5. In this question we will calculate how fast our program from question 4 will run.

   (a) (3 points) How many instructions will be necessary to calculate the dimming operation on the *whole* image in Question 4c? If you have not answered Question 4a or 4b, assume that you need 10 instructions for one **dim_pixel** subroutine. If you make further assumptions please state them clearly. (*Note: you can use approximations to simplify calculations.*)

   Solution:
   The inner loop in question 4c has 6 instructions. One of these instructions calls the subroutine that has 14 further instructions (including the `jr`). Thus per pixel we will need 20 instructions. For the entire image this loop will be executed 1'024 times 1'024 == 1'048'576 (approximately 1 million). The initial instructions can be ignored.
   In total we will need slightly more than 20 million instructions (20'971'520). The answer will depend on your answer to question 4 (or your assumption).

   (b) (3 points) For a real-time video application, you realize that you can afford at most 10 ms of time until this operation is completed. Assuming that you are using an *ideal single cycle MIPS architecture*, what is the minimum *clock frequency* that your processor has to run at, so that your program finishes within 10 ms?

   Solution:
   $$T = N \cdot CPI \cdot \frac{1}{f}$$
   Where T is the time to finish the operation, in this case 10 ms, N was calculated in the previous exercise to be 20 million, CPI for an ideal single cycle processor is 1. From here we can calculate the clock frequency (f) to be 2 GHz.

Hint:
$1\,s = 1000\,ms = 1'000'000\,\mu s = 1'000'000'000\,ns = 1'000'000'000'000\,ps$
$1\,Hz = 1\,\frac{1}{s}$; $1\,kHz = 1'000\,\frac{1}{s}$; $1\,MHz = 1'000'000\,\frac{1}{s}$; $1\,GHz = 1'000'000'000\,\frac{1}{s}$;