Important: This is an open book test. You can use any books, notes, or paper but no electronic device. *Do not log into the computer during the test, or use any electronic or communications device. Switch off your cell phones*. Any device with an ON-OFF switch should have its switch in the OFF position. Any calculations and rough work can be done on the back side of the test pages. If there is a syntax error in any program segment, just write it down and you will get full credit for the problem. You will lose five points for not writing your name.

1. [6 pt] What is a *linear address* in reference to the Linux kernel? How does it relate to logical and physical addresses?

2. [6 pt] Give at least two advantages of the bit-vector approach to manage free space in a disk. Why is it not recommended to use this approach in a large disk? Explain with an example of a 2TB disk with a 1KB block size.

3. [8 pt] How can you implement an indexed sequential file in Unix? Assume that the records in the file are not of the same size. Every record is assumed to have a key which is much smaller compared to the record length, say less than 5% of the average record length.

4. [6 pt] Why is the average search time to find a record in a file less for an indexed sequential file than for a sequential file?

5. [15 pt] A process has four page frames allocated to it. (All the following numbers are decimal, and everything is numbered starting from zero). The time of last loading of a page into each page frame, the time of last access to the page in each page frame, the virtual page number in each page frame, and the reference (R) and modify (M) bits for each page frame are as shown (the times are in clock ticks and the process start at time 0 to the event – not the number of ticks since the event to the present).

Virtual page no.	Page frame	Time loaded	Time referenced	R bit	M bit
2	0	079	101	1	0
1	1	082	122	1	1
3	2	105	126	0	0
0	3	106	134	1	1

A page fault to virtual page 4 has occurred at time 135. Which page frame will have its content replaced for each of the following memory management policies?

(a) FIFO

(b) LRU

(c) OPT (Look at the reference string in the next part to answer this part)

(d) Given the aforementioned state of memory just before the page fault, consider the following virtual reference string:

$$4, 3, 4, 0, 4, 5, 3, 4, 6, 4, 0$$

How many page faults will occur if the working set policy with LRU were used with a window size of 4 instead of a fixed allocation? Show when each page fault would occur.

6. [18 pt] Consider a disk with 256 cylinders, indexed from 0 to 255, with 0 being the innermost and 255 being the outermost cylinder. The system receives disk requests on the following tracks in the specified order

$$206, 62, 13, 114, 249, 32, 141, 42, 210$$

The head is currently on cylinder 24, and is moving towards inner cylinder. Give the total number of tracks traversed for the given requests using each of the following algorithms.

(a) FCFS scheduling

(b) SSTF scheduling

(c) SCAN scheduling

(d) C-SCAN scheduling, servicing requests as head moves inwards

(e) LOOK scheduling

(f) C-LOOK scheduling, servicing requests as head moves outwards