Process Design Decisions and Project Economics
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Module - 8
Chemical Project Economics
Lecture - 46
Tutorial (Part II)

Welcome, in the previous tutorial, we saw several problems on profitability analysis, replacement, time value of money, breakeven analysis. And today we shall continue the theme and we shall see some additional problems.

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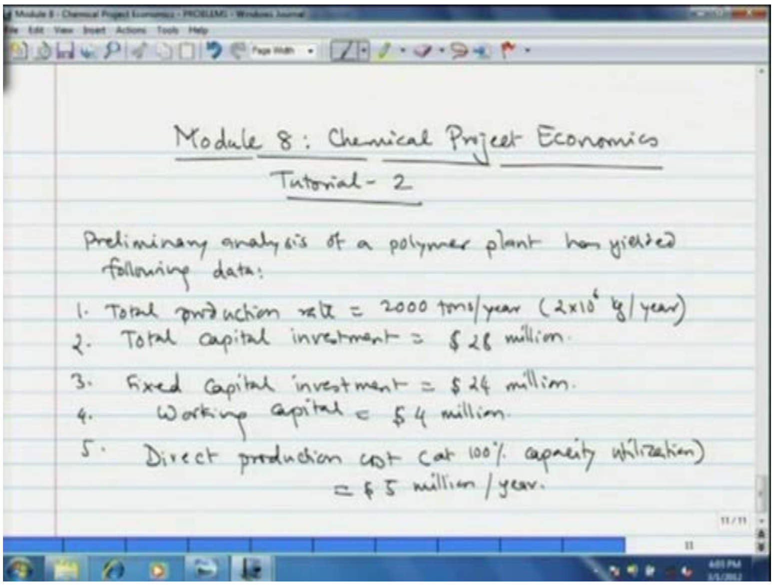

Let me give the statement of the first problem of today. Preliminary analysis of a polymer plant has yielded the following data. First the total production rate is 2000 tones per annum or 2 into 10 to power 6 kgs per year. Total capital investment is dollar 28 million, fixed capital investment is dollar 24 million, then the working capital dollar 4 million, then the direct production cost at 100 percent capacity utilization is dollar 5 million per year.

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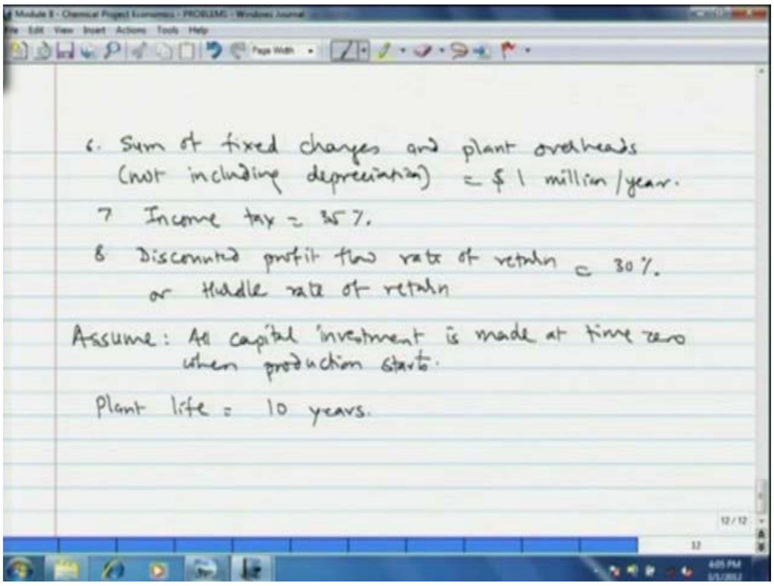

The sum of the fixed charges and plant overhead, but not including depreciation is 1 million dollars per year and income tax at 35 percent. And the discounted profit flow, rate of return or what we also called as the hurdle rate of return is 30 percent. We assume that, all capital investment is made at time 0, when the production starts and the plant life is 10 years now, we have the economic data on production in the form of a table.

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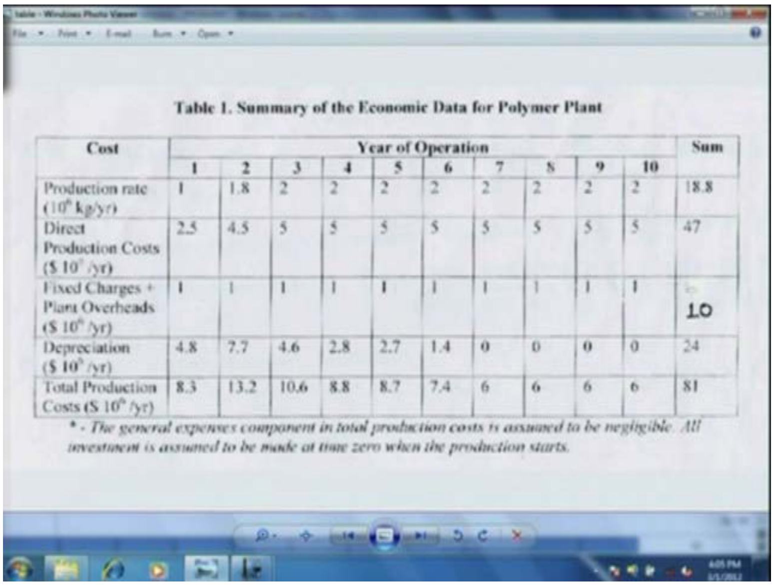

Table 1. Summary of the Economic Data for Polymer Plant

Cost	Year of Operation										Sum
	1	2	3	4	5	6	7	8	9	10	
Production rate (10^6 kg/yr)	1	1.8	2	2	2	2	2	2	2	2	18.8
Direct Production Costs ($ 10^6 /yr)	2.5	4.5	5	5	5	5	5	5	5	5	47
Fixed Charges + Plant Overheads ($ 10^6 /yr)	1	1	1	1	1	1	1	1	1	1	10
Depreciation ($ 10^6 /yr)	4.8	7.7	4.6	2.8	2.7	1.4	0	0	0	0	24
Total Production Costs ($ 10^6 /yr)	8.3	13.2	10.6	8.8	8.7	7.4	6	6	6	6	81

* - *The general expenses component in total production costs is assumed to be negligible. All investment is assumed to be made at time zero when the production starts.*

That you see now on screen, the 100 percent, the total installed capacity of the plant is 2000 tones or 2 into 10 to power 6 kgs per year but as you see on the screen, that summary of the economic data, all of this capacity is not utilized from time 0. In the first year, the production rate is only 50 percent that is, 1 tone or 1 into 10 to power 6 kgs per year in the 2 nd year, it is 1.8 and third year onwards, it is full capacity utilization, 2000 tones.

So, over a period of 10 years, the total production of the polymer is 18.8 into 10 to power 6 kgs per year. The direct production cost, first year it is 2.5 million, 2 nd year 4.5 million, third year onwards it is fixed at 5 million. Fixed charges plus plant overhead are constant throughout that is, 1 million dollars per year, depreciation we have calculated according to MACRS method.

Now, subsequently, we shall see one problem on accelerated cost recovery system analysis so for time being, you can take these values for granted. The depreciation in the 1 st year is 4.8 million dollars, 2 nd year 7.7 then 2.8 and the total depreciation over 10 years is 24 million dollars. And the total production cost varies like first year it is 8.3, 2 nd year 13.2, 3 rd year 10.6, 4 th year 8.8, 5 th year 8.7, 6 th year 7.4 and 7 th year onwards it is 6 million dollars. So, the total production cost is over a period of 10 years is 81 million dollars, the general expenses components in the total production cost is assumed to be negligible and all investment is assumed to be made at time 0, when the production starts.

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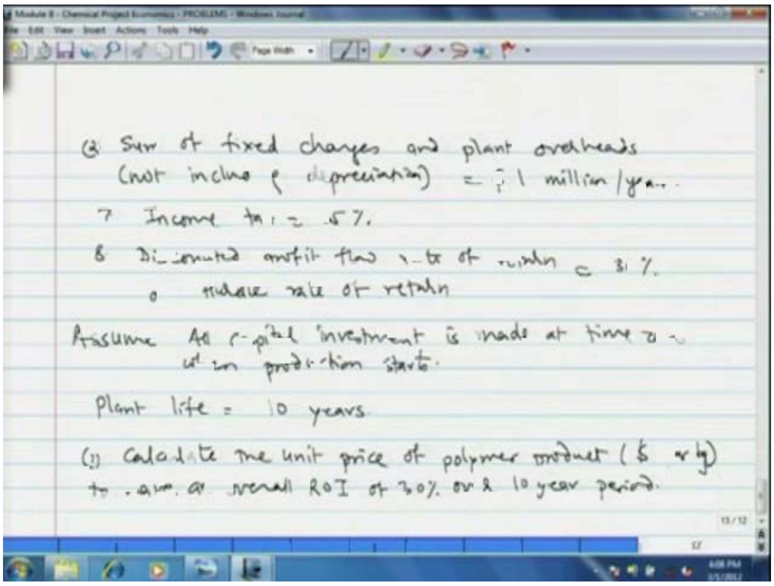

For this data, we have to estimate the unit price of the polymer product to have an overall or average return on investment of 30 percent over 10 year period. That is the first thing, that we have to find out, calculate the unit price of polymer product in dollar per kg to have an overall return on investment or ROI of 30 percent over 10 year period.

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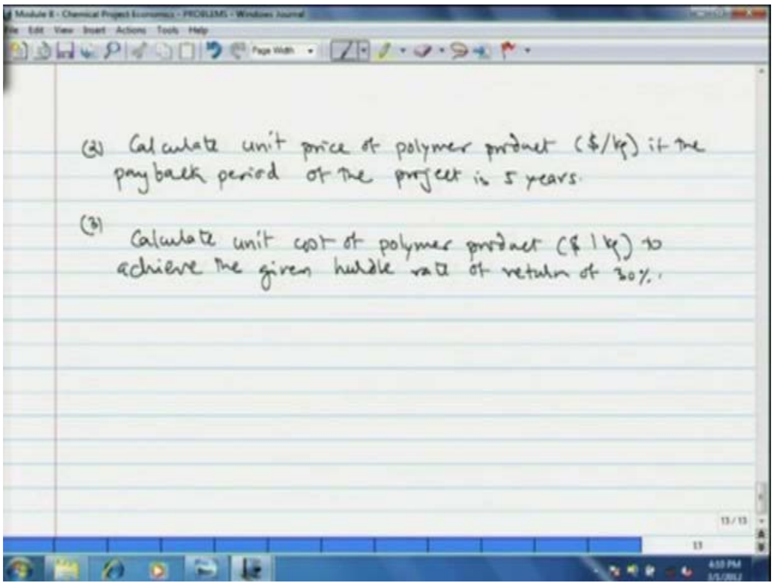

Then second, calculate the unit price of the polymer product, again in dollar per kg if the payback period of the project is 5 years. And third, calculate the unit cost of polymer product in dollar per kg to achieve the given hurdle rate of return of 30 percent.

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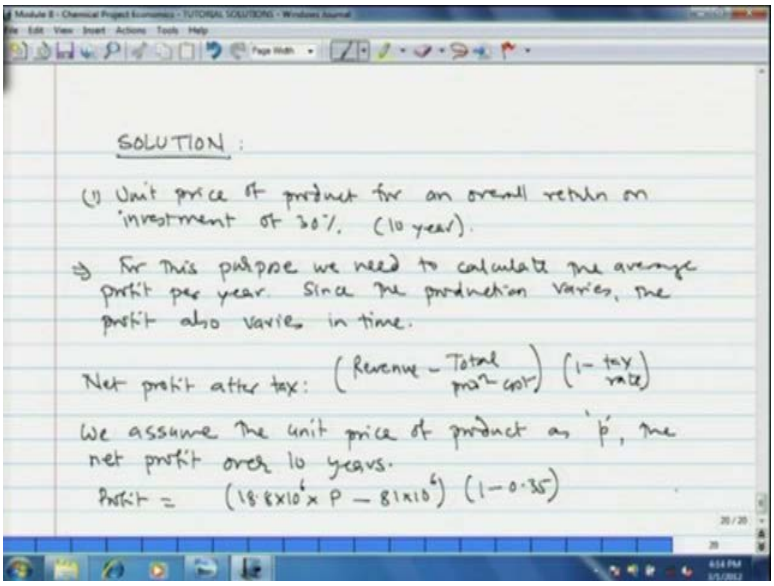

So, let us start the first bit of the problem firstly, we have to find out the unit price of the product, for an overall rate of return not annual but over 10 year period, for an overall return on investment of 30 percent over 10 year period. Now for this purpose, we have to calculate the average profit per year and since the production is varying in the first two year, it is lesser than the installed capacity, the profit also varies in time. So, that point we note, for this purpose, we need to calculate the average profit per year.

Since the production varies, the profit also varies in time, the net profit after tax is revenue minus total production cost into 1 minus tax return. We assume the unit price of the product as p and then the net profit over 10 years is 18.8 into 10 to power 6 into p, 18.8 into 10 to power 6 kgs is the overall production in 10 years minus the total production cost of 81 million dollars, 81 into 10 to power 6 into 1 minus 0.35.

Now here, we have not taken into account the depreciation usually, the net profit after tax is revenue minus total production cost minus depreciation. So, that is the profit before tax and into 1 minus tax rate but for simplicity, we have not taken depreciation here into account, although we have been given a depreciation of over a period of 10 years.

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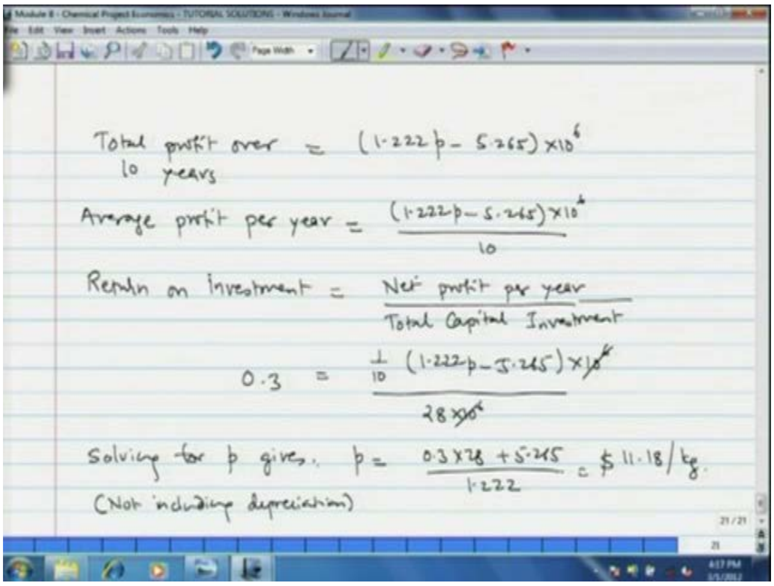

The total profit over 10 years is 1.222 into p minus 5.265 into 10 to power 6 and then average profit per year is, that divided by 10 and then the return on investment is profit per year. But, that is the net profit divided by the total capital investment and now, you substitute values, the total capital investment is 28 million dollars. So, the denominator is 28 into 10 to power 6 and a numerator is what we just calculated, 1 by 10 into 1.222 p minus 5.265 into 10 to power 6 and this has to be equal to 30 percent or 0.3.

So, solving for p gives, p is equal to 0.3 into 28 plus 5.265 divided by 1.222, we cancel 10 to power 6 from numerator denominator and this gives the unit product price as 11.18 dollars per kg. So, here so this is the unit price for product to have an overall return of 30 percent over 10 year period and again I point, note down here assumptions not including depreciation. If you include depreciation here then the return on investment is more than 30 percent so that is the first answer to the first bit of this problem.

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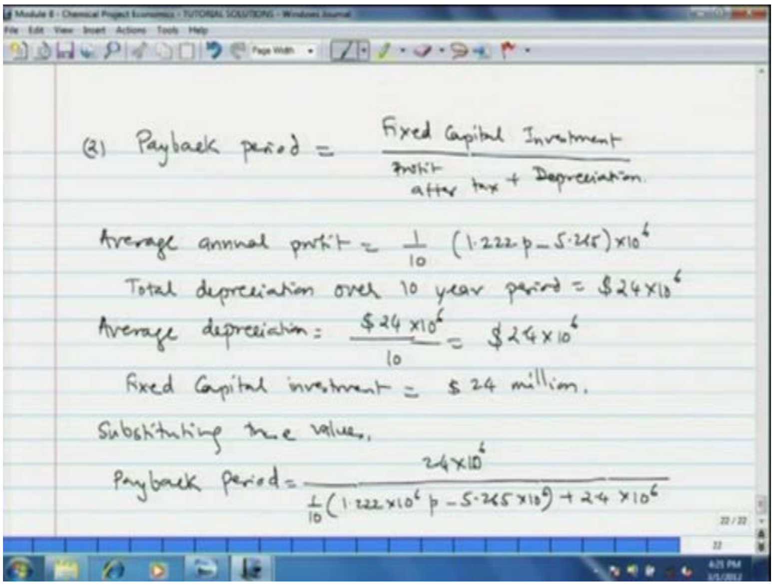

Now, in the second bit we have calculate the unit product price for a payback period of 5 years, payback period is defined as the fixed capital investment divided by net cash accruals, which is equal to profit after tax plus depreciation. We have already calculated in the previous bit, the average annual profit so that we take directly, average annual profit was 1 by 10 into 1.222 p minus 5.265 into 10 to power 6.

The total depreciation in 10 year period, if you seen the table is given as 24 million dollars so the average depreciation per year, we take 24 into 10 to power 6 divided by 10 as 2.4 into 10 to power 6 dollars or 2.4 million dollars. Fixed capital investment is the total capital investment minus the working capital, working capital is given as 4 million, total capital investment 28 million so fixed capital investment is 24 million.

Now, we substitute these values in the payback period, 24 into 10 to power 6 divided by average profit per year. So, total profit that, which has been say, 1.222 into 10 to power 6 p minus 5.265 into 10 to power 6 plus the average depreciation that is, 2.4 into 10 to power 6.

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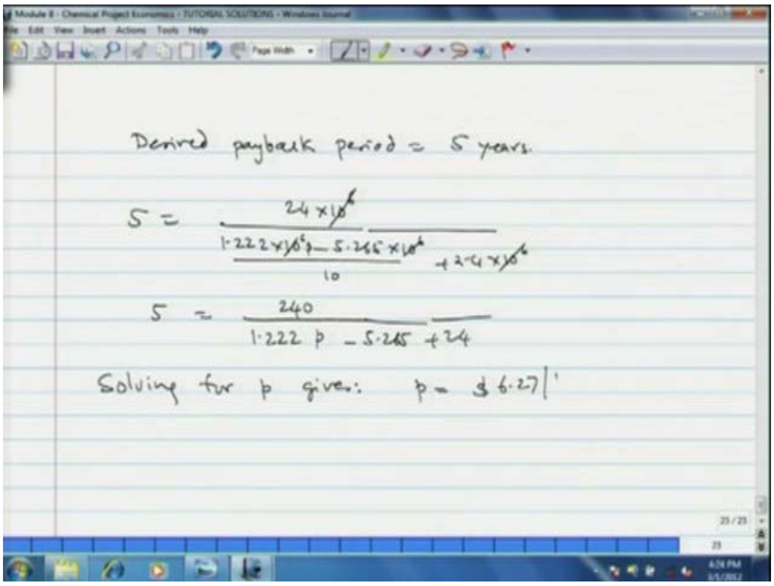

And then the desired payback period is 5 years and then we simplify and then if you solve for p, p equal to dollar 6.27 per k g. So, the answer to the second bit is, p is equal to dollar 6.27 per kg, this is the price of the polymer product for the payback period to be 5 years.

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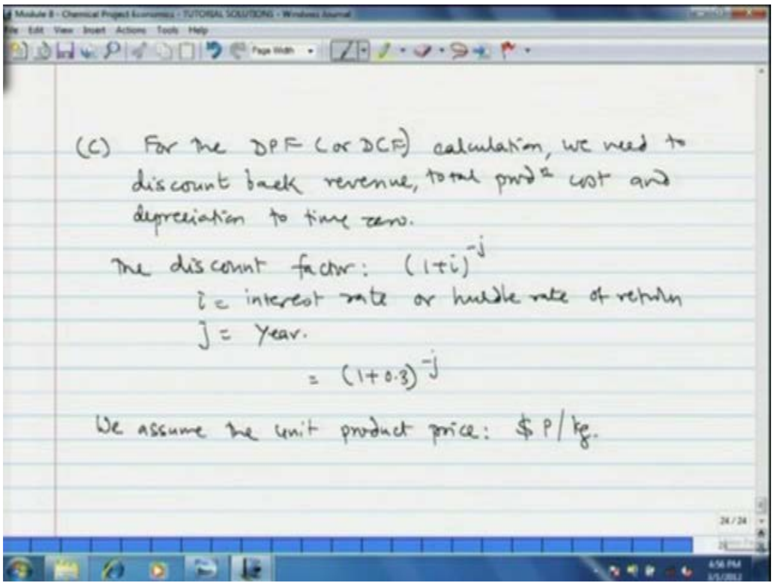

In the third problem, we have to do a discounted profit flow or discounted cash flow analysis with a given hurdle rate of return. So, for the DPF or DCF, discounted cash flow or discounted profit flow calculation, we need to discount that revenue then the total production cost, the depreciation to time 0 with an interest rate of 30 percent. The discount factor will be 1 plus i to the power minus j where, i is the interest rate or hurdle rate of return and j is the year, it is 1 plus 0.3 raise to minus j. And we again assume, the unit product rise to be P dollar per kg, we have to prepare a table of the discounted revenue, discounted profit, discounted depreciation.

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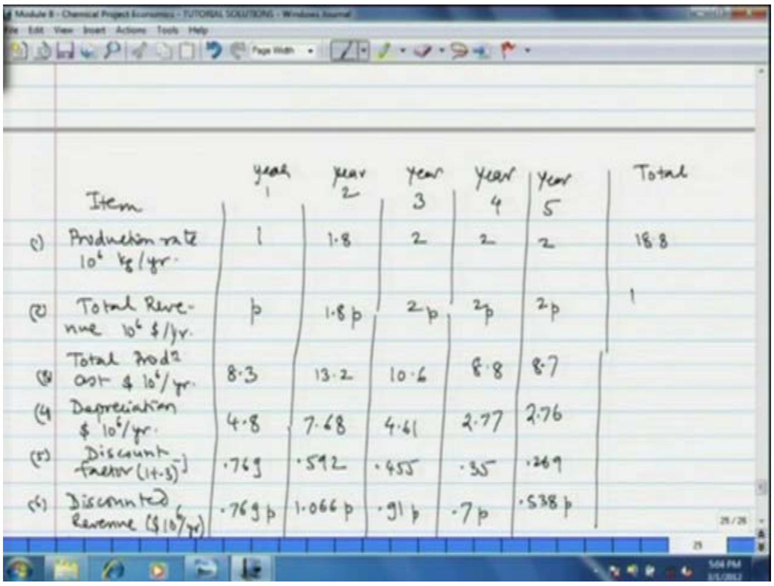

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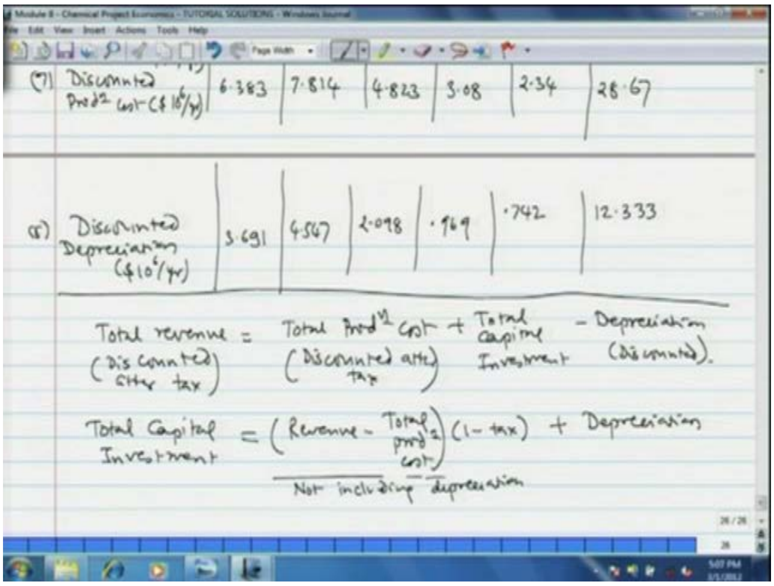

So, I will show here, the first some few years of table and then rest of the thing you can calculate yourself. So, item first is the production rate 10 to power 6 kg per year then second is a total revenue that is, again 10 to power 6 dollar per year then third item the total production cost then this again dollar 10 to power 6 per year. Then the depreciation dollar 10 to power 6 per year then fifth is the discount factor, this is 1 plus 0.3 raise to minus j, as we just said.

Then, the discounted revenue dollar 10 to power 6 per year then discounted production cost and finally, the discounted depreciation. Year 1 here, the production is half of the total installed capacity so 1 into 10 to power 6 kg per year or 1000 tons per year. Total revenue, we assume unit product price to be P per kg so total revenue in million dollars is p then the total production cost has been given to us as 8.3, depreciation has been given to us as 4.8.

Just look into the table, depreciation 4.8, total production cost 8.3, we have to calculate the discount factor. In the first year, the discount factor will be 1.3 raise to minus 1 that is, 0.769 and after multiplying by this 0.769 discount factor, to the first three items total revenue, total production cost and depreciation, we get the discounted price at time 0. So that, we do know discounted revenue 0.769 into p, discounted production cost is 0.769 into 8.3 that is, 6.383.

And then the discounted depreciation is 4.8 into 0.769 that is, 3.691 similarly for the second year, we have total production rate as 1.8 million kgs a year then the total revenue becomes 1.8 into p million dollars per year. The total production cost is given as 13.2, depreciation is given as 7.68 and then the discount factor is 1.3 raise to minus 2 now and that is, 0.592 and after multiplication with this discount factor to the first three items, we get discounted revenue as 1.066 P.

Then, the discounted production cost as 7.814 and the discounted depreciation as 4.547 and you can continue in this way, I am giving you directly the figures for the 3 rd year and then subsequently you have to calculate. I will give you the final answer, year 3 production rate 2, total revenue 2 p, total production cost 10.6, this depreciation 4.61 then discount factor 1.3 raise to minus 3 so 0.455.

Then discounted revenue 0.91 p, discounted production cost 4.823 and discounted depreciation is 2.098. Then for the forth year, we have again production rate of 2000 tons per year, total revenue 2 p then total production cost 8.8, depreciation 2.77, discount factor is now 0.35, 1.3 raise to minus 4. Discounted revenue is now 0.7 into p, 0.35 into 2 P so 0.7 p then discounted production cost 3.08.

And the discounted depreciation is 0.969 then for the 5 th year, production rate is 2000 tons or 2 into 10 to power 6 kgs year. Then the total revenue is again 2 p, total production cost is 8.7, total depreciation 2.76, discount factor 0.269, discounted revenue 0.538 into p, discounted production cost 2.34 and discounted depreciation is 0.742. And for rest of the 5 years, year 6, 7, 8, 9 and 10, I leave it as an exercise for you to work it out, it is pretty straight forward.

I have given example up to year 5 and now, I am giving answer for the total over 10 years, total production over 10 years is 18.8 into 10 to power 6 kgs per year, total revenue is 18.8 into p. Total production cost is 81 then total depreciation 24 million dollars then discount factor is that is not there, that total is not there then total discounted revenue at time 0 is 5.295 into p.

The discounted production cost is 28.67 and total discounted depreciation at time 0 is 12.333 now with this table, we have to go for the analysis. Total revenue is equal to total production cost now, this is of course, discounted after tax, total revenue discounted after tax is equal to total production cost discounted after tax plus total capital investment.

Now, this is at time 0 so there is no question of discounting, minus the depreciation again discounted. You can write in other way, total capital investment should be equal to revenue minus total production cost, not including depreciation that, I would like to find stress again, here I will write not including depreciation plus the depreciation. So that, this should be the case for the hurdle rate of return now, we put all the values that we have obtained.

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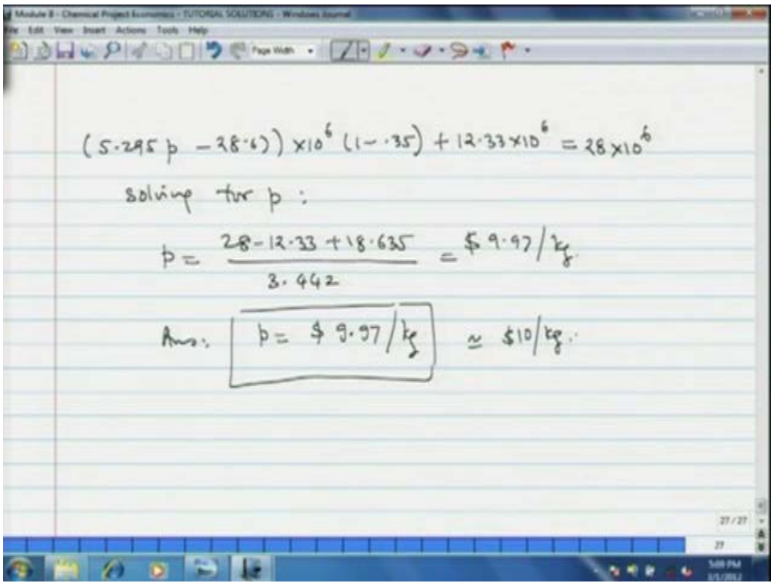

Revenue, we obtained discounted revenue was 5.295 into p then the total production cost was 28.67. And now, this into 10 to power 6 into the tax rate, 1 minus 0.35 plus total discounted depreciation 12.33 into 10 to power 6 and this should be equal to the total capital investment 28 into 10 to power 6. Now with this, solving for p, we get p is equal to 28 minus 12.33 plus 18.635 divided by 3.442 equal to dollar 9.97 per kg. So, that is the answer, to have the hurdle rate of return of 30 percent over the investment, the minimum product price should be dollar 9.97 per kg or approximately you can say dollar 10 per kg. So, that is the complete solution to the problem now, let us see the next problem that is on depreciation.

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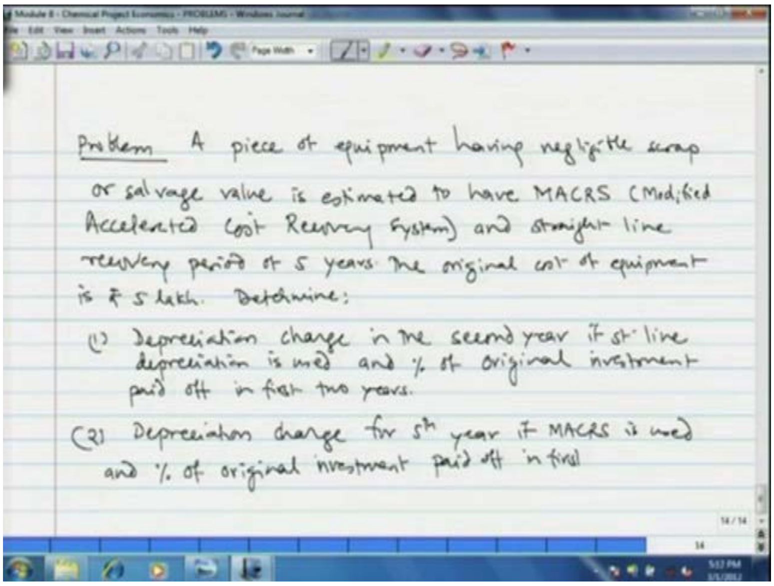

I will give the problem statement., a piece of equipment having negligible scrap value or salvage value is estimated to have a modified accelerated capital recovery system MACRS as abbreviated, modified accelerated capital recovery system or cost recovery system and straight line recovery period both, period of 5 years. The original cost of equipment is rupees 5 lakhs now, for this, determine first the depreciation charge in the 2 nd year, if straight line depreciation used and the percentage of original investment paid off in the first 2 years. Then Secondly, depreciation charge for the 5 th year, if the modified accelerated cost recovery system is used and the percentage of original investment paid off in the first 2 years so this is the problem statement.

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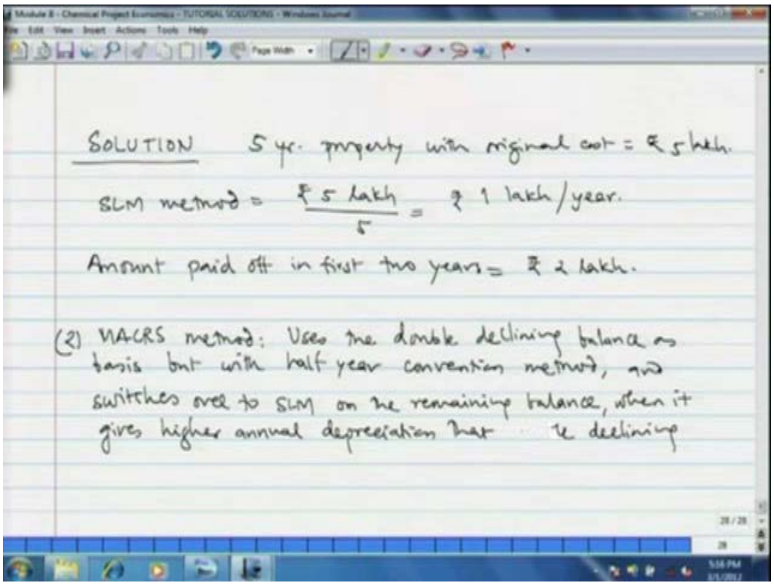

Let us see now the solution, we have a 5 year property with original cost of rupees 5 lakh so if straight line method is used, the depreciation per year is rupees 5 lakh by 5, we have not been given any scrap value, scrap value is said to be negligible. So that, the straightway depreciation over 5 years is rupees 5 lakh and that is, rupees 1 lakh per year. So, the amount paid off in first 2 years is rupees 2 lakh so that answers the first bit of the question.

Now in the second bit, we have to calculate the cost recovery in successive years now, MACRS method, let me first give you a brief description of MACRS method. It uses the double declining balance method, that we have seen in one of the lectures as basis but with a half year convention method. And then it switches over to the straight line method on the remaining balance, when it gives higher annual depreciation than obtained with double declining balance method. So, that point we note, the MACRS method uses double declining balance as basis but with half year convention method in the first year, and switches over to the straight line method on the remaining balance, when it gives higher annual depreciation than double declining.

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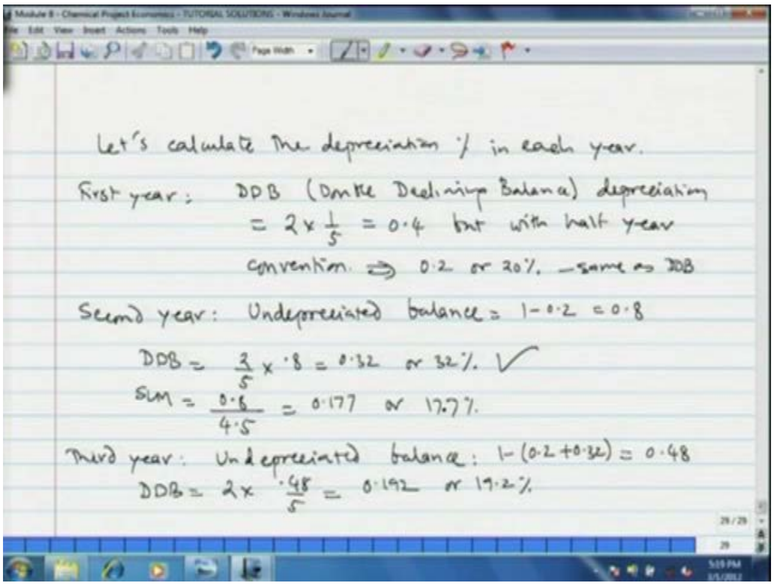

Now with this, let us calculate the depreciation percentage in each year, first year, we have a double declining balance method, that we denote as DDB, double declining balance with half year convention. So, for the first year, double declining balance gives a depreciation, DDB depreciation would be 2 into 1 divided by 5, 1 divided by 5 is the straight line and double of that so double declining. So, 0.4 for property that is, that has a unit price 1 but with half year convention so 0.4 becomes 0.2 now, the depreciation with straight line method is also 20 percent for 5 year property. So, 20 percent is same as DDB, in the second year, un-depreciated balance is 1 minus 0.2, 0.2 is the depreciation in the 1 st year so un-depreciated balance after 1 st year is 0.8.

So, the DDB method gives now, 2 by 5 into 0.8 that is equal to 0.32 or 32 percent depreciation, while straight line method gives 0.8 un-depreciated balance divided by 4.5. Because, it is half year convention, 0.8 is the un-depreciated balance with half year convention so 4.5 that is, 0.177. So, we go 177 is being lesser than 0.32 or 17.7 is lesser than 32 percent so we go for the double declining balance. So, the recovery in the 2 nd year is 32 percent, 3 rd year the un-depreciated balance from second year is 0.8 minus 0.32 or 1 minus 0.2 plus 0.32 that is equal to 0.48. Now, double declining balance gives 2 into 0.48 by 5 as the recovery that is, 0.192 or 19.2 percent.

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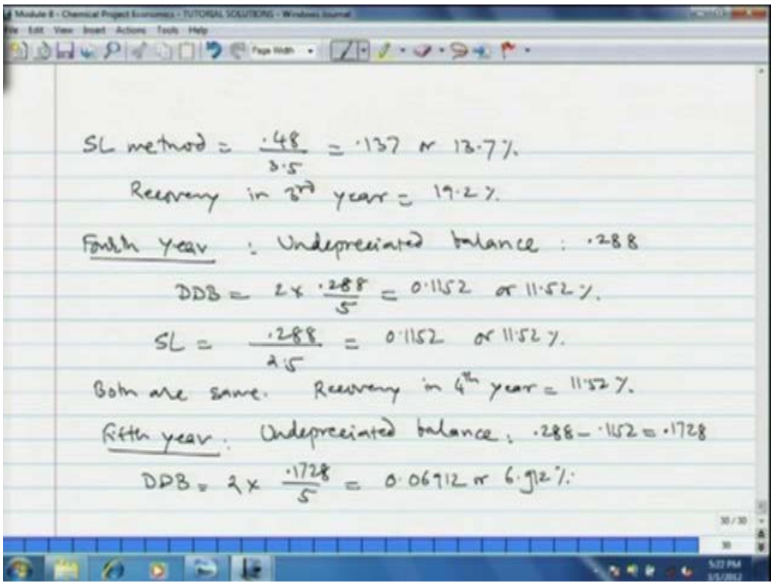

While the straight line method gives a recovery of 0.48 divided by 3.5 remaining so 0.137 or 13.7 percent, here again the DDB recovery is higher so we go for that. So, recovery in the 3 rd period or recovery in the 3 rd year is 19.2 percent, 4 th year the un-depreciated balance is 0.288, the previous balance minus 0.192 or 0.48 minus 0.192. Now here, the double declining balance gives a recovery of 2 into 0.288 by 5 that is equal to 0.1152 or 11.52 percent.

The straight line method gives a recovery of 0.288 divided by 2.5, which is also equal to 0.1152 or 11.52 percent and thus, both are same and therefore, you can take any of these as recovery. So, the recovery in 4 th year is 11.52 percent, in the 5 th year the un-depreciated balance from the previous year is 0.288 minus 0.1152 that is equal to 0.1728. And then here the double declining balance, DDB method gives a depreciation of 2 into 0.1728 by 5 that is equal to 0.06912 or 6.912 percent.

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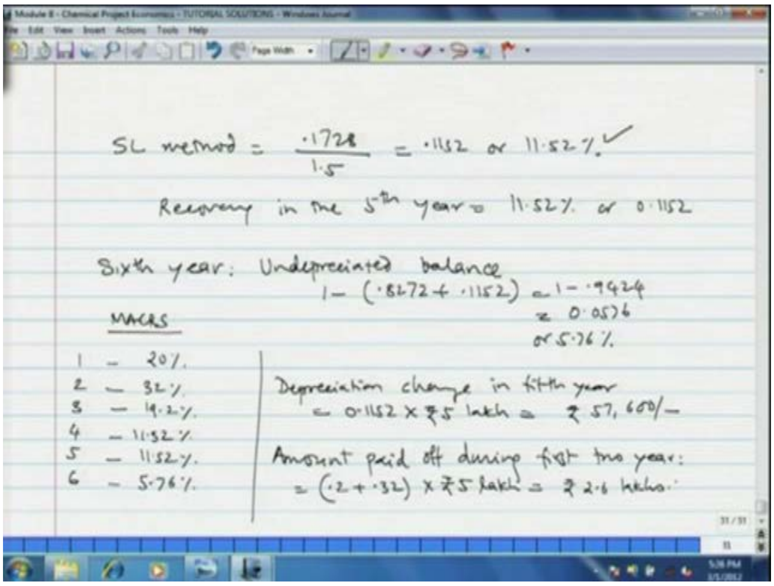

While the straight line method gives recovery of 0.1728 divided by 1.5 that is equal to 0.1152 or 11.52 percent. Now here, the recovery by straight line method is higher than that of double declining balance so as per the norm, we shift to straight line method so recovery in 5 th period or in the 5 th year is 11.52 percent or 0.1152. Now, in the 6 th year, we have depreciation charge left, because of the half year convention and therefore, the un-depreciated balance is 1 minus 0.8272 plus 0.1152, this is balance of two, the 5 th year, this is balance in 5 th year 1.1152 so 1 minus 0.9424 or 0.0576 or 5.76 percent.

So, that is how, we now summarize the recovery of MACRS system, 1 st year 20 percent, 2 nd year 32 percent, 3 rd year 19.2 percent, 4 th year 11.52 percent, 5 th year again 11.52 percent and 6 th year is 5.76 percent. Now, we have to calculate two things, first is the depreciation in the 5 th year, depreciation charge in 5 th year, so that is straight forward, 5 th year is 0.1152 or 11.52 percent of original cost, so 0.1152 into rupees 5 lakh that is rupees 57600.

And we have also to calculate, the amount paid off during the first 2 years, the cumulative amount in the first 2 years is 0.2 plus 0.32, 0.52 times the original cost so that turns out to be, rupees 2.6 lakhs. So, today, we have seen 2 problems on profitability analysis, using ratio analysis as well as the discounted profit flow or DCF or discounted cash flow technique. And then we have also seen a problem on depreciation, so this completes our module on chemical project economics.