Compilation and Example Functionality Test

```
Terminal
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mmg717@edge21:OpSys$ make
g++    -c -o helper.o helper.cc
g++ -Wall -c helper.cc main.cc
g++ -Wall -pthread -o main helper.o main.o
mmg717@edge21:OpSys$ ./main 5 6 2 3
Producer(2): Job ID 1 duration 3
Producer(1): Job ID 2 duration 7
Consumer(1): Job ID 1 executing sleep duration 3
Consumer(2): Job ID 2 executing sleep duration 7
Consumer(1): Job ID 1 completed
Producer(2): Job ID 3 duration 7
Producer(1): Job ID 4 duration 9
Consumer(1): Job ID 4 executing sleep duration 9
Consumer(3): Job ID 3 executing sleep duration 7
Consumer(2): Job ID 2 completed
Producer(1): Job ID 5 duration 8
Consumer(2): Job ID 5 executing sleep duration 8
Producer(2): Job ID 1 duration 7
Consumer(3): Job ID 3 completed
Producer(1): Job ID 2 duration 4
Consumer(3): Job ID 1 executing sleep duration 7
Producer(2): Job ID 3 duration 7
Consumer(1): Job ID 4 completed
Consumer(1): Job ID 2 executing sleep duration 4
Consumer(2): Job ID 5 completed
Consumer(2): Job ID 3 executing sleep duration 7
Producer(1): Job ID 4 duration 9
Producer(2): Job ID 5 duration 6
Producer(2): Job ID 1 duration 9
Producer(2): No more jobs to generate
Consumer(1): Job ID 2 completed
Consumer(1): Job ID 4 executing sleep duration 9
Consumer(3): Job ID 1 completed
Consumer(3): Job ID 5 executing sleep duration 6
Producer(1): Job ID 2 duration 3
Producer(1): No more jobs to generate
Consumer(2): Job ID 3 completed
Consumer(2): Job ID 1 executing sleep duration 9
Consumer(3): Job ID 5 completed
Consumer(3): Job ID 2 executing sleep duration 3
Consumer(1): Job ID 4 completed
Consumer(3): Job ID 2 completed
Consumer(2): Job ID 1 completed
Consumer(1): No more jobs left
Consumer(3): No more jobs left
Consumer(2): No more jobs left
mmg717@edge21:OpSys$ 
```

Error Handling Invalid Arguments (Non-integer argument and incorrect number of arguments)

```
mmg717@edge21:OpSys$ ./main 2 2/ 2 2
Argument number 2 is not a valid number!
Command line arguments are supposed to be positive integers
mmg717@edge21:OpSys$ ./main 1 2 2
Incorrect number of arguments!
mmg717@edge21:OpSys$
```

Example Outputs For Cases with 0 Used In Arguments

- Case with Buffer Size 0
- Case with 0 Producers
- Case with 0 Consumers
- Case with 0 Producers and 0 Consumers

```
mmg717@edge21:OpSys$ ./main 0 6 2 3
Consumer(1): No more jobs left
Consumer(2): No more jobs left
Consumer(3): No more jobs left
Producer(2): terminated due to a timeout
Producer(1): terminated due to a timeout
mmg717@edge21:OpSys$ ./main 5 6 0 3
Consumer(2): No more jobs left
Consumer(1): No more jobs left
Consumer(3): No more jobs left
mmg717@edge21:OpSys$ ./main 5 6 5 0
Producer(4): Job ID 1 duration 9
Producer(5): Job ID 2 duration 9
Producer(1): Job ID 3 duration 5
Producer(5): Job ID 4 duration 9
Producer(2): Job ID 5 duration 7
Producer(4): terminated due to a timeout
Producer(3): terminated due to a timeout
Producer(5): terminated due to a timeout
Producer(1): terminated due to a timeout
Producer(2): terminated due to a timeout
mmg717@edge21:OpSys$ ./main 5 6 0 0
mmg717@edge21:OpSys$
```

Error Handling When the Program is Interrupted Before the Semaphore Set is Deleted (Part 1)

```
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mmg717@edge21:OpSys$ ./main 2 2 2 2
Producer(2): Job ID 1 duration 8
Consumer(1): Job ID 1 executing sleep duration 8
Producer(2): Job ID 2 duration 4
Producer(2): No more jobs to generate
Consumer(2): Job ID 2 executing sleep duration 4
^C
mmg717@edge21:OpSys$ ./main 2 2 2 2
IPC_CREAT and IPC_EXCL were specified in semflg, but a semaphore set already exists for key.

Please verify status of semaphores using command line tools such as 'ipcs' and use 'ipcrm' for debugging.
 If the semaphore key is already in use by another user please change it in the 'helper.h' file.
mmg717@edge21:OpSys$ ipcs

------ Message Queues --------
key        msqid      owner      perms      used-bytes   messages

------ Shared Memory Segments --------
key        shmid      owner      perms      bytes      nattch     status
0x00000000 7045120    mmg717     600        524288     2          dest
0x00000000 6946817    mmg717     600        524288     2          dest
0x00000000 7143426    mmg717     600        524288     2          dest
0x00000000 7241731    mmg717     600        524288     2          dest
0x00000000 7438340    mmg717     600        524288     2          dest
0x00000000 7372805    mmg717     600        524288     2          dest
0x00000000 7667718    mmg717     600        524288     2          dest
0x00000000 7831559    mmg717     600        524288     2          dest
0x00000000 7929864    mmg717     600        524288     2          dest
0x00000000 7962633    mmg717     600        4194304    2          dest
0x00000000 8060938    mmg717     600        67108864   2          dest
0x00000000 8159243    mmg717     600        524288     2          dest
0x00000000 8257548    mmg717     600        524288     2          dest
0x00000000 8290317    mmg717     600        4194304    2          dest
0x00000000 8388622    mmg717     600        524288     2          dest
0x00000000 8486927    mmg717     600        524288     2          dest
0x00000000 8519696    mmg717     600        4194304    2          dest
0x00000000 10387473   mmg717     600        3846144    2          dest
0x00000000 10420242   mmg717     600        3846144    2          dest
0x00000000 10813459   mmg717     600        1429504    2          dest
0x00000000 10780692   mmg717     600        1429504    2          dest
0x00000000 11173909   mmg717     600        110592     2          dest
0x00000000 11206678   mmg717     600        110592     2          dest
0x00000000 11763735   mmg717     600        524288     2          dest
0x00000000 11796504   mmg717     600        4194304    2          dest
0x00000000 9633817    mmg717     600        524288     2          dest
0x00000000 11829274   mmg717     600        67108864   2          dest

------ Semaphore Arrays --------
key        semid      owner      perms      nsems
0x00000050 1376256    mmg717     666        3

mmg717@edge21:OpSys$ ipcrm -s 1376256
mmg717@edge21:OpSys$ ./main 2 2 2 2
Producer(1): Job ID 1 duration 7
Consumer(1): Job ID 1 executing sleep duration 7
Producer(2): Job ID 2 duration 10
Consumer(2): Job ID 2 executing sleep duration 10
```

Error Handling When the Program is Interrupted Before the Semaphore Set is Deleted (Part 2)

```
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------ Message Queues ---------
key         msqid        owner       perms       used-bytes    messages

------ Shared Memory Segments --------
key         shmid        owner       perms       bytes         nattch      status
0x00000000 7045120      mmg717      600         524288        2           dest
0x00000000 6946817      mmg717      600         524288        2           dest
0x00000000 7143426      mmg717      600         524288        2           dest
0x00000000 7241731      mmg717      600         524288        2           dest
0x00000000 7438340      mmg717      600         524288        2           dest
0x00000000 7372805      mmg717      600         524288        2           dest
0x00000000 7667718      mmg717      600         524288        2           dest
0x00000000 7831559      mmg717      600         524288        2           dest
0x00000000 7929864      mmg717      600         524288        2           dest
0x00000000 7962633      mmg717      600         4194304       2           dest
0x00000000 8060938      mmg717      600         67108864      2           dest
0x00000000 8159243      mmg717      600         524288        2           dest
0x00000000 8257548      mmg717      600         524288        2           dest
0x00000000 8290317      mmg717      600         4194304       2           dest
0x00000000 8388622      mmg717      600         524288        2           dest
0x00000000 8486927      mmg717      600         524288        2           dest
0x00000000 8519696      mmg717      600         4194304       2           dest
0x00000000 10387473     mmg717      600         3846144       2           dest
0x00000000 10420242     mmg717      600         3846144       2           dest
0x00000000 10813459     mmg717      600         1429504       2           dest
0x00000000 10780692     mmg717      600         1429504       2           dest
0x00000000 11173909     mmg717      600         110592        2           dest
0x00000000 11206678     mmg717      600         110592        2           dest
0x00000000 11763735     mmg717      600         524288        2           dest
0x00000000 11796504     mmg717      600         4194304       2           dest
0x00000000 9633817      mmg717      600         524288        2           dest
0x00000000 11829274     mmg717      600         67108864      2           dest

------ Semaphore Arrays --------
key         semid        owner       perms       nsems
0x00000050 1376256      mmg717      666         3

mmg717@edge21:OpSys$ ipcrm -s 1376256
mmg717@edge21:OpSys$ ./main 2 2 2 2
Producer(1): Job ID 1 duration 7
Consumer(1): Job ID 1 executing sleep duration 7
Producer(2): Job ID 2 duration 10
Consumer(2): Job ID 2 executing sleep duration 10
Producer(1): Job ID 1 duration 7
Producer(1): No more jobs to generate
Producer(2): Job ID 2 duration 4
Producer(2): No more jobs to generate
Consumer(1): Job ID 1 completed
Consumer(1): Job ID 1 executing sleep duration 7
Consumer(2): Job ID 2 completed
Consumer(2): Job ID 2 executing sleep duration 4
Consumer(1): Job ID 1 completed
Consumer(2): Job ID 2 completed
Consumer(1): No more jobs left
Consumer(2): No more jobs left
mmg717@edge21:OpSys$ ▊
```

Example Showing Seeding Used to Overcome Pseudo Random Problem – Exact Same Arguments Leading to Different Results

```
Terminal
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mmg717@edge21:OpSys$ ./main 2 2 2 2
Producer(1): Job ID 1 duration 6
Producer(2): Job ID 2 duration 2
Consumer(1): Job ID 1 executing sleep duration 6
Consumer(2): Job ID 2 executing sleep duration 2
Consumer(2): Job ID 2 completed
Producer(1): Job ID 1 duration 3
Producer(1): No more jobs to generate
Consumer(2): Job ID 1 executing sleep duration 3
Producer(2): Job ID 2 duration 1
Producer(2): No more jobs to generate
Consumer(1): Job ID 1 completed
Consumer(2): Job ID 1 completed
Consumer(1): Job ID 2 executing sleep duration 1
Consumer(1): Job ID 2 completed
Consumer(2): No more jobs left
Consumer(1): No more jobs left
mmg717@edge21:OpSys$ ./main 2 2 2 2
Producer(1): Job ID 1 duration 4
Consumer(1): Job ID 1 executing sleep duration 4
Producer(2): Job ID 2 duration 3
Consumer(2): Job ID 2 executing sleep duration 3
Producer(1): Job ID 1 duration 1
Producer(1): No more jobs to generate
Consumer(2): Job ID 2 completed
Consumer(2): Job ID 1 executing sleep duration 1
Consumer(1): Job ID 1 completed
Producer(2): Job ID 2 duration 7
Producer(2): No more jobs to generate
Consumer(1): Job ID 2 executing sleep duration 7
Consumer(2): Job ID 1 completed
Consumer(1): Job ID 2 completed
Consumer(2): No more jobs left
Consumer(1): No more jobs left
mmg717@edge21:OpSys$
```

Semaphore Initialization Error Handling: (Errors do NOT occur in normal operation of the program, they were artificially created by hard coding incorrect parameters in the "sem_init" function)

- When the error is detected the user is not required to manually clean up the created semaphore as the program deals with this.

```
Terminal
File Edit View Search Terminal Help
mmg717@voxel18:OpSys$ ./main 5 5 5 5
Error found in semaphore 'item' initialization due to:
Invalid value for cmd or semid.  Or: for a SEM_STAT operation, the index value specified in semid referre
d to an array slot that is currently unused.
mmg717@voxel18:OpSys$ make
g++ -Wall -c helper.cc main.cc
g++ -Wall -pthread -o main helper.o main.o
mmg717@voxel18:OpSys$ ./main 5 5 5 5
Error found in semaphore 'space' initialization due to:
Invalid value for cmd or semid.  Or: for a SEM_STAT operation, the index value specified in semid referre
d to an array slot that is currently unused.
mmg717@voxel18:OpSys$
```