Sample solution of the written examination in

Operating Systems

February 17th 2023

Last name: _____

First name: _____

Student number: _____

Mit dem Bearbeiten dieser schriftlichen Prüfung (Klausur) bestätigen Sie, dass Sie diese alleine bearbeiten und dass Sie sich gesund und prüfungsfähig fühlen. Mit dem Erhalt der Aufgabenstellung gilt die Klausur als angetreten und wird bewertet.

By attending this written exam, you confirm that you are working on it alone and feel healthy and capable to participate. Once you have received the examination paper, you are considered to have participated in the exam, and it will be graded.

- Use the provided sheets. Do *not* use own paper.
- You are allowed to use a *self prepared*, *single sided DIN-A4 sheet* in the exam. Only *hand-written originals* are allowed, but no copies.
- Do *not* use a red pen.
- Time limit: *90 minutes*
- Turn off your mobile phones!

Grade: _____

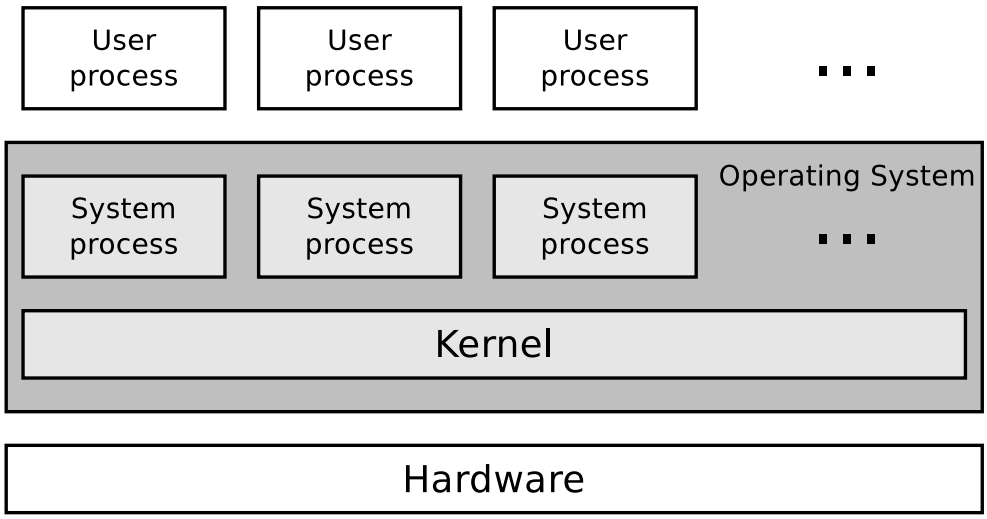
Questions:	1	2	3	4	5	6	7	8	9	10	11	12	**Σ**
Maximum Points:	10	9	12	7	7	7	3	6	8	8	6	7	90
Achieved Points:													

1.0: 90.0-85.5, **1.3**: 85.0-81.0, **1.7**: 80.5-76.5, **2.0**: 76.0-72.0, **2.3**: 71.5-67.5,
2.7: 67.0-63.0, **3.0**: 62.5-58.5, **3.3**: 58.0-54.0, **3.7**: 53.5-49.5, **4.0**: 49.0-45.0, **5.0**: <45

Question 1)

Points: ..... of 10

2 Points (1) The diagram shows the basic structure of an operating system.
Fill in the lines the name of the components marked by the arrow.



1 Point (2) Name <u>one</u> task for which batch processing is well suited.
Batch processing is well suited for the execution of routine tasks.

1 Point (3) Batch processing is always...
☐ interactive ☒ non-interactive

1 Point (4) Give the name of the quasi-parallel program or process execution.
Multitasking

1 Point (5) Describe what scheduling is.
Automatic creation of an execution plan (schedule), which is used to allocate time limited resources to users or their processes

1 Point (6) Describe the purpose of memory protection.
This way, a bug or crash of a single program does not affect the stability of other programs and the total system.

2 Points (7) Name the two basic cache write policies.
write-back and write-through

1 Point (8) Name the cache write policy that leads to inconsistencies.
write-back

Question 2)

Points: ..... of 9

1 Point (1) Linux implements a...

☒ monolithic kernel ☐ microkernel ☐ hybrid kernel

1 Point (2) Windows NT4/Vista/XP/7/8/10 implements a...

☐ monolithic kernel ☐ microkernel ☒ hybrid kernel

1 Point (3) Mark the concept that does not require any hardware support:

☐ Direct Memory Access ☐ Interrupt driven ☒ Busy waiting

2 Points (4) Name <u>one</u> advantage and <u>one</u> drawback of monolithic kernels.

Advantages:

- *Fewer context switching → better performance*
- *Grown stability*

Drawbacks:

- *Crashed components can not be started separately in the kernel and may cause the entire system to crash*
- *Kernel extensions cause a high development effort, because for each compilation of the extension, the complete kernel need to be recompiled*

1 Point (5) Name <u>two</u> RAID level that improves the reliability.

RAID 1 and RAID 5

1 Point (6) Name <u>two</u> RAID level that improves the data transfer rate for write operations.

RAID 0 and RAID 5

½ Point (7) Give the net capacity of a RAID 0 array.

The net capacity is n, if n is the number of drives.

½ Point (8) Give the net capacity of a RAID 1 array.

The net capacity is the capacity of the smallest drive.

1 Point (9) Give the number of drives that are allowed to fail in a RAID 5 array without data loss.

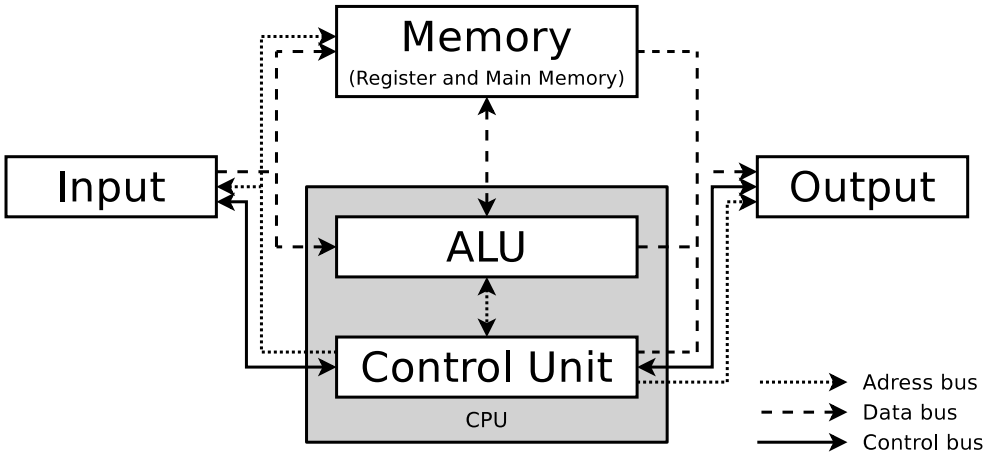
A single drive maximum is allowed to fail.

Question 3)

Points: ..... of 12

3 Points

(1) The diagram shows the Von Neumann Architecture. Fill into the boxes the missing components.



6 Points

(2) Explain briefly how the Von Neumann Cycle works (explain the six steps).

a) ***FETCH***: *Fetch command to be processed from the memory into the Instruction Register*

b) ***DECODE***: *Control Unit resolves the command into switching instructions for the ALU*

c) ***FETCH OPERANDS***: *Fetch any available parameters (operands) for the command from the memory*

d) ***EXECUTE***: *ALU carries out the command (switching instructions)*

e) ***UPDATE PROGRAM COUNTER***: *The Program Counter register is set to the next command*

f) ***WRITE BACK***: *Result generated is stored in a register, main memory, or sent to an output device*

2 Points

(3) Explain what the Memory Management Unit (MMU) is and explain its purpose.

The CPU uses the MMU and the page table for the translation of virtual memory addresses into physical addresses.

1 Point

(4) Give the maximum number of memory addresses that can be addressed with a 16-bit computer system.

2^{16} *addresses*

Question 4)

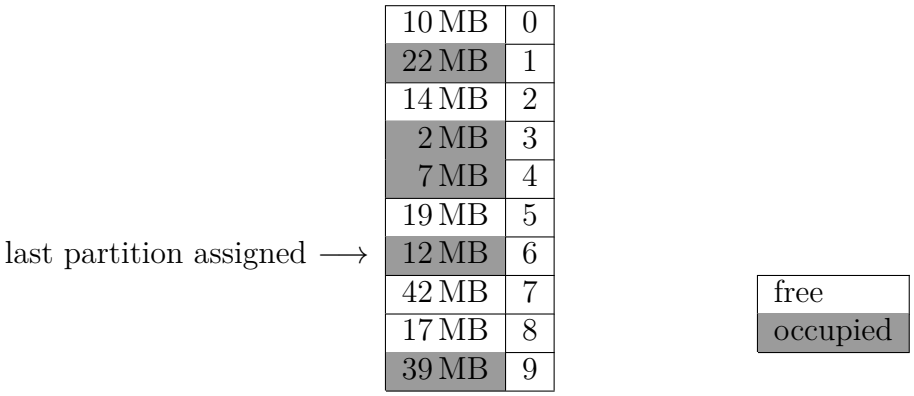
Points: ..... of 7

1 Point (1) Static partitioning can only be implemented using partitions of equal size.

☐ True ☒ False

3 Points (2) The following memory area belongs to a memory with dynamic partitioning. For each of the three algorithms, First Fit, Next Fit, and Best Fit, specify the number of the free partition that the corresponding algorithm uses to insert a process that requires 11 MB of memory.

a) First Fit: **2** b) Next Fit: **7** c) Best Fit: **2**



1 Point (3) Name the type(s) of fragmentation that can occur in static partitioning.

Internal fragmentation

1 Point (4) Name the type(s) of fragmentation that can occur in dynamic partitioning.

External fragmentation

1 Point (5) Name the type(s) of fragmentation that can occur in buddy memory allocation.

Internal and external fragmentation

Question 5)

Points: ..... of 7

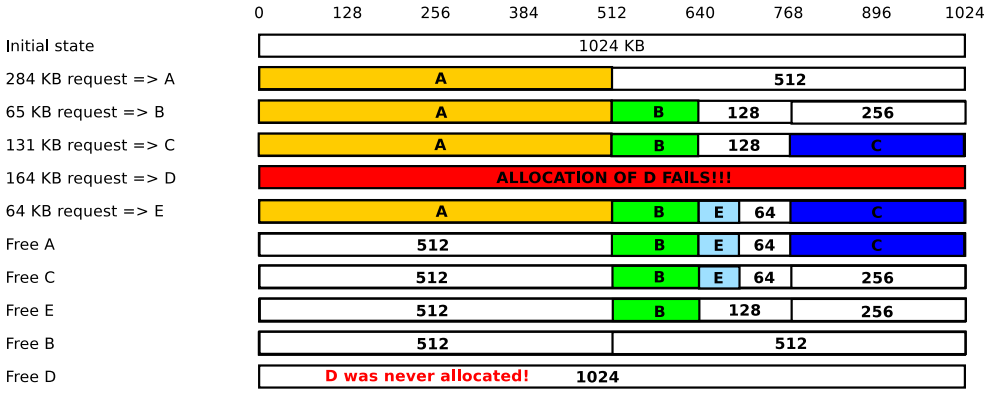
1 Point (1) Explain why virtual memory helps to make more efficient use of the main memory.

Processes do not need to be located in one piece inside the main memory. Therefore, the external fragmentation of the main memory is not a problem.

1 Point (2) Explain, what mapping is.

The virtual memory is mapped to the physical memory.

5 Points (3) Apply the Buddy Allocation algorithm to the memory depicted in the diagram.

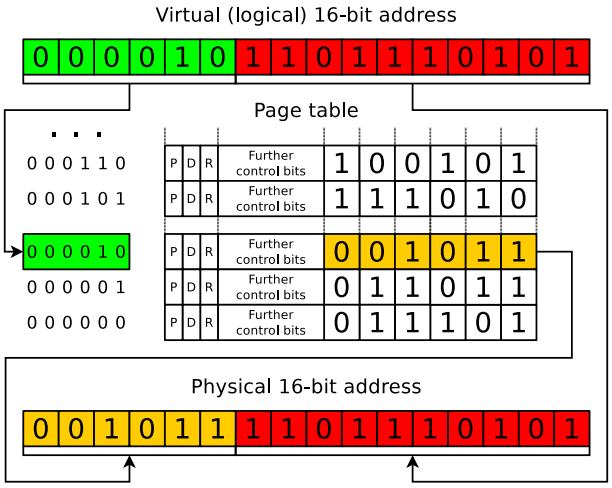


Question 6)

Points: ..... of 7

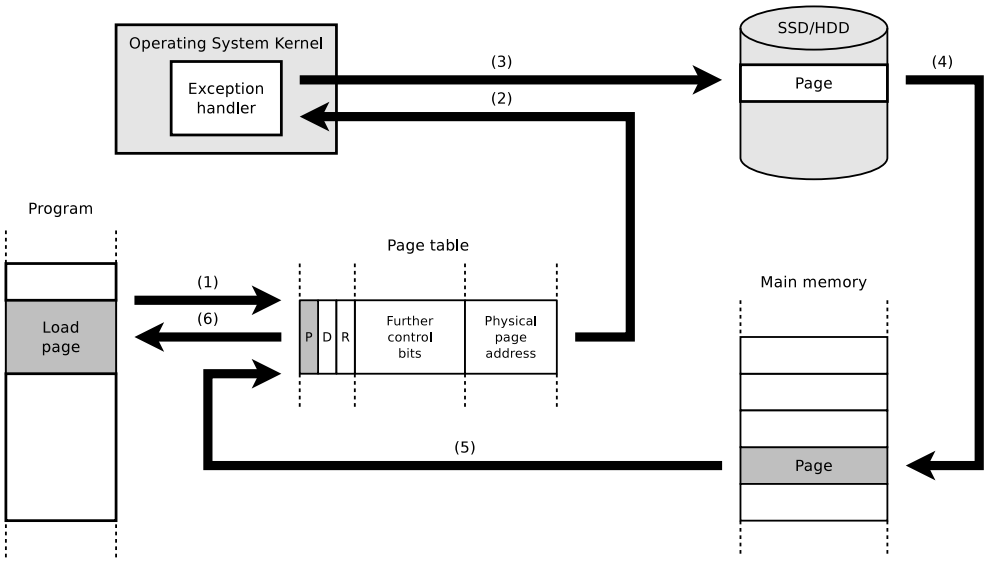
4 Points

(1) Calculate the physical 16-bit memory address using address translation with single level paging. Fill in the single bits in the physical 16-bit address.



3 Points

(2) The diagram shows a page fault exception. Describe the process stages.



(1) A process tries to request a page, which is not located in the physical main memory

(2) A software interrupt (exception) is triggered to switch from user mode to kernel mode

(3) allocate the page by using the controller and the device driver on the swap memory (SSD/HDD)

(4) copy the page into a free page of the main memory

(5) update the page table

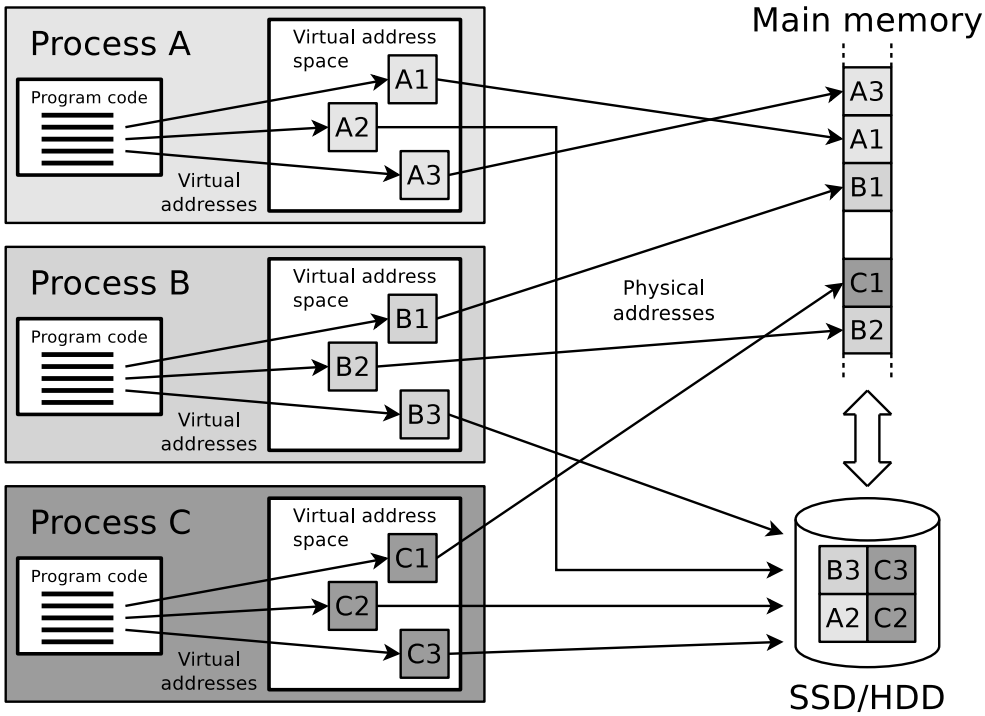
(6) return control to the process

Question 7)

Points: ..... of 3

3 Points

(1) Explain the relevant processes that can be observed in the diagram.
(!!! Focus on the memory management and the way, different memory technologies are used !!!)



*The diagram shows the process of **swapping**. The processes allocate virtual memory in form of **pages**, which are then mapped to physical pages. The relocation of the pages is called **swapping** and is done transparently for the processes. If the **main memory** has no more free capacity, the operating system must relocate (swap) data from the main memory to the **SSD/HDD***

Question 8)

Points: ..... of 6

4 Points

(1) Mark the statements as true or false.

Statement	**true**	**false**
Inodes store all metadata of files.		X
File systems address clusters and not blocks of the storage medium or storage drive.	X	
The smaller the clusters are, the more overhead for large files occur.	X	
The bigger the clusters are, the lesser capacity is lost due to internal fragmentation.		X
In UNIX, file extensions have always been of great significance.		X
Modern file systems operate so efficient that buffering by the operating system is no longer common.		X
Absolute path names describe the complete path from the root to the file.	X	
The separator in path names is identical for all operating systems.		X

1 Point

(2) Describe what information the super block of a file system stores.

It contains information about the file system, e.g. number of inodes and clusters.

1 Point

(3) Some file systems use a concept called Copy-on-write (COW). Mark the <u>two</u> answers that apply to such file systems.

When a file is modified, the old clusters in the file system that need to be modified...

☒ are preserved (not changed).
☐ are overwritten with the new modifications.
☐ are erased, by removing the cluster address in the inode.
☒ are copied into new clusters, where the modifications are made.

Question 9)

Points: ..... of 8

8 Points

(1) Perform the access sequence with the replacement strategy Least Frequently Used (LFU) with a cache with a capacity of 4 pages and calculate the hit rate and the miss rate.

Requests:	1	4	2	3	1	2	5	4	2	3	4	3	4	5
Page 1:	1_1	1_1	1_1	1_1	1_2	1_2	1_2	1_2	1_2	1_2	1_2	1_2	1_2	5_1
Page 2:		4_1	4_1	4_1	4_1	4_1	5_1	5_1	5_1	3_1	3_1	3_2	3_2	3_2
Page 3:			2_1	2_1	2_1	2_2	2_2	2_2	2_3	2_3	2_3	2_3	2_3	2_3
Page 4:				3_1	3_1	3_1	3_1	4_1	4_1	4_1	4_2	4_2	4_3	4_3

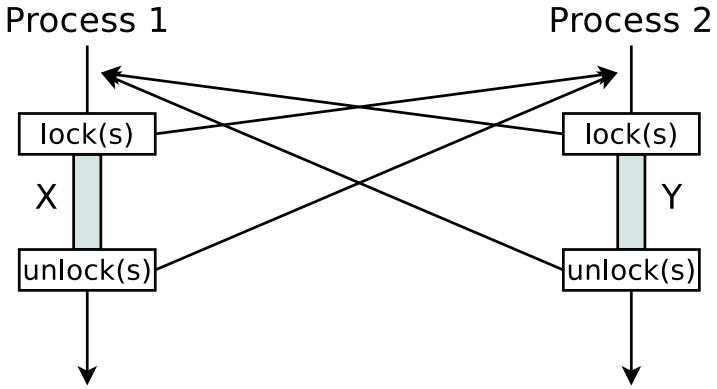
Hitrate: **6/14 = 0,43**

Missrate: **8/14 = 0,57**

Question 10)

Points: ..... of 8

1 Point (1) The figure demonstrates a process synchronization method. Add into the boxes the missing operations.



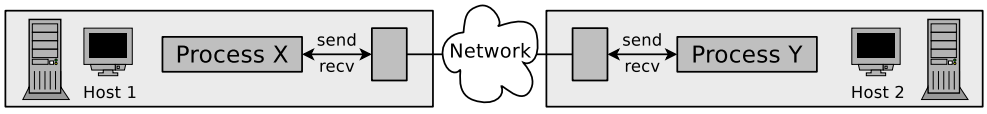
1 Point (2) Give the name of the process synchronization method shown in (1).

The diagram shows the process synchronization method ***Signal and Wait****.*

2 Points (3) Describe the functioning of the process synchronization method in (1).

The first process (P1 or P2) that reaches its critical section (X or Y) blocks the other process with lock(s) until it has finished its critical section and releases the other process afterward with unlock(s). This way, the execution order of the processes can be guaranteed and no CPU resources are wasted.

1 Point (4) Give the name of the process synchronization method shown in the diagram.



☐ shared memory ☐ pipe anonymous
☐ cricket ☒ socket
☐ message queue ☐ mutex

2 Points (5) Name <u>two</u> benefits of using the interprocess communication method in (4).

Sockets are full duplex-ready alternatives to pipes and shared memory. Sockets use port numbers for addressing and are managed by the operating system. Sockets can be used over the network and therefore over operating system boundaries.

1 Point (6) The interprocess communication method in (4) works bidirectonal.

☒ True
☐ False

Question 11)

Points: ..... of 6

6 Points

(1) Perform the deadlock detection with matrices and check if a deadlock occurs.

$$\text{Existing resource vector} = \begin{pmatrix} 9 & 6 & 8 & 7 & 6 & 7 \end{pmatrix}$$

$$\text{Current allocation matrix} = \begin{bmatrix} 3 & 1 & 0 & 1 & 1 & 1 \\ 2 & 0 & 2 & 3 & 2 & 0 \\ 2 & 1 & 2 & 0 & 0 & 3 \\ 1 & 3 & 2 & 1 & 0 & 1 \end{bmatrix} \qquad \text{Request matrix} = \begin{bmatrix} 4 & 3 & 0 & 1 & 2 & 3 \\ 1 & 0 & 2 & 2 & 3 & 1 \\ 5 & 6 & 2 & 2 & 1 & 2 \\ 2 & 0 & 4 & 4 & 4 & 2 \end{bmatrix}$$

The existing resource vector and the current allocation matrix are used to calculate the available resource vector.

$$\textit{Available resource vector} = \begin{pmatrix} 1 & 1 & 2 & 2 & 3 & 2 \end{pmatrix}$$

Only process 2 can run with this available resource vector. The following available resource vector results when process 2 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 3 & 1 & 4 & 5 & 5 & 2 \end{pmatrix}$$

Only process 4 can run with this available resource vector. The following available resource vector results when process 4 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 4 & 4 & 6 & 6 & 5 & 3 \end{pmatrix}$$

Only process 1 can run with this available resource vector. The following available resource vector results when process 1 has finished execution and deallocates its resources.

$$\textit{Available resource vector} = \begin{pmatrix} 7 & 5 & 6 & 7 & 6 & 4 \end{pmatrix}$$

Process 3 is blocked.

A deadlock occurs.

Question 12)

Points: ..... of 7

3 Points (1) Consider the following situation:

You start a **process A**, which uses `fork()` to create a child **process B**. Process A should be able to communicate via an interprocess communication method with process B. After the termination of the two processes the ressources of the interprocess communication should be erased automatically by the operating system.

Name the interprocess communication method you would use for this task and explain the reasons for your choice.

*For this task one should use **anonymous pipes**! They allow the communication between close related processes, which is the case in the situation mentioned above. One benefit is the simple use and the management of resources by the operating system, since when the last process, which has access to an anonymous pipe, terminates, the pipe gets erased by the operating system!*

1 Point (2) Explain what an environment variable in Linux is.

An environment variable is a named object that contains data used by one or more applications.

2 Points (3) Explain the function of the `grep` command-line tool and explain one use-case for `grep`.

`grep` *searches for **PATTERNS** in each **FILE**. **PATTERNS** is one or more patterns separated by newline characters, and grep prints each line that matches a pattern.*

`grep` *can be used for the following use cases:*

- *Searching for a given string in a single file*
- *Matching regular expression in files*
- *Display the lines which do not match a given pattern*

1 Point (4) You tried to run `script.sh` but the following happens:

```
$ ./script.sh
permission denied: ./script.sh
```

Give one solution for the command-line shell that allows to execute `script.sh`.

Some examples (each one will do the job)...

```
$ chmod 777 script.sh
$ chmod 700 script.sh
$ chmod 500 script.sh
```

```
$ chmod u+rwx script.sh
$ chmod u+rx script.sh
```