1. [5 points] What is the decimal value of the unsigned hexadecimal number A7?

   167

2. [5 points] Write the decimal number -108 as an 8-bit two’s complement binary number.

   That is -128 + 20 or 10010100

3. [5 points] Why does the MIPS multiply instruction use two registers, HI and LO, for the result?

   When you multiply two 32-bit numbers the result requires more than 32 bits, in fact it yields a 64 bit result hence using one register for the upper 32 bits (HI) and another for the lower 32 bits (LO).

4. [5 points] What decimal number does the 16-bit two’s complement number 1111111111111001 represent?

   -7 remember the trick is to ignore the leading 1s except for the last one. That is this number is that same as 1001 4-bit two’s complement number.

5. [5 points] Assume signed integers are 8 bits and two's complement. What is the range of decimal values that can be represented?

   -128 to 127

6. [5 points] How many bits are required to represent a register number is a MIPS instruction?

   There are 32 registers so we need 5 bits. The $\log_2(32) = 5$

7. [20 points] Write a MIPS assembly language program that reads an integer from the user, counts the number of times that integer can be divided by 2 before
reaching zero and prints the count to the console. Your program should use
prompts for input and output.

```mips
# this counts the number of time an integer can be divided by 2
# before it hits zero
.data
prompt: .asciiz "enter an integer: "
.align 2
output: .asciiz "the answer is "

.text
main:
    la $a0, prompt      # print input prompt
    li $v0, 4
    syscall

    li $v0, 5            # read the integer
    syscall

    move $t0, $v0        # move number to $t0

    li $t1, 0            # counter in $t1

loopbegin:
    slti $t2, $t0, 2    # if number < 2 then we're done
    bne $t2, $zero, loopend
    addi $t1, $t1, 1    # update counter
    srl $t0, $t0, 1     # divide by 2
    j loopbegin         # go back an do it again

loopend:
    la $a0, output      # print the output prompt
    li $v0, 4
    syscall

    li $v0, 1            # print the answer
    move $a0, $t1
    syscall

    jr $ra                # bye bye
```

8. [20 points] Consider the definition of list below that contains eight numbers.
Write a MIPS program that writes the list in reverse order to the console (10, 0, -15, etc.) Your program should be general and work if I modify the list of
numbers.

```assembly
# this counts the number of time an integer can be divided by 2
# before it hits zero
.data
list: .word 43, 22, 77, 96, 20, -15, 0, 10

.text
main:
    la $t0, list  # get address of list
    li $t1, 8    # 8 items in list
    addi $t0, $t0, 28  # jump to end of list
    li $v0, 1     # code for printing an integer

loop:
    beq $t1, $zero, endloop  # if counter is zero we're done
    lw $a0, 0($t0)  # put the number into a0 for printing
    syscall
    addi $t0, $t0, -4  # address to next item in list
    addi $t1, $t1, -1  # update counter
    j loop

endloop:
    jr $ra  # bye bye
```

9. [10 points] Suppose processor $P_1$ has a cycle time of 1 nanosecond and processor $P_2$ has a cycle time of 0.5 nanoseconds. Furthermore $P_1$ has a CPI of 2.5 for a program and $P_2$ has a CPI of 5 for the same program. Which machine is faster for the program and by what factor?

\[
\text{Time} = IC(CPI)(CT)
\]

\[
\begin{align*}
\text{Time}_1 &= IC(2.5)(1) = 2.5IC \\
\text{Time}_2 &= IC(5)(.5) = 2.5IC \\
\end{align*}
\]

The two processors have the same performance for program P.

10. [10 points] Assume that the execution time of a program $p$ on a processor is 200 seconds. Also assume that $p$ spends 20% of the execution time doing floating-point multiplications. What would the execution time be if we quadrupled
The program spends $200 \cdot 0.20$ or 40 seconds executing floating-point multiplications.

So $\text{Time} = 200 = 160 + 40$. If we speed up the multiplies by a factor of 4 then we would only spend 10 seconds multiplying. So the time would be 170 seconds.

$\text{Speedup} = \frac{200}{170} = 1.18$ times faster.

11. [5 points] If the clock cycle time for a processor is $2 \times 10^{-9}$ seconds what is the clock rate?

$\text{Rate} = \frac{1}{\text{cycle time}} = \frac{1}{2 \times 10^{-9}} = 500\text{MHz}$