R·C·A· INSTITUTES INC.
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Technical Lesson 65

TELEVISION - PART I

For years the world has produced men endowed with keen penetrating minds whose ambition it was to originate devices that would be of assistance to faculties already possessed by man. To successfully work along these lines and conduct intelligent research they have in many instances drawn upon the patterns laid out by nature.

The action of the telephone invented by Alexander Graham Bell, for instance, imitates the action of the human ear drum and because of the development of this invention the human ear is, figuratively speaking, capable of hearing sounds which originate at the ends of the world.

Before aviation progressed to its present state of development, hours upon hours were spent by engineers in observing the flight of birds, obviously a study of nature.

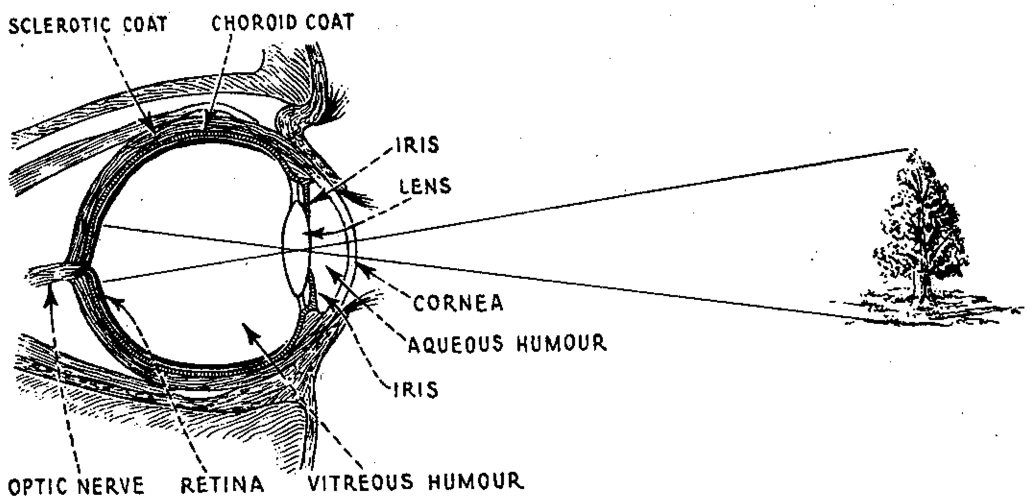

Figure 1

Greater and greater extension of sight beyond that possessed by the human eye has always been a goal of scientists. This was given an impetus by Galileo who developed a telescope with which he discovered the satellites of Jupiter, and from whose time modern physics may be said to have begun.

It does not require any great stretch of the imgination, therefore, to realize that scientists for years have directed their studies along a line of thought whereby existing models, both artifical and natural, have been drawn upon to furnish information leading to certain desired results.

So, in the study of television, we shall find that its progress has been slow.

We shall also learn that contributions have come from many sources, which at their time were perhaps remote from the goal but, nevertheless, progressing toward a central point out of which the necessary information was obtained to construct apparatus that would allow the eye to see an image beyond the barriers of light waves. At the very start, therefore, we will begin our study by first becoming acquainted with the marvelous system of television provided by nature - the human eye.

Here, without question, is a part of nature's handiwork which at the offset is a marvelous development. We are able to account for certain functions of the human eye, but true to natures method of doing things she allows the puny mind of man to go just so far; there the curtain is drawn and we are left to conjectures.

Figure 1 is a cross section of the eye which shows the parts of immediate interest to us; The Cornea, Aqueous Humor, Iris, Lens, Vitreous Humor, Retina, Sclerotic coat, Choroid coat and the Optic nerve.

The cornea is a bulging transparent tissue which forms a round window at the front of the eye ball admitting light to the lens. The amount of light thus admitted is controlled by the iris, in the center of which is an opening called the "pupil". The iris is composed of muscle fibers capable of expanding and contracting thus changing the size of the pupil. If the eye is directed toward a source of strong light these muscles act in a reflex manner to cause the iris to contract and in this way closing the pupil aperture. When in a dim light the pupil is opened by these muscles so as to admit all the light possible. Immediately back of the pupil is the lens, the shape of which is changed by the action of a set of muscles in order that it may bring to a focus upon the retina the light rays proceeding from an object to which the eye may be directed, and thus form an image upon the retina or screen, as it may be called. The retina, a delicate membrance, is composed of an enormous number of minute cells each connected to the brain by nerve filaments over which the brain receives the impulse. Just how this impulse of the inverted image thrown upon the cells of the retina is generated is not known but from some scientific sources the action is conceded to be caused by the presence of a light sensitive fluid in the cells of the retina. This fluid, present in the millions of minute cells, is affected by the light rays impinged upon it and an extremely fine mosaic image of the object is built up in varying degrees of light and delicate shadings.

The aqueous humor is a wattery fluid while the vitreous humor is a fluid of jelly like consistency. The two humors act to keep the eyeball distended and also act with the lens to form a real inverted image upon the retina. The choroid coat immediately back of the retina is intensely black and absorbes all the light rays reflected internally. The sclerotic coat (an opaque lining) covers the choroid coat in back of the eye ball and forms the cornea in front of the eye ball. When the eye lid is opened and objects before us are sufficiently illuminated, or the object is a self luminous body, vision is the result.

All the senses with which man is endowed are important but the two which stand out in our studies are the sense of "hearing" and the sense of "sight". If we were allowed to retain only one of the two we would no doubt choose sight because, with sight, material objects take on a concrete form. Impressions conveyed to the mind by the eyes make lasting records, and perhaps to a greater degree on our conscious mind than writing or the sounds of a language. To be able to see immediately allows us to mentally grasp that which is being unfolded before us to a much greater degree of satisfaction than the spoken or written word is capable of in as short a time.

For ages man has toiled and studied in an effort to improve the means given him by nature to better see objects, and most especially objects beyond normal range of vision (the unseen). It is unnecessary to say that attempts to change the human eye to produce greater vision is a dangerous undertaking and would be sure to fail, therefore, the only thing that could be done was to copy nature and produce an artificial device that would extend the range of vision. The study of how this was accomplished is interesting for it brings to us first hand the contributions of science which have been applied to television, and also the various divisions of scientific thought called upon to solve the problem, such as light, optics, chemistry, mechanics and electricity. Close attention will be required in this study to enable the student to recognize the closing of the links in the chain of discoveries, some of which were, perhaps, remote from the subject of television at the time, but eventually doing their share in the development.

It seems fairly well established that magnifying glasses were unknown to the ancients. Pliny, a Roman, in his historical writings tells us of the use of crystal globes filled with water which were employed as cauterizing agents by bringing the rays of the sun to a focus on the wound to be cauterized. In other Roman history we learn that letters seen through a glass filled with water appeared enlarged but indistinct. No attempt, however, was made to explain this phenomenon at the time.

Perhaps the earlist known record relating to the invention of lenses used as spectacles is that appearing in a manuscript from Florence, dated 1299. The year 1285 also is considered by some writers to be the date when spectacle lenses were first known and it was later discovered that a Florentine, Salvino Armati, was the inventor. Something of the science of optics, therefore, must have been known at this early date which tells us that these men had, to a certain degree, knowledge of light. Our first knowledge of lenses came from these ancients and since the use of lenses and light are both important in television we, too, must know something of the behavior of light rays when passed through mediums of optical density.

<u>Light - A Study in Optics</u>. What is the meaning of the word "light"? In searching for a definition we find that it means, "to illuminate or to become luminous". If an object is illuminated a disturbance in the ether is created which affects, to a marked degree, one of the organs of our body; namely, the eye. From this we can say that light is the external cause of the sensation of sight. This would lead us to believe that light is necessary to enable us to see. This is a correct belief as we shall soon learn.

There are luminous and non-luminous bodies. Under the first heading we have the sun, electric lamps, arc lamps, candles, the heated filaments of your vacuum tubes, and so on. Under non-luminous bodies we have the moon, wood and iron as common examples. A luminous body, then, is one which throws out light, while a non-luminous body becomes visible only after it has received light from a luminous body and reflects this light to the eye.

When you go to your room at night and snap on the electric switch controlling the current supply to an electric lamp the objects in the room receive light, part of which is absorbed and part reflected. From this we obtain our definition of the term "illumination" because the filament of the electric lamp, normally a non-luminous body, has been transformed to a condition of incandescence by an electric current and changed into a luminous body which emits light, and in turn illuminates the objects about the room. The light thus created follows certain laws, for example, a substance such as air or clear glass will allow light to pass through it, and we say that such substances are transparent. Ground glass, thin sheets of paper and oiled paper are substances which do not provide a perfect passage for light waves. They are termed translucent substances. Under the opaque classification we find many substances such as iron, wood, sheets of cardboard, and so on, which will not allow light to pass. This brings us to the study of how light travels - an important phase of the work because it has a great significance in television.

Physical optics embraces a study which attempts to explain, by hypothesis, the physical nature of light while geometrical optics deals with the explanation of light based upon fundamental facts which have been established by experiment and observation. It is with the latter that we shall interest ourselves.

Light travels in straight lines through any medium that is transparent and of uniform density. This fact is evident because of common phenomena which is familiar to everyone. Sunlight streaming through a crack or knot hole in a barn, or any building that is otherwise dark, illuminates the particles of dust floating in the air and forms straight lines of light. Another example is to place a large opaque substance, such as a cardboard, between your eyes and some illuminated object, thus preventing you from seeing the object. With nothing more than an ordinary wax candle and a piece of cardboard a simple device can be constructed to again show that light travels in straight lines. Figure 2 shows the arrangement. It is seen that an image of the candle flame appears upon the screen. This image is formed by the rays of light coming from the candle flame itself and since all the light that forms up the image enters through the pin hole in the cardboard all the rays that are not parrallel must cross in passing through the hole. From this we find that the light rays proceeding from the top of the candle flame forms its image at the bottom of the screen; the rays from the bottom of the flame strikes the top of the screen; the rays from the right of the flame appears at the left, and the rays from the left of the flame takes its position on the right of the screen, thus effecting a complete reversal of the image.

If the arrangement of Figure 2 is made into the form of a closed box, as shown in Figure 3, we have what is called a "pin hole camera" with which excellent pictures may be taken if sensitized photographic paper is used as a screen and the exposure is sufficiently long. This was known as early as 1550 by the scholars of Louvain, a seat of learning in Belgium, and was employed to study the eclipses of the sun. Here we have found our first artifical eye that will create images. Later on we will learn how this method can be improved upon by employing a lens in place of the pin hole.

Reflection of Light. When light rays strike a polished surface, such as a mirror, regular reflection takes place. For example, in Figure 4 consider "A" as a source of light. The light from "A", upon striking the surface of the mirror "M", will be turned away, that is, reflected in a certain definite direction. There is a law that determines the direction the reflected ray will take as follows: "The angle of reflection is equal to the angle of incidence and the two angles thus made will be in the same plane". Thus we learn that light striking the mirror at "M" will be reflected in the direction "M B". "A M" is called the incident ray, "M B" the reflected ray and "M N" the normal,

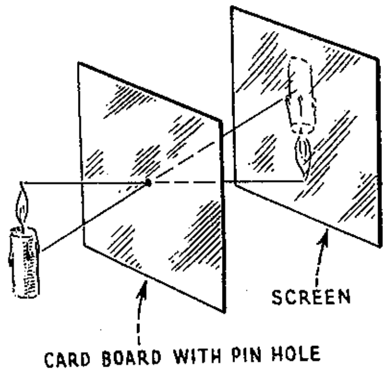

Figure 2

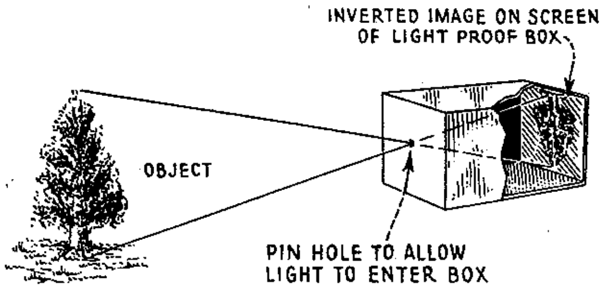

Figure 3

which is a perpendicular drawn to the surface of the mirror. Angle "A M N" is called the angle of incidence, and angle "B M N" the angle of reflection.

How many times have you in your boyhood days applied this principle in the school room, catching a sun beam on a small pocket mirror and then, by a change in the position of the mirror, cause the reflected light to dance across the blackboard and perhaps into the eyes of a student?

Now if we replace the mirror by a non-polished surface, such as a sheet of white paper, as suggested in Figure 5 another condition becomes apparent. No longer do we obtain regular reflection because the rough surface of the paper acts as hundreds of small mirrors, the placement of which have no orderly arrangement. The light, therefore, is reflected in all directions. Reflection of this nature is called irregular or diffused reflection and enables us to see other planets and stars as they become illuminated by the sun, the diffused reflection from them traveling to the earth.

Daylight, as we call it, is the sunglight repeatedly reduced in strength by an uncountable number of reflections from many surfaces, such as dust parti-

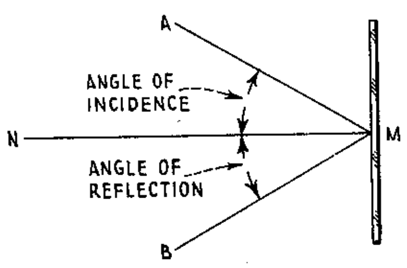

Figure 4

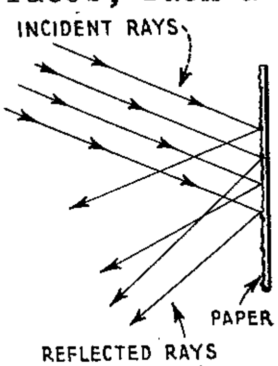

Figure 5

cles, the ground, shrubs, trees, houses, buildings, and so on. Later on you will be able to understand how diffused light is utilized in a television transmitter.

Now that we are familiar with some of the terms used in the study of light we can proceed to the study of mirrors which will bring out facts concerning the reflection of light rays.

An ordinary flat mirror, better termed a Plane mirror, is a plate of glass having a smooth surface which, after being cleaned, is coated on one side with a solution of silver nitrate, anmonium hydroxide, and some reducing agent such as formaldehyde. This film of silver adheres to the surface of the glass and, after drying, it is varnished to prevent the air from reaching the metallic coating of silver. The coating of silver furnishes a good reflecting surface for light rays.

Let us assume that "A B", Figure 6, is a plane mirror fastened to the wall. Point "C" is a source of light producing a ray of light "C M" normal to the mirror. "C D" is any other ray striking the mirror at "D". The ray "C M" is reflected back upon itself but the ray "C D" will be reflected along the line "D E" in such a way that the angles "C D F" and "E D F" are equal.

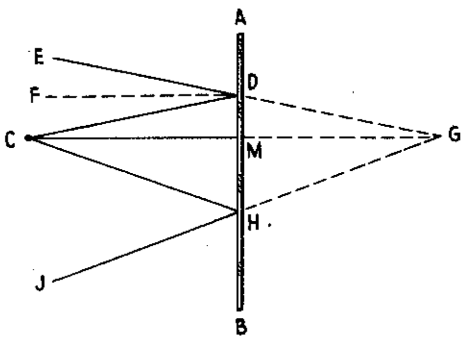

Figure 6

Now go back of the mirror and prolong the line "E D" and "C M" by dotted lines until they meet at point "G". We now have two triangles "C M D" and "G M D" which are similar and which make line "M G" equal to "M C". In the same way a third ray "C H" striking the mirror at "H" will be reflected in a line, the prolongation of which, if extended back of the mirror, will cut the line "C M" at "G". From this we are able to understand a peculiar fact concerning a reflecting surface such as a plane mirror. If you stand anywhere in front of this mirror light rays will strike the eye and appear as though they were originating at "G" instead of at "C" and you will have produced for yourself an optical illusion, for an image of the light source "C" will appear to you as being situated at point "G".

It was previously stated that an object to be seen must first be illuminated, which is true; also that light travels in straight lines and, furthermore, if an object is to be seen there must be no obstruction between the eye and the illuminated object that will act as a barrier to the light rays. By using a mirror, however, we can see around corners or view events taking place behind us, but this does not alter the law that light travels in straight lines because, between the object "C" and the mirror, there must be no obstruction for the light ray, neither can there be a barrier between the mirror and the eye. When you look into a mirror the objects you see appear to be located at some distance behind the mirror, as though you were looking through an opening in the wall, when actually they are not. The eye sees only an image of the objects because the light from the objects are reflected light rays striking the eye from the direction of the mirror, and since the eye sends an impulse to the brain only of the direction from which light enters it, the object appears to be in that direction. If the frame of a mirror could not be seen and the reflecting surfaces were not detected the eye would not be able to distinguish the difference between the real object and its image in the mirror.

Mirrors Having Curved Surfaces. A mirror of spherical or parabolic shape is sometimes employed in television work, a small portion of the spherical surface of the mirror being capable of reflecting light. A mirror of this type, shown in Figure 7, is called a concave mirror because it reflects light toward what would be the center of the mirror if it were completely cylindrical as suggested by the light dotted circular lines. To explain the terms necessary to understand the reflecting properties of spherical mirrors let "A B" be a section of this circular mirror made by a plane drawn normal to the surface. Point "O" of this surface will be the center of the mirror and the point shown at "M" will be the "vertex". A straight line drawn between "O" and "M" is given the name "Principal Axis". Any other line, such as "P A", drawn through "O" is called a secondary axis, and an axis, regardless of whether it is principal or secondary is always normal to the surface of the mirror. The angle formed by the lines "B O A" is called the aperture of the mirror.

Now let us study Figures 8 and 9 in order to illustrate a few more explanatory terms, the first one of which will be "Focus". A focus is a point from which light rays may diverge or a point toward which they may converge. In Figure 10 assume that light rays from the sun, for example, are moving toward a concave mirror in a path parallel to the principal axis of the mirror. On striking the reflecting surface of the mirror they will be reflected very nearly to point F midway between the vertex "M " and the center of the mirror "O" . The point "F" is called the "principal focus" of the mirror, and the distance from this point to the mirror is called the "focal length" of the mirror. Concentration of light rays in this manner from the sun can be so intense that a sheet of paper placed at the principal focus will promptly have a hole burned through it. In some systems of television mirrors of this kind are employed to concentrate reflected light from an object and direct it into a photoelectric cell.

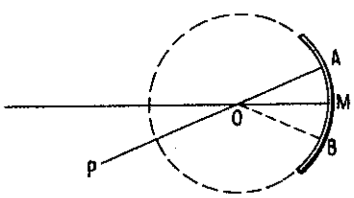

Figure 7

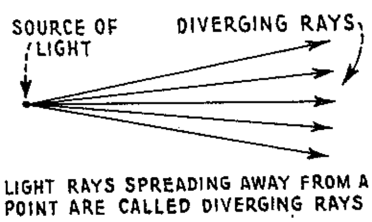

Figure 8

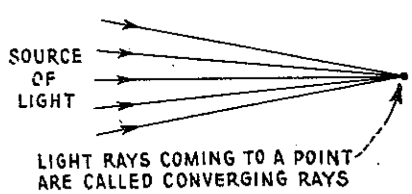

Figure 9

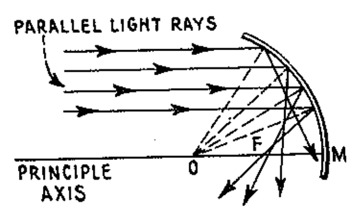

Figure 10

Figure 11 shows, fundamentally, the principal parts of a system utilized for scanning a subject. To scan (in the language of television) means to search out every minute feature of an object and flood it with an intense light. The object thus illuminated reflects the light by irregular or diffuse reflection. If light sensitive cells are placed in the path of this reflected light they will function in such a manner as to cause a current to flow through a circuit. Before going into further detail, however, we must pause long enough to become acquainted with what is known as the optical system of this group, namely the lenses, and to find out what effect they have upon the passage of light rays.

To explain this phenomenon certain terms hitherto not introduced must be explained. "Refraction" is a term used to describe the bending, i.e., the change in direction taken by a light ray in passing through mediums of different optical density.

In the study of optics, air, water, glass, liquid or solid bodies that are sufficiently transparent to allow light to pass, may be termed optical mediums.

By density is meant the compactness of the substance which makes up the medium; thus, air is less dense than water and water is less dense than glass.

In Figure 12 let the light parallel lines represent a body of water, the surface of which is denoted by "A B". Assume point "C" to represent the source of light and "C D" a ray of light. If the ray proceeding from "C" is perpendicular to the surface "A B", upon striking "A B" at "O" it will continue on through the water from "O" to "D" in the same straight line without any change in its direction having taken place. "C O" is called the NORMAL because it is perpendicular to the surface "A B".

Assume now that we move the source of the ray from C to any other position, for

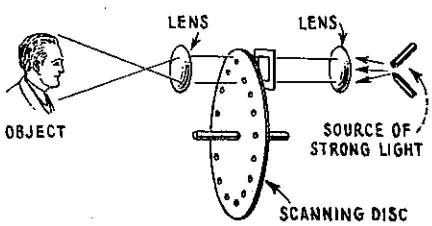

Figure 11

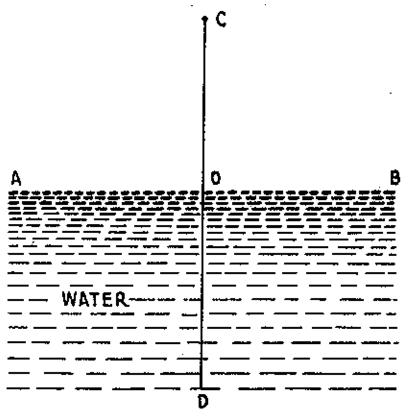

Figure 12

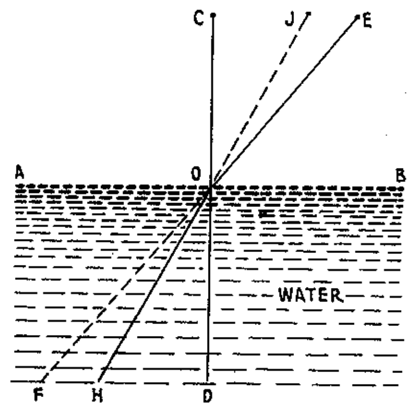

Figure 13

example, to point E Figure 13, so that in striking the surface "A B" it forms an angle with the normal "C O". The ray "E O", upon arriving at "O", the point where the two mediums join, will not continue through the denser medium in the same straight line to "F" but will be refracted (bent) as shown by the line "O H".

The path of the ray will not be "E O H"; the part "E O" is called the incident ray and "O H" the refracted ray. The angle "E O C" is called the angle of incidence, while angle "H O D" is called the angle of refraction.

When light passes from a rare medium to a dense medium the angle of refraction is smaller than the angle of incidence. Conversly if the ray "H O" passing through water meets the surface of air at point "O" it will not continue in a straight line to "J" but will be refracted (bent) away from the normal "C D" and take the path "O E".

Suppose glass was employed in place of the water in Figures 12 and 13, then the refracted ray "H O" would be closer to "D", and if the ray passed out of the glass into air it would be refracted further away from the normal than if it had passed out of the water.

Up to this point light has been spoken of as light rays. To explain why these rays are bent when passing from a rarer to a denser optical medium it will be necessary to digress and give a more complete explanation of the theory con-

cerning the propation of light upon the fundamental property of wave motion. **A spherical** wave is considered to remain spherical throughout its path of **travel.** This form of wave motion is conveniently shown as a number of equi-**distant** concentric circles spreading out from a point of light in ever widen-**ing** circles as shown in Figure 14.

The single ray idea is derived from the theory that while the wave front has a certain curvature each little particle of its surface is being continuously projected in straight lines along a radius of the sphere. The light wave then really exists and what we term "rays" are simply straight lines which show the direction in which the wave is traveling. The rays are always perpendicular to the front of the advancing wave and, in the instance of spherical waves, it is along a radius drawn from the point "L" as previously stated. If we consider "L" to be a mere point the rays diverging therefrom would be termed a "pencil of rays"; on the other hand if the point "L" is, for example, the sun, or any other distant luminous object far removed from the point of observation, the waves are for all intent and purpose without any appreciable curvature when they arrive at the point where they are to be a subject of study. In other words they are considered to be parallel lines of light.

With this in mind let us consider Figure 15 in which is again shown a body of water. Approaching this is a number of parallel lines called a beam of light.

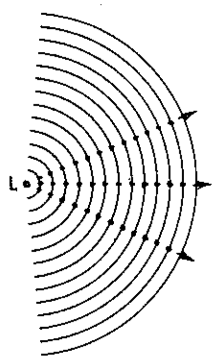

Figure 14

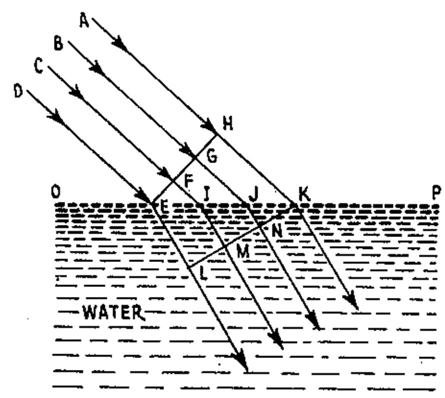

Figure 15

Since the water is of greater optical density than the air, the beam will have its velocity decreased upon entering the denser medium, conversely if the light beam passes from a dense medium to a rarer medium its velocity will increase. Therefore we will assume that the lightbeam "E F G H" is moving in the direction as indicated by the arrows, and as the light ray "D E" passes the surface "O P" its velocity will be less because it has entered a denser medium.

Assuming the denser medium to be uniform, rays "C F", "B G" and "A H" will all go through the same change in velocity as they pass the surface "O P". When ray "A H" passes the surface the ray "D E" will have traveled through the water only from "E" to "L" therefore the new wave front will now be "L M N K" and since the direction of light is always perpendicular to the wave front the direction now taken by the beam will be that shown by the arrows in the water.

We are now ready to study lenses and the behavior of light when passed through them. Lens is the name given to a solid of glass, a transparent medium which, due to the curvature of its surfaces, is capable of diverging or converging rays of light that pass through it. So far we have only traced the light from one medium into another; now we shall follow it from its source, to the medium, through and beyond it.

For our first example a sheet of plate glass will be used through which we shall consider a ray of light to be passing. The ray from source "A", Figure 16, on entering a sheet of plate glass at "B", the faces of which are parallel, will be refracted toward the normal. After passing through the glass, and upon emerging into the air again at "C", it will be refracted away from the normal by the same angular amount. The direction of the emerging ray "C D" will be parallel with the incident ray "A B" as shown by the dotted line "F C". This explains the reason why an object viewed through a sheet of plate glass appears somewhat displaced as to position but otherwise unchanged in form.

Light passing through an ordinary window pane is refracted in a similar manner but due to the thinness of the substance the change in position of the object viewed is too minute to be noticed. Now refer to Figure 17, a triangular glass prism, and again taking "A" as a source of light, the incident ray "A B", on

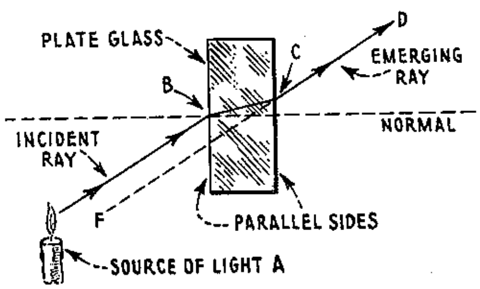

Figure 16

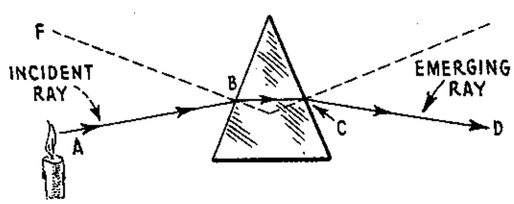

Figure 17

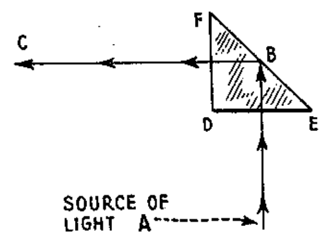

Figure 18

entering the prism at "B", will be bent toward the normal and becomes the incident ray on the surface at "C". On emerging into air it is refracted away from the normal in the direction "C D". From this we find that a ray of light in passing through a prism as shown is always refracted toward the base of the prism. Further, if the line of vision coincides with the line "C D" the candle will not be seen at "A" but will apear to the observer to be at "F". Therefore, an object viewed through a triangular prism always appears deflected toward the top of the prism.

Figure 18 represents a right-angled prism which may be classed as a total reflecting prism. The ray from source "A" entering the prism perpendicular to the side "D E" will pass through the prism without a change of direction until it strikes the face "E F" at an angle of 45° when it will be totally reflected and pass out of the prism normal to the surface "D F". A prism of this shape, having polished surfaces, makes the best known reflector.

Another type of lens we are interested in because of its use in television is called the "double convex lens" shown in perspective Figure 19. As a boy, how many times have you used this type of glass to burn holes in leaves, paper, and so on, by focusing the sun's rays?

If we place two prisms with their bases in contact and then fill the portion shown by the curved lines with glass, Figure 20, it is seen that a double convex lens is nothing more than a curved form of two prisms so placed. This can be brought out more clearly, perhaps, by a study of Figure 21 and noting the change in the light rays as they pass through what can be called an assembly of prisms with curved faces in contact. Keeping in mind what you learned concerning the behavior of light as it passed through the single prism as shown in Figure 17, we can see in Figure 21 that parallel light rays originating, for example, from the sun "S" will, when they strike the upper half of the lens, be bent downward, while the lower half of the lens acting as an equal number of inverted prisms will refract the light upward. The light emerging from both the upper and lower sides of the normal converg at the principal Focus "F".

Since we now understand the evolution of a double convex type lens we can study Figures 22, 23, and 24, from which we shall learn the principal action of lense on light rays incident on their surfaces.

Figure 19

Figure 20

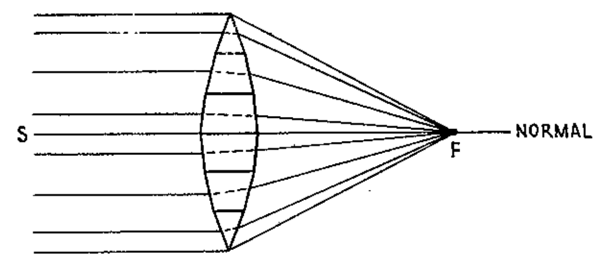

Figure 21

Point "F", Figure 22, is called the principal focus of the lens and is measured by the radius of the curvature of the lens. Now, suppose we place a source of light "L", which hereinafter we shall call a radiant, at the principal focus "F". Light rays from this point and incident on the surface of the lens will be refracted and upon emerging they will take parallel paths as shown. This you will note, is just the reverse of what happened in Figure 21.

Figure 23 shows that if a radiant "L" is placed to the left of the principal focus of a converging lens, the rays upon emerging from the lens will be bent downward and will meet at a point "L1" beyond the principal focus "F1" on the opposite side of the lens. If the radiant is placed at "L1" the rays will converge at point L. This pair of points at which the rays converge on both sides

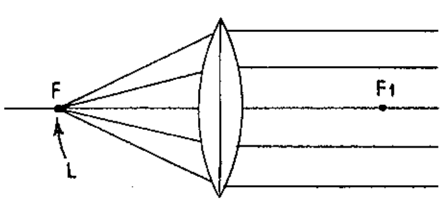

Figure 22

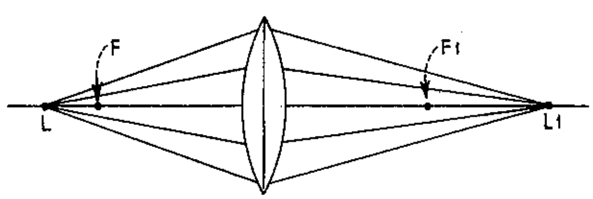

Figure 23

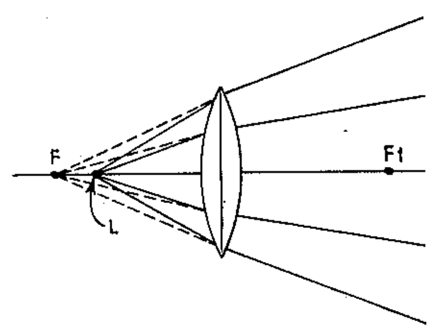

Figure 24

of the lens is called the "conjugate foci" and are so related that "L1" is an image of "L", or if "L1" is the radiant then "L" is the image of "L1".

The pin hole camera previously mentioned will reproduce the image of an object regardless of its distance from the aperture and with great clearness of outline, but if we attempt to increase the opening the image becomes indistinct. Now, this opening may be enlarged to obtain a greater increase in brightness, i.e., allow more light to strike the screen, if we place in the aperture a double convex lens, such as we have been discussing. Distinctness of outline will not be sacrificed if the screen and the object are at the conjugate foci of the lens. That is why, when you take a picture, you move the lens back and forth until the light rays striking the lens from the object are focused clearly upon the screen. In the camera the screen is the sensitized film or plate, as the case may be.

We see, therefore, that the lenses we have been studying are not only useful for refracting light but are also capable of producing images.

If the radiant "L" in Figure 24 is placed between the principal focus "F" and the lens we will find that the emerging rays will diverge, spread out, and never meet in a focus on that side of the lens. However, if these divergent rays are traced backward as shown by the dotted lines they will meet at "F". Our concern with lenses, therefore, is to know that with them we are able to collect rays of light and direct them according to our requirements. Because of lenses the simple microscope is of great assistance to vision in that it enables us to see images of an object which the eye accepts as the object itself.

The ordinary magnifying lens is a simple form of microscope which, when held the proper distance from the eye and the object, i.e., at a distance from the lens equal to its focal length, the details of the object, regardless of its form, appear enlarged because the details of the image have a large angular separation and are therefore more easily seen.

The lens of a telescope forms an image of some remote object producing the effect of moving closer to the object. For example, when you look through a spy glass, the results, so far as sight is concerned, is that of actually approaching the object itself. The clearness of detail, however, will depend upon the amount of light available. This recalls to mind the preliminary part of the lesson wherein we found that an object to be seen must be sufficiently illuminated, or a luminous body itself, before sight is even possible and this holds just as true when viewing an object through a telescope as it does with the naked eye. Furthermore the distance must not be so great that the arriving light waves are too weak because of smoke and fog through which they might be passing. There must be no obstructions such as tall buildings or other barriers in the path of the light wave. A free clear path must exist at all times.

Under certain conditions, then, we are able to extend the range of vision by means of an arrangement of lenses, but limitations soon make themselves evident for we find that the wall of a building or the side of a mountain is just as effective in obstructing our view as it was before we used the telescope.

To illustrate a point we are, perhaps, privileged to resort to the ridiculous. If so, let us assume that our eyes are so constructed that we can run them out of our head and turn them around the corner of a building; we would then in effect have an extendible optic nerve, but as was previously stated to make any such change is a physiological impossibility. To attain the result of television, however, such an effect must be produced and from a physical stand point it can be accomplished by the use of an electrical eye.

To obtain an electric eye was one of the difficulties encountered by scientists in their effort to place television on a successful experimental basis. Chemistry, however, came to the assistance of the early investigators along this line of endeavor in the development of a non-metallic element called "Selenium". This element was discovered in 1817 in the deposits of sulphuric acid chambers. In its native state selenium has an extremely high resistance (many times that of copper), but on being prepared by a heating process and brought to a temperature of 120° Centigrade (or 248° Fahrenheit) which is maintained for several hours and then allowed to gradually cool, it forms into a crystalline state changing in color from a blue to a dull slate.

The prepared selenium, it was found, possessed the property of varying in electrical resistance directly in proportion to the intensity of light waves to which it was exposed, the resistance decreasing as the light increased and increasing as the light decreased. In this element, therefore, the scientists placed high hopes, for in it were the essentials for a device which would oper-

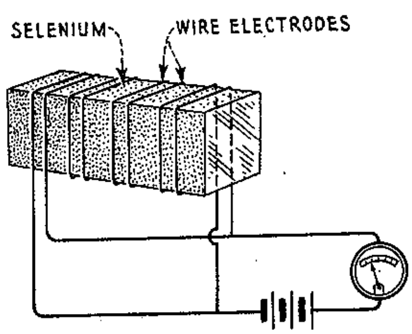

Figure 25

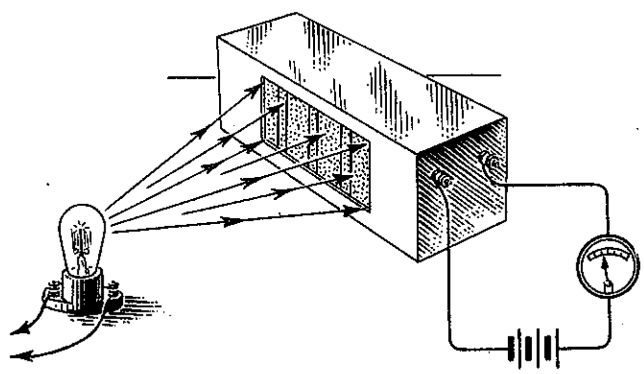
Figure 26

ate in such a manner that varying intensities of light could be made to cause a corresponding flow of electric current.

Selenium cells were made by placing a film of the prepared selenium over two german silver or platinum wires of No. 20 to No. 30 gauge wound on a small 2 by 1 inch mica form. The windings were spaced about one thirty second of an inch apart as shown in Figure 25 and then placed in a box provided with a window to admit light, somewhat as suggested in Figure 26.

The selenium cell found may uses, perhaps the most important, commercially, was in marine buoys and isolated lighthouses along the coast where it was employed to control switching mechanism to turn on the light when darkness set in and to turn it off at daylight, the light of the sun furnishing the requisite energy.

For television work, however, science was again disappointed because of the property of inertia inherent in the element. The change in its conductance lagged so far behind the instantaneous values of light to which it was exposed that a considerable time exposure was required before a proportional current would flow for a given intensity of light. Selenium, therefore, had to be abandoned as an electric eye for television.

A new development eventually appeared, the photoelectric cell, and at last was found a device that would follow with true fidelity the rapid variations of light and shade necessary to form an image and produce an instantenous current in proportion to the various delicate shading that forms a picture. The photoelectric cell is a vacuum tube depending for its action upon an electron emitting cathode and a centrally located anode.

The construction of the photoelectric cell of the type mentioned requires expensive and complicated apparatus. The glass envelope is blown to the required shape and evacuated by very efficient mercury pumps which work through liquid air traps. As the evacuation proceeds the cells are passed through an oven and baked in a heat of 400° Centigrade (or 752° Fahrenheit) which assists in driving out residual gases and water vapor absorbed by the glass envelope and elements. The potassium is then prepared by an exacting distilling process to separate

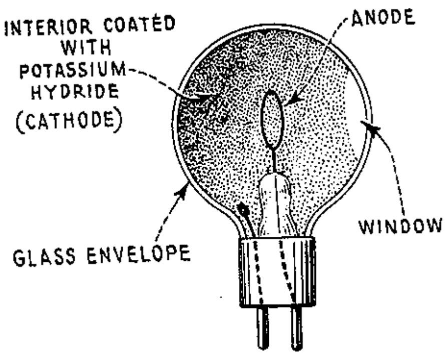

Figure 27

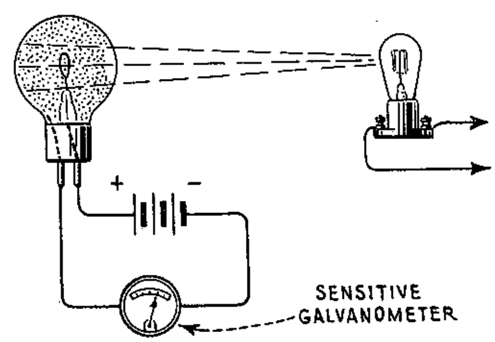

Figure 28

any impurities that might be present or introduced into the pumping system and condensed on the walls of the glass envelope or bulb. It is necessary, then, to apply a flame to one side of the bulb to clear away a portion of the condensed potassium hydride thus providing a small circular opening of clear glass. This is called the window and it is through this opening that light is allowed to enter and energize the potassium hydride. Finally, argon gas is introduced into the bulb in quantities that will give the best ionization results after which the bulb is sealed off.

Figure 27 shows the general design of the cell which is now ready for operation. Figure 28 shows the cell connected in a simple circuit and when light is allowed to enter the window a deflection of the galvonometer will be noticed, thus indicating that a current is passing through the cell.

What takes place is explained as follows: Light waves, passing through the circular opening or window of the glass envelope, strike the postassium hydride coating on the inside of the bulb. The potassium, having the property of emitting electrons when exposed to light waves and especially those predominating in blue violet light, emits clouds of electrons which are attracted at once to the positive electrode. This electrode is a loop or rectangle of wire made of some photoelectrically inactive material such as nickel or platinum. The electrons are considered to constitute an electric current which flows through the cell, and the circuit connected to the cell in which the source of electromotive force maintains the anode at positive potential.

By comparing the photoelectric cell with an ordinary receiving tube such as a 201-A type the principal upon which it operates may be more readily understood. It will be remembered that electrons are thrown off the heated filament of the vacuum tube and immediately drawn to the plate because of the positive potential applied to the plate. When considering the photoelectric cell the potassium hydride coating acts as does the filament in the ordinary tube but, unlike the receiving tube, it is cold, (that is, not heated), and is capable of throwing off electrons when exposed to the impact of light waves. The anode or central electrode performs the same work as the plate in an ordinary tube and since it is held at a positive potential by "B" batteries or some other source of electromotive force it attracts the electrons to it thereby producing a current flow. The direction of electron motion in the photoelectric cell is from the potassium hydride coating, the outside electrode or cathode, to the anode or central electrode, while in the receiving tube the direction of electron motion is from the central electrode (filament), toward and to the outside electrode or plate. Other metals being experimented with and capable of throwing off electrons when energized by light waves are caesium, sodium and rubidium.

Let us sum up the work we have been over. First we found that nature produced the first televisor, the eye, which generates an impulse resulting in vision. Next we discovered light to be absolutely necessary before vision was possible. History tells us that for years scientists have been constantly working to improve apparatus that would assist vision. First came the pin hole camera, then glass worked into the proper shape was found to cause light rays to converge forming an image of objects appearing before it, and thus was born the microscope and telescope.

The electrical era arrived and work was begun on apparatus that would enable one to talk with friends miles away by wire telephony. Then came the wireless telephone, and radio broadcasting of voice and music, resulting in the reception of sounds from London as distinct as listening to your own voice, and at last the ambition to couple all of this with an electric eye (Television) which would enable one to see with whom he was speaking.

Before attempting to grasp all of the ideas of a television system suppose we draw analogies and make comparisions along lines we are more or less familar.

Speech, music and other audible sounds produce sound waves which, in striking your ear drum, causes it to vibrate. The inner ear receives these vibrations and generates an impulse which is carried to the brain and the brain interprets this impulse.

Because speech and music can be heard for a comparatively short distance we make use of the telephone transmitter, or you may call it an electrical ear. You speak into this device, and immediately a rise and fall of electric currents take place corresponding to the sound waves that were created when you spoke. The telephone receiver, or electrical mouthpiece, converts the varying electrical currents back into sound waves forming intelligible words. Figure 29 conveys this idea in picture form.

Figure 30 illustrates the same idea with the exception that the message is conveyed by radio instead of by wires. In television our purpose is to transmit an image instead of sound, therefore, we shall have to change our terminal apparatus from an electrical ear and mouth to an electrical eye, and some device which will duplicate in light what the electrical eye observes. Essentially the apparatus, Figure 31, which sees consists of a source of intense light such as is produced by an arc lamp. This light is passed through a lens which converges the light rays to a small area. A rapidly revolving scanning disc,

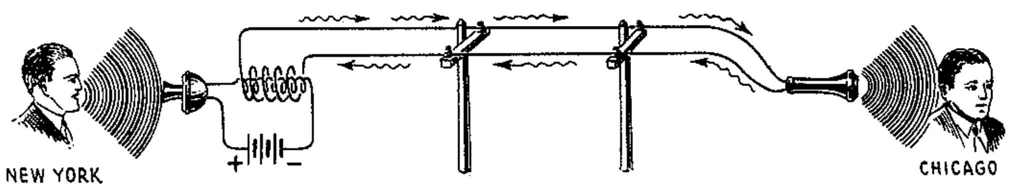

Figure 29

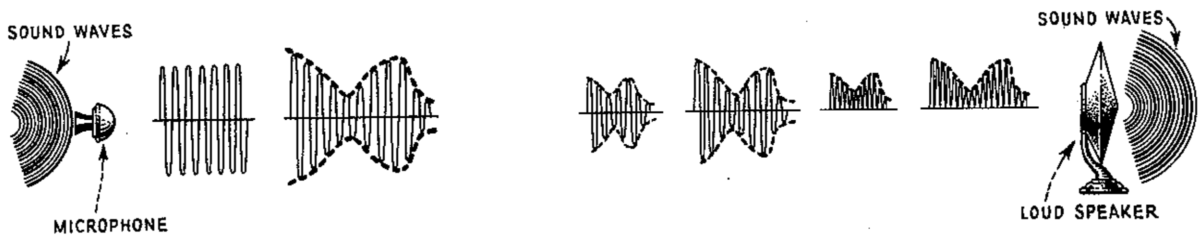

Figure 30

driven by a small motor, is placed in the path of the converging light rays in which a number of small holes have been drilled according to a spirally laid out pattern. A small frame placed between the disc and the converging light rays prevents light from passing through more than one of these openings at a time.

As the small intense pencil of light passes through the openings in the disc the features of various objects are rapidly explored. The light rays, upon striking the subject, are reflected and some of them find their way into a photoelectric cell, the electrical eye. A small electric current results within the cell which, by suitable leads, is carried into an amplifier where it is amplified and passed on to a transmitter. The transmitter energizes the antenna and from this point it is put on the air. The signal thus broadcast is picked up by a receiving antenna which is connected to a receiver, amplified at radio-frequency, detected, amplified at audio-frequency, and then passed on to operate a light originating device called a "neon tube". This tube produces a soft pinkish glow, the intensity of which depends upon the current strength originating in the photoelectric cell at the transmitter.

To see an image you look into a small frame having the same dimensions as the one mentioned in connection with the transmitter. Between this frame and the neon lamp a scanning disc exactly the same as the transmitter disc is revolved, and when it attains the same speed as the transmitting disc the image appears in the frame. This of course is simply a rapid comparision and it remains to take up the important points in a televisor system in order that we may learn how the image is transmitted and received.

Our next lesson tells us of the developments made with television apparatus.

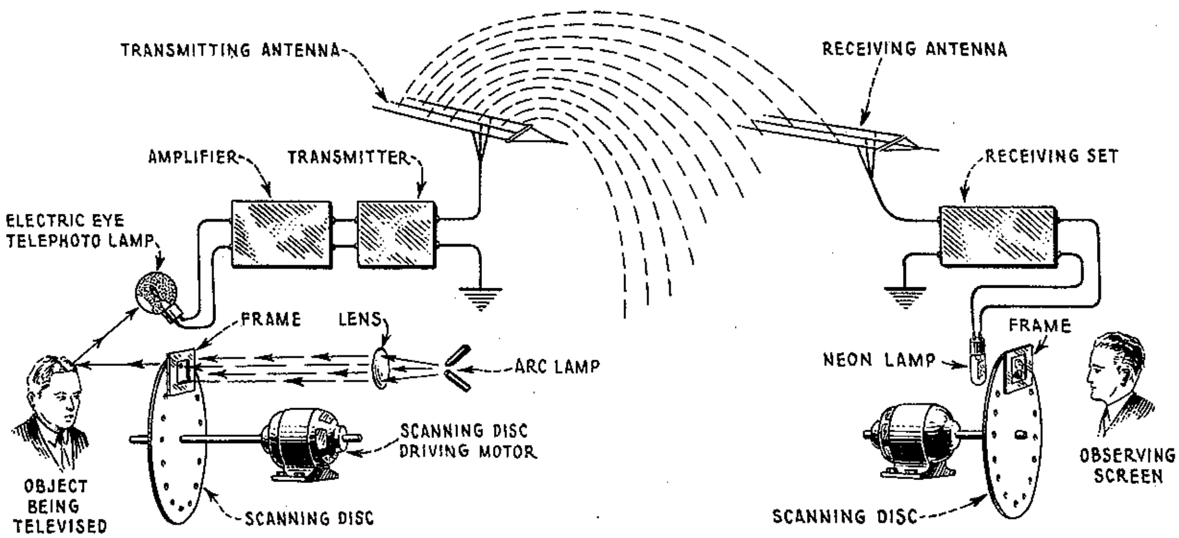

Figure 31

EXAMINATION - LESSON 65

1. What is the function of the lens of the human eye?
2. Give in your own words a definition of Light.
3. Through what substance will light travel?
4. What happens when light strikes a polished surface? A rough surface?
5. State why the direction of a light ray is changed when passing from a rare to a denser optical medium?
6. In what respect is a double convex lens similar to an assembly of prisms?
7. Explain diverging rays. Converging rays.
8. What device was first used to extend the range of vision?
9. Was selenium successful in television work?
10. What do you know about the telephoto cell?