Engineering Economic Analysis
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Lecture 11
Economic Equivalence: Meaning and Principles of Equivalence

Welcome tothe lecture on principles of equivalence. So in engineering economic analysis we need to find the equivalent amount at different time.

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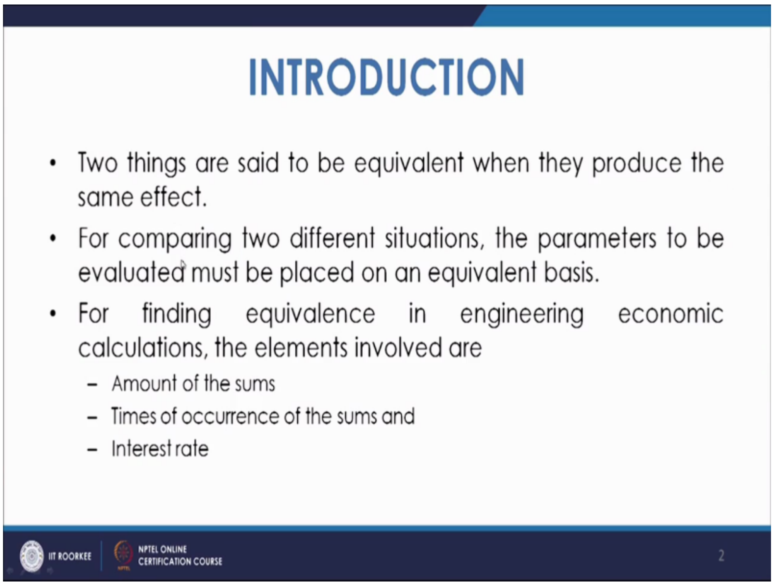

So far we have discussed about different interest, now the equivalence by definition two things are said to be equivalent when the produce the same effect. Means if we try to compare two things which are different we cannot say that they are equivalent unless we compare them on a certain basis. Suppose we try to find the equivalence between Rs. 500 and 10 KGs of sugar, so unless know the price of 1 KG of sugar we cannot find the equivalence between the two.

So we have first of all to have a basis then only we can have the equivalence. For comparing two different situations, the parameters to be evaluated must be placed on equivalent basis. So basically the end effects has to be considered, if suppose there are two different things and they have to be judged, in that case the effect they produce, they are to be seen with a common eye.

So in engineering economic analysis, basically what we deal with is, we used to see the cash flows at different times. Now we have basically to say whether two cash flows are equivalent or even a single cash flow, what will be the equivalent amount at a later time because anyway we have discussed about the time value of money. So basically value of money which is there now is going to change at a later time.

So basically there are three things which are dictating it, one is amount of sums. So basically in any cash flow diagram what you see is amount of monetary transactions. Then the times of occurrence of these sums. They may occur at a same time or they may occur at different times and then the interest rate. So all these three is to be taken into account. Now let us see one example where you are given a option of getting a reward from the organization.

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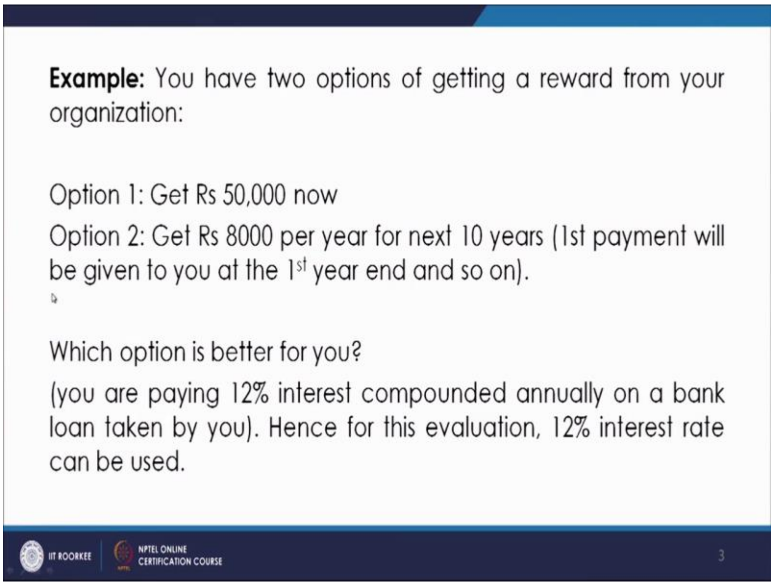

The organisation gives you two options, one is that you get Rs. 50,000 now. Another option which your organisation gives you is that you get 8000 per year for the next 10 years. So every year the payment will be made at the end of the year. So basically in this case if you look at you are basically getting 80,000 but for the next 10 years. Now how to evaluate which of the option is better economically?

You will have to see that what is the equivalent amount at a particular time. In this case what we see is, as we have seen in the earlier case, you have three things, amount of sums, times of occurrence of sums and interest rate. So if two of the things are equal, the third thing will anyway be equal for any cash to diagram.

If there are two cash flow diagrams and if the two of the three is same, the third has to be the same or the fixed one for the two cash flow to be equivalent. If not, if the interest rate is fixed and if the times of occurrence of the sums are different, then certainly the amount of sums will also be different at different times. So that is how equivalence can be maintained. Now let us see we have two judge which of the option is better.

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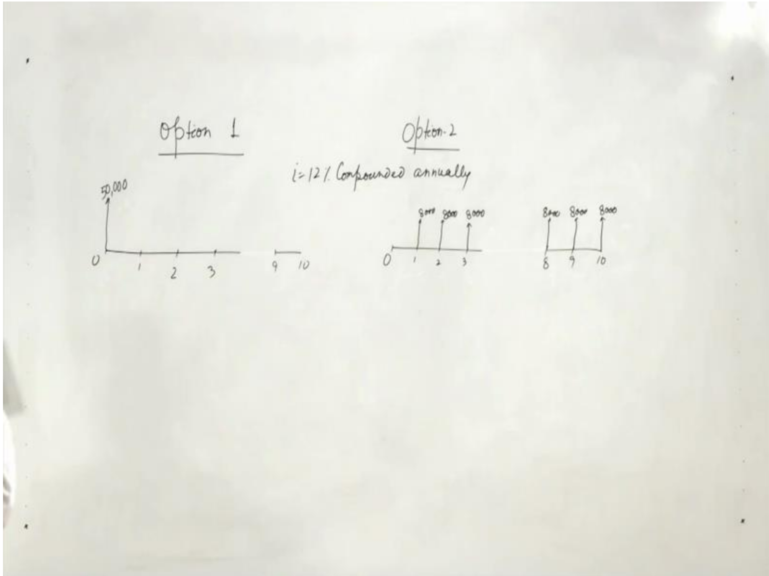

So in the option one, you are getting a cash flow diagram like this, you are getting Rs. 50,000 now and in the second option you are getting Rs. 8000 for the next 10 years. So option 2 gives you a cash flow diagram like this and every year end you are getting Rs. 8000. Now these other two options which we have. Now they cannot be compared unless you try to evaluate the amount at a particular time. Here you see that you have the interest rate fixed.

The condition is that you are paying 12% interest compounded annually on a bank loan, so basically this gives you a consideration of taking the interest rate. So interest rate is taken as 12% compounded annually. Now in this case you have to compare these two, so you have to keep the three factors as we discussed, in mind. One is the amount of sums which is different here.

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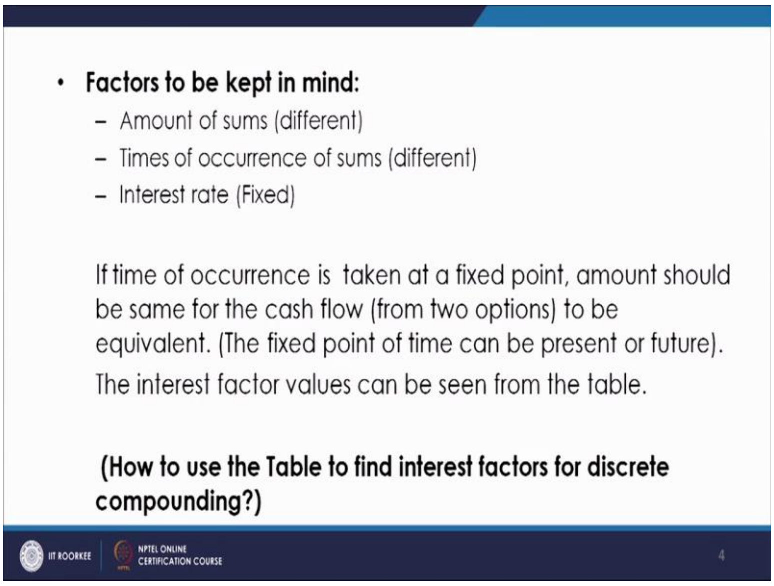

You are being paid 50,000 in the option one and you are being paid 10 times 8000 but at different times. So certainly the time of occurrence of sum is also different. And the interest rate is taken as the fixed one that is 12%.So if time of occurrence is taken a fixed point, amount should be same for the cash flow for the two options to be equivalent. That we have so far come across, that if we are taking a particular time because time of occurrence is different here.

Once we fix this time of occurrence, if we find the equivalent value at a particular time, in that case, automatically the amount of sum must be fixed for the two cash flow to be equivalent. Now, this time can be either the present time or a future time. You can have the equivalent value at this point or you can have the equivalent value at this point and then you can compare. Now it is better to compare using the present worth calculation.

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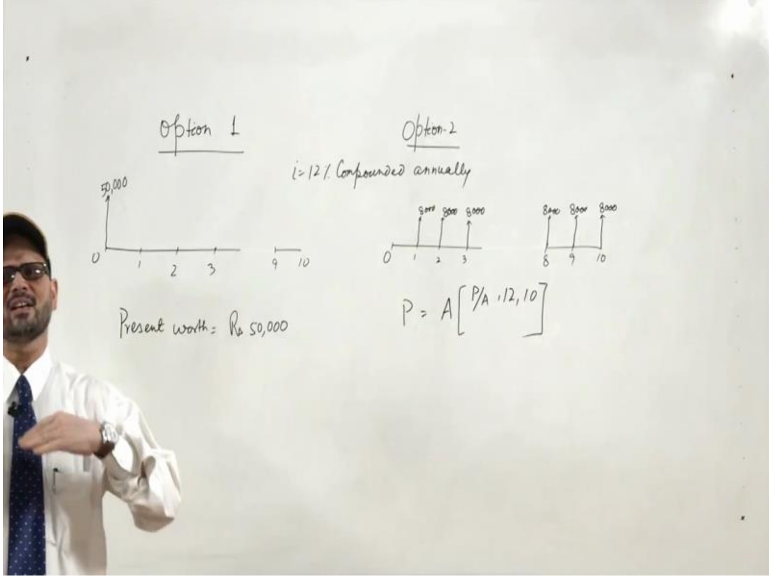

So anyway in this case what we see is that, the present worth is Rs. 50,000. Now if you calculate the present worth value of the option 2, in that case, you have we have already come across the different interest series factors, so basically present worth can be found out by multiplying the annual amount with a factor P why A and i is 12%, so 12 and n is 10. This basically gives you the equivalent present worth of this cash flow series at this particular point.

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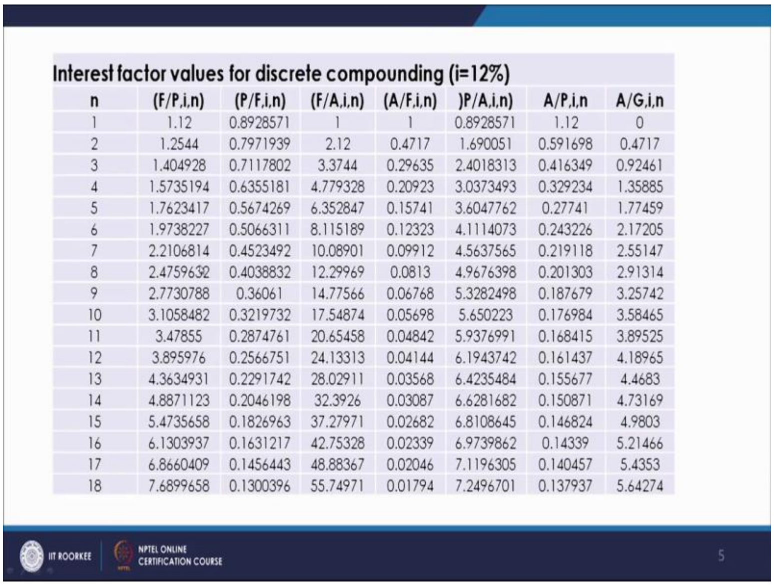

Interest factor values for discrete compounding (i=12%)

n	(F/P,i,n)	(P/F,i,n)	(F/A,i,n)	(A/F,i,n)	)P/A,i,n)	A/P,i,n	A/G,i,n
1	1.12	0.8928571	1	1	0.8928571	1.12	0
2	1.2544	0.7971939	2.12	0.4717	1.690051	0.591698	0.4717
3	1.404928	0.7117802	3.3744	0.29635	2.4018313	0.416349	0.92461
4	1.5735194	0.6355181	4.779328	0.20923	3.0373493	0.329234	1.35885
5	1.7623417	0.5674269	6.352847	0.15741	3.6047762	0.27741	1.77459
6	1.9738227	0.5066311	8.115189	0.12323	4.1114073	0.243226	2.17205
7	2.2106814	0.4523492	10.08901	0.09912	4.5637565	0.219118	2.55147
8	2.4759632	0.4038832	12.29969	0.0813	4.9676398	0.201303	2.91314
9	2.7730788	0.36061	14.77566	0.06768	5.3282498	0.187679	3.25742
10	3.1058482	0.3219732	17.54874	0.05698	5.650223	0.176984	3.58465
11	3.47855	0.2874761	20.65458	0.04842	5.9376991	0.168415	3.89525
12	3.895976	0.2566751	24.13313	0.04144	6.1943742	0.161437	4.18965
13	4.3634931	0.2291742	28.02911	0.03568	6.4235484	0.155677	4.4683
14	4.8871123	0.2046198	32.3926	0.03087	6.6281682	0.150871	4.73169
15	5.4735658	0.1826963	37.27971	0.02682	6.8108645	0.146824	4.9803
16	6.1303937	0.1631217	42.75328	0.02339	6.9739862	0.14339	5.21466
17	6.8660409	0.1456443	48.88367	0.02046	7.1196305	0.140457	5.4353
18	7.6899658	0.1300396	55.74971	0.01794	7.2496701	0.137937	5.64274

Now so far we have used the different types interest factor relationships to find these factor values but we can now onwards use the interest tables to calculate these interest factor values. Now these intrex table are supplied at the back of the textbooks. Also you can calculate on your own in the excel. How to use it? Let us see, this is the interest factor values for different discrete compounding that is i equal to 12%.

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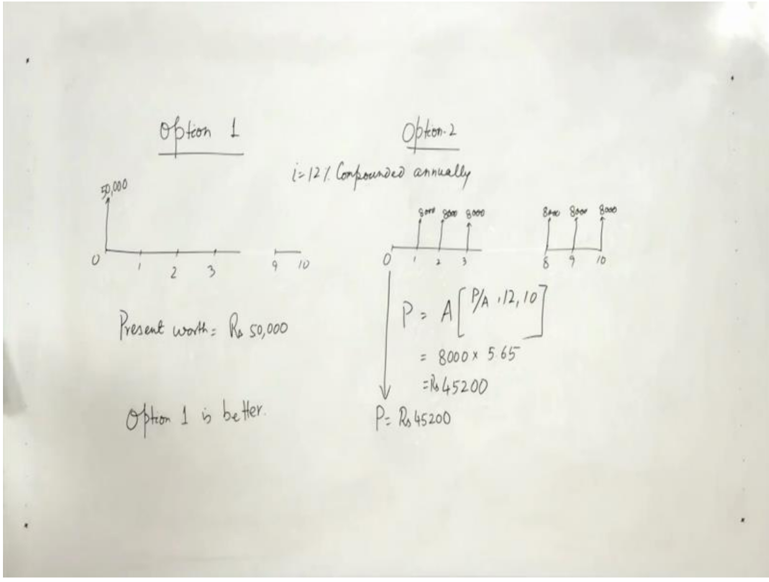

So in this case, you have n varying from 1 to 18 and these are the different factor values. So in this case, you have to get P by A 12 10. So if you see here P by A 12 10, this is the P by A and this is anyway 12% corresponding to 10 you come here and this is 5.65 6502. So A is given as 8000 multiplied by 5.65.

So this way if you have to take any value for any number of years or for any other factors, you have to just see that which is the row and column and which is the point which is intersecting and that particularly value will be taken directly from the table. So it comes as Rs. 45,200. Now what we see is, the two cash flows are basically giving you the present worth value at a particular time.

Now what we see is, its value from here you are getting P as Rs. 45,200. So now you can compare these two and obviously what you see is, in the option one, you are offered Rs. 50,000 whereas in the option 2 at present you are, whatever you are getting, that is worth of Rs. 45,200. It means option one is better for you. So in this way we can come to a decision which option will be better. We can also find the equivalent value at any future time.

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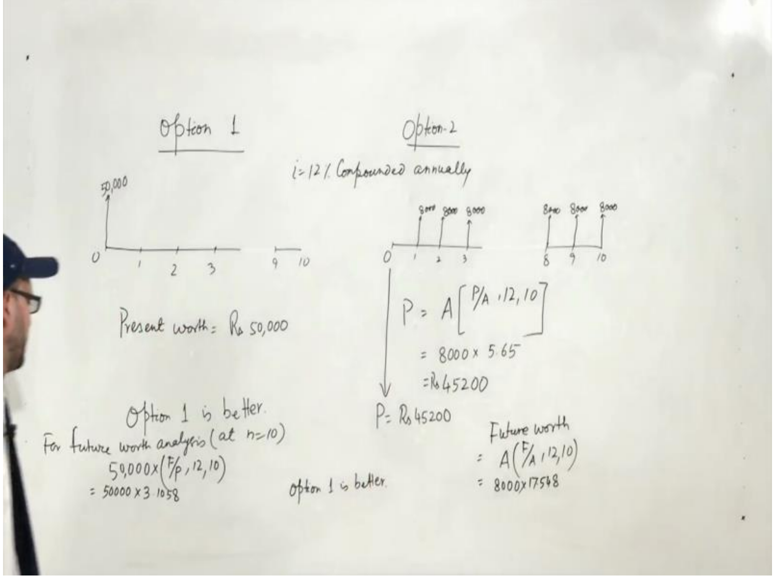

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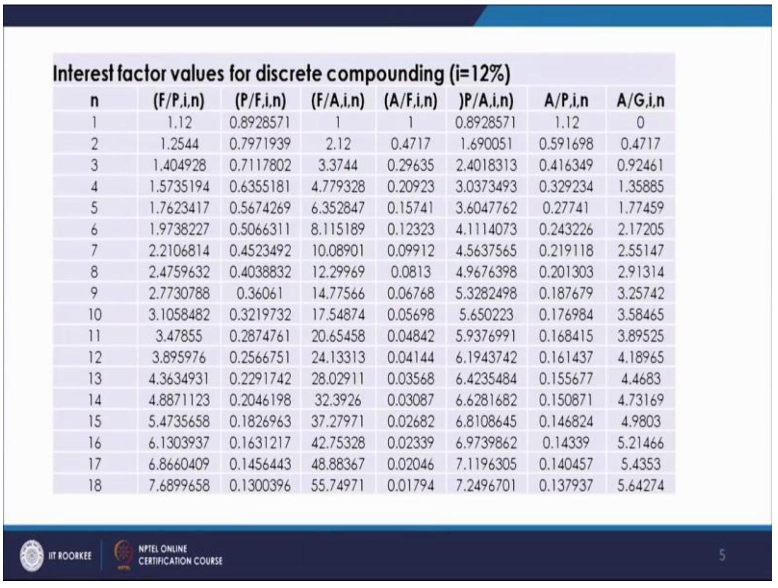

Interest factor values for discrete compounding (i=12%)

n	(F/P,i,n)	(P/F,i,n)	(F/A,i,n)	(A/F,i,n)	)P/A,i,n)	A/P,i,n	A/G,i,n
1	1.12	0.8928571	1	1	0.8928571	1.12	0
2	1.2544	0.7971939	2.12	0.4717	1.690051	0.591698	0.4717
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8	2.4759632	0.4038832	12.29969	0.0813	4.9676398	0.201303	2.91314
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11	3.47855	0.2874761	20.65458	0.04842	5.9376991	0.168415	3.89525
12	3.895976	0.2566751	24.13313	0.04144	6.1943742	0.161437	4.18965
13	4.3634931	0.2291742	28.02911	0.03568	6.4235484	0.155677	4.4683
14	4.8871123	0.2046198	32.3926	0.03087	6.6281682	0.150871	4.73169
15	5.4735658	0.1826963	37.27971	0.02682	6.8108645	0.146824	4.9803
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17	6.8660409	0.1456443	48.88367	0.02046	7.1196305	0.140457	5.4353
18	7.6899658	0.1300396	55.74971	0.01794	7.2496701	0.137937	5.64274

So suppose you want to calculate the future worth of this so this factor, if you go for future worth analysis at n equal to 10, in that case, 50,000 will be multiplied with. So option one gives you 50,000 multiplied by the factor F by P i 10, so this be F by P i is 12 and this is 10. And we can see further the value from here. F by 2, F by P i 10 and F by P i 10 is 3.1058. So this is 50,000 multiplied by 3.1058.

Similarly if you go for this, here the future worth can be found as A multiplied by F by A 12 10. So this will be 8000 multiplied by F by A 12 10, so it will be F by A 1210 and we will come here, this is 17.548. And after calculation you can see that, this one is more than this amount. So from this analysis also you can see that option one is better. So what we see that, you will have to find the equivalent value at a particular time and then only you can compare them.

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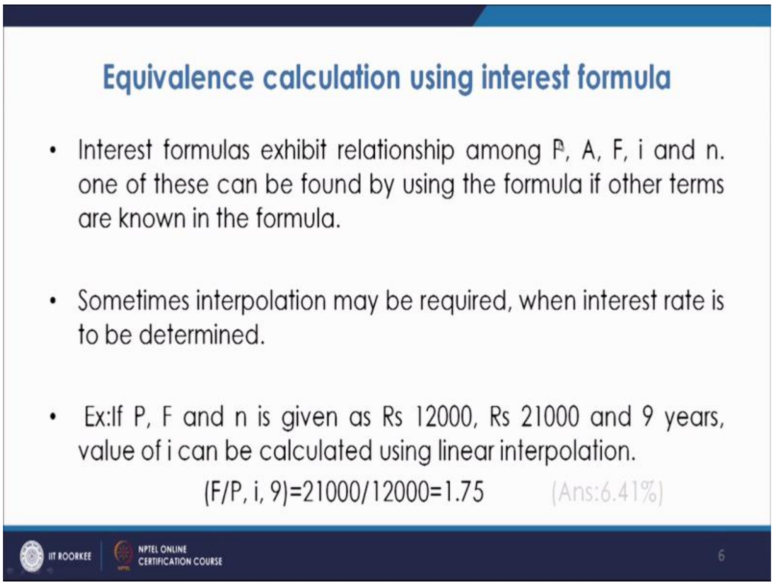

Equivalence calculation using interest formula. Now many a times, you have use the interest formula, in the interest formula normally we come across the terms like P, A, F, i and n. When we go for annual compounding, we come across these terms. The present sum this is annual amount or annuity, this is future sum, this is interest rate and this is number of years.

Now in the particular formula if one of these is not given and other quantities are given, you can always find that particular unknown quantity or parameter using the expression. Now sometimes interpolation may be required, when interest rate is to be determined. So sometimes when the interest rate is to be determined, we will see in the example, we have to basically use the linear interpolation formula.

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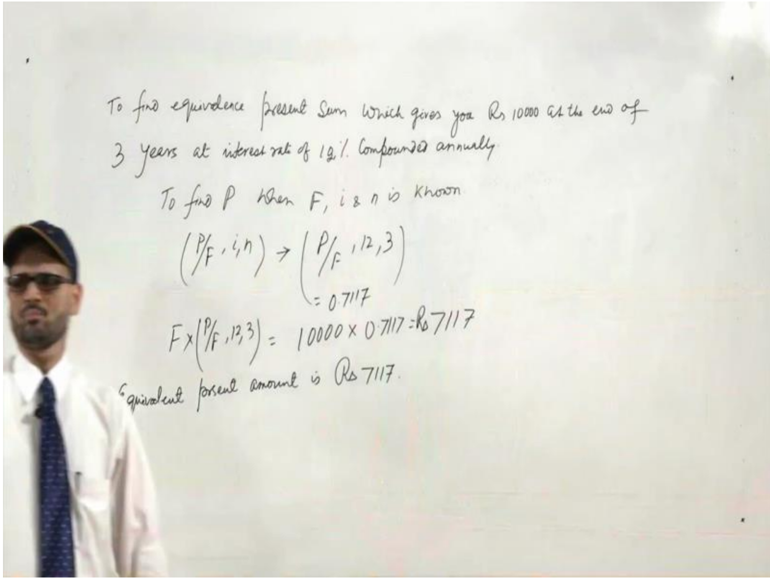

Now let us see the first case, when we can use the normal interest relationships to find a particular parameter. Suppose you have find equivalent present sum which gives you Rs. 10,000 at the end of three years at interest rate of 12% compounded annually. So in this case as we know, you have to find the P value. Whereas so to find P when F, i and n is known.

So in that case you can find P by using the factor and the factor P by F i n that is P by F and i is given as 12% and n is given as as 3 years. So P by F 12 3 we can further refer to the table, P by F 12 3 and P by F 12 3 comes out to be .7117. So it is.7117. This factor is to be multiplied with F so 10,000 F into P by F 12 3, that is 10,000 multiplied by 0.7117 that is 7117 rupees.

This is the equivalent amount at present time which will give you Rs. 10,000 and the end of three years at this particular interest rate. So you can say that equivalent present amount is Rs. 7117. So this is how you use these interest factors to find one of these A, P, i and n and F from the data given to you.

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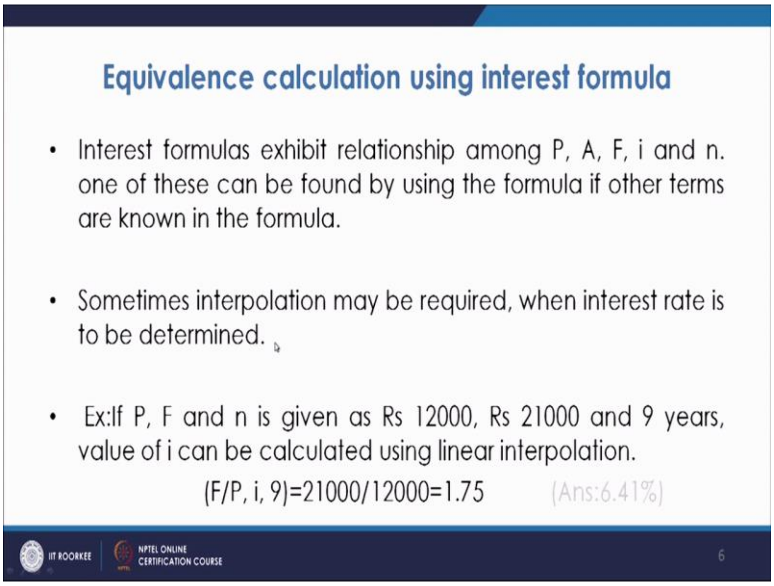

Now next is when you have to calculate the interest, you may have to go for interpolation. Let us see the example for this. So a problem is given to you where P, F and n is given as 12,000, 21,000 and 9 years and you have to find the equivalent interest rate. Basically this will be interest rate which will convert this Rs. 10,000 into Rs. 21,000 after 9 years. So basically in these cases the unknown is interest rate.

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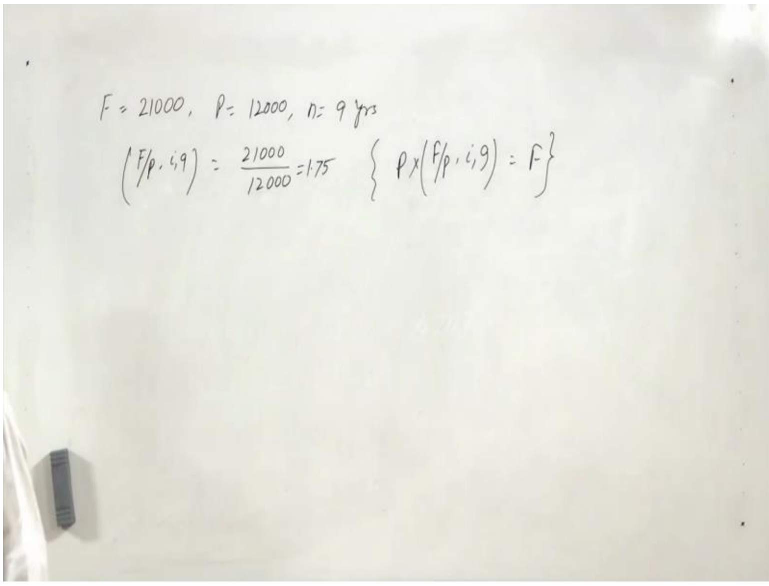

So in this case, what we see is, we have F as 21,000 and P as 12,000 and n as 9 years. Now F by P i 9, it comes out to be basically 21,000 by 12,000 because this amount when it will be multiplied with this factor, basically when P will be multiplied with this factor, it should give you the F. That is why F by P or you can write, this will be coming from this expression P into F by P i 9 should be equal to F.

So from this expression, basically you can get F by P i 9, that is 21,000 by 12,000. This comes out to be 1.75. Now although this expression is quite simple, it is nothing but 1 + i raised to the power - 9, so you can directly calculate I. However, in many cases, the relationship may be complex. So let us see how you can solve it using interpolation.

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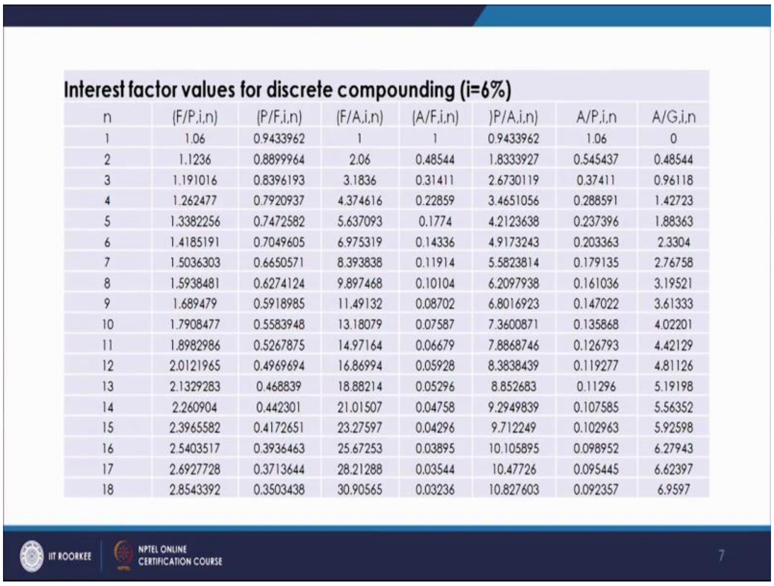

Interest factor values for discrete compounding (i=6%)

n	(F/P,i,n)	(P/F,i,n)	(F/A,i,n)	(A/F,i,n)	)P/A,i,n)	A/P,i,n	A/G,i,n
1	1.06	0.9433962	1	1	0.9433962	1.06	0
2	1.1236	0.8899964	2.06	0.48544	1.8333927	0.545437	0.48544
3	1.191016	0.8396193	3.1836	0.31411	2.6730119	0.37411	0.96118
4	1.262477	0.7920937	4.374616	0.22859	3.4651056	0.288591	1.42723
5	1.3382256	0.7472582	5.637093	0.1774	4.2123638	0.237396	1.88363
6	1.4185191	0.7049605	6.975319	0.14336	4.9173243	0.203363	2.3304
7	1.5036303	0.6650571	8.393838	0.11914	5.5823814	0.179135	2.76758
8	1.5938481	0.6274124	9.897468	0.10104	6.2097938	0.161036	3.19521
9	1.689479	0.5918985	11.49132	0.08702	6.8016923	0.147022	3.61333
10	1.7908477	0.5583948	13.18079	0.07587	7.3600871	0.135868	4.02201
11	1.8982986	0.5267875	14.97164	0.06679	7.8868746	0.126793	4.42129
12	2.0121965	0.4969694	16.86994	0.05928	8.3838439	0.119277	4.81126
13	2.1329283	0.468839	18.88214	0.05296	8.852683	0.11296	5.19198
14	2.260904	0.442301	21.01507	0.04758	9.2949839	0.107585	5.56352
15	2.3965582	0.4172651	23.27597	0.04296	9.712249	0.102963	5.92598
16	2.5403517	0.3936463	25.67253	0.03895	10.105895	0.098952	6.27943
17	2.6927728	0.3713644	28.21288	0.03544	10.47726	0.095445	6.62397
18	2.8543392	0.3503438	30.90565	0.03236	10.827603	0.092357	6.9597

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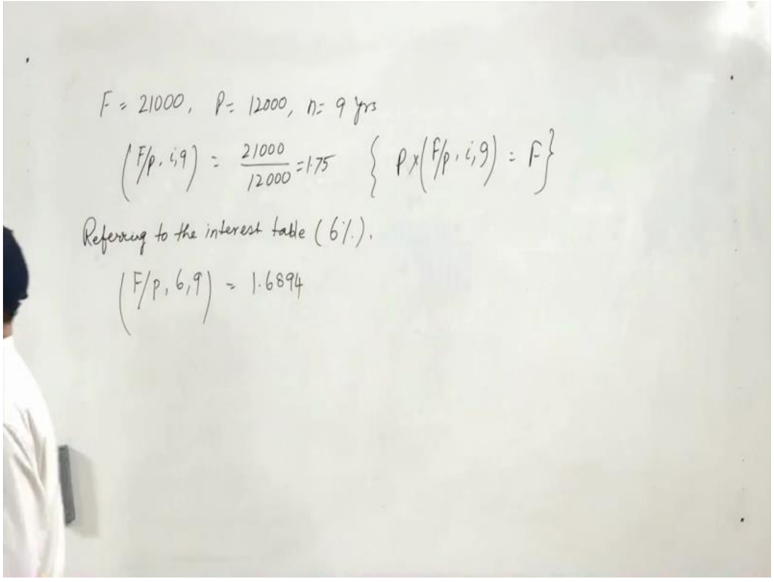

So for interpolation you have to see the table in which corresponding to 9 years, you have to find a value one value which is less than this and another value which is more than this. So for that you will refer to the table. Now if we see the 6% interest able as corresponding to the 9 years we get F by P i n as 1.6894. So referring to the interest table 6%, what we see is, F by P 6 9, we see from the table as 1.6894.

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Interest factor values for discrete compounding (i=7%)

n	(F/P,i,n)	(P/F,i,n)	(F/A,i,n)	(A/F,i,n)	)P/A,i,n)	A/P,i,n	A/G,i,n
1	1.07	0.9345794	1	1	0.9345794	1.07	0
2	1.1449	0.8734387	2.07	0.48309	1.8080182	0.553092	0.48309
3	1.225043	0.8162979	3.2149	0.31105	2.624316	0.381052	0.95493
4	1.310796	0.7628952	4.439943	0.22523	3.3872113	0.295228	1.41554
5	1.4025517	0.7129862	5.750739	0.17389	4.1001974	0.243891	1.86495
6	1.5007304	0.6663422	7.153291	0.1398	4.7665397	0.209796	2.30322
7	1.6057815	0.6227497	8.654021	0.11555	5.3892894	0.185553	2.73039
8	1.7181862	0.5820091	10.2598	0.09747	5.9712985	0.167468	3.14654
9	1.8384592	0.5439337	11.97799	0.08349	6.5152322	0.153486	3.55174
10	1.9671514	0.5083493	13.81645	0.07238	7.0235815	0.142378	3.94607
11	2.104852	0.4750928	15.7836	0.06336	7.4986743	0.133357	4.32963
12	2.2521916	0.444012	17.88845	0.0559	7.9426863	0.125902	4.70252
13	2.409845	0.4149644	20.14064	0.04965	8.3576507	0.119651	5.06484
14	2.5785342	0.3878172	22.55049	0.04434	8.745468	0.114345	5.41673
15	2.7590315	0.362446	25.12902	0.03979	9.107914	0.109795	5.75829
16	2.9521637	0.3387346	27.88805	0.03586	9.4466486	0.105858	6.08968
17	3.1588152	0.3165744	30.84022	0.03243	9.763223	0.102425	6.41102
18	3.3799323	0.2958639	33.99903	0.02941	10.059087	0.099413	6.72247
19	3.6165275	0.2765083	37.37896	0.02675	10.335595	0.096753	7.02418
20	3.8696845	0.258419	40.99549	0.02439	10.594014	0.094393	7.31631

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$F = 21000$, $P = 12000$, $n = 9$ yrs

$$\left(F/P, i, 9\right) = \frac{21000}{12000} = 1.75 \quad \left\{ P \times \left(F/P, i, 9\right) = F \right\}$$

Referring to the interest table (6%).

$$\left(F/P, 6, 9\right) = 1.6894, \quad \left(F/P, 7, 9\right) = 1.8384$$

The actual (equivalent) interest rate lies between 6% & 7% and can be found using linear proportion method.

$$i = 6 + \frac{1.75 - 1.69}{1.84 - 1.69}$$

And further we have to see for the same number of years that is n equal to 9, for 7% it comes out to be 1.8384. So F by P 7 9 is coming as 1.8384. So it means the real interest rate lies between 6 and 7%. The actual or equivalent interest rate lies between 6 and 7% and can be found using linear proportion method. So the actual rate of interest will be 6 + 1.75 - 1.69 we are converting it to two point decimal two point divided by 1.84 - 1.69.

So this comes out to be something close to 6.41%. So this way when we need, we can use these interpolation or linear proportion methods to find the equivalent value of interest rates.

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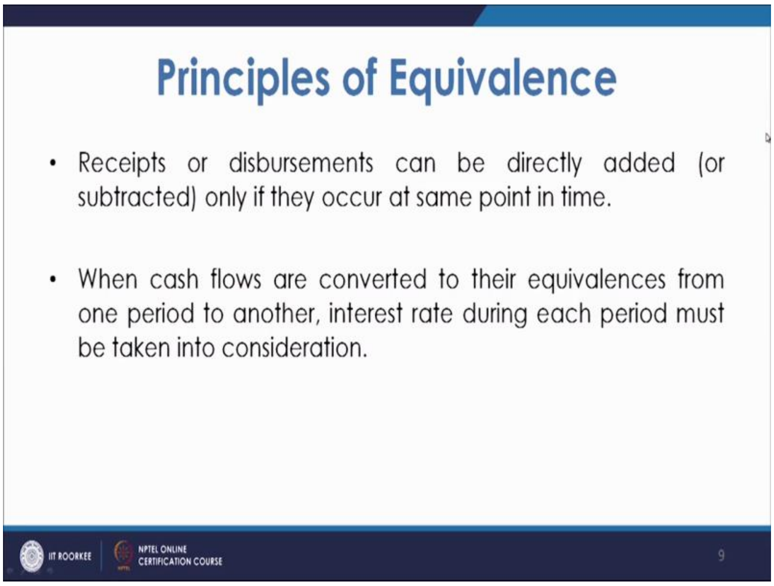

Now we will discuss about some of the other principles of equivalence. The first principle is, receipt or disbursement can be directly added or subtracted only if they can at same point in time. It means, if there is a cash flow and you want to find the equivalent value at a particular time, all other receipts or disbursements, their equivalent value has to be found at that particular time then only you can add them or subtract them.

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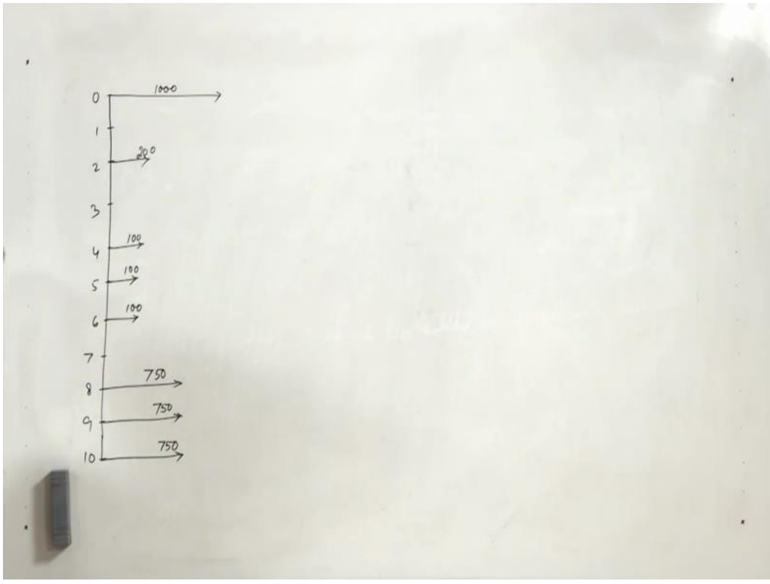

Unless you convert them to that particular time basis you cannot add them. So we can understand it by an example. Suppose there is a cash flow, now in this case, if you are having a deposit of suppose Rs. 1000 here, you are having a deposit of Rs. 200 here, you are having a deposit of Rs. 100 for consecutive three years here, you are having a deposit of 750 for 3 consecutive years.

Now in such problems if you have to find the equivalent value at the present time, you cannot add these quantities directly. You will have to convert its equivalent value at this particular time and we have so far understood how can we get the equivalent value of these amounts at a particular time by using the interest factors. And suppose the interest rate is taken as 12%, so in this case, what will be the equivalent present worth now? So to find equivalent present sum.

Now this equivalent present sum is at present time, so see this 1,000 will be directly added. So if it is P it will be equal to. The contribution of this Rs. 1000 will be as it is. So this will be 1000 + this 200 is made 2 years hence, so its equivalent value you have to get at this time. So this will be multiplied with a factor that is P by F i is 12 and n is 2. This is single payment series present worth factor.

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So you have paid this future amount and its present value will be multiplied by this amount. Now we can basically individually get the present worth values of these quantities, each one being multiplied when single payment present worth factors but that is not an intelligent way to solve it. So what we see is this is an equal payment series, so basically we can find its equivalent value either at this time or at this time.

If we try to find its equivalent value using the future time concept, at this time you will get the equivalent F for these three amounts. But if we to get the present worth component using these three amounts, we will get its value at here. So if suppose we use the F by A formula, so 100 will be used F by A 12 3. This will be the equivalent amount at this point 100 F by A 12 3.

Now this point where it has to go here. So this will be again multiplied with P by F 12 6. So this amount will be multiplied with P by F 12 6. Now left is these three amounts, again these three amounts can be done in the similar fashion to 750 multiplied by F by A 12 3, this will give you the amount here and again this is to be sent here. So this is to be multiplied with P by F 12 10, so it will be into P by F 12 10.

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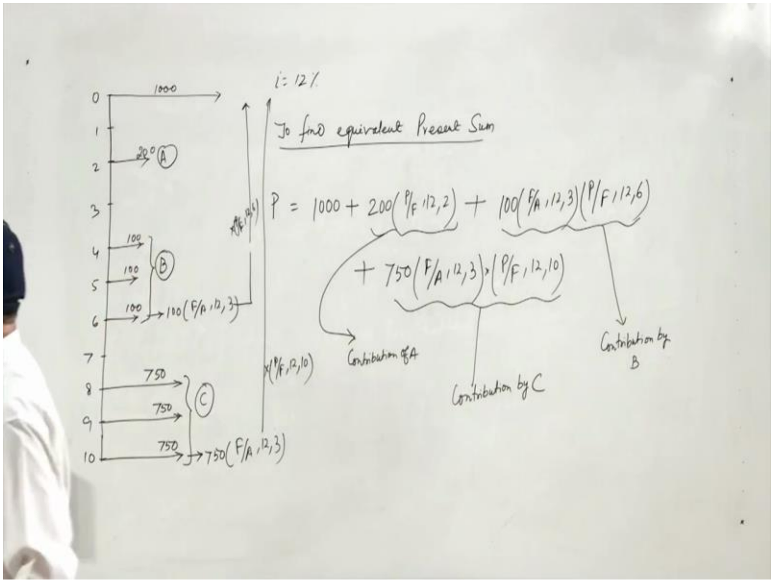

So what we saw is, if this is A, if this is B and if this is C, so this will be the contribution of A. Similarly when this amount multiplied with P by F 12 6, as we have done here, this amount will be contribution by B. And similarly, this amount again multiplied by this factor, it will be contribution by C. In this case what you see is you find the equivalent value at the present time and since 1000 is already there at the present time, you can directly add.

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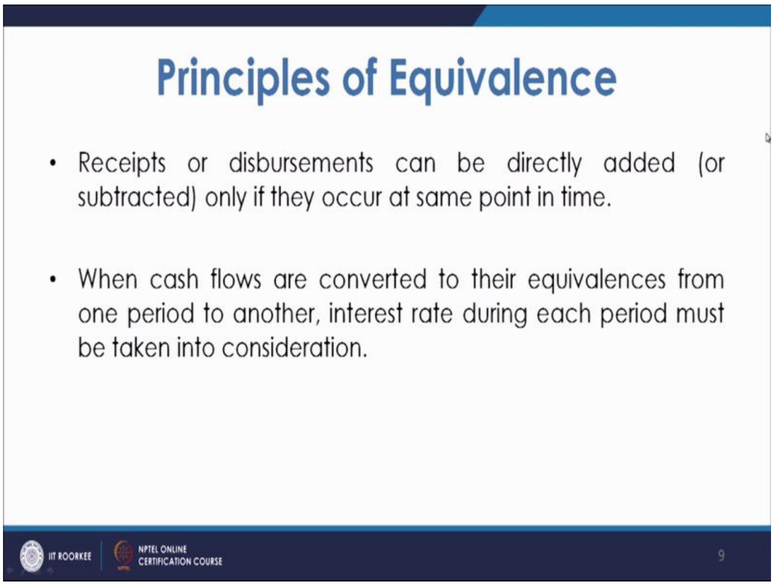

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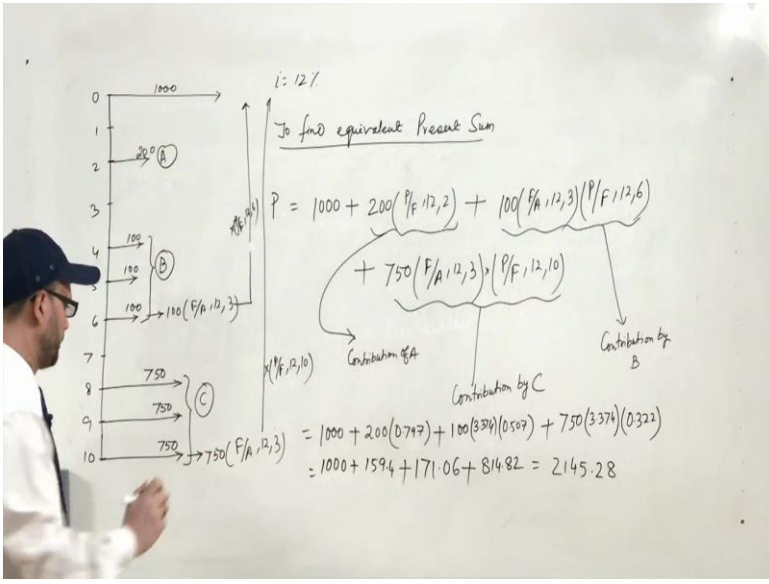

So what we see is that the receipts or disbursements, they are directly added but for that you have to convert them at a particular time in future and this time is the present time. And once we do the calculations, you can get the values.

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Interest factor values for discrete compounding (i=12%)

n	(F/P,i,n)	(P/F,i,n)	(F/A,i,n)	(A/F,i,n)	)P/A,i,n)	A/P,i,n	A/G,i,n
1	1.12	0.8928571	1	1	0.8928571	1.12	0
2	1.2544	0.7971939	2.12	0.4717	1.690051	0.591698	0.4717
3	1.404928	0.7117802	3.3744	0.29635	2.4018313	0.416349	0.92461
4	1.5735194	0.6355181	4.779328	0.20923	3.0373493	0.329234	1.35885
5	1.7623417	0.5674269	6.352847	0.15741	3.6047762	0.27741	1.77459
6	1.9738227	0.5066311	8.115189	0.12323	4.1114073	0.243226	2.17205
7	2.2106814	0.4523492	10.08901	0.09912	4.5637565	0.219118	2.55147
8	2.4759632	0.4038832	12.29969	0.0813	4.9676398	0.201303	2.91314
9	2.7730788	0.36061	14.77566	0.06768	5.3282498	0.187679	3.25742
10	3.1058482	0.3219732	17.54874	0.05698	5.650223	0.176984	3.58465
11	3.47855	0.2874761	20.65458	0.04842	5.9376991	0.168415	3.89525
12	3.895976	0.2566751	24.13313	0.04144	6.1943742	0.161437	4.18965
13	4.3634931	0.2291742	28.02911	0.03568	6.4235484	0.155677	4.4683
14	4.8871123	0.2046198	32.3926	0.03087	6.6281682	0.150871	4.73169
15	5.4735658	0.1826963	37.27971	0.02682	6.8108645	0.146824	4.9803
16	6.1303937	0.1631217	42.75328	0.02339	6.9739862	0.14339	5.21466
17	6.8660409	0.1456443	48.88367	0.02046	7.1196305	0.140457	5.4353
18	7.6899658	0.1300396	55.74971	0.01794	7.2496701	0.137937	5.64274

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1000 + 200 P by F 12 2, so we can refer to this. P by F 12 2 is .797 + 100 into F by A 12 3. So F by A 12 3 is 3.3744 multiplied by P by F 12 6, so P by F 12 6 again we can get from here .5066 so .507 + 750 multiplied by F by A 12 3, F by A 12 3 we have got 3.374 and P by F 12 10, so P by F 12 10 will be .3219 so 322. In this case, we can get the value 1000+159.4+this is 171.06+ 750 multiplied by 3.374 into .322, so this is 814.82.

So once we add them, it comes out to be 2145.28. So what we see is that an amount of 2145.28 is equivalent to this particular cash flow at this time. We have converted all this time, these cash flows at this time and then we have added them and we got this answer.

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Principles of Equivalence

- Receipts or disbursements can be directly added (or subtracted) only if they occur at same point in time.
- When cash flows are converted to their equivalences from one period to another, interest rate during each period must be taken into consideration.

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Next is when cash flows are converted to their equivalences from one period to another, interest rate during each period must be taken into consideration. So basically this we will discuss next when we will see that how the interest periods in the different period different rates in different periods have to be taken separately while calculating their equivalent values at a particular time. For then, thanks.