

1. No. if the access is read for both threads, then concurrency error will not occur.
2. b) , c) and d) are true

**Correct solution**

c) and d) are true

**Notes**

**Question** What does it mean when mutex is held by this thread?

**Question** What I do know is that `pthread_cond_wait` puts thread to sleep. My question here is, how come the mutex is not held when thread is in a blocked state/sleep?

3. a) Only b) causes starvation.
- b) Conditional variable is a queue that allows threads to be put themselves on to sleep (in blocked state) when thread it is not desired using `pthread_cond_wait` function.

Since there are no threads inside `cv1`, there is nothing to awake using `pthread_cond_signal`.

So, nothing will occur.

- c) System call is a subset of interrupt caused by user application to switch from user mode to kernel mode to perform privileged operations for the application.

Interrupt is a signal sent by hardware (e.g keyboard, mouse, hard drive) or software.

It tells the cpu to stop its activities and execute appropriate part of the operating system.

**Notes**

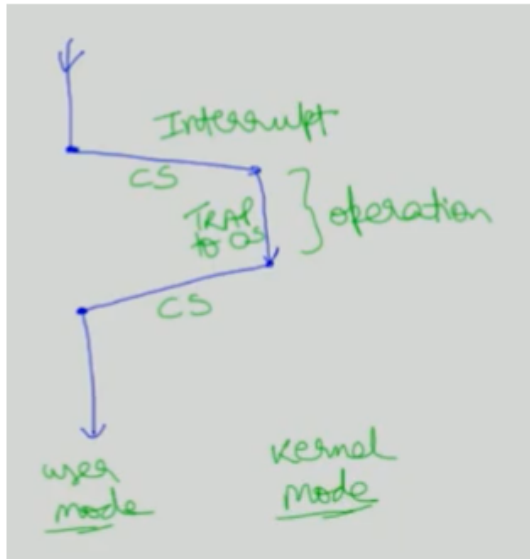
- I need to review how interrupt works. I had to look up the information.

**Question** How does interrupt work?

- **Interrupt**

- Is a signal
- there are two types of interrupts:
  - \* Hardware interrupt
    - Is signal generated by hardware (e.g RAM is full, Hard drive is full)
    - Is sent to operating system
  - \* Software interrupt
    - Is signal generated by software (e.g program crash, system call)

- Is sent to operating system
- May call trap instruction (esp. system call)



### References

1. venkatesan ramachandran, What is an Interrupt?, link
- d) No. This statement is false.

User level threads are generated in user-mode without kernel being aware about it.

### Notes

**Question** What is the difference between user-level thread and kernel-level thread?

**Question** Why is thread that is generated at user level using procedure call faster than kernel level thread?

**Question** What is procedure call? How does it work?

- **Procedure call**

- works in user-mode only
- doesn't require context switching
- doesn't need help from OS/Kernel
- no context-switching → faster

### References

1. Tech Dose, System call vs Procedure call, link

e) System calls do not generate processes. `fork()` does.

With this reason the program `run_stuff` generates only 1 additional process.

### Notes

**Question** What is a process? And how does process work?

**Question** How come system call doesn't generate process? And how come `fork()` generates process?

- **Process**

- Is a running program
- Has 3 states

1. **Running:**

- \* means a process is running on a processor
- \* means instructions are being executed

2. **Ready:**

- \* means a process is ready to run
- \* means OS has chosen not to run the program at the given moment

3. **Blocked:**

- \* means a process has performed some kind of operation that makes it not ready to run until some event takes place

```

41  typedef struct acct {
2      float balance;
3      pthread_mutex_t lock;
4      pthread_cond_t cond;
5  } account;
6
7  void transfer_amount(account *a1, account *a2, float amount) {
8
9      // lock critical section during the transfer process
10     pthread_mutex_lock(&a1->lock);
11     pthread_mutex_lock(&a2->lock);
12     // transfer amount
13     a1->balance -= amount;
14     a2->balance += amount;
15     pthread_mutex_lock(&a1->lock);
16     pthread_mutex_lock(&a2->lock);
17
18     // lock the transferring user if the balance is negative
19     if (a1->balance < 0) {
20         pthread_cond_wait(&a1->cond, &a1->lock);
21     }
22
23 }
```

**Correct Solution**

```

1  typedef struct acct {
2      float balance;
3      pthread_mutex_t lock;
4      pthread_cond_t cond;
5  } account;
6
7  void transfer_amount(account *a1, account *a2, float amount) {
8
9      pthread_mutex_lock(&a1->lock);
10     a1->balance -= amount;
11
12     while (a1->balance < 0) {
13         pthread_cond_wait(&a1->cond, &a1->lock);
14     }
15     pthread_mutex_lock(&a1->lock);
16
17     pthread_mutex_lock(&a2->lock);
18     a2->balance += amount;
19
20     if (a2->balance > 0) {
21         pthread_cond_signal(&a2->cond);
22     }
23     pthread_mutex_lock(&a2->lock);
24 }

```

**Notes**

- Realized that I do not know how to create barriers to critical section.

**Question** When do we use the while loop like lock?

**Question** Does the use of if statement to put thread into sleep acceptable?

**Question** How can we construct safe barriers around critical section?

- **Locks**
  - Ensures that any critical section executes is a single atomic operation
  - Guarantees that no more than single code can be active within the code
- **pthread\_mutex\_lock**
  - **Syntax:** pthread\_mutex\_t VAR
  - Is used to provide mutual exclusion between threads
  - If mutex is already locked, thread blocks until mutex is available
  - Must be properly initialized before use

**Static Way**

```
pthread_mutex_t lock = PTHREAD_MUTEX_INITIALIZER
```

### Dynamic Way

```
int rc = pthread_mutex_init(&lock, NULL);  
assert(rc == 0);
```

5. a) It would favour I/O bound process. I/O bound process are mostly about waiting for the completion of input or output.

And example of this is continuous typing on microsoft word.

Usually the I/O-bound process lasts a short period of time.

On the other hand, CPU-bound process involves the execution of algorithm that requires a huge computation time.

An example of this is running a simulation.

Because of this, CPU-bound process usually lasts a long period of time.

Because of this, the processing algorithm would favour I/O bound process over CPU bound process.

- b) Yes.

The processing algorithm favours algorithm with a short processing time in the past.

Using the explanation given in part a), we can write I/O bound processes are favoured over CPU-bound process

It follows from this information that if short I/O bound processes keep coming in, then CPU-bound process will never get a chance to run.

So, we can conclude the scheduling algorithm would cause starvation to CPU-bound processes.

6. 1) a) False  
b) True  
c) True  
d) False  
e) False  
f) False
- 2) a) Is one of simplest lock to build. It allows only one thread to enter at a time. The variable lock has two values 0 (free/available), 1 (in use/locked). Spinlock uses two operations. One is `acquire()` and another is `release()`. `acquire()` uses while loop and `test-and-lock` function to ensure atomic operation in critical section. A thread is in locked state until lock is freed.

- b) Is the amount of time where processes in the same queue runs until it repeats. The time slice or scheduling quantum must be a multiple of the time of timer-interrupt.
- c) Is a software interrupt sent by user application, so it traps into kernel mode, perform privileged operation, return to user mode from trap, and continue application with the returned result.

### Notes

- I feel weak about scheduling quantum

**Question** What is scheduling quantum?

7. 1) a) True  
b) True  
c) False  
d) True  
e) False  
f) False

### Correct Solution

- a) **False**
- b) True
- c) False
- d) True
- e) False
- f) False

### Notes

- I feel weak about PCB and context switch

**Question** What is response for changing from user mode to kernel mode on system call interrupt?

**Question** What is program counter?

**Question** What is stack pointer?

**Question** What is user register?

**Question** What is kernel state?

- 2) a) Is a function that is a part of spin lock. It is used as a conditional statement in while loop to make sure only one thread can enter the critical at a time. Test and lock returns false if lock variable in spin lock is freed (with value of 0).

**Correct Solution**

Is an atomic instruction. It is used to implement synchronization algorithm such as spinlock.

**Notes**

- I feel weak about test-and-set
- b) Is a type of scheduling algorithm where one process is favoured and executed first over the others. Some examples are MLFQ and SJF scheduling algorithm.

**Correct Solution**

Is a type of scheduling algorithm where a process can be interrupted by an OS. Once the time slice of a process is used, the next process is scheduled into running state.

**Notes**

- I don't feel confident about preemptive scheduling and non-preemptive scheduling

**Question** What is preemptive scheduling?

8. a) c) is the only scheduling algorithm that minimizes average wait time.
- b) A conditional variable is a queue where an undesired thread can be added and put to sleep (by switching to blocked state) by calling the function `pthread_cond_wait`.

When state is changed, one or more threads in conditional variable can be awakened.

A thread in conditional variable is put to sleep using the function `pthread_cond_wait`

And a thread in conditional variable is awakened using the function `pthread_cond_signal`

Semaphore is a signal. It uses integer variable shared between multiple threads.

Semaphore has two types: counting semaphore and binary semaphore.

Counting semaphore has count variable where `count = 0` means resource is not available.

Binary semaphore has count variable with two states 0 - locked / not available  
1 - available/free.

A situation where a conditional variable is favored over the other variable is during banking transaction. Here, we use conditional variable to put a particular thread to sleep if condition is not satisfied (i.e balance remaining is negative).

**Notes**

- I feel weak about conditional variable and semaphores

**Question** What is conditional variable?

**Question** What is semaphore?

- I feel that conditional variable is used to control specific thread where as semaphore is used to control a group of thread (like a traffic)

c) No.

Interrupt is a signal generated by either software or hardware.

It tells the cpu to stop its current activity and execute appropriate instruction in the operating system.

Mutual exclusion guarantees only one thread to enter critical section at a time.

The two are unrelated.

To achieve mutual exclusion, critical section must be atomic.

`pthread_mutex_lock()` is one of the locks that enforces mutual exclusion.

### Notes

- I feel weak about mutual exclusion

**Question** What is mutual exclusion?

**Question** What is necessary condition to ensure mutual exclusion?

d) I do not know but here is my best shot.

System call is a subset of interrupt sent by user application to context switch from user mode to kernel mode so privileged operations can be done.

User pointer is a pointer which points to an address in RAM dedicated for programs in user-mode.

When system call goes into kernel mode, it saves PC counter, CPU register, kernel state, and other resource information.

When a program returns from trap, it has to resume its program.

Before resuming program, we have to make sure all is well.

It is here where the validation of user pointer occurs.

### Notes

**Question** What is user pointer?



e) User-level threads

**Notes**

- I feel weak about user-level threads and kernel-level threads

**Question** What is user level thread?

**Question** What is kernel level thread?