Introduction to Materials Science and Engineering
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Lecture - 88
Steady and unsteady state diffusion

Let us discuss it steady and unsteady state diffusion.

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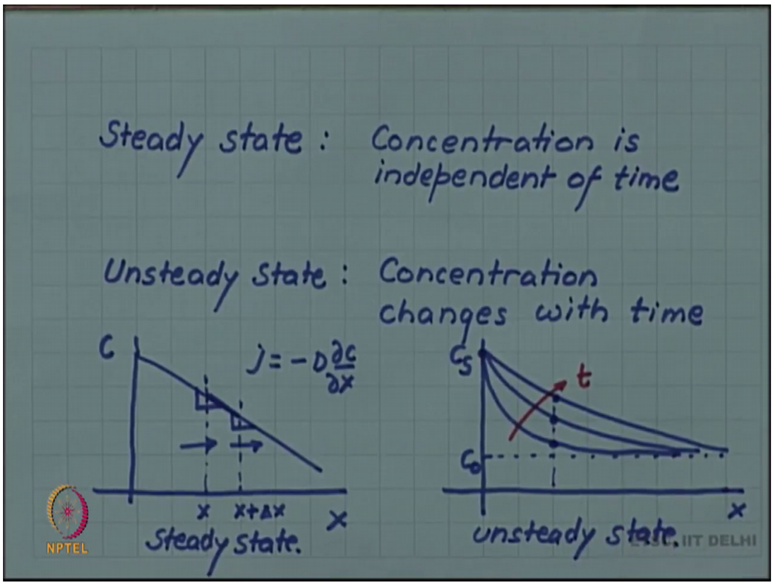

By steady and unsteady state we mean; by steady state we mean concentration is independent of time. An unsteady state means concentration changes with time. We have seen for example, if you have for the one dimensional case, which we discussed a concentration versus distance, if you have a straight line slope like this, then flux will be flux will be constant given by Fick's first law so, if I take any volume between X and X plus delta X.

So, the flux entering will also be the flux leaving, because the slopes are constant. So, there will be no accumulation of material in this volume and so the concentration in this volume also we will remain constant. So, this will be an example of a steady state. But, if you take another example like we had in carburization, where the initial concentration was very low the initial concentration C naught was very low, but we obtained a surface concentration C S due to the exposure to the carburizing atmosphere, which was much higher than C naught, then carbon started entering into the material and as a function of time; we saw that the concentration profile is evolving.

So, as a function of time the concentration profile is evolving so, at any given position at any given position, if we see the concentration increases with time. So, concentration changes with time this will be an example of unsteady state.

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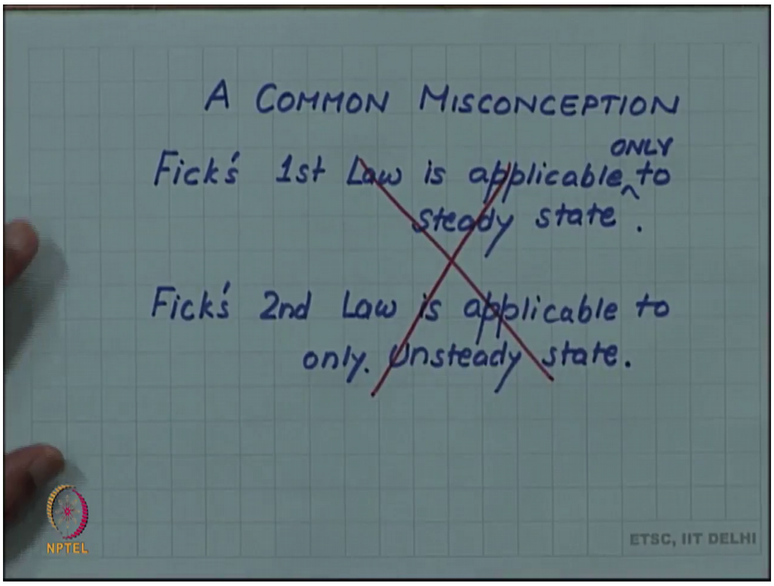

Now a common a common misconception in this regard is to think that, Fick's first law is the applicable only to steady state is applicable only to steady state and second law is applicable only to unsteady state; both these for these are misconception and they are not right.

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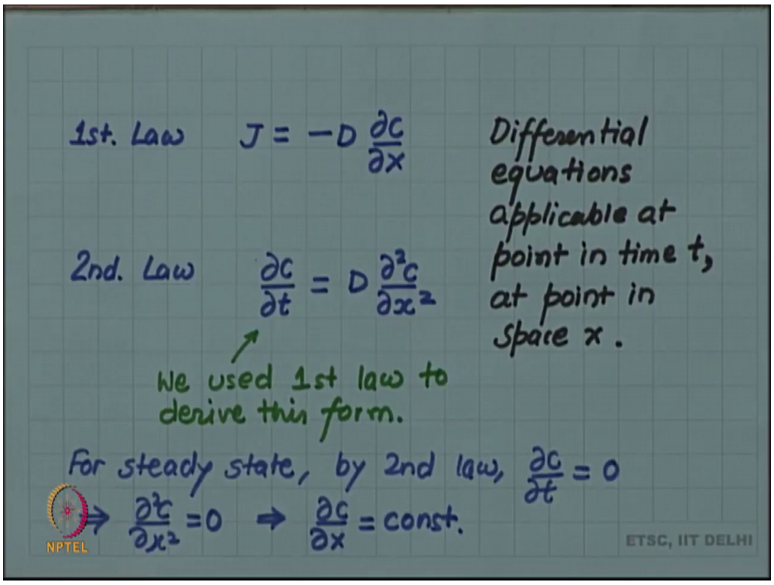

Let us see why? Both the laws the first law and the second law are differential equations. So, these are differential equations, which are applicable at a point in time at a point in time t, at a point in space X. So, it does not matter, whether the concentration is constant or changing with time both laws are applicable at a given point of time at a given point in a space, because that is what is meant by the differential coefficient, because in making these differential coefficients we take the limit of time tending to 0 delta change in time delta t tending to 0 and delta X tending to 0.

In fact, if you recall we actually used in deriving this form of Fick's second law we used first law. First law to derive this form you would not have been able to do that, if first law was applicable only to steady state and the second law was for unsteady state. Similarly, here we have we have the time derivative in the second law; we can use it for a steady state, so for a steady state by second law we have del C by del t is equal to 0; concentration will not be changing in the steady state this will imply del 2 C by del x square is equal to 0, which in turn will imply that del C by del x is constant that is the concentration gradient is constant, which we have just seen that I mean constant concentration gradient we get the steady state.

So, we get the steady state condition by applying the second law. So, there is no difference between in terms of a steady and unsteady state, there is no difference in the applicability of first law and second law, both laws are applicable to both situations.