Assignment 1

1. The CPU clock speed is around:
a. 1-4 THz
b. 1-4 GHz
c. 1-4 MHz
d. 1-4 KHz

Correct answer: b

2. What is the precision of float16 variables?
a. 20 digits
b. 16 digits
c. 7 digits
d. 3 digits

Correct answer: d

3. How many cores are there in the Rome processor?
a. 64
b. 128
c. 256
d. 512

Correct answer: a

4. Consider a 16-core processor with a clock speed of 4 GHz. Assume that each core performs 32 single-precision operations per second. Estimate the peak performance of this processor.
a. 128 GFLOPS
b. 256 GFLOPS
c. 1024 GFLOPS
d. 2048 GFLOPS

Correct answer: d
Clock speed = 4 GHz = 4*10^9 cycles/second
Single precision floating point operations (FLOPS) per cycle per core = 32
FLOPS per core: 32*clock speed = 32*4*10^9 = 128*10^9 = 128 GFLOPs

Multiply the FLOPS per core by the number of cores = 16*128 GFLOPs= 2048 GFLOPs single-precision peak performance: 2048 GFLOPs.

5. How much memory is required to store a matrix A of dimension (N, N, N), where $N=10^3$, if the elements are stored as doubles?

a. $8*10^9$ bits
b. $8*10^9$ bytes
c. $4*10^6$ bits
d. $4*10^6$ bytes

Correct answer: b
Explanation: The total number of elements in the matrix is NXNXN = (1000) ^3 = 10^9
Each double occupies 8 bytes.
Total Memory = Bytes per elements*Number of elements
Total Memory = 8*10^9 bytes.

6. If at a certain year the number of transistors in an IC is 2000, then according to Moore's Law, how many transistors will be in an IC after four years?

a. 4000
b. 8000
c. 16000
d. 32000

Correct answer: b
According to Moore's Law the number of transistors in IC double every two years.
The number of doublings after six years = 4/2= 2 doublings
Increase by $2^2 = 4$
Transistors after four years = 8000

7. How much time will it take to do elementwise addition of two arrays with 10^9 elements, using vectorization with vectors of 8 elements, on a processor with clock speed 2 GHz (in milliseconds)?

a. 62.5
b. 125
c. 500
d. 1000

Correct answer: a

Assume 1 vector addition per clock cycle. Each vectorized operation handles 8 elements.

To process 10^9 additions: Number of vector additions: $10^9 / 8 = 1.25*10^8$

If 1 vectorized addition takes 1 clock cycle, the total number of cycles required is equal to the number of vectorized additions: $1.25*10^8$ cycles required

Time taken = Cycles required/Clock speed = $1.25*10^8 / 2*10^9$

Time = 0.0625 seconds or 62.5 milliseconds

8. Approximately how many FLOPs are required to multiply two matrices of dimension NXN if N is large?
   a. 2N
   b. $2N^2$
   c. $2N^3$
   d. $2N^4$

Correct option: c

Explanation: The elements of the resulting C matrix can be written as C[i,j] = sum from k=1 to k=N (A[i,k]*B[k,j])

To compute one element: N(multiplications) + N-1(additions) = 2N-1 FLOPs

If N is large, FLOPs for one element = 2N

For N2 elements: 2N*N^2 = 2N^3 FLOPs

9. To compute the expression A*A + 1, in Python, where A is a 3D array of size 500x500x500 containing double-precision data, how many floating-point operations are required?
   (a) 25 MFLOPs
   (b) 125 MFLOPS
   (c) 250 MFLOPS
   (d) 625 MFLOPs

Correct option: c

Explanation: A*A does element wise multiplication in python, meaning each element is multiplied by itself. And A*A+1, adds 1 to each element after multiplication. Multiplication takes approximately 1 FLOP. And addition, also takes 1 FLOP each. The total FLOP for one element is: 1+1 = 2FLOPs.

There are (500)^3 elements in the matrix. Total FLOPs = 2* (500)^3 FLOPS or 250 MLOPs

10. In the previous question, assume the computation is performed on a processor with a clock speed of 5 GHz. The time required to compute the expression is (in milliseconds):

(a) 5
(b) 25
(c) 50
(d) 125

Correct option: c

The total number of cycles required is equal to the total number of FLOPs: 250*10^6

Time taken = Cycles required*Time per cycle = Cycle required/Clock speed

Time = 250*10^6 /5*10^9 = .050 seconds