**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. Change your cell phones to silent mode.* 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] Describe different elements found in a page table entry. Give a one-line description of each of those elements.

2. [6 pt] Look at the directory listing below:

```
$ ls -l
total 4
d--------- 4 sanjiv users 4096 Nov 19 13:44 foobar
```

How many subdirectories are contained in the directory `foobar`?

3. [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?

4. [6 pt] What is the difference between block-oriented devices and stream-oriented devices? Give two examples of each of them.

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 | 3 | 046 | 090 | 0 | 0 |
| 0 | 6 | 069 | 085 | 1 | 0 |
| 1 | 7 | 156 | 250 | 1 | 1 |
| 3 | 9 | 240 | 320 | 1 | 0 |

A page fault to virtual page 4 has occurred at time 331. 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:

$$6, 9, 1, 9, 2, 1, 4, 6, 5, 3, 2$$

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. [10 pt] Consider a machine with disk blocks of 2KiB. You have a new disk of size 1TiB. What is the theoretical maximum file size possible using the UFS scheme of file allocation?