Process Design Decisions and Project Economics

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Module - 8
Chemical Project Economics
Lecture - 10
Tutorial (Part I)

Welcome, in the previous 8 lectures, we have seen in detail the theoretical treatment of Chemical Project Economics. We got introduced ourselves to the basics of the project economics, then we saw the concept of process selection, site selection. And then we saw various aspects of analysis of the project economics, the time value of money, interest, depreciation, various yard sticks that are used for analysis or evaluation of the project; that is, the ratio analysis, incremental analysis, break even analysis, discounted cash flow techniques. In this lecture and the next lecture, we shall see various problems based on the theory that we have learnt. We shall first start with simple problems based on time value of money, and later on we shall see the problems on the replacement alternative investment, and then finally we shall see a detailed evaluation of the project based on the cost data.

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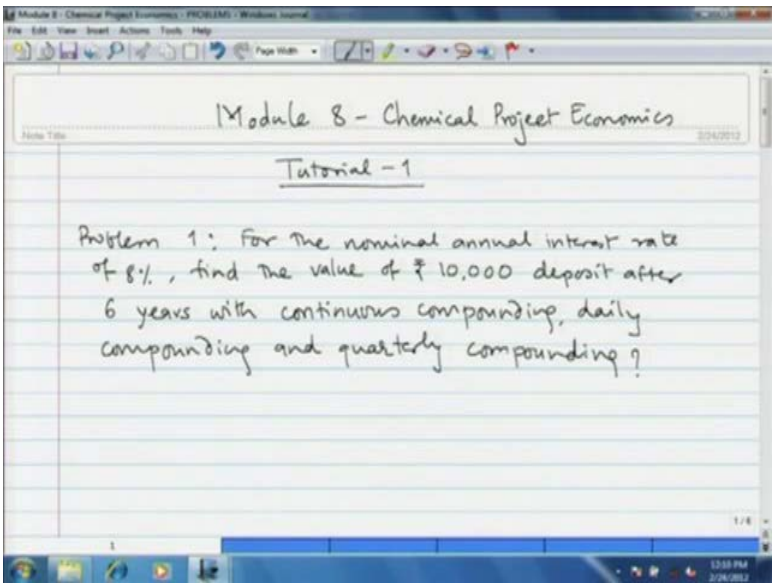

So, let us see the first problem of today's lecture or today's tutorial, problem 1, for the nominal annual interest rate of 8 percent, find the value of rupees 10,000 deposit after 6 years with continuous compounding, daily compounding and quarterly compounding.

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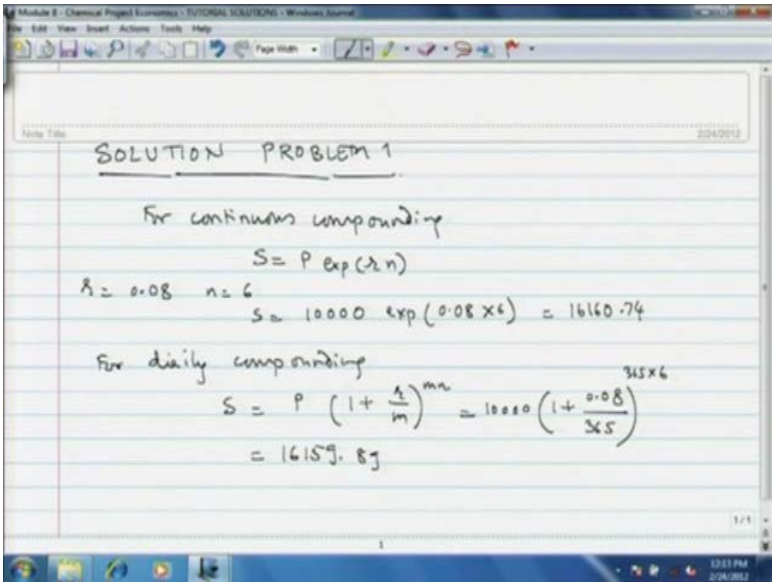

Now, we have already seen various formulae or theoretical treatment for these 3 kinds of techniques. For continuous compounding, the sum S over principle P gathered in certain amount of time is given as, P into exponential r into n where, r is the interest rate and n is the period of interest. Here, we are given interest rate of 8 percent, r is 0.08 and n is 6 years so, we substitute values here, S is equal to 10000 into exponential 0.08 into 6 and this gives us value of 16160.74.

So, that is the value of rupees 10000 deposit after 6 years with continuous compounding, at interest rate of 8 percent. Now, let us see for daily compounding, here the formula that we are going to use is, S is equal to P into, 1 plus r by m, into m into n where, r is the interest rate, m is the compounding period and m into n is the total compounding periods. Now, we have to substitute various values, for P we substitute 10000, the nominal interest rate r is 8 percent but, it is compounded daily. So m, the compounding period is 365 days a year and then, here at the numerator, we have 365 days into 6 years, so total compounding period. And S in this case, turns out to be 16159.89 rupees, so that is the value of 10000 rupee deposit with daily compounding.

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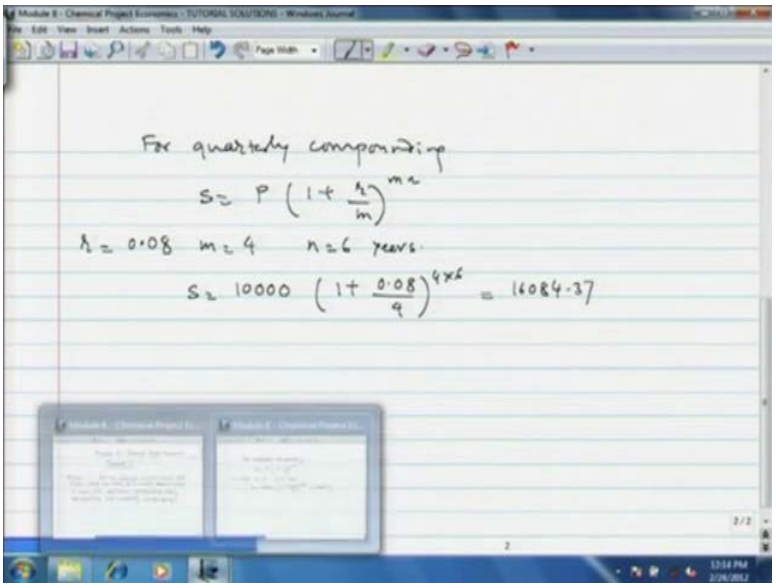

Now, let us see for quarterly compounding, here we use the same formula, S is equal to P into 1 plus r by m, into m into n, r is 0.08 here, m is 4, because four quarters in a year and n is 6 years. We substitute values and then, find that the deposit value is 16084.37. So, we have the three answers for continuous compounding, for daily compounding and for quarterly compounding so, that completes problem 1.

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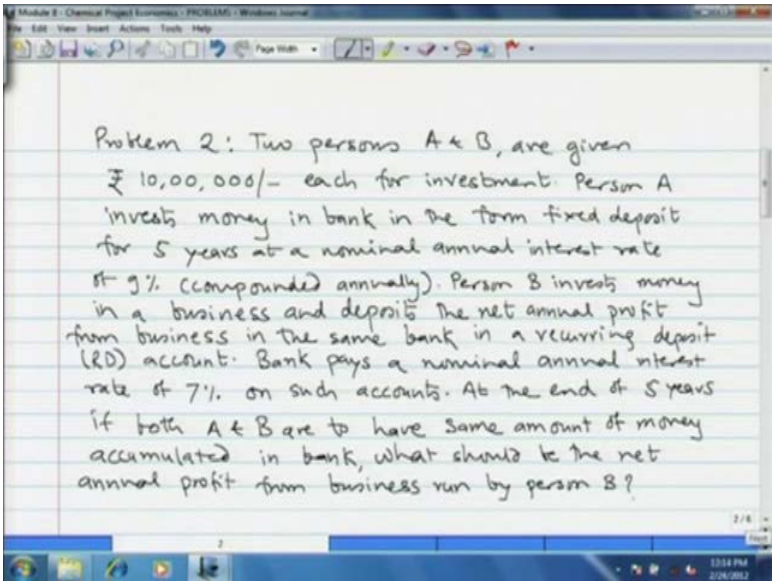

Now, let us see second problem, I will read the problem statement for you, two persons A and B are given rupees 10 lakh each for investment. Person A invest money in bank in

the form of fixed deposit for 5 years, at a nominal annual interest rate of 9 percent, which is compounded annually. Person B invest money in a business and deposits the net profit, net annual profit from the business in the same bank in a recurring deposit or RD account, bank pays a nominal annual interest rate of 7 percent on such accounts.

At the end of 5 years, if both A and B are to have the same amount of money accumulated in the bank, what should be the net annual profit from business run by person B, which he should deposit in his recurring deposit account. Now here, we have to use two formulae here, there are two concepts, one is the concept of simple compounding and next is the annuity.

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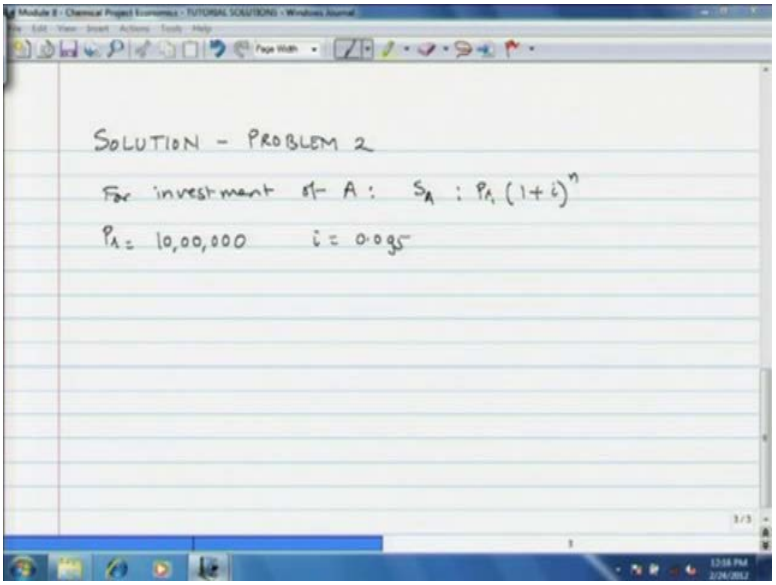

Person A is going to make fixed deposit so, for investment of A, the net amount that is accumulated in the bank, that we denote as S subscript A, will be equal to P r into 1 plus i to the power n, that is the maturity amount. We have principle equal to 10 lakhs and interest rate is 9.5 percent compounded annually.

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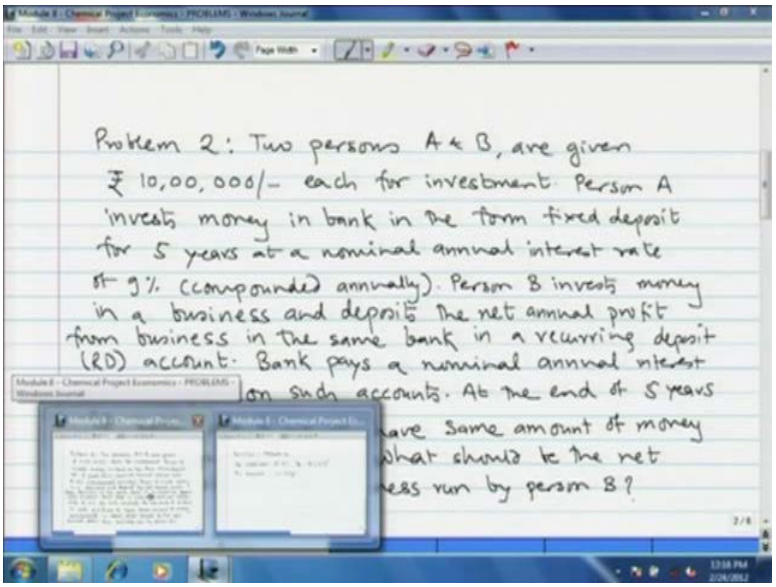

Here, we make a change here, the compounding is interest rate is 9.5 percent and not 9 percent, the annual interest rate is 9.5 percent.

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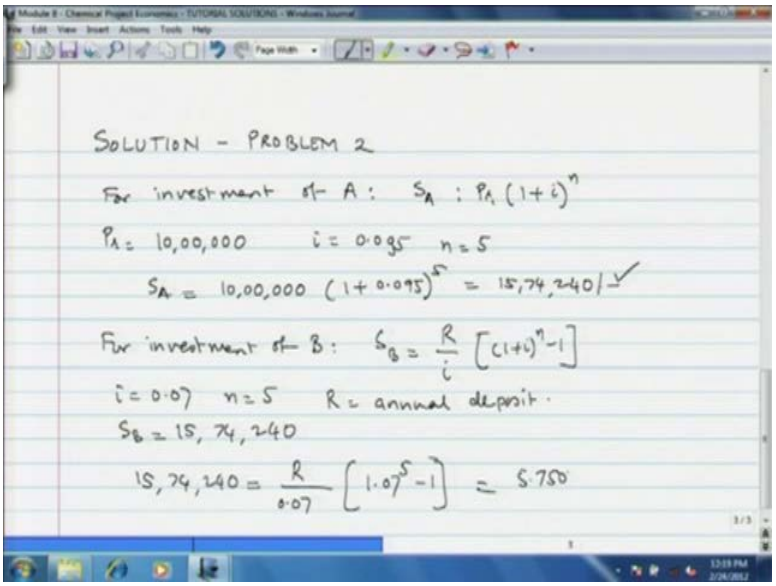

So, interest rate is 0.095, n is 5 years the period so, the maturity amount for A will be 10 lakh into 1 plus 0.095 raise to 5, which is equal to 1574240, so that is the maturity amount of person A. Now, person B has to have the same maturity amount however, the investment of person B is in the form of an annuity because, he is depositing the annual profit in the recurring deposit account.

So, for investment of B, the sum that will be accumulated in his account S B will be R by i into 1 plus i to the power n minus 1, so this formula we have derived. We substitute values here, i is 7 percent interest rate, n is 5 for investment of B, the formula is S B is equal to R by i into 1 plus r to the power n minus 1 where, r is his annual deposit, which we have to find out. The sum that should be accumulated in the account of B is known to us because, it should be the same as in case of A and now, we substitute values and solve for R.

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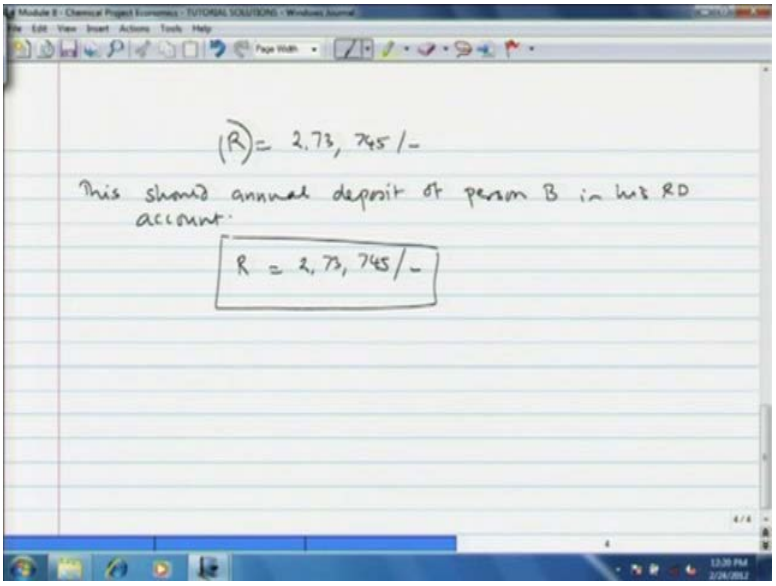

So, R turns out to be 273745 so, this should be the annual deposit of person B in his account, the recurring deposit account. So, we have the answer, R is equal to 273745 so, that completes problem 2 now, let us see the third problem.

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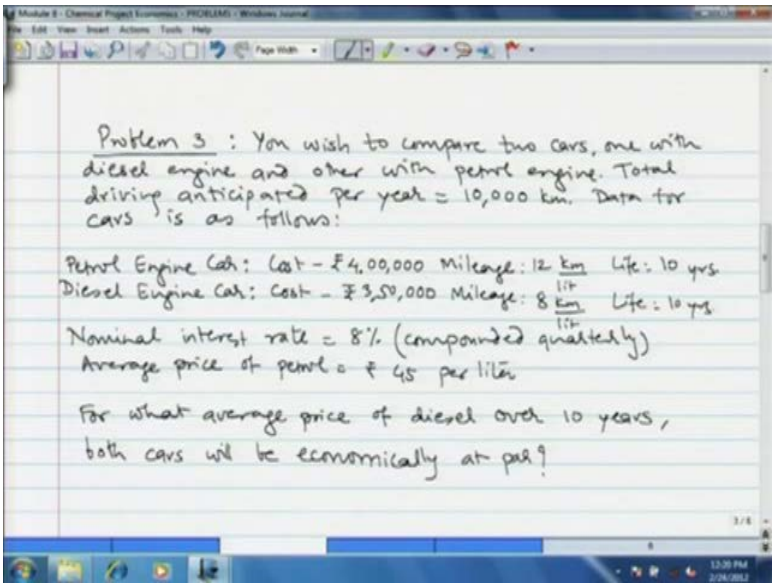

This problem is on alternate comparison of alternate investment, you wish to compare two cars, one with diesel engine and the other with petrol engine. The total driving anticipated per year is 10000 kilo meters, the data for the cars is as follows, petrol engine car the cost is rupees 4 lakh, the mileage is 12 kilometers per litre, the life span is 10 years. The diesel engine car cost is slightly less rupees 350000, the mileage is also less 8 kilometers per litre and the life span is same 10 years.

So, nominal annual interest rate can be taken as 8 percent compounded quarterly and the average price of petrol, which is fluctuating quite a lot so, we take an average price of petrol as rupees 45 per litre. For what average price of diesel over 10 years, both cars will be economy at economically at par so, that is the question, that we have to find out. The average cost of diesel over the period of operation, which will make the two cars economically safe. So, this problem is essentially about comparison of the fixed capital investment and operating or annual expenses so, let us see the solution.

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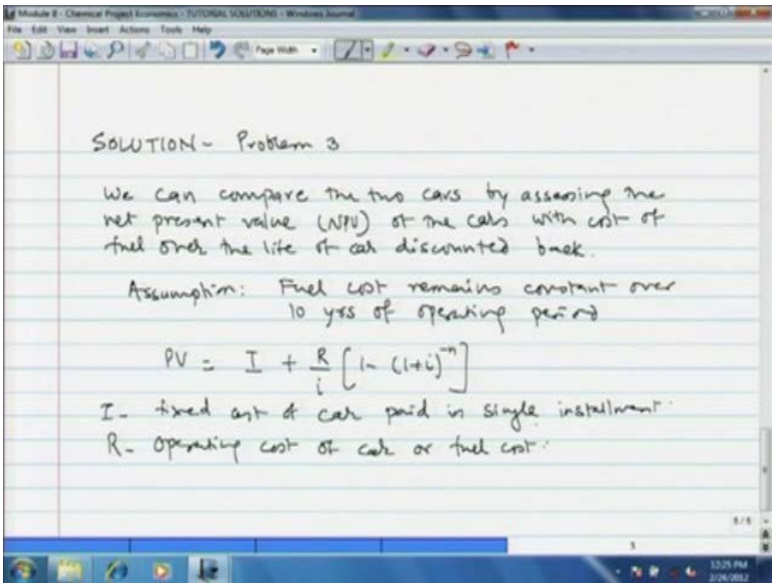

We can compare the two cars by assessing the net present value of the car with the cost of fuel over the life span of car, which is discounted back. Here, we make an assumption, that the price of fuel remains constant over the operation period, the cost of car is like fix capital investment and the cost of fuel is equivalent to the total production cost. So, the net present value is the initial investment I plus R by I into 1 minus, 1 plus i to the power minus n.

Now, this is essentially the annuity, if you deposit amount R in bank in every period, this is just opposite of the formula, that we have seen in the previous problem. In the previous problem, we have to compound the amount here, we have to discount the amount so, we have used discounting factor here, 1 minus 1 plus i to the power minus n by i is a discounting of the annuity. I will write here, I is the fixed cost of the car or paid in single installment, we assume that and R is the recurring cost or operating charges of the car. We also assume that the other cost like maintenance, insurance, these are same for both the cars.

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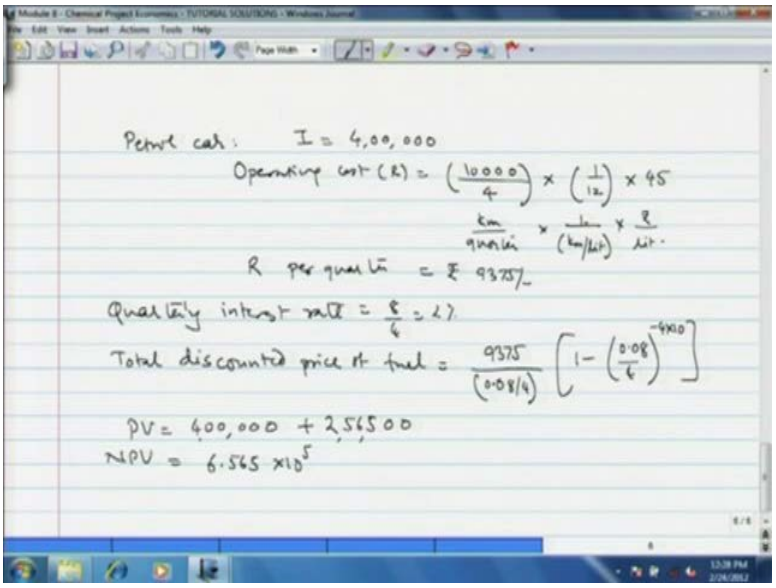

Now, let us see this thing for petrol car, the present value for petrol car here, I is rupees 4 lakh, average petrol price is 45 rupees a litre, mileage is 12 kilometer per litre and we have said, that the total driving per year is 10000 kilometers. So, the operating cost R is 10000 kilometers divided by 4 because, we are going to compound the interest quarterly. So, quarterly driving will be 10000 kilometer by 4 and then, the total fuel that is required will be, this divided by 1 by 12 because, that is the mileage and then, the total cost will be into 45.

So, this is the kilometer per quarter, this is the mileage litre, 1 divided by kilometer per litre and 2 rupees per litre, so this operating cost turns out to be total operating cost over one quarter is rupees 9375, R per quarter. Now, the nominal interest rate is 8 percent compounded quarterly so, the quarterly interest rate is 8 by 4 that is, 2 percent. Then, the total discounted price of the fuel will be 9375 divided by 0.08 by 4 into 1 minus 0.08 by 4 raise to minus 4 into 10 where, 10 years of operation, 4 quarters per year. And the net present value is then I, which is 4 lakh plus this total discounted price turns out to be 256500 and then, the total cost, total net present value N P V is 6.565 into 10 to power 5 is for the petrol car.

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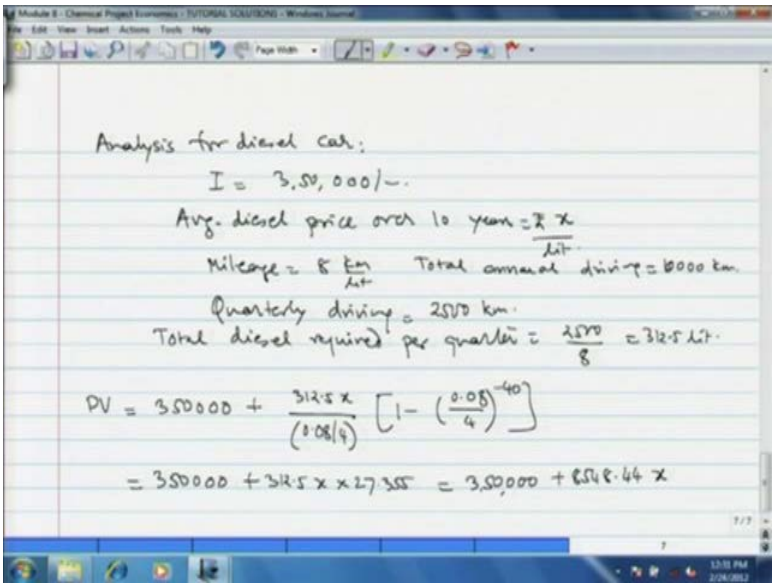

Now, let us do the same thing for diesel car here, we are going to use exactly the same formulae so, I directly put the numbers, here initial cost is 350000, we do not know the diesel price, that we have find out. So, we assume the average diesel price over 10 years as rupees x per litre then, mileage is given as 8 kilometer per litre, total annual driving is 10000 kilometer.

So, quarterly driving is 2500 kilometer, total fuel required, total diesel required per quarter is 2500 divided by 8 that is, 312.5 litres and then, the net present value of the diesel car will be the initial cost 350000 plus 312.5 into x that is, quarterly price of diesel divided by 0.08 by 4 that is, quarterly interest rate into 1 minus 0.08 divided by 4 raise to minus 40. So, this turns out to be 350000 plus 312.5 x into 27.355, which is equal to 350000 plus 8548.44 into x now, we have to find out x, at which both of the cars will be economically at par.

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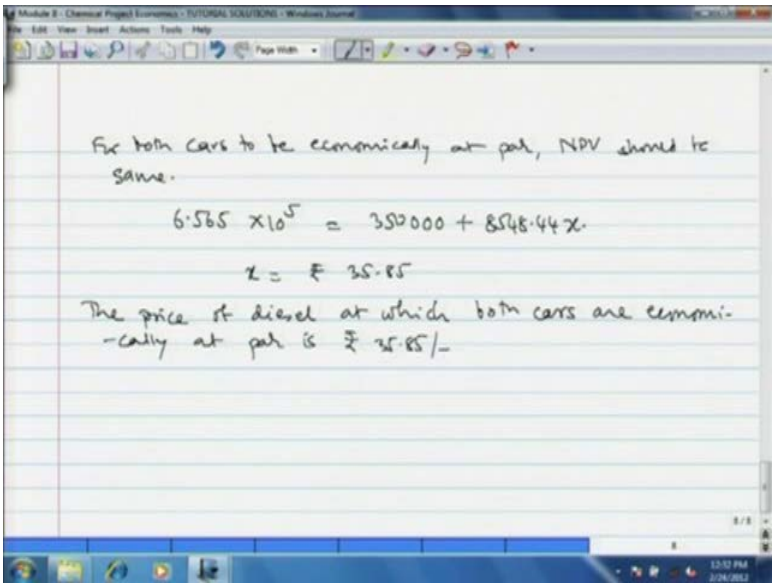

For both cars to be economically at par, the net present value should be same thus, we now compare the net present value of the patrol car, which we have found to be 6.5 lakhs or 6.565 into 10 to power 5 is equal to 350000 plus 8548.44 into x. So, x after solving this, x turns out to be rupees 35.85 so, the price of diesel, at which both cars are economically at par is rupees 35.85. Now, if the price of diesel goes beyond rupees 35.85 petrol car will be more economic, if it falls below 35.85 diesel car will be more economic. So, that completes the problem 3 now, let us see the next problem.

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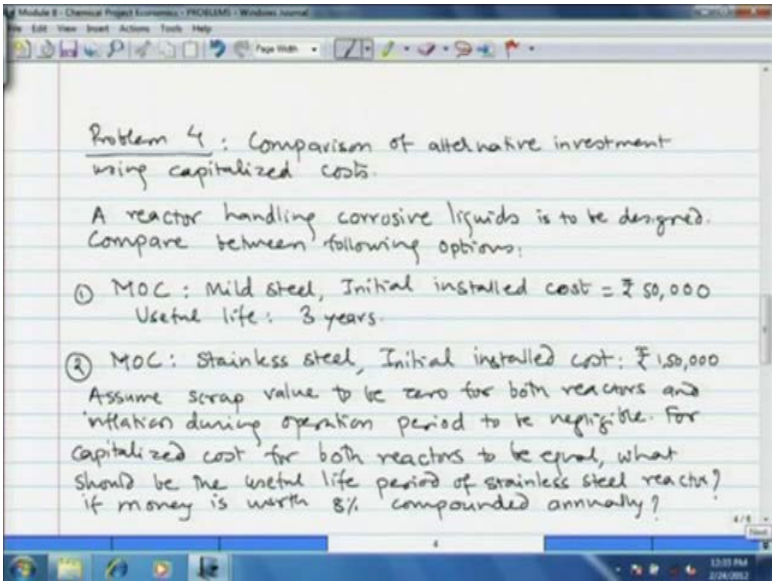

Now, here, we are going to compare alternative investment using capitalized cost now, I will read the problem statement for you. A reactor handling corrosive liquid is to be designed and we have 2 options for it, first option is the material of construction MOC as mild steel, initial installed cost as rupees 50000 and useful life only 3 years. And second reactor, that we have is with material of construction stainless steel, the initial installed cost as rupees 150000 and useful life is not known, that is what we have to find out. We can assume, that the scrap value to be 0, for both reactors and the inflation during the operational period is to be negligible. For the capitalized cost, for both reactors to be equal, what should be the useful life period of stainless steel reactor, if the money is worth 8 percent compounded annually.

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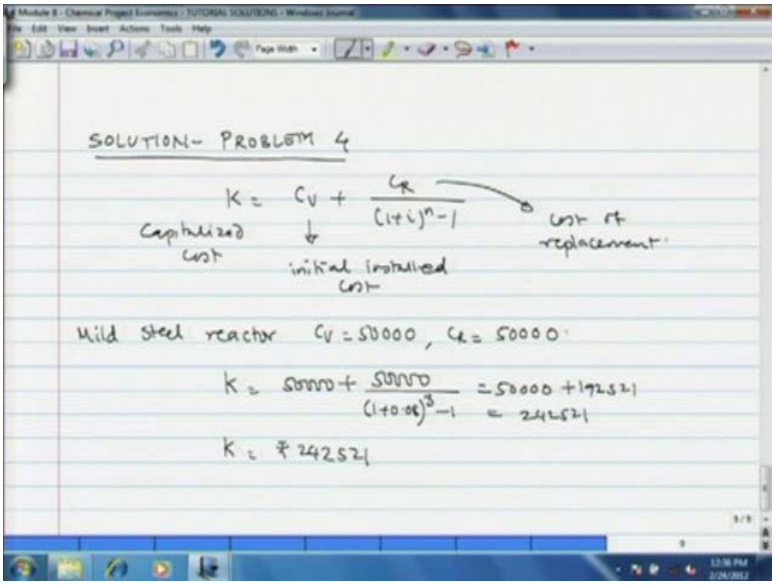

Now, we have already derived an expression for the capitalized cost and that, we write here, the capitalized cost K of an equipment is equal to C V plus C R divided by 1 plus i to the power n minus 1 here, C V is the initial installed cost and C R is the cost of replacement. Now, we have assumed that, the corrupt value of both of the reactors is 0 then, C R is same as C V. If there is any scrap value for the reactor then, the cost of replacement will be the initial installed cost minus the salvage value.

Now, we put for the mild steel reactor numbers, for mild steel reactor C V is 50000, C R is also 50000. And then K, the capitalized cost becomes 50000 plus 50000 divided by 1 plus 0.08 raise to 3, 3 is the operation, 3 years is the useful life and 1.08 raise to power 3

minus 1. So, this turns out to be 50000 plus 192521 is equal to 242521, so this is the capitalized cost for mild steel reactor.

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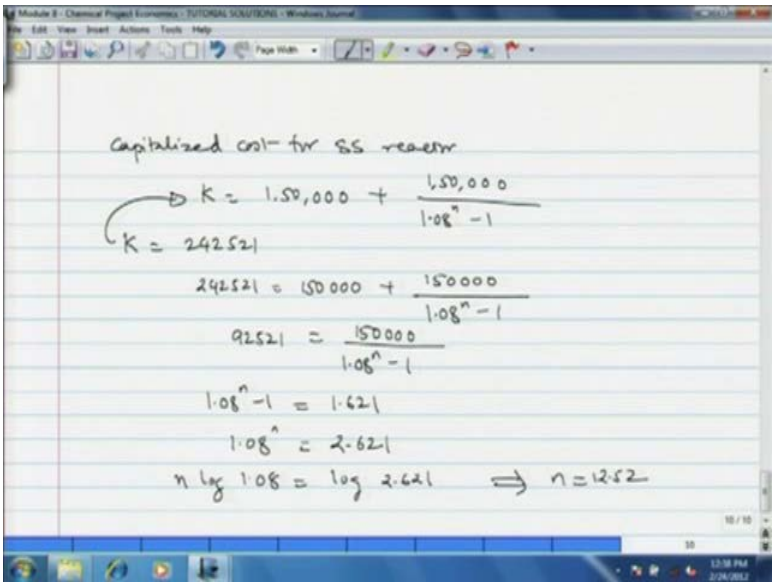

Now, let us see the capitalized cost for the stainless steel reactor, K is 150000 that is, initial installed cost plus the cost replacement, which is same divided by 1 plus 0.08 raise to n minus 1. Now, K has to be same, as that for mild steel reactor, which is equal to 242521 rupees that is what, we have found out. Now, if you put K here and solve for n now, we take log on both sides and this gives n equal to 12.5.

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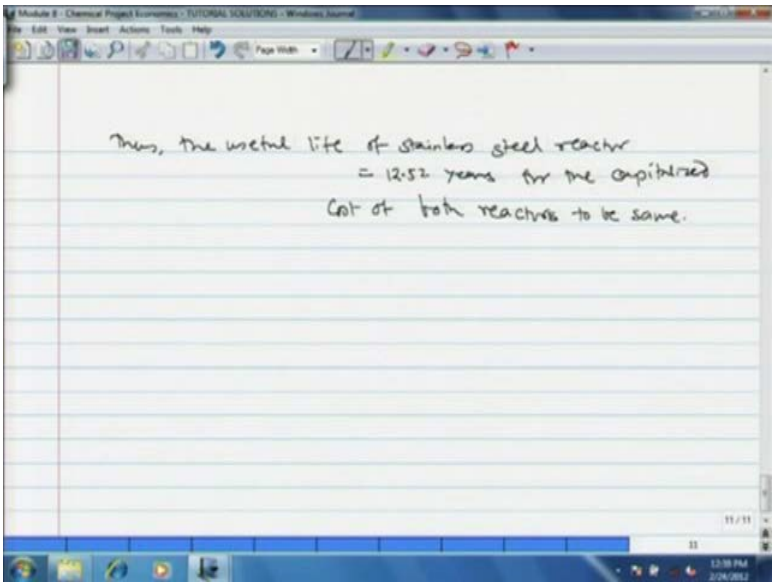

Thus, the useful life of the stainless steel reactor should be equal to 12.52 years, the capitalized cost of both equipment to be same. So, this completes problem 4 now, let us see the fifth problem of tutorial.

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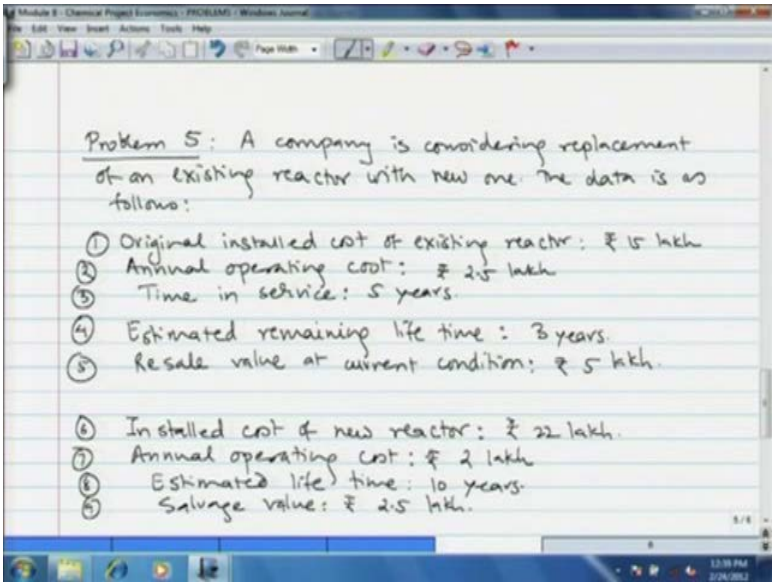

Here also, we have to compare alternative investment but, with a different methodology now, let us read the problem statement, a company is considering replacement of an existing reactor with new one. The data on both reactors is as follows, the original installed cost of the existing reactor rupees 15 lakh, the annual operating cost is rupees 2.5 lakhs, timing service old reactor is 5 years, the estimated remaining life time of the old reactor is 3 years, the resale value is estimated in current condition as rupees 5 lakhs. Now, the data for new reactor, the initial installed cost is rupees 22 lakh, the annual operating cost is rupees 2 lakhs, the estimated life time is 10 years and the salvage value after 10 years is rupees 2.5 lakhs.

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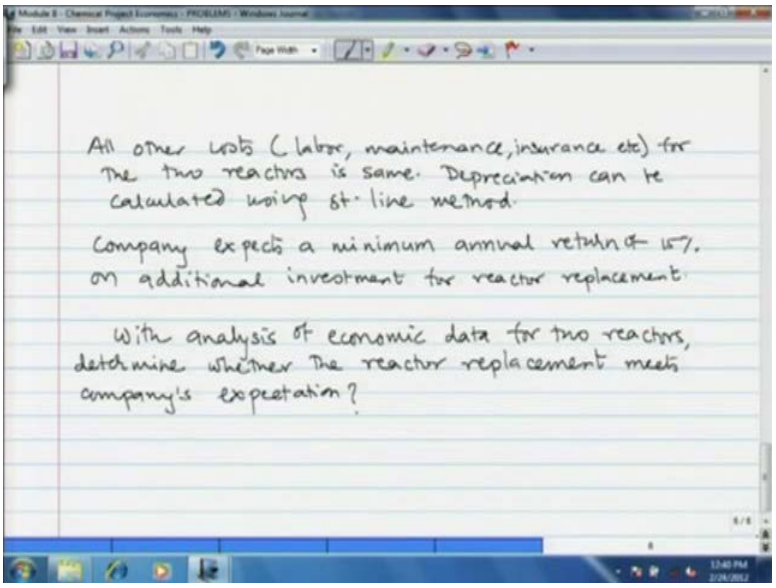

All other cost such as labor, maintenance, insurance, etcetera for the two reactors is same, depreciation can be calculated using straight line method and the company expects a minimum annual return of 15 percent on additional investment for the reactor replacement. With analysis of economic data for the two reactors, determine whether the reactor replacement meets company's expectation. Now here, we have to use the slightly different method than the capitalized cost because, operating cost is also involved so, let us start the solution.

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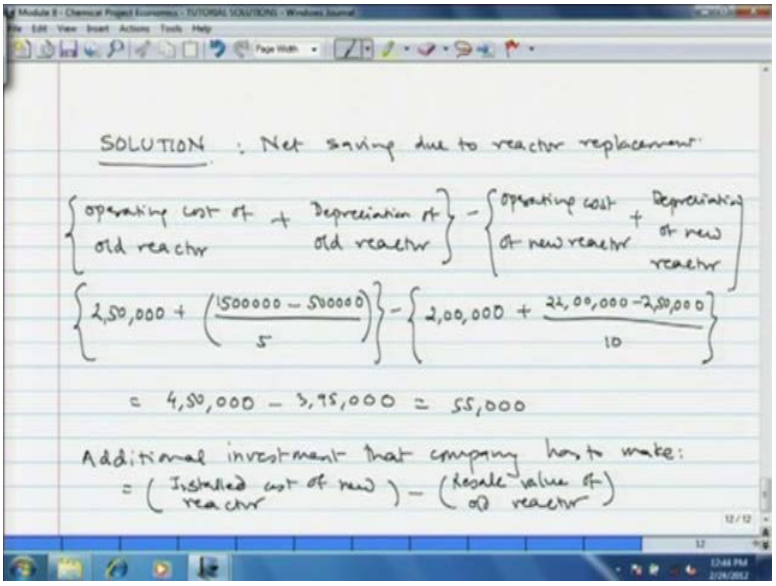

The net saving due to reactor replacement is the operating cost of old reactor plus the depreciation of old reactor, minus the operating cost of new reactor plus the depreciation of new reactor. Now, we put in numbers, the operating cost of old reactor is 250000 plus the depreciation 15 lakh was the original cost, resale value after 5 years is 5 lakhs divided by 5.

So, this is depreciation, that actually occurred over 5 years of service period minus the operating cost of new reactor is rupees 2 lakhs and then, the estimated depreciation is 22 lakhs, which is initial cost minus 250000, which is the envisaged salvage value divided by 10. So, this turns out to be 450000 minus 395000 is equal to 55000, the additional investment that company needs to make, is the installed cost of new reactor minus the salvage value of old reactor or resale value of old reactor.

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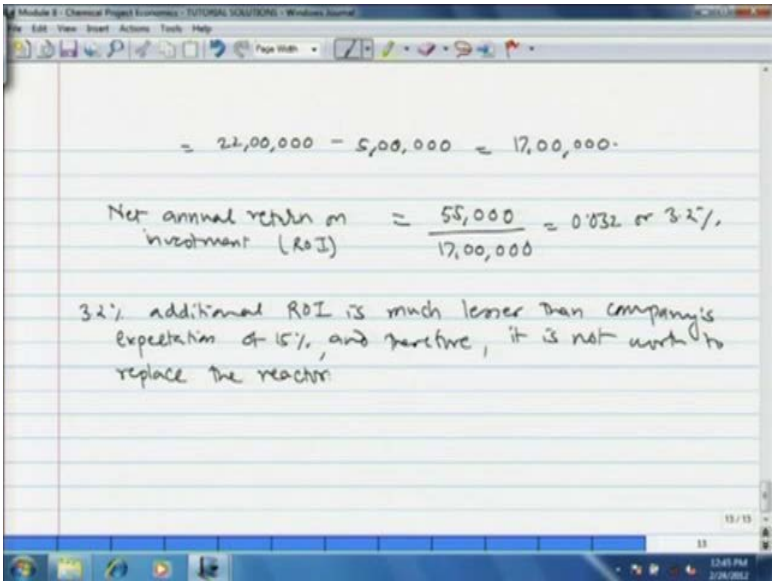

And this turns out to be 22 lakh minus 5 lakh, which is equal to 17 lakh however, the net saving is only 55000. So, the net annual return on investment is 55000 divided by 17 lakhs, which is equal to 0.032 or 3.2 percent. The company's expectation is 15 percent return on additional investment and 3.2 percent return is much smaller than company's expectation.

So, the replacement should not be made so, that point we note, 3.2 percent additional return on investment is much lesser than company's expectation of 15 percent and therefore, it is not worth to replace the reactor. So, today we have seen different problems related to the time value of money, interest, compounding, discounting, etcetera.

We shall do actual analysis of project cost based on the total capital investment, the fix capital, the operating capital and the net sales. And then, we shall try to find out, as how we can best evaluate a project using ratio analysis, break even analysis, and discount cash flow techniques. Let us see a problem on profitability analysis of a chemical plant, the problem statement is now appearing on the screen.

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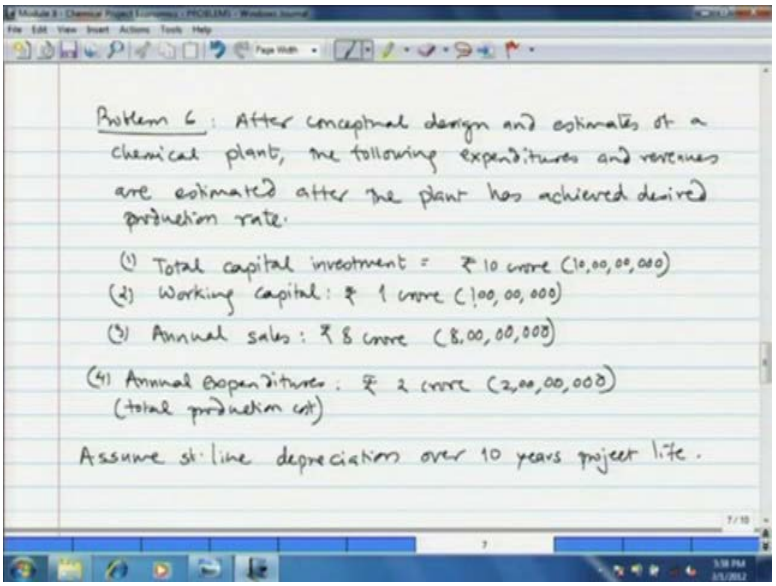

After conceptual design and estimates of a chemical plant, the following expenditures and revenues are estimated, after the plant has achieved the desired production rate. First, the total capital investment is rupees 10 crore, working capital is rupees 1 crore, annual sales are rupees 8 crore, annual expenditures or the total production cost is rupees 2 crore, we assume a straight line depreciation over 10 years of project life.

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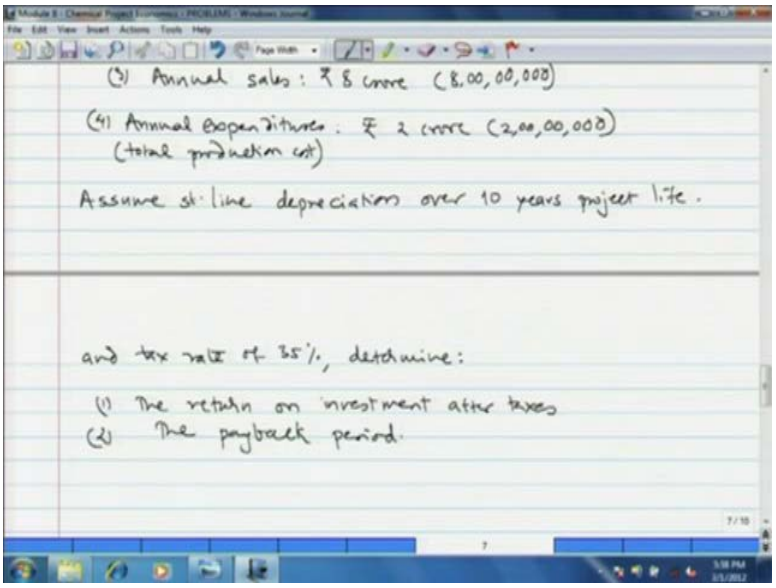

The tax rate is estimated at 35 percent and we have to determine the return on investment after taxes and the payback period for the plant.

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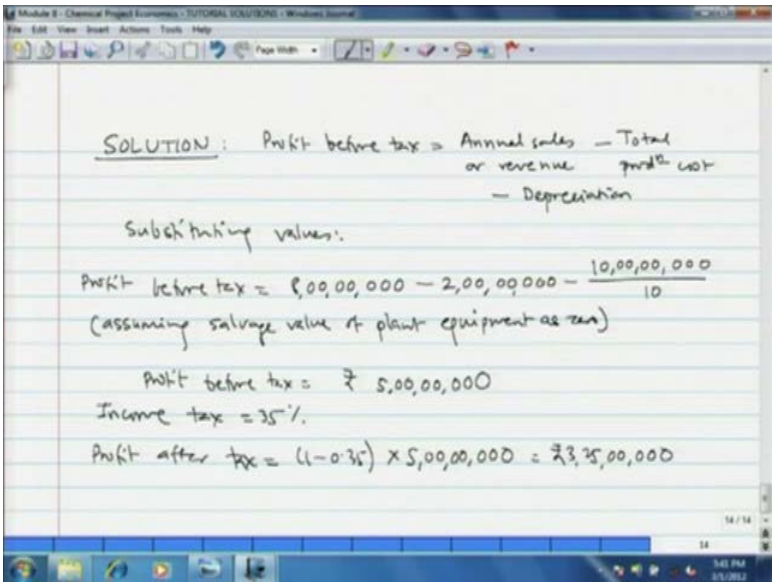

Now, let us start the solution, we know that the profit before tax is equal to the annual sales or revenue minus the total production cost minus the depreciation. Now, we substitute values, profit before tax is equal to annual sales, which is 8 crore minus the annual expenditure 2 crore or total production cost minus the depreciation and it is at straight line.

So, 10 crore divided by 10 years of project life, we assume salvage value to be 0 here, we note that point, assuming salvage value of plant equipment to be 0. And then, we get profit before tax as rupees 5 crore now, we have been given income tax at 35 percent. So, the profit after tax is 1 minus 0.35 into the profit before tax, 5 crore and this turns out to be rupees 3.25 crore. Now with this, we have to calculate the return on investment, return on investment is the net profit or profit after tax divided by the total capital investment. And then, you substitute values 3.25 crore divided by 10 crore, which is equal to 32.5 percent so, that is return on investment.

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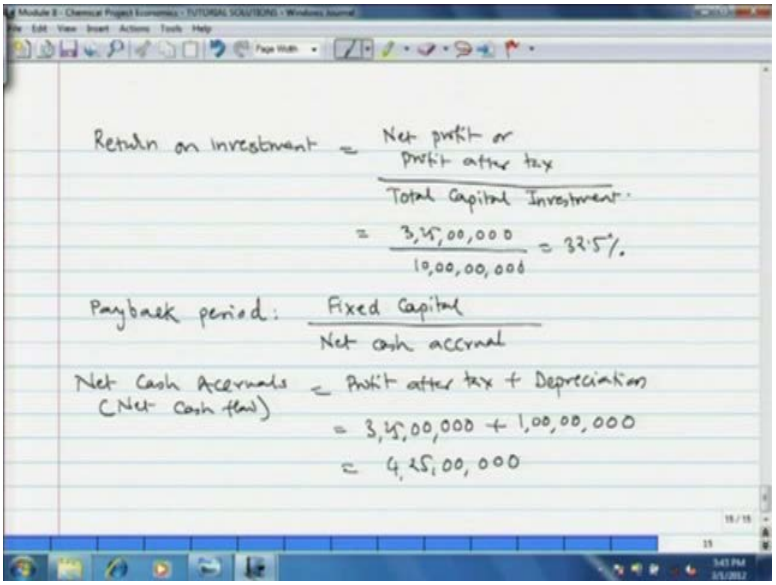

Next, we have to calculate the payback period, payback period is defined as fixed capital divided by the net cash accrual. Net cash accrual or net cash flow, as some books call it, is equal to the profit after tax, plus the depreciation. And then this is equal to 3.25 crore plus 1 crore of depreciation, that is equal to 4.25 crores. And then, payback period, substitute values is equal to fixed capital but, fixed capital is equal to the total capital investment minus the working capital divided by net cash accrual. So, 10 crore is the total capital investment, out of which 1 crore is the working capital divided by 4.25 crore, this turns out to be 2.18 years. So, the payback period for the plant is 2.18 years now, let us see one problem in only time value of money.

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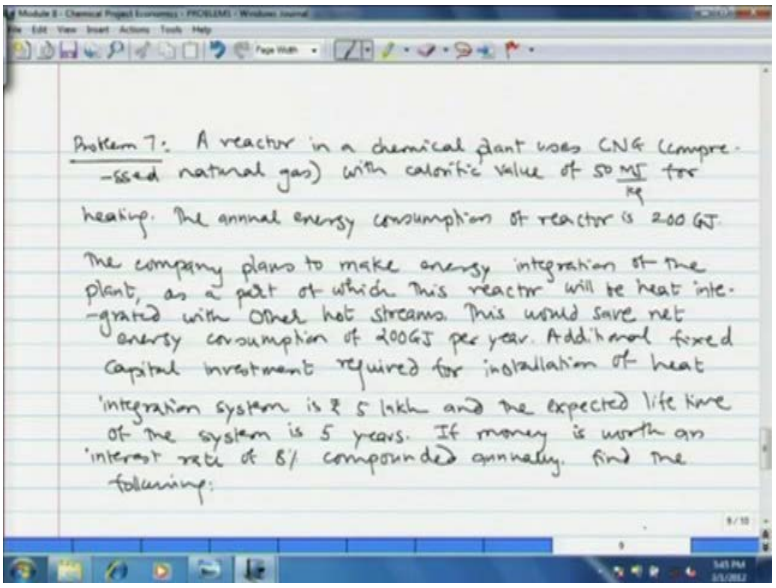

I will read the problem statement, reactor in a chemical plant uses CNG or compressed natural gas with calorific value of 50 mega joules per kg for heating. The annual energy consumption of the reactor is 200 gigajoules, the company plans to make energy integration of the plant, as a part of which, this reactor will be heat integrated with other hot streams in the process.

And obviously, this would save a net energy consumption of 200 gigajoules per year, the additional capital additional fixed capital investment required for the installation of heat integration system is estimated as rupees 5 lakh and expected life time of this system is 5 years. If the money is worth, an annual interest rate of 8 percent compounded annually then we have to find…

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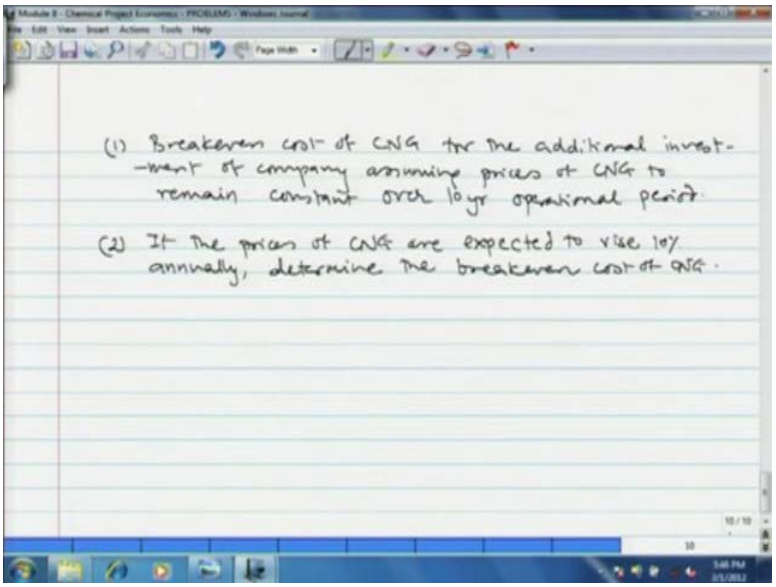

First, the breakeven cost of compressed natural gas for the additional investment of company, assuming prices of CNG to remain constant over the 5 year operational period. And then secondly, if the prices of CNG are expected to rise by 10 percent each year, determine the breakeven cost of CNG. Now here, we note a point, that at breakeven (Refer Slide Time: 42:36) the plant makes neither profit no loss.

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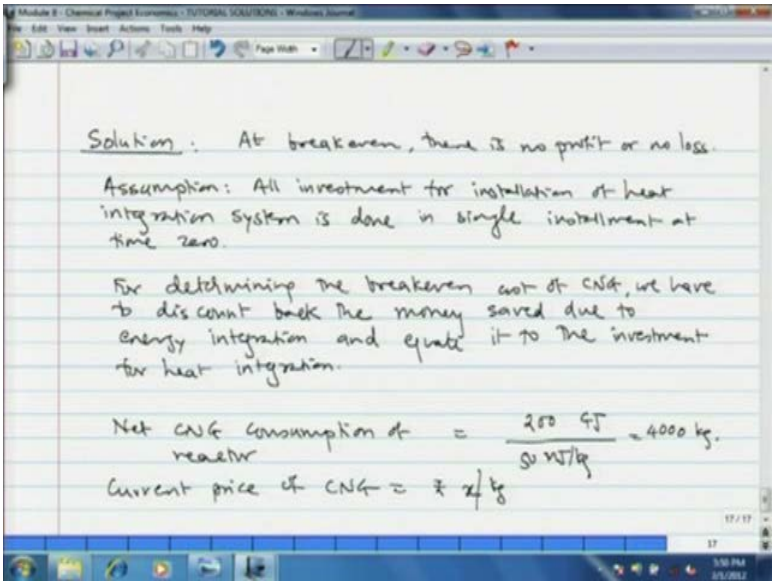

We have not been given here, the period of construction of the heat recovery system or heat integration system. But then, we can make assumption, that all of the investment for

the installation of heat integration system is done at once and at time is equal to 0, that assumption we note. Assumption, all investment for installation of heat recovery system or heat integration system is done in single installment at time equal to 0. Now, we have to calculate the breakeven cost of compress natural gas for that, we have to estimate the energy savings, the money worth energy savings over 5 year period. And that, we have to discount back to time 0 and see, whether it is equal to rupees 5 lakh of investment so, that is the approach, that point we note here.

For determining the breakeven cost of CNG, we have to discount back the money saved due to energy saving, money saved due to energy integration and equate it to the investment for heat integration. Now, the net CNG consumption of the reactor is 200 gigajoule divided by the calorific value of CNG 50 mega joule per kg that is, 4000 kgs now, we assume the current price of CNG to be rupees x per k g.

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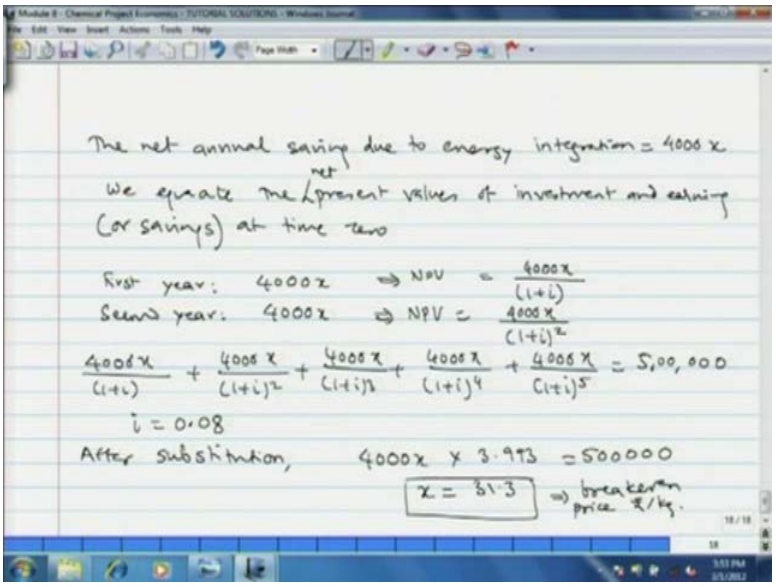

And then, the net annual saving due to energy integration is 4000 into x, we equate the present values or net present values of investment and earnings or savings in this case, at time 0. Now, first year, the profit of 4000 x, we assume to occur at the end of the year and then, the net present value of this money is 4000 x divided by 1 plus i. Then, second year, here again, we assume 4000 x because, x is assumed to remain constant and then, the net present value is 4000 x divided by 1 plus i square.

So, this is the net present value of the savings in the second year at time equal to 0, in this way we can sum up. So, 4000 x divided by 1 plus i plus 4000 x divided by 1 plus i square plus 4000 x divided by 1 plus i cube plus 4000 x, we have to divided by 1 plus i raise to 4 plus 4000 x divide by 1 plus i to the power 5 and is equal to rupees 5 lakh investment.

And interest rate, we have been given as 0.08 or 8 percent and then after substitution, we get 4000 x we can take common. And then, after putting 0.08 in place of i and summing up the series, we get 3.993, this you can easily work out on a calculator, which is equal to 5 lakh and then, x is 31.3. So, this is the price of CNG, at which there is no profit or no loss or the breakeven price, breakeven price in rupees per k g so, that is the solution to the first problem. Now, in the second sub problem, we have been given that, the cost of CNG is expected to rise annually by 10 percent.

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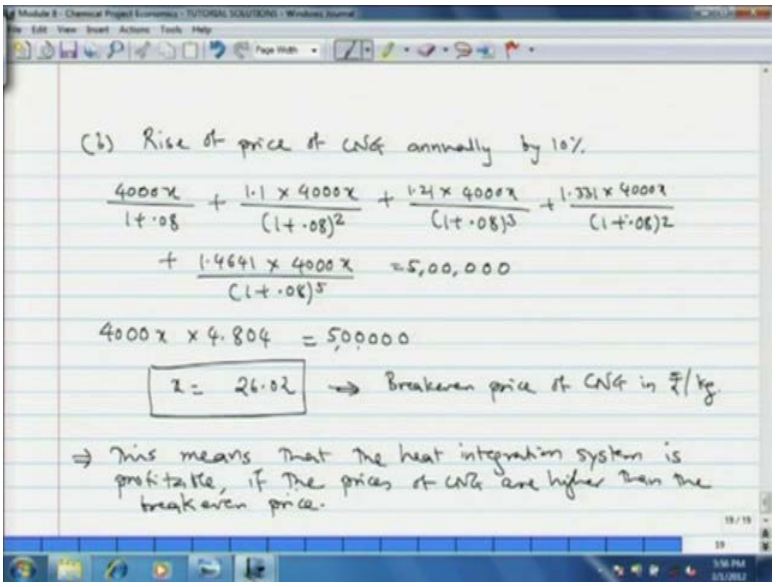

Section b this, rise of price of CNG annually by 10 percent now, in this case, we have to do exactly same thing however, our net earnings is going to increase with time. Because, the price of change is going to rise, we are going to save CNG due to energy integration, so the savings is going to rise. In the first year, it is going to be same, 4000 x divided by 1 plus i or i equal to 0.08 in the second year, the price is going to rise 10 percent. So, we have multiply the earnings of second year by 1.1, the denominator is 1 plus i square, in

the third year, 10 percent again over 1.1, so 1.21 into 4000 x 1 plus i cube. And then, 1.331 into 4000 x 1 plus 0.08 square plus and this is equal to 5000.

Now, again you take 4000 x common from right hand side and work out the series, that turns out to be 4.804, you can easily workout on a calculator, this is equal to 5 lakh and then, x equal to 26.02 so, this is the breakeven price of CNG in rupees per k g. So, if the prices of CNG are going to rise or expected to rise, then we save more and therefore, the breakeven price comes down 26, that means the system is profitable, if the prices are CNG or more than the breakeven price this means that, the heat integration system is profitable if the prices of CNG are higher than the breakeven price. So, this completes the first tutorial of chemical project economics, in the next tutorial, we shall also see problems related to depreciation, profitability analysis, ratio analysis, replacement, etcetera.