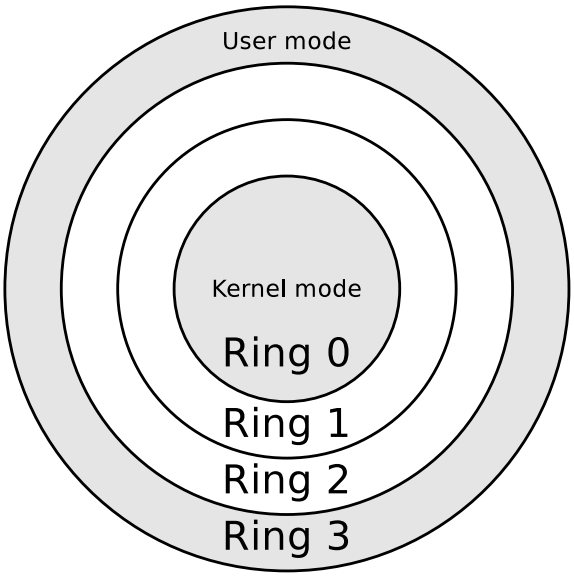
Solution of Exercise Sheet 7

Exercise 1 (System Calls)

1. x86-CPUs contain 4 privilege levels („rings“) for processes. Mark in the diagram (*clearly visible!*) the kernel mode and the user mode.



2. Name the ring to which the operating system is assigned.

   In ring 0 (= kernel mode) runs the kernel.

   Name the ring to which the user applications are assigned.

   In ring 3 (= user mode) run the applications.

3. Name the ring to which processes are assigned that have full access to the hardware.

   Processes in kernel mode (ring 0) have full access to the hardware.

4. Name a reason for the differentiation between user mode and kernel mode.

   It improves stability and security.

5. Explain what a system call is.

   If a user-mode process must carry out a higher privileged task (e.g. accessing hardware), it can accessing this the kernel via a system call. A system call is a function call in the operating system, which triggers a switch from user mode to kernel mode ($\Longrightarrow$ context switch).

6. Explain what a context switch is.

A process passes the control over the CPU to the kernel and is suspended until the request is completely processed. After the system call, the kernel passes the control over the CPU back to the user-mode process. The process continues its execution at the location, where the context switch was previously requested.

7. Name two reasons why user mode processes should not call system calls directly.

   Working directly with system calls is unsafe and the portability is poor.

8. Name an alternative if user mode processes shall not call system calls directly.

   Modern operating systems provide a library, which is logically located between the user mode processes and the kernel.

Exercise 2 (Processes)

1. Name the three sorts of process context information the operating system stores.

   User context, hardware context and system context.

2. Name the process context information that are not stored in the process control block.

   The user context, which is the allocated address space (virtual memory).

3. Explain why the process control block does not store all process context information.

   Depending on the architecture, the virtual memory of each process may be several GB in size. Therefore, the user context is just too big in size to store it twice.

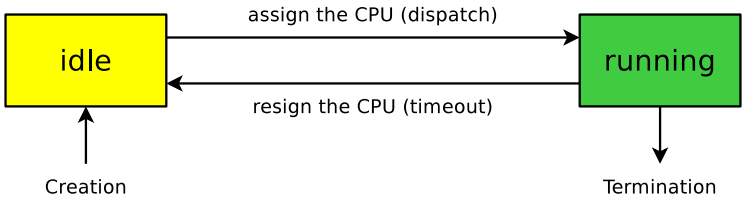
4. Explain the task of the dispatcher.

   It carries out the state transitions of the processes.

5. Explain the task of the scheduler.

   It specifies the execution order of the processes.

6. The process state model with 2 states is the smallest possible process model. Enter the names of the states in the diagram of the process state model with 2 states.



7. Does the process state model with 2 states make sense? Explain your answer shortly.

   The process state model with two states assumes that all processes are ready to run at any time. This is unrealistic because almost always do processes exist, which are blocked. The idle processes must be categorized into two groups:

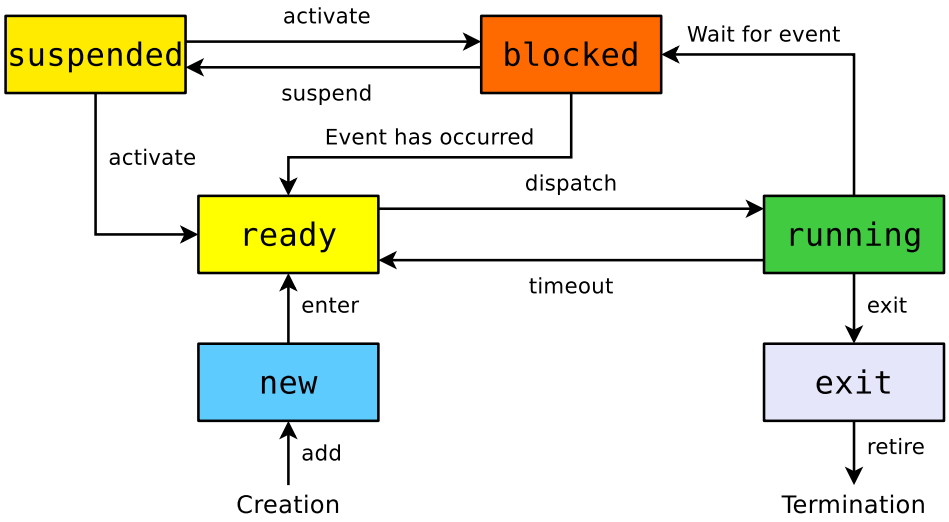
   - *Processes, which are ready.*
   - *Processes, which are blocked.*

8. Explain why we have extended the 3-state process model in class by the states `new` and `exit`.

   - `neu`: *The process (process control block) has been created by the operating system but the process is not yet added to the queue of processes in* ***ready*** *state. Motivation: On some systems, the number of executable processes is limited in order to save memory and to specify the degree of multitasking*

   - `exit`: *The execution of the process has finished or was terminated, but for various reasons the process control block still exists. Typically, resources are not yet released or the parent process has not yet accepted the return value of the child process.*

9. Enter the names of the states in the diagram of the process state model with 6 states.



10. Explain what a zombie process is.

A zombie process has completed execution (via the system call `exit`) but its entry in the process table exists until the parent process has fetched (via the system call `wait`) the exit status (return code). Its PID cannot yet be assigned to a new process.

11. Explain the task of the process table.

    For managing the processes, the operating system implements the process table. It contains for each process a record which is called process control block.

12. Give the number of waiting queues, the operating system manages for processes in „blocked“ state.

    For each event, there is a separate queue of processes waiting for this event.

13. Explain what happens if a new process is to be created, but the operating system has no more free process IDs (PID) left.

    In this case, no new process can be created.

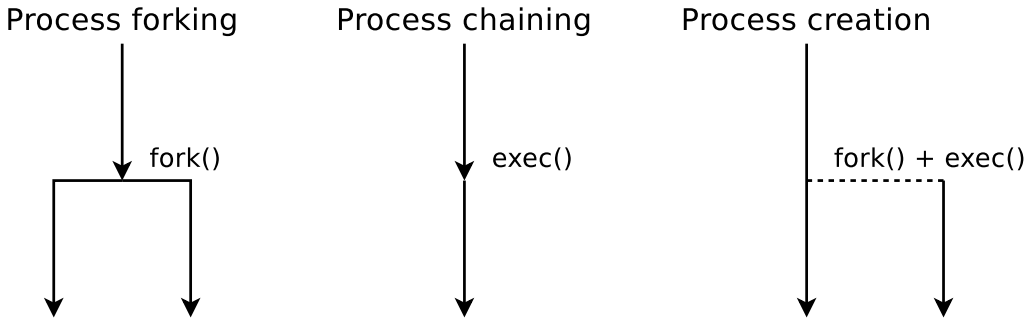
14. Describe the effect of calling the system call `fork()`.

    If a process calls `fork`, an identical copy is started as a new process.

15. Describe the effect of calling the system call `exec()`.

    The system call `exec` replaces a process with another one.

16. The three diagrams below show all existing ways of creating a new process. Specify for each diagram, which system call(s) are required to implement the illustrated way of process creation.



17. A parent process (PID = 75) with the characteristics, described in the table below, creates a child process (PID = 198) by using the system call `fork()`. Enter the four missing values into the table.

	Parent Process	**Child Process**
PPID	72	*75*
PID	75	198
UID	18	*18*
Return value of `fork()`	*198*	*0*

18. The following C source code creates a child process. Give the value of the `returnvalue` variable for the child process and for the parent process. In your answer, explain the importance of the return value in the parent process.

```
1  #include <stdio.h>
2  #include <unistd.h>
3  #include <stdlib.h>
4
5  void main() {
6    int returnvalue = fork();
7
8    if (returnvalue < 0) {
9      printf("Error.\n");
10     exit(1);
11   }
12   if (returnvalue > 0) {
13     printf("Parent Process.\n");
14     exit(0);
15   }
16   else {
17     printf("Child Process.\n");
18     exit(0);
19   }
20 }
```

In the child process, `fork()` has the return value 0.

In the parent process `fork()` has a positive return value. The return value then is equal to the PID of the newly created child process. This return value allows the parent process to identify the child process.

19. Describe what `init` is and what its task is.

`init` is the first process in Linux/UNIX. It has PID 1. All running processes originate from `init`. `init` is the father of all processes.

20. Name the differences of a child process from the parent process shortly after its creation.

The PID, the PPID, and the memory areas.

21. Describe the effect, when a parent process is terminated before the child process.

If a parent process terminates before the child process, it gets `init` as the new parent process assigned. Orphaned processes are always adopted by `init`. The PPID of the cild process then becomes value 1.

22. Describe what data the Text Segment contains.

    It contains the program code (machine code).

23. Describe what data the Data Segment contains.

    Initialized variables. Contains global variables (declaration is outside of functions), which get initial values assigned.

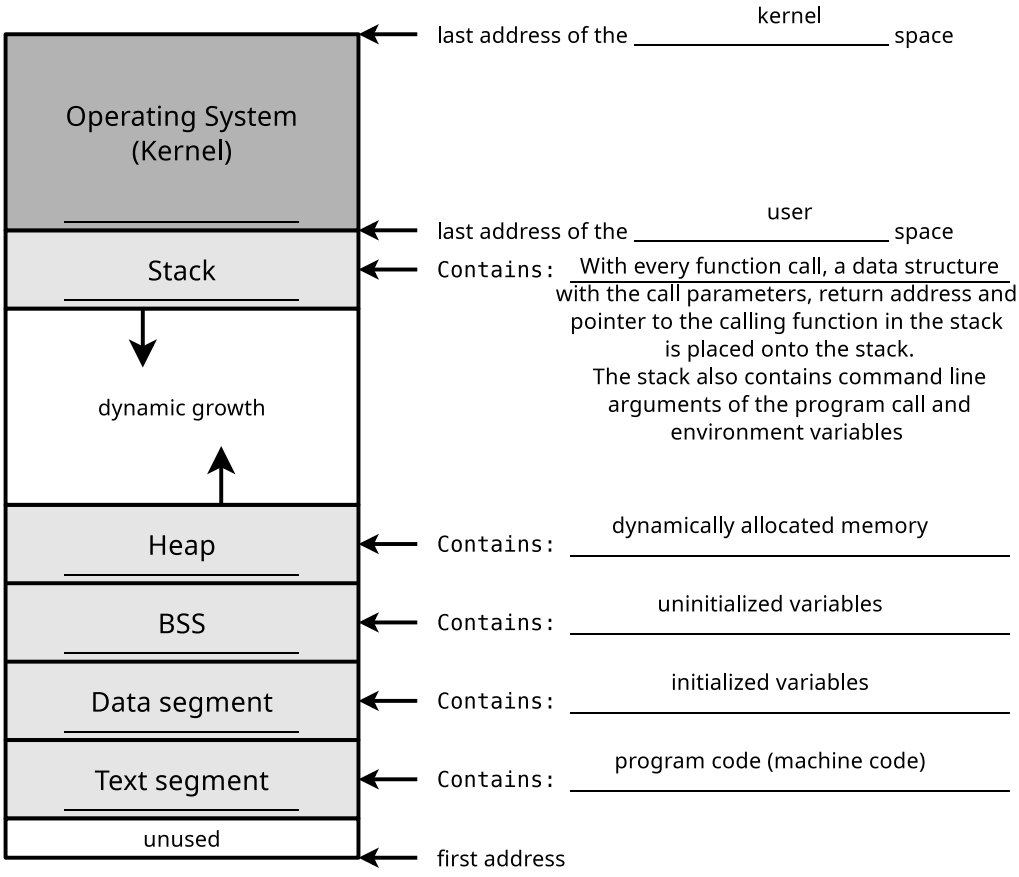
24. Describe what data the BSS contains.

    Uninitialized variables. Contains global variables (declaration is outside of functions), which get no initial values assigned.

25. Describe what data the Stack contains.

    Command line arguments, environment variables of the program call, call parameters and return address of functions, local variables of functions.

26. The figure shows the structure of a UNIX process in memory. Fill in the missing labels (technical terms) of the process-related data and the missing information about the content of this data.



Exercise 3 (Information about Processes in the Operating System)

The output of the `ps` command contains helpful information about the processes in the operating system.

```
$ ps -eFw
UID      PID   PPID  C      SZ    RSS PSR STIME TTY        TIME CMD
root       1      0  0   42090  12820   0 Aug29 ?      00:00:03 /sbin/initroot
root       2      0  0       0      0   4 Aug29 ?      00:00:00 [kthreadd]
...
bnc     2149   1782  1  258958 133484   7 Aug29 ?      00:11:20 xfwm4 --display :0.0  ...
bnc     2474   1782  0  137013  54512   8 Aug29 ?      00:03:28 xfce4-panel --display :0.0 ...
bnc     2478   1782  0  166034 138652  15 Aug29 ?      00:00:20 xfdesktop --display :0.0 ...
bnc     3252   2474  3 8590107 577484   9 Aug29 ?      00:51:07 /opt/google/chrome/chrome
bnc     3530   1721  0  157125  62824   0 Aug29 ?      00:00:44 /usr/libexec/gnome-terminal-server
bnc     3568   3530  0    3271   9556  15 Aug29 pts/0  00:00:01 bash
root    6706      1  0    7087  10556   3 Aug29 ?      00:00:00 /usr/sbin/cupsd -l
root    6737      1  0   44549  18680  12 Aug30 ?      00:00:00 /usr/sbin/cups-browsed
bnc    72577  72539  0    2773   7224   4 Aug31 pts/1  00:00:00 /bin/bash
bnc    90775  72577  1  279130 187352   9 09:39 pts/1  00:00:04 okular thesis.pdf
bnc    94414   3568  0    2861   4952   6 11:19 pts/0  00:00:00 ps -eFw
```

1. Explain the content of the column `UID`.

   User ID of the owner of the process.

2. Explain the content of the column `PID`.

   The unique process ID.

3. Explain the content of the column `PPID`.

   The unique process ID of the parent process.

4. Explain the content of the column `C`.

   CPU utilization of the process in percent.

5. Explain the content of the column `SZ`.

   virtual process size = text segment, heap and stack.

6. Explain the content of the column `RSS`.

   Resident Set Size = occupied physical memory (without swap) in kB.

7. Explain the content of the column `PSR`.

   Number of the CPU core assigned to the process.

8. Explain the content of the column `STIME`.

   Start time of the process

9. Explain the content of the column `TTY`.

   Teletypewriter = control terminal. Usually a virtual device: pts (pseudo terminal slave)

10. Explain the content of the column `TIME`.

    Consumed CPU time of the process (HH:MM:SS).

11. Name the parent process of the process that has printed this overview of the processes in the command-line interface.

    The `bash` process with PID 3568 is the parent process of the `ps` process with PID 94414.

Exercise 4 (Time-based Command Execution, Control Structures, Archiving)

1. Program a shell script, which reads two numbers as command line arguments. The script should check whether the numbers are identical, and print out the result of the check.

```
#!/bin/bash
#
# Skript: vergleich.bat
#
echo "Geben sie zwei Zahlen ein"
read -p "Zahl1:" zahl1
read -p "Zahl2:" zahl2
if [ $zahl1 -eq $zahl2 ] ; then
  echo "Die beiden Zahlen sind gleich groß."
else
  echo "Die beiden Zahlen sind nicht gleich groß."
fi
```

2. Extend the shell script in a way that if the numbers are not identical, it is checked, which one of the two numbers is the larger one. The result of the check should be printed out.

```
#!/bin/bash
#
# Skript: vergleich2.bat
#
echo "Geben sie zwei Zahlen ein"
read -p "Zahl1:" zahl1
read -p "Zahl2:" zahl2
if [ $zahl1 -eq $zahl2 ] ; then
  echo "Die beiden Zahlen sind gleich groß."
elif [ $zahl1 -gt $zahl2 ]; then
  echo "Zahl 1 mit Wert $zahl1 ist größer."
else
```

```
13   echo "Zahl 2 mit Wert $zahl2 ist größer."
14 fi
```

3. Program a shell script, which creates a backup of a directory of your choice. The script should create an archive file with the file extension `.tar.bz2` from the directory. The archive file should be stored in the directory `/tmp`. The name of the archive file should correspond to the following naming scheme:

   `Backup_<USERNAME>_<YEAR>_<MONTH>_<DAY>.tar.bz2`

   The fields `<USERNAME>`, `<YEAR>`, `<MONTH>` and `<DAY>` should be replaced by the current values.

```
1  #!/bin/bash
2  #
3  # Skript: archiv_erstellen.bat
4  #
5  ARCHIVNAME="Backup_`whoami`_`date +"%Y_%m_%d"`.tar.bz2"
6  VERZEICHNIS="/tmp/testverzeichnis"
7
8  # Archivdatei mit bz2-Kompression erstellen
9  # c => create an archive file.
10 # j => bz2 compression.
11 # v => show detailed output of command.
12 # f => filename of archive file.
13 tar -cjvf $ARCHIVNAME $VERZEICHNIS
14
15 # Archivdatei nach /tmp verschieben
16 mv $ARCHIVNAME /tmp
```

4. Program a shell script, which checks if already today an archive file was created according to the naming scheme of subtask 3. The result of the check should be printed out in the shell.

```
1  #!/bin/bash
2  #
3  # Skript: archiv_untersuchen.bat
4  #
5  DATEI="/tmp/Backup_`whoami`_`date +"%Y_%m_%d"`.tar.bz2"
6
7  if [ ! -f $DATEI ] ; then
8    echo "Die Datei $DATEI existiert nicht.";
9  else
10   echo "Die Datei $DATEI existiert.";
11 fi
```

5. Write two `cron` jobs. She first `cron` job should execute at 6:15 am on every day (except on weekends) the shell script from subtask 3, which creates the archive file with the backup.

   She second `cron` job should execute at 11:45 am on every day (except on weekends) the shell script from subtask 4, which checks, whether already today an archive file was created.

The output from the shell scripts should be appended to a file `/tmp/Backup-Log.txt`. If the archive file `Backup...tar.bz2` has been created successfully, this should be noted in the log file `/tmp/Backup-Log.txt`.

Before each new entry in the file, lines according to the following pattern (with current values) should be inserted into the log file `/tmp/Backup-Log.txt`.

```
*****************************
20.11.2013 --- Time: 21:39:51
```

Um die Lösung zu verstehen, hier im Vorfeld einige wichtige Informationen zur Crontabelle.

Jeder Auftrag / jede Zeile in der crontab besteht aus sechs Feldern. Die ersten fünf Felder werden benutzt, um den Ausführungszeitpunkt des Auftrags zu bestimmen. Im sechsten und letzten Eintrag wird das Programm, Skript oder Kommando festgelegt, das zu dem Ausführungszeitpunkt gestartet werden soll.

- *Spalte 1: Minute (`0-59` oder `*`)*
- *Spalte 2: Stunde (`0-23` oder `*`)*
- *Spalte 3: Tag (`1-31` oder `*`)*
- *Spalte 4: Monat (`1-12`, `Jan-Dec` oder `jan-dec` oder `*`)*
- *Spalte 5: Wochentag (`0-6`, `Sun-Sat` oder `sun-sat` oder `*`)*
- *Spalte 6: Auszuführender Befehl (Programmname und Pfad)*

Ein Eintrag in der Crontabelle darf auf keinen Fall einen Zeilenumbruch enthalten und nicht länger als 1024 Zeichen sein. Kommentare beginnen in der Crontabelle immer mit einer Raute (`#`). Es ist nicht nur möglich, einen Wert pro Zeitspalte anzugeben. Es können auch mehrere Werte pro Spalte angeben werden. Diese werden durch Kommas voneinander getrennt.

Zum Ausgeben und Bearbeiten der eigenen Crontabelle auf der Shell existiert der Befehl `crontab`:

- *`crontab -l`: Die eigene crontab ausgeben.*
- *`crontab -e`: Die eigene crontab bearbeiten.*
- *`crontab -r`: Die eigene crontab löschen.*

Der Editor, den der Befehl crontab aufruft, ist standardmäßig `vi`. Um die Crontabelle mit einem anderen Editor zu bearbeiten, muss die Shellvariable `EDITOR` erzeugt werden. Diese muss den Namen und wenn nötig noch den Pfad des bevorzugten Editors enthalten. Mit dem folgenden Befehl auf der Shell wird in Zukunft die Crontabelle immer mit dem Editor `nano` gestartet:

```
export EDITOR=/usr/bin/nano
```

Eine mögliche Lösung:

```
$ export EDITOR=/usr/bin/joe
$ crontab -e
```

Einträge in der Crontabelle passend zur Aufgabenstellung:

```
# 1. Spalte: 15. Minute der Stunde
# 2. Spalte: 6. Stunde des Tages
# 3. Spalte: An jedem Tag des Monates
# 4. Spalte: In jedem Monate des Jahres
# 5. Spalte: An den Wochentage Montag bis Freitag
# 6. Spalte: Kommando
15 6 * * 1-5 echo -e "**********************\n`date
+%d.%m.%Y\ ---\ %X`" >> /tmp/Backup-Log.txt &&
/pfad/zu/archiv_erstellen.bat >> /tmp/Backup-Log.txt
# 1. Spalte: 45. Minute der Stunde
# 2. Spalte: 11. Stunde des Tages
# 3. Spalte: An jedem Tag des Monates
# 4. Spalte: In jedem Monate des Jahres
# 5. Spalte: An den Wochentage Montag bis Freitag
# 6. Spalte: Kommando
45 11 * * 1-5 echo -e "**********************\n`date
+%d.%m.%Y\ ---\ %X`" >> /tmp/Backup-Log.txt &&
/pfad/zu/archiv_untersuchen.bat >> /tmp/Backup-Log.txt
```

Exercise 5 (Shell Scripts)

1. Program a shell script, which checks for a file, which is specified as an argument, whether it exists and if it is a file, a directory, a symbolic link, a socket or a named pipe.

   - The script should print out the result of the check.

```
1  #!/bin/bash
2  #
3  # Skript: datei_testen.bat
4  #
5  if test -e $1 ; then
6
7    echo "Die Datei existiert."
8
9    if test -d $1 ; then
10     echo "Die Datei ist ein Verzeichnis."
11   elif test -L $1 ; then
12     echo "Die Datei ist ein symbolischer Link."
13   elif test -S $1 ; then
14     echo "Die Datei ist ein Socket."
15   elif test -p $1 ; then
16     echo "Die Datei ist eine benannte Pipe (FIFO)."
17   fi
```

```
18 fi
```

2. Extend the shell script from subtask 1 in a way that if the file, which is specified as an argument, exists, it is checked, if the file could be executed and if write access would be possible.

```
1  #!/bin/bash
2  #
3  # Skript: datei_testen2.bat
4  #
5  if test -e $1 ; then
6
7    echo "Die Datei existiert."
8
9    if test -x $1 ; then
10     echo "Datei ist ausführbar"
11   else
12     echo "Datei ist nicht ausführbar"
13   fi
14
15   if test -w $1 ; then
16     echo "Datei ist schreibbar"
17   else
18     echo "Datei ist nicht schreibbar"
19   fi
20
21   if test -d $1 ; then
22     echo "Die Datei ist ein Verzeichnis."
23   elif test -L $1 ; then
24     echo "Die Datei ist ein symbolischer Link."
25   elif test -S $1 ; then
26     echo "Die Datei ist ein Socket."
27   elif test -p $1 ; then
28     echo "Die Datei ist eine benannte Pipe (FIFO)."
29   fi
30 fi
```

3. Program a shell script, which reads text from the command line, until the string `END` occurs.
   - The script should convert the text, which is read in from the command line, to uppercase.

```
1  #!/bin/bash
2  #
3  # Skript: einlesen.bat
4  #
5  while [ true ]
6  do
7    read EINGABE
8    if [ $EINGABE == "ENDE" ] ; then
9      exit
10   else
11     echo $EINGABE | tr '[:lower:]' '[:upper:]'
12   fi
```

```
13 done
```

4. Program a shell script, which prints out the number of running processes for all logged in users.

5. Extend the shell script from subtask 4 in a way that that the output is sorted.

   - The user with most processes should stand at the beginning.

6. Program a shell script, which checks after start every 10 seconds, if a file `/tmp/lock.txt` exists.

   - Each time after the script has checked the existence of the file, it should output an appropriate message on the shell.

   - Once the file `/tmp/lock.txt` exists, the script should terminate itself.

```
1  #!/bin/bash
2  #
3  # Skript: lock_testen.bat
4  #
5  while [ true ]
6  do
7    if test -f "/tmp/lock.txt" ; then
8      echo "Die Datei lock.txt ist vorhanden."
9      exit 0
10   else
11     echo "Die Datei lock.txt ist nicht vorhanden."
12   fi
13   sleep 10
14 done
```