

12/12/17



**School of Environment & Natural Resources (SENR)**  
**End-Semester 2017 (July-Dec Semester)**  
**M.Sc. 3rd Sem**  
**EES-554 : : Statistics & Computer Applications**

**Max Marks : 50**

**Time : 3 hours**

**Calculator is permitted. Some Useful Formulas and Tables are provided in Section E.**

**Section A : Answer ALL of the followings:**

**(1 x 5 = 5)**

1. What is p-value?
2. The events A and B are mutually exclusive. If  $P(A) = 0.5$  and  $P(B) = 0.2$ , then what is  $P(AB)$ , i.e., probability of occurrence of both A and B together ?
3. Which statistical score among z, t,  $\chi^2$  and F is independent of sample size?
4. For the following normal distribution  
$$P(x) = \frac{1}{2.3\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-5}{2.3}\right)^2};$$
What is the value of the mean?
5. If a test rejects the hypothesis when it is true, what type of error is this?

**Section B : Answer any FIVE of the following:**

**(2 x 5 = 10)**

6. What are biased and unbiased estimates?
7. What is standard error?
8. What are PERT & CPM? Which activities/nodes of the network are considered to be the part of CPM?
9. Discuss briefly about the statistical sampling techniques.
10. What is ANOVA? When should we use ANOVA?
11. What are "standard error of estimate" and the "coefficient of correlation"?
12. What is NULL hypothesis? Explain with an example.

**Section C : Solve any FIVE of the following:**

**(5 x 5 = 25)**

13. If 3% of electric bulbs manufactured by a company are defective, find the probability that in a sample of 100 bulbs, exactly 1 will be defective.
14. Find the area under the standard normal curve in the following cases :
  - (a) between  $z = -1.20$  and  $z = 2.40$
  - (b) to the right of  $z = -1.64$
  - (c) between  $z = -1.96$  and  $z = 1.96$(Use the z-score table for standard normal curve given on the next page.)
15. Design a test rule to test the hypothesis that a coin is fair if we take a sample of 64 tosses of the coin. Use the significance level of  $\alpha = 0.05$ .

16. The 95% confidence coefficients (two-tailed) for the normal distribution are given by  $\pm 1.96$ . What are the corresponding coefficients for the t-distribution if (a)  $\nu = 9$ , (b)  $\nu = 20$ , (c)  $\nu = 30$ , and (d)  $\nu = 60$ .
17. Five hundred ball bearings have a mean weight 5.02 grams and a standard deviation of 0.30 g. Find the probability that a random sample of 100 ball bearings chosen from this group will have a combined weight between 496 and 500 g.
18. In the past, the standard deviation of weights of certain 40.0-ounce packages filled by a machine was 0.25 ounce(oz). A random sample of 20 packages showed a standard deviation of 0.32 oz. Is the apparent increase in variability significant at 0.05 level?
19. Two samples of sizes 9 and 12 are drawn from two normally distributed populations having variances 16 and 25, respectively. If the sample variances are 20 and 8, determine whether the first sample has a significantly larger variance than the second sample at significance level of 0.05.
20. Find the best fitted line in the least square sense for the following set of data. Use X as independent variable and Y as dependent variable. Calculate  $R^2$ . What is the significance of  $R^2$  value?

|   |   |   |   |   |   |    |
|---|---|---|---|---|---|----|
| X | 3 | 5 | 6 | 8 | 9 | 11 |
| Y | 2 | 3 | 4 | 6 | 5 | 8  |

21. What do you understand by binomial, normal and poisson distributions? What's the difference between poisson and normal distribution? Where do we use poisson distribution?

**Section D : Answer any ONE of the following :**

**(10 x 1 = 10)**

22. What are  $t$ , and  $\chi^2$  statistics? What are their significance? Describe the context in which each of the statics is used.
23. A Christmas tree farm has 5000 trees that are mature and ready to be cut and sold. 100 of the trees are randomly selected and their heights measured. The mean ( $\mu_{s1}$ ) and standard deviation ( $\sigma_{s1}$ ) of the sampled trees are given as 59.22 and 10.11 inches. Set a 95% confidence interval on the mean height of all 5000 trees. If the trees sell for \$2.40 per foot, give a lower and upper bound on the value of the 5000 trees.
24. The intelligent quotients (IQs) of 16 students from one area of the city showed a mean of 107 and a standard deviation of 10, while the IQs of 14 students from another area of the city showed a mean of 112 and a standard deviation of 8. Is there a significant difference between the IQs of the two groups at significance levels of 0.05?

**Section E : Some Useful Formulas and Tables (The notations have their usual meaning):**

(i) The Poisson distribution :  $P(X) = \frac{\lambda^X e^{-\lambda}}{X!}$   $X = 0, 1, 2, \dots$

(ii) The normal distribution :  $Y = \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\frac{(X-\mu)^2}{\sigma^2}}$

(iii) Sampling distribution of Means :  $\mu_{\bar{X}} = \mu$  and  $\sigma_{\bar{X}} = \frac{\sigma}{\sqrt{N}}$

(iv) Sampling distribution of differences :

$$\mu_{S_1-S_2} = \mu_{S_1} - \mu_{S_2} \quad \text{and} \quad \sigma_{S_1-S_2} = \sqrt{\sigma_{S_1}^2 + \sigma_{S_2}^2}$$

(v) Z-score :  $\frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{N}}}$

(vi) t-score :

$$\frac{\bar{X} - \mu}{\frac{s}{\sqrt{N-1}}}$$

(vii) t-score for differences :

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sigma \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}} \quad \text{where} \quad \sigma = \sqrt{\frac{N_1 s_1^2 + N_2 s_2^2}{N_1 + N_2 - 2}}$$

(viii)  $\chi^2 = \frac{N s^2}{\sigma^2}$  ;  $\chi^2 = \sum_{j=1}^k (o_j - e_j)^2 / e_j$

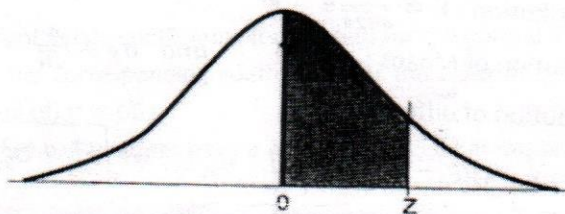
(ix)  $F = \frac{\hat{\sigma}_1^2 / \sigma_1^2}{\hat{\sigma}_2^2 / \sigma_2^2}$  where  $\hat{S}_1^2 = \frac{N_1 s_1^2}{N_1 - 1}$  and  $\hat{S}_2^2 = \frac{N_2 s_2^2}{N_2 - 1}$

(x) The coefficients  $a_0$  and  $a_1$  in a linear regression equation  $Y = a_0 + a_1 X$ , are given by

$$a_0 = \frac{(\Sigma Y)(\Sigma X^2) - (\Sigma X)(\Sigma XY)}{N \Sigma X^2 - (\Sigma X)^2} ; \quad a_1 = \frac{N \Sigma XY - (\Sigma X)(\Sigma Y)}{N \Sigma X^2 - (\Sigma X)^2}$$

**Table 1 . Table for z-score test:**

| Level of Significance $\alpha$            | 0.10                | 0.05               | 0.01              | 0.005             | 0.002             |
|---|---------------------|--------------------|-------------------|-------------------|-------------------|
| Critical Values of z for one tailed tests | -1.28 or<br>1.28    | -1.645 or<br>1.645 | -2.33 or<br>2.33  | -2.58 or<br>2.58  | -2.88 or<br>2.88  |
| Critical Values of z for one tailed tests | -1.645 and<br>1.645 | -1.96 and<br>1.96  | -2.58 and<br>2.58 | -2.81 and<br>2.81 | -3.08 and<br>3.08 |



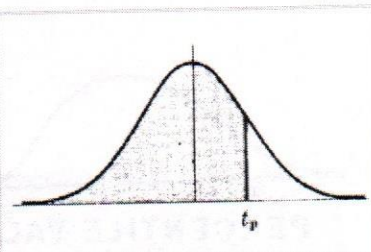
This table presents the area between the mean and the Z score. When  $Z=1.96$ , the shaded area is 0.4750.

Areas Under the Standard Normal Curve

| Z   | 0.00   | 0.01   | 0.02   | 0.03   | 0.04   | 0.05   | 0.06   | 0.07   | 0.08   | 0.09   |
|-----|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|
| 0.0 | 0.0000 | 0.0040 | 0.0080 | 0.0120 | 0.0160 | 0.0199 | 0.0239 | 0.0279 | 0.0319 | 0.0359 |
| 0.1 | .0398  | .0438  | .0478  | .0517  | .0557  | .0596  | .0636  | .0675  | .0714  | .0753  |
| 0.2 | .0793  | .0832  | .0871  | .0910  | .0948  | .0987  | .1026  | .1064  | .1103  | .1141  |
| 0.3 | .1179  | .1217  | .1255  | .1293  | .1331  | .1368  | .1406  | .1443  | .1480  | .1517  |
| 0.4 | .1554  | .1591  | .1628  | .1664  | .1700  | .1736  | .1772  | .1808  | .1844  | .1879  |
| 0.5 | .1915  | .1950  | .1985  | .2019  | .2054  | .2088  | .2123  | .2157  | .2190  | .2224  |
| 0.6 | .2257  | .2291  | .2324  | .2357  | .2389  | .2422  | .2454  | .2486  | .2517  | .2549  |
| 0.7 | .2580  | .2611  | .2642  | .2673  | .2704  | .2734  | .2764  | .2794  | .2823  | .2852  |
| 0.8 | .2881  | .2910  | .2939  | .2967  | .2995  | .3023  | .3051  | .3078  | .3106  | .3133  |
| 0.9 | .3159  | .3186  | .3212  | .3238  | .3264  | .3289  | .3315  | .3340  | .3365  | .3389  |
| 1.0 | .3413  | .3438  | .3461  | .3485  | .3508  | .3531  | .3554  | .3577  | .3599  | .3621  |
| 1.1 | .3643  | .3665  | .3686  | .3708  | .3729  | .3749  | .3770  | .3790  | .3810  | .3830  |
| 1.2 | .3849  | .3869  | .3888  | .3907  | .3925  | .3944  | .3962  | .3980  | .3997  | .4015  |
| 1.3 | .4032  | .4049  | .4066  | .4082  | .4099  | .4115  | .4131  | .4147  | .4162  | .4177  |
| 1.4 | .4192  | .4207  | .4222  | .4236  | .4251  | .4265  | .4279  | .4292  | .4306  | .4319  |
| 1.5 | .4332  | .4345  | .4357  | .4370  | .4382  | .4394  | .4406  | .4418  | .4429  | .4441  |
| 1.6 | .4452  | .4463  | .4474  | .4484  | .4495  | .4505  | .4515  | .4525  | .4535  | .4545  |
| 1.7 | .4554  | .4564  | .4573  | .4582  | .4591  | .4599  | .4608  | .4616  | .4625  | .4633  |
| 1.8 | .4641  | .4649  | .4656  | .4664  | .4671  | .4678  | .4686  | .4693  | .4699  | .4706  |
| 1.9 | .4713  | .4719  | .4726  | .4732  | .4738  | .4744  | .4750  | .4756  | .4761  | .4767  |
| 2.0 | .4772  | .4778  | .4783  | .4788  | .4793  | .4798  | .4803  | .4808  | .4812  | .4817  |
| 2.1 | .4821  | .4826  | .4830  | .4834  | .4838  | .4842  | .4846  | .4850  | .4854  | .4857  |
| 2.2 | .4861  | .4864  | .4868  | .4871  | .4875  | .4878  | .4881  | .4884  | .4887  | .4890  |
| 2.3 | .4893  | .4896  | .4898  | .4901  | .4904  | .4906  | .4909  | .4911  | .4913  | .4916  |
| 2.4 | .4918  | .4920  | .4922  | .4925  | .4927  | .4929  | .4931  | .4932  | .4934  | .4936  |
| 2.5 | .4938  | .4940  | .4941  | .4943  | .4945  | .4946  | .4948  | .4949  | .4951  | .4952  |
| 2.6 | .4953  | .4955  | .4956  | .4957  | .4959  | .4960  | .4961  | .4962  | .4963  | .4964  |
| 2.7 | .4965  | .4966  | .4967  | .4968  | .4969  | .4970  | .4971  | .4972  | .4973  | .4974  |
| 2.8 | .4974  | .4975  | .4976  | .4977  | .4977  | .4978  | .4979  | .4979  | .4980  | .4981  |
| 2.9 | .4981  | .4982  | .4982  | .4983  | .4984  | .4984  | .4985  | .4985  | .4986  | .4986  |
| 3.0 | .4987  | .4987  | .4987  | .4988  | .4988  | .4989  | .4989  | .4989  | .4990  | .4990  |
| 3.1 | .4990  | .4991  | .4991  | .4991  | .4992  | .4992  | .4992  | .4992  | .4993  | .4993  |
| 3.2 | .4993  | .4993  | .4994  | .4994  | .4994  | .4994  | .4994  | .4995  | .4995  | .4995  |
| 3.3 | .4995  | .4995  | .4995  | .4996  | .4996  | .4996  | .4996  | .4996  | .4996  | .4997  |
| 3.4 | .4997  | .4997  | .4997  | .4997  | .4997  | .4997  | .4997  | .4997  | .4997  | .4998  |
| 3.6 | .4998  | .4998  | .4999  | .4999  | .4999  | .4999  | .4999  | .4999  | .4999  | .4999  |
| 3.9 | .5000  |        |        |        |        |        |        |        |        |        |

Source: Adapted by permission from *Statistical Methods* by George W. Snedecor and William G. Cochran, sixth edition © 1967 by The Iowa State University Press, Ames, Iowa, p. 548.

**PERCENTILE VALUES ( $t_p$ )  
FOR STUDENT'S  $t$   
DISTRIBUTION**  
with  $n$  degrees of freedom (shaded area =  $p$ )

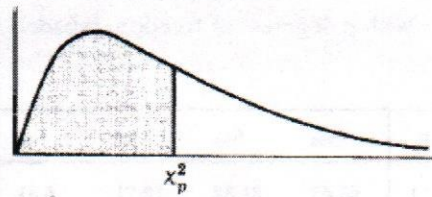


| $n$      | $t_{.995}$ | $t_{.99}$ | $t_{.975}$ | $t_{.95}$ | $t_{.90}$ | $t_{.80}$ | $t_{.75}$ | $t_{.70}$ | $t_{.60}$ | $t_{.55}$ |
|----------|------------|-----------|------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1        | 63.66      | 31.82     | 12.71      | 6.31      | 3.08      | 1.376     | 1.000     | .727      | .325      | .158      |
| 2        | 9.92       | 6.96      | 4.30       | 2.92      | 1.89      | 1.061     | .816      | .617      | .289      | .142      |
| 3        | 5.84       | 4.54      | 3.18       | 2.35      | 1.64      | .978      | .765      | .584      | .277      | .137      |
| 4        | 4.60       | 3.75      | 2.78       | 2.13      | 1.53      | .941      | .741      | .569      | .271      | .134      |
| 5        | 4.03       | 3.36      | 2.57       | 2.02      | 1.48      | .920      | .727      | .559      | .267      | .132      |
| 6        | 3.71       | 3.14      | 2.45       | 1.94      | 1.44      | .906      | .718      | .553      | .265      | .131      |
| 7        | 3.50       | 3.00      | 2.36       | 1.90      | 1.42      | .896      | .711      | .549      | .263      | .130      |
| 8        | 3.36       | 2.90      | 2.31       | 1.86      | 1.40      | .889      | .706      | .546      | .262      | .130      |
| 9        | 3.25       | 2.82      | 2.26       | 1.83      | 1.38      | .883      | .703      | .543      | .261      | .129      |
| 10       | 3.17       | 2.76      | 2.23       | 1.81      | 1.37      | .879      | .700      | .542      | .260      | .129      |
| 11       | 3.11       | 2.72      | 2.20       | 1.80      | 1.36      | .876      | .697      | .540      | .260      | .129      |
| 12       | 3.06       | 2.68      | 2.18       | 1.78      | 1.36      | .873      | .695      | .539      | .259      | .128      |
| 13       | 3.01       | 2.65      | 2.16       | 1.77      | 1.35      | .870      | .694      | .538      | .259      | .128      |
| 14       | 2.98       | 2.62      | 2.14       | 1.76      | 1.34      | .868      | .692      | .537      | .258      | .128      |
| 15       | 2.95       | 2.60      | 2.13       | 1.75      | 1.34      | .866      | .691      | .536      | .258      | .128      |
| 16       | 2.92       | 2.58      | 2.12       | 1.75      | 1.34      | .865      | .690      | .535      | .258      | .128      |
| 17       | 2.90       | 2.57      | 2.11       | 1.74      | 1.33      | .863      | .689      | .534      | .257      | .128      |
| 18       | 2.88       | 2.55      | 2.10       | 1.73      | 1.33      | .862      | .688      | .534      | .257      | .127      |
| 19       | 2.86       | 2.54      | 2.09       | 1.73      | 1.33      | .861      | .688      | .533      | .257      | .127      |
| 20       | 2.84       | 2.53      | 2.09       | 1.72      | 1.32      | .860      | .687      | .533      | .257      | .127      |
| 21       | 2.83       | 2.52      | 2.08       | 1.72      | 1.32      | .859      | .686      | .532      | .257      | .127      |
| 22       | 2.82       | 2.51      | 2.07       | 1.72      | 1.32      | .858      | .686      | .532      | .256      | .127      |
| 23       | 2.81       | 2.50      | 2.07       | 1.71      | 1.32      | .858      | .685      | .532      | .256      | .127      |
| 24       | 2.80       | 2.49      | 2.06       | 1.71      | 1.32      | .857      | .685      | .531      | .256      | .127      |
| 25       | 2.79       | 2.48      | 2.06       | 1.71      | 1.32      | .856      | .684      | .531      | .256      | .127      |
| 26       | 2.78       | 2.48      | 2.06       | 1.71      | 1.32      | .856      | .684      | .531      | .256      | .127      |
| 27       | 2.77       | 2.47      | 2.05       | 1.70      | 1.31      | .855      | .684      | .531      | .256      | .127      |
| 28       | 2.76       | 2.47      | 2.05       | 1.70      | 1.31      | .855      | .683      | .530      | .256      | .127      |
| 29       | 2.76       | 2.46      | 2.04       | 1.70      | 1.31      | .854      | .683      | .530      | .256      | .127      |
| 30       | 2.75       | 2.46      | 2.04       | 1.70      | 1.31      | .854      | .683      | .530      | .256      | .127      |
| 40       | 2.70       | 2.42      | 2.02       | 1.68      | 1.30      | .851      | .681      | .529      | .255      | .126      |
| 60       | 2.66       | 2.39      | 2.00       | 1.67      | 1.30      | .848      | .679      | .527      | .254      | .126      |
| 120      | 2.62       | 2.36      | 1.98       | 1.66      | 1.29      | .845      | .677      | .526      | .254      | .126      |
| $\infty$ | 2.58       | 2.33      | 1.96       | 1.645     | 1.28      | .842      | .674      | .524      | .253      | .126      |

Source: R. A. Fisher and F. Yates, *Statistical Tables for Biological, Agricultural and Medical Research* (6th edition, 1963), Table III, Oliver and Boyd Ltd., Edinburgh, by permission of the authors and publishers.

**PERCENTILE VALUES ( $\chi^2_p$ )  
FOR  $\chi^2$  (CHI-SQUARE)  
DISTRIBUTION**

with  $n$  degrees of freedom (shaded area =  $p$ )

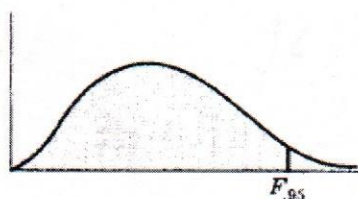


| $n$ | $\chi^2_{.995}$ | $\chi^2_{.99}$ | $\chi^2_{.975}$ | $\chi^2_{.95}$ | $\chi^2_{.90}$ | $\chi^2_{.75}$ | $\chi^2_{.50}$ | $\chi^2_{.25}$ | $\chi^2_{.10}$ | $\chi^2_{.05}$ | $\chi^2_{.025}$ | $\chi^2_{.01}$ | $\chi^2_{.005}$ |
|-----|-----------------|----------------|-----------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|-----------------|----------------|-----------------|
| 1   | 7.88            | 6.63           | 5.02            | 3.84           | 2.71           | 1.32           | .455           | .102           | .0158          | .0039          | .0010           | .0002          | .0000           |
| 2   | 10.6            | 9.21           | 7.38            | 5.99           | 4.61           | 2.77           | 1.39           | .575           | .211           | .103           | .0506           | .0201          | .0100           |
| 3   | 12.8            | 11.3           | 9.35            | 7.81           | 6.25           | 4.11           | 2.37           | 1.21           | .584           | .352           | .216            | .115           | .072            |
| 4   | 14.9            | 13.3           | 11.1            | 9.49           | 7.78           | 5.39           | 3.36           | 1.92           | 1.06           | .711           | .484            | .297           | .207            |
| 5   | 16.7            | 15.1           | 12.8            | 11.1           | 9.24           | 6.63           | 4.35           | 2.67           | 1.61           | 1.15           | .831            | .554           | .412            |
| 6   | 18.5            | 16.8           | 14.4            | 12.6           | 10.6           | 7.84           | 5.35           | 3.45           | 2.20           | 1.64           | 1.24            | .872           | .676            |
| 7   | 20.3            | 18.5           | 16.0            | 14.1           | 12.0           | 9.04           | 6.35           | 4.25           | 2.83           | 2.17           | 1.69            | 1.24           | .989            |
| 8   | 22.0            | 20.1           | 17.5            | 15.5           | 13.4           | 10.2           | 7.34           | 5.07           | 3.49           | 2.73           | 2.18            | 1.65           | 1.34            |
| 9   | 23.6            | 21.7           | 19.0            | 16.9           | 14.7           | 11.4           | 8.34           | 5.90           | 4.17           | 3.33           | 2.70            | 2.09           | 1.73            |
| 10  | 25.2            | 23.2           | 20.5            | 18.3           | 16.0           | 12.5           | 9.34           | 6.74           | 4.87           | 3.94           | 3.25            | 2.56           | 2.16            |
| 11  | 26.8            | 24.7           | 21.9            | 19.7           | 17.3           | 13.7           | 10.3           | 7.58           | 5.58           | 4.57           | 3.82            | 3.05           | 2.60            |
| 12  | 28.3            | 26.2           | 23.3            | 21.0           | 18.5           | 14.8           | 11.3           | 8.44           | 6.30           | 5.23           | 4.40            | 3.57           | 3.07            |
| 13  | 29.8            | 27.7           | 24.7            | 22.4           | 19.8           | 16.0           | 12.3           | 9.30           | 7.04           | 5.89           | 5.01            | 4.11           | 3.57            |
| 14  | 31.3            | 29.1           | 26.1            | 23.7           | 21.1           | 17.1           | 13.3           | 10.2           | 7.79           | 6.57           | 5.63            | 4.66           | 4.07            |
| 15  | 32.8            | 30.6           | 27.5            | 25.0           | 22.3           | 18.2           | 14.3           | 11.0           | 8.55           | 7.26           | 6.26            | 5.23           | 4.60            |
| 16  | 34.3            | 32.0           | 28.9            | 26.3           | 23.5           | 19.4           | 15.3           | 11.9           | 9.31           | 7.96           | 6.91            | 5.81           | 5.14            |
| 17  | 35.7            | 33.4           | 30.2            | 27.6           | 24.8           | 20.5           | 16.3           | 12.8           | 10.1           | 8.67           | 7.56            | 6.41           | 5.70            |
| 18  | 37.2            | 34.8           | 31.5            | 28.9           | 26.0           | 21.6           | 17.3           | 13.7           | 10.9           | 9.39           | 8.23            | 7.01           | 6.26            |
| 19  | 38.6            | 36.2           | 32.9            | 30.1           | 27.2           | 22.7           | 18.3           | 14.6           | 11.7           | 10.1           | 8.91            | 7.63           | 6.84            |
| 20  | 40.0            | 37.6           | 34.2            | 31.4           | 28.4           | 23.8           | 19.3           | 15.5           | 12.4           | 10.9           | 9.59            | 8.26           | 7.43            |
| 21  | 41.4            | 38.9           | 35.5            | 32.7           | 29.6           | 24.9           | 20.3           | 16.3           | 13.2           | 11.6           | 10.3            | 8.90           | 8.03            |
| 22  | 42.8            | 40.3           | 36.8            | 33.9           | 30.8           | 26.0           | 21.3           | 17.2           | 14.0           | 12.3           | 11.0            | 9.54           | 8.64            |
| 23  | 44.2            | 41.6           | 38.1            | 35.2           | 32.0           | 27.1           | 22.3           | 18.1           | 14.8           | 13.1           | 11.7            | 10.2           | 9.26            |
| 24  | 45.6            | 43.0           | 39.4            | 36.4           | 33.2           | 28.2           | 23.3           | 19.0           | 15.7           | 13.8           | 12.4            | 10.9           | 9.89            |
| 25  | 46.9            | 44.3           | 40.6            | 37.7           | 34.4           | 29.3           | 24.3           | 19.9           | 16.5           | 14.6           | 13.1            | 11.5           | 10.5            |
| 26  | 48.3            | 45.6           | 41.9            | 38.9           | 35.6           | 30.4           | 25.3           | 20.8           | 17.3           | 15.4           | 13.8            | 12.2           | 11.2            |
| 27  | 49.6            | 47.0           | 43.2            | 40.1           | 36.7           | 31.5           | 26.3           | 21.7           | 18.1           | 16.2           | 14.6            | 12.9           | 11.8            |
| 28  | 51.0            | 48.3           | 44.5            | 41.3           | 37.9           | 32.6           | 27.3           | 22.7           | 18.9           | 16.9           | 15.3            | 13.6           | 12.5            |
| 29  | 52.3            | 49.6           | 45.7            | 42.6           | 39.1           | 33.7           | 28.3           | 23.6           | 19.8           | 17.7           | 16.0            | 14.3           | 13.1            |
| 30  | 53.7            | 50.9           | 47.0            | 43.8           | 40.3           | 34.8           | 29.3           | 24.5           | 20.6           | 18.5           | 16.8            | 15.0           | 13.8            |
| 40  | 66.8            | 63.7           | 59.3            | 55.8           | 51.8           | 45.6           | 39.3           | 33.7           | 29.1           | 26.5           | 24.4            | 22.2           | 20.7            |
| 50  | 79.5            | 76.2           | 71.4            | 67.5           | 63.2           | 56.3           | 49.3           | 42.9           | 37.7           | 34.8           | 32.4            | 29.7           | 28.0            |
| 60  | 92.0            | 88.4           | 83.3            | 79.1           | 74.4           | 67.0           | 59.3           | 52.3           | 46.5           | 43.2           | 40.5            | 37.5           | 35.5            |
| 70  | 104.2           | 100.4          | 95.0            | 90.5           | 85.5           | 77.6           | 69.3           | 61.7           | 55.3           | 51.7           | 48.8            | 45.4           | 43.3            |
| 80  | 116.3           | 112.3          | 106.6           | 101.9          | 96.6           | 88.1           | 79.3           | 71.1           | 64.3           | 60.4           | 57.2            | 53.5           | 51.2            |
| 90  | 128.3           | 124.1          | 118.1           | 113.1          | 107.6          | 98.6           | 89.3           | 80.6           | 73.3           | 69.1           | 65.6            | 61.8           | 59.2            |
| 100 | 140.2           | 135.8          | 129.6           | 124.3          | 118.5          | 109.1          | 99.3           | 90.1           | 82.4           | 77.9           | 74.2            | 70.1           | 67.3            |

Source: Catherine M. Thompson, *Table of percentage points of the  $\chi^2$  distribution*, *Biometrika*, Vol. 32 (1941), by permission of the author and publisher.

## 95th PERCENTILE VALUES FOR THE F DISTRIBUTION

$n_1$  = degrees of freedom for numerator  
 $n_2$  = degrees of freedom for denominator  
 (shaded area = .95)



| $n_1 \backslash n_2$ | 1     | 2     | 3     | 4     | 5     | 6     | 8     | 12    | 16    | 20    | 30    | 40    | 50    | 100   | $\infty$ |
|----------------------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|----------|
| 1                    | 161.4 | 199.5 | 215.7 | 224.6 | 230.2 | 234.0 | 238.9 | 243.9 | 246.3 | 248.0 | 250.1 | 251.1 | 252.2 | 253.0 | 254.3    |
| 2                    | 18.51 | 19.00 | 19.16 | 19.25 | 19.30 | 19.33 | 19.37 | 19.41 | 19.43 | 19.45 | 19.46 | 19.46 | 19.47 | 19.49 | 19.50    |
| 3                    | 10.13 | 9.55  | 9.28  | 9.12  | 9.01  | 8.94  | 8.85  | 8.74  | 8.69  | 8.66  | 8.62  | 8.60  | 8.58  | 8.56  | 8.53     |
| 4                    | 7.71  | 6.94  | 6.59  | 6.39  | 6.26  | 6.16  | 6.04  | 5.91  | 5.84  | 5.80  | 5.75  | 5.71  | 5.70  | 5.66  | 5.63     |
| 5                    | 6.61  | 5.79  | 5.41  | 5.19  | 5.05  | 4.95  | 4.82  | 4.68  | 4.60  | 4.56  | 4.50  | 4.46  | 4.44  | 4.40  | 4.36     |
| 6                    | 5.99  | 5.14  | 4.76  | 4.53  | 4.39  | 4.28  | 4.15  | 4.00  | 3.92  | 3.87  | 3.81  | 3.77  | 3.75  | 3.71  | 3.67     |
| 7                    | 5.59  | 4.74  | 4.35  | 4.12  | 3.97  | 3.87  | 3.73  | 3.57  | 3.49  | 3.44  | 3.38  | 3.34  | 3.32  | 3.28  | 3.23     |
| 8                    | 5.32  | 4.46  | 4.07  | 3.84  | 3.69  | 3.58  | 3.44  | 3.28  | 3.20  | 3.15  | 3.08  | 3.05  | 3.03  | 2.98  | 2.93     |
| 9                    | 5.12  | 4.26  | 3.86  | 3.63  | 3.48  | 3.37  | 3.23  | 3.07  | 2.98  | 2.93  | 2.86  | 2.82  | 2.80  | 2.76  | 2.71     |
| 10                   | 4.96  | 4.10  | 3.71  | 3.48  | 3.33  | 3.22  | 3.07  | 2.91  | 2.82  | 2.77  | 2.70  | 2.67  | 2.64  | 2.59  | 2.54     |
| 11                   | 4.84  | 3.98  | 3.59  | 3.36  | 3.20  | 3.09  | 2.95  | 2.79  | 2.70  | 2.65  | 2.57  | 2.53  | 2.50  | 2.45  | 2.40     |
| 12                   | 4.75  | 3.89  | 3.49  | 3.26  | 3.11  | 3.00  | 2.85  | 2.69  | 2.60  | 2.54  | 2.46  | 2.42  | 2.40  | 2.35  | 2.30     |
| 13                   | 4.67  | 3.81  | 3.41  | 3.18  | 3.03  | 2.92  | 2.77  | 2.60  | 2.51  | 2.46  | 2.38  | 2.34  | 2.32  | 2.26  | 2.21     |
| 14                   | 4.60  | 3.74  | 3.34  | 3.11  | 2.96  | 2.85  | 2.70  | 2.53  | 2.44  | 2.39  | 2.31  | 2.27  | 2.24  | 2.19  | 2.13     |
| 15                   | 4.54  | 3.68  | 3.29  | 3.06  | 2.90  | 2.79  | 2.64  | 2.48  | 2.39  | 2.33  | 2.25  | 2.21  | 2.18  | 2.12  | 2.07     |
| 16                   | 4.49  | 3.63  | 3.24  | 3.01  | 2.85  | 2.74  | 2.59  | 2.42  | 2.33  | 2.28  | 2.20  | 2.16  | 2.13  | 2.07  | 2.01     |
| 17                   | 4.45  | 3.59  | 3.20  | 2.96  | 2.81  | 2.70  | 2.55  | 2.38  | 2.29  | 2.23  | 2.15  | 2.11  | 2.08  | 2.02  | 1.96     |
| 18                   | 4.41  | 3.55  | 3.16  | 2.93  | 2.77  | 2.66  | 2.51  | 2.34  | 2.25  | 2.19  | 2.11  | 2.07  | 2.04  | 1.98  | 1.92     |
| 19                   | 4.38  | 3.52  | 3.13  | 2.90  | 2.74  | 2.63  | 2.48  | 2.31  | 2.21  | 2.15  | 2.07  | 2.02  | 2.00  | 1.94  | 1.88     |
| 20                   | 4.35  | 3.49  | 3.10  | 2.87  | 2.71  | 2.60  | 2.45  | 2.28  | 2.18  | 2.12  | 2.04  | 1.99  | 1.96  | 1.90  | 1.84     |
| 22                   | 4.30  | 3.44  | 3.05  | 2.82  | 2.66  | 2.55  | 2.40  | 2.23  | 2.13  | 2.07  | 1.98  | 1.93  | 1.91  | 1.84  | 1.78     |
| 24                   | 4.26  | 3.40  | 3.01  | 2.78  | 2.62  | 2.51  | 2.36  | 2.18  | 2.09  | 2.03  | 1.94  | 1.89  | 1.86  | 1.80  | 1.73     |
| 26                   | 4.23  | 3.37  | 2.98  | 2.74  | 2.59  | 2.47  | 2.32  | 2.15  | 2.05  | 1.99  | 1.90  | 1.85  | 1.82  | 1.76  | 1.69     |
| 28                   | 4.20  | 3.34  | 2.95  | 2.71  | 2.56  | 2.45  | 2.29  | 2.12  | 2.02  | 1.96  | 1.87  | 1.81  | 1.78  | 1.72  | 1.65     |
| 30                   | 4.17  | 3.32  | 2.92  | 2.69  | 2.53  | 2.42  | 2.27  | 2.09  | 1.99  | 1.93  | 1.84  | 1.79  | 1.76  | 1.69  | 1.62     |
| 40                   | 4.08  | 3.23  | 2.84  | 2.61  | 2.45  | 2.34  | 2.18  | 2.00  | 1.90  | 1.84  | 1.74  | 1.69  | 1.66  | 1.59  | 1.51     |
| 50                   | 4.03  | 3.18  | 2.79  | 2.56  | 2.40  | 2.29  | 2.13  | 1.95  | 1.85  | 1.78  | 1.69  | 1.63  | 1.60  | 1.52  | 1.44     |
| 60                   | 4.00  | 3.15  | 2.76  | 2.53  | 2.37  | 2.25  | 2.10  | 1.92  | 1.81  | 1.75  | 1.65  | 1.59  | 1.56  | 1.48  | 1.39     |
| 70                   | 3.98  | 3.13  | 2.74  | 2.50  | 2.35  | 2.23  | 2.07  | 1.89  | 1.79  | 1.72  | 1.62  | 1.56  | 1.53  | 1.45  | 1.35     |
| 80                   | 3.96  | 3.11  | 2.72  | 2.48  | 2.33  | 2.21  | 2.05  | 1.88  | 1.77  | 1.70  | 1.60  | 1.54  | 1.51  | 1.42  | 1.32     |
| 100                  | 3.94  | 3.09  | 2.70  | 2.46  | 2.30  | 2.19  | 2.03  | 1.85  | 1.75  | 1.68  | 1.57  | 1.51  | 1.48  | 1.39  | 1.28     |
| 150                  | 3.91  | 3.06  | 2.67  | 2.43  | 2.27  | 2.16  | 2.00  | 1.82  | 1.71  | 1.64  | 1.54  | 1.47  | 1.44  | 1.34  | 1.22     |
| 200                  | 3.89  | 3.04  | 2.65  | 2.41  | 2.26  | 2.14  | 1.98  | 1.80  | 1.69  | 1.62  | 1.52  | 1.45  | 1.42  | 1.32  | 1.19     |
| 400                  | 3.86  | 3.02  | 2.62  | 2.39  | 2.23  | 2.12  | 1.96  | 1.78  | 1.67  | 1.60  | 1.49  | 1.42  | 1.38  | 1.28  | 1.13     |
| $\infty$             | 3.84  | 2.99  | 2.60  | 2.37  | 2.21  | 2.09  | 1.94  | 1.75  | 1.64  | 1.57  | 1.46  | 1.40  | 1.32  | 1.24  | 1.00     |

Source: G. W. Snedecor and W. G. Cochran, *Statistical Methods* (6th edition, 1967), Iowa State University Press, Ames, Iowa, by permission of the authors and publisher.