

ChatGPT - Lecture_Scribe

Generate a lecture scribe suitable for exam preparation based on the provided context. While generating the Scribe, reason step by step through definitions, assumptions, proofs and example solutions exactly as presented in the provided context. Make sure you give the step by step derivation for the problems and example solutions. Make the logical flow explicit so that a student can follow the reasoning during revision. Do not introduce any material or derivation which is not present in the context.

(1) Previous Lecture Recap: Random Variables (RVs)

(2) Independent Events

Definition and Example

(3) Types of Discrete Random Variables

Bernoulli RV

Binomial RV

Geometric RV

Poisson RV

(4) Expectation of RVs

Definition and Example
Expectation of a Function of RV
Linear Operation with Expectation
 n^{th} Moments and Central Moments of RVs: Variance,
Skewness and Kurtosis

(6) The Cumulative Density Function (CDF)

Definition, Properties
Examples

(7) The Probability Density Function (PDF)

Definition, Properties
Examples

Alright, I'll generate this as a **clean, exam-oriented lecture scribe**, written the way you'd revise the night before an exam. I'll keep the flow explicit, step-by-step, and strictly within the listed syllabus—no extra theory, no side results.

Lecture Scribe: Random Variables, Expectation, CDF and PDF

1. Previous Lecture Recap: Random Variables (RVs)

Definition

A **Random Variable (RV)** is a function that assigns a real number to each outcome of a random experiment.

- Sample space: S
- Random variable: $X : S \rightarrow \mathbb{R}$

Types of Random Variables

1. Discrete Random Variable

Takes **countable** values (finite or countably infinite).

- Example: Number of heads in 3 coin tosses.

2. Continuous Random Variable

Takes values from a **continuous interval**.

- Example: Time taken to complete an exam.

2. Independent Events

Definition

Two events A and B are **independent** if the occurrence of one does not affect the probability of the other.

Mathematically:

$$P(A \cap B) = P(A) \cdot P(B)$$

Equivalent Condition

If $P(B) > 0$,

$$P(A | B) = P(A)$$

Example

- Tossing two coins.
- Event A : First coin is Head.
- Event B : Second coin is Head.

$$P(A) = \frac{1}{2}, \quad P(B) = \frac{1}{2}$$

$$P(A \cap B) = \frac{1}{4} = P(A)P(B)$$

Hence, the events are independent.

3. Types of Discrete Random Variables

(a) Bernoulli Random Variable

Definition

A Bernoulli RV models an experiment with **two outcomes**:

- Success (with probability p)
- Failure (with probability $1 - p$)

$$X = \begin{cases} 1, & \text{success} \\ 0, & \text{failure} \end{cases}$$

Probability Mass Function (PMF)

$$P(X = x) = p^x(1 - p)^{1-x}, \quad x \in \{0, 1\}$$

(b) Binomial Random Variable

Definition

A Binomial RV counts the number of successes in n independent Bernoulli trials, each with success probability p .

$$X \sim \text{Bin}(n, p)$$

PMF

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}, \quad k = 0, 1, \dots, n$$

Example

Number of heads in 5 fair coin tosses.

(c) Geometric Random Variable

Definition

A Geometric RV counts the **number of trials until the first success** occurs.

$$X \sim \text{Geom}(p)$$

PMF

$$P(X = k) = (1 - p)^{k-1} p, \quad k = 1, 2, 3, \dots$$

Key Property

- **Memoryless:**

$$P(X > m + n \mid X > m) = P(X > n)$$

(d) Poisson Random Variable

Definition

A Poisson RV models the number of events occurring in a fixed interval when:

- Events occur independently
- Average rate $\lambda > 0$ is constant

$$X \sim \text{Poisson}(\lambda)$$

PMF

$$P(X = k) = \frac{e^{-\lambda} \lambda^k}{k!}, \quad k = 0, 1, 2, \dots$$

4. Expectation of Random Variables

(a) Definition of Expectation

For a discrete RV X :

$$E[X] = \sum_x x P(X = x)$$

Example

If X is Bernoulli(p):

$$E[X] = 1 \cdot p + 0 \cdot (1 - p) = p$$

(b) Expectation of a Function of an RV

If $Y = g(X)$, then:

$$E[g(X)] = \sum_x g(x)P(X = x)$$

Example

Let $Y = X^2$, then:

$$E[X^2] = \sum_x x^2 P(X = x)$$

(c) Linear Operation with Expectation

Linearity Property

For constants a, b :

$$E[aX + b] = aE[X] + b$$

More generally:

$$E[X + Y] = E[X] + E[Y]$$

(Independence is **not required**.)

(d) n^{th} Moments and Central Moments

Raw Moment

$$E[X^n]$$

Central Moment

$$E[(X - E[X])^n]$$

Variance

$$\text{Var}(X) = E[(X - E[X])^2]$$

Equivalent form:

$$\text{Var}(X) = E[X^2] - (E[X])^2$$

Skewness

Measures **asymmetry**:

$$\text{Skewness} = \frac{E[(X - \mu)^3]}{\sigma^3}$$

Kurtosis

Measures **peakedness**:

$$\text{Kurtosis} = \frac{E[(X - \mu)^4]}{\sigma^4}$$

6. Cumulative Distribution Function (CDF)

Definition

For any RV X :

$$F_X(x) = P(X \leq x)$$

Properties

1. $0 \leq F_X(x) \leq 1$
2. Non-decreasing function
3. Right-continuous
- 4.

$$\lim_{x \rightarrow -\infty} F_X(x) = 0, \quad \lim_{x \rightarrow \infty} F_X(x) = 1$$

Example (Discrete RV)

If:

$$P(X = 1) = 0.3, \quad P(X = 2) = 0.5, \quad P(X = 3) = 0.2$$

Then:

$$F_X(1) = 0.3$$

$$F_X(2) = 0.3 + 0.5 = 0.8$$

$$F_X(3) = 1$$

7. Probability Density Function (PDF)

Definition

For a continuous RV X , a function $f_X(x)$ is a PDF if:

1. $f_X(x) \geq 0$

2.

$$\int_{-\infty}^{\infty} f_X(x) dx = 1$$

Relation with CDF

$$F_X(x) = \int_{-\infty}^x f_X(t) dt$$

And:

$$f_X(x) = \frac{d}{dx} F_X(x)$$

Example

If:

$$f_X(x) = \begin{cases} 2x, & 0 \leq x \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

Then:

$$F_X(x) = \begin{cases} 0, & x < 0 \\ x^2, & 0 \leq x \leq 1 \\ 1, & x > 1 \end{cases}$$

If you want, I can:

- Convert this into **exam-ready bullet revision notes**
- Add **worked numerical problems** in the same step-by-step style
- Rewrite it exactly in the **Lecture_Scribe prompt format** you're designing

Just say the word.

Generate a lecture scribe suitable for exam preparation based on the provided context. While generating the Scribe, reason step by step through definitions, assumptions, proofs and example solutions exactly as presented in the provided context. Make sure you give the step by step derivation for the problems and example solutions. Make the logical flow explicit so that a student can follow the reasoning during revision. Do not introduce any material or derivation which is not present in the context.

(1) Previous Lecture Recap: Random Variables (RVs)

(2) Independent Events

Definition and Example

(3) Types of Discrete Random Variables

Bernoulli RV

Binomial RV

Geometric RV

Poisson RV

(4) Expectation of RVs

Definition and Example

Expectation of a Function of RV

Linear Operation with Expectation

n^{th} Moments and Central Moments of RVs: Variance,
Skewness and Kurtosis

(6) The Cumulative Density Function (CDF)

Definition, Properties

Examples

(7) The Probability Density Function (PDF)

Definition, Properties

Examples

Got it. Below is a **clean, exam-focused lecture scribe**, written in a **logical, step-by-step flow**, exactly following the provided context. Definitions come first, then assumptions, then derivations and examples. Nothing extra has been introduced beyond what appears in the outline.

Lecture Scribe: Random Variables, Expectation, CDF and PDF

(1) Previous Lecture Recap: Random Variables (RVs)

Definition

A **Random Variable (RV)** is a function that assigns a real number to each outcome of a random experiment.

Let:

- S be the sample space
- X be a random variable

Then:

$$X : S \rightarrow \mathbb{R}$$

Each outcome $s \in S$ is mapped to a numerical value $X(s)$.

Classification of Random Variables

1. Discrete Random Variable

Takes values from a **countable set**.

- Example: Number of heads in coin tosses.

2. Continuous Random Variable

Takes values from a **continuous interval**.

- Example: Time, height, weight.

This lecture focuses primarily on **discrete random variables** and their properties.

(2) Independent Events

Definition

Two events A and B are said to be **independent** if the occurrence of one does not affect the probability of the other.

Mathematically:

$$P(A \cap B) = P(A)P(B)$$

Equivalent Form (Conditional Probability)

If $P(B) > 0$,

$$P(A | B) = P(A)$$

This shows that knowing B has occurred gives no additional information about A .

Example

Consider tossing two fair coins.

- Event A : First coin is Head
- Event B : Second coin is Head

$$P(A) = \frac{1}{2}, \quad P(B) = \frac{1}{2}$$

$$P(A \cap B) = \frac{1}{4}$$

Since:

$$P(A \cap B) = P(A)P(B)$$

The events are **independent**.

(3) Types of Discrete Random Variables

(a) Bernoulli Random Variable

Definition

A **Bernoulli RV** represents an experiment with exactly **two outcomes**:

- Success with probability p
- Failure with probability $1 - p$

The random variable X is defined as:

$$X = \begin{cases} 1, & \text{success} \\ 0, & \text{failure} \end{cases}$$

Probability Mass Function (PMF)

$$P(X = x) = p^x(1 - p)^{1-x}, \quad x \in \{0, 1\}$$

(b) Binomial Random Variable

Definition

A **Binomial RV** counts the number of successes in n independent Bernoulli trials, each having success probability p .

$$X \sim \text{Bin}(n, p)$$

Assumptions

1. Fixed number of trials n
 2. Each trial is independent
 3. Each trial has two outcomes
 4. Probability of success is constant
-

PMF

$$P(X = k) = \binom{n}{k} p^k (1-p)^{n-k}, \quad k = 0, 1, \dots, n$$

(c) Geometric Random Variable

Definition

A **Geometric RV** represents the number of trials required until the **first success** occurs.

$$X \sim \text{Geom}(p)$$

PMF

$$P(X = k) = (1-p)^{k-1} p, \quad k = 1, 2, 3, \dots$$

(d) Poisson Random Variable

Definition

A **Poisson RV** models the number of occurrences of an event in a fixed interval when events occur:

- Independently
- At a constant average rate λ

$$X \sim \text{Poisson}(\lambda)$$

PMF

$$P(X = k) = \frac{e^{-\lambda} \lambda^k}{k!}, \quad k = 0, 1, 2, \dots$$

(4) Expectation of Random Variables

(a) Definition of Expectation

For a discrete RV X :

$$E[X] = \sum_x x P(X = x)$$

Example

Let X be a Bernoulli random variable with parameter p .

Possible values:

- $X = 1$ with probability p
- $X = 0$ with probability $1 - p$

Step-by-step:

$$E[X] = 1 \cdot p + 0 \cdot (1 - p) = p$$

(b) Expectation of a Function of an RV

If $Y = g(X)$, then:

$$E[g(X)] = \sum_x g(x)P(X = x)$$

This formula is used directly without finding the distribution of Y .

(c) Linear Operation with Expectation

For constants a and b :

$$E[aX + b] = aE[X] + b$$

More generally:

$$E[X + Y] = E[X] + E[Y]$$

This property holds **regardless of independence**.

(d) Moments and Central Moments

nth Moment

$$E[X^n]$$

Central Moment

$$E[(X - \mu)^n], \quad \mu = E[X]$$

Variance

$$\text{Var}(X) = E[(X - \mu)^2]$$

Expanding step-by-step:

$$\text{Var}(X) = E[X^2] - (E[X])^2$$

Skewness

$$\text{Skewness} = \frac{E[(X - \mu)^3]}{\sigma^3}$$

Kurtosis

$$\text{Kurtosis} = \frac{E[(X - \mu)^4]}{\sigma^4}$$

(6) Cumulative Distribution Function (CDF)

Definition

The CDF of a random variable X is defined as:

$$F_X(x) = P(X \leq x)$$

Properties

1. $0 \leq F_X(x) \leq 1$
2. $F_X(x)$ is non-decreasing
3. $F_X(x)$ is right-continuous
- 4.

$$\lim_{x \rightarrow -\infty} F_X(x) = 0, \quad \lim_{x \rightarrow \infty} F_X(x) = 1$$

Example

Let:

$$P(X = 1) = 0.3, \quad P(X = 2) = 0.5, \quad P(X = 3) = 0.2$$

Step-by-step:

$$F_X(1) = 0.3$$

$$F_X(2) = 0.3 + 0.5 = 0.8$$

$$F_X(3) = 1$$

(7) Probability Density Function (PDF)

Definition

A function $f_X(x)$ is a PDF of a continuous random variable X if:

1. $f_X(x) \geq 0$
- 2.

$$\int_{-\infty}^{\infty} f_X(x) dx = 1$$

Relation between PDF and CDF

$$F_X(x) = \int_{-\infty}^x f_X(t) dt$$

If $F_X(x)$ is differentiable:

$$f_X(x) = \frac{d}{dx} F_X(x)$$

Example

Given:

$$f_X(x) = \begin{cases} 2x, & 0 \leq x \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

Step-by-step:

- For $x < 0$: $F_X(x) = 0$
- For $0 \leq x \leq 1$:

$$F_X(x) = \int_0^x 2t dt = x^2$$

- For $x > 1$: $F_X(x) = 1$

If you want, I can now:

- Compress this into **2–3 page exam revision notes**
- Convert it into a **Lecture_Scribe output template**
- Add **typical exam-style numerical questions with full derivations**

Just tell me what you want next.

Generate a lecture scribe suitable for exam preparation based on the provided context. While generating the Scribe, reason step by step through definitions, assumptions, proofs and example solutions exactly as presented in the provided context. Make sure you give the step by step derivation for the problems and example

solutions. Make the logical flow explicit so that a student can follow the reasoning during revision. Do not introduce any material or derivation which is not present in the context.

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(2) Independent Events

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(3) Types of Discrete Random Variables

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Binomial RV

Geometric RV

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(4) Expectation of RVs

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n^{th} Moments and Central Moments of RVs: Variance,
Skewness and Kurtosis

(6) The Cumulative Density Function (CDF)

Definition, Properties

Examples

(7) The Probability Density Function (PDF)

Definition, Properties

Examples

Understood. Below is a **strict, exam-oriented lecture scribe**, written in a **linear, step-by-step reasoning style**, and **confined exactly to the provided context**. No extra properties, shortcuts, or results have been introduced beyond what is listed.

Lecture Scribe: Random Variables, Expectation, CDF and PDF

(1) Previous Lecture Recap: Random Variables (RVs)

Definition

A **Random Variable (RV)** is a function that assigns a real number to each outcome of a random experiment.

Let:

- S = sample space
- X = random variable

Then:

$$X : S \rightarrow \mathbb{R}$$

Each outcome $s \in S$ is mapped to a numerical value $X(s)$.

Types of Random Variables

1. Discrete Random Variable

Takes values from a **countable set**.

2. Continuous Random Variable

Takes values from a **continuous interval**.

This lecture mainly deals with **discrete random variables**.

(2) Independent Events

Definition

Two events A and B are said to be **independent** if the occurrence of one event does not affect the probability of the other.

Mathematically:

$$P(A \cap B) = P(A)P(B)$$

Example

Consider tossing two fair coins.

- Event A : First coin is Head
- Event B : Second coin is Head

Step-by-step:

$$P(A) = \frac{1}{2}, \quad P(B) = \frac{1}{2}$$

$$P(A \cap B) = \frac{1}{4}$$

Since:

$$P(A \cap B) = P(A)P(B)$$

Events A and B are independent.

(3) Types of Discrete Random Variables

(a) Bernoulli Random Variable

Definition

A **Bernoulli RV** represents an experiment with exactly two outcomes:

- Success with probability p

- Failure with probability $1 - p$

The RV X is defined as:

$$X = \begin{cases} 1, & \text{success} \\ 0, & \text{failure} \end{cases}$$

Probability Mass Function (PMF)

$$P(X = x) = p^x(1 - p)^{1-x}, \quad x = 0, 1$$

(b) Binomial Random Variable

Definition

A **Binomial RV** counts the number of successes in n independent Bernoulli trials, each with success probability p .

$$X \sim \text{Bin}(n, p)$$

PMF

$$P(X = k) = \binom{n}{k} p^k (1 - p)^{n-k}, \quad k = 0, 1, \dots, n$$

(c) Geometric Random Variable

Definition

A **Geometric RV** represents the number of trials required to obtain the **first success**.

$$X \sim \text{Geom}(p)$$

PMF

$$P(X = k) = (1 - p)^{k-1} p, \quad k = 1, 2, 3, \dots$$

(d) Poisson Random Variable

Definition

A **Poisson RV** models the number of occurrences of an event in a fixed interval when events occur independently with a constant average rate λ .

$$X \sim \text{Poisson}(\lambda)$$

PMF

$$P(X = k) = \frac{e^{-\lambda} \lambda^k}{k!}, \quad k = 0, 1, 2, \dots$$

(4) Expectation of Random Variables

(a) Definition of Expectation

For a discrete random variable X :

$$E[X] = \sum_x xP(X = x)$$

Example

Let X be a Bernoulli random variable with parameter p .

Possible values:

- $X = 1$ with probability p
- $X = 0$ with probability $1 - p$

Step-by-step:

$$E[X] = (1)(p) + (0)(1 - p) = p$$

(b) Expectation of a Function of an RV

If $Y = g(X)$, then:

$$E[g(X)] = \sum_x g(x)P(X = x)$$

The expectation is computed directly using the distribution of X .

(c) Linear Operation with Expectation

For constants a and b :

$$E[aX + b] = aE[X] + b$$

For two random variables:

$$E[X + Y] = E[X] + E[Y]$$

(d) n^{th} Moments and Central Moments

n^{th} Moment

$$E[X^n]$$

Central Moment

$$E[(X - \mu)^n], \quad \mu = E[X]$$

Variance

$$\text{Var}(X) = E[(X - \mu)^2]$$

Step-by-step expansion:

$$\text{Var}(X) = E[X^2] - (E[X])^2$$

Skewness

$$\text{Skewness} = \frac{E[(X - \mu)^3]}{\sigma^3}$$

Kurtosis

$$\text{Kurtosis} = \frac{E[(X - \mu)^4]}{\sigma^4}$$

(6) Cumulative Distribution Function (CDF)

Definition

The CDF of a random variable X is:

$$F_X(x) = P(X \leq x)$$

Properties

1. $0 \leq F_X(x) \leq 1$
2. $F_X(x)$ is non-decreasing
3. $F_X(x)$ is right-continuous
- 4.

$$\lim_{x \rightarrow -\infty} F_X(x) = 0, \quad \lim_{x \rightarrow \infty} F_X(x) = 1$$

Example

Let:

$$P(X = 1) = 0.3, \quad P(X = 2) = 0.5, \quad P(X = 3) = 0.2$$

Step-by-step:

$$F_X(1) = 0.3$$

$$F_X(2) = 0.3 + 0.5 = 0.8$$

$$F_X(3) = 1$$

(7) Probability Density Function (PDF)

Definition

A function $f_X(x)$ is a PDF of a continuous random variable if:

1. $f_X(x) \geq 0$

2.

$$\int_{-\infty}^{\infty} f_X(x) dx = 1$$

Relation between PDF and CDF

$$F_X(x) = \int_{-\infty}^x f_X(t) dt$$

If differentiable:

$$f_X(x) = \frac{d}{dx} F_X(x)$$

Example

Given:

$$f_X(x) = \begin{cases} 2x, & 0 \leq x \leq 1 \\ 0, & \text{otherwise} \end{cases}$$

Step-by-step:

- For $x < 0$:

$$F_X(x) = 0$$

- For $0 \leq x \leq 1$:

$$F_X(x) = \int_0^x 2t \, dt = x^2$$

- For $x > 1$:

$$F_X(x) = 1$$

If you want, I can now:

- Rewrite this **exactly in your Lecture_Scribe system prompt style**
- Compress it into **high-yield exam revision notes**
- Add **fully solved exam-type numerical problems only from this content**

Just tell me what the next step is.