

# Section 01: Probability Review

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## 1. Expectation

- (a) You've just started a new exercise regimen. You start on the 2nd floor of CSE1, and then make a random choice:
- With probability  $p_1$  you run up 2 flights of stairs.
  - With probability  $p_2$  you run up 1 flight of stairs.
  - With probability  $p_3$  you walk down 1 flight of stairs.

Where  $p_1 + p_2 + p_3 = 1$ .

You will do two iterations of your exercise scheme (with each draw being independent). Let  $X$  be the floor you're on at the end of your exercise routine. Recall you start on floor 2.

- (i) Let  $Y$  be the expected difference between your ending floor and your starting floor in one iteration. What is  $\mathbb{E}[Y]$  (in terms of  $p_1, p_2, p_3$ )?
- (ii) What is  $\mathbb{E}[X]$  (use your answer from the previous part)
- (iii) You change your scheme: instead of doing two independent iterations, you decide the second iteration of your regimen will just use the same random choice as your first (in particular they are no longer independent!). Does  $\mathbb{E}[X]$  change?
- (b) Let  $X_1, X_2, \dots, X_n$  be independent random variables drawn uniformly from  $(0, 1)$ . Define the random variable  $Y = \max\{X_1, \dots, X_n\}$ . What is  $\mathbb{E}[Y]$ ?

## 2. Linearity and Independence

Suppose we have two random variables  $X$  and  $Y$ , such that  $\mathbb{E}[X] = \mathbb{E}[Y] = 2$ . For each of the following quantities either:

- State the value of the quantity if we have enough information to find it, or
- Give examples of two different values the quantity could take if we do not.

(a)  $\mathbb{E}[X + Y]$

(b)  $\mathbb{E}[XY]$

(c)  $\mathbb{E}[X^2]$

(d)  $\mathbb{E}[X]^2$

Suppose we additionally know that  $X$  and  $Y$  are independent. Do any of the answers change?

### 3. Variance and Concentration

Anna and Kevin want to see if the students in the course like probability theory. You (because you're so friendly) know that 200 out of the 250 students in the course say they like probability theory, but Anna and Kevin don't believe you. They decide to use the following process to estimate the number of people who like probability theory:

- Choose a student uniformly at random (and independent from any previous choices).
- Record  $X_i = \begin{cases} 1 & \text{if the student likes probability} \\ 0 & \text{otherwise} \end{cases}$

They will choose 30 such students this way, and they define  $X = \frac{\sum_{i=1}^{30} X_i}{30}$ , the average of the  $X_i$ .

- What is  $\mathbb{E}[X_1]$ ?
- What is  $\text{Var}(X_1)$ ? Hint:  $p(1-p)$  is the variance of a Bernoulli random variable with probability of success  $p$ .
- What is  $\mathbb{E}[X]$ ?
- What is  $\text{Var}(X)$ ?

Kevin and Anna are worried that less than half the course likes probability theory. They will stop being worried if  $X \geq 0.5$ . Use Chebyshev's inequality to give a lower bound on the probability that they stop worrying.

**Theorem 1** (Chebyshev's Inequality). *If  $X$  is a random variable with finite mean  $\mu$  and finite variance  $\sigma^2$ , then for any real number  $k > 0$ :*

$$\Pr[|X - \mu| \geq k\sigma] \leq \frac{1}{k^2}$$