Name: _____

CIS 351 Sample P1 Problem

15 October 2025

P1: Pipeline Structure and Speedup

Consider the following process for baking cookies:

1. Mix sugar, flour, and water using a hand-held mixer for six minutes.
2. Pour the mixture into another bowl and add chocolate chips. Stir by hand for four minutes.
3. Spoon the cookie dough onto a baking pan (about four minutes).
4. Place the pan in the oven for fifteen minutes. One pan of cookies takes up the entire oven – you cannot have more than one pan in the oven at once.
5. Place the cookies on a cooling rack (about three minutes). (Assume you have unlimited space on the cooling rack.)

(a) Estimate the total time to bake a single batch of cookies (from when you begin mixing the sugar, flour, and water until all the cookies from the batch are on a cooling rack.)

(b) Suppose you want to pipeline the cookie-baking process, but are working alone. How many stages does your pipeline have? What steps are included in each stage?

(c) What is the primary limitation (i.e., structural hazard) that prevents you from adding a third stage?

(d) Draw a pipeline diagram showing the process of baking 5 batches of cookies using the pipeline you designed above.

(e) Estimate (i) the total time to bake 10 batches of cookies and (ii) the average time per batch.

(f) Your per-batch time is less than the time to make a single batch of cookies. What is the *primary* source of this time savings. (Be specific. Don't just say "pipelining".)

(g) Let k be the number of stages in the pipeline you designed above. The average time per batch is more than $\frac{1}{k}$ the time for a non-pipelined batch. (Using my example, the per-batch time in the 2-stage pipeline — 19.4 minutes – is more than $\frac{1}{2}$ of the 32-minute unpipelined time.)) Explain the primary factor that contributes to this less-than-optimal speedup.

CIS 351 Sample P1 Problem Solutions

Fri 13th Feb, 2026

P1: Pipeline Structure and Speedup

Consider the following process for baking cookies:

1. Mix sugar, flour, and water using a hand-held mixer for six minutes.
2. Pour the mixture into another bowl and add chocolate chips. Stir by hand for four minutes.
3. Spoon the cookie dough onto a baking pan (about four minutes).
4. Place the pan in the oven for fifteen minutes. One pan of cookies takes up the entire oven – you cannot have more than one pan in the oven at once.
5. Place the cookies on a cooling rack (about three minutes). (Assume you have unlimited space on the cooling rack.)

(a) Estimate the total time to bake a single batch of cookies (from when you begin mixing the sugar, flour, and water until all the cookies from the batch are on a cooling rack.) 32 minutes

(b) Suppose you want to pipeline the cookie-baking process, but are working alone. How many stages does your pipeline have? What steps are included in each stage?

Stage 1: Mix, Stir, Spoon
Stage 2: Bake, Remove

(c) What is the primary limitation (i.e., structural hazard) that prevents you from adding a third stage?

You are the structural hazard. In order to add a useful third stage, you would need to reduce the time of your longest stage (baking and putting cookies on the cooling rack). To do this you would need to be able to move the cookies to a cooling rack while also preparing the next batch.

There are several other reasonable ways to answer this question. For example, if your mixer was a Kitchen-Aid type stand mixer (that doesn't need constant attention), you might be able to get steps 2, 3, and 5 done while a batch is in the oven.

(d) Draw a pipeline diagram showing the process of baking 5 batches of cookies using the pipeline you designed above.

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MPS BPC
    MPS BPC
        MPS  BPC
             MPS PBC
                 MPS PBC
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(e) Estimate (i) the total time to bake 10 batches of cookies and (ii) the average time per batch.

194 minutes. Stage 1 takes 14 minutes. At this point, every 18 minutes, a "baking/removing" phase finishes. This is 19.4 minutes per batch.

(You could also claim that even the first stage 1 takes 18 minutes — this is how it would work in a CPU — giving a total time of 198 minutes.)

(f) Your per-batch time is less than the time to make a single batch of cookies. What is the *primary* source of this time savings. (Be specific. Don't just say "pipelining".)

The primary time savings is that you are mixing up batch $n+1$ while batch n is in the oven rather than waiting until batch n is on the cooling rack before beginning ot mix up batch $n+1$.

(g) Let k be the number of stages in the pipeline you designed above. The average time per batch is more than $\frac{1}{k}$ the time for a non-pipelined batch. (Using my example, the per-batch time in the 2-stage pipeline — 19.4 minutes – is more than $\frac{1}{2}$ of the 32-minute unpipelined time.)) Explain the primary factor that contributes to this less-than-optimal speedup.

The two stages don't take the same amount of time. Stage 1 takes 14 minutes while Stage 2 takes 18.