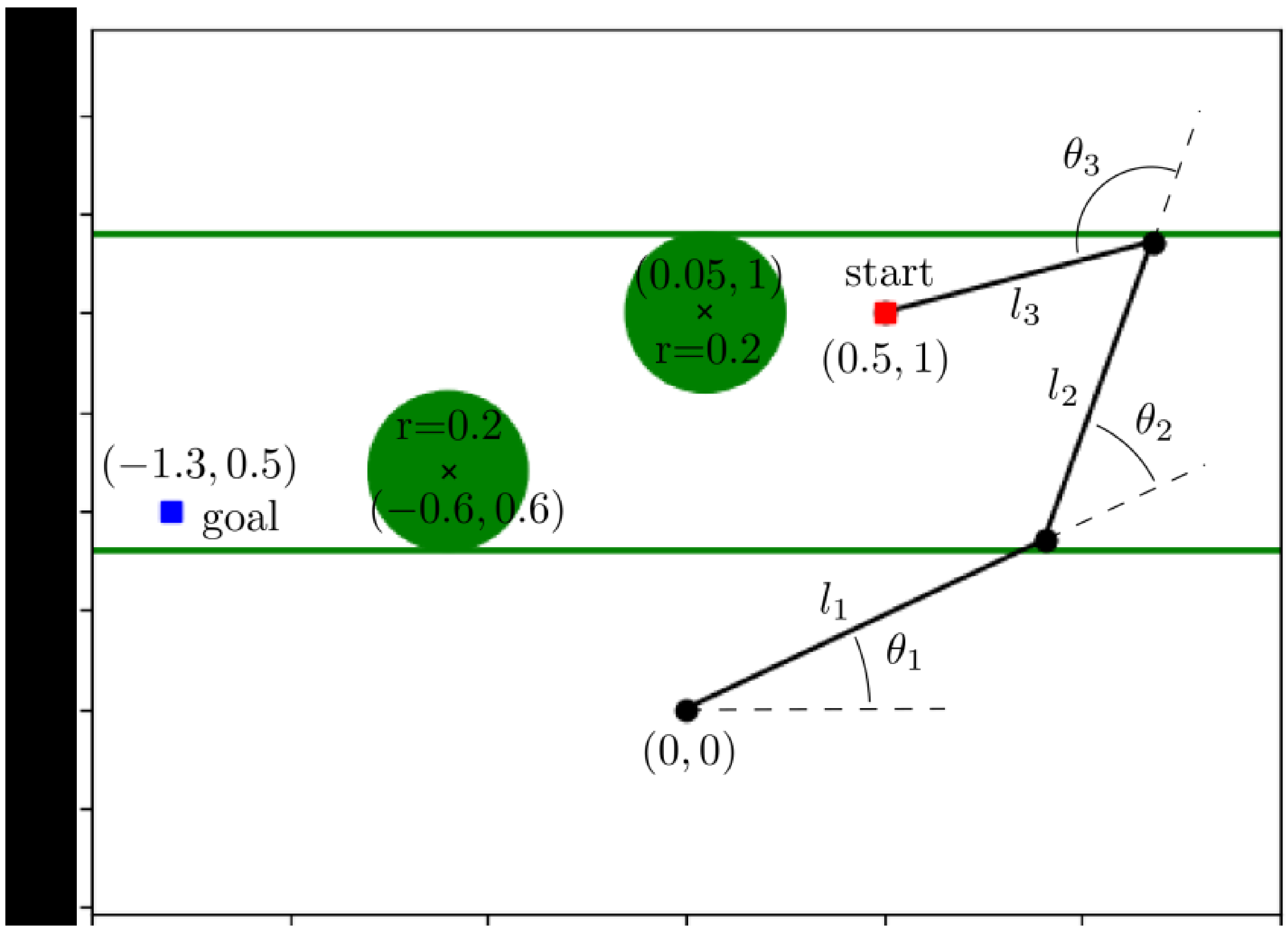
לראות את התוצאות אונליין (ביחד עם גיפים) יש ללחוץ על הלינק הבא (מומלץ):

Click [HERE (https://github.com/imishani/Robotics_course)](https://github.com/imishani/Robotics_course) Link to github repository

In [1]:
```python
from sympy import *
import numpy as np
import pandas as pd
from mpl_toolkits import mplot3d
from matplotlib import pyplot as plt
import math
from math import pi
```

In [2]:
```python
def DH(alpha, theta, a, d):
    return np.array([[cos(theta), -sin(theta)*cos(alpha), sin(theta)*sin(alpha), a*cos(theta)], [sin(theta), cos(theta)*cos(alpha), -cos(theta)*sin(alpha), a*sin(theta)]
            , [0, sin(alpha), cos(alpha), d], [0, 0, 0, 1]])
```



$question1:$

In [3]:
```python
'''from now on this is the implementation of the specific hw'''

theta1, l1, theta2, l2, theta3, l3 = symbols('theta1 l1 theta2 l2 theta3 l3')

A01 =DH(0, theta1, 1, 0)
A12 = DH(0, theta2, 0.8, 0)
A23 = DH(0, theta3, 0.7, 0)
A = simplify(np.dot(np.dot(A01,A12), A23))
A
```

Out[3]:

$$\begin{bmatrix} \cos(\theta_1+\theta_2+\theta_3) & -\sin(\theta_1+\theta_2+\theta_3) & 0 & 1.0\cos(\theta_1)+0.8\cos(\theta_1+\theta_2)+0.7\cos(\theta_1+\theta_2+\theta_3) \\ \sin(\theta_1+\theta_2+\theta_3) & \cos(\theta_1+\theta_2+\theta_3) & 0 & 1.0\sin(\theta_1)+0.8\sin(\theta_1+\theta_2)+0.7\sin(\theta_1+\theta_2+\theta_3) \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

In [4]:
```python
def circle(x, a, y, b, R):
    r = ((x-a)**2 + (y-b)**2)**0.5
    if r > R:
        return False
    return True
```

In [5]:
```python
q1 = np.random.randint(-180, 180, 10000)
q1 = (q1*np.pi)/180
q2 = np.random.randint(0, 180, 10000)
q2 = (q2*np.pi)/180
q3 = np.random.randint(-180, 180, 10000)
q3 = (q3*np.pi)/180

bubble_1, bubble_2, bubble_3 = [], [], []
free_1, free_2, free_3 = [], [], []
xxx, yyy = [], []
for ind in range(10000):
    Ai = A.subs([(theta1, q1[ind]), (theta2, q2[ind]), (theta3, q3[ind])])
    bi = Ai[:2,3]
    if bi[1] <= 0.4 or bi[1] >= 1.2 or circle(bi[0], 0.05, bi[1], 1, 0.2) or circle(bi[0], -0.6, bi[1], 0.6, 0.2):
        bubble_1.append(q1[ind]*(180/np.pi))
        bubble_2.append(q2[ind]*(180/np.pi))
        bubble_3.append(q3[ind]*(180/np.pi))
    else:
        free_1.append(q1[ind]*(180/np.pi))
        free_2.append(q2[ind]*(180/np.pi))
        free_3.append(q3[ind]*(180/np.pi))
        xxx.append(bi[0])
        yyy.append(bi[1])
```

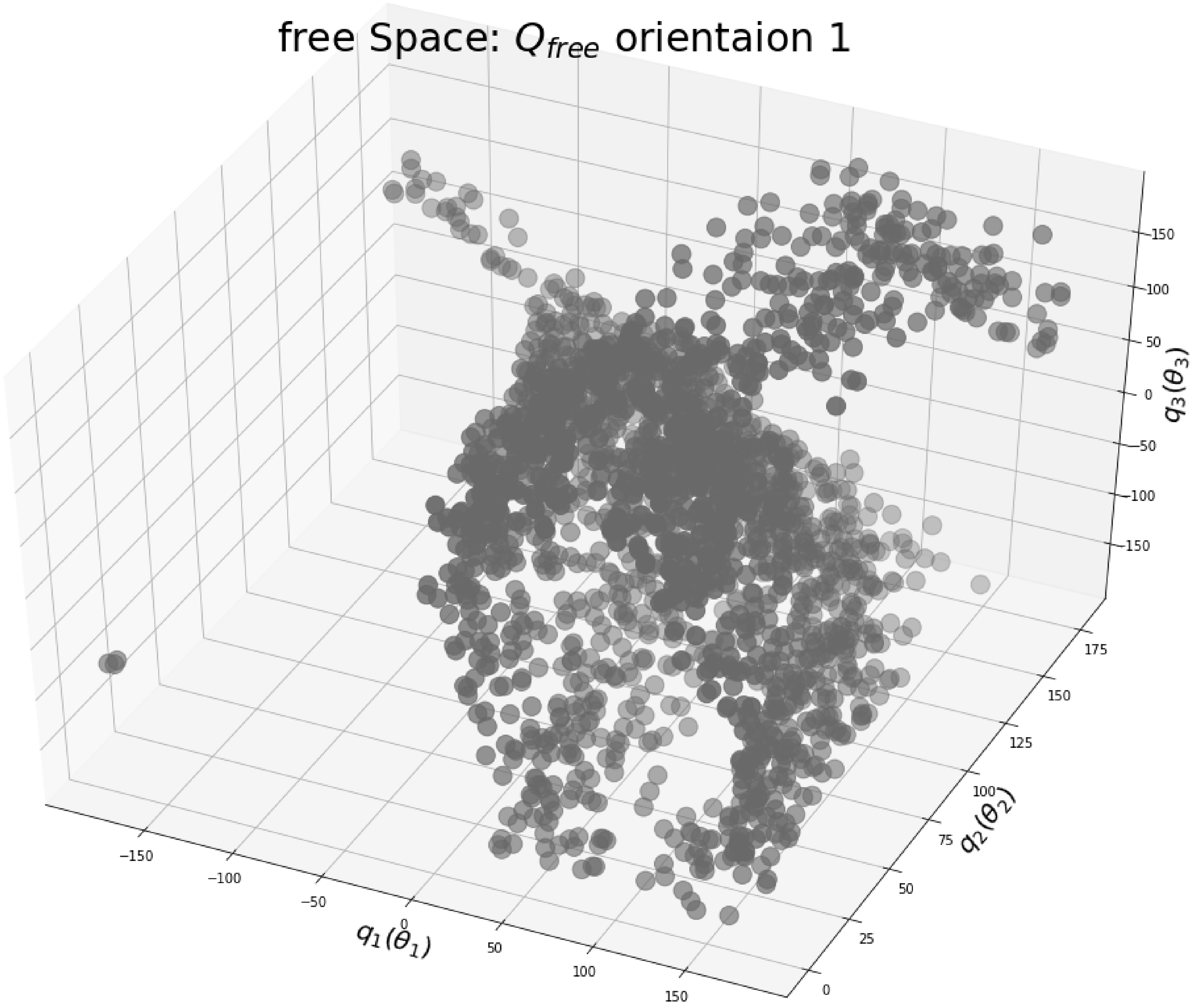
In [6]:
```python
def three_d(df, title, orientation):
    plt.close()
    fig = plt.figure(figsize=(20, 15))
    ax = fig.add_subplot(111, projection='3d')
    ax.scatter(df['q1'], df['q2'], df['q3'], c='dimgray', s=200, marker='o') #skyblue
    ax.view_init(orientation[0], orientation[1])
    ax.set_xlabel(r'$q _1  ( \theta _1) $', fontsize=20)
    ax.set_ylabel(r'$q _2  ( \theta _2) $', fontsize=20)
    ax.set_zlabel(r'$q _3  ( \theta _3) $', fontsize=20)
    plt.title(title, fontsize=30)
    plt.show()
```

In [7]:
```
obs = pd.DataFrame({'q1':bubble_1, 'q2':bubble_2, 'q3':bubble_3})
free = pd.DataFrame({'q1':free_1, 'q2':free_2, 'q3':free_3, 'x':xxx, 'y':yyy})
```

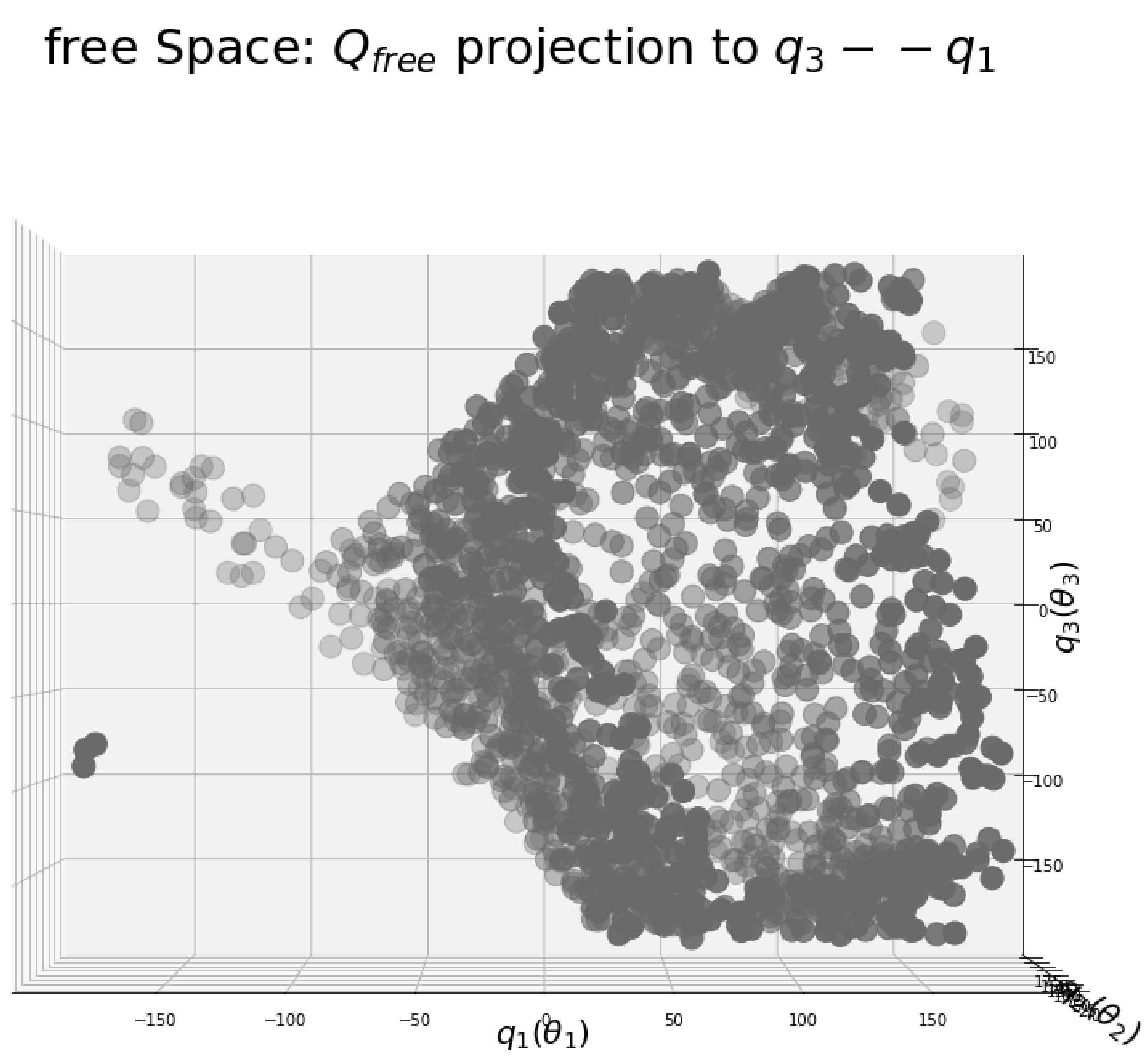
In [8]:
```
#three_d(obs, 'Obsticle Space: $ Q _{obs} orientaion 1 $', [30, 75])
```

In [9]:
```
# import qgrid
# qgrid.show_grid(free, show_toolbar=True)
```

In [10]:
```
three_d(free, 'free Space: $Q _{free}$ orientaion 1 ', (45, -65))
```

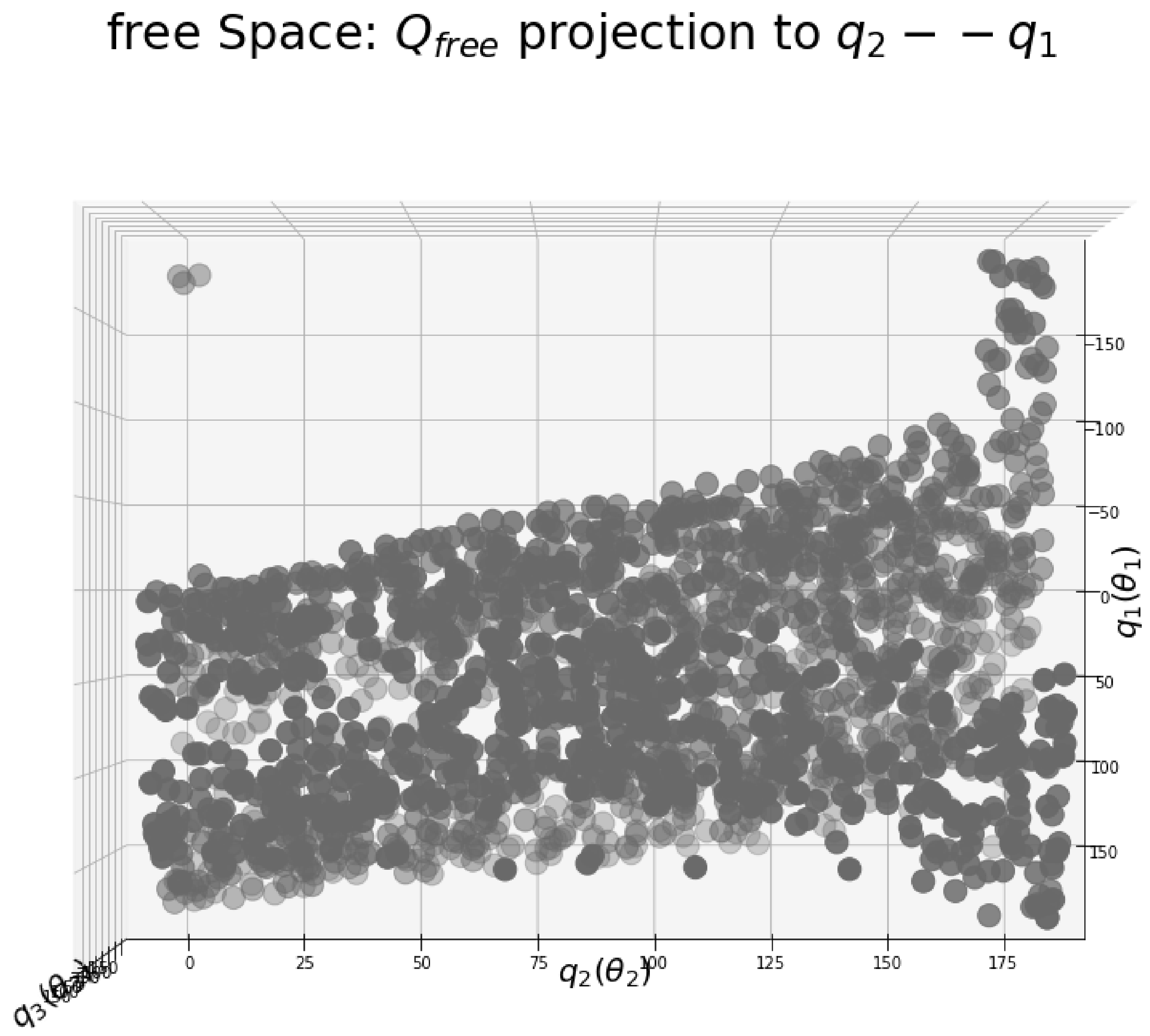


In [11]:
```
three_d(free, 'free Space: $Q _{free}$ projection to $q _{3}--q _{1}$', (0, -90))
```



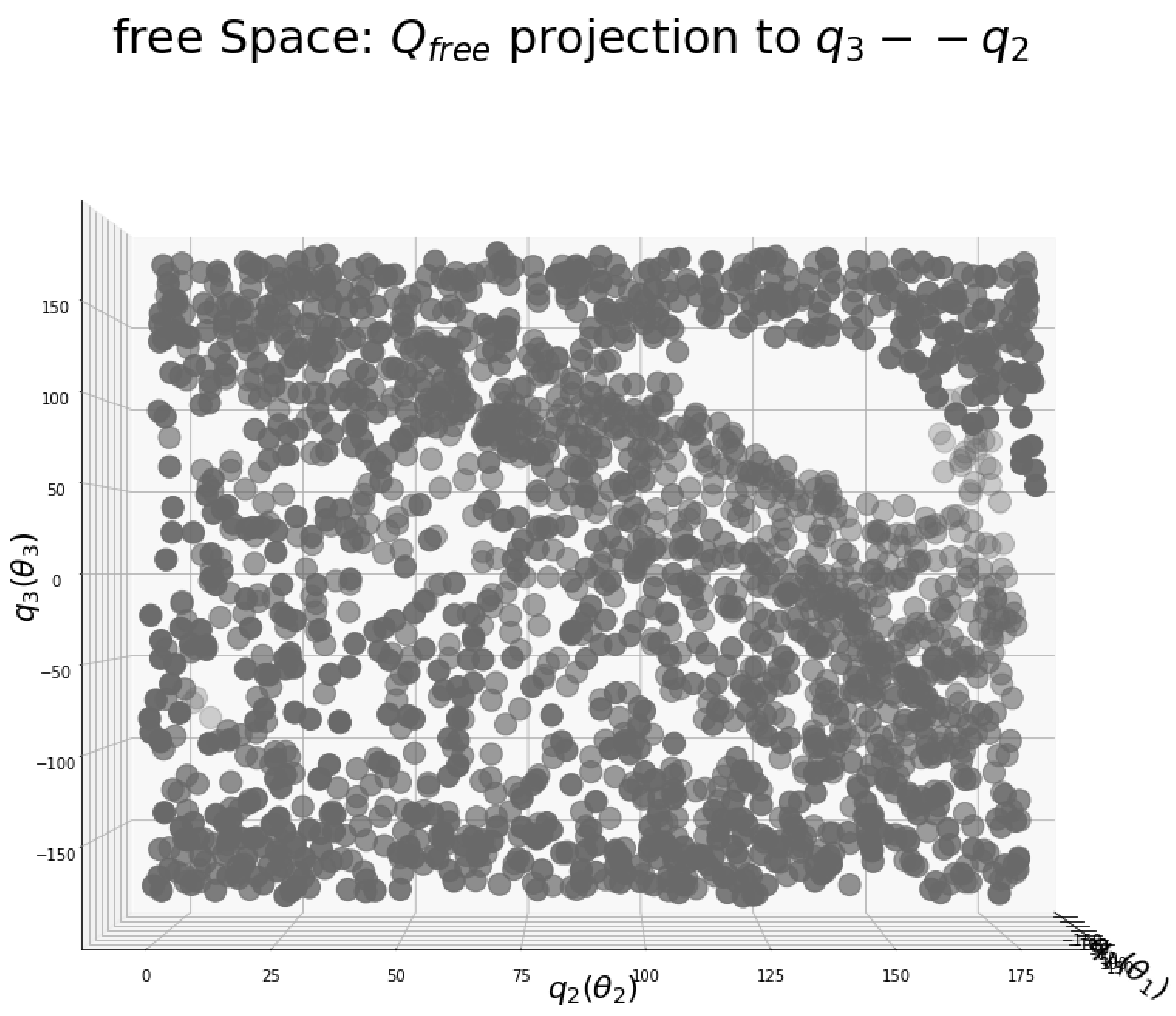
In [12]:

```
three_d(free, 'free Space: $Q _{free}$ projection to $ q _{2} -- q _{1}$', (90, 0))
```



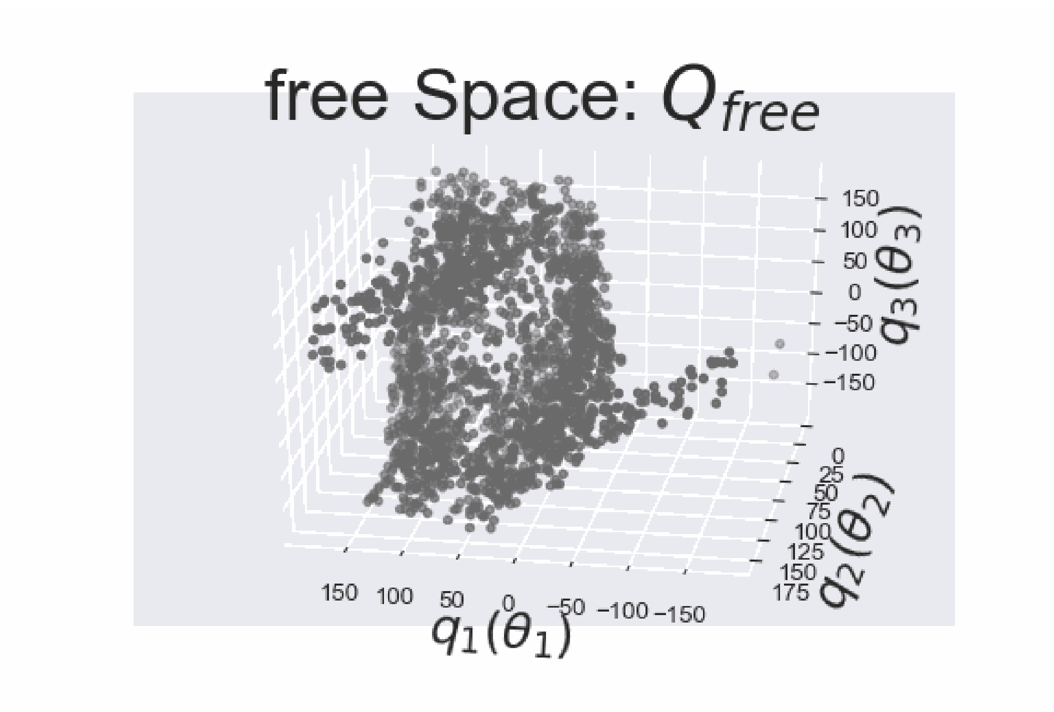
In [13]:

```
three_d(free, 'free Space: $Q _{free}$ projection to $ q _{3} -- q _{2}$', (0, 0))
```



In [14]:
```
from mpl_toolkits.mplot3d import Axes3D



# We are going to do 20 plots, for 20 different angles
for angle in range(70,210,2):

# Make the plot
    fig = plt.figure()
    ax = fig.gca(projection='3d')
    ax.scatter(free['q1'], free['q2'], free['q3'], c='dimgray', s=10, marker='o')
    ax.set_xlabel(r'$q _1  ( \theta _1) $', fontsize=20)
    ax.set_ylabel(r'$q _2  ( \theta _2) $', fontsize=20)
    ax.set_zlabel(r'$q _3  ( \theta _3) $', fontsize=20)
    plt.title('free Space: $Q _{free}$ ', fontsize=30)
    ax.view_init(30,angle)

    filename= 'togif\Volcano_step'+str(angle)+'.png'
    #plt.savefig(filename, dpi=96)
    plt.gca()
    plt.close(fig)
```

In [15]:
```
import glob
from PIL import Image


# Create the frames
frames = []
imgs = glob.glob("togif\*.png")
for i in imgs:
    new_frame = Image.open(i)
    frames.append(new_frame)

#Save into a GIF file that loops forever

frames[0].save('png_to_gif.gif', format='GIF',
               append_images=frames[1:],
               save_all=True,
               duration=300, loop=0)
```



:question 2

.a

נרצה לתכנן את המסלול של התפסנית מנקודת ההתחלה לנקודת הסיום.

תחילה, נגדיר את נקודות ההתחלה והסוף של המסלול. לאחר מכן, נגדיר עוד כ3 נקודות בדרך.
לאחר שנקבל את הנקודות דרכם נדרוש שהתפסנית תעבור, נתכנן את המסלול בשיטת הפולינומים (polynomial interpulation).
תוך שרשור פולינומים לצורך הורדת סדר המשוואה

In [18]:
```
sx, sy = 0.5, 1
gx, gy = -1.3, 0.5
```

יישום האינטרפולציה הפולינומיאלית:

$$\theta_i(t) = b_0 + b_1 t + b_2 t^2 + b_3 t^3$$

$$\theta_i(0) = \theta_{i-1,end}$$
$$\theta_i(T_i) = \theta_{i,end}$$
$$\dot{\theta}_i(0) = 0$$
$$\dot{\theta}_i(T_i) = 0$$

In [19]:
```
theta_s = np.array([30, 8.682187, 141.317813]) #i=0
theta_g = np.array([100, 70.588, 70.588]) #i=g

theta_p1 = np.array([30, 90, 120]) #i=1
theta_p2 = np.array([45, 100, 100]) #i=2
theta_p3 = np.array([60, 75, 80]) #i=3

def poly_iter(t, T, theta_start, theta_goal):
    return theta_start + ((3*((t/T)**2))-(2*((t/T)**3)))*(theta_goal-theta_start)
def linear_iter(t, T, theta_start, theta_goal):
    return theta_start + t*(theta_goal-theta_start)
```

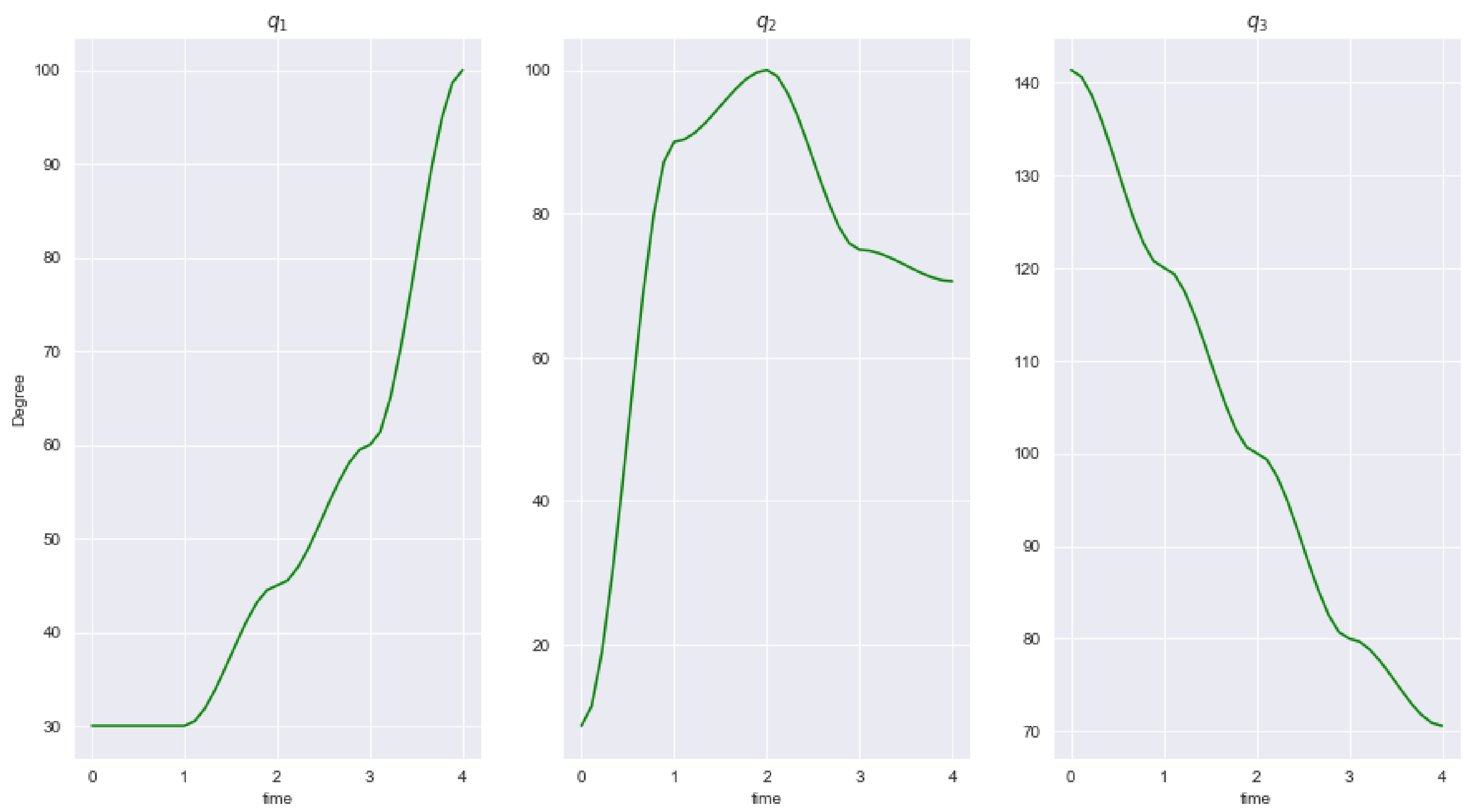
In [20]:
```
# print(cos(theta_p3[0]*(pi/180)) + 0.8*cos(theta_p3[0]*(pi/180) + theta_p3[1]*(pi/180)) + 0.7*cos(theta_p3[0]*(pi/180) + theta_p3[1]*(pi/180) + theta_p3[2]*(pi/180)))
# sin(theta_p3[0]*(pi/180)) + 0.8*sin(theta_p3[0]*(pi/180) + theta_p3[1]*(pi/180)) + 0.7*sin(theta_p3[0]*(pi/180) + theta_p3[1]*(pi/180) + theta_p3[2]*(pi/180))
```

In [21]:
```
t_array = np.linspace(0,1,10)
T = 1
rout_1 = [poly_iter(i, T, theta_s, theta_p1) for i in t_array]
rout_2 = [poly_iter(i, T, theta_p1, theta_p2) for i in t_array]
rout_3 = [poly_iter(i, T, theta_p2, theta_p3) for i in t_array]
rout_4 = [poly_iter(i, T, theta_p3, theta_g) for i in t_array]
```

In [22]:
```python
q1_time, q2_time, q3_time = [theta_s[0]], [theta_s[1]], [theta_s[2]]
x_time, y_time = [0.5], [1]
for rout in [rout_1, rout_2, rout_3, rout_4]:
    for q in rout[1:]:
        q1_time.append(q[0])
        q2_time.append(q[1])
        q3_time.append(q[2])
        x_time.append(cos(q[0]*(pi/180)) + 0.8*cos(q[0]*(pi/180) + q[1]*(pi/180)) + 0.7*cos(q[0]*(pi/180) + q[1]*(pi/180) + q[2]*(pi/180)))
        y_time.append(sin(q[0]*(pi/180)) + 0.8*sin(q[0]*(pi/180) + q[1]*(pi/180)) + 0.7*sin(q[0]*(pi/180) + q[1]*(pi/180) + q[2]*(pi/180)))
t = np.linspace(0, 4, 37)
```

גרף זוויות המנועים כתלות בזמן:

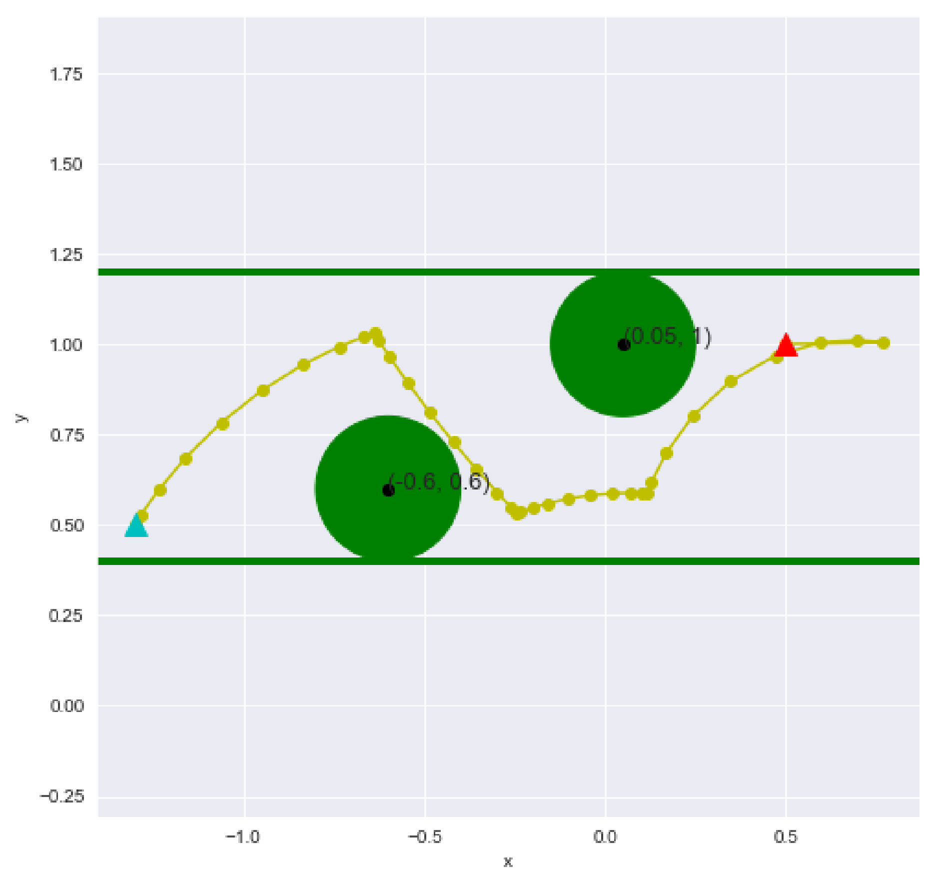
In [23]:
```python
import seaborn as sns

sns.set_style('darkgrid')

fig, axs = plt.subplots(1, 3, figsize=(15, 8))
axs[0].plot(t, q1_time, color='g')
axs[0].set_title('$q_1$')
axs[0].set_xlabel('time')
axs[0].set_ylabel('Degree')
axs[1].plot(t, q2_time, color='g')
axs[1].set_title('$q_2$')
axs[1].set_xlabel('time')
axs[2].plot(t, q3_time, color='g')
axs[2].set_title('$q_3$')
axs[2].set_xlabel('time')
plt.savefig('2_b.png')
plt.show()
```



גרף מיקום התפסנית במישור X-Y:

In [24]:
```python
fig, ax = plt.subplots(figsize=(8, 8))
plt.plot(x_time, y_time, color='y', marker='o') #rx_new, ry_new
plt.axhline(y=1.2, color='g', linestyle='-', lw=4)
plt.axhline(y=0.4, color='g', linestyle='-', lw=4)
plt.plot(sx, sy, "^r", ms=12)
plt.plot(gx, gy, "^c", ms=12)
circle1 = plt.Circle((0.05, 1), 0.2, color='g')
circle2 = plt.Circle((-0.6, 0.6), 0.2, color='g')
ax.add_artist(circle1)
ax.add_artist(circle2)
ax.set_xlabel('x')
ax.set_ylabel('y')
plt.plot(-0.6, 0.6,'black', marker='o')
plt.text(-0.6, 0.6, '({}, {})'.format(-0.6, 0.6), fontsize=13)
plt.plot(0.05, 1,'black', marker='o')
plt.text(0.05, 1, '({}, {})'.format(0.05, 1), fontsize=13)
plt.grid(True)
plt.axis("equal")
#plt.savefig('2_c.png')
```

Out[24]:
```
(-1.4036767040427507, 0.8692245003908856, 0.36000000000000004, 1.24)
```



In [25]:
```python
plt.close('all')
```

שימוש באלגוריתם PRM:

:[26] In
```
def points_on_circle(center=(0, 0), r=50, n=100):
    return [
        (
            center[0]+(math.cos(2 * pi / n * x) * r),
            center[1] + (math.sin(2 * pi / n * x) * r)

        ) for x in range(0, n + 1)]


top_circle = points_on_circle((0.05, 1), 0.2, 100)
bottom_circle = points_on_circle((-0.6, 0.6), 0.2, 100)
top_line = [(x, 1.2) for x in np.linspace(-1.5, 1.5, num=100)]
bottom_line = [(x, 0.4) for x in np.linspace(-1.5, 1.5, num=100)]
all_obs = top_circle + bottom_circle + top_line + bottom_line
```

:[27] In
```
ox, oy = [], []
for x in all_obs:
    ox.append(x[0])
    oy.append(x[1])
```

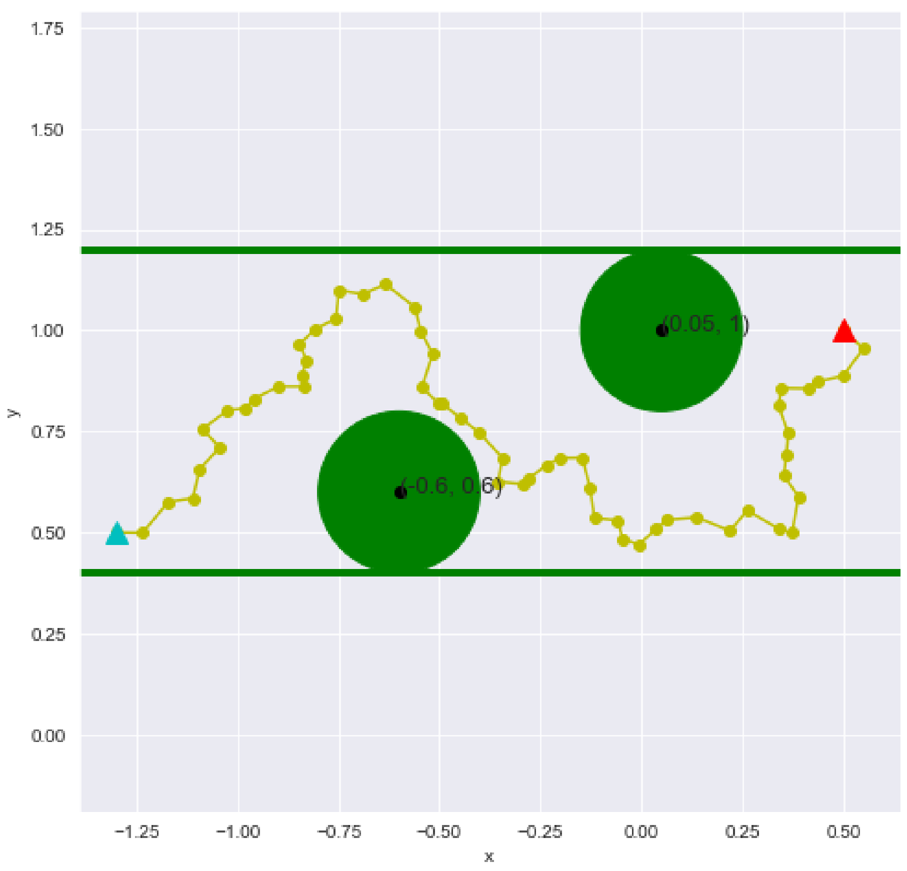
:[28] In
```
import sys
sys.path.insert(1, 'C:/Users/owner/PythonRobotics/PathPlanning/ProbabilisticRoadMap')
import probabilistic_road_map
```

:[29] In
```
rx, ry = probabilistic_road_map.PRM_planning(sx, sy, gx, gy, ox, oy, 0.01)
```

!goal is found

:[30] In
```
rx_new = rx.copy()
rx_new = rx_new[::-1]
ry_new = ry.copy()
ry_new = ry_new[::-1]
```

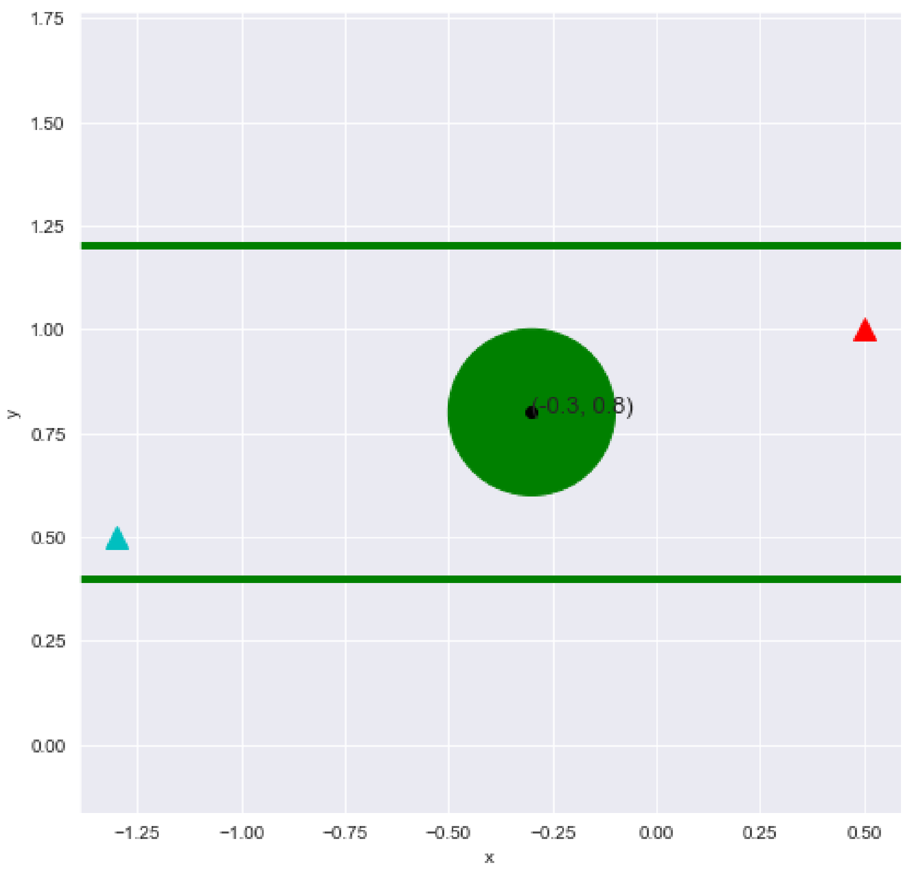
:[32] In
```
fig, ax = plt.subplots(figsize=(8, 8))
plt.plot(rx_new, ry_new, color='y', marker='o')
plt.axhline(y=1.2, color='g', linestyle='-', lw=4)
plt.axhline(y=0.4, color='g', linestyle='-', lw=4)
plt.plot(sx, sy, "^r", ms=12)
plt.plot(gx, gy, "^c", ms=12)
circle1 = plt.Circle((0.05, 1), 0.2, color='g')
circle2 = plt.Circle((-0.6, 0.6), 0.2, color='g')
ax.add_artist(circle1)
ax.add_artist(circle2)
ax.set_xlabel('x')
ax.set_ylabel('y')
plt.plot(-0.6, 0.6,'black', marker='o')
plt.text(-0.6, 0.6, '({}, {})'.format(-0.6, 0.6), fontsize=13)
plt.plot(0.05, 1,'black', marker='o')
plt.text(0.05, 1, '({}, {})'.format(0.05, 1), fontsize=13)
plt.grid(True)
plt.axis("equal")
#plt.savefig('PRM.png')
```



:question 3

In [33]:
```
plt.close('all')
fig, ax = plt.subplots(figsize=(8, 8))
#plt.plot(rx, ry, color='y', marker='o')
plt.axhline(y=1.2, color='g', linestyle='-', lw=4)
plt.axhline(y=0.4, color='g', linestyle='-', lw=4)
plt.plot(sx, sy, "^r", ms=12)
plt.plot(gx, gy, "^c", ms=12)
circle1 = plt.Circle((-0.3, 0.8), 0.2, color='g')
ax.add_artist(circle1)
plt.plot(-0.3, 0.8,'black', marker='o')
plt.text(-0.3, 0.8, '({}, {})'.format(-0.3, 0.8), fontsize=13)
ax.set_xlabel('x')
ax.set_ylabel('y')
plt.grid(True)
plt.axis("equal")
```

Out[33]:
```
(1.24 ,0.36000000000000004 ,0.59 ,1.3900000000000001-)
```



כעת, נתכנן מסלול באמצעות פונקציית פוטנציאל (2 יישומים שונים):

תחילה נגדיר את פונקציות הפוטנציאל, נגזור אותן ונקבל את גרדיאנט פונקציית הפוטנציאל:

In [34]:
```
zeta = 5  # attractive potential gain
eta = 0.5 # repulsive potential gain


def attractive_f(x, y, gx, gy):
    return np.array([zeta*(x - gx), zeta*(y - gy)])

def repulsive_f(x, y, gx, gy, q_star):
    dq = np.hypot(x+0.3, y-0.8) - 0.2
    grad_dq = np.array([(x+0.3)/(dq+0.2), (y-0.8)/(dq+0.2)])
    if dq <= q_star:
        return eta*((1/q_star) - (1/dq))*(1/(dq**2))*grad_dq
    return 0

def potential_grad(x, y, gx, gy, q_star):
    return -1*(attractive_f(x, y, gx, gy) + repulsive_f(x, y, gx, gy, q_star))
```

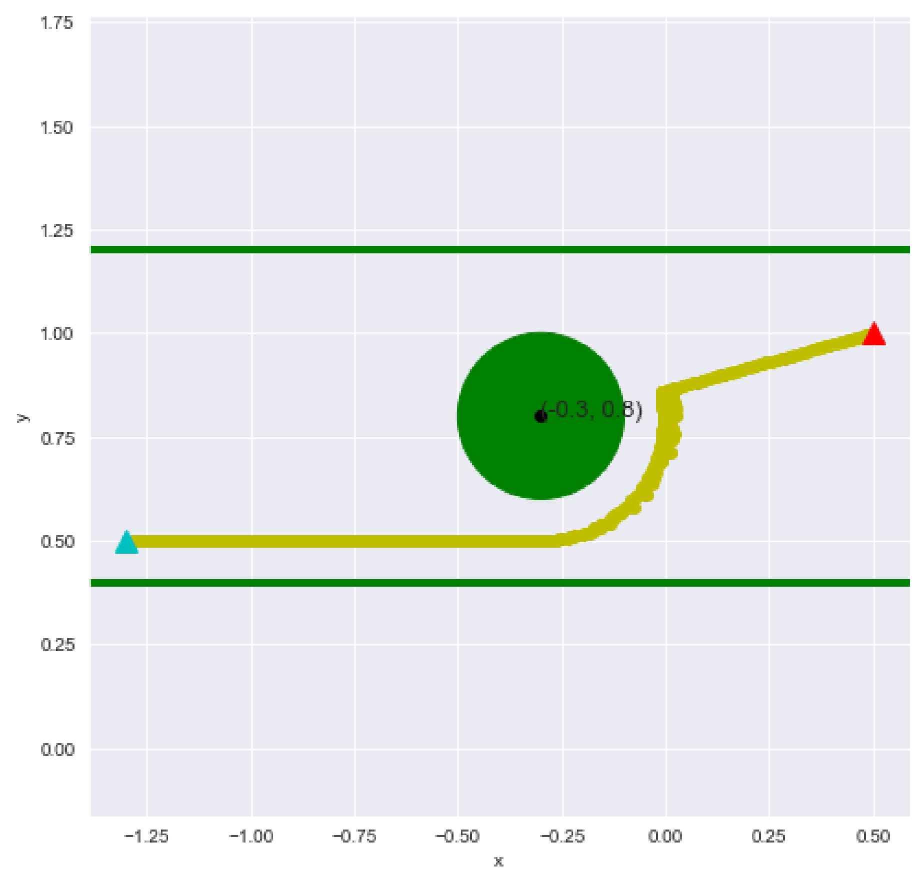
In [35]:
```
xx, yy =[], []
q = np.array([sx, sy])
p = potential_grad(q[0], q[1], gx, gy, 0.01)
```

כעת נבצע איטרציות עד שנגיע למטרה:

In [36]:
```
while np.hypot(p[0], p[1]) > 0.1:
    q += 0.001*p
    xx.append(q[0])
    yy.append(q[1])
    p = potential_grad(q[0], q[1], gx, gy, 0.1)
```

:[37] In
```python
plt.close('all')
fig, ax = plt.subplots(figsize=(8, 8))
#plt.plot(rx2, ry2, color='y', marker='o')
plt.plot(xx, yy, color='y', marker='o', lw=1)
plt.axhline(y=1.2, color='g', linestyle='-', lw=4)
plt.axhline(y=0.4, color='g', linestyle='-', lw=4)
plt.plot(sx, sy, "^r", ms=12)
plt.plot(gx, gy, "^c", ms=12)
circle1 = plt.Circle((-0.3, 0.8), 0.2, color='g')
ax.add_artist(circle1)
plt.plot(-0.3, 0.8,'black', marker='o')
plt.text(-0.3, 0.8, '({}, {})'.format(-0.3, 0.8), fontsize=13)
ax.set_xlabel('x')
ax.set_ylabel('y')
plt.grid(True)
plt.axis("equal")
#plt.savefig('3_a.png')
```

Out[37]:
```
(1.2399999999999998 ,0.36000000000000004 ,0.59 ,1.3900000000000001-)
```



יישום נוסף:

:[38] In
```python
sys.path.insert(1, 'C:/Users/owner/PythonRobotics/PathPlanning/PotentialFieldPlanning')
import potential_field_planning
```

:[39] In
```python
circle = points_on_circle((-0.3, 0.8), 0.2, 500)
all_obs2 = circle + top_line + bottom_line
```

:[40] In
```python
ox2, oy2 = [], []
for x in all_obs2:
    ox2.append(x[0])
    oy2.append(x[1])
```

:[42] In
```python
rx2, ry2 = potential_field_planning.potential_field_planning(sx, sy, gx, gy, ox2, oy2, 0.1, 0.05)
```

```
!!Goal
```

:[43] In
```python
plt.close(fig)
fig, ax = plt.subplots(figsize=(8, 8))
plt.plot(rx2, ry2, color='y', marker='o')
#plt.plot(xx, yy, color='y', marker='o')
plt.axhline(y=1.2, color='g', linestyle='-', lw=4)
plt.axhline(y=0.4, color='g', linestyle='-', lw=4)
plt.plot(sx, sy, "^r", ms=12)
plt.plot(gx, gy, "^c", ms=12)
circle1 = plt.Circle((-0.3, 0.8), 0.2, color='g')
ax.add_artist(circle1)
plt.plot(-0.3, 0.8,'black', marker='o')
plt.text(-0.3, 0.8, '({}, {})'.format(-0.3, 0.8), fontsize=13)
ax.set_xlabel('x')
ax.set_ylabel('y')
plt.grid(True)
plt.axis("equal")
plt.savefig('3_b.png')
```