welcome to this next lecture in the optics module lecture nine microscopes and telescopes in the last lecture we discussed about the basic principle of a simple microscope or a magnifying glass

so we saw that the magnification is given by an expression of the form the magnification is given by m is equal to magnification m is equal to d by f f is the focal length of the lens

so focal length focal length of the lens that is the simple microscope or the magnifying glass and d is the least distance for clear vision which is approximately equal to which is assumed as 25 centimeters we have already discussed that d depends on the person to person it varies from person to person but we assume that d is equal to 25 centimeters

so this is the magnification and we have also seen that there is a certain limitation in practice because f cannot take very small values and d is fixed and therefore there is a limitation on the magnification in practice there are several samples many samples which require very large magnification to be seen like biological samples like blood cells or bacteria if one has to visualize these the magnification required is very high and a simple microscope or a magnifying glass will not do

so what is done is we use what is called a compound microscope a second additional lens there could be more lenses but in its simplest form a compound microscope comprises of two lenses one additional lens which is compounding the effect of the first lens to give you a higher magnification hence the name compound microscope

so we will start first with the compound microscope and then we will come to the telescope the compound microscope

so first i am showing here a simple diagram of a compound microscope which comprises of two lenses one lens here it is called the objective lens because the object is placed close to this lens this is a metallic tube there are two cylindrical metallic tubes which are coaxially located and there is a knob adjustment knob i will show you a typical instrument there is a norm by which you can adjust the separation here or you can move the objective closer to the object or away from the object and this is the eye

so the separation between the two lenses can be changed to get a clear image by using the adjustment knob

so a compound microscope we will see the ray diagram and how the magnification takes place etcetera but in its simplest form it comprises of an objective lens here and an eyepiece here and this is the eye from where you see

so let me first show you the instrument how the instrument looks like

so let me show you a laboratory microscope a compound microscope which is used in the laboratory

so here

so let me show you a compound microscope i am showing it in a slightly in an angular fashion

so here is the microscope

so we have the p switches here and the objective lens which is here

so i can show you like this for example

so you can see that the eyepiece this is the objective the object is placed in front of this lens objective ah objective lens and the eyepiece is closer to i in other words we see from here that we see from here through the eyepiece and what i would also like you to note

so again let me rotate this and show you this fashion

so here is the objective and at this end we have the eyepiece you can see the size of the lenses the objective lens and the eyepiece here the lens we can also see the eyepiece here

so from front front side you can see the eyepiece it is a very small lens and if you keep the eye you will cover your eye will cover this lens is just to note that the eyepiece lens is almost of the same size as that of your eye lens

so let me again keep it like this and show you that the knob adjustment knob which i had shown

so let me show from the side here

so you can see that if the object is kept here then i can increase or decrease the separation between the object and the objective here

so the object is placed here you can increase or decrease

so that you get a clear vision when you see from the eyepiece which is here also note that the eyepiece there are in some microscope there are other adjustments but this itself can be varied you can see that the eyepiece lens here this can be pulled back

so that the separation between the objective and the eyepiece

so let me show you here

so the eyepiece is here objective is here the separation can be increased or decreased to get a clear vision but normally that is not required and once it is set you need to adjust only the position slightly between the object and the objective here to get a clear image there are other screws which are provided here

so this is not a ah a microscope which you see in a biology laboratory where the biological samples are seen this is in fact called a travelling microscope because it can also travel in different directions

so it can move laterally it can move horizontally

so you can there are additional screws provided for this this to move in this direction and that direction both the directions it can move hence it is called a travelling microscope widely used in the physics laboratory but basically this is the microscope tube which i had shown earlier which has an eyepiece and an objective in a special in a specialized specialized microscope you may have many more objectives here you can switch from one objective lens to another objective lens with a different focal length to get a higher magnification

so this is the a laboratory compound microscope

so let me come back to the discussion on the microscope

so let us come back here

so here it is

so the original diagram which i had shown that it is a tube one tube into other tube and the adjustment knob here the adjustment knob by which we can move the objective lens and here is the eye which you for observing the image the object is placed in front of the object lens and this is called eyepiece because it is closer to the eye which observes the image now we will see the ray diagram and the layout of the compound microscope to understand the picture more clearly how a object is magnified and how the image is formed these are the two lenses which i showed you earlier the objective and the eyepiece

so the object is a very small object because we are discussing about a microscope a microscope is used to observe very small objects

so there is a small object here in front of the objective f o is the focus of this objective and this small f o here the small f o is the focal length

so focal length of this lens and the object is placed a little bit away from the focal length and we know that this forms an image here using the lens equation you can find out ah the position of the image

so this is a inverted real image formed due to the first lens which is the objective in our case

so the image is formed here the second lens gives a magnified virtual image provided this image falls within the focal length of the second length f e here

is the focus point of the eyepiece f e is the focus of the eyepiece f o is the focus of the objective and small f e here is the focal length of the eyepiece
 so if the position of the object
 so this we can adjust by separate the by changing the separation between the object and the lens that is why i showed you there is a knob which changes the separation between the object and the objective
 so by changing this we can make the real image to form very close to the focus of the eyepiece but within the focal length that is slightly less than the focal length here
 so that we get a virtual a magnified virtual image the ray drive diagram drawing we can see here that the ray which passes through the middle of the lens midpoint of the lens passes undeviated there are other rays also which can be shown but i have shown only two ray to avoid complications and the ray which passes through the focus here any ray coming from the focus will be rendered parallel
 so this is coming parallel and the parallel ray will get again pass through the focus f e on the other side that is the second focus of the eyepiece and that is how this is going here and this ray bends towards this and if you project it back then it appears these rays appear to come from a virtual object a position which is positioned far away and this is a magnified image of the object note that the distance l which is the separation between the two that is the focal length here the focus and the focus of the eyepiece the separation between the focal point of the objective that is the second focus of the objective and the first focus of the eyepiece is called l is designated l and it is called the tube length its not really the physical tube length but it is called as the tube length because it is very close to the tube length actual tube length that is because fo and fe here are much smaller compared to the actual tube length of the microscope the tube length of the microscope
 so if you see the original diagram
 so we may say that this is the tube length almost the separation as the tube this is the tube and this is the length of the tube but its not exactly the tube length because the focus the typically the focal length of this objective is one one centimeter or less and typically this is also of the order of one centimeter or one point five centimeter whereas the tube itself is typically 15 to 20 centimeter in length the separation between them this l is typically 15 to 20 centimeter whereas these are approximately 1 centimeter because we use a objective and an eyepiece eye lens here eyepiece which is which have small focal lengths
 so l is the tube length
 so this ray diagram clearly illustrates how a small object first a real inverted image is formed by the objective in a position which is very close to the focus of the eyepiece but inside here that is closer to the eyepiece and therefore a position the object position is such that we get a virtual image an enlarge a magnified virtual image this is just like this part is the same as that in a simple microscope or magnifying glass which we have discussed in the last class now we have added only one more lens here which gives a first magnification here and then a second magnification here therefore we have magnification which is almost doubled this can be not really doubled it could be many more times
 so this could be seen as a image form due to the first lens followed by image form due to the second lens
 so here i have pre drawn another diagram just to make it clear again that we have this first length
 so i am first showing the first length lens here forming a real image

so first lens

so i had shown in the previous diagram only these two rays but here i also showed a parallel ray passing through the focus here and reaching the same point of course and this is the object and this is the real image formed by the objective

so f o f o and l now in the same position i am showing now the eyepiece how it forms a virtual image a magnified virtual image this is working like a magnifying glass and this is like an imaging lens now you superpose this over the other and what you have is the compound microscope the magnification here is m is equal to h dash by h h dash by h which is a dash b dash divided by a b and we can show that this is nothing but h dash by h is equal to f 2 b dash here divided by f divided by p times f 2 here because these two are similar triangles triangle f 2 b dash a dash and triangle m p f 2 are similar triangles and therefore we have h dash by h that is this by this is equal to this distance divided by this distance this distance is the focal length f o f o and f two b dash but f two b dash is very close to l because we have shown in the if we see the earlier diagram you can clearly see that it is this distance which is almost equal to the separation l and therefore f two b dash which is close to l and therefore we have magnification is equal to tube length l divided by f o

so the first magnification now the second magnification we have already derived in detail in the last class that the angular magnification that you get is d by f e where f e is the focal length of the eyepiece and therefore the net magnification

so the net magnification m the net magnification m is equal to the first linear magnification multiplied by m theta

so this is the overall magnification is equal to m linear and m theta which is equal to we have l divided by f o into multiplied by d by f e

so m the total magnification m is equal to l into d divided by f o into f e we can see that the magnification will be larger if f o and f e are smaller that is why one chooses the objective of a small focal length and i p is also of a small focal length similarly l if the tube length is large then the magnification can be large

so d is of course fixed d is the distance for least distance for clear vision which is taken as 25 centimeter we have already discussed in the last class that d actually varies from person to person however for on an average it is approximately 25 centimeter and we assume d as 25 centimeter l is the tube length

so if we take a typical example if we take an example just to get an idea what kind of magnification we have in a simple ah magnifying glass we had a magnification m which is equal to d by fe only this part only d by f e which was approximately 5 to 8 or maybe 10 that one can get but now let us see in an ah a typical example if you have an objective f o of focal length is equal to one centimeter and a one centimeter or one point five centimeter let me take 1. 5 centimeter and f e the eyepiece of focal length 2 centimeter you could also take smaller values and d is of co and a tube length l is typically approximately 15 centimeters 15 centimeters and d is equal to of course 25 centimeter we can see that the magnification m is equal to l into d that is twenty five divided by one point five into two all in centimeters and that is one point five into two is three goes five times

so this is one twenty five all centimeters cancel this dimensionless and the magnification is 125 whereas earlier we got a magnification of about 5 to 10 with a single magnifying glass now we have a magnification which is hundred and twenty five

so this clearly illustrates that by using an additional lens to enhance or to

compound the effect of a single lens we can get much larger magnifications in fact one can have focal lengths f o objective focal lengths which are a few millimeters one millimeter two millimeter in which case you can see that the magnification will go further higher and you can easily get magnification of the order of thousand
 so this is a compound microscope now lets move to there are many more problems which one can work out but let us now move to the telescope
 so what is the telescope
 so telescope recall that telescope is an instrument to measure to observe an object at a large distance tilly that is at a far away distance when you have an object which is at a far distance
 so you are observing from here
 so this is the human eye or eye lens
 so let me show this as the eye lens and this is the retina we have discussed in the last class if you have a big object but which subtends an angle a certain angle theta here or alpha at a certain distance which is u here then the angle alpha subtended at the i is alpha the same object if it moves away if it moves away lets say it moves to same height is the same object then this will subtend an angle which is smaller than alpha and if the object is at a very large distance then the angle subtended is very very small in other words if the object is almost like infinity for example let me take some practical numbers if i take some practical numbers for example you take let's take moon we take more moon has a mean diameter average diameter size diameter of approximately 3.
48 into 10 to the power of 3 kilometers and the distance from earth to moon earth to moon the distance is approximately three point four into 10 to the power of 5 kilometers the earth moon distance now the size here the diameter
 so we have a situation
 so here is the moon which is
 so here is the earth and an observer is here
 so what angle would this subtend here at the observer or into the observers i this is the diameter and this is the distance this is the distance
 so this theta how much will this be theta theta is equal to obviously this arc length is equal to r theta or theta is equal to the separation
 so theta is equal to three point four eight into ten to the power of three kilometers divided by three point eight four into ten to the power of five kilometers
 so this is less than nearly equal to less than if i say that this almost one it could be it may be about point eight
 so approximately point eight into ten power minus two radians ten power minus two radians approximately 10 power minus 2 radians that is the kind of angle that you have here subtended on the ion to the eye of an observer similarly if you take the distance of sun
 so sun if we take sun diameter average diameter of sun is approximately fourteen into ten to the power of five this kilometers the diameter of sun layer and the distance earth to sun earth to sun is approximately 1.
5 into 10 to the power of 8 kilometers or 15 into 10 power 7 kilometers as before the angle subtended theta is equal to 14 by 15 into 10 power minus 2 which is approximately 1 radian 1 into 10 power minus 2 radians approximately almost same obviously we can see it is very clear to us that our eye can clearly see the moon clearly see the sun although they are at a far away distance because the angle subtended is of the order of 10 power minus 2 radian the angle resolution the angular resolution which the human eye has is of the order of approximately it varies again from person to person of the order of 10 to the power of minus four radians for example if moon were to be one tenth of the size

so moon were to be one tenth of the size diameter even then we could have seen the moon because we can see the moon clearly quite big and clear now if the size reduces to one tenth i am sure we will still be able to see if it reduces to one tenth this theta will come down to ten power minus 3

so minus 3 radians the human eye can have an angular resolution of the order of 10 power minus 4 radians now coming back to the back to our discussion on telescope the important point which i wanted to show we wanted to illustrate by these numbers is that the angle theta is extremely small or the rays travel very close to the axis parallel to the axis the rays which come from the object are almost parallel with this if i keep back the telescope

so before we discuss the telescope let me show you a laboratory telescope here

so back again

so here is a laboratory telescope which i have just picked up from the physics laboratory

so here is the telescope

so we can see the this has an object lens here

so there is an object lens and an eyepiece here and as before you can see there is a knob

so we can move the knob and change the separation because this is clamped the tube which holds the object lens or objective is clamped and therefore we can change the separation we can change the separation between the object lens and the eyepiece by changing by moving this knob

so this is important we will see why that is important because by changing this we can adjust the the separation such that we get a clear image of a distant object

so we can see from the front here

so this is the object lens here

so this is the object lens and on the other side

so if we see like this

so this is the eyepiece eyepiece and as before you can see that the lens is quite small it is almost the same size as our eye

so here is the eyepiece and

so here is a typical telescope

so what is the difference that we see i showed you just now an objective of a microscope and now a telescope the basic difference we can see is we can see externally just by outside we could see is that there was an objective which was small a small objective lens now you have a slightly bigger objective lens and the ibis looks of course almost similar in that case but clearly the object lens which i showed you on the microscope was of smaller diameter otherwise they look similar now let us discuss the array diagram and try to understand more about the telescope

so come back to the discussion on the telescope

so object lens you can clearly see now i have showed a bigger lens here the objective and eyepiece is here of a small focal length whereas the objective is of a longer focal length and also a larger diameter parallel rays are coming from the object

so there are rays coming from the object there are also rays which are coming here but i have not shown them because just to avoid confusion i have chosen two rays because we can locate the position of the image by just having two rays one ray passing through the midpoint of the lens which goes undeviated here and the second ray which has passed which has come from the focal length you can see the focus focus is here

so the focus is somewhere here behind and this has come from the focus and therefore this must be rendered parallel after passing through the lens

so these two intersect here to where a real image a real inverted image is formed now the distance is very large therefore rays are almost parallel rays and therefore the image will be formed on the focal plane at the focus on the focal plane therefore the first thing that we see is and this image helps or this image acts as an object to get a magnified virtual image of the same by the eyepiece this functions as before the eyepiece functions as before that is it gives us a magnified image a virtual image of the object which is placed close to the focus of the eye in this case since the original since the actual real image inverted image is also formed at the focus of this lens that is the object lens we have f o and f e almost coinciding at the same position
 so that is why f e
 so this is the point where f e and f o are coinciding whereas focal length f o is larger f e is small
 so that we get a magnified virtual image the magnification is this would have been the angle subtended at the eye if the eye wire to be here without the telescope
 so if i were to be here if we were to observe the object directly alpha would have been the angle subtended but because of this arrangement now the angle subtended at the i is beta we can see here beta is the angle subtended at the i and therefore the angular magnification is beta divided by alpha that is the magnification beta divided by alpha beta is the angle because of the telescope and what is beta if you look at this diagram
 so beta here is h dash divided by f e
 so we can see that beta nearly equal to tan beta we are talking of extremely small angles that's why i put some numbers and showed you that alpha here is of the order of milli radians or 10 power minus 2 radians and therefore tan alpha is equal to alpha tan beta equal to beta holds good and therefore beta is equal to h dash here divided by f e the focal length of the eyepiece whereas alpha alpha here is equal to h dash divided by the focal length here
 so that is f o h dash divided by f o following convention because this is an inverted image of a erect object very far away it is minus h dash by f o we have used and there whereas this we have not used a minus h dash because this is whatever be the object the object itself is like this and therefore the image is also in the same direction there is no change of direction here we can see that the object was erect like this there is arrow pointing upwards the arrow was pointing upwards far away and the arrow is now pointing downwards
 so there is a inverted image which is formed whereas here it is in the same direction therefore h dash by f p by this which gives us minus f o by f e note that the angular magnification is equal to the magnitude is f o by f e therefore larger the focal length larger will be the angular magnification and smaller the ah focal length of the eyepiece larger will be the magnification but of course there is a limit for this smaller value because ah you we have already discussed why we cannot go below a certain value but f o can be made large if you have a small large focal length now magnification
 so exactly like this one can analyze one can simply take the first lens and look at this image formation then one can take the second lens and the compound effect is what the telescope forms compare the telescope and the microscope in the case of the microscope we had a fe which was small f o the object focal length was small and f e was here and the separation between f o and f e
 so let me keep the diagram just to recall
 so the separation
 so here is the ray diagram of the compound microscope just to recall
 so this is f o of and this is fv the points are well separated and the separation is called the tube length whereas in the case of a telescope f o and

f e coincide first difference between the two and the lens here has a large
focal length if you want to get a larger magnification magnification is just one
of the issues in the case of a telescope magnification is just one of the issues
there are several other important issues
 so a telescope a telescope telescope which is used to observe a distant object
which appears very small
 so magnification is required
 so magnification is an issue magnification however since the object is at a
very far away distance which subtends a very small angle at the eye to observe
an object which is very far away we should also have sufficient amount of light
entering from the object that is if i can draw here
 so there is an object here like sun
 so it is giving out radiation in all directions in all directions that is into
four pi star radians here or the area the surface area of four pi r square all
around and the radiation which enters a small cone a small cone which is formed
on the observer here is very very small the fractional light entering this cone
of angle alpha which is of the order of 10 power minus 2 radian is very very
small a very small fraction of it enters this i therefore when the unless we
have a large aperture here larger the aperture that is if i have a larger lens
here then instead of a smaller lens then the amount of light which enters the
eye would be much more compared to the amount of light which would enter if i
had a smaller lens let me draw a smaller lens here
 so i have a small lens same parallel beams but the amount of light which enters
this small lens is much smaller compared to the amount of light which enters
here therefore if the light is insufficient it will be
 so weak that it would be difficult to observe the object even though it is
magnified the object may have been sufficiently magnified but the amount of
light which enters through the objective lens is
 so small that it would be very weak or may be indistinguishable from the
background and therefore magnification is one issue but the second important
issue is the light gathering power light gathering power or capacity light
gathering capacity
 so this will depend on the size or the diameter of the objective diameter of
the objective larger the diameter larger will be the amount of light which
enters the objective in forming the image now larger diameter of the objective
makes it very heavy because the lens is made of glass and therefore this becomes
very heavy this implies it becomes very heavy very heavy and fabricating and
 so fabrication of such lens
 so difficult fabrication becomes difficult
 so i am just highlighting the points practical aspects fabrication becomes
difficult people have fabricated lenses of one meter diameter but it is
extremely difficult to fabrication become to fabricate such large lenses this is
very heavy
 so fabrication and supporting support supporting also be supporting this in the
tube
 so in the tube the tube has to hold the lens
 so supporting the tube supporting the lens in the tube in the telescope tube in
the telescope becomes becomes difficult difficult
 so what is the solution
 so it was proposed that instead of using a lens
 so instead of using a lens lens one may use a mirror a concave mirror
 so going over from lens to mirror that
 so how is that possible
 so the same configuration

so let me draw this diagram here

so we have parallel right coming from a distant object like this we have a large concave mirror a large concave mirror

so light is i am not showing on the other side which then focuses the if the focus is here lets say the focal point is here then the rays will form an inverted image at the focus

so at the focus an inverted image will be formed

so let me link just to make it clear

so these are the rays which form an inverted image just as in the case of the lens now but in front of the mirror in front of this mirror

so we have achieved a small inverted image of the distant object at the focus or on the focal plane of this concave mirror but because it is a mirror one can fabricate such a mirror by having different several pieces making into one mirror huge mirrors of the order of diameter dia of the order of diameter of the order of 5 meter to 10 meter have been fabricate 10 meter dia of the mirrors 5 meter to 10 meter have been fabricate you can have different segments pieces of the mirror which can be put together and second holding this can be held with a huge a metallic steel beam or something like this i am just showing some typical way it could be held

so this is a base and a metal support which is holding the mirror because now you can hold it everywhere if you had a lens if we have a lens and because the image is formed in the transmission you have to hold it only at the edges otherwise you will obstruct the lens

so holding only at the edges of a huge and heavy lens is extremely difficult but here is a mirror a concave mirror which can be held by providing steel or metallic support all over the mirror and mounting over huge supporting structures but the difficulty is in this case is that in this case the image was formed somewhere on the other side here

so the image was formed here and therefore you could have kept a eyepiece here to get the magnified image virtual image of this object but in this case this has to be observed

so the observer has to sit here

so we have to keep an eye piece here such that it is at but within the focal length of this

so that a magnified image can be seen a formation of a magnified image can be obtained here the problem is the lens has and the observer the observer i am showing just his eye

so the observers i here

so this is the eye of the observer has to be on the same path because the parallel rays are coming from everywhere from a far away distance

so these people are also the person observer and the lens are blocking are blocking the part of the light which is entering which is incident on the mirror however it is possible to have some other configurations wherein the image can be formed in the forward direction for example one of the configurations which is used

so before i proceed

so this kind of a telescope is called reflecting telescope reflecting telescope

so a reflecting telescope reflecting telescope is one where the objective is a concave mirror a reflecting mirror instead of the of lens which we have used as an objective earlier whereas the telescope that which we had seen earlier where lens is used as the objective here is called a refracting telescope

so a refracting telescope

so reflective

so telescopes telescope the principle is the same

so telescope can be reflecting or refracting

so this is refracting telescope refracting type refracting type which uses a lens an objective which is a biconvex lens whereas it could be reflective type reflective type where the first image the real inverted image is formed by a mirror using a mirror

so this using a mirror whereas usually a concave mirror and this uses a lens as the objective lens for objective this is the primary difference between a reflective type of telescope and a refracting type of telescope

so this is the object this forms subject the second part of the magnification process is identical that is you have a lens

so whether it is a reflecting type a refracting type where you have the object which is then viewed the virtual image is formed on the eyepiece here whereas in the case of a reflecting type of telescope the real image is then viewed through an eyepiece to get a virtual image a magnified virtual image

so these are the two types of telescopes reflecting type and reflective type of telescope finally we have one more type of telescope which is called terrestrial telescope terrestrial telescope i will briefly describe this terrestrial telescope the telescope that we had

so terrestrial telescope and astronomical telescope if you see in some of the books is written that astronomical telescope astronomical astronomical telescope astronomical telescope is a telescope used to observe celestial bodies celestial bodies such as sun moon stars here since they are usually in the form of spherically symmetric it does not matter whether you see the object inverted or it will always for example if you see sun like this or inverted it will look identical and therefore it does not matter even if you see the image as an inverted image therefore in astronomical telescope which is the telescope which is the normal telescope which i have just showed

so the normal telescope where you see an inverted magnified image here of the body of the object of the object which is far away arrow we have used only for our convenience but a celestial body like sun or moon or planets they do not have they are spherically symmetric and therefore therefore it does not matter whether it is inverted or not however a terrestrial telescope which is used to observe terrains or distant terrains terrain terrains or landscapes or objects which are on the earth but very far off which you want to see clearly for example using binoculars ah then you would not like to see an inverted image you would like to see an erect image and then we use what is called as a terrestrial telescope the principle is the same except that now we have

so we had an object lens here

so i am drawing it quickly which formed an image here a small inverted image of a distant object

so there is a distant object which formed a small image here inverted image now we use one more lens one more lens to invert this image

so this is placed at

so this separation here

so if we place a l a lens inside the telescope such that the image is formed at a distance to f from this lens to f f is the focal length of this lens here the in between length at a distance to f then you will see an inverted image inverted image of this which means erect image of the distant object erect image at a distance to f

so two f is the object distance here and two f is the image distance and magnification is just one because magnification is v by u

so it is two f by two f but magnification is minus one which means if the original object is like this we will get an inverted object image which is the erect image of the distant object now you use the eyepiece

so we use the eyepiece here

so this is the eyepiece such that it is at the focus of this to get a virtual image

so we have a virtual image formed i am drawing right in front without any scale

so we see that a virtual image is formed at a distance

so i have simply these are the actual rays ray paths actual ray paths but they appear to come from a point here

so this is the original eyepiece

so this is eyepiece this is the objective as before

so only thing that we have added is a lens here such that the original image is formed

so this distance now

so we have this distance if you recall the image is formed at f o and this is f e this is f e in an astronomical telescope the total separation the separation between the two lengths is l is equal to let me call it as l is equal to f o plus f e but in the case of a terrestrial telescope we have l

so this is astronomical this is length of the terrestrial telescope is f o plus two f plus two f

so four f four f plus f this is the primary difference between an astronomical telescope and a terrestrial telescope

so this let me write the title what i have discussed is a terrestrial telescope terrestrial telescope terrestrial telescope

so just to wind up therefore we have discussed refracting type of telescope reflective type of telescope astronomical telescope and terrestrial telescope

so in the case of an astronomical telescope that separation between the the distance between the objective and the eyepiece is f o plus f e whereas in the case of a terrestrial telescope we have to use an additional lens to re invert the image to get a erect image of the object

so that there is an additional distance of 4 f where f is the focal length of the lens which is introduced in between thanks you