1 Control

Control structures direct the flow of logic in a program. For example, conditionals (if-elif-else) allow a program to skip sections of code, while iteration (while), allows a program to repeat a section.

1.1 If statements

Conditional statements let programs execute different lines of code depending on certain conditions. Let’s review the if-elif-else syntax:

```
if <conditional expression>:
    <suite of statements>
elif <conditional expression>:
    <suite of statements>
else:
    <suite of statements>
```

Recall the following points:

- The else and elif clauses are optional, and you can have any number of elif clauses.
- A conditional expression is a expression that evaluates to either a true value (True, a non-zero integer, etc.) or a false value (False, 0, None, "", [], etc.).
- Only the suite that is indented under the first if/elif with a conditional expression evaluating to a true value will be executed.
If none of the conditional expressions evaluate to a true value, then the else suite is executed. There can only be one else clause in a conditional statement!

### 1.2 Boolean Operators

Python also includes the boolean operators and, or, and not. These operators are used to combine and manipulate boolean values.

- **not** returns the opposite truth value of the following expression.
- **and** stops evaluating any more expressions (short-circuits) once it reaches the first false value and returns it. If all values evaluate to a true value, the last value is returned.
- **or** short-circuits at the first true value and returns it. If all values evaluate to a false value, the last value is returned.

```python
>>> not None
True
>>> not True
False
>>> -1 and 0 and 1
0
>>> False or 9999 or 1/0
9999
```

### 1.3 Question

1. Alfonso will only wear a jacket outside if it is below 60 degrees or it is raining. Fill in the function `wears_jacket` which takes in the current temperature and a Boolean value telling if it is raining and returns `True` if Alfonso will wear a jacket and `False` otherwise.

This should only take one line of code!

```python
def wears_jacket(temp, raining):
    """
    >>> wears_jacket(90, False)
    False
    >>> wears_jacket(40, False)
    True
    >>> wears_jacket(100, True)
    True
    """
```
Solution:

```
return temp < 60 or raining
```
1.4 While loops

Iteration lets a program repeat statements multiple times. A common iterative block of code is the **while loop**:

```python
while <conditional clause>:
    <body of statements>
```

As long as `<conditional clause>` evaluates to a true value, `<body of statements>` will continue to be executed. The conditional clause gets evaluated each time the body finishes executing.

1.5 Questions

1. What is the result of evaluating the following code?

```python
def square(x):
    return x * x

def so_slow(num):
    x = num
    while x > 0:
        x = x + 1
    return x / 0

square(so_slow(5))
```

**Solution:** Infinite loop because `x` will always be greater than 0; the `num / 0` is never executed.

2. Fill in the `is_prime` function, which returns `True` if `n` is a prime number and `False` otherwise. After you have a working solution, think about potential ways to make your solution more efficient.

**Hint:** use the `%` operator: `x % y` returns the remainder of `x` when divided by `y`.

```python
def is_prime(n):
    if n == 1:
        return False
    k = 2
    while k < n:
        if n % k == 0:
            return False
        k = k + 1
    return True
```

**Solution:**
Alternatively, the while loop’s conditional expression could ensure that $k$ is less than the square root of $n$. 

```python
k += 1
return True
```
Environment Diagrams

An environment diagram keeps track of all the variables that have been defined and the values they are bound to.

```
x = 3

def square(x):
    return x ** 2

square(2)
```

When you execute assignment statements in an environment diagram (like \( x = 3 \)), you need to record the variable name and the value:

1. Evaluate the expression on the right side of the `=` sign
2. Write the variable name and the expression’s value in the current frame.

When you execute `def` statements, you need to record the function name and bind the function object to the name.

1. Write the function name (e.g., `square`) in the frame and point it to a function object (e.g., `func square(x) [parent=Global]`). The `[parent=Global]` denotes the frame in which the function was defined.

When you execute a call expression (like `square(2)`), you need to create a new frame to keep track of local variables.

1. Draw a new frame. \(^a\) Label it with
   - a unique index (f1, f2, f3 and so on)
   - the intrinsic name of the function (square), which is the name of the function object itself. For example, if the function object is `func square(x) [parent=Global]`, the intrinsic name is `square`.
   - the parent frame (`[parent=Global]`)
2. Bind the formal parameters to the arguments passed in (e.g. bind `x` to 3).
3. Evaluate the body of the function.

If a function does not have a return value, it implicitly returns `None`. Thus, the “Return value” box should contain `None`.

\(^a\)Since we do not know how built-in functions like `add(...)` or `min(...)` are implemented, we do not draw a new frame when we call built-in functions.
1. Draw the environment diagram so we can visualize exactly how Python evaluates the code. What is the output of running this code in the interpreter?

```python
>>> from operator import add
>>> def sub(a, b):
...     sub = add
...     return a - b
>>> add = sub
>>> sub = min
>>> print(add(2, sub(2, 3)))
```

**Solution:**

```
0
```

Output:
A higher order function (HOF) is a function that manipulates other functions by taking in functions as arguments, returning a function, or both.

### 3.1 Functions as Arguments

One way a higher order function can manipulate other functions is by taking functions as input (an argument). Consider this higher order function called `negate`.

```python
def negate(f, x):
    return -f(x)
```

`negate` takes in a function `f` and a number `x`. It doesn’t care what exactly `f` does, as long as `f` is a function, takes in a number and returns a number. Its job is simple: call `f` on `x` and return the negation of that value.

### 3.2 Question

1. Implement a function `keep_ints`, which takes in a function `cond` and a number `n`, and only prints a number from 1 to `n` if calling `cond` on that number returns True:

   ```python
def keep_ints(cond, n):
    """Print out all integers 1..i..n where cond(i) is true"

    >>> def is_even(x):
    ...     # Even numbers have remainder 0 when divided by 2.
    ...     return x % 2 == 0
    >>> keep_ints(is_even, 5)
    2
    4
    """

   >>> def is_even(x):
   ...     # Even numbers have remainder 0 when divided by 2.
   ...     return x % 2 == 0
   >>> keep_ints(is_even, 5)
   2
   4
   """

   Solution:
   ```python
   i = 1
   while i <= n:
       if cond(i):
           print(i)
       i += 1
   ```
3.3 Functions as Return Values

Often, we will need to write a function that returns another function. One way to do this is to define a function inside of a function:

```python
def outer(x):
    def inner(y):
        ...
    return inner
```

The return value of `outer` is the function `inner`. This is a case of a function returning a function. In this example, `inner` is defined inside of `outer`. Although this is a common pattern, we can also define `inner` outside of `outer` and still use the same `return` statement. However, note that in this second example (unlike the first example), `inner` doesn’t have access to variables defined within the `outer` function, like `x`.

```python
def inner(y):
    ...

def outer(x):
    return inner
```

3.4 Questions

1. Use this definition of `outer` to fill in what Python would display when the following lines are evaluated.

```python
def outer(n):
    def inner(m):
        return n - m
    return inner

>>> outer(61)
```

**Solution:**

```
<function outer.inner ...>
```

```python
>>> f = outer(10)
>>> f(4)
```

**Solution:**

```
6
```

```python
>>> outer(5)(4)
```
Solution:

1
2. Implement a function `keep_ints` like before, but now it takes in a number `n` and returns a function that has one parameter `cond`. The returned function prints out all numbers from 1..i..n where calling `cond(i)` returns True.

```python
def keep_ints(n):
    """Returns a function which takes one parameter cond and
    prints out all integers 1..i..n where calling cond(i)
    returns True."

    def do_keep(cond):
        i = 1
        while i <= n:
            if cond(i):
                print(i)
            i += 1
        return do_keep

    return do_keep

>>> def is_even(x):
    ... # Even numbers have remainder 0 when divided by 2.
    ... return x % 2 == 0
    >>> keep_ints(5)(is_even)
    2
    4
    """
```

Solution:

```python
def do_keep(cond):
    i = 1
    while i <= n:
        if cond(i):
            print(i)
        i += 1
    return do_keep
```

3. Write a function `and_add` that takes a one-argument function `f` and a number `n` as arguments. It should return a function that takes one argument, and does the same thing as the function `f`, except also adds `n` to the result.

```python
def and_add(f, n):
    """Return a new function. This new function takes an
    argument x and returns f(x) + n."

    return lambda x: f(x) + n

>>> def square(x):
    ... return x * x
    >>> new_square = and_add(square, 3)
    >>> new_square(4)  # 4 * 4 + 3
    19
    """
```

```
Solution:

```python
def g(x):
    return f(x) + n
return g
```