General instructions:

- This examination booklet has 9 pages.
- Do not forget to put down your name and student number on the exam books.
- The exam is closed book and closed notes.
- Explain your answers clearly and be concise. Do not write long essays.
- You have 90 minutes to complete the exam. Be a smart test taker, if you get stuck on one problem go on to the next. Don’t waste your time giving details that the question does not request.
- Show your work. Partial credit is possible, but only if you show intermediate steps.
- Good luck.

1. Contiguous Memory Allocation (20 pts)

   (a) (5 pts) True or false: In a uniprogramming system, physical addresses can never be generated at compile time. Explain your answer in brief.
(b) (6 pts) Do you need any hardware features to support static and dynamic relocation? If so, draw a picture showing how these hardware features might be used for virtual to physical address translations. If not, explain why not?
(c) (4 pts) True or false: The 50-percent rule states that 50% of memory is lost to external fragmentation when the first-fit policy is used.

(d) (5 pts) Is it possible to eliminate internal fragmentation in the best-fit policy? If so, explain how. If not, why not?
2. Paging and Segmentation (20 pts)

(a) (10 pts) What is a *translation look-aside buffer (TLB)*? Do you need a TLB for correct execution of programs?

(b) (10 pts) What data structures (tables) do you need to maintain to implement segmented paging? What are the three components of a virtual address in this scheme?
3. Demand Paging and Page Replacement (30 pts)

(a) (10 pts) In a demand paged system with a 100 nanosecond memory access time and a 10 millisecond page fault time, what must be the page fault rate to incur a 10% slowdown in the effective memory access time? (Hint: the page fault rate is the inverse of the page fault probability)
(b) (20 pts) Give a reference stream of page accesses (use alphabets or integers to represent page accesses) for which FIFO page replacement performs better (has fewer page faults) than LRU. Next, give a reference stream for which LRU performs better than FIFO. Your reference stream can be as short as you like and you can assume as many (or as few) physical memory frames as you like (your reference stream and frame choices should demonstrate the required behavior). Make sure you state the number of frames and show that one reference stream performs better than the other.
(a) (5 pts) Assuming that all files and directories are exactly one disk block in size, how many disk reads are required to locate the file named `/usr/bin/netscape` and read it into memory? Assume that the file descriptor for the root directory is already in memory. Explain your answer.

(b) (5 pts) Explain the steps that are performed when reading one byte of data from a modem. Assume that the CPU communicates with the modem using polling.
(c) (20 pts) Consider a file that is 1000 disk blocks in size. Assume that a disk block is appended to the end of the file, which causes the file size to grow to 1001 blocks. How many disk read and write operations are required to update the file and the file descriptor? Assume that the file is stored as a linked list with the pointer to the next file block stored at the end of each block. Also assume that both the file and the file descriptor are initially on disk and that file buffer cache is empty. How will your answer change if a multi-level index scheme is used instead of a linked file organization?