

Practice Examination

Sta 230: Probability

June 21, 2020

This is an open notes open book exam, so you can consult your notes and the course books (Pitman/Durrett). You may use a calculator, R or such to evaluate complicated expressions, but you are not allowed to search the internet or ask anyone about the problems. You may express fractions as fractions (simplified as much as possible), and report any numeric values with 3 digits.

You must show your work to get partial credit. Even correct answers will not receive full credit without justification.

Write your solutions as clearly as possible and make sure it's easy to find your answers (circle them if necessary), since you will not receive credit for work that I cannot understand or find. Good Luck!

Cheating on exams is a breach of trust with classmates and faculty, and will not be tolerated. But this is not a real exam.

Problem 1: The United States Senate contains two senators from each of the 50 states.

- a. If a committee of eight senators is selected at random, what is the probability it will contain at least one of the two senators from a specified state ?
- b. What is the probability that a group of fifty senators selected at random will contain one senator from each state ?
- c. Assume there are 47 republican senators and 53 democrats. What is the probability that a committee of 20 senators randomly selected will contain 13 republicans ?
- d. Assume you do not know how many democrats or republicans there are in the Senate. You observe a committee of 14 Senators that has been drawn at random contains 8 democrats. Provide a distribution over the number of Republicans in the full Senate.

Problem 2: A poll from the 2000 election looked at past data and forecasted that G.W. Bush had a vote share of 49.1% with variance of 2.2%.

[1.] Convert the above numbers 49.1 and 2.2 into α and β of a Beta distribution and state the Beta distribution on the parameter θ , the probability of someone in Florida voting for Bush.

[2.] In July a polling firm asked 509 people who they would vote for and got a response of 279 for Bush and 230 for Gore. If θ is the probability of voting for Bush then state

$$p(k = 279 \mid \theta, n = 509).$$

[3.] Given $p(k = 279 \mid \theta, n = 509)$ from part (2) and the prior distribution on θ given by the Beta distribution in part (1) state

$$f(\theta \mid k = 279, n = 509).$$

[4.] State $\mathbf{E}[\theta \mid k = 279, n = 509]$.

Problem 3: The pdf of X and Y is

$$f(x, y) = c(x + y^2), \quad 0 \leq x \leq 1, 0 \leq y \leq 1$$

and 0 otherwise.

Determine

1. c .
2. $f(x)$
3. $f(y)$
4. $f(x | y)$
5. $\mathbf{P}(X < 1/2 | Y = 1/2)$
6. $\mathbf{P}(X + Y < .2)$
7. If X and Y are independent.

Problem 4: . There are two dogs in a house. Each day the random variable $X \sim \text{Bin}(p)$ is the probability that the first dog is let outside. If the dogs are let outside then the number of barks are

$$(Y | X = 1) \sim \text{Pois}(\lambda_1), \quad (Y | X = 0) \sim \text{Pois}(\lambda_2).$$

1. If you observe over a day bark counts Y_1, \dots, Y_n state the probability that dog 1 was let outside that day, provide the same computation for dog 2.
2. What is $\mathbf{E}[Y]$ and $\mathbf{V}[Y]$.
2. State the joint, conditional, and marginal probabilities for X, Y .

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Problem 5: . You have a choice of placing your investments in one of six funds. The return in a year in dollars for the six firms are

$$X_1 \sim \text{Pois}(\lambda), \quad X_2, \dots, X_6 \stackrel{iid}{\sim} \text{Pois}(\lambda_2).$$

1. What is the probability that at least one the funds returned $\geq \$1$?
2. What is $\mathbf{E}[\max\{X_1, \dots, X_6\}]$?

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Problem 6: . Suppose X and Y are random variables with $\text{Var}(X) = 9$, $\text{Var}(Y) = 4$, and $\rho(X, Y) = -1/6$.

Determine

1. $\text{Var}(X + Y)$ and $\text{Var}(X - 3Y + 4)$.
2. $\text{Cov}(X, Y)$.

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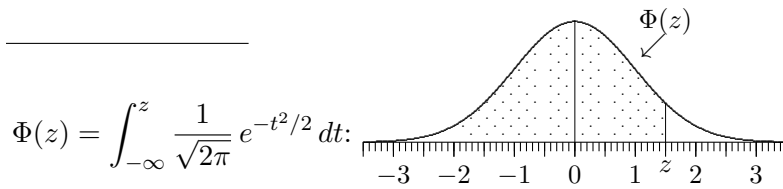


Table 1 CDF for Standard Normal.

z	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.0	.5000	.5040	.5080	.5120	.5160	.5199	.5239	.5279	.5319	.5359
0.1	.5398	.5438	.5478	.5517	.5557	.5596	.5636	.5675	.5714	.5753
0.2	.5793	.5832	.5871	.5910	.5948	.5987	.6026	.6064	.6103	.6141
0.3	.6179	.6217	.6255	.6293	.6331	.6368	.6406	.6443	.6480	.6517
0.4	.6554	.6591	.6628	.6664	.6700	.6736	.6772	.6808	.6844	.6879
0.5	.6915	.6950	.6985	.7019	.7054	.7088	.7123	.7157	.7190	.7224
0.6	.7257	.7291	.7324	.7357	.7389	.7422	.7454	.7486	.7517	.7549
0.7	.7580	.7611	.7642	.7673	.7704	.7734	.7764	.7794	.7823	.7852
0.8	.7881	.7910	.7939	.7967	.7995	.8023	.8051	.8078	.8106	.8133
0.9	.8159	.8186	.8212	.8238	.8264	.8289	.8315	.8340	.8365	.8389
1.0	.8413	.8438	.8461	.8485	.8508	.8531	.8554	.8577	.8599	.8621
1.1	.8643	.8665	.8686	.8708	.8729	.8749	.8770	.8790	.8810	.8830
1.2	.8849	.8869	.8888	.8907	.8925	.8944	.8962	.8980	.8997	.9015
1.3	.9032	.9049	.9066	.9082	.9099	.9115	.9131	.9147	.9162	.9177
1.4	.9192	.9207	.9222	.9236	.9251	.9265	.9279	.9292	.9306	.9319
1.5	.9332	.9345	.9357	.9370	.9382	.9394	.9406	.9418	.9429	.9441
1.6	.9452	.9463	.9474	.9484	.9495	.9505	.9515	.9525	.9535	.9545
1.7	.9554	.9564	.9573	.9582	.9591	.9599	.9608	.9616	.9625	.9633
1.8	.9641	.9649	.9656	.9664	.9671	.9678	.9686	.9693	.9699	.9706
1.9	.9713	.9719	.9726	.9732	.9738	.9744	.9750	.9756	.9761	.9767
2.0	.9772	.9778	.9783	.9788	.9793	.9798	.9803	.9808	.9812	.9817
2.1	.9821	.9826	.9830	.9834	.9838	.9842	.9846	.9850	.9854	.9857
2.2	.9861	.9864	.9868	.9871	.9875	.9878	.9881	.9884	.9887	.9890
2.3	.9893	.9896	.9898	.9901	.9904	.9906	.9909	.9911	.9913	.9916
2.4	.9918	.9920	.9922	.9925	.9927	.9929	.9931	.9932	.9934	.9936
2.5	.9938	.9940	.9941	.9943	.9945	.9946	.9948	.9949	.9951	.9952
2.6	.9953	.9955	.9956	.9957	.9959	.9960	.9961	.9962	.9963	.9964
2.7	.9965	.9966	.9967	.9968	.9969	.9970	.9971	.9972	.9973	.9974
2.8	.9974	.9975	.9976	.9977	.9977	.9978	.9979	.9979	.9980	.9981
2.9	.9981	.9982	.9982	.9983	.9984	.9984	.9985	.9985	.9986	.9986
3.0	.9987	.9987	.9987	.9988	.9988	.9989	.9989	.9989	.9990	.9990
3.1	.9990	.9991	.9991	.9991	.9992	.9992	.9992	.9992	.9993	.9993
3.2	.9993	.9993	.9994	.9994	.9994	.9994	.9994	.9995	.9995	.9995
3.3	.9995	.9995	.9995	.9996	.9996	.9996	.9996	.9996	.9996	.9997
3.4	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9997	.9998

$\Phi(0.6745) = 0.75$ $\Phi(1.6449) = 0.95$ $\Phi(2.3263) = 0.99$ $\Phi(3.0902) = 0.999$
 $\Phi(1.2816) = 0.90$ $\Phi(1.9600) = 0.975$ $\Phi(2.5758) = 0.995$ $\Phi(3.2905) = 0.9995$

Distributions

Binomial	$\Pr[X = x] = \binom{n}{x} p^x q^{(n-x)}, x = 0, 1, \dots, n$	$\mu = np, \sigma^2 = npq$
Poisson	$\Pr[X = k] = \lambda^k e^{-\lambda}/k!, k = 0, 1, \dots$	$\mu = \lambda, \sigma^2 = \lambda$
Poisson process	$\Pr[X = k t] = (\alpha t)^k e^{-\alpha t}/k!, k = 0, 1, \dots$	
Geometric	$\Pr[X = x] = pq^x, y = 0, 1, 2, \dots$	$\mu = q/p, \sigma^2 = q/p^2$
Hypergeometric	$\Pr[X = x] = \frac{\binom{M}{x} \binom{N-M}{n-x}}{\binom{N}{n}}, x = 0, 1, 2, \dots$	$\mu = n \frac{M}{N}$ $\sigma^2 = \frac{N-n}{N-1} n \frac{M}{N} (1 - \frac{M}{N})$
Exponential	$\Pr[X \leq x] = 1 - e^{-\lambda x}, x \in (0, \infty)$ $f(x) = \lambda e^{-\lambda x}, x > 0; 0, x \leq 0$	$\mu = 1/\lambda, \sigma^2 = 1/\lambda^2$
Uniform	$\Pr[X \leq x] = (x - a)/(b - a), x \in (a, b)$ $f(x) = \frac{1}{b - a}, a < x < b; 0, x \notin (a, b)$	$\mu = \frac{a+b}{2}, \sigma^2 = \frac{(b-a)^2}{12}$
Normal	$\Pr[X \leq x] = \Phi\left(\frac{x - \mu}{\sigma}\right), x \in \mathbb{R}$ $f(x) = \frac{1}{\sqrt{2\pi}\sigma} e^{-(x-\mu)^2/2\sigma^2}, x \in \mathbb{R}$	$\mu = \mu, \sigma^2 = \sigma^2$
Beta	$f_X(x) = \frac{\Gamma(\alpha + \beta)}{\Gamma(\alpha)\Gamma(\beta)} x^{\alpha-1} (1-x)^{\beta-1}, x \in [0, 1]$	$\mu = \frac{\alpha}{\alpha + \beta}$ $\sigma^2 = \frac{\alpha\beta}{(\alpha + \beta)^2(\alpha + \beta + 1)}$

$$P_k^n = \frac{n!}{(n-k)!} = \overbrace{(n)(n-1)\cdots(n-k+1)}^{k \text{ terms}}$$

$$\text{"n choose k": } \binom{n}{k} = \frac{n!}{k!(n-k)!} = \frac{(n)(n-1)\cdots(n-k+1)}{(k)(k-1)\cdots(1)}$$

$$(a+b)^n = \sum_{k=0}^n \binom{n}{k} a^k b^{n-k}$$

$$\sum_{k=0}^{\infty} ar^k = a/(1-r)$$

$$\sum_{k=0}^n ar^k = (a - ar^{n+1})/(1-r)$$

$$\Pr[X \leq x] = F(x) = \int_{-\infty}^x f(t) dt$$

$$f(x) = F'(x)$$

$$\mathbb{E}[g(X)] = \int g(x)f(x) dx$$

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

$$\mu = \mathbb{E}[X] = \int_{-\infty}^{\infty} xf(x) dx$$

$$\sigma^2 = \mathbb{E}[(X - \mu)^2] = \mathbb{E}[X^2] - \mu^2$$

A and B : $A \cap B$ **not A** : A^c

A or B : $A \cup B$

$$\mathbb{P}[A|B] = \mathbb{P}[A \cap B]/\mathbb{P}[B]$$

$$\mathbb{P}[B|A] = \mathbb{P}[A \cap B]/\mathbb{P}[A]$$

$$\mathbb{P}[A \cap B] = \mathbb{P}[A|B] \mathbb{P}[B]$$

$$\mathbb{P}[A \cup B] = \mathbb{P}[A] + \mathbb{P}[B] - \mathbb{P}[A \cap B]$$

Independent $\Leftrightarrow \mathbb{P}[A \cap B] = \mathbb{P}[A] \mathbb{P}[B]$;

Exclusive $\Leftrightarrow \mathbb{P}[A \cap B] = 0$

$$\text{Bayes: } \mathbb{P}[A_i|B] = \frac{\mathbb{P}[B|A_i]\mathbb{P}[A_i]}{\mathbb{P}[B|A_1]\mathbb{P}[A_1] + \dots + \mathbb{P}[B|A_k]\mathbb{P}[A_k]}$$

$$A_i \cap A_j = \emptyset, \quad \mathbb{P}[A_1] + \dots + \mathbb{P}[A_k] = 1$$

$$\text{Sterling: } n! \approx \sqrt{2\pi n} \left(\frac{n}{e}\right)^n$$

	Continuous	Discrete
Mean	$\mu = E[X] = \int_{-\infty}^{\infty} x f(x) dx$	$= \sum xp(x)$
Variance	$\sigma^2 = \text{Var}[X] = \int_{-\infty}^{\infty} (x - \mu)^2 f(x) dx$ $= E[X^2] - E[X]^2$	$= \sum (x - \mu)^2 p(x)$ $= E[X^2] - E[X]^2$
Expectation	$E[g(X, Y)] = \iint g(x, y) f(x, y) dx dy$	$= \sum_{x,y} g(x, y) p(x, y)$
Covariance	$\text{Cov}[X, Y] = \iint (x - \mu_x)(y - \mu_y) f(x, y) dx dy$ $= E[XY] - E[X]E[Y]$	$= \sum_{x,y} (x - \mu_x)(y - \mu_y) p(x, y)$ $= E[XY] - E[X]E[Y]$
Correlation coefficient	$\rho[X, Y] = \text{Cov}[X, Y] / \sigma_X \sigma_Y$	
Conditional	$f(x y) = f(x, y) / f_2(y)$	$= p(x, y) / p_2(y)$
Marginal	$f_1(x) = \int_{-\infty}^{\infty} f(x, y) dy$ $f_2(y) = \int_{-\infty}^{\infty} f(x, y) dx$	$= \sum_y p(x, y)$ $= \sum_x p(x, y)$
Independent	$\Leftrightarrow f(x, y) = f_1(x) f_2(y)$ $\Leftrightarrow f(x y) = f_1(x)$ $\Leftrightarrow f(y x) = f_2(y)$	$\Leftrightarrow p(x, y) = p_1(x) p_2(y)$ $\Leftrightarrow p(x y) = p_1(x)$ $\Leftrightarrow p(y x) = p_2(y)$

Conf. Intervals	$\mu = \bar{x} \pm z_{\alpha/2} S / \sqrt{n}$ $= \bar{x} \pm t_{\alpha/2} S / \sqrt{n}$ $p = \hat{p} \pm z_{\alpha/2} \sqrt{\hat{p}\hat{q}/n}$	Large Sample Small Sample (normal) Population Proportion
Diff. of Means	$\mu_1 - \mu_2 = (\bar{x}_1 - \bar{x}_2) \pm z_{\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$ $= (\bar{x}_1 - \bar{x}_2) \pm t_{\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$ $= \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{n}} \pm z_{\alpha/2} s_{\Delta} / \sqrt{n}$ $= \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{n}} \pm t_{\alpha/2} s_{\Delta} / \sqrt{n}$	Large Samples Small Samples Matched Pairs, large n Matched Pairs, small n , normal

Sample Mean	$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$	
Sample Variance	$s^2 = \frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2$	Deg fdm: $\nu = n - 1$
Regression slope	$b_1 = \hat{\beta}_1 = \frac{\sum_{i=1}^n (x_i - \bar{x})(y_i - \bar{y})}{\sum_{i=1}^n (x_i - \bar{x})^2}$	
Regression offset	$b_0 = \hat{\beta}_0 = \frac{\sum y_i - \hat{\beta}_1 \sum x_i}{n} = \bar{y} - \hat{\beta}_1 \bar{x}$	
Sum Square Error	$SSE = \sum (y_i - \hat{y}_i)^2$	
Estimate of variance	$\hat{\sigma}^2 = \frac{SSE}{n-2}$	
TSS	$SST = \sum (y_i - \bar{y})^2$	
CD	$r^2 = 1 - \frac{SSE}{SST}$	
F-dist	$F = \frac{S_1^2/\sigma_1^2}{S_2^2/\sigma_2^2}$	F-dist with $m-1, n-1$ d.o.f.