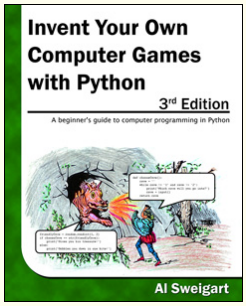
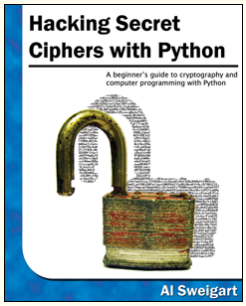
Chapter 3 – Functions





Functions

YouTube Lesson 9 - def Statements, arguments, and the None value

You're already familiar with the `print()`, `input()`, and `len()` functions from the previous chapters. Python provides several builtin functions like these, but you can also write your own functions. A *function* is like a mini-program within a program.

To better understand how functions work, let's create one. Type this program into the file editor and save it as *helloFunc.py*:

```
❶ def hello():
❷     print('Howdy!')
       print('Howdy!!!')
       print('Hello there.')
❸ hello()
   hello()
   hello()
```

The first line is a `def` statement ❶, which defines a function named `hello()`. The code in the block that follows the `def` statement ❷ is the body of the function. This code is executed when the function is called, not when the function is first defined.

The `hello()` lines after the function ❸ are function calls. In code, a function call is just the function's name followed by parentheses, possibly with some number of arguments in between the parentheses. When the program execution reaches these calls, it will jump to the top line in the function and begin executing the code there. When it reaches the end of the function, the execution returns to the line that called the function and continues moving through the code as before.

Since this program calls `hello()` three times, the code in the `hello()` function is executed three times. When you run this program, the output looks like this:

```
Howdy!
Howdy!!!
Hello there.
Howdy!
Howdy!!!
Hello there.
Howdy!
Howdy!!!
Hello there.
```

A major purpose of functions is to group code that gets executed multiple times. Without a function defined, you would have to copy and paste this code each time, and the program would look like this:

```
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
```

```
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
print('Howdy!')
print('Howdy!!!')
print('Hello there.')
```

In general, you always want to avoid duplicating code, because if you ever decide to update the code—if, for example, you find a bug you need to fix—you'll have to remember to change the code everywhere you copied it.

As you get more programming experience, you'll often find yourself *deduplicating* code, which means getting rid of duplicated or copy-and-pasted code. Deduplication makes your programs shorter, easier to read, and easier to update.

def Statements with Parameters

When you call the `print()` or `len()` function, you pass in values, called *arguments* in this context, by typing them between the parentheses. You can also define your own functions that accept arguments. Type this example into the file editor and save it as *helloFunc2.py*:

```
❶ def hello(name):
❷     print('Hello ' + name)

❸ hello('Alice')
  hello('Bob')
```

When you run this program, the output looks like this:

```
Hello Alice
Hello Bob
```

The definition of the `hello()` function in this program has a parameter called `name` ❶. A *parameter* is a variable that an argument is stored in when a function is called. The first time the `hello()` function is called, it's with the argument `'Alice'` ❸. The program execution enters the function, and the variable `name` is automatically set to `'Alice'`, which is what gets printed by the `print()` statement ❷.

One special thing to note about parameters is that the value stored in a parameter is forgotten when the function returns. For example, if you added `print(name)` after `hello('Bob')` in the previous program, the program would give you a `NameError` because there is no variable named `name`. This variable was destroyed after the function call `hello('Bob')` had returned, so `print(name)` would refer to a `name` variable that does not exist.

This is similar to how a program's variables are forgotten when the program terminates. I'll talk more about why that happens later in the chapter, when I discuss what a function's local scope is.

Return Values and return Statements

When you call the `len()` function and pass it an argument such as `'Hello'`, the function call evaluates to the integer value `5`, which is the length of the string you passed it. In general, the value that a function call evaluates to is called the *return value* of the function.

When creating a function using the `def` statement, you can specify what the return value should be with a `return` statement. A `return` statement consists of the following:

- The `return` keyword
- The value or expression that the function should return

When an expression is used with a `return` statement, the return value is what this expression evaluates to. For example, the following program defines a function that returns a different string depending on what number it is passed as an argument. Type this code into the file editor and save it as *magic8Ball.py*:

```
❶ import random
❷ def getAnswer(answerNumber):
❸     if answerNumber == 1:
          return 'It is certain'
      elif answerNumber == 2:
          return 'It is decidedly so'
      elif answerNumber == 3:
          return 'Yes'
```

```
        elif answerNumber == 4:
            return 'Reply hazy try again'
        elif answerNumber == 5:
            return 'Ask again later'
        elif answerNumber == 6:
            return 'Concentrate and ask again'
        elif answerNumber == 7:
            return 'My reply is no'
        elif answerNumber == 8:
            return 'Outlook not so good'
        elif answerNumber == 9:
            return 'Very doubtful'

❹ r = random.randint(1, 9)
❺ fortune = getAnswer(r)
❻ print(fortune)
```

When this program starts, Python first imports the `random` module ❶. Then the `getAnswer()` function is defined ❷. Because the function is being defined (and not called), the execution skips over the code in it. Next, the `random.randint()` function is called with two arguments, `1` and `9` ❹. It evaluates to a random integer between `1` and `9` (including `1` and `9` themselves), and this value is stored in a variable named `r`.

The `getAnswer()` function is called with `r` as the argument ❺. The program execution moves to the top of the `getAnswer()` function ❸, and the value `r` is stored in a parameter named `answerNumber`. Then, depending on this value in `answerNumber`, the function returns one of many possible string values. The program execution returns to the line at the bottom of the program that originally called `getAnswer()` ❺. The returned string is assigned to a variable named `fortune`, which then gets passed to a `print()` call ❻ and is printed to the screen.

Note that since you can pass return values as an argument to another function call, you could shorten these three lines:

```
r = random.randint(1, 9)
fortune = getAnswer(r)
print(fortune)
```

to this single equivalent line:

```
print(getAnswer(random.randint(1, 9)))
```

Remember, expressions are composed of values and operators. A function call can be used in an expression because it evaluates to its return value.

The None Value

In Python there is a value called `None`, which represents the absence of a value. `None` is the only value of the `NoneType` data type. (Other programming languages might call this value `null`, `nil`, or `undefined`.) Just like the Boolean `True` and `False` values, `None` must be typed with a capital *N*.

This value-without-a-value can be helpful when you need to store something that won't be confused for a real value in a variable. One place where `None` is used is as the return value of `print()`. The `print()` function displays text on the screen, but it doesn't need to return anything in the same way `len()` or `input()` does. But since all function calls need to evaluate to a return value, `print()` returns `None`. To see this in action, enter the following into the interactive shell:

```
>>> spam = print('Hello!')
Hello!
>>> None == spam
True
```

Behind the scenes, Python adds `return None` to the end of any function definition with no `return` statement. This is similar to how a `while` or `for` loop implicitly ends with a `continue` statement. Also, if you use a `return` statement without a value (that is, just the `return` keyword by itself), then `None` is returned.

Keyword Arguments and print()

Most arguments are identified by their position in the function call. For example, `random.randint(1, 10)` is different from `random.randint(10, 1)`. The function call `random.randint(1, 10)` will return a random integer between `1` and `10`, because the first argument is the low end of the range and the second argument is the high end (while `random.randint(10, 1)` causes an error).

However, *keyword arguments* are identified by the keyword put before them in the function call. Keyword arguments are often used for optional parameters. For example, the `print()` function has the optional parameters `end` and `sep` to specify what should be printed at the end of its arguments and between its arguments (separating them), respectively.

If you ran the following program:

```
print('Hello')
print('World')
```

the output would look like this:

```
Hello
World
```

The two strings appear on separate lines because the `print()` function automatically adds a newline character to the end of the string it is passed. However, you can set the `end` keyword argument to change this to a different string. For example, if the program were this:

```
print('Hello', end='')
print('World')
```

the output would look like this:

```
HelloWorld
```

The output is printed on a single line because there is no longer a new-line printed after `'Hello'`. Instead, the blank string is printed. This is useful if you need to disable the newline that gets added to the end of every `print()` function call.

Similarly, when you pass multiple string values to `print()`, the function will automatically separate them with a single space. Enter the following into the interactive shell:

```
>>> print('cats', 'dogs', 'mice')
cats dogs mice
```

But you could replace the default separating string by passing the `sep` keyword argument. Enter the following into the interactive shell:

```
>>> print('cats', 'dogs', 'mice', sep=',')
cats,dogs,mice
```

You can add keyword arguments to the functions you write as well, but first you'll have to learn about the list and dictionary data types in the next two chapters. For now, just know that some functions have optional keyword arguments that can be specified when the function is called.

Local and Global Scope


Global Scope and Local Scope

Parameters and variables that are assigned in a called function are said to exist in that function's *local scope*. Variables that are assigned outside all functions are said to exist in the *global scope*. A variable that exists in a local scope is called a *local variable*, while a variable that exists in the global scope is called a *global variable*. A variable must be one or the other; it cannot be both local and global.

Think of a *scope* as a container for variables. When a scope is destroyed, all the values stored in the scope's variables are forgotten. There is only one global scope, and it is created when your program begins. When your program terminates, the global scope is destroyed, and all its variables are forgotten. Otherwise, the next time you ran your program, the variables would remember their values from the last time you ran it.

A local scope is created whenever a function is called. Any variables assigned in this function exist within the local scope. When the function returns, the local scope is destroyed, and these variables are forgotten. The next time you call this function, the local variables will not remember the values stored in them from the last time the function was called.

Scopes matter for several reasons:

- Code in the global scope cannot use any local variables.
- However, a local scope can access global variables.
- Code in a function's local scope cannot use variables in any other local scope.

- You can use the same name for different variables if they are in different scopes. That is, there can be a local variable named `spam` and a global variable also named `spam`.

The reason Python has different scopes instead of just making everything a global variable is so that when variables are modified by the code in a particular call to a function, the function interacts with the rest of the program only through its parameters and the return value. This narrows down the list code lines that may be causing a bug. If your program contained nothing but global variables and had a bug because of a variable being set to a bad value, then it would be hard to track down where this bad value was set. It could have been set from anywhere in the program—and your program could be hundreds or thousands of lines long! But if the bug is because of a local variable with a bad value, you know that only the code in that one function could have set it incorrectly.

While using global variables in small programs is fine, it is a bad habit to rely on global variables as your programs get larger and larger.

Local Variables Cannot Be Used in the Global Scope

Consider this program, which will cause an error when you run it:

```
def spam():
    eggs = 31337
spam()
print(eggs)
```

If you run this program, the output will look like this:

```
Traceback (most recent call last):
  File "C:/test3784.py", line 4, in <module>
    print(eggs)
NameError: name 'eggs' is not defined
```

The error happens because the `eggs` variable exists only in the local scope created when `spam()` is called. Once the program execution returns from `spam`, that local scope is destroyed, and there is no longer a variable named `eggs`. So when your program tries to run `print(eggs)`, Python gives you an error saying that `eggs` is not

defined. This makes sense if you think about it; when the program execution is in the global scope, no local scopes exist, so there can't be any local variables. This is why only global variables can be used in the global scope.

Local Scopes Cannot Use Variables in Other Local Scopes

A new local scope is created whenever a function is called, including when a function is called from another function. Consider this program:

```
  def spam():
❶     eggs = 99
❷     bacon()
❸     print(eggs)

  def bacon():
      ham = 101
❹     eggs = 0

❺ spam()
```

When the program starts, the `spam()` function is called ❺, and a local scope is created. The local variable `eggs` ❶ is set to `99`. Then the `bacon()` function is called ❷, and a second local scope is created. Multiple local scopes can exist at the same time. In this new local scope, the local variable `ham` is set to `101`, and a local variable `eggs`—which is different from the one in `spam()`'s local scope—is also created ❹ and set to `0`.

When `bacon()` returns, the local scope for that call is destroyed. The program execution continues in the `spam()` function to print the value of `eggs` ❸, and since the local scope for the call to `spam()` still exists here, the `eggs` variable is set to `99`. This is what the program prints.

The upshot is that local variables in one function are completely separate from the local variables in another function.

Global Variables Can Be Read from a Local Scope

Consider the following program:

```
def spam():
    print(eggs)
eggs = 42
spam()
print(eggs)
```

Since there is no parameter named `eggs` or any code that assigns `eggs` a value in the `spam()` function, when `eggs` is used in `spam()`, Python considers it a reference to the global variable `eggs`. This is why `42` is printed when the previous program is run.

Local and Global Variables with the Same Name

To simplify your life, avoid using local variables that have the same name as a global variable or another local variable. But technically, it's perfectly legal to do so in Python. To see what happens, type the following code into the file editor and save it as *sameName.py*:

```
   def spam():
❶      eggs = 'spam local'
        print(eggs) # prints 'spam local'
   def bacon():

❷      eggs = 'bacon local'
        print(eggs) # prints 'bacon local'
        spam()
        print(eggs) # prints 'bacon local'

❸ eggs = 'global'
   bacon()
   print(eggs) # prints 'global'
```

When you run this program, it outputs the following:

```
bacon local
spam local
```

```
bacon local
global
```

There are actually three different variables in this program, but confusingly they are all named `eggs`. The variables are as follows:

❶ A variable named `eggs` that exists in a local scope when `spam()` is called.

❷ A variable named `eggs` that exists in a local scope when `bacon()` is called.

❸ A variable named `eggs` that exists in the global scope.

Since these three separate variables all have the same name, it can be confusing to keep track of which one is being used at any given time. This is why you should avoid using the same variable name in different scopes.

The global Statement

If you need to modify a global variable from within a function, use the `global` statement. If you have a line such as `global eggs` at the top of a function, it tells Python, "In this function, `eggs` refers to the global variable, so don't create a local variable with this name." For example, type the following code into the file editor and save it as *sameName2.py*:

```
  def spam():
❶     global eggs
❷     eggs = 'spam'


  eggs = 'global'
  spam()
  print(eggs)
```

When you run this program, the final `print()` call will output this:

```
spam
```

Because `eggs` is declared `global` at the top of `spam()` ❶, when `eggs` is set to `'spam'` ❷, this assignment is done to the globally scoped `eggs`. No local `eggs` variable is created.

There are four rules to tell whether a variable is in a local scope or global scope:

1. If a variable is being used in the global scope (that is, outside of all functions), then it is always a global variable.
2. If there is a `global` statement for that variable in a function, it is a global variable.
3. Otherwise, if the variable is used in an assignment statement in the function, it is a local variable.
4. But if the variable is not used in an assignment statement, it is a global variable.

To get a better feel for these rules, here's an example program. Type the following code into the file editor and save it as *sameName3.py*:

```
  def spam():
❶  global eggs
     eggs = 'spam' # this is the global


  def bacon():
❷  eggs = 'bacon' # this is a local
  def ham():
❸  print(eggs) # this is the global


  eggs = 42 # this is the global
  spam()
  print(eggs)
```

In the `spam()` function, `eggs` is the global `eggs` variable, because there's a `global` statement for `eggs` at the beginning of the function ❶. In `bacon()`, `eggs` is a local variable, because there's an assignment statement for it in that function ❷. In `ham()` ❸, `eggs` is the global variable, because there is no assignment statement or `global` statement for it in that function. If you run *sameName3.py*, the output will look like this:

```
spam
```

In a function, a variable will either always be global or always be local. There's no way that the code in a function can use a local variable named `eggs` and then later in that same function use the global `eggs` variable.

NOTE

If you ever want to modify the value stored in a global variable from in a function, you must use a `global` statement on that variable.

If you try to use a local variable in a function before you assign a value to it, as in the following program, Python will give you an error. To see this, type the following into the file editor and save it as *sameName4.py*:

```
  def spam():
      print(eggs) # ERROR!
❶    eggs = 'spam local'

❷ eggs = 'global'
   spam()
```

If you run the previous program, it produces an error message.

```
Traceback (most recent call last):
  File "C:/test3784.py", line 6, in <module>
    spam()
  File "C:/test3784.py", line 2, in spam
    print(eggs) # ERROR!
UnboundLocalError: local variable 'eggs' referenced before assignment
```

This error happens because Python sees that there is an assignment statement for `eggs` in the `spam()` function ❶ and therefore considers `eggs` to be local. But because `print(eggs)` is executed before `eggs` is assigned anything, the local variable `eggs` doesn't exist. Python will *not* fall back to using the global `eggs` variable ❷.

Functions as "Black Boxes"

Often, all you need to know about a function are its inputs (the parameters) and output value; you don't always have to burden yourself with how the function's

code actually works. When you think about functions in this high-level way, it's common to say that you're treating the function as a "black box."

This idea is fundamental to modern programming. Later chapters in this book will show you several modules with functions that were written by other people. While you can take a peek at the source code if you're curious, you don't need to know how these functions work in order to use them. And because writing functions without global variables is encouraged, you usually don't have to worry about the function's code interacting with the rest of your program.

Exception Handling

Error Handling

Right now, getting an error, or *exception*, in your Python program means the entire program will crash. You don't want this to happen in real-world programs. Instead, you want the program to detect errors, handle them, and then continue to run.

For example, consider the following program, which has a "divide-by-zero" error. Open a new file editor window and enter the following code, saving it as *zeroDivide.py*:

```
def spam(divideBy):
    return 42 / divideBy


print(spam(2))
print(spam(12))
print(spam(0))
print(spam(1))
```

We've defined a function called `spam`, given it a parameter, and then printed the value of that function with various parameters to see what happens. This is the output you get when you run the previous code:

```
21.0
3.5
Traceback (most recent call last):
```

```
  File "C:/zeroDivide.py", line 6, in <module>
    print(spam(0))
  File "C:/zeroDivide.py", line 2, in spam
    return 42 / divideBy
ZeroDivisionError: division by zero
```

A `ZeroDivisionError` happens whenever you try to divide a number by zero. From the line number given in the error message, you know that the `return` statement in `spam()` is causing an error.

Errors can be handled with `try` and `except` statements. The code that could potentially have an error is put in a `try` clause. The program execution moves to the start of a following `except` clause if an error happens.

You can put the previous divide-by-zero code in a `try` clause and have an `except` clause contain code to handle what happens when this error occurs.

```
def spam(divideBy):
    try:
        return 42 / divideBy
    except ZeroDivisionError:
        print('Error: Invalid argument.')

print(spam(2))
print(spam(12))
print(spam(0))
print(spam(1))
```

When code in a `try` clause causes an error, the program execution immediately moves to the code in the `except` clause. After running that code, the execution continues as normal. The output of the previous program is as follows:

```
21.0
3.5
Error: Invalid argument.
None
42.0
```

Note that any errors that occur in function calls in a `try` block will also be caught. Consider the following program, which instead has the `spam()` calls in the `try` block:

```
def spam(divideBy):
    return 42 / divideBy


try:
    print(spam(2))
    print(spam(12))
    print(spam(0))
    print(spam(1))
except ZeroDivisionError:
    print('Error: Invalid argument.')
```

When this program is run, the output looks like this:

```
21.0
3.5
Error: Invalid argument.
```

The reason `print(spam(1))` is never executed is because once the execution jumps to the code in the `except` clause, it does not return to the `try` clause. Instead, it just continues moving down as normal.

A Short Program: Guess the Number


Writing a Guess the Number Game

The toy examples I've show you so far are useful for introducing basic concepts, but now let's see how everything you've learned comes together in a more complete program. In this section, I'll show you a simple "guess the number" game. When you run this program, the output will look something like this:

```
I am thinking of a number between 1 and 20.
Take a guess.
10
Your guess is too low.
```

```
Take a guess.
15
Your guess is too low.
Take a guess.
17
Your guess is too high.
Take a guess.
16
Good job! You guessed my number in 4 guesses!
```

Type the following source code into the file editor, and save the file as *guessTheNumber.py*:

```
# This is a guess the number game.
import random
secretNumber = random.randint(1, 20)
print('I am thinking of a number between 1 and 20.')

# Ask the player to guess 6 times.
for guessesTaken in range(1, 7):
    print('Take a guess.')
    guess = int(input())

    if guess < secretNumber:
        print('Your guess is too low.')
    elif guess > secretNumber:
        print('Your guess is too high.')
    else:
        break    # This condition is the correct guess!

if guess == secretNumber:
    print('Good job! You guessed my number in ' + str(guessesTaken) + ' guesses!')
else:
    print('Nope. The number I was thinking of was ' + str(secretNumber))
```

Let's look at this code line by line, starting at the top.

```
# This is a guess the number game.
import random
```

```
secretNumber = random.randint(1, 20)
```

First, a comment at the top of the code explains what the program does. Then, the program imports the `random` module so that it can use the `random.randint()` function to generate a number for the user to guess. The return value, a random integer between 1 and 20, is stored in the variable `secretNumber`.

```
print('I am thinking of a number between 1 and 20.')


# Ask the player to guess 6 times.
for guessesTaken in range(1, 7):
    print('Take a guess.')
    guess = int(input())
```

The program tells the player that it has come up with a secret number and will give the player six chances to guess it. The code that lets the player enter a guess and checks that guess is in a `for` loop that will loop at most six times. The first thing that happens in the loop is that the player types in a guess. Since `input()` returns a string, its return value is passed straight into `int()`, which translates the string into an integer value. This gets stored in a variable named `guess`.

```
if guess < secretNumber:
    print('Your guess is too low.')
elif guess > secretNumber:
    print('Your guess is too high.')
```

These few lines of code check to see whether the guess is less than or greater than the secret number. In either case, a hint is printed to the screen.

```
else:
    break    # This condition is the correct guess!
```

If the guess is neither higher nor lower than the secret number, then it must be equal to the secret number, in which case you want the program execution to break out of the `for` loop.

```
if guess == secretNumber:
    print('Good job! You guessed my number in ' + str(guessesTaken) + ' guesses!')
```

```
else:
    print('Nope. The number I was thinking of was ' + str(secretNumber))
```

After the `for` loop, the previous `if...else` statement checks whether the player has correctly guessed the number and prints an appropriate message to the screen. In both cases, the program displays a variable that contains an integer value (`guessesTaken` and `secretNumber`). Since it must concatenate these integer values to strings, it passes these variables to the `str()` function, which returns the string value form of these integers. Now these strings can be concatenated with the `+` operators before finally being passed to the `print()` function call.

Summary

Functions are the primary way to compartmentalize your code into logical groups. Since the variables in functions exist in their own local scopes, the code in one function cannot directly affect the values of variables in other functions. This limits what code could be changing the values of your variables, which can be helpful when it comes to debugging your code.

Functions are a great tool to help you organize your code. You can think of them as black boxes: They have inputs in the form of parameters and outputs in the form of return values, and the code in them doesn't affect variables in other functions.

In previous chapters, a single error could cause your programs to crash. In this chapter, you learned about `try` and `except` statements, which can run code when an error has been detected. This can make your programs more resilient to common error cases.

Practice Questions

Q: 1. Why are functions advantageous to have in your programs?

Q: 2. When does the code in a function execute: when the function is defined or when the function is called?

Q: 3. What statement creates a function?

Q: 4. What is the difference between a function and a function call?

Q: 5. How many global scopes are there in a Python program? How many local scopes?

Q: 6. What happens to variables in a local scope when the function call returns?

Q: 7. What is a return value? Can a return value be part of an expression?

Q: 8. If a function does not have a return statement, what is the return value of a call to that function?

Q: 9. How can you force a variable in a function to refer to the global variable?

Q: 10. What is the data type of `None`?

Q: 11. What does the `import areallyourpetsnamederic` statement do?

Q: 12. If you had a function named `bacon()` in a module named `spam`, how would you call it after importing `spam`?

Q: 13. How can you prevent a program from crashing when it gets an error?

Q: 14. What goes in the `try` clause? What goes in the `except` clause?

Practice Projects

For practice, write programs to do the following tasks.

The Collatz Sequence

Write a function named `collatz()` that has one parameter named `number`. If `number` is even, then `collatz()` should print `number // 2` and return this value. If `number` is odd, then `collatz()` should print and return `3 * number + 1`.

Then write a program that lets the user type in an integer and that keeps calling `collatz()` on that number until the function returns the value `1`. (Amazingly enough, this sequence actually works for any integer—sooner or later, using this sequence, you'll arrive at `1`! Even mathematicians aren't sure why. Your program is exploring what's called the *Collatz sequence*, sometimes called "the simplest impossible math problem.")

Remember to convert the return value from `input()` to an integer with the `int()` function; otherwise, it will be a string value.

Hint: An integer `number` is even if `number % 2 == 0`, and it's odd if `number % 2 == 1`.

The output of this program could look something like this:

```
Enter number:
3
10
5
16
8
4
2
1
```

Input Validation

Add `try` and `except` statements to the previous project to detect whether the user types in a noninteger string. Normally, the `int()` function will raise a `ValueError` error if it is passed a noninteger string, as in `int('puppy')`. In the `except` clause, print a message to the user saying they must enter an integer.

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