Experimental Physics - II
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Lecture – 11
Basic Idea on Mirrors and Lenses and their Applications

Today we will discuss about some basic components in optics lab. If you go to optics lab for doing experiment, what are the common components, basic components we will use in optics lab?

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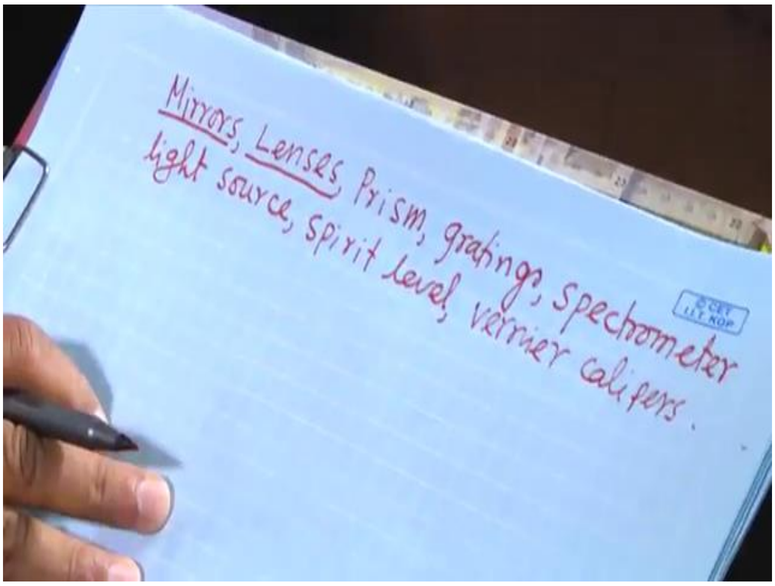

These components are, we can tell these mirrors, then lenses, then prism, then you can say gratings, then spectrometer, then light sources, also you need spirit level, then you need the knowledge of using Vernier calipers or slight calipers say etcetera there are many components. Today these are if you have this class 12 knowledge, you know most of the working principle of most of the components, but here just again I will revise that one. Let us start with the mirror and lenses.

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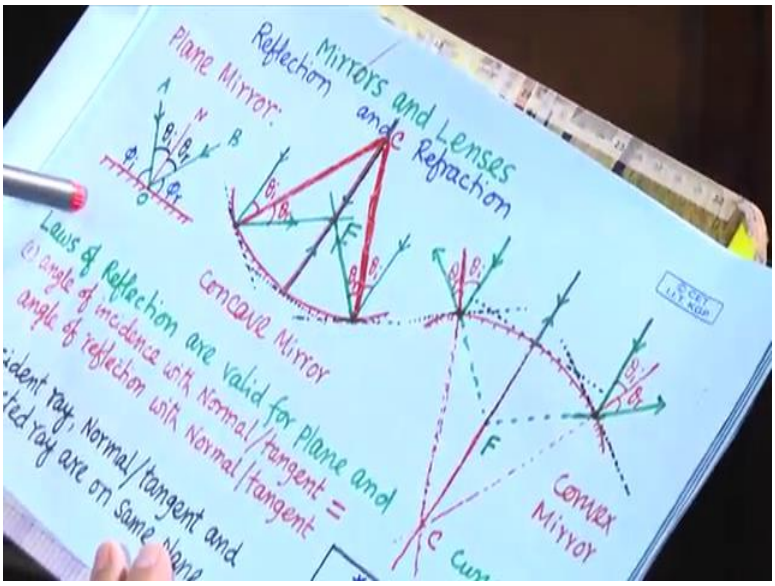

Mirror you know that; you know that mirror generally it is a three kinds of mirror we used plane mirror and concave mirror convex mirror.

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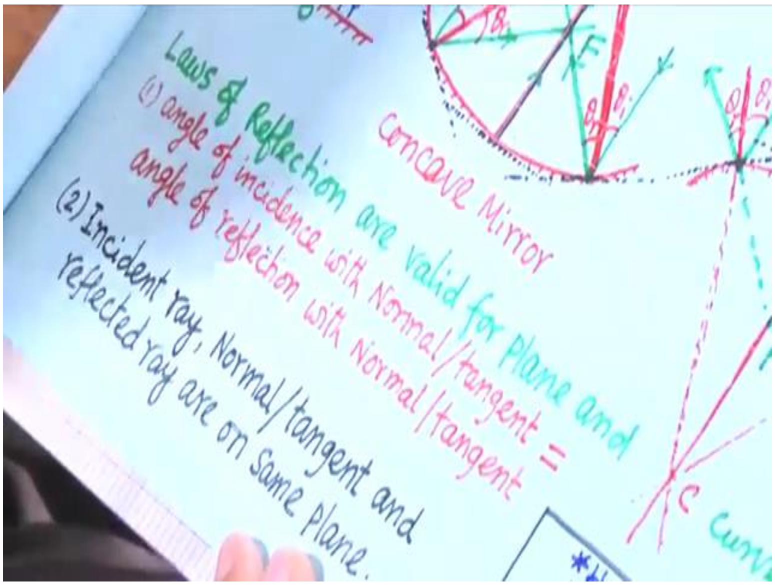

Mirror works on the principle of reflection laws of reflection we know, and we are quite familiar with the reflection from the plane mirror. This is the plane mirror and this NO is the normal. AO is the incident rays, then it is reflected from the mirror that is the OB is the reflective base. With normal this angle is incident angle is theta i and reflected angle is theta r, also angle one can define with the surface of the mirror. If that is phi i these angle incident angle with the surface of the mirror if it is phi i and this other one reflected one that is angle between the reflected one with the surface, that is phi r.

These laws of reflection tell that the angle of incidence with normal or tangent with normal or tangent. That tangent I have used this word is valid for the curved surface. This angle of incidence with normal or tangent is equal to the angle of reflection with the normal or tangent. Let us see the concave mirror, concave mirror this is the concave mirror. This concave mirror it is the curve one. It is a part of a sphere it is the part of its sphere; on small portion of a sphere is the concave mirror.

When it is a sphere it has it has center that is the C and what is the part of the mirror you are taking; middle of that one, it is a pole. these line is axis; I will tell you. here I am putting emphases on the reflection. one way is coming and falling at this point, now it is reflected; it is reflected from this point.

How it is reflected? It follows the laws of reflection; that means, angle of incidence will be equal to the angle of reflection. How we will find out? at this point you must draw a tangent; you have to draw tangent now normal to the tangent is this is the radius of the sphere these the radius of this sphere. This now this is the normal at this point from where this light is reflected.

Here also reflection light will be reflect in such a way it will follows the laws of reflection. This angle theta i will be equal to the theta r as if this part this small portion here, it is like a plane mirror. What about the from plane mirror what about the ray diagram. Here also similar ray diagram we are drawing, as if this tangent is the plane mirror; from this plane mirror this it is reflected as we have seen here.

Similarly, at this point also same way it is a reflected, this are tangent here also this along these axis is called principal axis basically pole and this Centre of the sphere so this line is principle axis and if light falls along these; you know these it is the normal; it is the normal at this point.

Light is along the normal it will reflected along the normal. Here instead angle 0 and reflected angle also 0. Now, similarly these convex mirror also if you see that these the incident ray at this point, now it is reflected from this point it is reflected. Here again we must draw tangent this tangent as if this plane mirror now on this tangent this the normal, angle of incidence with this normal will be equal to the angle of the reflection.

Here also its a from curves were here what I want to emphasize that the reflection from the mirror whether it is plane mirror whether it is curved mirror this reflection occurs; reflection occurs following the laws of reflection. If just I can write; I can write in general way. Angle of incidence which normal or tangent will be equal to the angle of incidence with normal or tangent right, then second law is it is generally we ignore it, but it is very important when you are going to draw it. At the time we draw on the plane of the paper.

That is why we do not realize, but in some when you are going to do experiment; there, this law second law is very important. When you are going to search the reflected ray in space in three dimension. Then in which way you will get the reflected rays that you can find out you can guess only following the second law of the reflection. Second law of the reflection is incident ray normal or tangent and the reflected ray will be on the same plane; that means, this is the incident ray, this is the normal or this is the normal or this is the tangent, and this is a reflected ray.

These they will be on the same plane because according to first law incident reflected ray will be equal to the incident ray. This ray whether it will be on this plane or it will be in this direction making the same angle with the normal it is possible. It can make a cone with the same angle violating without violating the first law it can reflected ray can be any line anyway on the cone with angle of theta r.

This second law is fixing that in which direction we will get the reflected ray, it will be only in one direction. That is, it will be this direction because incident and the normal or tangent are on the plane; on this plane, reflected ray must be on this plane. This action or working principle of the mirror is whether it is plane mirror or curve mirror. It is all the time it follows the laws of reflection. Another important fact I will tell you know but, in many experiment we need this concept.

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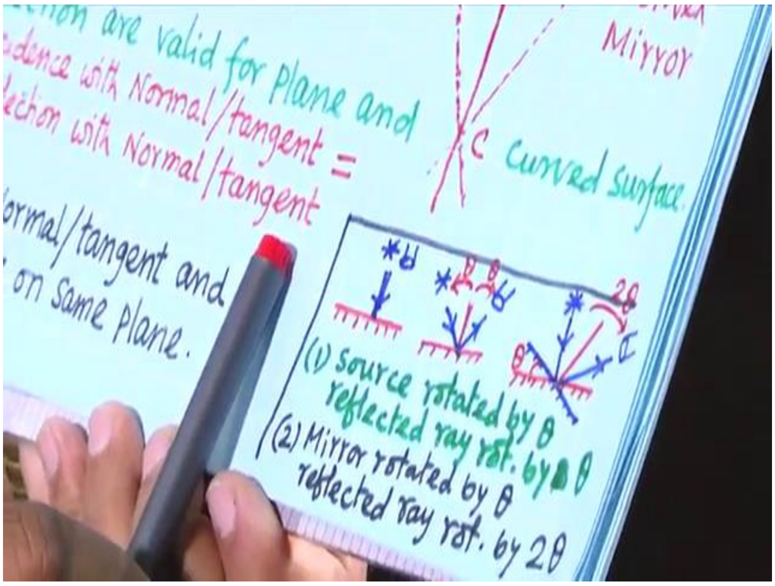

What is that? This on the mirror light is falling say this is the source from source light is falling on the mirror say falling perpendicularly. Reflected ray also it will follow the same path. I can put a detector here to detect the to catch the reflected rays. This concept is very important one experiment I know this the X-ray diffraction experiment is very common experiment for characterization structural characterization of the sample.

There this concept is very important and use this concept although you know but when in reality, I have seen that one has to really implement this knowledge to that experiment XRD X-ray diffraction experiment. Now, generally in XRD experiment we change the incident angle; we change the incident angle and catch the reflected rays is diffracted ray Bragg diffraction it is an equivalent to reflection under some condition. we can say that is the Bragg reflection. we must catch the reflection. We will vary the incident angle and then we will catch the reflected rays using a detector that is the experiment XRD experiment.

So now, how you will change the incident angle? very easy way generally to think that we will change the; we will change the position of the we will rotate this, we will rotate the source; we will rotate the source; we will rotate the source; that means, we normally it will make an angle; it will make an angle.

Following the laws of reflection, it will be reflected. Compared to this position now this source is rotated by angle theta from the normal; from the normal see them. Reflected ray will rotate in other way other direction by theta, or theta i and theta r, these two will be same. If I rotate the incident rotate the source; that means, incident ray by angle theta. detector will rotate the or reflected ray will rotate by theta on the other direction.

Now, generally in XRD experiment it is this source x source is very heavy and it is very difficult to rotate the source, but we must change the incident angle. Instead of rotating the source we rotate the mirror we rotate the mirror in that case we rotate the sample; sample surface is very smooth, and it was like a mirror. If I rotate the mirror by angle theta; by angle theta source is at the same position; source is at the same position.

Now, if I rotate the mirror by angle theta. This normal to the mirror; normal to the mirror it will also it will rotate by theta; that means, an incident angle now with the mirror; with the mirror will be theta. Now, source is at fixed position detector also was at this position right now if I change the source rotate the source by theta. Detector also have rotated by theta, but in this case, you can see that source is fixed if I rotate the mirror by angle theta, it will make incident angle theta, but detector now I must rotate by 2 theta because here this reflected ray. this is the angle theta now this other one reflected ray will form the angle with this normal that is also theta.

From this position; from this position source position now reflected rays or with respect to the incident ray reflected ray is rotated by compared to this is rotated by 2 theta. although in both cases incident angle is theta, but when you will rotate the source. detector must rotate by theta in this case, but other case when you will rotate the mirror and angle incident angle will be theta, but the detector has to rotated by 2 theta.

If mirror rotated by theta; that means, I am changing the incident angle by theta and detector to detect to catch the reflected rays we must catch we have to rotate the detector by 2 theta. That you know, but still I just remind you and this a very useful for XRD experiment this concept is required. Just I emphasized.

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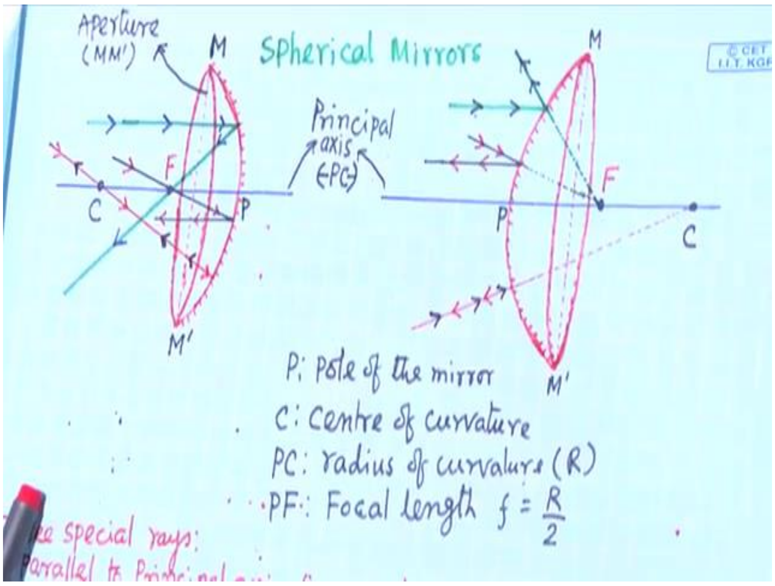

In case of mirror; let us discuss about the convex mirror and concave mirror. that there is they are spherical mirror. is a from a sphere it is a small portion of the sphere is taken. this is the mirror generally we just draw this part with the just draw this part ok, but it is a spherical part of its sphere. this aperture; aperture of these of this mirror the radius that the diameter of this of the diameter not diameter of the of the mirror diameter of the periphery of the mirror.

This circular this when you are taking this spherical part; this is a circular part. diameter of the circular that part is called the aperture. in these case M M dash is the aperture this is the diameter of the of the upper surface of the this or edge this of the of the mirror. that aperture we use this is the in terms of the incident rays. this size this aperture tells this what is the space on the mirror to enter the incident light.

Here nomenclature is this these concave mirror and these the convex mirror. this is the middle of this center of this mirror is the it’s called pole and this C is the radius of the or center of the curvature with the center of the curvature see or is the part of its sphere is the part of sphere. this is the center of the sphere this is the center of the sphere right and. this C P this light passing through the CP, that is the call principal axis that is the call principal axis. And, if you draw the reflection from this mirrors then you will see reflected rays, they will form the image.

For getting the image we must; we must draw the ray diagram. there are rules for that everything will happen due to the reflection as I told you discussed you, but all the time seeing this reflection measuring the angle it is not the easy way. if you follow some rules then it is easy to draw the ray diagram.

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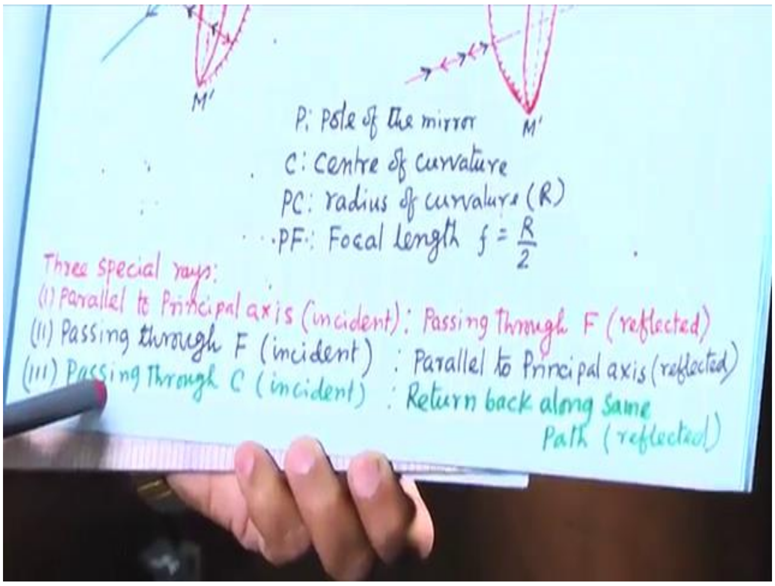

Here this three special rays three special rays one ray say parallel to the principal axis incident ray parallel to the principal axis incident ray parallel to the principal axis. this reflected one; reflected one; reflected one it will pass it will pass through a point F is called the focal point.

This is one rule will follow for drawing the ray diagram second this passing through F incident ray, if incident ray passing through [FL]; incident ray passing through [FL]; passing through F then reflected incident ray passing through F then incident reflected ray will be parallel to the principal axis parallel to the principal axis reflected one parallel to the principal axis.

These parallel to the principal axis third one is if incident rays passing through C incident ray passing through C and falling on the mirror then it will be reflected along the same path it will be reflected along the same path. this whatever three special rays whatever I told you. that these it's a it follows the laws of reflection. this ray is it will fall on this here is the perpendicularly. that is why it will return. other case also this same way one can explain from the basic laws of reflection. this whatever special ray whatever I told you this is valid for this convex mirror also right, but in this case, it is reflected as if; if you just extend in the back side of the mirror; extend the back side of the mirror. they will meet some point on the on the on the principal axis.

In this case here meeting this ray whatever F directly you have meeting. there is F here extended one. these are reflected as if this reflected ray is coming from this point reflected ray is coming. here this incident ray and then it's as if this incident ray this source is; source is here, or it is passing through as if it is following these this incident ray which is passing through this F. these extended one here also same way. in this case this focal point and center of curvature is on the other side of the mirror back side of the mirror it is on the front side of the mirror.

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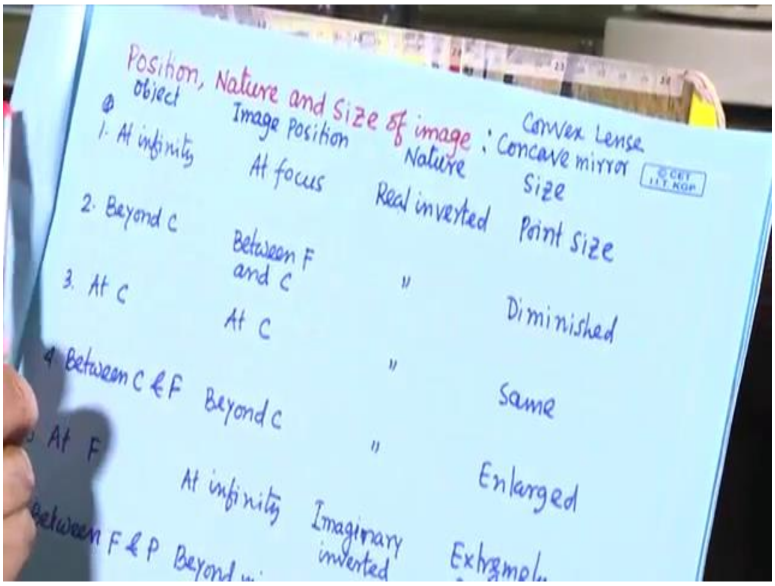

If we draw the ray diagram if we draw the ray diagram for a for say concave mirror say concave mirror. depending on the position of the depending on the position of the object depending on the position of the object we will see the image we will see the image of the object of at different distance and of different nature and of different size. if your object is at infinity ok; that means, parallel rays are coming and falling on the mirror.

This image position will be at the focus at the focal point of the mirror and it will be real image and inverted real image and inverted and it would be very small size point size this image size will be point size. If you if you put the object beyond C means the distance is greater than CP, then this image you will get between F and C and it will be real inverted image and it will be smaller size than the object size. that is why we have written diminished.

If you put at C object at C center of curvature; you will get the image also at the center of curvature and it will be real image and inverted one. this, but the size of the image will be same as the object size.

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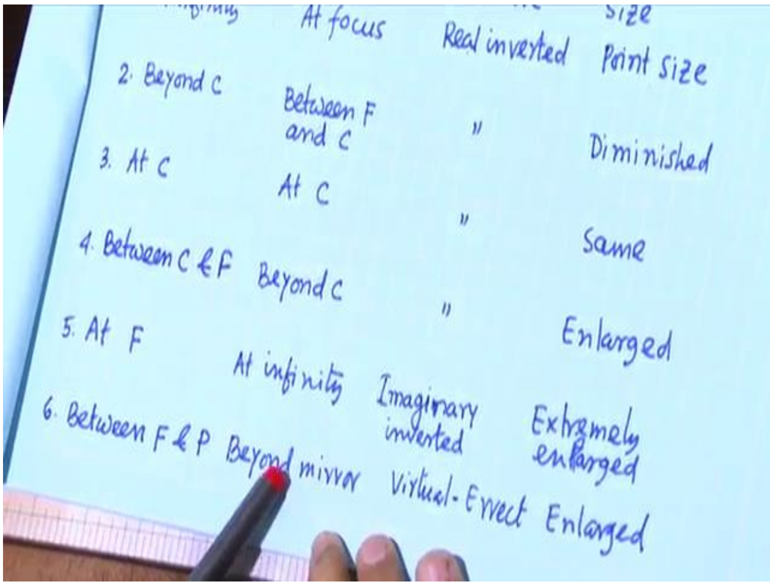

If you put; that means, you are reducing you are decreasing the distance of the image distance of the object with respect to the mirror. this and size of the image we are getting; size of the image we are getting larger and larger and image it is shifting it is shifting outwards. it was at focus now it is now image position is between focus and the center of curvature now at the center now beyond not center of curvature now beyond center of curvature now at infinity.

Now, it is the beyond mirror. if your position of the mirror this object between F and P pole. object distance is less than the focal length. then image you will get the beyond mirror behind the mirror and it you will get virtual and erect all this case you are getting inverted in this case you will get erect virtual erect and it will be enlarged. these position nature and size of the image whatever I told about the concave mirror. for convex mirror also you will get same thing.

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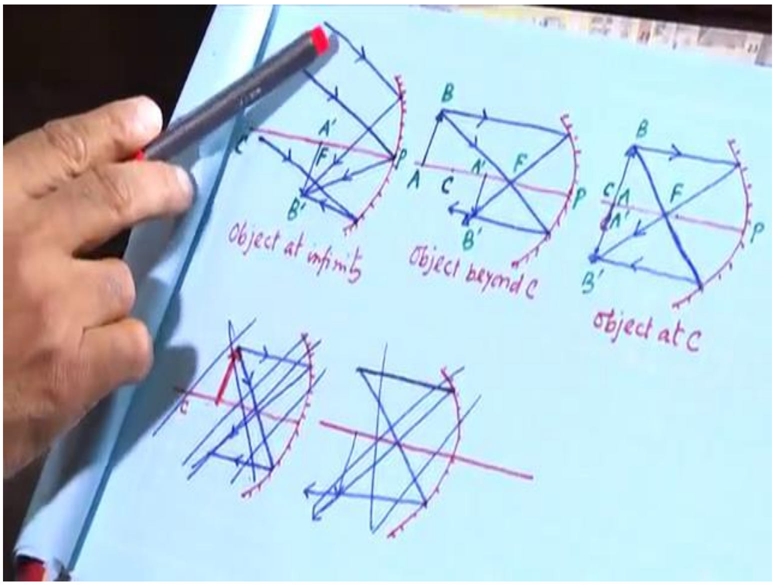

Just let me show I have I tried to draw I tried to draw it just let me show you. in this case object is at infinity. parallel rays are coming. they are meeting is here the at this point. that is why we are telling that the image will be point size image will be point size (Refer Time: 32:42) small size now object beyond C. this is the C center of curvature.

If it is the object, we will get the image between C and F now if it is at the center at this object is at the center of curvature C then you will get the image at the same point at C, but. these inverted one this is the real one. real images real inverted and size is increasing the in this case equal. other to I try to anyways. if you other three if you draw it. you will see this image will be larger and larger once you should try it. if you go for the second component very important component in the optical left is that spherical lens.

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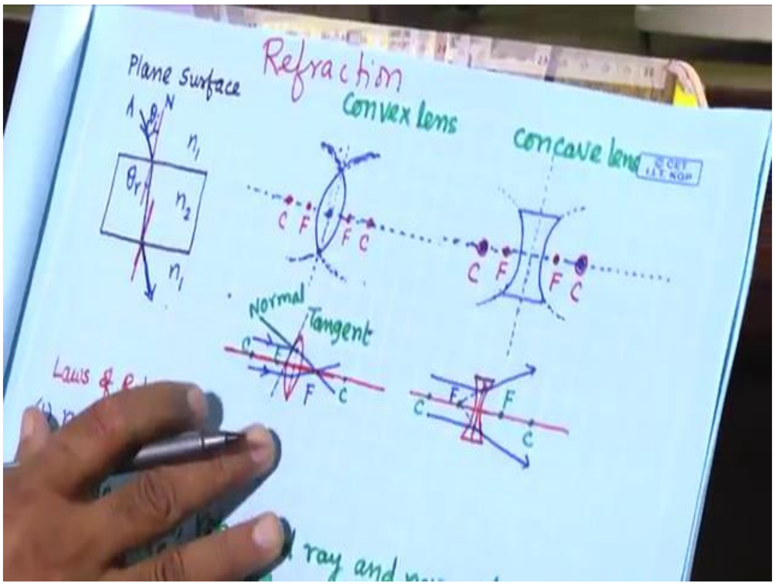

Before that let me. that they are also this reflect. in this case there is a principal of the refraction; principal of the refraction this is applicable. in this case refraction not reflection refraction ok; in case of mirror is the everything follows the laws of reflection in case of lens it follows the refraction.

What is refraction you know that this is the incident angle, and this is the refracted angle if and refraction only possible at the interface of the two medium where there is the interface of different refractive index n 1 and n 2. angle is theta i theta r refracted angle in this case they are refracted earlier I told that is a theta r is angle of reflection.

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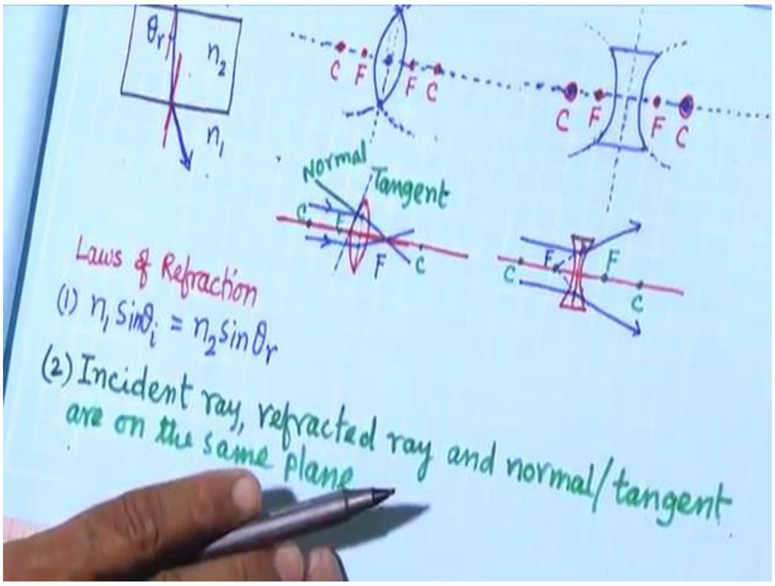

Laws of reflection are n 1 sin theta i equal to n 2 sin theta r. this is the Snell's law. you are quite familiar, and the incident ray reflected ray and normal or tangent are on the same plane. this is the incident this is the normal and this is the reflector they will got the same plane ok, same as the laws of reflection second law. this tangent as I told this in case of convex lens and concave lens is a curved surface.

Here also this ray diagram whatever we draw. refraction incident rays and then reflected rays. in which direction you will get the reflected rays it follows the laws of reflection. here I am trying to give emphasize that that in plane surface the way you deal you follow the laws of refraction. for curved surface also the same laws are followed only different is that. you have to you have to consider that the point of the incident ray on the curve surface.

There you must draw a tangent and you have to think this tangent is the surface like this surface like this now if you draw a normal on this tangent. normal that normal is like this and with respect to this normal. there will be refraction and that refraction will follow the Snell's law. refracted angle will be such that it will follow this law Snell's law. is the either convex lens or concave lens for both cases for both curved surface. this whatever the rays refracted rays we are drawing. that is following the; following the laws of refraction. in this case also same similar way I think I have yes, I think here I have written.

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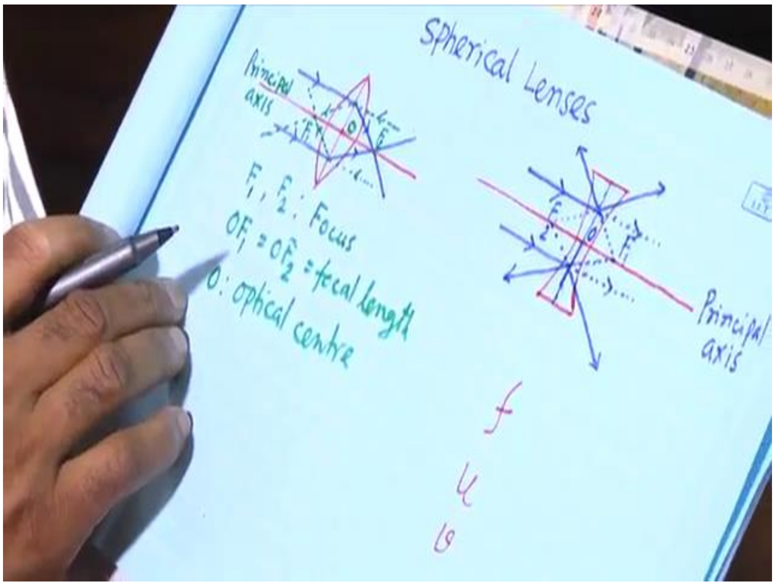

In this case also. this is the principal axis it is principal axis. here two curved surface in case of mirror you have seen one curved surface. it has it has center of curvature C. in this case C 1 C 2 also focus will be F 1 F 2 this radius of curvature of both one it may be same or may not be same but generally we will deal in the laboratory. having the same curvature both curve will have the same curvature radius of curvature. it will have two focal length ok; one is this side another is other side generally one is called primary focal primary focal length another is called secondary focal length.

How it is define primary focal length and secondary focal length not much important. it depends on the in which direction light is following falling. primary focal length we tell this F 1 when if we put light source if we put light source at the focal point. we will can generate the parallel rays. that focal length we tell this primary focal length and secondary focal length we tell this when parallel rays will follow on this lens and it will meet a refracted rays will pass through a point on the principal axis. there is the; there is the secondary focal length that way generally we define primary and secondary, but I do not think it is the have much importance.

If curvature is same or both then focal length OF 1. focal length here O is optical center is the middle. all distance is major from this; from this optical center O and other case in case of mirror all distance are measured from the; from the pole I did not mentioned. middle of the; middle of the there is a p whatever I showed you P their axis this is called pole. all distance is measured from that pole and here all distance is measured from this center of the lens.

I have drawn the ray diagram for this convex lens and this for concave lens. one thing you can see this mirror in case of mirror the or concave mirror is an equivalent ray diagram generally is the equivalent of convex lens and concave mirror no that is the that is the concave mirror and this convex lens and convex mirror and concave lens. they are ray diagram are more or less similar.

Now this purpose of this using this lens or mirror to form an image of an object. characteristics of the mirror or lens it is we expressed in terms of the radius of curvature or the focal length. So now, one parameter is focal length F or radius of curvature r then second things are that this where I will putting the object. that distance we tell this object distance this generally we expressed. focal length if it is this object distance, we expressed by say u and then where this image is formed. distance of this image from the pole case of mirror or from the optical center of the lens.

This is distance we tell in terms v. they are related; they are related that relation I will tell you; I will tell you.

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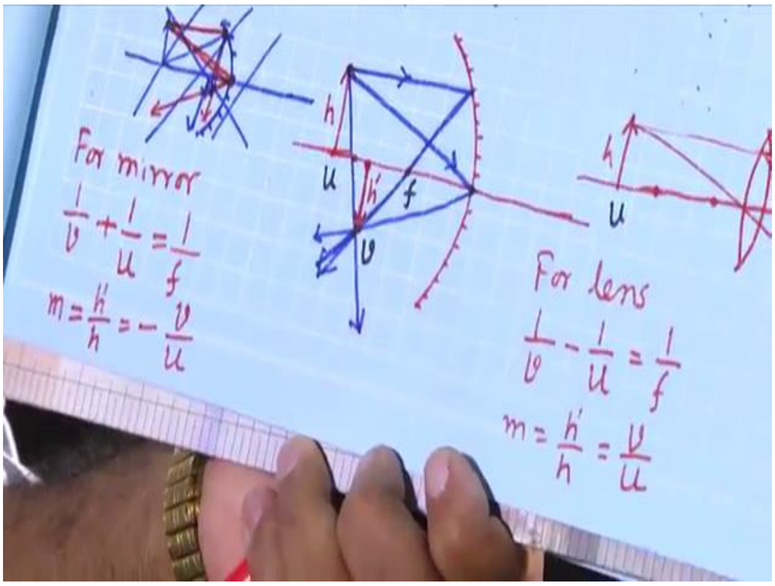

This relation in case of mirror; 1 by v plus 1 by u equal to 1 by f right and image size are different than the object size. this we express as a in terms of magnification. this magnification n is equal to image height divide by object height its comes equal to minus v by u and for lens this relation is 1 by v minus 1 by u equal to 1 by f and magnification is height of the image divide by height of the object equal to v by u here minus v by u here plus v by u here it is plus 1 by v plus 1 by here 1 by v minus 1 by u.

This here this difference is in sign relation are similar for magnification as well as this lens and mirror relation are similar. if you follow the sign convention then you can tell this if we put the object in left side of the mirror or lens. image whether it is on the left side or it is on the right side also from the sign you can tell this image you are getting.

Whether it is inverted one or it is erect one. if you follow the sign convention. those information we can tell from the sign. this sign convention will follow generally Cartesian sign convention Cartesian coordinate sign convention will follow. this is the x axis this is the y axis and then this is the z axis. forget z axis x and y let us concentrate or two dimension.

If it is the lens or mirror position. from distance will measure from the pole or from the optical center. this if this is the object and its height is a h and it is upward detection with respect to the principal axis x axis. it is along the y axis right positive y axis. this if; so, this will take as a positive if image or this can be image or the object if image or object is this way downward. this is the negative y axis. this will take as a negative.

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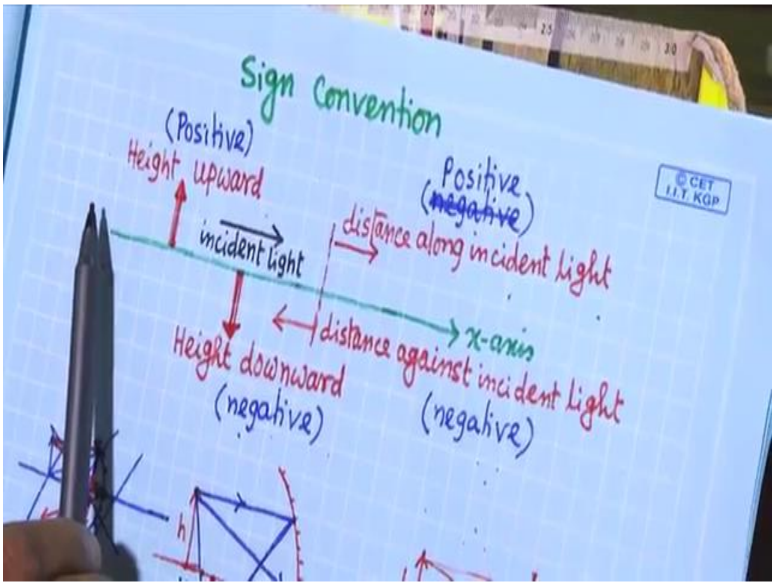

Similarly, if the distance distances object or image starting from the pole or optical center, if for measuring the distance if we must go against; the against the incident direction of the incident rays. this is the say direction of the incident ray. if we if we must measure the distance of an object or image against the incident ray direction; that means, in this direction.

This is negative x direction. that distance will take as a negative; that distance will take as a negative if distance of object or image we measure along the incident ray direction so; that means, this direction positive x direction. then that distance will take as a positive ok; u or v it will be positive or negative or the image or object height it will be positive or negative. that we can find out we will find out following the sign convention.

I think these are the information is just (Refer Time: 48:27) plus knowledge one meet and when we will do experiment with the laboratory this knowledge, we required we have this knowledge. But we must implement this knowledge in the laboratory only difference is that you know we know Ohm's law; any student will tell Ohm's law and when will go to laboratory for verification of the Ohm's law. we must change the current and measure the voltage see the change of the voltage or vice versa and then we have to find out that i versus v curve is a straight line. But we know the Ohm's law, but when we go to implement in the laboratory, we find difficulties as if on my experience what I have seen that.

Whatever the definition we have learnt as if it is a separate thing when we are walking the laboratory, we are dealing with the instrument only without thinking about the; about the theory whatever we have learnt separately in class. but it is not like this whatever we learn that Ohm's law we know very well whatever I told you know very well.

But when will go to lab, we have to remember whatever we are going to do in the laboratory, there we have to follow this theory whatever we have learn and when we are doing experiment, we have to look back the theory what we have learned. If we can combine these two these theory whatever we have learned and if you believe that you are going to implement in the laboratory for doing the experiment then you can do the experiment easily, you can understand the experiment easily. That is why your known things, I just repeated. I will stop here.

Thank you.