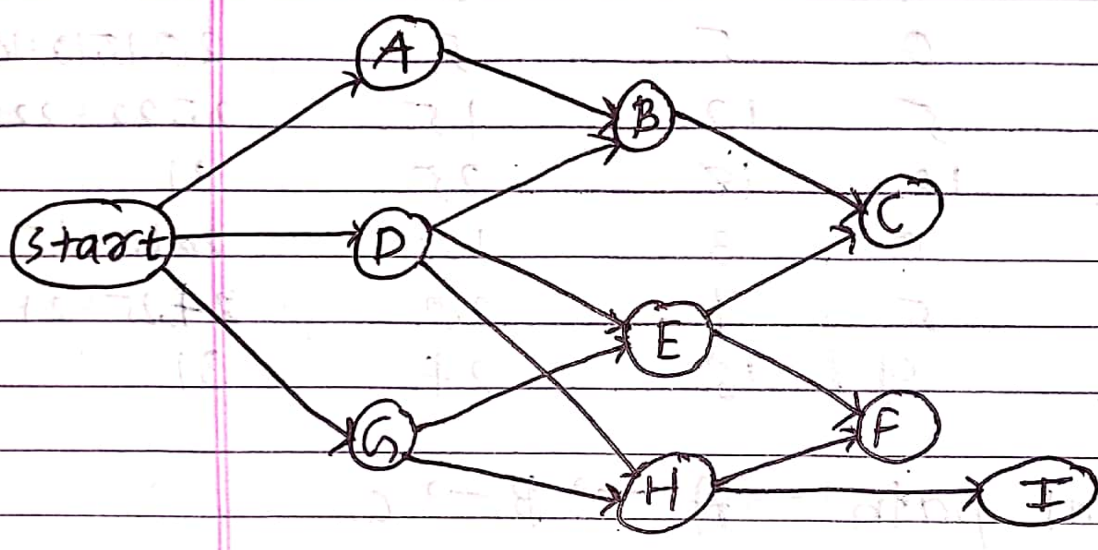
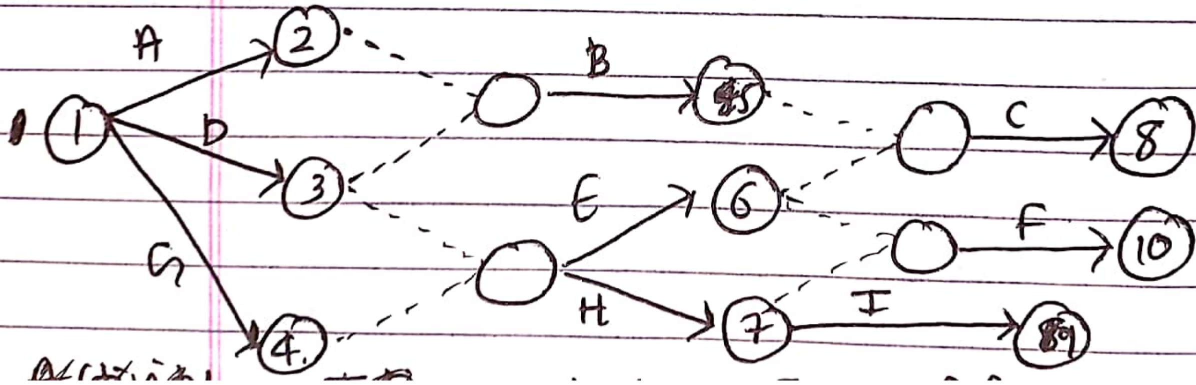
1

Numericals

* AON :-



* AOA :-



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			Es	EF	Ls	Lf
A	10	-	0	10	0	10
B	12	A, D	10	22	10	22,
C	9	B, E	22	31	22	31
D	5	-	0	5	5	20, 15, 10 = 10
E	7	D, G	5	12	15	25, 22 = 22
F	6	E, H	12	18	25	31
G	3	-	0	3	12	20, 15 = 15
H	4	D, G	5	9	20	24, 25 = 24
I	7	H	9	16	24	31

∴ critical path :- A → B → C.

CPM = critical path method.

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②

			ES	EF	LS	LF
H	10	–	0	10	0	10,15 = 10
I	8	H	10	18	15	28,25,23 = 23
J	6	H	10	16	10	28,16,31,21 = 16
K	4	J	16	20	21	25
L	2	J	16	18	31	33
M	4	J	16	20	16	20
N	4	I	18	22	23	27
O	5	I	18	23	25	30
P	5	I, J	16, 18 = 18	23	28	33
Q	5	L	18	23	33	38
R	5	M	20	25	20	25
S	3	N	22	25	27	30
T	3	Q	23	26	38	41
U	1	O, S	25	26	30	31
V	5	K, R	25	30	25	30
W	2	U	26	28	31	33
X	3	V	30	33	30	33
Y	8	P, W, X	33	41	33	41
Z	6	Y, T	41	47	41	47

* Total slack = LS − ES
= LF − EF.

Free slack = ES (earliest successor) − EF (activity) − 1.

* Time cost relationship :-

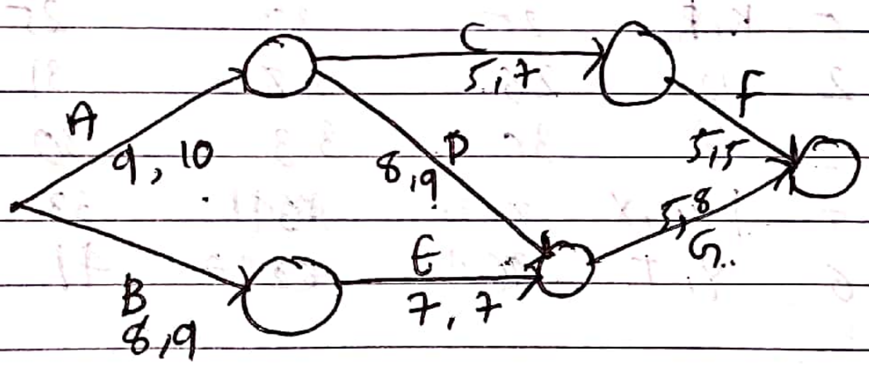
$$\text{Cost slope} = \frac{C_c - C_n}{T_c - T_n}$$

(3)

*

Activity	Tn	Cn	Tc	Cc	slope.
A	9	10	6	16	2
B	8	9	5	18	3
C	5	7	4	8	1
D	8	9	6	19	5
E	7	7	3	15	2
F	5	5	5	5	-
G	5	8	2	23	5
		\$55		\$104	

*



All paths = A − C − F = 19
A − D − G = 22 = critical path.
B − E − G = 20

Cost = ~~28~~ \$55 (of all activities).

t = 1,

To reduce ~~co~~ time by 1 day.
CP = A D G   A has least scope
so reducing time by adding cost of A.

$\therefore$ cost = 55 + 2 = 57.

ACF = 19 ADG = 21 BEG = 20.

$\therefore$ t = 2,

reducing A again by 1day.

$\therefore$ cost = ~~57~~ 57 + 2 = 59

$\therefore$ ACF = 17 ADG = 20 BEG = 20.

$\therefore$ t = 3,

A, E have same cost so considering both.

$\therefore$ cost = 59 + 2 + 2 = 63.

$\therefore$ ACF = 16 ADG = 19 BEG = 19.

$\therefore$ Now A is crashed to 6 so it cannot be reduced further.

Now ADG and BEG are critical paths.
reduction of G will cost = 5
reduction of D, E will cost = 5 + 2 = 7

$\therefore$ at t = 4, G is reduced by 1 time unit.
$\therefore$ cost = 63 + 5 = 68
ACF = 16 ADG = 18 BEG = 18.

at t = 4, 5, 6 As G can be crashed in total of 3 times.
$\therefore$ cost = 63 + 5 + 5 + 5 = 78
$\therefore$ ACF = 16 ADG = 16 BEG = 16

Now A and G cannot be reduced further

at t = 7.

C, D and E are reduced (as it cannot be reduced).

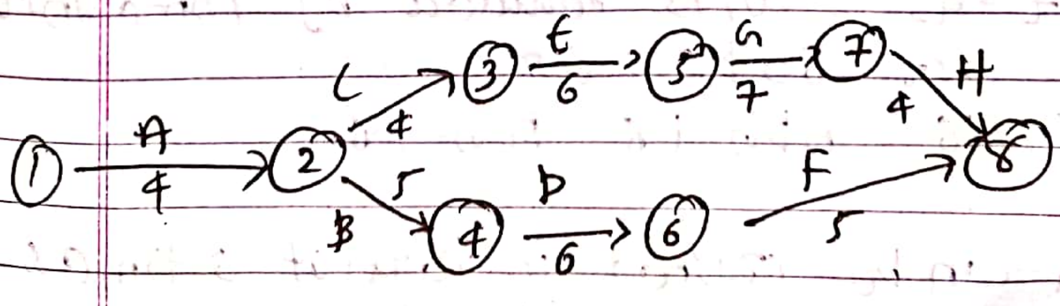
$\therefore$ cost = 78 + 1 + 5 + 2 = 86

$\therefore$ ACF = 15 ABG = 15 ABEG = 15

$\therefore$ project duration reduced from 22 to 15 and additional cost incurred = ~~58~~ 86 - 55 = 31 \$.

(4)

		TN	CN(K)	TC	CC(K)	slope
A	-	4	8	3	9	1
B	A	5	16	3	20	2
C	A	4	12	3	13	1
D	B	6	34	5	35	1
E	C	6	42	4	44	1000
F	D	5	16	4	16.5	0.5
G	E	7	66	4	72	6
H	G	4	2	3	5	3



∴ 2 paths:-

A B D F = 20

~~ABD~~ ACEGH = 25 = critical path.

∴ Total cost = 214.5

① To reduce to 24 weeks.

Now A, C, E = 1 (slope) but CC of A is smallest so reducing it.

∴ ABDF = 19

ACEGH = 24

∴ Total cost = 214.5 + 1 = 215.5

② To reduce to 23 weeks.

A cannot be reduced as $|TC - TN| = 0$.

∴ C, E = 1 but CC of C is smaller.

∴ ABDF = 19

ACEGH = 23

∴ Total cost = 215.5 + 1 = 216.5

③ To reduce it to 22 weeks.

Reducing E. ABDF = 19 ACEGH = 22

∴ Cost = 216.5 + 1 = 217.5.

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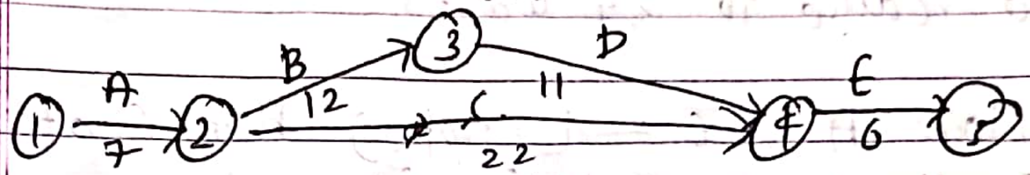
(3)

		TN	CN	TC	CC	slope
A	-	7	15	6	18	3
B	A	12	11	9	14	1
C	A	22	18.5	21	19	0.5
D	B	11	8	10	9	1
E	C, D	6	4	5	4.5	0.5
			56.5			



paths :- A - B - D - E = 36 = critical path.
A - C - E = 35

(1) To reduce it to 35 weeks.

E = 0.5 (least)

$\therefore$ ABDE = 35
ACE = 34

$\therefore$ cost = 56.5 + 0.5 = 57.

(2) To reduce it to 34 weeks.

E cannot be reduced.

B, D = 9 (smallest CC)

$\therefore$ D is reduced.

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ABDE = 34
ACE = 34

cost = 57 + 1 = 58

③ To reduce it to 33 weeks.

A = 3
B, C = 1 + 0.5 = 1.5 ∴ (< A)

∴ B, C is reduced.

∴ ABDE = 33
ACE = 33

∴ cost = 58 + 1.5 = 59.5

④ To reduce it to 32 weeks.
C, D, E can't be reduced.

∴ either reducing B from path 1 and A from path 2 or reducing A from both paths.

∴ ABDE = 32
ACE = 32

∴ cost = 59.5 + 3 = 62.5

∴ Project duration reduced to = 32 weeks
and cost increased by = 62.5 − 56.5 = 6 K$.

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* Direct and indirect costs:-

* Components of project expenses:-
1) Direct labour expenses.
2) Direct non labour expenses.
3) Overhead expenses (indirect expenses) and General and administrative expenses.
4) Profit and total billing.
5) contingency amount.

* Indirect cost apportionment approaches:-

6

i) Total indirect $\propto$ Total direct

ii) OH $\propto$ direct labour only

iii) G and A $\propto$ all direct costs.

iv) G and A $\propto$ DL, OH, DNL.

* Total indirect $\propto$ Total direct.

say OH = 200 G and A = 60

∴ total indirect = 260

project costs	Project A	project B	Total
DL	85	150	235
DNL	65	110	175
			Direct cost = 410

Type of cost	A	B
Direct = DL + DNL	85+65 = 150	150+110 = 260
Indirect = OH and G and A	$\frac{\text{Direct}}{\text{Total direct}} \times \text{Total indirect}$	"
	$\frac{150}{410} \times 260 = 95$	$\frac{260}{410} \times 260 = 165$
Total	245	425

* OH ∝ Direct labour only and G and A ∝ all direct

	Type of cost	A	B
Direct	DL+DNL	150	260
	OH	$\frac{DL \times OH(\text{initial})}{\text{total } DL}$	
		$\frac{85 \times 200}{235} = 72$	$\frac{150 \times 200}{235} = 128$
	G and A	$\frac{\text{all direct}}{\text{all direct}} \times \text{G and A (initial)}$	
		$\frac{150 \times 60}{410} = 22$	$\frac{260 \times 60}{410} = 38$
	Total =	244.	426.

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* OH ∝ direct labour only and G and A ∝ DL, OH and DNL

Type of cost	A	B
DL + DNL	150	260
OH	$\frac{DL \times OH}{total\ DL}$	
	$\frac{85 \times 200}{235}$	$\frac{150 \times 200}{235}$
	= 72	128
G and A	$\frac{(DL + DNL + OH) \times G\ and\ A}{total\ Direct + OH\ in\ total}$	
	$\frac{(85 + 65 + 72) \times 60}{610}$	$\frac{(150 + 110 + 128) \times 60}{610}$
	= 22	= 38
Total =	244	426.

7

OH = 120

G and A = 40

project costs	Mars project	pluto project	total
DL	50	100	150
DNL	40	10	50
	90	110	200

i) total indirect ∝ Total direct

	Mars	pluto	Total
DL + DNL	90	110	200
OH and G and A	72 $\left(\frac{90 \times 160}{200}\right)$	88 $\left(\frac{110 \times 160}{200}\right)$	160
			360

ii) ~~DL~~ OH ∝ Direct labour only and G and A ∝ all direct.

	mars	pluto	total
DL ~~+DNL~~	~~90~~ 50	100	150
OH	$\frac{50 \times 120}{150} = 40$	$\frac{100 \times 120}{150} = 80$	120
DNL	40	10	50
G and A	$\frac{90 \times 40}{200} = 18$	$\frac{110 \times 40}{200} = 22$	40
			300.

iii) OH ∝ Directly labour and G and A ∝ DL + OH + DNL

	Mars	pluto	total
DL + OH + DNL	50 + 40 + 40 = 130	100 + 80 + 10 = 190	320
G and A	$\frac{130 \times 40}{320} = 16.25$	23.75	40
			300

* Cash benefit analysis :-

- Net profit :- profit at end of project life.
- payback period :- Duration needed to recover all invested money.

  $\frac{\text{Initial investment}}{\text{Net annual cash flow}}$

- Return of investment ROI :- $\frac{\text{average annual profit}}{\text{Total investment}} \times 100.$

· Internal rate of return :- discount rate that would produce and NPV of 0

$$0 = \sum \text{cashflow} / (1+IRR)^{t}$$

* Net profit :-

(8)

year	A	B
0	-100000	-150000
1	-50000	-50000
2	10000	25000
3	10000	50000
4	50000	150000
5	100000	150000.

Net profit for A = -100000 + (-50000) + 10000 + 10000 + 50000 + 100000
= 20000.

Net profit for B = -150000 + (-50000) + 25000 + 50000 + 150000 + 150000
= 175000.

* Pay back period :-

* for project A, at year = 5, value of project turns to +ve which means
PP of A = 5 years $\left(\frac{150000}{20000} = \frac{\cancel{7.5}\text{ years}}{5\text{-}2}\right)$ 6

* for project B, at year = 4, value of project turns to +ve which means
pp of B = 4 years. $\left(\frac{200000}{175000}\right)$ 6
= ~~1.14 years~~
3.2 years

* Return of investment :-

	A	B
Net invest	150000	200000
Total profit	20000	175000
Average annual profit	$\frac{20000}{5}$	$\frac{175000}{5}$
	= 4000	= 35000
RoI	$= \frac{4000 \times 100}{150000}$	$= \frac{35000}{200000} \times 100$
	= 2.66 %	= 17.5 %

* Net present value :-

df = Discount factor $= \frac{1}{(1+r)^t}$

$\hookrightarrow$ ROI

$$NPV = \sum_{t=0}^{N} dt \times df \times \text{value at } t$$

t	A	B	dfactor 10%	dF x cost A	B
0	-100000	-150000	1	-100000	-150000
1	-50000	-50000	0.9091	-45455	-45455
2	10000	25000	0.8264	8264	20660
3	10000	50000	0.7513	7513	37565
4	50000	150000	0.6830	34150	102450
5	100000	150000	0.6209	62090	93135
			profit =	20000	175000
			NPV =	-33438	58355

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* IRR for project A :-

$$0 = -100000 - \frac{50000}{1+x} + \frac{10000}{(1+x)^2} + \frac{10000}{(1+x)^3} + \frac{50000}{(1+x)^4} + \frac{100000}{(1+x)^5}$$

$$0 = -100000(1+x)^5 - 50000(1+x)^4 + 10000(1+x)^3 + 10000(1+x)^2 + 50000(1+x) + 100000.0$$

$$\begin{aligned} 0 = & -100000(1+5x+10x^2+10x^3+5x^4+x^5) \\ & - 50000(1+4x+6x^2+4x^3+x^4) \\ & + 10000(1+3x+3x^2+x^3) + \\ & 10000(1+2x+x^2) \\ & + 50000(1+x) \\ & + 100000.0 \end{aligned}$$

$$0 = -(100000 + 500000x + 1000000x^2 + 1000000x^3 + 500000x^4 + 100000x^5)$$

$\therefore \quad x = 1.93\%$

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years	A	B	C
0	−40	−40	−200
1	5	20	55
2	10	25	55
3	15	15	55
4	25	10	55
5	20	5	55
Nett profit =	35	35	75

* payback period :-

for A :- 4 years

for B :- 2 years

for C :- 4 years

* NPV :

A	B	C	df 10% ratio	A	B	C
-40	-40	-2000	1	-40	-40	-200
5	20	55	0.9091	4.5	18.2	50
10	25	55	0.8264	8.3	20.6	45.5
15	15	55	0.7513	11.3	11.3	41.3
25	10	55	0.6830	17.1	6.8	37.6
30	5	55	0.6209	18.6	3.1	34.1
			NPV =	19.8	20	8.5

* ROI :-

$$A = \frac{35/5}{40} \times 100 = 17.5\%$$

$$B = \frac{35/5}{40} \times 100 = 17.5\%$$

$$C = \frac{75/5}{200} \times 100 = 7.5\%$$

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* Earned value analysis:-

PV = planned value = Budgeted cost of work scheduled = BCWS.

AC = Actual cost = Actual cost of work performed = ACWP.

EV = Earned value = Budgeted cost of work performed = BCWP.

Cost variance = CV = EV − AC = BCWP − ACWP
(CV < 0, over budget).

schedule variance = SV = EV − PV = BCWP − BCWS
(if SV < 0, behind schedule)

Cost performance index = CPI = $\frac{EV}{AC}$ = $\frac{BCWP}{ACWP}$
(if CPI < 1, over budget)

schedule performance index = SPI = $\frac{EV}{PV}$ = $\frac{BCWP}{BCWS}$
(if SPI < 1, behind schedule).

Estimate at completion = EAC = $\frac{BAC}{CPI}$ (Budget at completion)

schedule at completion = SAC = $\frac{\text{Total duration}}{SPI}$

Variance at completion = VAC = Budget at completion − Estimate at completion.

CSI = cost schedule index = CPI × SPI.

Estimated cost to complete the project = ETC = $\frac{BAC - EV}{CPI}$

EAC = AC + ETC.

10 Question :- 150 modules weeks = 30
Average :- 5 modules/week
Each module cost :- 7500.

Case A :- ~~weeks~~ weeks = 12
modules developed = 54
Amount spent = 5,00,000.

progress?? Time and cost at completion?

∴ BCWP = 54 × 7500 = 4,05,000

∴ BCWS = 12 × 5 × 7500 = 4,50,000.

∴ ACWP = 5,00000

∴ SV = BCWP − BCWS = −45,000
∴ SPI = BCWP / BCWS = 0.9

∴ CV = BCWP − ACWP = −95,000
∴ CPI = 0.81

∴ over bugět and behind schedule.

if completed $EAC = \frac{BAC}{CPI} = \frac{150 \times 7500}{0.81} = 1,38,8888$

~~if remaining~~ $\cancel{EAC = \frac{150 \times 7500 - 4,05,000}{0.81} + 500000}$

$SAC = \frac{\text{Total weeks}}{SPI} = \frac{30}{0.9} = 33.3$ weeks.

Case B :- week = 24   modules developed = 124
amount spend = 900000

progress = ?   SAC = ?   EAC = ?

$BCWP = 124 \times 7500 = 930000$

$BCWS = 24 \times 5 \times 7500 = 900000$

$ACWP = 900000$

$CV = 30000$ $CPI = 1.03$
$SV = 30000$ $SPI = 1.03$
∴ on time and under budget.
$EAC = \frac{150 \times 7500}{1.03} = 10,92,233$

$SAC = \frac{30}{1.03} = 29.1$ weeks.

(11)

1000 cups 50 days

20 cups per day

Budget per cup = 0.50

Total budget = 500

Case A:- Day = 10 cups = 150 cost = 90.

BCWS = $10 \times 20 \times 0.5 = 100$

BCWP = $150 \times 0.5 = 75$

ACWP = 90

∴ SV = −25 SPI = 0.75

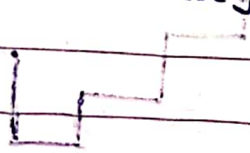
∴ CV = ~~0.75~~ −15 CPI = 0.833

Over budget, behind schedule.

∴ EAC = $\frac{5000}{0.833}$ = 600.

∴ VAC = BAC − EAC = −100

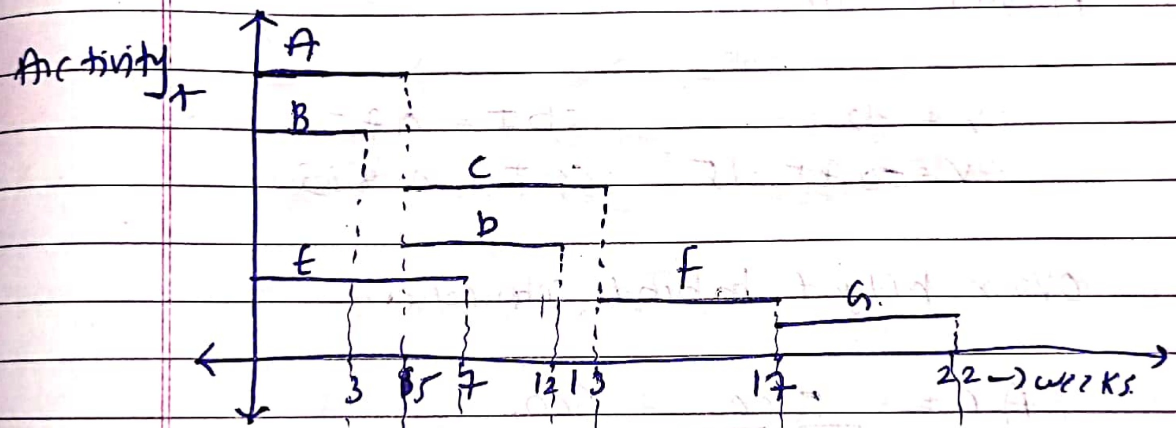
∴ SAC = $\frac{50}{0.75}$ = 66.67 days.

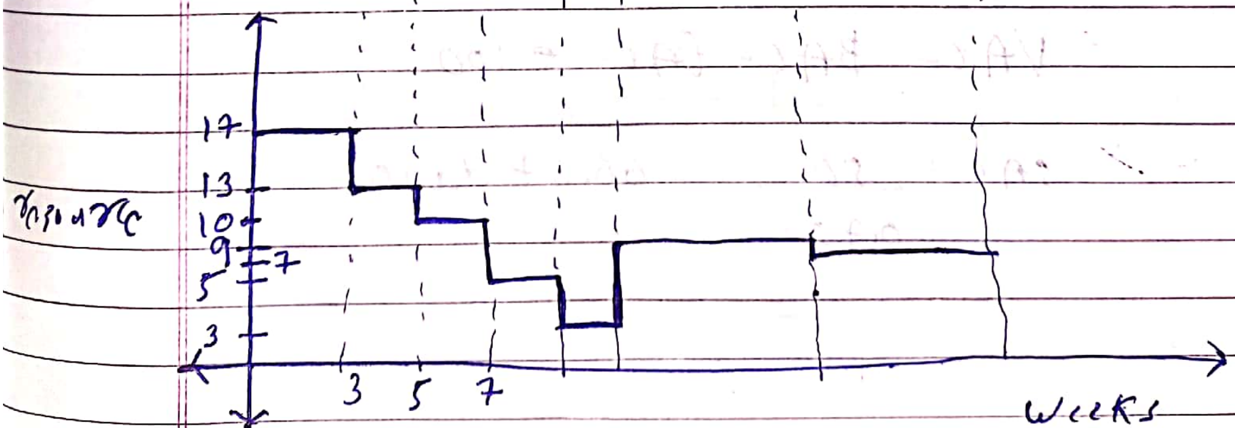


* Resource management :-

(12)

Activity	pred	duration	req labour	total labour
A	-	5	8	40
B	-	3	4	12
C	A, B	8	3	24
D	A, B	7	2	14
E	-	7	5	35
F	C, D, E	4	9	36
G	F	5	7	35





max = 17 min = 3 Diff = 14

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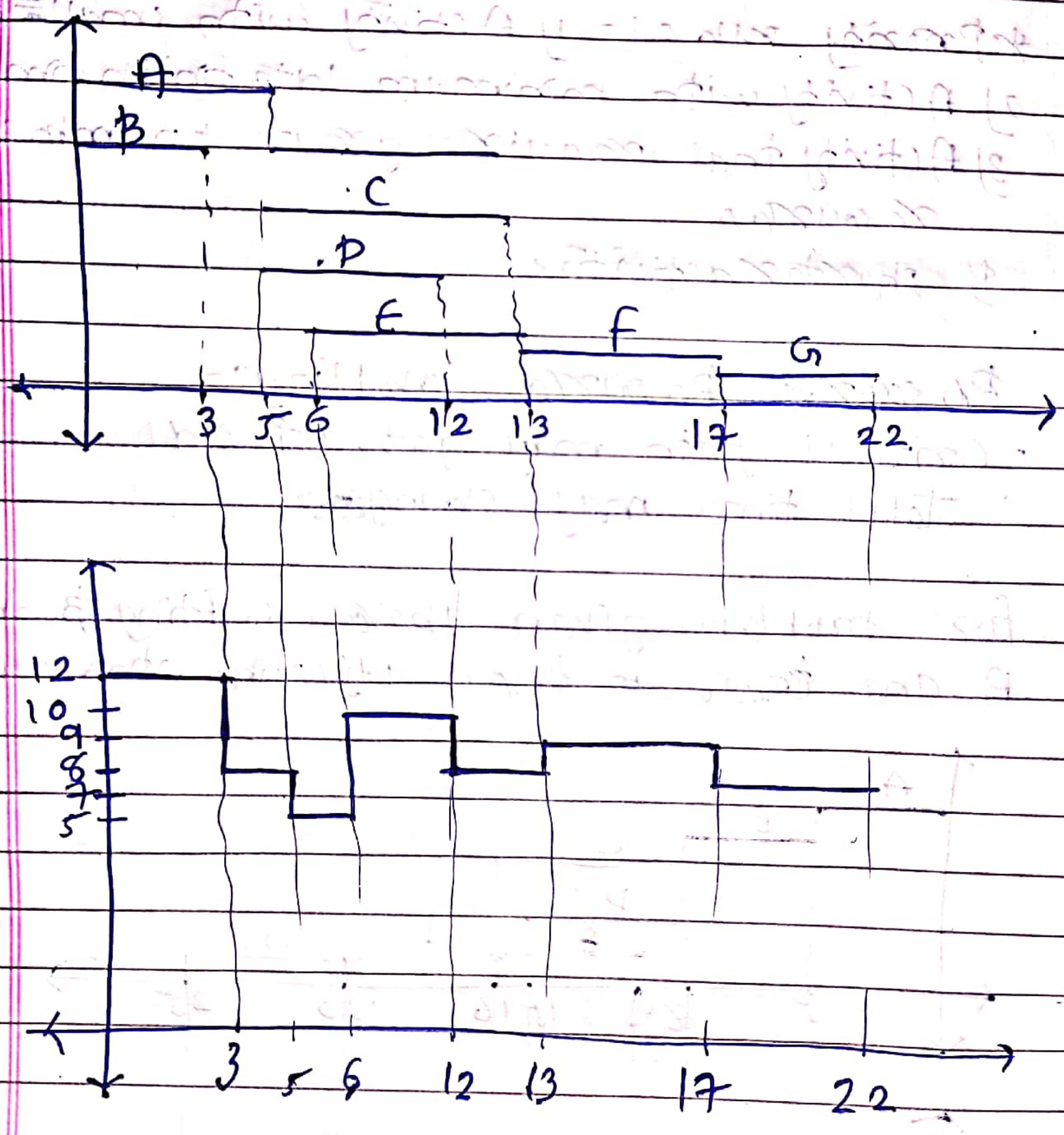
Resource levelling :- No change in critical path.

(max - min) should be minimal.

F can be shifted to G.



∴ max = 12 min = 5

∴ Diff = 7

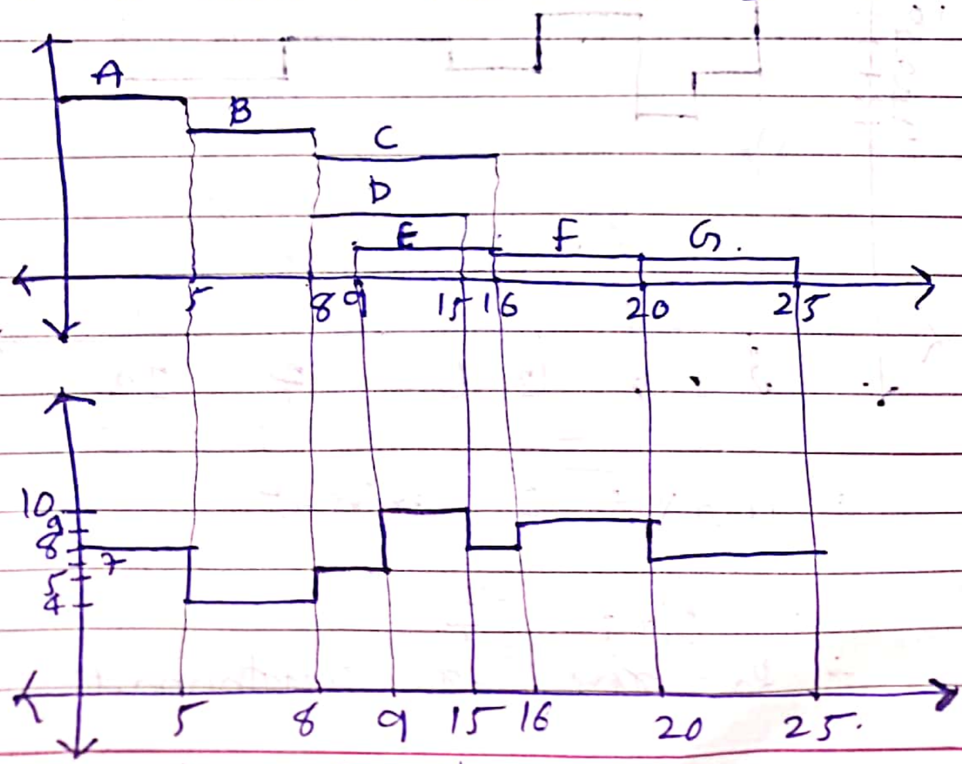
∴ Resources are smoothened.

* smoothning rules:- 1) Performing activities at a lower rate using available resource levels.
2) Activity sampling (splitting).
3) Modifying the network
4) use of alternative resources.

* Priority rules:- 1) Activity with smallest slack
2) Activity with minimum late finish time.
3) Activity that requires greatest number of resources.
4) shorter activities.

* ~~Resource~~ Resource levelling:-
· Critical path may get altered.
· Total time may changed.

for problem given above, shifting B ahead of A and ~~...~~ then adjusting other activities.



∴ max = 10 min = 4 Diff = 6.

* PERT :-

t_e = Expected time = $\frac{a + 4m + b}{6}$

V = Variance = $\frac{(b-a)^2}{6}$

σ = standard deviation = $\frac{b-a}{6}$

Z value = $\frac{T_s - t_e}{\sigma}$

where, T_s = target completion date.

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Activity	a	m	b	pred	te	SD/D
A	5	6	8	-	6.17	0.5
B	3	4	5	-	4	0.33
C	2	3	3	A	2.83	0.17
D	3.5	4	5	B	4.08	0.25
E	1	3	4	B	2.83	0.5
F	8	10	15	-	10.5	1.17
G	2	3	4	E, F	3	0.53
H	2	2	2.5	C, D	2.08	0.08.

Event	T_s
t_e	SD.

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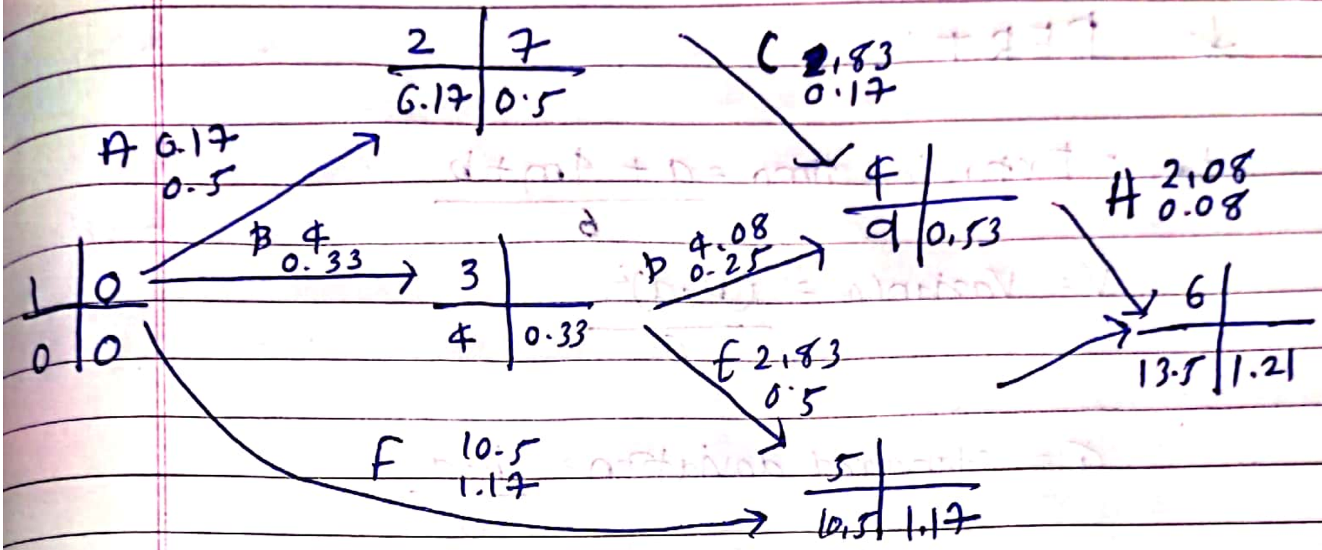

for ~~event~~ event 4,

$$t_e = \max(t_e \text{ of } 2 + t_e \text{ of } C,\ t_e \text{ of } 3 + t_e \text{ of } D)$$

$$= \max(6.17 + 2.83,\ 4 + 4.08)$$

$$= \max(9,\ 8.08)$$

$$= 9$$

$$SD = \max\left(\sqrt{SD\text{ of }2^2 + SD\text{ of }C^2},\ \sqrt{SD\text{ of }3^2 + SD\text{ of }D^2}\right)$$

$$= \max\left(\sqrt{0.5^2 + 0.17^2},\ \sqrt{0.33^2 + 0.25^2}\right)$$

$$= \max(0.53,\ 0.41)$$

$$= 0.53$$

$$Z \text{ for } 2 = \frac{7 - 6.17}{0.5} = 1.66$$