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SPRING 1987 EA-1B EXAM SOLUTIONS

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1. This is an Entry Age Normal cost method problem, which requires individual normal cost calculations. There are no tricks to this problem at all - simply crank and grind. Since all three participants were hired at the same age, generation of the Normal Cost is simplified. The problem gives us Nx and Dx values that we must use in the calculations.

Name	Entry Age	Projected Benefit	PVB at 65	PVB at Entry Age	PVL at Entry Age	Entry Age NC
Smith	30	35(120)	8(4200)	33600(55/980)	(12570-465)/980	1886/12.35
Brown	30	4200	33600	1886	12.3520	152.66
Green	30	4200	33600	1886	12.3520	152.66

Now, simply calculate the Accrued Liability on a retrospective basis:

Name	Current Age	EANC * (Nea-Nca)/Dca	A.L.
Smith	30	152.66(12570-12570)/980	-0-
Brown	40	152.66(12570- 5485)/450	2404
Green	50	152.66(12570- 2255)/200	7874
			10277

answer is B

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2. This problem requires an understanding of how to reflect experience in bringing one year's valuation results forward to the next year. With no pre-retirement decrements, the present value of benefits simply grows at interest each year if all assumptions are met. With no participants within two years of assumed retirement age, we know that all of the participants are included in the valuation results in both years, and there were no benefit payments in 1986.

   In this problem, the salaries grew at only 5%, so the projected benefit would actually decrease based on the ratio (1.05/1.06). Based on the information given, the fund can be brought forward with 10% interest.

   1-1-86 Valuation Balance Sheet: Aggregate Method

AAV	500,000		Normal Cost	60,000	
PVNC	450,000	balancing item	PVE / E	7.50	= 450,000/60,000
			Earnings	1,000,000	
PVB	950,000		PV of Earn	7,500,000	= 7.5 * 1,000,000

   It is necessary to derive the PV of Earnings, since that value must be used in generating the 1-1-87 valuation results. Since the PVE can be expressed as EARN * (1 + [(1+s)/(1+i)]1 + [(1+s)/(1+i)]2 + ...), the expected PVE is (1+i)*(PVEo-EARN).

   1-1-87 Valuation Balance Sheet

PVB	1,016,321	= 1.08(950,000)(1.05/1.06)	reflect interest and salary scale
AAV	616,000	= 1.10(500,000 AAVo + 60,000 contrib)	
PVNC	400,321	= PVB - AAV	
PVE	6,953,774	= 1.08(7,500,000-1,000,000)(1.05/1.06)	
NC %	5.76	= 400,321 / 6,953,774	answer is B

   if you want to do several extra steps, then calculate the normal cost:

EARN	1,050,000	= 1.05(1,000,000)
PVE/E	6.6226	= 6,953,774 / 1,050,000
NC	60,447	= 400,321 / 6.6226
NC %	5.76	= 60,447 / 1,050,000

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3. This problem can be answered correctly by applying general reasoning to the questions asked. For the first two parts, there is a rule that can be used: for an actuarial equivalent early retirement reduction factor, the effect of a change in interest rate or mortality table is the same as the effect on a life annuity. This can be proved by looking at the factor, which is N_{NRA}/N_x:

$$\frac{N_{NRA}}{N_x} = \frac{N_{x+1}}{N_x} \cdot \frac{N_{x+2}}{N_{x+1}} \cdots \frac{N_{NRA}}{N_{NRA-1}} \quad \text{and} \quad \frac{N_{x+1}}{N_x} = 1 - 1/\ddot{a}_x$$

If $\ddot{a}_x$ increases, then $1/\ddot{a}_x$ decreases, and $1-1/\ddot{a}_x$ increases, so the early retirement factor increases (and vice versa).

I. Reducing the mortality rates will increase the value of $\ddot{a}_x$, so the early retirement benefits will increase - TRUE.

II. Increasing the interest rate will decrease the value of $\ddot{a}_x$, so the early retirement benefits will decrease - FALSE.

For the effect of the change on the certain and life benefit, the optional form benefit is reduced to pay for the cost of the death benefit. If the mortality rates decrease, the death benefit is less valuable. The optional form benefit would be larger, because the reduction in benefits is less.

III. Reducing the mortality rates will increase the value of $\ddot{a}_x$, so the ten year certain and life benefit will increase - TRUE.

I and III only answer is B

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4. The mortality gain can be calculated using the standard formula for non-investment G/L:

non-inv G/L = ${}_eAL_1 - AL_1$

The actual accrued liability at 1/1/87 can be calculated directly from the information given. We have 95 retirees with joint and survivor benefits of \$1,000, 2 retirees with life annuity benefits of \$1,000, and 3 spouses with life annuity benefits of \$500:

$$\begin{aligned} \text{A. L.} &= 1000(95)[\ddot{a}_{66} + \tfrac{1}{2}(\ddot{a}_{63} - \ddot{a}_{66:63})] + 1000(2)(\ddot{a}_{66}) + 500(3)(\ddot{a}_{63}) \\ &= 1000(95)(8.409+.5(9.024-7.205)) + 1000(2)(8.409) + 500(3)(9.024) \\ &= 915{,}612 \end{aligned}$$

To calculate the expected accrued liability, the interest rate must be determined from the values given. The best way is to use the identity

$$v(p_{65})(\ddot{a}_{66}) = a_{65} \quad \Rightarrow \quad (1+i) = \frac{p_{65}(\ddot{a}_{66})}{(\ddot{a}_{65}-1)} = .98(8.409)/7.630$$

This gives 8.01% for the value of i.

$$\begin{aligned} \text{expected A. L.} &= (1+i)1000(100)[\ddot{a}_{65} + \tfrac{1}{2}(\ddot{a}_{62} - \ddot{a}_{62:65})] - (\text{actual BP + int}) \\ &= 1.08(1000)(100)[8.63+.5(9.23-7.44)] - 1.08(1000)(100) \\ &= 920{,}700 \end{aligned}$$

non-inv G/L = ${}_eAL_1 - AL_1 = 920{,}700 - 915{,}652 = 5088$ answer is E

5. This is an inspection problem, but the best way to work it is to set up your own expression for the summation first. Then you can compare it to the answer choices for the problem.

The participant is age 40 with 5 years of service, and the first vesting age is 42 with 7 years of service. The first four terms of the summation would be

Age	int	prob. of survival	exit	ben. svc	vest pct	ben rate	deferred annuity
42:	v^2	(l_{42}/l_{40})	q_{42}	(7)	(.25)	180	$(N_{65}^{(12)}/ D_{42})$
43:	v^3	(l_{43}/l_{40})	q_{43}	(8)	(.50)	180	$(N_{65}^{(12)}/ D_{43})$
44:	v^4	(l_{44}/l_{40})	q_{44}	(9)	(.75)	180	$(N_{65}^{(12)}/ D_{44})$
45:	v^5	(l_{45}/l_{40})	q_{45}	(10)	(1.0)	180	$(N_{65}^{(12)}/ D_{45})$

The key to the problem is that the D_x and N_x commutation functions only include mortality. You must use the l_x and q_x functions prior to exit, since they include both mortality and withdrawal.

The only two answers that are close are D and E. The t-35 term is the benefit service, and the next term is used to calculate the vesting percentage. Based on this item, the correct answer is E.

6. Under the ILP method, a change in plan benefits should be funded prospectively from current age to assumed retirement age. In this problem, the only thing to be careful of is that there are two employees at age 45. The problem gives us N_x and D_x values that we must use in our calculations.

#ees	Age	Hire Age	Change in Projected Benefit	PVB $600(80)/D_x$	ILP Normal Cost $PVB_x/(N_x-N_{65})/D_x$ * num ees
1	35	25	50(12)	48000/125=384	384/(1455/125)= 33 * 1 = 33
2	45	25	600	48000/55 =873	873/(570/55)= 84 * 2 = 168

The total ILP normal cost is 201, and the answer is C.

7. This problem requires you to determine the liability for a participant who was omitted from the valuation. Since all the participants are the same age, it is possible to determine a relationship between one dollar of earnings and one dollar of present value of benefits:

$$500{,}000 = (35{,}000+45{,}000+55{,}000+65{,}000)(1+j)^{17}(.50)N_{65}/D_{47}$$
$$2.5 = (1+j)^{17}(.50)N_{65}/D_{47}$$

The omitted employee's PVB is 2.5(25,000) = 62,500, which gives us

PVB	562,500	= 500,000 + 62,500
AAV	100,000	
PVNC	462,500	= 562,500 - 100,000

The PVE/E for the four original employees was (500,000-100,000)/40,000, which is 10.0. This value remains the same when the omitted employee is added in, since all of them are the same age.

NC 46,250 = 462,500 / 10.0 answer is E

8. Under the Individual Aggregate method, the normal cost is calculated on an individual basis. The assets are allocated to each participant, and the PVNC is calculated directly as PVB - allocated AAV. With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

Since the value of $\ddot{a}_{65}^{(12)}$ is not given, we have to reconstruct the 1/1/86 valuation to calculate the present value of benefits at 1/1/87:

1/1/86 valuation

	Smith	Brown
normal cost	510	274
current age	40	50
future service	25	15
$\ddot{a}_{\overline{n}\rceil .08}$	11.53	9.24
PVNC = NC * $\ddot{a}_{\overline{n}\rceil .08}$	5,880	2,533
allocated AAV	2,705	16,000
PVFB = AAV + PVNC	8,585	18,533

At this point we can solve for $\ddot{a}^{(12)}_{65}$, but it is easier to simply multiply the 1/1/86 PVB by 1.08 to give the 1/1/87 value.

1/1/87 valuation

	Smith	Brown	
PVFB	9,271	20,016	1/1/86 PVB * 1.08
Alloc weight	3,215	16,274	1/1/86 NC + AAV
allocated AAV	3,299	16,700	weight * (20,000/19,489)
PVNC = PVB - AAV	5,972	3,316	
future service	24	14	
$\ddot{a}_{\overline{n}\rceil .08}$	11.37	8.90	
normal cost	525	372	

The total normal cost is 525 + 372 = 898 answer is E

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9. This is an easy problem if you know the formula for non-investment G/L:

non-inv G/L = eAL1 - AL1

AL1 = 156,000
eAL1 = (1+1)(NCo+ALo) - (actual ben pmts + int)
= 1.08(10,000+135,100) - 0
= 156,708

G/L = 156,708 - 156,000 = 708 answer is D

10. Under the Aggregate method, the PVNC is calculated on an aggregate basis as PVB - AAV. The normal cost is calculated using the average temporary annuity to normal retirement age. In this problem, the retirement age varies based on participation service. Otherwise, it is a straightforward problem.

With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

Name	Age	Hire Age	Entry Age	ARA	Total Svc	Proj ben Svc*120	PVB $v^{ts}*\ddot{a}_{65}^{(12)}$	$\ddot{a}_{\overline{x:ARA-x}\rceil}$ .08
Smith	50	33	42	65	32	3,840	9,856	9.2442
Brown	65	40	57	67	27	3,240	21,394	1.9259
							31,251	11.1702

PVB 31,251
AAV 10,000
PVNC 21,251 = 31,251 - 10,000
PVL/L 5.5851 = 11.1702 / 2
NC 3,805 = 21,251 / 5.5851 answer is E

11. Under the Aggregate method, the PVNC is calculated on an aggregate basis as PVB - AAV. The normal cost is calculated using the average temporary annuity to normal retirement age. In this problem, we only have one participant, so there is no averaging at all. The real point to this problem is to test how well you handle salary scales.

With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

One unusual aspect is that you are given salary for 1986. This is more realistic than most problems; in effect the 1987 valuation is based on 1986 W-2 pay. To calculate the final average five year salary, the pay should be projected from age 54 to age 64, then multiplied by $\ddot{a}_{\overline{5}|}/5$:

1/1/87 valuation
Age=55, Age 54 pay = 32,000

Age 64 pay = $32{,}000(1.06)^{10}$ = 57,307

FAE5 = Age 64 pay * $\ddot{a}_{\overline{5}|.06}$ / 5

= 51,176

projected benefit = .4(51,176) = 20,471

PVB = $20{,}471 * \ddot{a}_{65}^{(12)} * v^{10}$

= 20,471(8.65)(.4632)

= 82,018

PVNC = 82,018 - 30,000

= 52,018

To calculate the PVE/E, write down the expression with interest rates and salary scales - you don't even have to put earnings in. Then the expression can be evaluated as an annuity certain

PVE/E = $[\ 1 + (1.06/1.08)^1 + (1.06/1.08)^2 + \ldots + (1.06/1.08)^9]$ 10 terms

= $\ddot{a}_{\overline{10}|1.89\%}$ = 9.2065

NC = 52,018 / 9.2065

= 5,650

answer is D

12. Under the Unit Credit method, the accrued liability is defined as the present value of the accrued benefit. The normal cost then becomes the present value of the benefit accrual during the year. In this problem, the computation of the normal cost is complicated by having multiple decrements. Instead of having a single retirement age, the present value factor is a summation:

$$\Sigma\ v^t\ {}_tp_x\ q_{x+t}\ \text{ERF}\ \ddot{a}^{(12)}_{x+t}$$

where ERF is the early retirement reduction factor. In this problem there are no reductions for early retirement:

1/1/87 valuation
Age 55, service 10 yrs

$$\begin{aligned} NC = 20(12)\ [&\quad v^8\ (1.0)\ (.20)\ 8.56 && \text{(age 63)} \\ &+ v^9\ (.80)\ (.30)\ 8.35 && \text{(age 64)} \\ &+ v^{10}\ (.56)\ (1.0)\ 8.14\ ] && \text{(age 65)} \\ = 240&(4.0389) \\ = 969 & && \text{answer is C} \end{aligned}$$

As a check on reasonableness of the summation in brackets, if the assumed retirement age is 63, the factor would be

$$v^8(8.56) = 4.62.$$

If the assumed retirement age is 65, the factor would be

$$v^{10}(8.14) = 3.77.$$

Since our result falls between these values, it is probably correct.

13. This gain and loss problem can't be worked using the standard formula for non-investment G/L. The reason is that the problem does not ask for the total gain or loss during the year (which includes mortality and early retirement). We should compare the accrued liability before and after the participant retires to calculate the gain or loss due to early retirement.

At 12-31-86, the participant is age 59 with 24 years of service. Under the Unit Credit method, the accrued liability is defined as the present value of the accrued benefit:

$$\text{active AL} = 24(\$25)(12)(N_{65}^{(12)}/D_{59})$$
$$= 24(300)(1{,}880/400)$$
$$= 33{,}840$$

As a retired employee, the accrued liability is simply the present value of the early retirement benefit:

$$\text{retired AL} = 24(\$25)(12)(1\text{-}5/15\text{-}1/30)(N_{59}^{(12)}/D_{59})$$
$$= 24(300)(.6333)(3{,}740/400)$$
$$= 42{,}636$$

The effect of this early retirement is a loss of

$42{,}636 - 33{,}840 = 8{,}796$ answer is D

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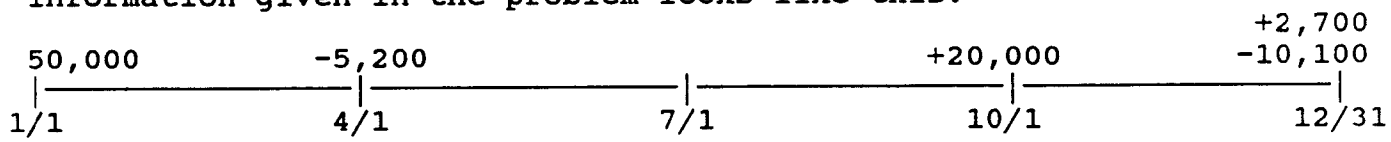
14. There are two ways to work these problems: (i) solve for the interest rate directly, or (ii) plug the answer ranges into an equation to see where the answer lies. If you can set up the equation for method (ii), then it is actually faster to use method (i).

Since the problem asks for the dollar weighted rate of return, we can ignore all the intervening market values. On a time diagram, the information given in the problem looks like this:



With an ending market value of 63,651, we can set up the following equation of value

$$50{,}000(1+i)-5{,}200(1+3i/4)+20{,}000(1+i/4)+2{,}700-10{,}100 = 63{,}651$$

$$6{,}251 = i\ [\ 50{,}000 - 5{,}200(3/4) + 20{,}000(1/4)\ ]$$

$$i = 6{,}251 / 51{,}100$$

$$i = 12.23\%$$

answer is D

If the problem had asked for the time weighted rate of return, then we use the market values before and after each cash flow. This measures the investment return without the cash flows affecting the result.

$$\text{time weighted return} = \frac{(50{,}515)}{(50{,}000)} \frac{(48{,}136)}{(50{,}515-5{,}200)} \frac{(63{,}651-2{,}700+10{,}100)}{(48{,}136+20{,}000)}$$

$$= 1.1191 \quad \Rightarrow \text{time weighted return is } 11.91\%$$

15. The Projected Unit Credit method is similar to traditional Unit Credit, except that the true accrued benefit under the plan is not used. Instead, a Funding Accrued Benefit is calculated based on current service, but with projected pay to retirement age.

In this problem, the benefit accrual in any year is 1% of pay. Since we're using Projected Unit Credit, the 1% is applied to projected pay. As with any other salary scale problem, the pay used in calculating the benefit goes through age 64, not age 65.

Name	Age	Age 60 Earn	Age 64 Earn	Benefit Accrual	P.V. factor $v^5\ddot{a}_{65}^{(12)}$	Normal Cost
Smith	60	72,000	90,898	909	5.6693	5,153
Brown	60	24,000	30,299	303	5.6693	1,718

The total normal cost is 5,153 + 1,718, or 6,871. The answer is D.

Technical note: The definition of Projected Unit Credit states that the Funding Accrued Benefit should be based on a projected benefit calculated using total benefit service. The resulting benefit is then pro-rated based on past service versus total service. The pro-ration must be based on the rates of benefit accrual applicable to the years of benefit service. In this plan, we could have calculated the benefit accrual as follows for Smith:

Projected benefit = 25(.01)(90,898) = 22,725

$$\text{Age 60 F.A.B.} = \frac{[\ 20(.01)\ ]}{[\ 25(.01)\ ]}\ 22{,}725 = 18{,}180$$

$$\text{Age 61 F.A.B.} = \frac{[\ 21(.01)\ ]}{[\ 25(.01)\ ]}\ 22{,}725 = 19{,}089$$

Benefit Accrual = 19,089 - 18,180
= 909

For this problem, it is much easier to simply write down the amount of benefit accrual. For harder problems with differing rates of benefit accrual, it may be advisable to calculate the F.A.B. In general, you can produce the correct F.A.B. by applying the plan's benefit formula to projected earnings and current service for an individual. This is based on the fact that the denominator in the ratio will cancel out with the service in the formula for the projected benefit.

16. Under the Individual Level Premium cost method, benefit changes are funded prospectively from the date of change. When the projected benefit under the plan changes, either due to plan amendments or salary changes, a new layer of normal cost is created.

In this end of year valuation problem, we should calculate the initial normal cost based on amortization from the effective date of the plan. The 12/31 normal cost will be that amount increased with a full year's interest.

With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

12/31/86 valuation
1-1-86 Age 54

Proj benefit = .50(36,000) = 18,000
PV fut ben = $18{,}000(v^{11})(\ddot{a}^{(12)}_{65})$
= 18,000(.4289)(8.33) = 64,307
1/1 ILP NC = $64{,}307 / \ddot{a}_{\overline{11}|.08}$
= 8,341
12/31 ILP NC = 8,341 * 1.08
= 9,008

12/31/87 valuation
1-1-87 Age 55

Proj benefit = .50(30,000) = 15,000
Benefit chg = 15,000 - 18,000 = -3,000
PV ben chg = $-3{,}000(v^{10})(\ddot{a}^{(12)}_{65})$
= -3,000(.4632)(8.33) = -11,575
1/1 NC chg = $-11{,}575 / \ddot{a}_{\overline{10}|.08}$
= -1,597
12/31 ILP NC = 9,008 + (-1,597 * 1.08)
= 7,283

answer is A

17. Under the Unit Credit cost method, the Accrued Liability is defined as the present value of the accrued benefit. With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

With the change in the valuation interest rate at 1-1-87, the question is asking for the UAL based on the new interest rate. We can calculate the accrued liability easily:

1/1/87 valuation (8% interest)
Age 64, service 6

$AL = 6(20)(12)(9/1.08)$
$= 12,000$
$UAL = AL - AAV = 12,000 - AAV$

The AAV must be derived based on the 1-1-86 valuation results:

1/1/86 valuation (7% interest)
Age 63, service 5

$NC = 20(12)(10)/(1.07)^2$
$= 2,096$

$AL = 5(20)(12)(10)/(1.07)^2$
$= 5 * NC = 10,481$

$UAL = 2,000 = AL - AAV \Rightarrow AAV = AL - 2,000$
$= 8,481$

We can bring the 1/1/86 AAV plus contribution forward to 1/1/87 at the 11% rate of interest earned, then calculate the 1/1/87 UAL:

1/1/87 valuation

$AAV = 1.11(8,481 + 2,096)$
$= 11,741$
$UAL = 12,000 - 11,741$
$= 259$

answer is A

18. Under the Entry Age Normal cost method, the normal cost is defined as the present value of future benefits at entry age, divided by the present value of future salary or lives at entry age. The problem gives us N_x and D_x values that we must use in the calculations.

The key to this problem is that the assumed retirement age is not age 65. The projected benefit and all funding must be based on the assumed retirement age of 60.

1/1/87 valuation
Age 50, entry age 40

Proj ben = 20(10)(12)[1 - .06(5)]
= 1,680

$$\text{EANC} = \frac{(\text{proj ben})(\ddot{a}^{(12)}_{60})(D_{60}/D_{40})}{(N_{40}-N_{60})/D_{40}}$$

$$= \frac{1{,}680(9.79)(151/652)}{(8{,}761-1{,}547)/652}$$

= 344

AL = retrospective accumulation of normal costs
= EANC(Nea-Nca)/Dca
= 344(8,761-3,902)/322
= 5,195 answer is B

19. Under the Frozen Initial Liability cost method, the normal cost is calculated on an aggregate basis. The PVNC is defined as PVB less UAL less AAV, all determined on an aggregate basis.

This is an unusual end of year valuation problem. We need to set up the 12/31/86 and 1/1/87 valautions to see what is similar.

12/31/86 valuation

AAV	200,000	
UAL	400,000	
PVNC	300,000	= 900,000 - 200,000 - 400,000
PVB	900,000	

01/01/87 valuation

AAV	260,000	= 200,000 + 60,000 contribution
UAL	370,000	= eUAL = (1+i)(NCo+UALo) - (contrib+int) 30,000 + 400,000 - 60,000 (same date - no int)
PVNC	270,000	= 900,000 - 260,000 - 370,000
PVB	900,000	

The PVNC at 1/1/87 looks correct - one normal cost payment has been paid, and the PVNC is lower by that amount (30,000). In order to calculate the normal cost at 1/1/87, we must use the average PVL/L at 12/31/86 and adjust it to include one fewer assumed normal cost payments:

if 1/1/86 age is x-1, 12/31/86 PVL/L = $(1 + v + v^2 + \ldots + v^{65-x})$

At 1/1/87, age is x, 01/01/87 PVL/L = $(1 + v + v^2 + \ldots + v^{64-x})$

= (12/31/86 PVL/L - 1.0)(1+i)

12/31/86 PVL/L = 10.0 = 300,000 / 30,000

01/01/87 PVL/L = (10.0-1.0)(1.08) = 9.72

01/01/87 NC = 270,000 / 9.72
= 27,778

answer is B

20. Under the Individual Level Premium cost method, benefit changes are funded prospectively from the date of change. When the projected benefit under the plan changes, either due to plan amendments or salary changes, a new layer of normal cost is created.

In this end of year valuation problem, we should calculate the initial normal cost based on amortization from the effective date of the plan. The 12/31 normal cost will be that amount increased with a full year's interest.

With no deaths or terminations prior to retirement, we discount liabilities prior to age 65 at interest only. We can use annuities certain for the temporary annuity to retirement age.

12/31/86 valuation
1-1-86 Age 44

Proj benefit = .30(200,000) = 60,000

PV fut ben = $60{,}000(v^{21})(\ddot{a}^{(12)}_{\overline{65}})$

= 60,000(.1987)(8.40) = 100,122

1/1 ILP NC = $100{,}122 \;/\; \ddot{a}_{\overline{21}|.08}$

= 9,255

12/31 ILP NC = 9,255 * 1.08

= 9,995 answer is A

This problem is a much easier version of number 16.

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