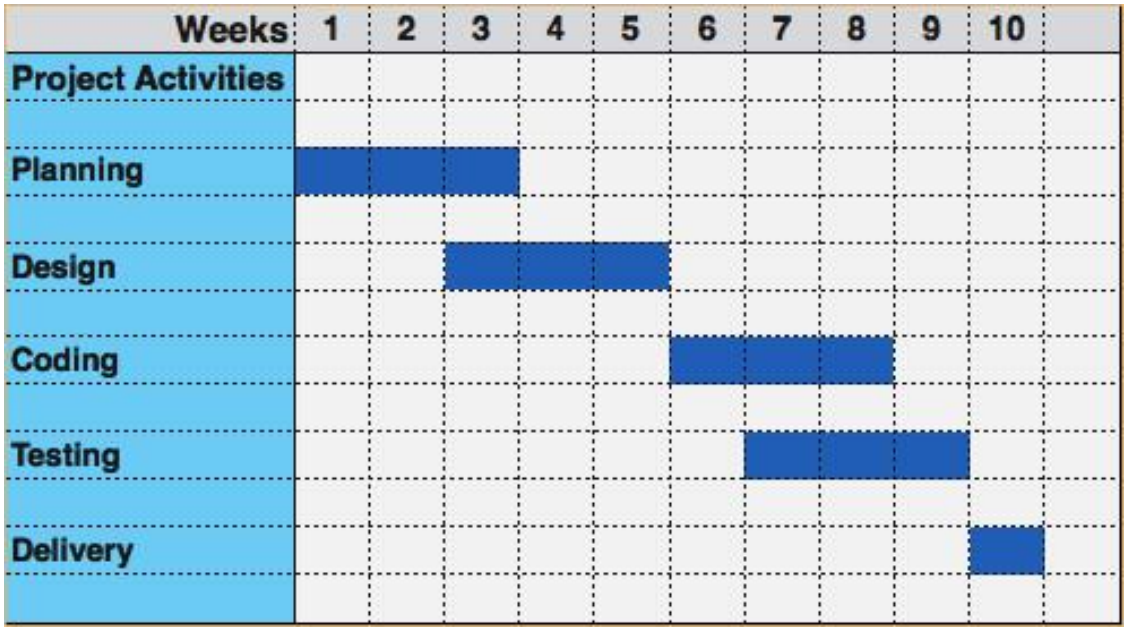
UNIT-3
Tools and techniques in Project management

GANTT Chart (Bar Chart)

It is pictorial representation showing the various job/activity to be done and the time

1. **Activities involved in the project**
2. **Start and end time of the activities**
3. **Duration of activity**



Advantages of Gantt chart

1. Simple to under stand
2. Easy to change
3. Simple and least complex means portraying progress.
4. Easy to identify specific elements that be either behind or ahead of schedule.

Limitations

1. It Can not indicate interdependencies of activities. Some activities are depend on the other activities and some are independent.

2. It can not show the progress of work

3. It can not reflect the uncertainty and tolerances in the duration time estimated for various activity.

Network techniques

Structurally, Network is graphical model depicting the inter-relationship between the various elements of the project work system.

It propagates holistic approach, that is individually nothing can be achieved and only when all of us work together.

Arithmetically, a network computes the time, cost and resource requirement for the project.

It highlights the importance of each activities.

Terms used in network

WBS: Break down the project into activities such that each activity is clearly identifiable and manageable.

Activity: This is physically identifiable part of the project that consumes time and resources. It is represented by an arrow.

Events(Node): These are the beginning and end of an activity.

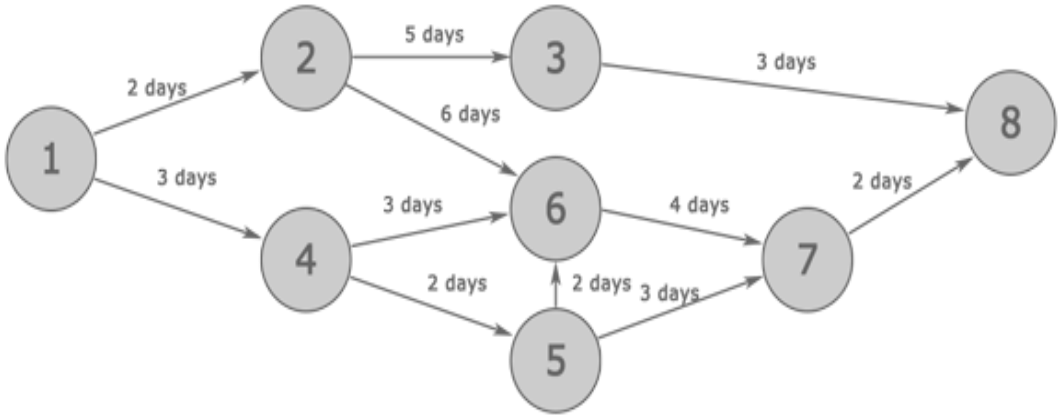
Path: This is a continuous chain of activities from the beginning to the end of the project.

Activity-On-Arrow(AOA) diagram: A network with activities represented on arrows and events on nodes.

Activity-On-Node(AON) diagram: A network with activities represented on nodes. Arrows indicate only the interdependencies between them.

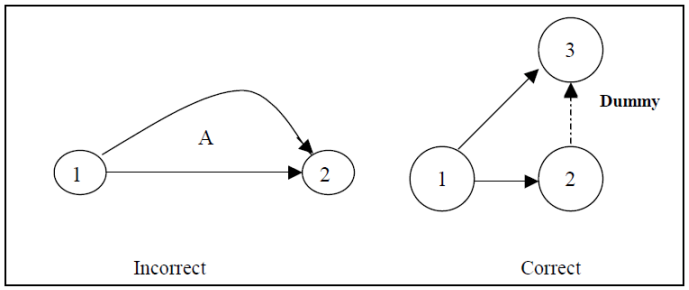
Network

Activity	Activity	Duration (days)
A	1-2	2
B	1-4	3
C	2-3	5
D	2-6	6
E	4-5	2
F	4-6	3
G	5-6	2
H	5-7	3
I	3-8	3
J	7-8	2



Network construction

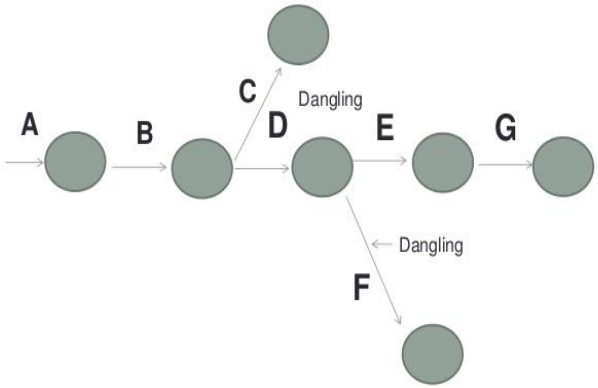
1. Activities progress from left to right.
2. Each activity is represented by only one straight and solid arrow.
3. If two activities having same start and end nodes, show one of them separately with dummy activity with dashed line.
4. An activity which shows the logical relationship between its immediate predecessor and successor activities.
5. Arrows should not cross each other as far as possible.
6. Avoid curved arrows, dangling arrows and looping of network.



Common errors committed in network construction

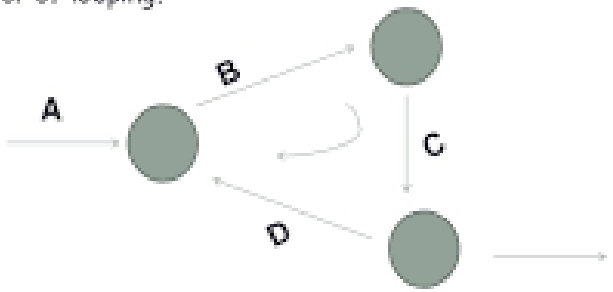
Dangling

Whenever an activity is disconnected from the network it is called dangling error.



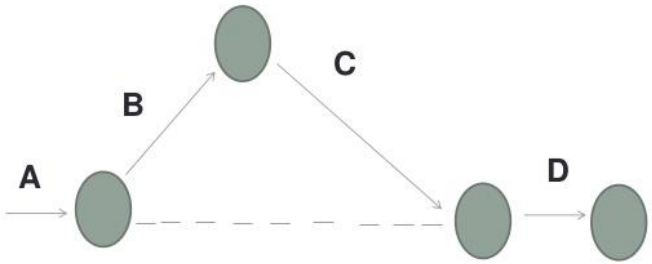
Looping

Looping error is also called as cycling error in a network diagram. Making an endless loop in a network is called as error of looping.



Redundancy

When the dummy activity is introduced and it is not required, it is called redundancy errors.



Type of network

1. CPM (Critical path method) network
2. PERT (Project evaluation review technique)

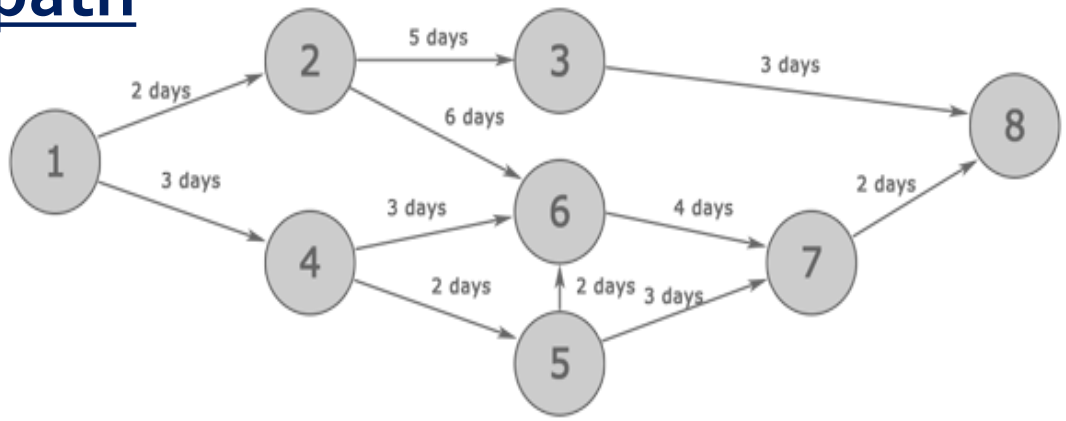
CPM does not incorporate uncertainties in job time, suitable for project activities having single time estimates. Determine the critical path, minimum project duration, floats available with each activity.

PERT is suitable for non- repitative projects, where job times are not estimable with certainty. So it is probabilistic nature

Difference between PERT and CPM

Basis for Comparing	PERT	CPM
Mode type	Probabilistic	Deterministic
Orientation	Event-oriented	Activity-oriented
Useful for	Estimating high precision time	Estimating reasonable time
Estimation	Three times	One time
Assessment of activity duration	Accurate duration of activities is not estimated	Accurate duration of activities is estimated
Classification of activities	Does not classify activities based on critical or non-critical nature	Classifies activities basis critical and non-critical nature
Activity type	Unpredictable	Predictable
Job types	Non-repetitive	Repetitive
Major application	Research and development projects	Construction projects
Major focus	Time	Time-cost
Consideration for uncertainty	Allowed	Not allowed

Critical path



Paths

1-2-3-8 = 10 day

1-2-6-7-8 = 14 days (Critical path)

1-4-6-7-8 = 12 days

1-4-5-6-7-8 = 13 days

1-4-5-7-8 = 10 days

Critical path: This is the longest path time –wise connecting the start and end events. The events laying along this path are critical in the sense that their occurrence can not be delayed if the scheduled completion time is to be met.

Earliest start and Late finish time

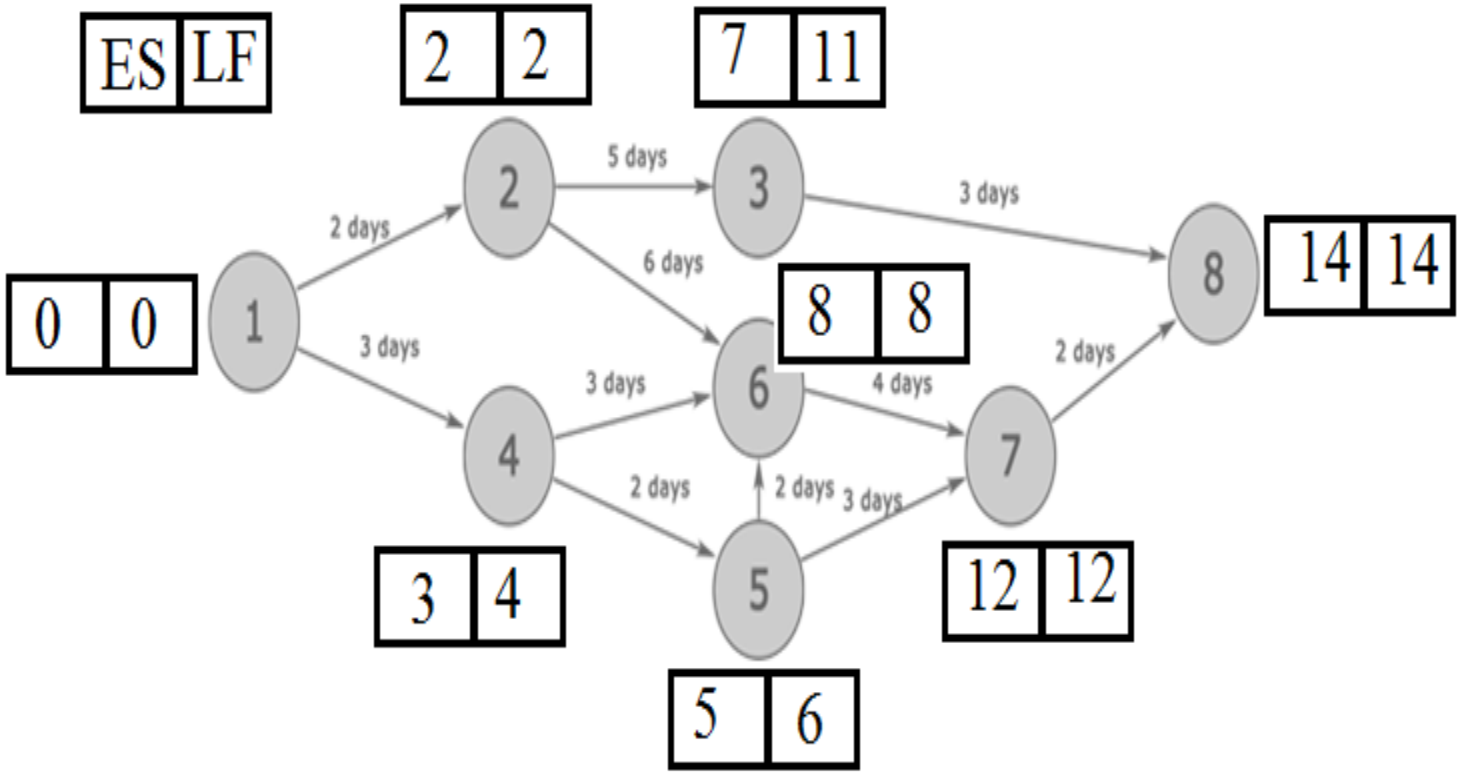
Early Start (ES) of an activity in a project is the earliest possible time that the activity can start.

Forward pass: To determine the ES times of events, the computations stars at Node 1 and advances recursively to the last Node “n”.

Late Finish (LF) represents the latest date an activity can finish, without delaying the finish of the project.

Backward pass: To determine the Latest Finish times of events. The computations start at the last Node “n” and end at Node 1.

Earliest start and Late finish time calculation



Float/Slack

Float is the length of the free time available within the estimated times of the non-critical path. The float time is zero along the critical path activities

Total Float (FT): **It is the amount of time by which an activity can be delayed without affecting project duration time.**

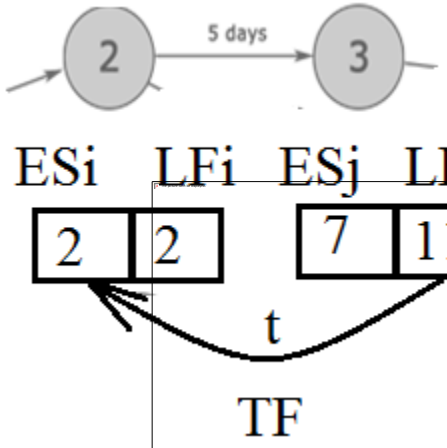
$$TF=(LF_j - ES_i)-t$$

Free Float (FF): **Free float is the how much an activity's completion time may be delayed without causing any delay in its immediate successor activity.**

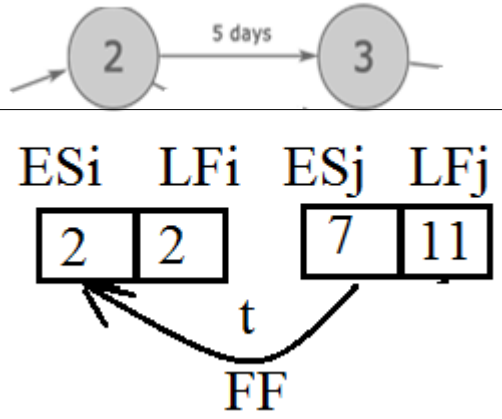
$$FF=(ES_j - ES_i)-t$$

Independent Float(IF): **It is the amount of time an activity can be delayed for start without affecting the completion of preceding activity.**

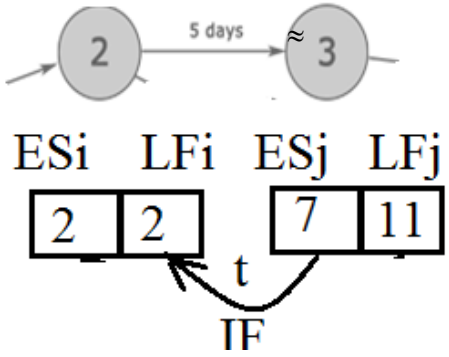
$$IF=(ES_j - LF_i)-t$$



$TF=(LF_j - ES_i)-t$



$FF=(ES_j - ES_i)-t$



$IF=(ES_j - LF_i)-t$

Interfering Float=TF~FF

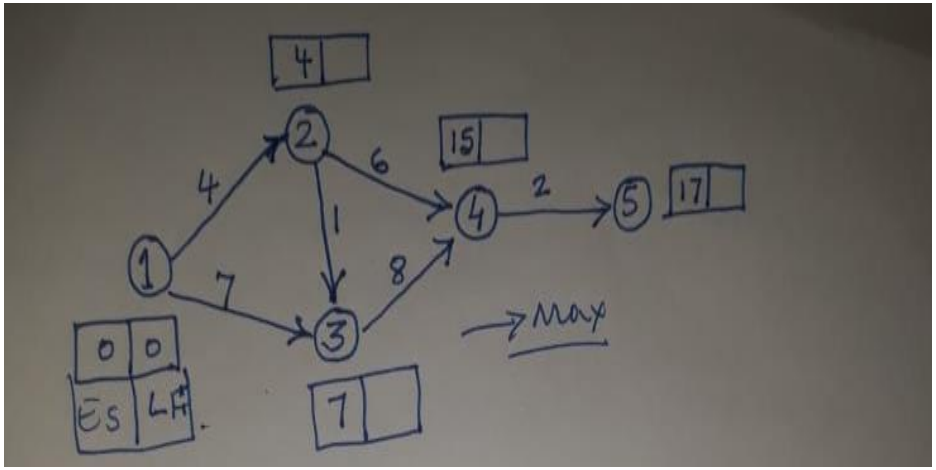
Problem 1: A project consists of following activities with their duration in days.

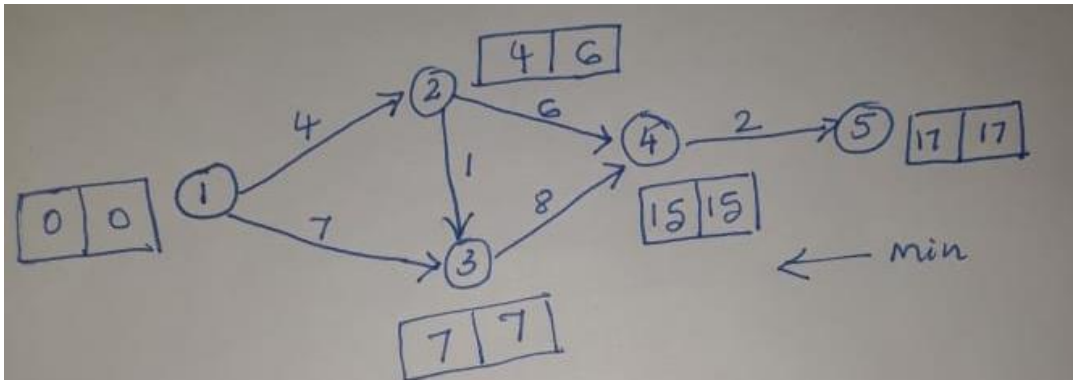
a) Draw a network for the above project

b) Identify the critical path and duration of the project

c) Calculate ES, EF, LS, LF, TF, FF and IF for each activity

Activity	Duration in days
1-2	4
1-3	7
2-3	1
2-4	6
3-4	8
4-5	2



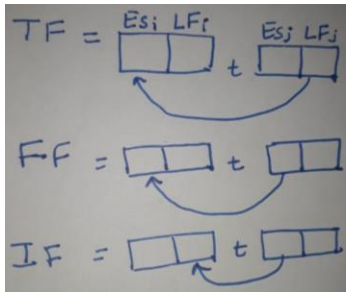


Paths

1-2-4-5=4+6+2=12 days

1-2-3-4-5= 4+1+8+2=15 days

1-3-4-5=7+8+2=17 days (CP) **EF=ES+t** **LS=LF-t**



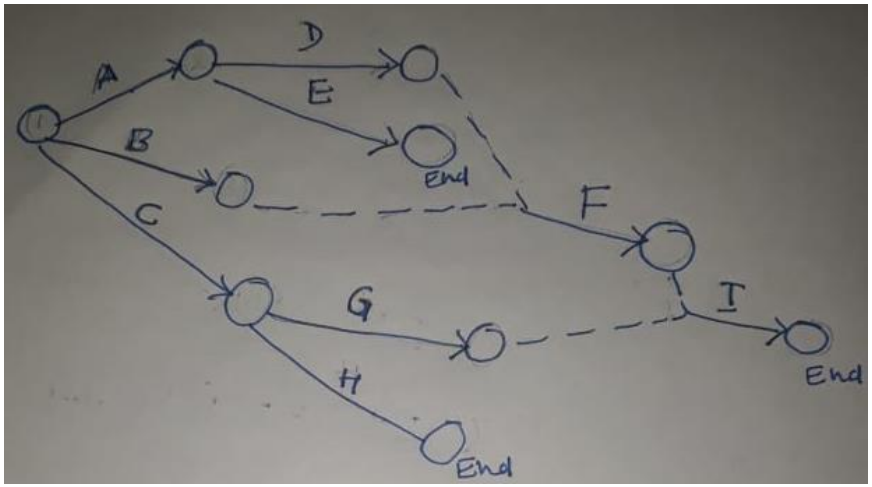
Activity	t	ES	LF	EF	LS	TF	FF	IF
1-2	4	0	6	4	2	2	0	0
1-3	7	0	7	7	0	0	0	0
2-3	1	4	7	5	6	2	2	0
2-4	6	4	15	10	9	5	5	3
3-4	8	7	15	15	7	0	0	0
4-5	2	15	17	17	15	0	0	0

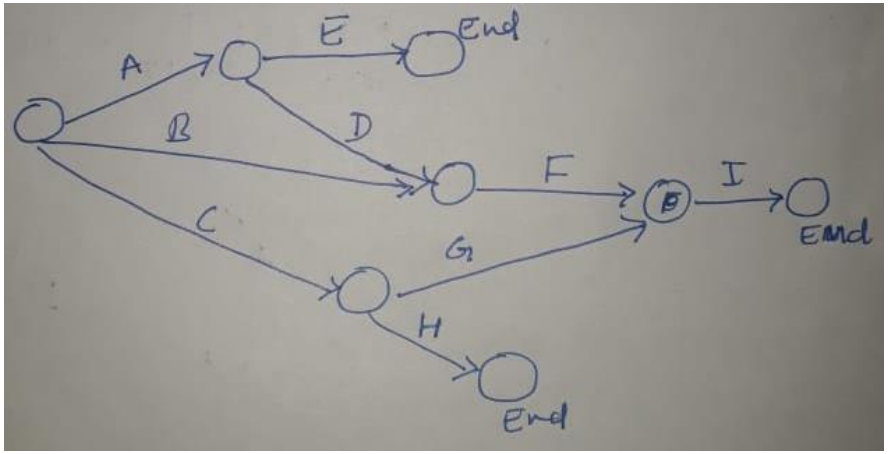
Problem 2: A Project consists of a series of tasks labeled A, B, C, D E, F, G, H, I. Their precedence and duration shown in the table.

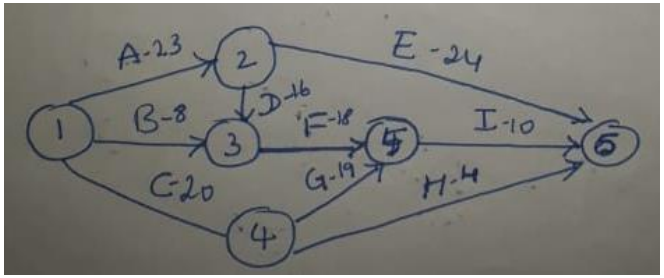
1) Draw network diagram
2) Find CP and project duration
3) Calculate, TF, FF, IF and Interfering Float

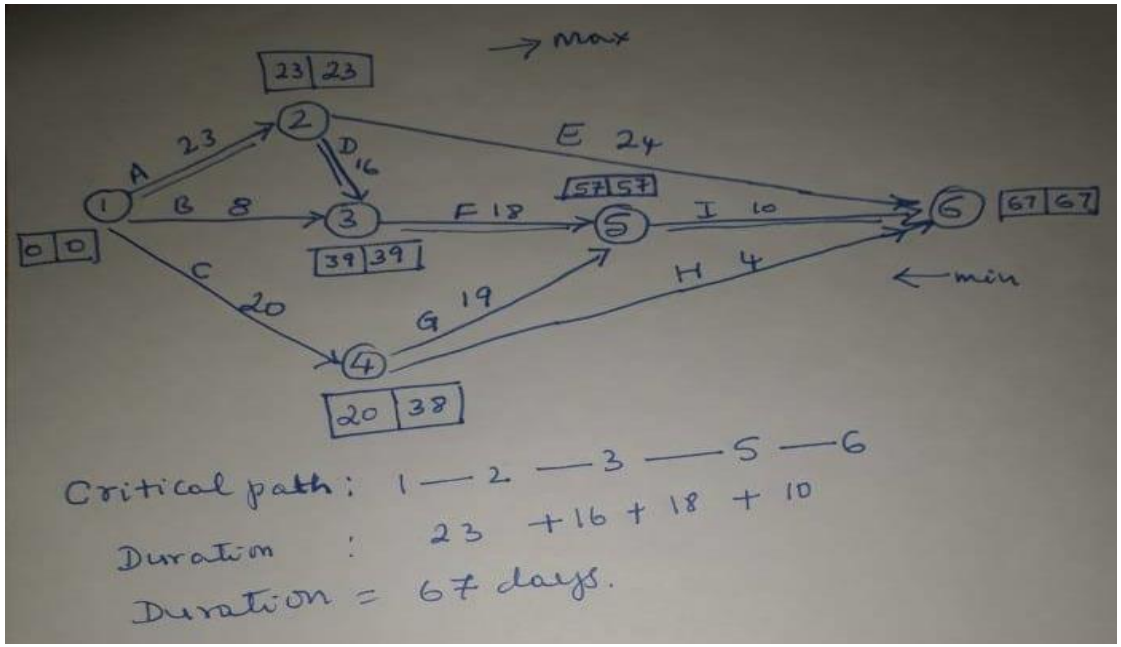
Activity	Precedence	Duration t
A	-	23
B	-	8
C	-	20
D	A	16
E	A	24
F	B,D	18
G	C	19
H	C	4
I	F,G	10

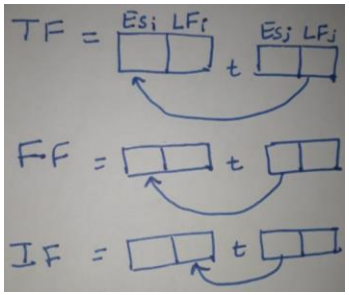
Activity	Precedence	Duration t
A	-	23
B	-	8
C	-	20
D	A	16
E	A	24
F	B,D	18
G	C	19
H	C	4
I	F,G	10









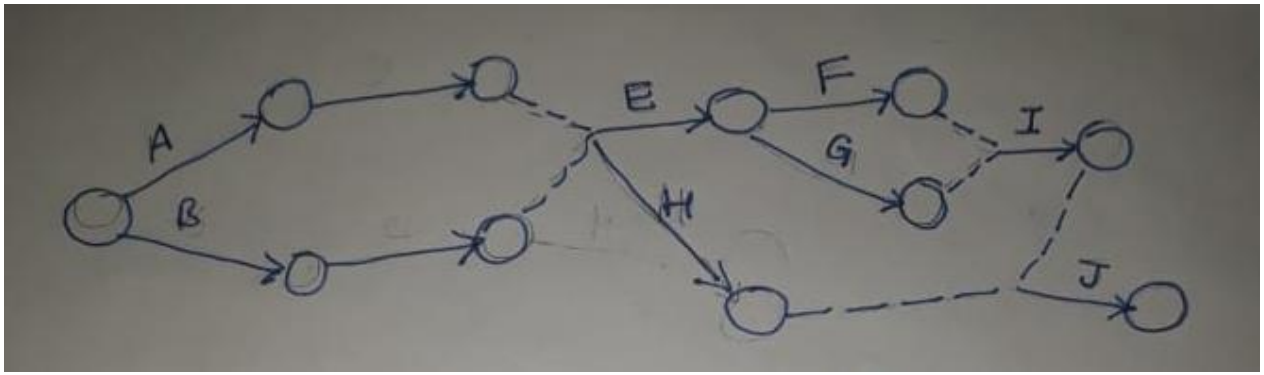


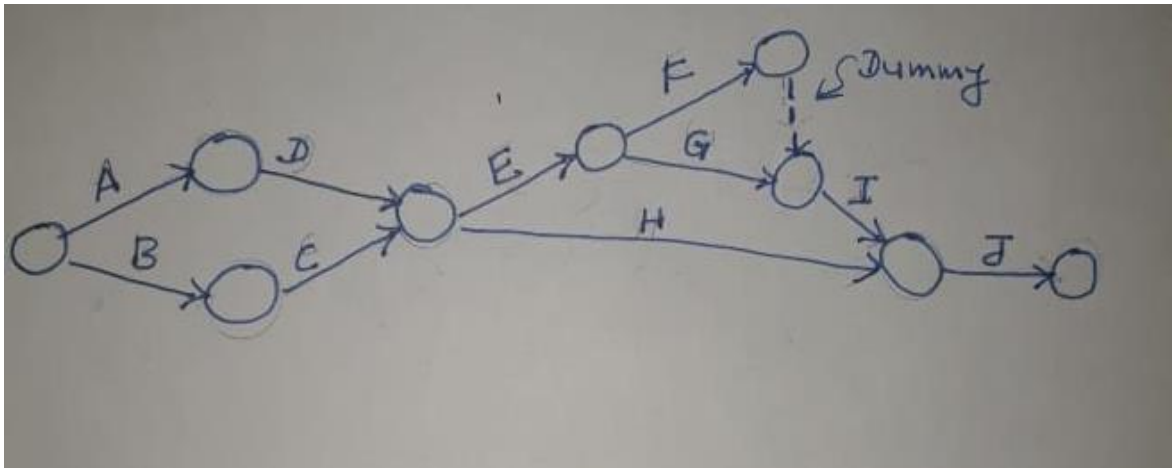
Activity	Activity	t	ES	LF	EF	LS	TF	FF	IF
A	1-2	23	0	23	23	0	0		
B	1-3	8	0	39	8	31			
C	1-4	20	0	38	20	18			
D	2-3	16	23	39	39	23			
E	2-6	24	23	67	47	43			
F	3-5	18	39	57	57	39			
G	4-5	19	20	57	39	38			
H	4-6	4	20	67	24	63			
I	5-6	10	57	67	67	57			

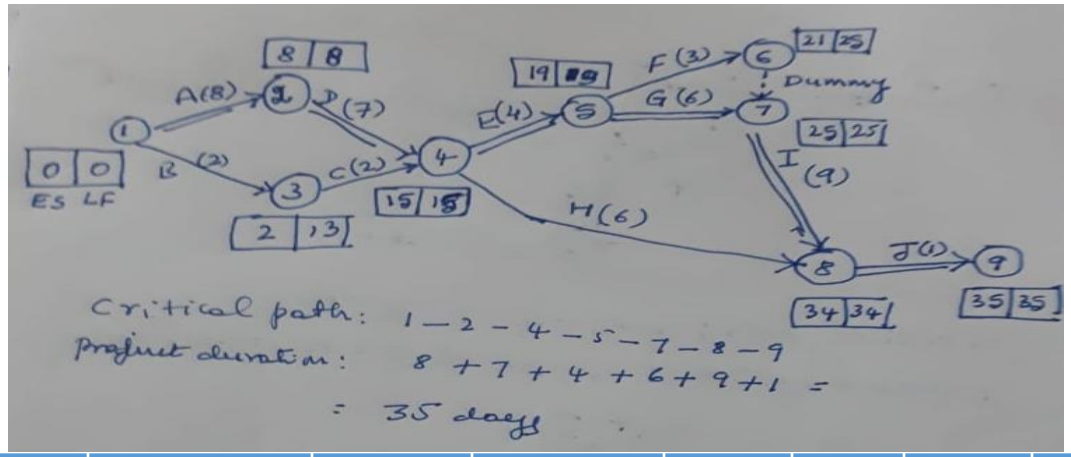
Problem 3: Draw the network for the following activities

1) Draw network diagram
2) Find CP and project duration
3) Calculate, TF, FF, IF and Interfering Float

Activity	Precedence	Duration t
A	-	8
B	-	2
C	B	2
D	A	7
E	C,D	4
F	E	3
G	E	6
H	C, D	6
I	F, G	9
J	I, H	1







Activity	Precedence	Activity	Duration t	ES	LF	EF	LS	TF	FF	IF
A	-	1-2	8	0	8	8	0	0		
B	-	1-3	2	0	13	2	11	11		
C	B	3-4	2	2	15	4	13	11		
D	A	2-4	7	8	15	15	8	0		
E	C,D	4-5	4	15	19	19	15	0		
F	E	5-6	3	19	25	22	22	2		
G	E	5-7	6	19	25	25	19	0		
H	C, D	4-8	6	15	34	21	28	7		
I	F, G	7-8	9	25	34	34	25	0		
J	I, H	8-9	1	34	35	35	34	0		

Time estimates

After the network has decided, need to find time required for execution of each activity.

Because of uncertainty involvement, difficulty to find exact time of activities.

Three kinds of time estimates

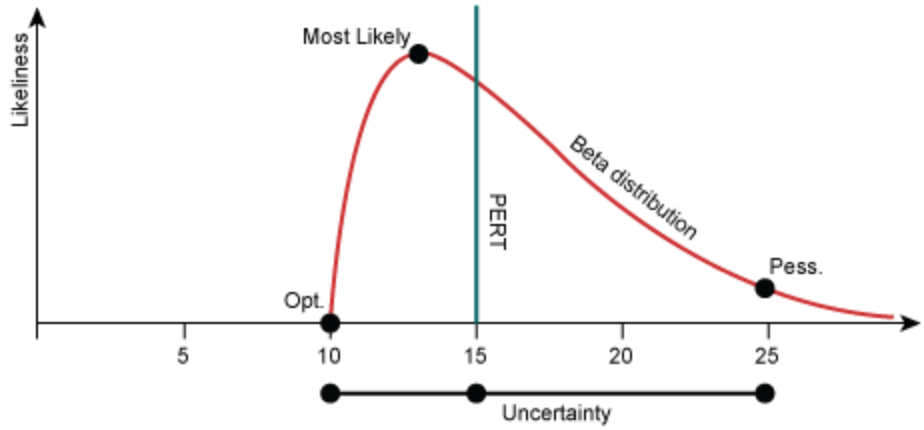
1. **Optimistic time estimate (t_o)**
2. **Pessimistic time estimate(t_p)**
3. **Most likely time estimates(t_m)**

1. Optimistic time estimate (t_o): This is the estimate of the shortest possible time in which an activity can be completed under ideal conditions.

2. Pessimistic time estimate(t_p): This is the maximum possible time it could take to accomplish the job. If every thing went wrong and abnormal situations preveiled, this would be the time estimate for the activity.

3. Most likely time estimates(t_m) : This is the time estimate which lies between the optimistic and pessimistic time estimates. It assumes that things go in the normal way, with a few setbacks, usual lapses in deliveries, no dramatic breakthroughs and so on.

Beta Distribution



fairly satisfactory results for the most activities.

Earliest Expected Time t_E

$$t_E = (t_o+4t_m+t_p)/6$$

Std deviation $$\sigma = (t_p-t_o)/6$$

Problem 4: R & D Activities for which the three estimates are given below along with its precedence activities

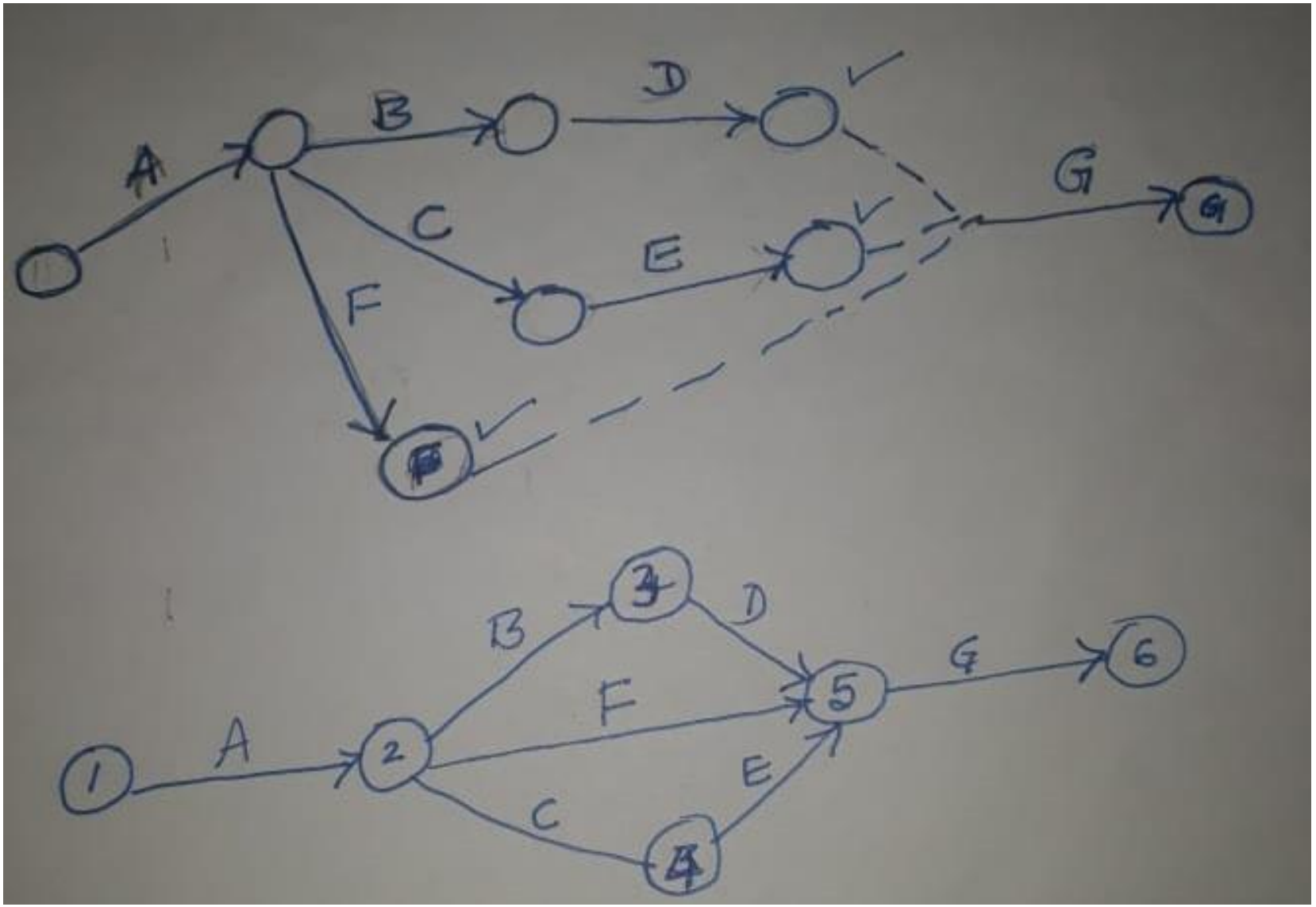
Activity	Preceding Activity	Optimistic time (t_o Week)	Most likely time (t_m week)	Pessimistic time (t_p week)
A	--	4	6	8
B	A	6	10	12
C	A	8	18	24
D	B	9	9	9
E	C	10	14	18
F	A	5	5	5
G	D,E,F	8	10	12

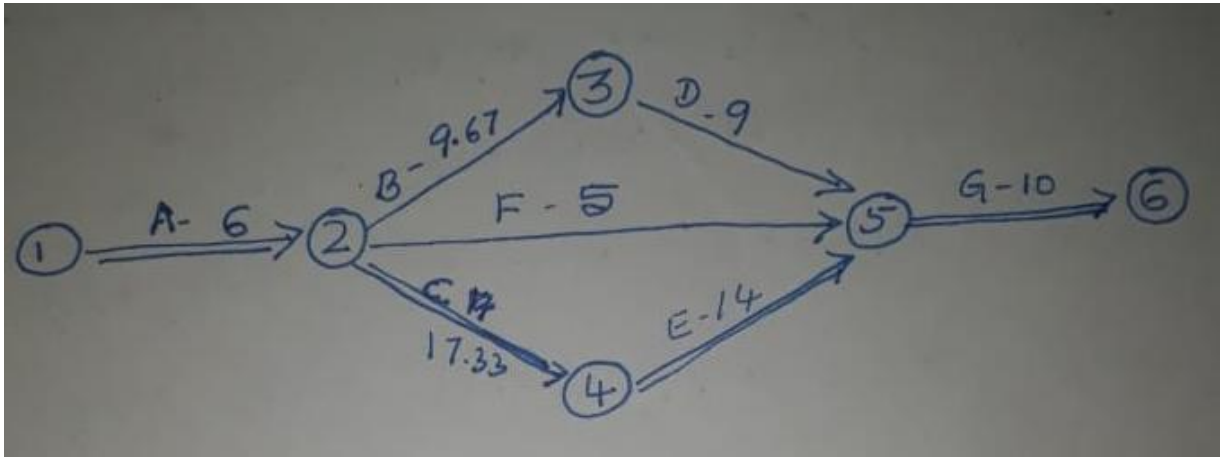
1. **Draw PERT network**
2. **Find critical path**
3. **If the scheduled time is 35 week, find the probability of completion of the work.**

$$t_E = (t_o + 4t_m + t_P)/6$$

$$\sigma^2 = \left(\frac{t_p - t_o}{6} \right)^2$$

Activity	Preceding Activity	t_o Week	t_m week	t_p week	Expected time t_E	Variance σ^2
A	--	4	6	8	6	0.44
B	A	6	10	12	9.67	1
C	A	8	18	24	17.33	7.11
D	B	9	9	9	9	0
E	C	10	14	18	14	1.77
F	A	5	5	5	5	0
G	D,E,F	8	10	12	10	0.44


A
B
C
D
E
F
G
1
2
3
4
5
6



Critical Path : A-C-E-G: 1-2-4-5-6

Project Duration: 6+17.33+14+10=34.66 week

$$\sigma_{C.P} = \sqrt{0.44 + 7.11 + 1.77 + 0.44} = 3.12 \text{week}$$

$$Z = \frac{T_s - T_E}{\sigma_{C.P}} = \frac{35 - 34.66}{3.12} = 0.1089$$

Probability of completion from Normal distribution table for $Z = 0.1089$

(Casio-fx-991MS) Mode-sd-shift-3(distb)-1(p)-0.1089 Ans 0.54336)

Probability of completion of project with 35 week=0.54336 , 54.336%

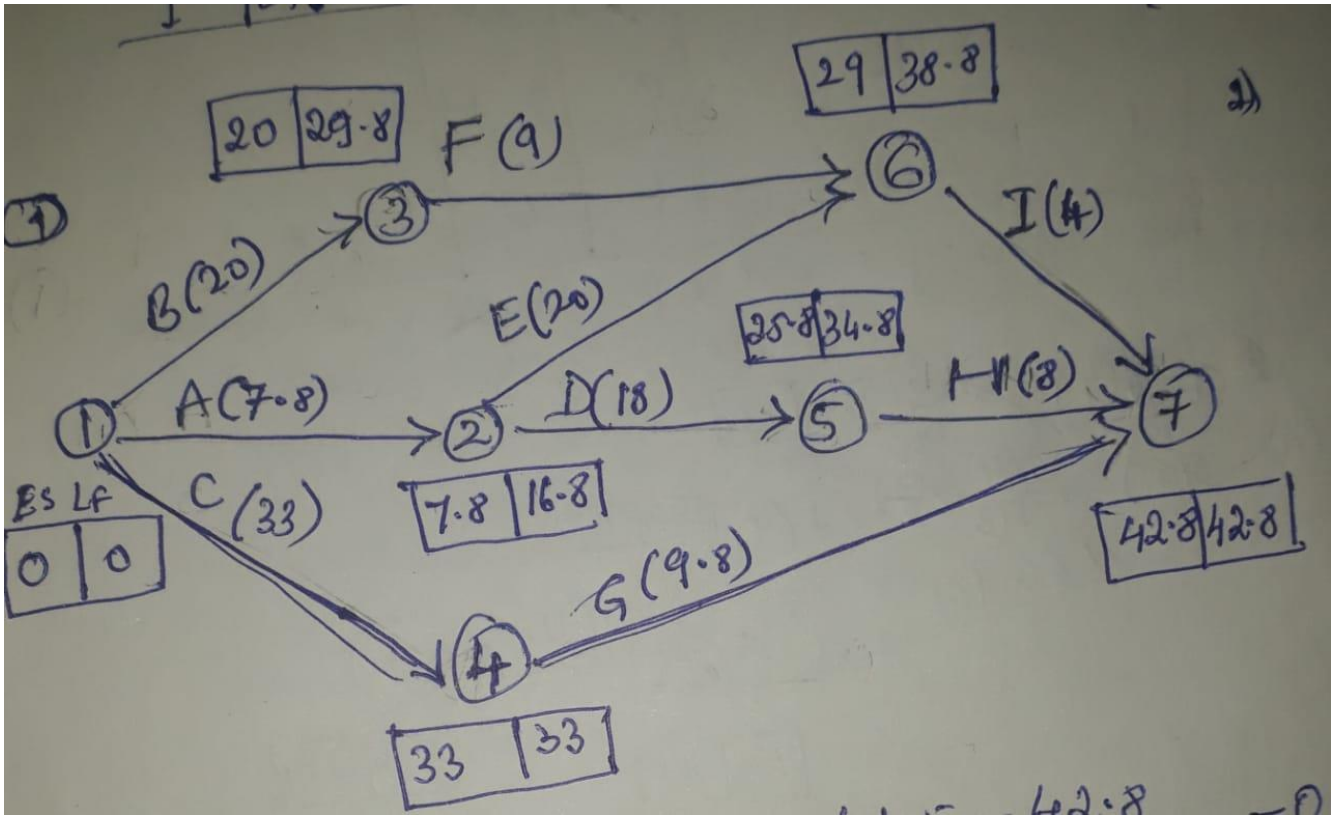
Problem 2: A project consists of activities A, B, C……. I, : X<Y means that the activity X must be completed before Y can start. X, Y <W means that W will start Only after completion of activity X, Y. With the notation construct the diagram for the following constraints.

A<D, A<E, B<F, C<G,D<H; E,F<I

The project has the following time schedule of the above activity;

1. Draw network
2. Determine CP and time
3. Determine probability of completion within 41.5 weeks
4. Determine duration of project that will have 95% chance of being completed.

Task	Preceding	t_m (weeks)	t_o (weeks)	t_p (weeks)	t_e (weeks)	σ^2
A	--	8	5	10	7.8	0.696
B	--	20	18	22	20	0.444
C	--	33	26	40	33	5.429
D	A	18	16	20	18	0.443
E	A	20	15	25	20	2.78
F	B	9	6	12	9	1
G	C	10	7	12	9.8	0.694
H	D	8	7	9	8	0.111
I	E,F	4	3	5	4	0.111



ii) Critical Path: 1-4-7
Duration of project: 42.8 weeks

$\sigma_{c.p}$ = Sq. root of (5.429+0.694) =2.474 weeks

iii) Z= (te-tc)/σ =(41.5-42.8)/2.474 = -0.5254
(From normal distribution table for Z= -0.5254)

(Casio-fx-991MS) Mode-sd-shift-3(distb)-1(p)—0.5254 Ans : 0.2996)

Probability of completion of project is 29.96%

iv)For P =95% Z = 1.645 (From normal distribution table)

Z= (te-tc)/σ

1.645=(te-42.8)/2.474

Te = 46.87 week

Crashing of Project

In many situations it becomes necessary to cut down the project duration. How can it be done? Activities that are critical need be to be crashed in order to reduce project durations as it is these activities that determine the project duration. But this has got its own cost implications. Reduction in project duration calls for more resources to be pumped in and hence, the direct costs increase. Whereas indirect costs such as equipment, rent, supervision charges, etc. reduce. Thus, it becomes necessary to identify a project duration up to which the project can be crashed so that overall project costs are minimum.

$$\text{Cost slope} = \frac{Cc - Nc}{Nt - Ct}$$

Cc = Crash cost

Nc = Normal cost

Nt = Normal time

Ct = Crash cost

Problem 5: Table below gives the time and cost data with respect to normal and crash periods of a project:

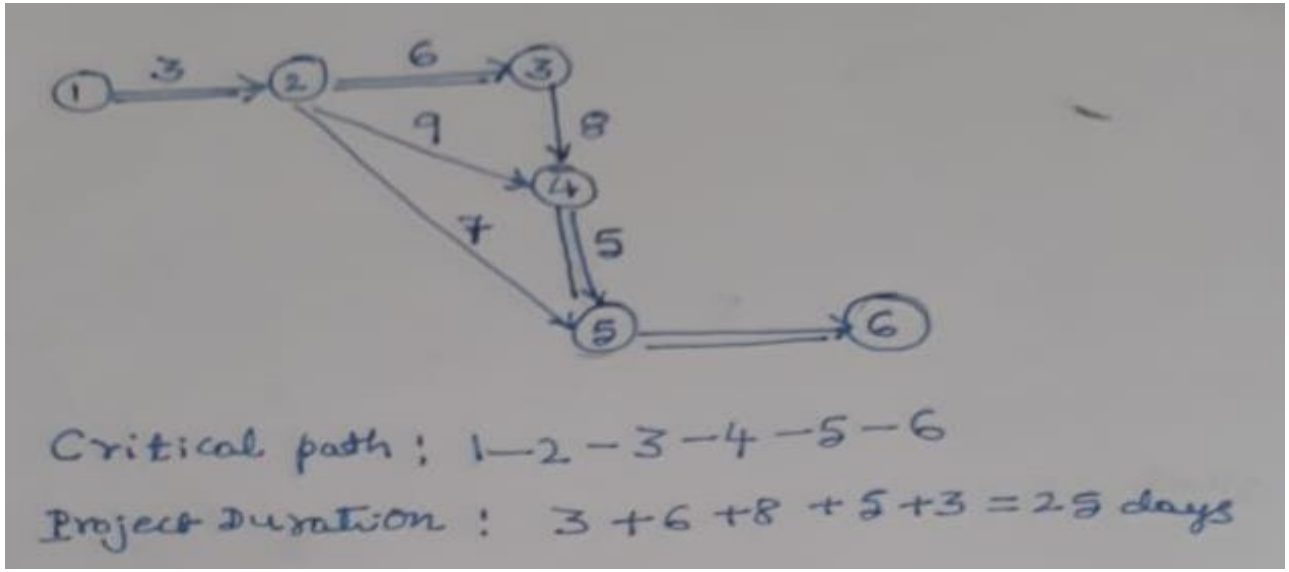
a) Draw the network of the project

b) What is the normal duration and cost of the project

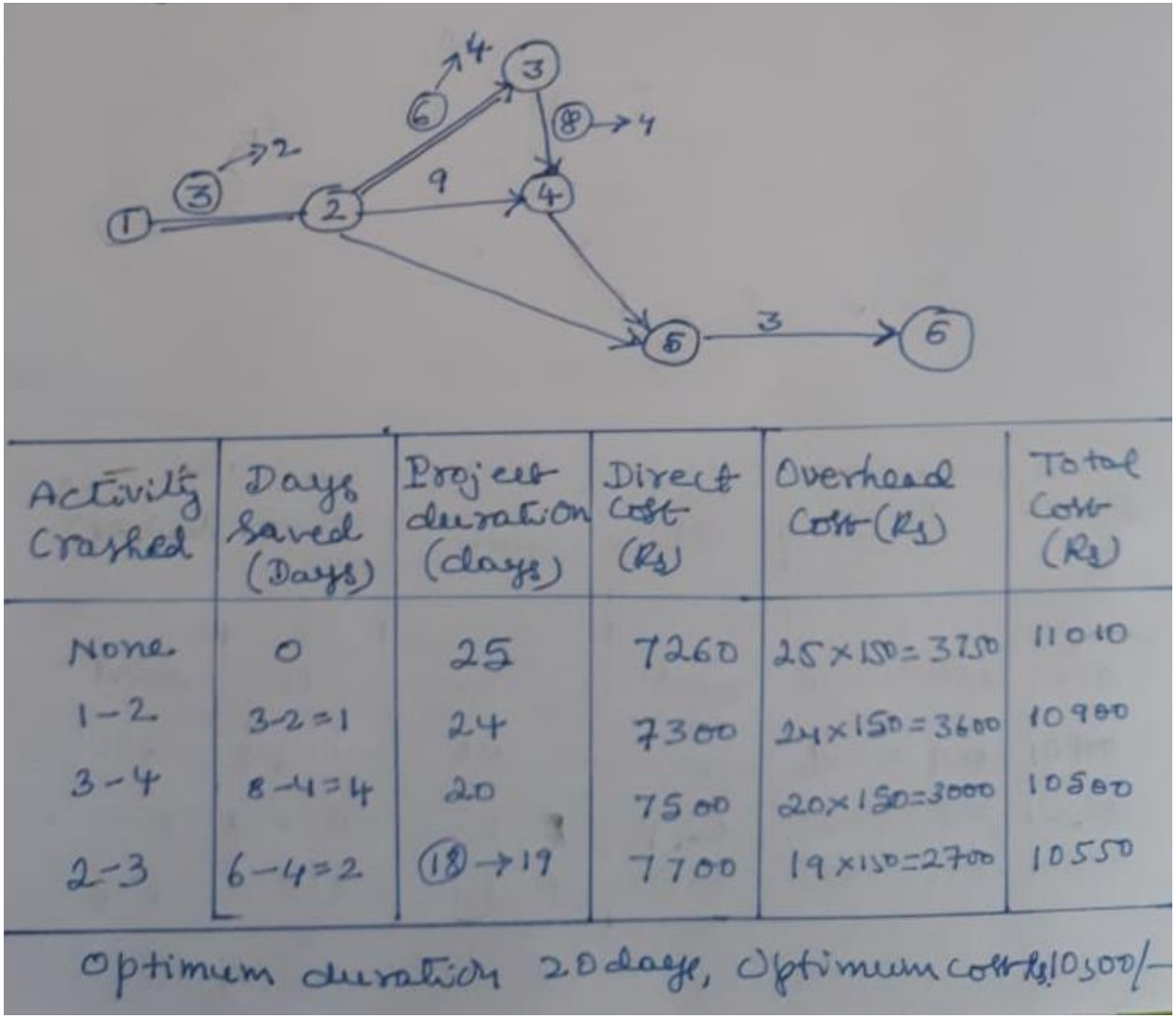
c) Determine the optimum project duration if the indirect cost is Rs. 150/day.

d) Determine the project cost if all activities are crashed indiscriminately.

Activity	Normal Time (Days)	Normal Cost (Rs)	Crashing Time (Days)	Crash Cost (day)
1-2	3	360	2	400
2-3	6	1400	4	1600
2-4	4	2000	5	2600
2-5	7	1000	5	1500
3-4	8	400	4	600
4-5	5	1600	3	2000
5-6	3	500	2	750



Activity	Normal Time (Days)	Normal Cost (Rs)	Crashing Time (Days)	Crash Cost (day)	Slope
1-2	3	360	2	400	40
2-3	6	1400	4	1600	100
2-4	4	2000	5	2600	150
2-5	7	1000	5	1500	250
3-4	8	400	4	600	50
4-5	5	1600	3	2000	200
5-6	3	500	2	750	250



Activity Crashed	Days Saved (Days)	Project duration (days)	Direct Cost (Rs)	Overhead Cost (Rs)	Total Cost (Rs)
None	0	25	7260	25×150=3750	11010
1-2	3-2=1	24	7300	24×150=3600	10900
3-4	8-4=4	20	7500	20×150=3000	10500
2-3	6-4=2	(18)→19	7700	19×150=2700	10550

Optimum duration 20 days, Optimum cost Rs 10500/-

The activity may be crashed for 1 day, then total cost is reduced to Rs. 10450

The following table gives the activities & other relevant data of a project

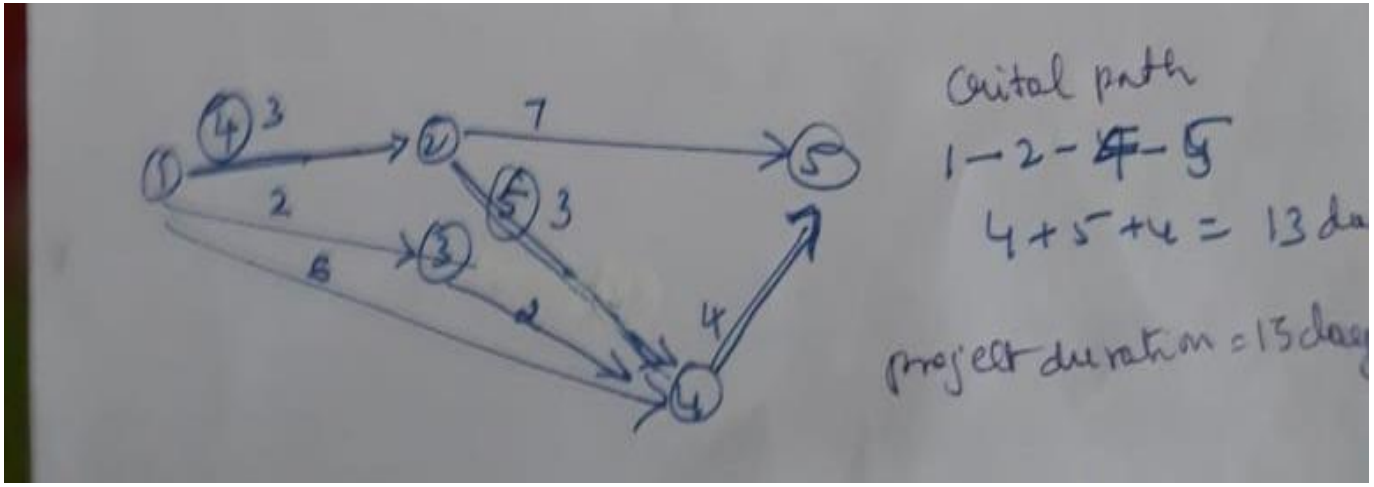
Act.	N_t	C_t	N_c	C_c	: slope
(1-2)	4	3	120	(180)	60
1-4	6	4	300	500	100
1-3	2	1	60	120	60
(2-4)	5	3	300	(500)	100
3-4	2	2	200	200	0
2-5	7	5	230	(350)	60
4-5	4	2	200	(480)	140

If indirect cost per day for project is Rs 100/-

a) Draw network b) find the normal duration & cost

c) Find the optimum duration and cost

d) Crash the number of days to the maximum possible extent.



E. P	Activity crashed	Days saved	Duration (days)	Direct cost (Rs)	Indirect cost (Rs)	Total cost (Rs)
1-2-4-5	—	—	13	1410	1300	2710
1-2-4-5	1-2	1	12	1470	1200	2670
1-2-4-5	2-4	2	10	1670	1000	2670
1-2-5	2-5	2	8	2070	800	2870
1-2-4-5	4-5	1				

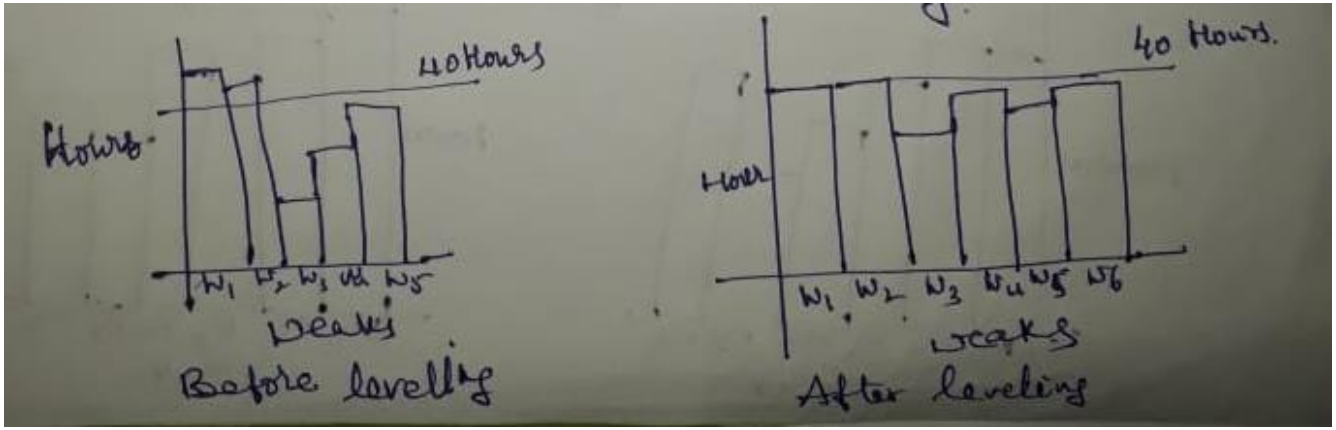
Resource allocation

Every organisation in any industry has its own resources, which consist of equipment, materials, people, time, and knowledge. Most organizations have very limited resources. These limited resources are utilized by the project management team based on the priority. This is a tough task to deal with, but with the help of an effective allocation plan, it becomes easier to effectively manage scarce project resources. By doing this planned resource allocation, cost of the company is saved and resources utilized efficiently.

To achieve this objectives, resource optimization techniques are used by project managme-

1) Resource leveling.
2) Resource smoothening.

Resource leveling

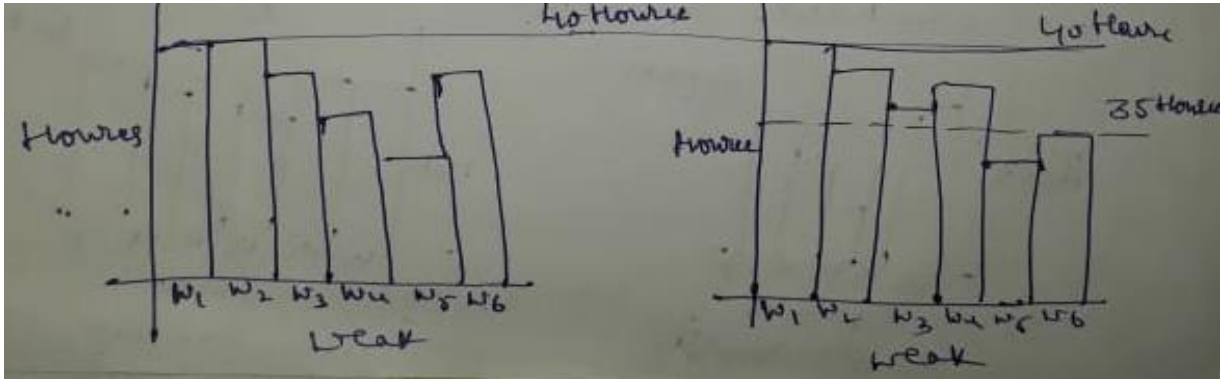


Resource leveling is technique of using limited resources at a constant level and resources optimized by extending the schedule and resources optimized by extending the schedule , so the project duration may change.

Resource leveling is used when:

- A critical resources may not available for a certain duration.
- To share a resource with another project
- The demand for a resource exceeds the supply

Resource smoothing



Resource smoothening is the resource allocation method without extending the schedule of the project. In this method of leveling, time is main constraint.

The project completion date and the critical path will stay the same. The activities can not be delayed more than their total and free float, so flexibility is reduced. The schedule will be optimized efficiently and cost effectively.

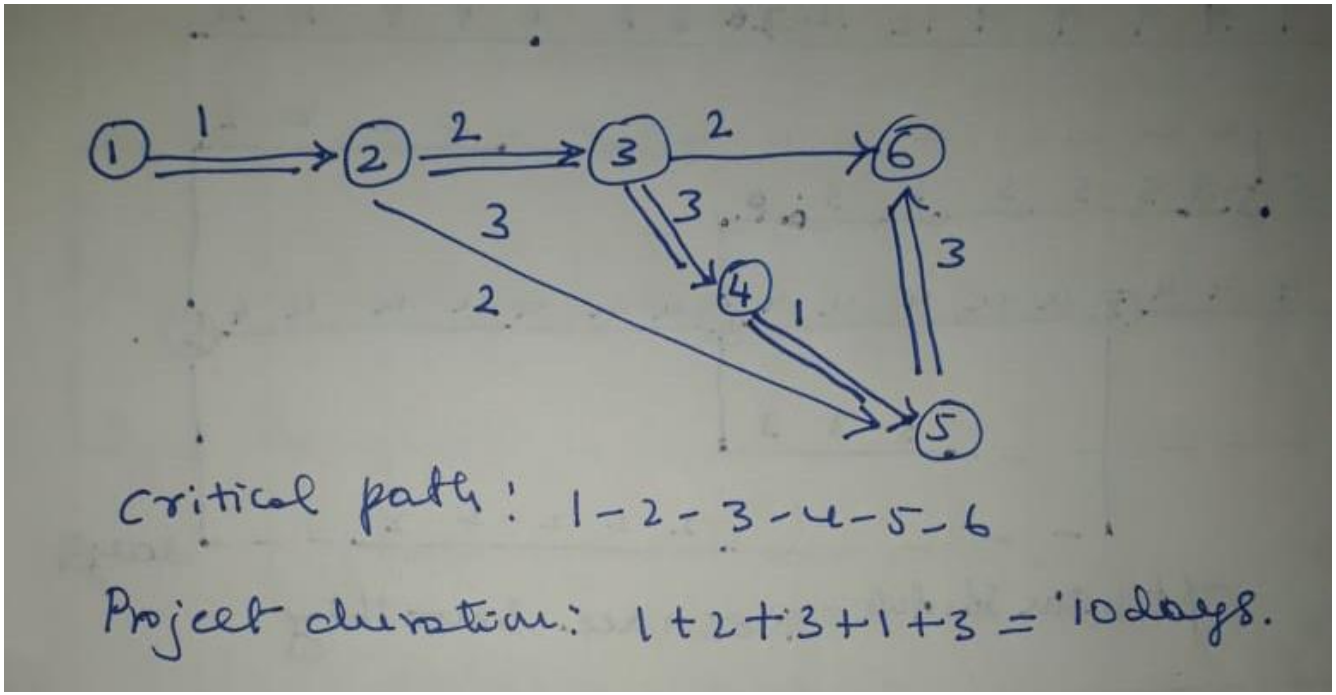
Difference between resource leveling and resource smoothening

- **In resource leveling , resources are main constraint , while in resource smoothing project end date is a constraint.**
- **In leveling the project end date may change while in smoothing it does not change while in smoothing it does not change.**
- **In resource leveling the critical path changes (generally increases) while in resource smoothing it does not, and activities can be delayed within their float.**
- **Resource leveling is used when resources are under or over allocated. Resource smoothing is used when resources are unevenly allocated.**

Suppose 10 men are available for the project, the details which are given below.

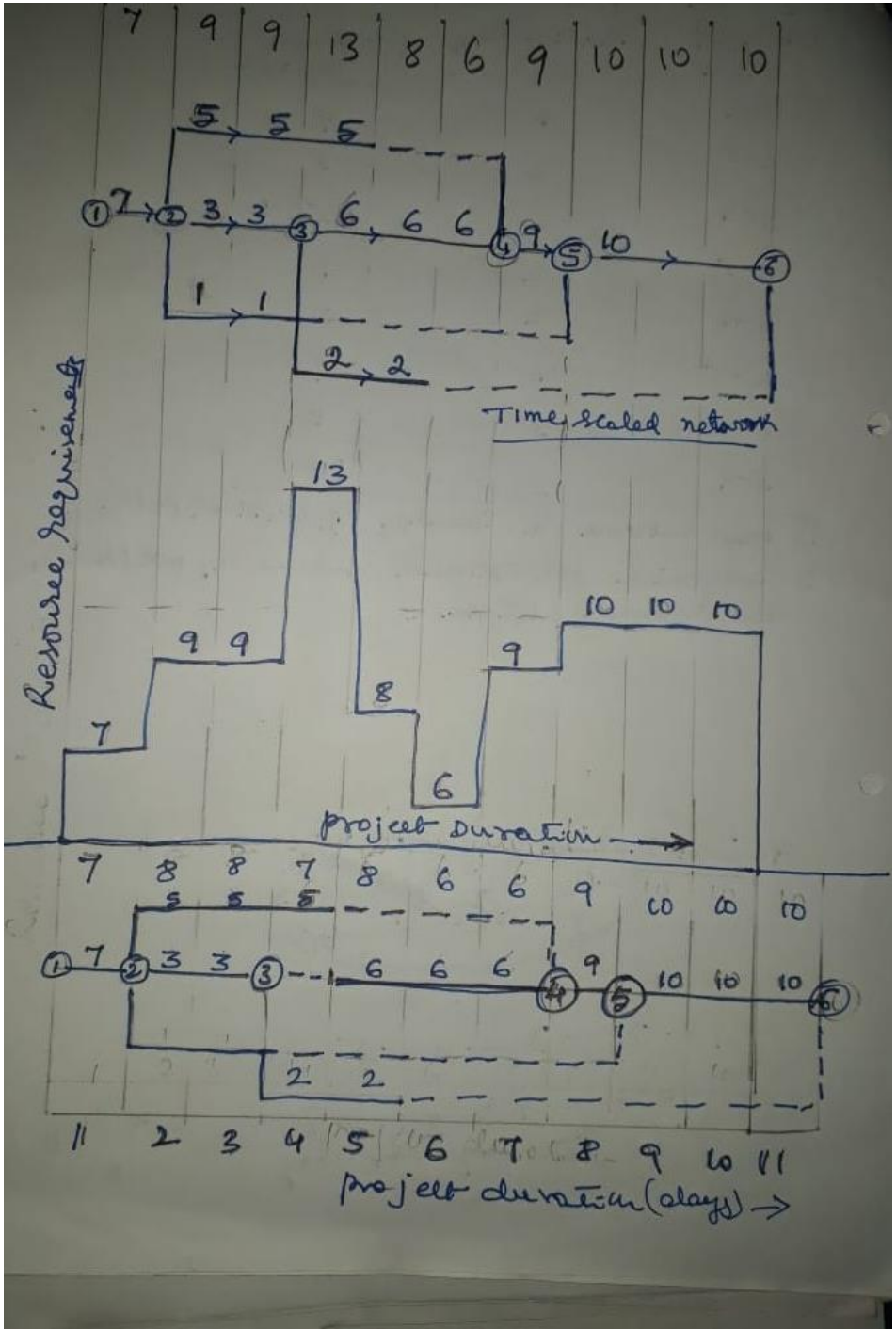
Activity	Duration (days)	No. of man required.
1–2	1	7
2–3	2	3
2–4	3	5
2–5	2	1
3–6	2	2
4–5	1	9
5–6	3	10
3–4	3	6

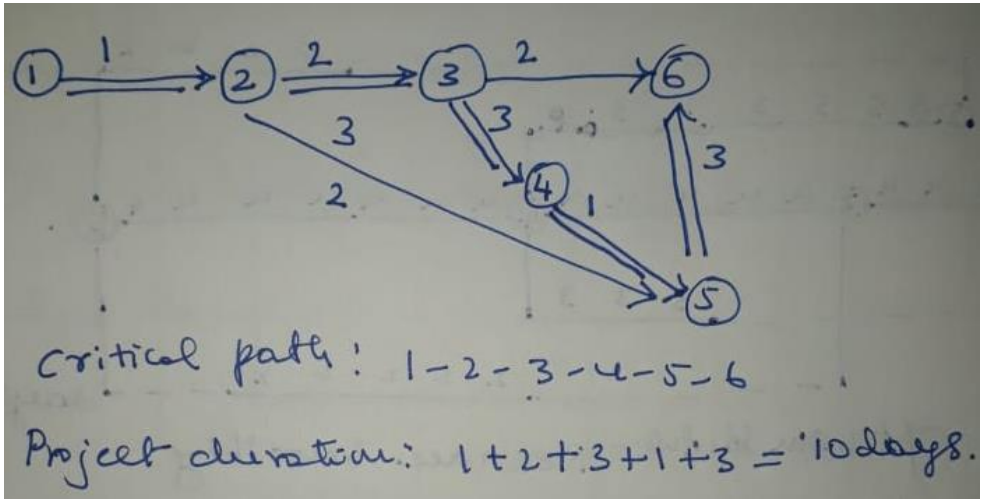
i) Draw network & identify critical path.
ii) Determine the Optimum schedule, prepare the resource histogram.



Critical path: 1-2-3-4-5-6

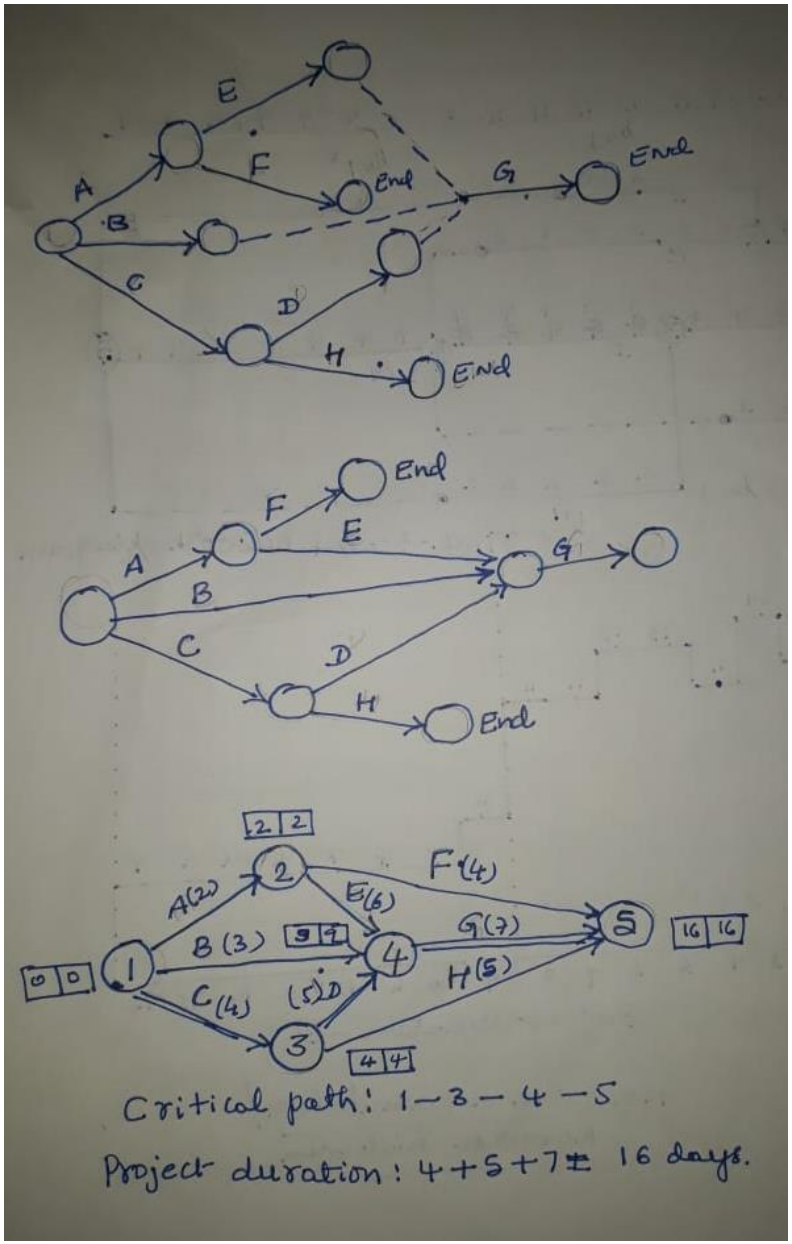
Project duration: 1+2+3+1+3 = 10 days.

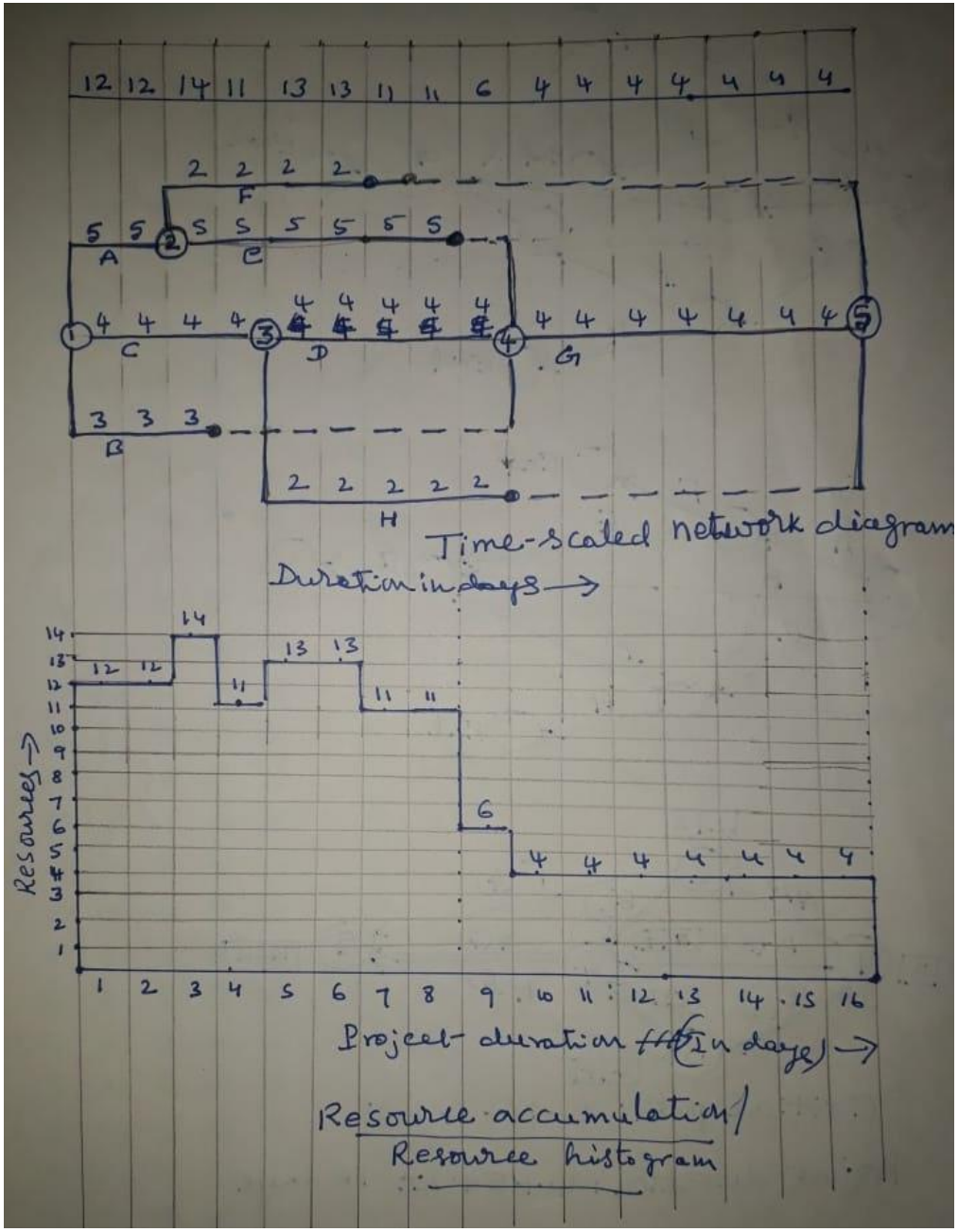

7 9 9 13 8 6 9 10 10 10
5 5 5
1 7 2 3 3 3 6 6 6 4 9 5 10 6
1 1
2 2
Time scaled network
Resource requirements
13
10 10 10
9 9
9
8
7
6
Project duration
7 8 8 7 8 6 6 9 10 10 10
5 5 5
1 7 2 3 3 3 6 6 6 4 9 5 10 10 10 6
2 2
1 2 3 4 5 6 7 8 9 10 11
Project duration (days)

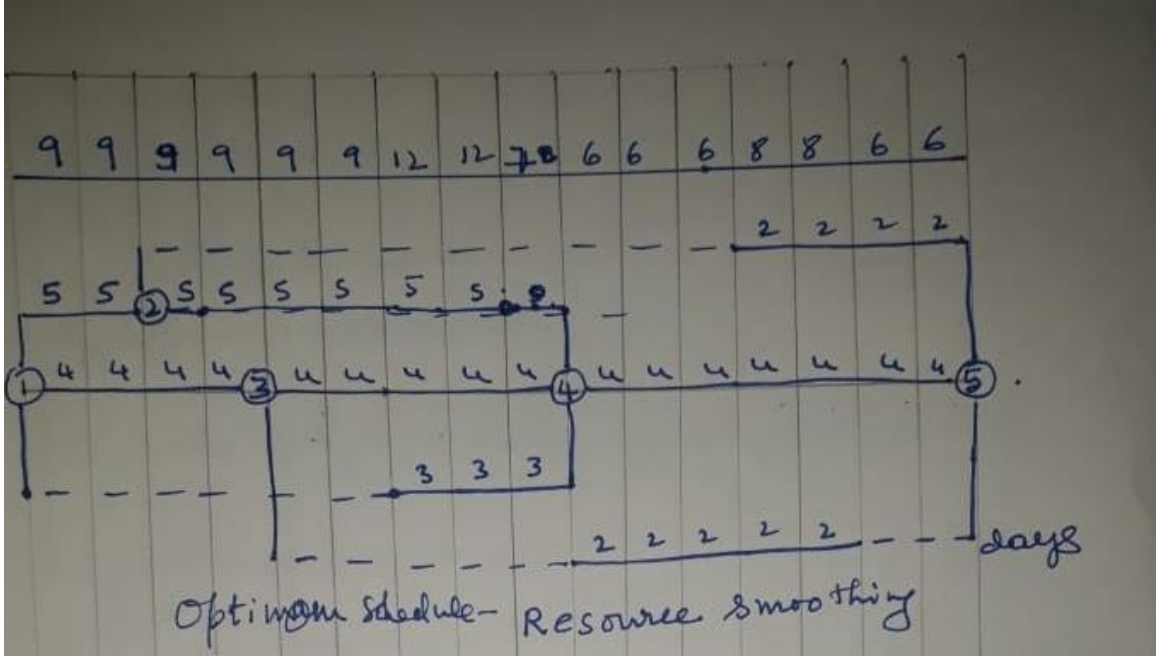


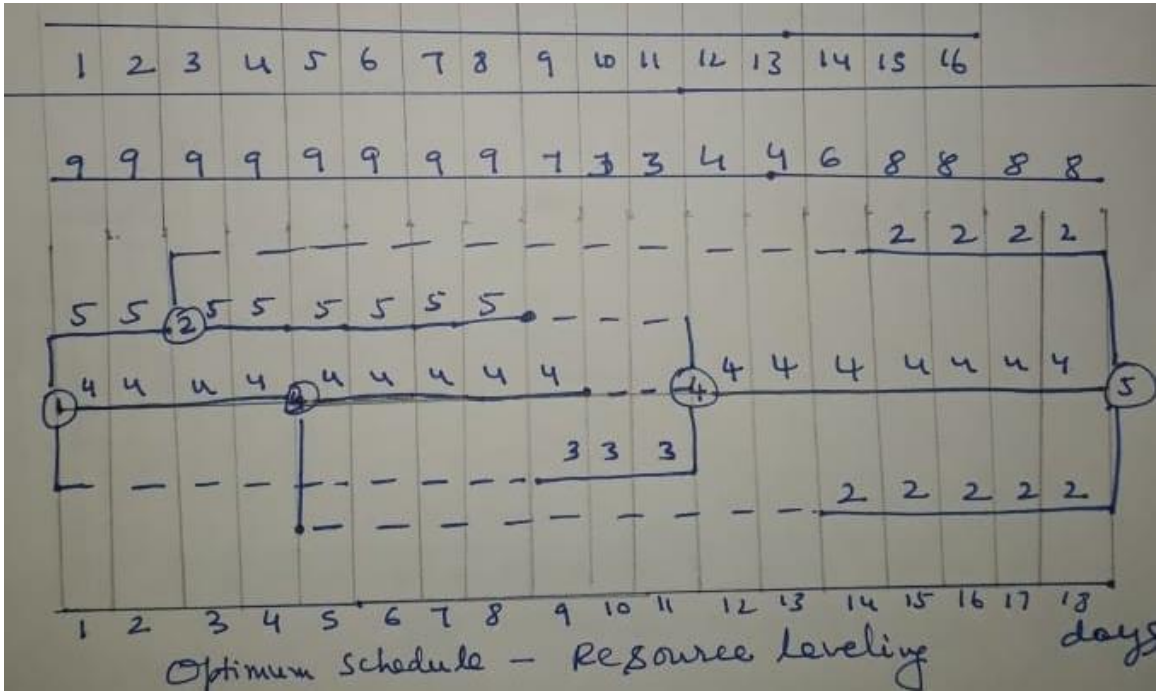
Critical path: 1-2-3-4-5-6

Project duration: 1+2+3+1+3 = 10 days.


E
A
F
End
G
End
B
C
D
H
End
End
F
E
A
G
B
C
D
H
End
2 2
A(2)
2
F(4)
E(6)
G(7)
5
16 16
B(3)
9 7
4
H(5)
0 0
1
C(4)
(5)D
3
4 4
Critical path: 1 – 3 – 4 – 5
Project duration: 4+5+7 = 16 days.


12 12 14 11 13 13 11 11 6 4 4 4 4 4 4 4
2 2 2 2
F
5 5 5 5 5 5 5 5
A
E
4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
C
D
G
3 3 3
B
2 2 2 2 2
H
Time-scaled network diagram
Duration in days →
Resources →
14 13 12 11 10 9 8 7 6 5 4 3 2 1
12 12 14 11 13 13 11 11 6 4 4 4 4 4 4 4
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16
Project duration (in days) →
Resource accumulation/
Resource histogram


days
Optimum Schedule- Resource Smoothing


days
Optimum Schedule – Resource Leveling