**NAMIBIA UNIVERSITY**
**OF SCIENCE AND TECHNOLOGY**

# FACULTY OF HEALTH AND APPLIED SCIENCES

## DEPARTMENT OF MATHEMATICS AND STATISTICS

| **QUALIFICATION:** Bachelor of science ; Bachelor of science in Applied Mathematics and Statistics | |
|---|---|
| **QUALIFICATION CODE:** 07BSOC; 07BAMS | **LEVEL:** 6 |
| **COURSE CODE:** RAA602S | **COURSE NAME:** REGRESSION ANALYSIS AND ANALYSIS OF VARIANCE |
| **SESSION:** JANUARY 2019 | **PAPER:** THEORY |
| **DURATION:** 3 HOURS | **MARKS:** 100 |

| **SECOND OPPORTUNITY EXAMINATION QUESTION PAPER** | |
|---|---|
| **EXAMINER** | **Dr D. Ntirampeba, Mr. R. Mumbuu** |
| **MODERATOR:** | **Dr C.R. Kikawa** |

## INSTRUCTIONS

1. Answer ALL the questions in the booklet provided.
2. Show clearly all the steps used in the calculations.
3. All written work must be done in blue or black ink and sketches must be done in pencil.

## PERMISSIBLE MATERIALS

1. Non-programmable calculator without a cover.

## ATTACHMENTS

1. The t-distribution table, F-distribution table, Z-distribution and Chi-square distribution table

**THIS QUESTION PAPER CONSISTS OF 6 PAGES** (Including this front page)

## QUESTION 1 [23 marks]

1.1 The Head of Department of Mathematics and Statistics at the Namibia University of Science and Technology (NUST) wanted to analyse the performance of Basic Business Statistics 1A students. He took a record of a sample of 6 students' continuous assessment marks and the marks obtained in their final examination in 2017.The results are as follows:

| Student | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Continuous Assessment mark | 86 | 53 | 71 | 60 | 62 | 79 |
| Final exams mark | 75 | 60 | 74 | 68 | 70 | 75 |

1.1.1 Compute the Pearson correlation coefficient and test whether the correlation is significant. Use $\alpha = 0.01$. [8]

1.2 The simple linear regression model is given by $y_i = \beta_0 + \beta_1 x + \varepsilon_i$, where $\beta_0$ and $\beta_1$ are intercept and slope respectively, and $\varepsilon_i$ is the error term.

1.2.1 Find the least squares estimates of $\beta_0$ and $\beta_1$ to fit a regression model to this data . [5]

1.2.2 Predict the final mark of a student who has a continuous assessment mark 73. [2]

1.2.3 Construct a 95 % confidence interval for $\beta_0$ and use it to test whether or not $\beta_0$ is statistically significant. [8]

## QUESTION 2 [10 marks]

2.1 To investigate the relationship between the curing time of concrete and tensile strength the following results were obtained

| Curing time (days) (x) | 1.5 | 2 | 2.5 | 3.25 | 6 | 10 |
|---|---|---|---|---|---|---|
| tensile strength (kg/cm$^2$)(y) | 22.4 | 24.5 | 26.3 | 30.2 | 33.9 | 35.5 |

Assume that the theoretical relationship between tensile strength and curing time of a concrete is given by

$y = ae^{\frac{b}{x}}$,

2.1.1 Find the regression coefficients $a$ and $b$. [8]

2.1.2 Predict the tensile strength after curing time of 4 days. [2]

**QUESTION 3 [16 marks]**

The results below were taken from a study on Namibia University of Science and Technology lecturers to determine whether their gender, rank, department, number of years since making rank and average merit ranking affects their salary per month.

- Salary(per thousand N$)
- Gender (0=Male(reference), 1=Female)
- Rank (0=Junior Lecturer (reference), 1=Lecturer, 2= Senior lecturer)
- Department (0=Mathematics (reference), 2=Humanities, 3=Hospitality and Hotel management)
- Years since making Rank
- Average Merit Ranking

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .873[a] | .763 | | 6.037 |

a. Predictors: (Constant), Merit, Gender, Dept1, Rank1, Rank2, Dept2, Years

**ANOVA[a]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 2575.681 | 7 | 367.954 | 10.097 | .000[b] |
| | Residual | 801.686 | 22 | 36.440 | | |
| | Total | 3377.367 | 29 | | | |

a. Dependent Variable: Salary

b. Predictors: (Constant), Merit, Gender, Dept1, Rank1, Rank2, Dept2, Years

**Coefficients[a]**

| Model | | Unstandardized Coefficients B | Std. Error | Standardized Coefficients Beta | t | Sig. |
|---|---|---|---|---|---|---|
| 1 | (Constant) | 21.575 | 6.423 | | 3.359 | .003 |
| | Gender | 8.373 | 2.856 | .394 | 2.932 | .008 |
| | Rank1 | 9.871 | 2.894 | .393 | 3.411 | .003 |
| | Rank2 | 18.400 | 3.009 | .767 | 6.115 | .000 |
| | Dept1 | 8.799 | 3.300 | .351 | 2.667 | .014 |
| | Dept2 | 15.794 | 2.933 | .702 | 5.385 | .000 |
| | Years | .605 | .491 | .174 | 1.231 | .231 |
| | Merit | 1.738 | 1.632 | .158 | 1.065 | .299 |

a. Dependent Variable: Salary

3.1 What type of regression analysis was used in this situation?

Justify your answer. [2]

3.2 Write down the statistical model for this regression analysis [2]

3.3 Interpret the constant and the rank1 coefficient [2]

3.4 For the estimates, associated with years and merit variables in the table above, test for their significance in the model. Use $\alpha = 0.05$ [4]

3.5 Comment on the goodness of the model based on model summary table [3]

3.6 Compute and interpret $R^2$ adjusted in the model summary table above. [3]

**QUESTION 4 [22 marks]**

A gardener is interested in the effect of four different insecticides on his garden. The following results were obtained from his garden at Goreangab dam.

| Insecticide | Number of insects killed per square meter | | | |
|---|---|---|---|---|
| **1** | 30 | 29 | 32 | 39 |
| **2** | 42 | 50 | 37 | 43 |
| **3** | 24 | 36 | 32 | 17 |
| **4** | 33 | 41 | 51 | 66 |

4.1 Construct the appropriate single-factor ANOVA table for these data. [8]

4.2 Determine whether these data provide sufficient evidence to support the claim that the type of insecticide affects pests differently at 5% level. [4]

4.3 Complete the Fisher's LSD post-hoc multiple comparison tests table below for these data at 5% level. [6]

| [i] | [j] | $\bar{y}_{i.} - \bar{y}_{j.}$ | $\lvert\bar{y}_{i.} - \bar{y}_{j.}\rvert$ | LSD |
|---|---|---|---|---|
| A | B | | | |
| | C | | | |
| | D | | | |
| B | C | | | |
| | D | | | |
| C | D | | | |

4.4 Use the completed LSD table in 4.3 to list all pairs of fertilisers with significant differences in mean number of insects killed by the insecticides at 5% level. [4]

**QUESTION 5 [16 marks]**

An experiment was installed to test 3 irrigation methods on the yield of maize plants. There were 3 irrigation methods and 4 soil types in a randomized complete block design. The yields are given in the table below.

| Blocks(Soil types) | Treatment(Irrigation methods) | | |
|---|---|---|---|
| | A | B | C |
| 1 | 3.9 | 3.7 | 3.8 |
| 2 | 3.5 | 4.0 | 4.5 |
| 3 | 4.3 | 4.4 | 4.8 |
| 4 | 4.0 | 4.2 | 4.9 |

5.1 Construct the analysis of variance table for this data. [6]

5.2 Test at 0.05 level of significance whether there are significant differences among the means obtained for the different types of irrigation methods (treatments). [5]

5.3 Test at 0.05 level of significance whether the differences among the means obtained for the different soil types (blocks) are significant. [5]

**QUESTION 6 [13 marks]**

The results below come from a study to determine whether the mismatch score, age, and gender affect the likelihood of heart transplant rejection. The response variable indicates whether a patient has had heart transplant rejection (1) or did not have heart transplant rejection (0).

| | Estimates | Std. Error | z-value | sign |
|---|---|---|---|---|
| Intercept | 2.7225 | 2.8420 | 0.9580 | 0.338 |
| Mismatch Score | 0.2647 | 0.6771 | 0.3910 | 0.696 |
| Age | -0.0522 | 0.0567 | -0.9200 | 0.357 |
| Gender | -0.3801 | 0.7597 | -0.5000 | 0.617 |

6.1 Compute and interpret the odds ratio of heart transplant rejection for a male (gender=1) [2]

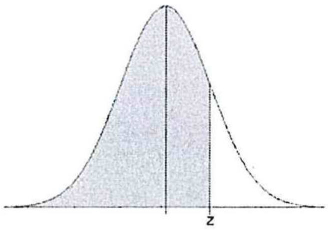
6.2 For the estimates associated with mismatch score and age variables in the table above, test for their significance in the model. Use $\alpha = 0.05$ [4]

6.3 Find the odds of heart transplant rejection for an individual who increases his mismatch score by 2 units and comment on your answer. [3]

6.4 Compute the 95% confidence interval for the odds ratio obtained in (6.3) above. [4]

END

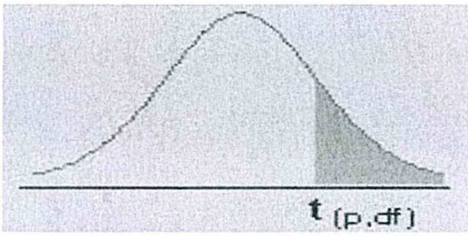
## Standard Normal Cumulative Probability Table




**Cumulative probabilities for POSITIVE z-values are shown in the following table:**

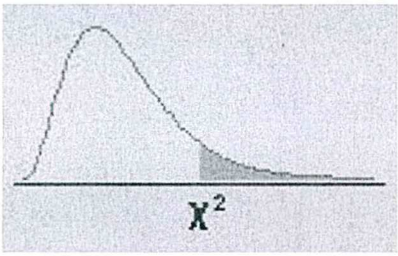
| z | 0.00 | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 | 0.06 | 0.07 | 0.08 | 0.09 |
|---|---|---|---|---|---|---|---|---|---|---|
| **0.0** | 0.5000 | 0.5040 | 0.5080 | 0.5120 | 0.5160 | 0.5199 | 0.5239 | 0.5279 | 0.5319 | 0.5359 |
| **0.1** | 0.5398 | 0.5438 | 0.5478 | 0.5517 | 0.5557 | 0.5596 | 0.5636 | 0.5675 | 0.5714 | 0.5753 |
| **0.2** | 0.5793 | 0.5832 | 0.5871 | 0.5910 | 0.5948 | 0.5987 | 0.6026 | 0.6064 | 0.6103 | 0.6141 |
| **0.3** | 0.6179 | 0.6217 | 0.6255 | 0.6293 | 0.6331 | 0.6368 | 0.6406 | 0.6443 | 0.6480 | 0.6517 |
| **0.4** | 0.6554 | 0.6591 | 0.6628 | 0.6664 | 0.6700 | 0.6736 | 0.6772 | 0.6808 | 0.6844 | 0.6879 |
| **0.5** | 0.6915 | 0.6950 | 0.6985 | 0.7019 | 0.7054 | 0.7088 | 0.7123 | 0.7157 | 0.7190 | 0.7224 |
| **0.6** | 0.7257 | 0.7291 | 0.7324 | 0.7357 | 0.7389 | 0.7422 | 0.7454 | 0.7486 | 0.7517 | 0.7549 |
| **0.7** | 0.7580 | 0.7611 | 0.7642 | 0.7673 | 0.7704 | 0.7734 | 0.7764 | 0.7794 | 0.7823 | 0.7852 |
| **0.8** | 0.7881 | 0.7910 | 0.7939 | 0.7967 | 0.7995 | 0.8023 | 0.8051 | 0.8078 | 0.8106 | 0.8133 |
| **0.9** | 0.8159 | 0.8186 | 0.8212 | 0.8238 | 0.8264 | 0.8289 | 0.8315 | 0.8340 | 0.8365 | 0.8389 |
| **1.0** | 0.8413 | 0.8438 | 0.8461 | 0.8485 | 0.8508 | 0.8531 | 0.8554 | 0.8577 | 0.8599 | 0.8621 |
| **1.1** | 0.8643 | 0.8665 | 0.8686 | 0.8708 | 0.8729 | 0.8749 | 0.8770 | 0.8790 | 0.8810 | 0.8830 |
| **1.2** | 0.8849 | 0.8869 | 0.8888 | 0.8907 | 0.8925 | 0.8944 | 0.8962 | 0.8980 | 0.8997 | 0.9015 |
| **1.3** | 0.9032 | 0.9049 | 0.9066 | 0.9082 | 0.9099 | 0.9115 | 0.9131 | 0.9147 | 0.9162 | 0.9177 |
| **1.4** | 0.9192 | 0.9207 | 0.9222 | 0.9236 | 0.9251 | 0.9265 | 0.9279 | 0.9292 | 0.9306 | 0.9319 |
| **1.5** | 0.9332 | 0.9345 | 0.9357 | 0.9370 | 0.9382 | 0.9394 | 0.9406 | 0.9418 | 0.9429 | 0.9441 |
| **1.6** | 0.9452 | 0.9463 | 0.9474 | 0.9484 | 0.9495 | 0.9505 | 0.9515 | 0.9525 | 0.9535 | 0.9545 |
| **1.7** | 0.9554 | 0.9564 | 0.9573 | 0.9582 | 0.9591 | 0.9599 | 0.9608 | 0.9616 | 0.9625 | 0.9633 |
| **1.8** | 0.9641 | 0.9649 | 0.9656 | 0.9664 | 0.9671 | 0.9678 | 0.9686 | 0.9693 | 0.9699 | 0.9706 |
| **1.9** | 0.9713 | 0.9719 | 0.9726 | 0.9732 | 0.9738 | 0.9744 | 0.9750 | 0.9756 | 0.9761 | 0.9767 |
| **2.0** | 0.9772 | 0.9778 | 0.9783 | 0.9788 | 0.9793 | 0.9798 | 0.9803 | 0.9808 | 0.9812 | 0.9817 |
| **2.1** | 0.9821 | 0.9826 | 0.9830 | 0.9834 | 0.9838 | 0.9842 | 0.9846 | 0.9850 | 0.9854 | 0.9857 |
| **2.2** | 0.9861 | 0.9864 | 0.9868 | 0.9871 | 0.9875 | 0.9878 | 0.9881 | 0.9884 | 0.9887 | 0.9890 |
| **2.3** | 0.9893 | 0.9896 | 0.9898 | 0.9901 | 0.9904 | 0.9906 | 0.9909 | 0.9911 | 0.9913 | 0.9916 |
| **2.4** | 0.9918 | 0.9920 | 0.9922 | 0.9925 | 0.9927 | 0.9929 | 0.9931 | 0.9932 | 0.9934 | 0.9936 |
| **2.5** | 0.9938 | 0.9940 | 0.9941 | 0.9943 | 0.9945 | 0.9946 | 0.9948 | 0.9949 | 0.9951 | 0.9952 |
| **2.6** | 0.9953 | 0.9955 | 0.9956 | 0.9957 | 0.9959 | 0.9960 | 0.9961 | 0.9962 | 0.9963 | 0.9964 |
| **2.7** | 0.9965 | 0.9966 | 0.9967 | 0.9968 | 0.9969 | 0.9970 | 0.9971 | 0.9972 | 0.9973 | 0.9974 |
| **2.8** | 0.9974 | 0.9975 | 0.9976 | 0.9977 | 0.9977 | 0.9978 | 0.9979 | 0.9979 | 0.9980 | 0.9981 |
| **2.9** | 0.9981 | 0.9982 | 0.9982 | 0.9983 | 0.9984 | 0.9984 | 0.9985 | 0.9985 | 0.9986 | 0.9986 |
| **3.0** | 0.9987 | 0.9987 | 0.9987 | 0.9988 | 0.9988 | 0.9989 | 0.9989 | 0.9989 | 0.9990 | 0.9990 |
| **3.1** | 0.9990 | 0.9991 | 0.9991 | 0.9991 | 0.9992 | 0.9992 | 0.9992 | 0.9992 | 0.9993 | 0.9993 |
| **3.2** | 0.9993 | 0.9993 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9994 | 0.9995 | 0.9995 | 0.9995 |
| **3.3** | 0.9995 | 0.9995 | 0.9995 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9996 | 0.9997 |
| **3.4** | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9997 | 0.9998 |

# The t-distribution



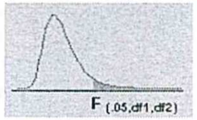

| df\p | 0.40 | 0.25 | 0.10 | 0.05 | 0.025 | 0.01 | 0.005 | 0.0005 |
|---|---|---|---|---|---|---|---|---|
| **1** | 0.324920 | 1.000000 | 3.077684 | 6.313752 | 12.70620 | 31.82052 | 63.65674 | 636.6192 |
| **2** | 0.288675 | 0.816497 | 1.885618 | 2.919986 | 4.30265 | 6.96456 | 9.92484 | 31.5991 |
| **3** | 0.276671 | 0.764892 | 1.637744 | 2.353363 | 3.18245 | 4.54070 | 5.84091 | 12.9240 |
| **4** | 0.270722 | 0.740697 | 1.533206 | 2.131847 | 2.77645 | 3.74695 | 4.60409 | 8.6103 |
| **5** | 0.267181 | 0.726687 | 1.475884 | 2.015048 | 2.57058 | 3.36493 | 4.03214 | 6.8688 |
| **6** | 0.264835 | 0.717558 | 1.439756 | 1.943180 | 2.44691 | 3.14267 | 3.70743 | 5.9588 |
| **7** | 0.263167 | 0.711142 | 1.414924 | 1.894579 | 2.36462 | 2.99795 | 3.49948 | 5.4079 |
| **8** | 0.261921 | 0.706387 | 1.396815 | 1.859548 | 2.30600 | 2.89646 | 3.35539 | 5.0413 |
| **9** | 0.260955 | 0.702722 | 1.383029 | 1.833113 | 2.26216 | 2.82144 | 3.24984 | 4.7809 |
| **10** | 0.260185 | 0.699812 | 1.372184 | 1.812461 | 2.22814 | 2.76377 | 3.16927 | 4.5869 |
| **11** | 0.259556 | 0.697445 | 1.363430 | 1.795885 | 2.20099 | 2.71808 | 3.10581 | 4.4370 |
| **12** | 0.259033 | 0.695483 | 1.356217 | 1.782288 | 2.17881 | 2.68100 | 3.05454 | 4.3178 |
| **13** | 0.258591 | 0.693829 | 1.350171 | 1.770933 | 2.16037 | 2.65031 | 3.01228 | 4.2208 |
| **14** | 0.258213 | 0.692417 | 1.345030 | 1.761310 | 2.14479 | 2.62449 | 2.97684 | 4.1405 |
| **15** | 0.257885 | 0.691197 | 1.340606 | 1.753050 | 2.13145 | 2.60248 | 2.94671 | 4.0728 |
| **16** | 0.257599 | 0.690132 | 1.336757 | 1.745884 | 2.11991 | 2.58349 | 2.92078 | 4.0150 |
| **17** | 0.257347 | 0.689195 | 1.333379 | 1.739607 | 2.10982 | 2.56693 | 2.89823 | 3.9651 |
| **18** | 0.257123 | 0.688364 | 1.330391 | 1.734064 | 2.10092 | 2.55238 | 2.87844 | 3.9216 |
| **19** | 0.256923 | 0.687621 | 1.327728 | 1.729133 | 2.09302 | 2.53948 | 2.86093 | 3.8834 |
| **20** | 0.256743 | 0.686954 | 1.325341 | 1.724718 | 2.08596 | 2.52798 | 2.84534 | 3.8495 |
| **21** | 0.256580 | 0.686352 | 1.323188 | 1.720743 | 2.07961 | 2.51765 | 2.83136 | 3.8193 |
| **22** | 0.256432 | 0.685805 | 1.321237 | 1.717144 | 2.07387 | 2.50832 | 2.81876 | 3.7921 |
| **23** | 0.256297 | 0.685306 | 1.319460 | 1.713872 | 2.06866 | 2.49987 | 2.80734 | 3.7676 |
| **24** | 0.256173 | 0.684850 | 1.317836 | 1.710882 | 2.06390 | 2.49216 | 2.79694 | 3.7454 |
| **25** | 0.256060 | 0.684430 | 1.316345 | 1.708141 | 2.05954 | 2.48511 | 2.78744 | 3.7251 |
| **26** | 0.255955 | 0.684043 | 1.314972 | 1.705618 | 2.05553 | 2.47863 | 2.77871 | 3.7066 |
| **27** | 0.255858 | 0.683685 | 1.313703 | 1.703288 | 2.05183 | 2.47266 | 2.77068 | 3.6896 |
| **28** | 0.255768 | 0.683353 | 1.312527 | 1.701131 | 2.04841 | 2.46714 | 2.76326 | 3.6739 |
| **29** | 0.255684 | 0.683044 | 1.311434 | 1.699127 | 2.04523 | 2.46202 | 2.75639 | 3.6594 |
| **30** | 0.255605 | 0.682756 | 1.310415 | 1.697261 | 2.04227 | 2.45726 | 2.75000 | 3.6460 |
| **inf** | 0.253347 | 0.674490 | 1.281552 | 1.644854 | 1.95996 | 2.32635 | 2.57583 | 3.2905 |

# The Chi-Square Distribution




| df\p | .995 | .990 | .975 | .950 | .900 | .750 | .500 | .250 | .100 | .050 | .025 | .010 | .005 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.00004 | 0.00016 | 0.00098 | 0.00393 | 0.01579 | 0.10153 | 0.45494 | 1.32330 | 2.70554 | 3.84146 | 5.02389 | 6.63490 | 7.87944 |
| 2 | 0.01003 | 0.02010 | 0.05064 | 0.10259 | 0.21072 | 0.57536 | 1.38629 | 2.77259 | 4.60517 | 5.99146 | 7.37776 | 9.21034 | 10.59663 |
| 3 | 0.07172 | 0.11483 | 0.21580 | 0.35185 | 0.58437 | 1.21253 | 2.36597 | 4.10834 | 6.25139 | 7.81473 | 9.34840 | 11.34487 | 12.83816 |
| 4 | 0.20699 | 0.29711 | 0.48442 | 0.71072 | 1.06362 | 1.92256 | 3.35669 | 5.38527 | 7.77944 | 9.48773 | 11.14329 | 13.27670 | 14.86026 |
| 5 | 0.41174 | 0.55430 | 0.83121 | 1.14548 | 1.61031 | 2.67460 | 4.35146 | 6.62568 | 9.23636 | 11.07050 | 12.83250 | 15.08627 | 16.74960 |
| 6 | 0.67573 | 0.87209 | 1.23734 | 1.63538 | 2.20413 | 3.45460 | 5.34812 | 7.84080 | 10.64464 | 12.59159 | 14.44938 | 16.81189 | 18.54758 |
| 7 | 0.98926 | 1.23904 | 1.68987 | 2.16735 | 2.83311 | 4.25485 | 6.34581 | 9.03715 | 12.01704 | 14.06714 | 16.01276 | 18.47531 | 20.27774 |
| 8 | 1.34441 | 1.64650 | 2.17973 | 2.73264 | 3.48954 | 5.07064 | 7.34412 | 10.21885 | 13.36157 | 15.50731 | 17.53455 | 20.09024 | 21.95495 |
| 9 | 1.73493 | 2.08790 | 2.70039 | 3.32511 | 4.16816 | 5.89883 | 8.34283 | 11.38875 | 14.68366 | 16.91898 | 19.02277 | 21.66599 | 23.58935 |
| 10 | 2.15586 | 2.55821 | 3.24697 | 3.94030 | 4.86518 | 6.73720 | 9.34182 | 12.54886 | 15.98718 | 18.30704 | 20.48318 | 23.20925 | 25.18818 |
| 11 | 2.60322 | 3.05348 | 3.81575 | 4.57481 | 5.57778 | 7.58414 | 10.34100 | 13.70069 | 17.27501 | 19.67514 | 21.92005 | 24.72497 | 26.75685 |
| 12 | 3.07382 | 3.57057 | 4.40379 | 5.22603 | 6.30380 | 8.43842 | 11.34032 | 14.84540 | 18.54935 | 21.02607 | 23.33666 | 26.21697 | 28.29952 |
| 13 | 3.56503 | 4.10692 | 5.00875 | 5.89186 | 7.04150 | 9.29907 | 12.33976 | 15.98391 | 19.81193 | 22.36203 | 24.73560 | 27.68825 | 29.81947 |
| 14 | 4.07467 | 4.66043 | 5.62873 | 6.57063 | 7.78953 | 10.16531 | 13.33927 | 17.11693 | 21.06414 | 23.68479 | 26.11895 | 29.14124 | 31.31935 |
| 15 | 4.60092 | 5.22935 | 6.26214 | 7.26094 | 8.54676 | 11.03654 | 14.33886 | 18.24509 | 22.30713 | 24.99579 | 27.48839 | 30.57791 | 32.80132 |
| 16 | 5.14221 | 5.81221 | 6.90766 | 7.96165 | 9.31224 | 11.91222 | 15.33850 | 19.36886 | 23.54183 | 26.29623 | 28.84535 | 31.99993 | 34.26719 |
| 17 | 5.69722 | 6.40776 | 7.56419 | 8.67176 | 10.08519 | 12.79193 | 16.33818 | 20.48868 | 24.76904 | 27.58711 | 30.19101 | 33.40866 | 35.71847 |
| 18 | 6.26480 | 7.01491 | 8.23075 | 9.39046 | 10.86494 | 13.67529 | 17.33790 | 21.60489 | 25.98942 | 28.86930 | 31.52638 | 34.80531 | 37.15645 |
| 19 | 6.84397 | 7.63273 | 8.90652 | 10.11701 | 11.65091 | 14.56200 | 18.33765 | 22.71781 | 27.20357 | 30.14353 | 32.85233 | 36.19087 | 38.58226 |
| 20 | 7.43384 | 8.26040 | 9.59078 | 10.85081 | 12.44261 | 15.45177 | 19.33743 | 23.82769 | 28.41198 | 31.41043 | 34.16961 | 37.56623 | 39.99685 |
| 21 | 8.03365 | 8.89720 | 10.28290 | 11.59131 | 13.23960 | 16.34438 | 20.33723 | 24.93478 | 29.61509 | 32.67057 | 35.47888 | 38.93217 | 41.40106 |
| 22 | 8.64272 | 9.54249 | 10.98232 | 12.33801 | 14.04149 | 17.23962 | 21.33704 | 26.03927 | 30.81328 | 33.92444 | 36.78071 | 40.28936 | 42.79565 |
| 23 | 9.26042 | 10.19572 | 11.68855 | 13.09051 | 14.84796 | 18.13730 | 22.33688 | 27.14134 | 32.00690 | 35.17246 | 38.07563 | 41.63840 | 44.18128 |
| 24 | 9.88623 | 10.85636 | 12.40115 | 13.84843 | 15.65868 | 19.03725 | 23.33673 | 28.24115 | 33.19624 | 36.41503 | 39.36408 | 42.97982 | 45.55851 |
| 25 | 10.51965 | 11.52398 | 13.11972 | 14.61141 | 16.47341 | 19.93934 | 24.33659 | 29.33885 | 34.38159 | 37.65248 | 40.64647 | 44.31410 | 46.92789 |
| 26 | 11.16024 | 12.19815 | 13.84390 | 15.37916 | 17.29188 | 20.84343 | 25.33646 | 30.43457 | 35.56317 | 38.88514 | 41.92317 | 45.64168 | 48.28988 |
| 27 | 11.80759 | 12.87850 | 14.57338 | 16.15140 | 18.11390 | 21.74940 | 26.33634 | 31.52841 | 36.74122 | 40.11327 | 43.19451 | 46.96294 | 49.64492 |
| 28 | 12.46134 | 13.56471 | 15.30786 | 16.92788 | 18.93924 | 22.65716 | 27.33623 | 32.62049 | 37.91592 | 41.33714 | 44.46079 | 48.27824 | 50.99338 |
| 29 | 13.12115 | 14.25645 | 16.04707 | 17.70837 | 19.76774 | 23.56659 | 28.33613 | 33.71091 | 39.08747 | 42.55697 | 45.72229 | 49.58788 | 52.33562 |
| 30 | 13.78672 | 14.95346 | 16.79077 | 18.49266 | 20.59923 | 24.47761 | 29.33603 | 34.79974 | 40.25602 | 43.77297 | 46.97924 | 50.89218 | 53.67196 |

## F Table for alpha=0.05




| df2/df1 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 20 | 24 | 30 | 40 | 60 | 120 | INF |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 161.4476 | 199.5 | 215.7073 | 224.5832 | 230.1619 | 233.986 | 236.7684 | 238.8827 | 240.5433 | 241.8817 | 243.906 | 245.9499 | 248.0131 | 249.0518 | 250.0951 | 251.1432 | 252.1957 | 253.2529 | 254.3144 |
| 2 | 18.5128 | 19 | 19.1643 | 19.2468 | 19.2964 | 19.3295 | 19.3532 | 19.371 | 19.3848 | 19.3959 | 19.4125 | 19.4291 | 19.4458 | 19.4541 | 19.4624 | 19.4707 | 19.4791 | 19.4874 | 19.4957 |
| 3 | 10.128 | 9.5521 | 9.2766 | 9.1172 | 9.0135 | 8.9406 | 8.8867 | 8.8452 | 8.8123 | 8.7855 | 8.7446 | 8.7029 | 8.6602 | 8.6385 | 8.6166 | 8.5944 | 8.572 | 8.5494 | 8.5264 |
| 4 | 7.7086 | 6.9443 | 6.5914 | 6.3882 | 6.2561 | 6.1631 | 6.0942 | 6.041 | 5.9988 | 5.9644 | 5.9117 | 5.8578 | 5.8025 | 5.7744 | 5.7459 | 5.717 | 5.6877 | 5.6581 | 5.6281 |
| 5 | 6.6079 | 5.7861 | 5.4095 | 5.1922 | 5.0503 | 4.9503 | 4.8759 | 4.8183 | 4.7725 | 4.7351 | 4.6777 | 4.6188 | 4.5581 | 4.5272 | 4.4957 | 4.4638 | 4.4314 | 4.3985 | 4.365 |
| 6 | 5.9874 | 5.1433 | 4.7571 | 4.5337 | 4.3874 | 4.2839 | 4.2067 | 4.1468 | 4.099 | 4.06 | 3.9999 | 3.9381 | 3.8742 | 3.8415 | 3.8082 | 3.7743 | 3.7398 | 3.7047 | 3.6689 |
| 7 | 5.5914 | 4.7374 | 4.3468 | 4.1203 | 3.9715 | 3.866 | 3.787 | 3.7257 | 3.6767 | 3.6365 | 3.5747 | 3.5107 | 3.4445 | 3.4105 | 3.3758 | 3.3404 | 3.3043 | 3.2674 | 3.2298 |
| 8 | 5.3177 | 4.459 | 4.0662 | 3.8379 | 3.6875 | 3.5806 | 3.5005 | 3.4381 | 3.3881 | 3.3472 | 3.2839 | 3.2184 | 3.1503 | 3.1152 | 3.0794 | 3.0428 | 3.0053 | 2.9669 | 2.9276 |
| 9 | 5.1174 | 4.2565 | 3.8625 | 3.6331 | 3.4817 | 3.3738 | 3.2927 | 3.2296 | 3.1789 | 3.1373 | 3.0729 | 3.0061 | 2.9365 | 2.9005 | 2.8637 | 2.8259 | 2.7872 | 2.7475 | 2.7067 |
| 10 | 4.9646 | 4.1028 | 3.7083 | 3.478 | 3.3258 | 3.2172 | 3.1355 | 3.0717 | 3.0204 | 2.9782 | 2.913 | 2.845 | 2.774 | 2.7372 | 2.6996 | 2.6609 | 2.6211 | 2.5801 | 2.5379 |
| 11 | 4.8443 | 3.9823 | 3.5874 | 3.3567 | 3.2039 | 3.0946 | 3.0123 | 2.948 | 2.8962 | 2.8536 | 2.7876 | 2.7186 | 2.6464 | 2.609 | 2.5705 | 2.5309 | 2.4901 | 2.448 | 2.4045 |
| 12 | 4.7472 | 3.8853 | 3.4903 | 3.2592 | 3.1059 | 2.9961 | 2.9134 | 2.8486 | 2.7964 | 2.7534 | 2.6866 | 2.6169 | 2.5436 | 2.5055 | 2.4663 | 2.4259 | 2.3842 | 2.341 | 2.2962 |
| 13 | 4.6672 | 3.8056 | 3.4105 | 3.1791 | 3.0254 | 2.9153 | 2.8321 | 2.7669 | 2.7144 | 2.671 | 2.6037 | 2.5331 | 2.4589 | 2.4202 | 2.3803 | 2.3392 | 2.2966 | 2.2524 | 2.2064 |
| 14 | 4.6001 | 3.7389 | 3.3439 | 3.1122 | 2.9582 | 2.8477 | 2.7642 | 2.6987 | 2.6458 | 2.6022 | 2.5342 | 2.463 | 2.3879 | 2.3487 | 2.3082 | 2.2664 | 2.2229 | 2.1778 | 2.1307 |
| 15 | 4.5431 | 3.6823 | 3.2874 | 3.0556 | 2.9013 | 2.7905 | 2.7066 | 2.6408 | 2.5876 | 2.5437 | 2.4753 | 2.4034 | 2.3275 | 2.2878 | 2.2468 | 2.2043 | 2.1601 | 2.1141 | 2.0658 |
| 16 | 4.494 | 3.6337 | 3.2389 | 3.0069 | 2.8524 | 2.7413 | 2.6572 | 2.5911 | 2.5377 | 2.4935 | 2.4247 | 2.3522 | 2.2756 | 2.2354 | 2.1938 | 2.1507 | 2.1058 | 2.0589 | 2.0096 |
| 17 | 4.4513 | 3.5915 | 3.1968 | 2.9647 | 2.81 | 2.6987 | 2.6143 | 2.548 | 2.4943 | 2.4499 | 2.3807 | 2.3077 | 2.2304 | 2.1898 | 2.1477 | 2.104 | 2.0584 | 2.0107 | 1.9604 |
| 18 | 4.4139 | 3.5546 | 3.1599 | 2.9277 | 2.7729 | 2.6613 | 2.5767 | 2.5102 | 2.4563 | 2.4117 | 2.3421 | 2.2686 | 2.1906 | 2.1497 | 2.1071 | 2.0629 | 2.0166 | 1.9681 | 1.9168 |
| 19 | 4.3807 | 3.5219 | 3.1274 | 2.8951 | 2.7401 | 2.6283 | 2.5435 | 2.4768 | 2.4227 | 2.3779 | 2.308 | 2.2341 | 2.1555 | 2.1141 | 2.0712 | 2.0264 | 1.9795 | 1.9302 | 1.878 |
| 20 | 4.3512 | 3.4928 | 3.0984 | 2.8661 | 2.7109 | 2.599 | 2.514 | 2.4471 | 2.3928 | 2.3479 | 2.2776 | 2.2033 | 2.1242 | 2.0825 | 2.0391 | 1.9938 | 1.9464 | 1.8963 | 1.8432 |
| 21 | 4.3248 | 3.4668 | 3.0725 | 2.8401 | 2.6848 | 2.5727 | 2.4876 | 2.4205 | 2.366 | 2.321 | 2.2504 | 2.1757 | 2.096 | 2.054 | 2.0102 | 1.9645 | 1.9165 | 1.8657 | 1.8117 |
| 22 | 4.3009 | 3.4434 | 3.0491 | 2.8167 | 2.6613 | 2.5491 | 2.4638 | 2.3965 | 2.3419 | 2.2967 | 2.2258 | 2.1508 | 2.0707 | 2.0283 | 1.9842 | 1.938 | 1.8894 | 1.838 | 1.7831 |
| 23 | 4.2793 | 3.4221 | 3.028 | 2.7955 | 2.64 | 2.5277 | 2.4422 | 2.3748 | 2.3201 | 2.2747 | 2.2036 | 2.1282 | 2.0476 | 2.005 | 1.9605 | 1.9139 | 1.8648 | 1.8128 | 1.757 |
| 24 | 4.2597 | 3.4028 | 3.0088 | 2.7763 | 2.6207 | 2.5082 | 2.4226 | 2.3551 | 2.3002 | 2.2547 | 2.1834 | 2.1077 | 2.0267 | 1.9838 | 1.939 | 1.892 | 1.8424 | 1.7896 | 1.733 |
| 25 | 4.2417 | 3.3852 | 2.9912 | 2.7587 | 2.603 | 2.4904 | 2.4047 | 2.3371 | 2.2821 | 2.2365 | 2.1649 | 2.0889 | 2.0075 | 1.9643 | 1.9192 | 1.8718 | 1.8217 | 1.7684 | 1.711 |
| 26 | 4.2252 | 3.369 | 2.9752 | 2.7426 | 2.5868 | 2.4741 | 2.3883 | 2.3205 | 2.2655 | 2.2197 | 2.1479 | 2.0716 | 1.9898 | 1.9464 | 1.901 | 1.8533 | 1.8027 | 1.7488 | 1.6906 |
| 27 | 4.21 | 3.3541 | 2.9604 | 2.7278 | 2.5719 | 2.4591 | 2.3732 | 2.3053 | 2.2501 | 2.2043 | 2.1323 | 2.0558 | 1.9736 | 1.9299 | 1.8842 | 1.8361 | 1.7851 | 1.7306 | 1.6717 |
| 28 | 4.196 | 3.3404 | 2.9467 | 2.7141 | 2.5581 | 2.4453 | 2.3593 | 2.2913 | 2.236 | 2.19 | 2.1179 | 2.0411 | 1.9586 | 1.9147 | 1.8687 | 1.8203 | 1.7689 | 1.7138 | 1.6541 |
| 29 | 4.183 | 3.3277 | 2.934 | 2.7014 | 2.5454 | 2.4324 | 2.3463 | 2.2783 | 2.2229 | 2.1768 | 2.1045 | 2.0275 | 1.9446 | 1.9005 | 1.8543 | 1.8055 | 1.7537 | 1.6981 | 1.6376 |
| 30 | 4.1709 | 3.3158 | 2.9223 | 2.6896 | 2.5336 | 2.4205 | 2.3343 | 2.2662 | 2.2107 | 2.1646 | 2.0921 | 2.0148 | 1.9317 | 1.8874 | 1.8409 | 1.7918 | 1.7396 | 1.6835 | 1.6223 |
| 40 | 4.0847 | 3.2317 | 2.8387 | 2.606 | 2.4495 | 2.3359 | 2.249 | 2.1802 | 2.124 | 2.0772 | 2.0035 | 1.9245 | 1.8389 | 1.7929 | 1.7444 | 1.6928 | 1.6373 | 1.5766 | 1.5089 |
| 60 | 4.0012 | 3.1504 | 2.7581 | 2.5252 | 2.3683 | 2.2541 | 2.1665 | 2.097 | 2.0401 | 1.9926 | 1.9174 | 1.8364 | 1.748 | 1.7001 | 1.6491 | 1.5943 | 1.5343 | 1.4673 | 1.3893 |
| 120 | 3.9201 | 3.0718 | 2.6802 | 2.4472 | 2.2899 | 2.175 | 2.0868 | 2.0164 | 1.9588 | 1.9105 | 1.8337 | 1.7505 | 1.6587 | 1.6084 | 1.5543 | 1.4952 | 1.429 | 1.3519 | 1.2539 |
| inf | 3.8415 | 2.9957 | 2.6049 | 2.3719 | 2.2141 | 2.0986 | 2.0096 | 1.9384 | 1.8799 | 1.8307 | 1.7522 | 1.6664 | 1.5705 | 1.5173 | 1.4591 | 1.394 | 1.318 | 1.2214 | 1 |