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

Notes

- **Previliged 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. Previleged instruction by **user mode** code [2]
  - Usually results in a switch to **kernel mode** → Operating system performs action → Returns control to oroginal 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**
- **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.

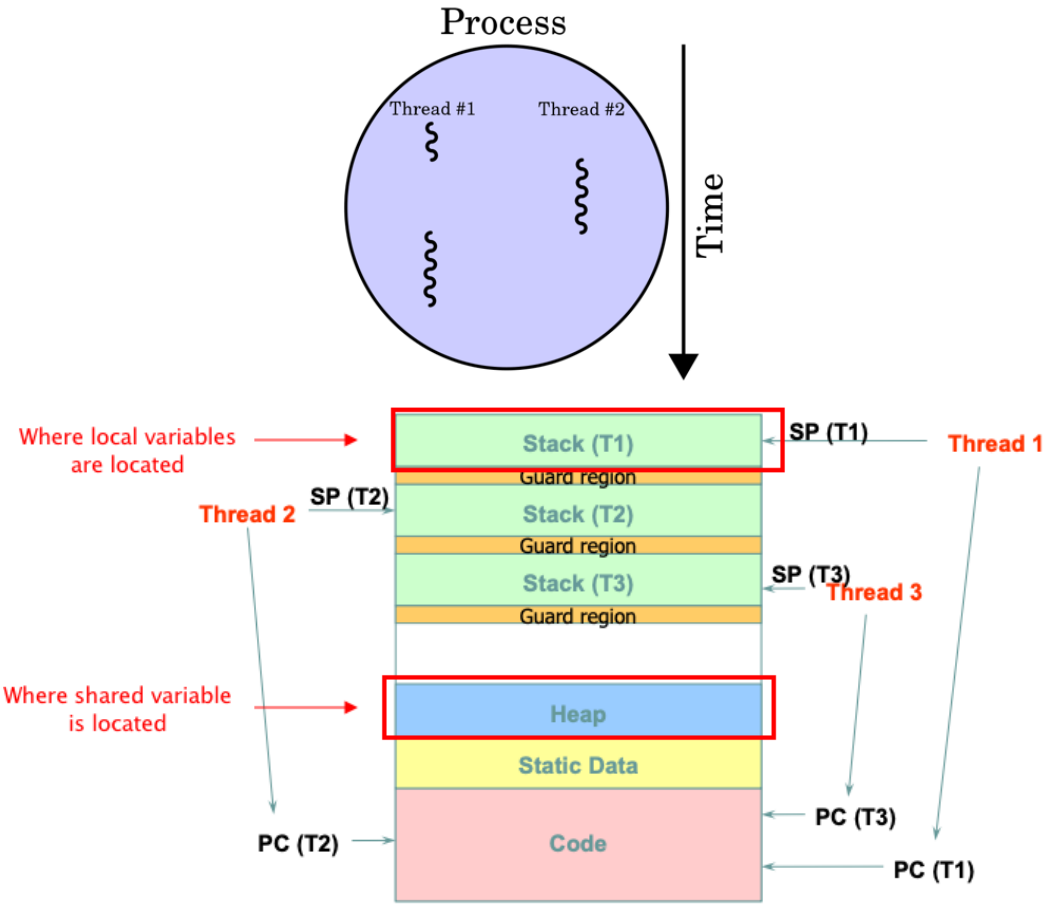
Notes

- 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 schdeduler [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**

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