Time Planning and Control

Precedence Diagram

Precedence Diagramming

ES	D	EF
	Activity ID	
LS	TF	LF

- An important extension to the original activity-on-node concept appeared around 1964.

- The sole relationship used in ***PERT/CPM network*** is finish to start type of dependency, with $Fs_{ij} = 0$.

- Precedence diagramming includes precedence relationships among the activities. In Addition, one may specify a ***"lag time"*** associated with any of the precedence relationships, which can be used to account for overlapping times among activities.

- The computation of activity times (published in 1973) is more complex than AON.

ES	D	EF
Activity ID		
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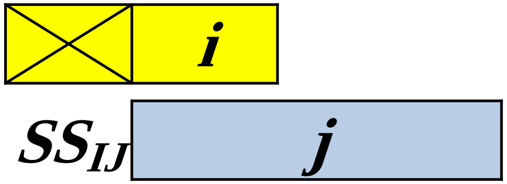
Lag / Lead Times

- In many cases, there is a delay between the completion of one activity and the start of another following or there is a need to show that one activity will ***overlap*** another in some fashion.
- 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.***
- **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.

Precedence Diagramming Relationships Types and constraint

1. Start-to-Start (SS_{ij})

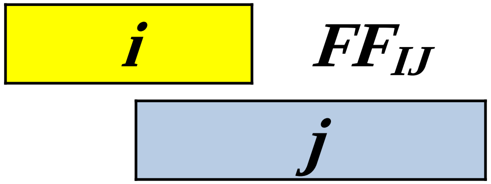
[(j) cannot start till (i) starts]



SS_{ij} is equal to the minimum number of time units that must be completed on the preceding activity (i) prior to the start of the successor (j). "Lag" is always applied to SS relation.

2. Finish-to-Finish (FF_{ij})

[(j) cannot finish till (i) finishes]



FF_{ij} is equal to the minimum number of time units that must remain to be completed on the successor (j) after the completion of the predecessor (i).

Precedence Diagramming Relationships Types and constraint

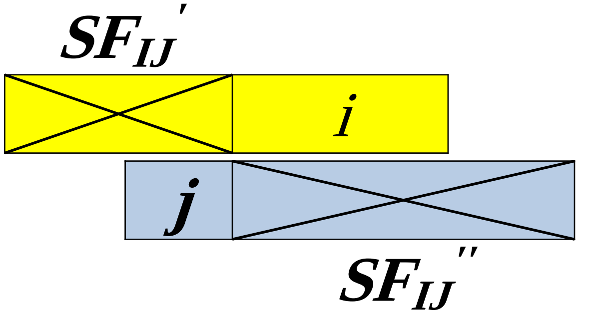
3. Finish-to-Start (FS_{ij})

[(j) cannot start till (i) finishes]

FS_{ij} is equal to the minimum number of time units that must transpire from the completion of the predecessor (i) prior to the start of the successor (j).

4. Start-to-Finish (SF_{ij})

[(j) cannot finish till (i) starts (rare)]

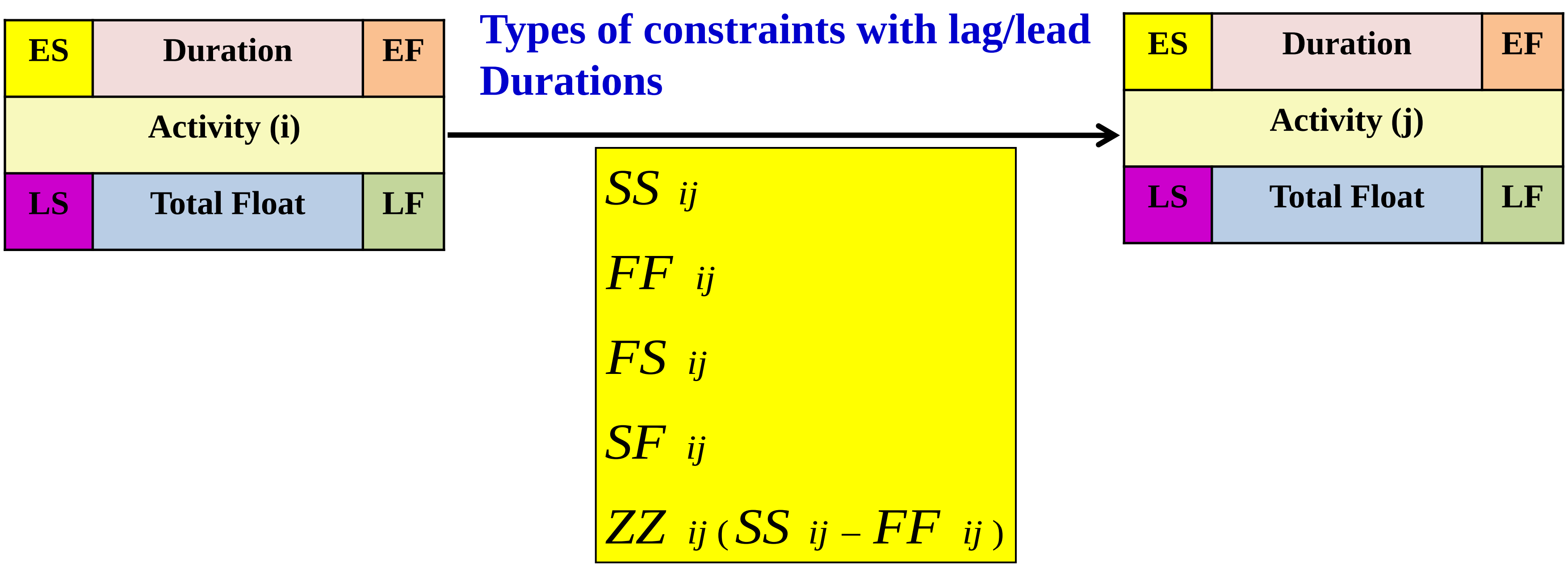


SF_{ij} is equal to the minimum number of time units that must transpire from the start of the predecessor (i) to the completion of the successor (j).

Precedence Diagramming Relationships Types and constraint

5. Start-to-Start and Finish-to-Finish (ZZ_{ij}):

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.



Precedence Diagram Computation

ES	D	EF
	Activity ID	
LS	TF	LF

Forward Pass Computations

$$[1]\ ES_j = \max_{\text{all } i} \begin{cases} \underline{\text{Initial Time}} \\ EF_i + FS_{ij} \\ ES_i + SS_{ij} \\ EF_i + FF_{ij} - D_j \\ ES_i + SF_{ij} - D_j \end{cases}$$

$$[2]\ EF_j = ES_j + D_j$$

Precedence Diagram Computation

ES	D	EF
	Activity ID	
LS	TF	LF

Backward Pass Computations

Terminal Time

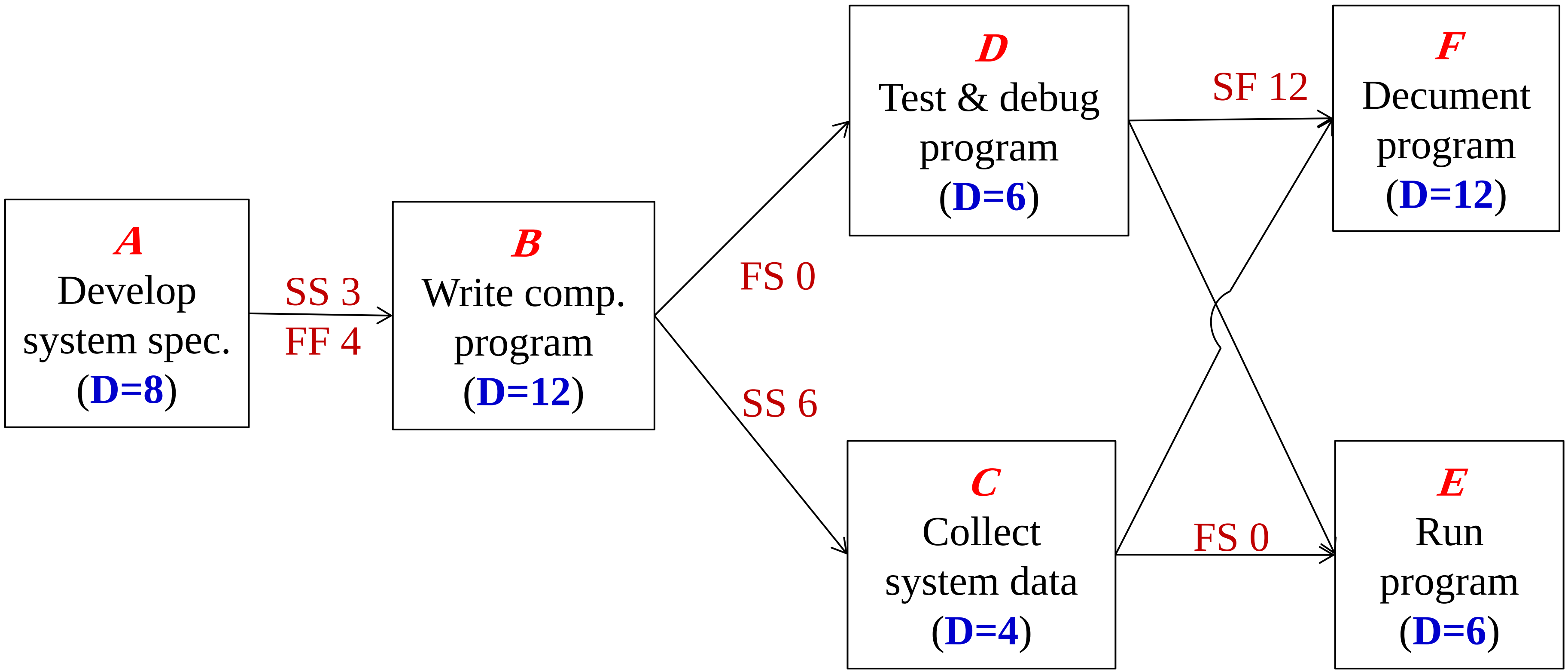
$$[3]\ LF_i = \text{Min. all}_j \left\{ \begin{array}{l} LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{array} \right\}$$

[4] $LS_i = LF_i - D_i$

Precedence Diagramming Calculations

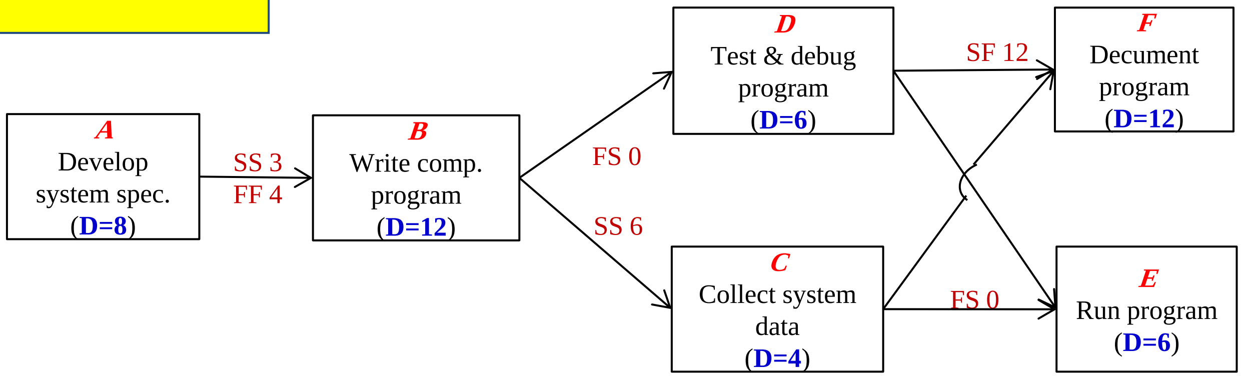
EXAMPLE

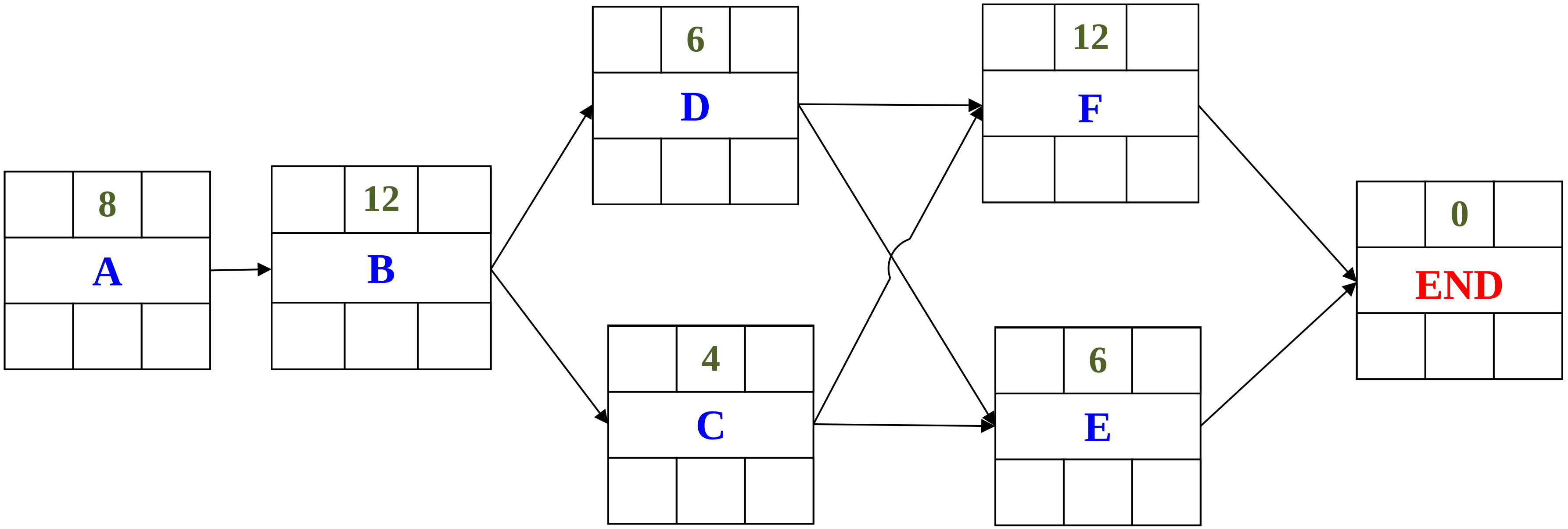
For the given precedence diagram, complete the forward and backward pass calculations. Assume the project starts at T=0, and no splitting on activities is allowed. Also assume that the project latest allowable completion time (project duration) is scheduled for 30 working days.



Precedence Diagramming Calculations

- ***AON diagram***





Precedence Diagramming Calculations

Example Computation

Forward Pass Computations

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

$$[2]\ EF_j = ES_j + D_j$$

Activity A

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

$$EF_A = ES_A + D_A = 0 + 8 = 8$$

Activity B

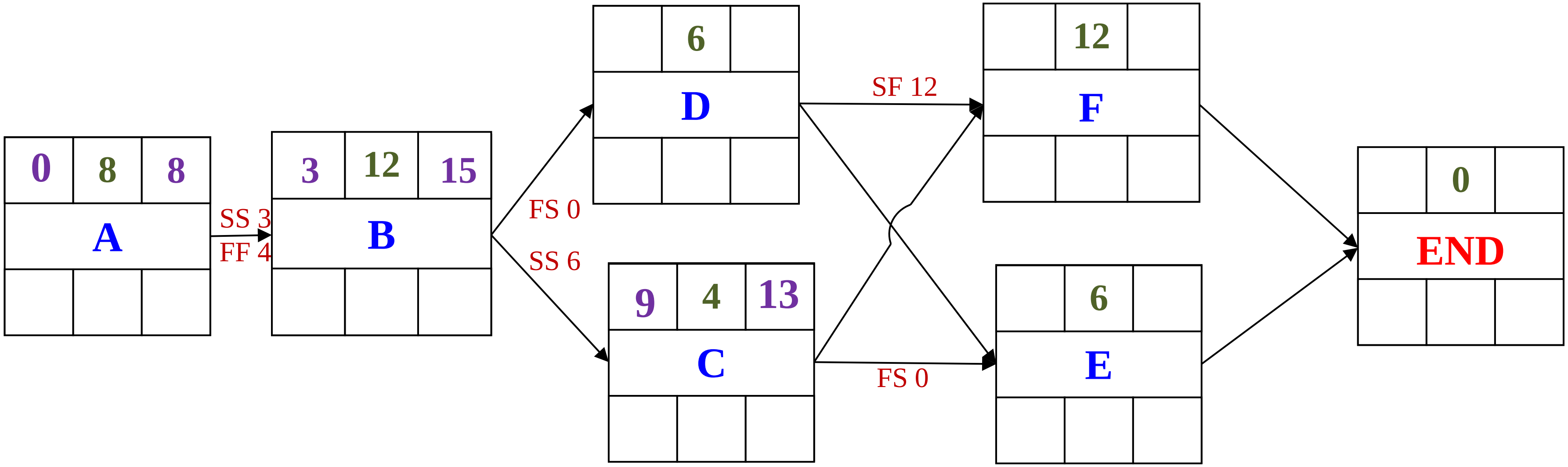
$$ES_B = Max\ (A)\begin{Bmatrix} \text{Initial Time} = 0 \\ ES_A + SS_{AB} = 0 + 3 = 3 \\ EF_A + FF_{AB} - D_B = 8 + 4 - 12 = 0 \end{Bmatrix}$$

$$EF_B = ES_B + D_B = 3 + 12 = 15$$

Activity C

$$ES_C = Max\ (B)\begin{Bmatrix} \text{Initial Time} = 0 \\ ES_B + SS_{BC} = 3 + 6 = 9 \end{Bmatrix}$$

$$EF_C = ES_C + D_C = 9 + 4 = 13$$



Precedence Diagramming Calculations

Example Computation

Forward Pass Computations

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

$$[2]\, EF_j = ES_j + D_j$$

Activity D

$$ES_D = Max(B)\begin{Bmatrix} \text{Initial Time} = 0 \\ EF_B + FS_{BD} = 15 + 0 = 15 \end{Bmatrix}$$

$$EF_D = ES_D + D_D = 15 + 6 = 21$$

Activity E

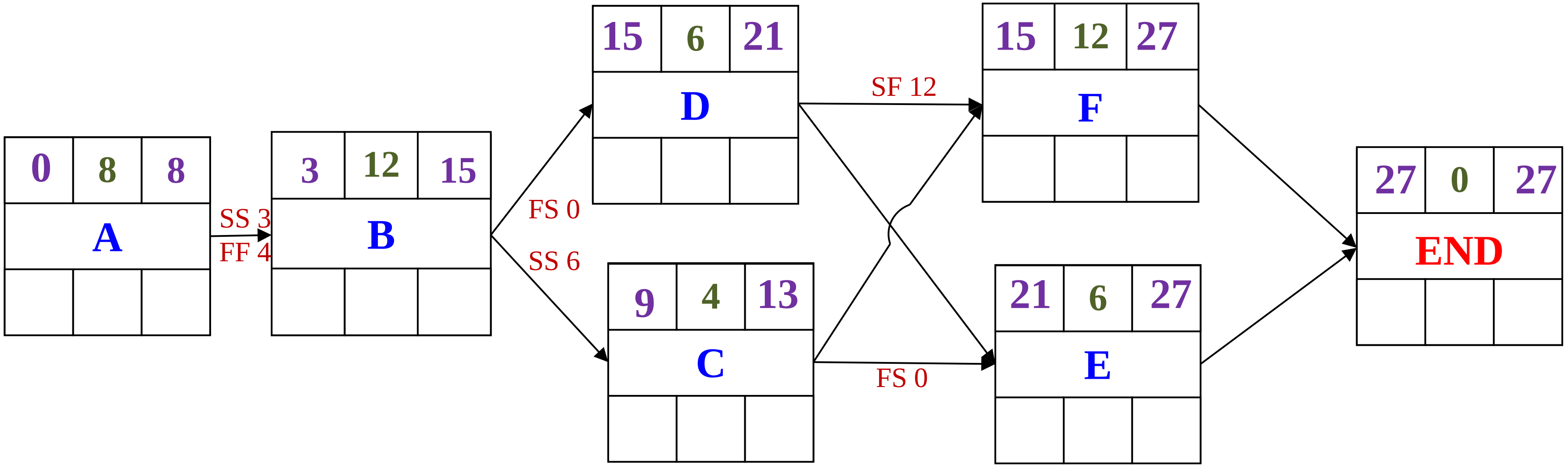
$$ES_E = Max\,(C, D)\begin{Bmatrix} \text{Initial Time} = 0 \\ EF_D + FS_{DE} = 21 + 0 = 21 \\ OR,\ EF_C + FS_{CE} = 13 + 0 = 13 \end{Bmatrix}$$

$$EF_E = ES_E + D_E = 21 + 6 = 27$$

Activity F

$$ES_F = Max\,(D)\begin{Bmatrix} \text{Initial Time} = 0 \\ ES_D + SF_{DF} - D_F = 15 + 12 - 12 = 15 \\ OR,\ EF_C + FS_{CF} = 13 + 0 = 13 \end{Bmatrix}$$

$$EF_F = ES_F + D_F = 15 + 12 = 27$$



Precedence Diagramming Calculations

Example Computation

Backward Pass Computations

$$[3]\ LF_i = Min_{(all\ j)} \begin{Bmatrix} \text{Terminal Time} \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{Bmatrix}$$

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

Activity F

$$LF_F = \text{Terminal Time} = 30$$
$$LS_F = LF_F - D_F = 30 - 12 = 18$$

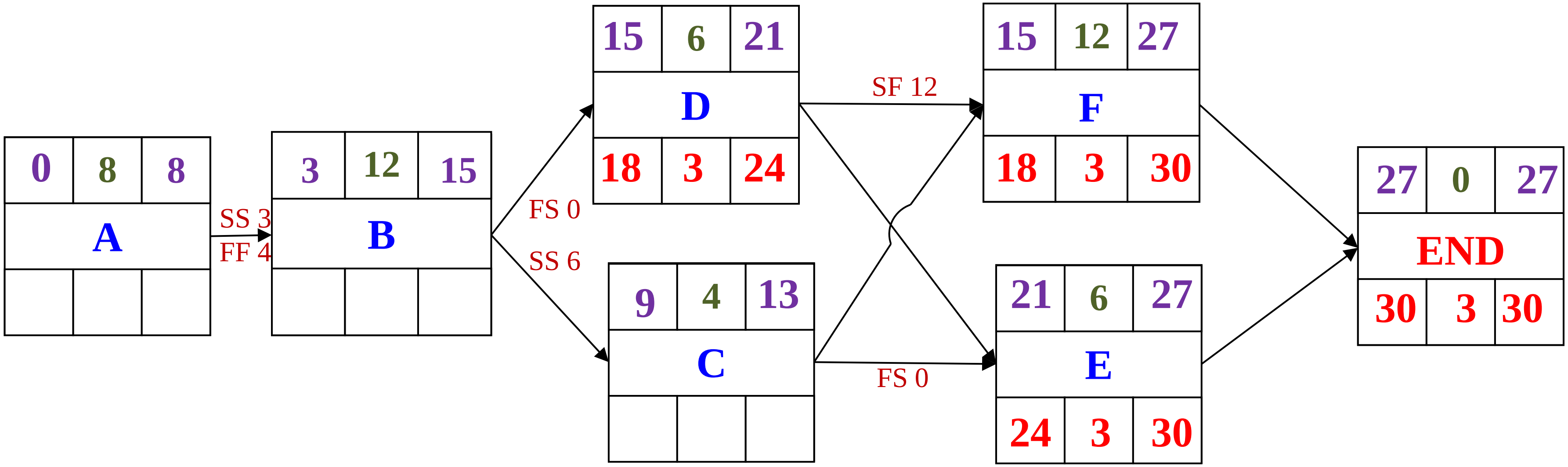
Activity E

$$LF_E = \text{Terminal Time} = 30$$
$$LS_E = LF_E - D_E = 30 - 6 = 24$$

Activity D

$$LF_D = Min_{(E,F)} \begin{Bmatrix} \text{Terminal Time} = 30 \\ LS_E - FS_{DE} = 24 - 0 = 27 \\ OR \\ LF_F - SF_{DF} + D_D = 30 - 12 + 6 = 24 \end{Bmatrix}$$

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



Precedence Diagramming Calculations

Example Computation

Backward Pass Computations

$$[3]\ \boldsymbol{LF_i = Min\ (all_j)\begin{Bmatrix} Terminal\ \ Time\ \ e \\ LS_j - FS_{ij} \\ LF_j - FF_{ij} \\ LS_j - SS_{ij} + D_i \\ LF_j - SF_{ij} + D_i \end{Bmatrix}}$$

$$[4]\ \boldsymbol{LS_i = LF_i - D_i}$$

Activity C

$$LF_C = Min\ (E)\begin{Bmatrix} Terminal\ \ Time\ \ e = 30 \\ LS_E - FS_{CE} = 24 - 0 = 24 \\ Or \\ LS_F - FS_{CF} = 18 - 0 = 18 \end{Bmatrix}$$

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

Activity B

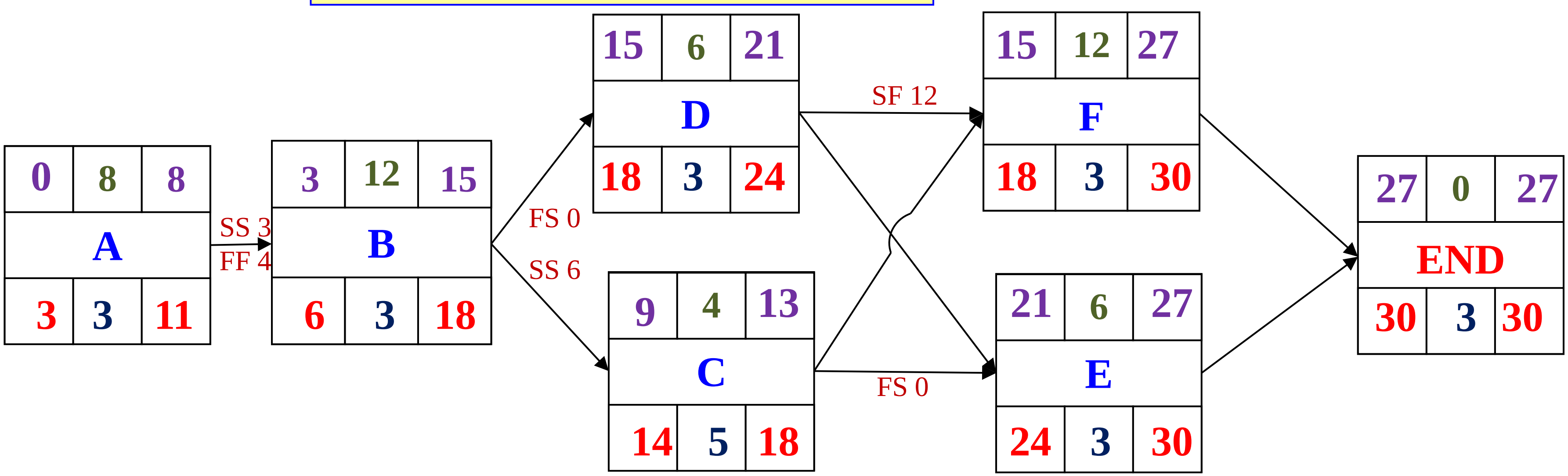
$$LF_B = Min\ (_{C,D})\begin{Bmatrix} Terminal\ \ Time\ \ e = 30 \\ LS_D - FS_{BD} = 18 - 0 = 18 \\ OR \\ LS_C - SS_{BC} + D_B = 14 - 6 + 12 = 20 \end{Bmatrix}$$

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

Activity A

$$LF_A = Min\ (_B)\begin{Bmatrix} Terminal\ \ Time\ \ e = 30 \\ LF_B - FF_{AB} = 18 - 4 = 14 \\ LS_B - SS_{AB} + D_A = 6 - 3 + 8 = 11 \end{Bmatrix}$$

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



Precedence Diagramming Calculations

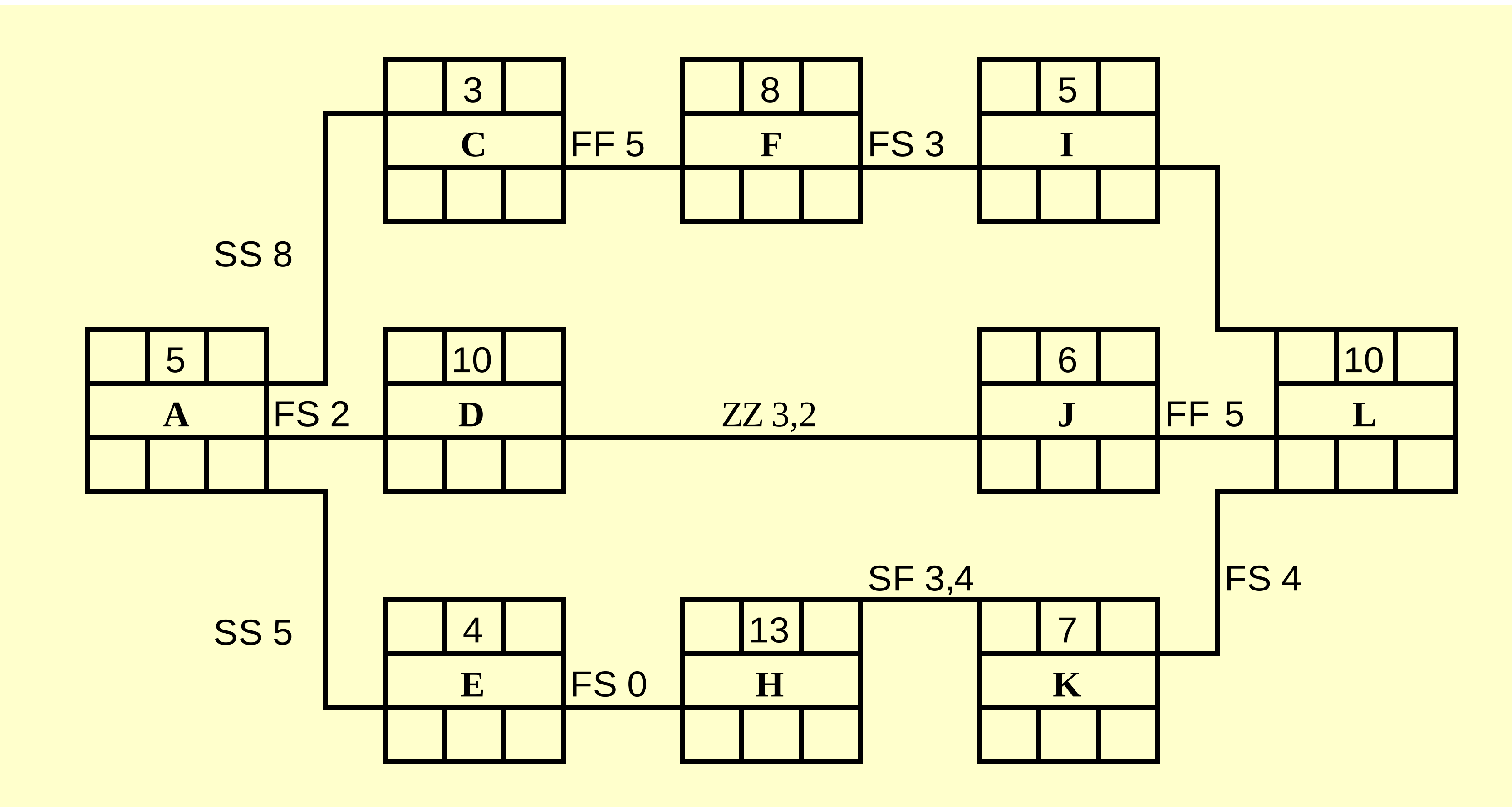
Computing Slack Time (Float Time)

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	No
B	3	15	6	18	3	No
C	9	13	14	18	5	No
D	15	21	15	21	3	No
E	21	27	24	30	3	No
F	15	27	18	30	3	No

Example 2

ES	D	EF
	Activity ID	
LS	TF	LF

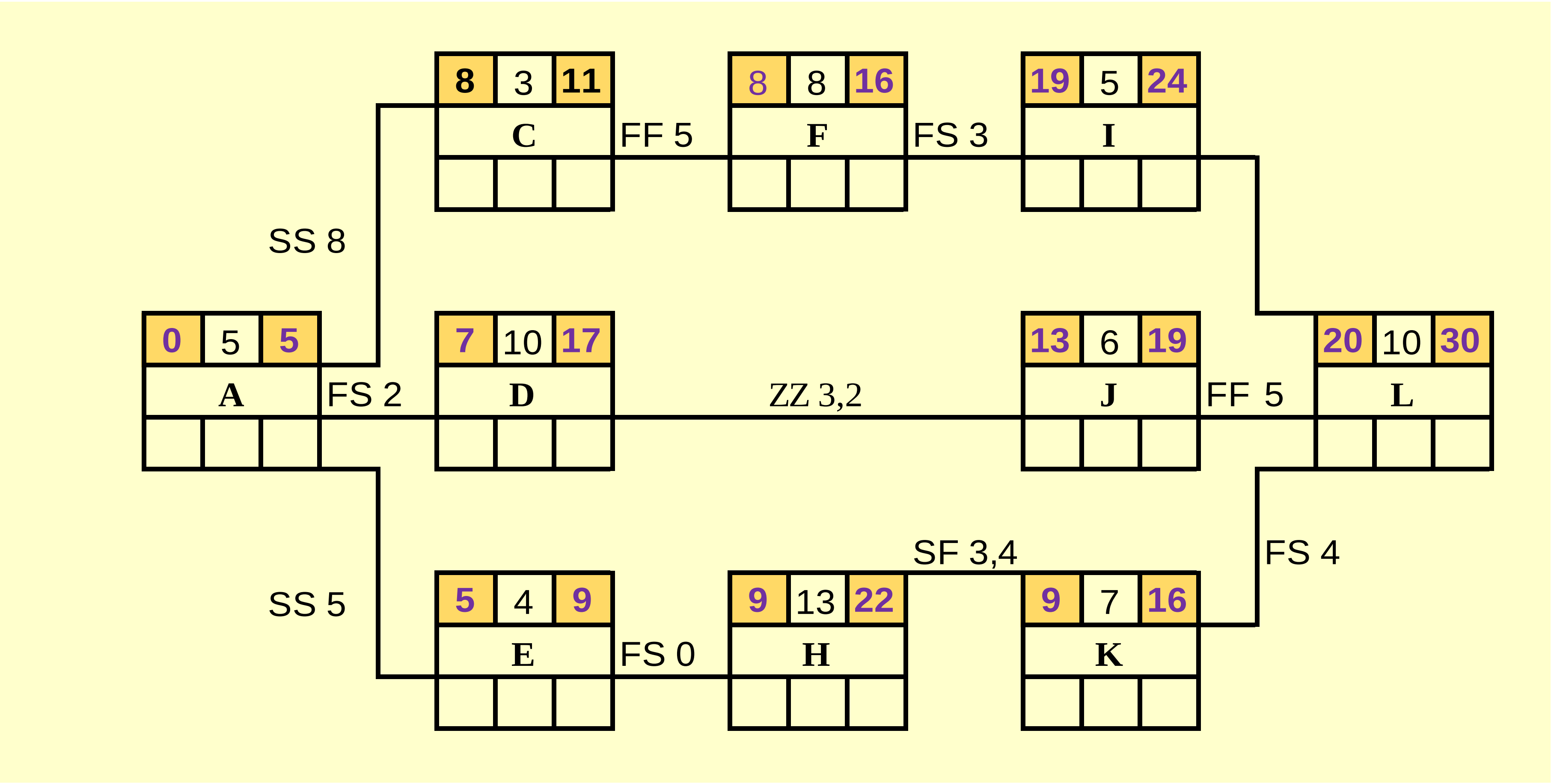
Given the precedence network for a small engineering project with activity durations in working days, it is required to compute the activity times (ES, EF, LS, and LF) and total floats (TF) and then indicate the critical activities.



Example 2

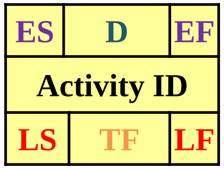
Calculate the Early activity times (ES and EF).

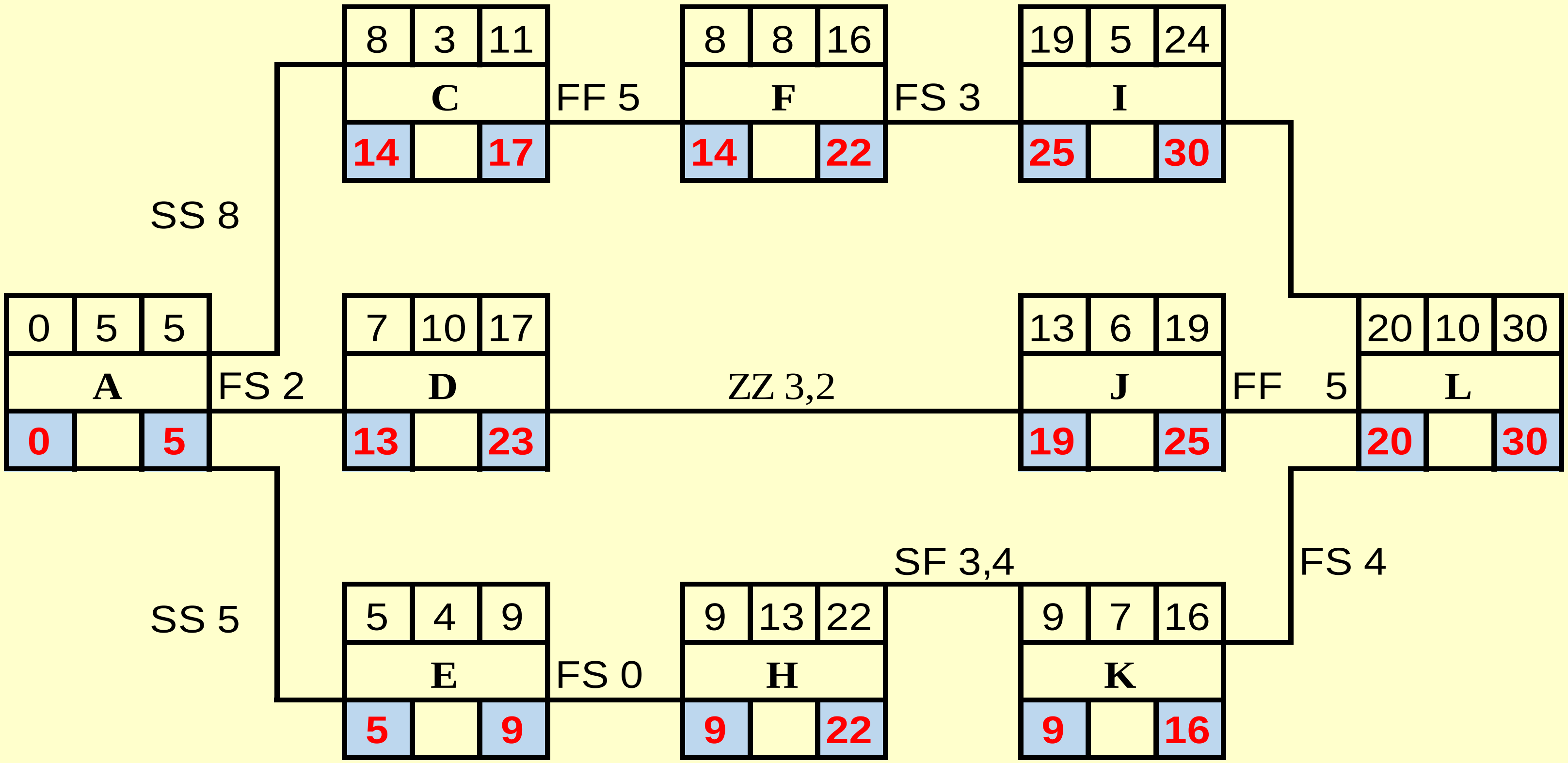
ES	D	EF
	Activity ID	
LS	TF	LF



Example 2

Calculate the late activity times (LS and LF).

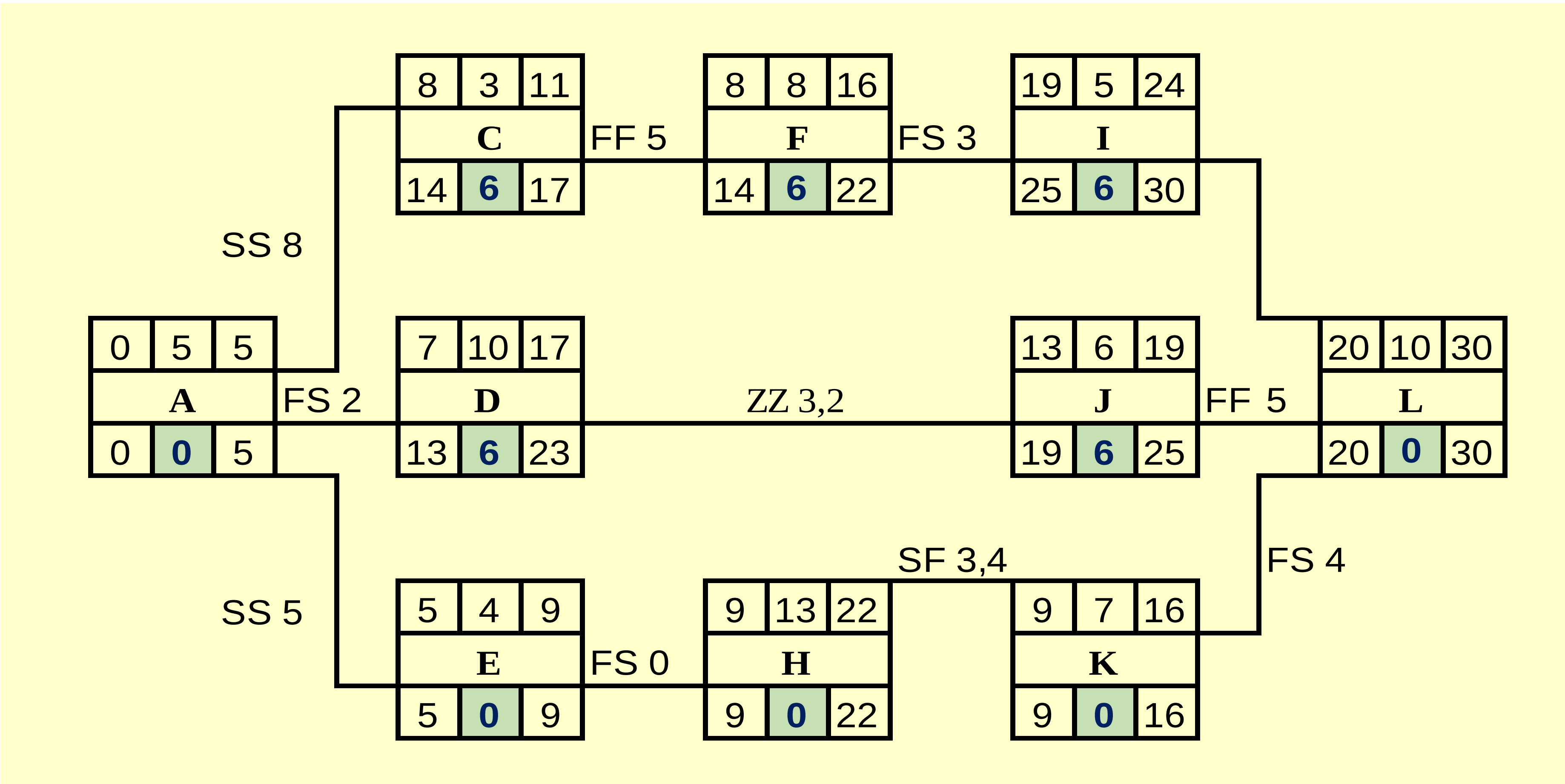




Example 2

Calculate Total Float for an activity.

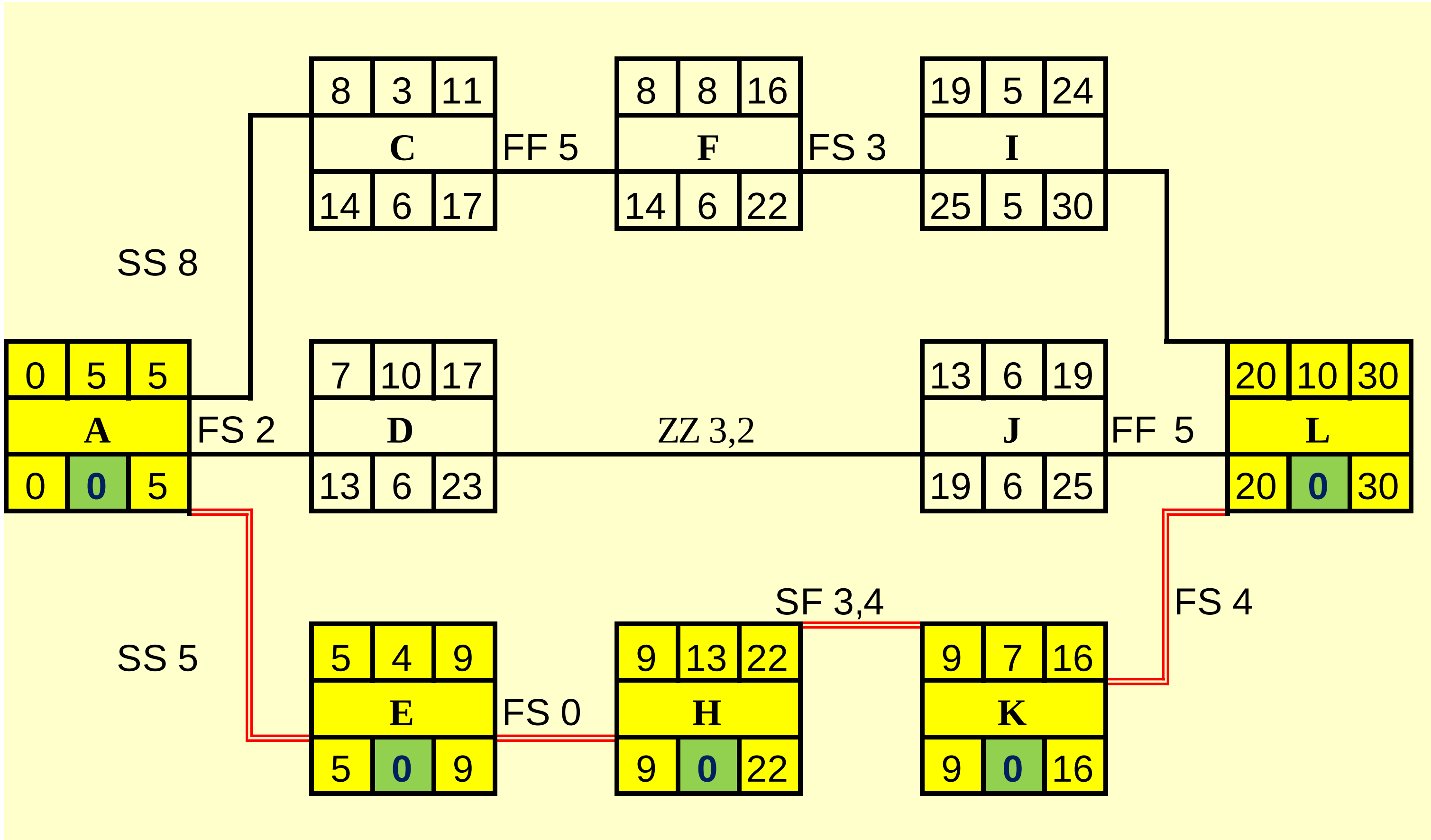
ES	D	EF
Activity ID		
LS	TF	LF



Example 2

Indicate the critical activities.

ES	D	EF
	Activity ID	
LS	TF	LF



Notes on Schedule

HAMMOCK ACTIVITY

- 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.
- 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.
- ***Examples:*** Dewatering, Haul road maintenance

Notes on Schedule

■ MILESTONES

- Milestones are points in time that have been identified as being important intermediate ***reference points*** during the accomplishment of the work.

- Milestone events can include dates imposed by the customer for the finishing of certain tasks as well as target dates set by the project manager for the completion of certain segments of the work.

Notes on Schedule

■ ***MILESTONES***

- Distinctive ***geometric figure*** is preferred to represent a milestone *(circles, ovals, or other shapes)* can be used.

- Any information pertaining to a milestone and considered to be useful may be entered.

Notes on Schedule

Reducing Project Duration

How can you shorten the schedule?

Via

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