```
[1]  import pandas as pd
     import numpy as np
     import math
     import matplotlib.pyplot as plt
     import seaborn as sns
```

```
[2]  x = np.arange(-1, 1.1, .1, dtype=float)
     y = np.array([1-i for i in x], dtype=float)
     stock_a = 0.1
     stock_a_risk = 0.1
     stock_b = 0.14
     stock_b_risk = 0.14
     riskfree_p = 0.04
```

```
[3]  market_df = pd.DataFrame({"stock_A": stock_a, "stock_B": stock_b,
     "risk_A": stock_a_risk, "risk_B": stock_b_risk}, index=[0])
```

```
[4]  market_df
```

	stock_A	stock_B	risk_A	risk_B
0	0.1	0.14	0.1	0.14

```
[5]  #set number of runs of random portfolio weights
     num_portfolios = 250

     #set up array to hold results
     results = np.zeros((num_portfolios,4))

     corr = 0.4

     for i in range(num_portfolios):
         #select random weights for portfolio holdings
         weights = np.random.random(2)

         #rebalance weights to sum to 1
         weights /= np.sum(weights)

         #calculate portfolio return and volatility
         portfolio_return = weights[0]*stock_a + weights[1]*stock_b
```

```
    portfolio_std_dev = np.sqrt(
        weights[0]**2*stock_a_risk**2 +
weights[1]**2*stock_b_risk**2 +
weights[0]*weights[1]*2*stock_a_risk*stock_b_risk*corr
    )

    #store results in results array
    results[i,0] = weights[0]
    results[i,1] = weights[1]
    results[i,2] = portfolio_return
    results[i,3] = portfolio_std_dev
```

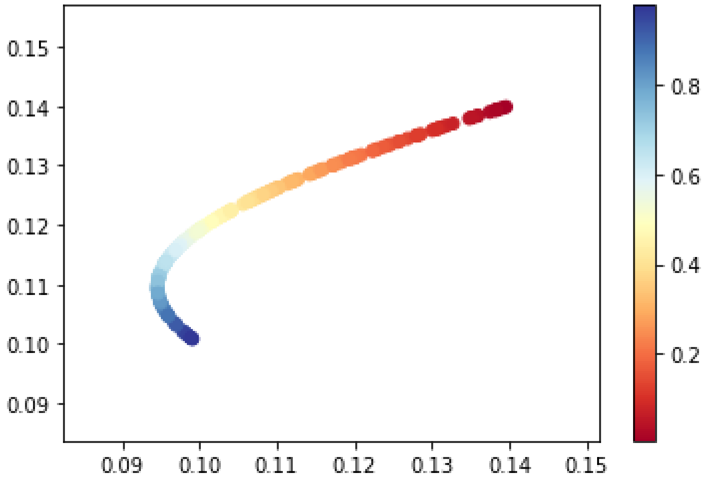
[6]

```
results_frame = pd.DataFrame(results, columns=["weight_A",
"weight_B", "combined_return", "combined_volatility"])
```

[7]

```
plt.scatter(results_frame.combined_volatility,results_frame.combi
ned_return,c=results_frame.weight_A,cmap='RdYlBu')
plt.colorbar()
```

```
<matplotlib.colorbar.Colorbar at 0x1a1e9cc470>
```



[8]

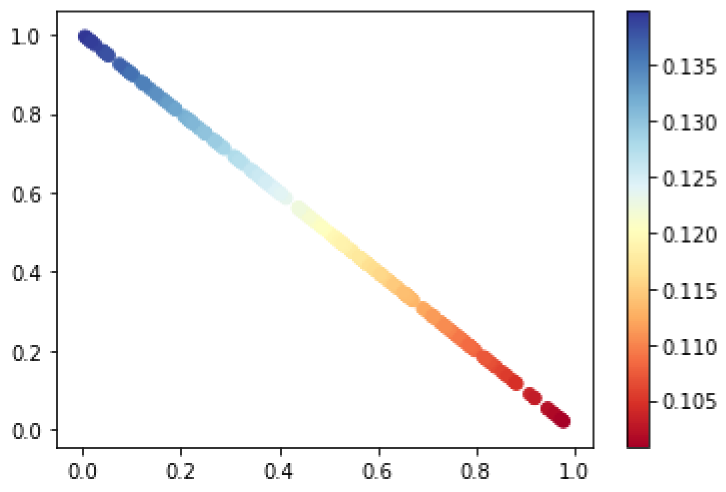
```
results_frame.loc[(results_frame.weight_A <= 0.51) &
(results_frame.weight_B <= 0.51)]
```

	weight_A	weight_B	combined_return	combined_volatility
36	0.503404	0.496596	0.119864	0.100834
46	0.509897	0.490103	0.119604	0.100533
	weight_A	**weight_B**	**combined_return**	**combined_volatility**
52	0.506987	0.493013	0.119721	0.100667

90	0.494195	0.505805	0.120232	0.101274

```
[9] plt.scatter(results_frame.weight_A, results_frame.weight_B,
    c=results_frame.combined_return,cmap='RdYlBu')
    plt.colorbar()
```

```
<matplotlib.colorbar.Colorbar at 0x1a1ea9cd30>
```




```
[10] tangent_p = pd.DataFrame({"market_weight": y, "riskfree_weight":
     x})
```

```
[11] tangent_p["riskfree_rate"] = riskfree_p
```

```
[12] tangent_p["market_rate"] = 0.120025
     tangent_p["market_risk"] = 0.101025
```

```
[13] tangent_p["combined_return"] = tangent_p.apply(lambda row:
     row.market_rate * row.market_weight + row.riskfree_weight *
     row.riskfree_rate, axis=1)
```

```
[14] tangent_p["combined_risk"] = tangent_p.apply(lambda row:
     math.sqrt(row.market_weight**2*row.market_risk**2), axis=1)
```

```
[15] tangent_p
```

	market_weight	riskfree_weight	riskfree_rate	market_rate	ma

	market_weight	riskfree_weight	riskfree_rate	market_rate	ma
0	2.000000e+00	-1.000000e+00	0.04	0.120025	0.1
1	1.900000e+00	-9.000000e-01	0.04	0.120025	0.1
2	1.800000e+00	-8.000000e-01	0.04	0.120025	0.1
3	1.700000e+00	-7.000000e-01	0.04	0.120025	0.1
4	1.600000e+00	-6.000000e-01	0.04	0.120025	0.1
5	1.500000e+00	-5.000000e-01	0.04	0.120025	0.1
6	1.400000e+00	-4.000000e-01	0.04	0.120025	0.1
7	1.300000e+00	-3.000000e-01	0.04	0.120025	0.1
8	1.200000e+00	-2.000000e-01	0.04	0.120025	0.1
9	1.100000e+00	-1.000000e-01	0.04	0.120025	0.1
10	1.000000e+00	-2.220446e-16	0.04	0.120025	0.1
11	9.000000e-01	1.000000e-01	0.04	0.120025	0.1
12	8.000000e-01	2.000000e-01	0.04	0.120025	0.1
13	7.000000e-01	3.000000e-01	0.04	0.120025	0.1
14	6.000000e-01	4.000000e-01	0.04	0.120025	0.1
15	5.000000e-01	5.000000e-01	0.04	0.120025	0.1
16	4.000000e-01	6.000000e-01	0.04	0.120025	0.1
17	3.000000e-01	7.000000e-01	0.04	0.120025	0.1
18	2.000000e-01	8.000000e-01	0.04	0.120025	0.1
19	1.000000e-01	9.000000e-01	0.04	0.120025	0.1
20	4.440892e-16	1.000000e+00	0.04	0.120025	0.1

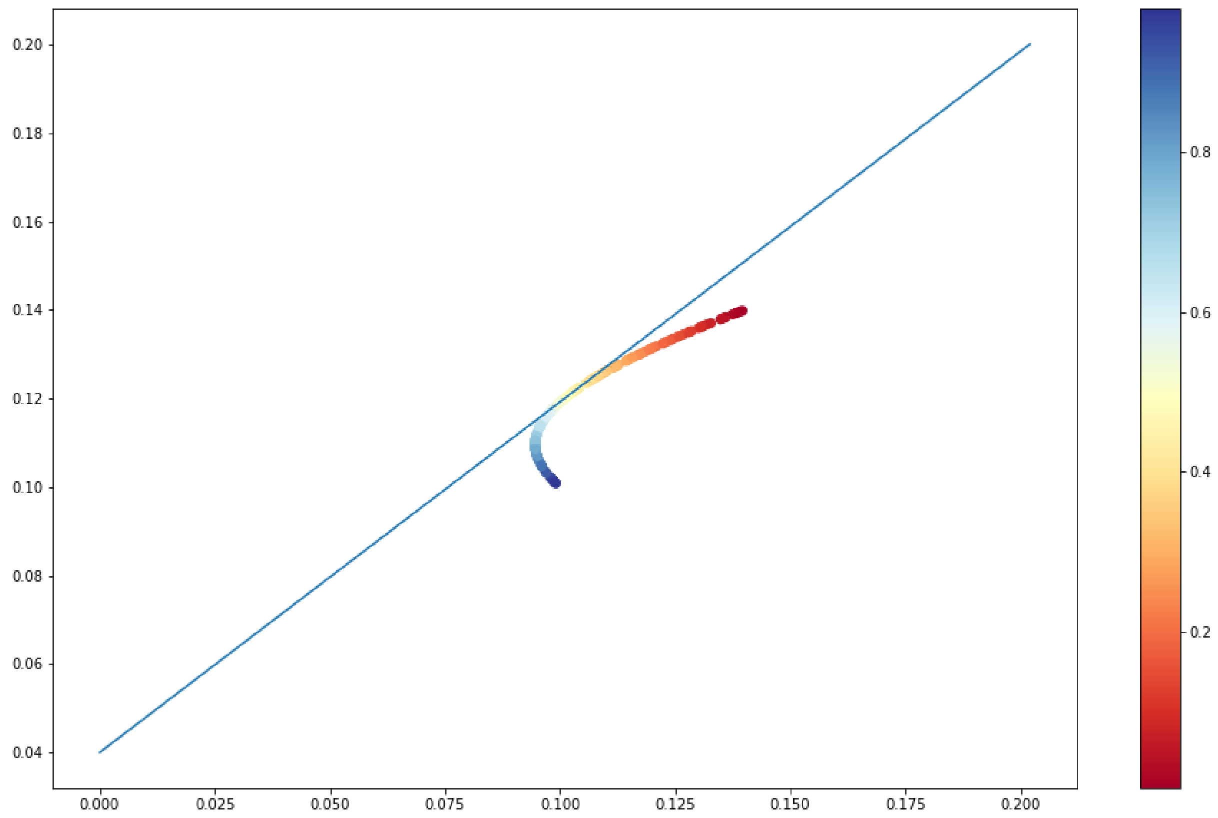
[16]

```
plt.figure(figsize=(16,10))
plt.plot(tangent_p.combined_risk,tangent_p.combined_return)

plt.scatter(results_frame.combined_volatility,results_frame.combi
ned_return,c=results_frame.weight_A,cmap='RdYlBu')

plt.colorbar()
```

```
<matplotlib.colorbar.Colorbar at 0x1a1ec431d0>
```



[17]