Manual Neural Network

This is really cool, and it's something I've wanted to do. I've got this and several other ways to do a similar thing. This one gets done first. It's going to mimic the TensorFlow API. When I get back to TensorFlow, I should have a better understanding.

From Jose

> In this notebook we will manually build out a neural network that mimics the TensorFlow API. This will greatly help your understanding when working with the real TensorFlow!

In [1]:
```
##  It can be useful to see errors to know how to fix them.
##+ However, it messes with the "compute all cells" type of
##+ stuff. Here, you can decide whether to see the errors or
##+ not. (In some places, I've put the error text in
##+ markdown cells.)

do_show_errors = False
```

Some Info About super() and Object Oriented Programming in General

In [2]:
```
class SimpleClassLecture0():

    def __init__(self):
        print("hello")
    ##endof:  __init__(self)



##endof:  SimpleClassLecture0
```

In [3]:
```
s = "world"
```

In [4]:
```
type(s)
```

Out[4]:
```
str
```

In [5]:
```
# s.<then press [Tab]>
# Gives a list of methods
```

In [6]:
```
x0 = SimpleClassLecture0
```

In [7]:
```
x0 # what we get without the parentheses - __init__ doesn't get called
```

Out[7]:
```
__main__.SimpleClassLecture0
```

In [8]:
```
x0 = SimpleClassLecture0()
```

```
hello
```

In [9]:
```
x0 # Instance of SimpleClassLecture and where it exists in memory
```

Out[9]:
```
<__main__.SimpleClassLecture0 at 0x2134fc82470>
```

In [10]:
```
class SimpleClassLecture1():

    def __init__(self):
        print("hello")
    ##endof:  __init__(self)

    def yell(self):
        print("YELLING")
    ##endof:  yell(self)

##endof:  SimpleClassLecture1
```

In [11]:
```
x1 = SimpleClassLecture1()
```

```
hello
```

In [12]:
```
#  I'm going to type 'x1.' then hit [Tab].
#+ it will autocomplete 'x1.yell', after
#+ which I'll add the parenthesis
x1.yell()
```

```
YELLING
```

In [13]:
```
# Now, I'll just type it all out.
x1.yell()
```

```
YELLING
```

In [14]:
```
##  adding in this illustration. These first calls will work fine.
sc = SimpleClassLecture1()
print("--- some separation ---")
sc.yell()
```

```
hello
--- some separation ---
YELLING
```

In [15]:
```
##  continuing with the illustration. This is called
##+ as if it were the lecture notes. It will throw
##+ an error/exception/whatever-you-want-to-call-it
if do_show_errors:
    sc_oops = SimpleClassLecture1("Basket Weaving 101")
    print("--- some separation ---") # won't execute b/c error before
    sc_oops.yell()                   # won't execute b/c error before
##endof:  if do_show_errors
```

OUTPUT (error) should be

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-87-6c1cabf9d07d> in <module>()
      2 ##+ as if it were the lecture notes. It will throw
      3 ##+ an error/exception/whatever-you-want-to-call-it
----> 4 sc_oops = SimpleClassLecture1("Basket Weaving 101")
      5 print("--- some separation ---") # won't execute b/c error before
      6 sc_oops.yell()                   # won't execute b/c error before

TypeError: __init__() takes 1 positional argument but 2 were given
```

Remember the code:

```
class SimpleClassLecture1():

    def __init__(self):
        print("hello")
    ##endof:  __init__(self)

    def yell(self):
        print("YELLING")
    ##endof:  yell(self)

##endof:  SimpleClassLecture1
```

In [16]:
```
class ExtendedClassLecture0(SimpleClassLecture1):

    def __init__(self):

        print("EXTEND!")

    ##endof:  __init__(self)

##endof:  ExtendedClassLecture0(SimpleClassLecture1)
```

In [17]:
```
y0 = ExtendedClassLecture0()
#  Remember, there's no 'super' call for '__init__'
```

```
EXTEND!
```

In [18]:
```
#  No 'super' with '__init__', but other things work
y0.yell()
```

```
YELLING
```

Now, let's use the `super` keyword.

In [19]:
```
class ExtendedClassLecture1(SimpleClassLecture1):

    def __init__(self):

        super().__init__()
        print("EXTEND!")
    ##endof:  __init__(self)

##endof:  ExtendedClassLecture(SimpleClassLecture)
```

In [20]:
```
y1 = ExtendedClassLecture1()
```

```
hello
EXTEND!
```

In [21]:
```
y1.yell()
```

```
YELLING
```

Here, we're going to add an argument to the `SimpleClass` `__init__` (i.e. its constructor). Since this is the final state in which Jose leaves it, I'm going to use `SimpleClassLecture` instead of continuing with `SimpleClassLecture2` . I'll do similarly with the extended class - using `ExtendedClassLecture` instead of staying with the pattern and using `ExtendedClassLecture2` .

In [22]:
```
class SimpleClassLecture():

    def __init__(self, name):
        print("hello " + name) #  Jose put the space here, which
                               #+ I consider the correct place.
                #+ a minute or so after 1701113954_2023-11-27T123914-0700
    ##endof:  __init__(self)

    def yell(self):
        print("YELLING")
    ##endof:  yell(self)

##endof:  SimpleClassLecture1
```

In [23]:
```
x = SimpleClassLecture("Dave")
```

```
hello Dave
```

In [24]:
```
x.yell()
```

```
YELLING
```

In [25]:
```
class ExtendedClassLecture(SimpleClassLecture):

    def __init__(self):

        super().__init__("Davidushka!")
        print("EXTEND!")

    ##endof:  __init__(self)

##endof:  ExtendedClassLecture(SimpleClassLecture)
```

In [26]:
```
y = ExtendedClassLecture()
```

```
hello Davidushka!
EXTEND!
```

In [27]:
```
y.yell()
```

```
YELLING
```

From the class material

In [28]:
```
class SimpleClass():

    def __init__(self, str_input):
        #  DWB: I'm not fixing his lack of space after "SIMPLE".
        #+      1701111285_2023-11-27T115445-0700
        print("SIMPLE" + str_input)
    ##endof:  __init__(self, str_input)

##endof:  SimpleClass
```

I'll do the same two illustrations.

In [29]:
```
if do_show_errors:
    sc = SimpleClass() # will throw an error
##endof:  if do_show_errors
```

OUTPUT (which is an error) should be:

```
---------------------------------------------------------------------------
TypeError                                 Traceback (most recent call last)
<ipython-input-29-1a19d7d610fd> in <module>()
----> 1 sc = SimpleClass() # will throw an error

TypeError: __init__() missing 1 required positional argument: 'str_input'
```

In [30]:
```
##  This one should work fine, though the lack of a space between
##+ "SIMPLE" and "Basket Weaving 101" - i.e.
##+ "SIMPLEBasket Weaving 101", grates on my nerves a bit. Q&R
sc = SimpleClass("Basket Weaving 101")
```

```
SIMPLEBasket Weaving 101
```

Remember the code (defined in the lecture notes)

```
class SimpleClass():

    def __init__(self, str_input):
        #  DWB: I'm not fixing his lack of space after "SIMPLE".
        #+      1701111285_2023-11-27T115445-0700
        print("SIMPLE" + str_input)
    ##endof:  __init__(self, str_input)

##endof:  SimpleClass
```

In [31]:
```
class ExtendedClassNoSuper(SimpleClass):

    def __init__(self):
        print('EXTENDED')
    ## endof:  __init__(self)

##endof:  ExtendedClassNoSuper
```

In [32]:
```
s = ExtendedClassNoSuper()
```

```
EXTENDED
```

With the output, remember that we *overwrote* the `__init__(self)` method.

What I'll call `ExtendedClass` is building upon the `ExtendedClassNoSuper` code. I could have added `Super` at the end (`ExtendedClassSuper`), or I could have done as the lecture notes did and call both `ExtendedClass` , with one replacing the other. Anyway, `ExtendedClass` will use `super` .

In [33]:
```
#  remember to use 'class' instead of 'def'
#+ (Oops, DWB 1701111919_2023-11-27T120519-0700)

class ExtendedClass(SimpleClass):

    def __init__(self):

        super().__init__(" My String") # Jose puts the space in the string here.
        print('EXTENDED')

    ##endof:  def __init__(self)

##endof:  ExtendedClass
```

In [34]:
```
s = ExtendedClass()
```

```
SIMPLE My String
EXTENDED
```

We've finished learning some OOP stuff - now for the Manual NN

I've put in a bunch of stuff which should give some general idea of what's going on (though there will be a lot of memory addresses rather than useful info). You can turn this on or off in the next cell.

In [35]:
```
global_do_show_steps_bool = True
```

Operation

Lecture Version - with Dave's additions

In [36]:
```
class Operation():

    def __init__(self, input_nodes=[],
                 do_show_steps=global_do_show_steps_bool):

        if do_show_steps:
            dashes = "-"*50
            print("\n\n" + dashes)
            print("In __init__")
            print()
        ##endof:  if do_show_steps

        self.input_nodes = input_nodes

        if do_show_steps:
            print("\n Now,   self.input_nodes = ")
            print("     " + str(self.input_nodes))
            print()
        ##endof:  if do_show_steps

        self.output_nodes = []

        for node in input_nodes:
            if do_show_steps:
                print("\n Current node is:")
                print("     node = " + str(node))
                print()
```

```
            ##endof:  if do_show_steps

            node.output_nodes.append(self)

            if do_show_steps:
                print("\n After assignment, node.output_nodes.append(self)")
                print("     node = " + str(node))
                print()
                print(dashes)
                print()
            ##endof:  if do_show_steps

        ##endof:  for node in input_nodes

        if do_show_steps:
            print("\n Before appending  self  to  _default_graph,")
            print("     _default_graph = ")
            print("                    " + str(_default_graph))
            print()
        ##endof:  if do_show_steps

        _default_graph.operations.append(self) #  Came back to add this
                                               #+ after we had created
                                               #+ the graph class

        if do_show_steps:
            print("\n After appending  self  to  _default_graph,")
            print("     _default_graph = ")
            print("                    " + str(_default_graph))
            print()
        ##endof:  if do_show_steps

    ##endof:  __init__(self, input_nodes=[]):

    def compute(self):
        pass
    ##endof:  compute(self)

##endof:  Operation
```

Course Notes Version

In [37]:
```
class OperationCNV():
    '''
    An Operation is a node in a "Graph". TensorFlow will also use this concept of a Graph.

    This Operation class will be inherited by other classes that actually compute the specific
    operation, such as adding or matrix multiplication.
    '''

    def __init__(self, input_nodes=[]):
        '''
        Initialize an Operation
        '''

        self.input_nodes = input_nodes #  The list of input nodes coming in to the node
        self.output_nodes = []          #  List of nodes that will consume the output
                                       #+ of this node

        #  For every node in the input, we append this operation (self) to the list of
        #+ to the list of the input nodes' consumers (i.e. this operation becomes an
        #+ output node)
        for node in input_nodes:
            node.output_nodes.append(self)
        ##endof:  for node in input_nodes

        #  There will be a global default graph (TensorFlow works this way)
        #+ We will append this particular operation (to the global default graph)
        #
        #  Append this operation to the list of operations in the currently-active
        #+ default graph
        _default_graph.operations.append(self)

    ##endof:  __init_(self, input_nodes=[])

    def compute(self):
        '''
        This is a placeholder function. It will be overwritten by the actual specific operation
        that inherits from this class
        '''
```

```
        pass

    ##endof:  compute(self)

##endof:  class OperationCNV()
```

Example Operations

Addition

Lecture Version - with Dave's additions

In [38]:
```
class Add(Operation):

    def __init__(self, x, y,
                 do_show_steps=global_do_show_steps_bool):

        self.do_show_steps = do_show_steps

        if self.do_show_steps:
            dashes = "-"*35
            print("\n" + dashes)
            print("\n Initializing an  Add  operation")
            print()
        ##endof:  if do_show_steps
        super().__init__([x, y])



    ##endof:  __init__(self, x, y)

    def compute(self, x_var, y_var):

        if self.do_show_steps:
            print("\n Now, computing the  Add  operation ")
            print()
        ##endof:  if do_show_steps

        self.inputs = [x_var, y_var]

        if self.do_show_steps:
            print("\n Now,   self.inputs = ")
            print("     " + str(self.inputs))
            print()
        ##endof:  if do_show_steps

        result_of_add = x_var + y_var

        if self.do_show_steps:
            print("\n We will return")
            print("     result_of_add = " + str(result_of_add))
            dashes = "-"*35
            print(dashes)
            print()
```

```
        ##endof:  if do_show_steps

        return result_of_add

    ##endof:  compute(self, x_var, y_var):

##endof:  class Add(Operation)
```

Course Notes Version

In [39]:
```
class addCNV(OperationCNV):

    def __init__(self, x, y):

        super().__init__([x, y])

    ##endof:  __init__(self, x, y)

    def compute(self, x_var, y_var):

        self.inputs = [x_var, y_var]
        return x_var + y_var

    ##endof:  compute(self, x_var, y_var)

##endof:  addCNV(OperationCNV)
```

Multiplication

Lecture Version - with Dave's additions

In [40]:
```
class Multiply(Operation):

    def __init__(self, x, y,
                 do_show_steps=global_do_show_steps_bool):

        self.do_show_steps = do_show_steps

        if self.do_show_steps:
            dashes = "-"*35
            print("\n" + dashes)
            print("\n Initializing a  Multiply  operation")
            print()
        ##endof:  if do_show_steps
        super().__init__([x, y])
    ##endof:  __init__(self, x, y)

    def compute(self, x_var, y_var):

        if self.do_show_steps:
            print("\n Now, computing the  Multiply  operation ")
            print()
        ##endof:  if do_show_steps

        self.inputs = [x_var, y_var]

        if self.do_show_steps:
            print("\n Now,   self.inputs = ")
            print("     " + str(self.inputs))
            print()
        ##endof:  if do_show_steps

        result_of_multiply = x_var * y_var

        if self.do_show_steps:
            print("\n We will return")
            print("     result_of_multiply = " + str(result_of_multiply))
            dashes = "-"*35
            print(dashes)
            print()
        ##endof:  if do_show_steps

        return result_of_multiply
```

```
    ##endof:  compute(self, x_var, y_var):

##endof:  class Multiply(Operation)
```

Course Notes Version

In [41]:
```
class multiplyCNV(OperationCNV):

    def __init__(self, a, b):

        super().__init__([a, b])

    ##endof:  __init__(self, a, b)

    def compute(self, a_var, b_var):

        self.inputs = [a_var, b_var]
        return a_var * b_var

    ##endof:  compute(self, a_var, b_var)

##endof:  multiplyCNV(OperationCNV)
```

Matrix Multiplication

Lecture Version - with Dave's additions

In [120]:
```
class MatMul(Operation):

    def __init__(self, x, y,
                 do_show_steps=global_do_show_steps_bool):

        self.do_show_steps = do_show_steps

        if self.do_show_steps:
            dashes = "-"*35
            print("\n" + dashes)
            print("\n Initializing a  MatMul  operation")
            print()
        ##endof:  if do_show_steps
        super().__init__([x, y])
    ##endof:  __init__(self, x, y)

    def compute(self, x_var, y_var):

        if self.do_show_steps:
            print("\n Now, computing the  MatMul  operation ")
            print()
        ##endof:  if do_show_steps

        self.inputs = [x_var, y_var]

        if self.do_show_steps:
            print("\n Now,   self.inputs = ")
            print("     " + str(self.inputs))
            print()
        ##endof:  if do_show_steps

        #  We're assuming we have numpy arrays (matrices), so we can
        #+ use the  var.dot()  operation
        result_of_matmul = x_var.dot(y_var)

        if self.do_show_steps:
            print("\n We will return")
            print("     result_of_matmul = " + str(result_of_matmul))
            dashes = "-"*35
            print(dashes)
            print()
        ##endof:  if do_show_steps
```

```
        return result_of_matmul

    ##endof:  compute(self, x_var, y_var):

##endof:  class MatMul(Operation)
```

Course Notes Version

In [121]:
```
class matmulCNV(OperationCNV):

    def __init__(self, a, b):

        super().__init__([a, b])

    ##endof:  __init__(self, a, b)

    def compute(self, a_mat, b_mat):

        self.inputs = [a_mat, b_mat]
        return a_mat.dot(b_mat)

    ##endof:  compute(self, a_mat, b_mat)

##endof:  matmulCNV(OperationCNV)
```

Placeholders

Lecture Version - with (maybe) Dave's additions

In [122]:
```
class Placeholder():

    def __init__(self):

        self.output_nodes = []

        _default_graph.placeholders.append(self) #  this is added in during
                                                 #+ the course of the lecture.
                                                 #+ whereas those before
                                                 #+ weren't

    ##endof:  __init__(self)

##endof:  Placeholder()
```

Course Notes Version

In [123]:
```
class PlaceholderCNV():
    '''
    A placeholder is a node that needs to be provided a value for
    computing the output in the graph.
    '''

    def __init__(self):

        self.output_nodes = []

        _default_graph.placeholders.append(self) #  this is added in during
                                                 #+ the course of the lecture.
                                                 #+ whereas those before
                                                 #+ weren't

    ##endof:  __init__(self)

##endof:  PlaceholderCNV()
```

Variables

Lecture Version - with (maybe) Dave's additions

In [124]:
```
class Variable():

    def __init__(self, initial_value=None):

        self.value = initial_value
        self.output_nodes = []

        _default_graph.variables.append(self)

    ##endof:  __init__(self, initial_value=None)

##endof:  class Variable
```

Course Notes Version

In [125]:
```
class VariableCNV():
    '''
    This variable is a changeable parameter of the Graph.
    (Jose said we can think of it as a weight.)
    '''

    def __init__(self, initial_value=None):

        self.value = initial_value
        self.output_nodes = []

        _default_graph.variables.append(self)

    ##endof:  __init__(self, initial_value=None)

##endof:  VariableCNV()
```

Graph

Lecture Version - with (maybe) Dave's additions

In [126]:
```
class Graph():

    def __init__(self):

        self.operations = []
        self.placeholders = []
        self.variables = []

    ##endof:  __init__(self)

    def set_as_default(self):

        global _default_graph
        _default_graph = self

    ##endof:  set_as_default(self)

##endof:  Graph()
```

Course Notes Version

In [127]:
```
class GraphCNV():
    '''
    No docstring in the course notes
    '''

    def __init__(self):

        self.operations = []
        self.placeholders = []
        self.variables = []

    ##endof:  def __init__(self)

    def set_as_default(self):
        '''
        Sets this Graph instance as the Global Default Graph
        '''

        global _default_graph
        _default_graph = self

    ##endof:  set_as_default(self)

##endof:  GraphCNV()
```

A Basic Graph

$$z = Ax + b$$

With $A = 10$ and $b = 1$

$$z = 10x + 1$$

Just need a placeholder for x and then, once x is filled in, we can solve it!

In [128]:
```
g = Graph()
```

In [129]:
```
g.set_as_default()
```

In [130]:
```
A = Variable(10)
```

In [131]:
```
b = Variable(1)
```

In [132]:
```
# Jose comments, "Will be filled out later"
x = Placeholder()
```

In [133]:
```
y = Multiply(A, x)
```

```
-----------------------------------

 Initializing a  Multiply  operation



--------------------------------------------------
In __init__


 Now,   self.input_nodes =
     [<__main__.Variable object at 0x00000213500C0470>, <__main__.Placeholder object at 0x00000213500C06A0>]


 Current node is:
     node = <__main__.Variable object at 0x00000213500C0470>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Variable object at 0x00000213500C0470>

--------------------------------------------------


 Current node is:
     node = <__main__.Placeholder object at 0x00000213500C06A0>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Placeholder object at 0x00000213500C06A0>

--------------------------------------------------


 Before appending  self  to  _default_graph,
     _default_graph =
               <__main__.Graph object at 0x00000213500C05C0>


 After appending  self  to  _default_graph,
     _default_graph =
```

```
<__main__.Graph object at 0x00000213500C05C0>
```

In [134]:
```
z = Add(y, b)
```

```
-----------------------------------

 Initializing an  Add  operation



--------------------------------------------------
In __init__


 Now,   self.input_nodes =
     [<__main__.Multiply object at 0x00000213500C04A8>, <__main__.Variable object at 0x00000213500C02E8>]


 Current node is:
     node = <__main__.Multiply object at 0x00000213500C04A8>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Multiply object at 0x00000213500C04A8>

--------------------------------------------------


 Current node is:
     node = <__main__.Variable object at 0x00000213500C02E8>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Variable object at 0x00000213500C02E8>

--------------------------------------------------


 Before appending  self  to  _default_graph,
     _default_graph =
               <__main__.Graph object at 0x00000213500C05C0>


 After appending  self  to  _default_graph,
     _default_graph =
```

```
<__main__.Graph object at 0x00000213500C05C0>
```

A Comment or 2

Now, we just need to actually compute the z. We need to add in 1) a traverse-post-order function, which allows a post order traversal of nodes, which is necessary to make sure the computation is done in the correct order; 2) a Session class, which actually executes this graph.

The Basic Graph with the Course Notes Version

In [135]:
```
g_CNV = GraphCNV()
```

In [136]:
```
g_CNV.set_as_default()
```

In [137]:
```
A_CNV = VariableCNV(10)
```

In [138]:
```
b_CNV = VariableCNV(1)
```

In [139]:
```
x_CNV = PlaceholderCNV()
```

In [140]:
```
y_CNV = multiplyCNV(A_CNV, x_CNV)
```

In [141]:
```
z_CNV = addCNV(y_CNV, b_CNV)
```

We got here, and everything computes, both for my lecture version and the course notes version. When I go through the next lecture, I'll commment out the Course Notes Version. I might come back and do the Course Notes Version. The problem now isn't the same variable names (though I added `'_CNV'` to all of them) - it's the `Graph.set_as_default` function.

DWB

`1701317785_2023-11-29T211625-0700`

Actually, I think both would be fine, but I'm not going to spend the extra time doing both.

`1701394493_2023-11-30T183453-0700`

Session

In [142]:
```
import numpy as np
```

Check on graphs, due to error.

In [143]:
```
g
```

Out[143]:
```
<__main__.Graph at 0x213500c05c0>
```

In [144]:
```
g_CNV
```

Out[144]:
```
<__main__.GraphCNV at 0x213500c07b8>
```

In [145]:
```
g == g_CNV
```

Out[145]:
```
False
```

Traversing Operation Nodes

Lecture Version of Classes - with Dave's additions - AND of Running the Session

In [146]:
```
def traverse_postorder(operation,
                       do_show_steps=global_do_show_steps_bool):

    '''
    PostOrder Traversal of Nodes. Basically makes sure computations are
    done in the correct order ( A*x first , then A*x + b ). Feel free
    to copy and paste this code. (DWB 1701792896_2023-12-05T091456-0700,
    nope, typing it out). It is not super important for understanding
    the basic fundamentals of deep learning.
    '''

    nodes_postorder = []
    def recurse(node):
        if do_show_steps:
            dashes = "-"*40
            print("\n" + dashes)
            print("\n Inside  recurse(node)")
            print()
            print("     node = " + str(node))
            print()
        ##endof:  if do_show_steps
        if isinstance(node, Operation):
            if do_show_steps:
                print("\n node, " + str(node))
                print(" is an  Operation")
            ##endof:  if do_show_steps
            for input_node in node.input_nodes:
                if do_show_steps:
                    print("\n Current  input_node = ")
                    print(str(input_node))
                ##endof:  if do_show_steps
                recurse(input_node)
            ##endof:  for input_node in node.input_nodes
        ##endof:  if isinstance(node, Operation)

        nodes_postorder.append(node)

    ##endof:  recurse(node)

    if do_show_steps:
        dashes = "-"*43
        print("\n\n" + dashes)
```

```
        print("\n Calling  recurse(operation)")
        print("\n     with operation = ")
        print(str(operation))
        print()
    ##endof:  if do_show_steps
    recurse(operation)

    if do_show_steps:
        print("\n\n")
        dashes = "-"*43
        print("\n\n")
        print("Exited the recursion")
        print("\n")
        print(" We now have  nodes_postorder = ")
        print(str(nodes_postorder))
        print()
    ##endof:  if do_show_steps
    return nodes_postorder

##endof traverse_postorder(operation)
```

In [166]:
```
class Session():

    ##  use  operation  and  feed_dict  as these are the names used by
    ##+ TensorFlow.  feed_dict matches placeholders to input values.
    ##+ Later on, we'll feed our network batches of data through that
    ##+ dictionary.
    def run(self, operation, feed_dict={},
            do_show_steps=global_do_show_steps_bool):

        if do_show_steps:
            print("\n\n   !!! Running the Session !!!\n")
        ##endof:  if do_show_steps

        nodes_postorder = traverse_postorder(operation)

        if do_show_steps:
            print("\n After running")
            print("   nodes_postorder = traverse_postorder(operation)")
            print(" we have")
            print(" nodes_postorder = ")
            print(str(nodes_postorder))
            print()
        ##endof:  if do_show_steps

        for node in nodes_postorder:
            if type(node) == Placeholder:
                if do_show_steps:
                    print("\n We have a  Placeholder  and will")
                    print(" assign  feed_dict[node]  to  node.output")
                    print(" ( which which means the value,")
                    print(" feed_dict[node] = " + str(feed_dict[node])) #"<probably not yet ready>")
                    print(" will be assigned.")
                    print()
                ##endof:  if do_show_steps
                node.output = feed_dict[node]
                if do_show_steps:
                    print("\n Checking, node.output = " + str(node.output)) #"<probably not yet ready>")
                    print()
                ##endof:  if do_show_steps
            ##endof:  if type(node) == Placeholder
            elif type(node) == Variable:
                if do_show_steps:
```

```
                print("\n We have a  Variable  and will")
                print(" assign  node.value  to  node.output")
                print(" ( which which means the value,")
                print(" node.value = " + str(node.value))
                print(" will be assigned.")
                print()
            ##endof:  if do_show_steps
            node.output = node.value
            if do_show_steps:
                print("\n Checking, node.output = " + str(node.output))
                print()
            ##endof:  if do_show_steps
        ##endof:  elif type(node) == Variable
        # # DWB commenting out the  else  and its assumption
        # else:
        #     # <s>OPERATION</s>
        ## ## DWB, my first attempt here was off.
        ## elif type(node) == Operation:
        elif isinstance(node, Operation):
            if do_show_steps:
                print("\n We have an  Operation  and will")
                print(" compute the output of the operation")
                print(" based on each input_node's output,")
                print(" for each node's input_nodes")
                print(" We will assign the result of the")
                print(" computation to  node.output")
                print()
                print(" Some pertinent parts:")
                print(str(node.input_nodes))
                print(" I'm not going to mess around finding")
                print(" the  output  of each  input_node  here,")
                print(" since it will become the  node.inputs")
                print()
            ##endof:  if do_show_steps
            node.inputs = \
              [input_node.output for input_node in node.input_nodes]

            #  For the next command,
            #+   node.output = node.compute((node_inputs))
            #+ asterisk is basically a sort of args asterisk.
            #+ Allows us to combine inputs
            #+ without knowing how many we might have. (Note: each of
            #+ the operations we've made only has two inputs, but it's
```

```
            #+ nice to have it generalized, as I'm sure Tensorflow has
            #+ it generalized. -DWB 1701796074_2023-12-05T100754-0700)

            if do_show_steps:
                print("\n We will now assign the value of")
                print(" node.output")
                print(" We will use")
                #  next line might need
                #+   for nd_inp in *node_inputs: print(nd_inp)
                #+ instead of  str(*node_inputs)
                #+ Nope, seems we're okay
                print(" node.inputs = " + str(node.inputs))
                print()
            ##endof:  if do_show_steps

            node.output = node.compute(*node.inputs)

            if do_show_steps:
                print("\n Inspecting, node.output = " + str(node.output))
                print()
            ##endof:  if do_show_steps

        ##endof:  elif isinstance(node, Operation)
        else:
            print()
            print("Session: SOMETHING IS WRONG, AND THINGS WILL PROBABLY BREAK")
            print()
        ##endof:  if/elif/else <type(node)>

        # Get things numpy-y
        if type(node.output) == list:
            node.output = np.array(node.output)
        ##endof:  if type(node.output) == list
    ##endof:  for node in nodes_postorder

    if do_show_steps:
        print("\n\n Looking at a few things, where we are getting")
        print(" errors, as shown in a cell below.")
        print()
        print("operation = " + str(operation))
        print()
        op_out = operation.output
        print("operation.output = " + str(op_out))
```

```
            print()
            print("\n Looking at  nodes_postorder = ")
            print(str(nodes_postorder))
            print()
            print(" Looking at nodes_postorder[0], which I hope is an Operation")
            print("     nodes_postorder[0] = " + str(nodes_postorder[0]))
            print()
            print("\n If we got an Operation, let's print its  output")
            print()
            if type(nodes_postorder[0]) == Operation:
                print("\n It is an operation, and")
                print("     nodes_postorder[0].output = " + \
                      str(nodes_postorder[0].output))
                print()
            ##endof:  if/else type(nodes_postorder[0]) == Operation
        ##endof:  if do_show_steps

        output_to_return = operation.output

        if do_show_steps:
            print("\n\n We will return the output of the operation,")
            equals_str = "="*60
            print("  " + equals_str)
            print("output_to_return = operation.output = " + \
                  str(output_to_return))
            print("  " + equals_str)
            print()
            print("\n\n   !!! Finished Running the Session !!!\n")
            print()
        ##endof:  if do_show_steps

        return output_to_return

    ##endof:  run(self, operation, feed_dict={}, do_show_steps=True)
##endof:  Session()
```

In [167]:
```
sess = Session()
```

In [168]:
```
result = sess.run(operation=z,
                  feed_dict={x:10},
                  do_show_steps=global_do_show_steps_bool)
```

```
   !!! Running the Session !!!



-------------------------------------------

 Calling  recurse(operation)

     with operation =
<__main__.Add object at 0x00000213500C0780>


----------------------------------------

 Inside  recurse(node)

     node = <__main__.Add object at 0x00000213500C0780>


 node, <__main__.Add object at 0x00000213500C0780>
 is an  Operation

 Current  input_node =
<__main__.Multiply object at 0x00000213500C04A8>

----------------------------------------

 Inside  recurse(node)

     node = <__main__.Multiply object at 0x00000213500C04A8>


 node, <__main__.Multiply object at 0x00000213500C04A8>
 is an  Operation

 Current  input_node =
<__main__.Variable object at 0x00000213500C0470>

----------------------------------------

 Inside  recurse(node)
```

```
    node = <__main__.Variable object at 0x00000213500C0470>


 Current  input_node =
<__main__.Placeholder object at 0x00000213500C06A0>

----------------------------------------

 Inside  recurse(node)

    node = <__main__.Placeholder object at 0x00000213500C06A0>


 Current  input_node =
<__main__.Variable object at 0x00000213500C02E8>

----------------------------------------

 Inside  recurse(node)

    node = <__main__.Variable object at 0x00000213500C02E8>






Exited the recursion


 We now have  nodes_postorder =
[<__main__.Variable object at 0x00000213500C0470>, <__main__.Placeholder object at 0x00000213500C06A0>, <__ma
in__.Multiply object at 0x00000213500C04A8>, <__main__.Variable object at 0x00000213500C02E8>, <__main__.Add
object at 0x00000213500C0780>]


 After running
   nodes_postorder = traverse_postorder(operation)
 we have
 nodes_postorder =
[<__main__.Variable object at 0x00000213500C0470>, <__main__.Placeholder object at 0x00000213500C06A0>, <__ma
in__.Multiply object at 0x00000213500C04A8>, <__main__.Variable object at 0x00000213500C02E8>, <__main__.Add
```

```
object at 0x00000213500C0780>]


 We have a  Variable  and will
 assign  node.value  to  node.output
 ( which which means the value,
 node.value = 10
 will be assigned.


 Checking, node.output = 10


 We have a  Placeholder  and will
 assign  feed_dict[node]  to  node.output
 ( which which means the value,
 feed_dict[node] = 10
 will be assigned.


 Checking, node.output = 10


 We have an  Operation  and will
 compute the output of the operation
 based on each input_node's output,
 for each node's input_nodes
 We will assign the result of the
 computation to  node.output

 Some pertinent parts:
[<__main__.Variable object at 0x00000213500C0470>, <__main__.Placeholder object at 0x00000213500C06A0>]
 I'm not going to mess around finding
 the  output  of each  input_node  here,
 since it will become the  node.inputs


 We will now assign the value of
 node.output
 We will use
 node.inputs = [10, 10]
```

```
 Now, computing the  Multiply  operation


 Now,   self.inputs =
     [10, 10]


 We will return
     result_of_multiply = 100
-----------------------------------


 Inspecting, node.output = 100


 We have a  Variable  and will
 assign  node.value  to  node.output
 ( which which means the value,
 node.value = 1
 will be assigned.


 Checking, node.output = 1


 We have an  Operation  and will
 compute the output of the operation
 based on each input_node's output,
 for each node's input_nodes
 We will assign the result of the
 computation to  node.output

 Some pertinent parts:
[<__main__.Multiply object at 0x00000213500C04A8>, <__main__.Variable object at 0x00000213500C02E8>]
 I'm not going to mess around finding
 the  output  of each  input_node  here,
 since it will become the  node.inputs


 We will now assign the value of
 node.output
 We will use
 node.inputs = [100, 1]
```

```
 Now, computing the  Add  operation


 Now,   self.inputs =
     [100, 1]


 We will return
     result_of_add = 101
-----------------------------------


 Inspecting, node.output = 101



 Looking at a few things, where we are getting
 errors, as shown in a cell below.

operation = <__main__.Add object at 0x00000213500C0780>

operation.output = 101


 Looking at  nodes_postorder =
[<__main__.Variable object at 0x00000213500C0470>, <__main__.Placeholder object at 0x00000213500C06A0>, <__ma
in__.Multiply object at 0x00000213500C04A8>, <__main__.Variable object at 0x00000213500C02E8>, <__main__.Add
object at 0x00000213500C0780>]

 Looking at nodes_postorder[0], which I hope is an Operation
     nodes_postorder[0] = <__main__.Variable object at 0x00000213500C0470>


 If we got an Operation, let's print its  output



 We will return the output of the operation,
  ============================================================
output_to_return = operation.output = 101
  ============================================================
```

```
!!! Finished Running the Session !!!
```

Course Notes Version of Classes AND of Running the Session

In [169]:
```
def traverse_postorder_CNV(operation):
    """
    PostOrder Traversal of Nodes. Basically makes sure computations are done in
    the correct order (Ax first , then Ax + b). Feel free to copy and paste this code.
    It is not super important for understanding the basic fundamentals of deep learning.
    """

    nodes_postorder = []
    def recurse(node):
        if isinstance(node, OperationCNV):
            for input_node in node.input_nodes:
                recurse(input_node)
        nodes_postorder.append(node)

    recurse(operation)
    return nodes_postorder

##endof traverse_postorder_CNV(operation)

##+ I just copy/pasted it and added the '_CNV'
##+ or "CNV" where necessary
##+ DWB 1701800683_2023-12-05T112443-0700
```

In [170]:
```
class SessionCNV():

    def run(self, operation, feed_dict = {}):
        """
          operation: The operation to compute
          feed_dict: Dictionary mapping placeholders to input values (the data)
        """

        # Puts nodes in correct order
        nodes_postorder = traverse_postorder_CNV(operation)

        for node in nodes_postorder:

            if type(node) == PlaceholderCNV:

                node.output = feed_dict[node]

            elif type(node) == VariableCNV:

                node.output = node.value

            else: # Operation

                node.inputs = [input_node.output for input_node in node.input_nodes]


                node.output = node.compute(*node.inputs)

            # Convert lists to numpy arrays
            if type(node.output) == list:
                node.output = np.array(node.output)

        # Return the requested node value
        return operation.output


##endof:  class SessionCNV()

##+ I just copy/pasted it and added the '_CNV'
##+ or "CNV" where necessary
##+ DWB 1701800683_2023-12-05T112443-0700
```

In [171]:
```
sess_CNV = SessionCNV()
```

In [172]:
```
result_CNV = sess_CNV.run(operation=z_CNV,
                          feed_dict={x_CNV:10})
```

In [173]:
```
result_CNV
```

Out[173]:
```
101
```

That worked. We also fixed the bug in my version. On we go! Time for Q&R as I continue forward.

Now, some matrix multiplication

Lecture Version of matrix multiplication

In [174]:
```
g_mat = Graph()

g_mat.set_as_default()

A_mat = Variable([[10, 20],[30, 40]])
b_mat = Variable([1, 2])

x_mat = Placeholder()

y_mat = MatMul(A_mat, x_mat)

z_mat = Add(y_mat, b_mat)
```

```
-----------------------------------

 Initializing a  MatMul  operation



--------------------------------------------------
In __init__


 Now,   self.input_nodes =
     [<__main__.Variable object at 0x00000213500C0E48>, <__main__.Placeholder object at 0x00000213500C0F60>]


 Current node is:
     node = <__main__.Variable object at 0x00000213500C0E48>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Variable object at 0x00000213500C0E48>

--------------------------------------------------


 Current node is:
     node = <__main__.Placeholder object at 0x00000213500C0F60>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Placeholder object at 0x00000213500C0F60>

--------------------------------------------------


 Before appending  self  to  _default_graph,
     _default_graph =
               <__main__.Graph object at 0x00000213500C0E80>


 After appending  self  to  _default_graph,
     _default_graph =
               <__main__.Graph object at 0x00000213500C0E80>
```

```
-----------------------------------

 Initializing an  Add  operation



--------------------------------------------------
In __init__


 Now,   self.input_nodes =
     [<__main__.MatMul object at 0x00000213500C0DD8>, <__main__.Variable object at 0x00000213500D8978>]


 Current node is:
     node = <__main__.MatMul object at 0x00000213500C0DD8>


 After assignment, node.output_nodes.append(self)
     node = <__main__.MatMul object at 0x00000213500C0DD8>

--------------------------------------------------


 Current node is:
     node = <__main__.Variable object at 0x00000213500D8978>


 After assignment, node.output_nodes.append(self)
     node = <__main__.Variable object at 0x00000213500D8978>

--------------------------------------------------


 Before appending  self  to  _default_graph,
     _default_graph =
               <__main__.Graph object at 0x00000213500C0E80>


 After appending  self  to  _default_graph,
     _default_graph =
```

```
<__main__.Graph object at 0x00000213500C0E80>
```

In [175]:
```
sess_mat = Session()
```

In [176]:
```
sess_mat.run(operation=z_mat, feed_dict={x_mat:10})
```

```
   !!! Running the Session !!!



-------------------------------------------

 Calling  recurse(operation)

     with operation =
<__main__.Add object at 0x00000213500C06D8>


----------------------------------------

 Inside  recurse(node)

     node = <__main__.Add object at 0x00000213500C06D8>


 node, <__main__.Add object at 0x00000213500C06D8>
 is an  Operation

 Current  input_node =
<__main__.MatMul object at 0x00000213500C0DD8>

----------------------------------------

 Inside  recurse(node)

     node = <__main__.MatMul object at 0x00000213500C0DD8>


 node, <__main__.MatMul object at 0x00000213500C0DD8>
 is an  Operation

 Current  input_node =
<__main__.Variable object at 0x00000213500C0E48>

----------------------------------------

 Inside  recurse(node)
```

```
     node = <__main__.Variable object at 0x00000213500C0E48>


 Current  input_node =
<__main__.Placeholder object at 0x00000213500C0F60>

----------------------------------------

 Inside  recurse(node)

     node = <__main__.Placeholder object at 0x00000213500C0F60>


 Current  input_node =
<__main__.Variable object at 0x00000213500D8978>

----------------------------------------

 Inside  recurse(node)

     node = <__main__.Variable object at 0x00000213500D8978>







Exited the recursion


 We now have  nodes_postorder =
[<__main__.Variable object at 0x00000213500C0E48>, <__main__.Placeholder object at 0x00000213500C0F60>, <__ma
in__.MatMul object at 0x00000213500C0DD8>, <__main__.Variable object at 0x00000213500D8978>, <__main__.Add ob
ject at 0x00000213500C06D8>]


 After running
   nodes_postorder = traverse_postorder(operation)
 we have
 nodes_postorder =
[<__main__.Variable object at 0x00000213500C0E48>, <__main__.Placeholder object at 0x00000213500C0F60>, <__ma
in__.MatMul object at 0x00000213500C0DD8>, <__main__.Variable object at 0x00000213500D8978>, <__main__.Add ob
```

```
ject at 0x00000213500C06D8>]


 We have a  Variable  and will
 assign  node.value  to  node.output
 ( which which means the value,
 node.value = [[10, 20], [30, 40]]
 will be assigned.


 Checking, node.output = [[10, 20], [30, 40]]


 We have a  Placeholder  and will
 assign  feed_dict[node]  to  node.output
 ( which which means the value,
 feed_dict[node] = 10
 will be assigned.


 Checking, node.output = 10


 We have an  Operation  and will
 compute the output of the operation
 based on each input_node's output,
 for each node's input_nodes
 We will assign the result of the
 computation to  node.output

 Some pertinent parts:
[<__main__.Variable object at 0x00000213500C0E48>, <__main__.Placeholder object at 0x00000213500C0F60>]
 I'm not going to mess around finding
 the  output  of each  input_node  here,
 since it will become the  node.inputs


 We will now assign the value of
 node.output
 We will use
 node.inputs = [array([[10, 20],
       [30, 40]]), 10]
```

```
 Now, computing the  MatMul  operation


 Now,   self.inputs =
     [array([[10, 20],
       [30, 40]]), 10]


 We will return
     result_of_matmul = [[100 200]
 [300 400]]
-----------------------------------


 Inspecting, node.output = [[100 200]
 [300 400]]


 We have a  Variable  and will
 assign  node.value  to  node.output
 ( which which means the value,
 node.value = [1, 2]
 will be assigned.


 Checking, node.output = [1, 2]


 We have an  Operation  and will
 compute the output of the operation
 based on each input_node's output,
 for each node's input_nodes
 We will assign the result of the
 computation to  node.output

 Some pertinent parts:
[<__main__.MatMul object at 0x00000213500C0DD8>, <__main__.Variable object at 0x00000213500D8978>]
 I'm not going to mess around finding
 the  output  of each  input_node  here,
 since it will become the  node.inputs
```

```
 We will now assign the value of
 node.output
 We will use
 node.inputs = [array([[100, 200],
       [300, 400]]), array([1, 2])]


 Now, computing the  Add  operation


 Now,   self.inputs =
     [array([[100, 200],
       [300, 400]]), array([1, 2])]


 We will return
     result_of_add = [[101 202]
 [301 402]]
-----------------------------------


 Inspecting, node.output = [[101 202]
 [301 402]]



 Looking at a few things, where we are getting
 errors, as shown in a cell below.

operation = <__main__.Add object at 0x00000213500C06D8>

operation.output = [[101 202]
 [301 402]]


 Looking at  nodes_postorder =
[<__main__.Variable object at 0x00000213500C0E48>, <__main__.Placeholder object at 0x00000213500C0F60>, <__ma
in__.MatMul object at 0x00000213500C0DD8>, <__main__.Variable object at 0x00000213500D8978>, <__main__.Add ob
ject at 0x00000213500C06D8>]

 Looking at nodes_postorder[0], which I hope is an Operation
     nodes_postorder[0] = <__main__.Variable object at 0x00000213500C0E48>
```

```
 If we got an Operation, let's print its  output



 We will return the output of the operation,
  ============================================================
output_to_return = operation.output = [[101 202]
 [301 402]]
  ============================================================



   !!! Finished Running the Session !!!
```

Out[176]:
```
array([[101, 202],
       [301, 402]])
```

Course Notes Version of matrix multiplication

In [177]:
```
g_mat_CNV = GraphCNV()

g_mat_CNV.set_as_default()

A_mat_CNV = VariableCNV([[10, 20],[30, 40]])
b_mat_CNV = VariableCNV([1, 1])

x_mat_CNV = PlaceholderCNV()

y_mat_CNV = matmulCNV(A_mat_CNV, x_mat_CNV)

z_mat_CNV = addCNV(y_mat_CNV, b_mat_CNV)
```

In [178]:
```
sess_mat_CNV = SessionCNV()
```

In [179]:
```
result_mat_CNV = sess_mat_CNV.run(operation=z_mat_CNV,
                                  feed_dict={x_mat_CNV:10})
```

In [180]:
```
result_mat_CNV
```

Out[180]:
```
array([[101, 201],
       [301, 401]])
```

Classification

Activation Function

In [181]:
```
import matplotlib.pyplot as plt
%matplotlib inline
```

Sigmoid as an Operation

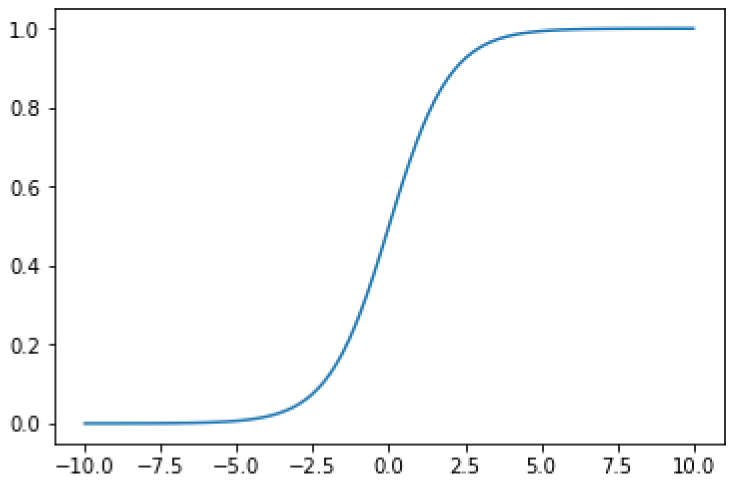
Lecture Version - with Dave's additions

In [182]:
```
def Sigmoid(z):
    return 1 / (1 + np.exp(-z))
##endof:  Sigmoid(z)
```

In [183]:
```
sample_z = np.linspace(-10, 10, 100)
sample_a = Sigmoid(sample_z)
```

In [184]:
```
plt.plot(sample_z, sample_a)
```

Out[184]:
```
[<matplotlib.lines.Line2D at 0x2135096a4e0>]
```



In [185]:
```
class Sigmoid(Operation):

    def __init__(self, z):
        super().__init__(z)
    ##endof:  __init(self, z)


    def compute(self, z_val):
        return 1 / (1 + np.exp(-z_val))
    ##endof:  compute(self, z)

##endof:  Sigmoid(Operation)
```

Course Notes Version

In [186]:
```
# class sigmoidCNV(Operation):
#
#     def __init__(self, z):
#
#     ##endof:  __init__(self, z)
#
#     def compute(self, z_val):
#
#     ##endof:  compute(self, z_val)
#
# ##endof:  sigmoidCNV(Operation)
```

Classification Example

In [191]:
```
from sklearn.datasets import make_blobs
```

Lecture Version

In [192]:
```
data = make_blobs(n_samples=50, n_features=2,
                  centers=2, random_state=75
                 )
# centers : how many blobs
```

In [193]:
```
data # first array is features, second array is labels
```

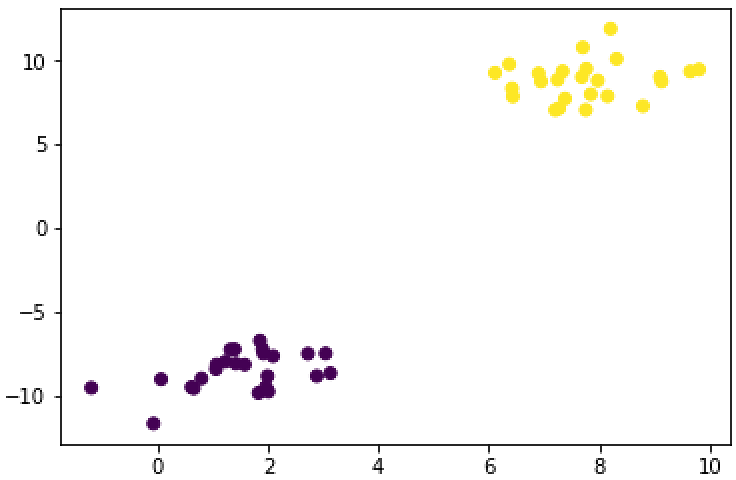
Out[193]:
```
(array([[ 7.3402781 ,  9.36149154],
       [ 9.13332743,  8.74906102],
       [ 1.99243535, -8.85885722],
       [ 7.38443759,  7.72520389],
       [ 7.97613887,  8.80878209],
       [ 7.76974352,  9.50899462],
       [ 8.3186688 , 10.1026025 ],
       [ 8.79588546,  7.28046702],
       [ 9.81270381,  9.46968531],
       [ 1.57961049, -8.17089971],
       [ 0.06441546, -9.04982817],
       [ 7.2075117 ,  7.04533624],
       [ 9.10704928,  9.0272212 ],
       [ 1.82921897, -9.86956281],
       [ 7.85036314,  7.986659  ],
       [ 3.04605603, -7.50486114],
       [ 1.85582689, -6.74473432],
       [ 2.88603902, -8.85261704],
       [-1.20046211, -9.55928542],
       [ 2.00890845, -9.78471782],
       [ 7.68945113,  9.01706723],
       [ 6.42356167,  8.33356412],
       [ 8.15467319,  7.87489634],
       [ 1.92000795, -7.50953708],
       [ 1.90073973, -7.24386675],
       [ 7.7605855 ,  7.05124418],
       [ 6.90561582,  9.23493842],
       [ 0.65582768, -9.5920878 ],
       [ 1.41804346, -8.10517372],
       [ 9.65371965,  9.35409538],
       [ 1.23053506, -7.98873571],
       [ 1.96322881, -9.50169117],
       [ 6.11644251,  9.26709393],
       [ 7.70630321, 10.78862346],
       [ 0.79580385, -9.00301023],
       [ 3.13114921, -8.6849493 ],
       [ 1.3970852 , -7.25918415],
       [ 7.27808709,  7.15201886],
       [ 1.06965742, -8.1648251 ],
       [ 6.37298915,  9.77705761],
       [ 7.24898455,  8.85834104],
       [ 2.09335725, -7.66278316],
       [ 1.05865542, -8.43841416],
```

```
        [ 6.43807502,   7.85483418],
        [ 6.94948313,   8.75248232],
        [-0.07326715, -11.69999644],
        [ 0.61463602,  -9.51908883],
        [ 1.31977821,  -7.2710667 ],
        [ 2.72532584,  -7.51956557],
        [ 8.20949206,  11.90419283]]),
 array([1, 1, 0, 1, 1, 1, 1, 1, 1, 0, 0, 1, 1, 0, 1, 0, 0, 0, 0, 0, 1, 1,
        1, 0, 0, 1, 1, 0, 0, 1, 0, 0, 1, 1, 0, 0, 0, 1, 0, 1, 1, 0, 0, 1,
        1, 0, 0, 0, 0, 1]))
```

In [194]:
```
features = data[0]
labels = data[1]
```

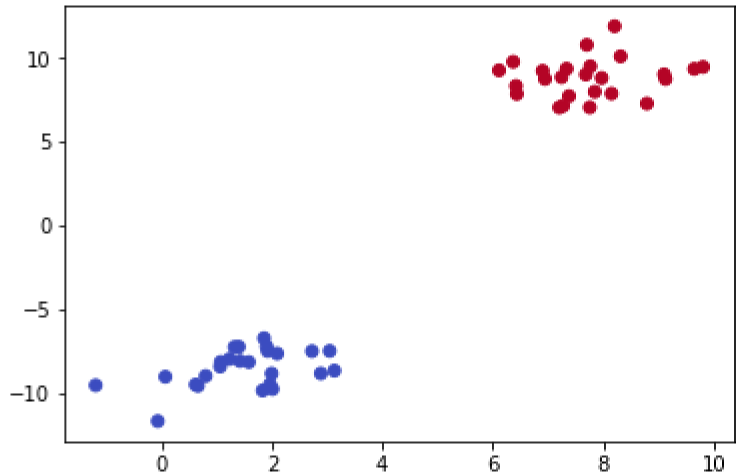
In [195]:
```
plt.scatter(features[:, 0], features[:, 1], c=labels)
```

Out[195]:
```
<matplotlib.collections.PathCollection at 0x21352ef82e8>
```



In [196]:
```
plt.scatter(features[:, 0], features[:, 1],
            c=labels, cmap='coolwarm')
```

Out[196]:
```
<matplotlib.collections.PathCollection at 0x21352f61c50>
```



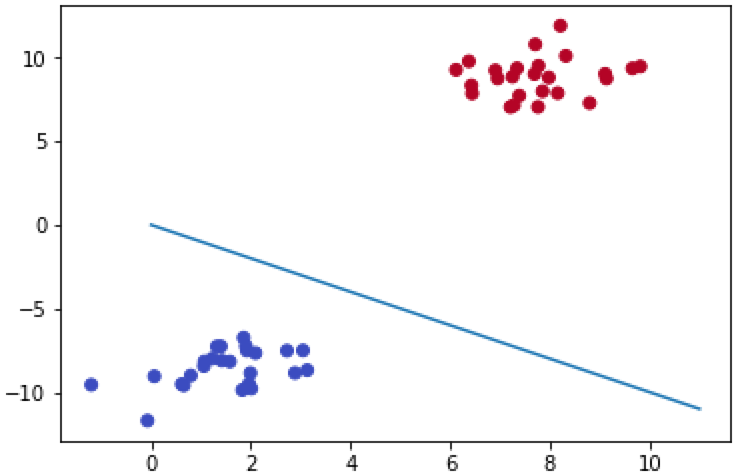
Course Notes Verison

In [197]:
```
# Later, maybe
```

Try to get a line separating the two blobs

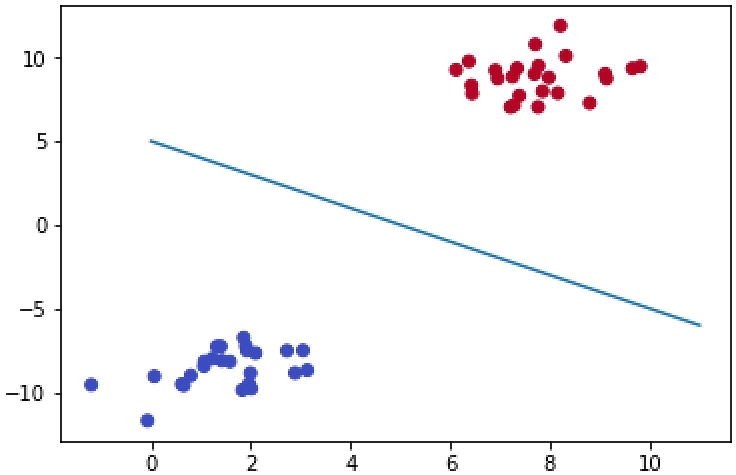
In [198]:
```
x = np.linspace(0, 11, 10)
y = -x
plt.scatter(features[:, 0], features[:, 1],
            c=labels, cmap='coolwarm')
plt.plot(x, y)
```

Out[198]: `[<matplotlib.lines.Line2D at 0x21352f23550>]`



In [199]:
```
# It looks as if it would be better to raise it
y = -x + 5
plt.scatter(features[:, 0], features[:, 1],
            c=labels, cmap='coolwarm')
plt.plot(x, y)
```

Out[199]: [<matplotlib.lines.Line2D at 0x21352f90518>]



Anything above that line belongs to the red class. Anything below the line belongs to the blue class.

Formalized as $y = mx + b$

Could be restated as $f_2 = mf_1 + b$ with $m = -1$ and $b = 5$

We want a placeholder ready, into which we can put the features.

Now, we're going to do a matrix representation to create a perceptron model and do our classification.

https://stackoverflow.com/a/59594891/6505499 (https://stackoverflow.com/a/59594891/6505499)
https://web.archive.org/web/20231231183005/https://stackoverflow.com/questions/59098171/how-to-insert-python-variable-into-latex-matrix-in-jupyter-notebook-markdown-cel (https://web.archive.org/web/20231231183005/https://stackoverflow.com/questions/59098171/how-to-insert-python-variable-into-latex-matrix-in-jupyter-notebook-markdown-cel)

https://www.physicsread.com/latex-column-vector-and-column-matrix/ (https://www.physicsread.com/latex-column-vector-and-column-matrix/)
https://web.archive.org/web/20231231183214/https://www.physicsread.com/latex-column-vector-and-column-matrix/
(https://web.archive.org/web/20231231183214/https://www.physicsread.com/latex-column-vector-and-column-matrix/)

https://tex.stackexchange.com/a/367971/188930 (https://tex.stackexchange.com/a/367971/188930)
https://web.archive.org/web/20231231183433/https://tex.stackexchange.com/questions/367960/creating-a-matrix-with-column-or-row-vectors-as-arguments (https://web.archive.org/web/20231231183433/https://tex.stackexchange.com/questions/367960/creating-a-matrix-with-column-or-row-vectors-as-arguments)

Course Notes Version

In [200]:
```
# Not now - Q&R
```

Defining the Perceptron

$$\begin{gathered} y = mx + b \\ y = -x + 5 \\ f_2 = m\, f_1 + b\,,\ m = 1 \\ f_2 = -f_1 + 5 \\ f_1 + f_2 - 5 = 0 \end{gathered}$$

Jose uses $f_{whatever}$ for a feauture

Convert to a Matrix Representation of Features

TL/DR

```
$$ \begin{bmatrix}  1 & 1 \end{bmatrix} \cdot \overleftarrow{\overrightarrow{ f }} - 5 = 0 $$
```

$$\begin{bmatrix} 1 & 1 \end{bmatrix} \cdot \overleftarrow{\overrightarrow{ f }} - 5 = 0$$

Verbosity Turned Up

For our matrix, continuing the *Defining the Perceptron* cell, we're basically looking at

```
FeatMatrix[ 1, 1 ] - 5 = 0
```

or, more nicely than Jose's

(1,1) * f - 5 = 0

we can use

```
$$ \begin{bmatrix} 1 & 1 \end{bmatrix} \cdot \textbf{f} - 5 = 0 $$
```

which gives us

$$\begin{bmatrix} 1 & 1 \end{bmatrix} \cdot \textbf{f} - 5 = 0$$

or, even better,

```
$$ \begin{bmatrix}  1 & 1 \end{bmatrix} \cdot \overset{\rightharpoonup} {\overset{\leftharpoondown f} - 5 = 0 $$
```

$$\begin{bmatrix} 1 & 1 \end{bmatrix} \cdot \overset{\rightharpoonup}{\overset{\leftharpoondown}{f}} - 5 = 0$$

where

Matrix Notes

The matrix, `$ \overset{\rightharpoonup} {\overset{\leftharpoondown} f} $` $\overset{\rightharpoonup} {\overset{\leftharpoondown} f}$ is defined as

`$$ \overline{\overline{ f }} \; \; \overset{\Delta} = \; \; \begin{bmatrix} f_1 \\ f_2 \end{bmatrix} $$`

$$ \overline{\overline{ f }} \; \; \overset{\Delta} = \; \; \begin{bmatrix} f_1 \\ f_2 \end{bmatrix} $$

My favorite matrix notation is

`$$ \overset{\rightharpoonup} {\overset{\leftharpoondown} f} $$`

$$ \overset{\rightharpoonup} {\overset{\leftharpoondown} f} $$

though I think a nice second is the one I just thought to try:

`$$ \overset{=} f $$`

$$ \overset{=} f $$

and third place going to the standard textbook form,

`$$ \textbf{f} $$`

$$ \textbf{f} $$

Example Point

Picking one that will quite obviously be in the red-dot side. We should get a positive number, since it's over the line. Jose went with $(8, 10)$

and blah! again.

```
In [ ]:
```

something else

In [ ]:

Using an Example Session Graph

Lecture Version

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

In [ ]:

Course Notes Verison

In [ ]:

```
# Maybe later
```

That's all for now, folks!