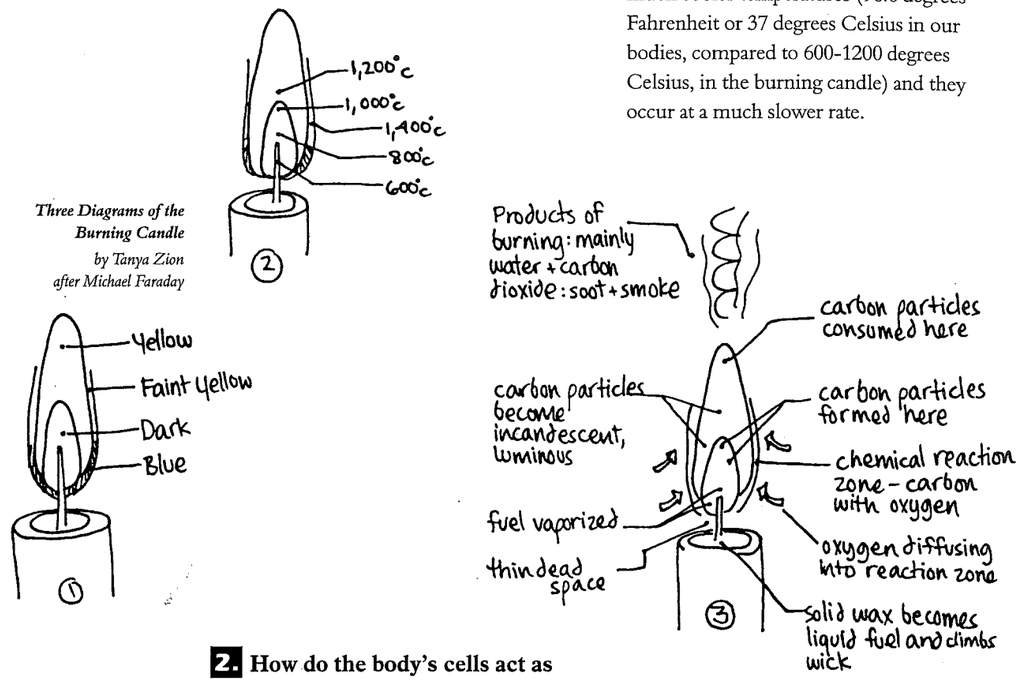
The great physicist, Michael Faraday (1791-1867), asked these and other questions in a series of six lectures — "The Chemical History of a Candle" — given to young people at the Royal Institute in London, during each winter season in the 1860s. Faraday, one of Albert Einstein's heroes, is best known for his discovery of the principle of electrical induction, which is the basis of harnessing electricity as an energy source. And yet, Faraday chose to focus his "Christmas Lectures" on the old-fashioned source of light, the candle, because he felt that most scientific laws in the universe are somehow connected to this subject.

Faraday pointed out that a flame is telling a complex chemical story. Here is a brief summary of that story: energy-rich wax and oxygen react to release energy (in the form of heat and light) as well as energy-poor carbon dioxide and water.

And here's the same story again, this time in more detail: (1) the solid wax of the candle melts, near the wick. (2) The liquid wax moves up the wick, and as it does, the candle's heat turns it into a gaseous mixture; (3) this gaseous mixture combines with oxygen in the blue area of the flame, giving rise to heat, light, water and carbon dioxide. (4) The same gaseous mixture doesn't combine with oxygen in the dark area of the flame; instead, carbon particles are formed here. (5) In the yellow area of the flame, the same carbon particles (soot) become incandescent, continue to give off light and heat, and (6) eventually, around the yellow area of the flame, carbon dioxide and water vapor are released.

In short, each burning candle has a history — a chemical history — which takes place very quickly. In a burning candle, each fraction of a second, billions and billions of wax molecules are transformed from solid to liquid to gaseous form, moving up the wick and through the flame. In this process, they produce many intermediary products — with the help of oxygen — in a series of complex chemical chain reactions, eventually releasing light, heat, carbon dioxide and water vapor.

In his lectures, Michael Faraday illustrated different aspects of this chemical process via simple demonstrations and experiments *(see diagrams below)*.



Three Diagrams of the Burning Candle
by Tanya Zion
after Michael Faraday

2. How do the body's cells act as "slow-burning candles"?

All living things need energy in order to exist. The ultimate source of energy in our bodies is the food we eat. Although the specific biochemical processes which break down this food are very different from those which break down the wax molecules of a candle, the overall reactants and products are the same. Energy-rich molecules react with oxygen to give off energy (usually in the form of heat and special molecules, which can be stored to power later biological reactions), carbon dioxide and water. So, when you're digesting a potato pancake (and, in fact, when you're simply living), you're actually going through the same overall process as a candle. But there are two big differences: in our bodies, these biochemical reactions occur at much cooler temperatures (98.6 degrees Fahrenheit or 37 degrees Celsius in our bodies, compared to 600-1200 degrees Celsius, in the burning candle) and they occur at a much slower rate.

Michael Faraday chose to focus on the old-fashioned source of light, the candle, because he felt that most scientific laws in the universe are somehow connected to this subject.

3. Where did all of this energy originate?

In the food we eat, as well as in the candles, all this energy had to come from somewhere. From where? As it turns out, from light! In the living world, plants "capture" light energy from the sun, which drives a reaction, which transforms this light energy into the chemical energy found in candles and our food. The resulting chemical energy, located in the sugars, is then transformed in biochemical reactions within the plants — and when we eat them, within our bodies — to produce other products, including fats and oils. There

are other ways for the fuel needed for candles to be formed — beeswax, paraffin from petroleum products, and the like — but in each case, the ultimate energy source for these fuels is light energy from the sun.

So here's the big picture. In an "energy-capturing" process (called **photosynthesis**) sunlight, water and carbon dioxide react in a plant to produce organic matter and oxygen. The reverse "energy-releasing" process (called **combustion**) takes place in a candle: oxygen combines with organic matter to release energy, in the form of light and heat, along with carbon dioxide and water. In each of our body's cells, a similar "energy-releasing" process (called cellular respiration) occurs, though at a much lower temperature and at a much slower rate.

4. How can the *shamash* ignite another candle, without losing its own energy?

As every good Boy Scout knows, there are three requirements for a fire: (1) a fuel source, (2) oxygen, and (3) a high temperature which starts the process ("igniting temperature"). As pointed out above, each candle has its own fuel source and oxygen is all around it. So, all that is needed to turn the "potential energy" of a cold Hanukkah candle into light and heat, is the high igniting temperature, which is provided by the *shamash*. In essence, the *shamash* (from the root word meaning "to serve"), initiates the combustion process in the Hanukkah candle. Then that ignited candle is on its own, releasing energy from its own wax.

Candles and Flames as a Source of Jewish Inspiration[1]

The Jewish tradition is rich with metaphors and analogies based on the symbols of candles and flames. Here are some examples:

- Just as the *shamash* lights other candles with its heat without diminishing itself, so Moshe is described as passing his prophetic and leadership spirit on to the seventy elders in the desert. *"God emanated from the spirit that was on Moshe on to the seventy elders. As the spirit rested upon them, they began to prophesy without end."*[2] Rashi, the medieval commentator, suggests an analogy: "To what may Moshe be compared? To a candle burning in a menorah (lamp) from which everyone may be lit without diminishing the light of the original candle."[3]
- Lubavitch Hasidism uses this analogy in describing every Jew as a candle with its own potential inner light. The Jew's mission is to ignite the flame of enthusiasm (*hitlahavut* — literally flaming energy) in him/herself and in all whom they meet.
- A different imagery is used in the poem *Happy is the Match* by Chana Szenes, the young Israeli female paratrooper who volunteered to jump behind Nazi lines into occupied Hungary during the Holocaust. She wrote what became a famous poem just before her capture and eventual execution by the Nazis. In the poem she compares herself to a match, which unlike the *shamash*, is consumed in igniting another candle, as a martyr whose sacrifice is not for naught. Her life served as such a match in sparking the heroic efforts of her generation of Israelis to defend and rebuild the Jewish people after the war.

  Happy is the match consumed in igniting the flame.
  Happy is the flame that burns deep in the hearts.
  Happy are the hearts with the strength to stop beating,
  to sacrifice themselves for the sake of honor.
  Happy is the match consumed in igniting the flame.

- On Hanukkah it is important to appreciate the role of one family, Mattathias and his five sons who single handedly inspired and led the Maccabean Revolt over 25 years until their final victory. When the Greeks "snuffed" out the life of one brother then there was a second and a third to replace him. They served as the *shamash* which literally and figuratively relit the *ner tamid,* the menorah in the Temple and in their people.

1. Michael Faraday, *The Chemical History of a Candle* and Jearl Walker, "The Amateur Scientist" from *Scientific American*, April, 1978.
2. *Numbers* 11:25 3. *Midrash Sifrei* on *Numbers* 11:17

2c.

Eight Ways of Looking at the Nature of Light

and its Analogies to the Jewish Imagery of Light

A candle (or a cruse of oil) that burns longer than normal violates our usual expectations of the laws of nature. A military victory of a few against an entire empire violates our sense of historical laws of power. In a similar way, as illustrated below, the very nature of light befuddles our usual categories. This makes light a perfect symbol for Judaism to use, both to represent the miracle of creation as well as to illustrate the miracle of redemption in history against incredible odds.

Each of the following topics will be presented first in a scientific perspective and then in one or more perspectives from the Jewish tradition. These eight possible analogies between the imagery of light in modern physics and the Jewish, in particular kabbalist, symbolic imagery of light, are not meant to be comprehensive, nor are they meant to present these very different ways of thought as identical systems. Certainly we are not claiming that modern physics "proves" Kabbalah or that Kabbalah prophetically predicts Einsteinian physics. However, human modes of thought are interrelated as we seek, by the power of imagination, to make sense of our universe at its most basic. The analogies of these world constructions may enlighten one another even if the parallels are at best very partial. In both modes of thought — Jewish mysticism and modern physics — there is a sense of stretching human understanding to the limits in the face of what is felt to be miraculous, at the edges of or beyond human conception. Both systems of symbols force us to look carefully at the light of the Hanukkah candles and to see them as a microcosm reflecting the basics of the spiritual and physical universe.

1 Light is Paradoxical and Transcends our Usual Conceptions

Scientific Perspective: What is light? The term usually refers to the part of the electromagnetic spectrum which people can see. (Parts of the electromagnetic spectrum which people cannot see include x-rays, microwaves, and radio waves). Light exists as both particles and waves. This is a rather strange idea. Our daily experience tells us that waves cannot be particles and particles cannot be waves. But there are some experiments in which light "behaves" as if it were made up of particles (called "*photons*"), and other experiments in which light "behaves" as if it were made up of waves. In the history of science, scientists have argued about whether light is a wave or a particle. Quantum mechanics, a central theory of twentieth century physics, shows that light is simultaneously "wave-like" and "particle-like." In fact, today scientists say everything in the universe has wave-like properties and particle-like properties, just in different degrees.

Jewish Perspective: The Kabbalah has always described the *Ein Sof*/Divine Infinity in paradoxical terms as the dark light which is invisible, immaterial and indescribable. Yet through the *sefirot* (the ten aspects of the Divine, the world and the human) the *Ein Sof* emanates into the physical world with its visible, differentiated vessels containing opposite, yet dialectically complementary, attributes like mercy and judgment or feminine and masculine.

2 Light is Unity within Diversity

Scientific Perspective: Each element in nature emits its own special light. It is commonly understood that white light contains all the colors we can see. If you take a prism and shine white light through it, a rainbow of colors will result. This "visible spectrum" is continuous and ranges from red to orange, yellow, green, blue and violet. What is not so commonly known is that each element in nature, when heated to a certain temperature, emits its own special light, something like its own "**spectrum fingerprint**." For this reason, astronomers can analyze the light from different stars in the sky and conclude what elements exist on those stars!

Reminiscent of the scientific notion that every substance is identifiable by a unique spectrum fingerprint of light, the Kabbalah thought of each human soul as having a unique aspect of the complete human soul created for Adam.

Jewish Perspective: The scientific perspective envisions white light as a basic entity that can be differentiated into what appear to be separate entities, white light being broken down into seven colors.

The Light of the Divine Face — by Sherman Rosenfeld

What's the meaning of "divine light"? For one answer, check out the daily prayer for "*shalom*," in the Jewish prayer book: "Bless us . . . all of us . . . with the light of your Face, because you have given us the light of your Face: the living Torah, the love of kindness, *tzedaka*, *bracha* (blessing), *rachamim* (compassion), *chayim* (life) and *shalom* (peace)."

Jews pray to God for "the light of Your face" and then the text lists a series of seven "attributes" of this divine light: "the living Torah, the love of kindness, *tzedaka, bracha, rachamim, chayim* and *shalom*." So you can think of this prayer as a prism of "divine light," just like the diffraction gradient above is a prism of white light.

Similarly, the kabbalist Moshe Cordovero[4] describes the *Ein Sof* as a kind of water or a kind of light that is differentiated into separate vessels whose characteristics are apparently opposites but are in fact all the same substance and not really contradictory but dialectically and dynamically related.

He compares the *Ein Sof* and the *sefirot*, the Divine infinity and the ten vessels of the world, to water pouring into vessels of different colors such as white, red, green and so forth. So the water, which is in fact colorless, appears to have the hues of the vessels. Similarly, light passing through a prism suddenly appears to be made of seven colors.

Reminiscent of the scientific notion that every substance is identifiable by a unique spectrum fingerprint of light, the Kabbalah thought of each human soul as having a unique aspect of the complete human soul created for Adam. The 16th century Italian kabbalist, Moshe Zacuto, regarded the unique *nitzoz* /spark within each of us as defining our destiny: "Every human being should know the root of one's own soul, so as to perfect it and to restore it to its origin, which is the essence of its being." If everyone develops his or her own soul roots, then humankind and the cosmos will be redeemed.

3 Light is the Basic Building Block of the Universe: Life is Energy, Energy is Matter and Matter is Energy

Scientific Perspective: According to Einstein's famous equation $\mathbf{E=mc^2}$ even a tiny quantity of mass can produce an enormous amount of energy *(see biography of Albert Einstein, page 200)*. This theoretical equation has been verified and utilized in many ways, such as in the creation of the atomic power which runs some electrical power plants. In essence, the equation says that matter **(m)** and energy **(E)** are not two distinct entities, but are interconnected by the speed of light **(c)**. Light is the primary substance. The accepted scientific theory today is that the universe started with the "Big Bang," a singular event, which generated unimaginably huge amounts of light. According to this view, this light eventually turned into the countless galaxies that make up the universe.

Jewish Perspective: Like Einstein, kabbalist thought imagines a world made out of an infinite magnitude of light which is then divided up into ten vessels or *sefirot* which make up the visible world but do not constitute static fixed entities. The spiritual and the physical are not radically different but simply the same substance conceived under different perspectives simultaneously.

4 Light is the Basis of Life

Scientific Perspective: Energy comes in many different forms, such as light, heat, electricity, movement and chemical energy. Often, these forms of energy can be converted into other forms of energy. For example, the chemical energy in the battery of a flashlight can be converted into light energy. While we may not think of light in these terms, light is a form of energy. In fact, life on Earth is completely dependent upon the light energy of the sun. Without the sun's energy, life could not exist.

Like Einstein, kabbalist thought does not make a fundamental distinction between the organic and inorganic. There is a dynamic flow of energy through both, which is essential to the life of the universe. Any blockage in the flow causes chaos.

Plants have the ability to convert the energy from sunlight into the chemical energy stored in sugars, in a process called *photosynthesis*. In this process (driven by sunlight), carbon dioxide and water are converted into sugars and oxygen. The food of all animals — people included — ultimately comes from this process which depends on light.

Jewish Perspective: Like Einstein, kabbalist thought does not make a fundamental distinction between the organic and inorganic. There is a dynamic flow of energy through both, which is essential to the life of the universe. Any blockage in the flow causes chaos. As the light of the Divine emanated into objects and continues to flow to them giving them life, it can also reverse its direction and change these temporary objects back into the light from whence they came. The flow outward and back is the dialectical process of the life of the universe and of God. The connection between the divine energy usually associated with the universe and the organic life of the individual human being is expressed in the oft-quoted proverb, *"The candle of God is the soul of the human."* [5]

Can You Produce Water from a Candle?!

Can fire produce water, when these two seem to be opposites?
Can water, which extinguishes a flame, be contained within a burning flame?

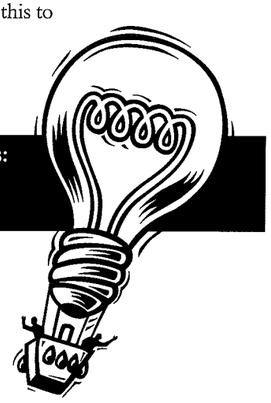
At first, it may not seem to make sense, but it's true! When a candle burns, water is produced. You can demonstrate this for yourself by placing a dry glass container over the top of a candle. Within a few seconds, you will notice that water vapor has moistened the inside of the container. In the process of cellular respiration, our body also burns food — at a much lower temperature — and produces carbon dioxide and water. We exhale the carbon dioxide and part of the water in our breath.

4. Safed, 16th century

5. *Proverbs* 20:27

5 Light Carries Information — Light is Knowledge

Scientific Perspective:
Everything we see in the physical world comes to us through the vehicle of light. Without light, we cannot see a thing. Think about it. When you look at something, all you see is the information carried by the light. In fact, light is the only thing you can see. We may think that we "see" various objects, but in reality all we see is the light that is reflected from those objects, light which carries information to our eyes and brains. Bob Miller, an artist who worked for many years at the Exploratorium, a science museum in San Francisco, has this to say: "My eye intercepts the little bit of light that's going through this little area in space, and I see the world out there with all its textures and colors. But all I'm really seeing is just that little bit of light. That's all I can see. And in some mysterious way, I 'project' this visual perception back on the real world. To me, that's miraculous."[6] In a sense, the human mind is the instrument of self-consciousness by which nature comes to know itself, and the eye is the an important source for that self-knowledge.



Light as perceived by the human eye carries an enormous amount of knowledge. Today, lasers of light can carry much more information than any telephone wire and the amount of brain space and computer memory needed to store visual information is much greater than that needed to store verbal knowledge. A picture is still worth a thousand words.

Jewish Perspective: In the Biblical creation story light serves this cognitive function and therefore before God creates anything else he says, *"Let there be light."* This light pre-exists the sun and moon whose light is more functional. By this light God sees the world, names it and evaluates it. The Rabbis analogize this first light to Torah, which they call in Aramaic *"oraita"* — a word interpreted as referring to light. They imagine God looking in the Torah of primordial light as a blue print for the creation. The mystics maintain that when a soul brings its unique aspect to illuminate an aspect of the Torah to which that soul corresponds, then it also, in turn, illuminates itself and illuminates the Torah and thereby the world.

The Hanukkah candle is also a medium to convey information and to propagate a message — ***pirsum hanes***. Therefore the Hanukkah candle may not be used to provide light or heat but only to proclaim to passersby the miracle of the light. While lighting the candle is important, observing it and decoding its message is even more important.

The Guiness Book of Records: What is the most powerful lamp in the world?

In Vancouver, Canada, in 1984, a high-pressure argon arc lamp was produced which has the power of 1,200,000 candles.

Professor Daniel Matt, author of *God and the Big Bang* and the translator and commentator of a future new edition of the Zohar, read this curious fact about the 1,200,000 candle power of the most powerful lamp. He was reminded of the Talmudic passage from the *Babylonian Talmud, Shabbat* 88a:

> Rabbi Simlai expounded: "When Israel said *'We will do'* before *'We will listen'*[7] [thereby demonstrating true faith by committing themselves to fulfill God's word before hearing the details], 600,000 ministering angels came down to grant each and every Israelite two crowns, one for *'We will do,'* and one for *'We will listen.'* As soon as Israel sinned, 1,200,000 angels of destruction descended and removed them, as it says: *The children of Israel were stripped of their ornaments from Mount Horeb."*

In other words, both the Jewish people at Sinai and the most powerful lamp in the world have 1,200,000 crowns of light!

7. *Exodus* 24:7

6. *Exploratorium Quarterly*, Volume 11, Issue 4

6 Light is Self-Propagating

Scientific Perspective:
Imagine an electric bell ringing in a glass container. Now imagine that the air inside the glass container is slowly removed by a vacuum. As the air is removed, the ringing would become fainter and fainter until no sound would be heard. Sound waves are transmitted though a medium, in this case the particles that make up air. (Other mediums through which sound can travel include water, wood, rock and metal.) Without a medium, no sound can travel. But light does not need a medium in order to be transmitted. The electro-magnetic waves are self-propagating, which is why we can see the light from stars millions of light years away from us, even though there is no air (or any other medium) in space. If a flashlight were placed alongside the ringing bell in the same glass container, we would still see the light after all the air had been removed, even though we wouldn't be able to hear the bell.

Jewish Perspective: Although Torah is compared to light, its propagation according to the Rabbis is totally unlike the self-propagation of light through a vacuum. Torah's knowledge is transmitted through the medium of the active human learner who necessarily refracts the light absorbed. Comparing study to the smashing of a hammer on a rock (Torah) that splits off sparks in every direction, the Rabbis saw the active role of the learner. In fact, Torah's light self-propagates in the biological — not the physical sense. For Torah is "fruitful and multiplies" itself in being transmitted through the human mind's eye. There is no principle of the conservation of Torah energy, rather the opposite is true, the more Torah is studied, the more is created; the more energy is spent on learning, the more energy there is for learning.

> There is no principle of the conservation of Torah energy, rather the opposite is true. The more Torah is studied, the more is created. The more energy is spent on learning, the more energy there is for learning.

7 Light is an Ultimate Reference Point

Scientific Perspective:
From the scientific point of view, the speed of light is an important point of reference. In Einstein's famous equation, $\mathbf{E = mc^2}$ (where **E** is energy, **m** is matter, and **c** is the speed of light), the speed of light is the "conversion factor" of energy and matter. Light is also a reference for what it means for something to be "straight," and it is used to create our most precise clocks.

Let's look at the first point of reference. One of the most surprising discoveries of the 20th century is that distance and time are not absolute, but merely relative to the speed of light!

This principle, part of Einstein's "theory of special relativity," can be illustrated by one of Einstein's famous "thought experiments." Imagine that you're traveling on a beam of light and someone on the side (an "observer") is watching you. In your hand is a flashlight. Now, while traveling on that beam of light, you turn on the flashlight. From the point of view of the "observer," how fast would *that* light travel? Our day-to-day logic tells us that the "observer" would see that light from the flashlight travels *twice* the speed of light. However, as it turns out, nothing can travel faster than the speed of light. On the contrary, *time and distance themselves* must change in relation to the constant speed of light. In other words, as an object travels at speeds closer to the speed of light (186,000

miles per second, or about 300,000 kilometers per second), time expands and distance contracts. As fantastic as this sentence sounds, it is true and verifiable. Fortunately, objects that can travel close to the speed of light are sub-atomic, so we normally don't experience this reality.

Jewish Perspective: In the Biblical creation story light is the measuring rod for each object created. By it everything is evaluated by Divine sight, *"God saw that it was good."* The Hebrew term for something just and good is *"yashar"* — straight in one's eyes, just as in physics light defines straightness.

8 The Interplay of Opposites Makes the World Discernible

Scientific Perspective: According to many physicists, the universe began when all matter and energy were condensed together into a tiny point. Then, in a singular event, a "Big Bang" explosion sent mass and energy shooting in all directions, forming galaxies as well as molecules and atoms. The distribution of space, matter and energy — in regard both to outer space as well as to the inner space of atoms — is central to our conception of the world. Opposites play off one another to bring about contrast to the universe as we know it: "space" is the absence of matter and "darkness" is the absence of light. These "sets of opposites" (and others like them) work paradoxically to constitute reality for us.

The description of reality for both Lurianic Kabbalah and modern physics involves the playoff of relatively empty space and energy/mass or, in other terms, darkness (as the absence of light) and light. World building, or *tikkun olam* as the kabbalists call it, involves gathering divine energy/ sparks of light which were dissipated in empty space in the original creation process (the kabbalist "Big Bang," so to speak) and redirecting them into different vessels.

Jewish Perspective: Sixteenth century Lurianic Kabbalah envisioned the creation of the world as beginning with a radical withdrawal of all light from the empty space which became the space of the universe. The Divine infinity/*Ein Sof* underwent a process of self-contraction called *tzimzum* and then its light went shooting back into the space (without filling it completely). The infinite light became finite material light that entered ten vessels, *sefirot*, which themselves broke, spreading the light even more. The description of reality for both Lurianic Kabbalah and modern physics involves the playoff of relatively empty space and energy/mass or, in other terms, darkness (as the absence of light) and light. World building, or *tikkun olam* as the kabbalists call it, involves gathering divine energy/ sparks of light which were dissipated in empty space in the original creation process (the kabbalist "Big Bang," so to speak) and redirecting them into different vessels.

Scientific Perspective: Darkness plays an equally important role in the realm of the psycho-biology of the eye. Our eyes are structured so that they respond to different amounts of light. A quantity of light which "makes a difference" is called a JND ("just noticeable difference"). As it turns out, starting with complete darkness, our eyes perceive a "just noticeable difference" with only a very small amount of light. The next JNDs involve increasingly greater amounts of light. Ironically, however, in terms of our perception, "discerning darkness from light" takes much less light energy than "discerning light from light." The more light we see, the more light energy is needed to produce a "just noticeable difference." Paradoxically, when an area is flooded with light, our eyes are less able to discern differences than when the same area has less light.

Jewish Perspective: The conception of darkness as mere absence of light, not as a malevolent or inertial substance of its own, helps us make sense of the Hasidic proverb of the Baal Shem Tov: *"A little bit of light can illumine a great deal of darkness."* This is reminiscent of Eleanor Roosevelt who said, "Instead of cursing the darkness, light a candle." Yet darkness continues to play a positive role even in its absence. In the Biblical creation God does not eradicate darkness when light is created. Rather, darkness receives its place — night — and light its place — day. The dialectics of light/darkness and matter/space are keys to understanding our spiritual and physical worlds.

Light and the Electromagnetic Spectrum

BY SHERMAN ROSENFELD

One of the most fascinating features of all electromagnetic waves, including light, is that they are "self-propagating." These waves are composed of two alternating fields of energy — an electric field and a magnetic field — which propagate each other even without a medium, such as air or water. (For a while, scientists argued that light — like sound — needs a medium in order to travel and they mistakenly postulated the existence of an "ether" to fill this function.)

A variety of electromagnetic waves make up what is called "the electromagnetic spectrum." These waves differ in their wavelengths, ranging from short wavelengths (such as x-rays, which are fractions of millimeters long) to longer wavelengths (such as radio waves, which are kilometers long). And there is another difference: the only electromagnetic waves which are visible to the human eye are light waves. Yet all electromagnetic waves have several common features: they are "self-propagating," they travel at the "speed of light" (186,000 miles or about 300,000 kilometer per second), and they have a dual nature, i.e., they exist simultaneously as both waves and as particles (photons). By contrast, sound waves, which can only travel through a medium like air, travel at only approximately 1100 feet (335 meters) per second in air.

Most of the light we see originates from very hot objects, like the sun, the surface of which reaches 6000 degrees Centigrade (10,000 degrees Fahrenheit). When humans discovered how to make fire, they simultaneously discovered how to produce light. The colors of a flame (or parts of the same flame) usually indicate different temperatures. For example, from lower to higher temperatures, the flame color moves from red to yellow to white and finally to blue.

White light is composed of the wavelengths of many colors. As Isaac Newton first demonstrated, when white light passes through a glass prism, it defracts and separates into a series of different colors, called the visible spectrum. Physically speaking, each different color represents a different wavelength and a different amount of energy. Longer wavelengths (less energy) are more reddish and shorter wavelengths (more energy) are more bluish or violet. For example, after a rain — or while running your sprinkler — a rainbow results when sunlight is refracted through droplets of water. From top to bottom, the colors of the rainbow are red, orange, yellow, green, blue, indigo, and violet.

Incidentally, don't confuse the "colors of light" with the "colors of pigments" (the latter are found not only in paints and plants but also in our clothes and most every object around us). These two sets of colors recombine differently. For example, the primary "colors of light" are red, green and blue light; when recombined they produce white light. The primary "colors of pigments" are yellow, blue and red; when combined they produce a dark brown color.

Why do these two sets of colors act differently? The source for both sets is visible light. But when white light hits an object, some of that light is absorbed and some is reflected. The reflected light is what we actually see as the "color" of that object; but all the other colors in the visual spectrum have been absorbed by the object. (For example, we see that most leaves are green. This means that all the other colors — mostly red and blue — are absorbed. We see "green" because it is the color NOT absorbed.) So "colors of pigments" act differently, when they are recombined, than "colors of light" do.