CS 219 – Assignment #1

Purpose: Become familiar with basic architecture and computer abstractions (Chapter 1)
Due: Wednesday (1/27)
Points: 100

Reading:

Chapter 1, Chapter 4

Assignment:

1) Based on lecture and the text, what are the classes of computing applications (five)? Provide a one sentence description of each. [5pts]

The classes of computing applications are desktop / laptop, servers, supercomputers, embedded computers, and mobile computing.

1. A personal computer is a computer designed for use by an individual, usually incorporating a graphics display, a keyboard, and a mouse.
2. A server is a computer used for running larger programs for multiple users, often simultaneously, and typically accessed only via a network.
3. A supercomputer is a class of computers with the highest performance and cost; they are configured as servers and typically cost tens to hundreds of millions of dollars.
4. An embedded computer is a computer inside another device used for running one predetermined application or collection of software.
5. Personal mobile devices (PMDs) are small wireless devices to connect to the internet; they rely on batteries for power, and software is installed by downloading apps.

2) Name five devices with embedded computers that you have used? [5 pts]

Five devices with embedded computers that I have used are digital watches, electronic calculators, fitness trackers, TVs, and digital phones.

3) According to the class text, what are the five classic components of a computer? [5 pts]

The five classic components of a computer are input, output, memory, processor, and datapath.

4) What is an Instruction Set Architecture (ISA)? [3 pts]

The instruction set architecture is an abstract interface between the hardware and the lowest-level software that encompasses all the information necessary to write a machine language program that will run correctly, including instructions, registers, memory access, I/O, and so on.

5) Define each of the following terms: [2 pts each]

a) volatile memory

Volatile memory is storage, such as DRAM, that retains data only if it is receiving power.

b) non-volatile memory

Non-volatile memory is a form of memory that retains data even in the absence of a power source and that is used to store programs between runs. A DVD disk is nonvolatile.

c) main/primary memory

Main or primary memory is memory used to hold programs while they are running; typically consists of DRAM in today's computers.

d) secondary memory

Secondary memory is nonvolatile memory used to store programs and data between runs; typically consists of flash memory in PMDs and magnetic disks in servers.

6) Define the following terms: [2 pts each]

a) response time

Response time, also called execution time, is the total time required for the computer to complete a task, including disk accesses, memory accesses, I/O activities, operating system overhead, CPU execution time, and so on.

b) throughput

Throughput, also called bandwidth, is another measure of performance, it is the number of tasks completed per unit of time.

7) Explain the impact on throughput and response time for each of the following changes in a computer system: [3 pts each]

a) Replacing the processor in a computer with a faster version

Both response time and throughput are improved.

b) Adding additional processors to a system that uses multiple processors for separate tasks – for example, searching the web.

No one task gets work done faster, so only throughput increases.

8) What are the hardware/software components affecting program performance (four)? [4 pts]

The hardware or software components affecting program performance are algorithm, programming language, compiler, and instruction set architecture.

9) For a color display using 10-bits for each of the primary colors (red, green, blue) per pixel and with a resolution of 1280 x 800 pixels, what should be the size (in bytes) of the frame buffer to store a single, complete frame? [5 pts]

Since 10 bits = 1.25 bytes, we have that each color of the pixel uses 1.25 bytes. So one pixel uses 3.75 bytes since there are 3 colors and each color uses 1.25 bytes. Also the frame consists of 1280 * 800 = 1,024,000 pixels. Therefore the size of the frame is 3.75 * 1,024,000 = 3,840,000 bytes.

10) If a computer connected to a 1 gigabit Ethernet network needs to send a 256 Kbytes file, how long would it take? [5 pts]

It would take 2.048 seconds for a computer connected to a 1 gigabit Ethernet network to send a 256 Kbytes file.

11) Assuming that cache memory is ten times faster than DRAM memory, that DRAM memory is 100,000 times faster than magnetic disk, and that flash memory is 1000 times faster than disk, find out how long it takes to read a file from a DRAM, a disk, and a flash memory if it takes 2 microseconds from the cache memory? [5 pts]

Given time equivalencies, 1,000 flash = disk; 100,000 DRAM = disk; and 1,000,000 DRAM = disk. Given that it takes 2 microseconds from the cache memory, it takes 2 seconds to read from a disk (1,000,000 * 2 microseconds), 20 microseconds (2s / 100,000) to read from a DRAM, and 2 milliseconds (2s / 1,000) to read from a flash memory.

12) Consider three different processors P1, P2, and P3 executing the same instruction set with clock rates and CPI's given in the following table. ***Must*** show calculations for credit.

Processor	Clock Rate	CPI
P1	2.25 GHz	1
P2	4.5 GHz	2.5
P3	3 GHz	1.5

a) Which processor has the highest performance? [5 pts]

Processor P1 has the highest performance of approximately .44 s (1 CPI / 2.25 GHz) compared to P2 with approximately .55 s (2.25 CPI / 4.5 GHz) and P3 with .5 s (1.5 CPI / 3 GHz).

b) If the processors each execute a program in 10 seconds, find (a) the number of cycles and (b) the number of instructions for each. [5 pts]

# of cycles = CPI * # of instructions
P1: 1 CPI * 22.5 instructions = 22.5 cycles
P2: 2.5 CPI * 18 instructions = 45 cycles
P3: 1.5 CPI * 20 instructions = 30 cycles

# of instructions = (CPU time * Clock rate) / CPI
P1: (10 seconds * 2.25GHz) / 1 CPI = 22.5 instructions
P2: (10 seconds * 4.5GHz) / 2.5 CPI = 18 instructions
P3: (10 seconds * 3GHz) / 1.5 CPI = 20 instructions

13) Use the following information for the questions below. ***Must*** show calculations for credit.

Processor	**Clock Rate**	**No. Instructions**	**Time**
P1	2 GHz	18×10^9	9 s
P2	1.5 GHz	27×10^9	6 s
P3	3 GHz	42×10^9	7 s

a) Find the IPC (instructions per cycle) for each processor. [5 pts]
IPC = 1 / CPI [(CPU Time * Clock rate) / Instruction count]
P1: 1 / ((9 s * 2 GHz) / 18e9) = 1,000,000,000 instructions per cycle
P2: 1 / ((6 s * 1.5 GHz) / 27e9) = 3,000,000,000 instructions per cycle
P3: 1 / ((7 s * 3 GHz) / 42e9) = 2,000,000,000 instructions per cycle

b) Which processor has the highest performance? [5 pts]
Processor P2 has the highest performance with 6 s CPU time and 3,000,000,000 instructions per cycle.

14) Consider two different implementations of the same instruction set architecture. There are four classes of instructions A, B, C, and D. The clock rate and CPI of each implementation are given in the following table. ***Must*** show calculations for credit.

	Clock Rate	**CPI Class A**	**CPI Class B**	**CPI Class C**	**CPI Class D**
P1	1.5 GHz	4	2	3	1
P2	2 GHz	1	3	3	3

a) Given a program with 10^6 instructions divided into classes as follows: 10% class A, 20% class B, 50% class C, and 20% class D, which implementation is faster? [10 pts]

CPU clock cycles (P1)

= (4 * 10e5) + (2 * 2 * 10e5) + (3 * 5 * 10e5) + (1 * 2 * 10e5) = 2.5e7

CPU clock cycles (P2)

= (1 * 10e5) + 3 * 2 * 10e5) + (3 * 5 * 10e5) + (3 * 2 * 10e5) = 2.8e7

CPU times (P1)

= 2.5e7 / 1.5 GHz = 16,666.67 ms

CPU times (P2)

= 2.8e7 / 2 GHz = 14,000 ms

Processor P2 is faster.

b) What is the global CPI for each implementation? [5 pts]

CPI (P1) = CPU clock cycles / Instruction count = 2.5e7 / 10e6 = 2.5

CPI (P2) = CPU clock cycles / Instruction count = 2.8e7 / 10e6 = 2.8

15) Compilers can have a profound impact on the performance of an application on a given processor. This problem will explore the impact compilers have on execution time. ***Must*** show calculations for credit.

	Compiler A		**Compiler B**	
	# Instructions	**Execution Time**	**# Instructions**	**Execution Time**
program a.	1.0×10^9	1 s	1.2×10^9	1.4 s
program b.	1.0×10^9	0.8 s	1.2×10^9	0.7 s

a) For the same program, two different compilers are used. The table above shows the execution time of the two different compiled programs. Find the average CPI for each program given that the processor has a clock cycle time of 1 nano second. [5 pts]

CPI = CPU time / (Instruction count * Clock cycle time)

Program A (Compiler A): 1 s / (1e9 * 10e-9) = .1 CPI

Program A (Compiler B): 1.4 s / (1.2e9 * 10e-9) = .12 CPI

Average CPI (Program A): ~ .108 CPI

Program B (Compiler A): 0.8 s / (1e9 * 10e-9) = .08 CPI

Program B (Compiler B): 0.7 s / (1.2e9 * 10e-9) = .06 CPI

Average CPI (Program B): ~.069 CPI

b) Assume the average CPIs found in a), but that the compiled programs run on two different processors are the same. How much faster is the clock of the processor running compiler A's code versus the clock of the processor running compiler B's code? [5 pts]

CPU time = (Instruction count * CPI) / Clock rate
CPU time (1) = CPU time (2)

$$\frac{\text{Instruction count (1)} * \text{CPI (1)}}{\text{Clock rate (1)}} = \frac{\text{Instruction count (2)} * \text{CPI (2)}}{\text{Clock rate (2)}}$$

$$\text{Clock rate (1)} = \frac{\text{Instructions count (1)} * \text{CPI (1)}}{\text{Instructions count (2)} * \text{CPI (2)}} * \text{Clock rate (2)}$$

$$= \frac{\text{1e9} * .108 \text{ CPI}}{\text{1.2e9} * .069 \text{ CPI}} * \text{Clock rate (2)}$$

Clock rate (1) = 1.305 * Clock rate (2); The clock of the processor running compiler A’s code is 1.305 times faster than the clock of the processor running compiler B’s code.