3.9 Types of Hypothesis Tests

MBC 638

Data Analysis and Decision Making

One-Sample Hypothesis Tests for Continuous Data (Purple)

Select: **Two-tail test** | **One-tail test**

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu = \mu_0$	H_0: $\mu \geq \mu_0$	H_0: $\mu \leq \mu_0$
	H_a: $\mu \neq \mu_0$	H_a: $\mu < \mu_0$	H_a: $\mu > \mu_0$

Choose: **Sample size**

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: **Test statistic**

$Z = \dfrac{\bar{x}-\mu_0}{\frac{s}{\sqrt{n}}}$	$t = \dfrac{\bar{x}-\mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: ***p*-value**

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: **Two-tail test** | **One-tail test**

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: **Sample size**

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: **Test statistic**

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: ***p*-value**

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

One-Sample Hypothesis Tests for Discrete Data (Orange)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $p = p_0$	H_0: $p \geq p_0$	H_0: $p \leq p_0$
H_a: $p \neq p_0$	H_a: $p < p_0$	H_a: $p > p_0$

Choose: Sample size

Must have	Where
$np \geq 5$	$p = \frac{X}{n}$
$n(1 - p) \geq 5$	X = no. of items of interest in sample
$n \geq 30$	

Calculate: Test statistic

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

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z	p = area left of Z	p = area right of Z

Two-Sample Hypothesis Tests for Discrete Data (Pink)

Select: **Two-tail test** | **One-tail test**

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $p_1 = p_2$	H_0: $p_1 \geq p_2$	H_0: $p_1 \leq p_2$
H_a: $p_1 \neq p_2$	H_a: $p_1 < p_2$	H_a: $p_1 > p_2$

Choose: **Sample size**

Must have

$n_1 + n_2 \geq 30$

Where

$p_1 = \frac{X_1}{n_1}$ and $p_2 = \frac{X_2}{n_2}$

X = no. of items of interest in sample

Calculate: **Test statistic**

$$Z = \frac{p_1 - p_2}{\sqrt{\frac{x_1 + x_2}{n_1 + n_2}\left[1 - \frac{x_1 + x_2}{n_1 + n_2}\right]\left[\frac{1}{n_1} + \frac{1}{n_2}\right]}}$$

Identify: ***p*-value**

Two-tail	Lower/left-tail	Upper/right-tail
p_1 = 2 × area past Z	p_1 = area left of Z	p_1 = area right of Z

Using the Charts: Introduction

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu = \mu_0$	H_0: $\mu \geq \mu_0$	H_0: $\mu \leq \mu_0$
	H_a: $\mu \neq \mu_0$	H_a: $\mu < \mu_0$	H_a: $\mu > \mu_0$

Choose: Sample size

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$Z = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$	$t = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu = \mu_0$	H_0: $\mu \geq \mu_0$	H_0: $\mu \leq \mu_0$
	H_a: $\mu \neq \mu_0$	H_a: $\mu < \mu_0$	H_a: $\mu > \mu_0$

Choose: Sample size

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$Z = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$	$t = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 1: Select Test

Select:	Two-tail test	One-tail test	
	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu = \mu_0$	H_0: $\mu \geq \mu_0$	H_0: $\mu \leq \mu_0$
	H_a: $\mu \neq \mu_0$	H_a: $\mu < \mu_0$	H_a: $\mu > \mu_0$

Choose: Sample size

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$Z = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$	$t = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	$H_0: \mu = \mu_0$	$H_0: \mu \geq \mu_0$	$H_0: \mu \leq \mu_0$
	$H_a: \mu \neq \mu_0$	$H_a: \mu < \mu_0$	$H_a: \mu > \mu_0$

Choose: Sample size

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$Z = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$	$t = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Hank's Hypothesis Statements:

$H_0: \mu_1 \leq \mu_2$

$H_a: \mu_1 > \mu_2$

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu = \mu_0$	H_0: $\mu \geq \mu_0$	H_0: $\mu \leq \mu_0$
	H_a: $\mu \neq \mu_0$	H_a: $\mu < \mu_0$	H_a: $\mu > \mu_0$

Choose: Sample size

Large	Small
$n \geq 30$	$n < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$Z = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$	$t = \dfrac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}}$
Can replace s with σ if known	$df = n - 1$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Hypothesis Tests for Continuous Data

Hypothesis Tests for Continuous Data

- Purple: one-sample test

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
    - Two samples and two sample means

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
    - Two samples and two sample means
    - Two-sample test appropriate

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
  - Two samples and two sample means
  - Two-sample test appropriate

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
  - Two samples and two sample means
  - Two-sample test appropriate
- External standard

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
  - Two samples and two sample means
  - Two-sample test appropriate
- External standard
  - One-sample test appropriate

Using the Charts, Step 1: Select Test

Select: **Two-tail test** | **One-tail test**

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: **Sample size**

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: **Test statistic**

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: ***p*-value**

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Hypothesis Tests for Continuous Data

- Purple: one-sample test
- Green: two-sample test
- Hank's process
  - Two samples and two sample means
  - Two-sample test appropriate
- External standard
  - One-sample test appropriate
- Continuous data: time, height, temperature, etc.

Using the Charts, Step 1: Select Test

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 2: Choose Sample Size

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 2: Choose Sample Size

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 2: Choose Sample Size

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select:	Two-tail test	One-tail test	
	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
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Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select:	Two-tail test	One-tail test	
	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select:	Two-tail test	One-tail test	
	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 3: Calculate Test Statistic

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
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Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

Select: **Two-tail test** | **One-tail test**

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: **Sample size**

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: **Test statistic**

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

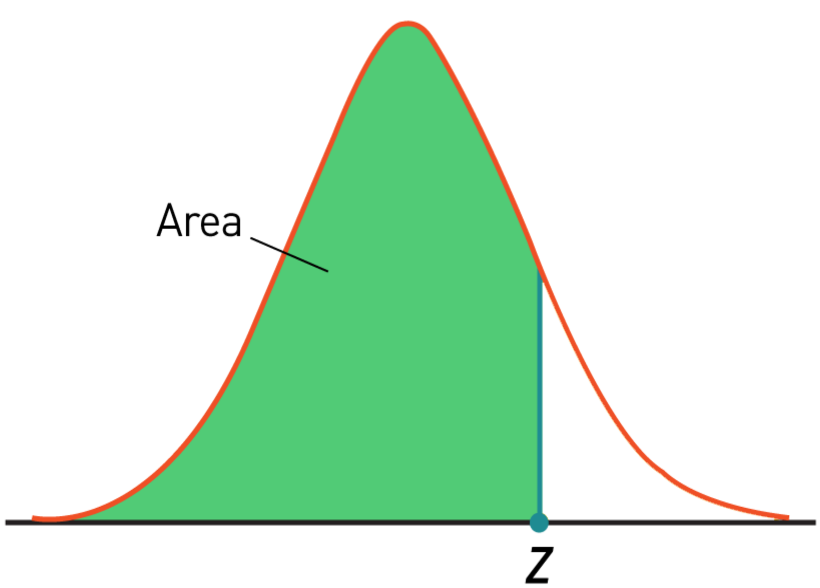
$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

$df = n_1 + n_2 - 2$

Identify: ***p*-value**

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Standard Normal Table: Area Left of *Z*



Using the Charts, Step 4: Identify *p*-Value

Select:	Two-tail test	One-tail test	
	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

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Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Using the Charts, Step 4: Identify *p*-Value

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
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Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
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Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Hypothesis Tests for Discrete Data

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- Discrete data: good/bad, right/wrong, defective/not

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- Discrete data: good/bad, right/wrong, defective/not
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Hypothesis Tests for Discrete Data

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    - One proportion calculated

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Hypothesis Tests for Discrete Data

- Discrete data: good/bad, right/wrong, defective/not
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    - One proportion calculated
    - Proportion compared to external standard

Hypothesis Tests for Discrete Data

- Discrete data: good/bad, right/wrong, defective/not
- Orange: one-sample test
  - One proportion calculated
  - Proportion compared to external standard
- Pink: two-sample test

Hypothesis Tests for Discrete Data

- Discrete data: good/bad, right/wrong, defective/not
- Orange: one-sample test
  - One proportion calculated
  - Proportion compared to external standard
- Pink: two-sample test
  - Two sample proportions compared

Hank's Process: Step 1

Hank's Process: Step 1

Is the mean time to process a job ticket in Hank's new and improved process, μ_2, really less than in his original process, μ_1?

Hank's Process: Step 1

Is the mean time to process a job ticket in Hank's new and improved process, μ_2, really less than in his original process, μ_1?

- H_0: $\mu_1 \le \mu_2$
- H_a: $\mu_1 > \mu_2$

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \ge \mu_2$	H_0: $\mu_1 \le \mu_2$
H_a: $\mu_1 \ne \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \ge 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	p = area left of Z or t	p = area right of Z or t

Hank's Process: Step 2

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Did we significantly improve the mean time to process a job ticket?

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- Mean process time
  - $\bar{x}_1$ = 17.23
  - $\bar{x}_2$ = 12.17

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Hank's Process: Step 2

Did we significantly improve the mean time to process a job ticket?

- Mean process time
  - $\bar{x}_1$ = 17.23
  - $\bar{x}_2$ = 12.17
- Standard deviation of process time
  - s_1 = 4.52
  - s_2 = 3.32

Hank's Process: Step 2

Did we significantly improve the mean time to process a job ticket?

- Mean process time
  - $\bar{x}_1$ = 17.23
  - $\bar{x}_2$ = 12.17
- Standard deviation of process time
  - s_1 = 4.52
  - s_2 = 3.32

Hank's Process: Step 2

Did we significantly improve the mean time to process a job ticket?

- Mean process time
  - $\bar{x}_1 = 17.23$
  - $\bar{x}_2 = 12.17$
- Standard deviation of process time
  - $s_1 = 4.52$
  - $s_2 = 3.32$

Hank's Process: Step 2 (cont.)

- Sample size (no. job tickets processed)
  - $n_1 = 30$
  - $n_2 = 30$

Hank's Process: Step 2 (cont.)

- Sample size (no. job tickets processed)
  - $n_1 = 30$
  - $n_2 = 30$
- Alpha level
  - $\alpha = 0.05$

Hank's Process: Step 3

Is our sample large or small?

Hank's Process: Step 3

Is our sample large or small?

- $n_1 + n_2 = 30 + 30 = 60$

Hank's Process: Step 3

Is our sample large or small?

- $n_1 + n_2 = 30 + 30 = 60$
- Large: $n_1 + n_2 \geq 30$

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large	Small
$Z = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$	$t = \dfrac{\bar{x}_1 - \bar{x}_2}{\sqrt{\dfrac{s_1^2}{n_1} + \dfrac{s_2^2}{n_2}}}$ $df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
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Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: *p*-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Hank's Process: Step 4

Calculate test statistic.

- We have a large sample, so we calculate Z

Hank's Process: Step 4

Calculate test statistic.

- We have a large sample, so we calculate Z

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Hank's Process: Step 4

Calculate test statistic.

- We have a large sample, so we calculate Z

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{17.23 - 12.17}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

Hank's Process: Step 4

Calculate test statistic.

- We have a large sample, so we calculate Z

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{17.23 - 12.17}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

$$= \frac{5.06}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

Hank's Process: Step 4

Calculate test statistic.

- We have a large sample, so we calculate Z

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{17.23 - 12.17}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

$$= \frac{5.06}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}} = \frac{5.06}{\sqrt{0.681 + 0.367}}$$

Remember Order of Operations: PEMDAS

1. **P**arentheses
2. **E**xponents (including square roots)
3. **M**ultiplication and **d**ivision
4. **A**ddition and **s**ubtraction

Hank's Process: Step 4 (cont.)

Calculate test statistic.

- We have a large sample, so we calculate *Z*

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{17.23 - 12.17}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

$$= \frac{5.06}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}} = \frac{5.06}{\sqrt{0.681 + 0.367}}$$

Hank's Process: Step 4 (cont.)

Calculate test statistic.

- We have a large sample, so we calculate *Z*

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} = \frac{17.23 - 12.17}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}}$$

$$= \frac{5.06}{\sqrt{\frac{4.52^2}{30} + \frac{3.32^2}{30}}} = \frac{5.06}{\sqrt{0.681 + 0.367}}$$

$$= 4.943$$

Hank's Process: Step 5

Use the test statistic ($Z = 4.943$) to find the area in the tail (the *p*-value).

Standard Normal Table

Z	0.00	0.01	0.02	0.03	0.04	0.05	…
⋮			⋮				
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	…
3.0	0.9987	0.9987	0.9987	0.9988	0.9988	0.9989	
3.1	0.9990	0.9991	0.9991	0.9991	0.9992	0.9992	
3.2	0.9993	0.9993	0.9994	0.9994	0.9994	0.9994	
3.3	0.9995	0.9995	0.9995	0.9996	0.9996	0.9996	
3.4	0.9997	0.9997	0.9997	0.9997	0.9997	0.9997	

Hank's Process: Step 5 (cont.)

Use the test statistic ($Z = 4.943$) to find the area in the tail (the p-value).

- 4.943 standard deviations is off the table.

Hank's Process: Step 5 (cont.)

Use the test statistic ($Z = 4.943$) to find the area in the tail (the p-value).

- 4.943 standard deviations is off the table.
- We'll use an Excel function.

Hank's Process: Step 5 (cont.)

Use the test statistic ($Z = 4.943$) to find the area in the tail (the p-value).

- 4.943 standard deviations is off the table.
- We'll use an Excel function.
  - `=NORM.S.DIST(4.943,true)`

Hank's Process: Step 5 (cont.)

Use the test statistic ($Z = 4.943$) to find the area in the tail (the p-value).

- 4.943 standard deviations is off the table.
- We'll use an Excel function.
  - `=NORM.S.DIST(4.943,true)`
  - 0.999999615

Hank's Process: Step 6

Which side of the curve is relevant?

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

	Two-tail	Lower/left-tail	Upper/right-tail
	H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
	H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

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

$df = n_1 + n_2 - 2$

Identify: p-value

Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Two-Sample Hypothesis Tests for Continuous Data (Green)

Select: Two-tail test | One-tail test

Two-tail	Lower/left-tail	Upper/right-tail
H_0: $\mu_1 = \mu_2$	H_0: $\mu_1 \geq \mu_2$	H_0: $\mu_1 \leq \mu_2$
H_a: $\mu_1 \neq \mu_2$	H_a: $\mu_1 < \mu_2$	H_a: $\mu_1 > \mu_2$

Choose: Sample size

Large	Small
$n_1 + n_2 \geq 30$	$n_1 + n_2 < 30$
(or σ known)	(or σ unknown)

Calculate: Test statistic

Large:

$$Z = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

Small:

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

$df = n_1 + n_2 - 2$

Identify: p-value

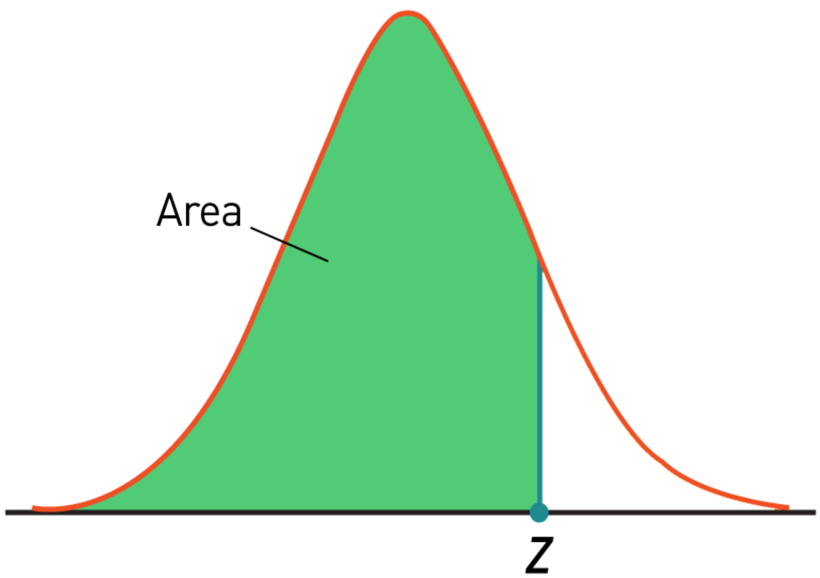
Two-tail	Lower/left-tail	Upper/right-tail
$p = 2 \times$ area past Z or t	$p =$ area left of Z or t	$p =$ area right of Z or t

Hank's Process: Step 6

Which side of the curve is relevant?

- Area right of the test statistic

Standard Normal Table: Area Left of Z



Hank's Process: Step 7

What is our p-value?

- $p = 1 - 0.999999615$

Hank's Process: Step 7

What is our p-value?

- $p = 1 - 0.999999615$
- $p \approx 0$

Hank's Process: Steps 8 and 9

Compare the p-value with α.

Hank's Process: Steps 8 and 9

Compare the *p*-value with α.

- *p*-value ≈ 0

Hank's Process: Steps 8 and 9

Compare the *p*-value with α.

- *p*-value ≈ 0
- $\alpha = 0.05$

Hank's Process: Steps 8 and 9

Compare the *p*-value with α.

- *p*-value ≈ 0
- $\alpha = 0.05$
- *p*-value $< \alpha$

Hank's Process: Steps 8 and 9

Compare the *p*-value with α.

- *p*-value ≈ 0
- $\alpha = 0.05$
- *p*-value $< \alpha$

Since *p*-value $< \alpha$, reject H_0.

Hank's Process: Step 10

What does it mean?

- The data is statistically significant at α.

Hank's Process: Step 10

What does it mean?

- The data is statistically significant at α.
- The difference in Hank's mean speed is too large to be explained by chance alone.

Hank's Process: Step 10

What does it mean?

- The data is statistically significant at α.
- The difference in Hank's mean speed is too large to be explained by chance alone.
- We made a statistically significant change in Hank's job ticket processing time!