

Creating Robust Automatically Graded Multipart Questions in Blackboard Using Simple Regular Expression Pattern Matching

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Abbreviations and Definitions

- Learning Management System (LMS): The learning content delivery system that is in place at the institution level and not provided by a third-party content publisher.
- Blackboard (BB): One particular LMS
- Fill-In-The-Blank (FITB): A question type provided in many LMSs that accepts textual input from students.
 - Fill-In-Multiple-Blanks (FIMB): A FITB question with multiple blanks
- Regular Expression (regex): A method of matching patterns contained in text

Learning Management System(LMS) Limitations for Numeric Questions

- Blackboard, Moodle, and Canvas make up over 75% of the share of the LMS market, so these are the companies to have in your mind throughout the presentation.
- Focus on Blackboard Learn (“classic Blackboard”), since that’s what my institution uses.
 - FIMB questions are available in BB Ultra. The FIMB and FIB question types are merged.

¹Hill, P. (2021). State of Higher Ed LMS Market for US and Canada: Year-End 2020 Edition. Retrieved from <https://philonedtech.com/state-of-higher-ed-lms-market-for-us-and-canada-year-end-2020-edition/>

Example:

A marketing manager needs to estimate the yearly mean dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.

The marketing manager can be **95%** confident that the true mean amount spent is between **\$[l]** and **\$[u]**. **Enter your answers to the nearest whole dollar amount.**

How Should We Construct the Question?

- An LMS typically provides the following options:
 - Calculated Formula
 - Essay
 - File Response
 - Fill in the Multiple Blanks
 - Jumbled Sentence
 - Matching
 - Multiple Answer
 - Multiple Choice
 - Short Answer
 - True/False
- Our goal: automatic assessment
 - Calculated Formula
 - ~~Essay~~
 - ~~File Response~~
 - Fill in the Multiple Blanks
 - Jumbled Sentence
 - Matching
 - Multiple Answer
 - Multiple Choice
 - ~~Short Answer~~
 - True/False
- More specific goals: questions that permit:
 - automatic assessment
 - the use of multiple parts
 - robustness to the variety of ways students can answer a question correctly

Example:

A marketing manager needs to estimate the yearly mean dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.

*The marketing manager can be **95%** confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.*

- For 95% confidence and $n = 100$, we get t critical value of $t_{0.025,99} = 1.984$, and the interval is

$$1400 \pm 1.984 \frac{250}{\sqrt{100}}$$

The lower bound is 1350.4, and the upper bound is 1449.6.

Option 1: Calculated Formula

- Pros:
 - Requires students to input an answer in a blank space rather than guess from a list
 - Answer is a fixed calculation of randomly generated numbers that change from student-to-student
 - Allows instructor to specify a range of acceptable answers to account for rounding.
- Con:
 - Only allows one computed quantity per question.

* Indicates a required field.

QUESTION

Question Title

* Question Text

For the toolbar, press ALT+F10 (PC) or ALT+FN+F10 (Mac).

B *I* U ~~S~~ Paragraph Open Sans,sa... 10pt

0 WORDS POWERED BY TINY

* Answer Formula

$\sqrt{}$ $\sqrt[n]{}$ $\frac{}{}$ () $(\frac{}{})$ \times π α Ω sin

Does not allow us to fully ask the confidence interval question we want.

Option 2: Calculated Numeric

- Pros:
 - Requires students to input an answer in a blank space rather than guess from a list
 - Allows instructor to specify a range of acceptable answers to account for rounding.
- Con:
 - Does not provide any randomization of numbers.
 - Only allows one computed quantity per question.

Create/Edit Numeric Answer Question

* Indicates a required field.

QUESTION

Question Title

* Question Text
For the toolbar, press ALT+F10 (PC) or ALT+FN+F10 (Mac).

B *I* U ~~S~~ Paragraph Open Sans,sa... 10pt

0 WORDS POWERED BY T

ANSWERS

* Correct Answer

Answer Range +/-

Does not allow us to fully ask the confidence interval question we want.

Option 3: Fill-In-Multiple Blanks (FIMB)

- Using letters within brackets, [l] and [u], we can create as many blanks as we want!
- Some quick math: Directions said to report the answers to the nearest whole number.
- We can specify the answers by filling in the “Exact Match” areas.

A marketing manager needs to estimate the yearly mean dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

ANSWERS FOR: L

Number of Answers

1

★ Answer 1

Exact Match

1350

☐ Case Sensitive

ANSWERS FOR: U

Number of Answers

1

★ Answer 1

Exact Match

1450

☐ Case Sensitive

Example of Student Response

A marketing manager needs to estimate the mean yearly dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$ and \$. Enter your answers to the nearest whole dollar amount.

It looks like this student understood the question!

Feedback

Deviation	250
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Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

Specified Answer for: l ✖ 1,350
The answer for this part of the question is incorrect.

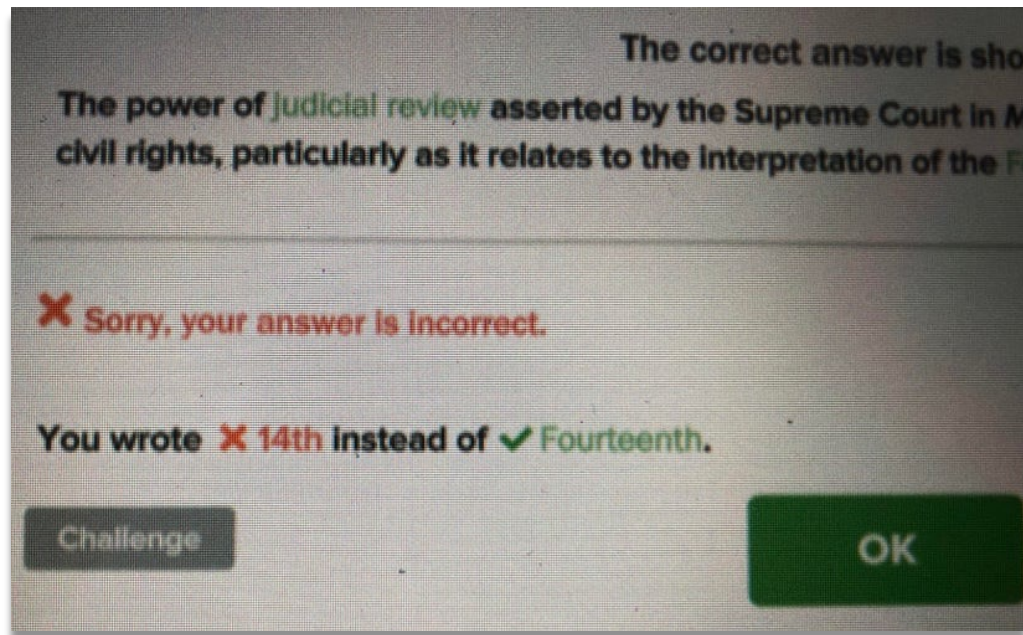
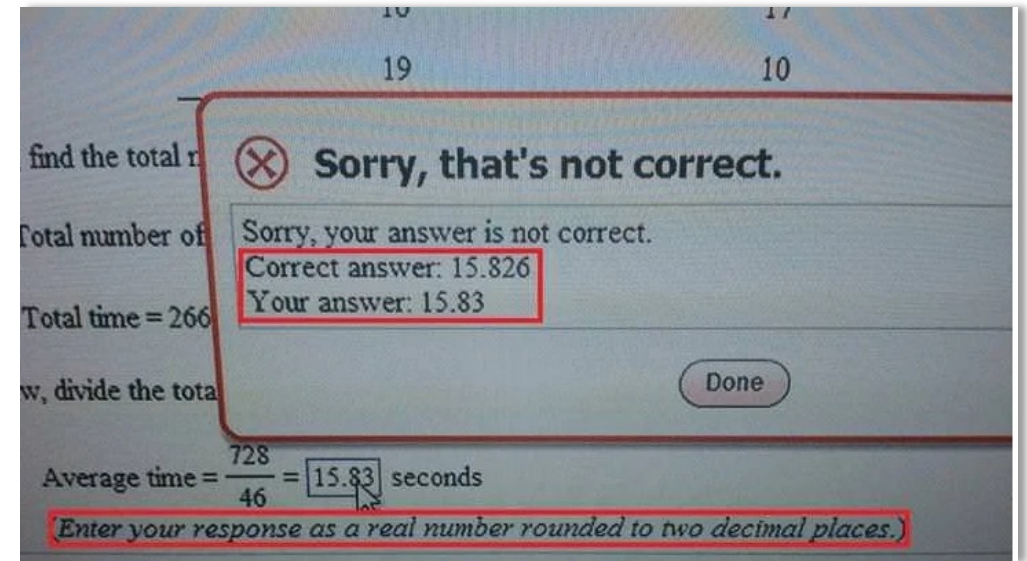
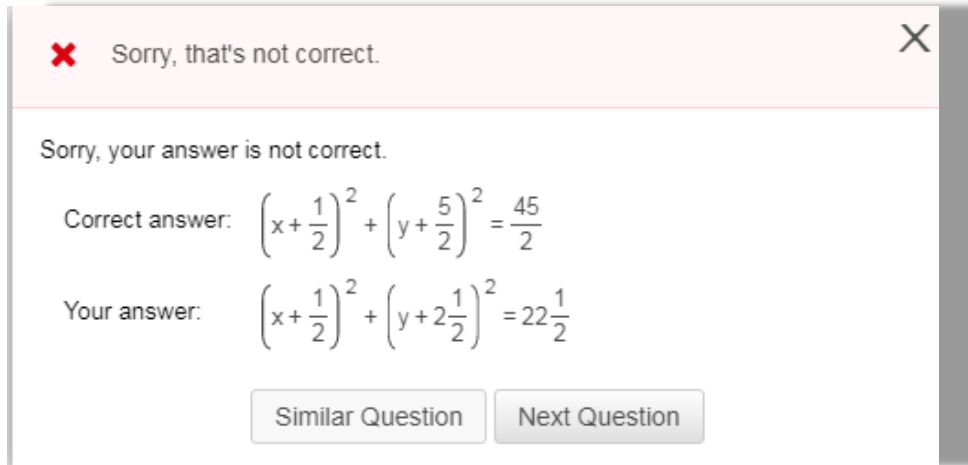
Specified Answer for: u ✖ 1,450
The answer for this part of the question is incorrect.

Correct Answers for: l		
Evaluation Method	Correct Answer	Case Sensitivity
✔ Exact Match	1350	

Correct Answers for: u		
Evaluation Method	Correct Answer	Case Sensitivity
✔ Exact Match	1450	

- The student misses the question because of an inconsequential—and not-incorrect—choice to use a comma.
- The instructor could have been more specific about acceptable input, but that moves the emphasis from learning concepts to training students to give the system “what it wants.”

Student Frustration with LMS-Based Homework



✖ 7) Approximately how many hives were there in 1946? Give your answer 0/1 to 2 significant figures and include units. *

5.8 million hives



Correct answers

5.8 millions

5.8 million

Screenshots like these can be easily found on message boards and even in memes.

One Remedy: Add More Correct Answers

This is a general problem among the top LMSs.

From a Canvas User Group:

*“A student will not get full credit for an answer if it is left blank, misspelled, or is incorrect. For each item in the dropdown menu, **instructors must try to account for all of the possible correct answers** that a student might give.”²*

From a user guide to Moodle:

*“Short answer questions require respondents to type a word or phrase in response to a question...Answers may or may not be case sensitive and can include more than one correct answer. **Acceptable answers can be a word or a phrase, but must match one of your correct answers exactly.**”³*

The screenshot shows the 'Answers' section of a Canvas LMS question editor. At the top, there's a dropdown menu labeled 'Show Possible Answers for' with 'color1' selected. Below this, there's a list of 'Possible Answer' entries. The first entry is 'Red' with a circled '1' next to it. Below 'Red' is a green-bordered box containing the text 'Comments, if the student chooses this answer:' followed by 'Correct!' with a red arrow pointing to it and a circled '2'. Below this box is another 'Possible Answer' entry 'red'. At the bottom right, there's a button labeled 'Add Another Answer' with a circled '3' next to it. At the bottom left, there are 'Cancel' and 'Update Question' buttons.

According to legend, the reptilian creature living in Lake Champlain is called...

Answer:

²Instructure (2022). How do I create a fill-in-multiple-blanks question? Retrieved from <https://community.canvaslms.com/t5/Instructor-Guide/How-do-I-create-a-Fill-in-Multiple-Blanks-quiz-question/ta-p/923>

³University of Massachusetts Amherst Information Technology. (2021). Short answer questions. Retrieved from <https://www.umass.edu/it/support/moodle/short-answer-questions>

Adding More Answers

Using this information, complete the following statement.
The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

ANSWERS FOR: L

Number of Answers

2

★Answer 1

Exact Match

1350

☐ Case Sensitive

Remove

★Answer 2

Exact Match

1,350

☐ Case Sensitive

Remove

ANSWERS FOR: U

Number of Answers

2

★Answer 1

Exact Match

1450

☐ Case Sensitive

Remove

★Answer 2

Exact Match

1,450

☐ Case Sensitive

Remove

Okay, now we have accounted for the comma!

Example of Student Response

QUESTION 1

A marketing manager needs to estimate the mean yearly dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.


The marketing manager can be 95% confident that the true mean amount spent is between \$

and \$

. Enter your answers to the nearest whole

dollar amount.

Student Feedback




A marketing manager needs to estimate the mean yearly dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.


The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

Specified Answer for: l





 \$1350

The answer for this part of the question is incorrect.

Specified Answer for: u

 \$1450

The answer for this part of the question is incorrect.

Correct Answers for: l		
Evaluation Method	Correct Answer	Case Sensitivity
 Exact Match	1350	
 Exact Match	1,350	
Correct Answers for: u		
Evaluation Method	Correct Answer	Case Sensitivity
 Exact Match	1450	
 Exact Match	1,450	

To be fair, the student should not have entered the dollar signs, \$, in the blanks since they were already built into the question text. But the student still gets the core concept of a confidence interval. I would not count off for this if I were hand-grading the question.

Desired Robustness Categories

- Spelling
- Word order
- Capitalization
- Filler words
- Punctuation
- Rounding
- Number formatting
- Special symbols

The “Contains” Option: A Good First Start

- “Contains” allows freedom for some extraneous input (like dollar signs).
- It is possible to assign several “Contains” input options per answer.
- If the student inputs a subset of the characters specified in the “Contains” area, the question will be marked as correct.
 - So, “\$1350”, “\$1350.50”, “1350.12342125”, etc. **will** be accepted for the lower bound, but “135” will not because it is missing a “0”.

ANSWERS FOR: L

Number of Answers: 2

*Answer 1: Contains 1350 ☐ Case Sensitive Remove

*Answer 2: Contains 1,350 ☐ Case Sensitive Remove

ANSWERS FOR: U

Number of Answers: 2

*Answer 1: Contains 1450 ☐ Case Sensitive Remove

*Answer 2: Contains 1,450 ☐ Case Sensitive Remove

“The Contains” Feature

This question looks pretty robust to variations in input...

A marketing manager needs to estimate the mean yearly dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250

Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$1350 and \$1450. Enter your answers to the nearest whole dollar amount.

Alternative sets of right answers:

- 1. Lower Bound: \$1,350, Upper Bound: \$1,450
- 2. Lower Bound: \$1,350.40, Upper Bound: 1450
- 3. Lower Bound: 1350, Upper Bound: 1,450.00

Sample Standard Deviation	250
---------------------------	-----

Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

Alternative sets of right answers:

- 1. Lower Bound: [l2], Upper Bound: [u2]
- 2. Lower Bound [l3], Upper Bound: [u3]
- 3. Lower Bound [l4], Upper Bound: [u4]

- Specified Answer for: l ☒ \$1350
- Specified Answer for: u ☒ 1,450
- Specified Answer for: l2 ☒ \$1,350
- Specified Answer for: u2 ☒ \$1,450
- Specified Answer for: l3 ☒ \$1350.40
- Specified Answer for: u3 ☒ 1450
- Specified Answer for: l4 ☒ 1350
- Specified Answer for: u4 ☒ 1,450.00

Student Response

Suppose the student works the problem by making some calculation choices:

- using $t_{0.025,99} = 1.98$


$$1400 \pm 1.98 \frac{250}{\sqrt{100}}$$

$$1400 \pm 49.5$$

Lower Bound: 1350.5

Upper Bound: 1449.5

Round to the nearest whole number to get 1351 to 1450.

 A marketing manager needs to estimate the mean yearly dollar amount spent by members of Amazon Prime to determine if targeted advertising efforts for the service at the point of checkout should be adjusted to reflect a difference in mean spending from previous amounts. She obtains the following sample statistics from a sample of 100 Amazon Prime members who recently made a purchase:

n	100
Sample Mean	1400
Sample Standard Deviation	250




Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

Specified Answer for: l  1351

The answer for this part of the question is incorrect.

Specified Answer for: u  1450

Correct Answers for: l		
Evaluation Method	Correct Answer	Case Sensitivity
 Contains	1350	
 Contains	1,350	
Correct Answers for: u		
Evaluation Method	Correct Answer	Case Sensitivity
 Contains	1450	

Q1: What will happen if the student inputs 1350.5?
 Q2: What will happen if the student inputs 1350120125?

Regular Expressions (Regex)

- A regex is a sequence of letters, symbols, and operators that can be used to find, validate, or parse text containing a specified pattern.
 - Everyday examples:
 - “find and replace” in text editing
 - input validation for online forms (valid email address; phone number)
- In LMS, the regex engine matches the based on its meeting some specified pattern
- A regex pattern extracts key elements from a student’s answer that relate to understanding the concept behind the question, allowing irrelevant differences in the input to be ignored
 - Example: If the answer is “cats and dogs”, the regex

```
(?i) cats?\s?and\s?dogs?\s?
```

will accept as “cats and dogs”, “cat and dogs”, “cat and dog, “CAT and DOG”, etc.
- Regex can be used to increase the robustness of FIMB questions by allowing for greater control over the variations in the way students can correctly answer questions.
- If students miss questions for non-substantive reasons, this can create a barrier to learning.

The Basics from Blackboard⁴:

- A dot, ., matches any single character except newline characters.
- Brackets [] match anything inside the square brackets for one character.
- A dash, – inside square brackets allows you to define a range.
 - Example: [0123456789] can be rewritten as [0–9] .
- A question mark (?) makes the preceding item in the regular expression optional.
 - Example: Dec(ember)? will match Dec and December.

Simple string examples:

- b.t - matches with bat, bet, but, bit, b9t because any character can take the place of the dot (.).
- b[aeui]t matches bat, bet, but, bit.
- b[a–z]t will accept any three-letter combination that begins with b and ends with t. A number won't be accepted as the second character.
- [A–Z] matches any uppercase letter.
- [12] matches the target character to 1 or 2.
- [0–9] matches the target character to any number in the range 0 to 9.

⁴ The text on this slide is taken directly from the official Blackboard help file at

https://help.blackboard.com/Learn/Instructor/Original/Tests_Pools_Surveys/Question_Types/Fill_in_Multiple_Blanks_Questions

Our Example with Regex

- We need to decide how much variability a “correct answer” should have, as this will define the structure of our regex.
- Imagine we were “hand grading”. What things would we tend to ignore, or at least not count off for?
 - In the example, we decided that
 - using a comma to indicate the thousands place was okay.
 - we didn’t like the fact that the students inputted dollar signs, but this didn’t indicate a major problem with the concept of confidence intervals.
 - slight variations in the final answer attributable to earlier rounding choices should be accounted for.

Regular Expressions (Regex)

- A regular expression (or regex) is pattern of letters, symbols, and operators that can be used to find characters, words, or whole sentences in a body of text.
 - Everyday examples:
 - “find and replace” in text editing
 - input validation for online forms (valid email address; phone number)
- In Blackboard, the regex engine parses the student’s input as “correct” or not based on its meeting some specified pattern
 - Example: If the answer is “cats and dogs”, the regex
`(?i) \b cats? \b . * \b dogs? \b`
will accept as “cats and dogs”, “cat & dogs”, “cat and dog”, “CAT and DOG”, etc.
- If students miss questions for non-substantive reasons, this can create a barrier to learning.
- Regex can be used to increase the robustness of FIMB questions by allowing for wider variations in the way students can correctly answer questions.

Useful Regex Building Blocks

- `.*`: the `*` after the `.` matches one or more characters
- `\d*`: matches one or more digits
 - `\d*` matches “357”, “9”, “42”, etc. but not “apple”)
- `?`: make the *previous* character or operator optional
 - `cats?` matches `cats` and `cat`
- `\s`: require a single space between a previous letter and a subsequent letter
 - `ca\s t` matches `ca t`; **cat will be counted as an error because `\s` is a mandatory space**
 - can use “`?`” operator to make a space optional: `ca\s?t` matches both `ca t` and `cat`
- `\s*`: allow (but don’t require) an unlimited amount of blank space between characters
 - `ca\s*?t` matches `ca t`, `ca t`, `cat`
- `(?i)`: makes the entire line expression case-insensitive
 - `(?i) dog` matches `DOG`, `dOG`, `Dog`, etc.
- `[...]`: match a single character to an element or range of elements inside the brackets
- `()`: A “capture group” will lead the regex to interpret everything inside the `()` as a unit
- `|`: Use the “OR” operator with a capture group allows for flexibility:
 - `(?i) Stop.*?((Hammertime) | (collaborate and listen))`
- `{a,b}`: look for the previous token occurring between `a` and `b` times (specifying only `a` or `b` gives lower and upper bounds, respectively).
 - `(ice) {2} baby` requires “ice ” (with the space) to occur twice before “baby”

Checking Regex Validity

- Within Blackboard, there is a method of checking the regex pattern against a correct answer using the “Check Pattern” option next to the answer.
- External regex testing sites can also be used, e.g., <https://regexr.com/>

Check Pattern

★ Indicates a required field.

ENTER PATTERN

★ Enter Answer Pattern

★ Enter Expected Correct Answer

Save & Exit

Exit

Check Pattern

Building a Regex

- For clarity, in the remainder of the presentation, the regex corresponding to a particular pattern will be written in `this font`.

- 1). Allow commas:

`1,?350`

`1,?450`

- The regex pattern is specified in the “Enter Pattern” box.
- The `? right` after the `,` indicates that the system should treat 1350 and 1,350 as identical inputs (the same goes for the upper bound).

Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

ANSWERS FOR: L

Number of Answers

1

★ Answer 1

Pattern Match

1,?350

Check Pattern

Answer 1

Check Pattern

★ Indicates a required field.

ENTER PATTERN

★ Enter Answer Pattern

1,?350

Success: The Answer Pattern matches the expected answer.

★ Enter Expected Correct Answer

1,350

Save & Exit

Exit

27 Check Pattern

Building a Regex (cont.)

2). Allow dollar signs and commas. The \$ is a special character, so it must be “escaped” with a backslash:

`\$?1,?350`

`\$?1,?450`

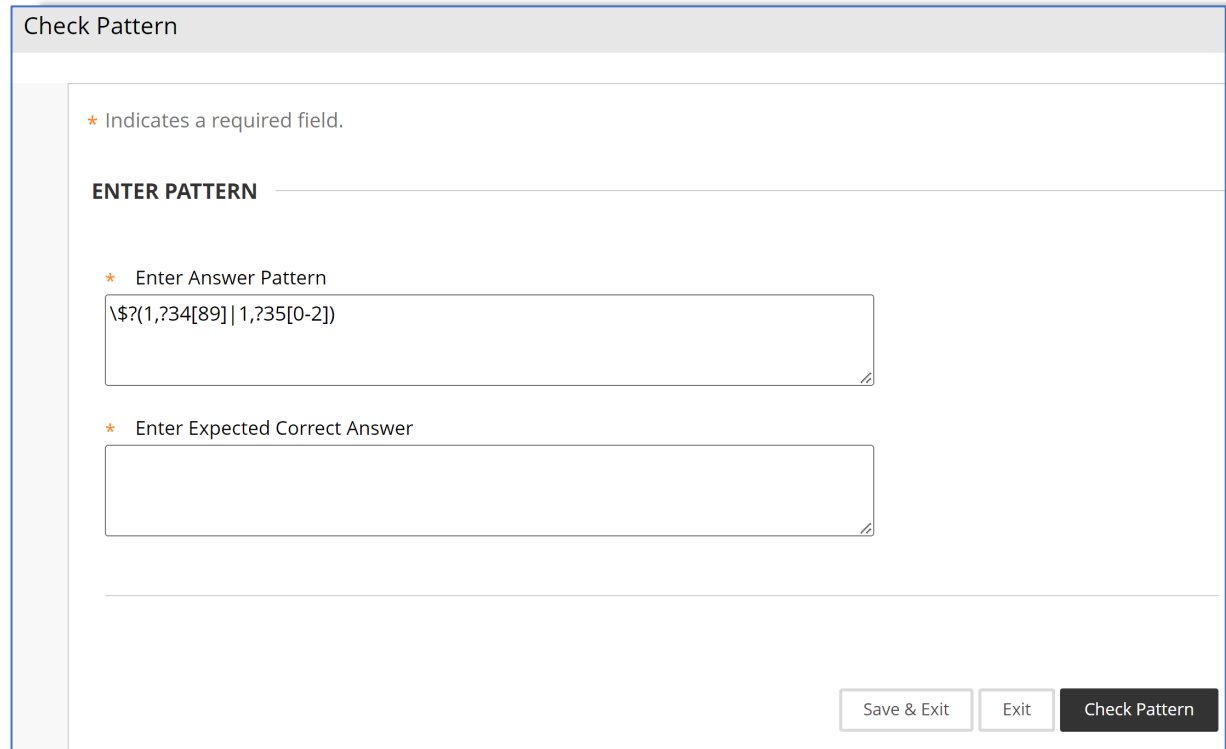
3). Now, allow for rounding differences.

- Let’s be somewhat generous: Any answer within 2 dollars of the correct value will be accepted as “correct.”

`\$? (1,?34[89] | 1,?35[0-2])`

`\$? (1,?44[89] | 1,?45[0-2])`

The OR symbol, |, tells Blackboard to accept either 1,34(8 or 9) OR 1,35 (0 through 2).



The screenshot shows a web-based tool titled "Check Pattern". It includes a legend at the top stating "★ Indicates a required field." Below this, there is a section labeled "ENTER PATTERN". Under this section, there are two input fields. The first field is labeled "★ Enter Answer Pattern" and contains the text `\$(1,?34[89] | 1,?35[0-2])`. The second field is labeled "★ Enter Expected Correct Answer" and is currently empty. At the bottom right of the interface, there are three buttons: "Save & Exit", "Exit", and "Check Pattern".

- A free web-based tool for generating number ranges: <https://3widgets.com/>.

Challenge: Allow for Non-Integer Input

- Even though our directions told the student to round each endpoint to the nearest whole dollar, we can make the question more robust by allowing rounding to the nearest cent
- For the lower bound, we want any number between \$1348.00 and \$1352.00
- For the upper bound, we want any number between \$1448.00 and \$1452.00.
- We'll make heavy use of the parentheses, () , which allows us to use operators on groups of characters
- Here's the expression for the lower bound (color coded by digit group):

```
\$? (1, ?34 [89] (\. [0-9] [0-9] ?) ? | 1, ?35 [01] (\. [0-9] [0-9] ?) ? | 1, ?352 \. ? (00 ?) ?)
```

Eating an Elephant, One Bite at a Time...

`\$? (1, ?34 [89] (\. [0-9] [0-9] ?) ? | 1, ?35 [01] (\. [0-9] [0-9] ?) ? | 1, ?352 \. ? (00 ?) ?)`

- Example Case: Student doesn't round and inputs \$1350.40 for the lower bound
 - `\$?` allows the first character to be a dollar sign or absent
 - `(` begins a **capture group**: everything inside `()` is treated as a single unit
 - `1, ?` allows for an optional comma after the "1".
 - The second character must be a "3".
 - The next character input is "5", activating the first OR operator, "`|`": move into the middle (blue) part of the expression.
 - The fourth character is a "0". The bracketed term `[01]` makes either "0" or "1" acceptable.
- Anything after "1350" is optional.
 - To indicate optional characters, include them in parentheses with a "?" `(\. [0-9] [0-9] ?) ?`
 - The student input a ".", which is a special regex character, so we have to "escape it" with a backslash.
 - The seventh character is "4". The term `[0-9]` accepts any integer between 0 and 9.
 - The last character is input is 0. The fact that the bracketed term has a ? attached indicates that the second decimal place is optional.

Let's Get More Complex

Calculate and interpret a 95% confidence interval for the mean retail sales of Umbrella Company using the fact that the sample mean is 16, the sample standard deviation is 2.3, and the sample size is 23. Input your answers in the statement below, to one decimal place.

We can be ____% confident that the _____ is between ____ and ____.

The student would compute the answer as:

$$\text{Lower Bound: } 16 - 2.074 \frac{2.3}{\sqrt{23}} = 15.005$$

$$\text{Upper Bound: } 16 + 2.074 \frac{2.3}{\sqrt{23}} = 16.995$$

- We can set up expressions to account for the rounding.
- What about the many ways students could interpret the interval?

Building the Regex

- Again, imagine we were grading “by hand”. What things would we tend to ignore, or at least not count off for?
- The student should definitely:
 - report the confidence level of 95%
 - mention the terms “mean” and “sales”
 - report the correct lower and upper bounds of the interval
- We might deduct a point for not mentioning the company in some way (either as “Umbrella”, or “Umbrella Company”).
- We might deduct a point for not mentioning “retail”
- Let’s make it so that if the student mentions at least “mean sales”, they get full points.
- But they could mention “mean retail sales of Umbrella Company” or “mean sales of Umbrella.”

Building the Regex

1). Let's start with the confidence level. The idea is for the student to write "95", as the "%" is already in the question, but let's make it more robust!

```
(95%?) | 95\%?\s*?(?i) (per(\s|\-)?cent\s*) | (ninety(\-|\s*)five\s*) (%|per(\s|\-)?cent\s*)?
```

- If the student types "95", we move on.
- To make "95%" also correct, we allow the option of the "%" sign by putting "?" after "%."
- The `\s*` accepts an optional unlimited number of spaces between before the "percent".
- Let's be generous and even allow "95%", "95 percent", "ninety-five percent", "ninety five %".
- The `(?i)` allows for the word "percent" to be completely case-insensitive: "perCeNT" is treated the same as "PERCENT" or "PERCENT"
- `per(\s|\-)?cent` allows the student to spell "percent" the old-timey way, "per cent", with a space `(\s)` between "per" and "cent" OR a hyphen
- The green block allows the student to fully spell out "ninety-five percent", with or without the hyphen.

Building the Regex

2). Now, to the interpretation part

```
(?i) (true\s*)? ((mean\s*?sales) | (mean\s*?retail\s*?sales)) \s* (of|at|in|for)? \s* (Umbrell?a|Company|Umbrell?a\s* Company)?
```

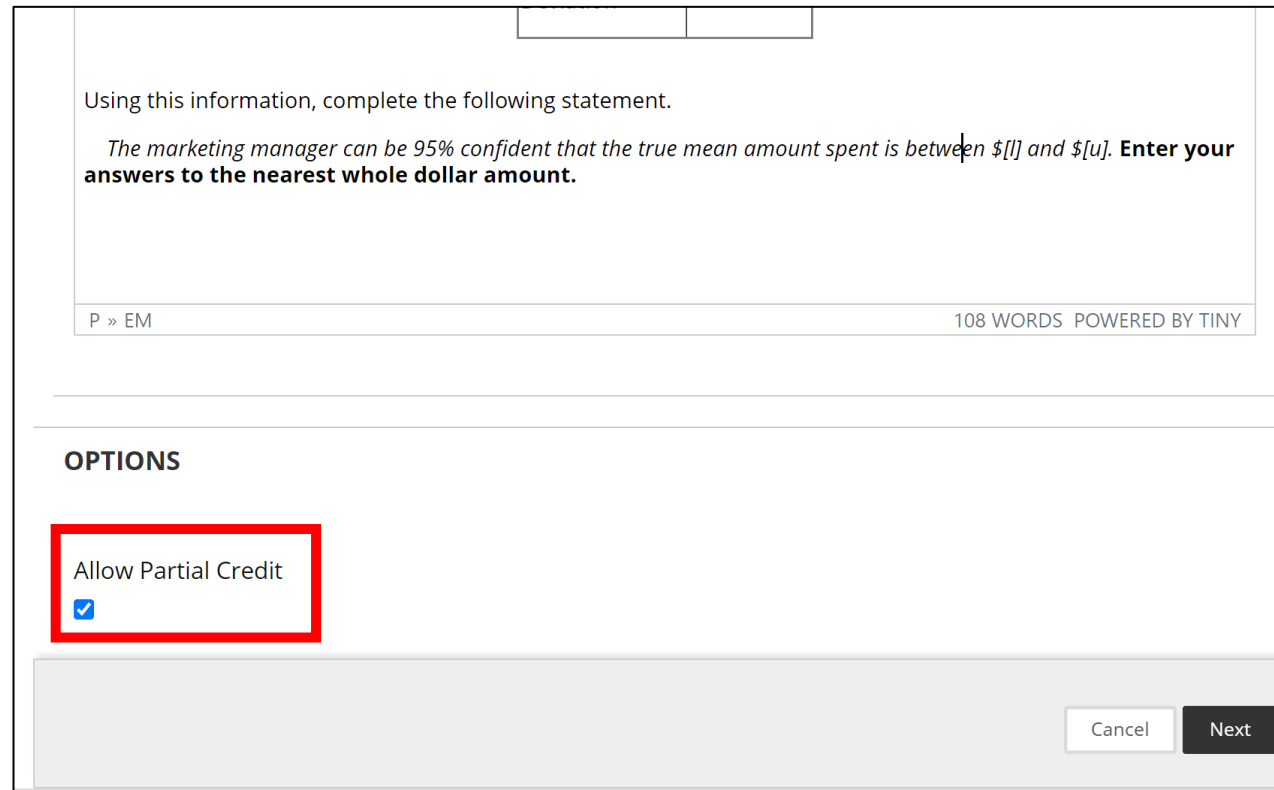
Suppose the student writes “true mean sales at Umbrella”

- `(?i)` makes everything case-insensitive
- `(true\s*)?` makes “true” optional
- At minimum, the student must write “mean sales”, but can write “mean retail sales.”
- Optionally, the student can incorporate more context by relating “mean sales” to the company given in the problem.
 - The `(of|at|in|for)?` is a non-comprehensive list of appropriate prepositions.
 - `(Umbrell?a|Company|Umbrell?a\s* Company)?` allows the student to write “Umbrella Company”, “Umbrella” or just “Company”
 - Just for fun, I added the “?” after the second “l” to allow the student to misspell “umbrella” by dropping an “l”.

3). Specifying the numerical lower bound and upper bound could be done as in the earlier examples.

Partial Credit and Individual Answer Feedback

- Blackboard's FIMB allow partial credit at the individual answer level (a fraction of the points per blank).
- Permits the instructor to provide feedback/answers on individual parts of the question.
- Option can be turned on or off (for example, "off" for exam periods).



Using this information, complete the following statement.

The marketing manager can be 95% confident that the true mean amount spent is between \$[l] and \$[u]. Enter your answers to the nearest whole dollar amount.

P » EM 108 WORDS POWERED BY TINY

OPTIONS

Allow Partial Credit ☒

Cancel Next

Partial Credit and Individual Answer Feedback

Test Canvas: AEF RegEx Training Examples

Create Question Reuse Question Upload Questions

Question Settings

Description
Instructions
Total Questions 6
Total Points 0

Select: All None Select by Type: - Question Type -

Delete Points Update Hide Question Details



Test Question Settings

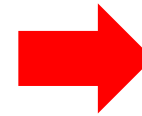
FEEDBACK

☒ Provide feedback for individual answers.

IMAGES, FILES, AND WEB LINKS

☐ Add images, files, and web links to individual feedback.
☐ Add images, files, and web links to answers.

Cancel Submit



★Answer 1 Pattern Match `\$(1,234[89]|1,235[0-2])` Check Pattern

Correct Response Feedback
For the toolbar, press ALT+F10 (PC) or ALT+FN+F10 (Mac).

Great work!

P » STRONG » SPAN 2 WORDS POWERED BY TINY

Incorrect Response Feedback
For the toolbar, press ALT+F10 (PC) or ALT+FN+F10 (Mac).

The answer for this part of the question is incorrect. Make sure that you have rounded to a whole number.

The Student View

- In this example, the student missed the second part of the question by not including the word “mean” in the interpretation.
- This would be a common mistake, so the general language used for this answer’s feedback mentions the possibility that the student left off that word.



Calculate and interpret a 95% confidence interval for mean retail sales using the fact that the sample mean is 16, the sample standard deviation is 2.3, and the sample size is 23. Input your answers in the statement below, to one decimal place.

We can be [c]% confident that the [m] is between [l] and [u].

Using regex expressions makes this question more robust to small semantic differences in input.

Specified Answer for: c ✔ 95
Good work!

Specified Answer for: m ✖ true retail sales

A confidence interval for a mean is a range of values within which the mean of a population will fall. Check to be sure if you left off "mean".

Specified Answer for: l ✔ 15
Good work!

Specified Answer for: u ✔ 17
Excellent!

Correct Answers for: c		
Evaluation Method	Correct Answer	Case Sensitivity
✔ Pattern Match	(95%?) 95\%?\s*?(?i) (per(\s \-)?cent\s*) (ninety(\s \-)?five\s*)(% per(\s \-)?cent\s)?	

What's Possible?

This problem uses the data in the modified HPRICE1.dta file in Chapter 3 of Wooldridge. You will be fitting the following model:

$$price = \beta_0 + \beta_1 sqft + \beta_2 bdrms + \varepsilon$$

where *price* is the estimated price of a house in thousands of dollars, *sqft* is the size of a house in square feet, *bdrms* is the number of bedrooms of the house, and ε is the random error term with the usual assumptions. Throughout this problem, when referring to variable names, use the names of the variables as given here.

a). Fit the model using software and obtain the output from the fitting procedure. Partial output from Stata is shown below. Fill in the missing information, indicated by the areas indicated by the shading .

Source	SS	df	MS	Number of obs	=	[n]
Model	580009	2	290004.58	F(2, 85)	=	72.96
Residual	337845.35	85	3974.65	Prob > F	=	0.0000
Total	917854.51	87		R - squared	=	0.6319
				Adj R - squared	=	[r22]
				Root MSE	=	[rmse]
price	Coef.	Std. Err	t	P> t	95% Conf. Interval	
sqft	[b1]	0.01382	9.29	0.000	.1009495	0.155922
bdrms	[b2]	9.48352	1.60	0.113	[l2]	[u2]
cons	-19.315	31.04662	-0.062	0.536	-81.04399	42.414

This problem uses the data in the modified HPRICE1.dta file in Chapter 3 of Wooldridge. You will be fitting the following model:

$$price = \beta_0 + \beta_1sqrft + \beta_2 bdrms + \epsilon$$

where price is the estimated price of a house in thousands of dollars, sqrft is the size of a house in square feet, bdrms is the number of bedrooms of the house, and ϵ is the random error term with the usual assumptions. Throughout this problem use the names of the variables as given here, and round answers to 3 decimal places.

- a). **Fit the model using software and obtain the output from the fitting procedure.**
- b). Write out the results in equation form using the variable names as given in the problem. Use the "^" symbol where appropriate.
- c) Test the following hypothesis at the $\alpha = 0.05$ level of significance by completing the following table.

$$H_0: \beta_1 = \beta_2 = 0 \quad H_1: \text{not all } \beta = 0$$

Test Statistic:
Critical Value (or P-Value)
Decision
Conclusion in the context of the problem

- d). Interpret the 95% confidence interval for β_1 in the context of the problem.
- e). What percentage of variation in selling price is explained by the model?
- f). Predict the selling price of a house that is **2,438** square feet and has **4** bedrooms using the estimated model.

Stata Output Students Should Get

```
. reg price sqrft bdrms
```

Source	SS	df	MS	Number of obs	=	88
				F(2, 85)	=	72.96
Model	580009.152	2	290004.576	Prob > F	=	0.0000
Residual	337845.354	85	3974.65122	R-squared	=	0.6319
				Adj R-squared	=	0.6233
Total	917854.506	87	10550.0518	Root MSE	=	63.045

price	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]	
sqrft	.1284362	.0138245	9.29	0.000	.1009495	.1559229
bdrms	15.19819	9.483517	1.60	0.113	-3.657582	34.05396
_cons	-19.315	31.04662	-0.62	0.536	-81.04399	42.414

a). Fit the model using software and obtain the output from the fitting procedure. Partial output from Stata is shown below. Fill in the missing information, indicated by the areas indicated by the shading .

Source	SS	df	MS	Number of obs	=	[n]
Model	580009	2	290004.58	F(2,85)	=	72.96
Residual	337845.35	85	3974.65	Prob > F	=	0.0000
Total	917854.51	87		R - squared	=	0.6319
				Adj R - squared	=	[r22]
				Root MSE	=	[rmse]
price	Coef.	Std. Err	t	P> t	95% Conf. Interval	
sqrft	[b1]	0.01382	9.29	0.000	.1009495	0.155922
bdrms	[b2]	9.48352	1.60	0.113	[l2]	[u2]
_cons	-19.315	31.04662	-0.062	0.536	-81.04399	42.414

b). Write out the results in equation form using the variable names as given in the problem. Use the "^" symbol where appropriate.

$$[p] = [b0] + [b11] \text{ sqrft} + [b22] \text{ bdrms}$$

c). Test the following hypothesis at the $\alpha = 0.05$ level of significance by completing the following table.

$$H_0: \beta_1 = \beta_2 = 0$$

$$H_1: \text{Not all } \beta = 0$$

Test Statistic	[f]
Critical Value (or P-Value)	[c]
Decision	[r](reject/fail to reject) the null hypothesis
Conclusion in the context of the problem	[d](can/cannot) conclude that square footage and bedrooms are jointly significant for predicting house prices.

d). Interpret the 95% confidence interval for β_1 in the context of the problem.

[confint]

e). What percentage of variation in selling price is explained by the model using square footage and number of bedrooms?

[rsq]

f). Predict the selling price of a house that is **2,438** square feet and has **4** bedrooms using the estimated model. **Report your answer to three (3) decimal places in thousands of dollars.**

\$(yhat)

Student View

price	Coef.	Std. Err	t	P> t	95% Conf. Interval	
sqrft	<input type="text"/>	0.01382	9.29	0.000	.1009495	0.155922
bdrms	<input type="text"/>	9.48352	1.60	0.113	<input type="text"/>	<input type="text"/>
_cons	-19.315	31.04662	-0.062	0.536	-81.04399	42.414

b). Write out the results in equation form using the variable names as given in the problem. Use the "^" symbol where appropriate.

=

+

sqrft

+

bdrms

c). Test the following hypothesis at the $\alpha = 0.05$ level of significance by completing the following table.

$H_0: \beta_1 = \beta_2 = 0$

H_1 : Not all $\beta = 0$

Test Statistic	<input type="text"/>
Critical Value (or P-Value)	<input type="text"/>
Decision	<input type="text"/> (reject/fail to reject) the null hypothesis
Conclusion in the context of the problem	<input type="text"/> (can/cannot) conclude that square footage and bedrooms are jointly significant for predicting house prices.

d). Interpret the 95% confidence interval for β_1 in the context of the problem.

e). What percentage of variation in selling price is explained by the model using square footage and number of bedrooms?

f). Predict the selling price of a house that is **2,438** square feet and has **4** bedrooms using the estimated model. **Report your answer to three (3) decimal places in thousands of dollars.**

\$

Interpret the 95% confidence interval for β_1 in the context of the problem.

- Target phrase (assuming price is reported in thousands).

We can be 95% confident that the increase in mean price for a one-square-foot increase in area is between \$0.101 and \$0.156.

- Many opportunities for variation in:

Category	Example
Spelling	confidnt; confidant; increse, increese
Word order/phrasing	Increase in mean price; mean increase in price
Rounding	0.101; 0.10; 0.16, 0.1559
Number formatting	.101; 0.101
Special Symbols	\$
Capitalization	We, Price, price
Filler words	“We can be”; “We are”; “between” “ranges from”

- The regex (this is one long string of code)

```
(?i).*\b(95|confidence\b|\bincrease\b)|(\bincrease\b.*\bmean\b)|(\bmean\b.*\bincrease\b)|(\bincrease\b)).*\bprice?\b.*(one|1)\b|-  
?(\bsqrft\b|\bsquare\b|\bunit\b).\bincrease\b.*.\$0?.10[01]\d*.\b.*\$0?.15[5-6]\d*
```

- `(?i) .*`: Allows “We can be”, “We are”, etc.
- `(95\%.*\bconfident\b|\bconfident\b.*95\%):` Allows “95% confident” or “confident 95%
- `((\bincrease\b.*\bmean\b)|(\bmean\b.*\bincrease\b)|(\bincrease\b)):` Allows “increase in mean, increase in the mean, mean increase, etc..
- `\b.*\b(one|1)\b\-\?(\bsqr?ft\b|\bsquare\b|\bunit\b).*\bincrease\b.*.:` Allows “for a one-unit increase”, for a one-square-foot increase in area”, etc.
- The expression `.*` used with word boundaries `\b` allow for great flexibility in structuring around keywords

Test the regex here: regexr.com/6rbbl

Adjusting the Robustness

- Using regexs gives precise control over what kinds of answers are acceptable for your class level.
- Separates the expression of content knowledge from verbiage.

- A more forgiving regex is

```
(?i) .* (95\%.*\bc.*f.*nt\b|\bc.*f.*nt\b.*95\%) .* ((\bin.*cr.*se\b.*\bmean\b
)|(\bmean\b.*\bin.*cr.*se\b)).*\bprices?\b.*\b(one|1)\b[\s\
]?(\bsqft\b|\bsquare\b|\bunit\b).*\bin.*cr.*se\b.*.\b\$?0?\b.10[01]\b\d*.\b.*
\$?0?\b.15[5-6]\b\d*.*
```

- Keywords “confident” and “increase” can now be misspelled due to the patterns `bc.*f.*nt` and `in.*cr.*se`
- “prices” (plural) is now acceptable using the “?” after “s”
- It would also be possible to make the lower and upper bounds separate blanks or break up the interpretation statement to increase opportunities for partial credit.

[Test the regex here: regexr.com/6qofn](https://regexr.com/6qofn)

Neat, But So What?

- Multi-part problems may be the ideal way to learn some concepts, but these questions usually require hand grading to account for the various ways students can be correct.
- Many third-party publishers have integrated assessment platforms with capabilities like this.
- If an instructor chooses to not use a homework system (e.g., teaching a specialized course, or just personal preference), the ability to assign these types of questions is limited "out of the box".
- Regexs can be complex to construct, but after initial effort, it is simple to make large pools of questions by creating a template changing a few parts of the question.
- Using regex makes making robust multi-part questions (relatively) simple just with a little knowledge of regular expressions.
- I am not an expert in regular expression ("regex") programming, so there may be more elegant solutions to certain problems than I present here.

Regex Tools

- A good introduction to regex: <https://www.regextutorial.org/>
- Regex tool for generating number ranges: <https://3widgets.com/>
- Test Regex expression validity: <https://regexr.com/>