1. Current implementations of the AMD64 architecture use 48-bit virtual addresses. Assuming a page size of 4 KB,

   (a) How many bits of the address would be used by the byte offset? (5 points) \( \log_2 4,096 = 12 \) bits

   (b) How many bits of the address would be used by the page number? (5 points) \( 48 - 12 = 36 \) bits

   (c) How many pages would there be in a process address space? (5 points) \( 2^{36} \) pages

2. Explain why the FIFO page replacement policy

   (a) Has a very low overhead. (5 points) It does not keep track of page accesses.

   (b) Produces more page faults than other policies. (5 points) It does not keep track of page accesses.

3. A 32-bit FFS file system has a block size of 4 kilobytes. How many blocks of a 510 kilobyte file can be accessed:

   (a) Directly from the i-node? (5 points) 12 (that’s 48K bytes) blocks

   (b) With one level of indirection? (5 points) \( \frac{(510 \text{ K} - 48\text{K})}{4\text{K}} = 116 \) (we round up to 512K) blocks

   (c) With two levels of indirection? (5 points) Zero blocks

   (Hint: The total of your three answers should equal to the number of blocks of the file.)
4. **Questions with short answers:** (6×5 points)

(a) What is the purpose of the UNIX mount() system call? __________________________________________

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(b) How does a journaling file system record metadata updates? ________________________________

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(c) What is the main disadvantage of letting the kernel handle TLB misses? _____________________

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(d) What is the purpose of the dirty bit in a virtual memory system? _____________________________

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(e) How can we prevent deadlocks by denying the circular wait condition? ______________________

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(f) Why can inverted page tables fully reside in main memory? ________________________________

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5. Alice is the owner of the file netsimulator whose protection bits are **-rwxr-xr-x**. She has assigned the group networks to the file.

(a) What can she do with the file? (5 points) **Anything she wants.**

(b) What can members of the networks group do? (5 points) **Reading and executing the file.**

(c) What can other users do? (5 points) **Reading and executing the file.**

6. When does **thrashing** happen? (5 points)

   What can we do to **prevent it**? (5 points)

7. In the **Windows page replacement policy**, what happens when a page is **expelled** from the resident set of a process? (5 points)