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** $\rightarrow$ 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** $\rightarrow$ Operating system performs action $\rightarrow$ 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]

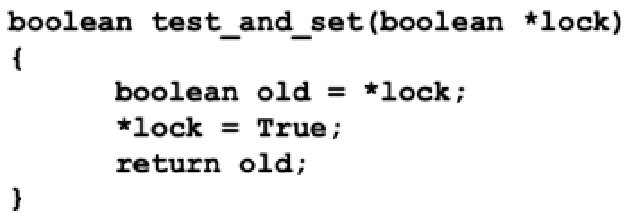
References

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

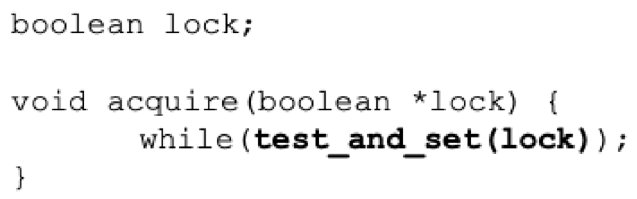
b) Lock

Notes

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

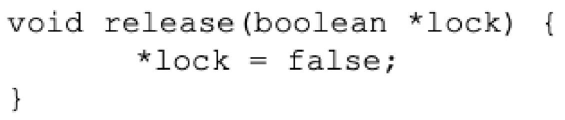


```
boolean test_and_set(boolean *lock)
{
      boolean old = *lock;
      *lock = True;
      return old;
}
```



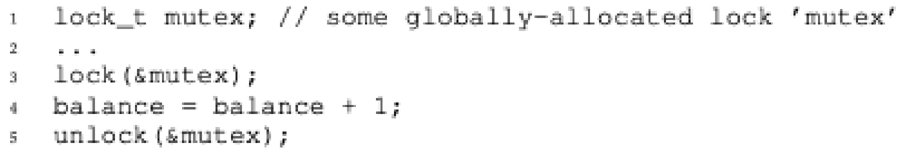
```
boolean lock;

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

    2. `release()`



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

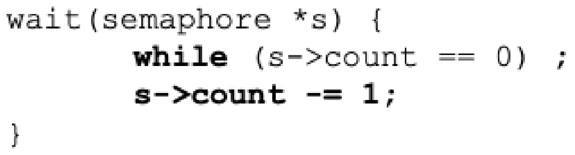
  - Is put around critical section to ensure critical section executes as if it's a single atomic instruction



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

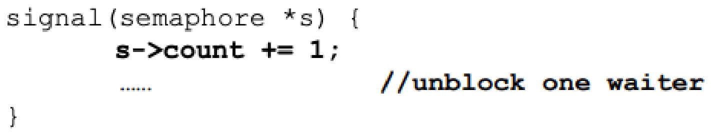
  - Can only be released by the thread that acquired it
  - Is used to protect shared resource (e.g. from race condition in files and data structure) [2]
- **Semaphore**
  - Is an abstract data types suitable for synchronization problems [2]

- 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