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# ENGINEERING MANAGEMENT

(GE 404)

1

## LECTURE #6

# Precedence Diagramming and Time Scaled Network

# Objectives of the Present lecture

2

- *To explain how to draw Precedence network diagrams*
- *To discuss how to calculate Early/Late Start/Finish Times in Precedence Network diagrams.*
- *To discuss steps involved in drawing the Time-scaled network diagrams*

# Precedence Diagramming

3

- Precedence diagramming is an extension to the original Activity-On-Node concept.
- Precedence diagramming includes precedence relationships among the activities.
- In addition, one may specify a “lag time” associated with any of the precedence relationships.
- A successor "lags" a predecessor, but a predecessor "leads" a successor.
- Lag time can be designated on a dependency line with a positive, negative, or zero value.
- The prime relationship used in PERT/CPM network is Finish-to-start type of dependency, with  $\underline{FS}_{ij} = 0$ .

# Activity Relationships

4

- **Finish-to-Start (FS)**
  - In a finish-to-start relationship, *the start of an activity depends on the completion of its preceding activity.*
  - Example: Footing excavation must be completed prior to placing concrete for the footing
- **Start-to-Start (SS)**
  - In a start-to-start relationship, *an activity can not start before its preceding activity starts*
  - Example: Project management activities can not start before the Project work starts
- **Finish-to-Finish (FF)**
  - In a finish-to-finish relationship, *the two activities are related by the fact that they must be completed at the same time*
  - Example: In a simple task of setting a flagpole, the backfilling task and the positioning the pole task will be finished at the same time.
- **Start-to-Finish (SF)**
  - In start-to-finish relationship, *the finish of an activity depends on the start of its preceding activity (A rare relationship)*
  - Example: In a Hospital emergency, the previous shift can not finish before the new shift starts
  - Say you're building a new gas pipeline. You would first finish construction and implementation of the new pipeline before you would begin shutting down and breaking down the old pipeline.

# Lag

5

- The amount of time that exists between the early finish of an activity and the early start of a specified succeeding activity
- Calculate lags for each link by determining the difference between the **ES** of each activity following a link line and the **EF** of the activity that precedes it

$$(LAG_{AB} = ES_B - EF_A)$$

- Limitations and Disadvantages of Lag:
  - Lag would complicate the scheduling process
  - Lags are not extensively used except where the time effects are substantial for special project type

# Finish-to-Start Activity Precedence Relationships with Lag Values

6



Note :  $\text{lag}_{ij} = FS_{ij}$  and  $\text{lag}_{jk} = FS_{jk}$

$$ES_j = EF_i + FS_{ij}$$

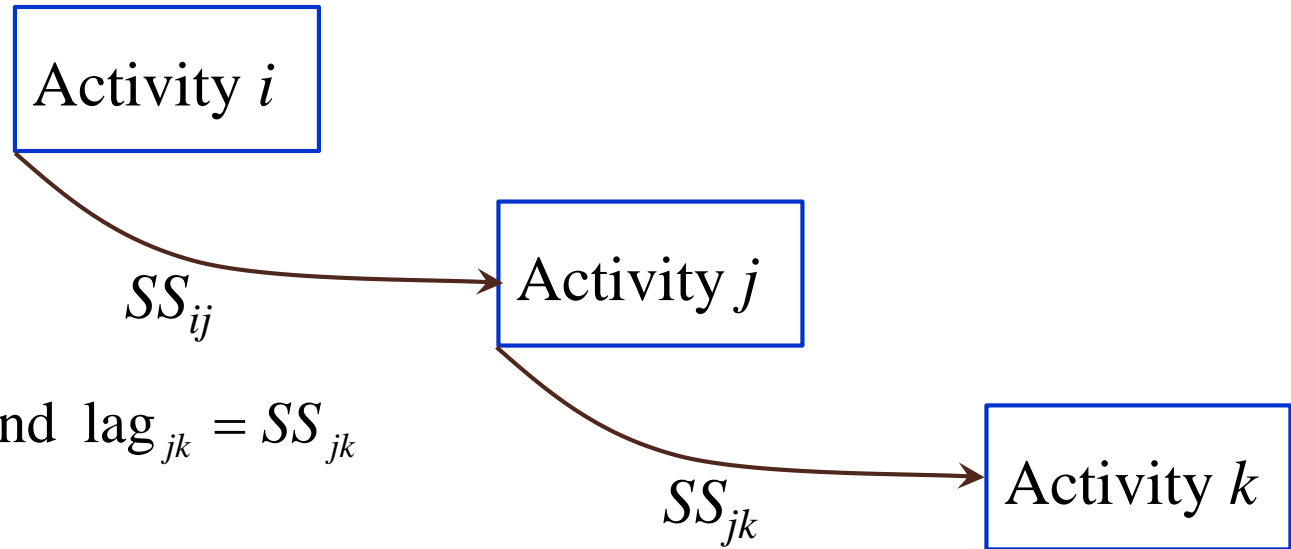
$$LS_i = LF_i - D_i$$

$$EF_j = ES_j + D_j$$

$$LF_i = LS_j - FS_{ij}$$

# Start-to-Start Activity Precedence Relationships with Lag Values

7



Note :  $lag_{ij} = SS_{ij}$  and  $lag_{jk} = SS_{jk}$

$$ES_j = ES_i + SS_{ij}$$

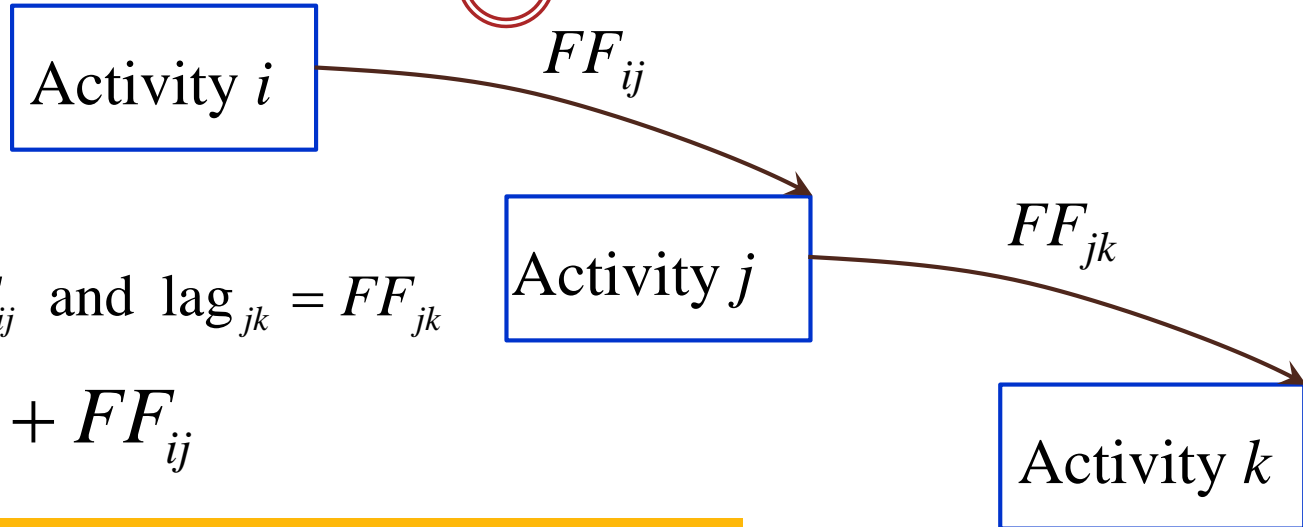
$$LS_i = LS_j - SS_{ij}$$

$$EF_j = ES_j + D_j$$

$$LF_i = LS_i + D_i = LS_j - SS_{ij} + D_i$$

# Finish-to-Finish Activity Precedence Relationships with Lag Values

8



Note :  $\text{lag}_{ij} = FF_{ij}$  and  $\text{lag}_{jk} = FF_{jk}$

$$EF_j = EF_i + FF_{ij}$$

$$ES_j = EF_i + FF_{ij} - D_j = EF_j - D_j$$

$$LS_i = LF_j - FF_{ij} - D_i = LF_i - D_i$$

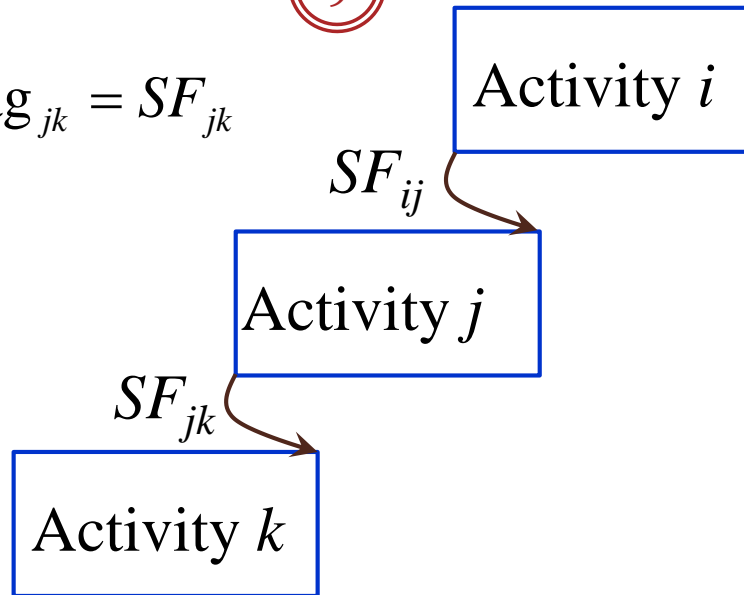
$$LF_i = LF_j - FF_{ij}$$



# Start-to-Finish Activity Precedence Relationships with Lag Values

9

Note :  $\text{lag}_{ij} = SF_{ij}$  and  $\text{lag}_{jk} = SF_{jk}$



$$EF_j = ES_i + SF_{ij}$$

$$LS_i = LF_j - SF_{ij}$$

$$ES_j = ES_i + SF_{ij} - D_j = EF_j - D_j$$

$$LF_i = LF_j - SF_{ij} + D_i = LS_i + D_i$$

# Note on $SF_{ij}$

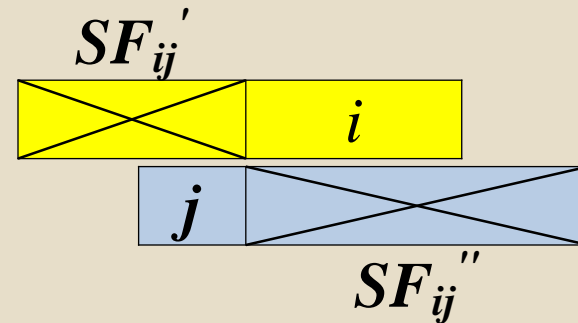
10

- Activity  $j$  cannot finish till  $i$  starts (rare)
- $SF_{ij}$  is equal to the minimum number of time units that must transpire from the start of the predecessor  $i$  to the completion of the successor  $j$ .

## Example

- For the shown diagram calculate total lag if

$$SF'_{ij} = 4 \text{ and } SF''_{ij} = 6$$



$$SF_{ij} = SF'_{ij} + SF''_{ij} = 4 + 6 = 10$$

The finish of  $j$  must lag 10 units after the start of  $i$

# Summary

11

Finish-to-Start Relationships with Lag Values  $FS_{ij}$  :

$$ES_j = EF_i + FS_{ij}$$

$$LF_i = LS_j - FS_{ij}$$

Start-to-Start Relationships with Lag Values  $SS_{ij}$  :

$$ES_j = ES_i + SS_{ij}$$

$$LF_i = LS_j - SS_{ij} + D_i$$

Finish-to-Finish Relationships with Lag Values  $FF_{ij}$  :

$$ES_j = EF_i + FF_{ij} - D_j$$

$$LF_i = LF_j - FF_{ij}$$

Start-to-Finish Relationships with Lag Values  $SF_{ij}$  :

$$ES_j = ES_i + SF_{ij} - D_j$$

$$LF_i = LF_j - SF_{ij} + D_i$$

# Generalized Equations

12

## FORWARD PASS COMPUTATIONS

$$ES_j = \text{Max}(\text{all}_i) \left( \begin{array}{l} \text{Initial Time} \\ EF_i + FS_{ij} \\ ES_i + SS_{ij} \\ EF_i + FF_{ij} - D_j \\ ES_i + SF_{ij} - D_j \end{array} \right)$$

$$EF_j = ES_j + D_j$$

## BACKWARD PASS COMPUTATIONS

$$LF_i = \text{Min}(\text{all}_j) \left( \begin{array}{l} \text{Terminal Time} \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{array} \right)$$

$$LS_i = LF_i - D_i$$

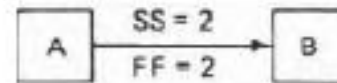
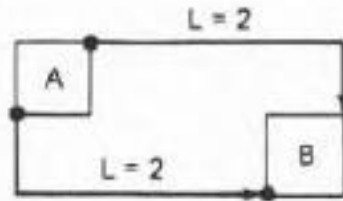
# Composite Start-to-Start and Finish-to-Finish ( $ZZ_{ij}$ ) Activity Precedence Relationships with Lag Values

13

$ZZ_{ij}$  is a combination of two constraints, i.e., a start-to-start and finish-to-finish relationship. It is written with the  $SS_{ij}$  time units first, followed by the  $FF_{ij}$  time units.

Example:  $ZZ_{ij} = 5, 6$

The start of activity  $j$  must lag 5 units after the start of activity  $i$  & The finish of activity  $j$  must lag 6 units after the finish of activity  $i$



# Representation

14

ES	Duration	EF
Activity (i)		
LS	Total Float	LF

$SS_{ij}$   
 $FF_{ij}$   
 $FS_{ij}$   
 $SF_{ij}$   
 $ZZ_{ij}(SS_{ij} - FF_{ij})$

Constraints with lag/lead Durations

ES	Duration	EF
Activity (j)		
LS	Total Float	LF

# Free and Total Floats in Overlapping Networks

15

Free Float of an activity can be defined as time span in which the completion of the controlling date of an activity may occur and not delay the termination of the project nor delay the early status of the following activity.

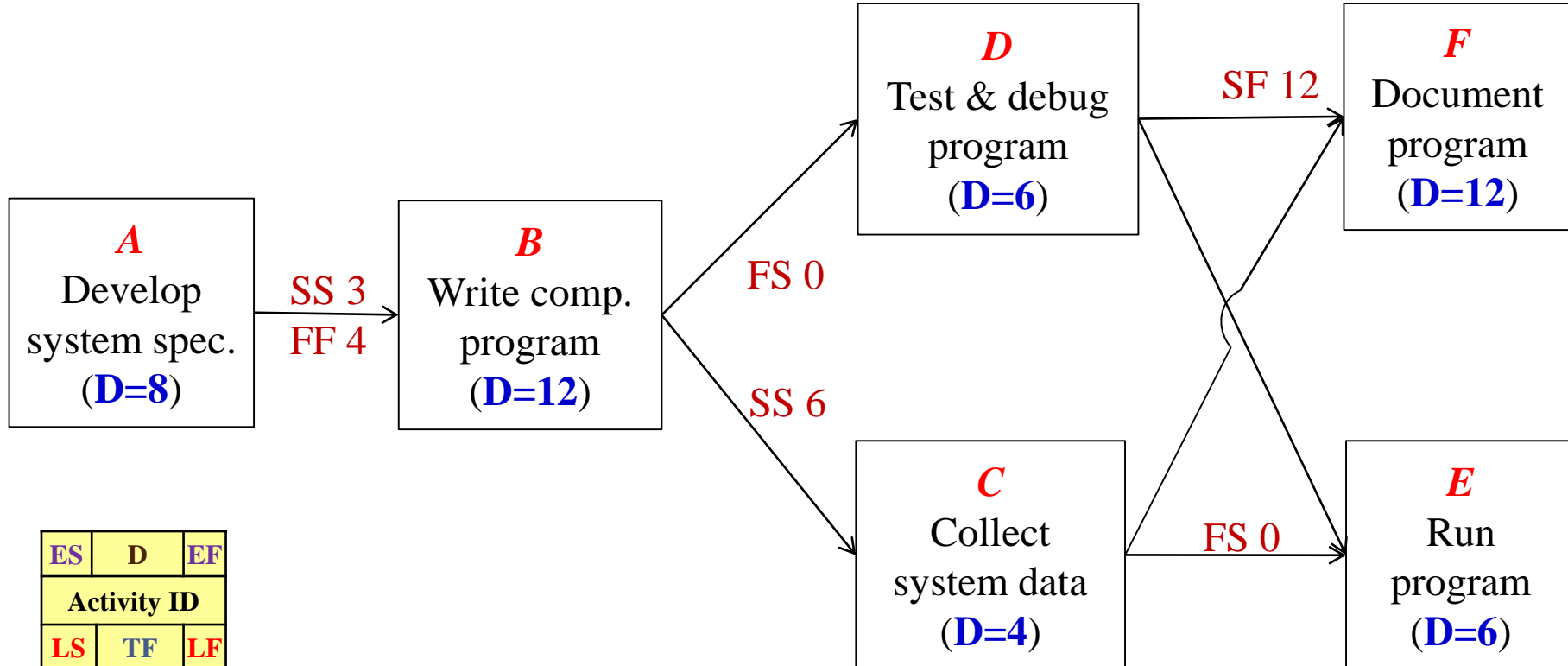
$$FF_i = \text{Min}(\text{all } j) \begin{pmatrix} ES_j - EF_i - FS_{ij} \\ ES_j - ES_i - SS_{ij} \\ EF_j - EF_i - FF_{ij} \\ EF_j - ES_i - SF_{ij} \end{pmatrix}$$

Total float (TF) equation is same as it was developed for the single relationship network.

# Problem-1

16

For the given precedence diagram, complete the forward and backward pass calculations. Assume the project starts at  $T=0$ , and no splitting on activities is allowed. Also assume that the project latest allowable completion time (project duration) is scheduled for 30 working days.



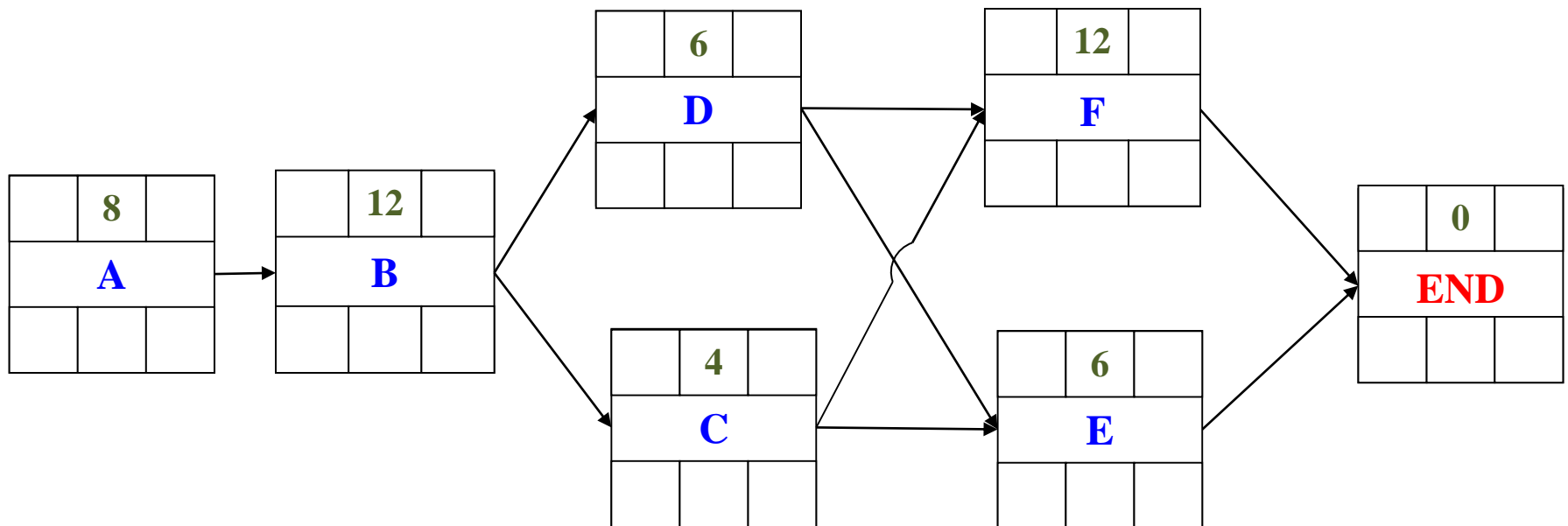


# Solution

## Step-1: Network diagram

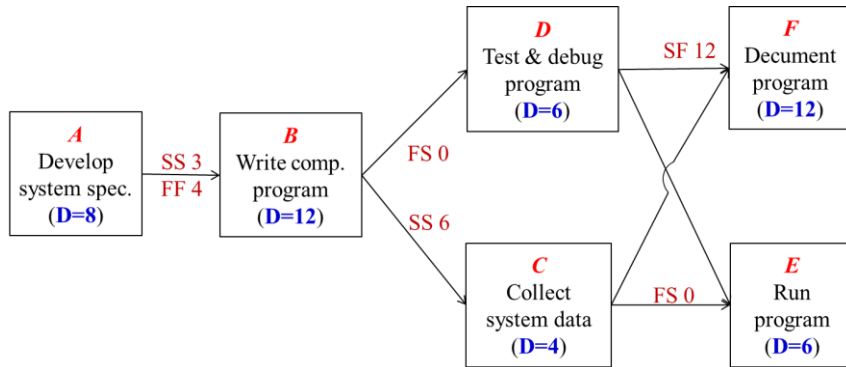
ES	D	EF
Activity ID		
LS	TF	LF

17



# Step-2: Forward Pass Computations

18



$$\begin{aligned}
 [1] ES_j &= \text{Max}(all_i) \left\{ \begin{array}{l} \text{Initial Time} \\ EF_i + FS_{ij} \\ ES_i + SS_{ij} \\ EF_i + FF_{ij} - D_j \\ ES_i + SF_{ij} - D_j \end{array} \right\} \\
 [2] EF_j &= ES_j + D_j
 \end{aligned}$$

Activity A

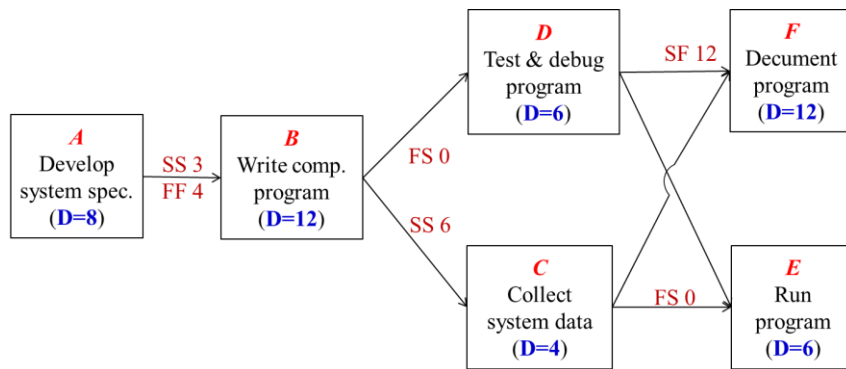
$$\begin{aligned}
 ES_A &= \text{Initial Time} = 0 \\
 EF_A &= ES_A + D_A = 0 + 8 = 8
 \end{aligned}$$

Activity B

$$\begin{aligned}
 ES_B &= \text{Max}(A) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ ES_A + SS_{AB} = 0 + 3 = 3 \\ EF_A + FF_{AB} - D_B = 8 + 4 - 12 = 0 \end{array} \right\} \\
 EF_B &= ES_B + D_B = 3 + 12 = 15
 \end{aligned}$$

Activity C

$$\begin{aligned}
 ES_C &= \text{Max}(B) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ ES_B + SS_{BC} = 3 + 6 = 9 \end{array} \right\} \\
 EF_C &= ES_C + D_C = 9 + 4 = 13
 \end{aligned}$$



$$\begin{aligned}
 [1] ES_j &= \text{Max}(all_i) \left\{ \begin{array}{l} \text{Initial Time} \\ EF_i + FS_{ij} \\ ES_i + SS_{ij} \\ EF_i + FF_{ij} - D_j \\ ES_i + SF_{ij} - D_j \end{array} \right\} \\
 [2] EF_j &= ES_j + D_j
 \end{aligned}$$

Activity D

$$\begin{aligned}
 ES_D &= \text{Max}(B) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ EF_B + FS_{BD} = 15 + 0 = 15 \end{array} \right\} \\
 EF_D &= ES_D + D_D = 15 + 6 = 21
 \end{aligned}$$

Activity E

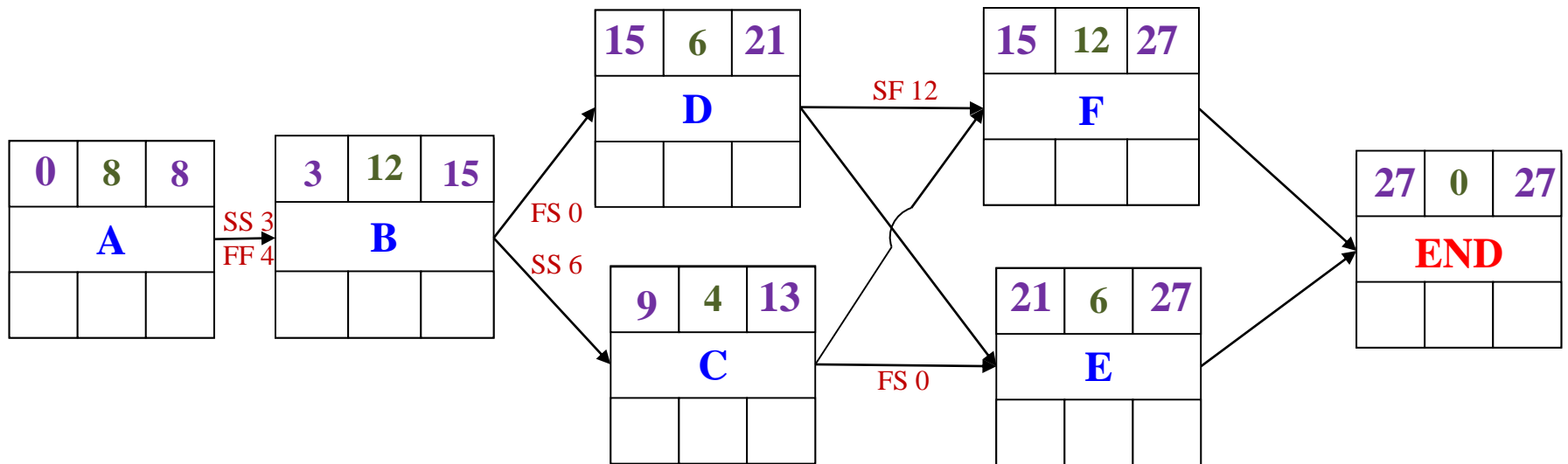
$$\begin{aligned}
 ES_E &= \text{Max}(C, D) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ EF_D + FS_{DE} = 21 + 0 = 21 \\ \text{OR, } EF_C + FS_{CE} = 13 + 0 = 13 \end{array} \right\} \\
 EF_E &= ES_E + D_E = 21 + 6 = 27
 \end{aligned}$$

Activity F

$$\begin{aligned}
 ES_F &= \text{Max}(D) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ ES_D + SF_{DF} - D_F = 15 + 12 - 12 = 15 \\ \text{OR, } EF_C + FS_{CF} = 13 + 0 = 13 \end{array} \right\} \\
 EF_F &= ES_F + D_F = 15 + 12 = 27
 \end{aligned}$$

# Contd.

20



# Step-3 Backward Pass Computations

## Activity F

$$LF_F = \text{Terminal Time} = 30$$

$$LS_F = LF_F - D_F = 30 - 12 = 18$$

## Activity E

$$LF_E = \text{Terminal Time} = 30$$

$$LS_E = LF_E - D_E = 30 - 6 = 24$$

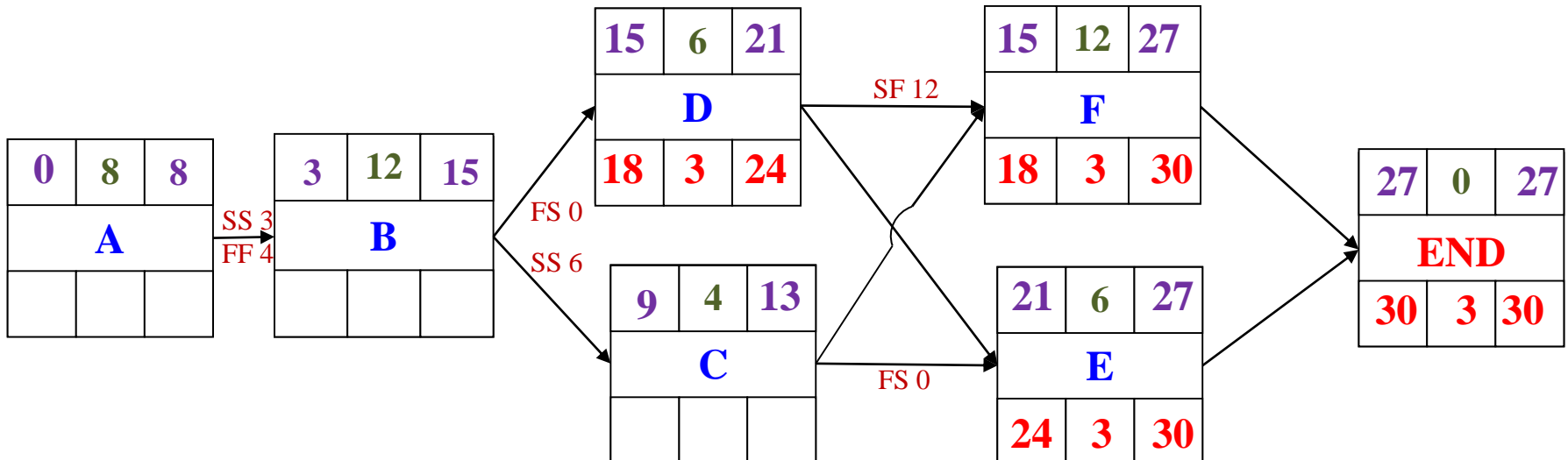
## Activity D

$$LF_D = \text{Min}(E, F) \left\{ \begin{array}{l} \text{Terminal Time} = 30 \\ LS_E - FS_{DE} = 24 - 0 = 24 \\ \text{or} \\ LF_F - SF_{DF} + D_D = 30 - 12 + 6 = 24 \end{array} \right.$$

$$LS_D = LF_D - D_D = 24 - 6 = 18$$

$$[3] LF_i = \text{Min}(all_j) \left\{ \begin{array}{l} \text{Terminal Time} \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{array} \right.$$

$$[4] LS_i = LF_i - D_i$$



### Activity C

$$LF_C = \text{Min}(E, F) \left\{ \begin{array}{l} \text{Terminal Time} = 30 \\ LS_E - FS_{CE} = 24 - 0 = 24 \\ \text{or} \\ LS_F - FS_{CF} = 18 - 0 = 18 \end{array} \right.$$

$$LS_C = LF_C - D_C = 18 - 4 = 14$$

### Activity B

$$LF_B = \text{Min}(C, D) \left\{ \begin{array}{l} \text{Terminal Time} = 30 \\ LS_D - FS_{BD} = 18 - 0 = 18 \\ \text{OR} \\ LS_C - SS_{BC} + D_B = 14 - 6 + 12 = 20 \end{array} \right.$$

$$LS_B = LF_B - D_B = 18 - 12 = 6$$

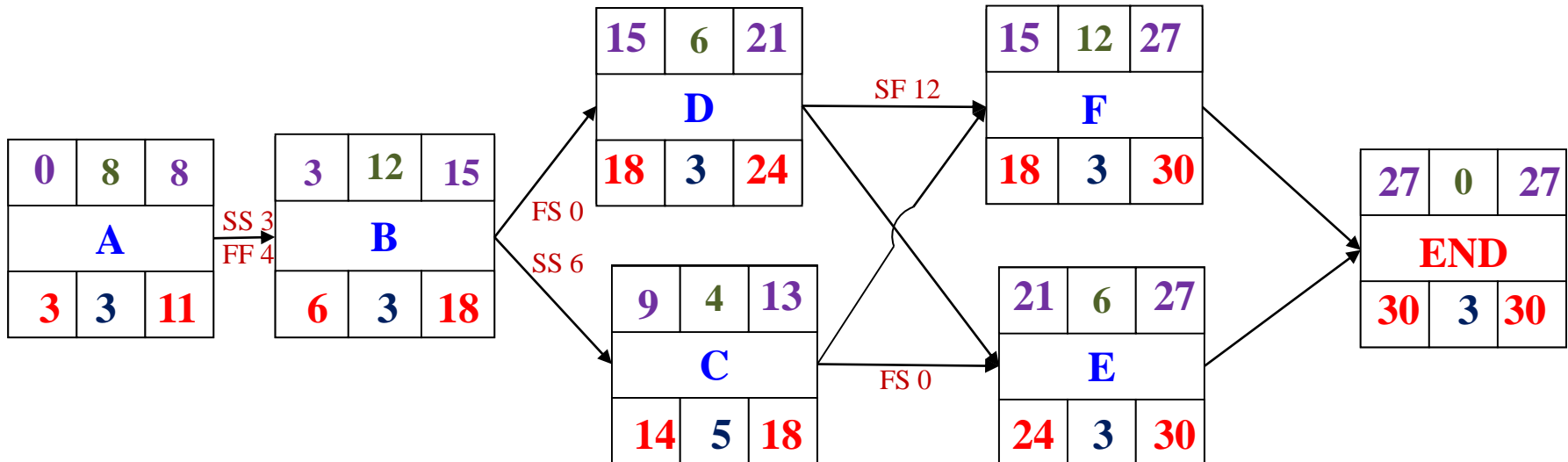
### Activity A

$$LF_A = \text{Min}(B) \left\{ \begin{array}{l} \text{Terminal Time} = 30 \\ LF_B - FF_{AB} = 18 - 4 = 14 \\ LS_B - SS_{AB} + D_A = 6 - 3 + 8 = 11 \end{array} \right.$$

$$LS_A = LF_A - D_A = 11 - 8 = 3$$

$$[3] LF_i = \text{Min}(all_j) \left\{ \begin{array}{l} \text{Terminal Time} \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{array} \right.$$

$$[4] LS_i = LF_i - D_i$$



## Step 4: Slack time (Float time)

23

Activity	Earliest Start ES	Earliest Finish EF	Latest Start LS	Latest Finish LF	Slack LS – ES	On Critical Path
A	0	8	3	11	3	Yes
B	3	15	6	18	3	Yes
C	9	13	14	18	5	No
D	15	21	15	21	3	Yes
E	21	27	24	30	3	Yes
F	15	27	18	30	3	Yes

Critical path is the path with the least total float = The longest path through the network.

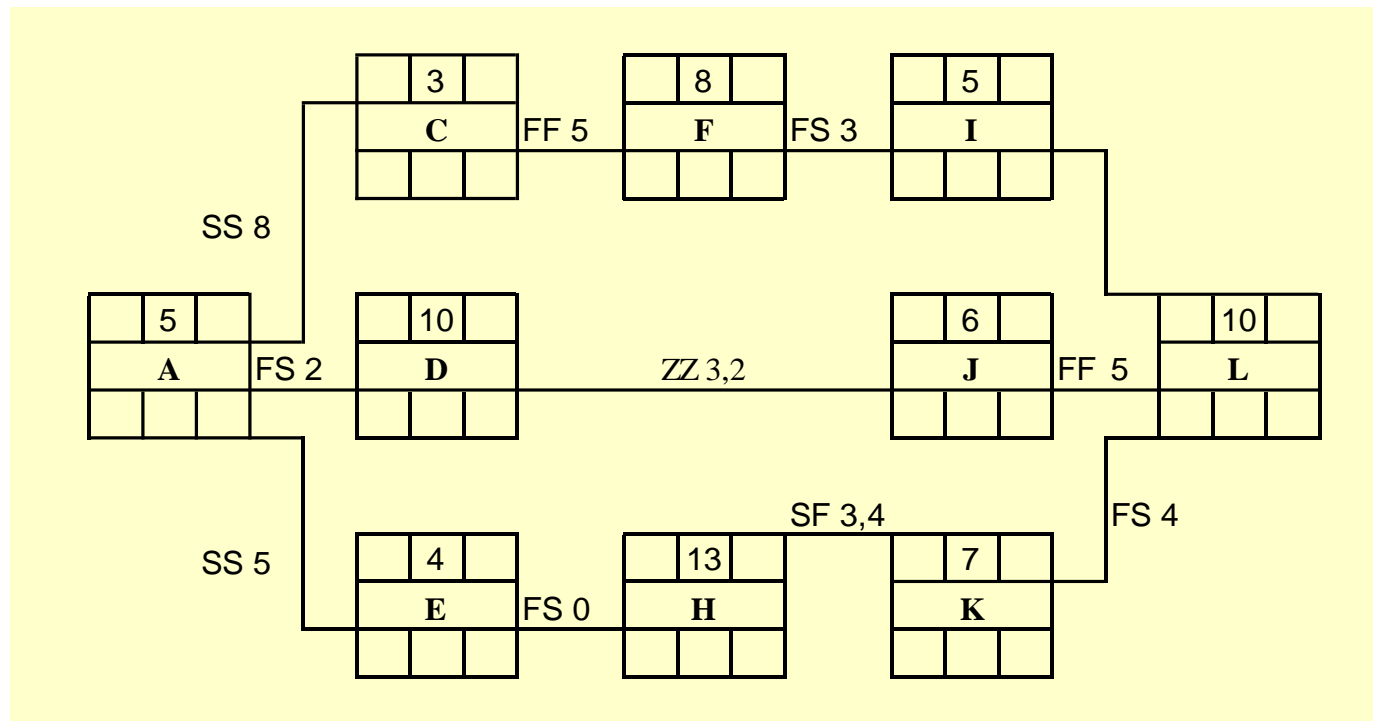
CP1: **A-B-D-E**, CP2: **A-B-D-F** ;

Critical Activities: A, B, D, E, and F

# Problem-2

24

Given the precedence network for a small engineering project with activity durations in working days, it is required to compute the activity times (ES, EF, LS, and LF) and total floats (TF) and then indicate the critical activities.

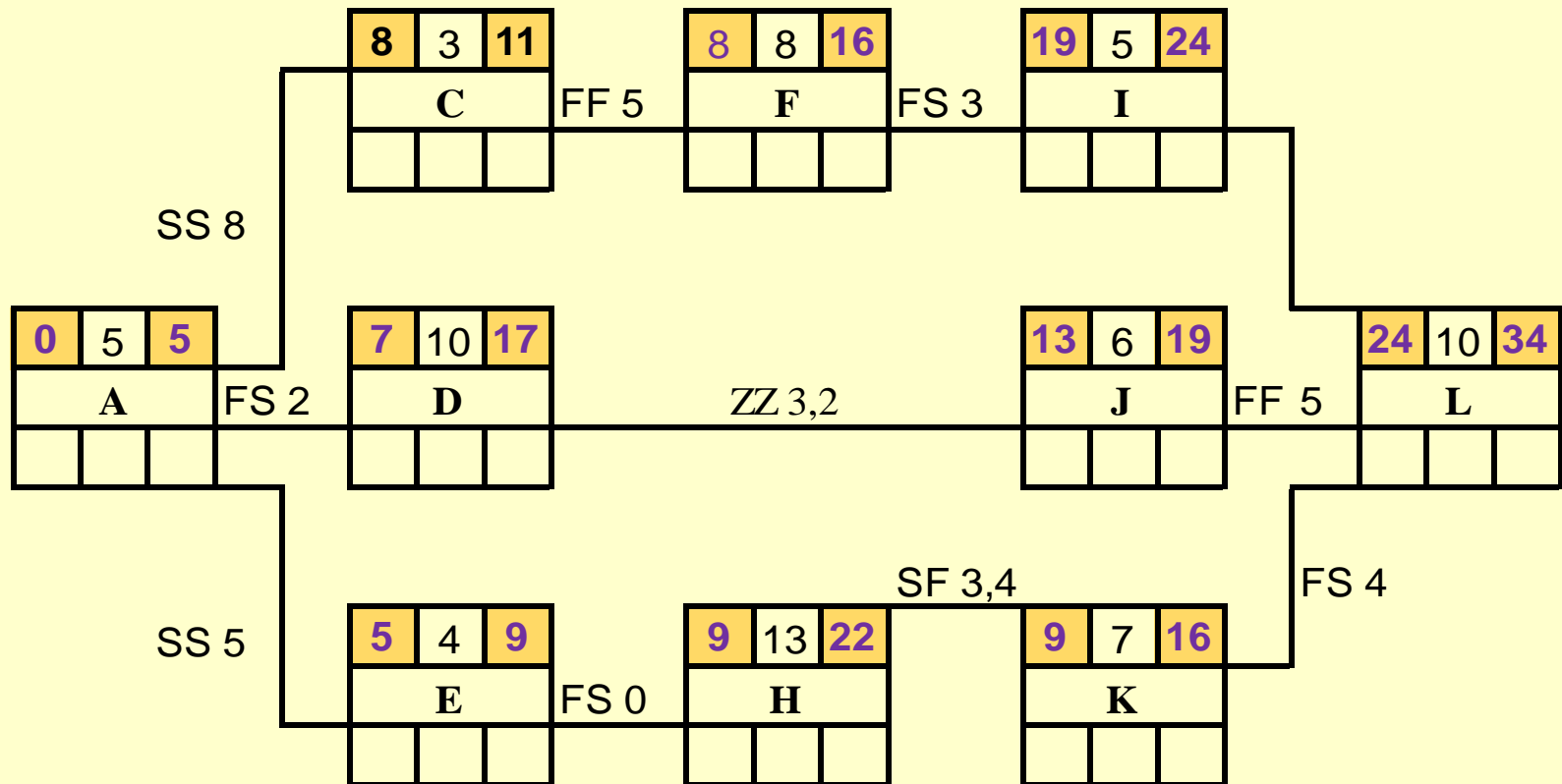




# Solution

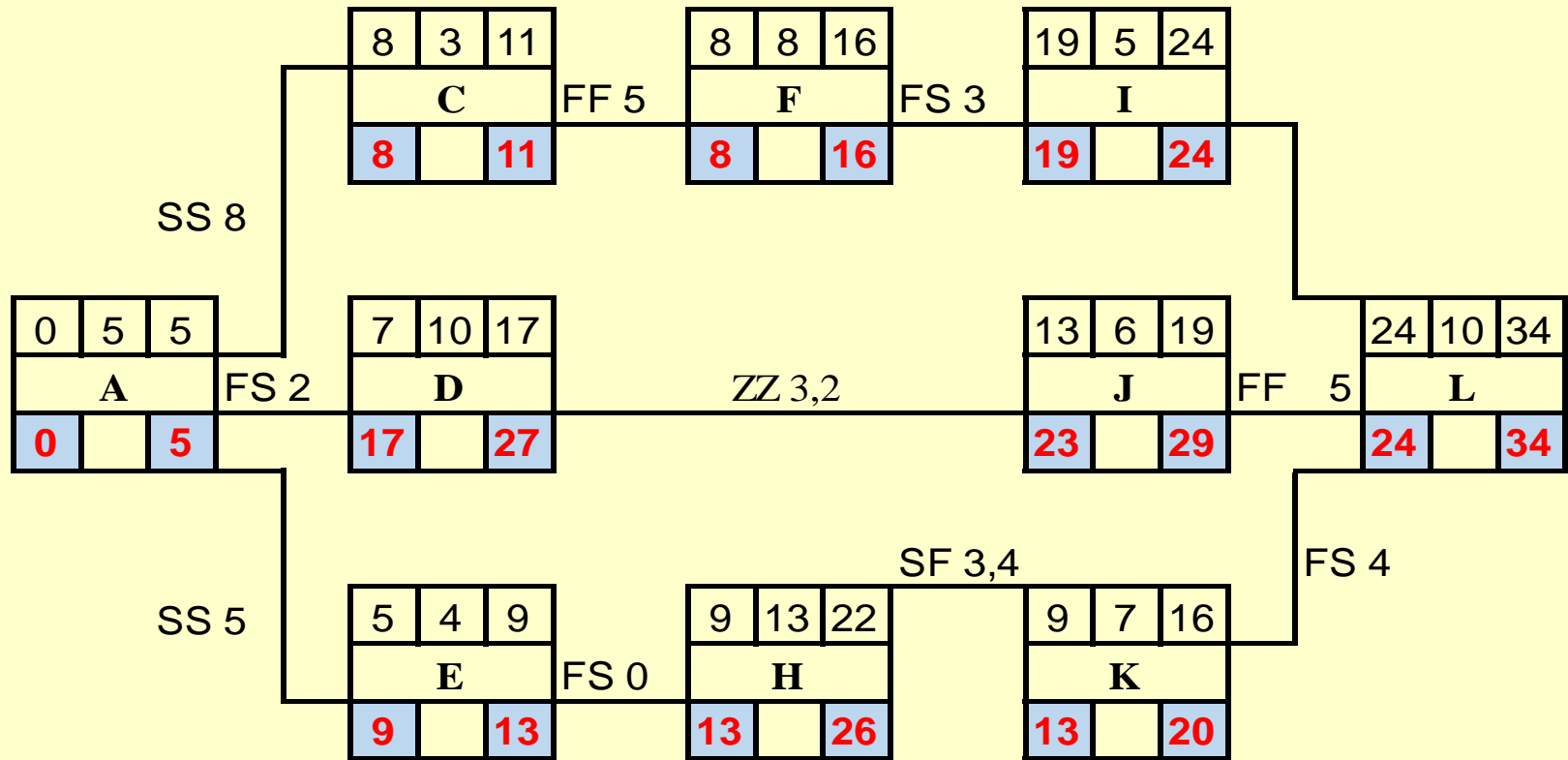
## Step-1: Calculate ES and EF

25



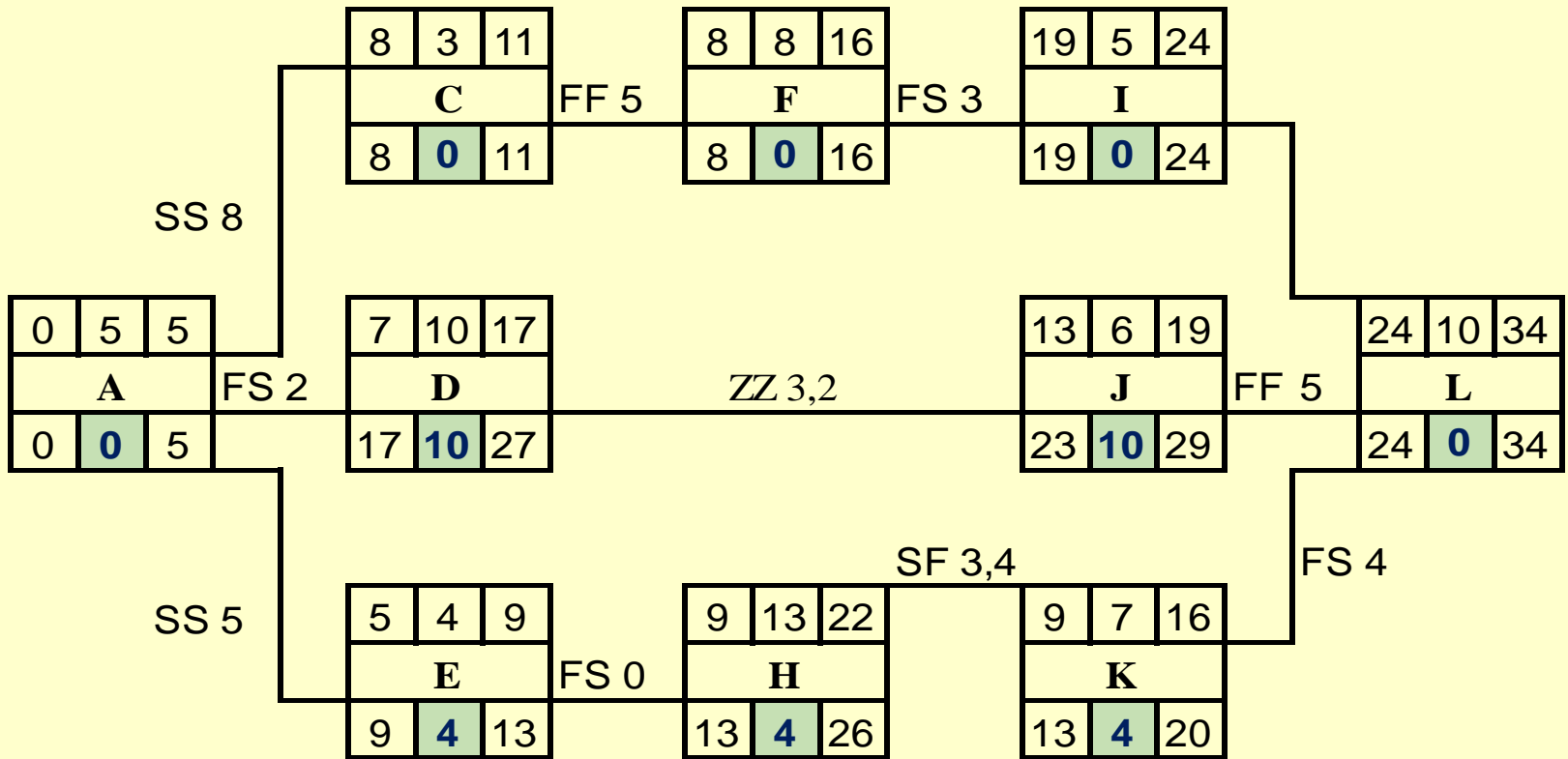
## Step-2: Calculate LS and LF

26

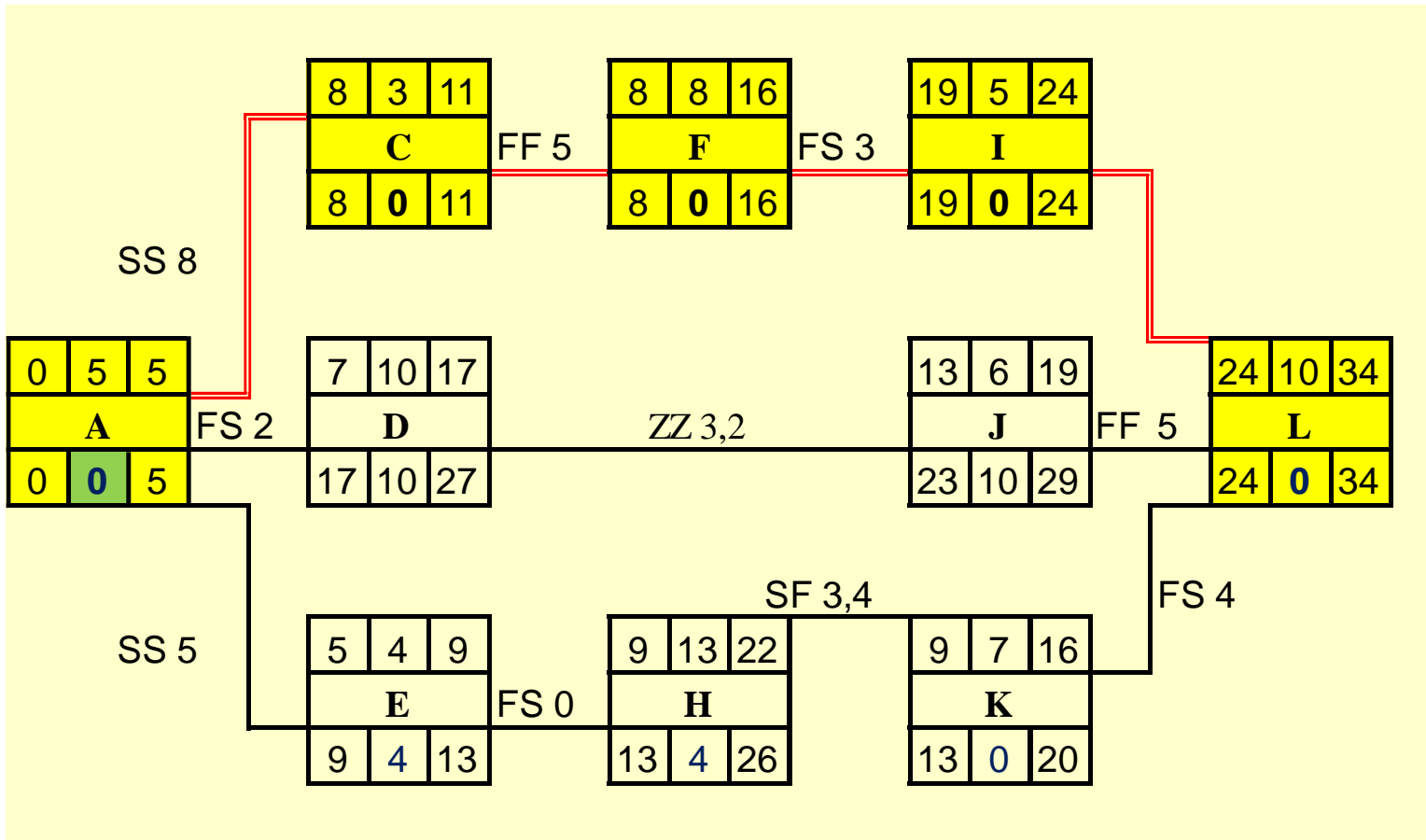


# Step-3: Calculate Total float

27



# Step 4: Indicate critical activities



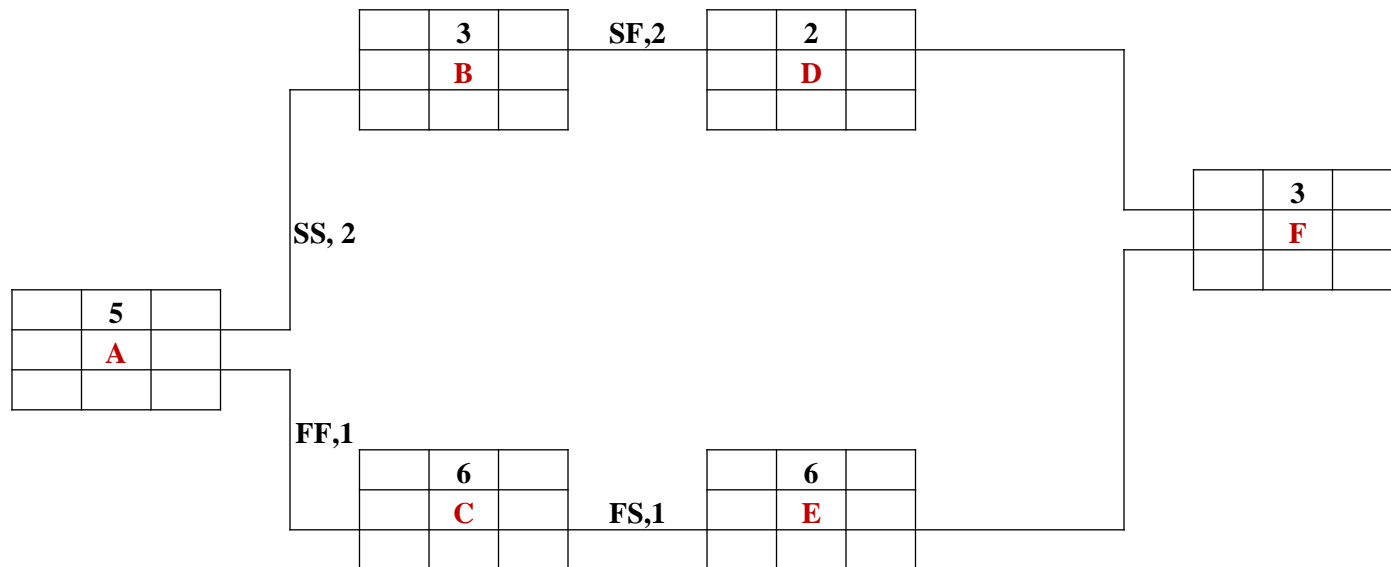
# Problem-3

29

Given below the precedence network for a small engineering project with activity durations in working days. Compute the activity times (ES, EF, LS, and LF), total floats (TF) and free floats. Also indicate the critical activities and find the critical path.

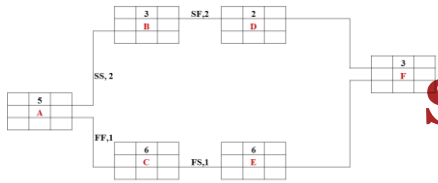
LEGENDS

<b>ES</b>	<b>D</b>	<b>EF</b>
	<b>Act</b>	<b>FF</b>
<b>LS</b>	<b>TF</b>	<b>LF</b>



# Solution

## Step-1: ES and EF Calculations



	Initial Time
[1]	$ES_j = \text{Max}(all_i)$
	$EF_i + FS_{ij}$
	$ES_i + SS_{ij}$
	$EF_i + FF_{ij} - D_j$
	$ES_i + SF_{ij} - D_j$
[2]	$EF_j = ES_j + D_j$

30

$$ES_A = \text{Initial time} = 0$$

$$EF_A = ES_A + D_A = 0 + 5 = 5$$

$$ES_B = \text{Max}(A) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ ES_A + SS_{AB} = 0 + 2 = 2 \end{array} \right\} = 2$$

$$EF_B = ES_B + D_B = 2 + 3 = 5$$

$$ES_C = \text{Max}(A) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ EF_A + FF_{AB} - D_C = 5 + 1 - 6 = 0 \end{array} \right\} = 0$$

$$EF_C = ES_C + D_C = 0 + 6 = 6$$

$$ES_D = \text{Max}(B) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ ES_B + SF_{BD} - D_D = 2 + 2 - 2 = 2 \end{array} \right\} = 2$$

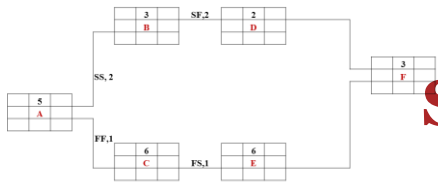
$$EF_D = ES_D + D_D = 2 + 2 = 4$$

$$ES_E = \text{Max}(C) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ EF_C + FS_{CE} = 6 + 1 = 7 \end{array} \right\} = 7$$

$$EF_E = ES_E + D_E = 7 + 6 = 13$$

$$ES_F = \text{Max}(D, E) \left\{ \begin{array}{l} \text{Initial Time} = 0 \\ EF_D + FS_{DF} = 4 + 0 = 4 \\ EF_E + FS_{EF} = 13 + 0 = 13 \end{array} \right\} = 13$$

$$EF_F = ES_F + D_F = 13 + 3 = 16$$



## Step-2: LF and LS Calculations

	Terminal Time
[3] $LF_i = \text{Min}(all_j)$	$LS_j - FS_{ij}$
	$LF_j - FF_{ij}$
	$LS_j - SS_{ij} + D_i$
[4] $LS_i = LF_i - D_i$	

31

$$LF_F = \text{Terminal time} = 16$$

$$LS_F = LF_F - D_F = 16 - 3 = 13$$

$$LF_E = \text{Min}(F) \left\{ \begin{array}{l} \text{Terminal Time} = 16 \\ LS_F - FS_{EF} = 13 - 0 = 13 \end{array} \right\} = 13$$

$$LS_E = LF_E - D_E = 13 - 6 = 7$$

$$LF_C = \text{Min}(E) \left\{ \begin{array}{l} \text{Terminal Time} = 16 \\ LS_E - FS_{CE} = 7 - 1 = 6 \end{array} \right\} = 6$$

$$LS_C = LF_C - D_C = 6 - 6 = 0$$

$$LF_D = \text{Min}(F) \left\{ \begin{array}{l} \text{Terminal Time} = 16 \\ LS_F - FS_{DF} = 13 - 0 = 13 \end{array} \right\} = 13$$

$$LS_D = LF_D - D_D = 13 - 2 = 11$$

$$LF_B = \text{Min}(D) \left\{ \begin{array}{l} \text{Terminal Time} = 16 \\ LF_D - SF_{BD} + D_B = 13 - 2 + 3 = 14 \end{array} \right\} = 14$$

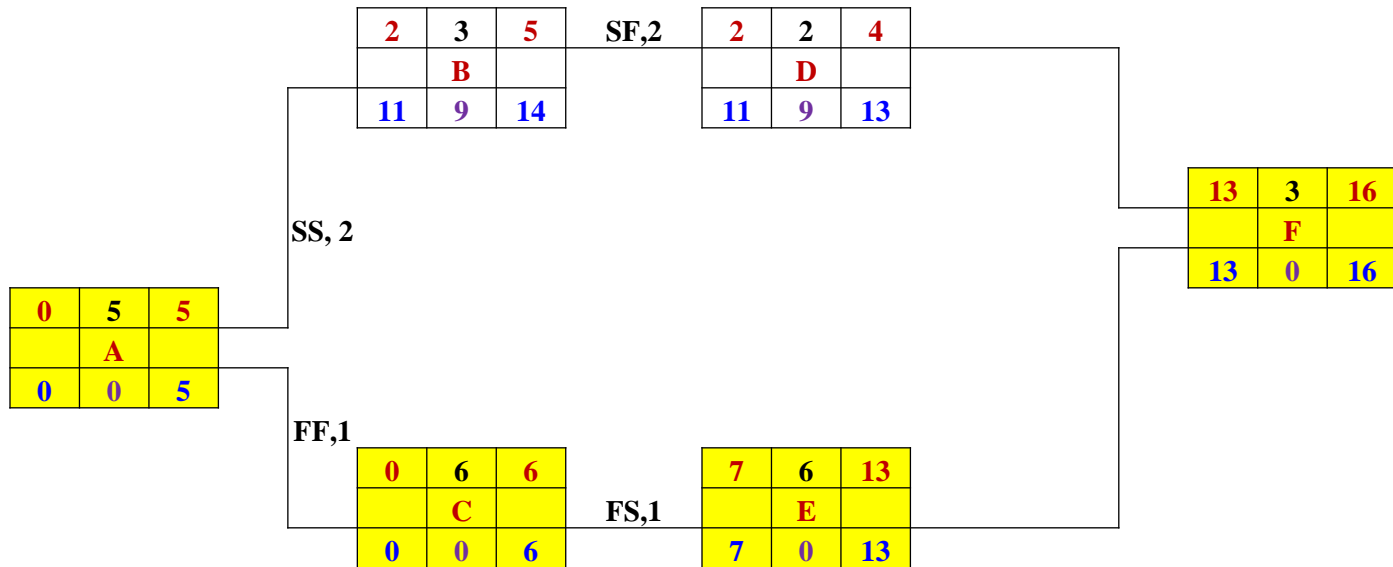
$$LS_B = LF_B - D_B = 14 - 3 = 11$$

$$LF_A = \text{Min}(B, C) \left\{ \begin{array}{l} \text{Terminal Time} = 16 \\ LS_B - SS_{AB} + D_A = 11 - 2 + 5 = 14 \\ LF_C - FF_{AC} = 6 - 1 = 5 \end{array} \right\} = 5$$

$$LS_A = LF_A - D_A = 5 - 5 = 0$$

# Contd.

32





## Step-3: FF Calculations

33

$$FF_i = \text{Min}(\text{all } j) \begin{pmatrix} ES_j - EF_i - FS_{ij} \\ ES_j - ES_i - SS_{ij} \\ EF_j - EF_i - FF_{ij} \\ EF_j - ES_i - SF_{ij} \end{pmatrix}$$

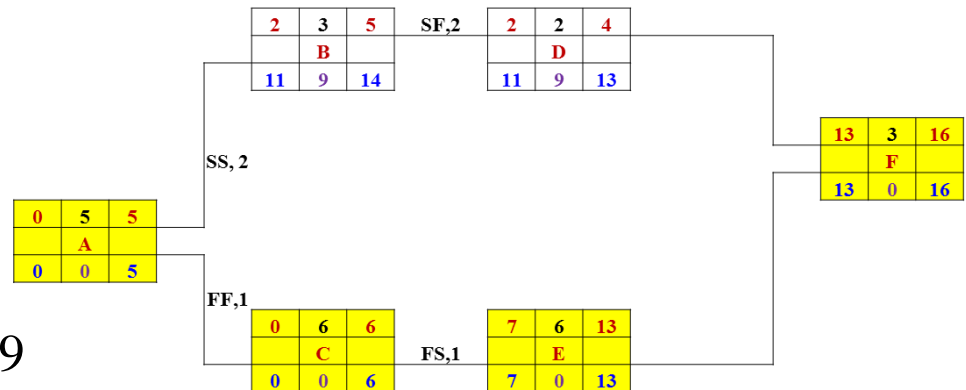
$$FF_A = \text{Min}(B, C) \left\{ \begin{array}{l} ES_B - ES_A - SS_{AB} = 2 - 0 - 2 = 0 \\ EF_C - EF_A - FF_{AC} = 6 - 5 - 1 = 0 \end{array} \right\} = 0$$

$$FF_B = EF_D - ES_B - SF_{BD} = 4 - 2 - 2 = 0$$

$$FF_C = ES_E - EF_C - FS_{CE} = 7 - 6 - 1 = 0$$

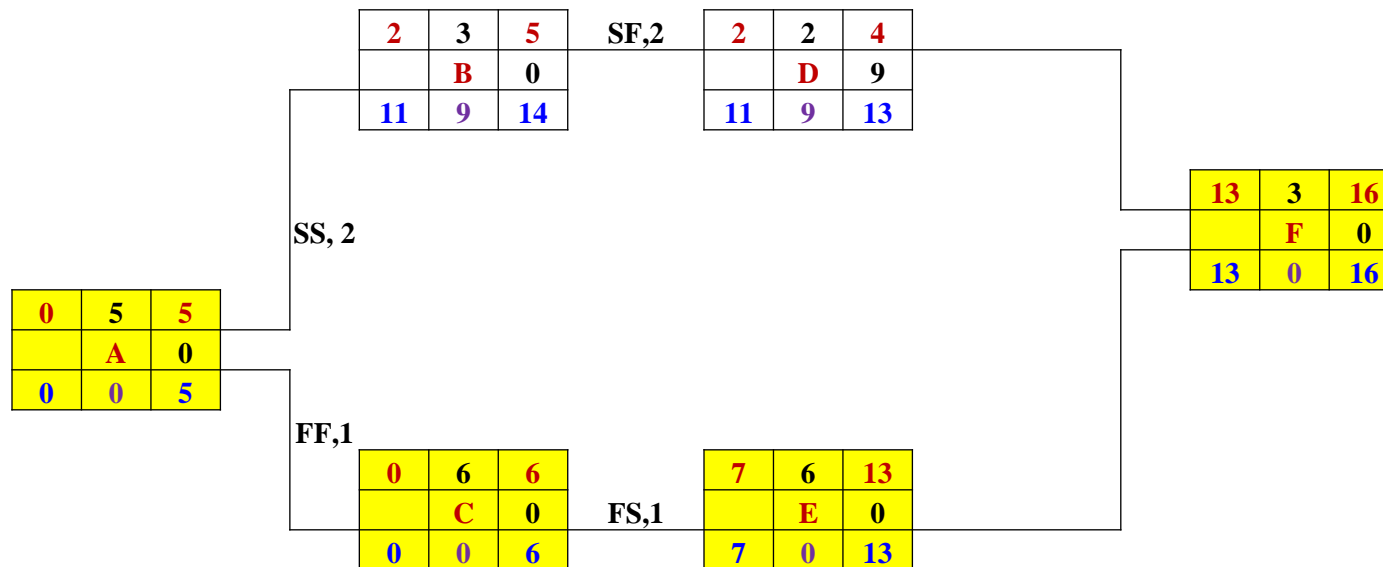
$$FF_D = ES_F - EF_D - FS_{DF} = 13 - 4 - 0 = 9$$

$$FF_E = ES_F - EF_E - FS_{EF} = 13 - 13 - 0 = 0$$



# Final Answer

34



Critical Activities: A; C; E; and F

Critical Path: A-C-E-F

# Hammock Activity



35

- An activity that extends from one activity to another, but which has no estimated duration of its own.
- It is time-consuming and requires resources, but its duration is controlled, not by its own nature, but by the two activities between which it spans.
  - Example: activity “A” ends on day 3 and activity “C” begins on day 10 and there is a set of activities that are summarized as activity “B” (the hammock activity) that must be done between activity “A” and activity “C.”
  - Activity “B” doesn’t have a specific duration—it has the duration of the time between day 3 and day 10.
  - If activity “A” takes longer than expected and ends on day 4, then the duration of activity “B” is now the duration of time between day 4 and day 10.
- Its ES and LS times are determined by the activity where it begins and its EF and LF times are dictated by the activity at its conclusion.

# Time-Scaled Networks

36

- Time-scaled networks are merely extension of bar charts
- Each activity is shown as **a one dimensional line** rather than as a two dimensional box
- The **horizontal length is equal to its estimated time duration** (beginning at its ES and ending with its EF values)
- **Vertical solid (or dashed) lines** indicate **sequential dependence** of one activity on another
- **Float times** are shown as **horizontal dashed lines**

# Free and Total Floats

37

## Free Float or activity Float

*Free float* is the amount of time that an **activity's completion time may be delayed** without affecting the earliest start of **succeeding activity**

Free float is “owned” by an individual activity

## Total Float or Path Float

*Total float* is the amount of time that an **activity's completion may be delayed** without affecting the earliest start of **any activity on the network critical path**

Total float is shared by all activities along a slack path

Total path float time for activity (i-j) is the total float associated with a path

# Advantages and Disadvantages

38

## Advantages

- Very suitable device for **checking daily project needs of different resources**, and for the advance detection of conflicting demands among activities for the same resource
- Useful for project **financial management** applications

## Disadvantages

- Because it is drawn by **manual drafting** methods, the level of effort needed to modify and update them is very large
- **Dependencies** among activities are **not always so obvious** as they are on the activity on node network.

# Problem-1

39

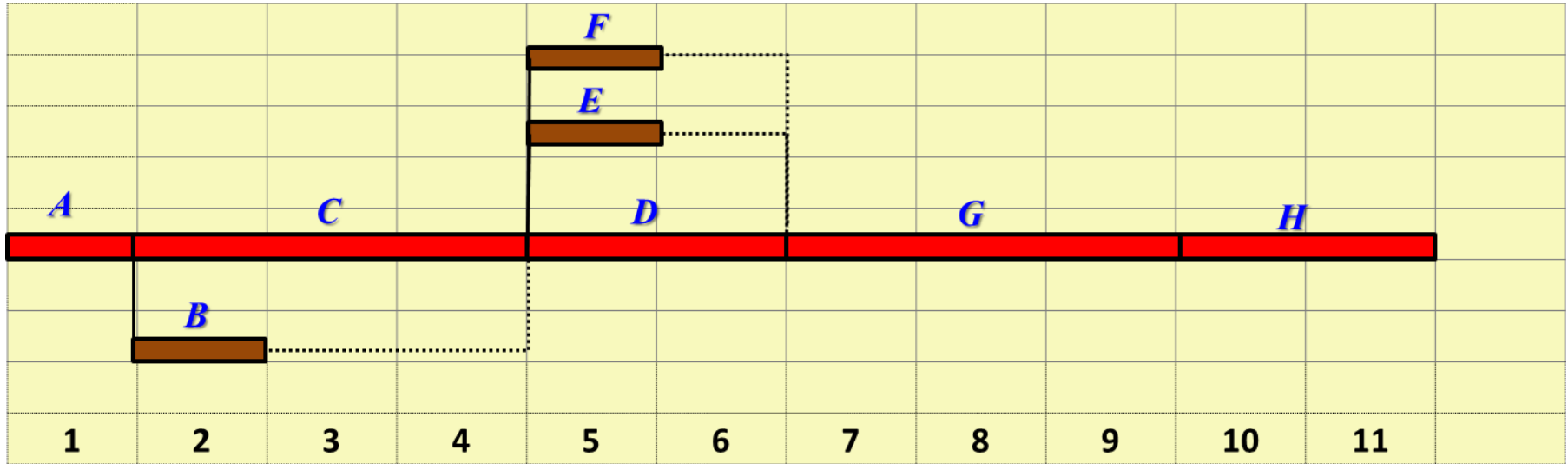
The following activity list represents the job logic and the durations of activities for a market survey project. Draw a time-scaled network for the project, determine project time and calculate the activities float times.

<i>Activity</i>	<i>Description</i>	<i>predecessors</i>	<i>Duration, week</i>
<i>A</i>	<i>Plan survey</i>	—	<i>1</i>
<i>B</i>	<i>Hire personnel</i>	<i>A</i>	<i>1</i>
<i>C</i>	<i>Design questionnaire</i>	<i>A</i>	<i>3</i>
<i>D</i>	<i>Train personnel</i>	<i>B, C</i>	<i>2</i>
<i>E</i>	<i>Select samples of customers</i>	<i>C</i>	<i>1</i>
<i>F</i>	<i>Print questionnaire</i>	<i>C</i>	<i>1</i>
<i>G</i>	<i>Conduct survey</i>	<i>D,E,F</i>	<i>3</i>
<i>H</i>	<i>Analyze results</i>	<i>G</i>	<i>2</i>

Activity	Description	predecessors	Duration, week
A	Plan survey	—	1
B	Hire personnel	A	1
C	Design questionnaire	A	3
D	Train personnel	B, C	2
E	Select samples of customers	C	1
F	Print questionnaire	C	1
G	Conduct survey	D,E,F	3
H	Analyze results	G	2

# Solution

40



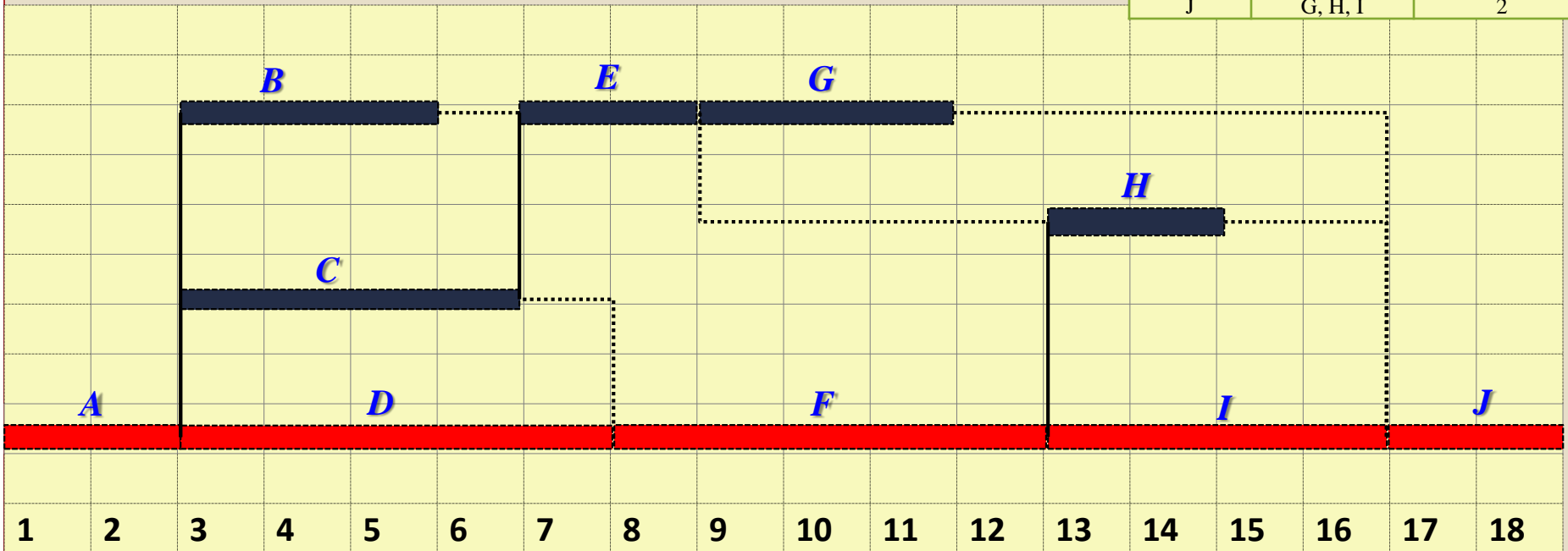
- Project completion time = **11** working days
- Critical Path: **A-C-D-G-H**.

Activity	A	B	C	D	E	F	G	H
Total float	0	2	0	0	1	1	0	0
Free float	0	2	0	0	1	1	0	0



# Problem-2

Activity	Depends on	Duration (day)
E	B, C	2
B	A	3
C	A	4
G	E	3
F	C, D	5
A	None	2
H	E, F	2
D	A	5
I	F	4
J	G, H, I	2



- Project completion time = **18** working days
- Critical Path: **A, D, F, I, J**.

Activity	A	B	C	D	E	F	G	H	I	J
Total float	0			0		0	5	2	0	0
Free float	0			0		0	5	2	0	0

# Shortening of Project Duration

42

- Reducing scope (or quality)
- Adding resources
- Concurrency (perform tasks in parallel)
- Substitution of activities

# Further Reading

43

Read more about the scheduling network models from:

1. Moder J., Phillips, C., and Davis, E. Project Management with CPM, PERT, and Precedence Diagramming, 3rd Edition.
2. Jimmie W. Hinze. “Construction Planning and Management,” Fourth Edition, 2012, Pearson.

# Thank You

44

## Questions Please

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