1. Compilers can have a profound impact on the performance of an application. Assume that for a program, compiler A results in a dynamic instruction count of $1.0 \times 10^9$ and has an execution time of $1.1$ s, while compiler B results in a dynamic instruction count of $1.2 \times 10^9$ and an execution time of $1.5$ s.

   a. Find the average CPI for each program given that the processor has a clock cycle time of $1$ ns. ($1$ ns = $10^{-9}$ second) [10 points]

   A:
   
   cycle: $1.1$ s / $1$ ns = $1.1 \times 10^9$
   
   CPI = cycle / instruction = $1.1 \times 10^9 / (1.0 \times 10^9) = 1.1$

   B:

   cycle: $1.5$ s / $1$ ns = $1.5 \times 10^9$
   
   CPI = cycle / instruction = $1.5 \times 10^9 / (1.2 \times 10^9) = 1.25$

   b. Assume the compiled programs run on two different processors. If the execution times on the two 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? [10 points]

   $1.5$ s / $1.1$ s = $1.36$
   
   B’s processor is $1.36$ times faster than A.

   or $1.1$ s / $1.5$ s = $0.73$
   
   The speed of A’s processor is $0.73$ times of the one of B’s processor.

   c. A new compiler is developed that uses only $6.0 \times 10^8$ instructions and has an average CPI of $1.1$. What is the speedup of using this new compiler versus using compiler A or B on the original processor with $1$ ns clock cycle time? [15 points]

   New:
   
   Cycles = CPI * instructions = $1.1 \times 6.0 \times 10^8 = 6.6 \times 10^8$
   
   Time = $6.6 \times 10^8 \times 1$ ns = $0.66$ s

   Speed up for A: $1.1$ s / $0.66$ s = $1.67$
   Speed up for B: $1.5$ s / $0.66$ s = $2.27$

2. Write two’s complements of 5 and -4 in 8-bit binaries, and use the complements to calculate 5 - 4. [20 points]

   5: 0000 0101
   -4: 1111 1100
   1: 0000 0001
3. Consider the following MIPS code:

```mips
LOOP:  slt $t2, $zero, $t1  # set less than
       beq $t2, $zero, DONE  # branch on equal
       addi $t1, $t1, -1     # Add immediate
       addi $s2, $s2, 3
       j LOOP  # jump
DONE:
```

a) Assume that register $t1 is initialized to the value 8 (in base 10), and $s2 is initialized to zero. What is the value of $s2 after executing the code segment above? [15 points]

This is a loop and the operation in the loop is adding 3 to a register. There are eight loops, and therefore we add eight 3 to register s2. The value of s2 after executing the code will be 24.

b) Convert the MIPS instructions above to C code. Assume that registers $s2 and $t1 contain the variables B and i, respectively. [15 points]

```c
for(int i = 8; i > 0; i--){
    B = B + 3;
}
```

c) How many MIPS instructions would be executed if the register $t1 was initialized to the value N? [15 points]

```
5(N-1) + 2
```