

1. a) Trap instruction is run in user mode, and privileged operation is run in kernel mode

Notes

- **Privileged Instructions**

- Is the instruction that can run only in **kernel mode**
- Attempt at execution in **user mode** → treated as an illegal operation & will not run.

- **Trap**

- Is a special hardware instruction
- Is a software generated interrupt ^[4]
- Is a type of synchronous interrupt ^[1]
- Is caused by an exceptional condition ^[1]
 1. Division by zero ^[1]
 2. Invalid memory access (segmentation fault) ^[1]
 3. Privileged instruction by **user mode** code ^[2]
- Usually results in a switch to **kernel mode** → Operating system performs action → Returns control to original process

- **Trap Instruction**

- Is executed when a user wants to invoke a service from the operating system (i.e. reading hard drive) in **user mode**
- Raise (the processor) privilege level to kernel mode

- **User Mode**

- Executing code has no ability to *directly* access hardware or reference memory ^[3]
- Crashes are always recoverable ^[3]
- Is where most of the code on our computer are executed ^[3]

- **Kernel Mode**

- Executing code has complete and unrestricted access to the underlying hardware ^[3]
- Is generally reserved for the lowest-level, most trusted functions of the operating system ^[3]
- Is fatal to crash; it will halt the entire PC (i.e the blue screen of death) ^[3]

References

- 1) Wikipedia, Trap (computing), link
- 2) University of Utah, CS5460: Operating Systems Lecture 3 - OS Organization, link
- 3) Coding Horror, Understanding User and Kernel Mode, link
- 4) ETH Zurich, Programming in Systems, link

- b) No. Lock uses a variable with binary states 0 (acquired) and 1 (available), where as semaphore uses counter variable that can have value greater than 1 to keep track of the amount of resource remaining.

Notes

- **Locks**

- Is a variable with two boolean states
 - * 1 - (available/unlock/free)
 - * 0 - (acquired/locked/held)
- Has two operations
 1. `acquire()`

```
boolean test_and_set(boolean *lock)
{
    boolean old = *lock;
    *lock = True;
    return old;
}

boolean lock;

void acquire(boolean *lock) {
    while(test_and_set(lock));
}
```

2. `release()`

```
void release(boolean *lock) {
    *lock = false;
}
```

- Is put around critical section to ensure critical section executes as if it's a single atomic instruction

```
1 lock_t mutex; // some globally-allocated lock 'mutex'
2 ...
3 lock(&mutex);
4 balance = balance + 1;
5 unlock(&mutex);
```

- Can only be released by the thread that acquired it
- Is used to protect shared resource (e.g. from race condition in files and data structure) ^[2]

- **Semaphore**

- Is an abstract data types suitable for synchronization problems ^[2]
- Has variable count that allows arbitrary resource count ^[1]
- Has two atomic operations
 1. (wait/P/decrement) - block until count > 0 then decrement variable

```
wait(semaphore *s) {
    while (s->count == 0) ;
    s->count -= 1;
}
```

2. (signal/V/increment) - increment count, unblock a waiting thread

```
signal(semaphore *s) {
    s->count += 1;
    ..... //unblock one waiter
}
```

- Can be signaled by any thread ^[2]

References

- 1) Wikipedia, Semaphore (programming), link
 - 2) Stack Overflow, Difference between binary semaphore and mutex, link
- c) If both access are read, then concurrency error will not occur.

Notes

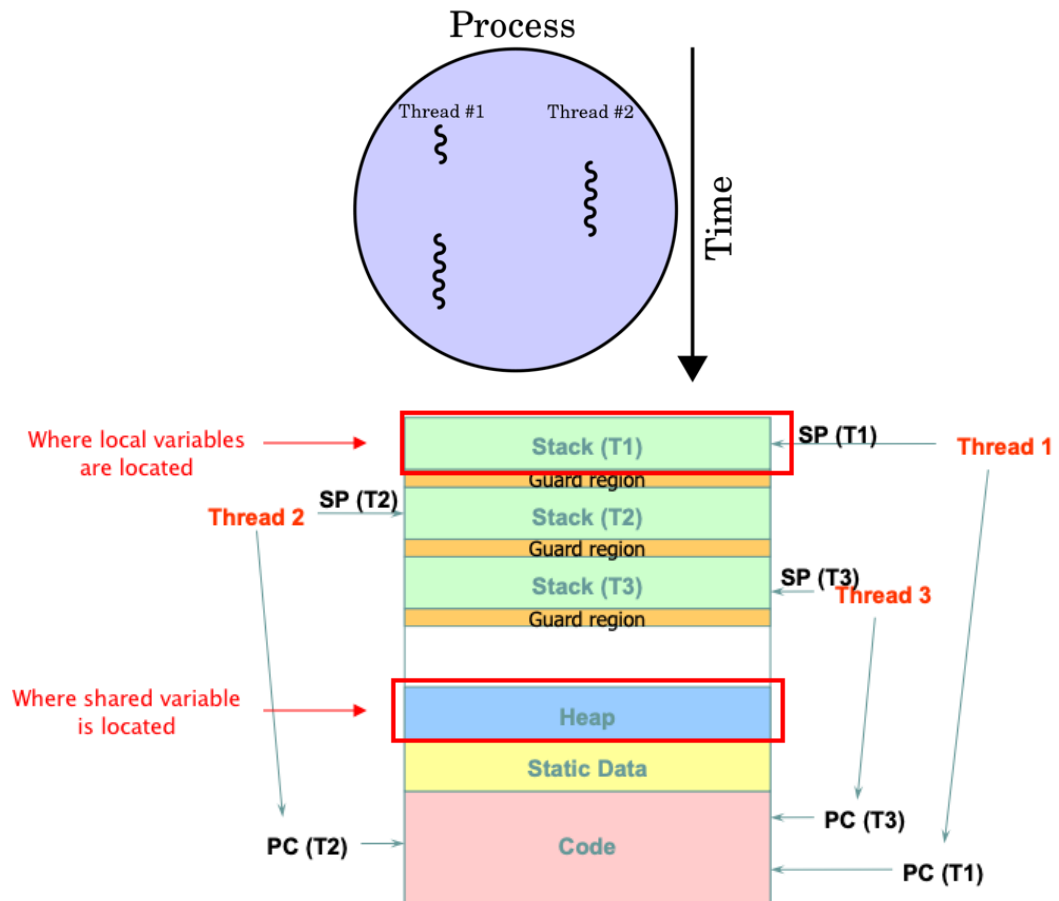
- What is concurrency error? Where and when does it occur?
- **Concurrency**
 - Is the ability of different parts or units of a program, algorithm, or problem to be executed out of order, without affecting the final outcome. ^[1]
- **Concurrency Error**
 - Two types of concurrency errors ^[3]
 1. **Deadlock:** A situation wherein two or more processes are never able to proceed because each is waiting for the others to do something

Key: Circular wait
 2. **Race Condition:** a timing dependent error involving shared state

- * **Data Race:** Concurrent accesses to a shared variable and at least one access is a write
- * **Atomicity Bugs:** Code does not enforce the atomicity programmers intended for a group of memory access
- * **Order Bugs:** Code does not enforce the order programmers intended for a group of memory access

- **Thread**

- Is the smallest sequence of programmed instructions that can be managed independently by a scheduler ^[2]



- A thread is bound to a single process
- A process can have multiple threads

References

- 1) Wikipedia, Concurrency (computer science), [link](#)
- 2) Wikipedia, Thread, [link](#)
- 3) Columbia University, Concurrency Errors, [link](#)

d) Notes

- **Virtualization of CPU**
 -
- **Limited Direct Execution**
 -