1. (40%) Name two differences between logical and physical addresses and explain the difference between internal and external fragmentation.

**Answer:**
Logical address is an address seen by the CPU while a physical address is seen by the memory. A physical address is limited to the amount of installed memory while a logical address is limited by the address size of the processor.

Internal fragmentation exists when memory is internal to a partition, but is not being used. External fragmentation exists when enough total memory space exists to satisfy a request, but it is not contiguous; storage is fragmented into a large number of small holes.

2. (20%) Given memory partitions of 100K, 500K, 200K, 300K, and 600K (in order), how would each of the First-fit, Best-fit, and Worst-fit algorithms place processes of 212K, 417K, 112K, and 426K (in order)? Which algorithm makes the most efficient use of memory?

**Answer:**

First-fit:
- 212K is put in 500K partition
- 417K is put in 600K partition
- 112K is put in 288K partition (new partition 288K = 500K - 212K)
- 426K must wait

Best-fit:
- 212K is put in 300K partition
- 417K is put in 500K partition
- 112K is put in 200K partition
- 426K is put in 600K partition

Worst-fit:
- 212K is put in 600K partition
- 417K is put in 500K partition
- 112K is put in 388K partition
- 426K must wait

In this example, Best-fit turns out to be the best.

3. (20%) Consider the following segment table:

<table>
<thead>
<tr>
<th>Segment</th>
<th>Base</th>
<th>Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>219</td>
<td>600</td>
</tr>
<tr>
<td>1</td>
<td>2300</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>90</td>
<td>100</td>
</tr>
</tbody>
</table>
What are the physical addresses for the following logical addresses?

a. 0,430
b. 1,10
c. 2,500
d. 3,400
e. 4,112

Answer:

a. 219 + 430 = 649
b. 2300 + 10 = 2310
c. illegal reference, trap to operating system
d. 1327 + 400 = 1727
e. illegal reference, trap to operating system

4. (20%) Consider the following page-replacement algorithms. Rank these algorithms on a fivepoint scale from “bad” to “perfect” according to their page-fault rate. Separate those algorithms that suffer from Belady’s anomaly from those that do not.

a. LRU replacement
b. FIFO replacement
c. Optimal replacement
d. Second-chance replacement

Answer:

<table>
<thead>
<tr>
<th>Rank</th>
<th>Algorithm</th>
<th>Suffer from Belady’s anomaly</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Optimal</td>
<td>no</td>
</tr>
<tr>
<td>2</td>
<td>LRU</td>
<td>no</td>
</tr>
<tr>
<td>3</td>
<td>Second-chance</td>
<td>yes</td>
</tr>
<tr>
<td>4</td>
<td>FIFO</td>
<td>yes</td>
</tr>
</tbody>
</table>