CH0401 Process Engineering Economics

Lecture 1e

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(Under section 3 of UGC Act 1956)

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Process Engineering Economics

1. **Introduction – Time Value of Money**
2. Equivalence
3. Equations for economic studies
4. Amortization
5. Depreciation and Depletion

Process Engineering Economics

1. **Introduction – Time Value of Money**
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Process Engineering Economics

1 **Introduction – Time Value of Money**

2 Equivalence

3 Equations for economic studies

4 Amortization

5 Depreciation and Depletion

Process Engineering Economics – **Depreciation**

Depreciation

Depreciation has many meanings, but only two are discussed in our syllabus

loss of value of capital with the time when equipment wears out or becomes obsolete.

the systematic allocation of costs of an asset that produces an income from operations.

In short, depreciation may be considered as a cost for protection of depreciating capital without interest over a period, which the capital (asset or equipment) is used.

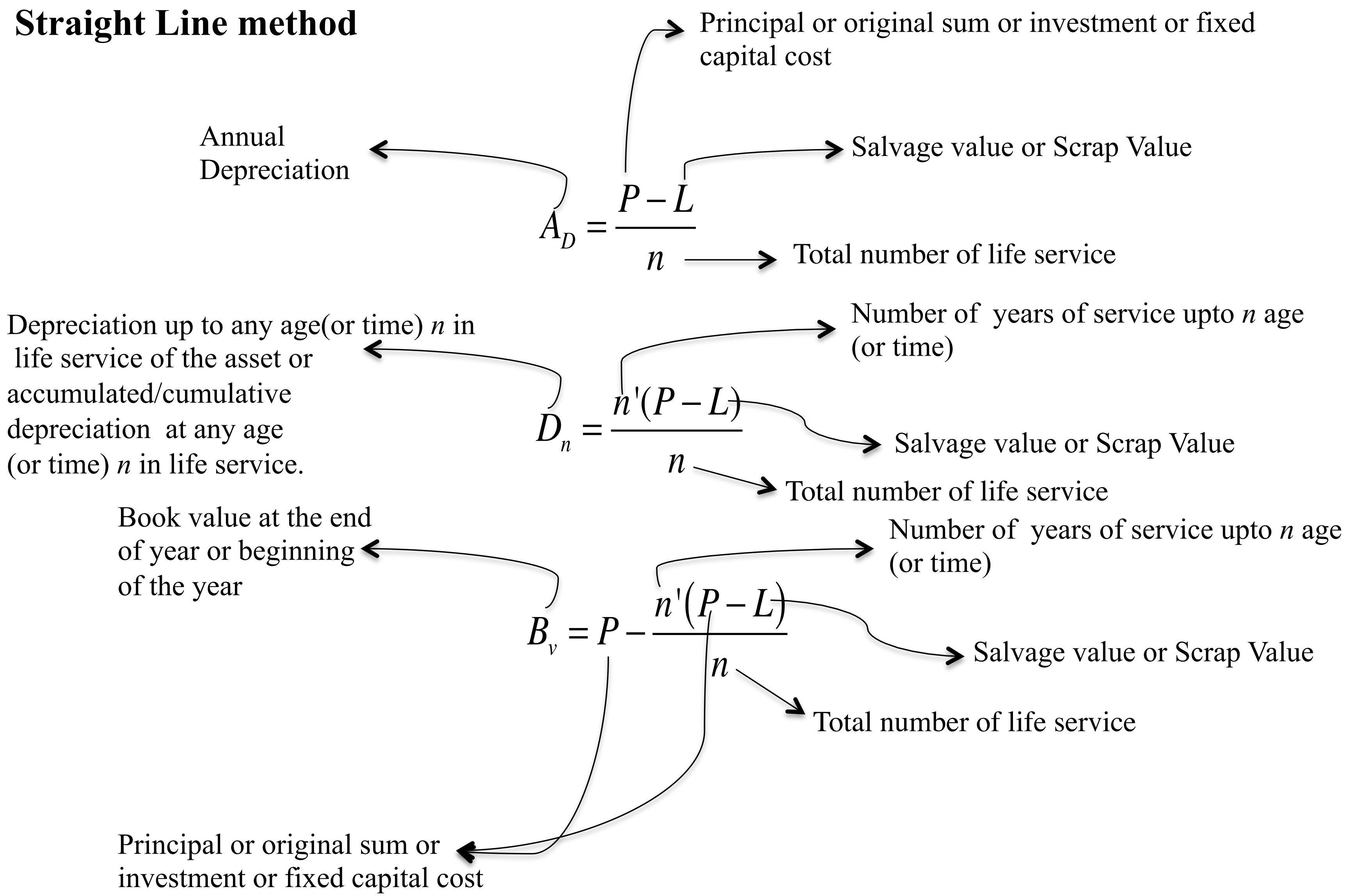
Process Engineering Economics – **Depreciation**

Depreciation- Methods

1. Straight Line method
2. Fixed Percentage (or) Declining Balance
3. Sinking fund
4. Sum-of-the-years' digits method

Process Engineering Economics – **Depreciation**

1. Straight Line method



Principal or original sum or investment or fixed capital cost

Annual Depreciation

Salvage value or Scrap Value

$$A_D = \frac{P-L}{n}$$

Total number of life service

Depreciation up to any age(or time) *n* in life service of the asset or accumulated/cumulative depreciation at any age (or time) *n* in life service.

Number of years of service upto *n* age (or time)

$$D_n = \frac{n'(P-L)}{n}$$

Salvage value or Scrap Value

Total number of life service

Book value at the end of year or beginning of the year

Number of years of service upto *n* age (or time)

$$B_v = P - \frac{n'(P-L)}{n}$$

Salvage value or Scrap Value

Total number of life service

Principal or original sum or investment or fixed capital cost

Process Engineering Economics – **Depreciation**

2. Fixed Percentage or Declining Balance Method

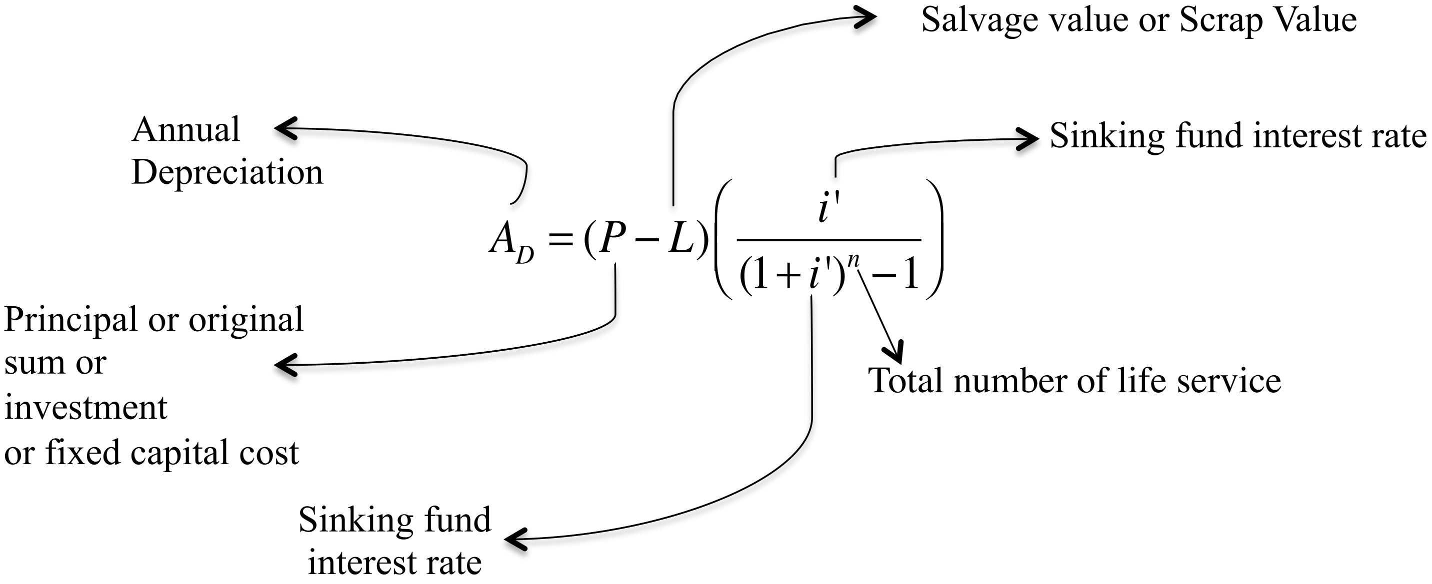
A_D = Depreciation factor (f) × Book value at the beginning of the year

$$f = 1 - \sqrt[n]{\frac{L}{P}}$$

Where, f = depreciation rate (or) depreciation factor expressed in percentage; L = salvage value or scrap value; P = principal/ original sum or fixed capital investment; B_v = book value at the end or beginning of the year; n = total number of life service

Process Engineering Economics – **Depreciation**

3. Sinking Fund Method



$$A_D = (P - L)\left(\frac{i'}{(1+i')^n - 1}\right)$$

Annual Depreciation

Salvage value or Scrap Value

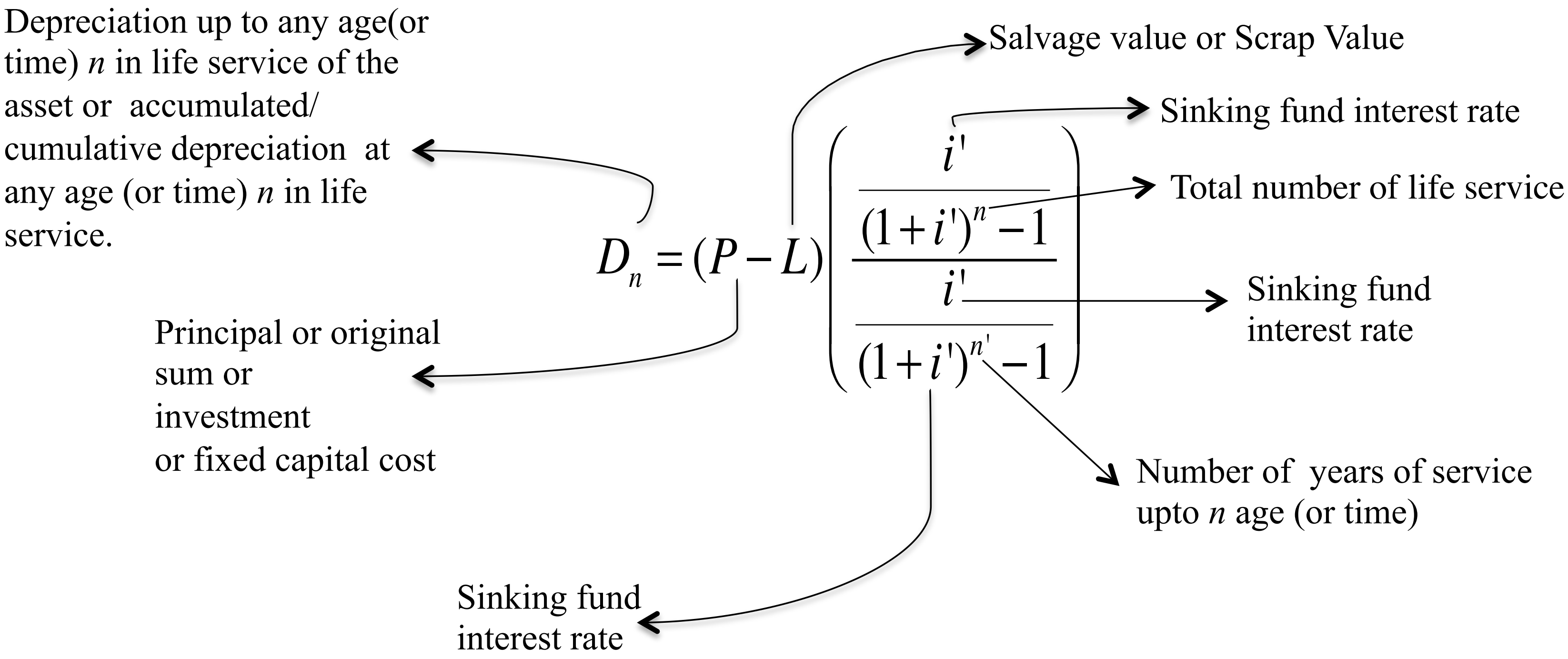
Sinking fund interest rate

Principal or original sum or investment or fixed capital cost

Total number of life service

Sinking fund interest rate

3. Sinking Fund Method



$$D_n = (P - L)\left(\frac{\frac{i'}{(1+i')^{n} - 1}}{\frac{i'}{(1+i')^{n'} - 1}} \right)$$

Depreciation up to any age(or time) *n* in life service of the asset or accumulated/ cumulative depreciation at any age (or time) *n* in life service.

Salvage value or Scrap Value

Sinking fund interest rate

Total number of life service

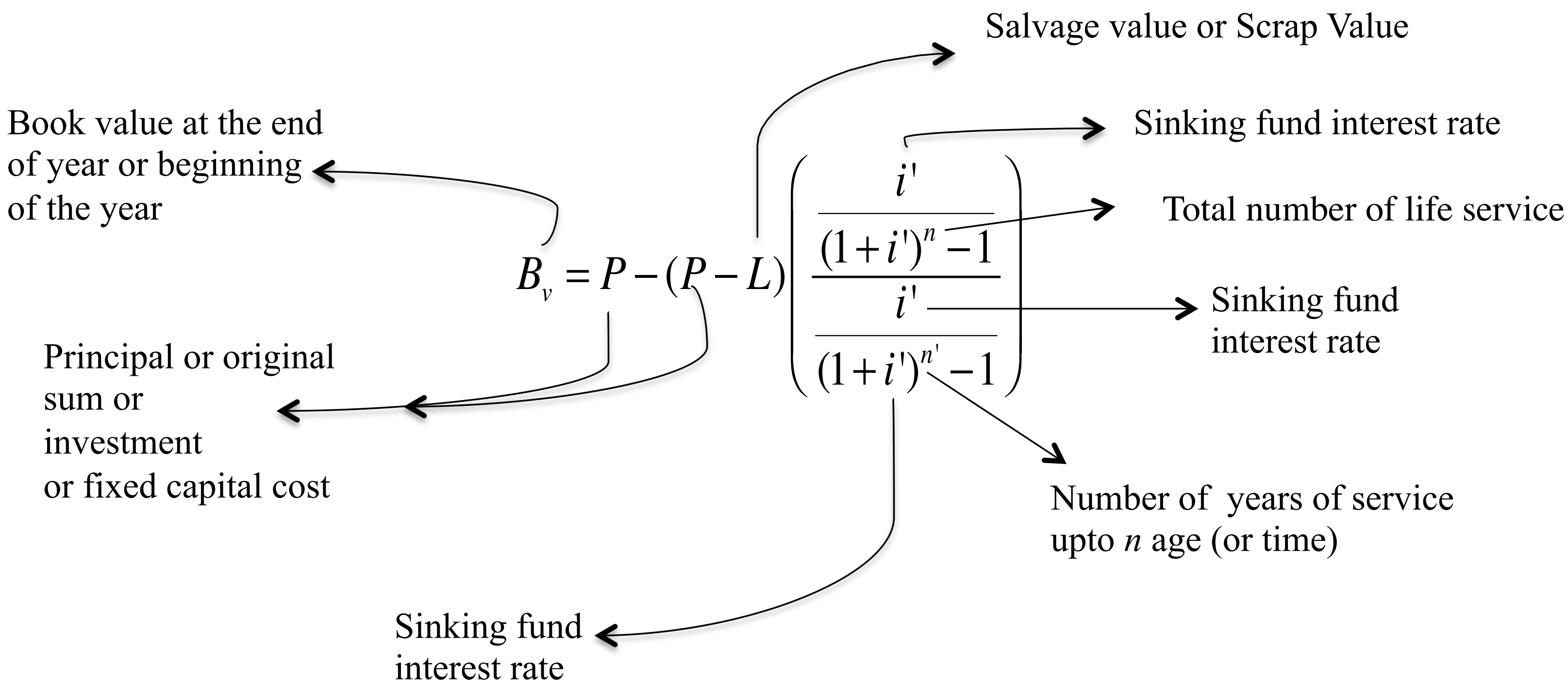
Sinking fund interest rate

Principal or original sum or investment or fixed capital cost

Number of years of service upto *n* age (or time)

Sinking fund interest rate

3. Sinking Fund Method



$$B_v = P - (P - L)\left(\frac{\dfrac{i'}{(1+i')^n - 1}}{\dfrac{i'}{(1+i')^{n'} - 1}} \right)$$

Salvage value or Scrap Value

Book value at the end of year or beginning of the year

Sinking fund interest rate

Total number of life service

Sinking fund interest rate

Principal or original sum or investment or fixed capital cost

Number of years of service upto *n* age (or time)

Sinking fund interest rate

Process Engineering Economics – **Depreciation**

4. Sum – the – years – digits method

$$A_D = (\text{Total Depriciable cost}) \times (\text{Depreciation factor})$$

$$\text{Total depreciable cost} = P - L$$

$$\text{Depreciation factor} = \frac{\text{decreasing order of life service of the asset}}{\text{sum-of-the-years digits}}$$

$$\text{sum-of-the-years digits} = \frac{n + n^2}{2}$$

$$B_V \text{ at the end of the year} = (\text{Book value at the begining of the year}) - (A_D)$$

Process Engineering Economics – **Depreciation**

Example problem

If a heat exchanger costs \$1,100 with 10 years of service life had a salvage value of \$100. Estimate the annual depreciation of heat exchanger by

1. Straight-line method
2. Fixed percentage (or) declining balance method
3. Sinking fund method
4. Sum-of-the-year's digits method.

Show the behavior of book value and depreciation in graph for each of the above-mentioned methods.

Process Engineering Economics – **Depreciation**

Solution:

Given: Principal (or) Original sum (or)

Initial Investment (or) Fixed capital cost = \$1,100

Service life of the heat exchanger = 10 years

Salvage value of the heat exchanger

at the end of 10th year is = \$100

Required: Annual depreciation by

1. Straight-line method
2. Fixed percentage (or) Declining Balance Method
3. Sinking – fund method
4. Sum – of –the – years – digits method and show all the methods behavior in a graph.

Process Engineering Economics – **Depreciation**

1. **Straight Line method**

Principal or original sum or investment or fixed capital cost

Annual Depreciation

Salvage value or Scrap Value

$$A_D = \frac{P-L}{n}$$

Total number of life service

Number of years of service upto *n* age (or time)

Depreciation up to any age(or time) *n* in life service of the asset or accumulated/cumulative depreciation at any age (or time) *n* in life service.

$$D_n = \frac{n'(P-L)}{n}$$

Salvage value or Scrap Value

Total number of life service

Book value at the end of year or beginning of the year

Number of years of service upto *n* age (or time)

$$B_v = P - \frac{n'(P-L)}{n}$$

Salvage value or Scrap Value

Total number of life service

Principal or original sum or investment or fixed capital cost

Process Engineering Economics – **Depreciation**

1. **Straight Line method**

$$A_D = \left(\frac{P - L}{n} \right)$$

$$A_D = \left(\frac{1100 - 100}{10} \right)$$

$$\underline{\underline{A_D = 100}}$$

Note: Annual depreciation in straight line method is constant for the entire service life of the equipment

Process Engineering Economics – **Depreciation**

1. **Straight Line method**

$$D_n = \frac{n'(P-L)}{n}$$

$$B_v = P - \frac{n'\left(P-L\right)}{n}$$

$$D_0 = \left(\frac{0(1100-100)}{10}\right) = 0$$

$$D_1 = \left(\frac{1(1100-100)}{10}\right) = 100$$

$$D_2 = \left(\frac{2(1100-100)}{10}\right) = 200$$

$$D_3 = \left(\frac{3(1100-100)}{10}\right) = 300$$

$$D_4 = \left(\frac{4(1100-100)}{10}\right) = 400$$

$$D_5 = \left(\frac{5(1100-100)}{10}\right) = 500$$

$$D_6 = \left(\frac{6(1100-100)}{10}\right) = 600$$

$$D_7 = \left(\frac{7(1100-100)}{10}\right) = 700$$

$$D_8 = \left(\frac{8(1100-100)}{10}\right) = 800$$

$$D_9 = \left(\frac{9(1100-100)}{10}\right) = 900$$

$$D_{10} = \left(\frac{0(1100-100)}{10}\right) = 1000$$

$$B_{V_0} = 1100 - 0(0)$$

$$B_{V_0} = 1100$$

$$B_{V_1} = 1100 - 1(100)$$

$\underline{\underline{B_{V_1} = 1000}}$ Similarly for other years as follows,

$$B_{V_2} = 900$$

$$B_{V3} = 800$$

$$B_{V_4} = 700$$

$$B_{V_5} = 600$$

$$B_{V_6} = 500$$

$$B_{V_7} = 400$$

$$B_{V_8} = 300$$

$$B_{V_9} = 200$$

$$B_{V_{10}} = 100$$

Process Engineering Economics – **Depreciation**

1. Straight Line method

$$A_D = \left(\frac{P-L}{n}\right)$$

$$A_D = \left(\frac{1100-100}{10}\right)$$

$$\underline{\underline{A_D = 100}}$$

Years (n)	Book value at the beginning of the year (B_v), \$	Annual Depreciation (A_D), \$	Depreciation upto any age (or time) (D_n) or Cumulative depreciation (C_D), \$	Book value at the end of the year (B_v), \$
0	1100	0	0	1100
1	1100	100	100	1000
2	1000	100	200	900
3	900	100	300	800
4	800	100	400	700
5	700	100	500	600
6	600	100	600	500
7	500	100	700	400
8	400	100	800	300
9	300	100	900	200
10	200	100	1000	100

$$D_n = \frac{n'(P-L)}{n}$$

$$D_0 = \left(\frac{0(1100-100)}{10}\right) = 0$$

$$B_v = P - \frac{n'(P-L)}{n}$$

$$B_{v0} = 1100 - \frac{0(1100-100)}{10} = 0$$

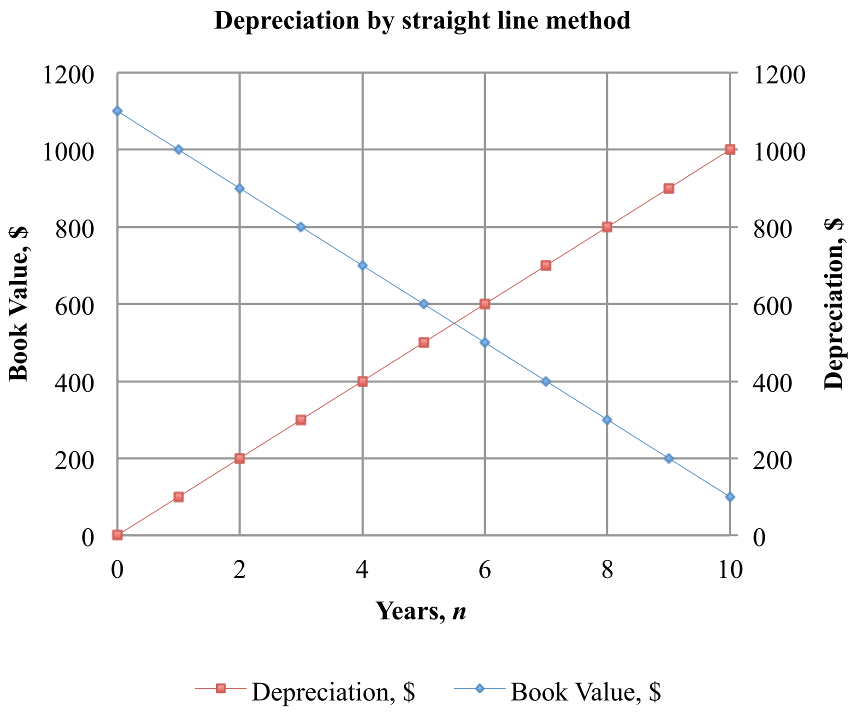
$$B_{v1} = 1100 - \frac{1(1100-100)}{10} = 1000$$

$$B_{v2} = 1100 - \frac{2(1100-100)}{10} = 900$$

Sum of D_n and B_v at the end of service life will be the original sum invested i.e. 1000+100=\$1100

Process Engineering Economics – **Depreciation**

1. Straight line method



Years (n)	Accumulated depreciation (or) Cumulative depreciation (C_D), $	Book value at the end of the year (B_v), $
0	0	1100
1	100	1000
2	200	900
3	300	800
4	400	700
5	500	600
6	600	500
7	700	400
8	800	300
9	900	200
10	1000	100

Process Engineering Economics – **Depreciation**

2. Fixed Percentage or Declining Balance Method

A_D = Depreciation factor (f) × Book value at the beginning of the year

$$f = 1 - \sqrt[n]{\frac{L}{P}} \qquad D_n = \frac{n'(P-L)}{n} \qquad B_{V\,@\text{end of the year}} = B_{V\,@\text{begining of the year}} - A_D$$

Where, f = depreciation rate (or) depreciation factor expressed in percentage; L = salvage value or scrap value; P = principal/ original sum or fixed capital investment; B_v = book value at the end or beginning of the year; n = total number of life service; D_n = Depreciation up to any age(or time) n in life service of the asset or accumulated/ cumulative depreciation at any age (or time) n in life service. n'=Number of years of service upto n age (or time)

Process Engineering Economics – **Depreciation**

2. Fixed Percentage or Declining Balance Method

$$f = 1 - \sqrt[n]{\frac{L}{P}}$$

$$f = 1 - \sqrt[10]{\frac{100}{1100}} = 0.213$$

A_D = Depreciation rate (*f*) × Book value at the beginning of the year

$$A_{D_1} = 0.213 \times 1100 = 234$$

$$A_{D_2} = 0.213 \times 866 = 185$$

$$A_{D_3} = 0.213 \times 681 = 145$$

$$B_{V_1} = 1100 - 234 = 866$$

$$B_{V_2} = 866 - 185 = 681$$

$$B_{V_3} = 681 - 145 = 536$$

$$B_{V_4} = 536 - 114 = 422$$

$$B_{V_5} = 422 - 90 = 332$$

$$B_{V_6} = 332 - 71 = 261$$

$$B_{V_7} = 261 - 56 = 205$$

$$B_{V_8} = 205 - 44 = 161$$

$$B_{V_9} = 161 - 34 = 127$$

$$B_{V_{10}} = 127 - 27 = 100$$

Note: Depreciation rate *f* in fixed percentage or declining balance method is constant for the entire service life of the equipment

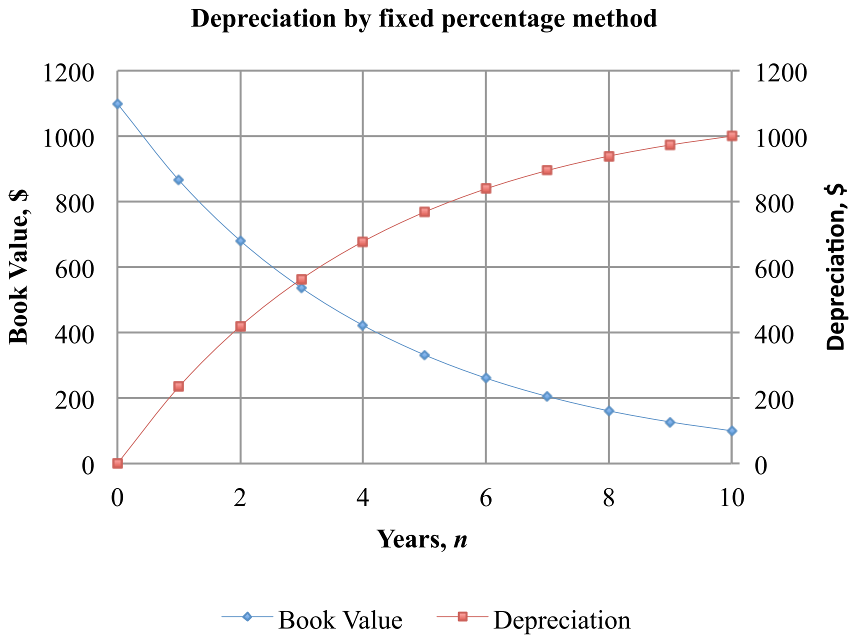
Process Engineering Economics – **Depreciation**

2. Fixed Percentage or Declining Balance Method

Years 'n'	Book value at the beginning of the year 'B_v'	Depreciation rate 'f'	Annual Depreciation (A_D), $	Cumulative depreciation (C_D), $ (or) D_n	Book value at the end of the year (B_v), $
0	1100	0	0	0	1100
1	1100	0.213	234	234	866
2	866	0.213	185	419	681
3	681	0.213	145	564	536
4	536	0.213	114	678	422
5	422	0.213	90	768	332
6	332	0.213	71	839	261
7	261	0.213	56	895	205
8	205	0.213	44	939	161
9	161	0.213	34	973	127
10	127	0.213	27	1000	100

Process Engineering Economics – **Depreciation**

2. Fixed Percentage or Declining Balance Method



Years ‘n’	**Cumulative depreciation (C_D), \$ (or) D_n**	**Book value at the end of the year (B_v), \$**
0	0	1100
1	234	866
2	419	681
3	564	536
4	678	422
5	768	332
6	839	261
7	895	205
8	939	161
9	973	127
10	1000	100

Process Engineering Economics – **Depreciation**

3. Sinking Fund Method

$$A_D = (P-L)\left(\frac{i'}{(1+i')^n - 1}\right)$$

$$D_n = (P-L)\left(\frac{\dfrac{i'}{(1+i')^n - 1}}{\dfrac{i'}{(1+i')^{n'} - 1}}\right)$$

$$A_D = (1100-100)\left(\frac{0.06}{(1+0.06)^{10} - 1}\right) = 76$$

$$D_1 = (1100-100)\left(\frac{\dfrac{0.06}{(1+0.06)^{10} - 1}}{\dfrac{0.06}{(1+0.06)^{1} - 1}}\right) = 76$$

$$B_v = P-(P-L)\left(\frac{\dfrac{i'}{(1+i')^n - 1}}{\dfrac{i'}{(1+i')^{n'} - 1}}\right)$$

$$B_V = 1100-(1100-100)\left(\frac{\dfrac{0.06}{(1+0.06)^{10} - 1}}{\dfrac{0.06}{(1+0.06)^{1} - 1}}\right) = 1100-1000\left(\frac{0.0758}{1}\right) = 1100-156 = 1024$$

In the same manner up to the end of tenth year A_D and D_n is calculated and tabulated

Note: Annual depreciation in sinking fund method is constant for the entire service life of the equipment

Process Engineering Economics – **Depreciation**

3. Sinking Fund Method

$$B_v = P - (P-L)\left(\frac{\dfrac{i'}{(1+i')^n - 1}}{\dfrac{i'}{(1+i')^{n'} - 1}}\right)$$

$$B_2 = 1100 - (1100-100)\left(\frac{\dfrac{0.06}{(1+0.06)^{10} - 1}}{\dfrac{0.06}{(1+0.06)^{2} - 1}}\right) = 1100 - 1000\left(\frac{0.075867}{0.48543}\right) = 1100 - 156 = 943$$

$$B_3 = 1100 - (1100-100)\left(\frac{\dfrac{0.06}{(1+0.06)^{10} - 1}}{\dfrac{0.06}{(1+0.06)^{3} - 1}}\right) = 1100 - 1000\left(\frac{0.075867}{0.314109}\right) = 1100 - 242 = 859$$

In the same manner up to the end of tenth year book value is calculated and tabulated

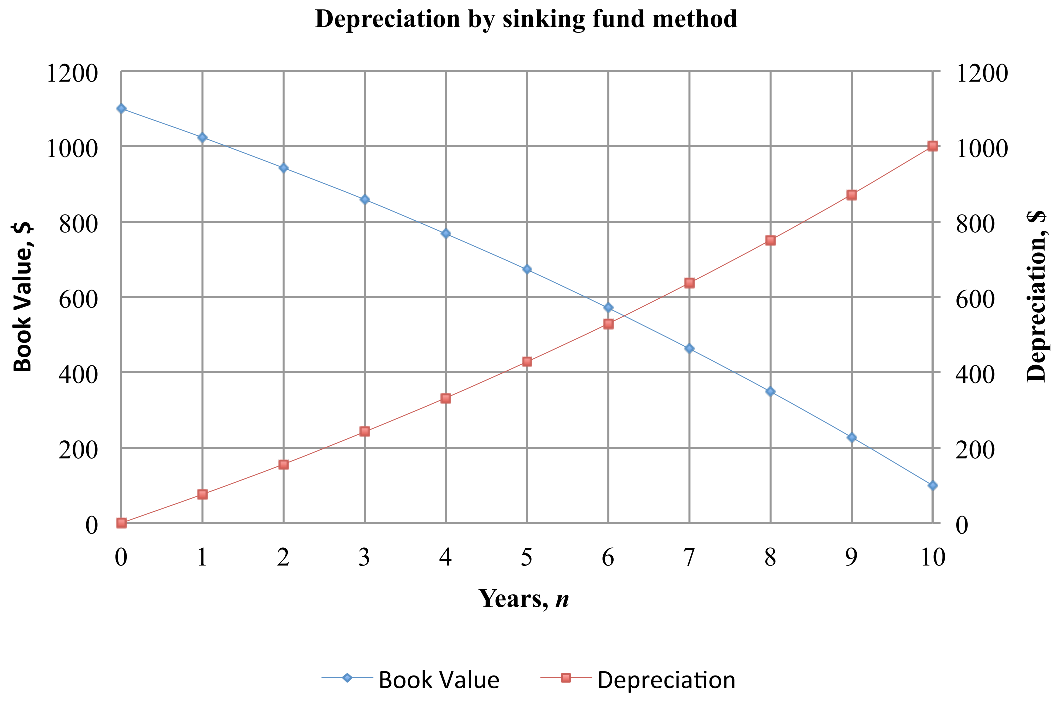
Process Engineering Economics – **Depreciation**

3. Sinking Fund Method

Years 'n'	Book value at the beginning of the year 'B_v'	Interest rate 'i'	Annual Depreciation (A_D), $	Cumulative depreciation (C_D), $ (or) D_n	Book value at the end of the year (B_v), $
0	1100	0.06	0	0	1100
1	1100	0.06	76	76	1024
2	1024	0.06	76	156	943
3	943	0.06	76	242	859
4	859	0.06	76	332	768
5	768	0.06	76	428	673
6	673	0.06	76	529	571
7	571	0.06	76	637	463
8	463	0.06	76	751	349
9	349	0.06	76	872	228
10	228	0.06	76	1000	100

Process Engineering Economics – **Depreciation**

3. Sinking Fund Method



Years 'n'	Book value at the end of the year (B_v), $	Cumulative depreciation (C_D), $ (or) D_n
0	1100	0
1	1024	76
2	943	156
3	859	242
4	768	332
5	673	428
6	571	529
7	463	637
8	349	751
9	228	872
10	100	1000

Process Engineering Economics – **Depreciation**

4. Sum – the – years – digits method

Sum-of-the-years digits = 1+2+3+4+5+6+7+8+9+10 = 55 (or) $\frac{n+n^2}{2}=\frac{10+10^2}{2}=55$

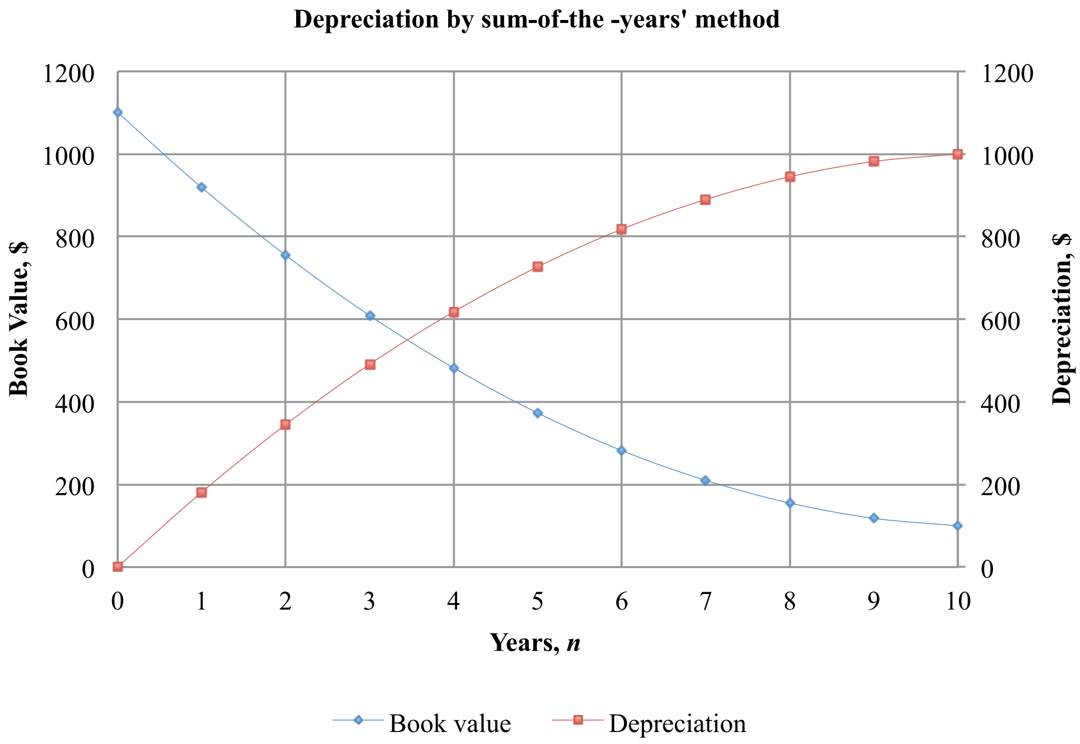
Note: Total depreciable cost in sum-of-the years digit's method is constant for the entire service life of the equipment

Years 'n'	Book value at the beginning of the year 'B_v', \$	Total depreciable cost $(P\text{-}L)$,\$	Depreciation factor	Annual Deprecation (A_D), \$	Cumulative depreciation (C_D), \$ (or) D_n	Book value at the end of the year (B_v), \$
0	1100	0	0	0	0	1100
1	1100	1000	$\frac{10}{55}$	$1000\times\frac{10}{55}=181$	181	919
2	919	1000	$\frac{09}{55}$	$1000\times\frac{09}{55}=164$	345	755
3	755	1000	$\frac{08}{55}$	$1000\times\frac{08}{55}=146$	491	609
4	609	1000	$\frac{07}{55}$	$1000\times\frac{07}{55}=127$	618	482
5	482	1000	$\frac{06}{55}$	$1000\times\frac{06}{55}=109$	727	373
6	373	1000	$\frac{05}{55}$	$1000\times\frac{05}{55}=91$	818	282
7	282	1000	$\frac{04}{55}$	$1000\times\frac{04}{55}=72$	890	210
8	210	1000	$\frac{03}{55}$	$1000\times\frac{03}{55}=55$	945	155
9	155	1000	$\frac{02}{55}$	$1000\times\frac{02}{55}=37$	982	118
10	118	1000	$\frac{01}{55}$	$1000\times\frac{01}{55}=18$	1000	100

Book value at the end of the year = Book value at the beginning of the year - Annual Depreciation
i.e. 1100 – 181 = \$919
919 – 164 = \$755
755 – 146 = \$609

Process Engineering Economics – **Depreciation**

4. Sum – the – years – digits method



Years **'n'**	**Book value at the end of the year (B_v), $**	**Cumulative depreciation (C_D),$ (or) D_n**
0	1100	0
1	919	181
2	755	345
3	609	491
4	482	618
5	373	727
6	282	818
7	210	890
8	155	945
9	118	982
10	100	1000

Process Engineering Economics – **Depreciation**

4. Sum – the – years – digits method

When all the data's of four different methods are combined together

Years	Straight - Line		Fixed percentage		Sinking fund		Sum-of-the-years	
	B_v	C_D	B_v	C_D	B_v	C_D	B_v	C_D
0	1100	0	1100	0	1100	0	1100	0
1	1000	100	866	234	1024	76	919	181
2	900	200	681	419	943	156	755	345
3	800	300	536	564	859	242	609	491
4	700	400	422	678	768	332	482	618
5	600	500	332	768	673	428	373	727
6	500	600	261	839	571	529	282	818
7	400	700	205	895	463	637	210	890
8	300	800	161	939	349	751	155	945
9	200	900	127	973	228	872	118	982
10	100	1000	100	1000	100	1000	100	1000

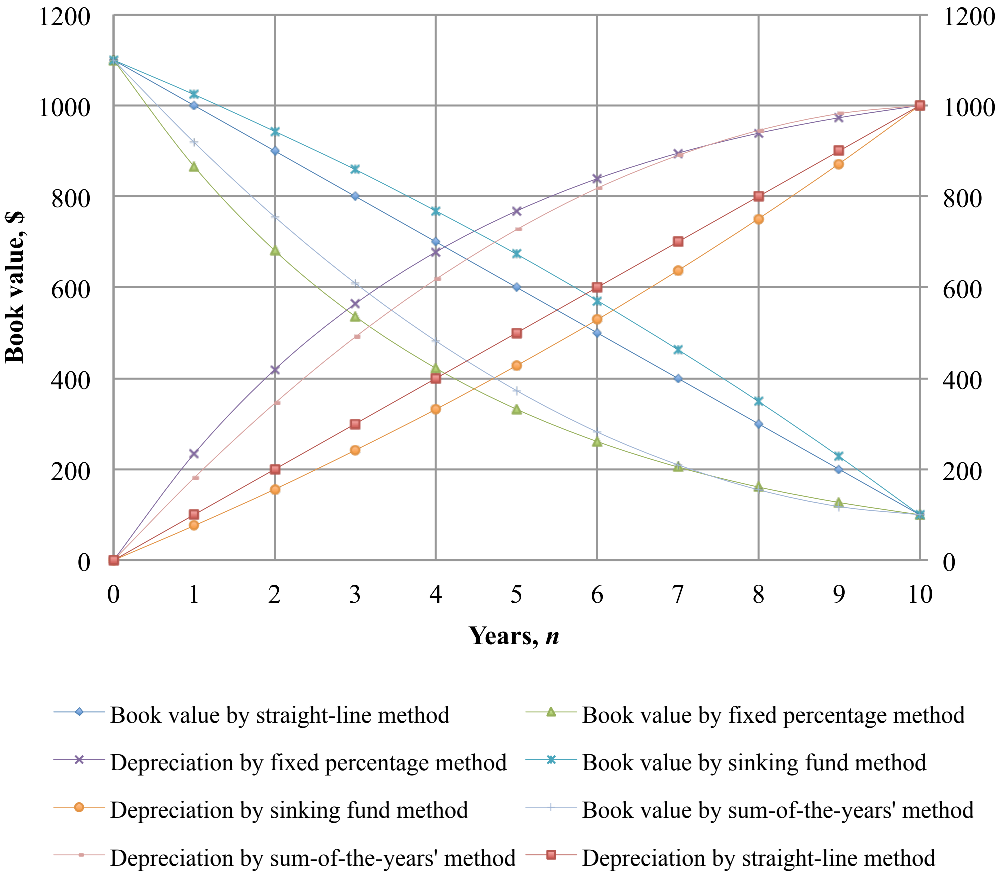
C_D represents cumulative depreciation

B_V represents book value at the end of the year

Process Engineering Economics – **Depreciation**

4. Sum – the – years – digits method

When all the data's of four different methods are combined together



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