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# 1. Homework 0 Reviewing Probability, Matrices and Vectors

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## Probability

You will need a sound foundation of probability to follow along in this course.

If you have not already, we suggest that you first take a probability course equivalent to 6.431x *Probability–the Science of Uncertainty and Data*, Course 1 of 4 in our Micromasters program. This course is offered again in September 2020.

If you do not have a probability background but would like to start pursuing the SDS Micromasters immediately, you may start with Course 2 of 4: 14.310x/Fx [Data Analysis for Social Scientists](#) and its SDS exam [Data Analysis in Social Sciences–Assessing your Knowledge](#). This course **does NOT require probability as prerequisite** and is offered this term. The setup of this course is more complicated than usual; see [enrollment logistics video](#).

## Matrices, Vectors and Basic Notions of Linear Algebra

Starting in *Unit 3 Method of Estimations*, you will also need to be very comfortable with **matrices and vectors** .

In addition, in *Unit 6. Linear Regression*, the notion of **rank** will be beneficial but **not strictly necessary**. Finally, basic understanding of the meaning of **eigenvalues and eigenvectors** will also be helpful but **not necessary for doing well in this course**.

## This homework

In this prerequisite homework, you will test and review your knowledge of probability, and matrices and vectors, and basic concepts on linear independence and rank. You will also have a chance to work on optional ungraded exercises eigenvalues and eigenvectors. These exercises are here to help you start preparing for the later units.

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 Timeline


What would be the timeline for finishing the Micromasters in Statistics and Data Science if one started with Data Analysis for Social Scientists on June 2nd since they have not ...

13

 Recommended resources for Matrix Algebra


I am rusty on my matrix algebra - I definitely don't remember how to compute eigenvectors. Is there a resource (preferably on edX or book format) that you can recommend ...

9

 Dissapointment


Dear all, dear edx Team, I purchased this master programm for around 1200 € and i have to admit, that i am utterly disappointed! Currently I am trying to work on the Homeo...

16

 it is ok to review books to answer the homework?


it is ok to review books to answer the homework, because i have some knowledge on the questions but of course i have to check on some books.

3

 No prerequisite probability or statistical knowledge


Hi, I enrolled in to the micro masters and this was the earliest course being offered so subscribed to it. Thing is I don't have required pre-requisite knowledge in statistics or pr...

16

 just a beginner


Hello, I am brand new to probabilities and statistics, I plan on getting a degree in cyber security. i was hoping to take classes that would prepare me for school since I have no ...

1

 Expected dates for the next run of this course


[Staff], what the expected date for the next run of this course i.e. 'Fundamentals of Statistics'?

2

 Unprepared with Pre-requisites


I enrolled in this course thinking that it will cover the fundamentals of Statistics, but I am not familiar with the pre-requisites mentioned here such as Matrices, Vectors, eigenv...

1

 I can't find homework zero


I can't find homework zero

2

 Change enrollment to course 1 or 2?


I have no recent knowledge of probability and therefore I would rather follow the first (Probability - The Science of Uncertainty and Data) or the second (Data Analysis in Social...

5

 Where are the 24 questions of homework, please help


There's homework 0 which is due 27th, where is it

2

 screenshots

Hi all, this seems to be a rather paper based course again, so in case you have a tablet to make your notes on, or are travelling often and don't have regular internet access, I'...

5

 My first course.

I decided to start the Micromaster about a month ago, the first course since that date that was enabled was this, the third of the micromaster. The first course of the microma...

8

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## 2. Discrete random variables

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### Normalization constant for the Poisson distribution

1/1 point (graded)


The probability mass function (pmf) of a **Poisson distribution** with parameter  $\lambda$  is given by

$$\text{Poi}(\lambda) = \frac{c\lambda^k}{k!}, \quad k = 0, 1, 2, \dots$$

Compute the value of  $c$ .

c =

e^(-lambda)




e<sup>−λ</sup>

STANDARD NOTATION

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You have used 1 of 2 attempts

 Show Answer

### Moments of Bernoulli variables

3/3 points (graded)

The  $n^{\text{th}}$  **moment** of a random variable  $X$  is defined to be the expectation  $\mathbb{E}[X^n]$  of the  $n^{\text{th}}$  power of  $X$ .

Recall that a **Bernoulli random variable with parameter  $p$**  is a random variable that takes the value 1 with probability  $p$ , and the value 0 with probability  $1 - p$ .

Let  $X$  be a Bernoulli random variable with parameter 0.7. Compute the **expectation values** of  $X^k$ , denoted by  $\mathbb{E}[X^k]$ , for the following three values of  $k$ :  $k = 1, 4$ , and 3203.

$\mathbb{E}[X] =$

0.7



$\mathbb{E}[X^4] =$

0.7



$\mathbb{E}[X^{3203}] =$


0.7



STANDARD NOTATION

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You have used 3 of 3 attempts

 Show Answer


### Variance of Bernoulli variables

3.0/3 points (graded)

Let  $X$  be a Bernoulli random variable with parameter  $p \in [0, 1]$ . Compute the **variance** of  $X$ , which is denoted by  $\text{Var}[X]$ .

$\text{Var}[X] =$

p\*(1-p)




p · (1 − p)

What value(s) of the parameter  $p$  maximize the variance? What values minimize it?

(For each question, enter the values of  $p$  as a list of **numbers**, separated by commas. For example, to enter the set  $\{0.2, 0.3\}$ , type **0.2, 0.3**, **without the braces**. Do NOT enter duplicate values, e.g. **0.2, 0.3, 0.3** will be graded as incorrect.)

The values of  $p$  for which  $\text{Var}[X]$  is minimized:


0, 1



0, 1

The values of  $p$  for which  $\text{Var}[X]$  is maximized:

0.5




0.5

STANDARD NOTATION

Submit

You have used 2 of 3 attempts

 Show Answer

### Sum of Bernoulli variables

1/1 point (graded)

Given  $n$  i.i.d. realizations  $X_1, \dots, X_n \sim \text{Ber}(p)$ , what is the distribution of  $\sum_{i=1}^n X_i$ ?

☐ Poisson with parameter  $pn$

☐ Gamma with parameters  $n$  and  $p$

☒ Binomial with parameters  $n$  and  $p$

☐ Bernoulli with parameter  $pn$



STANDARD NOTATION

Submit

You have used 1 of 3 attempts

 Show Answer

### Discrete uniform random variables

2/2 points (graded)

Recall that a **uniform random variable** is a random variable that takes values with equal probability,


Let  $X$  be a uniform random variable in the finite set  $\{1, 2, \dots, 20\}$ .

Compute the following quantities.

The probability that  $X$  is an even number:

$\mathbf{P}(X \text{ is an even number}) =$


0.5



The probability that  $X$  is a prime number:

$\mathbf{P}(X \text{ is a prime number}) =$


0.4



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Submit

You have used 1 of 2 attempts














 Show Answer

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 <b>Not able to submit the answer</b> I am not able to submit any answers	3
 <b>Buttons are Greyed Out</b> As is the case with others and their posts, I'm also unable to submit answers as the buttons are greyed out. Other answer option(s)?	1
 <b>Unable to submit/ submit button greyed out</b> Hi, I only submitted the first question and all other submit buttons are all greyed out. What should I do?	6
 <b>Not able to submit the answer</b> I am not able to submit the answer of 1st question also. If anyone could help me out in it.	1
 <b>Late register</b> Hi, i registered this course on 29th May, is that possible to submit my homework?	8
 <b>[staff] submit button disabled</b> [staff] Why the submit button is not getting enabled for me?	6
 <b>submit button</b> hi , i have a problem with the submit button, please will you fix it as soon as possible ?	3
 <b>[STAFF]Could not format HTML for problem. Contact course staff in the discussion forum for assistance.</b> Having this instead of variance question. Please help	2
 <b>λ = lambda</b> it would be good to mention how to define in the answer	2
 <b>Have the answer as the list of numbers as the question asks but the answer is a single number</b> Hi, for the last part of the question Variance of Bernoulli variables, I have the answer p as a list of the numbers but the answer shows only a single number and thus I am mar...	4
 <b>Some have been educated with the knowledge that 1 is a prime number....</b> I was taught that 1 is a prime number, that got me a wrong answer for the "Discrete uniform random variables" quiz	5
 <b>Is my answer really wrong ?</b> The values of $p$ for which $\text{Var}[X]$ is maximized: My answer was: [edited by staff] because I was considering the formula of $\text{Var}[X] = p*(1-p)$ with the presence of two parameters...	5
 <b>[STAFF] Question 1: Brackets</b> Hi staff, If I'm not mistaken, the way the formula in question 1 should be written is $(c*\text{lambda})^k$ , i.e. not only the lambda to the power of k.	5



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### 3. Gaussian random variables

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#### Moments of Gaussian random variables

5.0/5 points (graded)


Let  $X$  be a Gaussian random variable with mean  $\mu$  and variance  $\sigma^2$ . Compute the following moments:

Remember that we use the terms **Gaussian random variable** and **normal random variable** interchangeably.

(Enter your answers in terms of  $\mu$  and  $\sigma$ .)

$\mathbb{E}[X^2] =$


sigma^2+mu^2



$\sigma^2 + \mu^2$

$\mathbb{E}[X^3] =$


mu^3+3\*mu\*sigma^2



$\mu^3 + 3 \cdot \mu \cdot \sigma^2$

$\mathbb{E}[X^4] =$


mu^4+6\*mu^2\*sigma^2+3



$\mu^4 + 6 \cdot \mu^2 \cdot \sigma^2 + 3 \cdot \sigma^4$

$\text{Var}(X^2) =$

mu^4+6\*mu^2\*sigma^2+3



$\mu^4 + 6 \cdot \mu^2 \cdot \sigma^2 + 3 \cdot \sigma^4 - (\sigma^2 + \mu^2)^2$

Write  $\mathbf{P}(X > 0)$  in terms of the **cumulative distribution function (cdf)**  $\Phi$  of the standard Gaussian distribution, evaluated at a function of  $\mu$  and  $\sigma$ .


Recall that

$$\Phi(x) = \mathbf{P}(Z \leq x), \quad x \in \mathbb{R},$$

where  $Z \sim \mathcal{N}(0, 1)$  is a standard normal variable. (Enter Phi for  $\Phi$ , e.g. if the answer is  $\Phi(\mu)$ , enter Phi(mu).)

$\mathbf{P}(X > 0) =$

1-Phi(-mu/sigma)



$1 - \Phi\left(-\frac{\mu}{\sigma}\right)$

STANDARD NOTATION

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You have used 4 of 4 attempts

Show Answer

#### Covariance of Gaussians

4/4 points (graded)

Recall that **i.i.d.** stands for **independent and identically distributed**. A collection of random variables  $X_1, \dots, X_n$  are **i.i.d.** if all of them follow the same distribution, and each  $X_i$  does not contain information about the other realizations.

Let  $X, Y$  be i.i.d. **standard** normal random variables, that is,  $X, Y \sim \mathcal{N}(0, 1)$ .


Recall that the **covariance** of two random variables  $X$  and  $Y$ , denoted by  $\text{Cov}(X, Y)$ , is defined as

$$\text{Cov}(X, Y) = \mathbb{E}[(X - \mathbb{E}[X])(Y - \mathbb{E}[Y])]. \tag{1.3}$$

Compute the following variances and covariances.


$\text{Var}(X + Y) =$

2




$\text{Var}(XY) =$

1




$\text{Cov}(X, X + Y) =$

1



$\text{Cov}(X, XY) =$

0



STANDARD NOTATION

Submit

You have used 1 of 3 attempts

Show Answer

#### True or False: Variance, covariance and independence


2/2 points (graded)

For each of the statements below, determine whether it is true (meaning, always true) or false (meaning, not always true).

- For any two random variables,  $\text{Var}(X + Y) = \text{Var}(X) + \text{Var}(Y)$ .

☐ True


☒ False



- If the covariance,  $\text{Cov}(X, Y)$  between two random variables  $X, Y$  is 0, then  $X$  and  $Y$  are independent.

☐ True

☒ False



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You have used 1 of 3 attempts















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#### Discussion

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<div> Ditto on Buttons Greyed Out</div> <div>I have same greyed out button issues as others on this discussion.</div> <div>1</div>	
<div> needs urgent attention of the staff</div> <div>I have been trying to submit my answers but my submit buttons have turned grey and they are not accepting my solutions. If I fail to submit timely, I will miss my deadline. Pl...</div> <div>5</div>	
<div> [STAFF] Moment Generating Functions.</div> <div>A question to staff. As I understand we are supposed to know concepts of questions for homework 0 pretty well. Therefore my question is should we be comfortable with mo...</div> <div>8</div>	
<div> Problem Statement vanished</div> <div></div> <div>4</div>	
<div> If Stuck, Try A Numerical Approach</div> <div>I realize this might be a bit late but one way to approach some of these questions (as a last resort only) is to try to generate distributions and compute the variables asked for ...</div> <div>1</div>	
<div> Moment Generating Functions</div> <div>Hi All, For those who have a gap in knowledge about moments like me, without taking the previous course in this series, and yet wikipedia also fails to enlighten enough to an...</div> <div>2</div>	
<div> Hint for E[X^3] and E[X^4] in "3. Gaussian random variables"?</div> <div>Hi, I don't know how to solve these two in a relatively easy way. Any hint? I searched on the internet that one may use the Moment-generating function to solve them, but it w...</div> <div>34</div>	
<div> hi - can staff check my answer to Var(X square) ?</div> <div>i typed the result of the answer and that was not accepted? tks,</div> <div>1</div>	
<div> First part - expectations of Gaussian RV</div> <div>I tried different ways. And checked all the hints posted in this forum. But I'm still stuck on these. Anyone found some background material on this? Thanks a lot :)</div> <div>8</div>	
<div> To all the people who took the previous course</div> <div>If you have read the summary of the textbook you will notice that in section 4.4 the subject of Transforms is discussed. In this section moments are also explained and how y...</div> <div>2</div>	
<div> Answers</div> <div>Even after all the attempts the answer that is on the solution is so confusing that one cant even think of that solution. I have taken probability course but these concepts does...</div> <div>10</div>	
<div> One more way to compute E[X^3] and E[X^4]</div> <div></div> <div>3</div>	
<div> Are we supposed to know Kurtosis, Skewness from the previous course?</div> <div>I see people here discussing here these concepts. I can not recall where they were discussed in the probability course. Are we supposed to know them?</div> <div>2</div>	
<div> Refer to...</div> <div></div> <div>2</div>	

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## 4. Uniform random variables


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### Expectation, variance and probabilities


4/4 points (graded)

Let  $X$  be a uniform random variable in the interval  $[2, 8.5]$ . Find the following quantities (if needed, round to the nearest  $10^{-4}$ ):

$E[X] =$   

$\text{Var}[X] =$   

$P(X > 4) =$   

$P(\log(X) \leq 1) =$   

(Note that the logarithm is the natural one to base  $e$ )

STANDARD NOTATION

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You have used 2 of 4 attempts

 Show Answer

### Two independent copies

2/3 points (graded)

Let  $U, V$  be i.i.d. random variables uniformly distributed in  $[0, 1]$ . Compute the following quantities:

$E[|U - V|] =$   

$P(U = V) =$   

$P(U \leq V) =$   

STANDARD NOTATION

Submit

You have used 3 of 3 attempts

 Show Answer

### Maximum and sum of independent copies


1.0/1 point (graded)


Let  $X, Y$  be independent random variables uniformly distributed in  $[0, 1]$ . In the graph below, sketch


- the probability density  $f_{X+Y}(z)$  of  $X + Y$ ;
- the probability density  $f_{\max(X,Y)}(z)$  of  $\max(X, Y)$ .

(Be sure to sketch on the **entire domain** shown on the graph.)

**Drawing tip:** The spline tool draws a smooth curve connecting the points you click. To draw sharp corners, click on the point where the corner would be, then click again very close to it, and then continue onto the next point of your function.




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You have used 2 of 10 attempts

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### Maximum of uniform random variables

1/2 points (graded)

Let  $U_1, \dots, U_n$  be i.i.d. random variables uniformly distributed in  $[0, 1]$  and let  $M_n = \max_{1 \leq i \leq n} U_i$ .


Find the cdf of  $M_n$ , which we denote by  $G(t)$ , for  $t \in [0, 1]$ .

For  $t \in [0, 1]$ ,

$G(t) =$   

$t^n$

Now, let  $F_n(t)$  denote the cdf of  $n(1 - M_n)$ ; for  $t > 0$ , compute

$\lim_{n \rightarrow \infty} F_n(t) =$   

1

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You have used 2 of 3 attempts

 Show Answer

### Discussion

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 question in the answer of a question under the title '2 independent copies'	1
 Probability as double expectation? How did they write probability $P(U=V)$ , as a double expectation?	13
 Limit of $(1-t/n)^n$ Why does the limit goes to $e^{-t}$ ?	4
 Now, let $F_n(t)$ denote the cdf of $n(1 - M_n)$ ; for $t > 0$ , compute Does this mean given that the pdf is equal to $n(1 - M_n)$ ; for $t > 0$ find the CDF as $n \rightarrow \infty$ ? I have no idea what exactly this question is asking	13 new 22
 Q: Two independent copies Can anyone elaborate the question on Two independent copies. I dont understand how to calculate $E[ U-V ]$ .	8
 [TIPS FROM STAFF] - For the drawing exercise - **maximum and sum of independent copies** - it would be useful to recall the convolution theorem for probability! - For the exercise entitled - *...  Staff	6
 [staff] wrong grading the last question: Maximum of uniform random variables. $G(t) = ?$ I got the right answer, but in the beginning, it says 'invalid input, 'n' is not permitted'. And then it showed my...	5
 Probability Calculation Without giving away solution, can someone please help me understand why the probability can be derived using double expectation?	1
 Geometric Interpretation for abs value difference of iid RVs	3
 Why 'Maximum and sum of independent copies' does not work? A "project not found" message is displayed. How to we solve this problem?	7
 Any kind soul would like to explain me the passages of the solution of the exercise on Maximum and sum of independent copies? As above. I reviewed the probability section but I am kind of lost about the 3rd, 4th and 5th passage on the equation of $X+Y$ and also about how the final solution of the densit...	2
 answers marked as wrong i wrote down the correct answers to question one in decimal form but the grader marked them as wrong i rounded them to 3 decimal places i wasted so much time on this i ...	1
 [STAFF] What is the $1(U=V)$ notation as in $E[1(U=V)   V]$ ? I am familiar with conditional probabilities, I have just followed MITx - 6.431x, but I have never encountered the $1(U=V)$ notation as in $E[1(U=V)   V]$ , what does that mean? Than...	3



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## 5. Exponential random variables

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### Sums and products

2/3 points (graded)

Let  $X$  be an exponential random variable with parameter  $\lambda > 0$  and  $Y$  be a Poisson random variable with parameter  $\mu > 0$ . Assume that  $X$  and  $Y$  are independent. Compute the following quantities:

$$\mathbb{E}[X^2 + Y^2] =$$

2/lambda^2+mu+mu^2

✔

$\frac{2}{\lambda^2} + \mu + \mu^2$

$$\mathbb{E}[X^2 Y] =$$

2/lambda^2\*mu

✔

$\frac{2}{\lambda^2} \cdot \mu$

$$\text{Var}(2X + 3Y) =$$

4/lambda+9\*mu

✖

$\frac{4}{\lambda} + 9 \cdot \mu$

STANDARD NOTATION

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You have used 3 of 3 attempts

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### Estimators

1/1 point (graded)

Let  $X_1, \dots, X_n$  be i.i.d exponential random variables with parameter  $\lambda$  and let  $Z_i = \mathbf{1}(X_i \leq 1), i = 1, \dots, n$ . Recall that  $\mathbf{1}(X \leq 1)$  denotes the **indicator function** that takes the value 1 when  $X \leq 1$  and 0 otherwise.

What is the limit in probability, as  $n$  goes to infinity, of  $\frac{1}{n} \sum_{i=1}^n Z_i$ ?

$$\frac{1}{n} \sum_{i=1}^n Z_i \xrightarrow[n \rightarrow \infty]{\text{P}}$$

1-e^(-lambda)

✔

$1 - e^{-\lambda}$

STANDARD NOTATION

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You have used 2 of 3 attempts

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### Properties of the exponential distribution

2/2 points (graded)

Let  $X$  be an exponential random variable with parameter  $\lambda = 2$  that models the lifetime (in years) of a lightbulb. Compute the probability that the lightbulb lasts for at least 2 years. Round your answer to the nearest  $10^{-2}$ .

$$\mathbf{P}(X \geq 2) =$$

0.02

✔

Given the lightbulb has lasted 2 years, find the probability that it lasts for  $k$  more years for any positive integer  $k$ .

$$\mathbf{P}(X \geq k + 2 | X \geq 2) =$$

e^(-2\*k)

✔

$e^{-2 \cdot k}$

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Exponential random variables Expectation values

Hi, Why in the solution  $E(X^2)=2/\lambda^2$  rather than  $2*\lambda^2$ ? It looks like the relationship of  $\text{Var}(X) = E(X^2)-E(X)^2$  no longer hold using the value provided in the soluti...

3

Properties of exponential distribution

Dear All, I apparently don't have enough of Probability background, that is why I am missing a point with this task. I got it wrong in the second part. Solution says,  $(1 - \text{CDF}(k + ...$

6

Lightbulb question k+2 years?

In the second part you should calculate the probability that the lightbulb will last another k years, given it has lasted 2 years. Is this probability not  $P(k+2)$  and hence  $e^{-(2k-4)}$ ?

2

Estimators -- Limit in probability

Apologies if it sounds naive but this seems completely new to me. I'm unable to grasp what is meant by "limit in probability, as  $n$  goes to infinity". Does it mean the limiting pd...

4 new

Sums and products : Compound Poisson-Gamma in disguise ?

2

Properties of the exponential distribution: Part 2

Is Part 2 which asks us to find  $*P(X \geq k+2 \mid X \geq 2)*$  also going to be decimal form? Or would the answer be acceptable in expression in terms of  $*k*$ ? Thanks

9

Please note that for Exponential Distribution is Lambda, but for Poisson is Mu

I missed that by mistake, and although my answer was correct, conceptually, I missed that for Poisson I shouldn't be using Lambda, but Mu instead. If it would've been Lambd...

3

Key Lectures/topics to know from the \*Probability Course\*

Dear stuff, could you tell us what lectures from the \*probability class\* are \*key\* to do well on this class? It would help us both, review material or try to catch up, in these day...

6

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## 6. Probability tables

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### Gaussian probabilities

1/4 points (graded)

Let  $X \sim N(1, 2.25)$ . As a reminder, the 2.25 here represents the value of  $\sigma^2$ . Using the normal probability table below, compute the following probabilities:

Normal probability table

Show

$P(X > 1) =$

0.5

✔

$P(|X - 2| \leq 1) =$

0.1574

✖

$P(X^2 > 4) =$

0.0228

✖

$P(X^2 - 2X - 1 > 0) =$

0.5

✖

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You have used 2 of 3 attempts

Show Answer

### Approximation of Binomial variables

1/1 point (graded)

Using the normal probability table, evaluate approximately  $P(X > 400)$ , where  $X$  is a binomial random variable with parameters 1000 and .3.

Normal probability table

Show

$P(X > 400) \simeq$

0.0002

✔

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Solution may be wrong {  $P(X^2 > 4)$ } Solution is wrong  
Answer should be: 0.50282


Central Limit Theorem  
The CLT says: for IID with mean "mu" and variance "sigma^2",  $Z = (X_n - \mu)/(\sigma / \sqrt{n})$  is approximately standard normal. But in the answer for "Approximation of Bi...2


Gaussian probabilities -  $X^2$   
5


Probability calculation  
What if I'm pretty sure that my calculations were correct but the grader says that my answers are wrong. Dear staff members, could you please review my answers on "Gaussi...4


Use moments for Gaussian probabilities qn  
Hi I'm not looking for an answer (nor do I think this reveals an answer), but I'm wondering if it'd be possible to solve for  $P(X^2 > 4)$  by using the mean and variance computed ...2


Approximation of Binomial variables  
Problem "Approximation of Binomial variables" give me an error of "Invalid math syntax: 0.0". What kind of answer is it expecting? Thanks!8


Re-post : Crib  
To, the TAs, Please check answer to my 4th part of 1st question, the calculated answer which is shown in the solution is \*\*only 0.001 different in value\*\* from my given answer.2


Continuity correction factor  
Should we use the continuity correction factor here?2

Differences in Standard Normal Tables vs. "R" programming  
I noticed while trying to replicate the answers provided using "R" that my answers were slightly different then those provided by the Standard Normal Table. When the calcula...2

concepts covered  
where can I get a refresher of this topics?  
★ Following7

Probability of  $X^2$   
Does  $X^2$  convert to chi-square distribution? Any clue. Thanks2 new6

Crib  
Kindly check my answer of 4th part of 1st question.3

I have reviewed over and over the last equation of Gaussian Probabilities and I don't agree with the answer.  
 $P(Z < \sqrt{2}/1.5)$  is not 0.8264, as said in answer, but 0.8749. The right answer is not that was claimed to be.2

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## 7. Matrices and Vectors

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- Objectives:
- Recognize the dimensions of the product of two or more matrices.
  - Understand the concept of rank of a matrix, and how it relates to the invertibility of an  $n \times n$  matrix.
  - (Optional) Understand the concept of **eigenvalues** and **eigenvectors** of an  $n \times n$  matrix.

### Matrix Multiplication

6/6 points (graded)

Let  $\mathbf{A} = \begin{pmatrix} 1 & -1 & 2 \\ 0 & 3 & -4 \end{pmatrix}$  and let  $\mathbf{B} = \begin{pmatrix} -1 & 0 & 0 \\ 2 & 0 & 1 \\ 0 & 1 & 3 \end{pmatrix}$ . The dimensions of the product  $\mathbf{AB}$  are:

2

✔ rows  $\times$ 

3

✔ columns.

More generally, let  $\mathbf{A}$  be an  $m \times n$  matrix and  $\mathbf{B}$  be an  $n \times k$  matrix. What is the size of  $\mathbf{AB}$ ?

m

✔ rows  $\times$ 

k

✔ columns.

In addition, if  $\mathbf{C}$  is a  $k \times j$  matrix, what is the size of  $\mathbf{ABC}$ ?

m

✔ rows  $\times$ 

j

✔ columns.

Submit

You have used 1 of 3 attempts

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### Vector Inner product

1/1 point (graded)

Suppose  $\mathbf{u} = \begin{pmatrix} 1 \\ 3 \end{pmatrix}$  and  $\mathbf{v} = \begin{pmatrix} -1 \\ 1 \end{pmatrix}$ . The product  $\mathbf{u}^T \mathbf{v}$  evaluates the **inner product** (also called the **dot product**) of  $\mathbf{u}$  and  $\mathbf{v}$ , which evaluates to

$\mathbf{u}^T \mathbf{v} =$  2

✔

The inner product of  $\mathbf{u}$  and  $\mathbf{v}$  is sometimes written as  $\langle \mathbf{u}, \mathbf{v} \rangle$ .

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### Vector Outer product

4/4 points (graded)

Suppose  $\mathbf{u} = \begin{pmatrix} 1 \\ 3 \end{pmatrix}$  and  $\mathbf{v} = \begin{pmatrix} -1 \\ 1 \end{pmatrix}$ . The product  $\mathbf{uv}^T$  evaluates the **outer product** of  $\mathbf{u}$  and  $\mathbf{v}$ , which is a  $2 \times 2$  matrix in this case.

What is  $(\mathbf{uv}^T)_{1,1}$ ?

-1

✔

What is  $(\mathbf{uv}^T)_{1,2}$ ?

1

✔

What is  $(\mathbf{uv}^T)_{2,1}$ ?

-3

✔

What is  $(\mathbf{uv}^T)_{2,2}$ ?

3

✔

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?

Notation for matrix

Hi How is the notation for matrix in the answer? Please give me example how to write any matrix 2x2

6

✔

It is really hard to understand these question

In the way they are formatted. Is it possible to fix?

7

Linear Algebra Refresher

If you guys need a refresher on linear algebra, this is a good 4-page summary. https://minireference.com/static/tutorials/linear\_algebra\_in\_4\_pages.pdf

3

Outer Product

I am from India and in my whole education I never heard of Outer product of matrix, I think it is taught in western countries. good to know new things. I googled it and solved ...

4

Extra resource for linear algebra

If anyone needs to refresh their understanding of vectors and matrices, 3Blue1Brown has a great intuitive introduction to all the concepts necessary to complete this homew...

4

?

Variable issue

Greetings mentors and classmates, Hope you are all doing well, In the matrix multiplication question the second and third subquestions seem to be variable kind of questions...

3

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8. Linear Independence, Subspaces and Dimension

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Vectors  $\mathbf{v}_1, \dots, \mathbf{v}_n$  are said to be **linearly dependent** if there exist scalars  $c_1, \dots, c_n$  such that (1) not all  $c_i$ 's are zero and (2)  $c_1 \mathbf{v}_1 + \dots + c_n \mathbf{v}_n = \mathbf{0}$ .

Otherwise, they are said to be **linearly independent** : the only scalars  $c_1, \dots, c_n$  that satisfy  $c_1 \mathbf{v}_1 + \dots + c_n \mathbf{v}_n = \mathbf{0}$  are  $c_1 = \dots = c_n = 0$ .

The collection of non-zero vectors  $\mathbf{v}_1, \dots, \mathbf{v}_n \in \mathbb{R}^m$  determines a **subspace** of  $\mathbb{R}^m$ , which is the set of all linear combinations  $c_1 \mathbf{v}_1 + \dots + c_n \mathbf{v}_n$  over different choices of  $c_1, \dots, c_n \in \mathbb{R}$ . The **dimension** of this subspace is the size of the **largest possible, linearly independent** sub-collection of the (non-zero) vectors  $\mathbf{v}_1, \dots, \mathbf{v}_n$ .

Row and Column Rank

2/2 points (graded)

Suppose  $\mathbf{A} = \begin{pmatrix} 1 & 3 \\ 2 & 6 \end{pmatrix}$ . The rows of the matrix, (1, 3) and (2, 6), span a subspace of dimension

1

✔

. This is the **row rank** of  $\mathbf{A}$ .

The columns of the matrix,  $\begin{pmatrix} 1 \\ 2 \end{pmatrix}$  and  $\begin{pmatrix} 3 \\ 6 \end{pmatrix}$  span a subspace of dimension

1

✔

. This is the **column rank** of  $\mathbf{A}$ .

We will be using these ideas when studying **Linear Regression**, where we will work with larger, possibly rectangular matrices.

Submit

You have used 1 of 3 attempts

Show Answer

The rank of a matrix

3/3 points (graded)

In general, row rank is always equal to the column rank, so we simply refer to this common value as the **rank** of a matrix.

What is the largest possible rank of a  $2 \times 2$  matrix?

2

✔

What is the largest possible rank of a  $5 \times 2$  matrix?

2

✔

In general, what is the largest possible rank of an  $m \times n$  matrix?

☐  $m$

☐  $n$

☒  $\min(m, n)$

☐  $\max(m, n)$

☐ None of the above

✔

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Examples of rank

5/5 points (graded)

What is the rank of  $\begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$ ?

1

✔

What is the rank of  $\begin{pmatrix} 1 & -1 \\ 1 & 0 \end{pmatrix}$ ?

2

✔

What is the rank of  $\begin{pmatrix} 0 & 0 \\ 0 & 0 \end{pmatrix}$ ?

0

✔

What is the rank of  $\begin{pmatrix} 1 & 1 & 1 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{pmatrix}$ ?

2

✔

What is the rank of  $\begin{pmatrix} 1 & 1 & 0 \\ 0 & -3 & 2 \\ 0 & 0 & 1 \end{pmatrix}$ ?

3

✔

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The rank of a matrix continued

2/2 points (graded)

This question is meant to serve as an answer to the following: *If you sum two rank-1 matrices, do you get a rank-2 matrix? What about products? More generally, what rank is the sum of a rank- $r_1$  and a rank- $r_2$  matrix?*

Let  $\mathbf{A} = \begin{pmatrix} -1 & 1 \\ -3 & 3 \end{pmatrix}$ ,  $\mathbf{B} = \begin{pmatrix} 1 & -1 \\ -1 & 1 \end{pmatrix}$  and  $\mathbf{C} = \begin{pmatrix} 0 & 0 \\ 0 & 1 \end{pmatrix}$  and  $\mathbf{D} = \begin{pmatrix} 1 & 1 \\ 1 & 1 \end{pmatrix}$ . Observe that all four of these matrices are rank 1.

There are many ways to determine rank. Here is one useful fact that you could use for this problem:

“Every rank-1 matrix can be written as an outer product. Conversely, every outer product  $\mathbf{u}\mathbf{v}^T$  is a rank-1 matrix.”

For example,  $\mathbf{A} = \mathbf{u}\mathbf{v}^T$ ,  $\mathbf{B} = \mathbf{v}\mathbf{v}^T$ ,  $\mathbf{C} = \mathbf{w}\mathbf{w}^T$  and  $\mathbf{D} = \mathbf{x}\mathbf{x}^T$ , where

$$\mathbf{u} = \begin{pmatrix} 1 \\ 3 \end{pmatrix}, \mathbf{v} = \begin{pmatrix} -1 \\ 1 \end{pmatrix}, \mathbf{w} = \begin{pmatrix} 0 \\ 1 \end{pmatrix}, \mathbf{x} = \begin{pmatrix} 1 \\ 1 \end{pmatrix}.$$

Which combination of these matrices has rank 2? Choose all that apply.

☐  $\mathbf{A} + \mathbf{A}$

☐  $\mathbf{A} + \mathbf{B}$

☒  $\mathbf{A} + \mathbf{C}$

☐  $\mathbf{AB}$

☐  $\mathbf{AC}$

☐  $\mathbf{BD}$

✔

Which combination of these matrices has rank 1? Choose all that apply.

☒  $\mathbf{A} + \mathbf{A}$

☒  $\mathbf{A} + \mathbf{B}$

☐  $\mathbf{A} + \mathbf{C}$

☒  $\mathbf{AB}$

☒  $\mathbf{AC}$

☐  $\mathbf{BD}$

✔

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You have used 1 of 3 attempts

Show Answer

Invertibility of a matrix

0 points possible (ungraded)

An  $n \times n$  matrix  $\mathbf{A}$  is invertible if and only if  $\mathbf{A}$  has full rank, i.e.  $\text{rank}(\mathbf{A}) = n$ .

Which of the following matrices are invertible? Choose all that apply.

$$\mathbf{A} = \begin{pmatrix} 1 & 3 \\ 2 & 6 \end{pmatrix}$$
$$\mathbf{B} = \begin{pmatrix} 1 & 2 \\ 2 & 1 \end{pmatrix}$$
$$\mathbf{C} = \begin{pmatrix} 1 & 1 & 0 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}$$
$$\mathbf{D} = \begin{pmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{pmatrix}$$

☐  $\mathbf{A}$

☒  $\mathbf{B}$

☒  $\mathbf{C}$

☒  $\mathbf{D}$

✖

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Invertibility of a matrix Choice D

Hi, I don't understand the explanation given for choice D. The columns look independent of each other.

11

[STAFF] Questions of rank of a matrix continued: no partial credit?

I got many of the options right; however grader didn't give me any credit since I didn't get the full question correct. Could you please check if it is possible to get partial credit?...

1

Rank of sum and difference

Hi, Sorry, my previous question might have been too direct and reveal too much about the solution. Nevertheless, I am having issues figuring out the rank of the sum of two ...

7

Tipp

I find the explanation above tedious. here some more simple one: <https://people.math.osu.edu/costin.9/264H/Rank>

1

Notation in part 4

1

Help - Additional Material

Hello, If anyone needs a quick but great refresher, Dr. Strang from MIT has a new series. 5 short videos, but they are awesome. Makes this page of the HW a breeze to go thro...

4 new