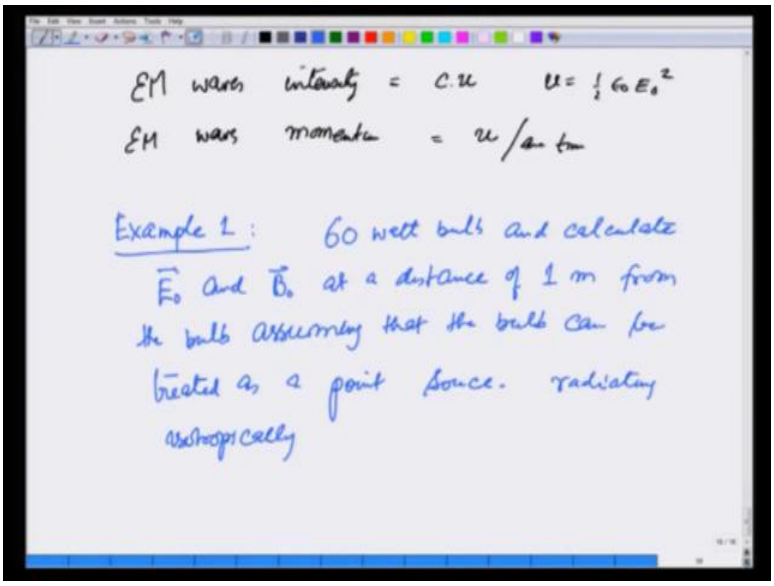
Introduction to Electromagnetism
Prof. Manoj K. Harbola
Department of Physics
Indian Institute of Technology, Kanpur

Module - 07
Lecture - 61
Energy and momentum carried by electromagnetic waves – examples

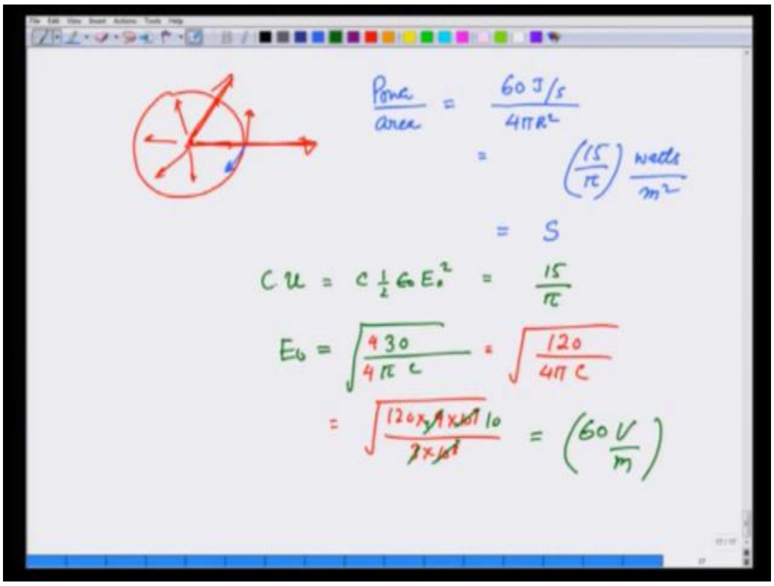
(Refer Slide Time: 00:12)



In the previous nature we saw that e m waves have any intensity which is equal to c times average energy density u which is one half epsilon 0 e 0 the amplitude square and e m waves also carry momentum which is equal to u percent unit area percent unit time and as a result they can apply a pressure they can carry a energy and give you heat. Now, in this lecture I am going to solve 2 examples to give you an idea what the kind of electromagnetic fields etcetera are related with. Electromagnetic radiation coming out of ordinary light or also what kinds of pressure do they apply. So, this lecture is essentially about numbers.

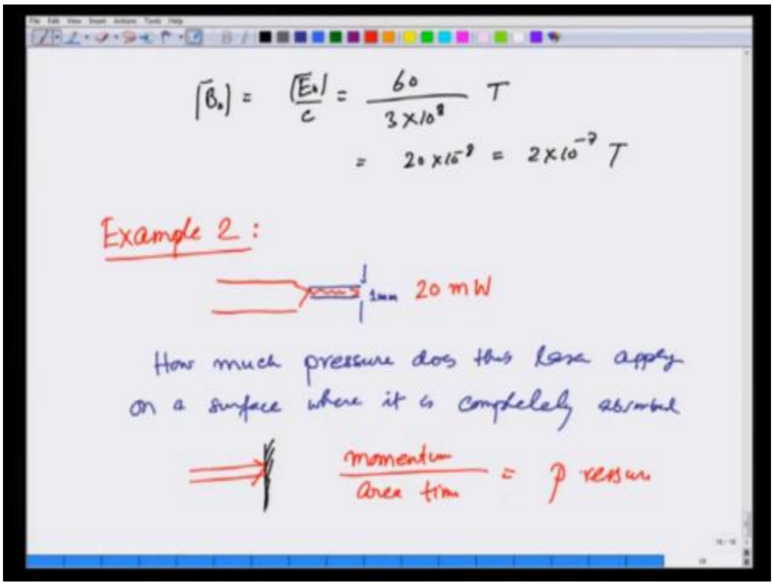
As example one now let us take a sixty watt bulb, that means light coming up out is equivalent to power being sixty watt and calculate electric field amplitude and magnetic field amplitude at a distance of one metre form the bulb under the assumption that a bulb can be treated as a point source. I am taking this bulb to be a point source which is radiating isotropic ally. That means, there is no particular direction in which radiates. So, what I have is a bulb here which is giving out radiation in all the direction and we want to see at one meter what the associated electric field is. So, all these electromagnetic waves are propagating in the radial direction.

(Refer Slide Time: 02:25)



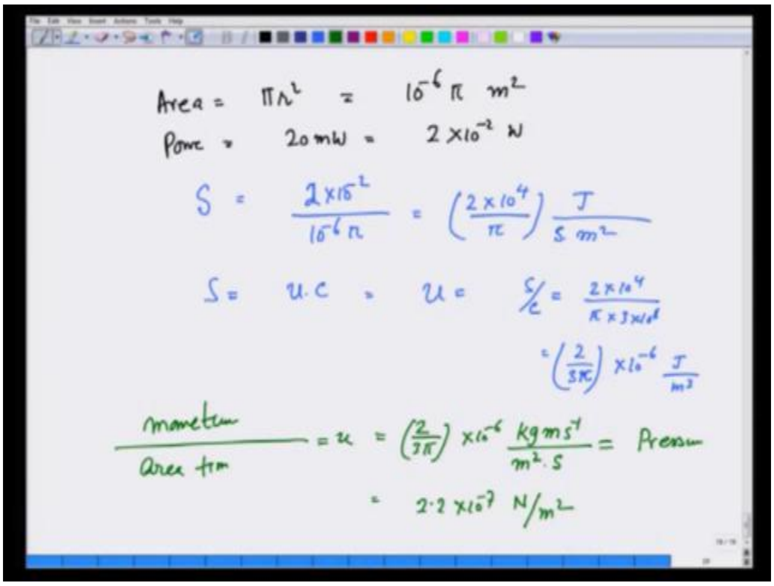
Let us look at one particular direction going to the right electric field is going to be perpendicular to that and so is going to be magnetic field. The power carried per unit area and in this case is going to be sixty jouls percent second divided by four pi r square r we have taken to be one meter. So, this is fifteen over pi watts percent meter square that is the power and what is this power per unit area or energy per unit area per unit time. This is preciously equal to the pointing vector. And therefore, what we have this c u which is c times half epsilon 0 e 0 square is equal to fifteen over pi and I want to calculate e 0. E 0 therefore, is going to be equal to thirty over pi c square root. Let's multiply to ease the calculation less multiply by 4 multiply by 4. So, this square root of hundred and twenty over four pi c which is equal to square root of 129 raise to 9 divided by 3 times 10 raise to 8t this gives me ten this gives me 3. So, this is 3600 which gives me 60 volts percent meter. Imagine this if you are standing one meter form a 60 watt bulb at a distance of 1 metre form it you have an electric field related to that radiation coming out of the bulb as 60 volts per meter over one metre that is volt difference is going to be 60 volts that is the how much the electric field is. Further away you go the power spreads over a larger area and therefore, electric field is going to go down. How about the corresponding magnetic field? The magnetic field magnitude is nothing, but e 0 over c.

(Refer Slide Time: 04:52)



So, this is going to be 60 over 3 time 10 raise to 8 Tesla which is 20 times 10 raise to minus 8 which is 2 times 10 raise to minus 7 Tesla. So, associated magnetic field is really very, very small. As example 2 I am going to talk about a laser pointer which is giving out laser light. And let us say this typical laser point that we see in the lab, in the auditorium. Let us say this is of power 20 mini watt a 20 mini watt power is coming out and since laser light is go as a beam let us say the radios of this beam is one millimetre. Therefore, what you want to know is, how much pressure does this laser apply on a surface, where it is completely absorbed. So, what we are seeing is I have a surface on which the laser beam which is coming gets absorbed completely. The pressure comes because of the momentum transferred per unit area per unit time is equal to the pressure.

(Refer Slide Time: 06:44)



We have a area is equal to pi r square which is ten raise to minus 6 pi metre square. We have power which is equal to 20 milli watt or 2 times 10 raise minus 2 watts and therefore, the s or the pointing vector is going to be 2 times 10 raise to minus 2 divided 10 raise to minus 6 pi which is 2 times 10 raise to 4 over pi joules per second meter square that is S. S is equal to u time c where u is the energy density and therefore, u is equal to s over c which is equal to 2 times ten raise to 4 over pi times 3 times 10 raise to eight which is 2 over 3 pi times ten raise to minus 6 joules per metre cube. How much the momentum carried? Momentum flow that means momentum across a surface per unit area per unit time is u which is 2 over 3 pi times 10 raise to minus 6. Now I can write it as momentum k g meter per second per unit area percent unit time and this is the moment on transfer and this is therefore, going to the pressure which comes out to be point 6 seven over 3 roughly point 2, 2 or 2 point 2 times ten raise to minus seven Newton's per metres square that is the answer.

So, what I have shown you to through this examples is that how much is roughly filled associated with radiation that we see in our lives and also how much is the pressure. You see that field are quite large in the order of 10 volts per metre and the pressure applied by light is very, very small of the order of ten raise to minus 6 or 10 raise to minus 7 Newton's per metres square.