TCSS 422: OPERATING SYSTEMS

INTRODUCTION

Wes J. Lloyd
School of Engineering and Technology
University of Washington - Tacoma

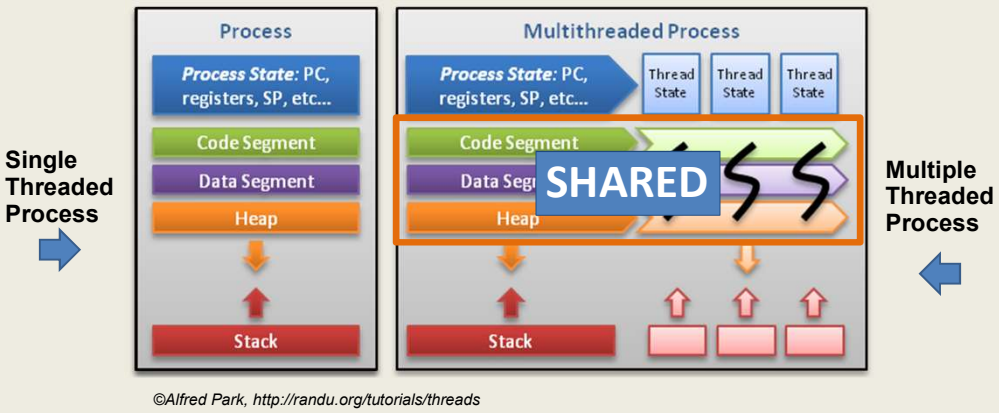
FEEDBACK 1/7

- What is the concept of abstraction, with respect to operating systems?
  - CPU
  - Memory
  - I/O (disk, network)
- What is the difference between memory virtualization in an operating system and "virtual memory" also known as "swap memory"?
- What is an operating system kernel?

OPERATING SYSTEM KERNEL

- Kernel is the central component of most computer operating systems
- The OS kernel provides a bridge to manage the communication between user applications and the hardware (CPU, memory, I/O devices)
- When a user process makes a request of the kernel, the request is called a "system call".
- Various kernel designs differ in how they manage calls and resources
- Kernel location in Linux
  - /boot

FEEDBACK - 3: PROCESS VS THREADS



©Alfred Park, http://randu.org/tutorials/threads

FEEDBACK – 4

- What is the difference between a thread and a process?
  - Every program runs as a process
  - Programs may have 0 to many threads
- For several threads within a process, what memory elements are shared?
- For two distinct processes:
  consider two instances A and B of the simpleloop.c sample program

  What memory elements are shared?

FEEDBACK - 5

- In multi-threaded programs, how do we synchronize access to global (shared) variables?
  - Chapters 26 – 32

FEEDBACK - 6

- The slides do not open. I tried to download the lexture to my iPad and it doesn't work.
- What are the requirements needed to do well in TCSS 422?

OBJECTIVES

- **Chapter 2 -** Introduction to operating systems
  - THREE EASY PIECES:
    - Virtualizing the CPU
    - Virtualizing Memory
    - Virtualizing I/O
  - Operating system design goals
- Chapter 4 – Processes
- Chapter 5 – Process API
- Chapter 6 – Limited Direct Execution

INTRODUCTION TO OPERATING SYSTEMS

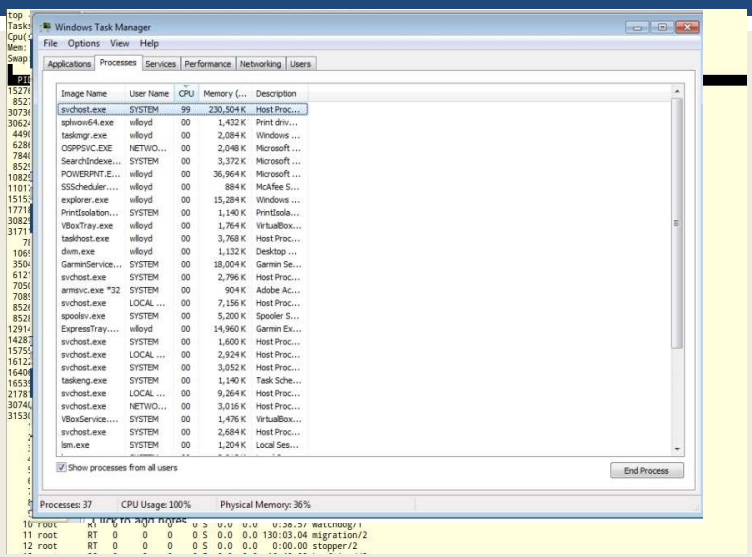
VIRTUAL MACHINE SURVEY

- Please complete the Virtual Machine Survey to request a "School of Engineering and Technology" remote hosted Ubuntu VM
- https://goo.gl/forms/SC8GzWAgIUfHZ0g33

OBJECTIVES

- **Chapter 2: Operating Systems – Three Easy Pieces**
  - Introduction to operating systems
  - Management of resources
  - Concepts of virtualization/abstraction
  - THREE EASY PIECES:
    - Virtualizing the CPU: simpleloop.c example
      
      pthread.c example
    - Virtualizing Memory: mem.c example
    - Virtualizing I/O
  - Operating system design goals

CONCURRENCY



CONCURRENCY

- Linux: 654 tasks
- Windows: 37 processes
- The **OS** appears to run many programs at once, juggling them
- Modern **multi-threaded** programs feature concurrent threads and processes
- ***What is a key difference between a process and a thread?***

CONCURRENCY - 2

```
1       #include <stdio.h>
2       #include <stdlib.h>
3       #include "common.h"
4
5       volatile int counter = 0;
6       int loops;
7
8       void
9
10
11
12
13
14  }
15  ...
```

Not the same as Java volatile:
Provides a compiler hint than an object may change value unexpectedly (in this case by a separate thread) so aggressive optimization must be avoided.

thread.c

Listing continues …

CONCURRENCY - 3

```
16      int
17      main(int argc, char *argv[])
18      {
19              if (argc != 2) {
20                      fprintf(stderr, "usage: threads <value>\n");
21                      exit(1);
22              }
23              loops = atoi(argv[1]);
24              pthread_t p1, p2;
25              printf("Initial value : %d\n", counter);
26
27              Pthread_create(&p1, NULL, worker, NULL);
28              Pthread_create(&p2, NULL, worker, NULL);
29              Pthread_join(p1, NULL);
30              Pthread_join(p2, NULL);
31              printf("Final value : %d\n", counter);
32              return 0;
33      }
```

- Program creates two threads
- Check documentation: "man pthread_create"
- worker() method counts from 0 to argv[1] (loop)

Linux "man" page

example

PTHREAD_CREATE(3) Linux Programmer's Manual PTHREAD_CREATE(3)

NAME top

pthread_create - create a new thread

SYNOPSIS top

```
#include <pthread.h>

int pthread_create(pthread_t *thread, const pthread_attr_t *attr,
                   void *(*start_routine) (void *), void *arg);

Compile and link with -pthread.
```

DESCRIPTION top

The **pthread_create**() function starts a new thread in the calling process. The new thread starts execution by invoking *start_routine*(); *arg* is passed as the sole argument of *start_routine*().

The new thread terminates in one of the following ways:

* It calls pthread_exit(3), specifying an exit status value that is available to another thread in the same process that calls pthread_join(3).

* It returns from *start_routine*(). This is equivalent to calling pthread_exit(3) with the value supplied in the *return* statement.

* It is canceled (see pthread_cancel(3)).

* Any of the threads in the process calls exit(3), or the main thread performs a return from *main*(). This causes the termination of all threads in the process.

The *attr* argument points to a *pthread_attr_t* structure whose contents are used at thread creation time to determine attributes for the new thread; this structure is initialized using pthread_attr_init(3) and related functions. If *attr* is NULL, then the thread is created with default attributes.

CONCURRENCY - 4

- Command line parameter argv[1] provides loop length
- Defines number of times the shared counter is incremented
- Loops: 1000

```
prompt> gcc -o thread thread.c -Wall -pthread
prompt> ./thread 1000
Initial value : 0
Final value : 2000
```

- Loops 100000

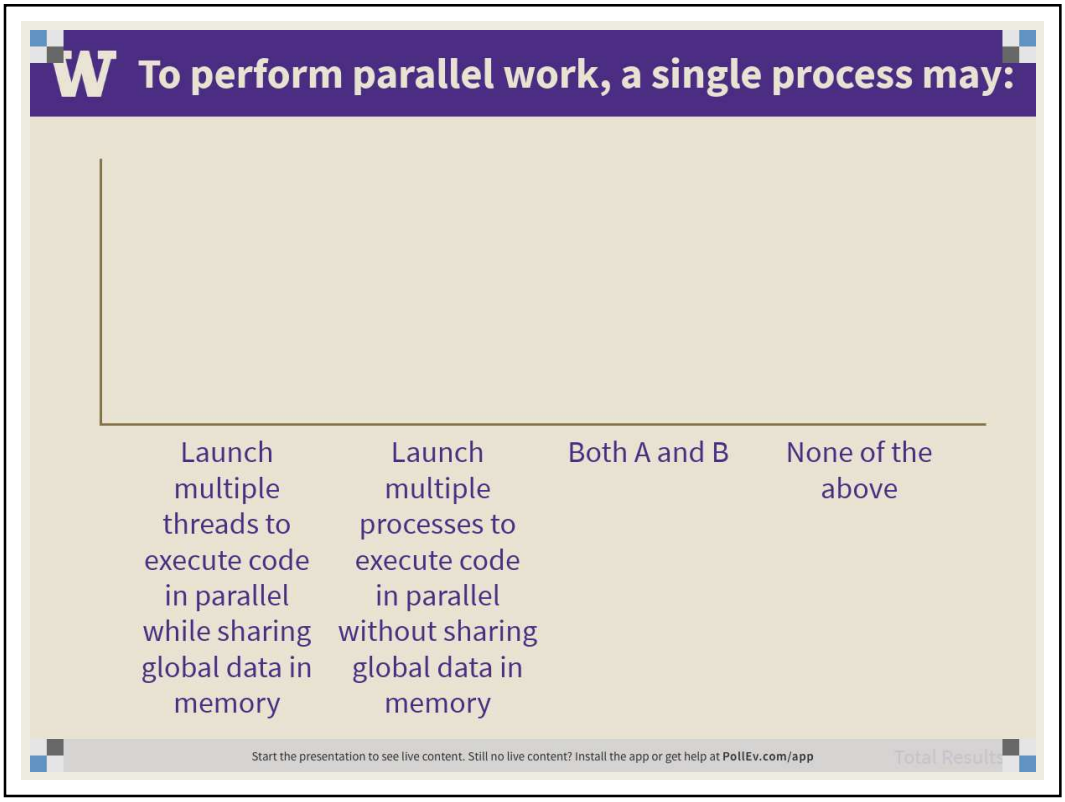
```
prompt> ./thread 100000
Initial value : 0
Final value : 143012 // huh??
prompt> ./thread 100000
Initial value : 0
Final value : 137298 // what the??
```

CONCURRENCY - 5

- When loop value is large why do we not achieve 200000 ?
- C code is translated to (3) assembly code operations

1. Load counter variable into register
2. Increment it
3. Store the register value back in memory

- These instructions happen concurrently and VERY FAST
- (P1 || P2) write incremented register values back to memory, While (P1 || P2) read same memory
- Memory access here is **unsynchronized** (**non-atomic**)
- *Some of the increments are lost*



PARALLEL PROGRAMMING

- To perform parallel work, a single process may:
- A. Launch multiple threads to execute code in parallel while sharing global data in memory
- B. Launch multiple processes to execute code in parallel without sharing global data in memory
- C. Both A and B
- D. None of the above

VIRTUALIZING I/O: PERSISTENCE

- DRAM: Dynamic Random Access Memory: DIMMs/SIMMs
  - Stores data while power is present
  - When power is lost, data is lost (*volatile*)
- Operating System helps "persist" data more **permanently**
  - I/O device(s): hard disk drive (HDD), solid state drive (SSD)
  - File system(s): "catalog" data for storage and retrieval

VIRTUALIZING I/O: PERSISTENCE - 2

```
1       #include <stdio.h>
2       #include <unistd.h>
3       #include <assert.h>
4       #include <fcntl.h>
5       #include <sys/types.h>
6
7       int
8       main(int argc, char *argv[])
9       {
10              int fd = open("/tmp/file", O_WRONLY | O_CREAT
                                | O_TRUNC, S_IRWXU);
11              assert(fd > -1);
12              int rc = write(fd, "hello world\n", 13);
13              assert(rc == 13);
14              close(fd);
15              return 0;
16      }
```

- open(), write(), close(): OS system calls for device I/O
- Note: man page for open(), write() require page number: "man 2 open", "man 2 write", "man close"

VIRTUALIZING I/O: PERSISTENCE - 3

- To write to disk, OS must:
  - Determine where on disk data should reside
  - Perform sys calls to perform I/O:
    - Read/write to file system (*inode record*)
    - Read/write data to file
- Provide fault tolerance for system crashes
  - Journaling: Record disk operations in a journal for replay
  - Copy-on-write - replicating shared data - *see ZFS*
  - Carefully order writes on disk

SUMMARY: OPERATING SYSTEM DESIGN GOALS

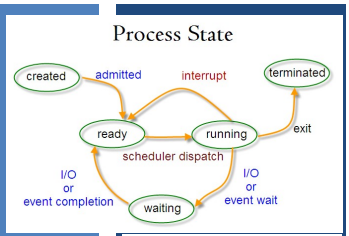
- **ABSTRACTING THE HARDWARE**
  - Makes programming code easier to write
  - Automate sharing resources – save programmer burden
- **PROVIDE HIGH PERFORMANCE**
  - Minimize overhead from OS abstraction (Virtualization of CPU, RAM, I/O)
  - Share resources fairly
  - Attempt to tradeoff performance vs. fairness → consider priority
- **PROVIDE ISOLATION**
  - User programs can't interfere with each other's virtual machines, the underlying OS, or the sharing of resources

SUMMARY: OPERATING SYSTEM DESIGN GOALS - 2

- **RELIABILITY**
  - OS must not crash, 24/7 Up-time
  - Poor user programs must not bring down the system:

    Blue Screen

- *Other Issues:*
  - Energy-efficiency
  - Security (of data)
  - Cloud: Virtual Machines



CHAPTER 4: PROCESSES

CPU VIRTUALIZING

- How should the CPU be shared?
- Time Sharing:
  Run one process, pause it, run another
- How do we SWAP processes in and out of the CPU efficiently?
  - Goal is to minimize **overhead** of the swap

PROCESS

A process is a running program.

- Process comprises of:
  - Memory
    - Instructions ("the code")
    - Data (heap)
  - Registers
    - PC: Program counter
    - Stack pointer

PROCESS API

- Modern OSes provide a Process API for process support
- Create
  - Create a new process
- Destroy
  - Terminate a process (ctrl-c)
- Wait
  - Wait for a process to complete/stop
- Miscellaneous Control
  - Suspend process (ctrl-z)
  - Resume process (fg, bg)
- Status
  - Obtain process statistics: (top)

PROCESS API: CREATE

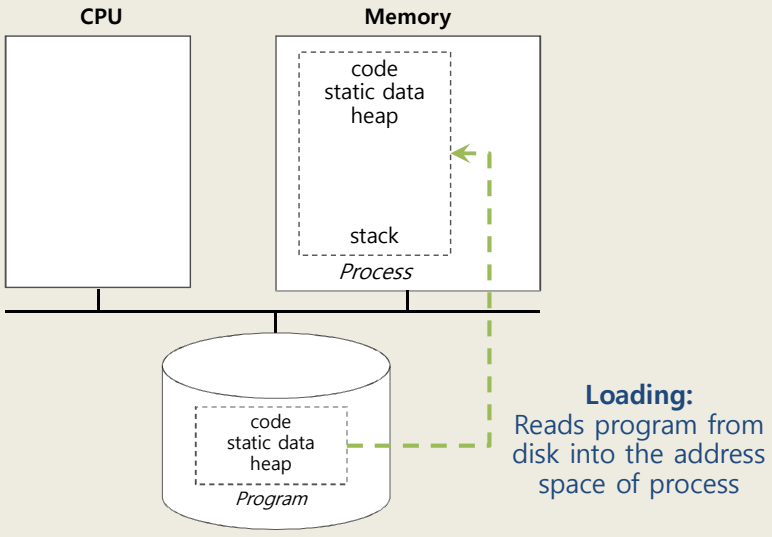
1. Load program code (and static data) into memory
   - Program executable code (binary): loaded from disk
   - Static data: also loaded/created in address space
   - **Eager loading**: Load entire program before running
   - **Lazy loading**: Only load what is immediately needed
     - Modern OSes: Supports paging & swapping
2. Run-time stack creation
   - Stack: local variables, function params, return address(es)

PROCESS API: CREATE

3. Create program's heap memory
   - For dynamically allocated data

4. Other initialization
   - I/O Setup
     - Each process has three open file descriptors: Standard Input, Standard Output, Standard Error

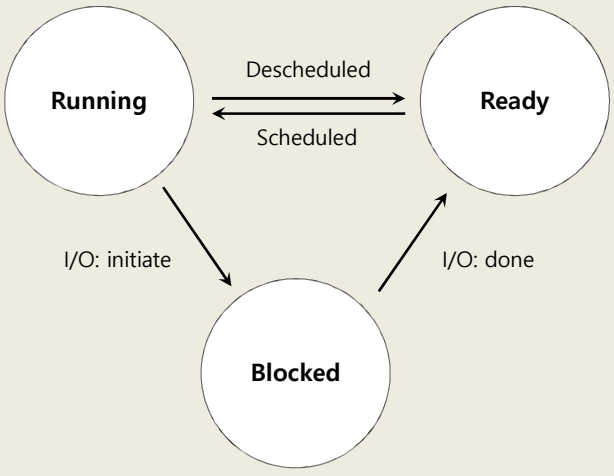
5. Start program running at the entry point: `main()`
   - OS transfers CPU control to the new process



PROCESS STATES

- **RUNNING**
  - Currently executing instructions
- **READY**
  - Process is ready to run, but has been preempted
  - CPU is presently allocated for other tasks
- **BLOCKED**
  - Process is **not** ready to run. It is waiting for another event to complete:
    - Process has already been initialized and run for awhile
    - Is now waiting on I/O from disk(s) or other devices

PROCESS STATE TRANSITIONS



PROCESS DATA STRUCTURES

- OS provides data structures to track process information
  - Process list
    - Process Data
    - State of process: Ready, Blocked, Running
  - Register context
- PCB (Process Control Block)
  - A C-structure that contains information about each process

XV6 KERNEL DATA STRUCTURES

- xv6: pedagogical implementation of Linux
- Simplified structures

```
// the registers xv6 will save and restore
// to stop and subsequently restart a process
struct context {
    int eip;    // Index pointer register
    int esp;    // Stack pointer register
    int ebx;    // Called the base register
    int ecx;    // Called the counter register
    int edx;    // Called the data register
    int esi;    // Source index register
    int edi;    // Destination index register
    int ebp;    // Stack base pointer register
};

// the different states a process can be in
enum proc_state { UNUSED, EMBRYO, SLEEPING,
                  RUNNABLE, RUNNING, ZOMBIE };
```

XV6 KERNEL DATA STRUCTURES - 2

```
// the information xv6 tracks about each process
// including its register context and state
struct proc {
    char *mem;                // Start of process memory
    uint sz;                  // Size of process memory
    char *kstack;             // Bottom of kernel stack
                              // for this process
    enum proc_state state;    // Process state
    int pid;                  // Process ID
    struct proc *parent;      // Parent process
    void *chan;               // If non-zero, sleeping on chan
    int killed;               // If non-zero, have been killed
    struct file *ofile[NOFILE]; // Open files
    struct inode *cwd;        // Current directory
    struct context context;   // Switch here to run process
    struct trapframe *tf;     // Trap frame for the
                              // current interrupt
};
```


LINUX: STRUCTURES

- **struct task_struct**, equivalent to struct proc
  - Provides process description
  - Large: 10,000+ bytes
  - /usr/src/linux-headers-{kernel version}/include/linux/sched.h
    - 1227 – 1587
- **struct thread_info**, provides "context"
  - thread_info.h is at:

    /usr/src/linux-headers-{kernel version}/arch/x86/include/asm/

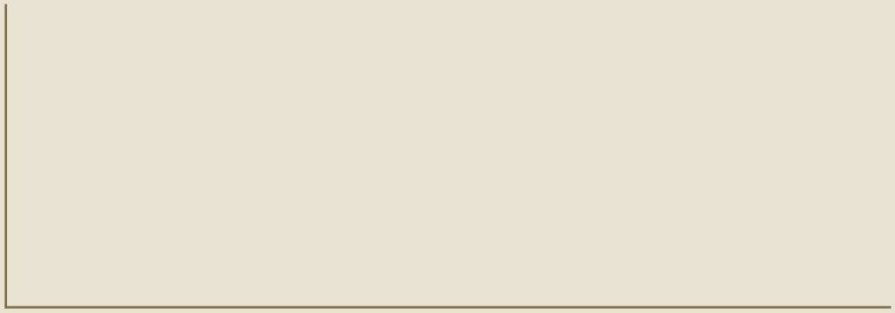
LINUX: THREAD_INFO

```
struct thread_info {
        struct task_struct      *task;          /* main task structure */
        struct exec_domain      *exec_domain;   /* execution domain */
        __u32                   flags;          /* low level flags */
        __u32                   status;         /* thread synchronous flags */
        __u32                   cpu;            /* current CPU */
        int                     preempt_count;  /* 0 => preemptable,
                                                   <0 => BUG */
        mm_segment_t            addr_limit;
        struct restart_block    restart_block;
        void __user             *sysenter_return;
#ifdef CONFIG_X86_32
        unsigned long           previous_esp;   /* ESP of the previous stack in
                                                   case of nested (IRQ) stacks
                                                */
        __u8                    supervisor_stack[0];
#endif
        int                     uaccess_err;
};
```


LINUX STRUCTURES - 2

- List of Linux data structures:
  http://www.tldp.org/LDP/tlk/ds/ds.html
- Description of process data structures:
  http://www.makelinux.net/books/lkd2/ch03lev1sec1
  2nd edition is online (dated from 2005):
  Linux Kernel Development, 2nd edition
  Robert Love
  Sams Publishing

When a process is in this state, it is advantageous for the Operating System to perform a CONTEXT SWITCH to perform other work



RUNNING READY BLOCKED All of the above None of the above

QUESTION: WHEN TO CONTEXT SWITCH

- When a process is in this state, it is advantageous for the Operating System to perform a CONTEXT SWITCH to perform other work:

- (a) RUNNING
- (b) READY
- (c) BLOCKED
- (d) All of the above
- (e) None of the above

CHAPTER 5: C PROCESS API

fork()

- Creates a new process - think of "a fork in the road"
- "Parent" process is the original
- Creates "child" process of the program from the **current execution point**
- Book says "pretty odd"
- Creates a **duplicate** program instance (these are **processes!**)
- **Copy** of
  - Address space (memory)
  - Register
  - Program Counter (PC)
- Fork returns
  - child PID to parent
  - 0 to child

FORK EXAMPLE

- p1.c

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>

int main(int argc, char *argv[]){
    printf("hello world (pid:%d)\n", (int) getpid());
    int rc = fork();
    if (rc < 0) {          // fork failed; exit
        fprintf(stderr, "fork failed\n");
        exit(1);
    } else if (rc == 0) { // child (new process)
        printf("hello, I am child (pid:%d)\n", (int) getpid());
    } else {               // parent goes down this path (main)
        printf("hello, I am parent of %d (pid:%d)\n",
        rc, (int) getpid());
    }
    return 0;
}
```


FORK EXAMPLE - 2

- Non deterministic ordering of execution

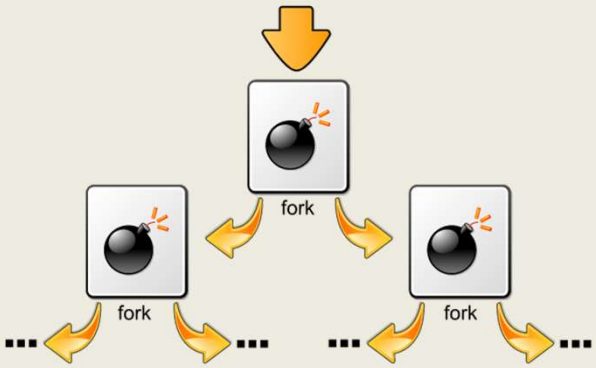
```
prompt> ./p1
hello world (pid:29146)
hello, I am parent of 29147 (pid:29146)
hello, I am child (pid:29147)
prompt>
```

or

```
prompt> ./p1
hello world (pid:29146)
hello, I am child (pid:29147)
hello, I am parent of 29147 (pid:29146)
prompt>
```

- CPU scheduler determines which to run first

:(){ :|: & };:



wait()

- wait(), waitpid()
- Called by parent process
- Waits for a child process to finish executing
- Not a sleep() function
- Provides some ordering to multi-process execution

FORK WITH WAIT

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <sys/wait.h>

int main(int argc, char *argv[]){
    printf("hello world (pid:%d)\n", (int) getpid());
    int rc = fork();
    if (rc < 0) {          // fork failed; exit
        fprintf(stderr, "fork failed\n");
        exit(1);
    } else if (rc == 0) { // child (new process)
        printf("hello, I am child (pid:%d)\n", (int) getpid());
    } else {               // parent goes down this path (main)
        int wc = wait(NULL);
        printf("hello, I am parent of %d (wc:%d) (pid:%d)\n",
        rc, wc, (int) getpid());
    }
    return 0;
}
```


FORK WITH WAIT - 2

- Deterministic ordering of execution

```
prompt> ./p2
hello world (pid:29266)
hello, I am child (pid:29267)
hello, I am parent of 29267 (wc:29267) (pid:29266)
prompt>
```

FORK EXAMPLE

- Linux example

exec()

- Supports running an external program
- 6 types: execl(), execlp(), execle(), execv(), execvp(), execvpe()
- execl(), execlp(), execle(): const char *arg

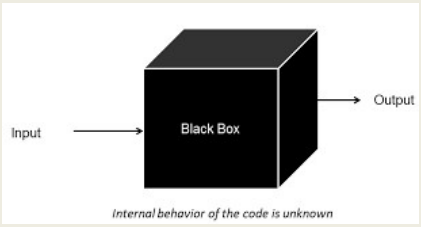
  List of pointers (terminated by null pointer)
  to strings provided as arguments… (arg0, arg1, .. argn)
- Execv(), execvp(), execvpe()
  Array of pointers to strings as arguments

  Strings are null-terminated
  First argument is name of file being executed

EXEC() - 2

- Common use case:
- Write a new program which wraps a legacy one
- Provide a new interface to an old system: Web services
- Legacy program thought of as a "black box"

- We don't want to know what is inside…



EXEC EXAMPLE

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <sys/wait.h>

int main(int argc, char *argv[]){
    printf("hello world (pid:%d)\n", (int) getpid());
    int rc = fork();
    if (rc < 0) {                    // fork failed; exit
        fprintf(stderr, "fork failed\n");
        exit(1);
    } else if (rc == 0) {            // child (new process)
        printf("hello, I am child (pid:%d)\n", (int) getpid());
        char *myargs[3];
        myargs[0] = strdup("wc");           // program: "wc" (word count)
        myargs[1] = strdup("p3.c");         // argument: file to count
        myargs[2] = NULL;                   // marks end of array
        …
```

EXEC EXAMPLE - 2

```
…
        execvp(myargs[0], myargs); // runs word count
        printf("this shouldn't print out");
    } else {                       // parent goes down this path (main)
        int wc = wait(NULL);
        printf("hello, I am parent of %d (wc:%d) (pid:%d)\n",
            rc, wc, (int) getpid());
    }
    return 0;
}
```

```
prompt> ./p3
hello world (pid:29383)
hello, I am child (pid:29384)
29 107 1030 p3.c
hello, I am parent of 29384 (wc:29384) (pid:29383)
prompt>
```


EXEC WITH FILE REDIRECTION (OUTPUT)

```
#include <stdio.h>
#include <stdlib.h>
#include <unistd.h>
#include <string.h>
#include <fcntl.h>
#include <sys/wait.h>

int
main(int argc, char *argv[]){
    int rc = fork();
    if (rc < 0) {          // fork failed; exit
        fprintf(stderr, "fork failed\n");
        exit(1);
    } else if (rc == 0) { // child: redirect standard output to a file
        close(STDOUT_FILENO);
        open("./p4.output", O_CREAT|O_WRONLY|O_TRUNC, S_IRWXU);
        …
```

FILE MODE BITS

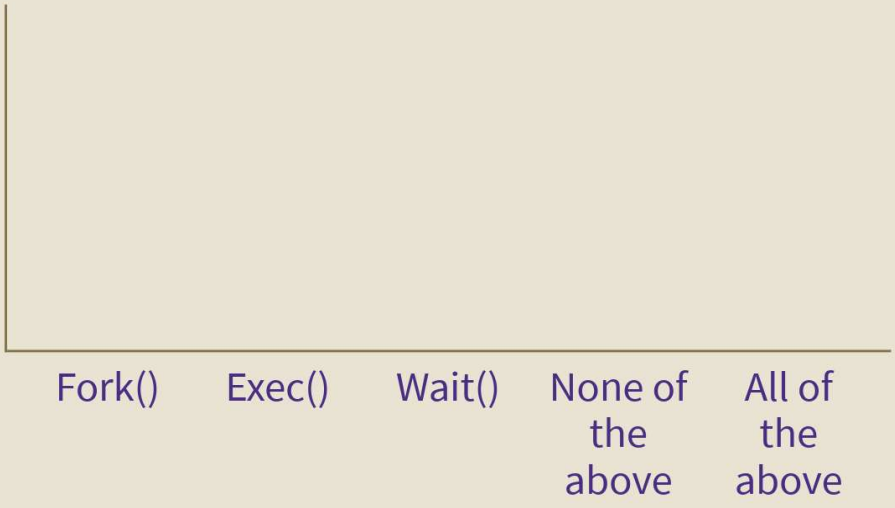
```
S_IRWXU
read, write, execute/search by owner
S_IRUSR
read permission, owner
S_IWUSR
write permission, owner
S_IXUSR
execute/search permission, owner
S_IRWXG
read, write, execute/search by group
S_IRGRP
read permission, group
S_IWGRP
write permission, group
S_IXGRP
execute/search permission, group
S_IRWXO
read, write, execute/search by others
S_IROTH
read permission, others
S_IWOTH
write permission, others
```


EXEC W/ FILE REDIRECTION (OUTPUT) - 2

```
        …
        // now exec "wc"...
        char *myargs[3];
        myargs[0] = strdup("wc");          // program: "wc" (word count)
        myargs[1] = strdup("p4.c");        // argument: file to count
        myargs[2] = NULL;                  // marks end of array
        execvp(myargs[0], myargs);         // runs word count
    } else {                          // parent goes down this path (main)
        int wc = wait(NULL);
    }
    return 0;
}
```

```
prompt> ./p4
prompt> cat p4.output
32 109 846 p4.c
prompt>
```

Which Process API call is used to launch a different program from the current program?



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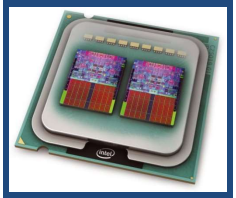
Total Results

QUESTION: PROCESS API

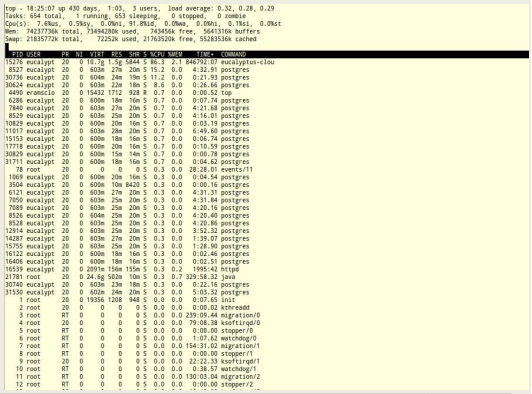
- Which Process API call is used to launch a different program from the current program?
- (a) Fork()
- (b) Exec()
- (c) Wait()
- (d) None of the above
- (e) All of the above

CH. 6: LIMITED DIRECT EXECUTION



VIRTUALIZING THE CPU

- How does the CPU support running so many jobs simultaneously?
- **Time Sharing**
- Tradeoffs:
  - Performance
    - Excessive overhead
  - Control
    - Fairness
    - Security
- Both HW and OS support is used



COMPUTER BOOT SEQUENCE: OS WITH DIRECT EXECUTION

- What if programs could directly control the CPU / system?

OS	Program
1. Create entry for process list 2. Allocate memory for program 3. Load program into memory 4. Set up stack with `argc` / `argv`	
5. Clear registers 6. Execute call `main()`	7. Run `main()` 8. Execute `return` from `main()`
9. Free memory of process 10. Remove from process list	

COMPUTER BOOT SEQUENCE: OS WITH DIRECT EXECUTION

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OS	Program
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Without *limits* on running programs, the OS wouldn't be in control of anything and would "just be a library"

DIRECT EXECUTION - 2

- **With direct execution:**

  How does the OS stop a program from running, and switch to another to support **time sharing**?

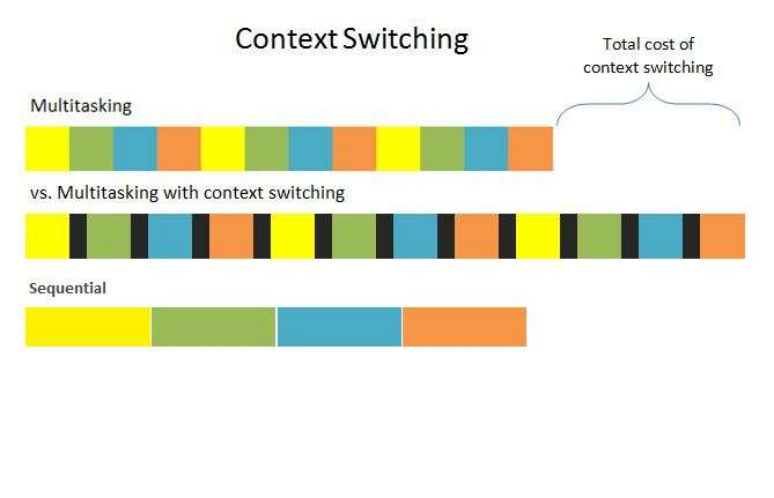
  How do programs share disks and perform I/O if they are given direct control? Do they know about each other?

  With direct execution, how can dynamic memory structures such as linked lists grow over time?

CONTROL TRADEOFF

- **Too little control:**
  - No security
  - No time sharing
- **Too much control:**
  - Too much OS overhead
  - Poor performance for compute & I/O
  - Complex APIs (system calls), difficult to use

CONTEXT SWITCHING OVERHEAD



LIMITED DIRECT EXECUTION

- OS implements LDE to support time/resource sharing
- Limited direct execution means "only limited" processes can execute DIRECTLY on the CPU in ***trusted*** mode
- TRUSTED means the process is trusted, and it can do anything… (e.g. it is a system / kernel level process)
- Enabled by ***protected (safe) control transfer***
- CPU supported context switch
- Provides data isolation

CPU MODES

- Utilize CPU Privilege Rings (Intel x86)
  - rings 0 (kernel), 1 (VM kernel), 2 (unused), 3 (user)

access ← no access

- **User mode**:
  Application is running, but w/o direct I/O access
- **Kernel mode**:
  OS kernel is running performing restricted operations

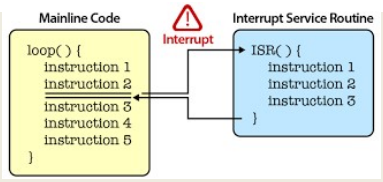
CPU MODES

- **User mode: ring 3 - untrusted**
  - Some instructions and registers are disabled by the CPU
  - Exception registers
  - HALT instruction
  - MMU instructions
  - OS memory access
  - I/O device access
- **Kernel mode: ring 0 – trusted**
  - All instructions and registers enabled

SYSTEM CALLS

- Implement restricted "OS" operations
- Kernel exposes key functions through an API:
  - Device I/O (e.g. file I/O)
  - Task swapping: context switching between processes
  - Memory management/allocation: malloc()
  - Creating/destroying processes

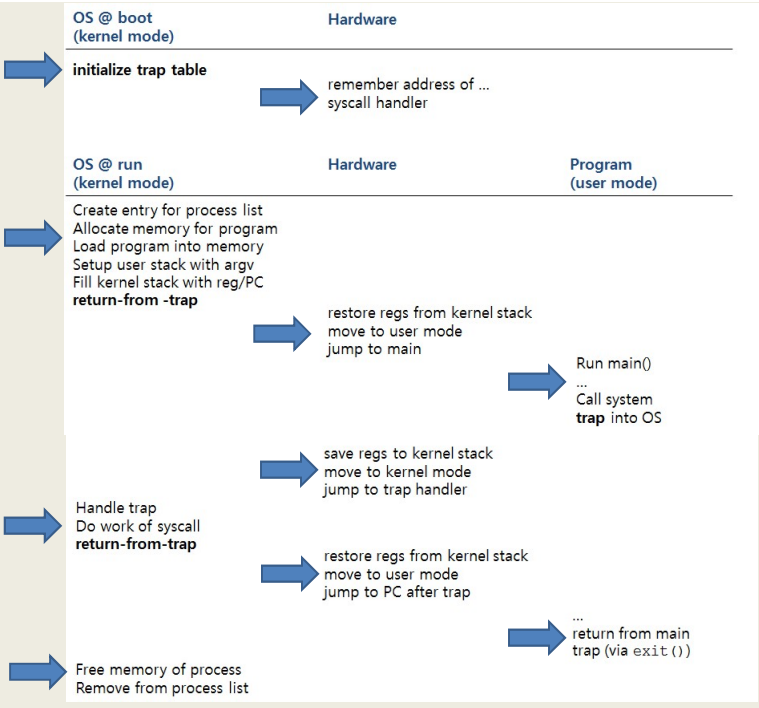
TRAPS: SYSTEM CALLS, EXCEPTIONS, INTERRUPTS

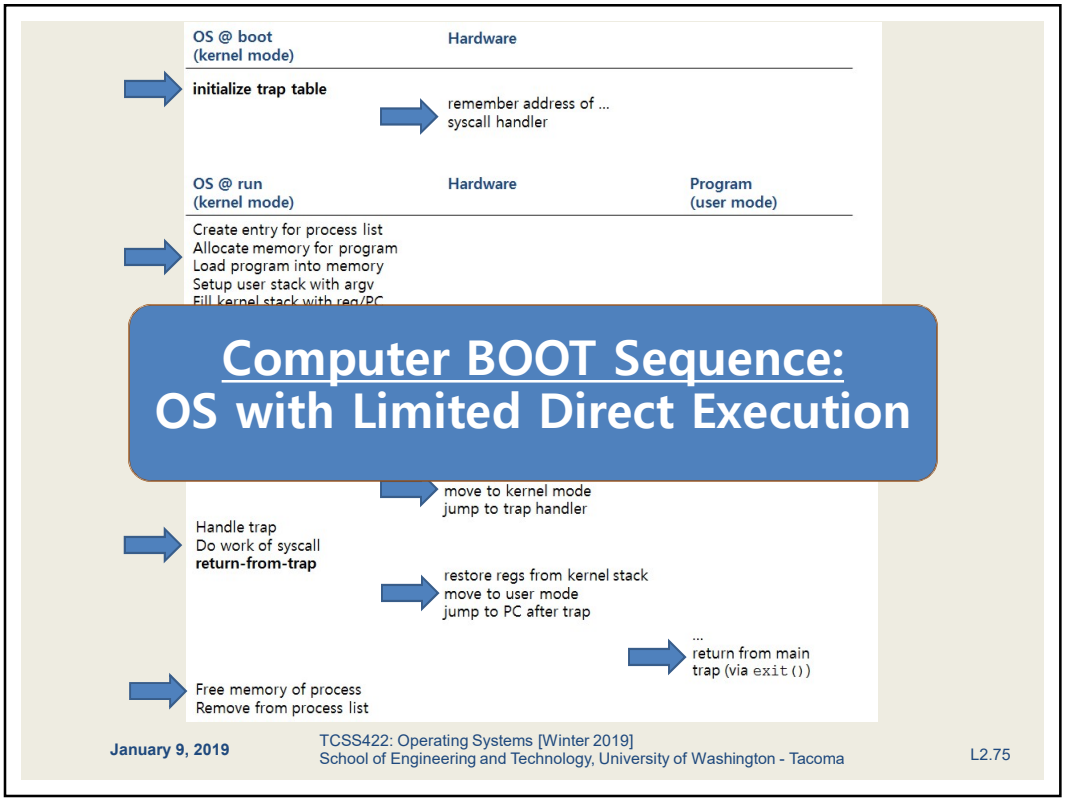


- Trap: any transfer to kernel mode
- Three kinds of traps
  - **System call:** (planned) user → kernel
    - SYSCALL for I/O, etc.
  - **Exception:** (error) user → kernel
    - Div by zero, page fault, page protection error
  - **Interrupt:** (event) user → kernel
    - Non-maskable vs. maskable
    - Keyboard event, network packet arrival, timer ticks
    - Memory parity error (ECC), hard drive failure

EXCEPTION TYPES

Exception type	Synchronous vs. asynchronous	User request vs. coerced	User maskable vs. nonmaskable	Within vs. between instructions	Resume vs. terminate
I/O device request	Asynchronous	Coerced	Nonmaskable	Between	Resume
Invoke operating system	Synchronous	User request	Nonmaskable	Between	Resume
Tracing instruction execution	Synchronous	User request	User maskable	Between	Resume
Breakpoint	Synchronous	User request	User maskable	Between	Resume
Integer arithmetic overflow	Synchronous	Coerced	User maskable	Within	Resume
Floating-point arithmetic overflow or underflow	Synchronous	Coerced	User maskable	Within	Resume
Page fault	Synchronous	Coerced	Nonmaskable	Within	Resume
Misaligned memory accesses	Synchronous	Coerced	User maskable	Within	Resume
Memory protection violation	Synchronous	Coerced	Nonmaskable	Within	Resume
Using undefined instruction	Synchronous	Coerced	Nonmaskable	Within	Terminate
Hardware malfunction	Asynchronous	Coerced	Nonmaskable	Within	Terminate
Power failure	Asynchronous	Coerced	Nonmaskable	Within	Terminate





MULTITASKING

- How/when should the OS regain control of the CPU to switch between processes?
- Cooperative multitasking (mostly pre 32-bit)
  - < Windows 95, Mac OSX
  - Opportunistic: running programs must give up control
    - User programs must call a special **yield** system call
    - When performing I/O
    - Illegal operations
  - (POLLEV)
    What problems could you for see with this approach?

MULTITASKING

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  - Op
    - When performing I/O
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    What problems could you for see with this approach?

A process gets stuck in an infinite loop.
→ **Reboot the machine**

What problems exist for regaining the control of the CPU with cooperative multitasking OSes?

Start the presentation to see live content. Still no live content? Install the app or get help at PollEv.com/app

Total Results

QUESTION: MULTITASKING

- What problems exist for regaining the control of the CPU with cooperative multitasking OSes?

MULTITASKING - 2

- Preemptive multitasking (32 & 64 bit OSes)
- >= Mac OSX, Windows 95+

- Timer interrupt
  - Raised at some regular interval (in ms)
  - Interrupt handling
    1. Current program is halted
    2. Program states are saved
    3. OS Interrupt handler is run (kernel mode)

- (PollEV) What is a good interval for the timer interrupt?

MULTITASKING - 2

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  - Rais
  - Inte
    1. Current program is halted
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- (PollEV) What is a good interval for the timer interrupt?

A timer interrupt gives OS the ability to run again on a CPU.

W For an OS that uses a system timer to force arbitrary context switches to share the CPU, what is a good value (in seconds) for the timer interrupt?

QUESTION: TIME SLICE

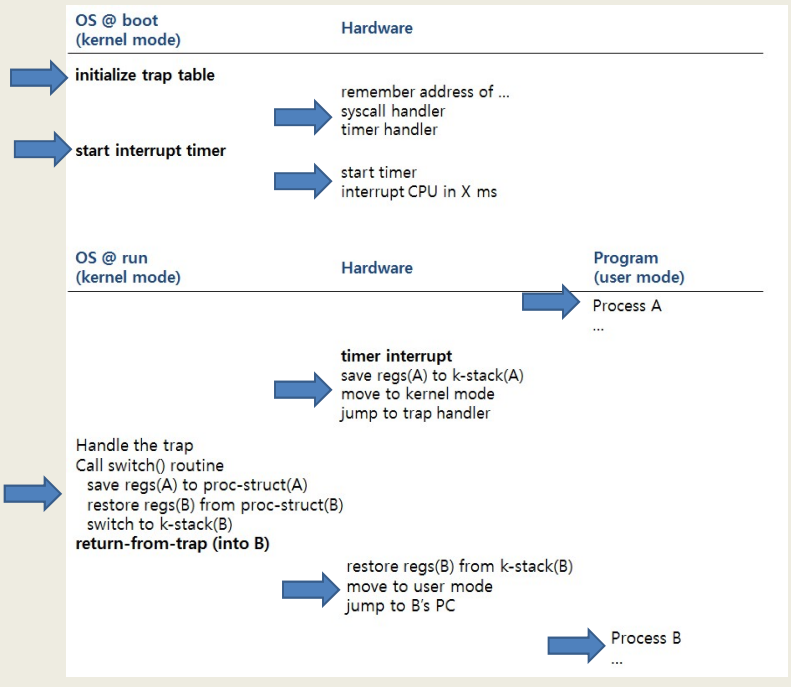
- For an OS that uses a system timer to force arbitrary context switches to share the CPU, what is a good value (in seconds) for the timer interrupt?

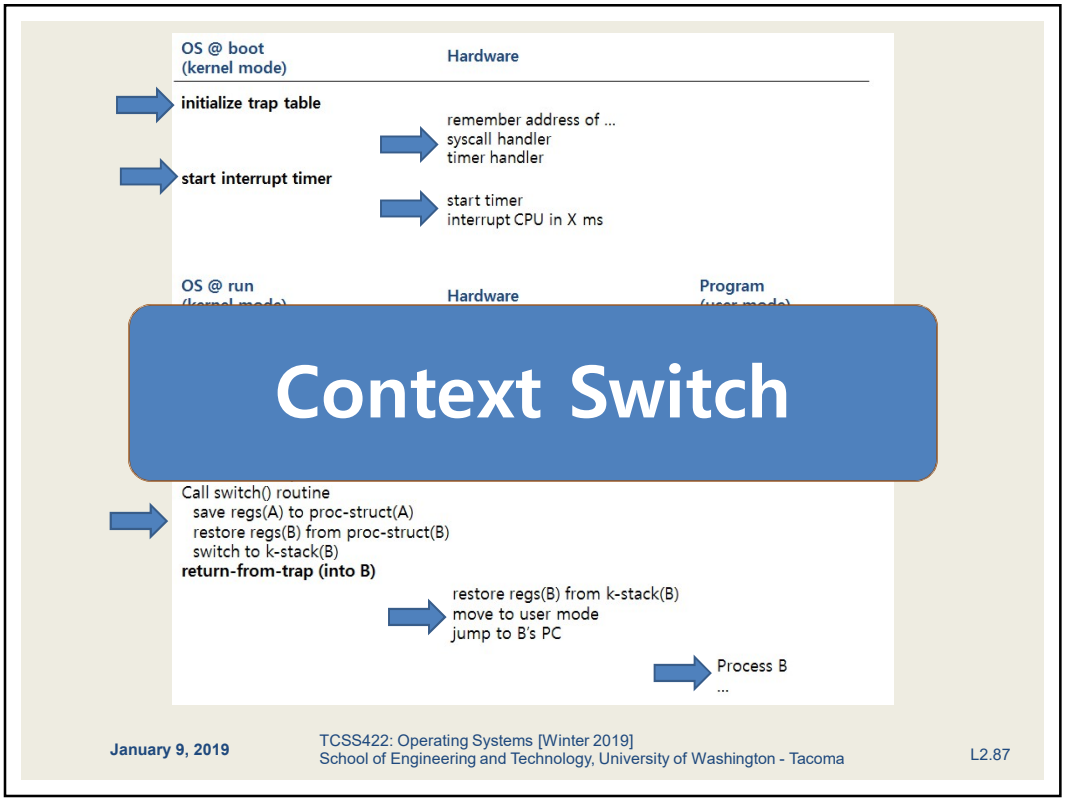
CONTEXT SWITCH

- Preemptive multitasking initiates "trap" into the OS code to determine:
  - Whether to continue running the **current process**, or switch to a **different one**.
  - If the decision is made to switch, the OS performs a context switch swapping out the current process for a new one.

CONTEXT SWITCH - 2

1. Save register values of the current process to its kernel stack
   - General purpose registers
   - PC: program counter (instruction pointer)
   - kernel stack pointer
2. Restore soon-to-be-executing process from its kernel stack
3. Switch to the kernel stack for the soon-to-be-executing process





INTERRUPTED INTERRUPTS

- What happens if during an interrupt (trap to kernel mode), another interrupt occurs?
- Linux
  - < 2.6 kernel: non-preemptive kernel
  - >= 2.6 kernel: preemptive kernel

PREEMPTIVE KERNEL

- Use "locks" as markers of regions of non-preemptibility (non-maskable interrupt)
- Preemption counter (`preempt_count`)
  - begins at zero
  - increments for each lock acquired (not safe to preempt)
  - decrements when locks are released
- Interrupt can be interrupted when `preempt_count=0`
  - It is safe to preempt (maskable interrupt)
  - the interrupt is more important

QUESTIONS