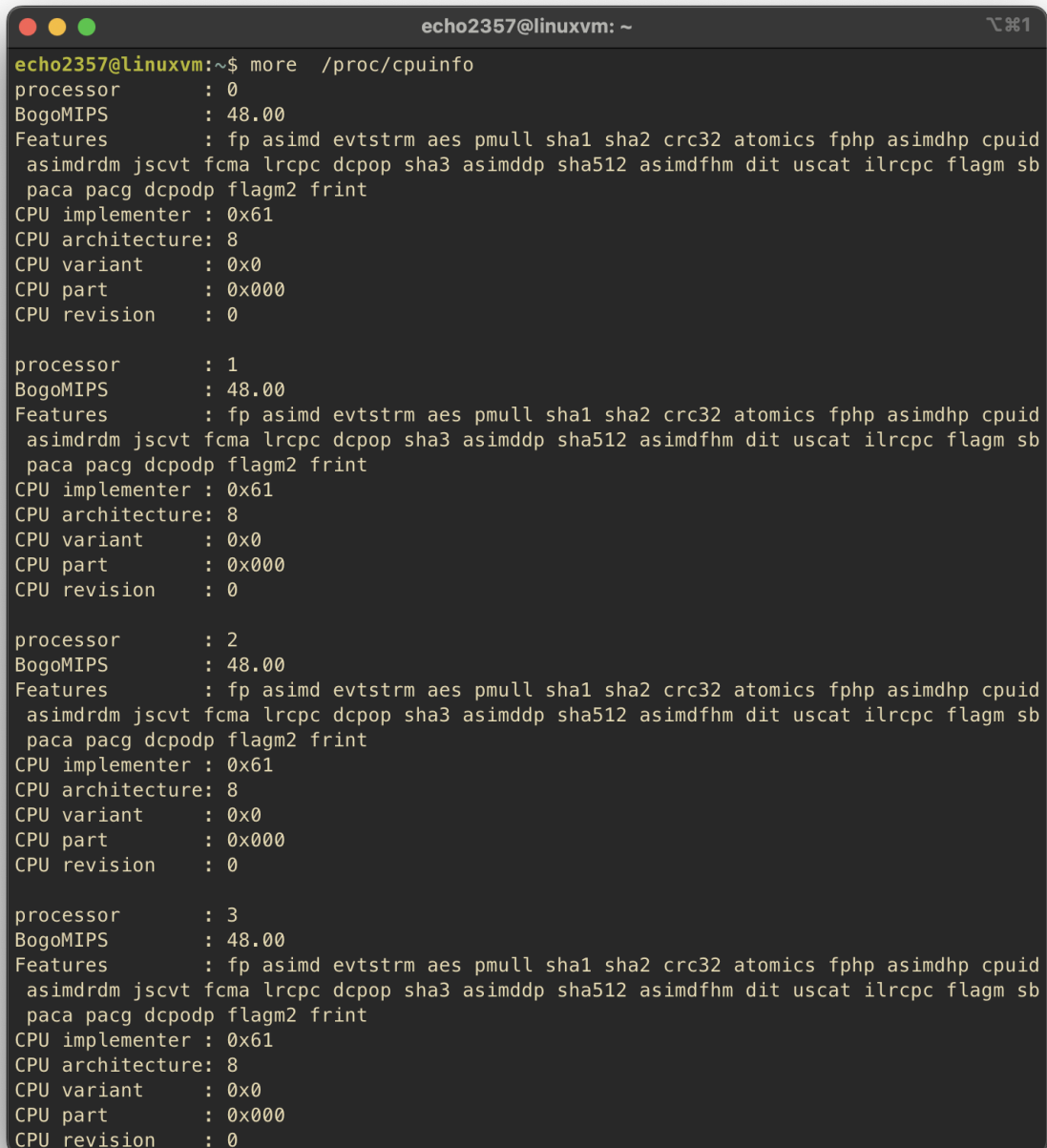


Lab 01

Echo Wang A01347203

Question 1

```
more /proc/cpuinfo
```



```
echo2357@linuxvm:~$ more /proc/cpuinfo
processor       : 0
BogoMIPS      : 48.00
Features       : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp cpuid
                 asimdrdm jscvt fcma lrcpc dcpop sha3 asimddp sha512 asimdfhm dit uscat ilrcpc flagm sb
                 paca pacg dcpodp flagm2 frint
CPU implementer : 0x61
CPU architecture: 8
CPU variant    : 0x0
CPU part       : 0x000
CPU revision   : 0

processor       : 1
BogoMIPS      : 48.00
Features       : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp cpuid
                 asimdrdm jscvt fcma lrcpc dcpop sha3 asimddp sha512 asimdfhm dit uscat ilrcpc flagm sb
                 paca pacg dcpodp flagm2 frint
CPU implementer : 0x61
CPU architecture: 8
CPU variant    : 0x0
CPU part       : 0x000
CPU revision   : 0

processor       : 2
BogoMIPS      : 48.00
Features       : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp cpuid
                 asimdrdm jscvt fcma lrcpc dcpop sha3 asimddp sha512 asimdfhm dit uscat ilrcpc flagm sb
                 paca pacg dcpodp flagm2 frint
CPU implementer : 0x61
CPU architecture: 8
CPU variant    : 0x0
CPU part       : 0x000
CPU revision   : 0

processor       : 3
BogoMIPS      : 48.00
Features       : fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimdhp cpuid
                 asimdrdm jscvt fcma lrcpc dcpop sha3 asimddp sha512 asimdfhm dit uscat ilrcpc flagm sb
                 paca pacg dcpodp flagm2 frint
CPU implementer : 0x61
CPU architecture: 8
CPU variant    : 0x0
CPU part       : 0x000
CPU revision   : 0
```

lscpu

```
echo2357@linuxvm: ~  
echo2357@linuxvm:~$ lscpu  
Architecture:          aarch64  
CPU op-mode(s):        64-bit  
Byte Order:            Little Endian  
CPU(s):                 4  
On-line CPU(s) list:   0-3  
Vendor ID:             Apple  
Model name:            -  
Model:                  0  
Thread(s) per core:    1  
Core(s) per socket:    4  
Socket(s):              1  
Stepping:               0x0  
BogoMIPS:               48.00  
Flags:                  fp asimd evtstrm aes pmull sha1 sha2 crc32 atomics fphp asimd  
                        hp cpuid asimdrdm jscvt fcma lrcpc dcpop sha3 asimddp sha512  
                        asimdfhm dit uscat ilrcpc flagm sb paca pacg dcpodp flagm2 fr  
                        int  
NUMA:  
NUMA node(s):          1  
NUMA node0 CPU(s):     0-3  
Vulnerabilities:  
Gather data sampling:   Not affected  
Itlb multihit:          Not affected  
L1tf:                   Not affected  
Mds:                     Not affected  
Meltdown:               Not affected  
Mmio stale data:        Not affected  
Reg file data sampling: Not affected  
Retbleed:                Not affected  
Spec rstack overflow:   Not affected  
Spec store bypass:      Vulnerable  
Spectre v1:              Mitigation; __user pointer sanitization  
Spectre v2:              Not affected  
Srbds:                   Not affected  
Tsx async abort:        Not affected  
echo2357@linuxvm:~$
```

(a) Definitions

- Processor: A logical CPU shown by `/proc/cpuinfo`. Each processor corresponds to a thread that the OS can assign tasks to
- Core: A physical CPU unit inside the processor.
- Hyperthreading: The number of logical processors could be more than the number or physical cores, as each core can handle multiple threads. However, in the case of my VM, they seem to be the same, i.e., no hyperthreading

(b) 4

(c) 4

(d) The QEMU hypervisor seems to abstract away actual hardware details about the processor, so there's no frequency info in the output of the 2 commands mentioned above. I used "`sudo dmidecode -t processor`" to read DMI data

about the processor, and got this:

```
echo2357@linuxvm: ~  
echo2357@linuxvm:~$ sudo dmidecode -t processor  
# dmidecode 3.5  
Getting SMBIOS data from sysfs.  
SMBIOS 3.0.0 present.  
  
Handle 0x0400, DMI type 4, 48 bytes  
Processor Information  
    Socket Designation: CPU 0  
    Type: Central Processor  
    Family: Other  
    Manufacturer: QEMU  
    ID: 00 00 00 00 00 00 00 00  
    Version: virt-9.1  
    Voltage: Unknown  
    External Clock: Unknown  
    Max Speed: 2000 MHz  
    Current Speed: 2000 MHz  
    Status: Populated, Enabled  
    Upgrade: Other  
    L1 Cache Handle: Not Provided  
    L2 Cache Handle: Not Provided  
    L3 Cache Handle: Not Provided  
    Serial Number: Not Specified  
    Asset Tag: Not Specified  
    Part Number: Not Specified  
    Core Count: 4  
    Core Enabled: 4  
    Thread Count: 4  
    Characteristics: None
```

QEMU reports to the guest OS that the static frequency of the physical processor is 2000MHZ

(e) aarch64

(f) 3996276 kB

```
cat /proc/meminfo | grep MemTotal
```

```
echo2357@linuxvm:~$ cat /proc/meminfo | grep MemTotal  
MemTotal:          3996276 kB
```

(g) 3032132 kB

```
cat /proc/meminfo | grep MemFree
```

```
echo2357@linuxvm:~$ cat /proc/meminfo | grep MemFree  
MemFree:           3032132 kB
```

(h) 5894

```
cat /proc/stat | grep "processes"
```

```
echo2357@linuxvm:~$ cat /proc/stat | grep "processes"  
processes 5894
```

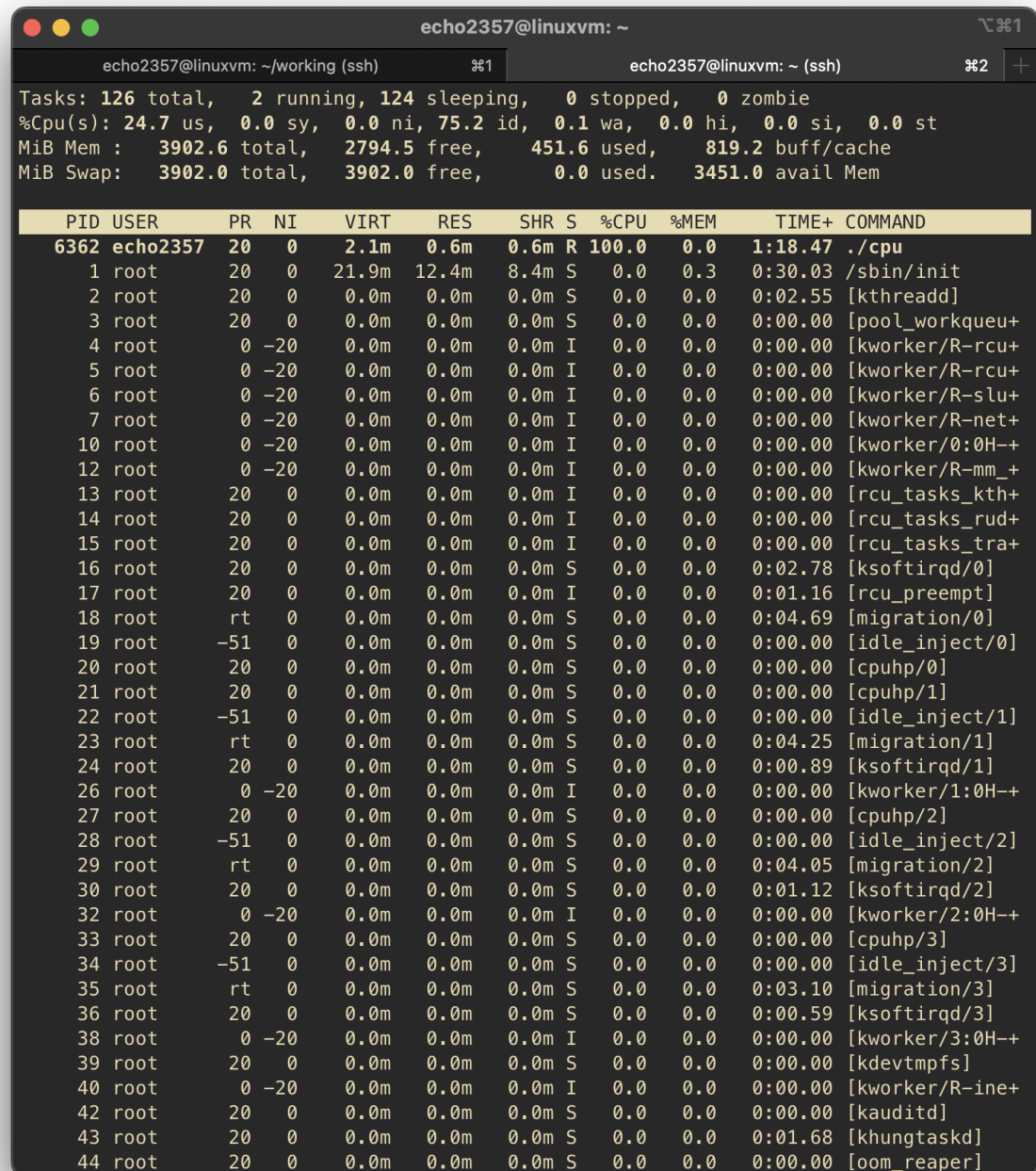
(i) 7883 voluntary context switches, 1016 nonvoluntary, 8899 in total

```
cat /proc/1/status | grep "ctxt_switches"
```

```
echo2357@linuxvm:~$ cat /proc/1/status | grep "ctxt_switches"
voluntary_ctxt_switches:        7883
nonvoluntary_ctxt_switches:    1016
```

Question 2

(a) 6342



The screenshot shows a terminal window with the title 'echo2357@linuxvm: ~'. The terminal displays system status information and a list of processes. The system status shows 126 total tasks, 2 running, 124 sleeping, 0 stopped, and 0 zombie. CPU usage is 24.7% (us), 0.0% (sy), 0.0% (ni), 75.2% (id), 0.1% (wa), 0.0% (hi), 0.0% (si), 0.0% (st). Memory usage is 3902.6 MiB total, 2794.5 MiB free, 451.6 MiB used, and 819.2 MiB buff/cache. Swap usage is 3902.0 MiB total, 3902.0 MiB free, 0.0 MiB used, and 3451.0 MiB avail. The process list shows the following columns: PID, USER, PR, NI, VIRT, RES, SHR, S, %CPU, %MEM, TIME+, and COMMAND. The first process is PID 6362, USER echo2357, PR 20, NI 0, VIRT 2.1m, RES 0.6m, SHR 0.6m, S R, %CPU 100.0, %MEM 0.0, TIME+ 1:18.47, and COMMAND ./cpu. The remaining processes are system daemons and kernel workers.

PID	USER	PR	NI	VIRT	RES	SHR	S	%CPU	%MEM	TIME+	COMMAND
6362	echo2357	20	0	2.1m	0.6m	0.6m	R	100.0	0.0	1:18.47	./cpu
1	root	20	0	21.9m	12.4m	8.4m	S	0.0	0.3	0:30.03	/sbin/init
2	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:02.55	[kthreadd]
3	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[pool_workqueu+
4	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-rcu+
5	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-rcu+
6	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-slu+
7	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-net+
10	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/0:0H+
12	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-mm+
13	root	20	0	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[rcu_tasks_kth+
14	root	20	0	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[rcu_tasks_rud+
15	root	20	0	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[rcu_tasks_tra+
16	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:02.78	[ksoftirqd/0]
17	root	20	0	0.0m	0.0m	0.0m	I	0.0	0.0	0:01.16	[rcu_preempt]
18	root	rt	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:04.69	[migration/0]
19	root	-51	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[idle_inject/0]
20	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[cpuhp/0]
21	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[cpuhp/1]
22	root	-51	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[idle_inject/1]
23	root	rt	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:04.25	[migration/1]
24	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.89	[ksoftirqd/1]
26	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/1:0H+
27	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[cpuhp/2]
28	root	-51	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[idle_inject/2]
29	root	rt	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:04.05	[migration/2]
30	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:01.12	[ksoftirqd/2]
32	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/2:0H+
33	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[cpuhp/3]
34	root	-51	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[idle_inject/3]
35	root	rt	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:03.10	[migration/3]
36	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.59	[ksoftirqd/3]
38	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/3:0H+
39	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[kdevtmpfs]
40	root	0	-20	0.0m	0.0m	0.0m	I	0.0	0.0	0:00.00	[kworker/R-ine+
42	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[kauditd]
43	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:01.68	[khungtaskd]
44	root	20	0	0.0m	0.0m	0.0m	S	0.0	0.0	0:00.00	[oom_reaper]

(b) 100% CPU and 0% memory

- (c) It's running, as indicated by the R in the S (status) column, which stands for "Running"

Question 3

(a)

PID of cpu-print process is 6452

```
ps aux | grep cpu-print
```

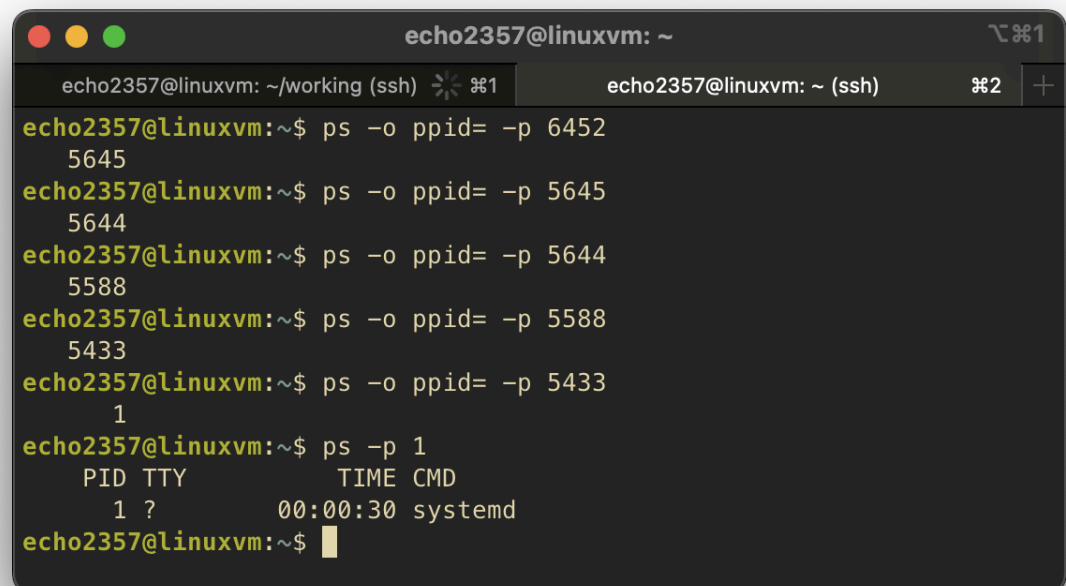
```
echo2357@linuxvm:~$ ps aux | grep cpu-print
echo2357    6452  0.0  0.0   2252  1280 pts/0    S+   08:03   0:00 ./cpu-print
echo2357    6529  0.0  0.0   6272  2048 pts/1    S+   08:05   0:00 grep --color=auto cpu-print
```

(b)

```
ps -o ppid = -p [current PID]
```

PID of 5 generations:

5645, 5644, 5588, 5433, 1(init)



```
echo2357@linuxvm: ~
echo2357@linuxvm: ~/working (ssh) %1 echo2357@linuxvm: ~ (ssh) %2 +
echo2357@linuxvm:~$ ps -o ppid= -p 6452
5645
echo2357@linuxvm:~$ ps -o ppid= -p 5645
5644
echo2357@linuxvm:~$ ps -o ppid= -p 5644
5588
echo2357@linuxvm:~$ ps -o ppid= -p 5588
5433
echo2357@linuxvm:~$ ps -o ppid= -p 5433
1
echo2357@linuxvm:~$ ps -p 1
  PID TTY          TIME CMD
    1 ?           00:00:30 systemd
echo2357@linuxvm:~$
```

(c)

```
ls -l /proc/6554/fd/
```

```
echo2357@linuxvm:~/working$ ./cpu-print > /tmp/tmp.txt &
[1] 6554
```

```
echo2357@linuxvm:~$ ls -l /proc/6554/fd/
total 0
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:15 0 -> /dev/pts/0
l-wx----- 1 echo2357 echo2357 64 Jan 10 08:15 1 -> /tmp/tmp.txt
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:15 2 -> /dev/pts/0
```

FD 0: Points to the terminal normally. We didn't redirect input, so it stays the terminal

FD 1: Points to the terminal normally, but as we redirected the output with the ">" operator to a text file, now it points to the file.

FD 2: Points to the terminal by default. Since there's no redirection, it remains pointing to the terminal.

So in IO redirection, the shell modifies the file descriptors of the process to the destination specified by the commands.

(d)

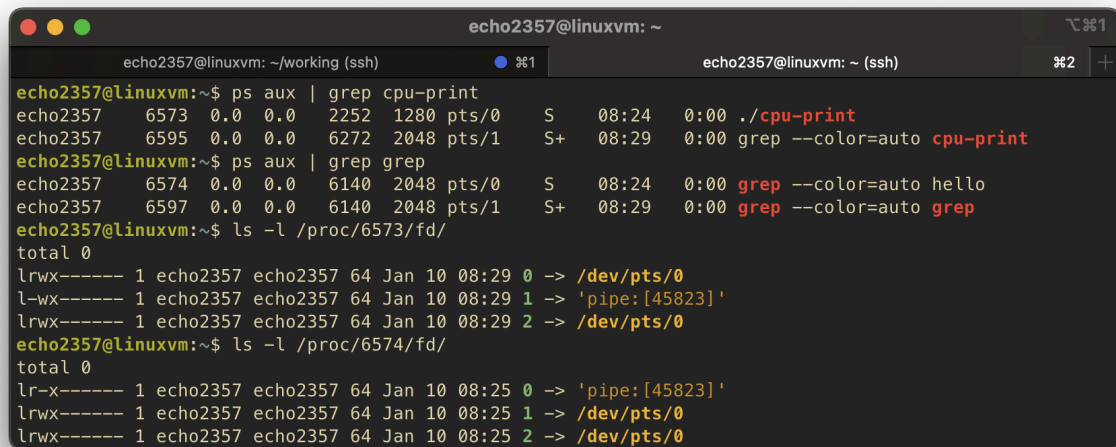
```
echo2357@linuxvm:~/working$ ./cpu-print | grep hello &
[4] 6574
```

```
ps aux | grep cpu-print
```

```
ps aux | grep grep
```

```
ls -l /proc/6573/fd/
```

```
ls -l /proc/6574/fd/
```



```
echo2357@linuxvm: ~
echo2357@linuxvm: ~/working (ssh)
echo2357@linuxvm:~$ ps aux | grep cpu-print
echo2357  6573  0.0  0.0  2252  1280 pts/0    S   08:24   0:00 ./cpu-print
echo2357  6595  0.0  0.0  6272  2048 pts/1    S+  08:29   0:00 grep --color=auto cpu-print
echo2357@linuxvm:~$ ps aux | grep grep
echo2357  6574  0.0  0.0  6140  2048 pts/0    S   08:24   0:00 grep --color=auto hello
echo2357  6597  0.0  0.0  6140  2048 pts/1    S+  08:29   0:00 grep --color=auto grep
echo2357@linuxvm:~$ ls -l /proc/6573/fd/
total 0
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:29 0 -> /dev/pts/0
l-wx----- 1 echo2357 echo2357 64 Jan 10 08:29 1 -> 'pipe:[45823]'
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:29 2 -> /dev/pts/0
echo2357@linuxvm:~$ ls -l /proc/6574/fd/
total 0
lr-x----- 1 echo2357 echo2357 64 Jan 10 08:25 0 -> 'pipe:[45823]'
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:25 1 -> /dev/pts/0
lrwx----- 1 echo2357 echo2357 64 Jan 10 08:25 2 -> /dev/pts/0
```

The pipe [45823] is modified by the shell to be the output (FD 1) of the process before the pipe operator, and the input (FD 0) of the process after the pipe operator, i.e., the pipe connects 2 processes. In this case, the data produced by `cpu-print` flows into the pipe, and the `grep hello` reads from the pipe to filter the lines containing the word "hello". The pipe is actually "redirecting" the output of one process as the input of another.

(e)

Implemented by shell code: `cd`, `history`

Executables: `ls`, `ps`

Commands implemented by shell code are also called "built-in shell commands", which are usually simpler, involving basic shell operations, and faster

Commands that invoke executables are usually more complex, and also tends to take longer.