Optimization in Chemical Engineering
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Lecture - 01
Introduction to Optimization

Welcome to the course Optimization in Chemical Engineering. In this first lecture of this course, I will try to introduce in a very simple language what optimization is all about. Optimization is important to all fields of discipline. So, it is important for engineers, it is important for scientist, it is important for working personnel's in fact, in our daily life it also plays a very important role knowingly or unknowingly we always perform optimization.

For example, when you want to choose a path from going from one place to another, you choose a shortest path, why? Because you want to minimize the time required for the journey or if you work may be you want to minimize the number of steps you are going to take; sometimes you want to work more.

So, that time you deliberately take the longer route. If you have some money on to put the money in the bank, you would go to the bank which offers the maximum return on your deposit. Similarly if you want to borrow money from a bank say for making a house or for some other purpose, you will go to the bank which charges the minimum rate of interest.

Suppose you have two friends staying in two different cities of India, you want to visit both of them and you want to plan your travel so that, it takes minimum time or your expenses also minimum. So, it is two friends staying in two different cities is an easy problem to solve.

But imagine you have 20 friends and they are all in different 20 cities of India and you want to make a travel plan, were you want to visit each friend only once and want to minimize the total tour time or the total distance covered or the total expenditure spent on this travel is not an easy problem to solve. So, certain optimization problem we just solve like that and we solve using our past experience. We do not need to have a knowledge or formal knowledge of optimization techniques.

Basically optimization is set of mathematical techniques that you would like to apply to find out a decision, which is best suitable for us. For example, visiting two friends staying in two different cities in India is an easy optimization problem to solve and you can solve it by using your common sense or past experience. But if you have 20 friends staying in 20 cities, you perhaps will need formal tools of optimization methods to come up with the best solution. You can come up with a solution using your common sense or past experience, but that may not be the best solution.

So, what you see from this brief discussion is that, optimization is all about making a decision and why do we have to make a decision? When you have several alternatives like let us again come back to any of these problems that we talked about, choosing several paths or choosing a proper travel plan. So, you have several alternatives and you have to choose the best alternative for you. So, optimization is all about choosing or making the best decision among several possible alternatives.

Now, let us look at a formal definition of optimization.

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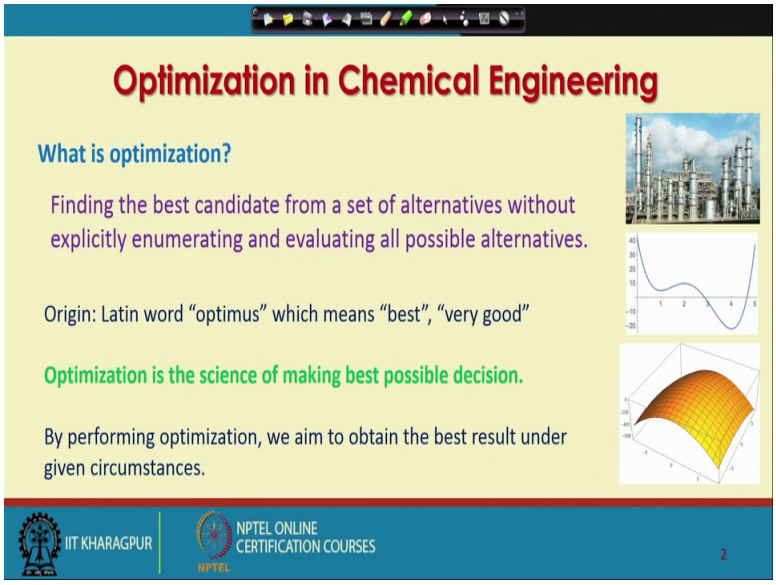

So, formally would like to say that optimization is finding the best candidate or best candidate solution from a set of alternative solutions, without explicitly enumerating and evaluating all possible alternatives. So, we will try to achieve or attain the optimal solution, without evaluating all possible alternatives. The word optimization origins from Latin word "optimus" which means "best" or "very good". So, optimization is the

science of making best possible decision. By performing optimization we aim to obtain the best result under given circumstances.

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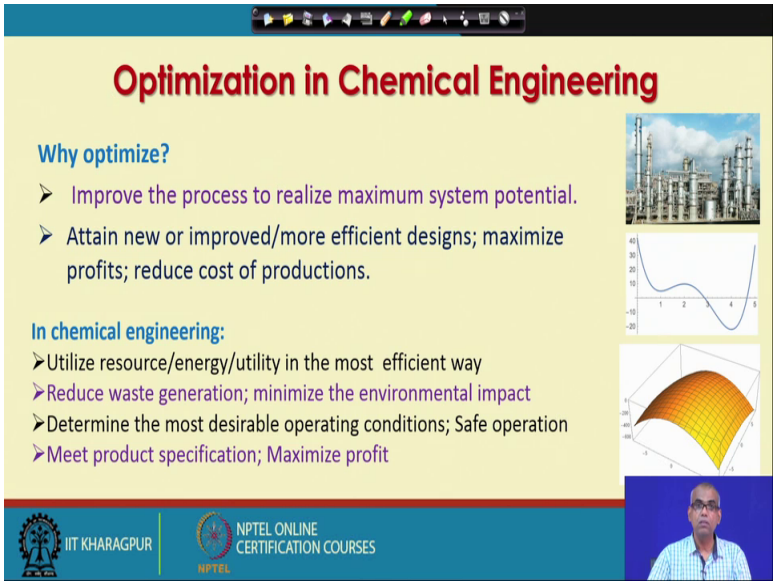

So, why do we want to optimize? It in general terms we want to improve the process to realize maximum system potential. We want to attain new or improved or more efficient designs, we want to maximize profits, we want to reduce the cost of production may be we want to minimize the effect or harmful effect on the environment.

In chemical engineering we would like to perform optimization to utilize raw materials resources, energy utility in the most efficient way. Also to reduce waste generation, minimize the environmental impact to determine the most desirable operating conditions, to determine the safe operating conditions, to meet product specification to maximize profit.

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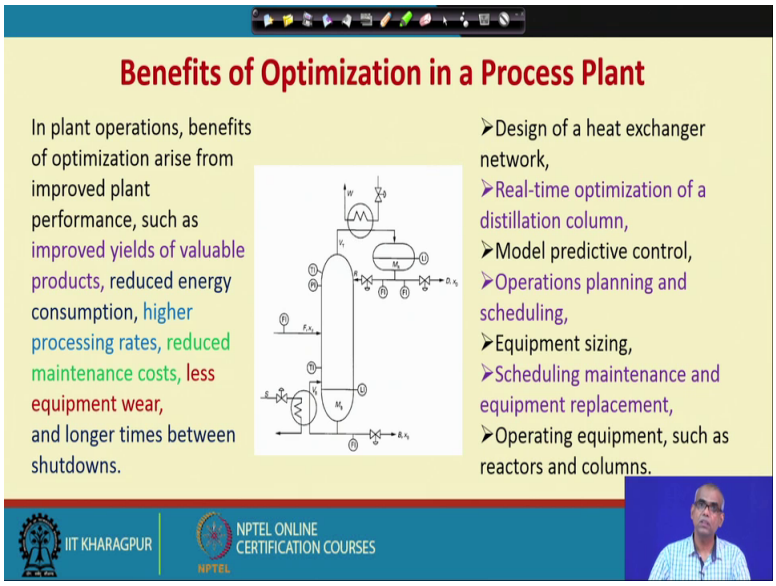

So, the benefits of optimization in a chemical process plant may be improved plant performance. So, in plant operations benefits of optimization arise from improved plant operation or performance such as improved yields available products, reduced energy consumption, higher processing rates, reduced maintenance cost, less equipment wear and longer times between shutdowns. So, with this descriptions we find out that during if optimization, we want to maximize or minimize something.

Often times we want to maximize say profit, we want to minimize cost. But it is not necessary that we will be maximize or minimize an economic criterion, we can also maximize or minimize a technical criterion. So, these leads to concept of objective function.

So, it is the value of the objective function that we would like to maximize or minimize during optimization. We will be talking more about objective function later, but I would like to stress upon the fact that this decision making is based on a criterion, which in the language of optimization is known as objective function and usually we will perform maximization or minimization on this objective function.

Let us now look at the picture of this distillation column. So, it is a systematic of simple distillation column, with 1 feet stream enters somewhere in the middle of the distillation column as shown in the systematic. The vapour comes out from the top of the distillation column is being condensed using a condenser getting accumulated in the reflex drum a

part of it is been taken out as a top product, and part of it is been send back to the distillation column as reflex. Similarly at the bottom of the distillation column there is a reboiler. So, the bottom liquid stream that comes out the distillation column is vaporized using the reboiler and enters again into the distillation column, a part of the bottom product is taken out as product.

Now, what are the optimization that can be perform in this single distillation column? If I plan a course on separation process or masters for operations, you have seen that there is an optimum location of it rate. So, these speed stream has to be put into an optimal location. You also perhaps have seen that using this reflex stream, it is possible to control the purity of the top product. So, determination of optimal feed location; determination of optimal reflex ratio are important optimal optimization parameters in case of distillation column. We will talk about many more such optimization examples throughout the course.

So, let us take a look at few more examples of optimization from chemical engineering. Design of a heat exchanger network is an important optimization task for chemical engineers, real time optimization of a distillation column, model predictive control this is basically a control algorithm, but the control algorithm works on the principle of optimization.

So, model predictive control basically uses a predictive model for a process and uses optimization techniques to find out or to establish the control of the process. Operations planning and scheduling is the very important optimization task, equipment sizing scheduling maintenance and equipment replacement.

Operating equipment such as reactors and columns you have to design them in the most optimal manner possible. Optimal shutdown optimal start off of plants are also important optimization task of practicing chemical engineers. So, these are just some of the common optimization problems chemical engineers frequently deal with.

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These are some optimization examples where you have learned from nature. See the wings of the aero plane or the design of the wings of the aeroplane has been inspired by the birds. The nose of the high speed train is inspired by the beak of kingfisher. You are familiar with this figure, you must have notice this figure in your biology book, this shows human evolution and this shows evolution of our computers, with this being the modern desktop computer.

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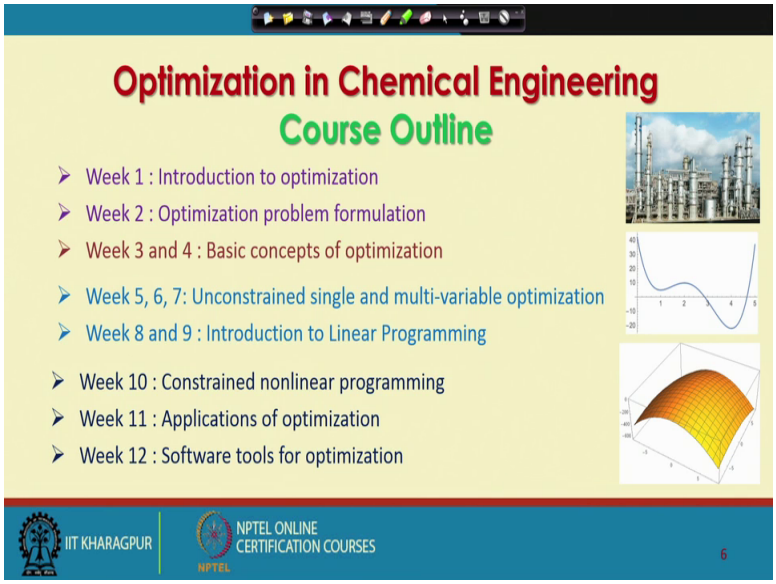

So, let us now briefly talk about the outline of the course. In the first week we will talk about introduction to optimization, week 2 we will talk about optimization problem formulation, week 3 and 4 we will talk about basic concepts of optimization, week 5 6 and 7 we will talk about unconstrained single and multi variable optimization, week 8 and 9 we will talk about linear programming.

Week 10 we will talk about constrained non-linear programming, week 11 we will talk about applications of optimizations, where we will talk about various case studies and apply the techniques that you have that we will learned till week 10 and finally, in the last week, week 12 we will introduce certain software tools for performing optimization.

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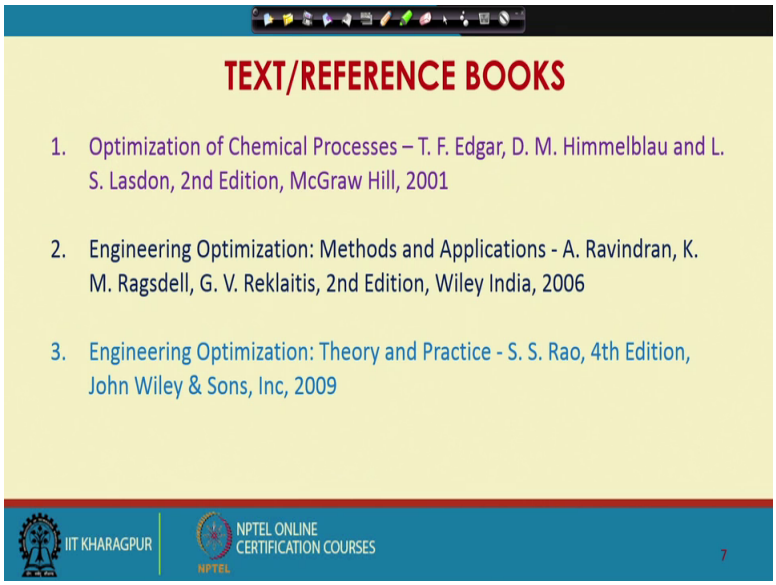

These are the text books or reference books that you can follow. First book is Optimization of Chemical Processes by T. F. Edgar and D. M. Himmelblau, L. S. Lasdon, 2nd edition McGraw Hill. Book number 2 Engineering Optimization methods and Applications written by A. Ravindran, K. M. Ragsdell and G. V. Reklaitis, 2nd edition Wiley India; Book number 3 Engineering Optimization Theory and Practice S. S. Rao, 4th Edition, John Wiley and Sons incorporated. So, our discussions will essentially be focused on these three books, but I believe you can follow any of these books.

The first book; Optimization of Chemical Processes are written by chemical engineers, the second book Engineering Optimization Methods and Applications also written by at least one chemical engineer G. V. Reklaitis. Engineering Optimization: Theory and

Practice by S. S. Rao this is also a good book, but most of the examples in this book will be from civil engineering or mechanical engineering disciplines.

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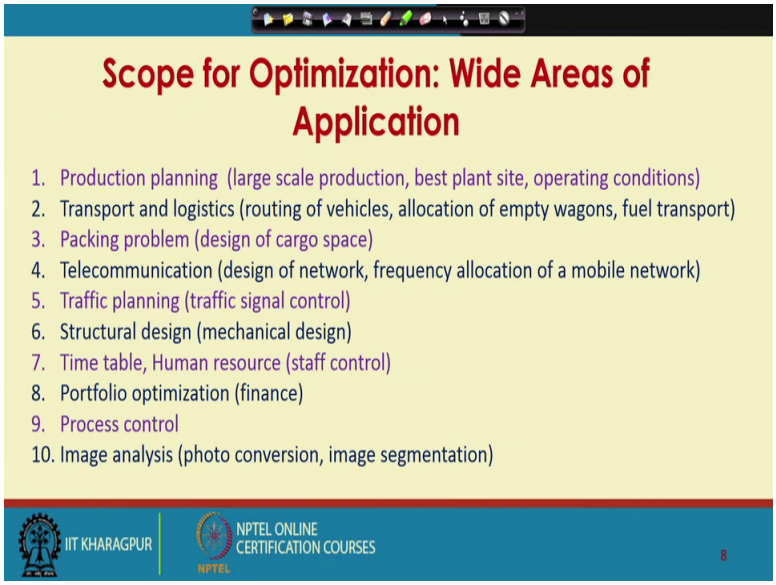

Optimization is not only for chemical engineers, optimization by itself is the discipline and this has wide areas of applications. Just to name few production planning important for large scale production, you have to choose the best plant site, you have to choose the most favorable operating conditions. Transport and logistics optimization plays a very important rule very important role in the business of transport and logistics. Important problems are routing of vehicles like routing of tracks, allocation empty wagons fuel transport etcetera.

Packing problem is another classical optimization problem; design of cargo space is an important practical problem; Telecommunication, design of network, frequency allocation of a mobile network are important practical optimization problems. Traffic planning here traffic signal control is an important optimization problem; structural design such as mechanical design; preparing timetable, staff control say staff control of your organization important optimization problems.

Portfolio optimization is an important optimization problem in financial sector, where if you have a good amount of money you would like to invest in various say you have various options to invest that money. Let us say you can buy shares you can deposit the

deposit in the bank with certain fixed rates, you can also invest say in gold, you can invest in land or there are other instruments as well.

So, how do you manage your funds how much money you put for buying shares, how much money you put for say investing in gold or lands etcetera is an important portfolio optimization. Optimization finds applications in process control, model predictive control is a good example optimization also is widely applied in image analysis such as say photo conversion from black and white image to color image it finds application, image segmentation is an important task any image analysis and optimization is also use there.

So, these are some different some optimization applications from different areas not necessarily chemical engineering areas, but for different areas. I just wanted to stress upon the fact that the scope of optimization is very very wide.

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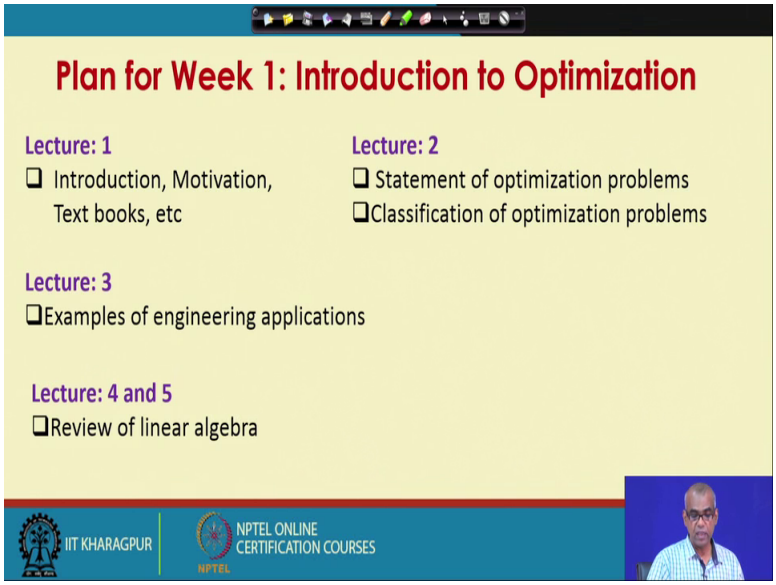

So, let us take a look at plan for the first week. So, lecture 1 in this lecture 1 we try to introduce very briefly what is optimization, what is the motivation for optimization, we introduce the text books.

In lecture 2 we will talk about statement of optimization problems and classification of optimization problems. Lecture 3 we will take some examples of engineering applications and lecture 4 and 5 we will review linear algebra particularly matrix algebra

and some of the linear algebra that may be required for learning optimization techniques later in the course. So, with this I would like to stop here lecture 1.