

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 <sup>[4]</sup>
- Is a type of synchronous interrupt <sup>[1]</sup>
- Is caused by an exceptional condition <sup>[1]</sup>
  1. Division by zero <sup>[1]</sup>
  2. Invalid memory access (segmentation fault) <sup>[1]</sup>
  3. Privileged instruction by **user mode** code <sup>[2]</sup>
- 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**

- **User Mode**

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

- **Kernel Mode**

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

### 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) <sup>[2]</sup>

- **Semaphore**

- Is an abstract data types suitable for synchronization problems <sup>[2]</sup>

- Has variable count that allows arbitrary resource count <sup>[1]</sup>
- 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 <sup>[2]</sup>

### References

- 1) Wikipedia, Semaphore (programming), [link](#)
- 2) Stack Overflow, Difference between binary semaphore and mutex, [link](#)

### c) Notes

- Thread