Question 1: Write-Behind Logging . . . . . [160 points]

(i) **[10 points] Importance of Hardware:**
Explain why database machines did not succeed in the 1980s.

(ii) **[10 points] Importance of Hardware:**
Explain why leveraging hardware accelerators is more important now as opposed to the 1980s.

(iii) **[10 points] Importance of Hardware:**
Distinguish between: (1) FPGAs and (2) GPUs.

(iv) **[10 points] Persistent Memory:**
Distinguish between: (1) DRAM and (2) PM.

(v) **[10 points] Persistent Memory:**
Distinguish between: (1) DRAM as hardware-managed cache and (2) PM next to DRAM.

(vi) **[10 points] Persistent Memory:**
Distinguish between: (1) CLFLUSH and (2) CLWB.

(vii) **[10 points] Persistent Memory:**
Explain the purpose of Asynchronous DRAM Refresh.

(viii) **[10 points] Persistent Memory:**
What are the key features of a PM allocator? How is it different from a DRAM allocator?

(ix) **[10 points] Storage Engine Architectures:**
Distinguish between: (1) In-place Updates and (2) PM-Aware In-place Updates engines.

(x) **[10 points] Storage Engine Architectures:**
Distinguish between: (1) Copy-On-Write Engine and (2) PM-Aware Copy-On-Write engines.

(xi) **[10 points] Storage Engine Architectures:**
Distinguish between: (1) Log-Structured Engine and (2) PM-Aware Log-Structured engines.

(xii) **[10 points] Write Behind Logging:**
Distinguish between: (1) WAL and (2) WBL.

(xiii) **[10 points] Write Behind Logging:**
What are the two purposes of a WAL? Why is it not a good fit for PM?

(xiv) **[10 points] Write Behind Logging:**
How does WBL use failed group commit timestamp ranges?

(xv) **[10 points] Write Behind Logging:**
How does WBL support instant recovery?

(xvi) **[10 points] Write Behind Logging:**
Why does WAL not support instant recovery?

End of Problem Set