The coursework is in two parts. Part 1 requires you to solve a problem involving calculation of Effective Access Times. Part 2 requires you to implement a simple HTTP server in Java. This document describes Part 1.

Part 1: EAT

Consider a computer system which uses demand paging virtual memory. The maximum degradation in memory performance which the owner is prepared to tolerate is 10% (see below for the formal definition of degradation) but the system as currently configured performs significantly worse than this. The owner can address the problem by adding more RAM or adding a Solid State Drive for swap space, or a combination of the two. There are a number of problem parameters, some of which are common for all coursework teams (see below), and some of which are specified differently for each team. The specific parameter set for your team will be made available to you separately.

1. **[8 marks]** The base access time (*a*) is the time it takes for the hardware to perform a single memory access when there is no page fault. The value of *a* is **150 nanoseconds** (this is the same for all teams). The Effective Access Time (EAT) is the average *actual* memory access time for the system, which is greater than *a* because of the time taken to service page faults. The page fault rate (*p*) and the average time taken to service a page fault (*S*) for the system as initially configured can be found in your team's parameter set. The formula to calculate the EAT is:

$$\text{EAT} = a + p\,S$$

Calculate the EAT for your initial system configuration. Show your working. Give your answer to 3 significant figures.

2. **[8 marks]** Performance *degradation* is measured as a percentage of the base access time. The calculation is:

$$\text{degradation} = 100 * (EAT - a) / a$$

For example, given a = 150 nanoseconds then, if EAT = 200 nanoseconds, degradation would be 100 * (200 – 150)/150 = 100 * 50/150 = 33.3%.

Calculate the degradation for your team's initial configuration. Show your working. Give your answer to 3 significant figures.

3. **[34 marks]** The system has two available slots for RAM. The system is initially configured with two 0.5 GiB chips, giving a total system memory of 1 GiB. Other available chip sizes are 1 GiB, 2 GiB, 4 GiB, 8 GiB and 16 GiB. Chips can only be installed in balanced pairs of equal size, so the only possible sizes for total system memory are 1 GiB, 2 GiB, 4 Gib, 8 Gib, 16 Gib and 32 GiB. The cost of new RAM is **$5 per GiB**. The only other change which can be made to the system is to install a new Solid State Drive (SSD), configured as swap space. The initial system configuration uses a conventional hard disk for swap space, which achieves an average data transfer rate when servicing page faults of **100 MiB/sec**. If an SSD is installed, the transfer rate becomes **400 MiB/sec**. A 32GB SSD is sufficient for this purpose, at a total cost of **$34**.

The following system characteristics have been empirically determined[1]:

- The page fault rate p is *inversely proportional* to the total system memory size. So increasing RAM will reduce p and thus reduce degradation.
- The page fault service time S obeys the following formula: $S = S_{min} + k / D$ where S_{min} is one of your team's parameters, D is the data transfer rate, and k is a constant (which you can calculate from the data provided). So increasing D (by installing an SSD) will reduce S and thus reduce degradation.

Determine the *cheapest* change which will bring the memory performance degradation down to 10% or less. This can be any combination of replacing the RAM and/or adding an SSD. You must state how much RAM is to be purchased and whether or not an SSD is to be purchased, and provide the overall cost. It is essential that you *justify* your answer by argument based on the data provided, demonstrating that your proposed solution not only *is* a solution, but is, in fact, *the cheapest possible* solution. Lucky guesses will gain no marks; partially correct reasoning will gain partial marks, even if the answer is incorrect.

Hint: There are 12 possible RAM/SSD combinations. It may help to order them first by cost and start by considering a combination near the middle of the range. But think carefully before eliminating alternatives: in some cases, a cheaper choice may be *more* effective at reducing the EAT than a more expensive one.

Submission

For Part 1 of the coursework, submit **one document** (Word, plain text or PDF) containing your answers.

[1] This is hypothetical. Real system characteristics will be more complex.