Question 1. *(15 points) Describe the difference between internal and external fragmentation. What effect does paging have on each type of fragmentation?*

Question 2. *(15 points) Explain why systems using paging choose a page size that is a power of 2 (e.g.,* $2^8 = 256$ *bytes,* $2^9 = 512$ *bytes, etc). Could a system use a page size that is not a power of 2?*

Question 3. *(15 points) Consider a byte-addressable system with a page size of 32 bytes and a total physical memory size of 512 bytes.*

1. *(5 points) How many bits are needed for a virtual address (such that a process can use all physical memory)? Of these, how many bits are needed for the page number* (p) *and how many for the offset* (d)*?*

2. *(10 points) Assuming the (partial) page table shown below, translate virtual address "124" to a physical address (i.e., the* k*th byte of physical memory). Show your calculations.*

Page	**Frame**
0	5
1	12
2	9
3	7
4	15
...	...

Question 4. *(15 points) In a paged memory system, explain the difference between the valid bits in the translation look-aside buffer (TLB) and the valid bits in a page table.*

Question 5. *(10 points) Assuming a system with 3 frames of physical memory, determine how the FIFO and MIN page replacement algorithms would handle the following reference streams:* $A, B, C, D, E, A, B, E, D, B, B, A$. *Also report the total number of page faults experienced for each algorithm.*

FIFO	A	B	C	D	E	A	B	E	D	B	B	A
F1												
F2												
F3												
Fault?												

MIN	A	B	C	D	E	A	B	E	D	B	B	A
F1												
F2												
F3												
Fault?												

Question 6. *(15 points) Give an intuitive explanation of how the second-chance (clock) algorithm approximates LRU page replacement. Rather than simply stating what the algorithm does, instead, explain how its behavior is similar to (but distinct from) an actual LRU replacement scheme.*

Question 7. *(15 points) Explain why a high degree of multiprogramming (i.e., many processes running at once) can lead to a situation in which the CPU utilization of the machine drops to near zero.*