1. A cheap laptop has 2 GB of main memory, 32-bit addresses and a page size of 4 KB. (3×5 points)

   a) How many page frames are there in main memory? ___________________ frames

   b) How many bits of the virtual address are taken by the byte offset? ____________ bits

   c) How many bits of the virtual address are taken by the page number? ____________ bits

2. The old UNIX Fast File System required all disk writes involving metadata updates to be performed in a synchronous fashion. (2×5 points)

   a) Why? __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________

   b) What was the main drawback of this approach? ________________________________

   __________________________________________________________________________

   __________________________________________________________________________

   __________________________________________________________________________

3. Consider a 64-bit UNIX file system where all block addresses are 8-byte long and file sizes can exceed 4GB. Assuming a 4KB page size, how many file blocks could it access? (3×5 points)

   a) With one level of indirection? _____________________________________________ blocks

   b) With two levels of indirection? ____________________________________________ blocks

   c) With three levels of indirection? __________________________________________ blocks

   You can detail here your computations for possible partial credit.
4. **Questions with short answers:** (6×5 points)

   a) Which page replacement policy supports *real-time processes*? ____________________________

   ______________________________________________________________________________________

   ______________________________________________________________________________________

   b) What is the *main advantage* of *journaling file systems* with *asynchronous metadata updates*? _______

   ______________________________________________________________________________________

   ______________________________________________________________________________________

   c) What is the purpose of the `lseek()` system call? ________________________________

   ______________________________________________________________________________________

   ______________________________________________________________________________________

   d) What is the purpose of the *valid bit* in a virtual memory system? __________________________________

   ______________________________________________________________________________________

   ______________________________________________________________________________________

   e) Where do UNIX file systems store *file names*? __________________________________________

   ______________________________________________________________________________________

   ______________________________________________________________________________________

   f) What is the major disadvantage of *very large block sizes* in file systems? ________________

   ______________________________________________________________________________________

   ______________________________________________________________________________________
5. Consider the following multilevel page table organization. It was said in class that that organization was ideally suited to virtual memory systems with 32-bit addresses and 4 KB pages. Why? (5 points)

![Page Table Diagram]

6. Give examples of an access control list and a ticket in the UNIX/LINUX file systems? (2×5 points)
   a) Access control list: ____________________________________________________________________
   b) Ticket: _____________________________________________________________________________

7. Consider the classical BSD clock replacement policy with a single hand. (3×5 points)
   a) What happens when the hand of the clock reaches a valid page? ________________
      ______________________________________________________________________________________
      ______________________________________________________________________________________
      ______________________________________________________________________________________
   b) What happens when the hand of the clock reaches a page that was marked invalid? ______________
      ______________________________________________________________________________________
      ______________________________________________________________________________________
      ______________________________________________________________________________________
   c) What happens when a process tries to access a page that was marked invalid? ______________
      ______________________________________________________________________________________
      ______________________________________________________________________________________