IBN AL-HAITHAM

PROCEEDINGS OF THE CELEBRATIONS
OF 1000TH ANNIVERSARY
HELD UNDER THE AUSPICES OF
HAMDARD NATIONAL FOUNDATION
PAKISTAN

Edited by
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INTRODUCTION

The Hammad National Foundation of Pakistan is to be felicitated on the publication of these seven treaties of Ibn al-Haitham in a period pregnant with tremendous possibilities for creative effort in the field of science and technology in this country. The new education policy is a great leap in this direction and the excited interest released by the life and works of Ibn al-Haitham augurs well at this turning point of our educational destiny.

Through his Institute of Health and Tibi Research, the President of the Foundation has already revived the Tibi Pharmacopoeia with many a prophylactic remedy for our physical frame. His efforts in the new direction signalization nothing less than a system of dynamic therapy for our educational framework which is languishing under the deadweight of many a quack palliative borrowed wholesale from the scientists of the West.

The first great quality of a good physician, even prior to the prognosis or diagnosis of a case is the framing into a frame of the dying flicker of confidence which the patient has in his reserve powers of self-observation and self-medication. This publication and its follow-up could spark into action a similar sense of confidence in the heart of the educator who is waging a losing battle against insurmountable difficulties. It implies the discovery of supreme possibilities for reconstruction and re-creation which can be unearthed by an objective study of the rich heritage handed down to us from the golden period of Islamic Science. This could provide the most effective antidote for the pale palliatives and L.S.D. which have drugged the educational system during recent years. The Berkeley course of science and mathematics is the most recent sample of this foreign wizardry foisted upon the teachers and the taught of this country.

The Military Celebrations and this follow-up publication envisage a programme for the recovery of our scientific heritage of the past. Hitherto we have been charmed into a state of leesidity by the praises and the publicity of our ancient achievements. It was no better than a psychic hallucination. The publication of the Arabic text of these treaties of al-Haitham was a salvaging operation which recovered them from the archives of ancient libraries and although edited and improved by celebrated Orientalists like Professor Konow they still left something to be desired.

The translators had to wage an unflagging battle against the understanding of the mathematical and technical sections of the text, especially the diagrams, which sometimes abounded in errors and misreadings of the original Arabic. They had also to spell out the text into the language and terminology of modern science. They have accomplished this task with an adequate degree of accuracy and exactness.

The pioneering effort of the Dastur al-Ma‘arif in publishing the Arabic text was in itself a great achievement. But the task of transforming this lore of ancient wisdom into an effective instrument for the creation of dynamic future was yet to come. The publication of this book signals our entry into this second stage.

These treaties reveal a great Muslim scientist at his best in more than one field. Although are they tantamount to the salvaging of a few gems from the vast ocean of creative thought from al-Haitham, they are fairly representative of his great genius as a seeker after truth. They reveal his independent, indefatigable effort for working out the various stages of his scientific method, his keen sense of observation of isolated facts, his power of constructive imagination in schematizing them into a working hypothesis, and its verification through experimentation under varying but controlled conditions and circumstances and the formulation of a theory. It was followed by a still further instructive process of verification of fundamental postulates.

The Foundation has in the offering a rich and strenuous programme for continuing this great task of the recovery of our rich heritage in a hitherto unexplored esplanade. It is expected that it would prove one of the surest gauges for the commencement of an era of new science in Pakistan.

The Light of The Moon

The moon is different from other heavenly bodies because of its different phases with regard to light. Some portion of the moon is bright at one time, while the same portion appears to be dark at other times. On account of these observations, scholars have concluded that the moon does not have its own light but acquires it from some other source. They have also concluded that it gets its light from the sun. In support of their view they give the following reasons: (i) The bright portion of the moon which faces the sun, is bounded by an arc which hinges out towards the sun. (ii) The closer it is to the sun, the smaller is its luminous portion. (iii) The full moon appears as bright when it is in front of the sun and reflects all the light which it gets from the sun. Though the moon is not exactly in front of the sun in this state at the time of lunar eclipse its surface, which reflects light is exactly in front of the sun; that is why when the earth comes in between the sun and the moon, the lunar eclipse occurs.

On account of the above mentioned reasons all scholars, philosophers and physicists agree that the moon gets its light from the sun. Though they differ on almost all other issues to some extent, yet they all concur in this respect. But there is no definite reason to prove that their views are based on irrefutable facts. Nor is there any reason to believe that there is no possibility other than this. Nevertheless, it is possible that these ancient scholars or any one of them might have given some reasons that could not reach us. It is also possible that the people might have taken it as a self-evident truth and might not have felt the necessity of providing proofs for it. Similarly the statements of these scholars do not provide any guidance as to how the sunlight which falls on the moon is reflected to the earth.

A group of philosophers have argued that the moon is non-luminous and dark; and when any ray of light from the sun falls on it, it is reflected to the earth. They have also said that the moon is a spherical dense body having a smooth and shining surface. Therefore the rays of sunlight falling on the moon, reach the earth after being reflected. They have quoted the example of a mirror to prove their point of view. They have stated that mirrors and other such bodies reflect their light in the same way. But none of these statements explains how the moon gets light from the sun and how it reflects its light or what phenomenon occurs. The said group of philosophers tell only that the moon acquires its light from the sun, but they have not given any acceptable reason to prove their view. Moreover, the statements of these scholars do not throw any light about this being the only possibility. Under these circumstances it has been decided to

*Translated into Urdu from Arabic by Hazin Naimuddin Zubaizy Rendered into English by Professor Abdul Qadair Chaudry.
was necessary that we should investigate into this problem and by making deep observations, shall collect facts and provide reasons to remove all misgivings about it.

We started our study on this problem on the basis of our observations of other luminous heavenly bodies. From these observations we have come to the conclusion that there are three possibilities about the light of the luminous body, reaching some other body: (i) Every point of the luminous body which is opposite to the other body will appear to be luminous. (ii) The entire surface of the luminous body is so small that it cannot be seen by the eye. (iii) The light which falls on any portion of a body from some other source is reflected. This phenomenon occurs in the case of all luminous bodies and mirrors which appear to be bright.

Or the refracted light is visible on the surface of the body. It happens in the case of all transparent bodies.

When we study the light of the moon in the light of the above conditions, we learn that every part of the moon which comes in front of the sun is seen apparently bright, but actually only that part of the moon is luminous which is facing the sun. This is a common every-day observation on which we base our conclusion, that when a portion of the moon in front of the earth is facing the sun, and the earth comes in between the moon and the sun, lunar eclipse occurs. It means that when the moon to the sun is totally or partially obscured, only that part which is deprived of light becomes dark. In the latter case we have to admit that the moon does not have its own light but acquires it from some other source.

In the case of a self-luminous body, its light can only be visible when some opaque body comes in between the luminous body and the observer. If the opaque body completely covers the whole of its surface, the body becomes totally invisible and if it covers only a part of it, then the actual covered part becomes invisible. Moreover, if two bodies were situated in such a way that both can be seen simultaneously, they can be seen only if one covers the other completely. In this case they are far away from observation and so it is difficult to distinguish one from the other. Similarly it is a common observation that if any body, which is not spherical, will change its shape and this change will become very prominent when the distance between earth and the body becomes very large. Now if we want to study the light of the moon with a view to finding whether the moon is self-luminous or not, we must realize that the moon depends upon the above mentioned conditions. But still it is not proved that the moon is a self-luminous body because it may be said that the moon is spherical in shape and a portion of it is self-luminous when the moon is bounded by sun and moon is continuously rotating round its axis.

As the changing distance, there is a well-known fact that change occurring in the shape of the object of the visible body due to change in distance will only be up to a certain extent that either the body appears to be much bigger or some parts of it will become comparatively more prominent, or some portion will become totally invisible, but it is not possible that a curved bright body will appear as a general area may be seen in the shape of a crescent all the time.

If the light of the moon is lighted by stars then there are two possibilities, one that there is a crescent in the shape of the stars at the time of eclipse and the other that there is a curved bright body. However, it is also possible that both these factors together may be the cause of change in the shape of the moon. If we accept the first possibility then it is necessary that the body should be opposite to that portion of the moon facing the sun, because that is the only way that the moon is dark at the time of eclipse and the area of this darkened part of the moon is not significant.

It is this area which produces that point actually opposite to the sun. If such an intervening body is responsible for this change in the shape of the moon which is seen at the time of eclipse, then at this time all stars which are near the moon should also be in eclipse. However, this is not possible, one can imagine that it is almost completely and moving planets which are akin to the shape of the moon remain as they are. It is common observation that at the time of eclipse, no other stars on the planet is eclipsed. Moreover, it is well known that the time of eclipse can be in the vicinity of some other solar star. In that case the change in the shape of the moon at the time of eclipse will be due to the intervening body and all such stars would also be visible, which is also against acknowledged facts. It is undeniably a very convincing argument that there were some intervening bodies, some must have existed which were eclipsed in eclipse. But in any case it will not be true to say that the light of moon is its own at the time of eclipse; the reason for eclipse is some other body which covers some portion of the moon.

There is another significant fact as well, i.e., when a circular body is at a particular angle with the eye of observation it shall become increasingly visible. The appearance of the moon during its movement from one place to another makes the middle of the sky or directly moving appearance of the radiant part would be variable but this change in the shape of the moon shall also be visible at all places. The moon may be seen at those times does not look alike. Consequently, there is no such particular appearance of the moon due to the reason of its shape and the moon shall appear as a crescent at every place. The moon may be seen as crescent shaped from some places on the earth and it may be seen as a different shape from some other places. It is not at all necessary that it should look alike when viewed from different positions or situations. Geometrically it is not true to say that each part of the convex surface should be limited within two arcs, except in the case when the surface is circular convex.

We will discuss how the light of moon reaches the earth.

In this context all of us will establish those principles which may be used for reasoning for the light of moon. One group of philosophers is definite about this and its detail is as follows:

1. When it comes out from a body and reaches any such medium which is transparent, a lamplike reflection occurs. But if any such medium is different from the first medium in transparency, then these rays are refracted according to a defined principle. This principle is that where both the transparent bodies coincide. After refraction, the rays proceed in a straight line again.

The rays of light reflected by a luminous body are reflected at definite angles. These angles are formed by the rays of light coming out in a direction lying in the same place as the normal. The straight lines are perpendicular to the reflecting surface at which the point of reflection lies.

The eye acquires the perception of visible objects in the form of straight lines such that the medium is compound of two such media as are different from each other in their transparencies, and the rays reach the eye in a refracted shape.

1. The eye perceives visible objects as straight lines with the proviso that the medium in the middle is the air. The surface of the reflecting body actually parts that body. The operation of reflection takes place at a fixed point. Perception is in the direction of these visible objects. The imaginary perpendicular lines emanating from this fixed point compose identical angles.

If a body emits a ray of light and the eye is also on the same plane as the rays, the eye will perceive the body depending the ray. The eye perceives an object an object in the direction of these lines, and then any ray of light which passes the direction of lines, will pass in the same direction, whether it is the same medium of a uniform medium, or due to the change of medium it refracts.

This position which we have stated is true and reasonable to philosophers and this is accepted true from the way of inductive method. If we had time here, then we could discuss it in detail but these reasons are stated with detail in relevant books.
It is a fact that the light coming out from every bright portion of the moon falls at a point which is directly opposite to it. Now we begin the discussion and in this respect one reliable principle which is proved by arguments is that when sunlight falls on the moon and at this state the moon also gets bright and the spreading light from it reaches the earth, is the light of that portion which is bright and opposite to the earth. But we can understand from this that moonlight is exactly the same as the light of a bright body. It is known that when the light of the moon falls on the earth, it is not of that kind as may be visible by the body which is itself luminous, because in this way light may be seen through transparent bodies and in no case is the moon transparent, because if the moon is transparent, solar eclipse cannot occur when the moon comes into the middle of the earth and the sun.

But we assume that the light coming out of the moon to the earth is not the light which is being reflected from the sun. We present this theory by these diagrams in detail.

Let us explain this with facts with the help of a diagram. Let there be a circle with centre having two diameters TC (passing through T) and BDA (passing through B). Let there be two points K and L lying on the small arc AC. Join FK and FL, EH and DH and DI.

Let there be a circle with points A, B, C on it. The centre of the circle is D. We take two points E and F such that one point is on BDA produced. Now we say that there is no line in between E and F for which we make two equal angles at the arc ACB. We have the following reasons for our assumption. In the first place, this is not possible because if it were possible, then it would not be a circle and if a line were to be reflected at point E and F would have been reflected at two equal angles. This can be stated in detail in this way: that the angle ECF and angle FCB are equal to the angle FCA. Now if we join line EC it will meet DF at a point which can be at any point on the line EC and CP and this ‘act’ is not possible. So there can be no such line which touches the line CD so that angle ECF and CDB are equal to the angle GCA when the angle EGB is larger than the angle FCA, though we have supposed them to be equal. We thus conclude that in between the points E and F there is one line which can be reflected at equal angles on both sides of the arc ACB and this is what we wanted to prove.

Keeping in mind the two points, we may say that in between the two points there is only one line which can be reflected at equal angles on the circumference between two points, if as there are more than one line that can be reflected at equal angles at two points, then they must make equal angles with the radii at those two points. So it is proved that from two points E and F of the convex circle arc ABC, two or more lines cannot be reflected at equal angles. It is clear from this figure that if every line reflects from the two points on the circumference of the circle at equal angles, each line which is in between the two such points will also pass at equal angles.

Let us explain this above facts with the help of a diagram. Let there be a circle with centre having two diameters TDC (passing through T) and BDA (passing through B). Let there be two points K and L lying on the small arc AC. Join FK and FL, EH and DH and DI.
Z in between the lines HA and DB. In this case the reflecting line through Z would intersect DB or HA. If this intersection takes place at any point K, then the reflecting lines would pass between K and E because KE is the line which makes equal angles with HA or DB, which again is not possible.

Now since ED is equal to HD, the angle EDT is equal to the angle HDT and ET is equal to DK. The ratio between HD and DK is the same as the ratio between ED and DT. So the triangles HDK and DTE are congruent. Therefore the angle HDT is equal to the angle EDT. But the angle HDK is greater than the angle HDA. So the angle EDA will be greater than the angle HDA. Now taking away the common angle HDT, the remaining angle CIE will be greater than the angle CDA. Therefore the arc CB will be greater than the arc TA. And that is what we wanted to prove.

Similarly, let there be a circle with centre D and an arc ABC. Let there be two points Z and E on the same plane such that ZB and EB make equal angles with BD and EB is greater than ZB.

So we have proved that the points lying between HA and DB cannot be reflected at equal angles at any point on the arc CDE except any point on the arc AB.

In the same way let there be a circle ABC and two points K and T on it, D being the centre. The point E lies on DC produced so that EC is equal to EB, and the angles HTF are reflected at equal angles. Now the arc BC is greater than the arc AT, because if DA and DT are joined, the angle FAD and HAD will be equal. Similarly the angles FTD and EDT will be equal. But the angle FAD is greater than the angle FTD. Therefore the assumed arc is greater than the arc ETD, and ED is assumed to be equal to EB, so the angle which the arc of a circle makes with BD will be equal to the angle EDA. But it is given that HD does not intersect AD or AK because A lies above DH. Let these be a point K which makes angle HKD equal to angle EDT.

Now we have to prove that the arc BC will be greater than the arc BA. Take any point H on EB such that HB is equal to ZB. Now ZB = HB, HB = DB and the angle ZBD = the angle HBD. Therefore ZB:DB = HB:DB or angle ZB = HB, so the triangles ZBD and HBD are equiangular. Therefore the angle ZDB = the angle HDB. But the angle EDB is greater than the angle CDB. Then the angle EDB is also greater than ZDB. So the arc CB must be greater than the arc BA.

Now, let us consider another case. Let there be a straight line from A, the centre of the moon, to B, point of the earth. Let the point B be on or above the horizon. Let these be a big circle passing through the centre of the moon and the sun. Let there be a point on the big circle opposite to the centre of the sun. Let this point be joined to the centre of the sun with the help of an arc which is not less in length than the length of the arc which the radius of the projected circle makes with the body of the sun. We shall prove that the line AB when produced will not meet the body of the sun.

Support AB produces the body of the sun at any point C. Let T be the vertex of the projected cone. Join TB and produce it to meet the body of the sun at any point D. As TBD lies on the projected circle and C is another point on the sun, CD cannot be greater than the diameter of the sun.

Take a point Z on TB, such that AB = ZB. Join AZ. Let E be the centre of the earth. Join AE, ZE and TE.

Evidently, TE will pass through the point opposite to the centre of the sun and the angle formed at T will not be less than the angle between the radius of the projected circle and the diameter of the sun.

As the point Z lies inside the projected circle and also in the heaven of the moon (because BZ:AB) so the angle ZET will not be greater than the angle between the radius of the projected circle and the diameter of the sun. Therefore, the sum of the angles AZE and ZET will not be less than the angle between the radius of the projected circle and the diameter of the sun. This means that AZE will be greater than the angle subtended by the diameter of the sun or the angle ABE will not be less than a right angle. Therefore AE is greater than AB and ZE is greater than AZ. But AB and AZ are equal angles smaller than AE and ZE, the angles AZE and ABZ have the same base AZ. But the angle ABZ is greater than the angle AZE and the angle AZE is less than the angle which the diameter of the sun makes. So the angle CBD will be greater than the angle that the body of the sun makes which means that CD will be greater than the diameter of the sun. This is contrary to our hypothesis. Hence the line AB produced will not meet the sun at any point D, and is what we wanted to prove.
Let there be a point P on the surface of the moon intercepted by the two tangent planes. Now let us pass a plane through AB and T which must meet the sun. The line of intersection of the moon cut by the planes will be a circle, say TDK, where K is the point on the surface of the moon which is towards the sun. The light coming from the sun and reflected from the moon to the earth must spread in the direction of the point A. The reflection of the light can be positive at such a point where the angle of incidence and the angle of reflection are equal, and such a point can evidently be T. But we have taken K to be positive on the moon which is towards the sun.

Let there be a point T on the surface of the sector of the moon cut off by the two tangent planes tangent to the sun. Let us draw a plane through A, B, and T. It will certainly meet the sun between these two points of contact where the ray from the sun, meeting in surface of the moon and reflected towards the earth, will make equal angles with the produced radius of the moon at the point, but the plane does not meet A and B will meet the sun on the side of cross-section of the moon in the direction opposite T. But it has been proved earlier that if there are two points in the circle outside it, through one of them a diameter is drawn, then at no point on the semicircle lying opposite the second point can the lines through those points make equal angles. Therefore, the point T which lies opposite to the direction towards which the plane through A and B meets the sun, can be reflected to A. So we conclude that at no point on T or between the tangent planes can the light of the sun be reflected to the earth.

Let us suppose that the distance between the sun and the moon is not less than 1/2 of the circumference of the circle through their centres. Let us suppose that the two places touching the sun at A and K. Let us join A and T and K to the centre of the moon. Now AKB and ATB are tangents to the sun. Therefore, they must be greater than the distance between the centres of the sun and the moon. Now BTA and TKB are greater than 1/2 of the circumference of the circle through the centres of the sun and the moon.

Let the planes through A, B, and T meet the surface of the circle at the points L, M, and the plane A, K, and T. Since the distance between the sun and the moon is less than 1/2 of the circumference of the circle through the centres of the sun and the moon, the angles there formed will be less than 90°.

According to Ptolemy the length KB and TB must be greater than the diameter of the earth, the diameter of the earth is 3½ times the diameter of the sun and the diameter of the sun is 18½ times the diameter of the moon. Taking LM equal to a unit of length, the diameter of the moon will be 210 units and the distance of the sun is equal to 4,000 units.

The line which makes equal angles between 1 and 2 and the line of the moon can be reflected to the point A, if it is reflected at L and M. It has also been proved that every point between B and B, at which equal angles are formed and light is reflected to A, must be on the arc LM.

So the light which is reflected towards a surface through the centres of the sun and the moon and the point A must be reflected at a point on LM.

Moreover, we have established that the arc LM is larger than the circle BCD, but LM is not greater than the circle from which light can be reflected touching the sun and passing through the centre of the moon and reaching A.

If the distance between the sun and the moon is not less than 1/2 of the circumference of the circle through the centres of the sun and the moon, then this portion of the moon will be less than 1/2 of the required length. So if the sphere of the moon is divided into 36 equal sectors then this portion will be in the sector which is towards the sun. But in this way the distance of the sun from the moon will be less than its circumference. All this discussion goes to prove that there is no point on the surface of the moon at which the light of the sun can be reflected to the earth.

Now the thing to explain is that light goes from the moon to the sun and then from the moon to the earth in a straight line and at no place does reflection take place. Research scholars believe that the light coming from the sun does not travel in a straight line at the time of entering the air from the earth, because they are reflected in the concave heaven which is closer than the earth. In their opinion, light travels in a straight line, as long as its path lies in the same kind of atmosphere. But the light of the sun reaching the moon does not pass through the sky but through the air, especially at the time of the appearance of the crescent. In such circumstances the light must reach the moon after reflection. However, the path of the light of the sun which travels in a straight line and is not intercepted by the air, does not reach the moon at all. The same is true about moonlight and it also does not reach the earth in a straight line.

The above views of the scholars are based on a wrong notion. In their astronomical discussions, they are considering the light of the moon and the sun from the moon to the earth, goes unbroken and un-refracted from them. They wrongly believe that the ray of light goes from the eye to the body and so they think that the ray of sight reaches the heavenly bodies and reflexion does not take place on the way, and it is not the light that travels but the ray from the eye, that goes to the body. Moreover, if the ray of sight reaches anywhere, it is negligible and there hardly any difference between these rays and the rays travelling in straight lines.

We have also proved earlier that the path of light travelling in a straight line can be reflected from the moon to the earth. But any extremist might say that the light from the sun to the moon is reflected to the earth but there is reflexion on the way. So the proof given, by us will not be valid, because we have not taken into consideration of the possibility of reflexion. But think that these rays of light cannot possibly reach the earth ever if reflexion occurs on the way. But the real reason for the view is that in spite of the possibility that some of the rays of the sun might be refracted, the rays reaching the moon can in no case be refracted.

Let us suppose A to be the centre of the sun and B to be that of the moon. Let us join AB and produce it to Z, such that it meets the surface of the sun at C and other side of the moon at Z. Let us draw a plane through AB cutting the concave heaven and the sphere of the sun. Let us consider a circle DEZ in the plane through AB and draw a line from C touching the circle DEZ. Let it be called CET. Let us rotate the plane about CZ as AX in. Now, the cone with CA as vertex and CE as one of the generators will have its base towards T.
we assume that there were some solid body at that point of the concave heaven with a small hole in it. In this way, the light emerging from this hole must reach more than one point on the earth, which is contrary to our supposition. Hence we come to the conclusion that the light from the sun to the moon and from the moon to the earth is not refracted.

The lines on which the light reaching a fixed point travels are easily lines which fix the directions of the perceived vector's ray of the eye. Now, if the above mentioned case is taken to be correct, the result will be that if the moon is seen from this point on the earth, many moons will be visible because the above supposed hole will be receiving light from different parts of the moon. It is an acknowledged fact that in seeing an illuminated body, the perceived vector's ray of the eye travels in the direction in which the rays of light emerging from this illuminated body travel, whether these rays are in a straight line or are refracted on the way. But the moon is not visible like that from any point on the earth. The point can be further explained in the following manner:

Let B be the centre of the moon, and A be a point on the concave heaven from where the whole moon is visible. Let A also represent the point from which the light coming from the moon can be refracted towards a point on the earth. Let there be a point on a great circle between B and A.

Now, the light, which is being reflected from the sun to the point A, will travel in a straight line up D. Let this light be reflected from a point. Let it be coming from a point H on the sun so that AN and NH make equal with BH, the radius of the moon at N.

Let us consider two planes through B, touching the sun. Now, the light coming from the sun to the moon must be travelling in these two planes. The portion of the light of the sun which is reflected to the earth will also be between these two planes. It means that the point N will be on that part of the surface of the moon which will be intercepted between these two planes.

Let the area of the moon be CDZ. The portion of the moon between these two arcs is the only part from which light can be reflected. Let the area of the moon be cut by the lines BH and BT (tangent to the surface), which light can be reflected towards the point A will be nearer E than L, and similarly the point N, at which the ray from E is reflected to any point of the earth will be nearer C than K, i.e., the arc NM will be smaller than the arc KL.

We know that the distance between the sun and the moon varies inversely as the distance between the moon and the concave heaven. The ratio between the arc KC and MC may increase or decrease according to the increase or decrease in the distance between the moon and the concave heaven. So the portion of the moon from which the light can be reflected towards the earth will be a very small portion of the visible surface of the moon.

In any case, whether the light reaches the earth in straight lines or by refraction, the reflection from the surface of the moon cannot take place before the entry of the light in the cone of light. The light entering the cone, the rays coming from the sun are refracted, with the exception of those rays which fall on a very small portion of the moon. But the small portion cannot permanently remain the same and go on changing according to the revolution and rotation of the moon. The cone referred to in the previous figure is not a fixed cone, but will be different for the observers at different places, and the location of this cone changes with the place of observation.

During the time of the appearance of the moon, the light, which reaches the surface of the moon from the concave heaven, can be reflected. In this situation, the point from which reflection can take place, will be near the center of the visible part of the moon and its distance from the extremity of the visible surface will be greater than its distance from the center. Let us explain the point with the help of a diagram.

Let A and B be the centre of the moon and the earth respectively. Let there be a point C on the earth. Join AC and BC. From C draw two lines, in the planes A B C, touching the moon at D and E. Join DE, DA and EA. Evidently CA will be the right bisector of ED.

Let us produce the plane ABC so that it reaches the concave heaven. Let this plane cut the surface of the earth at H and Z making the angles BZ and BHA as right angles.

Taking the radius of the earth as 1 unit, the distance of the moon will be 40 units. According to Ficherman, the length of the line AB will not be less than 35 units and the distance of the concave heaven will not be greater than 35 units. Angles AHB being right angles, AZ and AH will not be less than 42 1/2 units. So the angles BAH and BZH will be 1/2 each. So, when the moon is just on the horizon, the angle BAC will be at most be equal to 1 + 1/2 degrees. So, the angle CAZ will be 55 degrees. So, the light which reaches towards the centre of the moon will be very near the line AC and the angle contained at the point of reflection is almost straight. The angle, near A between the reflected line and CA will be double the angle between them near C.

The line from the centre of the moon reaching the concave heaven will be equidistant from the visible surface of the moon and its centre. Any line from the centre of the moon, which goes to any point on the concave heaven from which the light reaches the moon, will cut the visible surface of the moon at a point which is near the middle of this part than the circumference. In this way, the light which is reflected from this surface of the moon passes through the centre of the moon. So, the lines through the centre of the moon touching the concave heaven are no more those which are in the middle of it and go to the parts of the earth where the moon is visible. The portion of the surface of the moon from which the light is being reflected will be near the circumference of the visible position of the moon.

The reflection can be possible from any point on the surface of the moon provided the light can reach that point from the concave heaven, because its distance will be less than 1/2 of the distance between the centre of the moon and the middle of its circumference. So, the area from which reflection is possible, will be the middle of the visible portion of the moon and its width will be less than 1/2 of the breadth of visible portion. So the portion of the surface from reflection is possible will be less than 1/16 of the visible portion. Neglecting the distance of the moon, the line from the center of the moon to the upper part of the concave heaven will fall on the visible portion of the moon and near its middle then the side. The line of vision of the eye going towards the moon will fall on the visible surface of the moon and will include the line through the centre of the moon, which touches the concave heaven making angle at the angle at the moon. It has been proved that the distance of the surface of the moon from whose reflection is possible, from middle of the visible portion is 2/3 of its distance from the corners. Moreover, when the visible portion of the moon is towards the pole (so is the case at the time of the appearance of the comet), its upper surface is illuminated which means that the portion from which reflection is possible is nearer the middle of the visible portion.

If a body is dense and transparent and the light from some illuminated body is falling on it, but it is not reflected from that body, then the vision falling on such a body will not be reflected from it. Consequently, the actual colour of the body will be visible to the observer. If the light reflected from such a body reaches the eye after reflection, then the colour of the primary from which light is emerging will be visible along with the light of its own body. Sometimes if the illuminated body is very bright, the colour of the reflecting body is not
visible but only the colour of the luminous body is visible. This phenomenon can be clearly observed if a bright and polished surface is placed opposite to the rays of the sun, then the part of the surface from which light is being reflected is no brighter than we cannot see towards it. The glass of this portion is proportion to the brightness of the surface. However, if the surface is not very bright and unpolished, the part of the surface from which rays of the sun are being reflected is comparatively brighter. Moreover, in a latter case, a part of the surface reflecting the light will share the colour of the sun and the remaining part will be showing the actual colour of the surface.

The above condition holds good for all other bodies and when the light falls on them the colour shown on them are either their own or that of the bodies from which the light is falling on them. As has been explained earlier, in the latter case the vision of the eye is reflected towards the illuminated body from the tangent plane. Sometimes the visibility of some colour is due to the fact that it is either the colour of some intersecting body or some transparent medium. In any case, a detailed discussion on the visible colours is beyond the scope of this discussion.

Now we have to prove that the light of the sun cannot be reflected from the moon to the earth straight or through refraction. Let us now consider the colour of the moon, which is either its actual colour and is visible when the light of the sun falls on it or is the colour of the light of the sun. In other case, it is either reflected from the sun or is visible to the eye when the perceptual vision of the eye is reflected from the moon to the sun. It is also possible that the brightness visible on the moon is the colour of some intersecting media which is in between the eye and the moon or the sun and the moon. In short, the colour of the moon is due to one or number of causes listed above.

Evidently, the bright colour of the moon cannot be that of any body coming in between the eye and the moon, because if that case the intersecting body will remain between the eye and the moon and the whole moon will be of the same colour all the time, which is against our common observations. Moreover, only that part of the moon is visible which is opposite to the sun, and at the time of the eclipse of the moon it becomes significantly dark. Similarly the moon cannot be a medium between the sun and the moon whose colour is visible on the moon.

Let us consider the possibility that the special colour of the moon is visible when the light of the sun falls on it. We have discussed earlier that there is no possibility of the reflection of the light of the sun from the major portion of the surface of the moon. So the reflection of the light of the sun coming to the moon can be reflected from a very small area lying at its centre which in mathematical language is termed as a point. In this case, the observer could see only this point on the surface of the moon which again is contrary to our observations. So we conclude that the bright colour of the moon, which is visible on the earth is not due to the reflection but the main reason for that may be that the light of the moon bright at the moon and because the surface of the moon is not glassed, the real colour of the moon is visible in this light.

It may be argued that when the light of the sun is reflected from a point on the moon, the remaining part of the moon is also illuminated. But in such a case, the centre of the moon will be very bright and the remaining portion of the moon will be comparatively dark and the furthest border of the moon will be quite dark. But this is against the known fact. The moon of the first night is visible in the form of crescent because only a small sector of the moon faces the earth is bright. Moreover, no part of the crescent or even the full moon is brighter than the other parts. So it is wrong to think that the part of the moon, on which the light of the sun falls does not become bright or the light falling at a place spreads to the other part of the moon. We have also proved that if reflection was taking place at a certain point, the revolution and rotation of the moon would go on changing the position of that point and the position of the point would be different from different points of observations on the earth.

From the above discussion, it is clear that the light of the moon reaches the earth from every point on its surface at which the light of the sun is falling. However, this light is not the result of reflection. In fact, that part of the moon, on which the rays of the sun fall, becomes bright and due to the atomic property of the moon it looks bright from every point opposite to it.

Light

Light is a branch of physics. It travels in the form of straight lines and so it's study becomes an academic pursuit. Under physics we discuss illumination, the nature of the rays of light and the physical properties of light. All those objects through which light can travel freely are known as transparent objects. This study also comes that light, the rays of light and the subject of transparency belong to physical sciences and academic pursuits.

We shall now deal with the meanings of these phenomena. Collectively we can say that the appearance of a body depends upon its brilliance and is simply an "atomic shape" of that body. This shape is not constant as long as the atomic make-up of that body remains unaltered.

Light proceeds from an illuminated or a bright body. The body gives light because of its internal atomic structure and the internal light which falls on dense bodies gives rise to its "lateral appearance". This observation is based on the researches of eminent philosophers but academic researchers say that a hot body gives out heat and if this body is illuminated, it gives out light also.

These researchers performed certain experiments on the sun and found out that when a parallel beam falls on a concave mirror, the reflected rays of light come together to a single point. If we place something on this point, it will catch fire after a few minutes. These observations also found out that the rays of the sun, while passing through the air, raise the temperature of the air and similarly if these rays enter a dense body, this body also gains some heat. These observations give rise to the belief that the light of the sun actually consists of heat rays and all kinds of light are similar in nature so far as their property of heat is concerned. They can, however, differ in intensity. The light which burns will naturally be very strong and the rays of light which do not raise the temperature will naturally be very weak. For example, it is very hot and, therefore, it heats the surrounding air. The air directly in contact with the source of fire will become much hotter as compared to the air separated by a large distance. If, therefore, we place a body at a sufficient distance from the fire, it will not catch fire and if that body is brought close to the fire, it will catch fire. The reason is obvious; the distance from the fire matters very much. In short, the fire can burn only when its temperature is high and not otherwise.

We draw the same conclusion in the case of light.
such observations convince us that solid objects also attract light but they do not transmit it. Light is transmitted only through transparent bodies and then it can fall on solid bodies placed behind the transparent luminous bodies. Rays of light proceeding from the luminous body are transmitted through the transparent medium and then they fall on the solid body placed opposite to it. It is obvious that the solid body will receive light only as long as the transparent body transmits it.

We can feel the presence of light by introducing a solid object in its path. Since the rays of light are cut, the transparent body does not receive them, nor does the solid body placed behind it. We, therefore, can conclude that every physical body, be it transparent or opaque, has the property of absorbing light. The only difference is that a transparent body transmits the light falling on it, whereas an opaque object does not do so. It is, therefore, clear that the properties of a transparent body are different from those of an opaque body.

We come to the conclusion from the above that every physical body absorbs light. A transparent body has the additional property of transmitting the light. This is the aspect of vision which lends a body its brilliance and beauty. Transparent bodies are of several types and, therefore, transparency varies from body to body.

We have pointed out that rays of light passed from a luminous body and fall on any object which has been placed opposite or in vicinity. We shall now describe how this happens and how light is transmitted through transparent bodies.

We shall first deal with the light proceeding from a luminous body and passing through a transparent medium. It falls on any opaque object placed opposite to it. The light of the sun, moon and stars comes to us after having passed through the atmosphere which is clear and transparent. This light falls on all material bodies on the earth and passes through the thin layer of water provided it is clear. If water is contained in a transparent vessel, say a glass vessel, the light passes from this vessel also and falls on the object placed opposite. The same holds true for all other transparent bodies. Light passing through them strikes the opaque objects placed opposite. We, therefore, conclude that light can pass through all transparent bodies.

As regards the question as to how light passes through transparent bodies and also to the fact that the light is transmitted through transparent bodies along straight lines but it does not scatter when it is allowed to fall normally. It would be correct to say that light proceeds along straight lines and in all possible directions if it is issuing from a point source. This subject has been explained thoroughly in the book, *Kitab-ul-Malikzad.*

If you seek the proof of the propagation of light along straight lines, take the example of a dark room in which light is entering through a small hole. You will see that the light will be seen along straight lines. The presence of these rays of light will be made visible by the dust particles hanging in the atmosphere of the room. If we place a stick parallel to these rays of light, our conclusion will be proved.

If there are no dust particles in the room and the light falls on the wall opposite to the hole through which it is entering, you can stretch a thread along the path of the light. You will see that light actually proceeds along straight lines. If you move the thread up and down, you will find that it will deviate from its original direction. This phenomenon has been discussed in greater detail in the *Kitab-ul-Malikzad.*

Diffusion of light through transparent bodies is a physical property of all lights. We, however, say that this property is restricted to transparent bodies only. The reason is that transparent bodies do not transmit light in any direction other than straight but this concept does not stand the test of scrutiny. Had the diffusion of light been the property of transparent bodies alone, light could have been transmitted through a specific direction only.

The fact is that light proceeds in all directions. Rays of light can be parallel to each other, they can intersect each other, they can proceed in a straight direction and they can go obliquely. If more than one luminous bodies are present somewhere, light will issue from each of them and the straight lines which they will make will be of different types.

We thus come to the conclusion that the same property which makes light pass through transparent bodies makes it proceed along the straight lines also. The same rays of light cannot proceed in opposite directions. When light is transmitted through transparent bodies, it maintains its straight direction. Thus both the property of light as well as the transparent body are maintained.

Light which proceeds along a straight line is called a ray; or we may say that a ray is that light which proceeds from a luminous body and passes through a transparent medium along a straight line. We do not ordinarily perceive these straight lines because they are not separated from each other.

Researchers have treated an optic ray as an ordinary ray and they have confined their discussion to the rays of light which issue from the sun or from a fire. Ancient philosophers held that we see a body only when a ray of light proceeds from our eye and falls on that object. This phenomenon makes that object visible, and this ray of light is actually a part of the ray of light which passes through a transparent medium along a straight line and enters our eye. The presence of these rays of light will be made visible by the dust particles hanging in the atmosphere of the room. If we place a stick parallel to these rays of light, our conclusion will be proved.

The fact is that the rays of light fall on an object along straight lines. They are subjected to reflection from that object and enter our eyes, giving us the perception of seeing. Light is scattered from a point source in all possible directions and, therefore, we see the objects all around us. If light is proceeding from a point source in many directions, it is obvious that the solid objects around us will also reflect the light in many directions. Our vision is affected by only those rays of light which come along favorable directions and, therefore, we see only those objects which are placed in front of us or on our sides.

The light which passes along straight lines is to be composed of rays. Researchers say that these rays maintain their straight direction, whether the light is coming from the sun, the moon, the stars or a fire.

We now come back to our original subject, i.e., transparent bodies. We have discussed that light is transmitted through a transparent body. There are two types of transparent bodies, celestial and non-celestial. Celestial bodies are of the same type because their basis is the same, whereas non-celestial bodies are of three types: air, water and many other bodies like glass, crystal etc. The power of transmission is different with different bodies except for the celestial ones. The power of transmission of air depends upon its density. The examples of dense air are mist, smog and dust-laden air. By fine and rare air we mean the air confined in our room or the one which we breathe and experience on the hills.

Rain air is far more transparent than dense air. Similarly, water and other liquids have different degrees of the transmission of light. Some kinds of water are more transparent; for example, the sea water and other types are less transparent, as also the water in motion or coloured water. Similarly, other media are transparent to a lesser or higher degree. Transparent glasses, crystals and similar media also differ in their power.

Apparently the atmosphere about us has a unique power of the transmission of light. All the stars have this unique property after having travelled huge distances. All other media except space possess density to some extent because the light falls on them. They give rise to a secondary light
The rays of light striking a transparent body will have an angle of incidence. The angle of reflection will be equal to the angle of incidence, and the ray of light will be refracted according to Snell's law. If the body is a liquid or a gas, the ray of light will be deviated in the same manner as if it were passing through a transparent medium.

When water is incident on a glass plate, the angle of refraction will be different from the angle of incidence. The refractive index of glass is greater than that of water, and the ray of light will be refracted. If the plate is held at a certain angle to the light source, the angle of refraction will change, and the ray of light will be deviated in a different direction.

The same principle applies to the reflection of light. When light strikes a mirror, it will be reflected at an angle equal to the angle of incidence. The angle of reflection will be the same as the angle of incidence.

In some cases, the light will be absorbed by the body, and there will be no reflection or refraction. This is known as absorption. Absorption is important in the study of the properties of materials, and it is often used in the design of optical instruments.

When light passes through a transparent body, the density of the body will affect the path of the light. If the body is dense, the light will be deviated more than if it were passing through a less dense medium. This is known as the refractive index of the body.

In summary, the study of light and its interaction with different media is important in many fields, including physics, chemistry, and engineering. Understanding the principles of refraction and reflection is essential for designing optical devices, such as lenses and mirrors, and for understanding the behavior of light in different environments.

As an example, we can consider the phenomenon of dispersion. When light passes through a prism, the different colors of light are separated, and they appear as a spectrum. This is because different colors of light have different wavelengths, and they are refracted at different angles.

In conclusion, the study of light and its properties is a fundamental aspect of science, and it is essential for understanding the behavior of materials and the functioning of optical devices.
possible particle of water and if we further divide this particle, it will no more be water but it will acquire the form of air. If we begin dividing this small amount of air, we will come to the smallest particle and if we try to further divide this smallest particle, it will also change its shape and acquire the form of fire. If we start dividing this small portion of fire into smaller and smaller portions, we will come to the smallest possible part which will not be divisible any more because in this universe there is hardly anything rarer than fire.

Space is rarer than fire and if fire can possibly acquire the form of space, it will be divided into smaller and smaller particles and it will be converted into the atoms of space. Further division of these atoms will not be possible and if we do it imaginatively, the particles of space will be exhausted after having undergone further division. These particles will not be divisible any more because it is impossible to have anything rarer than space. If we conceive of any division of space, it will be nothing but imaginary. Philosophers say that space possesses the greatest amount of transparency meaning thereby that no physical body is rarer than space and it is erroneous to say that it will be so in the future because, according to the opinion of these philosophers, whatever species and forms of matter which were to come into existence, have already come.

Both the concepts are correct, i.e., transparency does not have any limit in imagination, nor do any physical bodies and its greatest amount is associated with space.

Whatever we have said about transparency and transparent bodies is governed by a certain branch of learning. We have explained here all what we intended to do. Philosophers maintain that a body becomes visible only when the rays of light fall on it. Light as a matter of fact is a secondary effect of heat and it almost comes out of the luminous bodies in the same way as heat comes out of the bodies. By a ray of light we mean that light which is diffused and reflected by a transparent body, whether this light is coming from the sun, the moon, the stars or a fire.

By transparent bodies we mean those bodies through which light can pass easily and this affects our vision. Transparent bodies are of two types: one in which light passes through the entire body and the other type is that which allows the light to pass through a certain portion only. The first type has two branches; in one we count the celestial bodies and the other covers all bodies other than the celestial ones. Non-occidental bodies have three kinds of their own-air, water and transparent bodies like glass. Transparent bodies allow the light to pass through them. Transparency has different forms and the variation is determined by the angles of refraction. If we have two transparent bodies whose power of transmission is different and the rays of light are diffused through both of them then the angle of refraction which the refracted ray makes with the normal will be smaller in the medium of greater transparency. We have discussed these phenomena in detail in this chapter.

Light Of The Stars

A number of philosophers consider that the stars derive their light from the sun and they say that the stars themselves do not emit light. Their ideas are based on the assumption which they already had about the moon, namely, that the sun is the life-sustaining part of the moon varies continuously, and the variations concerning the light of the moon can be observed clearly during the eclipse and also during that interval when it emanates the sun. Thus, they have concluded that the moon derives its light from the sun, and in itself, it is a dark body. They have ascribed the same idea to the stars and have begun to think that the stars, too, derive their light from the sun, like the moon. But they could not present a convincing proof in support of their conclusion, neither could they point out any reason on the basis of which this idea could be proved. It is, therefore, obvious that it is only a conjecture. When some of the followers of these philosophers talked to me about it and pressed me to accept their idea, I thought it opportune to make investigation into the light of the stars and related characteristics. During these investigations, I came to the conclusion that the stars themselves emit light, and their light is due to certain properties which they possess by themselves; further, with the exception of moon, none among the stars derives its light from the sun. I have, for this purpose, compiled this treatise so that the readers may know the reality; the weakness in the rationalization of those people who differ on this point should also be known.

It is obvious that all stars are spherical, and the same argument can be advanced to prove their spherical shape, as is advanced in the case of the sun and the moon. In brief, this argument runs as follows:

A body which appears circular from all angles and at all distances must have a spherical shape, because in the case of the bodies that are not spherical, a change in the angle from which they are looked at, may cause a change in their shape. All other bodies, whether they are plane or cubic or of any other form, change their shape with the change in the direction from which they are viewed. Now take the case of the stars. During revolution they change their position in relation to our sight but in spite of all this shifting each one of them looks circular. This fact strongly supports the view that all stars are spherical shaped.

This fact alone is sufficient to prove that the stars emit light. For, if they had derived their light from the stars, there must have been a change in their form relative to the sun and we should have seen them in different shapes. In that case each of them would have appeared as a crescent when in the vicinity of the sun and as the case with the moon, when it is at a short distance from the sun. The reason why the moon appears as a crescent in this case is as follows:

* Translated from Arabic into Urdu by Hakim Nooruldeen Zabari and rendered into English by Professor Hazarri Askari.
The parts of the moon, which face the sun, are different from those facing the earth. It is evident that only those parts of the moon confronting the sun give light and only a small fraction of this part which is lit up, faces the earth; it is this small portion that can be observed from the earth. With the exception of this bright part, the remaining part of the moon which faces the earth cannot be seen because of its being dark. As a whole, the illuminated part of the moon is very small as compared to the dark part of the moon in the position when it is very close to the sun. Both parts of the moon that face the sun and the earth respectively, from two separate circles, crossing each other. In this way, that part of the moon which is seen in the illuminated state from the earth is enclosed between two circles and is made up of two curves of the circles which intercept each other. Now a small part of a sphere, which is made by such intercepting curves, the convexity of which is on the same side, can only be crescent in shape. These are the reasons why, on the first and the last days of the month, the moon looks very small crescent, when it is comparatively closer to the sun. Taking the case of the stars, many of which can be seen, before sunrise in the east, and after sunset in the west, we find that none of them has a form of a crescent. From this it can be concluded that none of the stars derives its light from the sun. They are self-luminous.

The conclusion, which we have drawn can be questioned on the ground that the stars are of very small size. Hence, in spite of their being actually crescent-shaped it may be that due to the smallness of their size, they do not look crescent-shaped but appear spherical from a long distance. The contradiction in this argument is very obvious. For, if this were the case and they had not looked crescent-shaped at times, when they should have appeared as such, they must have been seen as very small size stars then. And if that were the actual state of affairs, the stars, which are seen in the east at sunrise and in the west at sunset, should have appeared smaller than than at other occasion but this is not the case. Hence it is incorrect to say that any of these stars assumes a crescent shape at any time. From this, it is proved that all these stars are self-luminous, and none of them derive its light from the sun. It has been found that all the fixed stars have the same nature and the same composition, and there is no difference between their physical proportion, so that it is proved that some of them are self-luminous. It follows that all of them are self-luminous and they emit light.

In the same way, some fixed stars lie in the orbit of the moon. Thus, every month the moon gets close to them, and some times it happens that in the beginning of the month, when it is crescent, it gets so close to any of these stars that the moon appears adjacent to the star. This occurs specially in the case of the Venus. Thus if the stars have derived their light from the sun, they would have appeared in the form of the crescent like the moon, while near the moon, because of their proximity this phenomenon is not visible. In the case of the sun, however, the moon appears as if to that of the moon; and the stars, like the moon, are spherical. No star or planet however seems to be in the shape of a crescent. It is therefore clear that none of these objects receive its light from the sun. The same is the case with the rest of the stars because all of them have the same nature and the same composition. Moreover there are certain stars and planets which are close to the pole, and are therefore away from the orbit of the sun. They never get very close to the sun and never face it. The arc which they subside with the sun is quarter of a circle or less than a quarter. This arc is never greater than the quarter of a circle. When some of these stars rise an hour after the setting of the sun, those among them that lie westward subtend an arc with the sun which is not more than the quarter of a circle. Had they derived their light from the sun, all these stars in the west would have been semi-circular in shape like the moon under the same conditions.

The conclusion is that the stars are not more than the sun and the star is greater than the sun in the shape of the sun. Hence its bright portion is higher than the portion which can be observed, except for a small curved part which is seen as a crescent. But the fixed stars are higher than the sun and the whole of their bright portion, which faces the sun also faces the earth. This is so because the sun is nearer the earth than the stars and the distance of each of the stars is very small. In this case, the bright zone of the star covers a large area of the earth, which looks to be a small bright sphere. The same is true of the stars that are closer to the earth.

We can say in reply to this objection that all the above arguments become harmless if we only study the cases of the Venus and the Mercury. These two are nearer to the earth than the other stars and the planets, and are also not very far from the sun. Their appearance when they are close to the sun is that which makes it difficult to see them from away from the sun. None of them locks a crescent or of any other shape but only spherical, even during the beginning of the month, when the Venus is very close to the moon, which itself is crescent then. At that time, the Venus is close to the sun, and the distance between the sun and the Venus is the same as the distance between the sun and the moon, and they enjoy identical positions in the sky. Had the light of the Venus been derived from the sun as is the case with the moon, the Venus would have appeared to have a different shape at a time when it is close to the sun and with it away from the sun.

The same obtains in the case of the Mercury, which also looks spherical like the Venus at all times. This shows that the Venus and the Mercury do not receive their light from the sun. These two planets are nearer the moon than the fixed stars and the remaining three planets that are higher up in the sky. So, if these two planets, the Venus and the Mercury are self-luminous, I follow that the other three planets and the fixed stars, being higher in the sky should also be self-luminous because firstly, they are at a greater distance from the earth and secondly, they have the same nature and the same composition.

We therefore conclude that none of the stars or the planets derives its light from the sun and hence all of them emit light themselves.

The above statement shows that the natural source of the light of the stars is their own bodies and this light is not borrowed from any external source. The moon is the only exception among the heavenly bodies that does not emit light of its own. If this statement is taken into consideration, it would appear that any idea contrary to what has been said is wrong. This was the purpose of the publication of this discourse.

The discourse on the light of the stars thus comes to a close.
Space and its Nature

OBSERVERS and research workers differ in their views about the nature of space and allied phenomena. Certain philosophers have expressed the idea that the space occupied by a certain body we mean the surface which covers it, while others are of the view that the space of a body is an imaginary vacuum which is filled by that particular body. In spite of our best efforts we have not succeeded in finding any theories that are made by old thinkers, which deals with the proposition thatAssociation does not deny that the nature of space and ancillary facts. So it seems necessary to discuss this topic in detail so that the reality about space and its allied facts comes out in such a way that the differences of opinion are resolved.

2. Theories of space

Space is a vast proposition and has many applications. Each thing can be called a space; for example, if somebody asks about a certain body as to where it is or what place it occupies, the answer will be termed as space and may pertain to more than one meaning of space. When we ask about a certain person as to where he is, and that person is not present in that particular city, we shall then say that he has gone to such and such town. This suggests that space can be applied to a city also. Similarly, if someone asks about a person as to where he lives, the answer may well be that he lives in such and such street and this answer suggests that space can be applied to a certain street or city. Again, if we ask about a certain person as to where he is, the answer can be that he is in such and such organization, or house. It is clear from this answer that the meaning of space can also be applied to a certain organization, to a certain house or to a certain building. It is also apparent that space can be applied to either of these meanings and explanations and there is no difference of opinion left whether space is occupied by a man or a body. A problem which remains to warrant our imagination and which may give rise to different shades of opinion is the definition of space of a body, namely, that space covers those dimensions which do not exceed the dimensions of the body itself. Whatever we shall discuss about space, it will pertain to this very definition. We, therefore, mean the following two aspects of the bodily space:

1. The surface which covers that body. The surface here means the air that circumscribes the body if that body is placed in air. Similarly we shall count the surface of water if the body is placed in water. Here surface means that (imaginary) body which circumscribes a body in such a way that it does not form a part of that body. A certain group of philosophers accepts this definition of space as true.

2. According to the second definition, the space of a body is that imaginary area which the body has occupied for the simple reason that it can be imagined about anybody that it was not previously at the particular place which it now occupies. Accordingly the present space of the body may also be imagined to be occupied.

It is a different matter whether that space was formerly occupied by air, water or any other substance. In this statement we have used the word space in the meaning which we have mentioned in the beginning and imagine space means the line which limits such circumference.

A group of philosophers believes in this definition and according to these two definitions space can be applied to all the meanings mentioned earlier.

Now the only question remains as to how the nature of space can be determined and how one definition can be preferred to the other. Or do we come to the conclusion that neither of the two definitions is better? We shall take stock of the situation keeping one standard in view, i.e., which definition is exposed to more objections or doubts and if the definitions are equally susceptible to these objections, we shall have to decide whether or not there is a definition which is comparatively less exposed to objections and doubts.

As regards the question of surface, there may be one objection, viz., when the shape of a body changes, the surface also changes correspondingly. But, in certain bodies, the surface changes in such a way that the dimensions of this surface increase, though the measurements of the body do not change. For instance, there is a body whose two surfaces are parallel to each other. If we divide this body such a way that the new surfaces are also parallel to its original surfaces, then these two pieces are joined together and the new and original surfaces of a parallel surface come together. The present surface of this body will then exceed its original surface. The reason is that the number of the surfaces will increase as a result of this division and this increase will be equal to the original surface. In this condition, the space of this body will actually be the surface of air which circumscribes it and coincides with its own surface which is double the former surface. It is apparent that now the space of this body is almost double the original space, although there has been no increase in the dimensions of the body itself. It implies that the body has increased but the fact remains that the body has neither increased nor has there been any improvement in its size. Another example is that of a water container made of leather. The internal surface of the container will be known as the space of water. We now exclude some amount of water from this container. The internal surface of the container has now come to be called the space of water and the situation will continue to be like this, irrespective of the number of times we take some water out of the container. The situation differs from the defect that the mass of the body is continuously decreasing but its space is not decreasing. This is because of the internal surface of the container which does not change under any conditions, forms the space of a substance which can increase or decrease in its quantity and it is a great defect. Similarly if we take a solid of a uniform surface and dig a cavity of any shape in its surface, the total surface will be increased but the original inside, though that is the body has decreased appreciably. This proves that the space of the body will be more than what it was in the beginning, though the quantity of matter has decreased. This gives rise to another conclusion that there can be several spaces of a body which will have different masses under different conditions irrespective of the fact whether the mass of the body has changed or not.

Such a body is easily subjected to external influence. Examples may be quoted of wax, tin or water, which can change their shape without any change in the quantity of their individual masses. The surface which circumscribes a cube of wax will be known as its space. If we now give it a spherical shape with that very quantity of matter, its space will be in accordance with its spherical surface which circumscribes it. It is, therefore, important that when a cube takes spherical shape, its surface should be less than when it was a cube.

We have mentioned this fact elsewhere that in all such bodies whose surface areas are equal, spherical shapes will be the biggest and if a body of constant mass is given the shape of a cube and then that of a polygon, the surface area will be less in the former case than the latter because when the area of a polygon is equal to that of a cube, the mass of the cube will be comparatively less and the mass of the polygon will be more. Similarly if a body of constant mass is given the shape of a polygon, a cylinder, a cone, etc., it is clear that the mass of the body in all cases will remain constant but its surface area will increase according to the shape given to it. If we say that the space of a body is the surface which circumscribes it, it is imperative that the space of that body is likely to undergo changes and can have unlimited number of aspects. Then no space can be preferred to any other and any space in all these aspects which we have mentioned earlier, can be termed as the space of a particular body.

In the above discussion, we have brought out certain doubts and it is not possible to remove any one of them. So we cannot say that a line which circumscribes a body is the space of that body and if at all we say, it will be an imaginary definition completely detached from reality in the same way as a house, street, or city can be termed as a space only provisorily.
3. Objectives to the Second Definition

If we define space as an imaginary vacuum which is filled by a substance, the definition is exposed to the doubt that vacuum does not exist. So if we term vacuum by, it is possible that space may not be present while the body is actually present because whenever we accept the existence of a body, it is imperative that we accept its space. So the existence of a body proves the existence of space. We therefore have to accept the existence of both. Those who do not believe in the existence of space do not accept it as a strong reason to support this notion.

In order to remove this objection, we can define space as the limits which is determined by a substance. Accordingly when we say that imaginary vacuum is synonymous with space, we mean by space those imaginary limits which define the dimensions of a body. We, therefore, form and define imaginary limits by this imaginary vacuum as if by a body and these imaginary limits are exactly equal to the dimensions of the body. It is apparent that if two dimensions of exactly the same body are coincident with each other, they will be one and the same because these imaginary limits will actually make a line which does not have any breadth and whenever a straight line which has length only and does not move with any curvature with any constant length, the result will be a straight line. The reason is that whenever such a straight line coincides with the other, there is no possibility of any increase in the length and because these straight lines do not have any width; therefore, the result will also be one straight line which will give rise to another straight line. In this condition, this imaginary vacuum which has been filled by a certain body, if considered separately from the substance, will give us dimensions beside the body but they will be exactly equal to the limits of the body and they will correspond to the shape of this body. But we must be clear about one thing here and it is that the vacuum connected with a body is not space. We actually mean those dimensions which coincide with the dimensions of the body itself and that will be another way that they will become one and the same. It is also apparent from this that such imaginary dimensions cannot be considered completely different from the real ones. We have, therefore, to derive this condition that a body does not have such pre-determined limits as may be imagined without that body. Such dimensions, therefore, will never be free of the body which fills them. We shall give an example here which will illustrate the nature of space. Suppose we take a cup or a vessel. There will be a limited distance between two opposite points which lie opposite each other on the internal surface of the vessel. There should not be any difficulty in understanding this phenomenon. Similarly we can conceive of imaginary perpendicular dimensions issuing from the base of the vessel.

The internal dimensions of any such body will not undergo any change. If air is present in this vessel and then we fill it with water and let the water and the air be of the same quality as the same as those of the vessel. If we now take out this water and fill the vessel with any other liquid, then these very dimensions will apply to the other liquid also. So we can say that the dimensions between any two opposite points on the internal surface of the vessel can be the dimensions of any body which is present inside the vessel. The vessel can be filled with any compound substance. All these dimensions will possess properties different from those of another liquid. The internal dimensions of the vessel can be imagined and they remain the same under all conditions allowing no change whatever. So if we pour any liquid in this vessel, it will have its own dimensions corresponding to its own quantity and these dimensions will not change unless we change the quantity, although these dimensions may undergo a change in shape.

It is also apparent that every body will have its own distinct and individual dimensions. If we pour different liquids in this vessel one after the other, the dimensions will change correspondingly, although the internal dimensions of the vessel do not undergo any change whatever. And these very dimensions of the vessel will become the dimensions of the substance which has been poured into it or in such a way that if we pour a certain substance in the vessel, the internal dimensions of the vessel will become coincident with the dimensions of the substance and there will be no difference between them.

The same principle applies to all substances which are susceptible to external influence, e.g., air, water or any other fluid. It is apparent that all these substances undergo a change in shape but not in their dimensions. The change becomes apparent in their shape only and not in their dimensions. The change in shape does not affect the mass of a body. The shape of air as it can be illustrated in another way. Suppose a liquid like water has a fixed quantity and it is poured into vessels of different shapes. If we pour the same liquid in a glass in such a way that the glass is filled every time, the water present in the glass will have the same shape, although the shape of water was different before it was poured into the glass. The water will take the shape of the glass and in such a way that the internal surface of the glass remains the same in correspondence with its internal dimensions. It is, therefore, clear that the internal dimensions of the glass determine the shape of the liquid which is poured into it. It is also proved that the dimensions of the internal surface of the glass are unchangeable and any liquid which is poured into this glass, takes on these very dimensions irrespective of the fact whether the atoms of these liquids are alike or different from each other. The liquid leaves its own shape and takes the shape of the internal surface of the glass but it must be clearly understood in this example that the factor which determines the shape of a certain substance is the internal surface of the glass and not the dimensions which exist between two opposite points on the internal surface. The substance inside the glass exists between two opposite points in such a way that the external dimensions of this substance are coincident with the internal dimensions of the vessel or, in other words, the substance as a whole behaves coincident with the space between two opposite points situated on the internal surface of the glass. These dimensions do not undergo any change. The internal dimensions of a vessel are actually determined by that imaginary space which is filled by the substance poured into this vessel and although these dimensions are never free of the substance which occupies them, yet they can be considered as such and thus their appreciable presence can be imagined to be connected to one or another form of matter.

Whenever a certain body circumvents another body, this circumventing body's internal space actually takes within its boundaries certain unchangeable dimensions. These surfaces are such that the circumventing substance also coincides with its surface with the former one. When the circumventing body is withdrawn and its space is taken by another body, the dimensions of this body coincide with the dimensions of the substance and these dimensions can be the imaginary ones.

4. Conclusion

From the above, it will be seen that the imaginary dimensions that exist between every two opposite points of a circumventing body are actually formed by that imaginary space which is filled by the body and it is better to call these dimensions as the dimensions of the body itself, as against the internal dimensions of the space which means the circumventing surface. Such a definition is exposed to certain doubts as against the first definition in which the external dimensions of a circumventing substance are taken as the internal dimensions of the body. This definition does not offer itself as a prey to any doubts or objections. So we come to the conclusion that the first definition of the space is correct and on the basis of this definition we can say that the space of a body actually means those dimensions in which this body is completely occupied and its dimensions are not changed at all. Once this body is put into space, there is absolutely no difference left between the two surfaces. So this imaginary space is exactly equal to the body contained in it. Once we accept this truth, it is automatically proved that by the space of a body we actually mean its dimensions.

If we make the objection that according to this definition space becomes synonymous with the body and a body is after all composed of matter and that it is impossible to have another body leaving absolutely no gap between their surfaces, the answer will be that a body is not put into another body because every body is made of its own space-form. This form may be different from the matter of another body and, therefore, both the bodies cannot be made to occupy the same space. They will have their own respective spaces. We know that space is nothing material, nor does it have any resistance. Space is actually determined by only those dimensions which are capable of accepting matter as it is. Those dimensions are only those dimensions which are free of any body. There is no factor opposing the coincidence of the dimensions of this space and any other body because the dimensions of space are free from the idea of imaginary dimensions of any body. They do not have any breadth and they can cover the dimensions of any body without any difficulty. This explanation copes with the objection that a body cannot exist in the same space because they have the same space itself a body like the other one. This treatment provides an explanation of our statement made above. It is thus proved that by the space of a body we actually mean its dimensions and it cannot fill the space at all. This space is exactly equal to the body as regards its shape and size and this is our aim.