Question 6

a. Number of bytes per track = $\frac{2 \times 2^{20}}{2 \times 64} = 2^{14}$ bytes

Time spent to read one track excluding gaps = $\frac{1}{60} \times 0.8$ seconds

Burst bandwidth = $\frac{2^{14}}{0.8/60} = 1228800$ bytes/sec = 1.172 MegaBytes/sec

b. Sustained bandwidth = $\frac{2^{14}}{1/60} = 983040$ bytes/sec = 0.9375 MegaBytes/sec

c. Average rotational latency = $\frac{1}{2} \times \frac{1}{60} = 0.0083$ seconds = 8.3 milliseconds

d. Data transfer time for sector = size of sector/burst bandwidth =

$$\frac{2^{11}}{1228800} = 0.00167 \text{ seconds} = 1.67 \text{ milliseconds}$$

Sector transfer time = seek time + average rotational delay + data transfer time = 16 + 8.3 + 1.67 = 25.97 milliseconds

Question 7

a. The next I/O request could be for any of the cylinders 1, 2, ..., 8192 with equal likelihood. The number of cylinders traveled in these cases would be $|3000 - 1|, |3000 - 2|, \ldots, |3000 - 8192|$. Hence the average number of cylinders is:

$$= \frac{2999 + 2998 + \cdots + 1 + 0 + 1 + 2 + \cdots + 5192}{8192}$$

$$= \frac{2999 \times 3000/2 + 5192 \times 5193/2}{8192}$$

$$= 2194.77 \text{ (Recall that } 1 + 2 + \cdots + n = n \times (n + 1)/2)$$

b. 3840 revolutions per minute = 64 revolutions per second

Average Rotational latency = 0.0078 seconds = 7.8 milliseconds

Transfer time for a block = 0.48 milliseconds (see the similar example worked out in class, or see Example 11.5 in the textbook, page 521). Note that you have to account for the fact that a block consists of 8 sectors AND 7 gaps.

Seek time for next I/O: $1 + 2194.77/500 = 5.4$ milliseconds

Expected block access time: seek time + rotational latency + data transfer time = $5.4 + 7.8 + 0.48 = 13.68$ milliseconds
Question 8

1. \((\sigma_{P_1} R_1 \bowtie \sigma_{P_2} R_2) = \phi\)

2. It does not change.

3. The condition does not hold. The correct condition is: 
   \[
   (\sigma_{P_1 \bowtie P_2} (R_1 \bowtie R_2) = (\sigma_{P_1} R_1 \bowtie R_2) \cup \left( R_1 \bowtie \sigma_{P_2} R_2 \right) - B(\sigma_{P_1} R_1 \bowtie \sigma_{P_2} R_2)
   \]