1 Problems

1. (a) A program repeatedly performs a three-step process: It reads in a 4-KB block of data from disk, does some processing on that data, and then writes out the result as another 4-KB block elsewhere on the disk. Each block is laid out using contiguous sectors and randomly located on a single track on the disk. Each sector is 512 bytes. The disk rotates at 7200 RPM, has an average seek time of 8 ms, and has a transfer rate of 20 MB/sec. the controller overhead is 2 ms. The processing step takes 20 million clock cycles, and the clock rate is 400 MHz. What is the overall speed of the system in blocks processed per second?
Solution:
Step 1: Read the data. First we need the average rotational delay:

$$0.5/7200\text{RPM} = 4.167\text{ms}.$$

Next calculate the time to read 4-KB:

$$4\text{-KB}/(20\text{-MB/s}) = 0.195\text{ms}.$$

Finally, calculate the total read time:

$$\begin{aligned}\text{Time} &= \text{rotational delay} + \text{seek time} + \text{overhead} + \text{transfer time} \\ &= 4.167\text{ms} + 8\text{ms} + 2\text{ms} + 0.195\text{ms} = 14.362\text{ms}\end{aligned}$$

Step 2: Process the data.

$$20 \text{ million cycles}/(400\text{MHz}) = 50\text{ms}.$$

Step 3: Write the data to disk. This takes the same time as the read.
So, it takes 78.7 ms to process 1 block, i.e. 12.7 blocks per second.

(b) Now suppose the program reads in a 400-KB block of data that is heavily fragmented and writes back one contiguous block of data to disk. The processing step now takes 2 billion clock cycles. What is the overall speed of the system in blocks processed per second?
Solution:
Step 1: Read the data. The data is heavily fragmented, so first we need to figure out how many sectors we need to read:

$$400\text{-KB}/512\text{-B} = 800\text{sectors}.$$

Next we need to calculate how long it takes to read one sector:

$$0.5\text{-KB}/(20\text{-MB/s}) = 0.024\text{ms}.$$

Finally, calculate the total read time:

$$\text{Time} = (800\text{sectors})(4.167\text{ms} + 8\text{ms} + 2\text{ms} + 0.024\text{ms}) = 11353\text{ms}$$

Step 2: Process the data.

$$2 \text{ billion cycles}/(400\text{MHz}) = 5000\text{ms}.$$

Step 3: Write the data to disk. Now we write back to one contiguous block, so this will not be the same as the read time as in (a). First we calculate how long to write 400KB to disk:

$$400\text{-KB}/(20\text{-MB/s}) = 19.5\text{ms}.$$

$$\begin{aligned}\text{Time} &= \text{rotational delay} + \text{seek time} + \text{overhead} + \text{transfer time} \\ &= 4.167\text{ms} + 8\text{ms} + 2\text{ms} + 19.5\text{ms} = 33.667\text{ms}\end{aligned}$$

Combining these times to get the total time to process 1 block:

$$\text{Total Time} = 11.353\text{s} + 5\text{s} + 0.033667\text{s} = 16.38\text{s}.$$

So, we can process 0.06 blocks per second.