ASSIGNMENT 3 CMPT 300 SUMMER 2014

1. Consider the following slightly modified description of Smaug's world as described in assignment 2. Each modification is shown in **BOLD CAPITALIZED** text.
The fierce dragon Smaug is guarding his hoard of treasure. Smaug is a large and perpetually hungry dragon with a very sensitive nose. Smaug likes to sleep on his bed of treasure. He only wakes up to eat, to battle any foolhardy treasure hunter that decides to try and kill him to win all of his treasure, or to play with any thief that tries to sneak in and steal some of his treasure.
Smaug is a magical dragon who lives in a cave. The only entrance to Smaug's cave is in a secluded valley. When a sheep or a cow wanders into that secluded valley it is enchanted and cannot leave the valley. When anyone wishes to visit Smaug's cave they have to travel along a magical path that seems to go on forever in order to find the valley.
When Smaug has no visitors he eats and sleeps. Smaug is particularly fond of sheep as a tasty snack. His nose is so sensitive he only wakes up to eat if he smells three sheep and one cow in the valley. While he is eating those four beasts, he ignores any additional beast that wanders into the valley and becomes enchanted. When he is done eating the four beasts he takes one deep breath to see if he can smell another snack before he goes back to sleep on top of his hoard. If he smells another snack of three sheep and one cow he will eat it before he takes another deep breath then has another snack (if it is available). If he does not smell a snack he goes to sleep.
This quiet existence is occasionally interrupted by the arrival of visitors. Visitors to Smaug's cave are trying to obtain some of Smaug's treasure. Smaug's treasure is more important to Smaug that any tasty snack. If Smaug is asleep (not napping) his nose will wake him up when any visitor is walking along the magical path. If Smaug is awake (eating a snack) Smaug will detect any new visitors on the path when he takes a deep breath after finishing his snack. If there is a visitor walking along the path Smaug will interact with a visitor then go to sleep for a short 10 minute nap (when the time is up he will wake up again). After his nap he will take a deep another deep breath. If there are any visitors Smaug will interact with the next visitor, then take another ten minute nap. This will continue until all visitors have been interacted with. Sometimes Smaug wakes up and smells one or more visitors walking along the path AND a snack is waiting to be eaten. If he smells a visitor, he will interact with the visitor first. When he wakes up from his nap after interacting with the last he will then eat his snack. However, Smaug is a confident dragon. If he is eating when the visitor or visitors arrive, he will finish his partially finished snack of four beasts before he interacts with the visitor. After Smaug finishes dealing with all visitors and snacks he is exhausted and goes to sleep.
Smaug has two types of visitors, treasure hunters who plan to battle Smaug and kill him to obtain all his treasure and thieves who plan to sneak in and steal some of his treasure. When visitors arrive outside the valley that contains the entrance to Smaug's cave they must find the single magically concealed path into the valley. The spell on the path will cause then to wander through the valley not reaching Smaug's cave until Smaug is ready to meet them (after he smells them). When Smaug is ready, the spell allows the next visitor to see the entrance to the cave and enter the cave. When a treasure hunter enters Smaug's cave, Smaug fights the treasure hunter. Smaug is never killed by a treasure hunter but some fight well enough that Smaug gets tired and allows them to leave with a reward of 10 JEWELS for providing him with exercise. If Smaug defeats a treasure hunter he will let the treasure hunter leave (instead of eating him) if the treasure hunter bribes him with 5 jewels. Since

treasure hunters do not like to be eaten they always take five jewels with them just in case they are defeated (most are). When a thief enters Smaug's cave Smaug plays with the thief. If the thief wins the game he is sent home with 8 JEWELS, if the thief loses he must pay 20 JEWELS to leave the cave. No thief is stupid enough to come without 20 JEWELS in his pocket. Smaug enjoys playing games with thieves, but finds fighting treasure hunters to be a boring task. Therefore, Smaug will always choose to let a thief come to play before he lets a treasure hunter come to fight. If there are no treasure hunters or thieves he will eat any available snack.

Assume each of the following

- The first process in the simulation will spawn smaug, and will spawn (over time) each of the cows, sheep, hunters and thieves.
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- Sheep arrive (new sheep processes are created) at random times. The length of the interval between the arrivals of successive sheep is drawn from a uniform distribution. The length of interval n is the length of time between the arrival of sheep n and the arrival of sheep n+1.The distribution of possible interval lengths is uniform between 0 seconds and MaximumSheepInterval seconds (0 probability of an arrival interval outside this range).
- Cows arrive (new cow processes are created) at random times. The length of the interval between the arrivals of successive cows is drawn from a uniform distribution. The distribution of possible interval lengths is uniform between 0 seconds and MaximumCowInterval seconds (0 probability of an arrival interval outside this range).
- Similarly, thieves and treasure hunters arrive at random intervals drawn from a uniform distribution. The distribution of possible interval lengths is uniform between 0 seconds and MaximumHunterInterval seconds (0 probability of an arrival interval outside this range).
- Similarly, thieves and treasure hunters arrive at random intervals drawn from a uniform distribution. The distribution of possible interval lengths is uniform between 0 seconds and MaximumHunterInterval seconds (0 probability of an arrival interval outside this range).
- Smaug's treasure initially contains 500 jewels
- The probability that a particular treasure hunter or thief will not be defeated is winProb.
- Your program should request the values of maximumSheepInterval, maximumCowInterval, maximumHunterInterval, maximumThiefInterval and winProb from the user and used those values to initialize your simulation.

Your simulation should terminate when any one of the following conditions is met

Smaug has eaten 36 sheep and 12 cows
Smaug has defeated 48 treasure hunters or 36 thieves
Smaug has no treasure
Smaug has 1000 jewels.

When your simulation terminates you must assure that no zombie (defunct) processes remain. At no time during execution should you have more than 10 zombies. You must also assure that all semaphores and mutexes allocated are released before your simulation terminates. To check if there are semaphores or shared memory still allocated use the ipcs function in LINUX.

Your program should produce output (to the screen) each time something happens. That is when you run your program it should produce output that includes the following messages (in the order they actually happen).

A sheep has been enchanted

A cow has been enchanted
A treasure hunter has entered the valley
A thief has entered the valley
Smaug is going to sleep
Smaug has been woken up
Smaug is eating a sheep
A sheep is born
A cow is born

A sheep has been eaten
A sheep has woken up to be eaten
A sheep is ready to eat.
Sheep grazes for ……….. ms
Cow grazes for ……… ms
Smaug is eating a cow
Smaug is eating a sheep
A cow is born
A cow dies
A cow has been eaten
A treasure hunter has been defeated
A treasure hunter receives treasure
Smaug is fighting a treasure hunter
Smaug is playing with a thief
Smaug's treasure includes …. jewels
A thief has been defeated
A thief receives a jewels
A thief leaves
A treasure hunter leaves
Smaug is playing with a thief
Smaug finished eating one sheep
Smaug finished eating one cow
Smaug has defeated a thief
Smaug has finished a meal (3 sheep processes and 1 cow process have been terminated)
Smaug has finished a battle (1 treasure hunter processe/thread has been terminated)
Smaug has finished a game (1 thief process/thread has been terminated)
Treasure hunters have arrived at Smaug's cave
Smaug has added to his treasure he now has M jewels
Smaug has lost some treasure he now has M jewels
Smaug has no more treasure
You may add additional messages if you wish. When your are debugging your process oriented solution you may also want to keep track of which process is printing the message, by printing the pid along with each message.

a. [50] Implement a C solution to this problem, using processes, shared variables, mutexes and semaphores. Use C libraries sem.h for semaphores and shm.h for shared memory. Make a shared variable to hold a copy of each semaphore counter. Use that shared variable when you check semaphore values, do not use semcntl() to directly check the semaphore values. To protect that shared variable holding the value of the semaphore's counter use a mutex

b. [30] Implement a C solution for part of this problem using threads and semaphores. Use pthreads library and C library semaphore.h

Consider a series of processes that are sharing a variety of resources.

a. [6 points] To avoid or recover from deadlocks it is necessary to be able to determine if a system is likely to deadlock. This decision may be made based on the 'state' of the system. Consider the system with the state given below. In point form, explain what the terms in these equations represent in terms of the system resources and the processes presently running in the system.

$$R = \begin{bmatrix} 5 & 4 & 1 & 4 \\ 6 & 3 & 3 & 1 \\ 2 & 3 & 0 & 2 \\ 1 & 4 & 1 & 3 \\ 3 & 0 & 2 & 4 \\ 2 & 7 & 1 & 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 1 & 1 & 2 \\ 1 & 1 & 0 & 0 \\ 2 & 2 & 0 & 1 \\ 0 & 2 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 0 \end{bmatrix} \quad A = \begin{bmatrix} 0 & 1 & 2 & 1 \end{bmatrix}$$

$$E = \begin{bmatrix} 6 & 8 & 4 & 6 \end{bmatrix}$$

b. [14 points] Use the banker's algorithm to determine if the state given in C is a safe state for this system. For this state of the system can you state that any of the processes will deadlock. If you can state that processes will deadlock which process will deadlock?

2. [20 points] Consider a disk with N tracks numbered from 0 to N-1. Assume that requested sectors are distributed randomly and evenly over the disk.

a) Calculate the probability of a seek of length j when the head is currently positions over track t. HINT: determine the total number of combinations, recognizing that all track positions for the destination of the seek are equally likely.

b) Calculate the probability of a seek of length K

c) Calculate the average number of tracks traversed by a seek HINT: Use the formula for expected value

$$E(x) = \sum_{i=0}^{N-1} i \sum \Pr[x = i]$$

3. Consider a hard disk. The disk has N=128 tracks and 24 sectors per track. The seek time per track is 1 ms. the rotation speed of the disk is 7200rpm.
   a) [4 points] Assume that once the head is in position above the appropriate track you need to wait an average of half a rotation of the disk before the head can read your data. What are the maximum and minimum rotational latency of this disk? What is the average rotational latency of this disk?
   b) [16 points] The following sequence of disk access requests have been received by the computer systems. The numbers are the track numbers. Numbering starts at 0 (the centremost track on the disk). 24, 68, 3, 17, 57, 49, 91, 121
   Determine the actual average seek length for this particular series of accesses based on each of the following algorithms. Assume the read head starts at track 62.
      - Shortest seek first (move the fewest number of tracks to the next entry)
      - Circular Scan algorithm (read while moving from centre to the outside of the disk)
   c) [20 points] Assume that we have 8 of these disks, and we are using RAID 1 to combine these 8 disks. For this particular RAID system 1strip holds 1 track of data. The data for a particular file is loaded into tracks in the following order. Track 0 disk 0, Track 0 disk 1, Track 0 disk 2, Track 0 disk 3, Track 1 disk 0, Track 1 disk 1, … , Track 1 disk 3, …, Track 128 disk 0, …, and Track 128 disk 3 and the same data is simultaneously loaded onto Track 0 disk 4, Track 0 disk 5, Track 0 disk 6, Track 0 disk 7, Track 1 disk 4, Track 1 disk 5, … , Track 1 disk 7, …, Track 128 disk 4, …, and Track 128 disk 7. (This is illustrated in the diagram below). The second 4 four disks are used to create a second copy of the data. Assume that the raid controller is capable of simultaneously accessing all disks. The raid controller contains eight buffers that each holds one track of data. Each of these buffers is reserved for the use of one of the eight disks. Assume that
      i. Transferring one track of data from the disk, to one of the RAID controller's internal buffers takes 0.4 seconds
      ii. A track of data must be completely loaded into the buffer of the RAID controller before it can be transferred to memory using the DMA
      iii. All RAID controller buffers must be emptied (transferred to memory using the DMA) before any RAID controller buffer can be refilled.
      iv. The DMA transfer rate (RAID controller buffer to memory is 4 GBytes per second (1 GByte is 2^{30} bytes)
      v. The DMA setup time is negligible.
      vi. One DMA transfer is used to transfer the contents of one buffer to memory
      vii. The data being read is contiguous beginning at the start of Track 0 on platter 0 and filling a total of 14 tracks.
      viii. Each track holds 60 Mbytes of data.

   How long does it take to transfer the file from the disk to memory? How long would in take to transfer the file if the data were stored on track 0 to track 13 on disk 0 and disk 4? How would your answer differ if you were reading data from memory and writing it to the RAID 1 disks? When you answer each of these questions show step by step how you determined the length of time each transfer would take. Indicate in words what each quantity included in your calculated times represents.