good morning to all of you we will continue with our discussion on electrostatics in the last class i introduced the concept of a dipole and we were calculating the electric field of a dipole at certain positions and

so let me recall a dipole consists of

so this is an electric dipole it consists of a negative charge minus q and a plus q separated by a distance which i am calling two a

so this is a dipole two equal charges one minus q one plus q separated by a certain distance two a note that the total charge of the system is zero but as we saw last time in spite of this fact it still produces an electric field because the two charges plus and minus are displaced with respect to each other

so in the last class we calculated the electric field at a certain distance x from the center of the dipoles and we showed that e is equal to p by two pi epsilon zero x cube into i cap

so this is the x axis ah sorry this is what i cap here

so p was defined as q times two a times i

so the charge multiplied by the separation between the target charges and its a direction from minus charge to the plus charge that is the definition for this quantity p which is called the dipole moment dipole moment is a characteristic of the dipole itself it depends on the charges and it depends on the separation between the two charges

so q times two a is the magnitude of the dipole moment and the direction of the dipole moment is along ah the line joining minus charge to the plus charge

so one thing to notice here is that the electric field decreases as one by cube of the distance from the center of the dipole to this point on the axis compare this with electric field of a point charge the electric field of a point charge reduces as 1 by square of distance this is reducing as 1 by cube of distance

so that's along the axis we have got a simplified expression and this expression is valid for large separation that means x must be much greater than two a we can now calculate also through a simple ah calculation the electric field on the equatorial plane

so this is plus q

so minus q here plus q here

so this is the x axis and this is the y axis and

so i take a point here point p at which i want to calculate the electric field

so remember this particular charge will produce an electric field in this direction this particular charge will produce an electric field in this direction

so the electric field is directed towards the negative charge because of the negative charge and away from the positive charge for a positive charge and this is on the equatorial plane here

so let me assume this distance is y and

so let me draw a horizontal line here and this angle i call theta which is the same as this angle and this distance is a

so what is the electric field produced by the plus charge

so let me write e plus q one by four pi epsilon zero q by distance square

so let me call this r

so r square and it is along this direction

so this direction has two components one along the x axis and one along the y axis

so let me draw this here

so here is my y axis here the electric field goes like this because of the positive charge and this angle i am calling theta and this is my x axis

so x component is minus cos theta i cap and y component is sine theta

so sin theta j cap the electric field because of this plus charge at this point

has two components along the x axis and along the y axis which i am given by minus cos theta i cap plus sin theta j cap similarly the electric field because of the minus two charge is one by four pi epsilon zero q by r square again this distance is also r because i am taking the point p on the equatorial plane and then this now this angle is also theta
 so i will have again minus cos theta i cap and then i will i have now y component is negative
 so minus sin theta j cap
 so the electric field of the minus charge is along this direction the electric field of the plus charge is along this direction
 so i can calculate the total electric field at the point p which is given by e is equal to e because of plus q plus e because of minus q which is equal to one by four pi epsilon zero q by r square
 so i had minus 2 cos theta i cap the j cap component cancels off and i am left with an i cap component only which is minus 2 cos theta now i want to express theta in terms of the distances
 so if you go back to this figure and see this is theta
 so cos theta is equal to a by r
 so i have essentially e is equal to one by four pi epsilon zero q by r square minus two cos theta is a by r into i cap
 so this is equal to q by ah four pi epsilon zero
 so two a with a minus sign here i and r cube and this is nothing but minus p by four pi epsilon zero r cube now r is the distance from the positive charge to the point where i am calculating or is also the distance from the minus charge
 so i can express r in terms of a and y
 so i get the following expression r square is equal to a square plus y square
 so e total becomes minus p by four pi epsilon zero ah a square plus y square is to the power three by two it is r cube
 so i have a square plus y square square three by two
 so if y is much much greater than a then e becomes equal to minus p by four pi epsilon zero into y cube
 so you see here again that the electric field produced by the dipole on it the equatorial plane is also varying as one by y cube where y is the distance of this point from the centre of the dipole just like for the extra x dependence the rate was one by x cube here it is one by y cube and the directional electric field is along the minus p direction this is also obvious from here because if i plot the figure here now minus q plus q
 so on the equatorial plane somewhere here this plus charge produces a field like this the minus charge produces a field like this
 so the net field actually is in this direction the y components cancel x components add and you know that p vector is like this mind from minus to plus and the electric field is like this in this direction
 so that is a minus p cap direction minus p vector direction
 so that is the electric field along the equatorial plane and electric field along the axis varied as one by x cube in in principle i can calculate the electric field at any other point simply by writing the total electric field as a sum of the electric field because of plus q and minus q and you can always calculate but here in this in this course you will just calculate along these two ah directions which we are where we get simplified expressions
 so i must mention here again that these expressions we have got are for distances much larger than the size of the dipole now it is possible to define what is called as a point dipole by letting the separation between the two charges become smaller and smaller that is a tends to zero a can be tending to zero and the same time q tends to infinity

so that q times two a is a constant this becomes a constant p and that is called a point dipole the separation between the two charges is very small smaller and smaller at the same time the charge is increasing
 so that you have a very small dipole and that's like a point dipole
 so why are we discussing dipoles i will show you some physical significance of these dipoles
 so let me show you some slides ok
 so here is a slide which shows ah where the dipoles appear in a in actual system on the left of the figure i have shown a neutral atom consisting of a positively charged nucleus which is shown as the dark sphere and surrounded by a cloud of electrons the electrons form a a cloud around the nucleus and usually the center of the positive charge and the center of the negative charge coincide at the center of the entire system and
 so the dipole moment of this is zero there is no dipole the total charge is also zero and this is this is typical atom when the in the absence of any external electric field now what happens when i apply an external electric field suppose i put this atom inside a capacitor which contains two plates where there is a very strong electric field then the electric field suppose as shown in the second figure the electric field is pointing upward
 so what happens is the electric field pointing upward ah pull pulls the electron down electron cloud downwards and shifts the position of the center of the negative charge with respect to positive charge
 so you have a small shift between the negative center and the positive centre forming a small dipole
 so the presence of the electric field converts the atom which had this centers of the positive negative charges coinciding into a dipole and this dipole then creates its own electric field
 so the electric field created by the dipole adds to the electric field that you have supplied from outside to calc to get the total electric field
 so we will come to this picture again little later when we discuss dielectrics because dielectrics and insulators consist of atoms and when they are put in the electric fields then you you displace the negative and positive centers of each of the atoms in the dielectric resulting in a certain effect which we will discuss later as a very interesting molecule which has a very strong dipole moment this is water molecule water is h two o it consists of two hydrogen atoms and one oxygen atom and the bonds are formed such that as drawn in the figure there is an angle of about 105 degrees between the h o axis of the two h o axis
 so what happens in this bond formation is electrons actually ah are more crowded towards the oxygen atom leaving the hydrogen atom as positive with the result that the center of the negative charge and the center of the positive charge of the whole system is separated resulting in a dipole moment
 so water is a molecule which has a dipole moment even in the absence of any external electric field like in the earlier example i showed an atom in which dipole gets generated when you are playing electric field here the dipoles are already formed in water the water is ah has a fine finite dipole moment and the dipole moment of water is given approximately here as six point one ten to the minus thirty coulomb meter now this particular dipole moment of water molecule has extremely profound consequences because of the strong dipole moment its an excellent solvent for ionic substances like salt if water molecule was not a dipole it would have been a poor solvent and what would have happened is all chemical and biochemical reactions would have been impossible
 so in fact we can say that our existence as living beings depends on these electric dipoles of water molecule and you may ask why don't the oxygen atoms and the hydrogen atoms stay along a straight line that is explained by the

quantum mechanics principle of quantum mechanics which explains why the molecule has this particular shape

so this is a very important molecule in ah in living systems and it has a permanent dipole it is called a polar molecule because it shows a dipole moment even in the absence of electric fields ok

so dipoles are very important and this is the reason why we started to look at electric fields of a dipole now let us also see what will happen if i keep this dipole in an external electric field

so let me assume that i have a dipole which i mark here as minus q and plus q this is the axis of the dipole let me assume that this dipole now on this dipole i apply an external electric field please remember this is the external electric field not the electric field of the dipole but the externally applied electric field i apply electric field from outside uniform electric field

so e is the same everywhere it is pointing upwards in the figure now what is going to happen this electric field is going to have a force on the minus q charge in this direction force will be minus q e and on this charge it will have a force in this direction q e two forces on the two points of the dipole equal magnitude

so net force becomes zero plus qe on this charge minus qe on this charge total force on the charge on the dipole system become zero but because the two forces are acting at two different points this will induce a torque in the system and we can actually calculate the amount of torque that this will force will generate

so i can calculate the torque by noting this distance

so if this angle is theta

so this this is the electric field actually

so theta is the angle between the dipole moment and the electric field direction which is being applied from outside

so this distance

so this distance i have called it two a

so this distance is two a sin theta two a cos theta sorry sir this is not theta sorry

so this is two a sin theta this angle is theta this angle is theta

so these are two opposite angles here theta and theta

so this is two a sin theta

so the net torque let me calculate is the force q e multiplied by two a sin theta the magnitude of the torque network magnitude now q into two a is the dipole moment

so p e sign into sin theta now if you look at the figure again here

so you had the minus q plus q this is p this is e and this is theta

so what is this product p cross e magnitude this is p e sin theta p cross e is p times e into sin theta the sine of the angle between these two

so the magnitude of the torque is nothing but p sin theta and what is the torque time to do this force is trying to pull it this time this force is trying to push it

so this torque is trying to align the dipole along the electric field

so this this charge will suppose this point is fixed around this point this two charges will move like this and align itself until theta becomes zero when theta becomes zero the net torque becomes zero

so this dipole is tending to rotate in this direction and this is the direction if i look at this vector in the upper direction that is the direction of right handed screw

so i can define the torque as a vector tau is equal to p cross e

so the net torque on the dipole is a cross product of the dipole moment and the

electric field the magnitude of this torque is p e sin theta and the direction is shown by this vector which is p cross c direction of p cross the vector
 so whenever you put a dipole in an electric field external uniform electric field if you put like this the positive charge tends to align like this and the negative charge and then when theta becomes finally zero the torque becomes zero and the dipole gets aligned like this now i will leave a problem to you please think of any other situation any other position when the torque can be zero again on the dipole please try to find out if there is any other position but and
 so in a uniform electric field there is no net force on the dipole but there is a net torque on the dipole
 so if you put electric field if you put a dipole with an inside uniform electric field that electric field will tend to align the dipoles such that p and d become parallel to each other now what will happen if the electric field is non uniform
 so non uniform electric field that means electric field depends on position now i do not want to discuss a general situation but a one particular situation where i will assume that there is a minus q here and there is a plus q here and this is aligned already
 so ah
 so this is the electric field
 so let me assume that electric field direction is this and let me assume that electric field is not uniform now
 so the electric field may be increasing with x if i call this x direction here or may be decreasing with it
 so electric field is different at different values of x now what is going to happen there will be a force here q e ah on this charge let me call e at minus q and this is q times e at plus q
 so this force is ah ok
 so this force is along the x direction this force is along the minus x direction
 so net force along x direction is equal to q times e at plus q minus e at minus q
 so this this force is trying to push it this time this force is trying to pull it
 so effectively the net force is the difference between these two
 so if e minus q is bigger than e plus q that means if there is a decrease of electric field like this this force will be negative which means that the dipole will be pulled in the minus x direction this is the force along the plus x direction
 so i have the dipole sitting here there is a force trying to push this there is a try force time to pull this
 so the net force on this will depend on this quantity
 so if my electric field is stronger on this side and gets weaker as i move up electric field at this point is more than electric field at this point the force on this is greater in this downward direction than the force on this
 so the resultant force will be in the downward direction
 so in a non uniform electric field what happens is the dipoles are pulled towards stronger electric fields because electric field is decreasing in this direction the electric field here is larger than electric field here the charges are exactly the same
 so the downward force is more than the upward force
 so the net force on this dipole is to pull it towards the larger electric field and it comes here this is exactly the reason why in the first experiment which i

showed you charged glass rod was picking up paper

so what happens is when you have a charged rod kept near a small object like a thin piece of paper then it induces the the positive charge on the on the glass rod induces a dipole in the material and because the electric field is stronger near the glass rod than away from the glass rod it pulls the dielectric towards the glass rod

so we will discuss a little later more discussion more more discussion on electric fields inside matter but for now this non uniform electric field actually results in a force on the dipole if you have a uniform energy field there is no net force there is only a torque on the dipole

so this will become important when we discuss ah more subjects more discussion on dielectrics etc a little later now before i move to further discussion on continuous charge systems etc i thought i will mention to you some very interesting facts which appear in nature okay i want to show you some very interesting effects that take place in biological systems with electric fields

so we as human beings have um essentially five primary sensors we can see over a certain spectrum of radiation from 400 nanometers to about 800 nanometers of light we can hear sound over a frequency from a few hertz to 20 kilo hertz we can smell we can taste and we can have a feeling of touch a sense of touch now nature produces many other signals for example there is radiation in the ultraviolet region there is radiation in infrared region there are electric fields and magnetic fields etcetera which we do not seem to be sensing but there are in nature many biological many natural systems which use some of these for sensing

so i will show you something here which is very interesting ah that electrostatics is playing a very important role in nature

so research has shown that flowers have a small negative charge on them and when bees are flying they are stroking their wings and this through friction gives them a small positive charge

so the bees have a small positive charge the flowers have a slight negative charge

so as the b flies towards the flower it senses this electric field because the electric field actually affects its hair on its on its body and that results in the b sensing the electric field

so when the b lands on the flower the pollens being negatively charged stick to the b and b carries the pollen and as we know this is helped this this helps the flower to pollinate and not only that when the bees when one bee has visited a flower the electric field of the flower after the bee leaves is slightly different from before and the bees which come afterwards are able to sense the change in the electric field and know that this particular flower has may be nest less nectar because this has already been visited by some b earlier there are we all have seen many spider webs the spider webs are covered by electrically conductive glue and it seems that whenever you have a charged particle crossing nearby it could be some charged particles like pollens or insects and then these webs actually get attracted towards the insect and catch the insect the webs also seem to distort the electric field of the earth over a small distance which can be sensed by many insects such as bees

so very interesting effects that take place in nature and i am sure all of you have heard about the very strong electric field some fishes use for their navigation or catching prey ah and one of the most famous one of them is the electric eel

so it actually produces different kinds of electric fields low voltage pulses to sense the environment extremely high voltages up to 600 volts to stun or kill the prey and

so depending on the requirement it either produces low voltage pulses for sensing or short sequence of pulses for hunting and finally a high voltage volley a string of high voltage pulses for captioning or different or different defending itself there are other animals like elephant elfmatinos fish which actually uses electric fields to navigate in murky waters sharks which are extremely sensitive to electric fields that they can detect voltage gradients of one one billionth of a volt and of course electric rays which also generate voltages ranging from a few volts to 220 volts

 so these are actually effects that we find in biological systems which are able to use electrostatics for their applications we as humans do not seem to possess real sensitivities towards these effects these electric fields and magnetic fields ok

 so what we have discussed till now is how to calculate the total electric field produced by a distribution of point charges we know the electric field produced by each point charge through coulomb's law and then we actually use the principle of superposition to calculate the total electric field if you are given a distribution of point charges

 so we add the electric field produced by each point charge at that at a point where we want to calculate and add vectorially and get the total electric field now there are many situations where we would like to look at what are called as continuous charge distributions

 so there are three types of charge distributions one is called volume charge density this is usually written as rho and has units of coulombs per meter cube then you have surface charge density usually written as sigma coulombs per meter square and then you have line charge density usually written as lambda coulomb per meter this is rho sigma and lambda

 so these are the volume charge density is the charge per unit volume surface charge density is charged per unit area and line charge density is the charge per unit length now these are three greek letters you will come across many of these greek letters in your courses in physics chemistry mathematics etcetera

 so it may be interesting for you to know that there are actually 24 greek alphabets

 so these are alpha beta gamma delta epsilon zeta eta theta iota kappa lambda mu nu psi omicron pi rho sigma tau epsilon phi chi psi omega there are 24 greek alphabets and you will find this use of these in many many situations we have already seen epsilon zero we will now come across lambda which is the charge per unit length will come across sigma charge per unit area and rho which is the charge per unit volume and you will see many other of these theta is an angle that we typically use delta is used in differential calculus etcetera etcetera

 so we will come across many of these symbols its worthwhile for you to remember these symbols and be able to write them freely and nicely in your class notes ok

 so how do i define these various charge distributions

 so first is volume charge density this is defined as per unit volume

 so let me take an example i have a sphere in which a charge of capital q the sphere is of radius r charge of capital q is distributed uniformly throughout the volume of the sphere its like having uniform distribution of mass in a sphere

 so the here is the charge is another characteristic of a particle

 so i have charge distributed uniformly i take a small unit volume inside and i can define this is the charge per unit volume and it has units of coulomb per meter cube now we must remember the charge is actually quantized and they are charges distributed like particle charges

 so the volume that we need to take is large compared to the separation between these charges but small compared to the size macroscopic size of an object and

so the charge it is like mass per unit volume that we that we define density where you take a small volume a small small infinitesimal volume containing a large number of molecules but that volume must be small compared to the macroscopic size

so you take a small volume say delta v and calculate the charge in that volume delta v and that charge comes out to be delta q

so you define rho as delta q by delta v in the limit of delta v tending to zero

so you have a charge per unit volume

so we will later on calculate what is the electric field produced by such a distribution of charges ah after we discuss certain new concepts in electrostatics

so that is how we define the volume charge density which is charge per unit volume now i come to surface charge now to explain surface charge density let me take the following situation let me assume that i have a thin thin sheet of thickness d its a its a huge surface that

so let me take in this an area a let me assume that in this volume the charge density is rho starts per unit volume in this small it's a small thin layer of material it has charge distributed across the volume and rho is this volume charge density inside this material

so the charge contained in this in this volume which i have drawn here which is equal to the volume of this material which is the surface area multiplied by the thickness this is the volume into rho this is the volume of the material and this is the volume charge density

so that the charge contained now i write this like this a times rho into d now what i do is i let the thickness of this surface tend to zero and at the same time increase rho to infinity such that rho times d is a constant and this is called sigma

so in the limit of thickness d going to zero i would just have a sheet having a certain charge i am letting the thickness go to zero simultaneously letting the charge density go to infinity

so that the product of charge density into thickness becomes a constant sigma and

so this becomes a times sigma

so i will have sigma is equal to q by a which is charge per unit area remember q was the charge within this volume as i let my thickness go to zero the charge is in that area and

so i define the charge per unit area as sigma and

so this is the charge which is supposed to be on one surface all the charge start sitting on the surface and i have obtained this as a limiting process of a volume charge density i can similarly define a line charge density by considering the following

so i take a a cylinder of cross sectional area a and in this cylinder i take a length l and let me assume again i have a volume charge density rho

so the charge contained within this volume of cross sectional area a and length l

so what is the volume of this volume is equal to a times l this surface area multiplied by the length is the volume

so and the charge density is rho

so total charge q is equal to rho times a times l

so ah

so i write this as rho times a into l now what i do is i decrease the area of this cylinder towards zero a tending to zero row tending to infinity

so that rho times a becomes a constant which i call lambda

so i am letting the thickness the the the cylinder area cross section go to

zero simultaneously increasing the charge density
 so that this product remains a constant lambda and then i get the charge contained in this length l is lambda times l and
 so i get lambda is charge per unit length
 so this is called a line charge its a line and you know line has no thickness
 so the line is just one line in which it has no thickness and the charge i can define the charge
 so i take a unit length of this of this line and i will find a charge is equal to lambda
 so what i have done is i have shown you that starting from volume charge density i can define a surface charge density by having a certain thin surface thin sheet and allowing the thickness of the sheet to go to zero at the same time letting the surf the charge density go to infinity volume charges equal to infinity with the result that i land up with a single sheet of charge which is called surface charge density which is called sigma and then i showed you through a cylinder that i can make the area of the cross sectional cylinder core to zero and the charge density rho to infinity
 so that the product remains a constant lambda and i get lambda as the charge per unit length
 so there are three kinds of primary charges charge densities line charge density coulomb per meter surface charge density coulomb per meter square and volume charge density coulomb per meter cube
 so we will use these later on after we discuss some more of electrostatics we will calculate what is the electric field produced by a line charge density ah typical line charge density surface choice density and volume charge density
 so it will be interesting at that time to we will come back to these charge densities i have just introduced them here
 so in principle it is possible for example if i am given a line charge like this
 so line charge density lambda if i want to calculate the electric field at any point what i would have to do is to take a small element here and calculate the electric field because of this element at this point and add up all the elements on the line charge to get the total electric field here
 so i will later on i will use a very general principle which is which we will discuss after this ah after this preliminary discussion on charge densities and i will show you how to calculate the electric field of this and at that time we will come back to this method and will compare the two methods and i will show you that that method is much more powerful than this method ok
 so so till now what we have seen is essentially a calculation of electric fields we have seen electric field lines we have calculated the electric field your dipole due to dipole and
 so on now we want i want to introduce an alternative discussion of calculation of electric fields the question is given a charge distribution i have been able to calculate electric field given the electric field can i calculate the charge distribution
 so this particular question was answered by a very famous scientist call call friedrich gauss a german scientist who lived in the year 1777 to 1855 he is a great scientist who has contributed to many fields including mathematics astronomy optics literature and magnetism statistics and surveying geodesy he is considered as one of the greatest mathematicians of all times in fact at the age of 18 gauss discovered how to construct a 17 sided polygon using only a ruler and a compass that was an amazing discovery at that time and after that he has contributed significantly to the development of these many fields which i just now mentioned

so what we will do is he introduced a very very important law in electrostatics called gauss's law which relates electric fields and charges charge distributions and which will be very useful for us when we discuss ah electric fields produced by different kinds of charge distributions now before i discuss gauss's law we would need to introduce certain concepts in mathematics which i will very briefly introduce here now we know that angles in a plane are measured in radians

so how do you measure an angle in radians

so what we draw what we do is we take this point draw a circle around this point of radius r this cuts an arc length l on the circle

so we define the angle theta in radians as l by r this distance divided by this distance is the angle in radians

so if you take a there is there is no requirement on r if you take a bigger circle or bigger radius l will also correspondingly increase

so this angle will be independent of the radius you have chosen

so you take a certain around this point you draw a circle of radius r calculate the arc length subtended which is intersected by these lines this chords and you from there you can calculate what is the angle in radians

so if you take the entire circle we know that the if you if you take a point and the entire circle l becomes equal to two pi r and the entire angle is two pi

so two pi radians all of you know the two pi radians in the entire circle this is pi by 2 radians etcetera etcetera

so this is a one of the very interesting definitions of angles here and this is in a plane now i want to introduce an angle for not a plane but in three dimensions

so we define what is called as a solid angle

so suppose i have a point here i draw a sphere around this point sphere of radius r and if you draw a cone around this from this point onto the sphere it intersects the sphere in a certain radius is it in a certain area say s this is the area

so i was i have a sphere and i i i draw a cone here

so that's a cone and the cone comes out from the center and intercepts the sphere on an area

so i will define this angle this solid angle as s by r square the area intercepted by this cone on the sphere divided by the square of the distance you see it's dimensionless here

so you have s is area which has units which is dimensions of square of length that's square of length

so that's s by r square that's called the solid angle

so you can actually define solid angles of surfaces subtended at some point

so if i want to define the solid angle subtended by the sun on the earth what i do is i calculate what is the

so i in principle i have to imagine a sphere of radius equal to the distance from here to the sun drawn the sun will intersect the sphere in a certain area which is the area of the sun and i will calculate what is the solid angle subtended by the sun on my eye here that will give me the solid angle of the sun similarly i can calculate the solid angle subtended by the moon

so for example the solid angle solid angle subtended by the sun on earth is approximately six point eight into ten to the minus five and there is a unit called star radiance it is a unit of solid angle radian is the angle for is a unit of angle stereo cyridine is a unit of solid angle

so the sun subtends a solid angle of six point eight to the minus five the solid angle by supplemented by moon on earth is approximately six point seven into ten to the minus five almost equal the sun is much bigger than the moon but

it is also much farther away

so for the sun the area is much bigger in this figure if i see the area of the sun is much bigger but r is also much bigger

so s by r square is the solid angle subtended by the sun on the earth

so this is the point on the earth i am sitting on the earth here and i am looking at the sun the sun subtends a solid angle of s by r square the moon is somewhere here much closer its area is much smaller but is much closer to me and it subtends the same solid angle now actually the two solid angles are almost equal and that is the reason why you can form complete solar eclipse

so the sun the moon can completely block the sun because if you look in the direction the solid angle subtended by the sun and the moon are exactly the same towards you almost the same

so this the moon can completely cover the sun now i leave a small problem to you

so what is the

so i want to hold the sheet of paper a small circular sheet of paper at a distance of 25 centimeters from my eyes what is the radius of the circular piece of paper required to just block the moon that means i am looking at the moon

so i must have a small

so my eyes are here

so i must hold a small piece of paper here

so that the moon is covered

so the the the remove gets completely covered by this small sheet of paper

so i leave this problem to you just try to estimate and at night if you have some time just go out and look at the small piece of paper and look at the moon and you will see that you can actually completely block the moon by a small sheet of paper

so this is the solid angle

so you define the solid angle as the ratio of the area intercepted by this cone on a sphere of radius r divided by the square of the distance of that from the point of observation here and that defines the solid angle now just like as we discussed for the sun and the moon if you take if you take two spheres say for example one sphere of this size another sphere which is bigger in size around this point and if you draw a cone

so here they will intersect at a certain area here they will intersect in a different area

so let me assume this is r one this is r two let me call this s one this is s two various because both of them subtend the same solid angle d ah d omega the solid angle here

so let me call the solid angle as d omega please remember this is small omega this is capital omega is equal to s one by r one square which is also equal to s two by r two square areas s one and s two are different this could be the moon this could be the sun areas are different distances are different but both of them subtend the same solid angle now let me imagine that i have a point charge located at this point we have already seen earlier electric field lines

so i if it is a positive charge these field lines are coming out radially away from the point charge

so let me draw more lines here positive charge electric field lines are coming out

so i draw a sphere around this and i draw another sphere notice two things the number of lines crossing this inner sphere is the same as the number of lines crossing the outer sphere these lines do not represent anything flowing please remember these lines represent electric field lines they are only direction showing directions of electric field if the lines are closer together like at

the towards the center the electric field is larger if you move further away the electric field lines get separated out and the electric field decreases the number of lines crossing the inner sphere and outer sphere are the same
 so now let me take ah let me take the lines which are appearing between two areas here
 so let me assume the as before the inner circle of radius r one and outer circle of radius r two
 so how many lines
 so the number of lines crossing this area and the number of lines crossing this area are the same because these lines do not intersect and all those lines which are starting from here if i draw more lines here there are certain number of lines crossing the area here they will all be crossing the same this area also because both of them subtend the same solid angle here
 so the area is increasing
 so the area of this this this area is increasing because d omega the solid angle here is s one by r one square is equal to s two by r two square
 so the area is increasing as one by
 so area s one is equal to r one square into the solid angle d omega s two is is equal to r two square times the same d omega
 so as you can see here the area covered by this the same solid angle on the inner sphere and outer sphere are different and it is in the ratio of the radius
 so s one to s two is essentially r one square by r two square and i also know that the same number of lines are crossing this area s one and the area is two and as i mentioned the spacing between the lines represents something like the electric field
 so what happens is because the number of lines crossing is the same and the area is increasing as square of the distance the electric field must be dropping as one by square over distance which is nothing but the from the coulomb's law
 so electric field here and here has a ratio depending on the distance square area
 so area increases the square of distance electric field decreases as square of the distance with the result that the number of lines crossing here and number of lines crossing here are exactly the same
 so in the next lecture i will introduce the concept of flux electric electrostatic flux and we will then discuss the very important law in electrostatics called gauss's law which will relate electric field to the charge and it will be very useful uh is a very useful technique to calculate electric fields for given charge distributions or calculate the charge distribution for given electric field
 so we will do this in the next class thank you very much you