Chapter 9
Process management

Chapter 9 Outline

- In this chapter we will learn about:
  - ✓ Processes and process concepts
  - ✓ Examining processes
  - ✓ Adjusting process priority and job control
  - ✓ Signals, orphans and zombies

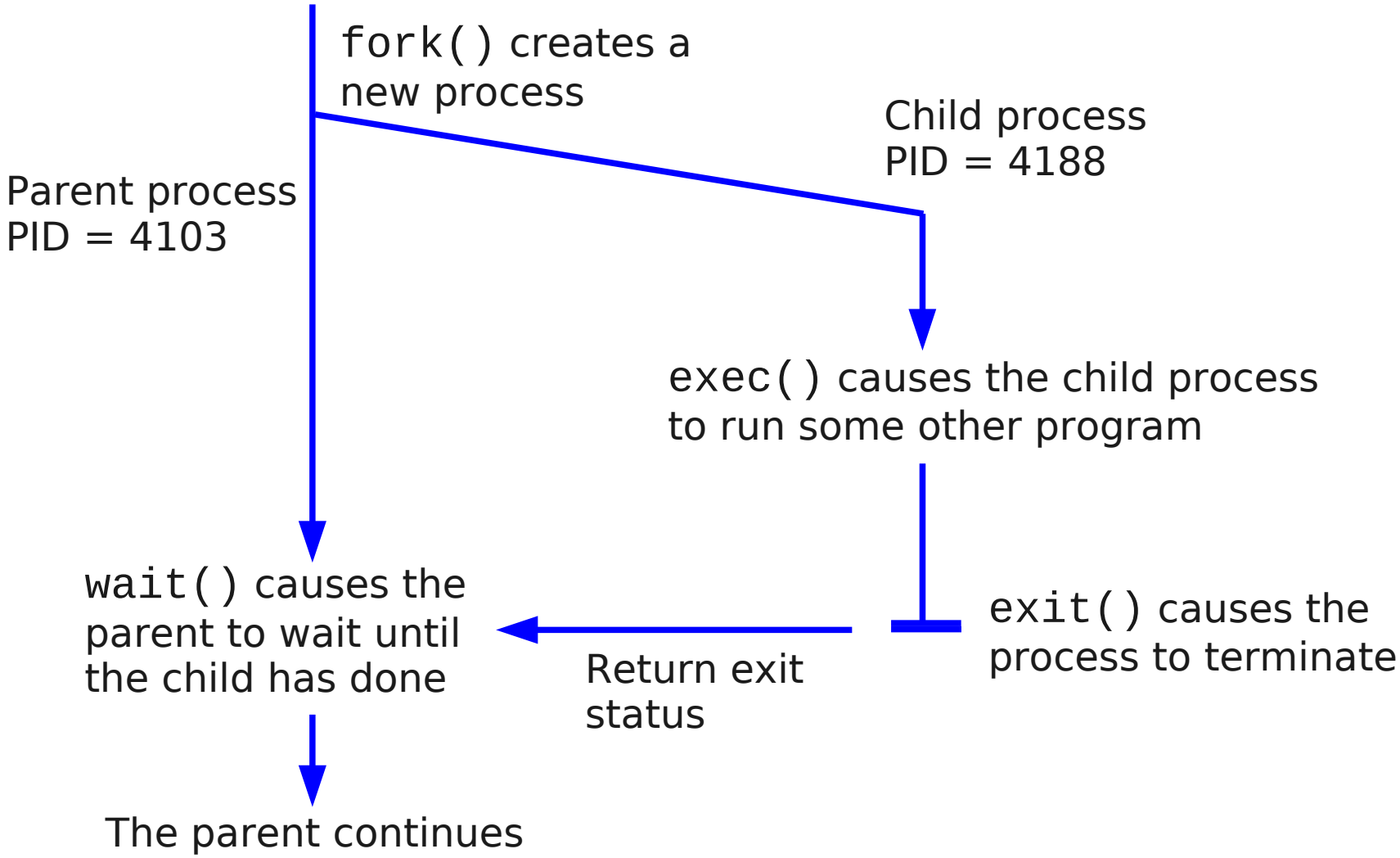
Process concepts

- Process concepts
  - Processes
  - Typical process life cycle

Processes

- A process represents an active instance of a program
- Some processes are started by users
  - Typing commands on a command line
  - Selecting applications from a desktop menu
- Some processes are started automatically, usually at boot time
  - Provide system sevices e.g. file servers, print services, web servers
  - Known as “daemons”
- At any one time, a linux system is likely to have between 50 and 500 processes
- Linux performs *pre-emptive multitasking* between processes allowing them to share resources (including CPU time) on the computer
- Each process has a numeric identifier, called its *process ID* (PID)

Typical process life cycle

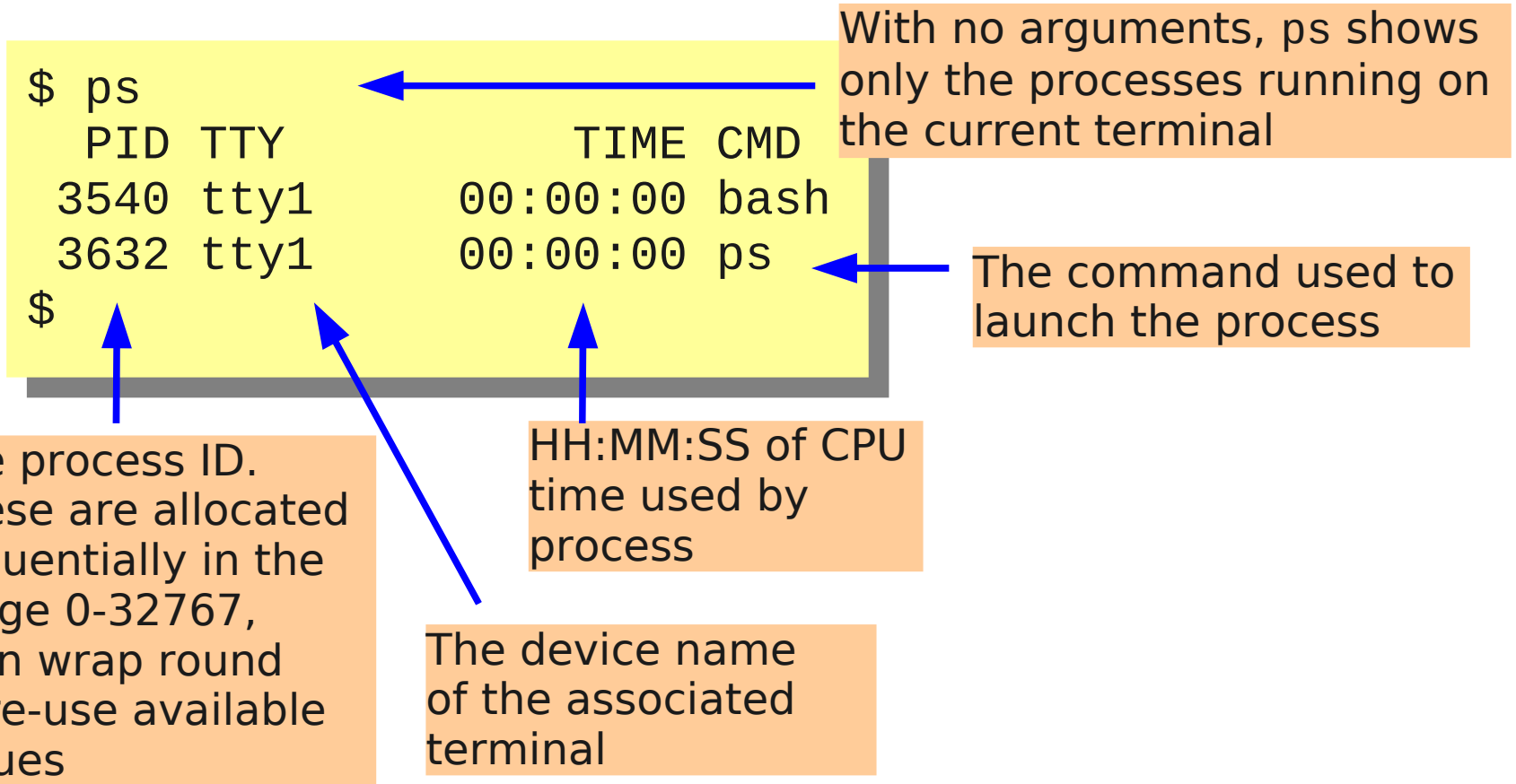


Examining processes

- Examining processes
  - Listing processes with ps
  - Command line options for ps
  - Long process listings
  - Listing system processes
  - Listing processes with pstree
  - Showing process activity with top
  - KDE System Guard

Listing processes with ps

- The ps command lists the processes running on the system



Command line options for ps

- A confusing set of option flags control which processes are shown and how much detail is shown about each process
  - Try `man ps` for details
- Process selection flags include:

Flag	Meaning
`x`	List processes that have no controlling terminal
`a`	Show processes belonging to other users
`U user`	Show processes owned by *user*

- Process detail flags include:

Flag	Meaning
`l`	Show long format (more detail)
`u`	Show detailed “user oriented” format
`e`	Show the process environment
`f`	Show processes as a hierarchical tree

“Long” process listings

- The 'l' option provides additional detail for each process

```
$ ps l
F   UID   PID  PPID PRI  NI  VSZ  RSS WCHAN  STAT TTY      TIME COMMAND
0   500  3540  3539  15   0 2884 1700 wait4  S    pts/1    0:00 /bin/bash
0   500  3553  2186  15   0 2868 1648 schedu S    tty1     0:00 -bash
0   500  4107  3540  19   0 3680 1708 -      R    pts/1    0:00 ps l
$
```

ID of the user running the process

ID of the process

ID of the parent process

Priority (lower values mean higher priority)

“NICE” value

Memory usage

What the process is waiting for

Process status:
R Runnable
S Sleeping
T Suspended
Z Zombie

“Long” process listings (continued)

- The 'u' option shows a slightly different set of fields:

```
$ ps u
USER    PID %CPU %MEM    VSZ   RSS TTY    STAT START   TIME COMMAND
chris  3540  0.0  0.3   2884 1700 pts/1  S    16:07   0:00 /bin/bash
chris  3553  0.0  0.3   2868 1648 tty1   S    16:07   0:00 -bash
chris  4172  0.0  0.1   2668  720 pts/1  R    20:39   0:00 ps u
$
```

Percentage of CPU time this process is using

Percentage of memory this process is using

Time (HH:MM) when process was started

Listing system processes

- The command `ps ax` shows all processes

```
$ ps ax
PID TTY      STAT   TIME COMMAND
    1 ?        S      0:04 init [3]
    2 ?        SW     0:00 [keventd]
    3 ?        SWN    0:00 [ksoftirqd_CPU0]
    4 ?        SW     0:00 [kswapd]
    ....
  724 ?        S      0:00 /sbin/syslogd
  727 ?        S      0:00 /sbin/klogd -c 1 -2
 1081 ?        S      0:00 /sbin/portmap
 1115 ?        S      0:00 /sbin/rpc.statd
 1278 ?        S      0:00 /usr/sbin/acpid
    ....
 8432 ?        S      0:00 login -- tux
 8433 tty1     S      0:00 -bash
 8453 tty1     R      0:00 ps ax
```

This list has been heavily edited

Kernel processes

Daemons

User processes

Listing processes with `pstree`

- The `pstree` command shows the parent/child relationships of processes as a tree using “ASCII art”

```
$ pstree -u
init-+-acpid
     |-bdflush
     |-cardmgr
     |-cpufreqd
     |-cron
     |-cupsd(lp)
     |-dhcpcd
     |-httpd2-prefork---5*[httpd2-prefork(wwwrun)]
     |-kalarmd(chris)
     |-kamix(chris)
     |-kdeinit(chris)-+-artsd
     |                |-3*[kdeinit]
     |                |-kdeinit---bash---pstree
     |                `-soffice.bin---soffice.bin---4*[soffice.bin]
     |-10*[kdeinit(chris)]
     |-kdm-+-X
     |     `-kdm---kde(chris)---kwrapper
```

Showing process activity with `top`

- The `top` command shows a real-time display of process activity which automatically updates at regular intervals
  - Shows the 'top' screenful of processes sorted on a selected column
    - %CPU, %Memory, etc.
  - Interactive commands allow
    - selection of whose processes to show
    - selection of which field to sort on
    - selection of refresh interval
    - killing of processes
  - 'h' command shows help screen, 'q' quits

An example of top

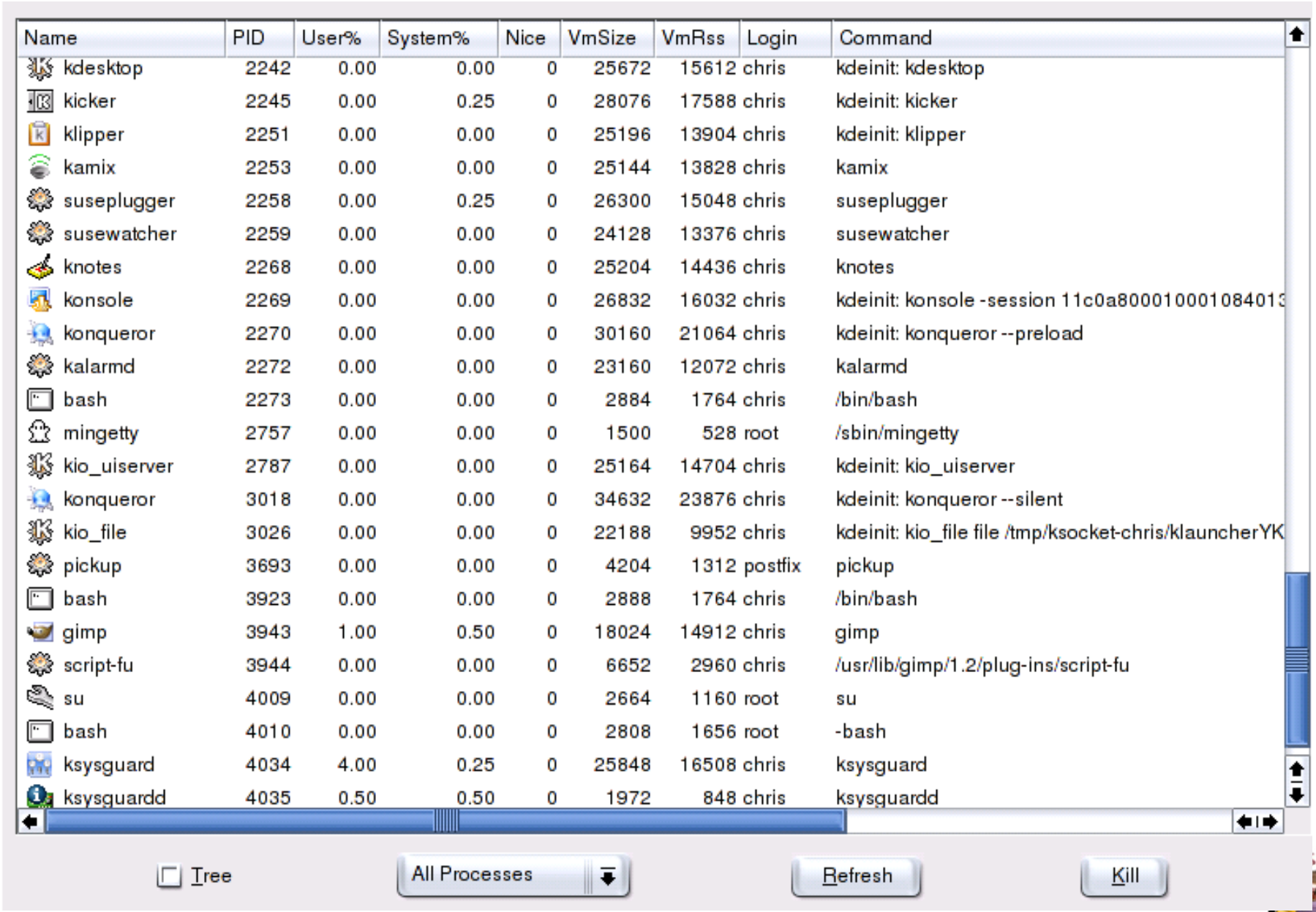
```
top - 19:39:49 up  9:07,  4 users,  load average: 0.72, 0.28, 0.13
Tasks:  96 total,   2 running,  94 sleeping,   0 stopped,   0 zombie
Cpu(s):  98.4% user,   1.6% system,   0.0% nice,   0.0% idle
Mem:    514372k total,   472548k used,    41824k free,    82732k buffer
Swap:  1036184k total,     2688k used,  1033496k free,   145852k cached
```

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
3942	**chris**	**25**	**0**	**272**	**272**	**220**	**R**	**93.1**	**0.1**	**0:54.76**	**soak**
2232	chris	-51	0	6336	6260	4656	S	3.0	1.2	0:02.32	artsd
2003	root	15	0	44836	19m	4608	S	1.3	3.9	2:48.67	X
3922	**chris**	**16**	**0**	**952**	**952**	**748**	**R**	**1.3**	**0.2**	**0:01.69**	**top**
2562	chris	15	0	75556	73m	50m	S	0.7	14.7	2:38.78	soffice.
3946	chris	18	0	1032	1032	816	S	0.7	0.2	0:00.02	xwd
2269	chris	15	0	15980	15m	13m	S	0.3	3.1	0:28.87	kdeinit
1	root	15	0	256	256	220	S	0.0	0.0	0:04.94	init
2	root	15	0	0	0	0	S	0.0	0.0	0:00.25	keventd
3	root	34	19	0	0	0	S	0.0	0.0	0:00.01	ksoftirq
4	root	15	0	0	0	0	S	0.0	0.0	0:00.26	kswapd
5	root	25	0	0	0	0	S	0.0	0.0	0:00.00	bdflush
6	root	15	0	0	0	0	S	0.0	0.0	0:00.27	kupdated
7	root	16	0	0	0	0	S	0.0	0.0	0:00.04	kinoded

KDE System Guard

- KDE system guard is a graphical application for displaying the process table and charting the system load
- *Process controller window* provides functionality similar to `top`
- *System load window* supports charting of a number of 'sensors'
  - Discussed in Chapter 10
- Able to monitor process activity on remote machines
  - Connects to `ksysguardd` daemon on target machine
  - Allows graphical monitoring of activity on (non-graphical) servers

KDE System Guard process controller



Name	PID	User%	System%	Nice	VmSize	VmRss	Login	Command
kdesktop	2242	0.00	0.00	0	25672	15612	chris	kdeinit: kdesktop
kicker	2245	0.00	0.25	0	28076	17588	chris	kdeinit: kicker
klipper	2251	0.00	0.00	0	25196	13904	chris	kdeinit: klipper
kamix	2253	0.00	0.00	0	25144	13828	chris	kamix
suseplugger	2258	0.00	0.25	0	26300	15048	chris	suseplugger
susewatcher	2259	0.00	0.00	0	24128	13376	chris	susewatcher
knotes	2268	0.00	0.00	0	25204	14436	chris	knotes
konsole	2269	0.00	0.00	0	26832	16032	chris	kdeinit: konsole -session 11c0a800010001084013
konqueror	2270	0.00	0.00	0	30160	21064	chris	kdeinit: konqueror --preload
kalarmd	2272	0.00	0.00	0	23160	12072	chris	kalarmd
bash	2273	0.00	0.00	0	2884	1764	chris	/bin/bash
mingetty	2757	0.00	0.00	0	1500	528	root	/sbin/mingetty
kio_uiserver	2787	0.00	0.00	0	25164	14704	chris	kdeinit: kio_uiserver
konqueror	3018	0.00	0.00	0	34632	23876	chris	kdeinit: konqueror --silent
kio_file	3026	0.00	0.00	0	22188	9952	chris	kdeinit: kio_file file /tmp/ksocket-chris/klauncherYK
pickup	3693	0.00	0.00	0	4204	1312	postfix	pickup
bash	3923	0.00	0.00	0	2888	1764	chris	/bin/bash
gimp	3943	1.00	0.50	0	18024	14912	chris	gimp
script-fu	3944	0.00	0.00	0	6652	2960	chris	/usr/lib/gimp/1.2/plug-ins/script-fu
su	4009	0.00	0.00	0	2664	1160	root	su
bash	4010	0.00	0.00	0	2808	1656	root	-bash
ksysguard	4034	4.00	0.25	0	25848	16508	chris	ksysguard
ksysguardd	4035	0.50	0.50	0	1972	848	chris	ksysguardd

Tree | All Processes | Refresh | Kill

Exercise: Using ps and top

1. Use an appropriate ps command to find the process that is running the daemon 'syslogd'
   - What is the process ID? _____
   - Who owns this process? _____
   - What is the process ID of its parent? _____
   - Hint: use grep to search the output of ps for the process you want
2. Run the top command
   - How long has the system been up? _____
   - What is the total amount of memory in the machine? _____
   - How much memory is linux using? _____
   - Using the help screen as a guide, sort the top listing on (a) the process ID and (b) the %CPU utilisation of the processes

Process priority and job control

- Process priority and job control
  - Adjusting process priority
  - Job control in the shell

Adjusting process priority

- Process priorities are adjusted dynamically and cannot be set explicitly
- The `nice` command adjusts the 'nice' level of a process which affects its dynamic priority
- Nice values range from -20 (highest priority) to +19 (lowest priority)

```
$ nice -n +5 long_running_CPU_bound_program
```

- Only root can start a process with negative niceness (nastiness?)
- The `renice` command adjusts the nice level of a running process

```
$ renice  +1  -u  tux
```

← All processes owned by tux

```
$ renice  +2  1712
```

← Process 1712 only

The 'r' command in `top` can also be used to adjust nice levels

  - Only root can adjust the nice level downwards

Job control in the shell

- The bash shell is able to manage multiple jobs
  - Jobs can be started in the foreground – shell waits for it to finish
  - Jobs can be started in the background by appending '&' to the command – shell prompts for another command immediately
- The following job control commands are available:
  - `jobs` Lists the current jobs
  - `^Z` Stop (pause) the current foreground job
  - `bg` Restart a foreground job in the background
  - `fg` Bring a background job into the foreground
  - `kill` Terminate a job

Job control in the shell (continued)

```
$ xclock -update 1 &
[1] 3197
$ xeyes &
[2] 3198
$ jobs
[1]-  Running                 xclock -update 1 &
[2]+  Running                 xeyes &
$ fg
xeyes

[2]+  Stopped                 xeyes
$ kill %1
$ fg
xeyes

[1]   Terminated              xclock -update 1
```

Job started in background

Shell reports job number and PID

'+' indicates the current job

Bring current job into foreground

^Z stops (pauses) the current job

'%1' means job number 1

^C terminates the foreground job

Shell reports termination of job 1

Exercise: Using job control

- The program `soak` (written especially for this exercise), simply soaks up CPU time in an infinite loop. If started with a command line argument, it will print that argument, the process ID, and a loop counter every pass through the loop

```
$ ./soak A
soak A 4487 0
soak A 4487 1
^C
$
```

- The program `sleep` (a standard tool) simply sleeps for a specified number of seconds, then exits

```
$ sleep 10
$
```

- We will use these two programs to investigate background processes and the use of 'nice' values

Exercise: Using job control (continued)

1. Start 2 instances of `soak` (with no argument) and one instance of `sleep 20`, all in the background
2. List your background jobs with the `jobs` command
   - What are their job numbers and process ids? _____
3. Wait 20 seconds
4. Re-run the jobs command.
   - How many jobs are there now? _____
   - When does the shell notify you that a background job is done? _____
5. Run the command `ps u`
   - What are the PIDs of the two instances of soak? _____
   - What percentage of CPU time are these processes using? _____
6. Kill both background jobs using `kill` and the job numbers

Exercise: Adjusting the `nice` value

7. Start 2 more instances of `soak`, the first with a nice value of 0 (the default) and the second with a nice value of +10
8. Execute `ps u` and examine the %CPU use of both instances
   - Can you see any difference? _____
9. Adjust the nice level of the first `soak` to match that of the second (+10)
10. Re-examine the %CPU usage of both processes. Can you see a change? (It may take a few seconds to see a significant change)
11. Try to adjust the nice level of the first `soak` back down to zero.
    - What happens? _____
12. Kill both jobs
13. Finally, start 2 more instances of `soak` and examine them using `top`. Within `top`, adjust the nice values of the processes, observe their %CPU usage, and finally kill both processes

Signals, orphans and zombies

- Signals, orphans and zombies
  - Sending signals
  - Signal types
  - Signal handlers
  - Orphan processes
  - Zombie processes
  - Getting rid of zombies

Sending signals

- Signals are software interrupts delivered to a process by the kernel
  - Linux defines over 30 signal types, `kill -l` will give the full list
- Some signals can be generated by the terminal driver in response to specific key combinations
  - This only works for programs running in the foreground

`^C` Send SIGINT signal

`^\` Send SIGQUIT signal

- If a program is not running in the foreground, or has no attached terminal, signals can be delivered using the `kill` command:

```
$ kill -15 4321
$ kill -SIGTERM 4321
$ kill 4321
```

Signals can only be sent to a process by its owner (or by root)

SIGTERM is the default type sent by kill

- The `killall` command is similar but specifies processes by name

```
$ killall  -SIGHUP  xinetd
```

Signal types

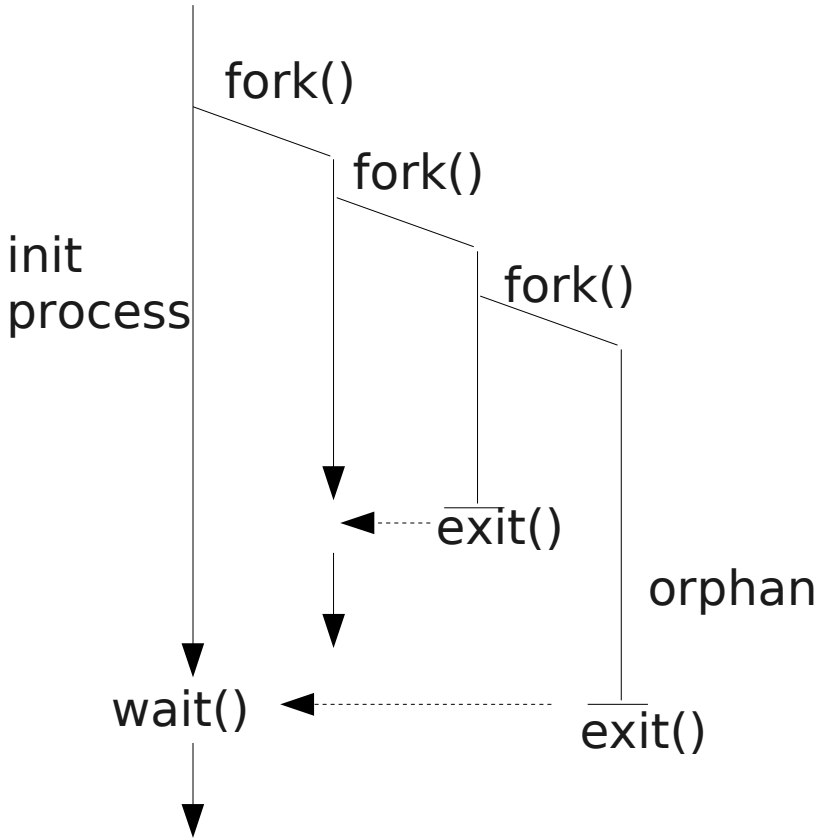
Number	Signal Name	Description	Default Handling
1	SIGHUP	Most shells send this signal to all child processes when they terminate	Kill process
2	SIGINT	Sent by terminal driver in response to ^C. Intended as a graceful termination	Kill process
3	SIGQUIT	Sent by terminal driver in response to ^\	Kill process and write core dump
9	SIGKILL	This signal cannot be caught or ignored	Kill process
15	SIGTERM	This is the default signal sent by the kill command	Kill process
18	SIGCONT	Causes a stopped or traced process to continue	Continue process

Signal handlers

- A process can elect how it wants to react on receipt of a signal by nominating a *handler* for that signal type
  - A function that will be called when the signal is delivered
  - Within a shell script, the `trap` command defines signal handlers
- If a handler is not specified, each signal type has a default behaviour
  - For most signals, the default is to kill the process
  - For some signals, the default is to ignore the signal
- Signals 9 (SIGKILL) and 19 (SIGSTOP) cannot be caught or ignored
  - Use SIGKILL as a last resort – the program has no opportunity to clean up
- Some programs respond to a signal by re-reading their config file
  - The SIGHUP signal is conventionally used for this
  - Allows services to be re-configured on the fly without stopping them

Orphan processes

- Sometimes, a parent process exits without waiting for its child(ren) to finish
  - Any children are automatically inherited by the `init` process



Zombie processes

- Occasionally, a parent process will not wait for its children but will block on some other event
- Processes that exit when no process is waiting for them become 'zombies'
  - Cannot be laid to rest as they want to pass back their exit status
  - Marked as <defunct> in a `ps` listing
  - In the worst case, zombies accumulate and fill the process table so that no more processes can be started
- The way to get rid of zombies is to kill their parent
  - The zombies will then be inherited by `init`
- Zombies are generally a result of bad program design

Getting rid of zombies

```
$ ps l
F   UID   PID  PPID  STAT TTY      TIME COMMAND
0   500  2359  2358  S    pts/1    0:00 /bin/bash
0   500  3705  3704  S    pts/2    0:00 /bin/bash
0   500  3766  2358  S    pts/3    0:00 /bin/bash
0   500  3876  2359  S    pts/1    0:00 ./myprog
0   500  3877  3876  Z    pts/1    0:00 [myprog] <defunct>
0   500  3878  3876  Z    pts/1    0:00 [myprog] <defunct>
0   500  3879  3876  Z    pts/1    0:00 [myprog] <defunct>
0   500  3882  3876  Z    pts/1    0:00 [myprog] <defunct>
0   500  3883  2359  R    pts/1    0:00 ps l
```

Killing the parent will usually eliminate the zombies

Notice that the zombies have a common parent

Exercise: Sending signals

1. You should be logged in as tux for this exercise
2. Start an instance of `soak` in the background like this:

```
$ soak “Annoying output” &
```

3. Start another terminal window and use `ps` to find the process ID of the `soak` program
4. Send `soak` a signal to terminate it
5. Return to the original window, verify that the process has stopped
6. Repeat the experiment, using `killall` instead of `kill` to kill the `soak` process by name
7. Try to kill the `init` process by sending it a SIGKILL. What happens?

Exercise: Killing zombies

8. Run the program `zombify` (in your home directory) in the background
   - This program is written specially for this exercise. It creates four child processes then pauses indefinitely. The child processes immediately exit and so become zombies
9. Examine the process table
   - How many zombie (defunct) processes do you see?
   - Write down the PIDs of the zombies: _____
   - ... and the PID of their parent _____
10. Try to kill one of the zombies by sending it a SIGKILL signal
    - Did this work?
11. Kill the parent process
    - Verify that the parent and the zombies are now all gone

Quiz

- Name four programs that allow you to display a list of processes
- Describe the circumstances that lead to the formation of zombies
- Which type of signal cannot be caught or ignored?
- Which type of signal is sent by the terminal driver in response to ^C?
- Explain the difference between the commands `kill 1` and `kill %1`
- In the output from `ps l`, what does an 'R' in the STAT column mean?
- True or false?
  - The `ps` command can display the processes running on a remote machine
  - A program's priority can be set to a fixed level using the bash shell
  - The command `kill 1234` sends a SIGTERM signal to process 1234
  - The `top` command can order processes based on %CPU utilisation