# OPERATING SYSTEMS ASSIGNMENT

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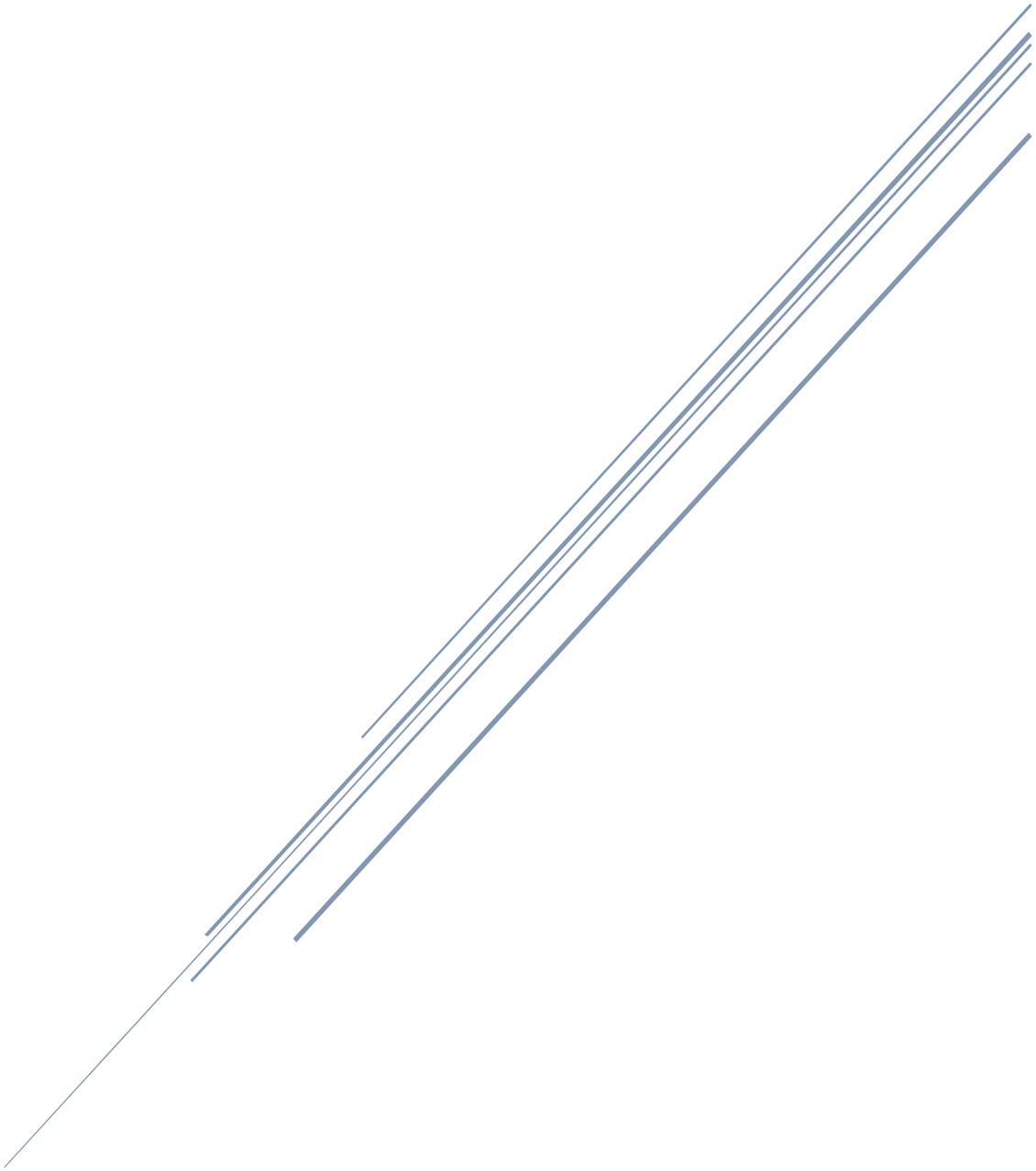

Curtin University

Operating Systems – COMP2006

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# Introduction:

The following report is for the Operating Systems Assignment for 2018. It will discuss about how mutual exclusion has been achieved for processes and threads in shared memory for the *First Reader's and Writer's Problem*. The report will also detail the available test cases I have used to ensure that my program works correctly with the synchronization between different child processes.

# Process SDS:

For the process implementation of the First *Reader's Writers Problem*, mutual exclusion is achieved by having the writer child process wait for all of the readers that are currently executing in their remainder sections (The Reading Part for readers), also by having the reader child processes waiting for a single writer to finish writing and leave its critical section so the readers are allowed to begin reading again since reader's have priority over writers. This waiting is implemented by using semaphores stored in an array and passing that whole array into shared memory.

This waiting is implemented by using semaphores stored in an array and passing that whole array into shared memory. For the readers the critical section happens when you are trying to update the **"readcount"** shared memory variable. This ensures that as long as you have one reader reading, other readers are allowed to come and read. It isn't until the last reader finishes reading, the semaphore that protects **"readcount"** will need to be checked if there are no more readers so it is allowed to unlock the lock for writers to begin writing. In the program the semaphore that refers to this is called ***"mutex_lock"*** which is at index 1 of the semaphore array in the program.

```
sem_wait(&semaphores[1]);   /* Ensure mutual exclusion on readcount */

(*(readcount))++;

if( (*(readcount)) == 1 )
{
    /* rw_mutex to see if any writing is being performed */
    sem_wait(&semaphores[0]);
}
// Unlock so readers can read
sem_post(&semaphores[1]);
```

Figure 2.1: Checking if there is at least one reader reading

```
            // Lock the readcount variable
            sem_wait(&semaphores[1]);
            (*(readcount))--;
            // When there are no more readers currently reading
            if( (*(readcount)) == 0)
            {
                // Unlock the rw_mutex so another reader or writer may use it
                sem_post(&semaphores[0]);
            }
            sem_post(&semaphores[1]);   // Unlocks the mutex so you can read
```

Figure 2.2: Checking to see that there are no more readers

Next, there is the read/write semaphore which is used inside the "if" statement of the reader's function and used at the start and the end of the writer's function. This is used to do the controlling/business logic to prevent the writers from writing if there is at least one reader about to read the **"data_buffer"** and to notify the reader's when the writer has finished executing in its critical section. This semaphore is called **"rw_mutex"** and it is indexed at element 0 in the array.

```
            if( (*(readcount)) == 1 )
            {
                /* rw_mutex to see if any writing is being performed */
                sem_wait(&semaphores[0]);
            }
```

Figure 2.3: When there is one reader it should wait for the writer to finish writing

```
            // When there are no more readers currently reading
            if( (*(readcount)) == 0)
            {
                // Unlock the rw_mutex so another reader or writer may use it
                sem_post(&semaphores[0]);
            }
```

Figure 2.4: When there are no readers reading, release the lock

Next, there is a **"trackerArray"** in shared memory that is used to determine how many readers still have to read a particular element of the array inside the **"data_buffer"**. This needs to be mutually excluded to prevent a race condition for multiple readers from updating the **"trackerArray"** at the same time because the reading is done in the remainder section of the reader. The updating for the **"trackerArray"** doesn't have to be mutually excluded for the **"writer()"** function because it happens when the writer is in its critical section. The semaphore that refers to this is called **"array_track_sem"** which is indexed at element 2 in the array.

```
            sem_wait(&semaphores[2]);
            // Once read, decrement the number of readers left to read this value
            trackerArray[j%BUFFER_SIZE] = trackerArray[j%BUFFER_SIZE] - 1;
            sem_post(&semaphores[2]);
```

Figure 2.5: Ensures mutual exclusion of the trackerArray

Finally, there is a semaphore that protects the write out to file function. This lock used as a precaution to the write out of file function so multiple writers or readers cannot access the **"writeOutFile"** function simultaneously because a writer/reader might finish it's writing early while another one is trying to write out to file. The semaphore that referes to this is called **"write_out_sem"** and is indexed at element 3 in the array.

```
    // Lock Writing out to file
    sem_wait(&semaphores[3]);
    writeOutFile(getpid(), datacount, "reader-%d has finished reading %d pieces
    of data from the data_buffer\n");
    sem_post(&semaphores[3]);
```

Figure 2.6: Write out to file semaphore

The semaphores required, ***"trackerArray"*** and the ***"data_buffer"*** were implemented using shared memory. The following POSIX shared memory functions were used to create shared memory, and their respective functions to close the shared memory:

```
shm_open()
ftruncate()
mmap()
sem_destroy()
sem_unlink()
close()
munmap()
```

# Thread SDS:

In order to achieve mutual exclusion for a multi-threaded solution to the ***"Readers-Writers Problem"***, it uses all the above implementation of semaphores except as mutexes and they are refered as:

```
pthread_mutex_lock(&mutex);
pthread_mutex_unlock(&mutex);
```

Figure 3.1: For binary mutexes they use lock and unlock instead of wait and post

There are also an extra conditional mutex that is used to signal writers. In the reader() function, there is a while loop that checks if the variable **"letWriters"** is positive because it wants a reader to grab the conditioned mutex and waits for the writer's to finish writing so a reader can read. Essentially, when a writer arrives into the while loop, it releases the mutex and waits for the condition to be signalled which is done in the writer's function as soon as the writer has finished reading to let all readers know that they are allowed to begin reading the data buffer. In this case a signal is not used, but instead a broadcast is because the program wants to be able to release the lock for all the readers.

```
// Reader grabs the mutex lock
pthread_mutex_lock(&mutex);
// When a reader wants to read come in
while(sharedMem->letWriters)
{
    // Conditional Wait
    pthread_cond_wait(&cond, &mutex);    // Readers Busy Waiting
}
pthread_mutex_unlock(&mutex);
```

Figure 3.2: Conditioned wait in reader's function

```
pthread_mutex_lock(&mutex);
sharedMem->letWriters--;
sharedMem->writing--;
pthread_cond_broadcast(&cond);
pthread_mutex_unlock(&mutex);
```

Figure 3.3: The end of the writers() function. When a writer is about to finish writing it decrements it's count bringing it back to zero and broadcasts it back to the readers() function to allow readers to start reading.

For all of the threads, the shared resources are stored as global variables to ensure that the reader and writer functions can access them (for locking/unlocking) and incrementing/decrementing shared counters. In order to allocate memory for all the buffers malloc() was used and free() was used to clean up memory, this was used to ensure valgrind didn't give any memory leaks. These functions were used in order to create and clean up the pthreads:

```
pthread_mutex_init()
pthread_create()
pthread_join()
pthread_mutex_destroy()
```

# Testing:

In order to test each implementations of the programs, multiple input files were used. In order to cover all test cases different input files and input arguments were used. The cases I tested for were:

- Standard Test Case
  - FILE_SIZE = 100
  - BUFFER_SIZE = 20

And for each of these cases I test for these command line arguments, The command line arguments are given in the format of (R W t1 t2) all separated by spaces:

- Standard Values given from Assignment Specification
  - 5 2 1 1
- Readers Greater than Writers (Same values as Standard Values)
  - 5 2 1 1
- Zero Sleep Times
  - 1 5 0 0
- Readers Less than Writers
  - 3 5 1 1
- No Readers or Writers:
  - 1 0 3 2
  - 0 1 3 2
- EXTREME (**Note: This test case is too much to fit in the report so please refer to the sim_out file in the electronic submission under TestFiles directory**)
  - 1000 1000 0 0

All of the testing was performed at Curtin University in Building 314 on Level 2 in room 219 on the lab machines. Sepcifically machine a-06.

# Errors:

There were no known errors with running **"Simple Data Sharing"** program between both processes and threads. No memory leaks have been resulted from running these programs as they were all tested with valgrind.

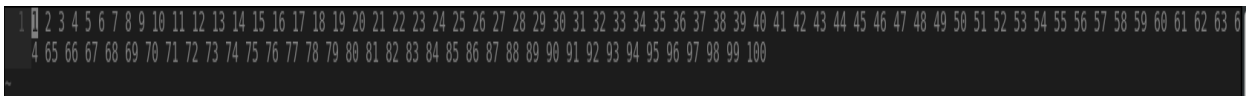
# Side Note:

***Though I do want to point out something with the threads. If you were to run any command line parameters but the t2 time is zero. eg. 1 2 3 0, the program would seem appear like it is in deadlock or running an infinite loop but I can assure the program still terminates successfully it just takes longer to end because due to the writer's wait time being zero the writer is constantly skipping the if() statement inside the writer() function causing an infinite loop until reader() function to finish reading. But once ther program terminates it writes the correct output to the sim_out file.***

With the above implication, it is just my theory on what I think is happening in the program. A theory that might fix this is to implement a bounded buffer which I attempted and successfully failed so my Boolean conditions covered for this.

# Input Files:

All of the test files were written as one line separated with spaces with integers ranging from 1 to the file size for simplicity for reading. The name of the input file is called shared_data.txt. Refer to the README for more.




# Expected Results and Actual Results:

**Note:** I call a function called printReaderArray() that prints all of the elements a certain reader has read at the end of the while loop for each process and thread and that shows what elements that each reader has read from the data_buffer. In the code this will be removed.

All expected output will be exactly the same as the actual output except they might appear in a different order because of the sleep and wait times in context with the printf() statements. The actual outputs below will show each reader reading the contents of the data_buffer and then a cat output of the sim_out file.

**Processes:**

**Test Case 1: Readers Greater Than Writers**

Input : 5 2 1 1

Output:

```
[18821354@lab219-a06 Process]$ ./sds 5 2 1 1
---WRITER 14708 has printed 52 elements
---WRITER 14707 has printed 48 elements
Reader ID 14703 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Reader ID 14704 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Reader ID 14705 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Reader ID 14702 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Reader ID 14706 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
---READER 14703 has printed 100 elements
---READER 14704 has printed 100 elements
---READER 14705 has printed 100 elements
---READER 14702 has printed 100 elements
---READER 14706 has printed 100 elements
[18821354@lab219-a06 Process]$ cat sim_out
writer-14708 has finished writing 52 pieces of data to the data buffer
writer-14707 has finished writing 48 pieces of data to the data buffer
reader-14703 has finished reading 100 pieces of data from the data_buffer
reader-14704 has finished reading 100 pieces of data from the data_buffer
reader-14705 has finished reading 100 pieces of data from the data_buffer
reader-14702 has finished reading 100 pieces of data from the data_buffer
reader-14706 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Process]$
```

**Test Case 2: Readers Less Than Writers**

Input : 2 5 1 1

Output:

```
[18821354@lab219-a06 Process]$ ./sds 2 5 1 1
---WRITER 15355 has printed 19 elements
---WRITER 15356 has printed 13 elements
---WRITER 15353 has printed 24 elements
---WRITER 15352 has printed 21 elements
---WRITER 15354 has printed 23 elements
Reader ID 15350 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
Reader ID 15351 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
---READER 15350 has printed 100 elements
---READER 15351 has printed 100 elements
[18821354@lab219-a06 Process]$ cat sim_out
writer-15355 has finished writing 19 pieces of data to the data buffer
writer-15356 has finished writing 13 pieces of data to the data buffer
writer-15353 has finished writing 24 pieces of data to the data buffer
writer-15352 has finished writing 21 pieces of data to the data buffer
writer-15354 has finished writing 23 pieces of data to the data buffer
reader-15350 has finished reading 100 pieces of data from the data_buffer
reader-15351 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Process]$
```

**Test Case 3: Zero Sleep Times**

Input : 1 5 0 0

Output:

```
[18821354@lab219-a06 Process]$ ./sds 1 5 0 0
---WRITER 15756 has printed 33 elements
---WRITER 15757 has printed 18 elements
---WRITER 15755 has printed 30 elements
---WRITER 15759 has printed 5 elements
Reader ID 15754 has completed reading :[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39
, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85,
 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100]
---WRITER 15758 has printed 14 elements
---READER 15754 has printed 100 elements
[18821354@lab219-a06 Process]$ cat sim_out
writer-15756 has finished writing 33 pieces of data to the data buffer
writer-15757 has finished writing 18 pieces of data to the data buffer
writer-15755 has finished writing 30 pieces of data to the data buffer
writer-15759 has finished writing 5 pieces of data to the data buffer
writer-15758 has finished writing 14 pieces of data to the data buffer
reader-15754 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Process]$
```

**Test Case 4: No Readers or Writers**

Input : 1 0 3 2, 0 1 3 2

Output:

```
[18821354@lab219-a06 Process]$ ./sds 1 0 3 2
Readers/Writers cannot be 0 or negative number
[18821354@lab219-a06 Process]$ ./sds 0 1 3 2
Readers/Writers cannot be 0 or negative number
[18821354@lab219-a06 Process]$
```

**Threads:**

**Test Case 1: Readers Greater Than Writers**

Input : 5 2 1 1

Output:

```
[18821354@lab219-a06 Threads]$ ./sds 5 2 1 1
---WRITER 140253659817728 has printed 44 elements
---WRITER 140253651425024 has printed 56 elements
READER ID 140253693388544 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140253693388544 has printed 100 elements
READER ID 140253668210432 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140253668210432 has printed 100 elements
READER ID 140253676603136 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140253676603136 has printed 100 elements
READER ID 140253684995840 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140253684995840 has printed 100 elements
READER ID 140253701781248 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140253701781248 has printed 100 elements
[18821354@lab219-a06 Threads]$ cat sim_out
writer-1502766848 has finished writing 44 pieces of data from the data_buffer
writer-1494374144 has finished writing 56 pieces of data from the data_buffer
reader-1536337664 has finished reading 100 pieces of data from the data_buffer
reader-1511159552 has finished reading 100 pieces of data from the data_buffer
reader-1519552256 has finished reading 100 pieces of data from the data_buffer
reader-1527944960 has finished reading 100 pieces of data from the data_buffer
reader-1544730368 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Threads]$
```

**Test Case 2: Readers Less Than Writers**

Input : 2 5 1 1

Output:

```
[18821354@lab219-a06 Threads]$ ./sds 2 5 1 1
---WRITER 140628505843456 has printed 12 elements
---WRITER 140628480665344 has printed 17 elements
---WRITER 140628489058048 has printed 23 elements
---WRITER 140628497450752 has printed 22 elements
---WRITER 140628514236160 has printed 26 elements
READER ID 140628531021568 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140628531021568 has printed 100 elements
READER ID 140628522628864 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 140628522628864 has printed 100 elements
[18821354@lab219-a06 Threads]$ cat sim_out
writer--1608329472 has finished writing 12 pieces of data from the data_buffer
writer--1633507584 has finished writing 17 pieces of data from the data_buffer
writer--1625114880 has finished writing 23 pieces of data from the data_buffer
writer--1616722176 has finished writing 22 pieces of data from the data_buffer
writer--1599936768 has finished writing 26 pieces of data from the data_buffer
reader--1583151360 has finished reading 100 pieces of data from the data_buffer
reader--1591544064 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Threads]$
```

**Test Case 3: Zero Sleep Times**

Input : 1 5 0 0

Output: ***NOTE: THIS TEST CASE TOOK ABOUT 20MINS TO RUN***

```
[18821354@lab219-a06 Threads]$ ./sds 1 5 0 0
---WRITER 139912282371840 has printed 17 elements
---WRITER 139912315942656 has printed 29 elements
---WRITER 139912290764544 has printed 16 elements
---WRITER 139912299157248 has printed 20 elements
---WRITER 139912307549952 has printed 18 elements
READER ID 139912324335360 has completed reading :[1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48
49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100]
---READER 139912324335360 has printed 100 elements
[18821354@lab219-a06 Threads]$ cat sim_out
writer--572262656 has finished writing 17 pieces of data from the data_buffer
writer--538691840 has finished writing 29 pieces of data from the data_buffer
writer--563869952 has finished writing 16 pieces of data from the data_buffer
writer--555477248 has finished writing 20 pieces of data from the data_buffer
writer--547084544 has finished writing 18 pieces of data from the data_buffer
reader--538299136 has finished reading 100 pieces of data from the data_buffer
[18821354@lab219-a06 Threads]$
```

**Test Case 4: No Readers or Writers**

Input : 1 0 3 2, 0 1 3 2

Output:

```
[18821354@lab219-a06 Threads]$ ./sds 1 0 3 2
Readers/Writers cannot be zero or negative number
[18821354@lab219-a06 Threads]$ ./sds 0 1 3 2
Readers/Writers cannot be zero or negative number
[18821354@lab219-a06 Threads]$
```

# Code:

All of the code will be be attached to the hard copy of this report. If you are looking at the soft copy please refer to the actual .c and .h files