

# **Quantitative Reasoning & Interview Preparation**

Informal Notes for Problems on Probability, Estimation, and Financial Intuition

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## 1 Introduction

This document is a curated portfolio of algorithmic solutions. Each selected problem includes:

- a brief problem summary,
- the key idea,
- an algorithm outline,
- a correctness sketch,
- time and space complexity,
- a reference C++ implementation.

The focus is on clarity, correctness, and reasoning.

## 2 How This Book Is Written

This book is intended to mirror how problems are discussed in quantitative development technical interviews and presented by a candidate on a whiteboard.

The emphasis is on:

- stating assumptions explicitly,
- building intuition before formalism,
- using diagrams where helpful,
- sanity-checking results,
- (optionally) using pseudocode for simulation-style verification.

This is **not** a formal mathematics text. Proofs are informal, notation is kept light, and equations are used only when they improve understanding.

Each entry is a *final explanation*, not a transcript of exploratory work.

### 2.1 Coin Flips: Simulation vs Expectation

#### Problem

Flip a fair coin  $n$  times. Let  $X$  be the number of heads. What is  $\mathbb{E}[X]$ ? How could we sanity-check the result via simulation?

#### Assumptions

- The coin is fair:  $P(\text{Heads}) = P(\text{Tails}) = \frac{1}{2}$ .
- Flips are independent.

#### Intuition

Each flip contributes either 1 head or 0 heads. On average, a single flip contributes  $\frac{1}{2}$  head, so across  $n$  flips we expect about  $\frac{n}{2}$  heads.

**Reasoning**

Write  $X = \sum_{i=1}^n I_i$ , where  $I_i = 1$  if flip  $i$  is heads and 0 otherwise.

Then:

$$\mathbb{E}[X] = \sum_{i=1}^n \mathbb{E}[I_i]$$

and since  $\mathbb{E}[I_i] = P(I_i = 1) = \frac{1}{2}$  for a fair coin:

$$\mathbb{E}[X] = n \cdot \frac{1}{2} = \frac{n}{2}.$$

**Procedure (Simulation Pseudocode)**

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**Algorithm 1:** Monte Carlo sanity check for  $\mathbb{E}[X]$ 

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**Input:**  $n$  flips per trial,  $T$  trials

**Output:** Estimated mean number of heads

**sumHeads**  $\leftarrow$  0;

**for**  $t \leftarrow 1$  **to**  $T$  **do**

**heads**  $\leftarrow$  0;

**for**  $i \leftarrow 1$  **to**  $n$  **do**

        sample  $U \sim \text{Uniform}(0, 1)$ ;

**if**  $U < 1/2$  **then**

**heads**  $\leftarrow$  **heads** + 1;

**sumHeads**  $\leftarrow$  **sumHeads** + **heads**;

**return** **sumHeads**/ $T$ ;

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**Sanity Check**

- For  $n = 1$ ,  $\mathbb{E}[X] = 0.5$  makes sense.
- For large  $n$ , the estimate should concentrate near  $n/2$ .
- If you plot the histogram of heads across trials, it should look roughly binomial.

**Takeaway**

For  $n$  independent fair coin flips, the expected number of heads is:

$$\mathbb{E}[X] = \frac{n}{2}.$$

Simulation provides a quick sanity check without changing the underlying reasoning.