5. (20 points) Answer the following questions about computer processors:
a. Describe what a core and hardware thread is on a modern processor, and the difference between them?

A CPU core is a hardware component that has a dedicated set of registers, arithmetical logical unit(s), addressing unit and a control unit that can execute instructions, manipulate data in memory and handle interrupts.
A hardware thread is a technique that allows CPU vendors to connect multiple instruction and data pipelines to a single core, providing additional sets of registers that allows the core to switch between the pipelines without offloading state to main memory, thus increasing performance of IO intensive applications. They may be exposed to the operating system and programmers as appearing to be additional cores.

b. How many cores do the fastest processors from each manufacturer have? Give an example (specific model, specs, and price).
(a) Intel CPU (x86)

https://ark.intel.com/content/www/us/en/ark/products/194146/intel-xeon-platinum-9282-processor-77m-cache-2-60-ghz.html
Intel Xeon Platinum 9282 Processor
Launch Date: Q2'19
Lithography: 14nm
# of Cores: 56
# of Threads: 112
Processor Base Frequency: 2.60Ghz
Max Turbo Frequency: 3.80Ghz
Cache: 77MB
TDP: 400W
"Prices for these models will not be made public since the processors are BGA-only and will be sold directly to select OEMs in 2U quad-blade configurations. These new server blades will start shipping in Q2 2019."
https://www.notebookcheck.net/Intel-presents-new-56-core-Xeon-Platinum-server-grade-CPUs.415676.0.html

(b) AMD CPU (x86)

https://www.amd.com/en/products/cpu/amd-epyc-7742
AMD EPYC 7742
Launch Date: Q2’19
# of Cores: 64
# of Threads: 128
Processor Base Frequency: 2.25Ghz
Max Turbo Frequency: 3.40Ghz
Total L3 Cache: 256MB
TDP: 225W
Price: $7,522.99 https://www.newegg.com/amd-epyc-7742-socket-sp3/p/N82E16819113581

(c) IBM CPU (Power9)

Power9 - instruction set developed by IBM

https://en.wikichip.org/wiki/ibm/microarchitectures/power9
https://en.wikichip.org/wiki/ibm/power/02cy296
Model: 02CY296
Launch Date: November 2018
# of Cores: 22
# of Threads: 88
Processor Base Frequency: 2.75Ghz
Max Turbo Frequency: 3.80Ghz
L3: 110MB
TDP: 190W

(d) ThunderX CPU (ARM)

https://www.marvell.com/documents/6vi7chuyqr17kc25llol/
ThunderX_CP™ Family of Workload Optimized Compute Processors
# of Cores: up to 48
Processor Frequency: up to 2.5Ghz
Cache: 78K-Icache and 32K-D cache per core, 16 MB shared L2 cache

(e) NVIDIA GPU

Nvidia Quadro RTX 8000
GPU Memory 48 GB GDDR6
Memory Interface 384-bit
Memory Bandwidth 672 GB/s
NVIDIA CUDA Cores 4,608
NVIDIA Tensor Cores 576
NVIDIA RT Cores 72
Single-Precision Performance 16.3 TFLOPS
Tensor Performance 130.5 TFLOPS
Price: $5531.99
https://www.amazon.com/PNY-VCQRTX8000-PB-NVIDIA-Quadro-Graphic/dp/B07NH3HKG9

c. Why do we not have processors running at 1THz today (as might have been predicted in the year 2000)?

Increasing clock frequencies lead to a higher thermal loss. Sufficient cooling is required to maintain operational temperatures, otherwise the chip will be damaged and fail. Chips that operate at higher clock frequencies endures higher thermal stress, and would have lower mean time before failure.
Secondly, an increase in clock frequencies implies an increase in voltage, and thus power consumption. In data centers and other intensive environments, power costs is an important factor.

d. Describe Moore's Law. Is it going to go on forever? If not, when will it end? Justify your answer to why it will end and when.

Moore's Law states that the number of transistors that can be packed into a given unit of space will double about every two years. Many experts agrees that Moore's Law is coming to an end in 2020s, where manufacturing smaller transistors becomes physically impossible. As transistors are made smaller, eventually it reaches a certain point where quantum tunneling of electrons would render the miniaturized transistors produces inconsistent results and becomes non-functional.