IBN AL-HAITHAM

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Edited by

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INTRODUCTION

THE Hamdard National Foundation of Pakistan is to be felicitated on the publication of these seven treatises 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 Tibbi Research, the President of the Foundation has already revived the Tibbi Pharmacopoeia with many a prophylactic restorative for our physical frame. His efforts in the new direction signalize 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 salesmen of the West.

The first great quality of a good physician, even prior to the prognosis or diagnosis of a case is the fanning into a flame of the dying flicker of confidence which the patient has in his reserve powers of self preservation and self-creation. 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 Muslim Science. This could provide the most effective anodyne 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 Millenary 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 somnolence by the praises and the publicity of our ancient achievements. It was no better than a psychic barbiturate. The publication of the Arabic text of these treatises 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 Krenkow they still left something to be desired.

The translators had to wage an unflailing 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 Dairat al-Maarif 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 signalizes our entry into this second stage.

These treatises 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 incessant, indefatigible 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 inductive process of verification of fundamental postulates.

The Foundation has in the offing a rich and strenuous programme for continuing this great task of the recovery of our rich heritage in a hitherto unexplored enclave. It is expected that it would prove one of the surest guarantees 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: (*a*) The bright portion of the moon which faces the sun, is bounded by an arc which bulges out towards the sun. (*b*) The closer it is to the sun, the smaller is its luminous portion. (*c*) 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 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 those people might have taken it for 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

*Translated into Urdu from Arabic by Hakim Naimuddin Zubairy Rendered into English by Professor Abdul Ghafur Chaudri.

was necessary that we should investigate into this problem and by making deep observations, should 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. This is the condition in the case of those bodies which are self-illuminated.

(*ii*) The light that falls on any portion of a body from some other source is reflected. This phenomenon occurs in case of all lustrous bodies and mirrors which appear to be bright.

(*iii*) 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, and no one differs on this point. Therefore, 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 light to the moon is totally or partially obstructed, 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 invisible when some opaque body comes in between the luminous body and our eyes. If the opaque body 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 very 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 that body and the eye is 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 realise that the phases of the moon depend upon the above mentioned conditions. But still it is not proved that the moon is not a self-luminous body because it may be said that the moon is spherical in shape and a portion of it is self-luminated. This bright portion is bounded by an arc and the moon is continuously rotating round its axis in such a way that it has its two constant poles, which are situated in such a way that the straight line passing through these poles perpendicularly intersects the line joining the centres of the sun of the moon.

It can be argued that the bright portion of the moon is towards the upper part of the sun. Under its above mentioned movements the moon moves, remaining at a constant distance from the sun, its bright portion comes into sight part by part. There will be an imaginary semi-circle formed during these movements when the the moon is exactly opposite to the sun, a semi-circle which moves due to the revolution of the moon and the lower portion of the moon is bright; but as the moon is facing the sun in position, the bright portion of the moon appears to be dim and as these motions continue, the waxing and waning of the moon takes place; this process goes on constantly. Similarly it can also be assumed that the moon is a spherical and self-luminated body and the whole of its surface is luminous, but it is encircled by another semi-circular, opaque and dense body which is moving round the moon and due to the movements of this body, the visible bright portion of the moon changes its shape.

Both these causes prove that the phases of the moon do not provide sufficient proof for the assumption that the moon acquires its light from the sun. Unless both these arguments are refuted, it cannot be proved that the moon is dark and non-luminous.

But we think that, if the characteristics of the heavens assumed by the philosophers are admitted, then, when the moon and the sun are opposite to reach other at the time of lunar eclipse, the full moon should be visible as a luminous body. A portion of the moon becomes dark only because of the earth coming in between the sun and the moon. This event is the only reason to assert that the moon gets its light from the sun.

In view of the last argument, there is no need to discuss the above mentioned objections in detail but we should know how far these objections are valid. So if we admit that the moon has its own light, then the occurrence of the lunar eclipse and the changing of its shapes can be due to the following four possible causes:

(*i*) Change in the volume of the moon;

(*ii*) Change in the distance between this object and the eye;

(*iii*) Change in the shape; and

(*iv*) The intrusion of some foreign body between the eye and that body.

If any or some of these causes are there, the body appears to be changing its shapes. If we consider the light of the moon, there is no denying the fact that the

volume of the moon is unchangeable. As for the changing distance, it 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 upto this extent that either the body will appear to be smaller or 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 which is visible as a crescent may be seen in the shape of a crescent all the time.

If the light of the moon were its own then there are two possibilities for the change of its shape at the time of eclipse. Either some other body gets between the moon and the eye or the change in the shape of the moon is due to some defective observation. It is also possible that both these facts 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 this portion which is dark at the time of eclipse and the area of this darkened part of the moon is not significant. It is this very 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. But this is not the case and many such complete 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 moon eclipse, no other star on the planet is eclipsed. Moreover, the moon at the time of eclipse can be in the vicinity of some other complete star. In that case the change in the shape of moon at the time of eclipse will be due to the intervening body and all such stars would also be invisible, which is also against acknowledged facts. It is undoubtedly a very convincing argument that if there were some intervening bodies, some must have existed which would have been permanently in eclipse. 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 observer, then its shape looks like that of a crescent. The appearance of the moon during its movement from horizon to the middle of the sky or inversely moving appearance of the radiant part would be variable but this change in the shape at those places where the moon may be seen at those times does not look alike. Consequently, there is no such particular appearance of the moon due to which reason the moon should look alike at every place. The moon may be seen as crescent shaped from some places on the earth and it may be seen as of a different shape from some other places. It is not necessary that it should look alike when viewed from different portions 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 first of all we 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 :

Light, when it comes out from a body and reaches any such medium which is transparent, proceeds rectilinearly through the transparent medium. But if any such medium is different from the first medium in transparence, then these rays are refracted according to a defined principle. This refraction occurs at the place where both the transparent bodies concide. After refraction, the rays proceed in a straight line again.

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

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

2. The eye perceives visible objects as straight lines with the proviso that the medium in the middle is the same. The surface of the reflecting body actually meets 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 comprise identical angles.

If a body emits a ray of light and if the eye is also on the same plane as the rays, the eye will also perceive the body emitting the ray. The eye perceives 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 the line is straight due to a uniform medium, or due to the change of medium it refracts.

This principle 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.

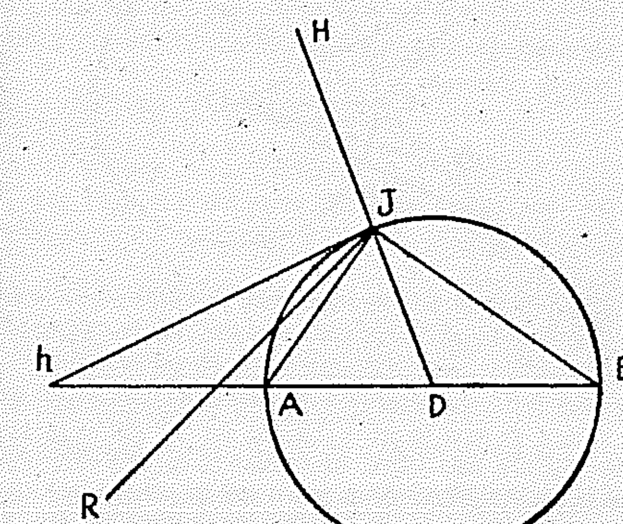
Now while studying the light of the moon, we take a ruler of a fixed length, breadth and height. This ruler is uniformly straight and plane. We mark two parallel lines at the both the ends of the ruler. These marks should be equal in size as well as in breadth. In the middle one of these lines we make a cavity. This cavity is similar to a smooth semi-circle circular. In the middle of it, a round and small hole is made and straight line is drawn from this hole to centre of the mark on the other side. This straight line should be parallel to the outer surface of the ruler, in such a way that the distance of this line should be the same as the distance between the outer surface of the ruler and the centre of the hole which is on the mark of the other side. In the breadth of this mark, the length of this line makes such an angle at the centre of the hole which is at the mark of the other side which is not less than the angle formed by diameter of the moon on the eye. And it would also be necessary that the remaining part of the length of the two marks and the breadth of that mark on which the hole was made when added together, must be less than that line which is formed by joining the centres of the holes. Then we tear that line till this hole reaches the point of the mark but this hole should be smooth as far as possible.

Now we take another ruler longer than the first one but of an equal breadth. Now we join these in such a way that the mark with the hole is at the side where the other ruler should be fixed to it. Now at this place where the two rulers meet one another, we make two axes which can rotate. The free corner of the other ruler is fixed in any square body, e.g., a brick etc. Now this instrument is used in such a way in the case of light that it is fixed in such a position that the moon is opposite to it and we see it through the hole which was made in the first ruler. Then the ruler is moved slowly up to the time, when the full moon is visible from that hole and the cavity. The ruler is moved up and down in such a way that the marked hole of one side is exactly visible where the diameter of the moon is visible. Then this hole is covered from the other side but it is necessary that there is a point in the cavity where the body of the moon is also visible along the circumference. Now we look at the moon from this place. It should be remembered that only such parts of the moon are visible as may be seen from that hole, because the remaining part of both marks forms an angle from the hole to marks ; this is not less that angle formed by the diameter of the moon on the eye. When we see the moon this way, the distance between the eye and the hole is increased and if a small dense body is put opposite to that hole in the beginning, that body will be seen as a bright object. When this light comes out from that hole and reaches that body, then it will be known that this light is a part of that light which was coming out from the hole. The reason for this is that the light travels in the direction of the straight lines and these lines are those which perceive the light. By looking through the said hole, only that portion is visible from that cavity which is coming from that portion of the moon. This proves that the light so seen is that which is being emitted by that portion of the moon which can be seen through the cavity. Now in this state, if we put any light body against that hole and move it slowly, and if we observe how the light comes of the hole, it will be seen that the light will become gradually dimmer but the cavity remains bright up to such time as any part of it is open and light seems to be coming out from that part. This means that the light enters every part which is open because if the light does not enter through this cavity but enters through any specific portion, the light would have continued coming till this portion became completely covered. It is thus obvious that the light coming out from that hole is in fact the whole of the light which has entered the cavity but it is worth stating that the dimming of the light entering through the hole is not felt many a time. So it is essential that the shape of the ruler should be fixed in a proper way and the unnecessary part of the hole is covered up to that stage as that only small portion of the surface of moon is visible and both of whose ends have been joined to one part of the cavity and light enters the cavity through the hole and falls at that dense body which has been put opposite to the hole. On this occasion we should see that only the portion left open such that it can be felt as it comes out and the quantity of the light is minimum. So it is proper that the hole should be covered by an object having a small hole in it. It will be found that light which is coming out from the small hole of the ruler and reaching the dense body is that light which is coming out from a specific part of the moon in a small quantity and this part is the minimum of the moon from which the light is coming. It is thus proved that light comes out from the hole of the moon and its whole light falls at that point which is opposite to the bright portion.

It is possible people are doubtful about accepting this reality due to the reason that in the case of crescent it is not possible when the crescent appears in the beginning and some times it has no light, specially when the distance between the crescent and sun is very small and the objection can also be raised that, however small the crescent may be, the light of each portion of it should reach that point which is opposite to it. As an answer to this question one might say that the light of moon, though the moon is large, at the time when the atmosphere is bright seems to be dim, particularly when the sun is about to rise and just after sunset and when the moon appears towards the end of the day, though before sunrise and after sun set its light grows brighter. The basic fact is this that when the moon and the sun are on the horizon and when in the day time any portion of the moon is opposite to the earth the light of the moon is not visible from that portion of the world. This is a definite and known reality.

It is a fact that the light coming out from every bright portion of the moon falls at a point which is 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 in 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 self-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.

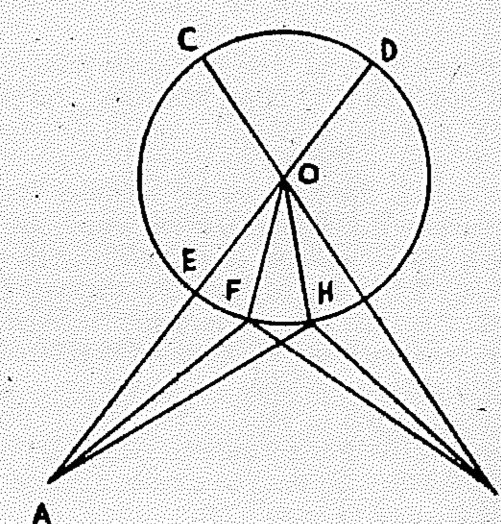
But we assume that the light coming out of the moon to the earth is not the light which is being reflected from the sun. We present this theory by these diagrams in detail.



Let 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. E is a point on BDA produced. Now we say that there is no line which is in between E and F and which makes two equal angles at the arc ACB. We have the following reason for our assumption. In the first place, this is not possible because, if it were possible, then in between E and F a line would have been reflected at two equal angles. This can be stated in detail in this way: that one angle ECF and angle FCB are equal to the angle FCA. Now if we join EC it will meet DE at a point which can be at any place on the line EC and CF and this 'again' is not possible. So there can be no such line which intersects the line CD so that angles ECF and CDB, are equal to the angle GCA when the angle ECB 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 no such line which can be reflected at equal angles on both sides of the arc ACB and this is what we wanted to prove.

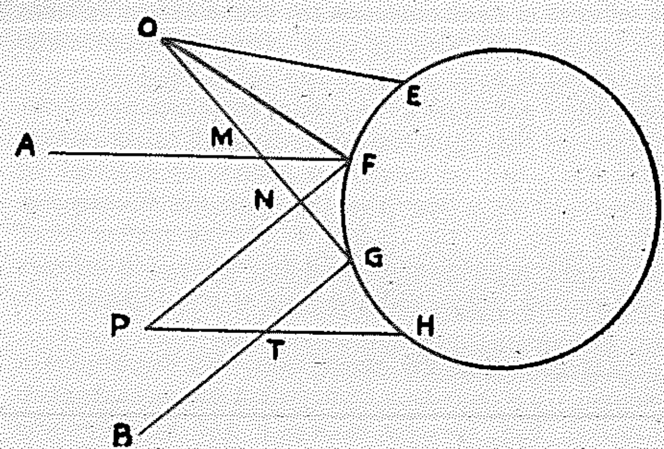
Keeping in mind the two points, we may say that in between the two points there is only one line which can be reflected at equal angles on the circumference between two points, as if there are more than one line that can be reflected at equal angles at two points, then they must make equal angles with the radii at those two points. So it is proved that from two points E and F of the convex circle 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 circumferense 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 the above facts with the help of a diagram. Let there be a circle with a centre having two diameters TDC (passing through F) and BDA (passing through E). Let there be two points K and H lying on the small arc AC. Join FK and FH, EK and EH, DK and DH.



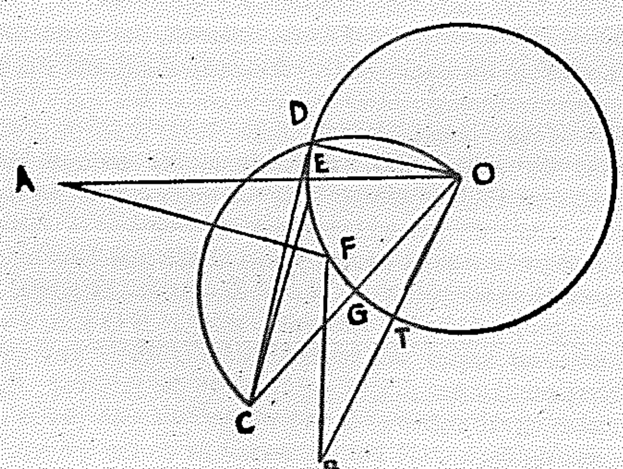
Now if at K, EK and FK are reflected, the angle EKD is equal to the angle FKD. Similarly if EH and FH are reflected, the angle EHD will be equal to the angle FHD. But in the triangle EKD the angle EHD must be greater than the angle EKD. Similarly in the triangle FHD the angle FKD is greater than the angle FHD. So there is a contradiction. Hence our assumption is correct. Let there be a circle having points C,A,B and T on it. Let there be three points D, H and E outside the circle. If from points D and H two lines reflect at E in such a way that these angles will be HAB and DBE, at any point lying on the arc CABT on line can be reflected which makes equal angles at E and whose reflection lies at any point on the arc CT but it does not lie on the arc AB. If this were possible, this reflection would be from a point

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.



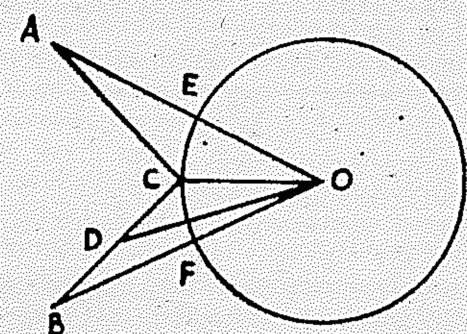
So we have proved that the points lying between HA and DB cannot be reflected at equal angles at any point on the arc CABT except at any point on the arc AB.

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 to EC and H on DB produced such that EC is equal to HB 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 ETD will be equal. But the angle FAD is greater than the angle FTD. Therefore the angle HAD is greater than the angle ETD, But ED is assumed to be equal to HD, so the angle which the arc of a circle makes with HD will be equal to the angle EDH. But it is given that HD does not intersect AD or AH because A lies above DH. Let these be a point K which makes angle HKD equal to angle ETD.



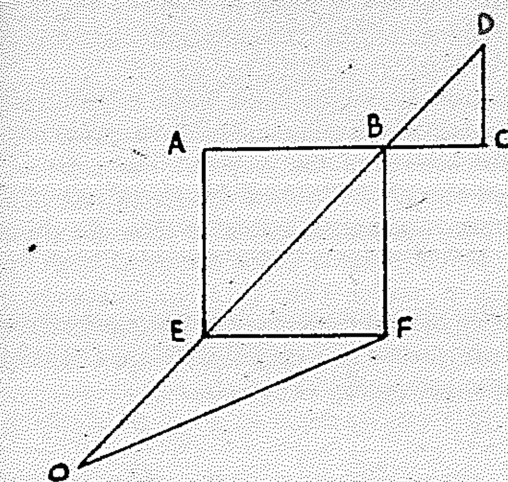
Now since ED is equal to HD, the angle ETD is equal to the angle HKD and DT is equal to DK. The ratio between HD and DK is the same as the ratio between ED and DT. So the triangles HDK and DTE are congruent. Therefore the angle HDK will be equal to the angle EDT. But the angle HDK is greater than the angle HDA. So the angle EDA will be greater than the angle HDA. Now taking away the common angle HDT the remaining angle CBE will be greater than the angle TDA. 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.



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, DB=DB and the angle ZBD=the angle HBD. Therefore ZB:DB as 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 centres 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.

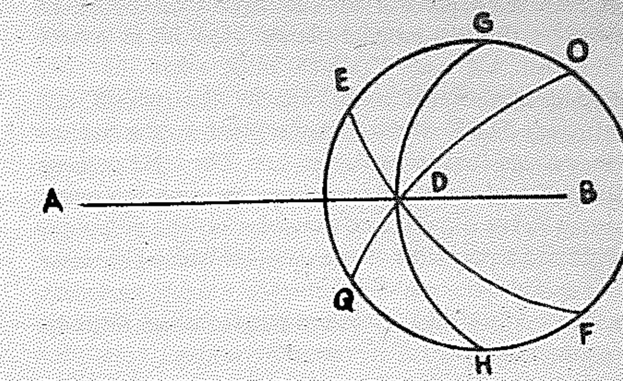


Suppose AB produced meets the body of the sun at any point C. Let T be the vertex of the projected cone. Join TB and produce it to meet the body of the sun at any point D. As TBD lies on the projected cone and C is another point on the sun, CD cannot be greater than the diameter of the sun.

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.

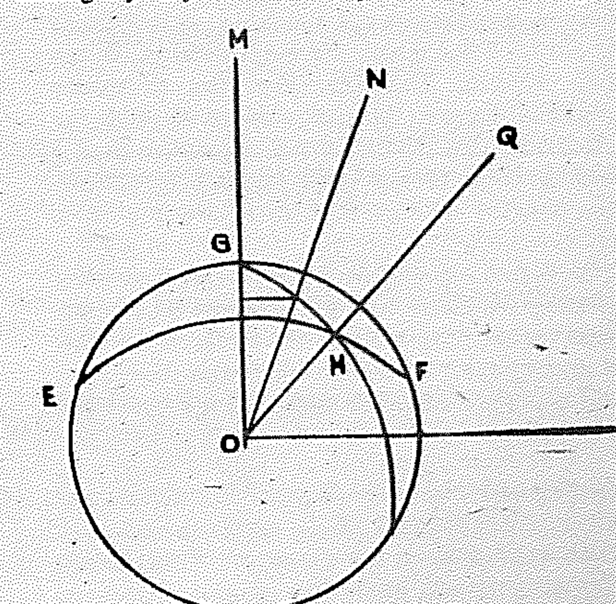
Evidently, TE will pass through the joint opposite to the centre of the sun and the angle formed at T will not be less than the angle between the radius of the projected circle and the diameter of the sun.

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 AEZ will not be less 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 greter than BZ. At AB and BZ arc equal angles smaller than AE and ZE, the triangles AEZ and ABZ have the same base AZ. But the angle ABZ is greater than the angle AEZ and the angle AEZ is not 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.



Keeping in view all the above results, we come to the conclusion that the light of the moon reading the earth cannot be the result of reflection. We can illustrate this statement by means of the following arguments:—

Let there be a point A on the surface of earth at which the light of the moon is falling, when the moon is on or above the horizon. Let B be the centre of the moon. As has been proved above, the line AB produced cannot meet the body of the sun at any point. Let two planes pass through the line AB and touch the sum. Then the light from the sun falling on the moon between the portion cut by the two planes will be reflected on to the earth in a way such that the incident ray and the reflected ray will be in one plane. Since the incident ray and the reflected ray form equal angles with the perpendiculars to the surface of reflection (i.e., the radius of the moon produced) and since all of the three lines are to be uniplaner, it is therefore evident that the surface containing the incident and reflected rays must pass through the centre of the moon and also through A, which is not possible in this case so far as the points on the above two planes are concerned. So the points of contact of the planes and the sun cannot be such where from the issuing ray may be reflected by the moon to the point A.



Let there be a point T 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 cross-section 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 possible 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 point on the moon which is towards the sun.

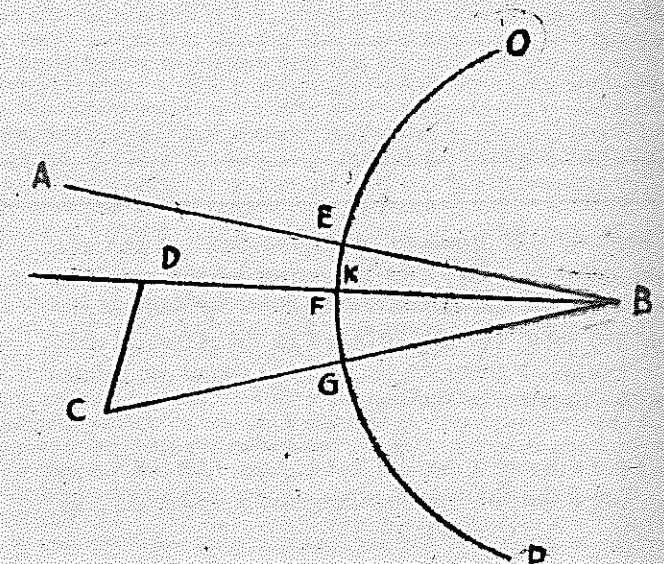
Let there be a point T on the surface of the sector of the moon cut between the two planes tangent to the sun. Let us draw a plane through A, B and T. It will certainly meet the sun between the two planes that are tangent to the sun. Now the light which falls at A must spread between these two planes and point 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 that point but the plane through T, 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 plane of a circle outside it, through one of them a diameter is drawn, then at no point on the semicircle lying opposite to the second point can the lines through these points make equal angles. Therefore, the point T which lies opposite to the direction towards which the plane through T, A and B meets the sun, can the light be reflected to A. So we conclude that at no point on or between the tangent planes can the light of sun be reflected to earth.

Let us suppose that the distance between the sun and the moon is not less than $\frac{1}{4}$ of the circumference of the circle through their centres. Let us suppose that the two planes touching the sun at T and K. Let us join 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. It means that HB or TB will be greater than $\frac{1}{4}$ 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 sun at a point L and the Plane A, K and BAT. Since the distance between the sun and the moon is less than $\frac{1}{4}$ of the circumference of the circle through the centres of the sun and the moon, the angles there formed will no 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 $3\frac{2}{5}$ times the diameter of the moon and the diameter of the sun is $18\frac{4}{5}$ times the diameter of the moon. Taking LM equal to a unit of length, the diameter of moon will be 210 units and the diameter of the sun is equal to 4,000 units.

The line that makes equal angles between A and T can meet the surface of the moon at one point only. At that point the arc LC will be divided in such a way that its portion towards C is smaller than the portion towards L. So the point at which the equal angles will be formed will be between A and T. Let this point be named as F. Similarly the light coming from K and reflected towards A will also be at a point on the arc CM, which will be similar in position to the point F.



Now since angle TBA is equal to the angle KBA and so arc LC is equal to arc MC, therefore arc LC will be greater than arc SC.

Arc MF will be greater than arc CF. So arc SF will be less than the half arc LM.

It means the angle subtended at the centre by SF will be less than half the angle subtended by the arc LM.

So at no point on SF can the ray from the sun be reflected to the point A on the earth.

Let us draw a plane through A & B passing through the centre of the sun. Evidently it will be between the two planes through AB touching the sun. Let there be a circle DCH on the surface of the moon and let the tangents through B to the surface of the sun touch sun at Z and E. Let these lines cut the circle CHD at T and K. Evidently ZE will be less than the diameter of the sun.

It has been proved earlier that the points on the surface of the moon at which the lines from A and E can make equal angles will be L and the similar point

about A and Z will be M. The light through E and Z can be reflected to the point A, if it is reflected at L and M. It has also been proved that every point, lying between BZ and BH 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 less than the arc TK. But arc LM is the greatest arc from which light can be reflected touching the sun and passing through the centre of the moon and reaching A.

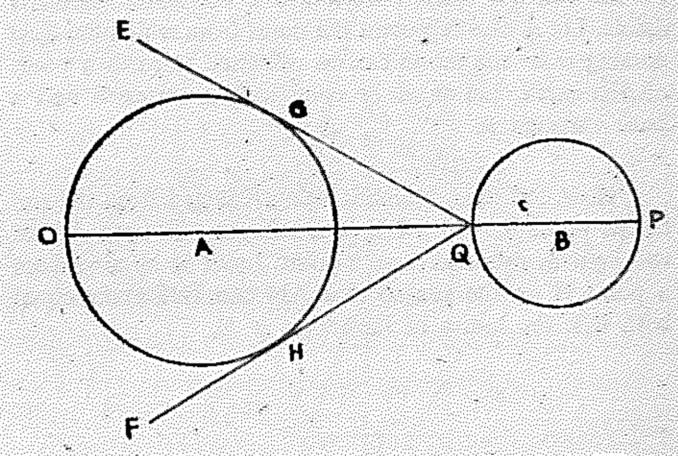
If the distance between the sun and the moon is not less than $\frac{1}{4}$ of the circumference of the circle through the centres of the sun and the moon, then this portion of the moon will be less than the required length. So if the sphere of the moon be div ded into 36 equal sectors then this portion 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 sun to the moon and then from moon to the earth in a straight line and at no place does refraction take place. Research scholars believe that the light coming from the heaven does not travel in a straight line at the time of entering the air around the earth, because they are refracted in the concave heaven which is clearer than the air. In their opinion, light travels in a straight line, so 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 heaven but through the air, specially at the time of the appearance of the crescent. In such circumstances the light must reach the moon after refraction. However the part 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 argue that the light from the sun to the moon and then from the moon to the earth, goes along unbroken and un-refracted lines. 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 refraction 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 there is any refraction anywhere, it is negligible and there is hardly any difference between these rays and the rays travelling in straight lines.

We have also proved earlier that no part of the 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 refraction on the way. So the proof given by us will not be valid, because we have not taken into consideration the possibility of refraction. But I think that these rays of light cannot possibly reach the earth even if refraction occurs on the way. But the real reason for my 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 concave heaven and draw a line from C touching the circle DEZ. Let it be called CET. Let us rotate the plane about CZ as AX is. Now, the cone with C as vertex and CE as one of the generators will have its base towards T.



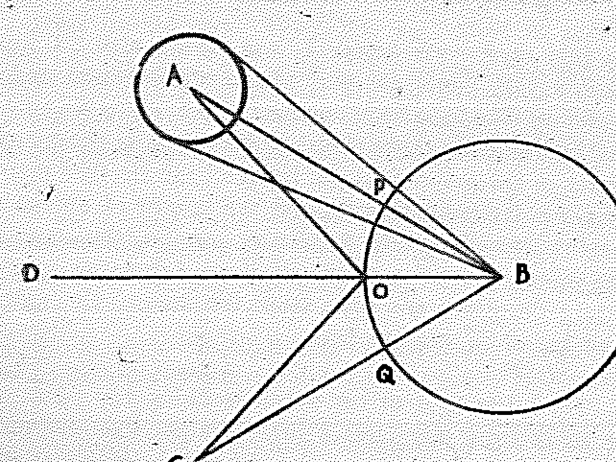
This cone with vertex C and generators CT and CK is a very important part of the phenomenon under discussion. The light from any part of the sun to the moon must be inside the above mentioned cone. Now, the curved surface of the moon does not intersect the air. The moon completes its revolution around the sphere of air, so it remains away from the sphere of air. So, the straight lines joining the moon to the sun do not cross the sphere of air. Therefore the light from the sun to the moon must travel in straight lines.

Now, the light of the moon reaching any point on the earth must also travel in a straight line. Suppose refraction takes place at a point in between the moon and the earth. If the light of the moon were to reach a point on the earth from more than one point in the concave heaven, if 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 really lines which fix the direction of the percepting vision 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 perceiving visionary ray from 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 cone with a vertex B and a base through A.

Now, the light, which is being reflected from the sun to the point A, will travel in a straight line upto A. 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 BN, 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 between these two planes. The portion of the moon from which the light of the sun 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 arcs of the moon be CD and ZE. The portion of the moon between these two arcs is the only part from which light can be reflected. Let the arcs of the moon be cut by the lines BH and BT (tangents to the sun from B) at L and K. The point N, at which the rays from H is being reflected towards the point A will be nearer E than L, and similarly the point M, at which the ray from T is being reflected to any point of the earth will be nearer C than K, i.e., the arc NM will be smaller than the arc LK.

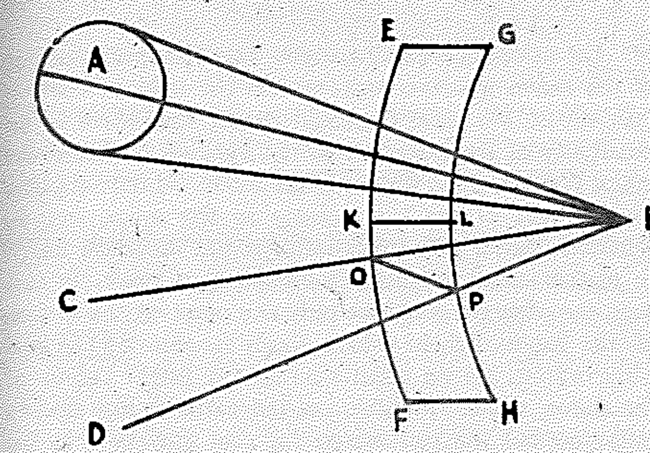
We know that the distance between the sun and the moon varies inversely as the distance between the moon and the concave heaven. The ratio between the arcs KC and MC will increase or decrease according to the increase or decrease in the distance between the sun and the moon. So the portion of the moon from which 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 mentioned above and when the light enters 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 this small portion also cannot permanently remain the same and goes on changing according to the revolution and rotation of the moon. The cone referred in the previous figure is not a fixed one, 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 centre of the visible part of the moon and its distance from the extremities of the visible surface will be greater than its distance from the centre. 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.

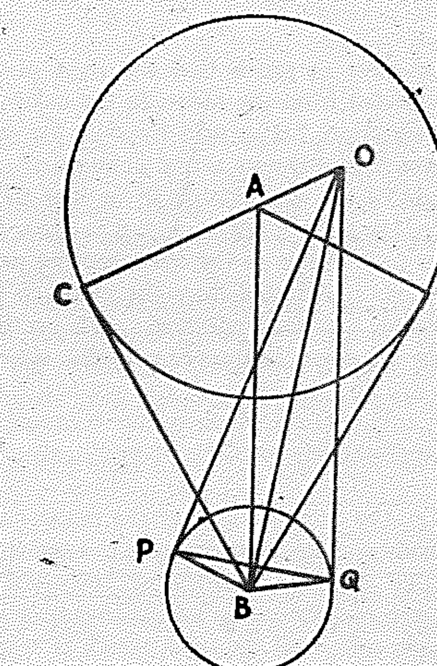


Let us produce the plane ABC so that it reaches the concave heaven. Let this plane cut the surface of the earth at H and Z making the angles BZA and BHA as right angles.

Taking the radius of the earth as 1 unit, the distance of the moon will be 50 units. According to Ptolemy, the length of the line AB will not be less than $53\frac{1}{2}$ units and the distance of the concave heaven will not be greater than $33\frac{1}{2}$ units. Angles AHB being right angles, AZ and AH will not be less than $42\frac{3}{25}$ units. So the angles BAH and BAZ will be $36\frac{1}{2}$ degrees each. So, when the moon is just on the horizon, the angle BAC will at the most be equal to $1\ 1\frac{1}{30}$ degrees. So, the angle CAZ will be $35\frac{1}{2}$ degrees. So, the light which refracts towards the centre of the moon will be very near the line AC and the angle contained at the point of refraction is almost straight. The angle, near A between the refracted 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 time 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 among those which spread 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 where 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 $\frac{1}{4}$ 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 $\frac{1}{4}$ 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 lines from the centre of the moon to the upper part of the concave heaven will fall on the visible portion of the moon and near its middle than the sides. 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 acute 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 (as is the case at the time of the appearance of the crescent), 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 non-transparent and the light from some illuminous 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 illuminous bod 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 so bright that we cannot see towards it. The glaze of this portion is porportion 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 this 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 illuminous body from the tangent plane. Sometimes the visibility of some colour is due to the fact that it is either the colour of some intercepting body or some transparent medium. In any case, a detailed discussion on the visible colours is beyond the scope of this discourse.

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 it is the colour of the light of the sun. In either case, it is either reflected from the sun or is visible to the eye when the perceptive 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 intercepting 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 in that case the intercepting 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 there 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 which 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 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 lighted 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 reflection but the real reason for that may be that the light of the sun bright as the moon and because the surface of the moon is not glazed, 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 farthest 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 facing 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 sun. 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 its 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 under physics. We thus come to the conclusion 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 does not change 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 lateral 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 researchers 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. Fire, for example, 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 lights

*Translated from Arabic into Urdu by Hakim Naimuddin Zubairy and rendered into English by Professor Ali Nasir Zaidi.

also. The strong light can cause fire, whereas a weak light is harmless, but all types of lights issue from luminous bodies only in the same way as fire issues from a burning body.

Luminous bodies are of two types: the stars and the fire. Light proceeding from these bodies falls on the surrounding objects which reflect it towards us and we feel we are seeing those objects.

This subject has also been discussed in the book, *Kitab-ul-Manazir* and it has been brought out that light must proceed from a luminous body. If we place a solid body in front of a luminous body, the former must be lighted provided that there is no obstacle between these two bodies, nor are the two bodies separated by a very large distance.

All physical bodies, whether they be transparent or solid, are capable of absorbing light. Certain bodies have the capacity of transmitting light through them and, therefore, we call them transparent bodies. We can see the objects placed on the other side of such bodies.

Transparent bodies are of two types and light is transmitted through them in two ways. One possibility is this that light is transmitted through the entire body and the second possibility could be that light passes through certain portions of this body. Air, water, glass and similar other objects belong to the first class. In the second class, we can take the thin sheet of cloth through which light will only partially pass. Light can proceed through the small holes contained in the cloth but no light can be transmitted through the threads or strands because they constitute solid bodies. Since the fibres of thin cloth are themselves very thin, our eyes cannot distinguish the rays of light which pass through the holes and which are precluded by the threads. Our eyes perceive only those rays which pass through the fine holes of the cloth and the rays which are stopped by the fibres, do not exercise any effect on our vision. Our vision does not perceive very fine objects. We thus come to the conclusion that media like air, water and glass are entirely different from cloth and the objects of this type.

A transparent body, strictly speaking, is that through which light can pass easily, e.g., air, water, glass and similar other objects. Solid objects accept light in the same way but they cannot transmit it.

If we place a solid object in front of a candle or any other luminous body and there is no obstacle in between the two, light will be reflected from the solid body provided this body is not located at a very large distance from us, nor is it located at a very large distance from the luminous body.

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 also 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. We, therefore, can conclude that every physical body, be it transparent or opaque, has the property of accepting 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 accepts light. A transparent body has the additional property of transmitting the light. This is the atomic aspect which lends a transparent 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 proceed 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 sheet 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 opaque 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, the fact is that light is transmitted through trransparent 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-Manazir*.

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 light will be coming along straight lines. The presence of these rays of light will be made visible by the dust particles hanging free in the atmosphere of the room. If we place a stick parallel to these rays of light, our contention will be proved.

If there are no dust particles in the room and 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-Manazir*.

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 would have been transmitted along specific directions 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 properties 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 our eye. Our eye shoots out rays of light which proceed along straight lines and when these rays of light strike an object, we feel that we are seeing that object. In other words, the power of seeing spreads along straight lines and these straight lines constitute the rays of light.

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 favourable 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 base 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, smoke 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.

Rare air is far more transparent than dense air. Similarly, water and other transparent media have different powers 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 different distances from us and their light comes to us 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 in the same way as all dense bodies do. But the secondary light coming from transparent bodies is much weaker. This subject has been discussed in the first chapter of the *Kitab-ul-Manazir*.

We shall make a brief mention of that discussion here. Secondary light breaks at dawn and makes things visible even before the sun rises. At this time of the day we see the objects more clearly than we do at night. At this time the sun is not exactly opposite the earth and the rays of light take a straight course. We have discussed this subject with reasons and proofs in the *Kitab-ul-Manazir* and we have pointed out that the earth does not cut the rays of light issuing from the sun. The light which falls on our earth actually comes from the space which is intercepted between the earth and the sun. There is no obstacle in between. This atmosphere is illuminated by the sun at dawn and this light is perceived by us.

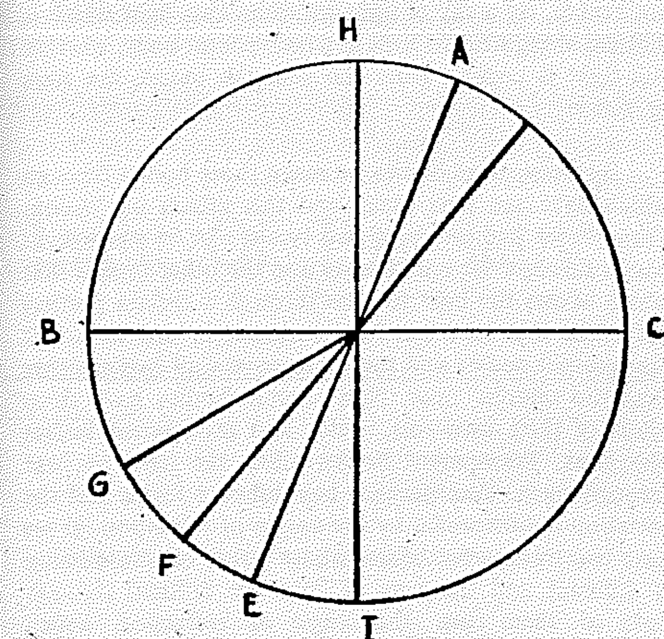
When the rays of the sun are incident on glass and other transparent bodies, some of the light is transmitted through them but simultaneously secondary light is also produced. Our eyes are affected by this light only when a white body is placed near water or the transparent body concerned in the opposite direction to the direction of the incident rays. You will find a new light on this white body which will be weaker comparatively but which was not there before. We have discussed this phenomenon in the *Kitab-ul-Manazir* and here only a brief mention will suffice. Whenever these rays of light fall on any transparent body except space, this secondary light is produced in the same way as the dense bodies give rise to this light when they are exposed to the sun. But the secondary light coming from transparent bodies is much weaker than that which issues from dense bodies. We have already mentioned that all dense bodies have the tendency to absorb as do the transparent bodies.

It must be mentioned here that the secondary light issuing from transparent bodies is not due to the light passing through them; it may be due to those rays of light which enter into them from the opposite direction. The secondary light coming from these bodies is found to be in the opposite direction. There is no specific reason for the absorption of light in physical bodies except for their density which is opposite to transparency, because a body which is not dense, is known as transparent and when a body is transparent, light passes through it easily. If a body is extremely transparent and completely devoid of density, light will pass through it and will not be absorbed for obvious reasons. When light is absorbed by a dense body, the phenomenon is governed by the density of that body. It has been proved that all bodies, however transparent they may be, possess density to some extent. Secondly all transparent bodies possess a different degree of transparency which is due to the amount of density present in them. The greater the density of a body, the smaller will be its transparency and *vice versa*.

Philosophers believe that space has the greatest amount of transparency. There is nothing more transparent than space although different bodies may differ in the amount of transparency. Some old philosophers have thrown light on this aspect particularly Abu Saad Bin Sohail, who has explained it with geometrical proofs. We give a gist of his reasoning here. We now say that whenever the rays of light are incident on a transparent body, they pass through it along straight lines and when this light enters any transparent body whose transparency is different from the one of the former body, light will be reflected through the latter and will not be able to maintain the same direction as before. We have discussed this aspect in the 7th chapter of the *Kitab-ul-Manazir*, where we have mentioned that reflection takes place at specific angles. When the rays of light pass from a rare to a denser medium, reflected rays bend towards the normal drawn at the point of incidence. If rays of light fall on a transparent body normally, there is no deviation in the path of the reflected rays. When, on the other hand, the rays of light proceed from a denser to a rarer body, the reflected rays bend away from the normal, and when these rays of light come out of the transparent medium, they make the same angle with the normal of the surface as the incident rays had originally made with the normal before they entered the transparent medium. When the rays of light pass from a rare medium and enter such media as are denser than the first and these two media differ in their density, light will suffer more reflection in the denser medium. In other words, light proceeding from a rare to a denser medium bends towards the normal and the light proceeding from a denser to a rare medium, bends away from the normal. If light proceeds to two rare media, it will suffer more reflection in the rare medium, i.e., it will bend away from the normal. Ptolemy has also discussed this phenomenon in his book on Optics. He has described that, when a ray of light enters a transparent body after having crossed another transparent medium, it will suffer refraction. He has also said that light suffers more refraction when it enters from air to glass as compared to the light which enters from air to water because glass is denser than water.

Ptolemy has also described that when the rays of light proceed towards a rare medium and the rays suffer refraction, the emergent rays will maintain exactly the same direction as before. It is apparent from this discussion that when a ray of light suffers refraction from two successive media such that the second medium is denser than the first the rays will suffer more refraction through the second medium. Refraction therefore takes place according to the density of a certain medium. The greater the density of the second medium the larger will be the angle of refraction.

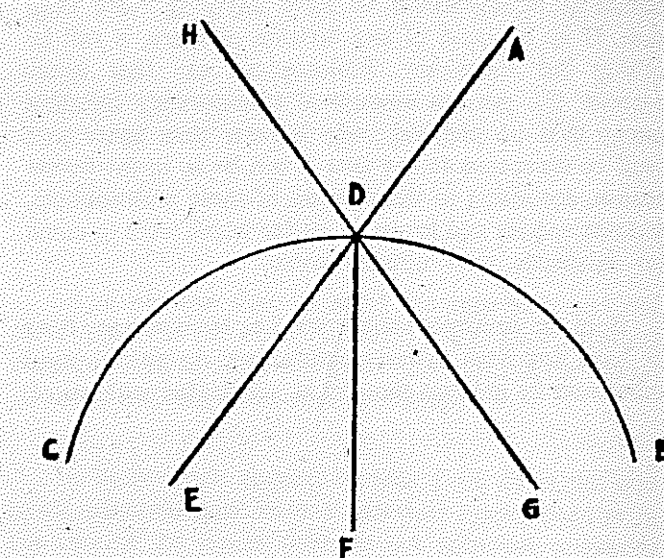
Whenever a ray of light strikes any transparent body after having passed through the first transparent body and degree of transparency in the second medium is more than in the first one the ray will suffer more refraction through the second medium. We give an example here.



We have two transparent bodies which differ in the amount of transparency. Point A is located in the rarer medium. The plane passes from the point A in a perpendicular direction such that the straight line BC marks the boundary between the rarer and the denser media. A ray of light starting from the point A suffers refraction at the point D. A normal has been drawn at the point D. Since the ray is entering from a rarer to a denser medium it will suffer more refraction in the second medium with the result that the value of the angle of refraction will be greater than that of the angle of incidence. If on the other hand a ray of light proceeds from the second to the first medium i.e. from a medium of greater density to a medium of lesser density the refracted ray will bend away from the normal i.e. the angle of refraction will be more than the angle of incidence.

We can draw a circle keeping B as centre. In this circle we can have as many rays of incidence as we like and there will be a correspondingly large number of refracted rays. Just as an angle can have the least possible value, similarly a medium can have the least possible value of transparency. Ptolemy has said that a ray of light suffers refraction through space because space is rarer as compared to air. This shows that the light issuing from the sun and stars reaches us after having undergone refraction through air.

To give another example we have a denser body in the form of a sphere, the ray of light AD proceeds from the point A and suffers refraction at a point D situated on the spherical circle BDC. The incident ray AD gives rise to the refracted ray DE because DF is the normal to the spherical surface. If on the other hand the ray of light is proceeding from the denser spherical body to the rarer medium outside i.e. ED is the incident ray, then D will be the refracted ray. In other words the angle of refraction will be smaller than the angle of incidence in the first case and it will be bigger than the angle of incidence in the second. Suppose the sun is situated at the point A and a ray of light AD proceeds from A and strikes the spherical surface at the point D, then naturally DE will be the refracted ray. If the space through which a ray of light is coming becomes rarer then the ray of light will suffer more refraction towards the normal.



This aspect can be shown by different radii in the spherical body. Whatever I have described is based on the opinion of philosophers who have studied and conducted research on this topic. It means that there can be many rare as well as denser media and bodies.

Experts in physical sciences maintain that every aspect of physical bodies has a certain limit; it is not unlimited and the angles which can be divided indefinitely are governed by imaginary limits but the angles pertaining to physical bodies cannot be divided indefinitely. These angles in a certain body remain unaltered. Their indefinite division is impossible because every physical body can be divided upto a certain limit only and this limit determines its shape. If we divide the body beyond this limit it will no more retain its original shape and will acquire a different shape altogether.

As an example we take water. If we go on dividing a certain quantity of water, we will come to the smallest 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 will be 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 shoots out of the luminous bodies in the same way as heat comes out of hot bodies. By a ray of light we mean that light which is diffused along straight lines in 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-celestial bodies have three kinds of their own—air, water and transparent bodies like glass. Transparent bodies allow the light to pase 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 willi 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 size of the lit-up parts 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 faces 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 ideas 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 ratiocination 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 spherically shaped.

This fact alone is sufficient to prove that the stars emit light. For, if they had derived their light from the sun, 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 as is the case with the moon, when it is at a short distance from the sun. The reasons why the moon appears as a crescent in this case are as follows:

* Translated from Arabic into Urdu by Hakim Naimuddin Zubairy and rendered into English by Professor Hameed Askari.

The parts of the moon, which face the sun, are different from these facing the earth. It is evident that only that part of the moon confronting the sun gives 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 concavity of which is on the same side, can only be crescent in shape. These are the reasons why, on the first and the last dates of the month, the moon looks in the form of a 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 the form of a crescent. From this it can be concluded that none of the stars derives their 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 contradition 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 of very small size 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 then than at other occasion. But this is not the case. Hence it is not correct 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 derives 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 properties, so that if 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 so happens that in the beginning of the month, when it is a 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 due to their proximity their form, when they face the sun is similar 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 them receives 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 lie close to the poles, 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 subtend 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. This is so because all the stars are spherical, and their side facing the sun appears to be bright, while the other side is dark. In the case, when the arc between the sun and the stars is not greater than the quarter of a circle, only half the part of its side facing the sun appears luminous and the remaining part is dark. In such a case, the stars would have appeared as the parts of a circle, because at times, when the moon appears as the part of a circle, it has the same position as described above in the context of the stars. Thus if the stars received their light from the sun, those stars which are seen in the western sky on the northern and the southern horizons, would have appeared in the above-mentioned shape every night. Also, the same would have been the appearance of those stars which are seen below one half of the sky, one hour before sun rise, on the northern and southern horizons.

A similar state of affairs holds good when the arc subtended between the sun and the stars is greater than the quarter of a circle and less than the semi-circle. We know that when the arc between the sun and the moon is of this size, the moon appears almost circular. If the stars, too, were non-luminous like the moon, the stars in the west, from sunset to midnight and the stars in the east from midnight to sunrise would have appeared in the same shape as the moon. It follows, therefore, that the stars would have appeared in the shape of a complete circle at one time, and in the shape of a portion of a circle at other times, as is the case with the moon. Since this is not the case with the stars, we can but conclude that the no star derives its light from the sun. It is only the moon that does so. If someone thinks that the stars might be receiving light from a source other than the sun, the answer to this probability is that if this luminous star, which by supposition is a source of light for other stars

is stationary and fixed, then it would be necessary that all stars, which come very close to it should appear in the shape of a crescent or in the shape of a portion of a circle. But no star or planet has been found to have this characteristic. If we assume that the said luminous star is in motion, there will be no difference between this star and the sun. Hence such an idea is absurd.

It is also said that when the moon is close to the sun, it looks crescent-shaped because it is nearer the sun than the earth.

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 size of each of the stars is very small. In this case, the bright zone of the star covers a large area of the star, which looks to be a small bright sphere. The same is true of the stars that are still higher.

We can say in reply to this objection that all the above arguments become baseless if only we 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 get closer to the sun, is the same as it is when they are away from the sun. None of them looks 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 a 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 wtth the moon, the Venus would have appeared to have a different shape at a time when it is close to the sun han with i is 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, it follows 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 real 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 come 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 by 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 theory of these old thinkers, which deals with the proposition *in toto*, nor do they point out any particular way which may disclose the nature of space and auxiliary facts. So it seems necessary to discuss this topic in detail so that the reality about space and its allied details 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 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 section or street of a 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 each 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 spaces cover 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 circumvents 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 circumvents 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.

*Translated into Urdu from the Arabic by Hakim Naimuddin Zubairy. Translated into English by Prof. Ali Nasir Zaidi

2. According to the second definition, the space of a body is that imagined 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 unoccupied. 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 imaginary space implies those limits which circumvent it. 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 both 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 which circumvents that body also changes correspondingly and that, in certain bodies, the surface changes in such a way that the dimensions of this circumventing 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 any other two surfaces, then these two peces are joined with each other so that one original andone new 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 circumvents 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 will even now continue 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 suffers from the defect that the mass of the body is continuously decreasing but its space is not decreasing proving thereby that 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 decidedly be greater than the original one, though the quantity of matter in 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 surfaces which circumvent 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 circumvents 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 shape 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 respectively 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 circumvents, 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 circumvents a body is the space of that body and if at all we say this, it will be an imaginary definition completely divorced from reality in the same way as a house, street, or city can be termed as a space only proverbially.

3. Objection 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 as space of a body, 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 it lies within space. So the existence of a body proves the existence of space. We, therefore, have to accept the existence of space but those who do not believe in the existence of space do not accept it as a strong reason in support thereof.

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, mean such imaginary limits by this imaginary vacuum as are filled by a body and the dimensions of these limits are exactly equal to the dimensions of the body. It is apparent that if two dimensions of exactly the same limits are coincident with each other, they will be one and the same because these imaginary dimensions will actually be a line which does not have any breadth and whenever a straight line which has length only and does not have any breadth is coincident with any other straight line, the resultant will also be a straight line. The reason is that whenever such a straight line is coincident with the other, there is not a possibility of any increase in the length and because these straight lines do not have any width; therefore, the resultant 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 besides the body but they will be exactly equal to the limits of the body and they will correspond to the shape of this very 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 too in such a way that they become one and the same. It is also apparent from this that such imaginary dimensions cannot be conceived completely divorced from the body. We have, therefore, to derive this conclusion that a body does not fill 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 quote 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 imaginary points which lie opposite to each other on the internal surface of this vessel. There should not be any difficulty in understanding this phenomenon. Similarly we can conceive of imaginary perpendicular directions 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, the dimensions of water will be 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 liquid whose atoms 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 whatsoever. 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 also change correspondingly, although the internal dimensions of the vessel do not undergo any change whatsoever. And these very dimensions of the vessel will become the dimensions of the substance which has been poured into it. All this proves 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 easily undergo a change in their shape but not in their dimensions. The change becomes apparent in their shape only and not in their mass because the change in shape does not affect the mass of a body. This fact can be illustrated in another way. Suppose a liquid like water has a fixed quantity and is poured into vessels of different shapes. If we pour the water of every vessel 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 same shape as and when it is poured into this glass. The reason is that the internal surface of the glass remains the same in correspondence with its internal dimensions. It is, therefore, proved 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 over 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 these 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 becomes coincident with the space between every 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 substance, the circumventing body's internal surface actually takes within its boundaries certain unchangeable dimensions. These surfaces are such that the circumventing substance also coincides 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 substances 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 has been occupied by the former body and so this imaginary space is preferred and deserves to be called space, as against the definition that the circumventing surface of a body is its space for it has been made clear that if we take this surface to be the space, we invite several objections and doubts. The definition presented above does not expose itself to such doubts and objections. The crux of the whole problem is that the imaginary dimensions between every two opposite points of a circumventing substance can be the space of the body which exists within this space. These dimensions coincide and cover the body in such a way that no difference is left between the two surfaces. It is proved from the above statement that the imaginary dimensions which exist opposite to each other in a circumventing body are formed by that imaginary space which is filled by this body and it is better to call these dimensions to be the body itself, as against the definition of its space which means the circumventing surface. Such a definition is exposed to certain doubts as against the first definition in which the internal 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 that 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 put a body within 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 specific form of matter. 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 places. We know that space is not something material, nor does it have any resistance. Space is actually determined by only those dimensions which are capable of accepting matter as it is. These dimensions are only imaginary and they can accept the dimensions 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 include the idea of length only. 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 be allowed to enter into the physical space because the space is 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 those dimensions which may be free of matter. This space is exactly equal to the body as regards its shape and size and this is our aim.