# HW6

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## 0.1 ### HW 6

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**I worked by myself on this assignment.**

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```
[1]: import numpy as np

     %matplotlib inline
     import matplotlib.pyplot as plt
```

### 0.1.1  1: Find and plot the roots of $f_1$ and $f_2$

$f_1(x_1, x_2) = x_1^3 - x_2^3 + x_1$

$f_2(x_1, x_2) = x_1^2 - x_2^2 + 1$

Find all points $r_1$ and $r_2$ such that $f_1(r_1, r_2) = 0$ and $f_2(r_1, r_2) = 0$.

Plot all points $r_1$ and $r_2$.

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https://matplotlib.org/tutorials/intermediate/legend_guide.html

https://moonbooks.org/Articles/How-to-plot-a-circle-in-python-using-matplotlib-/

https://matplotlib.org/3.3.1/api/_as_gen/matplotlib.pyplot.contour.html

```
[2]: # f_1 = lambda x, y: (x ** 3) - (y ** 3) + x
     # f_2 = lambda x, y: (x ** 2) + (y ** 2) - 1

     x = np.linspace(-3, 3, 100)
     y = np.linspace(-3, 3, 100)

     X, Y = np.meshgrid(x,y)

     F = X**3 - Y**3 + X
     F2 = X**2 + Y**2 - 1.0
```

1

```
fig, ax = plt.subplots()

CS1 = ax.contour(X,Y,F,[0], colors=['red'])
CS2 = ax.contour(X,Y,F2,[0], colors=['blue'])

ax.set_aspect(1)


plt.title('$\\bf{Roots\ of\ f_1\ and\ f_2}$', fontsize=12)
plt.xlim(-1.25,1.25)
plt.ylim(-1.25,1.25)
plt.grid(linestyle='--')

# adding labels to the contour graph was surprisingly obnoxious
labels = ['$f_1$', '$f_2$']
for i in range(len(labels)):
    if i == 0:
        CS1.collections[i].set_label(labels[i])
    else:
        CS2.collections[0].set_label(labels[i])
plt.legend(loc='upper left')

plt.show()
```
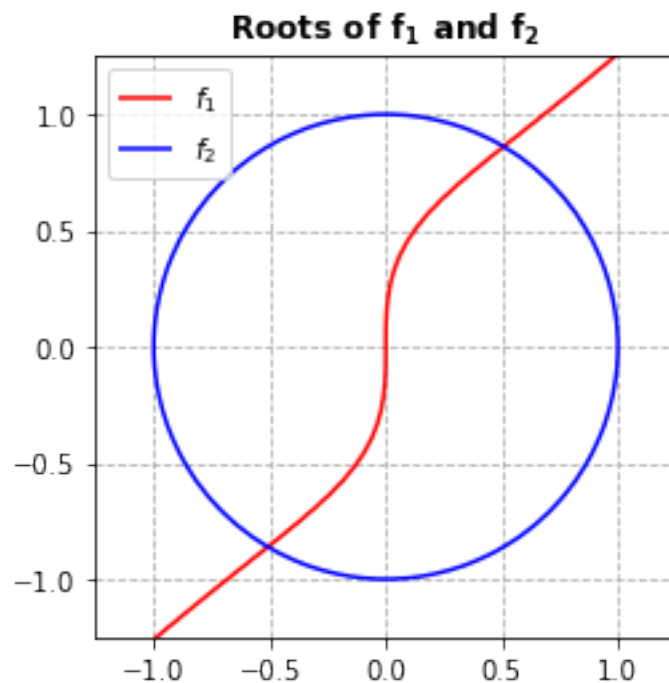
### 0.1.2 2: By hand calculate the Jacobian matrix of the system $(f_1, f_2)$

https://en.wikipedia.org/wiki/Jacobian_matrix_and_determinant

We get:

$$J_f(x_1, x_2) = \begin{bmatrix} \frac{\partial f_1}{\partial x_1} & \frac{\partial f_1}{\partial x_2} \\ \frac{\partial f_2}{\partial x_1} & \frac{\partial f_2}{\partial x_2} \end{bmatrix} = \begin{bmatrix} 3x_1^2 + 1 & -3x_2^2 \\ 2x_1 & -2x_2 \end{bmatrix}$$

### 0.1.3 3: Use Newton's method for systems to find the solution to the given equations $f_1 = 0$ and $f_2 = 0$

http://hplgit.github.io/Programming-for-Computations/pub/p4c/._
p4c-solarized-Python031.html

```python
def Newton_system(F, J, x, eps):
    """
    Solve nonlinear system F=0 by Newton's method.
    J is the Jacobian of F. Both F and J must be functions of x.
    At input, x holds the start value. The iteration continues
    until ||F|| < eps.
    """
    F_value = F(x)
    F_norm = np.linalg.norm(F_value, ord=2)  # l2 norm of vector
    iteration_counter = 0
    while abs(F_norm) > eps and iteration_counter < 100:
        delta = np.linalg.solve(J(x), -F_value)
        x = x + delta
        print(x)
        F_value = F(x)
        F_norm = np.linalg.norm(F_value, ord=3)
        iteration_counter += 1

    # Here, either a solution is found, or too many iterations
    if abs(F_norm) > eps:
        iteration_counter = -1
    return x, iteration_counter
```

```python
def F(x):
    return np.array(
        [x[0]**3 - x[1]**3 + x[0],
         x[0]**2 + x[1]**3 -1])

def J(x):
    return np.array(
```

```
        [[((3 * (x[0]**2)) + 1), (-(3 * x[1]**2))],
         [(2 * x[0]), (-2 * x[1])]]])
```

[10]:
```
tol = 1e-8

init_x = -0.5
init_y = -0.5
step_size = 0.1
num_iterations = 10

for i in range(num_iterations):
    init_x += step_size
    init_y = -1
    for ii in range(num_iterations):
        init_y += step_size
        Newton_system(F, J, [init_x, init_y], tol)
```

```
[4.232875   2.03072222]
[4.41725276 8.6422827 ]
[-162.20745255  -38.10756898]
[-64.9733209 756.6591233]
[3072794.37601031    23163.58320766]
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[-9.46056910e+18 -3.52422788e+14]
[7.98731136e+19 6.21031820e+28]
[-1.49937736e+66 -2.48018726e+48]
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[            inf 1.53718092e+162]
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[ 194120.05578546 9859755.97018176]
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[-7.74272537e+53 -1.66690628e+40]
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```

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```

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```

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```

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```
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```

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[inf inf]
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```

/usr/local/lib/python3.7/site-packages/ipykernel_launcher.py:3: RuntimeWarning:
overflow encountered in double_scalars
  This is separate from the ipykernel package so we can avoid doing imports

```
until
/usr/local/lib/python3.7/site-packages/ipykernel_launcher.py:3: RuntimeWarning:
invalid value encountered in double_scalars
  This is separate from the ipykernel package so we can avoid doing imports
until
/usr/local/lib/python3.7/site-packages/ipykernel_launcher.py:4: RuntimeWarning:
overflow encountered in double_scalars
  after removing the cwd from sys.path.
/usr/local/lib/python3.7/site-packages/ipykernel_launcher.py:4: RuntimeWarning:
invalid value encountered in double_scalars
  after removing the cwd from sys.path.


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```

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[1.09977587e+27 1.18715638e+39]
[-7.60658308e+89 -6.52802971e+65]
[-5.07105382e+089  2.13075859e+131]
[nan nan]
[0.34392857 1.2177381 ]
```

```
[31.93477741 10.51942818]
[ 33.4003028  118.72375219]
[-35043.22855143  -2696.95158725]
[-5.18472440e+02  3.85500975e+06]
[5.52411156e+16 1.00179518e+09]
[3.68274106e+16 5.07685930e+23]
[-1.77657782e+54 -9.34837978e+39]
[-1.18317532e+54  4.36961022e+79]
[3.52572957e+184 2.58500749e+133]
[0.25889655 2.15665517]
[-82.4183812   -5.65909249]
[ -55.88340406 -203.27165586]
[-103329.69210935   -7943.28327206]
[  131619.30506722 33924171.43740805]
[-1.48890307e+17 -2.24121092e+12]
[-9.86914962e+16  2.50990244e+24]
[8.01052123e+55 1.23853009e+41]
[5.34218096e+55 7.66978387e+81]
[-4.22280267e+189 -2.04866867e+137]
[0.15930147 4.87709559]
[-762.90219196   -8.25381007]
[  -509.98813451 -11854.84836441]
[-1.70675216e+09 -3.16653551e+06]
[-1.12107439e+09  4.86918189e+12]
[5.14758571e+28 2.72872930e+21]
[4.47789965e+28 3.72298215e+42]
[-5.76193704e+98 -8.33557023e+70]
[-3.84129136e+098  3.47408655e+141]
[nan nan]
[4.25196850e-02 3.83522289e+15]
[-6.63363835e+47 -1.25578477e+16]
[-4.42242557e+47 -5.84032640e+78]
[-2.25227196e+188 -1.29142044e+126]
[ 0.76138672 -0.18894965]
[0.41809459 2.32439786]
[-37.66534819   -2.00185024]
[ -25.45155382 -124.28437324]
[-47189.96468714   -2062.16032374]
[ -27574.88607307 2033115.31182722]
[1.50345959e+14 2.76577263e+10]
[1.13181151e+14 3.82681522e+20]
[-2.4757598e+47 -2.1656174e+34]
[-1.65048859e+47  2.34494935e+68]
[3.90623058e+157 1.93515607e+115]
[ 0.66491803 -0.08745902]
[0.3105196  5.80012615]
[-457.78255089   -1.98182494]
[  -305.51959023 -17700.17135369]
```

```
[-9.23440169e+09 -2.76307186e+06]
[-6.15638658e+09 -1.32679852e+12]
[-1.90580685e+26 -4.10318119e+21]
[3.90215353e+33 8.41822917e+42]
[-7.64412685e+94 -1.64246113e+76]
[6.22722615e+114 1.34883929e+152]
[0.58756466 0.0378202 ]
[  0.16730778 -15.14678933]
[8.69189976e+03 3.59112999e+00]
[   5795.19858234 3507742.70502031]
[-3.72995037e+15 -1.01785163e+10]
[-2.48663489e+15 -1.76008123e+20]
[-1.09638289e+45 -2.18837061e+35]
[9.53956710e+50 2.39448297e+70]
[-7.19575880e+159 -1.14211655e+121]
[0.52290909 0.19806061]
[-0.05450833 -3.14099359]
[241.75866075    6.14702837]
[ 162.23656301 1651.51194987]
[-15400925.07892788    -147523.14466203]
[-9.28402799e+06  1.07160726e+10]
[6.62162243e+22 4.97011069e+16]
[4.48399920e+22 1.23511565e+33]
[-2.10100626e+76 -2.76912878e+55]
[-1.40067077e+076  3.83403710e+110]
[nan nan]
[0.46478365 0.41317308]
[-0.40914303 -1.43328826]
[-22.40181912  -6.39365547]
[-14.31655298    3.20750276]
[-8.84748271 15.73535578]
[141.70017682  57.34352771]
[ 568.05181536 2930.09781628]
[-27473687.56980111   -1030653.58231291]
[7.58096738e+08 5.51696807e+11]
[-1.10903173e+26 -2.09407525e+20]
[7.80982082e+28 2.19257972e+40]
[-6.74831140e+91 -8.56182738e+68]
[1.40103924e+091 3.66524441e+137]
[ nan -inf]
[0.40734694 0.72265306]
[-0.55669513 -0.13673469]
[-0.04609062  4.47492989]
[421.12594927  10.03796904]
[ 282.49517639 3078.16197124]
[-56850281.95186375   -476770.90161529]
[-2.99191040e+07  1.13476629e+11]
[2.44132843e+25 1.69711215e+18]
```

```
[1.62824823e+25 1.44015346e+36]
[-9.17224616e+82 -1.17246366e+61]
[-6.11471847e+082  6.87335519e+121]
[nan nan]
[0.34519022 1.21807971]
[32.75875553 10.7840114 ]
[ 34.46958569 123.83799732]
[-38368.43331495  -2892.66852297]
[-3.87022847e+02  4.43019941e+06]
[1.12322136e+17 8.60174811e+08]
[7.48814239e+16 2.44451554e+24]
[-9.75381089e+55 -9.15244049e+40]
[-6.50217181e+55  4.18835835e+81]
[5.64992991e+188 1.36167128e+137]
[0.27348837 2.17302326]
[-72.0588327   -4.78231428]
[ -48.84265348 -186.30946401]
[-89429.73591417  -6269.08280287]
[   43090.66287406 20896994.19321714]
[-1.06104736e+17 -4.51149070e+11]
[-7.07347263e+16  9.76090676e+22]
[6.57366404e+51 3.45217284e+39]
[1.64771372e+54 5.95874866e+78]
[-6.42027232e+181 -4.90915596e+132]
[0.18821875 4.952125  ]
[-601.11845041   -5.73776141]
[  -401.70942267 -10586.22318204]
[-1.53480996e+09 -2.21708345e+06]
[-1.01844079e+09  2.28394392e+12]
[5.84651293e+27 1.16251245e+21]
[3.06133849e+28 6.75717736e+41]
[-5.03911893e+96 -1.03430036e+70]
[-3.35941262e+096  5.34888613e+139]
[nan nan]
[8.64864865e-02 3.93006013e+15]
[-3.50929062e+47 -5.12346183e+15]
[-2.33952708e+47 -4.00611964e+78]
[-1.37408523e+188 -4.68621268e+125]
[ 0.70730645 -0.19350358]
[0.39088084 2.27307298]
[-39.74540849  -2.23174798]
[ -26.87843391 -124.28305374]
[-45338.87382985  -2203.57645663]
[ -24585.68451274 2386243.97889214]
[2.73514703e+14 2.90361740e+10]
[1.87099274e+14 4.22023910e+20]
[-2.0086731e+47 -3.9480201e+34]
[-1.33881433e+47  7.79343134e+68]
```

```
[1.76781084e+159 5.21697879e+115]
[ 0.6279322  -0.09120763]
[0.2910278  5.55287156]
[-441.9477032    -2.29022956]
[  -295.01493323 -14287.22492253]
[-5.04674080e+09 -2.16133958e+06]
[-3.36442567e+09  3.71823154e+11]
[7.57105387e+24 6.19876755e+20]
[1.28799535e+33 1.92139327e+41]
[-2.75362316e+90 -1.23737280e+74]
[1.54583544e+115 7.65545729e+147]
[0.56416071 0.0348852 ]
[  0.15306618 -16.38363721]
[1.20675690e+04 5.11660932e+00]
[   8045.8991455  4745608.51621523]
[-6.65285645e+15 -1.91206060e+10]
[-4.43523931e+15 -2.03002843e+20]
[-9.43124002e+44 -4.50192931e+35]
[2.30901675e+52 1.01336838e+71]
[-2.25343462e+160 -1.16994228e+123]
[0.51071698 0.19606918]
[-0.0638549  -3.16631004]
[305.14506032    8.15885971]
[ 204.85285439 1996.68895273]
[-21657821.13337392    -226642.26552201]
[-1.16344101e+07  2.56061585e+10]
[7.21209836e+23 1.48888643e+17]
[4.81278964e+23 1.10844985e+34]
[-1.41488544e+78 -2.66736799e+57]
[-9.43244315e+077  3.55742599e+114]
[nan nan]
[0.4625 0.4125]
[-0.41110184 -1.43475576]
[-22.01975077  -6.30744442]
[-14.08481021   2.92893168]
[-8.79113441 15.4569285 ]
[134.48907503  55.89220272]
[ 572.70238186 2834.09645049]
[-24912709.25562751  -1015428.72960256]
[8.76105316e+08 5.37346867e+11]
[-8.86924224e+25 -2.35770630e+20]
[1.96347862e+29 2.77939689e+40]
[-5.46758479e+91 -2.72864319e+69]
[9.23538980e+093 3.72274682e+138]
[ nan -inf]
[0.4146383  0.72420213]
[-0.54977075 -0.13744652]
[-0.03923164  4.45236646]
```

```
[438.97473379   10.38369008]
[ 294.45469575 3233.52045362]
[-63173274.17448526    -521712.65609517]
[-3.28441879e+07  1.35939251e+11]
[3.82332470e+25 2.23186801e+18]
[2.54973188e+25 2.49072671e+36]
[-3.03007740e+83 -3.17534265e+61]
[-2.01999623e+083  5.04140046e+122]
[nan nan]
[0.36256818 1.22405303]
[51.1327403   16.65670118]
[ 60.89626062 263.805226  ]
[-196453.13676481   -10295.46825775]
[2.08187284e+04 5.52596025e+07]
[-4.05417722e+18 -5.75397288e+11]
[-2.70278490e+18 -4.59533044e+24]
[-1.79518418e+55 -6.21009852e+42]
[2.30751050e+60 1.92826618e+85]
[          -inf -2.22474724e+145]
[0.30214634 2.18963415]
[-58.30680819  -3.70803468]
[ -39.50211022 -159.42614996]
[-67921.13329806   -4275.46538498]
[-7.39897966e+03  9.55749081e+06]
[5.89513544e+16 3.53368631e+10]
[3.93009090e+16 1.70154658e+22]
[-6.2675808e+49 -3.3436241e+38]
[1.59084732e+54 5.58991105e+76]
[-5.48979587e+175 -4.44634750e+130]
[0.22981579 5.00592105]
[-462.08926724    -3.78357331]
[ -308.69441958 -9479.89200088]
[-1.42625864e+09 -1.51866371e+06]
[-9.4978365e+08  9.3091342e+11]
[4.24258270e+26 4.41632589e+20]
[1.05953464e+29 9.75197733e+40]
[-4.37656008e+93 -5.16627887e+69]
[-2.89911089e+093  1.33452187e+139]
[nan nan]
[1.42857143e-01 3.98890253e+15]
[-2.22140792e+47 -2.27937287e+15]
[-1.48093861e+47 -3.60819506e+78]
[-1.58599922e+188 -2.67175769e+125]
```

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Honestly, I couldn't figure out the issue with Newton's method for systems...