THE UNIVERSITY OF QUEENSLAND AUSTRALIA | CREATE CHANGE

ECON1310
Introductory Statistics for Social Sciences

Tutorial 10: HYPOTHESIS TESTING II

Tutor: Francisco Tavares Garcia

LBRT #2 (2nd) is open!

LBRT #2 (Second Attempt) now available

Posted on: Thursday, 19 January 2023 09:00:00 o'clock AEST

Dear Students,

A reminder that **LBRT #2 (Second Attempt)** is now available until **4pm Friday 20 January.** This LBRT can be accessed via Blackboard under Assessment > LBRTs (Lecture Block Review Tasks) > LBRT #2.

Please note that you will have **90 minutes (1.5 hrs)** to complete the quiz. The quiz will **automatically submit** once the 90 minutes have elapsed. It should also be noted that **no access will be available after 4pm Friday**. Therefore, please give yourself enough time to complete the quiz (i.e. start at 2:30pm Friday at the latest to give yourself a full 90 minutes).

You will be able to **view** both your **score and feedback** at **9am Monday 23 January**. Please note that if you completed the first attempt for the LBRT, your **best score** from the 2 attempts will contribute towards your final grade.

In preparation for LBRT #2, please familiarise yourself with the **Practice LBRT test**, (which shows you how the questions will appear) and the **General Information for Completing LBRTs** document. Details can be found under Assessment > LBRTs (Lecture Block Review Tasks).

Best of luck!

Dominic

CML 04 (2nd) and 05 (1st)

CML 4 and 5 Reminder

Posted on: Wednesday, 18 January 2023 09:00:00 o'clock AEST

Dear Students,

A reminder that:

1. **CML 4 (2nd Attempt)** is now open and will **close at 4pm this Friday** (20 January)
2. **CML 5 (1st Attempt)** is now open and will **close at 4pm on Monday 23 January** (Week 8)
3. Please note that you **MUST check, save and submit** your CMLs, are they do not auto-submit.

Feel free to email me if you have any questions.

Best of luck!

Dominic

ECON1310

Tutorial 10 – Week 11

HYPOTHESIS TESTING II

At the end of this tutorial you should be able to

- Carry out one-tail and two-tail hypothesis tests using the *p*-value method.
- Carry out one-tail and two-tail hypothesis tests for population proportions.
- Carry out hypothesis tests for the difference between two means using the pooled variance method.

Q1. GEI developed a new bulb whose design specifications call for a mean light output of 960 lumens (compared to an earlier model that provided only 750 lumens). The company's data indicate that the standard deviation of light output for this type of bulb is 18.4 lumens, and light output is approximately normally distributed. From a sample of 20 new bulbs, the testing committee found an average light output of 954 lumens per bulb. At a 0.05 significance level can GEI conclude that its new bulb is producing the specified mean 960 lumen output? Use the **p-value approach.**

The University Of Queensland Australia

(Poll)

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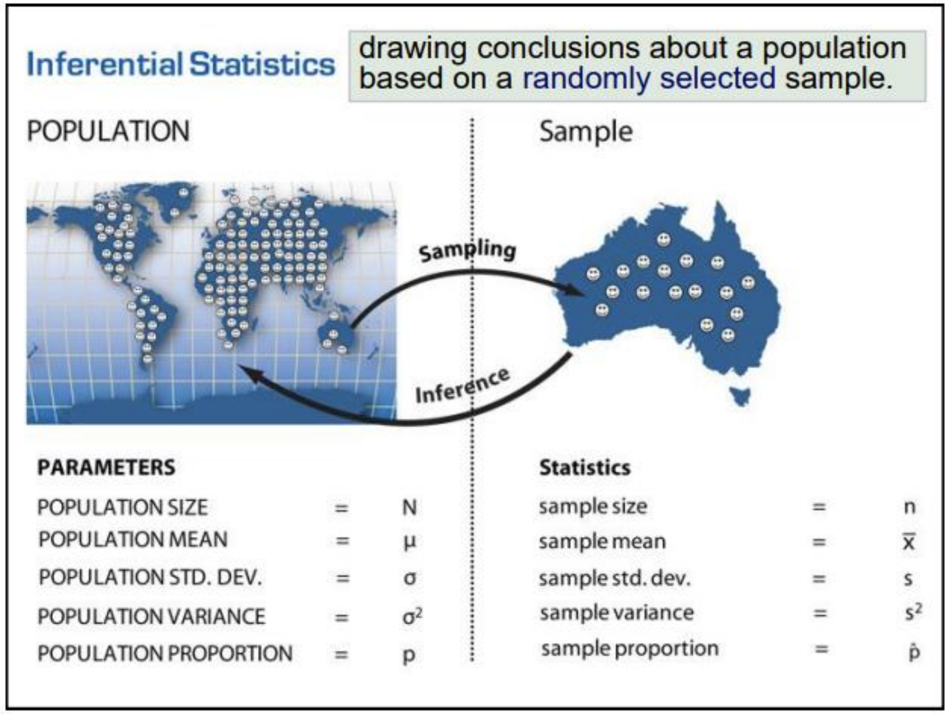
1. What symbol would you give to the value 960 lumens? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n



2. What symbol would you give to the value 18.4 lumens? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

3. What symbol would you give to the value 20 new bulbs? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

4. What symbol would you give to the value 954 lumens? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

5. What symbol would you give to the value 0.05 significance level? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

(Poll)

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- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

2. What symbol would you give to the value 18.4 lumens? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

3. What symbol would you give to the value 20 new bulbs? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
- x̄ (x bar)
- Level of Confidence (LOC)
- α (alpha)
- n

4. What symbol would you give to the value 954 lumens? (Single Choice) *

- σ (sigma)
- s
- μ (mu)
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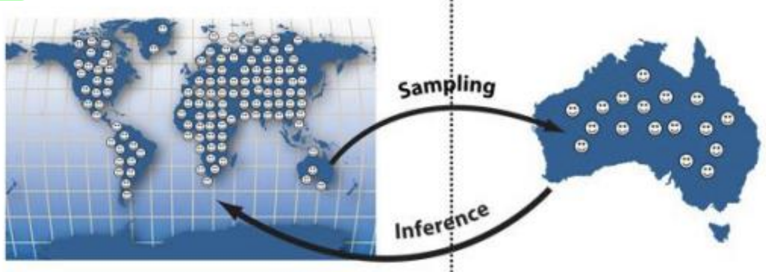
Inferential Statistics drawing conclusions about a population based on a randomly selected sample.

POPULATION | Sample



PARAMETERS			Statistics		
POPULATION SIZE	=	N	sample size	=	n
POPULATION MEAN	=	μ	sample mean	=	$\bar{x}$
POPULATION STD. DEV.	=	σ	sample std. dev.	=	s
POPULATION VARIANCE	=	σ^2	sample variance	=	s^2
POPULATION PROPORTION	=	p	sample proportion	=	$\hat{p}$

adm T10 Q1 Q2 Q3

μ = 960 lumens
σ = 18.4 lumens
n = 20 new bulbs
$\bar{X}$ = 954 lumens
α = 0.05

Q1. GEI developed a new bulb whose design specifications call for a mean light output of 960 lumens (compared to an earlier model that provided only 750 lumens). The company's data indicate that the standard deviation of light output for this type of bulb is 18.4 lumens, and light output is approximately normally distributed. From a sample of 20 new bulbs, the testing committee found an average light output of 954 lumens per bulb. At a 0.05 significance level can GEI conclude that its new bulb is producing the specified mean 960 lumen output? Use the **p-value approach.**

1. What type of problem is it? (Single Choice) *

- ◯ Population Mean (Seagull) (no sample)
- ◯ Population Mean (Pelican) (σ is known)
- ◯ Population Mean (Shag) (σ is unknown but s is known)
- ◯ Population Mean difference (salmon vs trout) (σ are unknown)
- ◯ Population Proportion (Freaky fish) (proportion)

2. What table will we use? (Single Choice) *

- ◯ Z table (standard normal distribution)
- ◯ t table (Student's t-distribution)

(Poll)

3. What is the value of α (alpha)? (Single Choice) *

- ◯ 0.01
- ◯ 0.02
- ◯ 0.03
- ◯ 0.04
- ◯ 0.05
- ◯ 0.1

4. What type of test is it? (Single Choice) *

- ◯ one tail test (upper tail >)
- ◯ one tail test (lower tail <)
- ◯ two tail test (=)

μ = 960 lumens
σ = 18.4 lumens
n = 20 new bulbs
$\bar{X}$ = 954 lumens
α = 0.05

Q1. GEI developed a new bulb whose design specifications call for a mean light output of 960 lumens (compared to an earlier model that provided only 750 lumens). The company's data indicate that the standard deviation of light output for this type of bulb is 18.4 lumens, and light output is approximately normally distributed. From a sample of 20 new bulbs, the testing committee found an average light output of 954 lumens per bulb. At a 0.05 significance level can GEI conclude that its new bulb is producing the specified mean 960 lumen output? Use the **p-value approach.**

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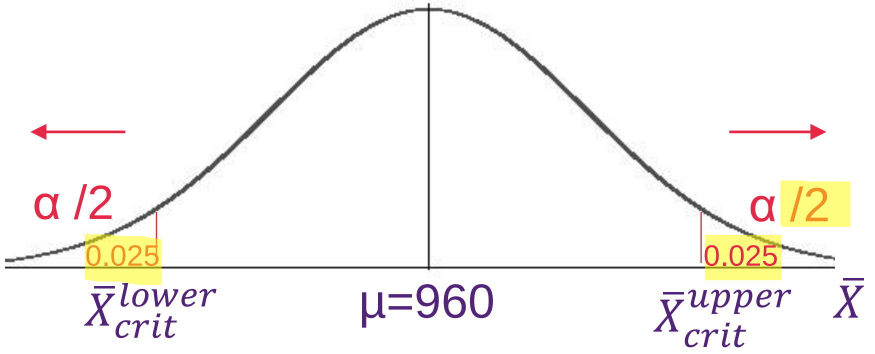
Step 1: State H_0 and H_1

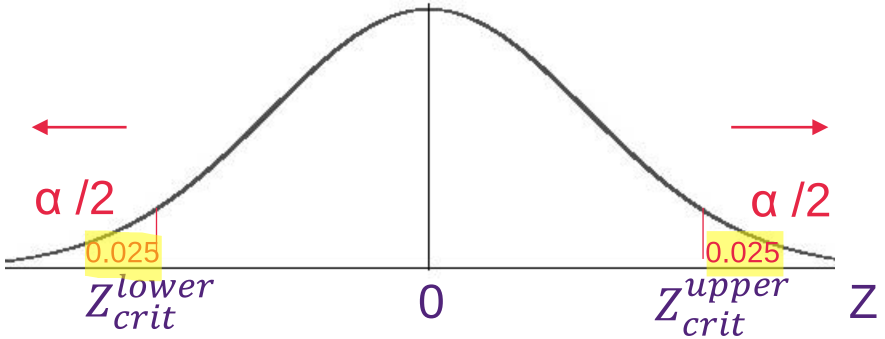
H_0: μ = 960

H_1: μ ≠ 960

Two tail test

Rejection regions





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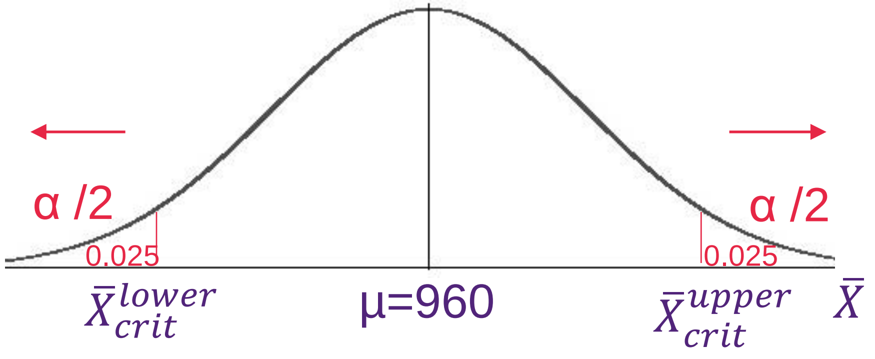
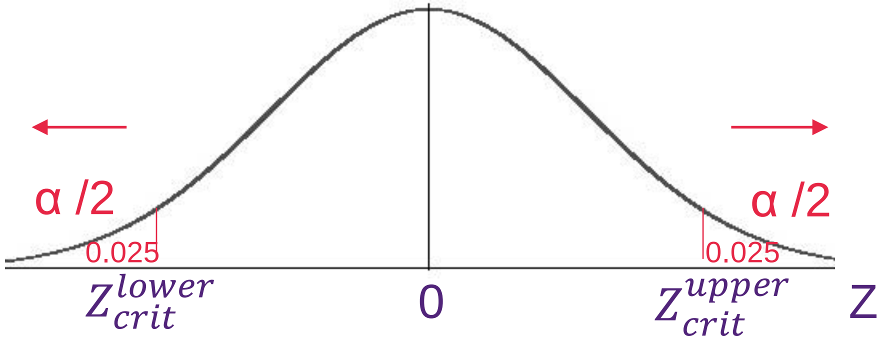
Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

Step 2: Decision rule
Reject H_0 if $|Z_{calc}| > Z_{crit}$

Rejection regions





adm T10 Q1 Q2 Q3

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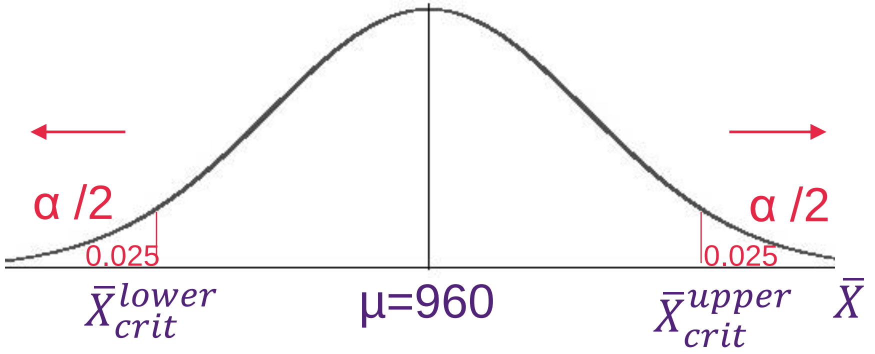
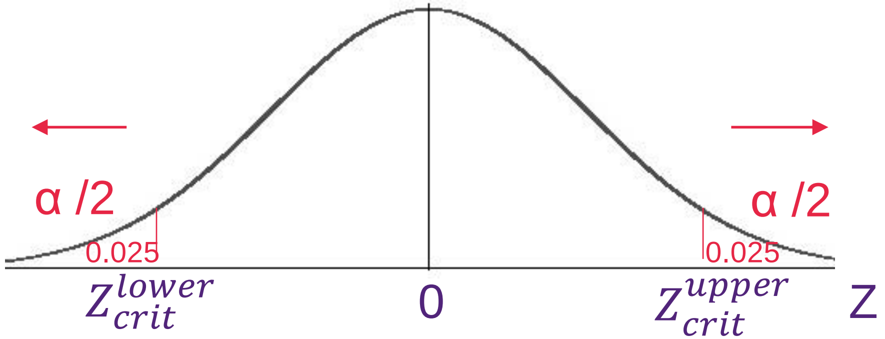
Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

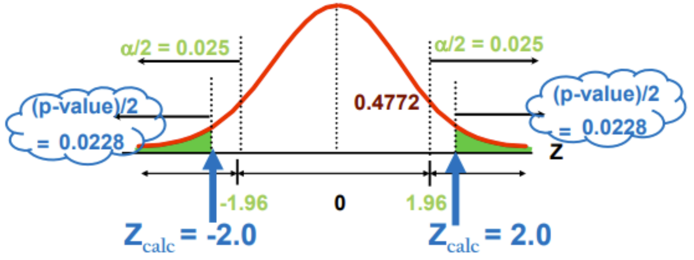
Rejection regions





Step 4: Decision **(using p-value method)**

Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 = **0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

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μ = 960 lumens
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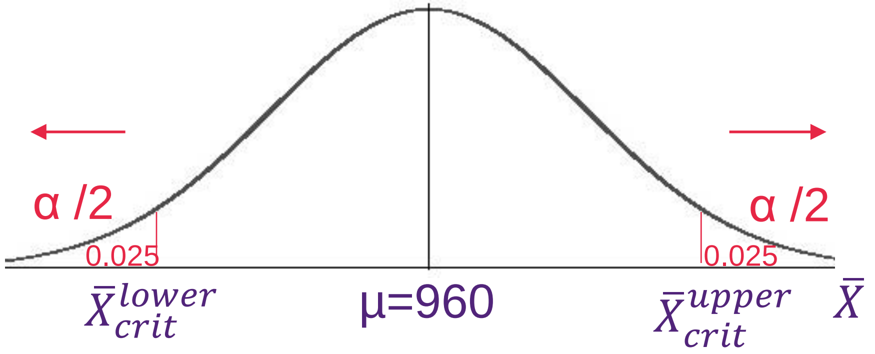
Step 1: State H_0 and H_1
H_0: $\mu = 960$
H_1: $\mu \neq 960$

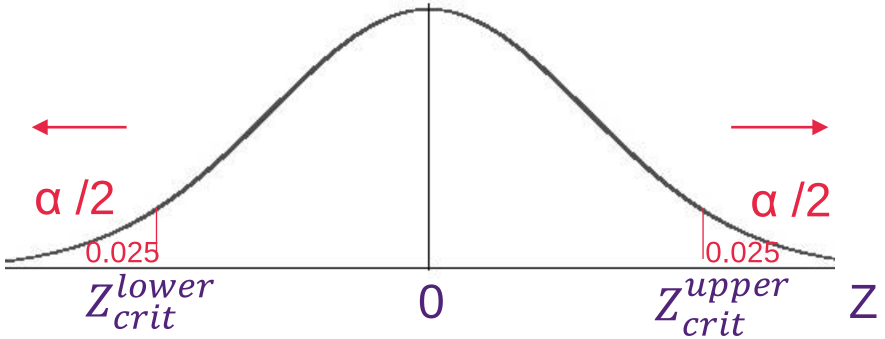
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = ?$$

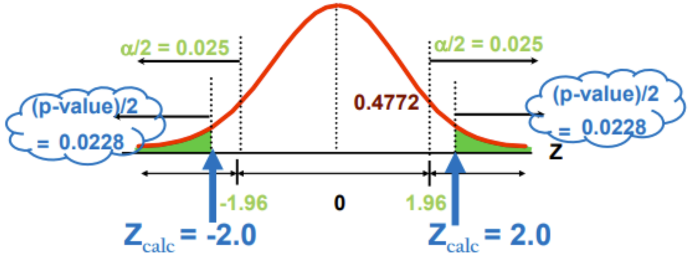
Rejection regions





Step 4: Decision **(using p-value method)**

Is the tail area(s) beyond the test statistic(s) larger or smaller than α?



p-value = 0.0228 + 0.0228 = **0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

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H_0: μ = 960

H_1: μ ≠ 960

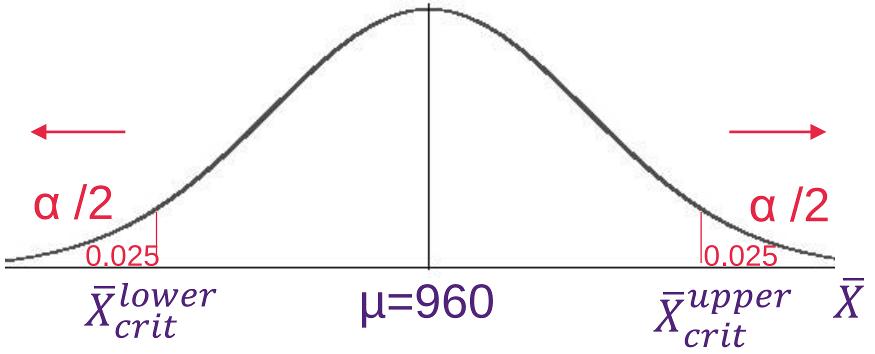
Step 2: Decision rule

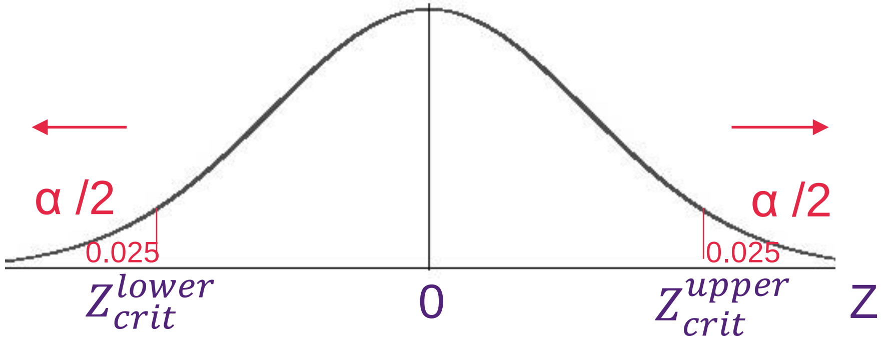
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = = \frac{954 - 960}{\frac{18.4}{\sqrt{20}}} = -1.46$$

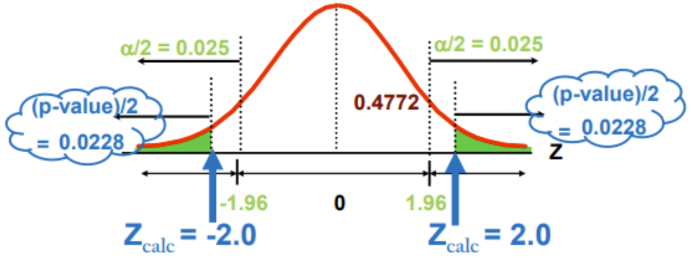
Rejection regions





Step 4: Decision (using p-value method)

Is the tail area(s) beyond the test statistic(s) larger or smaller than α?



p-value = 0.0228 + 0.0228 = **0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

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Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

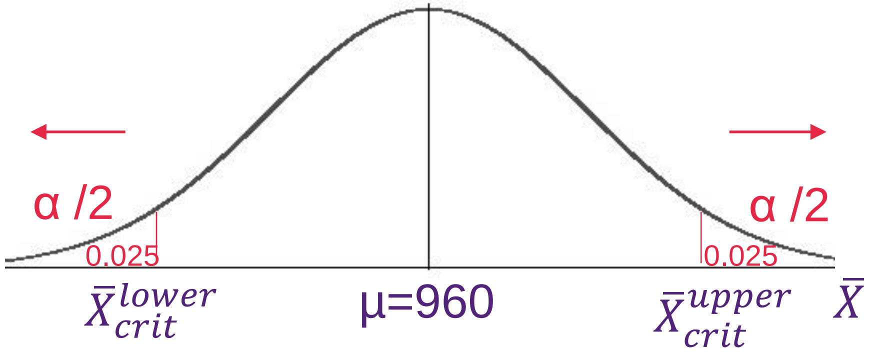
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

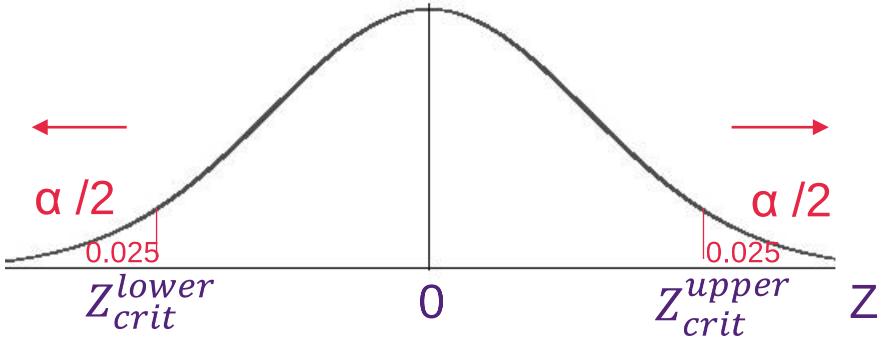
Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = = \frac{954 - 960}{\frac{18.4}{\sqrt{20}}} = -1.46$$

P-value = P(Z < -1.46)

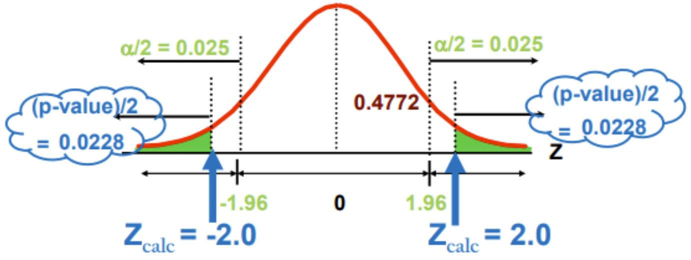
Rejection regions





Step 4: Decision **(using p-value method)**

Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 **= 0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

adm T10 Q1 Q2 Q3

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Step 1: State H_0 and H_1
H_0: μ = 960
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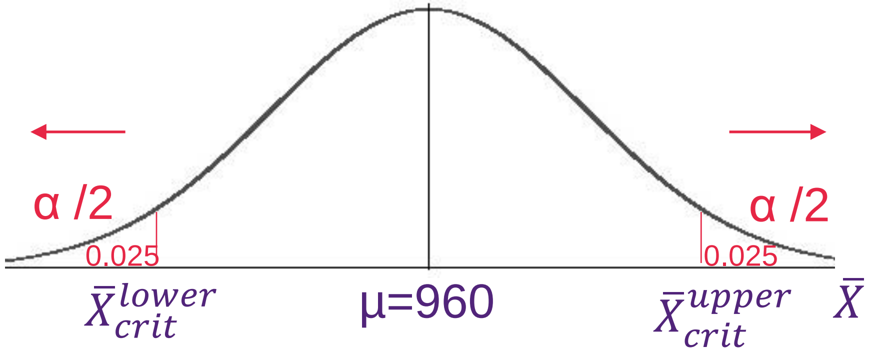
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

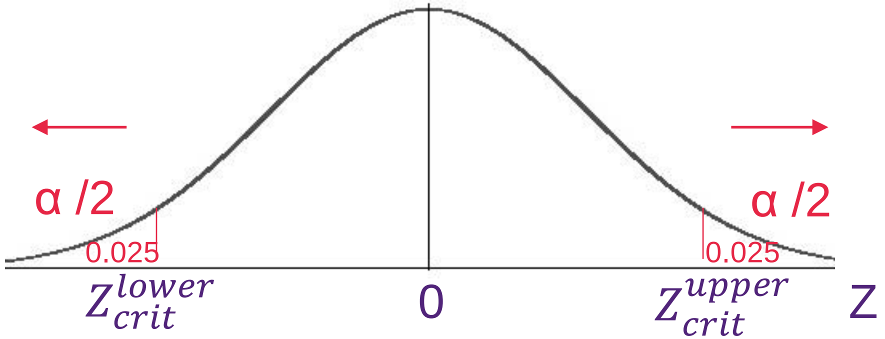
Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = = \frac{954 - 960}{\frac{18.4}{\sqrt{20}}} = -1.46$$

P-value = P(Z < -1.46) = 0.5 – P(-1.46 < Z < 0)
= 0.5 – P(0 < Z < 1.46)

Rejection regions





Step 4: Decision (using p-value method)

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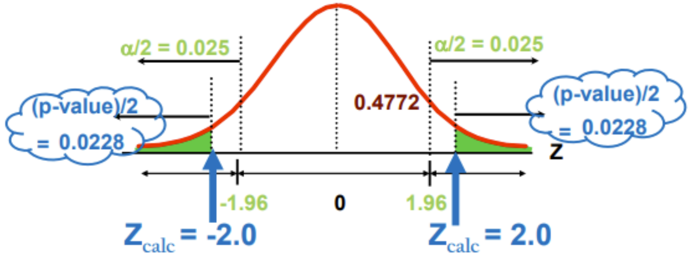

p-value = 0.0228 + 0.0228 **= 0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

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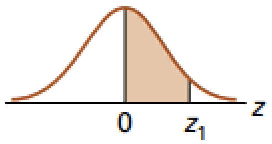
TABLE A.5 Areas of the standard normal distribution $\mu = 0, \sigma = 1$

The entries in this table are the probabilities that a standard normal random variable is between 0 and z_1 (the shaded area).



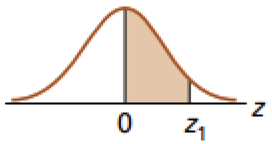
1.46

z_1	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
1.2	.3849	.3869	.3888	.3907	.3925	.3944	.3962	.3980	.3997	.4015
1.3	.4032	.4049	.4066	.4082	.4099	.4115	.4131	.4147	.4162	.4177
1.4	.4192	.4207	.4222	.4236	.4251	.4265	.4279	.4292	.4306	.4319
1.5	.4332	.4345	.4357	.4370	.4382	.4394	.4406	.4418	.4429	.4441
1.6	.4452	.4463	.4474	.4484	.4495	.4505	.4515	.4525	.4535	.4545
1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
1.8	.4641	.4649	.4656	.4664	.4671	.4678	.4686	.4693	.4699	.4706
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767

adm T10 Q1 Q2 Q3

TABLE A.5 Areas of the standard normal distribution $\mu = 0, \sigma = 1$

The entries in this table are the probabilities that a standard normal random variable is between 0 and z_1 (the shaded area).



1.46

z_1	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	.0000	.0040	.0080	.0120	.0160	.0199	.0239	.0279	.0319	.0359
0.1	.0398	.0438	.0478	.0517	.0557	.0596	.0636	.0675	.0714	.0753
0.2	.0793	.0832	.0871	.0910	.0948	.0987	.1026	.1064	.1103	.1141
0.3	.1179	.1217	.1255	.1293	.1331	.1368	.1406	.1443	.1480	.1517
0.4	.1554	.1591	.1628	.1664	.1700	.1736	.1772	.1808	.1844	.1879
0.5	.1915	.1950	.1985	.2019	.2054	.2088	.2123	.2157	.2190	.2224
0.6	.2257	.2291	.2324	.2357	.2389	.2422	.2454	.2486	.2517	.2549
0.7	.2580	.2611	.2642	.2673	.2704	.2734	.2764	.2794	.2823	.2852
0.8	.2881	.2910	.2939	.2967	.2995	.3023	.3051	.3078	.3106	.3133
0.9	.3159	.3186	.3212	.3238	.3264	.3289	.3315	.3340	.3365	.3389
1.0	.3413	.3438	.3461	.3485	.3508	.3531	.3554	.3577	.3599	.3621
1.1	.3643	.3665	.3686	.3708	.3729	.3749	.3770	.3790	.3810	.3830
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1.7	.4554	.4564	.4573	.4582	.4591	.4599	.4608	.4616	.4625	.4633
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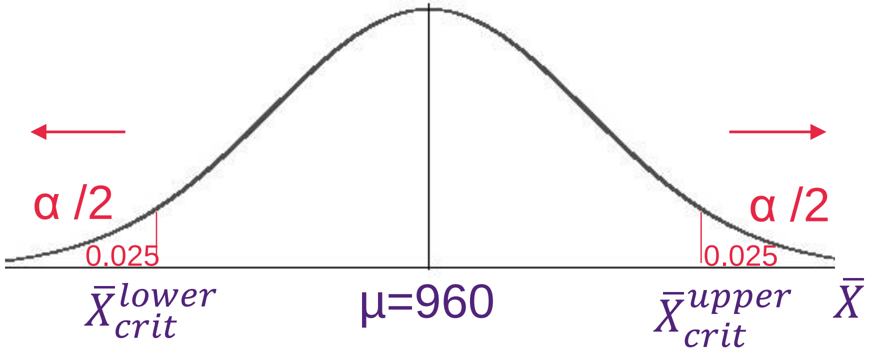
1.9	.4713	.4719	.4726	.4732	.4738	.4744	.4750	.4756	.4761	.4767

μ = 960 lumens
σ = 18.4 lumens
n = 20 new bulbs
$\bar{X}$ = 954 lumens
α = 0.05

Q1. GEI developed a new bulb whose design specifications call for a mean light output of 960 lumens (compared to an earlier model that provided only 750 lumens). The company's data indicate that the standard deviation of light output for this type of bulb is 18.4 lumens, and light output is approximately normally distributed. From a sample of 20 new bulbs, the testing committee found an average light output of 954 lumens per bulb. At a 0.05 significance level can GEI conclude that its new bulb is producing the specified mean 960 lumen output? Use the **p-value approach.**

Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

Rejection regions

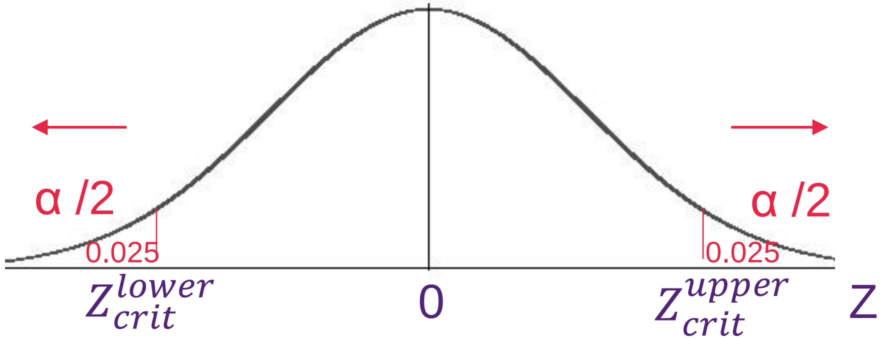


Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}

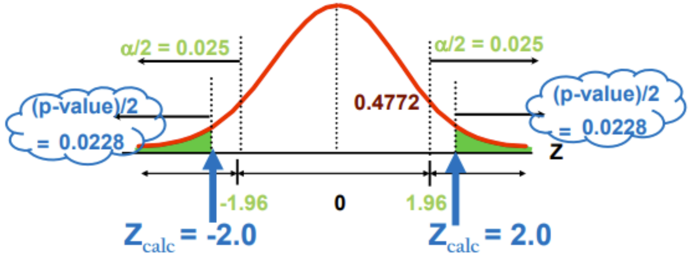
$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = = \frac{954 - 960}{\frac{18.4}{\sqrt{20}}} = -1.46$$

P(Z < -1.46) = 0.5 – P(-1.46 < Z < 0)
= 0.5 – P(0 < Z < 1.46) = 0.5 – 0.4279 = 0.0721



Step 4: Decision **(using p-value method)**

Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 = **0.0456**

p-value = 4.56 % < α = 5% so REJECT H_0

adm T10 Q1 Q2 Q3

μ = 960 lumens
σ = 18.4 lumens
n = 20 new bulbs
$\bar{X}$ = 954 lumens
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Q1. GEI developed a new bulb whose design specifications call for a mean light output of 960 lumens (compared to an earlier model that provided only 750 lumens). The company's data indicate that the standard deviation of light output for this type of bulb is 18.4 lumens, and light output is approximately normally distributed. From a sample of 20 new bulbs, the testing committee found an average light output of 954 lumens per bulb. At a 0.05 significance level can GEI conclude that its new bulb is producing the specified mean 960 lumen output? Use the **p-value approach.**

Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}

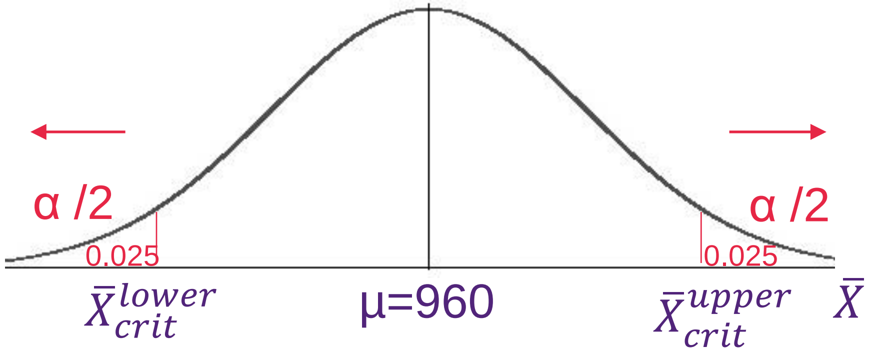
$$Z_{calc} = \frac{\bar{X} - \mu}{\sigma_{\bar{X}}} = \frac{\bar{X} - \mu}{\frac{\sigma}{\sqrt{n}}} = = \frac{954 - 960}{\frac{18.4}{\sqrt{20}}} = -1.46$$

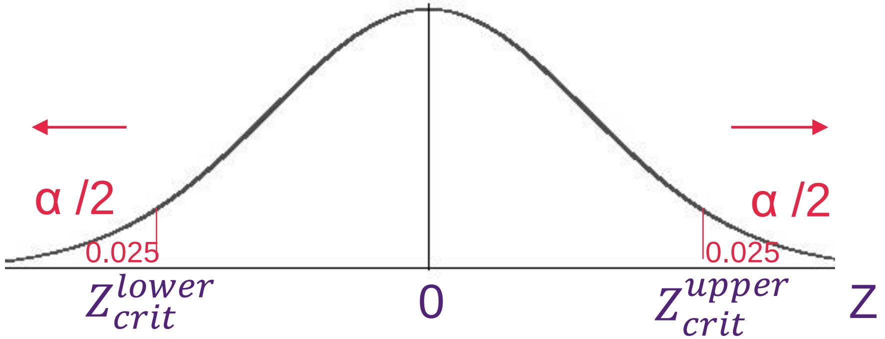
P(Z < -1.46) = 0.5 – P(-1.46 < Z < 0)
= 0.5 – P(0 < Z < 1.46) = 0.5 – 0.4279 = 0.0721

Area of one tail

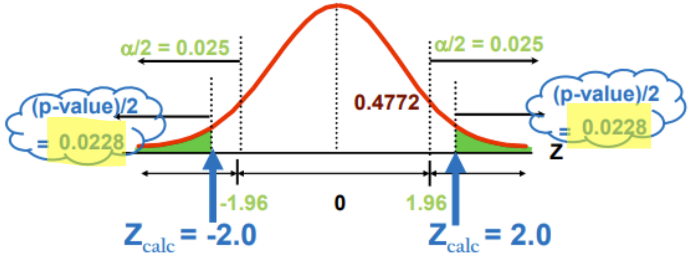
p-value (two tails) = 0.0721 * 2 = 0.1442

Rejection regions





Step 4: Decision **(using p-value method)**
Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 = 0.0456
p-value = 4.56 % < α = 5% so REJECT H_0

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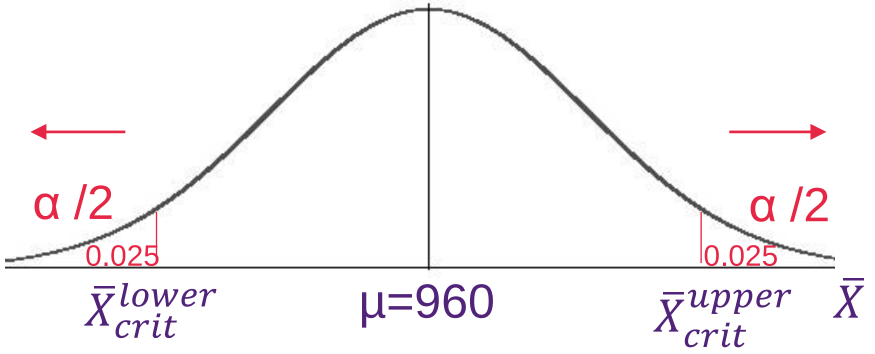
Step 1: State H_0 and H_1
H_0: μ = 960
H_1: $\mu \neq$ 960

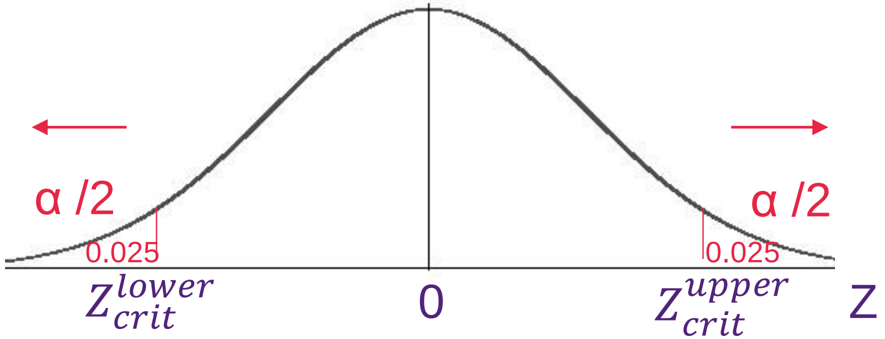
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}
p-value (two tails) = 0.1442

Step 4: Make a decision
p-value < α

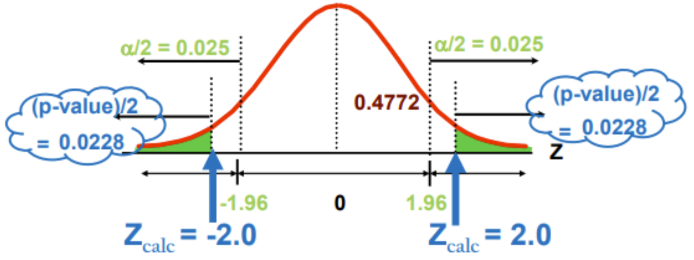
Rejection regions





Step 4: Decision **(using p-value method)**

Is the tail area(s) beyond the test statistic(s) larger or smaller than α?



p-value = 0.0228 + 0.0228 **= 0.0456**

p-value = 4.56 % < α = 5% so **REJECT H_0**

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

μ = 960 lumens
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$\bar{X}$ = 954 lumens
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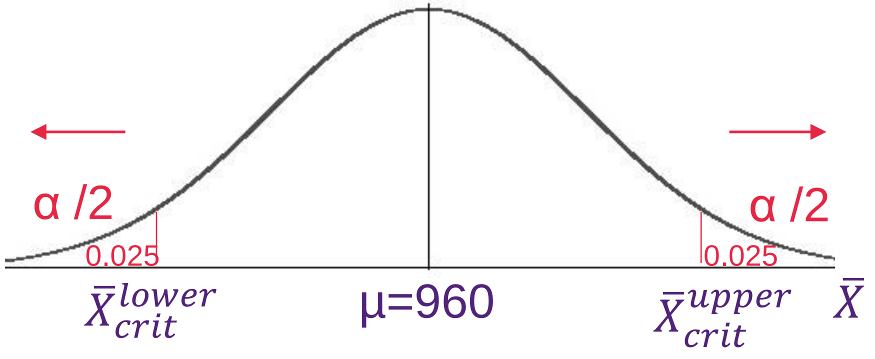
Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

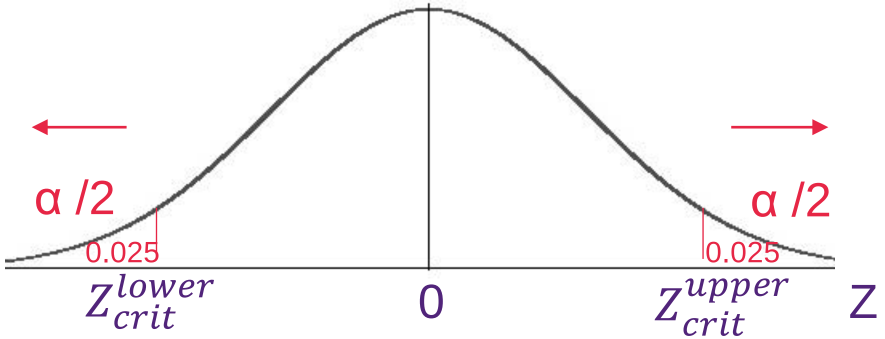
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

Step 3: Calculate Z_{calc}
p-value (two tails) = 0.1442

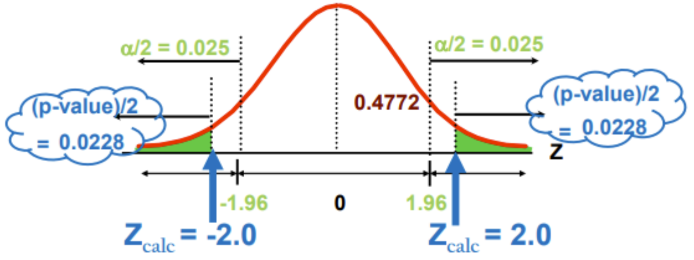
Step 4: Make a decision
p-value < α → 0.1442 < 0.05 ?

Rejection regions





Step 4: Decision **(using p-value method)**
Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 = **0.0456**
p-value = 4.56 % < α = 5% so REJECT H_0

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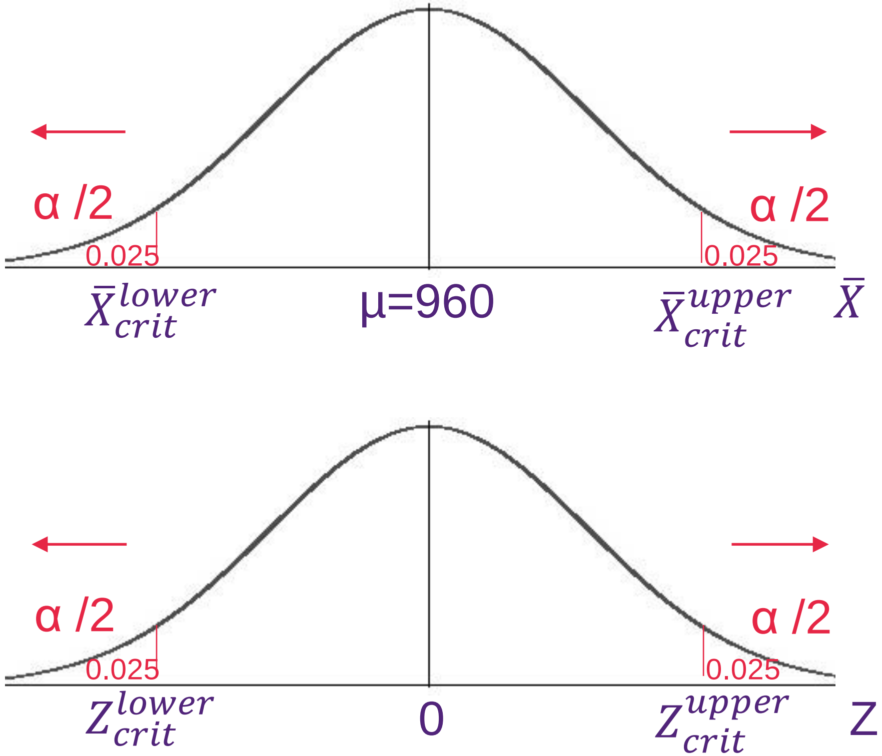
Step 1: State H_0 and H_1
H_0: μ = 960
H_1: μ ≠ 960

Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

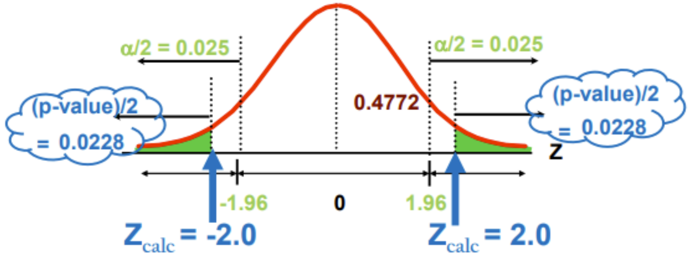
Step 3: Calculate Z_{calc}
p-value (two tails) = 0.1442

Step 4: Make a decision
p-value < α → 0.1442 < 0.05 → Do not reject H_0.

Rejection regions



Step 4: Decision **(using p-value method)**
Is the tail area(s) beyond the test statistic(s) larger or smaller than **α**?



p-value = 0.0228 + 0.0228 = **0.0456**
p-value = 4.56 % < α = 5% so REJECT H_0

THE UNIVERSITY OF QUEENSLAND AUSTRALIA

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Step 1: State H_0 and H_1
H_0: $\mu = 960$
H_1: $\mu \neq 960$

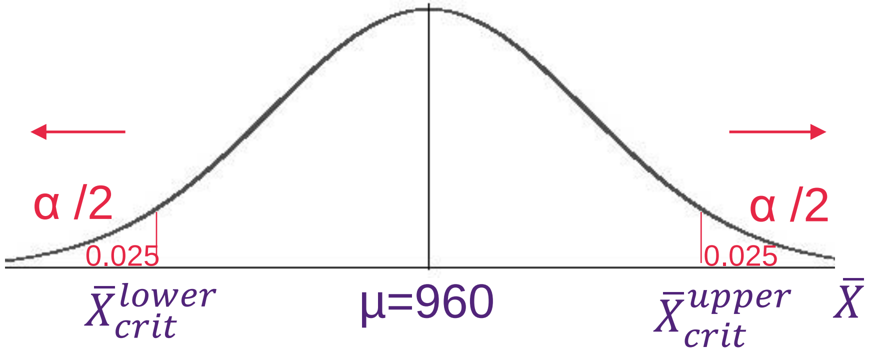
Step 2: Decision rule
Reject H_0 if p-value < α = 0.05

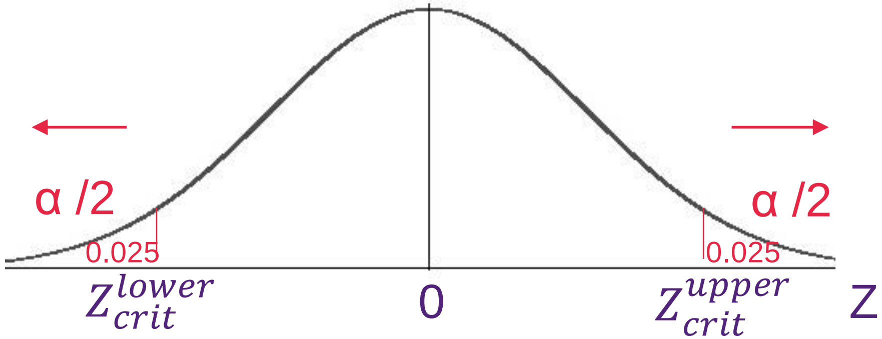
Step 3: Calculate Z_{calc}
p-value (two tails) = 0.1442

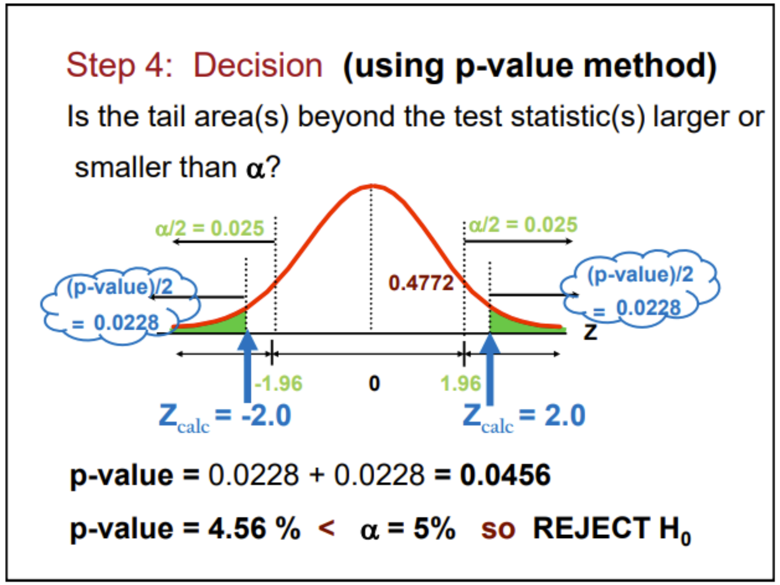
Step 4: Make a decision
p-value < α → 0.1442 < 0.05 → Do not reject H_0.

Step 5: Conclusion
There is insufficient evidence at the 5% level of significance to suggest average light output is different from 960 lumens.

Rejection regions







Q2. An electric company indicates 18% of all households in a particular community own personal computers. A study of 80 families with school-age children in this community found 22 of the families owned computers.

a) Test whether the proportion of families with school-age children owning computers is higher than in the overall general community. Using $\alpha = 0.02$, do the hypothesis test in two ways.
   i) Firstly, use the critical value of the test statistic.
   ii) Secondly, use the critical value of the sample proportion.

b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

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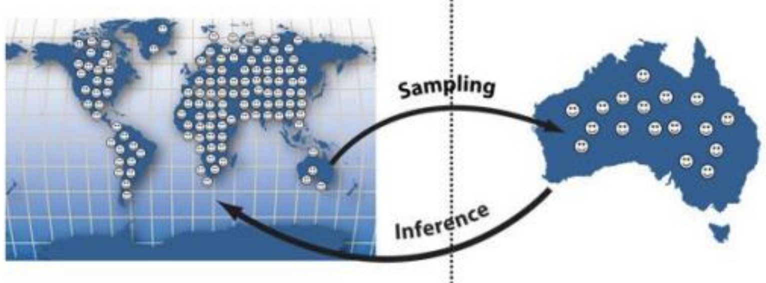
(Poll)

Inferential Statistics: drawing conclusions about a population based on a randomly selected sample.

POPULATION | Sample



PARAMETERS			Statistics		
POPULATION SIZE	=	N	sample size	=	n
POPULATION MEAN	=	μ	sample mean	=	$\bar{x}$
POPULATION STD. DEV.	=	σ	sample std. dev.	=	s
POPULATION VARIANCE	=	σ²	sample variance	=	s²
POPULATION PROPORTION	=	p	sample proportion	=	p̂

1. **What symbol would you give to the value 18% of all households?** (Single Choice) *
   - σ (sigma)
   - s
   - p
   - p̂ (p hat)
   - Level of Confidence (LOC)
   - α (alpha)
   - n

2. **What symbol would you give to the value 80 families?** (Single Choice) *
   - σ (sigma)
   - s
   - p
   - p̂ (p hat)
   - Level of Confidence (LOC)
   - α (alpha)
   - n

3. **What symbol would you give to the value 22 of the families?** (Single Choice) *
   - σ (sigma)
   - s
   - p
   - p̂ (p hat)
   - Level of Confidence (LOC)
   - α (alpha)
   - n

4. **What symbol would you give to the value 0.02?** (Single Choice) *
   - σ (sigma)
   - s
   - p
   - p̂ (p hat)
   - Level of Confidence (LOC)
   - α (alpha)
   - n

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AUSTRALIA

Q2. An electric company indicates 18% of all households in a particular community own personal computers. A study of 80 families with school-age children in this community found 22 of the families owned computers.

a) Test whether the proportion of families with school-age children owning computers is higher than in the overall general community. Using $\alpha = 0.02$, do the hypothesis test in two ways.

(Poll)

1. What symbol would you give to the value 18% of all households? (Single Choice) *

- σ (sigma)
- s
- p
- p̂ (p hat)
- Level of Confidence (LOC)
- α (alpha)
- n

2. What symbol would you give to the value 80 families? (Single Choice) *

- σ (sigma)
- s
- p
- p̂ (p hat)
- Level of Confidence (LOC)
- α (alpha)
- n

3. What symbol would you give to the value 0.02? (Single Choice) *

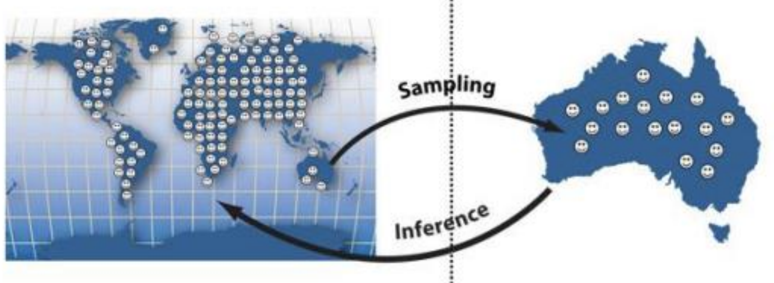
- σ (sigma)
- s
- p
- p̂ (p hat)
- Level of Confidence (LOC)
- α (alpha)
- n

4. How much is p̂ (p hat)? (Single Choice) *

- 0.02
- 0.18
- 0.275
- 22
- 80

Inferential Statistics drawing conclusions about a population based on a randomly selected sample.

POPULATION | Sample



PARAMETERS			Statistics		
POPULATION SIZE	=	N	sample size	=	n
POPULATION MEAN	=	μ	sample mean	=	x̄
POPULATION STD. DEV.	=	σ	sample std. dev.	=	s
POPULATION VARIANCE	=	σ^2	sample variance	=	s^2
POPULATION PROPORTION	=	p	sample proportion	=	p̂

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p = 18% = 0.18
n = 80 families
$\hat{p}$ = 22/80 = 0.275
α = 0.02

Q2. An electric company indicates 18% of all households in a particular community own personal computers. A study of 80 families with school-age children in this community found 22 of the families owned computers.

a) Test whether the proportion of families with school-age children owning computers is higher than in the overall general community. Using $\alpha = 0.02$, do the hypothesis test in two ways.

1. What type of problem is it? (Single Choice) *

- Population Mean (Seagull) (no sample)
- Population Mean (Pelican) (σ is known)
- Population Mean (Shag) (σ is unknown but s is known)
- Population Mean difference (salmon vs trout) (σ are unknown)
- Population Proportion (Freaky fish) (proportion)

2. What table will we use? (Single Choice) *

- Z table (standard normal distribution)
- t table (Student's t-distribution)

(Poll)

3. What is the value of α (alpha)? (Single Choice) *

- 0.01
- 0.02
- 0.03
- 0.04
- 0.05
- 0.1

4. What type of test is it? (Single Choice) *

- one tail test (upper tail >)
- one tail test (lower tail <)
- two tail test (=)

adm T10 Q1 Q2 Q3

p = 18% = 0.18
n = 80 families
$\hat{p}$ = 22/80 = 0.275
α = 0.02

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(Poll)

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- 0.01
- 0.02
- 0.03
- 0.04
- 0.05
- 0.1

4. What type of test is it? (Single Choice) *

- one tail test (upper tail >)
- one tail test (lower tail <)
- two tail test (=)

p = 18% = 0.18
n = 80 families
$\hat{p}$ = 22/80 = 0.275
α = 0.02

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   i) Firstly, use the critical value of the test statistic.
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b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

Step 1: State H_0 and H_1

Summary: Rearranged useful formulae

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

$$p = \hat{p} - Z\sigma_{\hat{p}} \quad (use\ correct\ sign\ of\ Z)$$

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

34

adm T10 Q1 Q2 Q3

THE UNIVERSITY OF QUEENSLAND
AUSTRALIA

p = 18% = 0.18
n = 80 families
$\hat{p}$ = 22/80 = 0.275
α = 0.02

Q2. An electric company indicates 18% of all households in a particular community own personal computers. A study of 80 families with school-age children in this community found 22 of the families owned computers.

a) Test whether the proportion of families with school-age children owning computers is higher than in the overall general community. Using α = 0.02, do the hypothesis test in two ways.
   i) Firstly, use the critical value of the test statistic.
   ii) Secondly, use the critical value of the sample proportion.

b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

Step 1: State H_0 and H_1
H_0:
H_1: p > 0.18

One tail test

Summary: Rearranged useful formulae

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

$$p = \hat{p} - Z\sigma_{\hat{p}} \quad (\textit{use correct sign of } Z)$$

$$\hat{p} = p + Z\sigma_{\hat{p}} \quad (\textit{use correct sign of } Z)$$

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THE UNIVERSITY OF QUEENSLAND AUSTRALIA

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ii) Secondly, use the critical value of the sample proportion.

b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

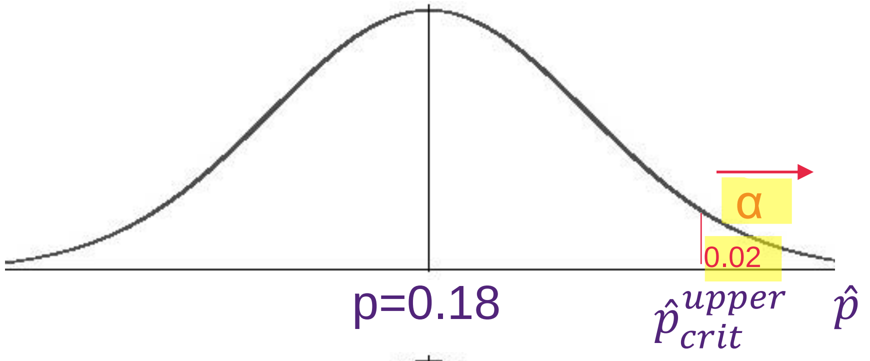
Step 1: State H_0 and H_1

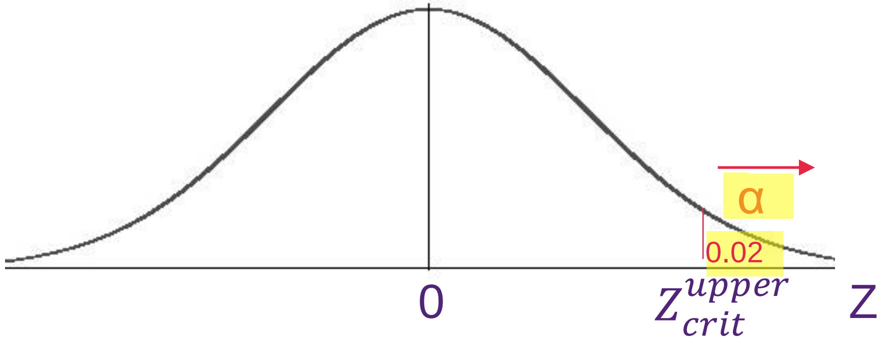
H_0: p ≤ 0.18 or could be p = 0.18

H_1: p > 0.18

One tail test

Rejection regions





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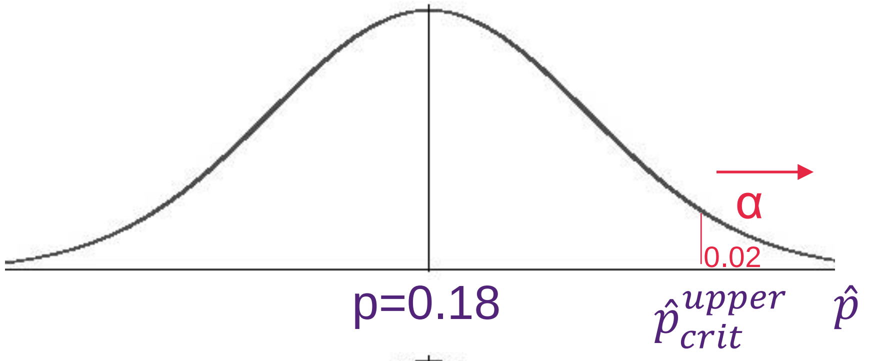

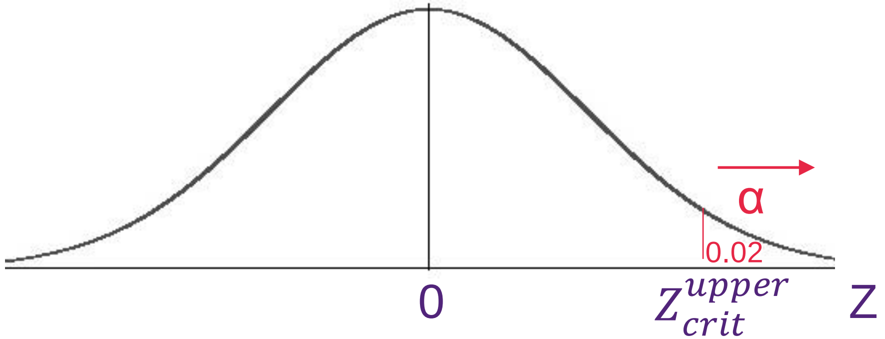

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
H_1: p > 0.18

Step 2: Decision rule
Reject H_0 if $|Z_{calc}| > Z_{crit}$

Summary: Rearranged useful formulae

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

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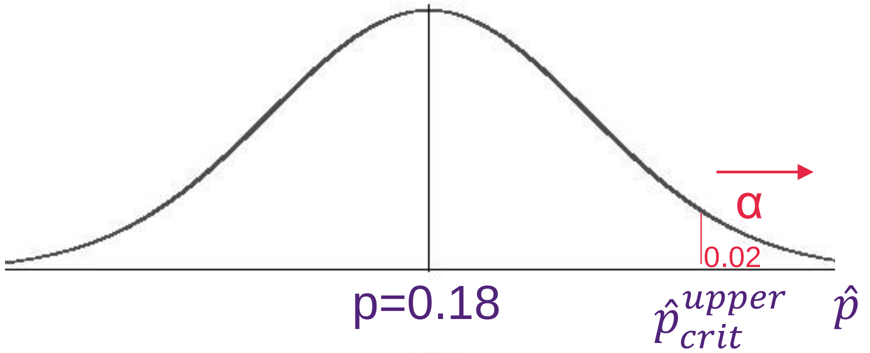

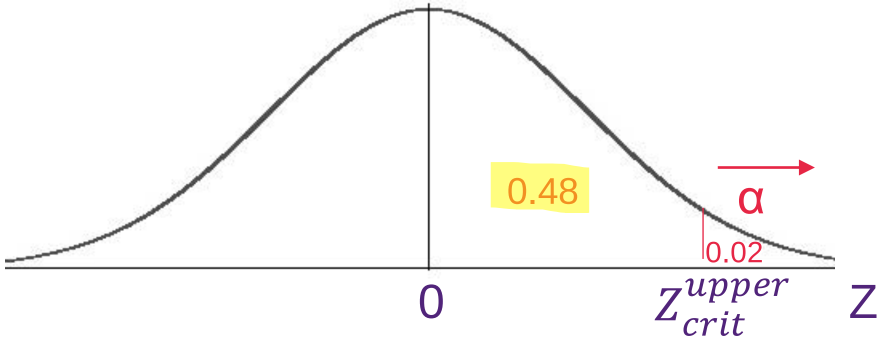

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
H_1: p > 0.18

Step 2: Decision rule
Reject H_0 if $Z_{calc} > Z_{crit}$ = ?

Summary: Rearranged useful formulae

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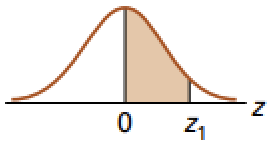
34

adm T10 Q1 Q2 Q3

TABLE A.5 Areas of the standard normal distribution $\mu = 0, \sigma = 1$

The entries in this table are the probabilities that a standard normal random variable is between 0 and z_1 (the shaded area).



0.48

z_1	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
2.0	.4772	.4778	.4783	.4788	.4793	.4798	.4803	.4808	.4812	.4817
2.1	.4821	.4826	.4830	.4834	.4838	.4842	.4846	.4850	.4854	.4857
2.2	.4861	.4864	.4868	.4871	.4875	.4878	.4881	.4884	.4887	.4890
2.3	.4893	.4896	.4898	.4901	.4904	.4906	.4909	.4911	.4913	.4916
2.4	.4918	.4920	.4922	.4925	.4927	.4929	.4931	.4932	.4934	.4936
2.5	.4938	.4940	.4941	.4943	.4945	.4946	.4948	.4949	.4951	.4952
2.6	.4953	.4955	.4956	.4957	.4959	.4960	.4961	.4962	.4963	.4964
2.7	.4965	.4966	.4967	.4968	.4969	.4970	.4971	.4972	.4973	.4974
2.8	.4974	.4975	.4976	.4977	.4977	.4978	.4979	.4979	.4980	.4981
2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
3.2	.4993	.4993	.4994	.4994	.4994	.4994	.4994	.4995	.4995	.4995
3.3	.4995	.4995	.4995	.4996	.4996	.4996	.4996	.4996	.4996	.4997
3.4	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4997	.4998
3.5	.4998									
4.0	.49997									
4.5	.499997									
5.0	.4999997									
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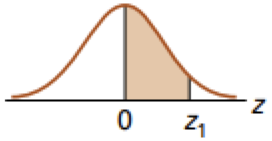

z_1	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
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2.9	.4981	.4982	.4982	.4983	.4984	.4984	.4985	.4985	.4986	.4986
3.0	.4987	.4987	.4987	.4988	.4988	.4989	.4989	.4989	.4990	.4990
3.1	.4990	.4991	.4991	.4991	.4992	.4992	.4992	.4992	.4993	.4993
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adm T10 Q1 Q2 Q3

The University of Queensland
AUSTRALIA

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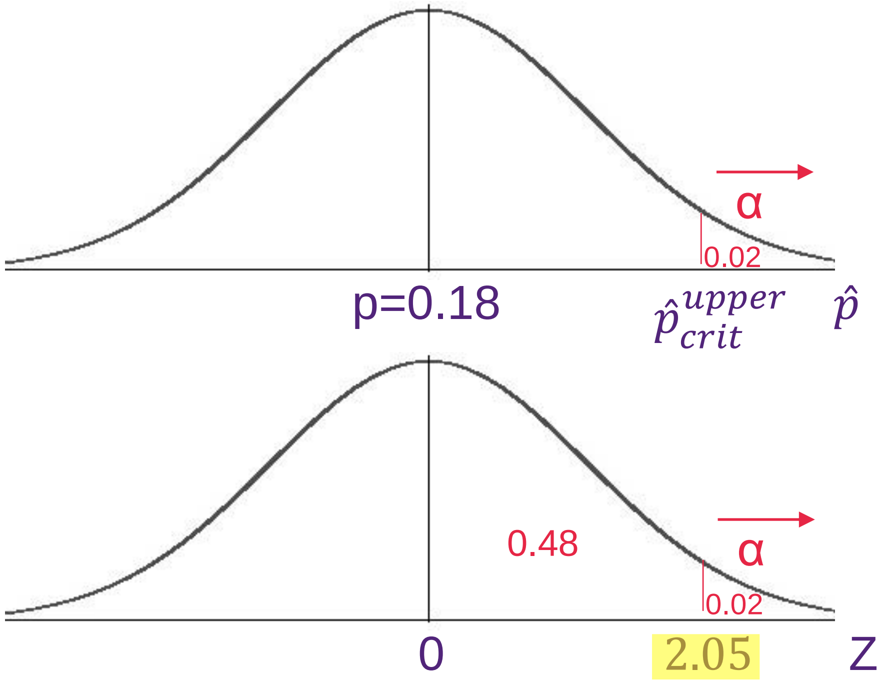
b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
H_1: p > 0.18

Step 2: Decision rule
Reject H_0 if $Z_{calc} > Z_{crit}$ = 2.05

Rejection regions



Summary: Rearranged useful formulae

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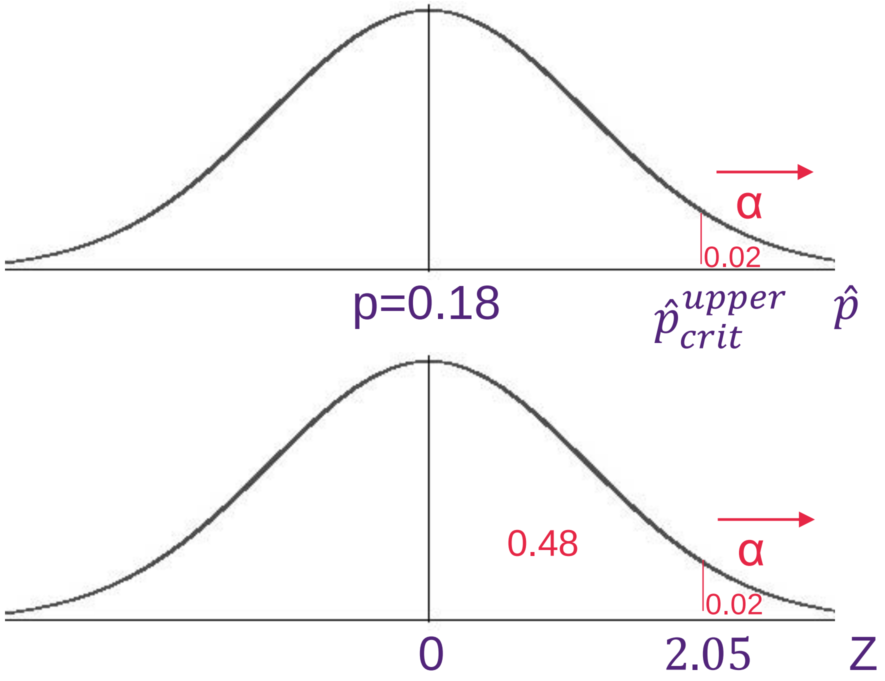

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Step 2: Decision rule
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Step 3: Calculate Z_{calc}

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

Summary: Rearranged useful formulae

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

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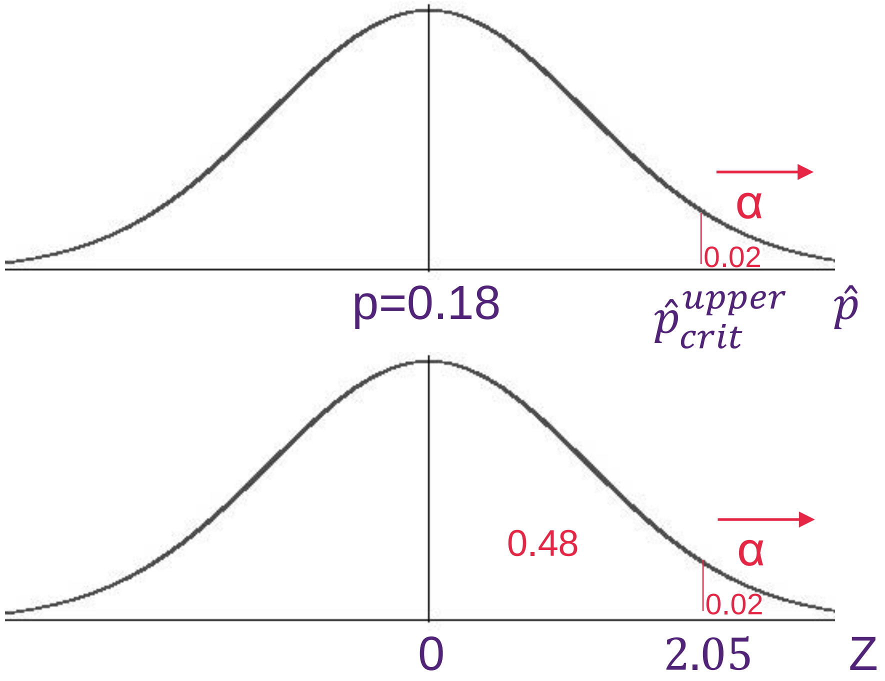

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Step 2: Decision rule
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Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\hat{p}-p}{\sigma_{\hat{p}}} = \frac{\hat{p}-p}{\sqrt{\frac{p(1-p)}{n}}} = \frac{0.275-0.18}{\sqrt{\frac{0.18(1-0.18)}{80}}} = 2.21$$

Summary: Rearranged useful formulae

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AUSTRALIA

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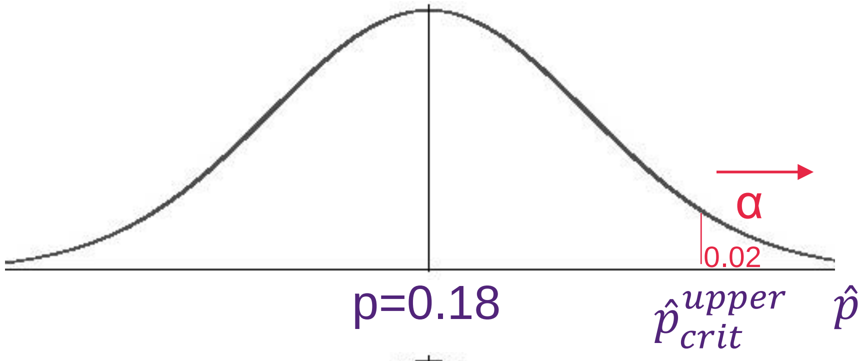

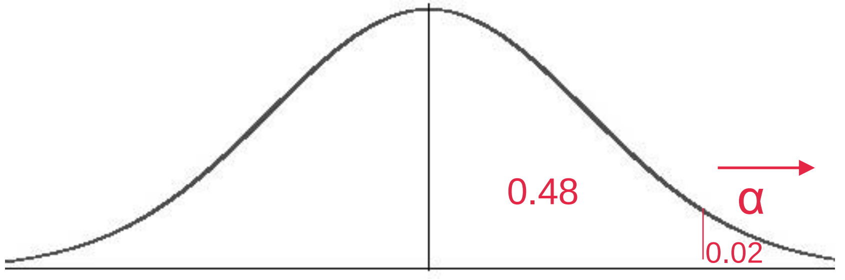

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
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Step 2: Decision rule
Reject H_0 if $Z_{calc} > Z_{crit}$ = 2.05

Step 3: Calculate Z_{calc}

$$Z_{calc} = \frac{\hat{p} - p}{\sigma_{\hat{p}}} = \frac{\hat{p} - p}{\sqrt{\frac{p(1-p)}{n}}} = \frac{0.275 - 0.18}{\sqrt{\frac{0.18(1-0.18)}{80}}} = 2.21$$

Step 4: Make a decision
$Z_{calc} > Z_{crit} \rightarrow$ 2.21 > 2.05 ?

Summary: Rearranged useful formulae

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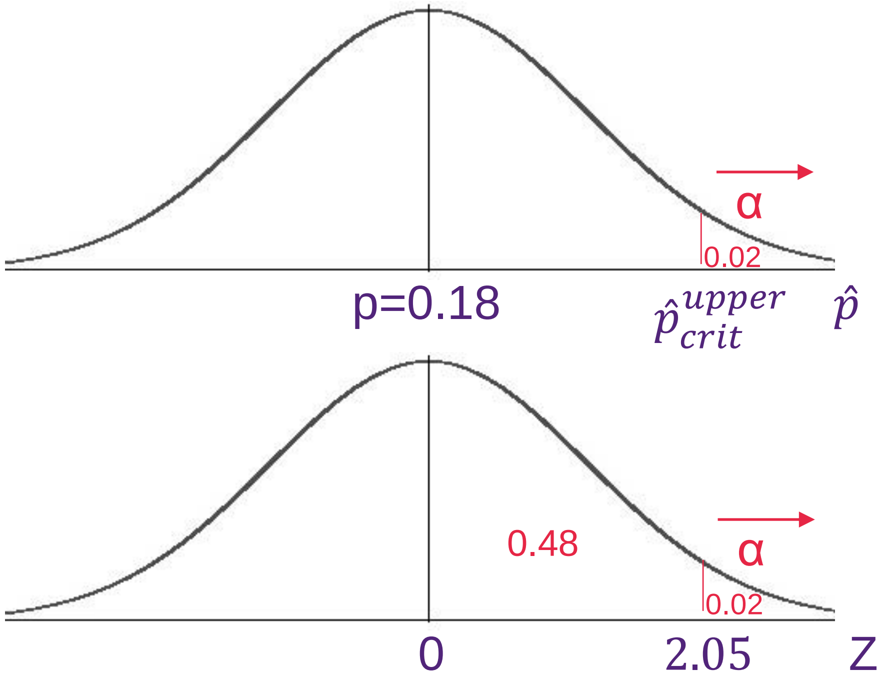

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Step 3: Calculate Z_{calc}

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$Z_{calc} > Z_{crit}$ → 2.21 > 2.05 → Reject H_0.

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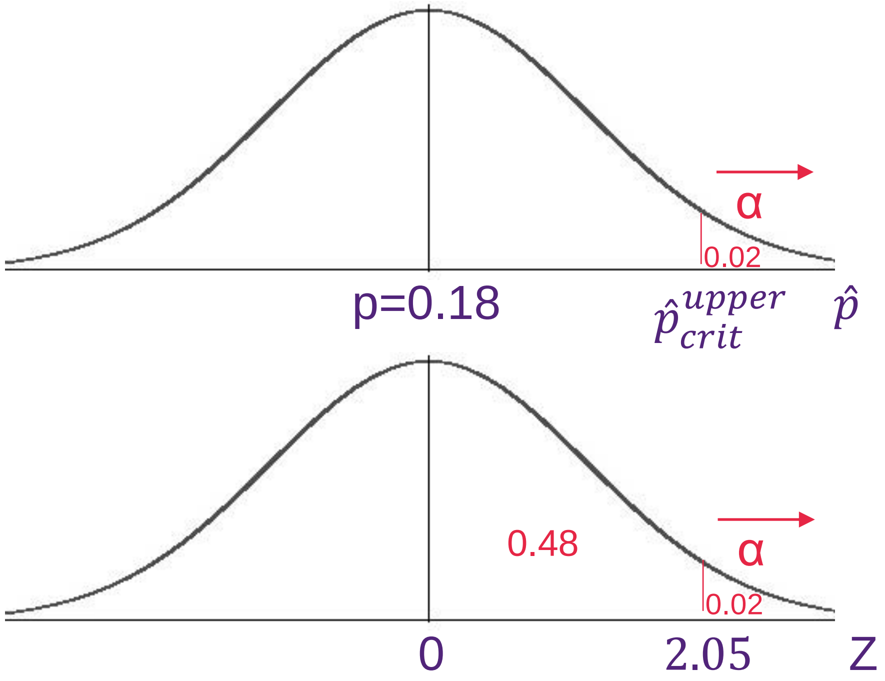

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Step 4: Make a decision
$Z_{calc} > Z_{crit}$ → 2.21 > 2.05 → Reject H_0.

Step 5: Conclusion
There is sufficient evidence to suggest that the population of families with children who own computers is higher than 18% at 2% level of significance.

Summary: Rearranged useful formulae

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

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The University Of Queensland AUSTRALIA

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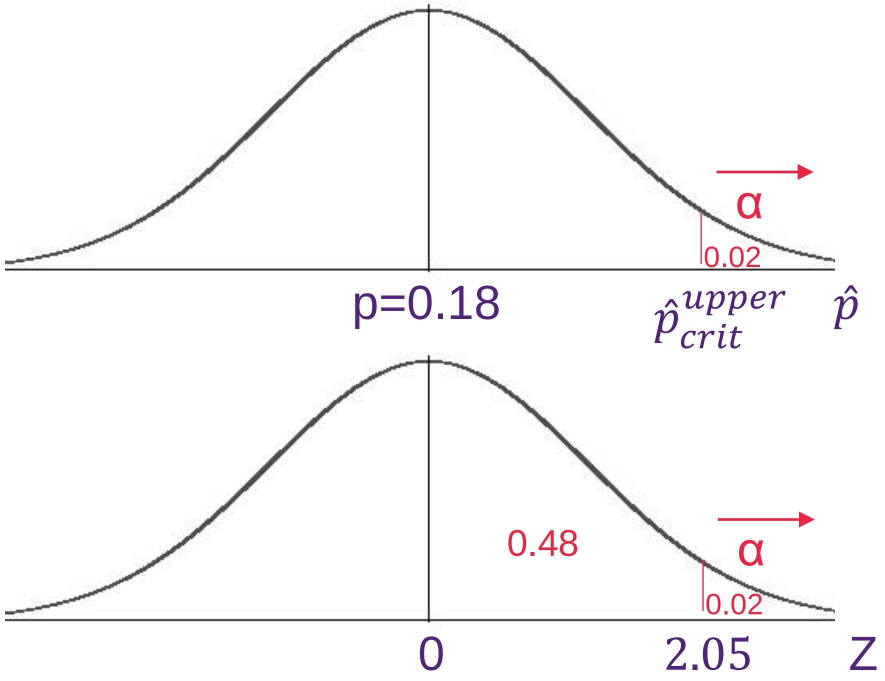
Rejection regions



Step 1: State H_0 and H_1
H_0: p ≤ 0.18
H_1: p > 0.18

Step 2: Decision rule
Reject H_0 if

Summary: Rearranged useful formulae

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

$$p = \hat{p} - Z\sigma_{\hat{p}} \quad (use\ correct\ sign\ of\ Z)$$

$$\hat{p} = p + Z\sigma_{\hat{p}} \quad (use\ correct\ sign\ of\ Z)$$

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

34

adm T10 Q1 Q2 Q3

p = 18% = 0.18
n = 80 families
$\hat{p}$ = 22/80 = 0.275
α = 0.02

Q2. An electric company indicates 18% of all households in a particular community own personal computers. A study of 80 families with school-age children in this community found 22 of the families owned computers.

a) Test whether the proportion of families with school-age children owning computers is higher than in the overall general community. Using $\alpha = 0.02$, do the hypothesis test in two ways.
   i) Firstly, use the critical value of the test statistic.
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b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

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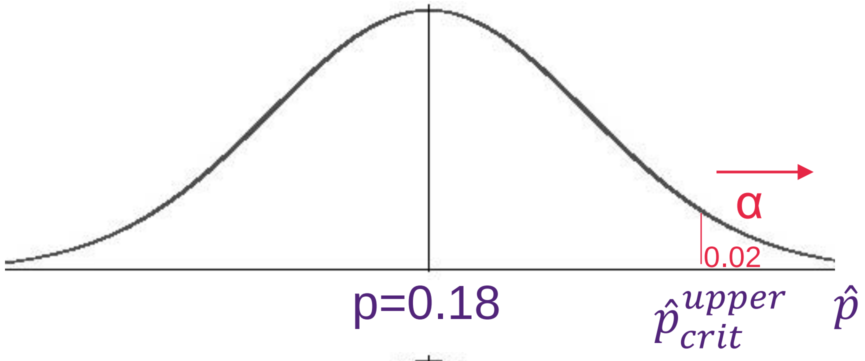

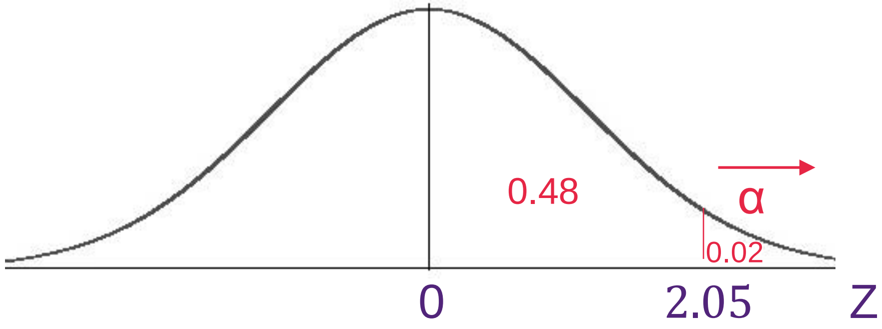

Step 1: State H_0 and H_1

H_0: p ≤ 0.18

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Reject H_0 if $\hat{p} > \hat{p}_{crit}^{upper} = p + Z_{crit} * \sqrt{\frac{p(1-p)}{n}}$

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34

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b) If the proportion of families with school-age children owning computers was actually 17%, what error (if any) had been made in part a?

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
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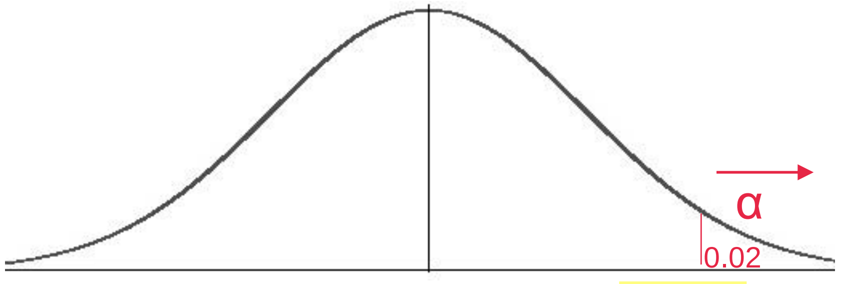
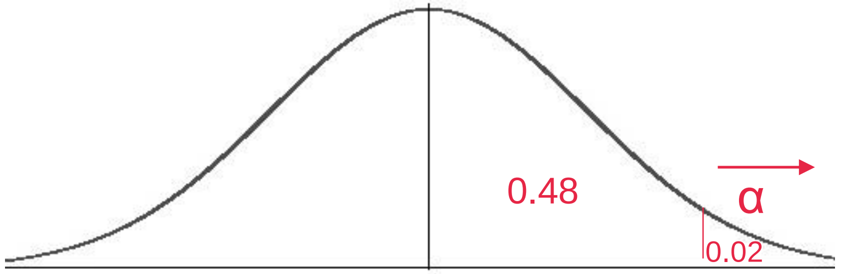
Step 2: Decision rule

Reject H_0 if $\hat{p} > \hat{p}_{crit}^{upper}$ = p + Z_{crit} * $\sqrt{\frac{p(1-p)}{n}}$

= 0.18 + 2.05 * $\sqrt{\frac{0.18(1-0.18)}{80}}$ = 0.268

Rejection regions





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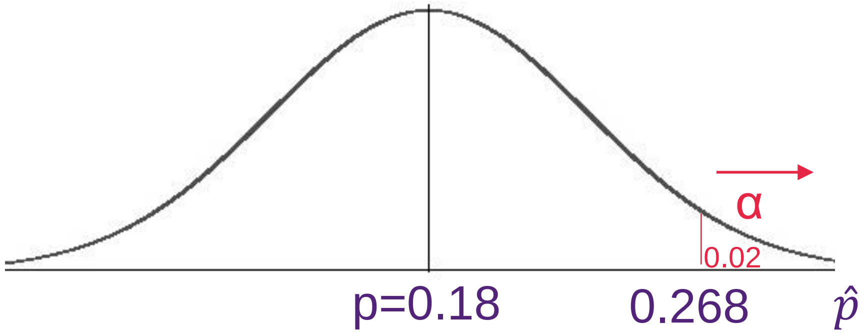

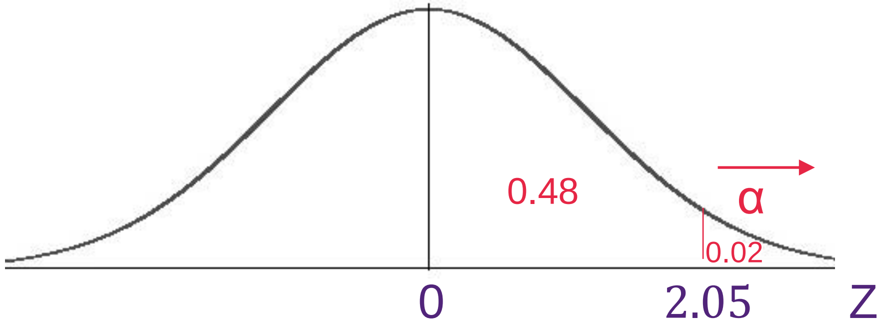

Step 1: State H_0 and H_1
H_0: p ≤ 0.18
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Step 2: Decision rule
Reject H_0 if $\hat{p} > \hat{p}_{crit}^{upper}$ = 0.268

Step 3: Calculate $\hat{p}$
$\hat{p}$ = 0.275

Summary: Rearranged useful formulae

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

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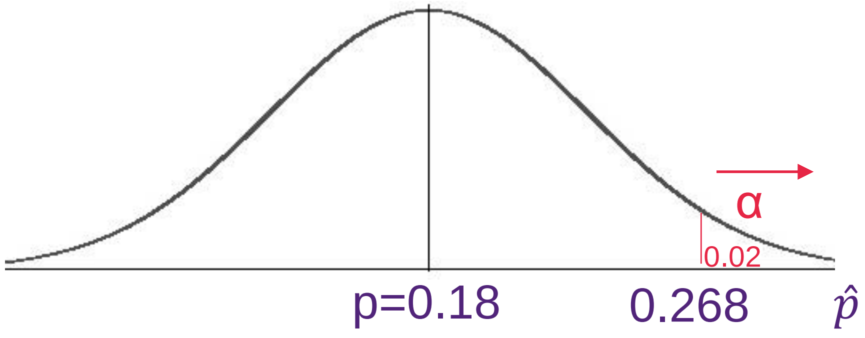

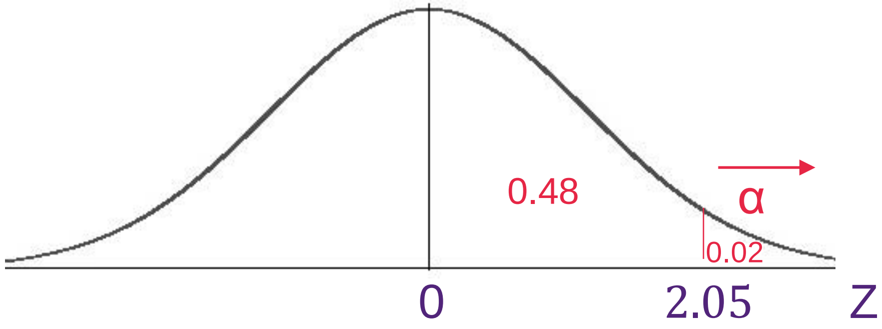

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Step 3: Calculate $\hat{p}$
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Step 4: Make a decision
$\hat{p} > \hat{p}_{crit}^{upper}$ = 0.275 > 0.268 ?

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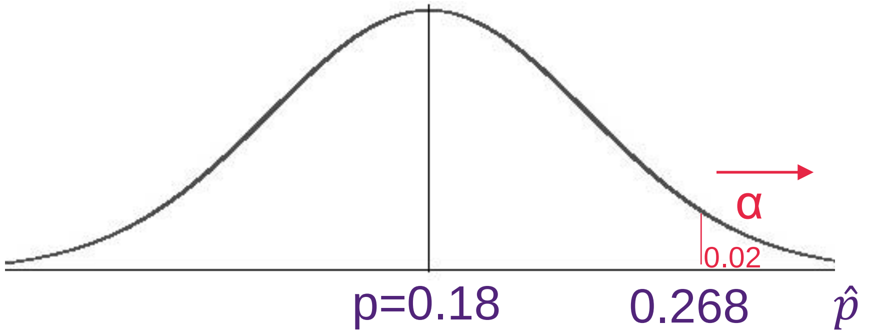

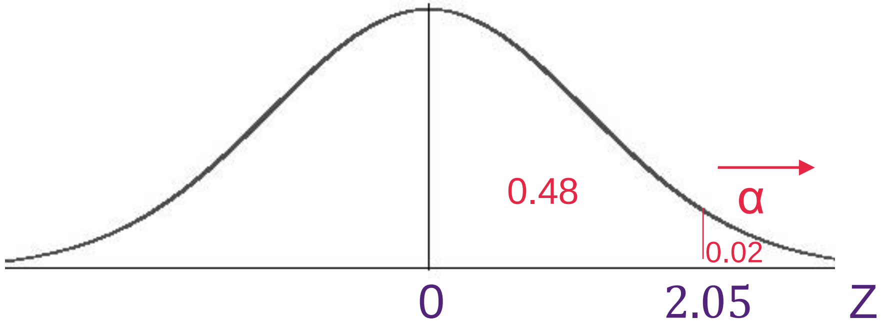

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Step 3: Calculate $\hat{p}$
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Step 4: Make a decision
$\hat{p} > \hat{p}_{crit}^{upper}$ → 0.275 > 0.268 → Reject H_0.

Step 5: Conclusion
There is sufficient evidence to suggest that the population of families with children who own computers is higher than 18% at 2% level of significance.

Summary: Rearranged useful formulae

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

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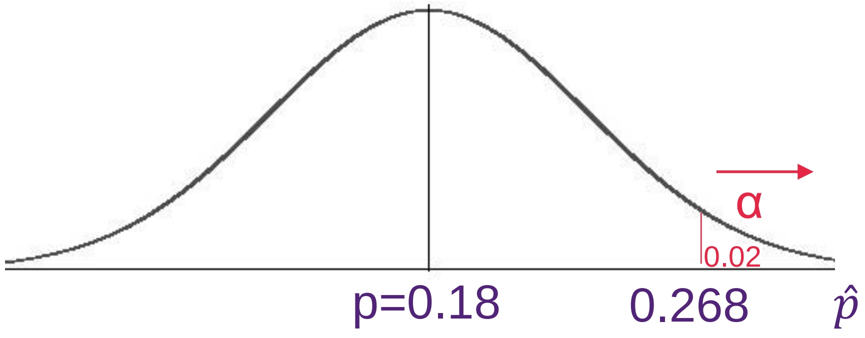

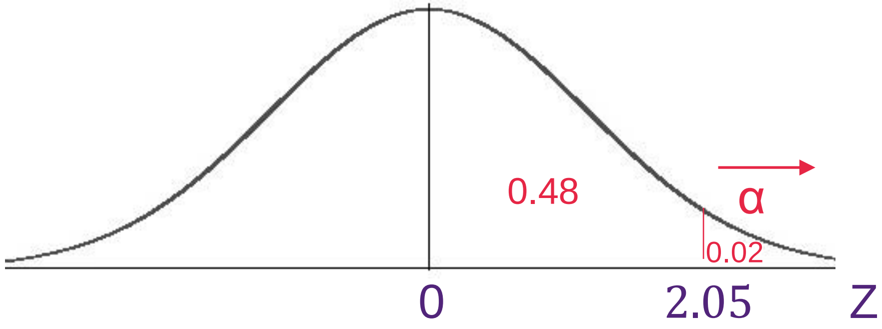

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Step 5: Conclusion
There is sufficient evidence to suggest that the population of families with children who own computers is higher than 18% at 2% level of significance.

Error Table Associated with Hypothesis Testing Decisions.

Possible Outcomes from Decisions

Statistical Decision	Actual (reality) Situation: H_0 True	Actual (reality) Situation: H_0 False
Do Not Reject H_0	✓	**Type II Error**
Reject H_0	**Type I Error**	✓

18

adm T10 Q1 Q2 Q3

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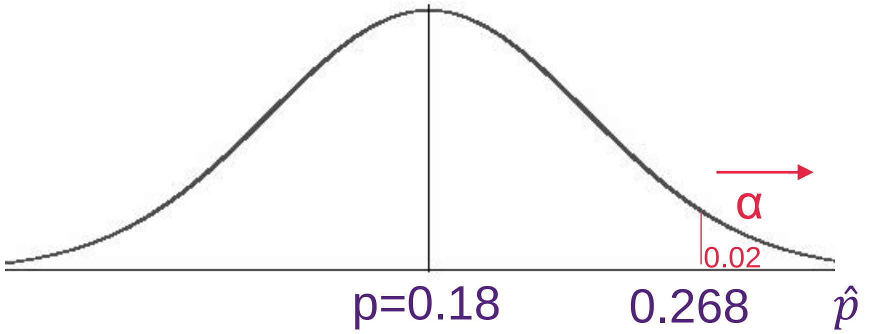

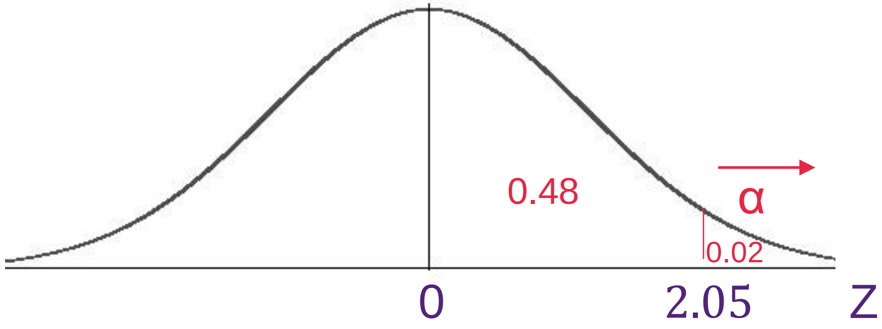

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There is sufficient evidence to suggest that the population of families with children who own computers is higher than 18% at 2% level of significance.

Error Table Associated with Hypothesis Testing Decisions.

Possible Outcomes from Decisions

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Statistical Decision	H_0 True	H_0 False
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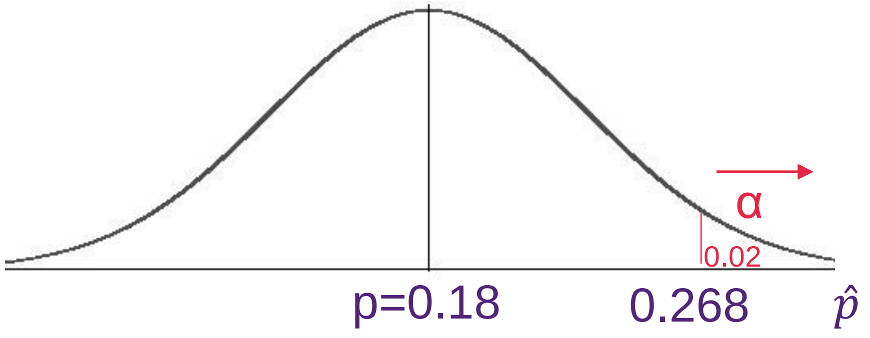

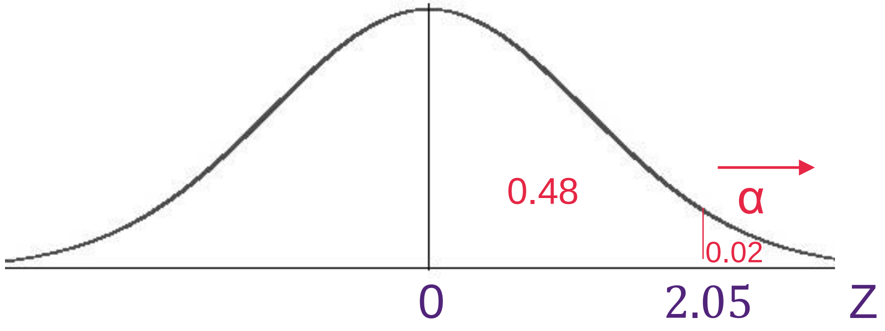

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Step 3: Calculate $\hat{p}$
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Step 4: Make a decision
$\hat{p} > \hat{p}_{crit}^{upper} \rightarrow 0.275 > 0.268 \rightarrow$ Reject H_0.

Step 5: Conclusion
There is sufficient evidence to suggest that the population of families with children who own computers is higher than 18% at 2% level of significance.

Error Table Associated with Hypothesis Testing Decisions.

Possible Outcomes from Decisions

Statistical Decision	Actual (reality) Situation: H_0 True	Actual (reality) Situation: H_0 False
Do Not Reject H_0	✓	**Type II Error**
Reject H_0	**Type I Error**	✓

18

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Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

To test the new adhesive, 25 tiles are attached using the old adhesive and 28 using the new adhesive. The mean and variance of drying times were found to be 7.244 hrs and 1.6209 hr^2 for the old, and 6.64 hrs and 1.1275 hr^2 for the new. From past experience it is known that the drying times are normally distributed.

a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

d) Estimate with 95% confidence the difference between the mean drying times of the two products.

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(Poll)

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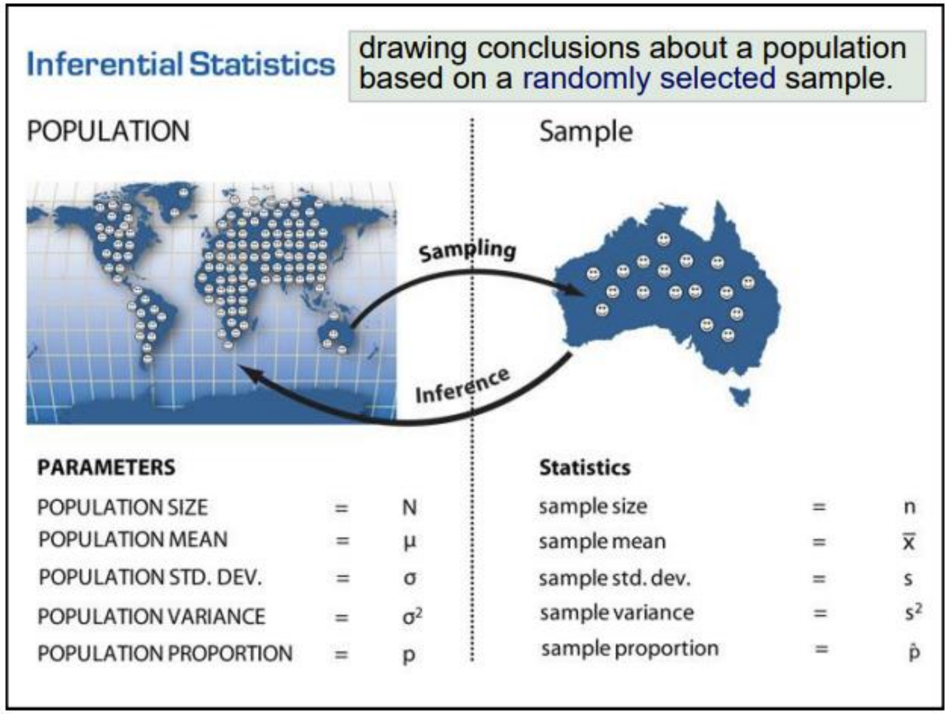

1. What symbol would you give to the values 25 and 28 tiles? (Single Choice) *

- σ (sigma)
- s
- s^2 (s squared)
- μ (mu)
- $\bar{x}$ (x bar)
- α (alpha)
- n

2. What symbol would you give to the values 7.244 and 6.64 hours? (Single Choice) *

- σ (sigma)
- s
- s^2 (s squared)
- μ (mu)
- $\bar{x}$ (x bar)
- α (alpha)
- n

3. What symbol would you give to the values 1.6209 and 1.1275 hr^2? (Single Choice) *

- σ (sigma)
- s
- s^2 (s squared)
- μ (mu)
- $\bar{x}$ (x bar)
- α (alpha)
- n

4. What symbol would you give to the values 5% significance level? (Single Choice) *

- σ (sigma)
- s
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(Poll)

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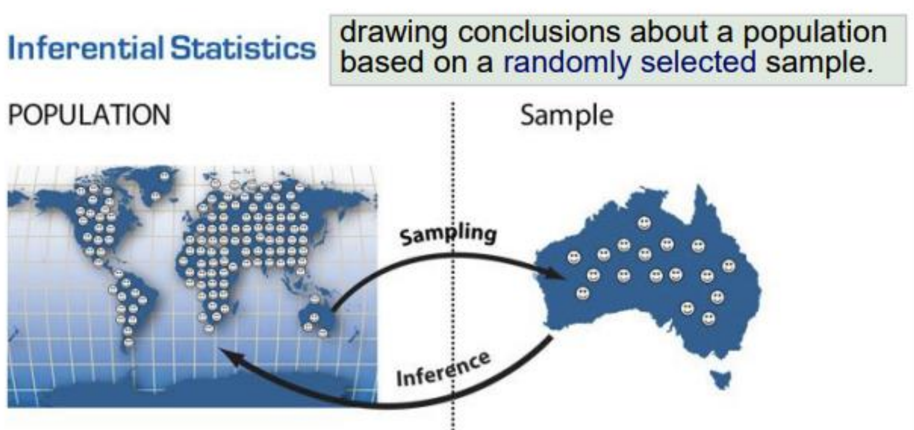

PARAMETERS			Statistics		
POPULATION SIZE	=	N	sample size	=	n
POPULATION MEAN	=	μ	sample mean	=	$\bar{x}$
POPULATION STD. DEV.	=	σ	sample std. dev.	=	s
POPULATION VARIANCE	=	σ^2	sample variance	=	s^2
POPULATION PROPORTION	=	p	sample proportion	=	$\hat{p}$

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3. What symbol would you give to the values 1.6209 and 1.1275 hr^2? (Single Choice) *

- σ (sigma)
- s
- s^2 (s squared)
- μ (mu)
- $\bar{x}$ (x bar)
- α (alpha)
- n

4. What symbol would you give to the values 5% significance level? (Single Choice) *

- σ (sigma)
- s
- s^2 (s squared)
- μ (mu)
- $\bar{x}$ (x bar)
- α (alpha)
- n

adm T10 Q1 Q2 Q3

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	Old	New
n	25	28
$\bar{X}$	7.244	1.6209
s²	6.64	1.1275
$\alpha = 5\% = 0.05$		

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

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1. What type of problem is it? (Singl

- Population Mean (Seagull) (no sample)
- Population Mean (Pelican) (σ is known)
- Population Mean (Shag) (σ is unknown but s is known)
- Population Mean difference (salmon vs trout) (σ are unknown)
- Population Proportion (Freaky fish) (proportion)

3. What is the value of α (alpha)? (Single Choice) *

- 0.01
- 0.02
- 0.03
- 0.04
- 0.05
- 0.1

(Poll)

2. What table will we use? (Single Choice) *

- Z table (standard normal distribution)
- t table (Student's t-distribution)

4. What type of test is it? (Single Choice) *

- one tail test (upper tail >)
- one tail test (lower tail <)
- two tail test (=)

adm T10 Q1 Q2 Q3

	Old	New
n	25	28
$\bar{X}$	7.244	1.6209
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	Old	New
n	25	28
$\bar{X}$	7.244	1.6209
s²	6.64	1.1275
α = 5% = 0.05		

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

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a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

Step 1: State H_0 and H_1

H_0:

H_1:

Confidence interval estimation for the difference between two different population means **μ_1 - μ_2** is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

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H_0:

H_1: $\mu_O - \mu_N > 0$

One tail test

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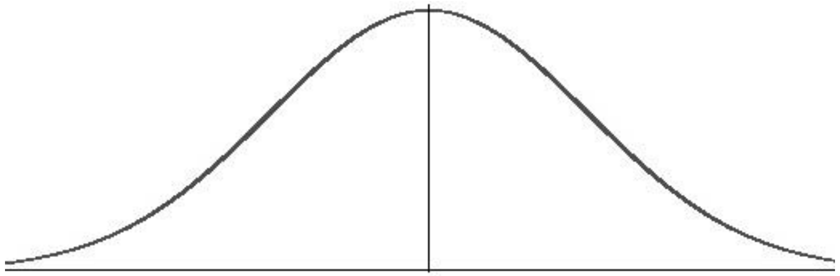

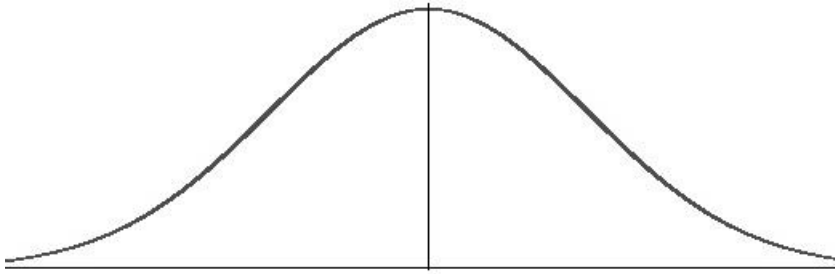

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What is the difference?

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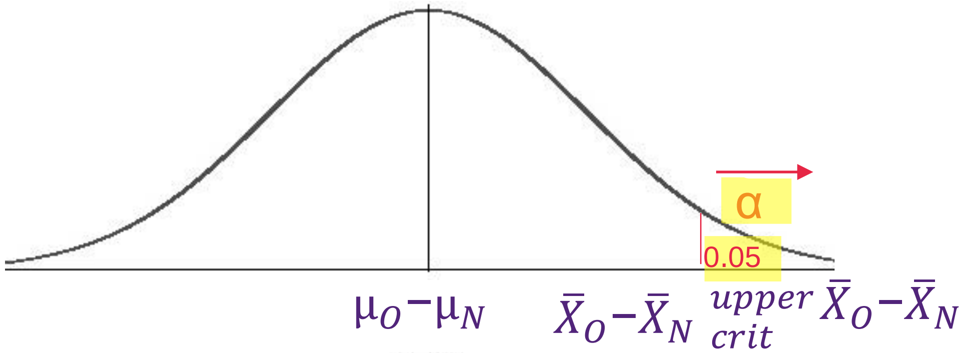

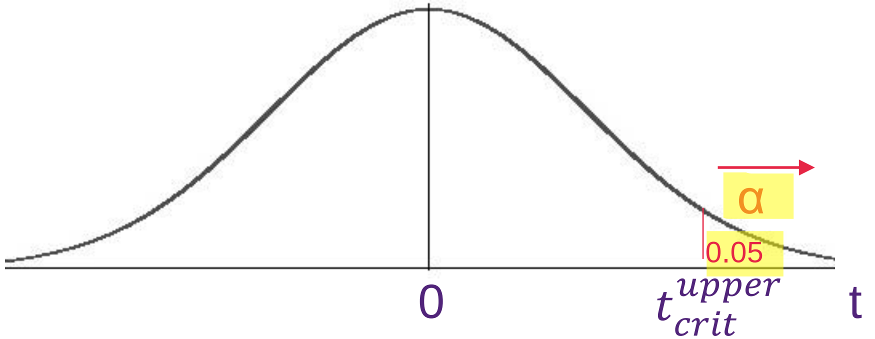

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adm T10 Q1 Q2 Q3

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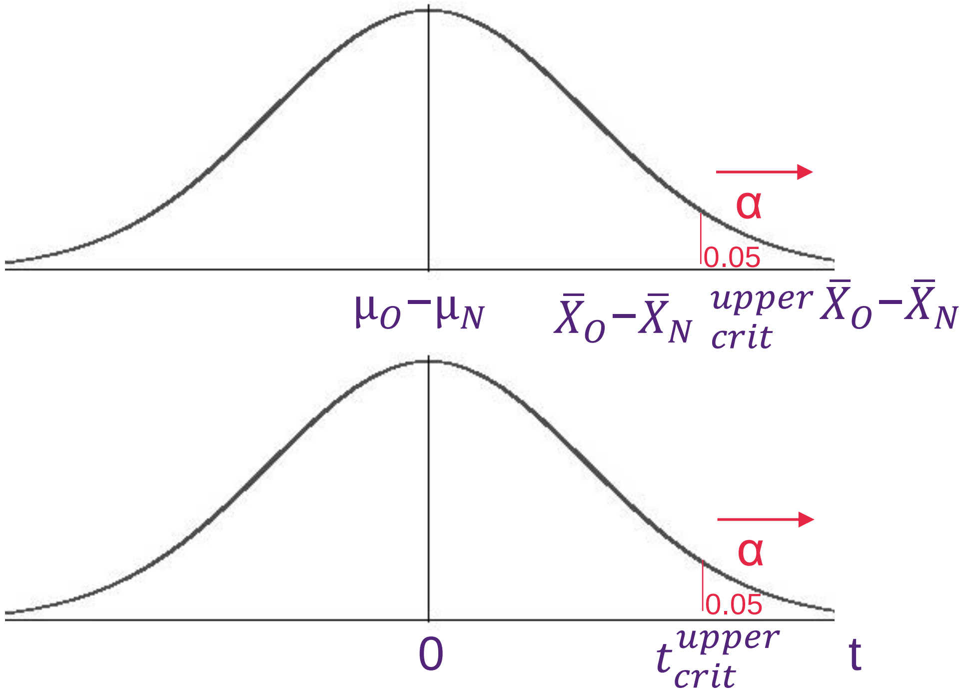

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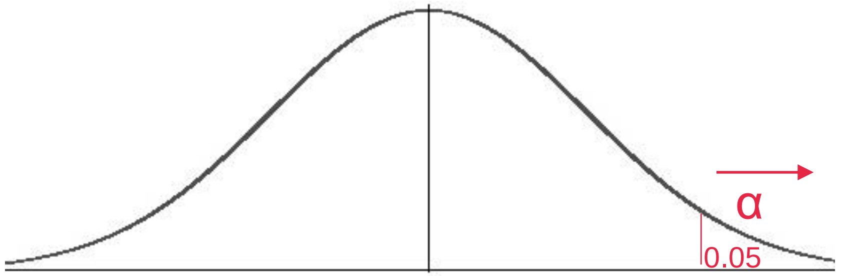

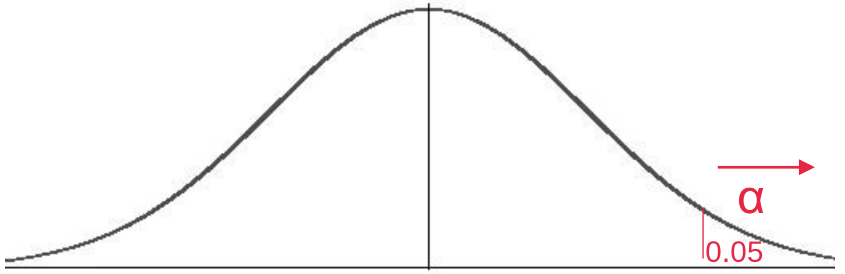

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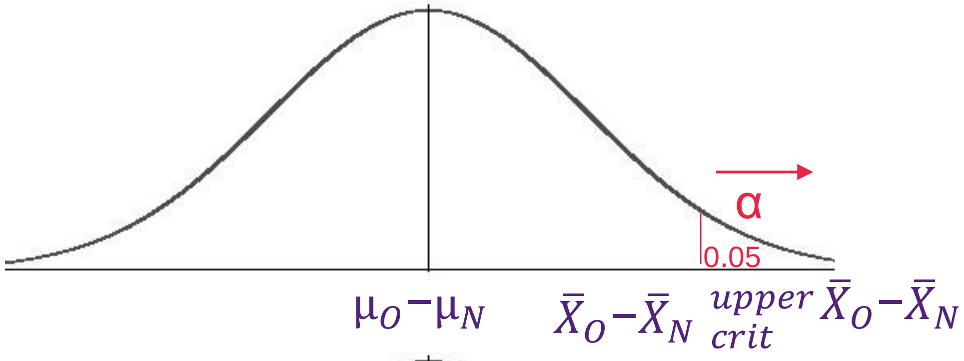

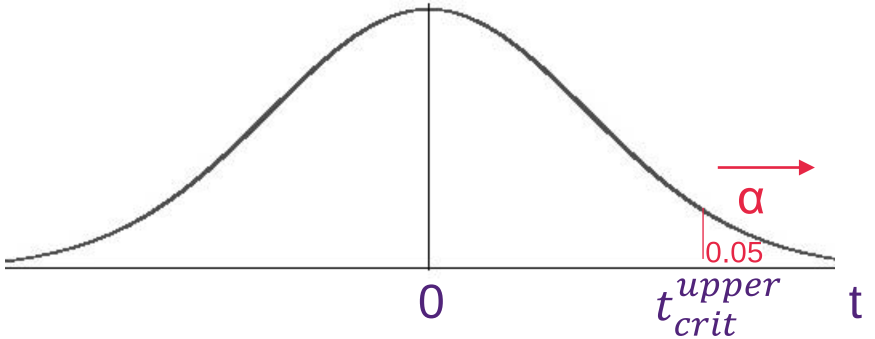

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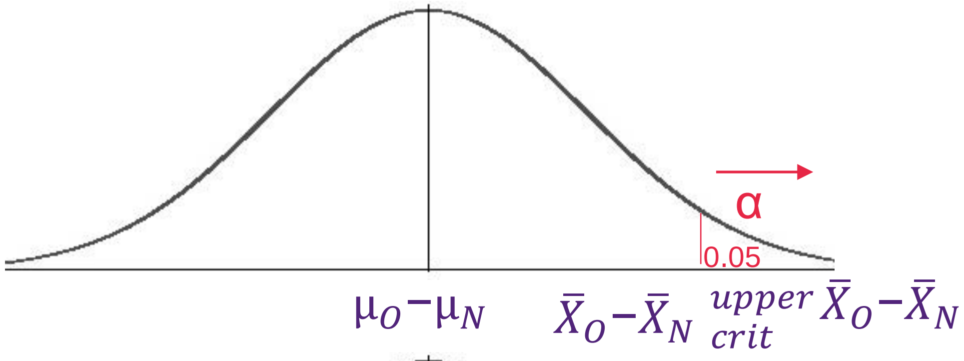

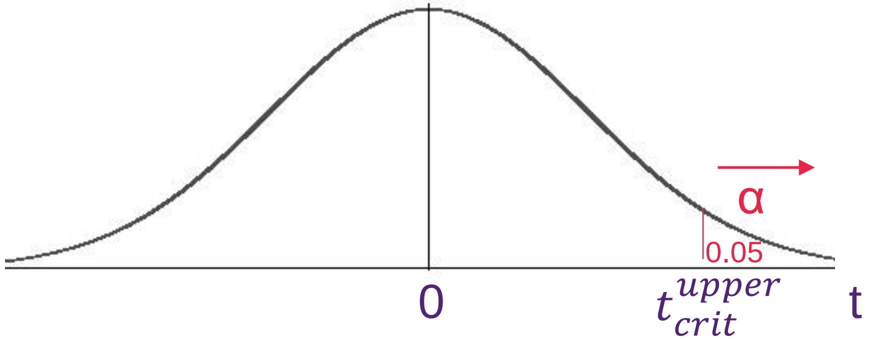

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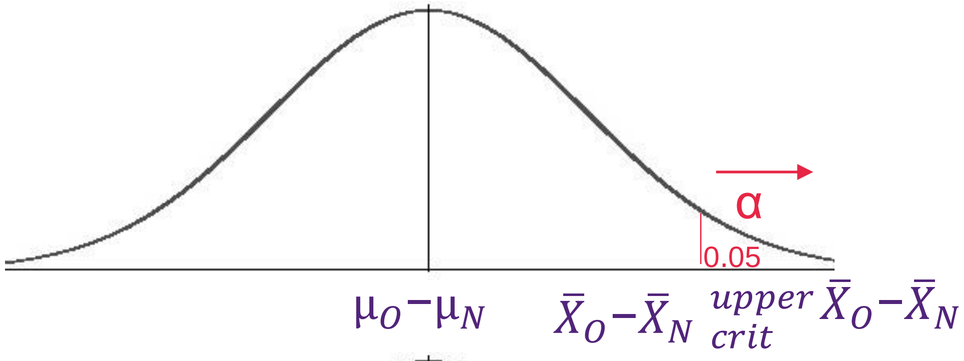

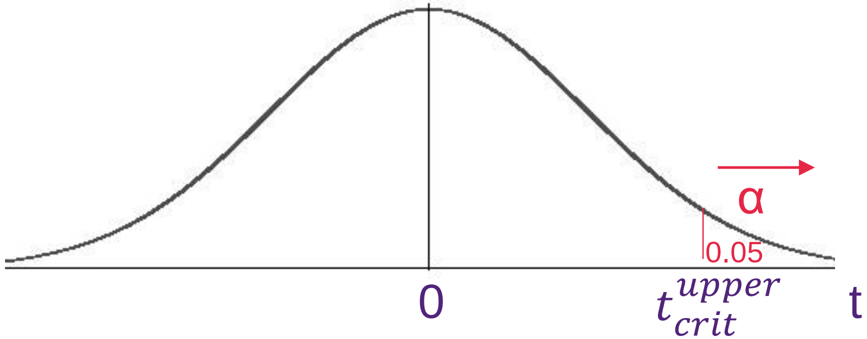

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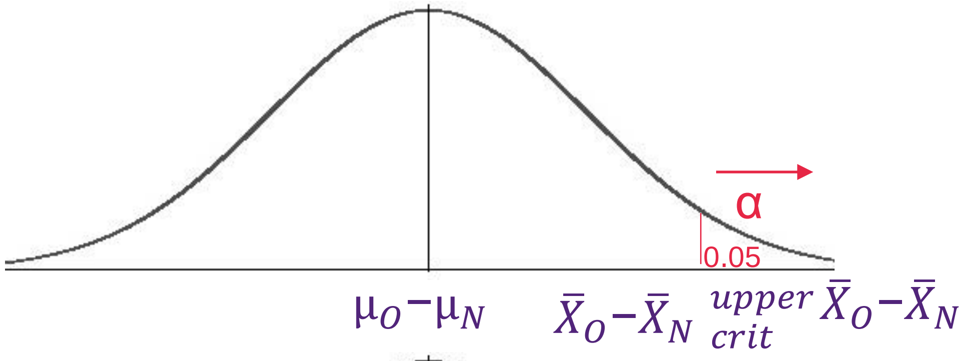

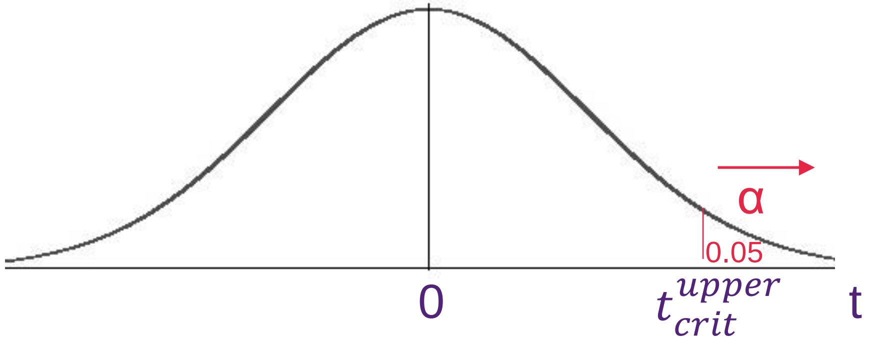

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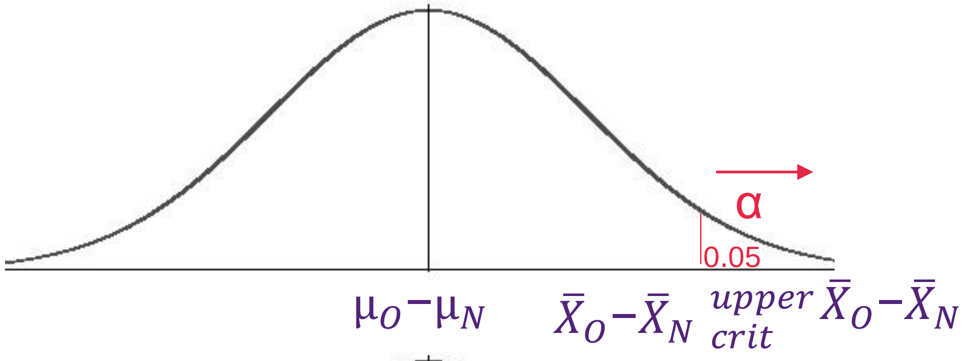

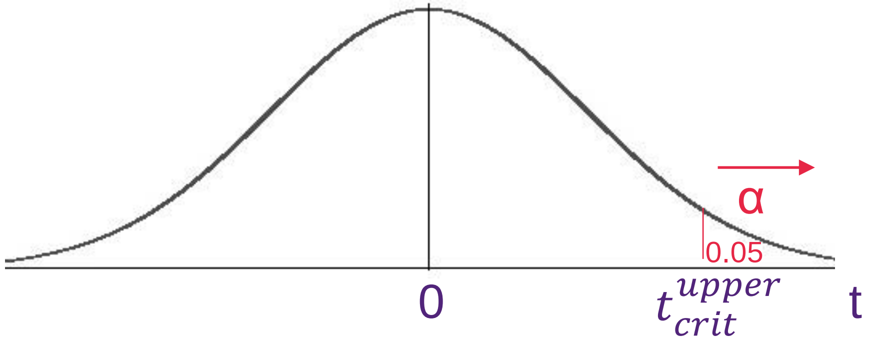

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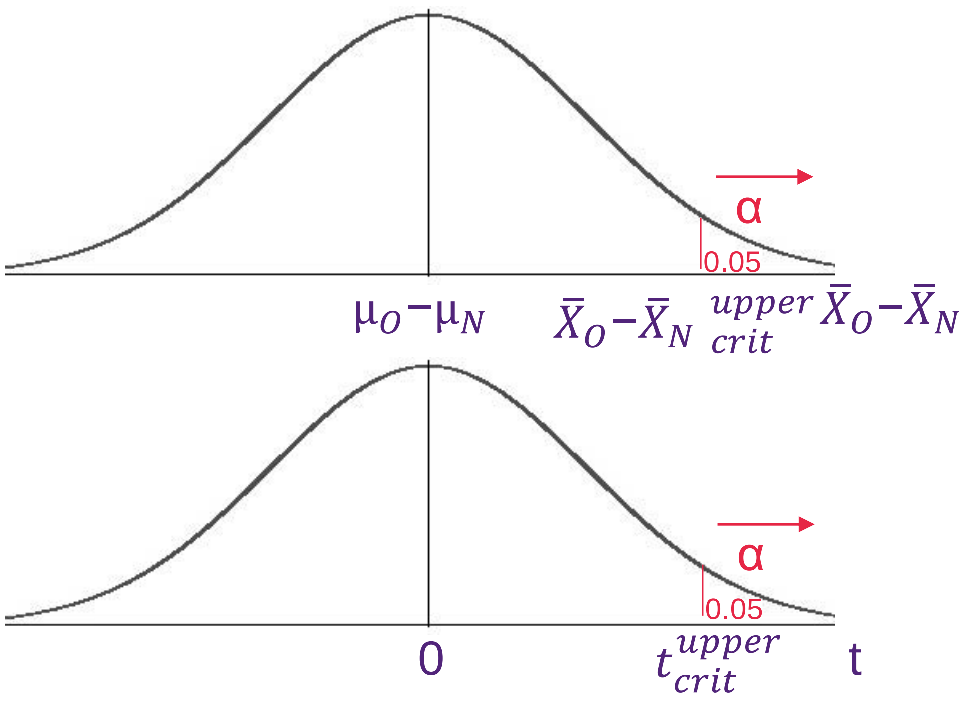

Step 1: State H_0 and H_1

H_0: μ_O - μ_N ≤ 0

H_1: μ_O - μ_N > 0

Step 2: Decision rule

Reject H_0 if p-value < α = 0.05

Step 3: Calculate t_{calc}

t_{calc} = 1.88

$t_{crit} = t_{\alpha, n_1+n_2-2} = t_{0.05,\,51}$

Confidence interval estimation for the difference between two different population means **μ_1 - μ_2** is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1 - \bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}$$

$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

adm T10 Q1 Q2 Q3

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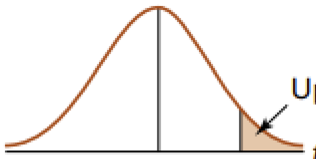
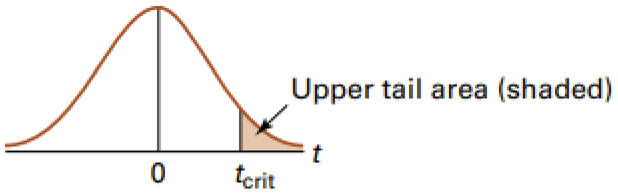


$t_{0.05,\,51}$
and
1.88 at 51df

	Upper tail areas					
df	$t_{.10}$	$t_{.05}$	$t_{.025}$	$t_{.01}$	$t_{.005}$	$t_{.001}$
51	1.298	1.675	2.008	2.402	2.676	3.258
52	1.298	1.675	2.007	2.400	2.674	3.255
53	1.298	1.674	2.006	2.399	2.672	3.251
54	1.297	1.674	2.005	2.397	2.670	3.248
55	1.297	1.673	2.004	2.396	2.668	3.245
56	1.297	1.673	2.003	2.395	2.667	3.242
57	1.297	1.672	2.002	2.394	2.665	3.239
58	1.296	1.672	2.002	2.392	2.663	3.237
59	1.296	1.671	2.001	2.391	2.662	3.234
60	1.296	1.671	2.000	2.390	2.660	3.232
61	1.296	1.670	2.000	2.389	2.659	3.229
62	1.295	1.670	1.999	2.388	2.657	3.227
63	1.295	1.669	1.998	2.387	2.656	3.225
64	1.295	1.669	1.998	2.386	2.655	3.223
65	1.295	1.669	1.997	2.385	2.654	3.220
66	1.295	1.668	1.997	2.384	2.652	3.218
67	1.294	1.668	1.996	2.383	2.651	3.216
68	1.294	1.668	1.995	2.382	2.650	3.214
69	1.294	1.667	1.995	2.382	2.649	3.213
70	1.294	1.667	1.994	2.381	2.648	3.211
71	1.294	1.667	1.994	2.380	2.647	3.209
72	1.293	1.666	1.993	2.379	2.646	3.207
73	1.293	1.666	1.993	2.379	2.645	3.206
74	1.293	1.666	1.993	2.378	2.644	3.204
75	1.293	1.665	1.992	2.377	2.643	3.202



			Upper tail areas			
df	$t_{.10}$	$t_{.05}$	$t_{.025}$	$t_{.01}$	$t_{.005}$	$t_{.001}$
		1.88				

$t_{0.05,\,51}$

and

1.88 at 51df

$t_{0.05,\,51}$

and

1.88 at 51df

adm T10 Q1 Q2 Q3

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s²	1.6209	1.1275
$\alpha = 5\% = 0.05$		

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

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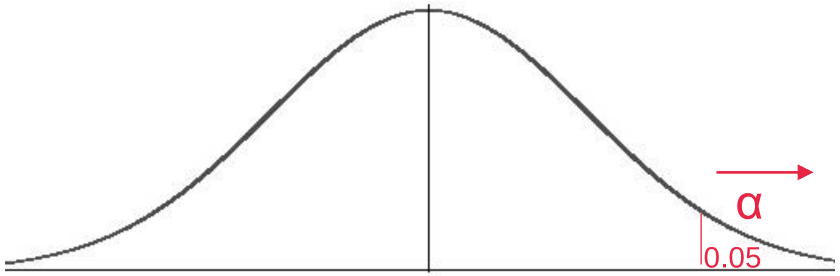
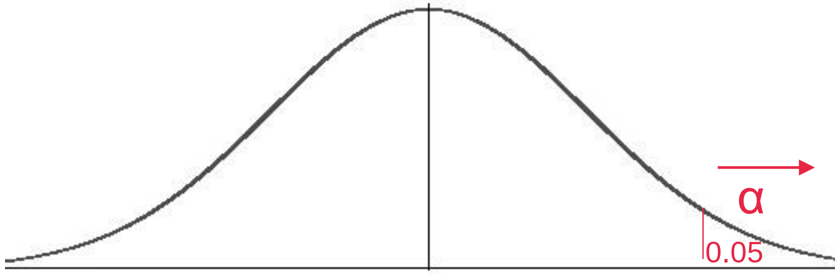
a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

Rejection regions





Step 1: State H_0 and H_1

H_0: $\mu_O - \mu_N \le 0$

H_1: $\mu_O - \mu_N > 0$

Step 2: Decision rule

Reject H_0 if p-value < $\alpha = 0.05$

Step 3: Calculate t_{calc}

$t_{calc} = 1.88 \rightarrow 0.025 <$ p-value < 0.05

$t_{crit} = t_{\alpha, n_1+n_2-2} = t_{0.05,\,51} = 1.675$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1 - \bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}$$

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$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s²	1.6209	1.1275
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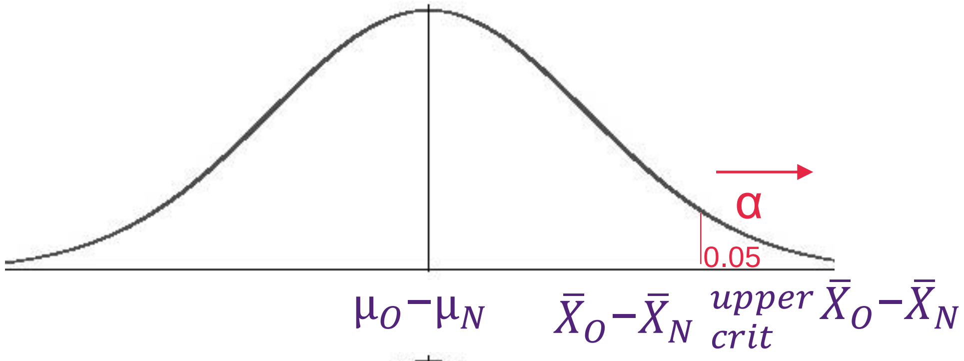

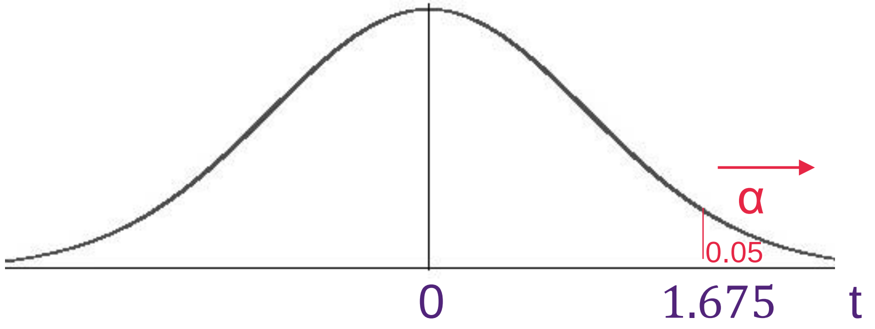

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t_{calc} = 1.88 → 0.025 < p-value < 0.05

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Step 4: Make a decision

p-value < α = 0.05 ?

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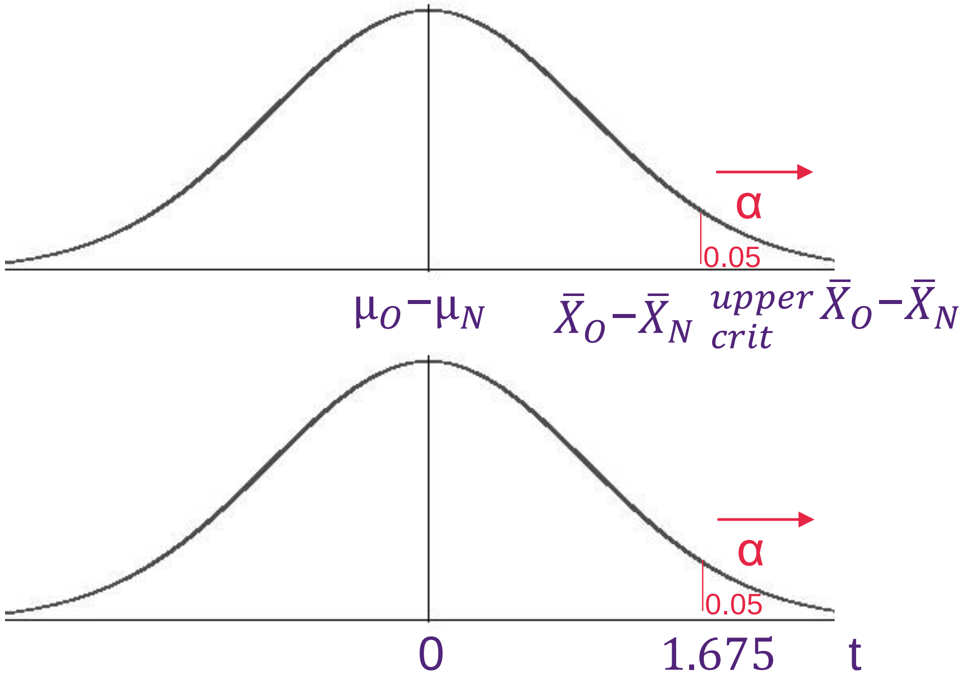

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t_{calc} = 1.88 → 0.025 < p-value < 0.05

$t_{crit} = t_{\alpha, n_1+n_2-2} = t_{0.05,\,51}$ = 1.675

Step 4: Make a decision

p-value < α = 0.05 → Reject H_0.

Confidence interval estimation for the difference between two different population means **μ_1 - μ_2** is:

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adm T10 Q1 Q2 Q3

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	Old	New
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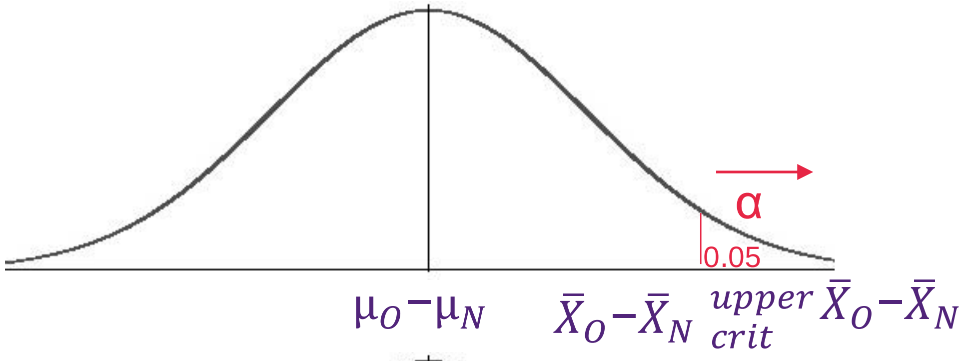

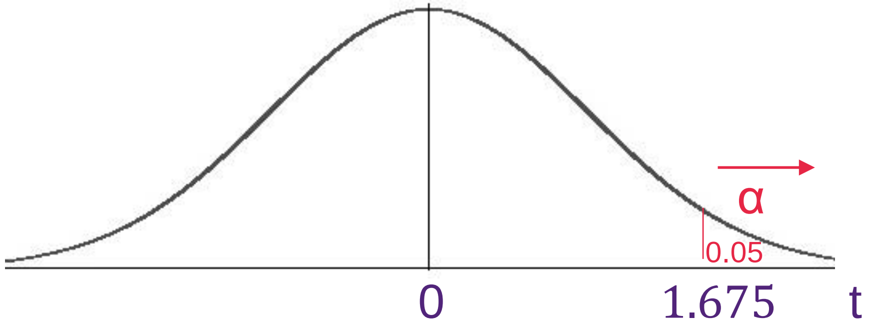

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t_{calc} = 1.88 → 0.025 < p-value < 0.05

$t_{crit} = t_{\alpha, n_1+n_2-2} = t_{0.05,\,51}$ = 1.675

Step 4: Make a decision

p-value < α = 0.05 → Reject H_0.

Step 5: Conclusion

There is sufficient evidence at the 5% level of significance to suggest the new adhesive is superior to the old one.

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	Old	New
n	25	28
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a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

b) What assumptions underlie your analysis?

Assumptions:

- Variables μ_O and μ_N (drying times) are normally distributed.

Assumptions

1. The variances in both populations of variable X are assumed equal: *because we are pooling the* *<u>sample variances</u>* *to get a better estimate of the common variance in each population.*
2. Variable X is normally distributed in each population: *because typically use small samples and the t distribution is needed in calculating the sampling error.*
3. Samples are to be independently and randomly selected from the populations: *because the variance formula does not include any allowance for covariance.*

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adm T10 Q1 Q2 Q3

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s^2	1.6209	1.1275
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b) What assumptions underlie your analysis?

Assumptions:

- Variables μ_O and μ_N (drying times) are normally distributed.
- The samples are randomly and independently taken.
- Variances of the variables (drying times) are equal.

Assumptions

1. The variances in both populations of variable X are assumed equal: *because we are pooling the sample variances to get a better estimate of the common variance in each population.*
2. Variable X is normally distributed in each population: *because typically use small samples and the t distribution is needed in calculating the sampling error.*
3. Samples are to be independently and randomly selected from the populations: *because the variance formula does not include any allowance for covariance.*

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	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s^2	1.6209	1.1275
$\alpha = 1\% = 0.01$		

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

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a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

	Old	New
n	25	28
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s^2	1.6209	1.1275
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$$\bar{X} \pm t_{\alpha/2,\, df} * s_{\bar{X}} = \bar{X} \pm t_{\alpha/2,\, n-1} * \frac{s}{\sqrt{n}} = ?$$

$$t_{\alpha/2,\, n-1} = t_{0.005,\, 27} = ?$$

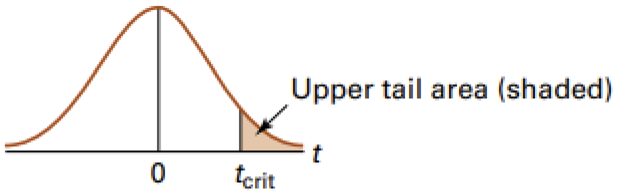
Confidence Interval Estimate for μ, (σ unknown, and only have s).

Lower limit: $\bar{X} - t_{\alpha/2,\, n-1} \frac{s}{\sqrt{n}}$

Upper limit: $\bar{X} + t_{\alpha/2,\, n-1} \frac{s}{\sqrt{n}}$

where $t_{\alpha/2,\, n-1}$ is the critical value t_{crit} of the t distribution with:

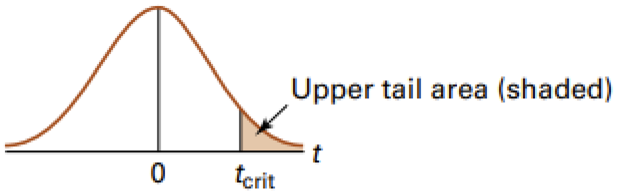
- n -1 degrees of freedom
- an area of α/2 in **each** tail
- t distribution assumptions must be satisfied



$t_{0.005,\,27}$

	Upper tail areas					
df	$t_{.10}$	$t_{.05}$	$t_{.025}$	$t_{.01}$	$t_{.005}$	$t_{.001}$
26	1.315	1.706	2.056	2.479	2.779	3.435
27	1.314	1.703	2.052	2.473	2.771	3.421
28	1.313	1.701	2.048	2.467	2.763	3.408
29	1.311	1.699	2.045	2.462	2.756	3.396
30	1.310	1.697	2.042	2.457	2.750	3.385
31	1.309	1.696	2.040	2.453	2.744	3.375
32	1.309	1.694	2.037	2.449	2.738	3.365
33	1.308	1.692	2.035	2.445	2.733	3.356
34	1.307	1.691	2.032	2.441	2.728	3.348
35	1.306	1.690	2.030	2.438	2.724	3.340
36	1.306	1.688	2.028	2.434	2.719	3.333
37	1.305	1.687	2.026	2.431	2.715	3.326
38	1.304	1.686	2.024	2.429	2.712	3.319
39	1.304	1.685	2.023	2.426	2.708	3.313
40	1.303	1.684	2.021	2.423	2.704	3.307
41	1.303	1.683	2.020	2.421	2.701	3.301
42	1.302	1.682	2.018	2.418	2.698	3.296
43	1.302	1.681	2.017	2.416	2.695	3.291
44	1.301	1.680	2.015	2.414	2.692	3.286
45	1.301	1.679	2.014	2.412	2.690	3.281
46	1.300	1.679	2.013	2.410	2.687	3.277
47	1.300	1.678	2.012	2.408	2.685	3.273
48	1.299	1.677	2.011	2.407	2.682	3.269
49	1.299	1.677	2.010	2.405	2.680	3.265
50	1.299	1.676	2.009	2.403	2.678	3.261

adm T10 Q1 Q2 Q3



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32	1.309	1.694	2.037	2.449	2.738	3.365
33	1.308	1.692	2.035	2.445	2.733	3.356
34	1.307	1.691	2.032	2.441	2.728	3.348
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41	1.303	1.683	2.020	2.421	2.701	3.301
42	1.302	1.682	2.018	2.418	2.698	3.296
43	1.302	1.681	2.017	2.416	2.695	3.291
44	1.301	1.680	2.015	2.414	2.692	3.286
45	1.301	1.679	2.014	2.412	2.690	3.281
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50	1.299	1.676	2.009	2.403	2.678	3.261

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s^2	1.6209	1.1275
$\alpha = 1\% = 0.01$		

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

To test the new adhesive, 25 tiles are attached using the old adhesive and 28 using the new adhesive. The mean and variance of drying times were found to be 7.244 hrs and 1.6209 hr^2 for the old, and 6.64 hrs and 1.1275 hr^2 for the new. From past experience it is known that the drying times are normally distributed.

a) At the 5% significance level using the p-value approach, can we conclude that the new adhesive is superior to the old?

b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

$$\bar{X} \pm t_{\alpha/2,\, df} * s_{\bar{X}} = \bar{X} \pm t_{\alpha/2,\, n-1} * \frac{s}{\sqrt{n}} = ?$$

$$t_{\alpha/2,\, n-1} = t_{0.005,\, 27} = 2.771$$

Confidence Interval Estimate for μ, (σ unknown, and only have s).

Lower limit: $\bar{X} - t_{\alpha/2,\, n\text{-}1} \frac{s}{\sqrt{n}}$

Upper limit: $\bar{X} + t_{\alpha/2,\, n\text{-}1} \frac{s}{\sqrt{n}}$

where $t_{\alpha/2,\, n\text{-}1}$ is the critical value t_{crit} of the t distribution with:

- n -1 degrees of freedom
- an area of α/2 in **each** tail
- t distribution assumptions must be satisfied

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s^2	1.6209	1.1275
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$$\bar{X} \pm t_{\alpha/2,\,df} * s_{\bar{X}} = \bar{X} \pm t_{\alpha/2,\,n-1} * \frac{s}{\sqrt{n}} =$$

$$6.64 \pm 2.771 * \frac{\sqrt{1.1275}}{\sqrt{28}} = ?$$

Confidence Interval Estimate for μ, (σ unknown, and only have s).

Lower limit: $\bar{X} - t_{\alpha/2,\, n\text{-}1} \frac{s}{\sqrt{n}}$

Upper limit: $\bar{X} + t_{\alpha/2,\, n\text{-}1} \frac{s}{\sqrt{n}}$

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- n -1 degrees of freedom
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	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s²	1.6209	1.1275
α = 1% = 0.01		

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b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

$$\bar{X} \pm t_{\alpha/2,\,df} * s_{\bar{X}} = \bar{X} \pm \; t_{\alpha/2,\,n-1} * \frac{s}{\sqrt{n}} =$$

$$6.64 \pm 2.771 * \frac{\sqrt{1.1275}}{\sqrt{28}} = 6.64 \pm 0.556\text{n-1}$$

$$6.084 < \mu_N < 7.196$$

It is estimated with 99% confidence that average drying times for the new adhesive are between 6.084 and 7.196 hours.

Confidence Interval Estimate for μ, (σ unknown, and only have s).

Lower limit: $\bar{X} - t_{\alpha/2,\,n\text{-}1}\frac{s}{\sqrt{n}}$

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adm T10 Q1 Q2 Q3

	Old	New
n	25	28
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s²	1.6209	1.1275
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b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

d) Estimate with 95% confidence the difference between the mean drying times of the two products.

Confidence interval estimation for the difference between two different population means **$\mu_1 - \mu_2$** is:

$$(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}$$

$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

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CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

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adm T10 Q1 Q2 Q3

	Old	New
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α = 5% = 0.05		

$(\bar{X}_1 - \bar{X}_2)$ = 7.244 – 6.64 = 0.604

$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p{}^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)} = \sqrt{1.359688\left(\frac{1}{25}+\frac{1}{28}\right)} = 0.3208$$

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$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

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CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

$t_{\alpha/2,\, n_1+n_2-2} = t_{0.025,\, 51}$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

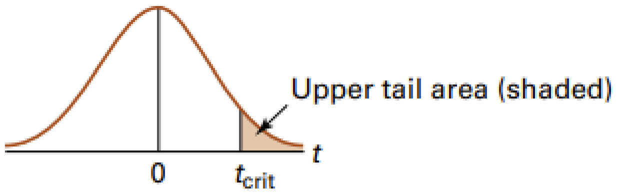
$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}$$

$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

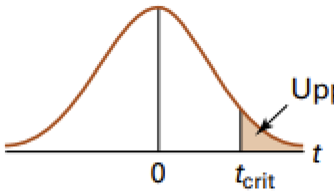
adm T10 Q1 Q2 Q3



$t_{0.025,\,51}$

df	$t_{.10}$	$t_{.05}$	$t_{.025}$	$t_{.01}$	$t_{.005}$	$t_{.001}$
			Upper tail areas			
51	1.298	1.675	2.008	2.402	2.676	3.258
52	1.298	1.675	2.007	2.400	2.674	3.255
53	1.298	1.674	2.006	2.399	2.672	3.251
54	1.297	1.674	2.005	2.397	2.670	3.248
55	1.297	1.673	2.004	2.396	2.668	3.245
56	1.297	1.673	2.003	2.395	2.667	3.242
57	1.297	1.672	2.002	2.394	2.665	3.239
58	1.296	1.672	2.002	2.392	2.663	3.237
59	1.296	1.671	2.001	2.391	2.662	3.234
60	1.296	1.671	2.000	2.390	2.660	3.232
61	1.296	1.670	2.000	2.389	2.659	3.229
62	1.295	1.670	1.999	2.388	2.657	3.227
63	1.295	1.669	1.998	2.387	2.656	3.225
64	1.295	1.669	1.998	2.386	2.655	3.223
65	1.295	1.669	1.997	2.385	2.654	3.220
66	1.295	1.668	1.997	2.384	2.652	3.218
67	1.294	1.668	1.996	2.383	2.651	3.216
68	1.294	1.668	1.995	2.382	2.650	3.214
69	1.294	1.667	1.995	2.382	2.649	3.213
70	1.294	1.667	1.994	2.381	2.648	3.211
71	1.294	1.667	1.994	2.380	2.647	3.209
72	1.293	1.666	1.993	2.379	2.646	3.207
73	1.293	1.666	1.993	2.379	2.645	3.206
74	1.293	1.666	1.993	2.378	2.644	3.204
75	1.293	1.665	1.992	2.377	2.643	3.202

adm T10 Q1 Q2 Q3



$t_{0.025,\,51}$

	Upper tail areas					
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51	1.298	1.675	2.008	2.402	2.676	3.258
52	1.298	1.675	2.007	2.400	2.674	3.255
53	1.298	1.674	2.006	2.399	2.672	3.251
54	1.297	1.674	2.005	2.397	2.670	3.248
55	1.297	1.673	2.004	2.396	2.668	3.245
56	1.297	1.673	2.003	2.395	2.667	3.242
57	1.297	1.672	2.002	2.394	2.665	3.239
58	1.296	1.672	2.002	2.392	2.663	3.237
59	1.296	1.671	2.001	2.391	2.662	3.234
60	1.296	1.671	2.000	2.390	2.660	3.232
61	1.296	1.670	2.000	2.389	2.659	3.229
62	1.295	1.670	1.999	2.388	2.657	3.227
63	1.295	1.669	1.998	2.387	2.656	3.225
64	1.295	1.669	1.998	2.386	2.655	3.223
65	1.295	1.669	1.997	2.385	2.654	3.220
66	1.295	1.668	1.997	2.384	2.652	3.218
67	1.294	1.668	1.996	2.383	2.651	3.216
68	1.294	1.668	1.995	2.382	2.650	3.214
69	1.294	1.667	1.995	2.382	2.649	3.213
70	1.294	1.667	1.994	2.381	2.648	3.211
71	1.294	1.667	1.994	2.380	2.647	3.209
72	1.293	1.666	1.993	2.379	2.646	3.207
73	1.293	1.666	1.993	2.379	2.645	3.206
74	1.293	1.666	1.993	2.378	2.644	3.204
75	1.293	1.665	1.992	2.377	2.643	3.202

adm T10 Q1 Q2 Q3

	Old	New
n	25	28
$\bar{X}$	7.244	6.64
s²	1.6209	1.1275
α = 5% = 0.05		

$(\bar{X}_1 - \bar{X}_2) = 7.244 - 6.64 = 0.604$

$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p{}^2(\frac{1}{n_1}+\frac{1}{n_2})} = \sqrt{1.359688(\frac{1}{25}+\frac{1}{28})} = 0.3208$

Q3. The executives of an adhesive manufacturing company whose product is used to attach heat shield tiles to the space shuttle are concerned about the performance of their product. They find the drying time is excessive. The R&D laboratory has produced a new adhesive that the company hopes is superior to the old one.

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b) What assumptions underlie your analysis?

c) Estimate with 99% confidence the average drying time of the new adhesive.

d) Estimate with 95% confidence the difference between the mean drying times of the two products.

CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

$t_{\alpha/2,\, n_1+n_2-2} = t_{0.025,\, 51} = 2.008$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2} \qquad s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

adm T10 Q1 Q2 Q3

	Old	New
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CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

$= 0.604 \pm 2.008 * 0.3208$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

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CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

= 0.604 ± 2.008 * 0.3208

$-0.040 < \mu_O - \mu_N < 1.248$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2} \qquad s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

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It is estimated with 95% level of confidence that old drying times are between 1.248 hours longer and 0.04 hours shorter than the new adhesives times.

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c) Estimate with 99% confidence the average drying time of the new adhesive.

d) Estimate with 95% confidence the difference between the mean drying times of the two products.

CI: $\mu_O - \mu_N = (\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}$

= 0.604 ± 2.008 * 0.3208

$-0.040 < \mu_O - \mu_N < 1.248$

Confidence interval estimation for the difference between two different population means $\mu_1 - \mu_2$ is:

$$\boxed{(\bar{X}_1 - \bar{X}_2) \pm t_{\alpha/2,\, n_1+n_2-2} * s_{\bar{X}_1-\bar{X}_2}}$$

$$s_p^2 = \frac{(n_1-1)s_1^2 + (n_2-1)s_2^2}{n_1+n_2-2}$$

$$s_{\bar{X}_1-\bar{X}_2} = \sqrt{s_p^2\left(\frac{1}{n_1}+\frac{1}{n_2}\right)}$$

$\bar{X}_1 - \bar{X}_2$ = **point estimate** for difference between the means of the two populations

ECON1310

Tutorial 10 – Week 11

HYPOTHESIS TESTING II

At the end of this tutorial you should be able to

- Carry out one-tail and two-tail hypothesis tests using the *p*-value method.
- Carry out one-tail and two-tail hypothesis tests for population proportions.
- Carry out hypothesis tests for the difference between two means using the pooled variance method.

Thank you

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Reference
Black et al. (2016), Australasian Business Statistics, 4th Edition, Wiley Australia.