now define an important quantity in this regard which is called as a latent heat which is what is written here
so will erase this part and this ah latent heat can be now discussed um
so ah it is also true that ah the amount of heat required depends on the nature of the substance or the type of material that you are putting or you are considering ok
so the definition of ah latent heat is it is the heat per kg that must be added must be added or removed or removed ah when a substance when a substance undergoes a phase change or change in phase from one to another ok and this latent heat is accompanied no change in temperature as we have seen
so is the ah per kg is a heat required per kg of the substance ah which is undergoing a phase change from one phase to another phase and as we have seen that it ah is accompanied by no change in temperature
so there are three kinds of latent heat which we can define one is called as the latent heat of melting
so we will talk about three kinds of ah latent heat for that let us remove this part for now
so the three kinds of latent heat one will call it as l m ah which is latent heat of melting but as i said that it is also called as latent heat of fusion ah
so this is latent heat of melting or fusion ah which is associated with melting of ice to water and number two is l v
so its latent heat of vaporization
so latent heat of vaporization and number three its ah latent heat of sublimation ok
so ah and the s i unit of ah latent heat is s i unit is joule per cage ok
so this is ah by and large the definition and kind of ah latent heat
so let us see some representative values for some known substances let us just talk about liquids for now you will get data for ah solids also
so let us talk about the latent heat of melting and the latent heat of vaporization for some of the known liquids
so we have material and let us call is the melting point melting point and let us call it t m ah and it is expressed in say degree centigrade ah now it's l m which is latent heat of melting in joule per kg ah and let's call also a let's also record the boiling point ah i am simply writing it as p t ah as point ah just to save some space here and this is again in degree centigrade and let us call it by t b and now l v ah again in joule per kg
so these are the parameters that we are using and let us write as ammonia whose melting point is minus 77.8 degree centigrade ah the value of l m that is the latent heat of melting or fusion is 33.2 into 10 to the power 4 its boiling point is 33.4 and it's 13.7 into 10 to the power 5 that's for ammonia which is known as
so your nh3 and now it's benzene and this is um 5.5 is the melting point this is 12.6 into ten to the power four ah this is eighty point one degree centigrade and its three point nine four into ten to the power five ah
so this is for benzene and for mercury ah this is minus 38.9 ah and it is 1.14 into 10 to the power 4 while mercury has a very large boiling point which is 356.6 ah degree centigrade and it's 2.96 into 10 to the power 5 and water this has a melting point as 0 0.0 uh and which is equal to a 33.5 into 10 to the power 4 and this is 100 degree centigrade and this is a 222.6 into 10 to the power 5 ah one interesting thing that you can note here is that the order of magnitude for lm and lv for all these four liquids that we have considered are ah same that is all our lm which is latent heat of melting is

of the order of ten to the power four ah and this is ten to the power five so this between ten to the power four and ten to the power five and this is between 10 to the power 5 and 10 to the power 6 while the melting point and the boiling points are very different such as the melting point of ammonia is minus 77.8 kelvin 8 degree centigrade whereas it's 33.4 degree centigrade and so on and for mercury the boiling point is very high and the melting point is below the freezing point of water but however the lv and lm have somewhat similar in ah dimensions or in in the order of magnitude now let me ah give you an example of the sublimation

so where a system directly gets converted from a solid phase to a gaseous phase now this is it is this one of the applications of a colored printer so you have seen color printer which has become very popular in office use and also sometimes in home use

so what happens is that there are mainly three colors that are there ah these so i am giving you an example of sublimation

so we consider this color printers ah the color printers primarily uses three colors which are cyan which is blue and yellow and magenta so they are kept in three different containers there and the printer head which is connected with a heating filament ah transports this colors in three steps one for each of the color from the container to the paper so this printer head has a heating element which directly converts the the pigments which is the colors in solid form to a gaseous form and there is a coating on the paper which absorbs this and makes a mark so all other colors that you see in a color print out are combinations of these colors

so the sublimation occurs when the printer head which has a heating filament directly converts the dye or the color in a solid form to a gaseous form which is later absorbed by the material of the paper and printing is done so now we ah we move on and talk about another interesting part of the thermal properties of matter which we call as a heat transfer so transfer of heat from one body to another body or transfer of heat from one body to its surrounding is what we are going to talk about when we take up this heat transfer for discussion

so now we will talk about heat transfer and this heat transfer is is an interesting component or rather ah subject in this thermal properties of matter and the transfer of heat takes place mainly in three ways one is called as a convection ah two is called as the conduction and 3 is called as the radiation and

so so what is let us start with this first one called as convection so you must have seen ah that fire is lighting and the fluid or the air around it what happens to it is that it gets heated up and hot air expands and because it expands the density goes down and it becomes lighter so lighter air just resides in the vicinity of fire now bernoulli's principle says that this should rise and the neighboring cooler air which is more dense should rush in to fill the void and now they come in contact with the fire and becomes warm expands becomes lighter move up and more air will coming and that's the way the there is a heat current that is set up and this heat current is called as a convection current and this process is called as convection ok

so a heat current is established which is known as convection current you must have seen that in television that there are fire in buildings and this black smoke that comes out and it rises into the air and it rises into the air because of this convection current or with because of this process of convection and there are a number of interesting different phenomena that

occurs due to the convective current of air that that is around us

so let us look at the second one or the second mode of heat transfer which is called as the conduction and um

so this conduction is a process whereby heat is transferred directly through a material um and

so is basically ah the transfer of heat from one material to another mediated by another material medium and this can be sort of understood in this particular fashion when you have two bars which are kept and they are connected by and there is a area of cross section that is there

so there are two bodies which are kept at different temperature let us call them as this one as hot at a temperature t one this one is cold at a temperature t two such that your t one is greater than t two and its connected by a material medium which has a cross sectional area let us call it as a

so a is the cross sectional area

so the ah heat that flows from the hot body to the cold body

so heat q is a proportional to the area of cross section ah it is proportional to the temperature difference between the cross section ah between the two ends of the of the rod and it is also proportional to the time for which the process takes place that is they are allowed to be in touch and its inversely proportional to the length of the the connecting medium and if we put everything together

so it becomes equal to q ah is a delta t t by l and we have to put a proportionality constant which is put by a capital k and k is known as thermal conductivity

so k is called as a thermal conductivity of the of the medium and it is expressed in joule per um meter per second centigrade or kelvin depending on ah you how you are expressing it there now let us try to do some problems here in order to gain more understanding on this thing and we have a problem which is from the book and this problem is stated as the following

so an iron bar is a problem on thermal conductivity and we are stating the problem to begin with an iron bar which is ah 0.1 meter long ah area is point zero two meter square ah and ah also the thermal conductivity we are all expressing it in terms of one for the iron

so k1 is equal to 79 now this is given in what per meter per kelvin and and the brass bar and the brass bar with the specifications as again as one meter and same area of cross section but with different thermal conductivity because we know that the material the thermal conductivity depends on the material 100 109 watt per meter inverse per kelvin um are soldered end to end soldered means they are joint end to end and

so this is the figure for that

so this is iron and this is brass ah this is kept at a temperature which is higher let us call it as temperature t 1 and this is kept at a temperature t 2 which is written here the free ends the free ends um of the iron bar of the iron bar and the brass bar on the brass bar are kept at the free ends of the the free ends of the iron bar and the brass bar are kept at kept at t one equal to three seventy three kelvin and p two equal to two 273 kelvin respectively

so now the question is twofold one is that obtain the temperature at the junction that is at this point let us call this point as o obtain the temperature of the junction let us call it as t o second part is that ah the equivalent thermal conductivity of the compound bar and the third question is ah the heat current obtain the equivalent thermal conductivity and obtain the heat current ah

so let us put this obtained here the heat current um through the

so the question is ah simple that we are talking about thermal conductivities of material

so we have an iron bar here whose free end is kept at a temperature 373 kelvin which is at t1 is soldered with a brass bar which the free end of which the right side of which is kept at a temperature t2 which is 273 kelvin the question is what is the temperature at the junction ah second question is that if i call this as one bar without really you know talking it has two bars if it is a compound bar what is the thermal conductivity of the compound bar and the third question is that ah what is the heat current that flows through the compound bar one understanding or assumption is that there is no heat loss otherwise

so thermal conductivity whatever heat gets conducted from the from one end that is the left end of the iron bar will actually flow through the heat current will same heat current will flow through the brass bar ok

so this is the question and the question is easy to solve ah just that we have to erase some part of the board in order to this problem let us try to do it as much as we can without doing that

so ah

so so we understand that there is a steady condition that is achieved that is heat will start flowing from the hot end to the cold end and the passage of heat will continue until a temperature equilibrium is established in the whole material and

so under that steady condition ah that heat that flows through the iron bar is equal to the heat that flows through the ah passes through the brass bar

so this is given by h1 which is equal to k1 1 t 1 minus t 0 that is the temperature difference

so this is at t 1 and this junction is at t 0 and this is l one and this is equal to a k two a two and t zero minus t two divided by l two now if you have a look at it ah l one and l two are same ah here both are equal to point one meter and similarly a one and a two are same which are ah both to be point zero two meter square

so we land up with ah

so just two

so a one equal to a two and l one equal to l two

so we land up with a simple equation which is ah k1

so this is equal to my h2

so h1 is the heat that passes ah from the iron rod and this is the that passes through the brass rod

so at thermal equilibrium they are same

so i get an equation which is k 1 ah t 1 minus t 0 equal to a k 2 t zero minus t two ah one can easily solve this to get ah t zero or a t o ah its at the junction ah

so t o equal to ah k 1 t 1 plus a k 2 t 2 divided by a k 1 plus k

so this is my temperature that at equilibrium will exist at the junction now since we have ah looked at the question one can raise the question for now and all the data are of course can be written here ok

so we have

so if you take it as a compound bar then my h which is equal to h 1 equal to h2 which is equal to my k1 a ah t1 minus t0 divided by l equal to a k2 a t 0 minus t 2 divided by l and

so this is my ah the heat flow now i can put in the t 0 that i have obtained in part 1 that is this thing and i will get a h which upon simplification will look like a a t 1 minus t 2 divided by l and one by k one plus one by k two

so thats the heat flow and
so this can be understood that if i now take this rod as a compound bar and write this formula simply as some k prime and a t 1 minus t 2 divided by l this is of course the heat flow per unit time the time has not entered into this consideration
so your k prime will now be written as if you compare between the two k prime is written as ah twice of k1 k2 divided by k1 plus k2
so that is the effective or the equivalent conductivity that exists for the compound bar now the third question the heat current has to be computed through the compound bar
so the heat current can be computed as the following
so the heat current through the compound bar is a k prime a and a t 1 minus t 2 divided by a 2 l and
so this is uh
so now we can put the value of k prime from part 2 and get the effective conductivity or effective heat current for the compound bar which is now t 1 minus t 2 divided by twice l
so that's the answer to the third part
so this is the heat conductivity calculation for a compound bar
so let us look at the third mode of heat transfer which is called as a radiation
so radiation is a process in which energy is transferred by ah means of by means of electromagnetic waves ah now the good thing about electromagnetic waves is that it does not require a material medium to propagate
so since it doesn't require a material medium radiation does not require a material medium for the heat to flow and
so and also that the radiation occurs very quickly with the speed of light and we know that speed of light is very large which is ah 3 into 10 to the power of 8 meter per second that's the speed of light
so the radiation occurs at a very fast rate and
so
basically this is how the the sun rays that come to the earth which ah most of which between the space between the sun and the earth there is no material medium and radiation emitted by a body by virtue of its temperature is called as a thermal radiation and these thermal radiation when it falls on another body it either is perfectly absorbed or it could be partially absorbed and partially reflected or it could be all reflected and this particular fact has an implications or an understanding on the kind of or the colour of the clothes that we wear in summer and winter in summer one would like to wear a light colored dress because you want a light colored dress which absorbs very little thermal radiation or heat and it reflects most of it while in winter we would like to wear dark colored clothes which absorbs a lot of thermal radiation and reflects very little in fact this is also the reason that the the bottom of the vessels are painted black in order for the heat to ah to be heated very quickly
so these are some of the interesting examples of radiation and there is one particular formula that i would like to mention here which is called as the stefan boltzmann law of radiation and what it says is that ah the radiant energy ah or radiant energy which is the thermal radiation ah q emitted in a time t ah by an object that has a temperature ah that has an absolute temperature temperature t a surface area a and an emissivity which is the emission power ah and an mcvt ah small e um
so this is given by ah q equal to e sigma t to the power 4 a and t and

this sigma is known as stefan bohlmann constant and this has a value which is 5.67 into 10 to the power minus 8 joule per second per meter square kelvin to the power 4 and this is often quoted as a 2 to the power 4 law where the radiant energy or the thermal energy due to radiation is proportional to the fourth power of the temperature expressed in absolute scale
so if we know the emissivity of a certain body you will hear about black bodies sun is a perfectly black body black bodies are will be talk to you and you know the emissivity etc the sigma is the stefan bolemann constant t is the temperature in absolute scale is the area of that which is exposed to the radiation and t is the time for which is exposed to radiation is given by this formula ah and it is called as a stephen boltzmann formula the next thing that we want to do is called as
so newton's law of cooling
so suppose ah we have taken a liquid ah in a container and say it's a thermos with which has a temperature or a thermometer that is inserted into the liquid and the liquid is at a certain temperature say at room temperature we have inserted the liquid into the container i inserted a thermometer
so as to note down the reading and now what we do is that we raise the temperature of the liquid by adding heat such that the temperature is raised beyond the room temperature say the room temperature is 27 degree centigrade and this container is taken in which we have this is the liquid that is there there is a thermometer which is kept with two
so this is a thermometer and there is also say a place for a stirrer to stir it gently
so you want to stir the liquid gently and it's initially at 27 degrees centigrade now it's put under flame and say the temperature of that goes up to 40 degree centigrade and you can consider the this container to be a thermos with a two hole lead there are two holes on the lead one is to insert the thermometer the other is to insert the stirrer and now what you can do is that you can now you remove the flame that is heat is no longer given after the temperature has attained 40 degree centigrade and you want to record the temperature after a fixed interval of time
so you can record the temperature after say 5 minutes of time or 10 minutes or 15 minutes depending upon how what you are interested in and what you want to know is that how the temperature is going down with time
so let's talk about delta t which is the difference in temperature
so you measure it at t equal to zero and then at five minutes at 10 minutes at 15 minutes and
so on and the temperatures that are found to be say t 0 t 1 t 2 d 3 and
so on and you want to note down a delta t which is equal to a t 0 t 1 minus t 0 or t 0 minus t 1 ah t 0 minus t 1 c 2 because you have heated up the substance and this is t 1 minus t 2.
so this is delta t 1 this is delta t 2 and
so on
so you want to record this delta t or the change in temperature with time and what one finds is that one finds a curve like that
so there are these data point that you get which fall on these ah this line and say this is in minutes ok
so ah what happens is that we want to ah this is called as newton's law of cooling and according to newton's law of cooling the heat loss
so this is newton's law of cooling which states that the heat loss of a body which is minus dq dt the minus sign represents that there is a loss
so this heat loss ah is directly proportional to the delta t or the temperature difference of the body and its surrounding okay

so this is the law

so one can write it as minus dq dt equal to some k delta t ah where k is some constant and let us now talk about a body of mass m

so

this substance a has mass m and specific heat c

so mass m and specific heat c

so specific heat capacity say c

so this body is at temperature ah t2 temperature of the body means the liquid or the substance that you are talking about temperature t two and ah say the t one is the temperature of the surrounding

so temperature of the body is t two t two and temperature of surrounding is t1

so if the temperature falls by a small amount dt2 in a certain time interval dt that is small t

so this body is this substance is here what we have referred to is of the substance here or the material and which are the mass m specific capacity c and the temperature is at t t2 which says 40 degree centigrade after being heated and the temperature of the surrounding is a room temperature which is t1 which is 27 degree centigrade and now this is left to cool which means that no more heat is applied

so according to ah newton's law of cooling we know that the heat current or the rate of change of heat is ah proportional to the temperature difference between the body and the surrounding ah now let us understand that in a certain time intervals small d t in time interval small d t i mean small d t means what i mean is this in time interval d t ah the temperature of the temperature of the body of the body falls by dt2 because t2 is the temperature of the body

so it falls by dt2 and

so then the heat that is involved here is equal to m c d t 2 and

so if i take if i divide by the time the small time interval

so this is equal to m c d t 2 by t and which is equal to dq dt now according to the law of cooling dq dt equal to

so this is equal to a minus ah k minus k and ah t 2 minus t 1 and

so i need to solve this i need to solve this in order to get a relationship ah which tells me that how as a function of time the temperature of the substance that is there falls and which finally would come to equilibrium thermal equilibrium if you wait for long enough and to validate this curve that is delta t versus the time curve

so in order to solve that let us let us solve this equation which now looks like a minus m c d t 2 d t which is equal to k t 2 minus t 1

so our d t 2 divided by t 2 minus t 1 equal to a minus k over m c d t which ah let us call it as a minus k capital k dt ah this ah capital k is another constant this is small k ah

so we can write it as you know in order to sort of eliminate any confusion let us write it as k 1 d t where k 1 equal to k over m c and this equation can be simply integrated and one will get a log base e t 2 minus t 1 equal to minus k 1 t plus some constant of integration and that will be t 2 ah when we take this log to the other side or take i mean exponentiate it it becomes t 1 plus sum c exponential minus k 1 t where this c prime is nothing but equal to exponential c okay

so this is the the temperature this the way the temperature falls as a function of time which is an exponential decay which is seen ah in this particular case okay

so ah with this we stop ah here on discussing thermal properties of matter and

just a very quick recapitulation of what we have done ah we have talked about
 um heat being a function of uh is a form of energy and we have talked about
uh temperature concept of temperature and we have talked about different
temperature scales such as celsius and fahrenheit and then we have also
introduced the kelvin scale of temperature which underscores or emphasizes the
 the concept of absolute zero below which nothing can be cooled ah and then we
have talked about um specific heat ah the concept of specific heat for ah
solids liquids ah and gases and then how to calculate specific heat we have
also talked about thermal expansion of solids liquids and gases and then we
have talked about change of state how matters change one from one state to
another and the concept of latent heat therein which is very important because
 the latent heat is a form of heat which is the system accepts it in order to
change while changing its state from one form to another and it's accompanied
with no change in temperature and then we have talked about transfer of heat
from one body to another or transfer of feed from a body to its surrounding
which essentially can be done in three ways which are convection conduction
and radiation especially the radiation part is important because radiation
requires no material medium to propagate and it's actually sort of mediated by
electromagnetic waves you