

## Everything you've always wanted to know about hypothesis testing

$$\text{(Test Statistic}^* = \frac{\text{(estimator)} - \text{hypothesized value}}{\text{standard error}})$$

Null Hypothesis	Estimator (Statistic)	Sampling Dist. Std. Dev.	Sampling Dist. Std. Error	Conditions for use	Test Statistic
$H_0: \mu = \mu_0$	$\bar{x}$	$\frac{\sigma}{\sqrt{n}}$	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$	Large random sample: ( $n \geq 30$ )	$z^* = \frac{\bar{x} - \mu_0}{s/\sqrt{n}}$
<p><b>Note: Paired samples (dependent samples) are a special case of one-sample statistics (<math>H_0: \mu_d = 0</math>)</b></p>					
$H_0: p = p_0$	$\hat{p} = \frac{X}{n}$	$\sqrt{\frac{p(1-p)}{n}}$	$s_{\hat{p}} = \sqrt{\frac{p_0(1-p_0)}{n}}$	Random Sample $np_0 \geq 5, n(1-p_0) \geq 5$	$z^* = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}}$
$H_0: \mu_1 - \mu_2 = 0$ or $H_0: \mu_1 = \mu_2$ (independent samples)	$\bar{x}_1 - \bar{x}_2$	$\sqrt{\frac{\sigma_1^2 + \sigma_2^2}{n_1} + \frac{\sigma_2^2}{n_2}}$	$s_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$	Large random samples ( $n_1 \geq 30$ and $n_2 \geq 30$ )	$z^* = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$
		$\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$	$s_{\bar{x}_1 - \bar{x}_2} = \sqrt{2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$ $s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$	Small samples ( $\sigma_1^2 = \sigma_2^2, n_1 < 30$ or $n_2 < 30$ , two random samples from independent approximately normal populations)	$t^* = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{s_p^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}}$ , d.f. = $n_1 + n_2 - 2$
$H_0: p_1 - p_2 = 0$ or $H_0: p_1 = p_2$	$\hat{p}_1 - \hat{p}_2$	$\sqrt{p(1-p) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$	$s_{\hat{p}_1 - \hat{p}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$	Small sample ( $\sigma_1^2 = \sigma_2^2$ , two random samples from approximately normal populations)	$t^* = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$ d.f. = $n_1 + n_2 - 2$ ( $n_1 = n_2$ ), d.f. = (software) ( $n_1 = n_2$ ) or $\min\{n_1 - 1, n_2 - 1\}$
		$\sqrt{p(1-p) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$	$s_{\hat{p}_1 - \hat{p}_2} = \sqrt{\hat{p}(1-\hat{p}) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$ where $\hat{p} = \frac{\bar{x}_1 + \bar{x}_2}{n_1 + n_2}$	$n_1 \hat{p}_1 \geq 5, n_1(1-\hat{p}_1) \geq 5$ $n_2 \hat{p}_2 \geq 5, n_2(1-\hat{p}_2) \geq 5$	$z^* = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}(1-\hat{p}) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}}$
$H_0: \beta_1 = 0$	$\hat{\beta}_1$ (OR: $b$ )	$\sigma_{\hat{\beta}_1}$	$s_{\hat{\beta}_1}$ (from computer printout - shows as "Stdev" for predictor variable)	For each $x$ , the corresponding values of $y$ are normally distributed and all have the same standard deviation. The mean values of the $y$ 's lie on a line.	$t^* = \frac{\hat{\beta}_1}{s_{\hat{\beta}_1}}$ , d.f. = $n - 2$

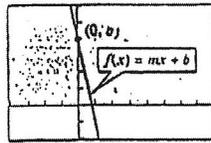
# Everything you've always wanted to know about confidence intervals.

(CI = (estimator) ± (margin of error)  
 = (estimator) ± (critical value)(standard error) )

Parameter	Estimator (Statistic)	Sampling Dist. Std. Dev.	Sampling Dist. Std. Error	Conditions for use	Critical Value	Confidence Interval
$\mu$	$\bar{x}$	$\frac{\sigma}{\sqrt{n}}$	$s_{\bar{x}} = \frac{s}{\sqrt{n}}$	Large random sample: ( $n \geq 30$ )	$z_{\alpha/2}$	$\bar{x} \pm z_{\alpha/2} \frac{s}{\sqrt{n}}$
				Small random sample: ( $n < 30$ , parent population approximately normal)	$t_{\alpha/2}$	$\bar{x} \pm t_{\alpha/2} \frac{s}{\sqrt{n}}$ d.f. = $n - 1$
<b>Note: Paired samples (dependent samples) are a special case of one-sample statistics</b>						
$p$	$\hat{p} = \frac{X}{n}$	$\sqrt{\frac{p(1-p)}{n}}$	$s_{\hat{p}} = \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$	Random sample $n\hat{p} \geq 5, n(1-\hat{p}) \geq 5$	$z_{\alpha/2}$	$\hat{p} \pm z_{\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$
$\mu_1 - \mu_2$ (independent samples)	$\bar{x}_1 - \bar{x}_2$	$\sqrt{\frac{\sigma_1^2}{n_1} + \frac{\sigma_2^2}{n_2}}$	$s_{\bar{x}_1 - \bar{x}_2} = \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$	Large random sample ( $n_1 \geq 30$ and $n_2 \geq 30$ )	$z_{\alpha/2}$	$(\bar{x}_1 - \bar{x}_2) \pm z_{\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$
			$s_p^2 = \frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}$ $s_{\bar{x}_1 - \bar{x}_2} = \sqrt{2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right) s_p^2}$	Small sample ( $\sigma_1^2 = \sigma_2^2, n_1 < 30$ or $n_2 < 30$ , two random samples drawn from independent, approximately normal populations) Small sample ( $\sigma_1^2 \neq \sigma_2^2$ , two random samples drawn from independent, approximately normal populations)	$t_{\alpha/2}$	$(\bar{x}_1 - \bar{x}_2) \pm t_{\alpha/2} \sqrt{s_p^2 \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}$ d.f. = $n_1 + n_2 - 2$
$p_1 - p_2$	$\hat{p}_1 - \hat{p}_2$	$\sqrt{\frac{p_1(1-p_1)}{n_1} + \frac{p_2(1-p_2)}{n_2}}$	$s_{\hat{p}_1 - \hat{p}_2} = \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$	Random samples $n_1\hat{p}_1 \geq 5, n_1(1-\hat{p}_1) \geq 5$ $n_2\hat{p}_2 \geq 5, n_2(1-\hat{p}_2) \geq 5$	$z_{\alpha/2}$	$(\hat{p}_1 - \hat{p}_2) \pm z_{\alpha/2} \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$ or $min(n_1 - 1, n_2 - 1)$
$\beta_1$ (slope of regression line)	$\hat{\beta}_1$	$\sigma_{\hat{\beta}_1}$	$s_{\hat{\beta}_1}$ (from computer printout - shows as "Stdev" for predictor variable)	For each $x$ , the corresponding values of $y$ are normally distributed and all have the same standard deviation. The mean values of the $y$ 's lie on a line.	$t_{\alpha/2}$	$\hat{\beta}_1 \pm t_{\alpha/2} s_{\hat{\beta}_1}, d.f. = n - 2$

**Linear Function**

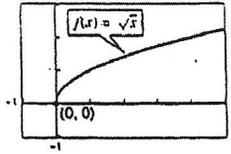
$f(x) = mx + b$



Domain:  $(-\infty, \infty)$   
 Range:  $(-\infty, \infty)$   
 y-intercept:  $(0, b)$

**Square Root Function**

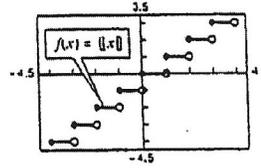
$f(x) = \sqrt{x}$



Domain:  $(0, \infty)$   
 Range:  $(0, \infty)$   
 Intercept:  $(0, 0)$

**Greatest Integer Function**

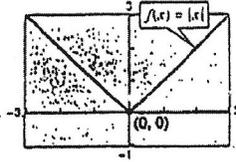
$f(x) = \lfloor x \rfloor$



Domain:  $(-\infty, \infty)$   
 Range: all integers  
 Intercept:  $(0, 0)$

**Absolute Value Function**

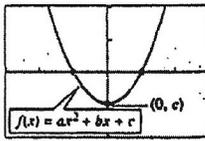
$f(x) = |x|$



Domain:  $(-\infty, \infty)$   
 Range:  $(0, \infty)$   
 Intercept:  $(0, 0)$

**Quadratic Function**

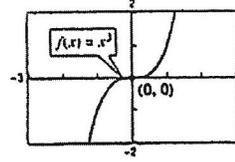
$f(x) = ax^2 + bx + c$



Domain:  $(-\infty, \infty)$   
 Range:  $(-\infty, \infty)$   
 y-intercept:  $(0, c)$   
 x-intercept:  
 $\left( \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}, 0 \right)$

**Cubing Function**

$f(x) = x^3$

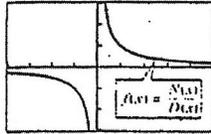


Domain:  $(-\infty, \infty)$   
 Range:  $(-\infty, \infty)$   
 Intercept:  $(0, 0)$

**Rational Function**

$$f(x) = \frac{N(x)}{D(x)} = \frac{a_n x^n + \dots + a_1 x + a_0}{b_m x^m + \dots + b_1 x + b_0}$$

$N(x)$  and  $D(x)$  are polynomials.

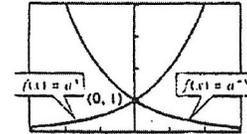


Domain: all real numbers,  $D \neq 0$   
 Range:  $(-\infty, 0) \cup (0, \infty)$   
 y-intercept:  $(0, f(x))$ , if  $f(0)$  exists  
 x-intercept(s): zeros of  $N$   
 Vertical asymptotes: zeros of  $D$   
 Horizontal asymptote:  
 $y = 0$  if  $n < m$   
 $y = a_n/b_m$  if  $n = m$

**Exponential Function**

$f(x) = a^x, a > 0$

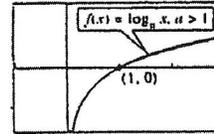
$f(x) = a^{-x}, a > 0$



Domain:  $(-\infty, \infty)$   
 Range:  $(0, \infty)$   
 y-intercept:  $(0, 1)$   
 Asymptote:  $y = 0$

**Logarithmic Function**

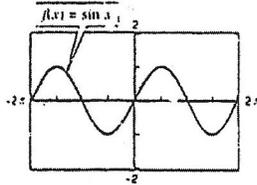
$f(x) = \log_a x, a > 1$



Domain:  $(0, \infty)$   
 Range:  $(-\infty, \infty)$   
 x-intercept:  $(1, 0)$   
 Asymptote:  $x = 0$

**Sine Function**

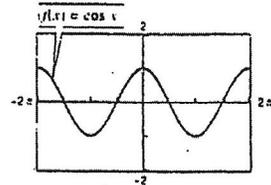
$f(x) = \sin x$



Domain: all real numbers  
 Range:  $[-1, 1]$   
 Period:  $2\pi$

**Cosine Function**

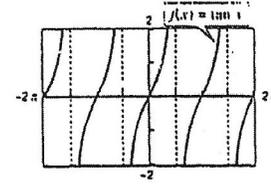
$f(x) = \cos x$



Domain: all real numbers  
 Range:  $[-1, 1]$   
 Period:  $2\pi$

**Tangent Function**

$f(x) = \tan x$



Domain: all  $x = \frac{\pi}{2} + n\pi$   
 Range:  $(-\infty, \infty)$   
 Period:  $\pi$   
 Vertical asymptotes:  $x = \frac{\pi}{2} + n\pi$

# ALGEBRA HELP SHEET

## Sets and The Real Number System

Natural Numbers: 1, 2, 3, 4, 5, 6, ...

Prime Numbers: 2, 3, 5, 7, 11, 13, 17, ...

Composite Numbers: 4, 6, 8, 10, 12, ...

Whole Numbers: 0, 1, 2, 3, 4, 5, 6, ...

Integers: ..., -3, -2, -1, 0, 1, 2, 3, ...

Rational Numbers: Any number that can be written in the form  $\frac{a}{b}$  ( $b \neq 0$ ) where  $a$  and  $b$  are integers.

Irrational Numbers: Any decimal that cannot be written in the form  $\frac{a}{b}$  ( $b \neq 0$ ) where  $a$  and  $b$  are integers.

i.e., numbers whose decimal representations neither terminate nor repeat. e.g.,  $\sqrt{3}, \pi$

Real Numbers: The union of the rational and irrational numbers

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## Equality and Properties of Real Numbers:

If  $a, b$  and  $c$  are real numbers, then

Reflexive property:  $a = a$

Symmetric property: If  $a = b$ , then  $b = a$ .

Transitive Property: If  $a = b$  and  $b = c$ , then  $a = c$ .

Closure properties:  $a + b$  is a real number

$a - b$  is a real number

$ab$  is a real number

$\frac{a}{b}$  is a real number ( $b \neq 0$ )

Commutative Property:  $a + b = b + a$

$ab = ba$

Associative Property:  $(a + b) + c = a + (b + c)$

$(ab)c = a(bc)$

Distributive Property:  $a(b + c) = ab + ac$

0 is the additive identity

1 is the multiplicative identity

$a$  and  $-a$  are additive inverses

$a$  and  $\frac{1}{a}$  ( $a \neq 0$ ) are multiplicative inverses.

Double negative rule:  $-(-a) = a$ .

## Arithmetic of Real Numbers:

$a - b = a + (-b)$

If no denominator is 0, then

$\frac{a}{b} = \frac{c}{d}$  if and only if  $ad = bc$ .

$\frac{a}{b} \cdot \frac{c}{d} = \frac{ac}{bd}$  and  $\frac{a}{b} + \frac{c}{d} = \frac{ad + bc}{bd}$

$\frac{a}{b} - \frac{c}{d} = \frac{ad - bc}{bd}$

$\frac{a}{b} \div \frac{c}{d} = \frac{a}{b} \cdot \frac{d}{c} = \frac{ad}{bc}$

$\frac{a}{b} + \frac{c}{b} = \frac{a + c}{b}$  and  $\frac{a}{b} - \frac{c}{b} = \frac{a - c}{b}$

$\frac{a}{b} \cdot \frac{c}{d} = \frac{ad + bc}{bd}$  and  $\frac{a}{b} - \frac{c}{d} = \frac{ad - cb}{bd}$

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## Multiplying Polynomials:

$a(b + c + d + \dots) = ab + ac + ad + \dots$

$(a + b)^2 = a^2 + 2ab + b^2$

$(a - b)^2 = a^2 - 2ab + b^2$

$(a + b)^3 = a^3 + 3a^2b + 3ab^2 + b^3$

$(a - b)^3 = a^3 - 3a^2b + 3ab^2 - b^3$

$(a + b)^4 = a^4 + 4a^3b + 6a^2b^2 + 4ab^3 + b^4$

$(a - b)^4 = a^4 - 4a^3b + 6a^2b^2 - 4ab^3 + b^4$

## Factoring Polynomials:

$ax + bx = x(a + b)$

$(a + b)x + (a + b)y = (a + b)(x + y)$

$a^2 - b^2 = (a + b)(a - b)$

$a^3 - b^3 = (a - b)(a^2 + ab + b^2)$

$a^3 + b^3 = (a + b)(a^2 - ab + b^2)$

$a^4 - b^4 = (a - b)(a + b)(a^2 + b^2)$

$a^4 + b^4 = (a^2 + \sqrt{2}ab + b^2)(a^2 - \sqrt{2}ab + b^2)$

$a^4 + b^4 = (a^2 + \sqrt{2}ab + b^2)(a^2 - \sqrt{2}ab + b^2)$

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## Radical Expressions:

If  $n$  is a positive integer ( $n > 1$ ) and all radicals represent real numbers, then

$\sqrt[n]{a} = a^{1/n}$

$x^{m/n} = \sqrt[n]{x^m} = (\sqrt[n]{x})^m$

$\sqrt[n]{a^n} = |a|$  if  $n$  is even

$\sqrt[n]{a^n} = a$  if  $n$  is odd

$\sqrt{ab} = \sqrt{a}\sqrt{b}$  and  $\sqrt{\frac{a}{b}} = \frac{\sqrt{a}}{\sqrt{b}}$  ( $b \neq 0$ )

## Applications of Radicals:

Pythagorean Theorem:

If  $a$  and  $b$  are the lengths of two legs of a triangle and  $c$  is the length of the hypotenuse, then  $a^2 + b^2 = c^2$

Distance Formula:

The distance  $d$  between the points  $P(x_1, y_1)$  and  $Q(x_2, y_2)$  is given by the formula

$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2}$

## Quadratic Formula

If  $p(x) = ax^2 + bx + c$ ,  $a \neq 0$  and  $b^2 - 4ac \geq 0$ , then the real zeros of  $p$  are

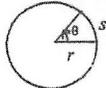
$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$

If  $b^2 - 4ac > 0</$

# TRIGONOMETRY HELP SHEET

## Definition of a Radian

One radian is the measure of a central angle  $\theta$  that subtends (intercepts) an arc  $s$  equal in length to the radius  $r$  of the circle.  
Arc length = Radius when  $\theta = 1$  radian



## Conversion: Degrees $\longleftrightarrow$ Radians

- To convert degrees to radians multiply by  $\frac{\pi}{180}$  rad
- To convert radians to degrees multiply by  $\frac{180}{\pi}$  rad

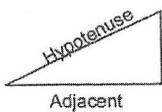
## Uniform Circular Motion

A point on a circle of radius  $r$  moves a distance  $s$  on the circumference of the circle, in an amount of time  $t$ .  $\theta$  is measured in radians

Angular Velocity	Arc Length
$\omega = \frac{\theta}{t}$	$s = r\theta$
Linear Velocity	Area of a sector
$v = \frac{s}{t}$	$A = \frac{1}{2}r^2\theta$
$v = r\omega$	

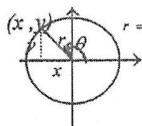
## Definition of the Six Trigonometric Functions

Right Triangle definitions, where  $0 < \theta < \pi/2$



$$\begin{aligned} \sin \theta &= \frac{\text{opp.}}{\text{hyp.}} & \csc \theta &= \frac{\text{hyp.}}{\text{opp.}} \\ \cos \theta &= \frac{\text{adj.}}{\text{hyp.}} & \sec \theta &= \frac{\text{hyp.}}{\text{adj.}} \\ \tan \theta &= \frac{\text{opp.}}{\text{adj.}} & \cot \theta &= \frac{\text{adj.}}{\text{opp.}} \end{aligned}$$

## Circular function definitions, where $\theta$ is any angle



$$\begin{aligned} \sin \theta &= \frac{y}{r} & \csc \theta &= \frac{r}{y} \\ \cos \theta &= \frac{x}{r} & \sec \theta &= \frac{r}{x} \\ \tan \theta &= \frac{y}{x} & \cot \theta &= \frac{x}{y} \end{aligned}$$

## Quotient Identities

$$\tan u = \frac{\sin u}{\cos u} \quad \cot u = \frac{\cos u}{\sin u}$$

## Reciprocal Identities

$$\begin{aligned} \sin u &= \frac{1}{\csc u} & \csc u &= \frac{1}{\sin u} \\ \cos u &= \frac{1}{\sec u} & \sec u &= \frac{1}{\cos u} \\ \tan u &= \frac{1}{\cot u} & \cot u &= \frac{1}{\tan u} \end{aligned}$$

## Pythagorean Identities

$$\sin^2 u + \cos^2 u = 1$$

$$1 + \tan^2 u = \sec^2 u$$

$$1 + \cot^2 u = \csc^2 u$$

## Even/Odd Identities

$$\sin(-u) = -\sin u$$

$$\cos(-u) = \cos u$$

$$\tan(-u) = -\tan u$$

## Function Identities

$$\sin\left(\frac{\pi}{2} - u\right) = \cos u$$

$$\cos\left(\frac{\pi}{2} - u\right) = \sin u$$

$$\tan\left(\frac{\pi}{2} - u\right) = \cot u$$

## Sum and Difference Formulas

$$\sin(u \pm v) = \sin u \cos v \pm \cos u \sin v$$

$$\cos(u \pm v) = \cos u \cos v \mp \sin u \sin v$$

$$\tan(u \pm v) = \frac{\tan u \pm \tan v}{1 \mp \tan u \tan v}$$

## Double-Angle Formulas

$$\sin 2u = 2 \sin u \cos u$$

$$\begin{aligned} \cos 2u &= \cos^2 u - \sin^2 u \\ &= 2 \cos^2 u - 1 \\ &= 1 - 2 \sin^2 u \end{aligned}$$

$$\tan 2u = \frac{2 \tan u}{1 - \tan^2 u}$$

## Half-Angle Formulas

$$\sin \frac{u}{2} = \pm \sqrt{\frac{1 - \cos u}{2}}$$

$$\cos \frac{u}{2} = \pm \sqrt{\frac{1 + \cos u}{2}}$$

$$\tan \frac{u}{2} = \frac{1 - \cos u}{\sin u} = \frac{\sin u}{1 + \cos u}$$

The signs of  $\sin u/2$  and  $\cos u/2$  depend on the quadrant in which  $u/2$  lies.

## Power-Reducing Formulas

$$\sin^2 u = \frac{1 - \cos 2u}{2}$$

$$\cos^2 u = \frac{1 + \cos 2u}{2}$$

$$\tan^2 u = \frac{1 - \cos 2u}{1 + \cos 2u}$$

## Sum-to-Product Formulas

$$\sin u + \sin v = 2 \sin\left(\frac{u+v}{2}\right) \cos\left(\frac{u-v}{2}\right)$$

$$\sin u - \sin v = 2 \cos\left(\frac{u+v}{2}\right) \sin\left(\frac{u-v}{2}\right)$$

$$\cos u + \cos v = 2 \cos\left(\frac{u+v}{2}\right) \cos\left(\frac{u-v}{2}\right)$$

$$\cos u - \cos v = -2 \sin\left(\frac{u+v}{2}\right) \sin\left(\frac{u-v}{2}\right)$$

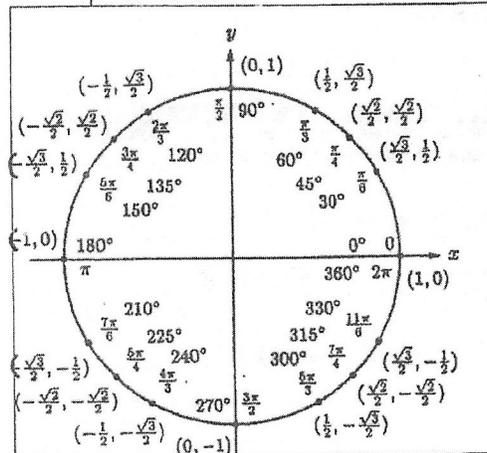
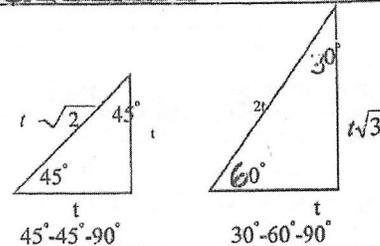
## Product-to-Sum Formulas

$$\sin u \sin v = \frac{1}{2} [\cos(u-v) - \cos(u+v)]$$

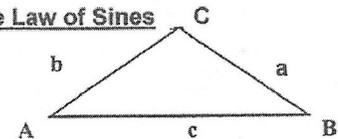
$$\cos u \cos v = \frac{1}{2} [\cos(u-v) + \cos(u+v)]$$

$$\sin u \cos v = \frac{1}{2} [\sin(u+v) + \sin(u-v)]$$

$$\cos u \sin v = \frac{1}{2} [\sin(u+v) - \sin(u-v)]$$



## The Law of Sines



$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

or

$$\frac{a}{\sin A} = \frac{b}{\sin B} = \frac{c}{\sin C}$$

## The Law of Cosines

$$a^2 = b^2 + c^2 - 2bc \cos A$$

$$b^2 = a^2 + c^2 - 2ac \cos B$$

$$c^2 = a^2 + b^2 - 2ab \cos C$$

or

$$\cos A = \frac{b^2 + c^2 - a^2}{2bc}$$

$$\cos B = \frac{a^2 + c^2 - b^2}{2ac}$$

$$\cos C = \frac{a^2 + b^2 - c^2}{2ab}$$

## Heron's Formula for Area of a triangle

If the semiperimeter is  $s$ , where

$$s = \frac{a+b+c}{2}$$

$$\text{then } A = \sqrt{s(s-a)(s-b)(s-c)}$$

## Trig. Form of a complex Number:

$$x + iy = r[\cos(\theta + 2n\pi) + i \sin(\theta + 2n\pi)],$$

$n$  any integer

## Chapter 3: Numerical Summaries of Data

**Sample mean:**

$$\bar{x} = \frac{\sum x}{n}$$

**Population mean:**

$$\mu = \frac{\sum x}{N}$$

**Range:**

Range = largest value – smallest value

**Population variance:**

$$\sigma^2 = \frac{\sum (x - \mu)^2}{N}$$

**Sample variance:**

$$s^2 = \frac{\sum (x - \bar{x})^2}{n - 1}$$

**Coefficient of variation:**

$$CV = \frac{\sigma}{\mu}$$

**z-score:**

$$z = \frac{x - \mu}{\sigma}$$

**Interquartile range:**

IQR =  $Q_3 - Q_1$  = third quartile – first quartile

**Lower outlier boundary:**

$$Q_1 - 1.5 \text{ IQR}$$

**Upper outlier boundary:**

$$Q_3 + 1.5 \text{ IQR}$$

## Chapter 4: Summarizing Bivariate Data

**Correlation coefficient:**

$$r = \frac{1}{n - 1} \sum \left( \frac{x - \bar{x}}{s_x} \right) \left( \frac{y - \bar{y}}{s_y} \right)$$

**y-intercept of least-squares regression line:**

$$b_0 = \bar{y} - b_1 \bar{x}$$

**Slope of least-squares regression line:**

$$b_1 = r \frac{s_y}{s_x}$$

**Equation of least-squares regression line:**

$$\hat{y} = b_0 + b_1 x$$

## Chapter 5: Probability

**General Addition Rule:**

$$P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$$

**General Method for Computing Conditional Probability:**

$$P(B | A) = \frac{P(A \text{ and } B)}{P(A)}$$

**Multiplication Rule for Independent Events:**

$$P(A \text{ and } B) = P(A)P(B)$$

**General Multiplication Rule:**

$$P(A \text{ and } B) = P(A)P(B | A) = P(B)P(A | B)$$

**Addition Rule for Mutually Exclusive Events:**

$$P(A \text{ or } B) = P(A) + P(B)$$

**Permutation of  $r$  items chosen from  $n$ :**

$${}_n P_r = \frac{n!}{(n - r)!}$$

**Rule of Complements:**

$$P(A^c) = 1 - P(A)$$

**Combination of  $r$  items chosen from  $n$ :**

$${}_n C_r = \frac{n!}{r!(n - r)!}$$

## Chapter 6: Discrete Probability Distributions

Mean of a discrete random variable:

$$\mu_X = \sum [x \cdot P(x)]$$

Variance of a discrete random variable:

$$\sigma_X^2 = \sum [(x - \mu_X)^2 \cdot P(x)] = \sum [x^2 \cdot P(x)] - \mu_X^2$$

Standard deviation of a discrete random variable:

$$\sigma_X = \sqrt{\sigma_X^2}$$

Mean of a binomial random variable:

$$\mu_X = np$$

Variance of a binomial random variable:

$$\sigma_X^2 = np(1-p)$$

Standard deviation of a binomial random variable:

$$\sigma_X = \sqrt{np(1-p)}$$

Mean of Poisson random variable:

$$\mu_X = \lambda t$$

Variance of Poisson random variable:

$$\sigma_X^2 = \lambda t$$

Standard deviation of Poisson random variable:

$$\sigma_X = \sqrt{\lambda t}$$

## Chapter 7: The Normal Distribution

z-score:

$$z = \frac{x - \mu}{\sigma}$$

Convert z-score to raw score:

$$x = \mu + z\sigma$$

Standard deviation of the sample mean:

$$\sigma_{\bar{x}} = \frac{\sigma}{\sqrt{n}}$$

z-score for a sample mean:

$$z = \frac{\bar{x} - \mu}{\sigma_{\bar{x}}}$$

Standard deviation of the sample proportion:

$$\sigma_{\hat{p}} = \sqrt{\frac{p(1-p)}{n}}$$

z-score for a sample proportion:

$$z = \frac{\hat{p} - p}{\sigma_{\hat{p}}}$$

## Chapter 8: Confidence Intervals

Confidence interval for a mean, standard deviation known:

$$\bar{x} - z_{\alpha/2} \frac{\sigma}{\sqrt{n}} < \mu < \bar{x} + z_{\alpha/2} \frac{\sigma}{\sqrt{n}}$$

Sample size to construct an interval for  $\mu$  with margin of error  $m$ :

$$n = \left( \frac{z_{\alpha/2} \cdot \sigma}{m} \right)^2$$

Confidence interval for a mean, standard deviation unknown:

$$\bar{x} - t_{\alpha/2} \frac{s}{\sqrt{n}} < \mu < \bar{x} + t_{\alpha/2} \frac{s}{\sqrt{n}}$$

Confidence interval for a proportion:

$$\hat{p} - z_{\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}} < p < \hat{p} + z_{\alpha/2} \sqrt{\frac{\hat{p}(1-\hat{p})}{n}}$$

Sample size to construct an interval for  $p$  with margin of error  $m$ :

$$n = \hat{p}(1-\hat{p}) \left( \frac{z_{\alpha/2}}{m} \right)^2 \quad \text{if a value for } \hat{p} \text{ is available}$$

$$n = 0.25 \left( \frac{z_{\alpha/2}}{m} \right)^2 \quad \text{if no value for } \hat{p} \text{ is available}$$

Confidence interval for the variance of a normal distribution:

$$\frac{(n-1)s^2}{\chi_{\alpha/2}^2} < \sigma^2 < \frac{(n-1)s^2}{\chi_{1-\alpha/2}^2}$$

Confidence interval for the standard deviation of a normal distribution:

$$\sqrt{\frac{(n-1)s^2}{\chi_{\alpha/2}^2}} < \sigma < \sqrt{\frac{(n-1)s^2}{\chi_{1-\alpha/2}^2}}$$

## Chapter 9: Hypothesis Testing

Test statistic for a mean, standard deviation known:

$$z = \frac{\bar{x} - \mu_0}{\sigma / \sqrt{n}}$$

Test statistic for a mean, standard deviation unknown:

$$t = \frac{\bar{x} - \mu_0}{s / \sqrt{n}}$$

Test statistic for a proportion:

$$z = \frac{\hat{p} - p_0}{\sqrt{\frac{p_0(1-p_0)}{n}}}$$

Test statistic for a standard deviation:

$$\chi^2 = \frac{(n-1) \cdot s^2}{\sigma_0^2}$$

## Chapter 10: Two-Sample Confidence Intervals

Confidence interval for the difference between two means, independent samples:

$$\bar{x}_1 - \bar{x}_2 - t_{\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}} < \mu_1 - \mu_2 < \bar{x}_1 - \bar{x}_2 + t_{\alpha/2} \sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}$$

Confidence interval for the difference between two means, matched pairs:

$$\bar{d} - t_{\alpha/2} \frac{s_d}{\sqrt{n}} < \mu_d < \bar{d} + t_{\alpha/2} \frac{s_d}{\sqrt{n}}$$

Confidence interval for the difference between two proportions:

$$\hat{p}_1 - \hat{p}_2 - z_{\alpha/2} \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}} < p_1 - p_2 < \hat{p}_1 - \hat{p}_2 + z_{\alpha/2} \sqrt{\frac{\hat{p}_1(1-\hat{p}_1)}{n_1} + \frac{\hat{p}_2(1-\hat{p}_2)}{n_2}}$$

## Chapter 11: Two-Sample Hypothesis Tests

Test statistic for the difference between two means, independent samples:

$$t = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Test statistic for the difference between two means, matched pairs:

$$t = \frac{\bar{d} - \mu_0}{s_d / \sqrt{n}}$$

Test statistic for the difference between two proportions:

$$z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}(1-\hat{p}) \left( \frac{1}{n_1} + \frac{1}{n_2} \right)}}$$

Test statistic for two standard deviations:

$$F = \frac{\text{Larger of } s_1^2 \text{ and } s_2^2}{\text{Smaller of } s_1^2 \text{ and } s_2^2}$$

where  $\hat{p}$  is the pooled proportion  $\hat{p} = \frac{x_1 + x_2}{n_1 + n_2}$

## Chapter 12: Tests with Qualitative Data

Chi-square statistic:

$$\chi^2 = \sum \frac{(O - E)^2}{E}$$

Expected frequency for independence or homogeneity:

$$E = \frac{\text{Row total} \cdot \text{Column total}}{\text{Grand total}}$$

Expected frequency for goodness-of-fit:

$$E = np$$

## Chapter 13: Inference in Linear Models

Residual standard deviation:

$$s_e = \sqrt{\frac{\sum(y - \hat{y})^2}{n - 2}}$$

Standard error for  $b_1$ :

$$s_b = \frac{s_e}{\sqrt{\sum(x - \bar{x})^2}}$$

Confidence interval for slope:

$$b_1 - t_{\alpha/2} \cdot s_b < \beta_1 < b_1 + t_{\alpha/2} \cdot s_b$$

Confidence interval for the mean response:

$$\hat{y} \pm t_{\alpha/2} \cdot s_e \sqrt{\frac{1}{n} + \frac{(x^* - \bar{x})^2}{\sum(x - \bar{x})^2}}$$

Test statistic for slope  $b_1$ :

$$t = \frac{b_1}{s_b}$$

Prediction interval for an individual response:

$$\hat{y} \pm t_{\alpha/2} \cdot s_e \sqrt{1 + \frac{1}{n} + \frac{(x^* - \bar{x})^2}{\sum(x - \bar{x})^2}}$$

## Chapter 14: Analysis of Variance

Treatment sum of squares:

$$SSTr = n_1(\bar{x}_1 - \bar{x})^2 + n_2(\bar{x}_2 - \bar{x})^2 + \dots + n_I(\bar{x}_I - \bar{x})^2$$

Treatment mean square:

$$MSTr = \frac{SSTr}{I - 1}$$

Error sum of squares:

$$SSE = (n_1 - 1)s_1^2 + (n_2 - 1)s_2^2 + \dots + (n_I - 1)s_I^2$$

Error mean square:

$$MSE = \frac{SSE}{N - I}$$

F statistic for one-way ANOVA:

$$F = \frac{MSTr}{MSE}$$

Test statistic for Tukey-Kramer test:

$$q = \frac{|\bar{x}_i - \bar{x}_j|}{\sqrt{\frac{MSE}{2} \left( \frac{1}{n_i} + \frac{1}{n_j} \right)}}$$

## Chapter 15: Nonparametric Statistics

Test statistic for the sign test:

$$z = \frac{x + 0.5 - n/2}{\sqrt{n/2}} \quad \text{if } n > 25$$

If  $n \leq 25$ , the test statistic is  $x$ , the number of times the less frequent sign occurs.

Mean of  $S$ , the sum of the ranks for the rank-sum test:

$$\mu_S = \frac{n_1(n_1 + n_2 + 1)}{2}$$

Standard deviation of  $S$ , the sum of the ranks for the rank-sum test:

$$\sigma_S = \sqrt{\frac{n_1 n_2 (n_1 + n_2 + 1)}{12}}$$

Test statistic for the rank-sum test:

$$z = \frac{S - \mu_S}{\sigma_S}$$

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