Question 2: (15 marks)
    a) Why is the memory system of a computer organized as a hierarchy? What are the basic elements of a memory hierarchy?

To balance the need for high performance (short access time) [1 mark] with the need for great capacity/ low cost per bit [1 mark]
Basic Elements: (1) In-board memory (CPU Registers, Cache, Main Memory) [1 mark]
                (2) Out-board memory (Magnetic Disk, Optical Devices) [1 mark]
                (3) Off-line storage (Magnetic Tape) [1 mark]
    b) Give a precise definition of hit ratio, as applied to cache memory.

Hit Ratio: "Fraction of memory accesses involving only cache memory." [3 marks]
    c) Locality of reference is an important feature of programs, in the context of memory hierarchies. Explain what locality of reference means and why is it important in view of the above 2 items.

Locality of Reference: "Memory addresses in the vicinity of a referenced word are likely to be referenced in the near future." OR: "Memory references tend to cluster." [3 marks]
Examples: Loops, subroutines, tables, records. [1 mark]
Importance: Memory locations most likely to be accessed soon can be placed closer to the top of the memory hierarchy. Thus, frequency of processor access to the memory should decrease as we move down the memory hierarchy. [3 marks]

Question 3: (20 marks)
Suppose physical addresses are 32 bits wide, in a byte-addressable multiplexed system bus. Suppose there is a cache containing 256K words of data (not including tag bits), and each cache block contains 4 words. For each of the following cache configurations, specify how the 32-bit address would be partitioned. Justify your answers.
    1. direct mapped

Multiplexed bus → data lines = address lines = 32 lines
4 words per block → 2 address bits to locate words within a block [3 marks]
Byte-addressable → 2 address bits to locate bytes within a word [2 marks]
Cache size = 256 K words / 4 = 64 K lines (blocks) = 2^{16} [3 marks]
→ L = 16 [2 marks]
T = 32 – 16 – 2 – 2 = 12 [3 marks]

Tag	Line	Word	Byte
12	16	2	2

    2. 2-way set associative

2 blocks per set → # sets = 64 K /2 = 32 K = 2^{15} [3 marks]
→ S = 15 [2 marks]
T = 32 – 15 – 2 – 2 = 13 [2 marks]

Tag	Set	Word	Byte
13	15	2	2