Processes

Andre M. Maier, DHBW Ravensburg
dhbw@andre-maier.com

What is a process?

- A process is an instance of a program that is being executed
- A process may have one or more child processes and be a child of its parent process.
- Instructions within one process may be executed concurrently by multiple threads.

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Program vs. Process

- Baking analogy
  - CPU → Baker
  - Input Data → Cake Ingredients
  - Program → Recipe
- “... a program is something that may be stored on disk, not doing anything.” [1]

[1] Andrew S. Tanenbaum, Modern Operating Systems, 4th Edition

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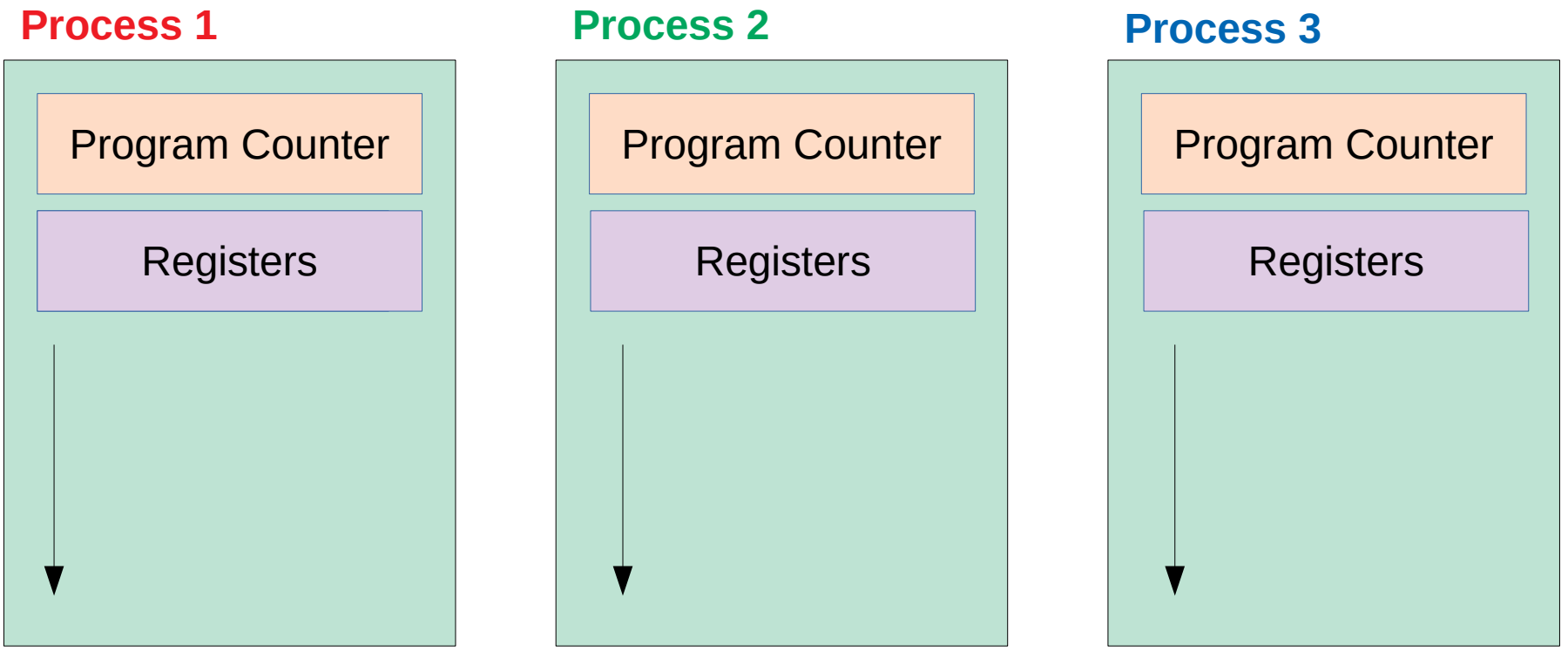
Process Model



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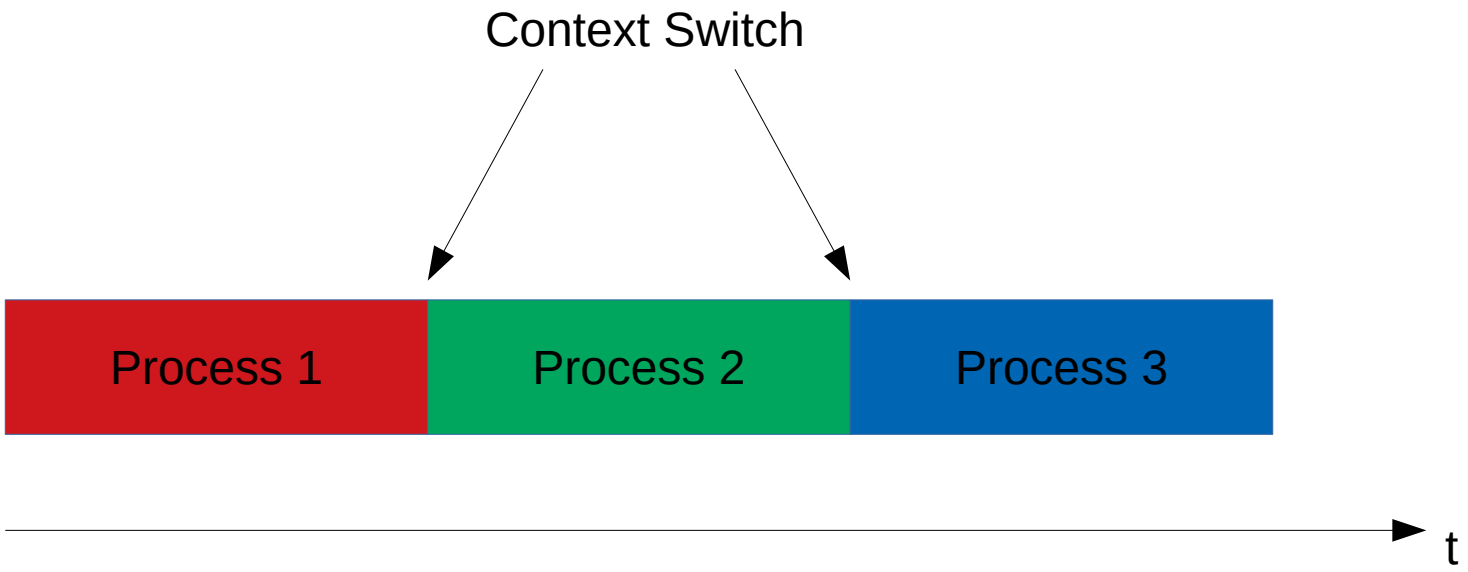
Execution on a Single-Core CPU



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Context Switch (1)

- A context completely describes a process's current state of execution.
  - Program counter
  - Registers
  - Virtual address space
- During a context switch ...
  - the current process's execution is suspended
  - the context information for that process is stored
  - the context of the next process is retrieved from memory and restored in the CPU's registers
  - the execution of the new process is resumed at the location indicated by the program counter

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Context Switch (2)

- Hardware context switching
  - Context switch completely performed by CPU hardware
- Software context switching
  - Context switch performed by the operating system
  - Often preferred for performance and portability reasons
- Context switches are performed by a component called *dispatcher*, which is part of the scheduler. The dispatcher also alters the flow of execution that is required in a context switch.

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Processes vs. Threads

- A single process can have multiple threads.
- A thread represents a separate, independent, path of execution within a process.
- All threads of a process share the process's address space (memory).
- Each thread has its own execution stack
  - Multiple threads can call the execute the same function concurrently
- Advantages of threads over processes
  - less context switching time
  - easier, more efficient, communication between threads
  - concurrency within a process

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Process-related OS Objectives

- Maximize processor utilization
- Allocate resources to processes
- Prioritize execution
- Allow for user creation of processes
- Provide mechanisms for synchronization and inter-process communication

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Process Control Block (PCB)

Process ID
State
Priority
Owner
Memory Pointers
Context data
I/O status information
Accounting information
...
...

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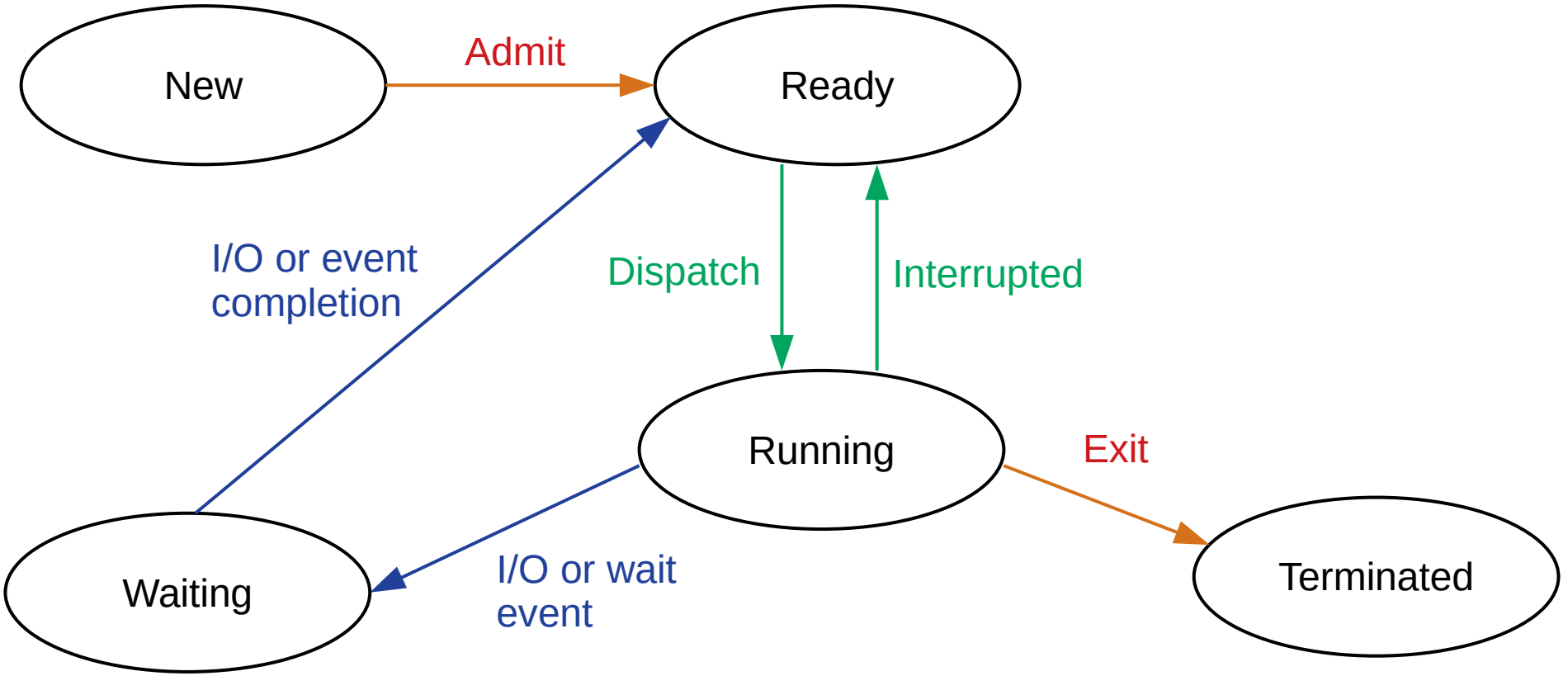
Process States



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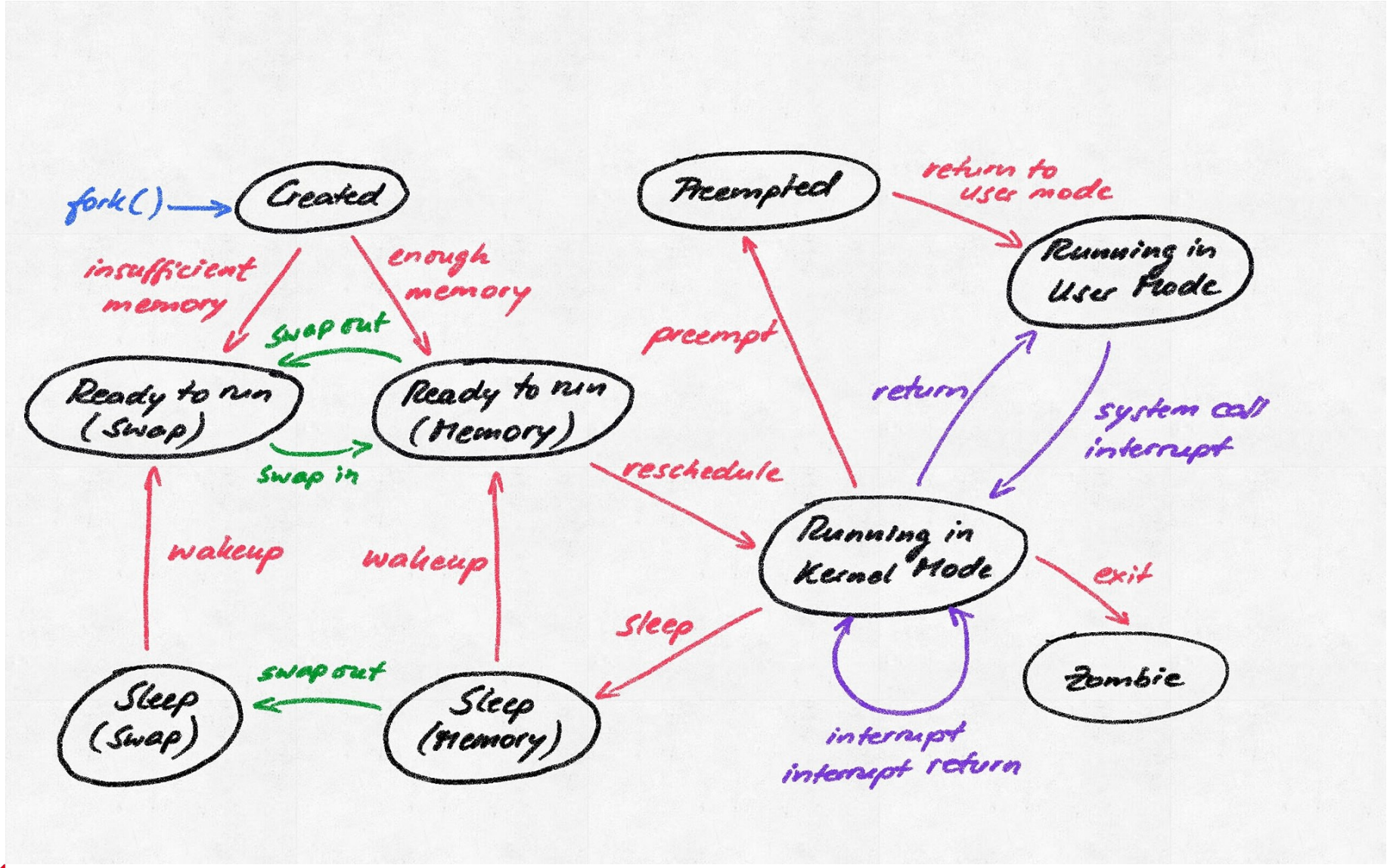
On Linux ...



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Lab Exercises (1)

- Make yourself familiar with the following Unix/Linux tools.
  - `ps`
  - `pstree`
  - `top`, `htop`
  - GUI system resource monitor
- Find out how you can use `ps` to identify and display
  - the PID of a process with a certain name
  - the process state of a process with a certain PID or name
- Write and run a C program that contains an empty infinite loop. Examine its execution by using the tools mentioned above.

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Lab Exercises (2)

- Change the program to put the process to sleep for 1 second in the endless loop. Explain in detail how this change affects process execution.
- Make yourself familiar with the following bash features:
  - `jobs`
  - `bg`, `fg`
  - `&`
- What do *bash jobs* have to do with processes?

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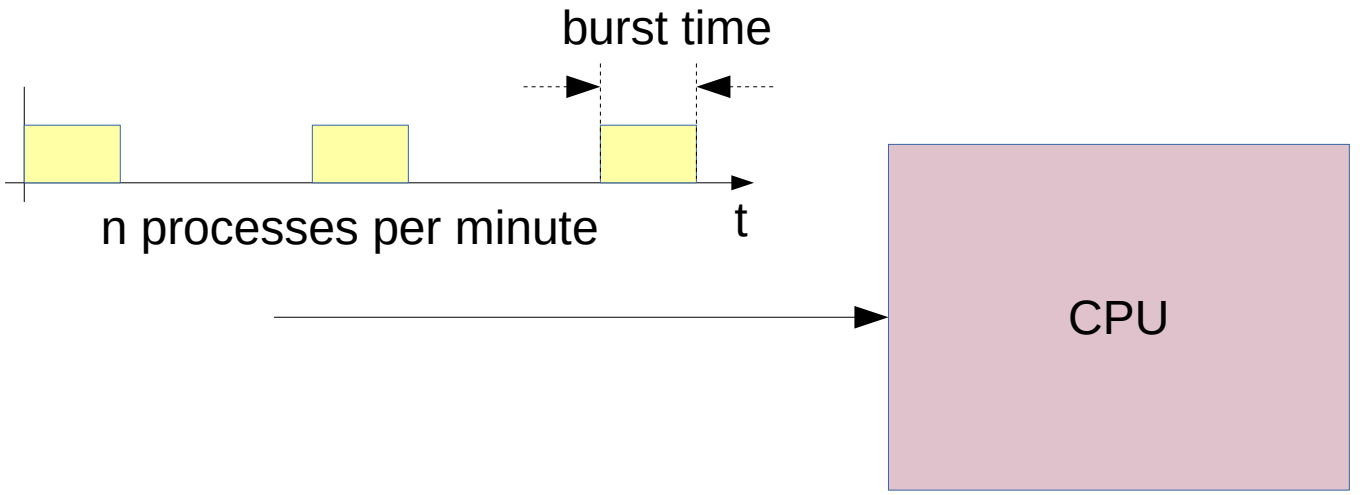
Lab Exercises (3)

- Analyze the following C program and explain what it does.

```
#include <unistd.h>
int main(int argc, char** argv)
{
   while(1)
      fork();
   return 0;
}
```

- Open your GUI system resource monitor, compile and run the program.
- What security mechanism does Linux provide to prevent such code from causing harm?

CPU Utilization (1)



$$CPU\ Utilization = \frac{Burst\ Time}{Period\ Time}$$

Example:
Processes arrive at a rate of 12 processes per minute. The average burst time is 4 seconds. Determine the average CPU utilization (in percentage).

CPU Utilization (2)

- In Linux, *top* or *uptime* shows the “load average” on a system.
- Three numbers: System load average over the last 1min, 5min, 15min.
- The number is the number of processes in either a *runnable* or *uninterruptable* (e.g. waiting for some I/O) state.
- Interpretation
  - 100% utilization on a single core CPU -> 1.0
  - 100% utilization on a quad core CPU -> 4.0

Questions for Review

- What is the difference between a process and a program?
- What are the steps that are involved in a context switch?
- Explain the five-state process model.
- Explain how a fork bomb works and how it can potentially compromise a computer system.
- The following load average values are shown on a Linux system running on a quad core processor:
  7.12, 2.02, 0.83
  What conclusions can you draw on the workload of this system?