

VIP Cheatsheet: Statistics

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Parameter estimation

▮ **Random sample** – A random sample is a collection of n random variables X_1, \dots, X_n that are independent and identically distributed with X .

▮ **Estimator** – An estimator $\hat{\theta}$ is a function of the data that is used to infer the value of an unknown parameter θ in a statistical model.

▮ **Bias** – The bias of an estimator $\hat{\theta}$ is defined as being the difference between the expected value of the distribution of $\hat{\theta}$ and the true value, i.e.,

$$\text{Bias}(\hat{\theta}) = E[\hat{\theta}] - \theta$$

Remark: an estimator is said to be unbiased when we have $E[\hat{\theta}] = \theta$.

▮ **Sample mean and variance** – The sample mean and the sample variance of a random sample are used to estimate the true mean μ and the true variance σ^2 of a distribution, we noted \bar{X} and s^2 respectively, and we note that

$$\bar{X} = \frac{1}{n} \sum_{i=1}^n X_i \quad \text{and} \quad s^2 = s^2 = \frac{1}{n-1} \sum_{i=1}^n (X_i - \bar{X})^2$$

▮ **Central Limit Theorem** – Let us have a random sample X_1, \dots, X_n following a given distribution with mean μ and variance σ^2 , then we have:

$$\bar{X} \underset{n \rightarrow +\infty}{\sim} \mathcal{N}\left(\mu, \frac{\sigma}{\sqrt{n}}\right)$$

Confidence intervals

▮ **Confidence level** – A confidence interval $CI_{1-\alpha}$ with confidence level $1 - \alpha$ of a true parameter θ is such that $1 - \alpha$ of the time, the true value is contained in the confidence interval:

$$P(\theta \in CI_{1-\alpha}) = 1 - \alpha$$

▮ **Confidence interval for the mean** – When determining a confidence interval for the mean μ , different test statistics have to be computed depending on which case we are in. The following table sums it up:

Distribution	Sample size	σ^2	Statistic	$1 - \alpha$ confidence interval
$X_i \sim \mathcal{N}(\mu, \sigma)$	any	known	$\frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} \sim \mathcal{N}(0,1)$	$\left[\bar{X} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}, \bar{X} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} \right]$
	small	unknown	$\frac{\bar{X} - \mu}{\frac{s}{\sqrt{n}}} \sim t_{n-1}$	$\left[\bar{X} - t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}, \bar{X} + t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}} \right]$
$X_i \sim \text{any}$	large	known	$\frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} \sim \mathcal{N}(0,1)$	$\left[\bar{X} - t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}}, \bar{X} + t_{\frac{\alpha}{2}} \frac{\sigma}{\sqrt{n}} \right]$
		unknown	$\frac{\bar{X} - \mu}{\frac{s}{\sqrt{n}}} \sim \mathcal{N}(0,1)$	$\left[\bar{X} - t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}}, \bar{X} + t_{\frac{\alpha}{2}} \frac{s}{\sqrt{n}} \right]$
$X_i \sim \text{any}$	small	any	Go home!	Go home!

▮ **Confidence interval for the variance** – The single-line table below sums up the test statistic to compute when determining the confidence interval for the variance:

Distribution	Sample size	μ	Statistic	$1 - \alpha$ confidence interval
$X_i \sim \mathcal{N}(\mu, \sigma)$	any	any	$\frac{s^2(n-1)}{\sigma^2} \sim \chi^2_{n-1}$	$\left[\frac{s^2(n-1)}{\chi^2_{\frac{\alpha}{2}}}, \frac{s^2(n-1)}{\chi^2_{\frac{\alpha}{2}}} \right]$

Hypothesis testing

▮ **Errors** – In a hypothesis test, we note α and β the type I and type II errors respectively. By noting T the test statistic and R the rejection region, we have:

$$\alpha = P(T \in R | H_0 \text{ true}) \quad \text{and} \quad \beta = P(T \notin R | H_1 \text{ true})$$

▮ **p-value** – In a hypothesis test, the p-value is the probability under the null hypothesis of having a test statistic T at least as extreme as the one that we observed T_0 . In particular, when T follows a non-central symmetric distribution under H_0 , we have:

Case	Left-sided	Right-sided	Two-sided
p-value	$P(T < T_0 H_0 \text{ true})$	$P(T > T_0 H_0 \text{ true})$	$P(T > T_0 H_0 \text{ true})$

▮ **Sign test** – The sign test is a non-parametric test used to determine whether the median of a sample is equal to the hypothesized median. By noting V the number of samples falling to the right of the hypothesized median, we have:

Statistic when $n_p < 1$	Statistic when $n_p > 1$
$V \underset{H_0}{\sim} \mathcal{B}\left(n, \frac{1}{2}\right)$	$Z = \frac{V - \frac{n}{2}}{\frac{\sqrt{n}}{2}} \underset{H_0}{\sim} \mathcal{N}(0,1)$

▮ **Testing for the difference in two means** – The table below sums up the test statistic to compute when performing a hypothesis test where the null hypothesis is:

$$H_0 : \mu_X - \mu_Y = \theta$$

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Table of Contents Engineering Statistics Guide Sheet

1. Understanding the eBook Engineering Statistics Guide Sheet
 - The Rise of Digital Reading Engineering Statistics Guide Sheet
 - Advantages of eBooks Over Traditional Books
2. Identifying Engineering Statistics Guide Sheet
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Engineering Statistics Guide Sheet
 - User-Friendly Interface
4. Exploring eBook Recommendations from Engineering Statistics Guide Sheet
 - Personalized Recommendations
 - Engineering Statistics Guide Sheet User Reviews and Ratings
 - Engineering Statistics Guide Sheet and Bestseller Lists

5. Accessing Engineering Statistics Guide Sheet Free and Paid eBooks
 - Engineering Statistics Guide Sheet Public Domain eBooks
 - Engineering Statistics Guide Sheet eBook Subscription Services
 - Engineering Statistics Guide Sheet Budget-Friendly Options
6. Navigating Engineering Statistics Guide Sheet eBook Formats
 - ePub, PDF, MOBI, and More
 - Engineering Statistics Guide Sheet Compatibility with Devices
 - Engineering Statistics Guide Sheet Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Engineering Statistics Guide Sheet
 - Highlighting and Note-Taking Engineering Statistics Guide Sheet
 - Interactive Elements Engineering Statistics Guide Sheet
8. Staying Engaged with Engineering Statistics Guide Sheet
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Engineering Statistics Guide Sheet
9. Balancing eBooks and Physical Books Engineering Statistics Guide Sheet
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Engineering Statistics Guide Sheet
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Engineering Statistics Guide Sheet
 - Setting Reading Goals Engineering Statistics Guide Sheet
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Engineering Statistics Guide Sheet
 - Fact-Checking eBook Content of Engineering Statistics Guide Sheet
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
- Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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