※ 注意：請於試卷內之「選擇題作答區」依序作答。

I、單選題：(每題5分)

1. Consider the die toss experiment. Define the events
   $X$: {Observe an event number}
   $Y$: {Observe a number less than or equal to 4}
   Assuming the die is fair, which of the following statements is true(正確的)?
   (A) Event $X$ and $Y$ are mutually exclusive.
   (B) Event $X$ and $Y$ are dependent.
   (C) Event $X$ and $Y$ are independent.
   (D) $P(X) = P(Y^c)$.
   (E) $P(X^c) = P(Y)$.

2. Which of the statements about the following probability distribution is false(不正確的)?

$$p(x) = \frac{2^x e^{-2}}{x!} \qquad (x = 0,1,2,\ldots)$$

   (A) $x$ is a discrete random variable.
   (B) The name of this probability distribution is exponential probability distribution.
   (C) The mean of $x$ is 2.
   (D) The standard deviation of $x$ is 1.41.
   (E) None of the above.

3. Which of the following statements is false(不正確的)?
   (A) The range, variance and standard deviation measure the variability of the data set.
   (B) The range gives you how wide the data set is and the advantage of using it is that it is easy to compute; a disadvantage is that it only uses the smallest and largest values of the data set.
   (C) An advantage of the variance is that it does take all of the values of the data set into account; a disadvantage is that it is harder to calculate than the range.
   (D) An advantage of standard deviation is that it is expressed in the original units of the problem so that it is easier to interpret than the variance; it takes all the observations into account and gives a measure of the distance the observations are from the mean.
   (E) None of the above.

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4. Which of the following statements is false(不正確的)?
   (A) The random variable $x$ in $p(x)=(0.4)^{x-1}(0.6)$, $(x=0,1,2,\ldots)$ is a geometric random variable.
   (B) The random variable $x$ in $p(x)=\frac{\binom{10}{x}\binom{15}{5-x}}{\binom{25}{5}}$, $(x=0,1,2,3,4,5)$ is a hypergeometric random variable.
   (C) The random variable $x$ in $p(x)=\binom{6}{x}(0.2)^{x}(0.8)^{6-x}$, $(x=0,1,2,3,4,5,6)$ is a binomial random variable.
   (D) The random variable $x$ in $p(x)=\frac{10!}{x!(10-x)!}(0.9)^{x}(0.1)^{10-x}$, $(x=0,1,2,\ldots,10)$ is a binomial random variable.
   (E) The random variable $x$ in $f(x)=\frac{\Gamma(r+\lambda)}{\Gamma(r)\Gamma(\lambda)}x^{r-1}(1-x)^{\lambda-1}$, $0<x<1,\ r>0,\ \lambda>0$ is said to have a gamma distribution.

5. $X$ is a random variable having a gamma distribution with parameters $r$ and $\lambda$, Suppose E($X$) = 2 and Var($X$) = 7, then
   (A) $r$ = 4/7, $\lambda$ = 2/7.
   (B) $r$ = 2, $\lambda$ = 7.
   (C) $r$ = 1/2, $\lambda$ = 7/4.
   (D) $r$ = -10/7, $\lambda$ = 5/7.
   (E) $r$ = 10/7, $\lambda$ = 5/7.

6. Let $X$ be a normal distributed variable with mean $\mu$ and variance $\sigma^2$. Consider the problem of estimating $\mu$ from a random sample of observations on $X_1, X_2, \ldots, X_n$. Three estimators are proposed.

$$\overline{X}=\frac{1}{n}\sum_{i=1}^{n}X_i \qquad \hat{\mu}=\frac{1}{n+1}\sum_{i=1}^{n}X_i \qquad \tilde{\mu}=\frac{1}{2}X_1+\frac{1}{2n}\sum_{i=2}^{n}X_i$$

   Which of the following statements is true(正確的)?
   (A) $\overline{X}$ and $\hat{\mu}$ satisfy the properties of unbiasedness and consistency; $\tilde{\mu}$ satisfies consistency.
   (B) All three estimators satisfy the properties of unbiasedness and consistency.
   (C) Only $\overline{X}$ satisfies the properties of unbiasedness and consistency; $\hat{\mu}$ and $\tilde{\mu}$

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satisfy consistency.

(D) Only $\overline{X}$ satisfies the properties of unbiasedness and consistency; $\hat{\mu}$ satisfies consistency while $\tilde{\mu}$ does not.

(E) Only $\overline{X}$ satisfies the properties of unbiasedness and consistency; $\tilde{\mu}$ satisfies consistency while $\hat{\mu}$ does not.

7. Refer to question 6, which of the following statements is true(正確的)?
   (A) Only $\overline{X}$ satisfies the property of asymptotic efficiency.
   (B) Only $\overline{X}$ and $\hat{\mu}$ satisfy the property of asymptotic efficiency.
   (C) Only $\overline{X}$ and $\tilde{\mu}$ satisfy the property of asymptotic efficiency.
   (D) Only $\hat{\mu}$ and $\tilde{\mu}$ satisfy the property of asymptotic efficiency.
   (E) All three estimators satisfy the property of asymptotic efficiency.

8. A store manager selling TV sets observes the following sales on 10 different days. Calculate the regression of $Y$ on $X$ where

$$Y = \text{number of TV sets sold}$$
$$X = \text{number of sales representatives}$$

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $Y$: | 3 | 6 | 10 | 5 | 10 | 12 | 5 | 10 | 10 | 8 |
| $X$: | 1 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 3 | 2 |

(A) The regression equation is $\hat{Y} = 1.40 + 0.08X$.
(B) The regression equation is $\hat{Y} = 5.90 + 1.00X$.
(C) The regression equation is $\hat{Y} = 1.40 - 0.08X$.
(D) The regression equation is $\hat{Y} = 5.90 + 0.08X$.
(E) None of the above.

9. Refer to question 8, the *t*-statistics for $\alpha$ and $\beta$ are
   (A) 2.27 and 0.81
   (B) 1.78 and 0.81
   (C) 2.27 and 0.18
   (D) 1.87 and 0.09
   (E) None of the above

10. Refer to question 8, the value of $R^2$ equals
    (A) 0.763　(C) 0.076　(E) 0.067
    (B) 0.061　(D) 0.241

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Ⅱ、單選題：（每題4分）

11. Which of the following methods of probability sampling is usually most efficient in a statistical sense?
    a. Cluster sampling.
    b. Stratified sampling.
    c. Simple random sampling.
    d. Two stage sampling.
12. In drawing a simple random sample, and determining how large a sample to take, which of the following factors is *not* considered?
    a. The estimated level of reliability.
    b. The variance of the population or sample.
    c. The desired interval range.
    d. The desired confidence level.
13. Probability sampling implies
    a. All elements have an equal chance of selection.
    b. The selected sample elements have an equal chance of selection, with respect to one another.
    c. All elements of the population have a known probability of selection.
    d. It is restricted since the probability of selection is restricted to less than one.
14. A stratified sample is of greatest statistical efficiency when
    a. The variances within strata are large.
    b. The variances within strata are small.
    c. The sample is a significant portion of the population.
    d. The sample is large.
15. Suppose you wish to draw a simple random sample of a population of college students. You will ask them whether they favor allocating a portion of their student fees to a certain program. You want to have a sample large enough to be confident, at the two sigma level, that the sample will be within a $\pm$ 2% of the true figure.
    Approximately what size sample would you use?
    a. 312
    b. 625
    c. 1250
    d. 2500

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※ 注意：請於試卷內之「非選擇題作答區」作答，並應註明作答之題號。

Ⅲ、計算題：

1. **EPA limits on vinyl chloride.** The EPA sets an airborne limit of 5 part per million (ppm) on vinyl chloride, a colorless gas used to make plastics, adhesives, and other chemicals. It is both a carcinogen and a mutagen. A major plastics manufacturer, attempting to control the amount of vinyl chloride its workers are exposed to, has given instructions to halt production if the mean amount of vinyl chloride in the air exceeds 3.0 ppm. A random sample of 50 air specimens produced the following statistics: $\bar{x} = 3.1$ ppm, $s = .5$ ppm.
   a. Do these statistics provide sufficient evidence to halt the production process? Use $\alpha = .01$. (5分)
   b. If you were the plant manager, would you want to use a large or a small value for $\alpha$ for the test in part a? Explain. (5分)
   c. Find the $p$-value for the test and interpret its value. (5分)

2. **Likelihood of getting a routine medical checkup.** Who is more likely to get a routine medical checkup, employed or unemployed people? To answer this question, a team of physicians and public health professors collected data on a sample of over 2,200 individuals. Of the 1,140 individuals who were employed, 642 visited a physician for a routine checkup within the past year. In contrast, 740 of the 1,160 unemployed individuals had a routine medical checkup within the past year.
   a. Set up the null and alternative hypotheses for testing whether there is a difference between the percentages of employed and unemployed people who had a recent routine medical checkup. (3分)
   b. Compute the test statistic for the test. (3分)
   c. Give the rejection region for the test using $\alpha = .01$. (3分)
   d. The research team reported the p-value for the as $\approx 0$. Do you agree? (3分)
   e. Make the appropriate conclusion. (3分)

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**Areas under the Standard Normal Curve from 0 to *z***

| $z$ | 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 | 0.0398 | 0.0438 | 0.0478 | 0.0517 | 0.0557 | 0.0596 | 0.0636 | 0.0675 | 0.0714 | 0.0753 |
| 0.2 | 0.0793 | 0.0832 | 0.0871 | 0.0910 | 0.0948 | 0.0987 | 0.1026 | 0.1064 | 0.1103 | 0.1141 |
| 0.3 | 0.1179 | 0.1217 | 0.1255 | 0.1293 | 0.1331 | 0.1368 | 0.1406 | 0.1443 | 0.1480 | 0.1517 |
| 0.4 | 0.1554 | 0.1591 | 0.1628 | 0.1664 | 0.1700 | 0.1736 | 0.1772 | 0.1808 | 0.1844 | 0.1879 |
| 0.5 | 0.1915 | 0.1950 | 0.1985 | 0.2019 | 0.2054 | 0.2088 | 0.2123 | 0.2157 | 0.2190 | 0.2224 |
| 0.6 | 0.2257 | 0.2291 | 0.2324 | 0.2357 | 0.2389 | 0.2422 | 0.2454 | 0.2486 | 0.2518 | 0.2549 |
| 0.7 | 0.2580 | 0.2612 | 0.2642 | 0.2673 | 0.2704 | 0.2734 | 0.2764 | 0.2794 | 0.2823 | 0.2852 |
| 0.8 | 0.2881 | 0.2910 | 0.2939 | 0.2967 | 0.2995 | 0.3023 | 0.3051 | 0.3078 | 0.3106 | 0.3133 |
| 0.9 | 0.3159 | 0.3186 | 0.3212 | 0.3238 | 0.3264 | 0.3289 | 0.3315 | 0.3340 | 0.3365 | 0.3389 |
| 1.0 | 0.3413 | 0.3438 | 0.3461 | 0.3485 | 0.3508 | 0.3531 | 0.3554 | 0.3577 | 0.3599 | 0.3621 |
| 1.1 | 0.3643 | 0.3665 | 0.3686 | 0.3708 | 0.3729 | 0.3749 | 0.3770 | 0.3790 | 0.3810 | 0.3830 |
| 1.2 | 0.3849 | 0.3869 | 0.3888 | 0.3907 | 0.3925 | 0.3944 | 0.3962 | 0.3980 | 0.3997 | 0.4015 |
| 1.3 | 0.4032 | 0.4049 | 0.4066 | 0.4082 | 0.4099 | 0.4115 | 0.4131 | 0.4147 | 0.4162 | 0.4177 |
| 1.4 | 0.4192 | 0.4207 | 0.4222 | 0.4236 | 0.4251 | 0.4265 | 0.4279 | 0.4292 | 0.4306 | 0.4319 |
| 1.5 | 0.4332 | 0.4345 | 0.4357 | 0.4370 | 0.4382 | 0.4394 | 0.4406 | 0.4418 | 0.4429 | 0.4441 |
| 1.6 | 0.4452 | 0.4463 | 0.4474 | 0.4484 | 0.4495 | 0.4505 | 0.4515 | 0.4525 | 0.4535 | 0.4545 |
| 1.7 | 0.4554 | 0.4564 | 0.4573 | 0.4582 | 0.4591 | 0.4599 | 0.4608 | 0.4616 | 0.4625 | 0.4633 |
| 1.8 | 0.4641 | 0.4649 | 0.4656 | 0.4664 | 0.4671 | 0.4678 | 0.4686 | 0.4693 | 0.4699 | 0.4706 |
| 1.9 | 0.4713 | 0.4719 | 0.4726 | 0.4732 | 0.4738 | 0.4744 | 0.4750 | 0.4756 | 0.4761 | 0.4767 |
| 2.0 | 0.4772 | 0.4778 | 0.4783 | 0.4788 | 0.4793 | 0.4798 | 0.4803 | 0.4808 | 0.4812 | 0.4817 |
| 2.1 | 0.4821 | 0.4826 | 0.4830 | 0.4834 | 0.4838 | 0.4842 | 0.4846 | 0.4850 | 0.4854 | 0.4857 |
| 2.2 | 0.4861 | 0.4864 | 0.4868 | 0.4871 | 0.4875 | 0.4878 | 0.4881 | 0.4884 | 0.4887 | 0.4890 |
| 2.3 | 0.4893 | 0.4896 | 0.4898 | 0.4901 | 0.4904 | 0.4906 | 0.4909 | 0.4911 | 0.4913 | 0.4916 |
| 2.4 | 0.4918 | 0.4920 | 0.4922 | 0.4925 | 0.4927 | 0.4929 | 0.4931 | 0.4932 | 0.4934 | 0.4936 |
| 2.5 | 0.4938 | 0.4940 | 0.4941 | 0.4943 | 0.4945 | 0.4946 | 0.4948 | 0.4949 | 0.4951 | 0.4952 |
| 2.6 | 0.4953 | 0.4955 | 0.4956 | 0.4957 | 0.4959 | 0.4960 | 0.4961 | 0.4962 | 0.4963 | 0.4964 |
| 2.7 | 0.4965 | 0.4966 | 0.4967 | 0.4968 | 0.4969 | 0.4970 | 0.4971 | 0.4972 | 0.4973 | 0.4974 |
| 2.8 | 0.4974 | 0.4975 | 0.4976 | 0.4977 | 0.4977 | 0.4978 | 0.4979 | 0.4979 | 0.4980 | 0.4981 |
| 2.9 | 0.4981 | 0.4982 | 0.4982 | 0.4983 | 0.4984 | 0.4984 | 0.4985 | 0.4985 | 0.4986 | 0.4986 |
| 3.0 | 0.49865 | 0.4987 | 0.4987 | 0.4988 | 0.4988 | 0.4989 | 0.4989 | 0.4989 | 0.4990 | 0.4990 |
| 4.0 | 0.49997 | | | | | | | | | |

*Note:* If $z = 0.93$, $p(0 \le Z \le z) = 0.3238$.

*Source: Statistical Analysis for Decision Making*, Morris Hamburg, 4th edition, 1987. Reprinted with the permission of Harcourt Brace College Publishers.

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Percentage Points of the *t*-Distribution

| d.f. | 1T = 0.4<br>2T = 0.8 | 0.25<br>0.5 | 0.1<br>0.2 | 0.05<br>0.1 | 0.025<br>0.05 | 0.01<br>0.02 | 0.005<br>0.01 | 0.0025<br>0.005 | 0.001<br>0.002 | 0.0005<br>0.001 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0.325 | 1.000 | 3.078 | 6.314 | 12.706 | 31.821 | 63.657 | 127.32 | 318.31 | 636.62 |
| 2 | .289 | 0.816 | 1.886 | 2.920 | 4.303 | 6.965 | 9.925 | 14.089 | 22.327 | 31.598 |
| 3 | .277 | .765 | 1.638 | 2.353 | 3.182 | 4.541 | 5.841 | 7.453 | 10.214 | 12.924 |
| 4 | .271 | .741 | 1.533 | 2.132 | 2.776 | 3.747 | 4.604 | 5.598 | 7.173 | 8.610 |
| 5 | 0.267 | 0.727 | 1.476 | 2.015 | 2.571 | 3.365 | 4.032 | 4.773 | 5.893 | 6.869 |
| 6 | .265 | .718 | 1.440 | 1.943 | 2.447 | 3.143 | 3.707 | 4.317 | 5.208 | 5.959 |
| 7 | .263 | .711 | 1.415 | 1.895 | 2.365 | 2.998 | 3.499 | 4.029 | 4.785 | 5.408 |
| 8 | .262 | .706 | 1.397 | 1.860 | 2.306 | 2.896 | 3.355 | 3.833 | 4.501 | 5.041 |
| 9 | .261 | .703 | 1.383 | 1.833 | 2.262 | 2.821 | 3.250 | 3.690 | 4.297 | 4.781 |
| 10 | 0.260 | 0.700 | 1.372 | 1.812 | 2.228 | 2.764 | 3.169 | 3.581 | 4.144 | 4.587 |
| 11 | .260 | .697 | 1.363 | 1.796 | 2.201 | 2.718 | 3.106 | 3.497 | 4.025 | 4.437 |
| 12 | .259 | .695 | 1.356 | 1.782 | 2.179 | 2.681 | 3.055 | 3.428 | 3.930 | 4.318 |
| 13 | .259 | .694 | 1.350 | 1.771 | 2.160 | 2.650 | 3.012 | 3.372 | 3.852 | 4.221 |
| 14 | .258 | .692 | 1.345 | 1.761 | 2.145 | 2.624 | 2.977 | 3.326 | 3.787 | 4.140 |
| 15 | 0.258 | 0.691 | 1.341 | 1.753 | 2.131 | 2.602 | 2.947 | 3.286 | 3.733 | 4.073 |
| 16 | .258 | .690 | 1.337 | 1.746 | 2.120 | 2.583 | 2.921 | 3.252 | 3.686 | 4.015 |
| 17 | .257 | .689 | 1.333 | 1.740 | 2.110 | 2.567 | 2.898 | 3.222 | 3.646 | 3.965 |
| 18 | .257 | .688 | 1.330 | 1.734 | 2.101 | 2.552 | 2.878 | 3.197 | 3.610 | 3.922 |
| 19 | .257 | .688 | 1.328 | 1.729 | 2.093 | 2.539 | 2.861 | 3.174 | 3.579 | 3.883 |
| 20 | 0.257 | 0.687 | 1.325 | 1.725 | 2.086 | 2.528 | 2.845 | 3.153 | 3.552 | 3.850 |
| 21 | .257 | .686 | 1.323 | 1.721 | 2.080 | 2.518 | 2.831 | 3.135 | 3.527 | 3.819 |
| 22 | .256 | .686 | 1.321 | 1.717 | 2.074 | 2.508 | 2.819 | 3.119 | 3.505 | 3.792 |
| 23 | .256 | .685 | 1.319 | 1.714 | 2.069 | 2.500 | 2.807 | 3.104 | 3.485 | 3.767 |
| 24 | .256 | .685 | 1.318 | 1.711 | 2.064 | 2.492 | 2.797 | 3.091 | 3.467 | 3.745 |
| 25 | 0.256 | 0.684 | 1.316 | 1.708 | 2.060 | 2.485 | 2.787 | 3.078 | 3.450 | 3.725 |
| 26 | .256 | .684 | 1.315 | 1.706 | 2.056 | 2.479 | 2.779 | 3.067 | 3.435 | 3.707 |
| 27 | .256 | .684 | 1.314 | 1.703 | 2.052 | 2.473 | 2.771 | 3.057 | 3.421 | 3.690 |
| 28 | .256 | .683 | 1.313 | 1.701 | 2.048 | 2.467 | 2.763 | 3.047 | 3.408 | 3.674 |
| 29 | .256 | .683 | 1.311 | 1.699 | 2.045 | 2.462 | 2.756 | 3.038 | 3.396 | 3.659 |
| 30 | 0.256 | 0.683 | 1.310 | 1.697 | 2.042 | 2.457 | 2.750 | 3.030 | 3.385 | 3.646 |
| 40 | .255 | .681 | 1.303 | 1.684 | 2.021 | 2.423 | 2.704 | 2.971 | 3.307 | 3.551 |
| 60 | .254 | .679 | 1.296 | 1.671 | 2.000 | 2.390 | 2.660 | 2.915 | 3.232 | 3.460 |
| 120 | .254 | .677 | 1.289 | 1.658 | 1.980 | 2.358 | 2.617 | 2.860 | 3.160 | 3.373 |
| ∞ | .253 | .674 | 1.282 | 1.645 | 1.960 | 2.326 | 2.576 | 2.807 | 3.090 | 3.291 |

*Note:* 1T = area under one tail; 2T = area under both tails.
For 25 degrees of freedom (d.f.), $P(t > 2.060) = 0.025$ and $P(t < -2.060 \text{ or } t > 2.060) = 0.05$.

*Source: Biometrika Tables for Statisticians*, Vol. I. Edited by E. S. Pearson and H. O. Hartley, 3rd edition, 1966.


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**Upper Percentage Points of the Chi-Square Distribution**
**($\nu$ is the Degrees of Freedom and $Q$ is the Area in the Right Tail)**

| $\nu$ \ $Q$ | 0.250 | 0.100 | 0.050 | 0.025 | 0.010 | 0.005 | 0.001 |
|---|---|---|---|---|---|---|---|
| 1 | 1.32330 | 2.70554 | 3.84146 | 5.02389 | 6.63490 | 7.87944 | 10.828 |
| 2 | 2.77259 | 4.60517 | 5.99146 | 7.37776 | 9.21034 | 10.5966 | 13.816 |
| 3 | 4.10834 | 6.25139 | 7.81473 | 9.34840 | 11.3449 | 12.8382 | 16.266 |
| 4 | 5.38527 | 7.77944 | 9.48773 | 11.1433 | 13.2767 | 14.8603 | 18.467 |
| 5 | 6.62568 | 9.23636 | 11.0705 | 12.8325 | 15.0863 | 16.7496 | 20.515 |
| 6 | 7.84080 | 10.6446 | 12.5916 | 14.4494 | 16.8119 | 18.5476 | 22.458 |
| 7 | 9.03715 | 12.0170 | 14.0671 | 16.0128 | 18.4753 | 20.2777 | 24.322 |
| 8 | 10.2189 | 13.3616 | 15.5073 | 17.5345 | 20.0902 | 21.9550 | 26.125 |
| 9 | 11.3888 | 14.6837 | 16.9190 | 19.0228 | 21.6660 | 23.5894 | 27.877 |
| 10 | 12.5489 | 15.9872 | 18.3070 | 20.4832 | 23.2093 | 25.1882 | 29.588 |
| 11 | 13.7007 | 17.2750 | 19.6751 | 21.9200 | 24.7250 | 26.7568 | 31.264 |
| 12 | 14.8454 | 18.5493 | 21.0261 | 23.3367 | 26.2170 | 28.2995 | 32.909 |
| 13 | 15.9839 | 19.8119 | 22.3620 | 24.7356 | 27.6882 | 29.8195 | 34.528 |
| 14 | 17.1169 | 21.0641 | 23.6848 | 26.1189 | 29.1412 | 31.3194 | 36.123 |
| 15 | 18.2451 | 22.3071 | 24.9958 | 27.4884 | 30.5779 | 32.8013 | 37.697 |
| 16 | 19.3689 | 23.5418 | 26.2962 | 28.8454 | 31.9999 | 34.2672 | 39.252 |
| 17 | 20.4887 | 24.7690 | 28.5871 | 30.1910 | 33.4087 | 35.7185 | 40.790 |
| 18 | 21.6049 | 25.9894 | 28.8693 | 31.5264 | 34.8053 | 37.1565 | 42.312 |
| 19 | 22.7178 | 27.2036 | 30.1435 | 32.8523 | 36.1909 | 38.5823 | 43.820 |
| 20 | 23.8277 | 28.4120 | 31.4104 | 34.1696 | 37.5662 | 39.9968 | 45.315 |
| 21 | 24.9348 | 29.6151 | 32.6706 | 35.4789 | 38.9322 | 41.4011 | 46.797 |
| 22 | 26.0393 | 30.8133 | 33.9244 | 36.7807 | 40.2894 | 42.7957 | 48.268 |
| 23 | 27.1413 | 32.0069 | 35.1725 | 38.0756 | 41.6384 | 44.1813 | 49.728 |
| 24 | 28.2412 | 33.1962 | 36.4150 | 39.3641 | 42.9798 | 45.5585 | 51.179 |
| 25 | 29.3389 | 34.3816 | 37.6525 | 40.6465 | 44.3141 | 46.9279 | 52.618 |
| 26 | 30.4346 | 35.5632 | 38.8851 | 41.9232 | 45.6417 | 48.2899 | 54.052 |
| 27 | 31.5284 | 36.7412 | 40.1133 | 43.1945 | 46.9629 | 49.6449 | 55.476 |
| 28 | 32.6205 | 37.9159 | 41.3371 | 44.4608 | 48.2782 | 50.9934 | 56.892 |
| 29 | 33.7109 | 39.0875 | 42.5570 | 45.7223 | 49.5879 | 52.3356 | 58.301 |
| 30 | 34.7997 | 40.2560 | 43.7730 | 46.9792 | 50.8922 | 53.6720 | 59.703 |
| 40 | 45.6160 | 51.8051 | 55.7585 | 59.3417 | 63.6907 | 66.7660 | 73.402 |
| 50 | 56.3336 | 63.1671 | 67.5048 | 71.4202 | 76.1539 | 79.4900 | 86.661 |
| 60 | 66.9815 | 74.3970 | 79.0819 | 83.2977 | 88.3794 | 91.9517 | 99.607 |
| 70 | 77.5767 | 85.5270 | 90.5312 | 95.0232 | 100.425 | 104.215 | 112.317 |
| 80 | 88.1303 | 96.5782 | 101.879 | 106.629 | 112.329 | 116.321 | 124.839 |
| 90 | 98.6499 | 107.565 | 113.145 | 118.136 | 124.116 | 128.299 | 137.208 |
| 100 | 109.141 | 118.498 | 124.342 | 129.561 | 135.807 | 140.169 | 149.449 |
| $X$ | +0.6745 | +1.2816 | +1.6449 | +1.9600 | +2.3263 | +2.5758 | +3.0902 |

*Note:* For 25 d.f., $P(\chi^2 > 37.6525) = 0.05$.
For $\nu > 100$ take

$$\chi^2 = \nu\left\{1 - \frac{2}{9\nu} + X\sqrt{\frac{2}{9\nu}}\right\}^3 \quad \text{or} \quad \chi^2 = \tfrac{1}{2}\{X + \sqrt{(2\nu - 1)}\}^2,$$

according to the degree of accuracy required. $X$ is the standardized normal deviate corresponding to $P = 1 - Q$ and is shown in the bottom line of the table.

*Source: Biometrika Tables for Statisticians*. Vol. I. Edited by E. S. Pearson and H. O. Hartley, 3rd edition, 1966. Reprinted with the permission of the Biometrika Trustees.

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**Upper 5% Points of the *F*-Distribution**

| n \ m | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 15 | 20 | 24 | 30 | 40 | 60 | 120 | ∞ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 161.4 | 199.5 | 215.7 | 224.6 | 230.2 | 234.0 | 236.8 | 238.9 | 240.5 | 241.9 | 243.9 | 245.9 | 248.0 | 249.1 | 250.1 | 251.1 | 252.2 | 253.3 | 254.3 |
| 2 | 18.51 | 19.00 | 19.16 | 19.25 | 19.30 | 19.33 | 19.35 | 19.37 | 19.38 | 19.40 | 19.41 | 19.43 | 19.45 | 19.45 | 19.46 | 19.47 | 19.48 | 19.49 | 19.50 |
| 3 | 10.13 | 9.55 | 9.28 | 9.12 | 9.01 | 8.94 | 8.89 | 8.85 | 8.81 | 8.79 | 8.74 | 8.70 | 8.66 | 8.64 | 8.62 | 8.59 | 8.57 | 8.55 | 8.53 |
| 4 | 7.71 | 6.94 | 6.59 | 6.39 | 6.26 | 6.16 | 6.09 | 6.04 | 6.00 | 5.96 | 5.91 | 5.86 | 5.80 | 5.77 | 5.75 | 5.72 | 5.69 | 5.66 | 6.63 |
| 5 | 6.61 | 5.79 | 5.41 | 5.19 | 5.05 | 4.95 | 4.88 | 4.82 | 4.77 | 4.74 | 4.68 | 4.62 | 4.56 | 4.53 | 4.50 | 4.46 | 4.43 | 4.40 | 4.36 |
| 6 | 5.99 | 5.14 | 4.76 | 4.53 | 4.39 | 4.28 | 4.21 | 4.15 | 4.10 | 4.06 | 4.00 | 3.94 | 3.87 | 3.84 | 3.81 | 3.77 | 3.74 | 3.70 | 3.67 |
| 7 | 5.59 | 4.74 | 4.35 | 4.12 | 3.97 | 3.87 | 3.79 | 3.73 | 3.68 | 3.64 | 3.57 | 3.51 | 3.44 | 3.41 | 3.38 | 3.34 | 3.30 | 3.27 | 3.23 |
| 8 | 5.32 | 4.46 | 4.07 | 3.84 | 3.69 | 3.58 | 3.50 | 3.44 | 3.39 | 3.35 | 3.28 | 3.22 | 3.15 | 3.12 | 3.08 | 3.04 | 3.01 | 2.97 | 2.93 |
| 9 | 5.12 | 4.26 | 3.86 | 3.63 | 3.48 | 3.37 | 3.29 | 3.23 | 3.18 | 3.14 | 3.07 | 3.01 | 2.94 | 2.90 | 2.86 | 2.83 | 2.79 | 2.75 | 2.71 |
| 10 | 4.96 | 4.10 | 3.71 | 3.48 | 3.33 | 3.22 | 3.14 | 3.07 | 3.02 | 2.98 | 2.91 | 2.85 | 2.77 | 2.74 | 2.70 | 2.66 | 2.62 | 2.58 | 2.54 |
| 11 | 4.84 | 3.98 | 3.59 | 3.36 | 3.20 | 3.09 | 3.01 | 2.95 | 2.90 | 2.85 | 2.79 | 2.72 | 2.65 | 2.61 | 2.57 | 2.53 | 2.49 | 2.45 | 2.40 |
| 12 | 4.75 | 3.89 | 3.49 | 3.26 | 3.11 | 3.00 | 2.91 | 2.85 | 2.80 | 2.75 | 2.69 | 2.62 | 2.54 | 2.51 | 3.47 | 2.43 | 2.38 | 2.34 | 2.30 |
| 13 | 4.67 | 3.81 | 3.41 | 3.18 | 3.03 | 2.92 | 2.83 | 2.77 | 2.71 | 2.67 | 2.60 | 2.53 | 2.46 | 2.42 | 2.38 | 2.34 | 2.30 | 2.25 | 2.21 |
| 14 | 4.60 | 3.74 | 3.34 | 3.11 | 2.96 | 2.85 | 2.76 | 2.70 | 2.65 | 2.60 | 2.53 | 2.46 | 2.39 | 2.35 | 2.31 | 2.27 | 2.22 | 2.18 | 2.13 |
| 15 | 4.54 | 3.68 | 3.29 | 3.06 | 2.90 | 2.79 | 2.71 | 2.64 | 2.59 | 2.54 | 2.48 | 2.40 | 2.33 | 2.29 | 2.25 | 2.20 | 2.16 | 2.11 | 2.07 |
| 16 | 4.49 | 3.63 | 3.24 | 3.01 | 2.85 | 2.74 | 2.66 | 2.59 | 2.54 | 2.49 | 2.42 | 2.35 | 2.28 | 2.24 | 2.19 | 2.15 | 2.11 | 2.06 | 2.01 |
| 17 | 4.45 | 3.59 | 3.20 | 2.96 | 2.81 | 2.70 | 2.61 | 2.55 | 2.49 | 2.45 | 2.38 | 2.31 | 2.23 | 2.19 | 2.15 | 2.10 | 2.06 | 2.01 | 1.96 |
| 18 | 4.41 | 3.55 | 3.16 | 2.93 | 2.77 | 2.66 | 2.58 | 2.51 | 2.46 | 2.41 | 2.34 | 2.27 | 2.19 | 2.15 | 2.11 | 2.06 | 2.02 | 1.97 | 1.92 |
| 19 | 4.38 | 3.52 | 3.13 | 2.90 | 2.74 | 2.63 | 2.54 | 2.48 | 2.42 | 2.38 | 2.31 | 2.23 | 2.16 | 2.11 | 2.07 | 2.03 | 1.98 | 1.93 | 1.88 |
| 20 | 4.35 | 3.49 | 3.10 | 2.87 | 2.71 | 2.60 | 2.51 | 2.45 | 2.39 | 2.35 | 2.28 | 2.20 | 2.12 | 2.08 | 2.04 | 1.99 | 1.95 | 1.90 | 1.84 |
| 21 | 4.32 | 3.47 | 3.07 | 2.84 | 3.68 | 2.57 | 2.49 | 2.42 | 2.37 | 2.32 | 2.25 | 2.18 | 2.10 | 2.05 | 2.01 | 1.96 | 1.92 | 1.87 | 1.81 |
| 22 | 4.30 | 3.44 | 3.05 | 2.82 | 2.66 | 2.55 | 2.46 | 2.40 | 2.34 | 2.30 | 2.23 | 2.15 | 2.07 | 2.03 | 1.98 | 1.94 | 1.89 | 1.84 | 1.78 |
| 23 | 4.28 | 3.42 | 3.03 | 2.80 | 2.64 | 2.53 | 2.44 | 2.37 | 2.32 | 2.27 | 2.20 | 2.13 | 2.05 | 2.01 | 1.96 | 1.91 | 1.86 | 1.81 | 1.76 |
| 24 | 4.26 | 3.40 | 3.01 | 2.78 | 2.62 | 2.51 | 2.42 | 2.36 | 2.30 | 2.25 | 2.18 | 2.11 | 2.03 | 1.98 | 1.94 | 1.89 | 1.84 | 1.79 | 1.73 |
| 25 | 4.24 | 3.39 | 2.99 | 2.76 | 2.60 | 2.49 | 2.40 | 2.34 | 2.28 | 2.24 | 2.16 | 2.09 | 2.01 | 1.96 | 1.92 | 1.87 | 1.82 | 1.77 | 1.71 |
| 26 | 4.23 | 3.37 | 2.98 | 2.74 | 2.59 | 2.47 | 2.39 | 2.32 | 2.27 | 2.22 | 2.15 | 2.07 | 1.99 | 1.95 | 1.90 | 1.85 | 1.80 | 1.75 | 1.69 |
| 27 | 4.21 | 3.35 | 2.96 | 2.73 | 2.57 | 2.46 | 2.37 | 2.31 | 2.25 | 2.20 | 2.13 | 2.06 | 1.97 | 1.93 | 1.88 | 1.84 | 1.79 | 1.73 | 1.67 |
| 28 | 4.20 | 3.34 | 2.95 | 2.71 | 2.56 | 2.45 | 2.36 | 2.29 | 2.24 | 2.19 | 2.12 | 2.04 | 1.96 | 1.91 | 1.87 | 1.82 | 1.77 | 1.71 | 1.65 |
| 29 | 4.18 | 3.33 | 2.93 | 2.70 | 2.55 | 2.43 | 2.35 | 2.28 | 2.22 | 2.18 | 2.10 | 2.03 | 1.94 | 1.90 | 1.85 | 1.81 | 1.75 | 1.70 | 1.64 |
| 30 | 4.17 | 3.32 | 2.92 | 2.69 | 2.53 | 2.42 | 2.33 | 2.27 | 2.21 | 2.16 | 2.09 | 2.01 | 1.93 | 1.89 | 1.84 | 1.79 | 1.74 | 1.68 | 1.62 |
| 40 | 4.08 | 3.23 | 2.84 | 2.61 | 2.45 | 2.34 | 2.25 | 2.18 | 2.12 | 2.08 | 2.00 | 1.92 | 1.84 | 1.79 | 1.74 | 1.69 | 1.64 | 1.58 | 1.51 |
| 60 | 4.00 | 3.15 | 2.76 | 2.53 | 2.37 | 2.25 | 2.17 | 2.10 | 2.04 | 1.99 | 1.92 | 1.84 | 1.75 | 1.70 | 1.65 | 1.59 | 1.53 | 1.47 | 1.39 |
| 120 | 3.92 | 3.07 | 2.68 | 2.45 | 2.29 | 2.17 | 2.09 | 2.02 | 1.96 | 1.91 | 1.83 | 1.75 | 1.66 | 1.61 | 1.55 | 1.50 | 1.43 | 1.35 | 1.25 |
| ∞ | 3.84 | 3.00 | 2.60 | 2.37 | 2.21 | 2.10 | 2.01 | 1.94 | 1.88 | 1.83 | 1.75 | 1.67 | 1.57 | 1.52 | 1.46 | 1.39 | 1.32 | 1.22 | 1.00 |

*Note:* $m$ = degrees of freedom for the numerator
$n$ = degrees of freedom for the denominator

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