Solution Manual for Real Time System by Jane W. S. Liu

Real Time System by Jane W. S. Liu (Pearson), the book builds on the student's background in **Operating System**, **Embedded System**. It covers techniques for scheduling, resource access control, and validation that are, or are likely to be, widely used in real time computing and communication systems. Each algorithm, protocol, or mechanism is defined by pseudo code or simple rules that can serve as a starting point of implementation. With few exceptions, each scheduling algorithm is accompanied that your application will meet its real time requirement when scheduling according to the algorithm.

Here, in next successive posts, I am going to post solutions for the same Text-book (Real Time System by Jane W. S. Liu). If you find any difficulty or wants to suggest anything, feel free to comment...:)

Link: http://targetiesnow.blogspot.in/p/solution-manual-for.html

Real Time System by Jane W. S. Liu Chapter 3.1 Solution

Q. 3.1: Because sporadic jobs may have varying release times and execution times, the periodic task model may be too inaccurate and can lead to undue under utilization of the processor even when the inter release times of jobs are bounded from below and their executions are bounded from above. As an example, suppose we have a stream of sporadic jobs whose inter release times are uniformly distributed from 9 to 11. Their execution times are uniformly distributed from 1 to 3.

a. What are the parameters of the periodic task if we were to use such a task to model the stream?

Solution: http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu.html

Real Time System by Jane W. S. Liu Chapter 3.2 Solution

Q.3.2: Consider the real-time program described by the psuedo code below. Names of jobs are in italic.

At 9 AM, *start*: have breakfast and go to office;
At 10 AM,
    if there is class,
    teach;
    Else, *help* students;
When *teach* or *help* is done, *eat_lunch*;
Until 2 PM, *sleep*;
If there is a seminar,
    If topic is interesting,
        listen;
    Else, *read*;
Else
    write in office;
When seminar is over, *attend* social hour;
discuss;
jog;

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_29.html

Real Time System by Jane W. S. Liu Chapter 3.3 Solution

Q.3.3: *job_1* | *job_2* denotes a pipe: The result produced by *job_1* is incrementally consumed by *job_2*. (As an example, suppose that *job_2* reads and displays one character at a time as each handwritten character is recognized and placed in a buffer by *job_1*.) Draw a precedence constraint graph to represent this producer-consumer relation between the jobs.

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_8405.html?spref=fb

Real Time System by Jane W. S. Liu Chapter 3.4 Solution

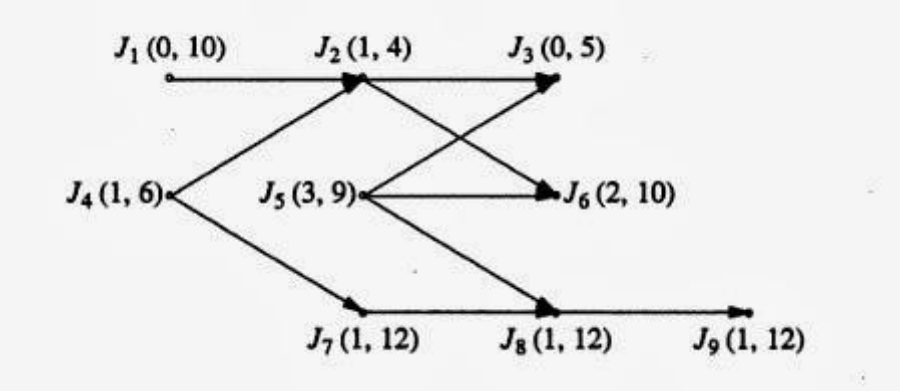
Q.3.4: Draw a task graph to represent the flight control system described in Figure 1-3.

a) Assume the producers and consumers do not explicitly synchronize (i.e., each consumer uses the latest result generated by each of its producers but does not wait for the completion of the producer.)

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3066.html

Real Time System by Jane W. S. Liu Chapter 4.1 Solution

Q.4.1: The feasible interval of each job in the precedence graph in figure 4P-1 is given next to its name. The execution time of all jobs are equal to 1.

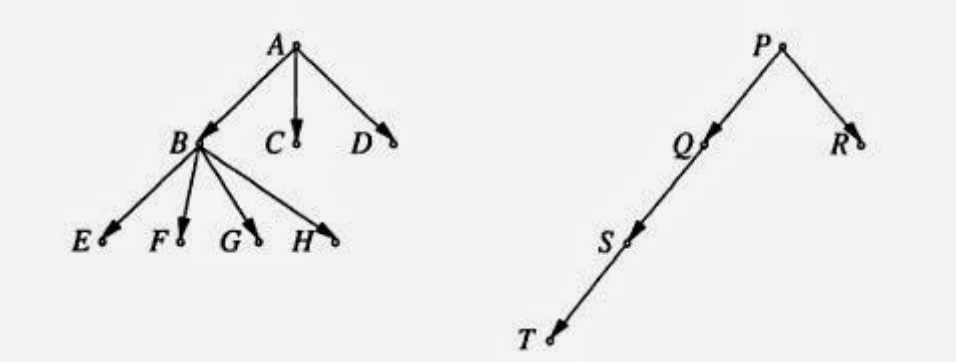


a) Find the effective release times and deadlines of the jobs in the precendence graph in Figure 4P-1.

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_9175.html

Real Time System by Jane W. S. Liu Chapter 4.2 Solution

Q.4.2: The execution times of the jobs in the precedence graph in figure 4P-2 are all equal to 1, and their release times are identical. Give a non preemptive optimal schedule that minimizes the completion time of all jobs on three processors. Describe briefly the algorithm you used to find the schedule.



Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_4082.html

Real Time System by Jane W. S. Liu Chapter 4.4 Solution

Q.4.4: Consider a system that has five periodic tasks, A, B, C, D, and E, and three processors P_1, P_2, P_3. The periods of A, B, and C are 2 and their execution times are equal to 1. The periods of D and E are 8 and their execution times are 6. The phase of every task is 0, that is, the first job of the task is released at time 0. The relative deadline of every task is equal to its period.

a) Show that if the tasks are scheduled dynamically on three processors according to the LST algorithm, some jobs in the system cannot meet their deadlines.

Sol:

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_1862.html

Real Time System by Jane W. S. Liu Chapter 4.5 Solution

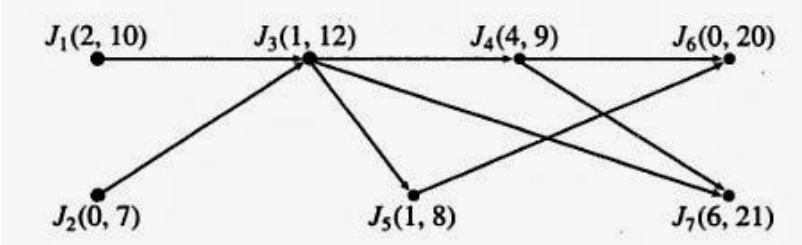
Q.4.5: A system contains nine non-preemptable jobs named Ji, for i = 1, 2, ..., 9. Their execution times are 3, 2, 2, 2, 2, 4, 4, 4, 4, and 9, respectively, their release times are equal to 0, and their deadlines are 12. J_1 is the immediate predecessor of J_9, and J_4 is the immediate predecessor of J_5, J_6, J_7, and J_8. There are no other precedence constraints. For all the jobs, J_i has a higher priority than J_k if i < k.

a) Draw the precedence graph of the jobs.

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_6447.html

Real Time System by Jane W. S. Liu Chapter 4.7 Solution

Q.4.7: Consider the set of jobs in Figure 4-3. Suppose that the jobs have identical execution time. What maximum execution time can the jobs have and still can be feasible scheduling on one processor? Explain your answer.



Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3971.html

Real Time System by Jane W. S. Liu Chapter 5.1(a)(b) Solution

Q.5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemption should be kept small.

a) (6, 1), (10, 2), and (18, 2)

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_5855.html

Real Time System by Jane W. S. Liu Chapter 5.1(c)(d) Solution

Q5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemptions should be kept small.

c) (4, 0.5), (5, 1.0), (10, 2), and (24, 9)

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_3069.html

Real Time System by Jane W. S. Liu Chapter 5.1(e)(f) Solution

Q.5.1: Each of the following systems of periodic tasks is scheduled and executed according to a cyclic schedule. For each system, choose an appropriate frame size. Preemptions are allowed, but the number of preemptions should be kept small.

e) (5, 0.1), (7, 1.0), (12, 6), and (45, 9)

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_793.html

Real Time System by Jane W. S. Liu Chapter 5.2 Solution

Q.5.2: A system uses the cyclic EDF algorithm to schedule sporadic jobs. The cyclic schedule of periodic tasks in the system uses a frame size of 5, and a major cycle containts 6 frames. Supose that the initial amounts of slack time in the frames are 1, 0.5, 0.5, 0.5, 1, and 1.

a. Suppose that a sporadic job S(23, 1) arrives in frame 1, sporadic jobs S_2(16, 0.8) and S_3(20, 0.5) arrive in frame 2. In which frame are the accepted sporadic jobs scheduled?

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_2408.html

Real Time System by Jane W. S. Liu Chapter 5.3 Solution

Q.5.3: Draw a network flow graph that we can use to find a preemptive cyclic schedule of the periodic tasks

T1 = (3,7,1); T2 = (4,1); T3 = (6,2.4,8).

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_4437.html

Real Time System by Jane W. S. Liu Chapter 5.4 Solution

Q.5.4: A system contains the following periodic tasks:

T1 = (5,1); T2 = (7,1,9); T3 = (10,3) and T4 = (35,7).

If the frame size constraint (5-1) is ignored, what are the possible frame sizes ?

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_8734.html

Real Time System by Jane W. S. Liu Chapter 6.4 Solution

Q.6.4: A system T contains for periodic tasks, (8, 1), (15, 3), (20, 4), and (22, 6). Its total utilization is 0.80. Construct the initial segment in the time interval (0, 50) of a rate-monotonic schedule of the system.

Solution http://targetiesnow.blogspot.in/2013/10/real-time-system-by-jane-w-s-liu_1931.html

Real Time System by Jane W. S. Liu Chapter 6.5 Solution

Q.6.5: Which of the following systems of periodic tasks are schedulable by the rate-monotonic algorithm? By the earliest-deadline-first algorithm? Explain your answer.

a. T = {(8, 3), (9, 3), (15, 3)}

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6564.html

Real Time System by Jane W. S. Liu Chapter 6.8 Solution

Q.6.8: a) Use the time demand analysis method to show that the rate-monotonic algorithm will produce a feasible schedule of the tasks (6,1), (8,2) and (15,6).

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6444.html

Real Time System by Jane W. S. Liu Chapter 6.6 Solution

Q.6.6: Give two different explanation of why the periodic tasks (2,1), (4,1) and (8,2) are schedulable by the rate monotonic algorithm.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2.html

Real Time System by Jane W. S. Liu Chapter 6.7 Solution

Q.6.7: This problem is concerned with the performance an behavior of rate-monotonic an earliest-deadline-first algorithms.

a. Construct the initial segments in the time interval (0, 750) of a rate-monotonic schedule and an earliest-deadline-first schedule of the periodic tasks (100, 20) (150, 50), and (250, 100) whose total utilization is 0.93.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_714.html

Real Time System by Jane W. S. Liu Chapter 6.9 Solution

Q.6.9: The Periodic Tasks (3,1), (4,2), (6,1) are scheduled according to the rate-monotonic algorithm.

a) Draw Time Demand Function of the tasks

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_4718.html

Real Time System by Jane W. S. Liu Chapter 6.10 Solution

Q.6.10: Which of the following fixed-priority task is not schedulable? Explain your answer.

T1(5,1) T2(3,1) T3(7,2.5) T4(16,1)

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_3.html

Real Time System by Jane W. S. Liu Chapter 6.11 Solution

Q.6.11: Find the maximum possible response time of tasks T4 in the following fixed-priority system by solving the equation w4(t) = t, iteratively

T1 = (5,1), T2 = (3,1), T3 = (8,1.6), and T4 = (18,3.5)

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6263.html

Real Time System by Jane W. S. Liu Chapter 6.13 Solution

Q.6.13: Find the length of an in-phase level-3 busy interval of the following fixed-priority tasks:

T_1 = (5, 1), T_2 = (3,1), T_3 = (8, 1.6), and T_4 = (18, 3.5)

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_4.html

Real Time System by Jane W. S. Liu Chapter 6.15 Solution

Q.6.15: A system consists of three periodic tasks: (3, 1), (5, 2), and (8, 3).

a. What is the total utilization?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_9426.html

Real Time System by Jane W. S. Liu Chapter 6.21 Solution

Q.6.21: a) Use the time-demand analysis method to show that the set of periodic tasks {(5, 1), (8, 2), (14, 4)} is schedulable according to the rate-monotonic algorithm.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_1209.html

Real Time System by Jane W. S. Liu Chapter 6.23 Solution

Q.6.23: A system contains tasks T1 = (10,3), T2 = (16,4), T3 = (40,10) and T4 = (50,5). The total blocking due to all factors of the tasks are b1 = 5, b2 = 1, b3 = 4 and b4 = 10, respectively. These tasks are scheduled on the EDF basis. Which tasks (or task) are (or is) schedulable? Explain your answer.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_5.html

Real Time System by Jane W. S. Liu Chapter 6.31 Solution

Q.6.31: Interrupts typically arrive sporadically. When an interrupt arrives, interrupt handling is serviced (i.e., executed on the processor) immediately and in a nonpreemptable fashion. The effect of interrupt handling on the schedulability of periodic tasks can be accounted for in the same manner as blocking time. To illustrate this, consider a system of four tasks: T_1 = (2.5, 0.5), T_2 = (4, 1), T_3 = (10, 1), and T_4 = (30, 6). Suppose that there are two streams of interrupts. The interrelease time of interrupts in one stream is never less than 9, and that of the other stream is never less than 25. Suppose that it takes at most 0.2 units of time to service each interrupt. Like the periodic tasks interrupt handling tasks (i.e., the stream of interrupt handling jobs) are given fixed prioriteies. They have higher priorities than the periodic tasks, and the one with a higher rate (i.e., shorter minimum interrelease time) has a higher priority.

a. What is the maximum amount of time each job in each periodic task may be delayed from completion by interrupts?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_3964.html

Real Time System by Jane W. S. Liu Chapter 7.1 Solution

Q.7.1: A system contains three periodic tasks. They are (2.5,1), (4,0.5), (5,0.75), and their total utilization is 0.475.

a) The system also contains a periodic server (2,0.5). The server is scheduled with the periodic tasks rate-monotonically.

1) Suppose that the periodic server is a basic sporadic server. What are the response time of the following two aperiodic jobs: One arrives at 3 and has execution time 0.75, and one arrives at 7.5 and has execution time 0.6.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_6.html

Real Time System by Jane W. S. Liu Chapter 7.2 Solution

Q.7.2: A system contains three periodic tasks. They are (3,1), (4,0.5), (5,0.5).

The task system also contains a sporadic server whose period is 2. The sporadic server is scheduled with the periodic tasks rate-monotonically. Find the maximum utilization of the server if all deadlines of periodic tasks are surely met.

1) Suppose that the server in part (a) is a pure polling server. What are the response time of the following two aperiodic jobs: one arrives at 2.3 and has execution time 0.8 , and one arrives at 12.7 and has execution time 0.6 ?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2439.html

Real Time System by Jane W. S. Liu Chapter 7.3 Solution

Q.7.3: Consider a system containing the following periodic tasks: T1 = (10,2), T2 = (14,3) and T3 = (21,4). A periodic server of period 8 is used to schedule aperiodic jobs.

a) Suppose that the server and the tasks are scheduled rate-monotonically.

1) If the periodic server is a deferrable server, how large can its maximum execution budget be ?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_7.html

Real Time System by Jane W. S. Liu Chapter 7.4 Solution

Q.7.4: Consider a system that contains two periodic tasks T1 = (7,2) and T2 = (10,3). There is a bandwidth preserving server whose period is 6. suppose that the periodic tasks and the server are scheduled rate-monotonically.

a) Suppose that the server is deferrable server.

1) What is the maximum server size ?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_8.html

Real Time System by Jane W. S. Liu Chapter 7.5 Solution

Q.7.5: Suppose that the periodic tasks in the previous problem are scheduled along with a server on the earliest deadline first basis.

a) What is the maximum server size if the server size if the server is a deferrable server? Is this size a function of the period of the server? If not, why not? If yes, what is the best choice of server size?

b) What is maximum server size if the server is a total bandwidth server?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_5481.html

Real Time System by Jane W. S. Liu Chapter 7.19 Solution

Q.7.19: Davis *et al.*, suggested a dual priority scheme for scheduling aperiodic jobs in the midst of periodic tasks. According to dual priority scheme, the system keeps three bands of priority, each containing one or more priority levels. The highest band contains real time priorities: they are for hard real time tasks. Real time priorities are assigned to hard real time tasks according to some fixed priority scheme. The middle priority band is for aperiodic jobs. The lowest priority band is also hard real time tasks. Specifically, when jobs $J_{i,k}$ in a periodic task Ti = (pi, ei, Di) is released , it has a priority in the lowest priority band until its priority promotion time. At its priority promotion time, its priority is raised to its real time priority. Let Wi denote the maximum response time of all jobs in Ti when they execute at the real time priority of the task. The priority promotion time of each job is Yi = Di - Wi from its release time. Since Wi can be computed off line or at admission control time, the release promotion time Yi for jobs in each tasks Ti needs to be computed only once. By delaying as much as possible the scheduling of every hard real time jobs at its real time priority, the scheduler automatically creates slacks for aperiodic jobs.

a) Give an intuitive argument to support the claim that this scheme will not cause any periodic job to miss its deadline if the system of periodic tasks is schedulable.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu.html

Real Time System by Jane W. S. Liu Chapter 7.23 Solution

Q.7.23: Suppose that the intervals between arrivals of sporadic jobs are known to be in the range (a,b). The execution time of each sporadic job is at most e (<= a) units.
Suppose relative deadlines of sporadic jobs are equal to a. You are asked to design a bandwidth preserving server that will be scheduled rate monotonically with other periodic tasks. Sporadic jobs waiting to be completed are executed on the first in first out basis in the time intervals where the periodic server is scheduled. Choose the period and utilization of this server so that all sporadic jobs will be completed by their deadlines and the utilization of the sporadic server is as small as possible.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_9.html

Real Time System by Jane W. S. Liu Chapter 8.1 Solution

Q.8.1: A system contains five jobs. There are three resources X, Y and Z. The resources required of the jobs are listed below.

J_1: [X;2]

J_2 : NONE

J_3 : [Y;1]

J_4 : [X;3 [Z;1]]

J_5 : [Y;4 [Z;2]]

The priority J_i is higher than the priority of J_j for i < j. What are the maximum blocking times of the jobs under the nonpreemptable critical section protocol and under the priority ceiling protocol?

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_10.html

Real Time System by Jane W. S. Liu Chapter 8.2 Solution

Q.8.2: A system contains the following four periodic tasks. The tasks are scheduled by the rate monotonic algorithm and the priority ceiling protocol.

$T_1 = (3,0.75)$ $b_1 = 0.9$
$T_2 = (3.5,1.5)$ $b_2 = 0.75$
$T_3 = (6,0.6)$ $b_3 = 0.9$
$T_4 = (10,1)$

b_i is the blocking time of T_i. Are the tasks schedulable ? Explain your answer.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_1120.html

Real Time System by Jane W. S. Liu Chapter 8.3 Solution

Q.8.3: Consider a fixed priority system in which there are five tasks Ti, for i = 1, 2, 3, 4 and 5, with decreasing priorities. There are two resources X and Y. The critical sections of T_1,T_2, T_4 and T_5 are [Y;3], [X;4], [Y;5 [X;2]] and [X;10] respectively. (Note that T_3 does not require any resource.) Find the blocking time b_i(rc) of the tasks.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_2315.html

Real Time System by Jane W. S. Liu Chapter 8.7 Solution

Q.8.7: A system contains the following five periodic tasks. The tasks are scheduled rate monotonically.

$T_1 = (6, 3, [X;2])$
$T_2 = (20, 5, [Y;2])$

$T_3 = (200, 5, [X;3 [Z;1]])$

$T_4 = (210, 6, [Z;5 [Y;4]])$

Compare the schedulability of the system when the priority ceiling protocol is used versus the NPCS protocol.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_11.html

Real Time System by Jane W. S. Liu Chapter 8.10 Solution

Q.8.10: Given a system consisting of the following tasks whose periods, execution times and resource requirements are given below.

T_1 = (2, 0.4, [X, 3; 0.3])

T_2 = (3, 0.75, [X, 1; 0.3][Y, 1; 0.4])

T_3 = (6, 1.0, [Y, 1; 0.4][Z, 1; 0.5 [X, 1; 0.4]])

T_4 = (8, 1.0, [X, 1; 0.5][Y, 2; 0.1] [Z, 1; 0.4])

There are 3 units of X, 2 units of Y and 1 unit of Z. The tasks are scheduled by EDF algorithm and the stack based protocol.

a) Find the preemption ceiling of each resource and the maximum blocking time for each task.

Solution http://targetiesnow.blogspot.in/2013/11/real-time-system-by-jane-w-s-liu_12.html