STAT 201 Chapter 8.3 & 9.3

Interval & Testing for Mean

Recall Means Sampling Distributions

- The mean of the sampling distribution for a sample mean will always equal the population mean $\mu_{\bar{x}} = \mu_x$
- The standard error, the standard deviation of the sample mean, is:

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

Confidence Intervals

- Often, we do not know the population mean
- We use our sample means to make inference on the population parameter

- We **MUST** make sure that the data is obtained through randomization and that distribution of the data is approximately normal
  - For this we require n>30
  - Otherwise, we can make a graph to confirm

Confidence Intervals When We Know σ

- We use our sample means to make interval inference on the population mean

$$\bar{x} \pm z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$$

- $\bar{x}$ is our **point-estimate** for the population proportion
- $z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$is our **margin of error**

Confidence Intervals Bounds When We Know σ

$$\bar{x} \pm z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$$

Lower Bound = $\bar{x} - z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$

Upper Bound = $\bar{x} + z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$

Confidence Intervals: Margin of Error When We Know σ

- $z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$ is our **margin of error**
  - **As n increases**, $\left(\frac{\sigma}{\sqrt{n}}\right)$ decreases, causing the margin of error to decrease causing the width of the confidence interval to narrow
  - **As n decreases**, $\left(\frac{\sigma}{\sqrt{n}}\right)$ increases, causing the margin of error to increase causing the width of the confidence interval to widen

Confidence Intervals: Margin of Error When We Know σ

- $z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$ is our **margin of error**
  - **As the confidence level α decreases**, z decreases causing the margin of error to decrease, causing the width of the confidence interval to narrow
  - **As the confidence level α increases**, z increases causing the margin of error to increase, causing the width of the confidence interval to grow wider

What if We do not know σ

- Can we find something to replace σ in $z_{\frac{\alpha}{2}}\left(\frac{\sigma}{\sqrt{n}}\right)$?
- Yes! We can use the sample standard deviation s to "replace" σ. However, we might lose some "information" or "freedom"
- Recall $s = \sqrt{Variance} = \sqrt{\frac{\boldsymbol{\sum(x-\bar{x})^2}}{\boldsymbol{n-1}}}$

Representing Information: Degree of Freedom

- Originally, we know σ and we have n observations. So we have n information to use to find the interval; or we can say we have n "degree of freedom" (free data)
- Now, since we do not know σ, we first use n observations to estimate the sample standard deviation, s. So we lose "1" information for the estimation s, so that we have only n-1 "degree of freedom". We lose 1 "degree of freedom" by estimating unknown σ.

Confidence Intervals When We Don't Know σ

- We use our sample means to make inference on the population mean

$$\bar{x} \pm t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$$

- $\bar{x}$ is our **point-estimate** for the population proportion
- $t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$ is our **margin of error**

Confidence Intervals Bounds When We Don't Know σ

$$\bar{x} \pm t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$$

Lower Bound = $\bar{x} - t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$

Upper Bound = $\bar{x} + t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$

Confidence Intervals: Margin of Error When We Don't Know σ

- $t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$ is our **margin of error**
  - **As n increases**, t decreases and $\left(\frac{s}{\sqrt{n}}\right)$ decreases, causing the margin of error to decrease causing the width of the confidence interval to narrow
  - **As n decreases**, t increases and $\left(\frac{s}{\sqrt{n}}\right)$ increases, causing the margin of error to increase causing the width of the confidence interval to widen

Confidence Intervals: Margin of Error When We Don't Know σ

- $t_{\frac{\alpha}{2},n-1}\left(\frac{s}{\sqrt{n}}\right)$ is our **margin of error**
  - **As the confidence level α decreases**, t decreases causing the margin of error to decrease, causing the width of the confidence interval to narrow
  - **As the confidence level α increases**, t increases causing the margin of error to increase, causing the width of the confidence interval to grow wider

Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 95% confidence with n=10
- This means $\alpha = 1 - .95 = .05$ and the degrees of freedom = 10 - 1 = 9
- t = 2.262

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
two-tails	**1.00**	**0.50**	**0.40**	**0.30**	**0.20**	**0.10**	**0.05**	**0.02**	**0.01**	**0.002**	**0.001**
df											
1	0.000	1.000	1.376	1.963	3.078	6.314	12.71	31.82	63.66	318.31	636.62
2	0.000	0.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	22.327	31.599
3	0.000	0.765	0.978	1.250	1.638	2.353	3.182	4.541	5.841	10.215	12.924
4	0.000	0.741	0.941	1.190	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	0.000	0.727	0.920	1.156	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	0.000	0.718	0.906	1.134	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	0.000	0.711	0.896	1.119	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	0.000	0.706	0.889	1.108	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	0.000	0.703	0.883	1.100	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	0.000	0.700	0.879	1.093	1.372	1.812	2.228	2.764	3.169	4.144	4.587

Zoom In

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
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- A is the degrees of freedom, n-1
- B is the significance level – for confidence intervals we look for α in the two-tail row
- C is the t-value associated with the provided degrees of freedom and significance level

Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 99% confidence with n=9
- This means $\alpha = 1 - .99 = .01$ and the degrees of freedom = 9 - 1 = 8
- t = 3.355

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	0.50	0.25	0.20	0.15	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
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Zoom In

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- A is the degrees of freedom, n-1
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Finding t for Our Confidence Intervals

- Say we were trying to find the t-value for a 90% confidence with n=11
- This means $\alpha = 1 - .90 = .10$ and the degrees of freedom = 11 - 1 = 10
- t = 1.812

cum. prob	$t_{.50}$	$t_{.75}$	$t_{.80}$	$t_{.85}$	$t_{.90}$	$t_{.95}$	$t_{.975}$	$t_{.99}$	$t_{.995}$	$t_{.999}$	$t_{.9995}$
one-tail	**0.50**	**0.25**	**0.20**	**0.15**	**0.10**	**0.05**	**0.025**	**0.01**	**0.005**	**0.001**	**0.0005**
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Zoom In

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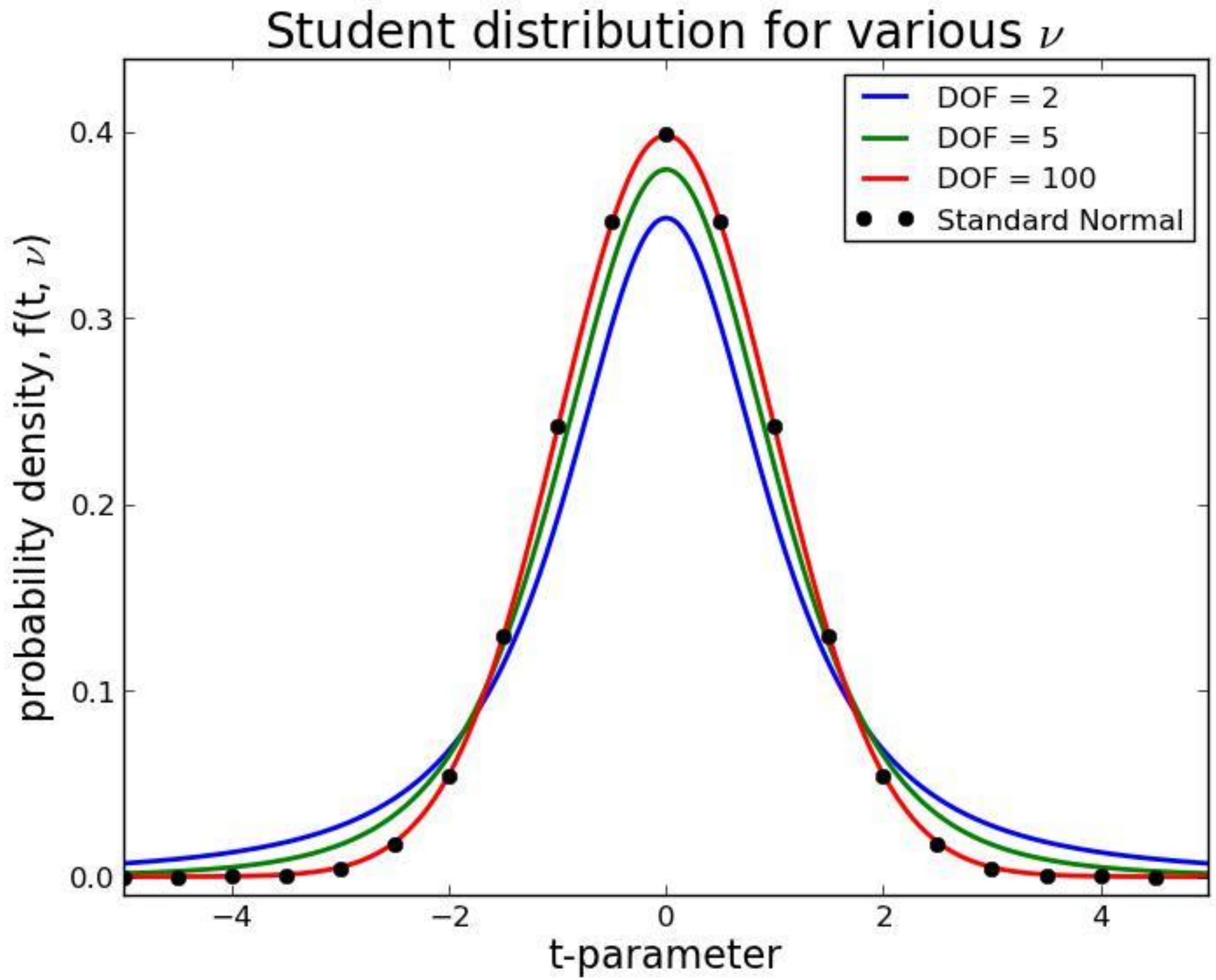
Properties of the t-distribution

1. The t-distribution is different for different degrees of freedom
2. The t-distribution is centered and symmetric at 0
3. The area under the curve is 1 and ½ on either side of 0
4. The density (curve) approaches 0 as we move away from 0
5. The t-distribution has fatter tails than the standard normal
6. As the sample size increases t gets close to z

Red properties are the same for normal distribution.


Student distribution for various ν
DOF = 2
DOF = 5
DOF = 100
Standard Normal
probability density, f(t, ν)
0.0
0.1
0.2
0.3
0.4
−4
−2
0
2
4
t-parameter

Example

- Suppose a random sample of 81 students from the University of South Carolina was taken. Among the sampled students the sample mean, number of times they inappropriately used the word "like" in a five minute conversation, was 13 times with a sample standard deviation of 2.
- Our sample mean = $\bar{x}$ = 13
- Our sample standard deviation = s = 2

Example

- Our sample mean = $\bar{x}$ = 13
- Our sample standard deviation = s = 2
- Check Assumptions
    - n>30 so it is safe to assume the distribution of $\bar{x}$ is bell-shaped
    - The data is from a random sample

Example

- Our sample mean = $\bar{x}$ = 13
- Our sample standard deviation = s = 2
- 95% Confidence Interval for population mean:

$$\bar{x} \pm t_{\frac{.05}{2},80}\left(\frac{s}{\sqrt{n}}\right)$$

= (11.5578, 14.4422)

Example

(11.5578, 14.4422)

- We are 95% confident that the true population mean of number of times a University of South Carolina student inappropriately says “like” in a five minute conversation is between 11.5578 and 14.4422 times, or more specifically between 12 and 14 times.

Example

- What if I do not tell you the sample mean is 13 and sample standard deviation 2, instead give you the original data, do you know what to do?
- This time, you need to calculate the sample mean $\bar{x}$ and sample standard deviation s using Statcrunch, then use the interval formula to find the confidence interval.

Example 2

- Suppose a random sample of 20 kids was chosen in a fat camp. Among the sampled kids we saw a bell-shaped distribution with a sample mean of number of pounds lost was 2 and a population standard deviation of 4.
- Our sample mean = $\bar{x}$ = 2
- Our population standard deviation = σ = 4

Example 2

- Check Assumptions
  - N<30 **BUT** we were told it is safe to assume the data was bell-shaped which indicates the distribution of $\bar{x}$ is bell-shaped
  - The data is from a random sample

Example 2

- 90% Confidence Interval for population mean number of pounds lost at fat camp was:

$$\bar{x} \pm z_{.90}\left(\frac{\sigma}{\sqrt{20}}\right)$$

$$= 2 \pm (1.64)\left(\frac{4}{\sqrt{20}}\right)$$

(.5331, 3.4669)

Example 2

(.5331, 3.4669)

- We are 90% confident that the true population mean number of pounds lost at fat camp per kid is between .5331 and 3.4669 pounds.

From Confidence Intervals to Testing

- As we see in the last example we can come up with interesting observations of our confidence intervals

- Next we will learn how to formally test whether or not the population mean is a particular value based off our sample mean (without knowing standard deviation σ)

Hypothesis Test for Means: Step 1

- State Hypotheses:
  - **Null hypothesis**: that the population mean equals some μ_o
    - $H_o: \mu \leq \mu_o$ (one sided test)
    - $H_o: \mu \geq \mu_o$ (one sided test)
    - $H_o: \mu = \mu_o$ (two sided test)
  - **Alternative hypothesis:** What we're interested in
    - $H_a: \mu > \mu_o$ (one sided test)
    - $H_a: \mu < \mu_o$ (one sided test)
    - $Ha: \mu \neq \mu_o$ (two sided test)

Hypothesis Test for Means: Step 2

- Check the assumptions
  - The variable must be quantitative
  - The data are obtained using randomization
  - We’re dealing with data from the normal distribution
    - If n>30
    - If a histogram of the data is approximately normal

Hypothesis Test for Means: Step 3

- Calculate Test Statistic, t*
  - The test statistic measures how different the sample mean we have is from the null hypothesis
  - We calculate the t-statistic by assuming that μ_0 is the population mean

$$t = \frac{(\bar{x} - \mu_o)}{\frac{s}{\sqrt{n}}}$$

Hypothesis Test for Means: Step 4

- Determine the P-value
  - The P-value describes how unusual the data would be if H_o were true.
  - We will use software to find this

Hypothesis Test for Means: Step 4

- Determine the P-value
  - The P-value describes how unusual the sample data would be if H_o were true.
  - Again, we will use software or your calculator to find this, or I will give it to you.

Alternative Hypothesis	Probability	Formula for the P-value
$H_a\!: p > p_o$	Right tail	P(T>t)
$H_a\!: p < p_o$	Left tail	P(T<t)
$H_a\!: p \neq p_o$	Two-tail	2*P(T<-|t|)

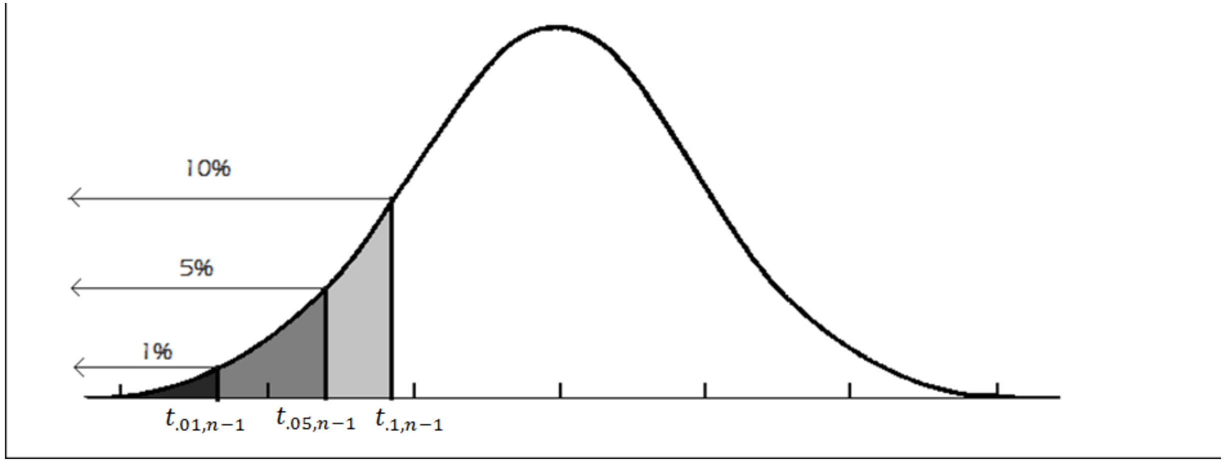
Hypothesis Test for Means: Step 5

- Summarize the test by reporting and interpreting the P-value
  - Smaller p-values give stronger evidence against H_o
- If p-value$\leq (1 - confidence) = \alpha$
  - Reject H_o, with a p-value = ____, we have sufficient evidence that the alternative hypothesis might be true
- If p-value$> (1 - confidence) = \alpha$
  - Fail to reject H_o, with a p-value = ____, we do not have sufficient evidence that the alternative hypothesis might be true

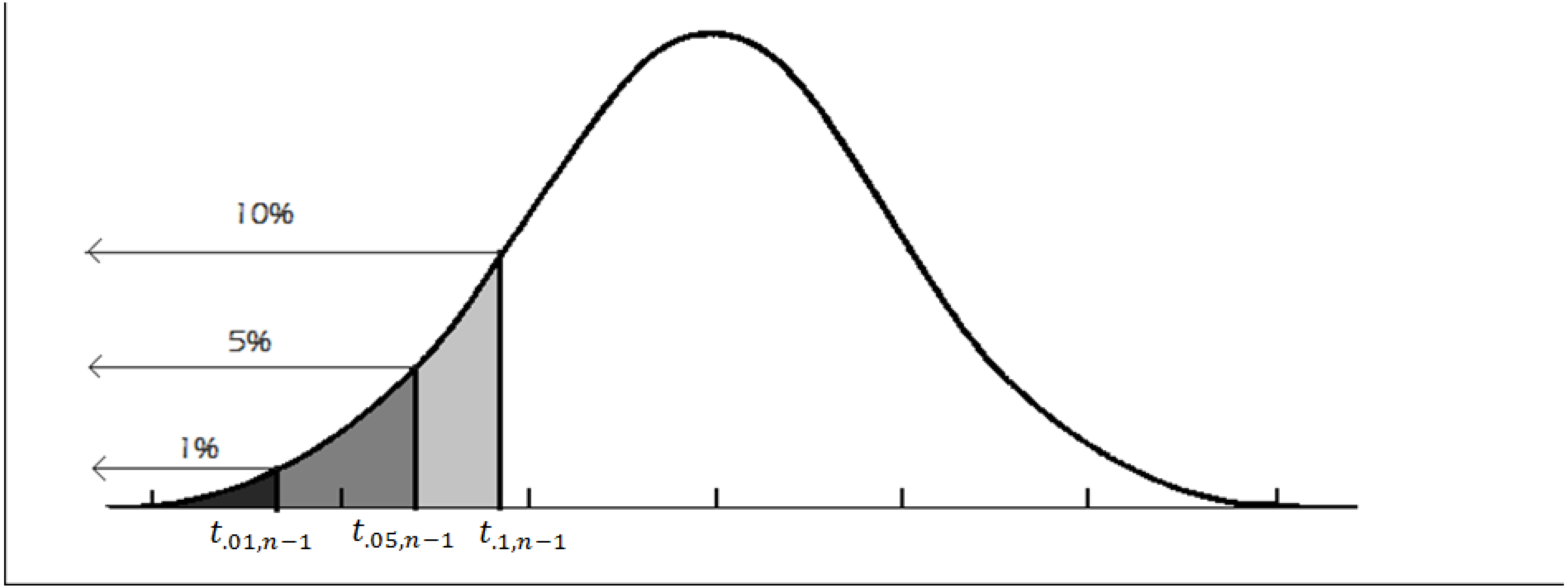
Hypothesis Test for Means– Step Five with Pictures

- For a left tailed test: $H_a: \mu < \mu_o$ → We have rejection regions for H_o are as follows

Confidence	Reject (test stat)	Reject (p-value)
0.90	Test-stat<-$t_{.10,n-1}$	P-value<.1
0.95	Test-stat<-$t_{.05,n-1}$	P-value<.05
0.99	Test-stat<-$t_{.01,n-1}$	P-value<.01



Zoom In



Hypothesis Test for Means– Step Five with Pictures

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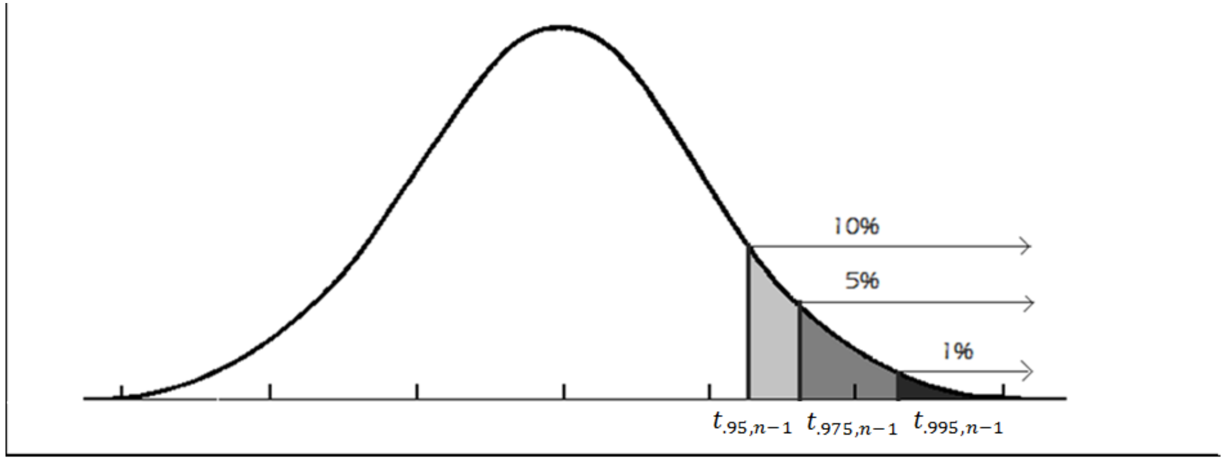
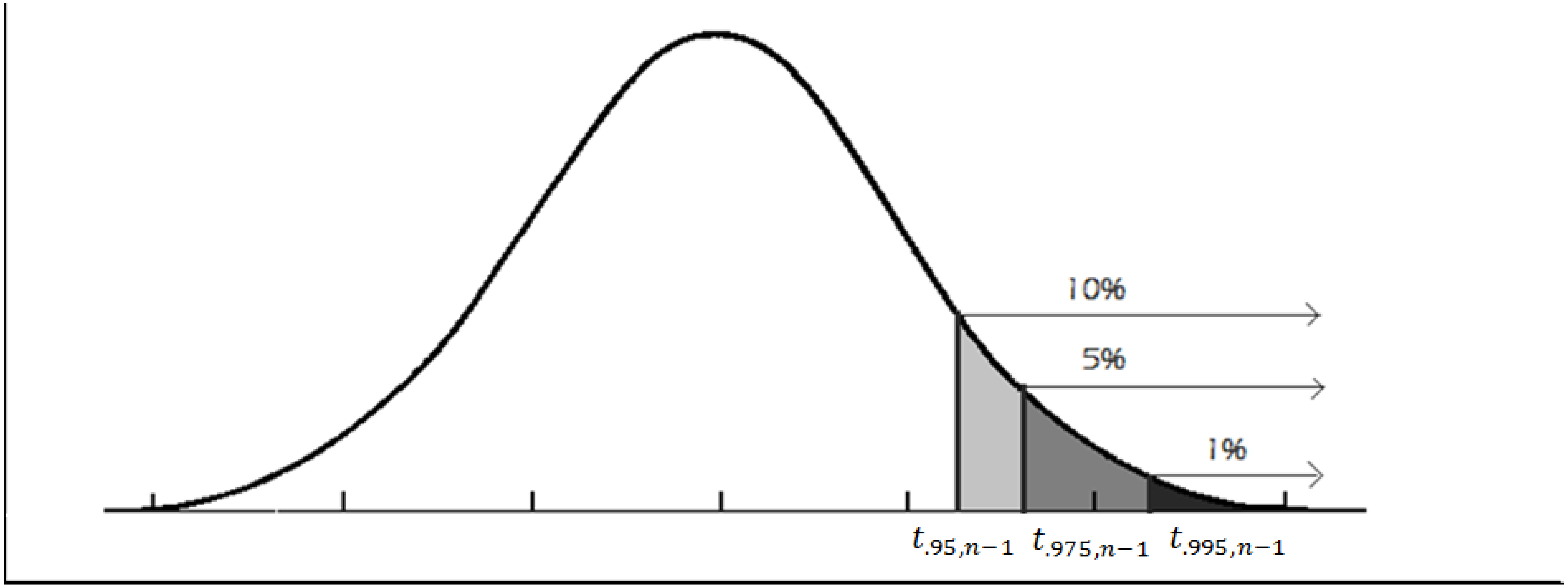
0.99	Test-stat<-$t_{.99,n-1}$	P-value<.01



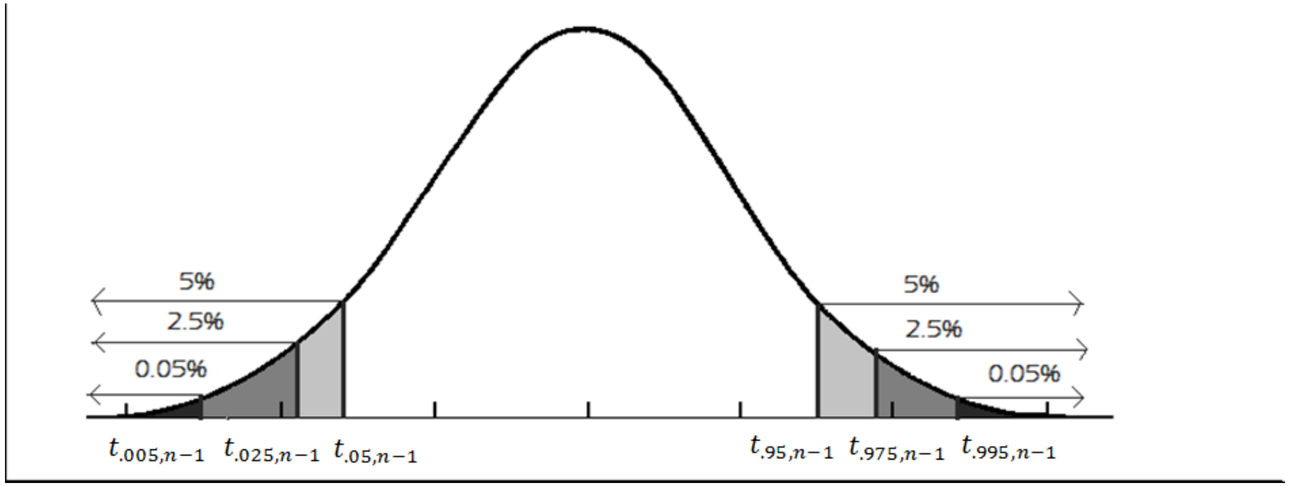
Zoom In



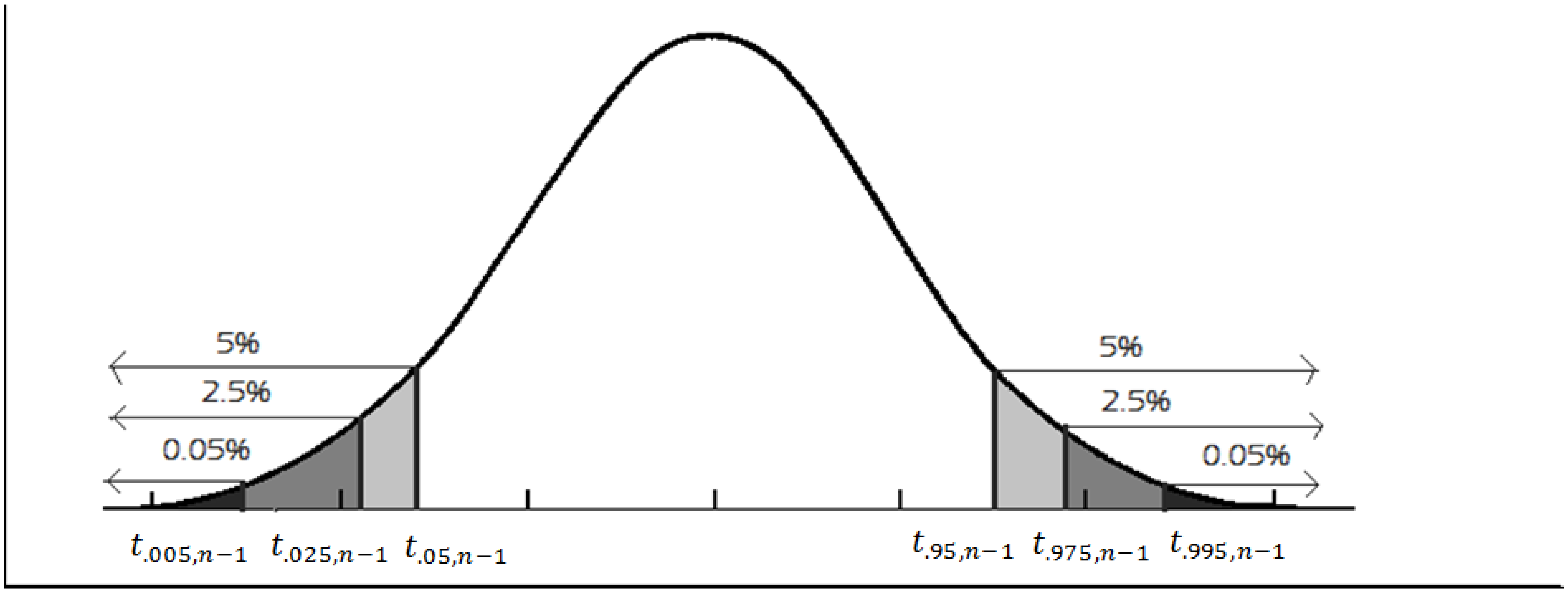
Hypothesis Test for Means– Step Five with Pictures

- For a two tailed test: $H_a: \mu \neq \mu_o \rightarrow$ We have rejection regions for H_o are as follows

Confidence	Reject (test stat)	Reject (p-value)
0.90	|Test-stat|<-$t_{.90,n-1}$	P-value<.1
0.95	|Test-stat|<-$t_{.95,n-1}$	P-value<.05
0.99	|Test-stat|<-$t_{.99,n-1}$	P-value<.01



Zoom In



Example 1

- An engineer at Budweiser came up with the idea of selling beers with a new designed machine! He wishes to show that the mean number of ounces bottled by his new machine greater than 4.5oz at a .05 significance level, or 95% confidence.
- A random sample of ten cans produces the data below

  4.5, 5.6, 4.9, 3.8, 4.1, 4.3, 4.4, 4.7, 5.0, 4.6

Example 1 – Step One

- A random sample of ten produces the data below

  4.5, 5.6, 4.9, 3.8, 4.1, 4.3, 4.4, 4.7, 5.0, 4.6

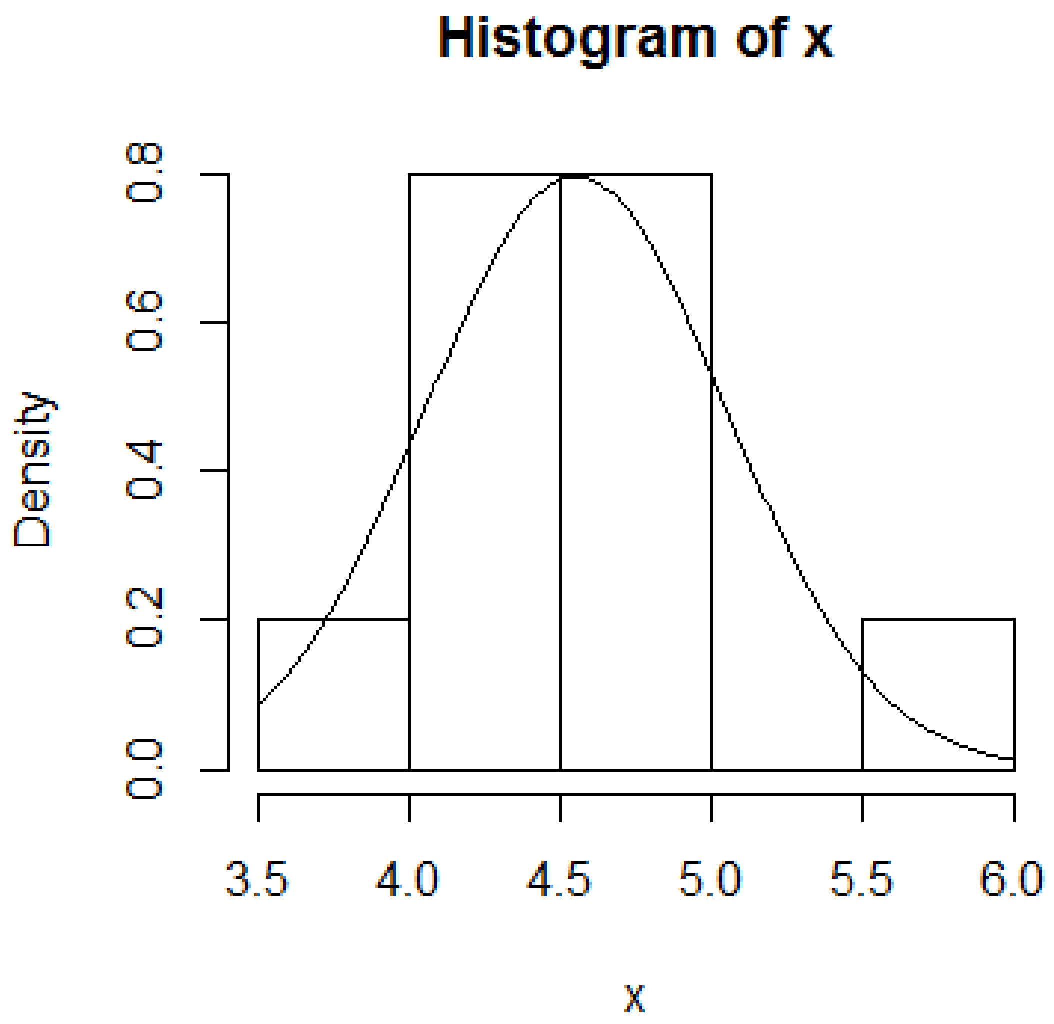
- State the Hypotheses: we are interested in whether or not the mean is **greater than 4.5 oz**
  - H_o: $\mu \leq 4.5$
  - H_a: $\mu > 4.5$

Example 1 – Step Two

- A random sample of ten produces the data below

  4.5, 5.6, 4.9, 3.8, 4.1, 4.3, 4.4, 4.7, 5.0, 4.6
- Check Assumptions:
  - The data is quantitative
  - The sample is randomly selected
  - Even though $n<30$, a histogram of the data shows approximately normal

Check it!



Example 1 – Step Three

- Calculate Test Statistic

Variable	Sample Mean $(\overline{x})$	Standard Deviation (s_x)	Standard Error $(s_{\overline{x}})$
Ounces Filled	4.59	.5043	.1595

$$t^* = \frac{(\bar{x} - \mu_o)}{\frac{s}{\sqrt{n}}} = \frac{4.59 - 4.5}{\frac{.5043}{\sqrt{10}}} = \frac{.09}{.1595} = .5643$$

Example 1 – Step Four

- Determine P-value

  P-value from software is .2932

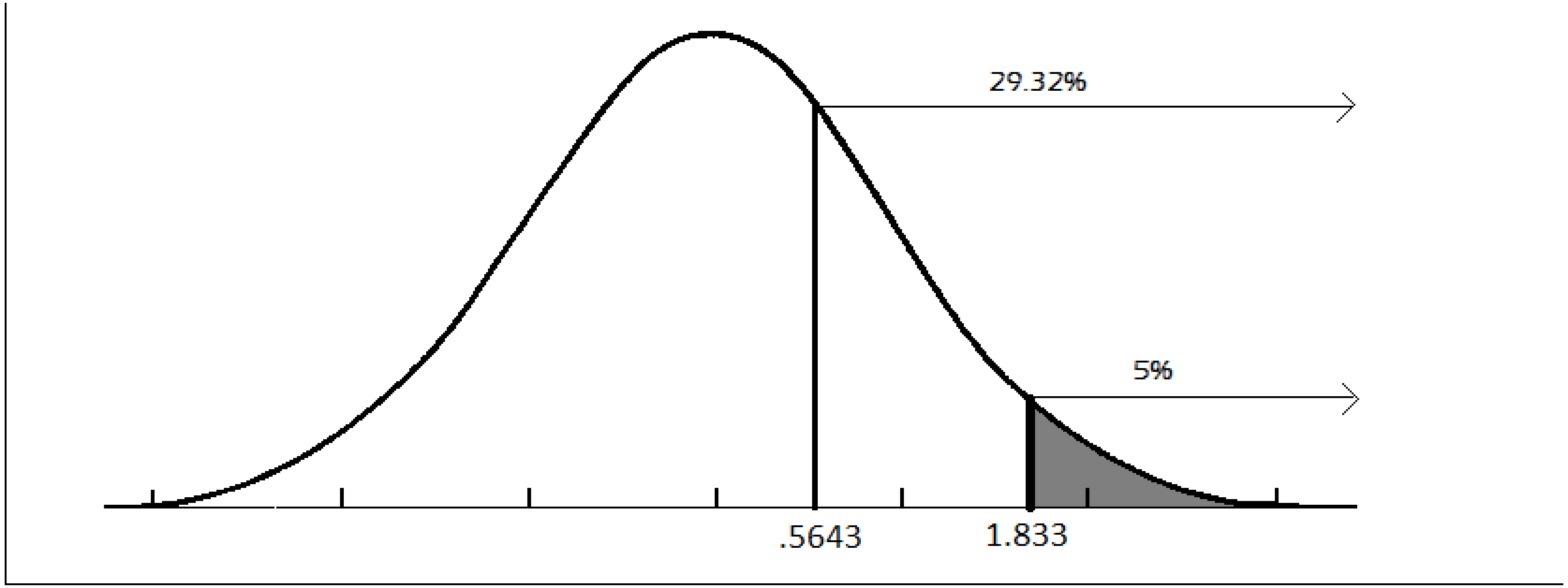
Example 1 – Step Five

- State Conclusion
  - Since .2932>.05 we fail to reject H_o

  At the .05 level of significance, or 95% confidence level, there isn't sufficient evidence that the mean fill is greater than 4.5 oz

Example 1 – Step Five with Pictures

- State Conclusion
  - Anything with a p-value<.05 or a t-value>$t_{1-\alpha,n-1}$ = $t_{.95,9}$ = 1.833 will be in the rejection region
  - Since .2932>.05 we fail to reject H_o



Zoom In