Q1. CPU Performance Calculation (10 points):

- Given a CPU with a clock frequency of 3 GHz and a CPI (Cycles Per Instruction) of 2.5, calculate the execution time for a program that has 5 million instructions.

- Define the performance of this CPU in terms of instructions per second.

$$\text{CPU Time} = \frac{\text{instruction Count} \times \text{CPI}}{\text{Clock rate}}$$

Given: 3GHz
2.5 CPI
5Mil

3GHz is = 3 billion

$$\text{CPU Time} = \frac{5000\,000 \times 2.5}{3000\,000\,000}$$

$$= \frac{12500000}{3000\,000\,000}$$

$$= 0.00416$$

∴ The execution time for a program that has 5Mil instructions would take 0.00416 seconds.

Define Performance $P = \frac{1}{\text{execution time}}$

$$P = \frac{1}{0.00416} = 240.38 \text{ IPS}$$

The execution time for a program that has 5 million instructions would take 0.00416 seconds and the performance of this CPU in terms of IPS is 240.38.

Q2. Clock Period and Frequency Relationship (10 points):

- If the clock frequency of a CPU is doubled from 2 GHz to 4 GHz, explain how this affects the clock period. Calculate the new clock period.

Old frequency = 2GHz
New frequency = 4GHz

2GHz = 2 billion
4GHz = 4 billion

$$\text{CPU Time} = \frac{\text{Clock Cycle}}{\text{Clock rate}}$$

$$\text{Old} = \frac{1}{2000000000}$$

$$\text{Old} = 5\times10^{-10}$$

$$\text{New} = \frac{1}{4000000000}$$

$$\text{New} = 2.5\times10^{-10}$$

$\therefore$ The new clock period is 2.5×10^{-10} and affects the clock period by reducing it by half.

The clock period being 2.5x10^-10 is half of the original clock period. In terms of performance, this clock period is faster and better than the previous one. In terms of energy, I've noticed the higher the clock period the more power it takes from my analysis in question 4, this one being 4Ghz, it would consume more energy.

Q3. Energy Efficiency Evaluation (15 points):

- Consider a CPU that performs 2×1092×109 operations and consumes 65 Watts of power. Calculate the CPU's operations per Watt using the given formula. Discuss what this value suggests about the CPU's energy efficiency.

Question 3

$$\text{Operations per watt} = \frac{\text{Number of operations}}{\text{Power Consumtion}}$$

$$2 \times 1092 \times 109 = 238056$$

$$= \frac{238056}{65}$$

$$= 3662.4$$

$\therefore$ The operations per watt value is 3662.4.

Energy efficiency is an important part of modern computers. Essentially, the higher the number operations per watt, the more energy efficient the computer is. The calculation resulted in 3662.4 OPW meaning that the computer is energy efficient. Furthermore, energy efficient computers are better for the environment. They have better battery life than non-energy efficient computers and do not heat up like some computers which can get very hot and even damage the cooling systems over time.

Q4. Comparative Analysis (15 points):
Compare two CPUs where:

CPU A has a clock rate of 2.5 GHz, CPI of 3, and performs 1×1091×109 operations using 60 Watts.

CPU B has a clock rate of 3.2 GHz, CPI of 2.8, and performs 1.2×1091.2×109 operations using 75 Watts.

CPU B has a better clock rate which will be faster in terms of IPS, CPI which will have better performance, operations which use 75 watts meaning that it uses more power.

Overall, CPU B outperforms CPU A.

Calculate the CPU time for a program with 8 million instructions and the overall ssj_ops per Watt for both CPUs. Which CPU is more energy-efficient?

Calculat CPU Time

2.5 Ghz = 2.5 billion

$$\text{CPU Time} = \frac{\text{Instruction Count} \times \text{CPI}}{\text{Clock rate}}$$

$$\text{CPU A} = \frac{8000\,000 \times 3}{250\,000\,000} = \frac{240\,00\,000}{250\,000\,000} = 0.096$$

CPU A = 0.096 seconds

$$\text{CPU B} = \frac{8\,000\,000 \times 2.8}{320\,000\,000}$$

3.2 Ghz = 3.2 billion

$$= \frac{22400\,000}{320\,000\,000}$$

CPU B = 0.07 seconds

CPU A time is 0.096 seconds and CPU B time is 0.07 seconds. This means that CPU B is faster in terms of processing time. The overall performance is high with 0.07 seconds and is comparable to other CPU's depending on the price range.

Overall ssj_ops per Watt for both CPUs

$$\text{ssj ops} = \frac{\text{Number of operations}}{\text{Power consumtion}}$$

$$\text{CPU A} = \frac{118\,919}{60}$$

$1 \times 10^9 1 \times 10^9$
= 118 919 operation

CPU A = 1981.983

∴ The ssj ops is 1981.983

$1.2 \times 10^9 1.2 \times 10^9$
= 142 728.96

$$\text{CPU B} = \frac{142\,728.96}{75}$$

CPU B = 1903.052

∴ The ssj ops is 1903.052

The overall ssj_ops per watt for CPU A is 1981.983. For CPU B, it's 1903.052. With CPU B having a lower ssj_ops, this means that it uses more power in terms of watts, making CPU A more power efficient.

The Standard Performance Evaluation Corp (SPEC), according to their benchmark, finds that CPU B at 40% target load would use 140 watts. Moreover, CPU A would use fewer watts because the overall ssj ops performance is lower than CPU B's.

MIPS program output: