Start coding or generate with AI.

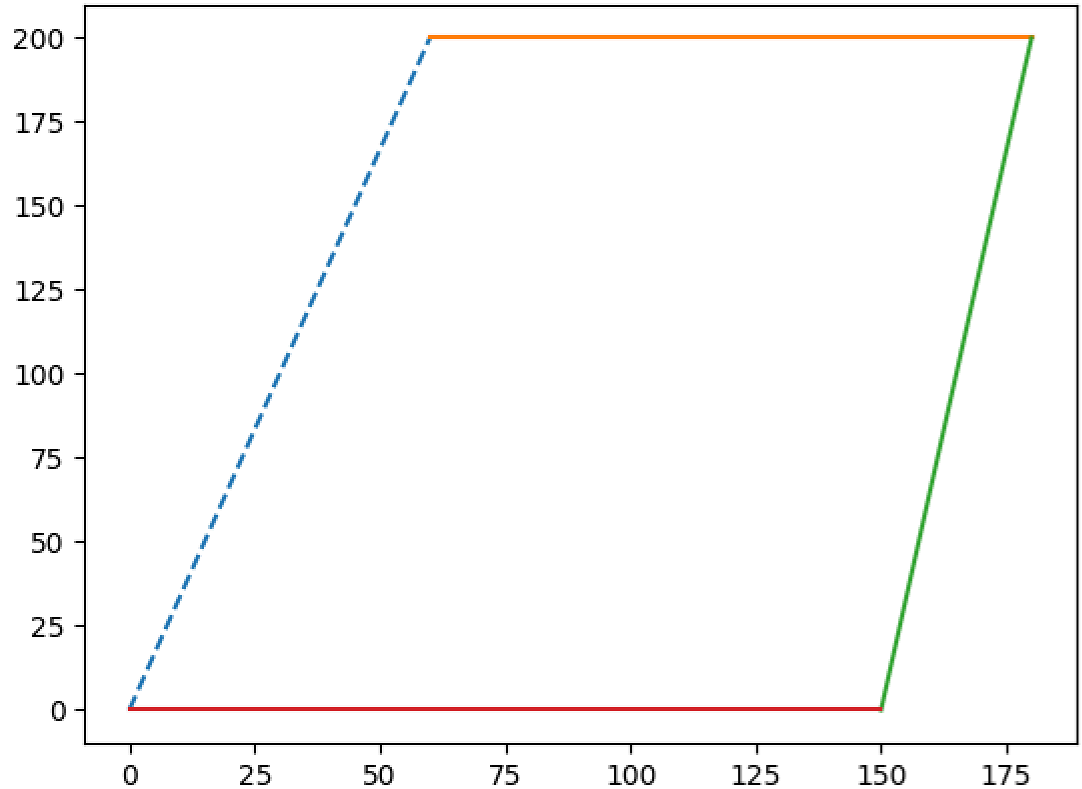
Solver for 4 Bar Configs!

```
import matplotlib.pyplot as plt
import numpy as np
import matplotlib.animation as anim
from IPython.display import HTML
```

## Basic Function of 4 Bar Solver

```
# Inputs

ground_x = 200
ground_y = 60
ground_ang = float(np.angle(ground_x + ground_y*1j))

lengths = {'G': float(np.abs(ground_x + ground_y*1j)), # Ground
           '1': 120, # Drive Link
           '2': 0, # Connector Link
           '3': 150, # Output Link
           }
lengths['2'] = float(np.abs(ground_x + (lengths['3'] - lengths['1'])*1j))

angles = {'G': 180 * np.pi/180, # Required to be 180 to solve. Map if you wan other angles
          '1': np.pi/2 + ground_ang}
omegas = {'G':0,
        '1': 1.5} # Rad/s
alphas = {'G':0,
          '1':.4} # Rad/s

config = True

vectors = {'G': 0}
vectors['G'] = lengths['G'] * np.exp(angles['G'] * 1j)
vectors['1'] = lengths['1'] * np.exp(angles['1'] * 1j)


# Using the coordinate @ end of L1 to find the B & C Angles

C = vectors['G'] + vectors['1']

unit_i = -1 * C/ np.abs(C)
unit_j = unit_i * 1j

# Finding the unknown angles
```

```
Ax = (lengths['2']**2 + np.abs(C)**2 - lengths['3']**2) / (2 * np.abs(C))
Bx = np.abs(C) - Ax

Ay = np.sqrt(lengths['2']**2 - Ax**2)
By = np.sqrt(lengths['3']**2 - Bx**2)
if config:
    By = By * -1
else:
    Ay = Ay * -1

vectors['2'] = unit_i * Ax + unit_j * Ay
vectors['3'] = unit_i * Bx + unit_j * By

angles['2'] = np.angle(vectors['2'])
angles['3'] = np.angle(vectors['3'])



# Plotting
curr = complex(0,0)
for l in vectors.keys():
    prev = complex(curr)
    curr = curr + vectors[l]
    if l == "G":
        linestyle = "--"
    else:
        linestyle = ""

    prev_plt = prev * np.exp(-1j * (ground_ang + np.pi/2))
    curr_plt = curr * np.exp(-1j * (ground_ang + np.pi/2))

    plt.plot([np.real(prev_plt), np.real(curr_plt)],
             [np.imag(prev_plt), np.imag(curr_plt)],
             linestyle)
```




```
staticLengths = np.array( [[np.imag(vectors['2']), np.imag(vectors['3'])],
                            [np.real(vectors['2']), np.real(vectors['3'])]])
vel = np.array([-1 * np.imag(vectors['1']), -1*np.real(vectors['1'])]) * omegas['1']

omegas['2'], omegas['3'] = np.linalg.solve(staticLengths, vel)

staticLengthsCross = np.array(
    [[np.imag(vectors['1'] * 1j), np.imag(vectors['2']*1j), np.imag(vectors['3']*1j)],
    [np.real(vectors['1'] * 1j), np.real(vectors['2']*1j), np.real(vectors['3']*1j)]]
)
sqvel = np.array([omegas['1']**2, omegas['2']**2, omegas['3']**2])
acc = np.array([np.imag(vectors['1']), np.real(vectors['1'])]) * alphas['1']

#rhs = -1 * np.dot(staticLengthsCross,sqvel) - acc
alphas['2'], alphas['3'] = np.linalg.solve(staticLengths,
                                           -1 * np.dot(staticLengthsCross,sqvel).reshape((2,1
```

## Iteration

Making above functional

```
def kinematics(lengths, angles, omegas, alphas, config):
        vectors = {'G': 0}
        vectors['G'] = lengths['G'] * np.exp(angles['G'] * 1j)
        vectors['1'] = lengths['1'] * np.exp(angles['1'] * 1j)
```

```
    # Using the coordinate @ end of L1 to find the B & C Angles

    C = vectors['G'] + vectors['1']

    unit_i = -1 * C/ np.abs(C)
    unit_j = unit_i * 1j

    # Finding the unknown angles

    Ax = (lengths['2']**2 + np.abs(C)**2 - lengths['3']**2) / (2 * np.abs(C))
    Bx = np.abs(C) - Ax

    Ay = np.sqrt(lengths['2']**2 - Ax**2)
    By = np.sqrt(lengths['3']**2 - Bx**2)
    if config:
            By = By * -1
    else:
            Ay = Ay * -1

    vectors['2'] = unit_i * Ax + unit_j * Ay
    vectors['3'] = unit_i * Bx + unit_j * By

    angles['2'] = np.angle(vectors['2'])
    angles['3'] = np.angle(vectors['3'])

    staticLengths = np.array( [[np.imag(vectors['2']), np.imag(vectors['3'])],
                        [np.real(vectors['2']), np.real(vectors['3'])]])
    vel = np.array([-1 * np.imag(vectors['1']), -1*np.real(vectors['1'])]) * omegas['1']

    omegas['2'], omegas['3'] = np.linalg.solve(staticLengths, vel)

    staticLengthsCross = np.array(
    [[np.imag(vectors['1'] * 1j), np.imag(vectors['2']*1j), np.imag(vectors['3']*1j)],
    [np.real(vectors['1'] * 1j), np.real(vectors['2']*1j), np.real(vectors['3']*1j)]]
    )
    sqvel = np.array([omegas['1']**2, omegas['2']**2, omegas['3']**2])
    acc = np.array([np.imag(vectors['1']), np.real(vectors['1'])]) * alphas['1']

    #rhs = -1 * np.dot(staticLengthsCross,sqvel) - acc
    alphas['2'], alphas['3'] = np.linalg.solve(staticLengths,
                                            -1 * np.dot(staticLengthsCross,sqvel).reshape

    return(vectors, omegas, alphas)
```

## Pitch Link

Running for pitch link

Desired output Angles:

```
ankle_pitch = [-50, +30]
```

Inputs:

```
ground_x = 200
ground_y = 60
ground_ang = float(np.angle(ground_x + ground_y*1j))

lengths = {'G': float(np.abs(ground_x + ground_y*1j)), # Ground
           '1': 120, # Drive Link
           '2': 0, # Connector Link
           '3': 150, # Output Link
           }
lengths['2'] = float(np.abs(ground_x + (lengths['3'] - lengths['1'])*1j))

angles = {'G': 180 * np.pi/180, # Required to be 180 to solve. Map if you wan other angles
          '1': np.pi/2 + ground_ang}
omegas = {'G':0,
        '1': 2} # Rad/s
alphas = {'G':0,
          '1':0} # Rad/s
config = True

lim = [angles['1'] + i * np.pi/180 for i in [-68, 40]]


resolution = 360


kin = {
    'G': np.zeros(resolution,dtype=complex),
    'link1': np.zeros(resolution,dtype=complex),
    'omega1': np.zeros(resolution, dtype=float),
    'alpha1': np.zeros(resolution, dtype=float),
    'link2': np.zeros(resolution,dtype=complex),
    'omega2': np.zeros(resolution, dtype=float),
    'alpha2': np.zeros(resolution, dtype=float),
    'link3': np.zeros(resolution,dtype=complex),
    'omega3': np.zeros(resolution, dtype=float),
    'alpha3': np.zeros(resolution, dtype=float)
}

angs = np.linspace(lim[0], lim[1], resolution)

for i in range(len(angs)):
    angles['1'] = angs[i]
    kin_vals = kinematics(lengths, angles, omegas, alphas, config)

    kin['G'][i] = kin_vals[0]['G']

    kin['link1'][i] = kin_vals[0]['1']
```

```
    kin['omega1'][i] = kin_vals[1]['1']
    kin['alpha1'][i] = kin_vals[2]['1']

    kin['link2'][i] = kin_vals[0]['2']
    kin['omega2'][i] = kin_vals[1]['2']
    kin['alpha2'][i] = kin_vals[2]['2'][0]

    kin['link3'][i] = kin_vals[0]['3']
    kin['omega3'][i] = kin_vals[1]['3']
    kin['alpha3'][i] = kin_vals[2]['3'][0]
```

Analysis:

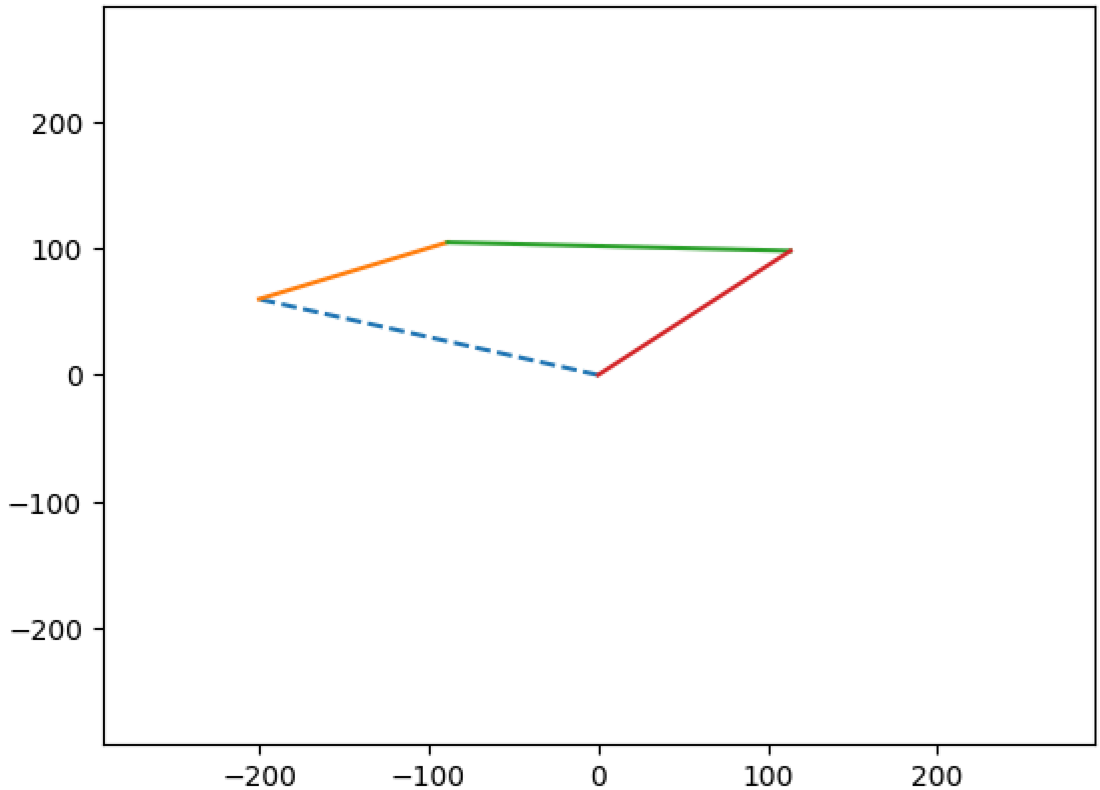
```
output_angles = [np.angle(-1 * a) - ground_ang for a in kin['link3']]
input_angles = [np.angle(a) - ground_ang for a in kin['link1']]

max_ang = max(output_angles)
min_ang = min(output_angles)

print("Max Output Angle: " + str(max_ang) + " rad = " + str(max_ang * 180/np.pi) + " deg")
print("Min Output Angle: " + str(min_ang) + " rad = " + str(min_ang * 180/np.pi) + " deg")
print("Input Travel: [" + str(input_angles[0] *180/np.pi - 90) + "deg, " + str(input_angles[1
print("Output Travel: [" + str(min_ang * 180/np.pi - 90) + "deg, " + str(max_ang * 180/np.pi

print("Desired Output Travel: [" + str(ankle_pitch[0]) + "deg, " + str(ankle_pitch[1]) + "deg
```

```
Max Output Angle: 2.1034710389033777 rad = 120.52001285716214 deg
Min Output Angle: 0.7137501759383301 rad = 40.89487270798628 deg
Input Travel: [-68.0deg, 40.0deg]
Output Travel: [-49.10512729201372deg, 30.520012857162143deg]
Desired Output Travel: [-50deg, 30deg]
```

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

curr = complex(0,0)
links = np.zeros(4, object)

linknames = ['G', 'link1', 'link2', 'link3']

i = 0
for n in range(4):
    l = linknames[n]
    prev = complex(curr)
    curr = curr + kin[l][i]
    if l == "G":
        linestyle = "--"
    else:
        linestyle = ""

    prev_plt = prev * np.exp(-1j * (ground_ang))
    curr_plt = curr * np.exp(-1j * (ground_ang))
```

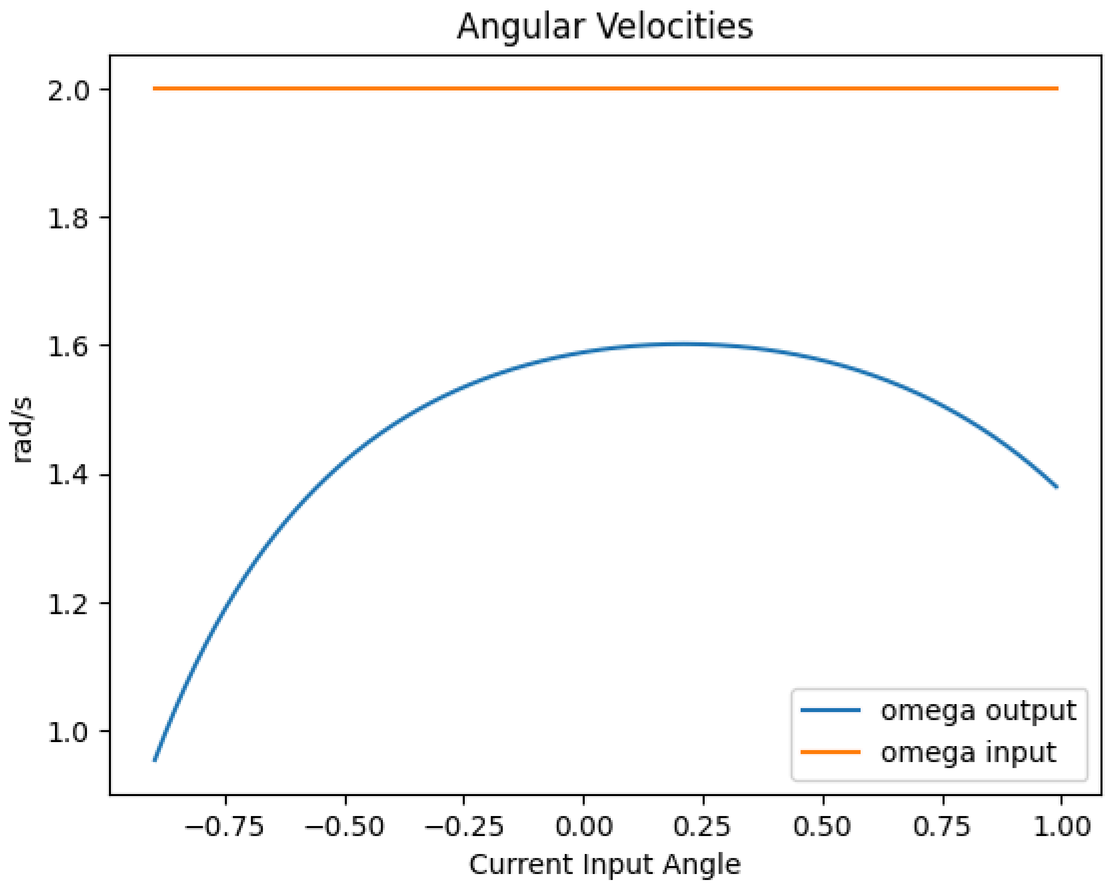
```
    links[n] = ax.plot([np.real(prev_plt), np.real(curr_plt)],
             [np.imag(prev_plt), np.imag(curr_plt)],
             linestyle)[0]

ax.set_xlim(-1 * lengths['G']*1.4, lengths['G']*1.4)
ax.set_ylim(-1 * lengths['G']*1.4, lengths['G']*1.4)
```

```
(-292.3285822494954, 292.3285822494954)
```




```
fig, ax = plt.subplots()
ax.plot(angs - np.pi/2, kin['omega3'], label = "omega output")
ax.plot(angs - np.pi/2,kin['omega1'], label = "omega input")
ax.legend()
ax.set_xlabel("Current Input Angle")
ax.set_ylabel("rad/s")
ax.set_title("Angular Velocities")
```

```
Text(0.5, 1.0, 'Angular Velocities')
```

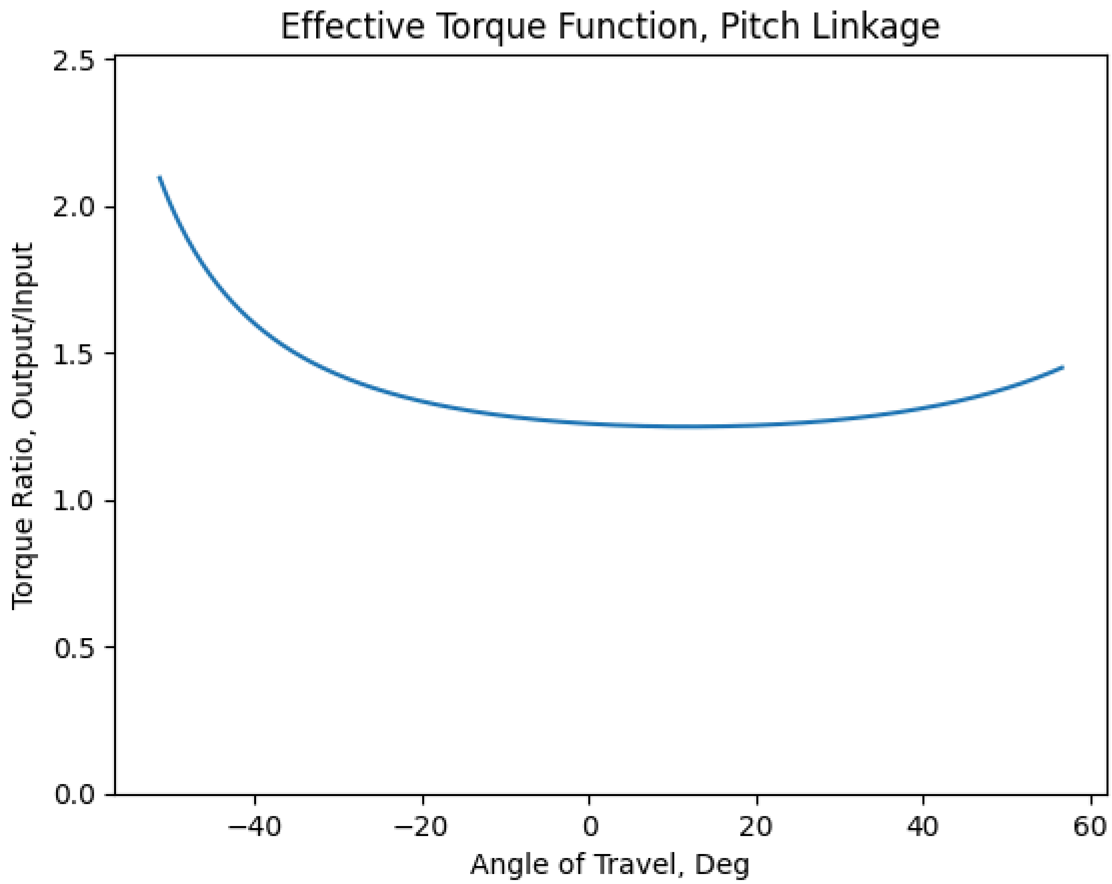



$\tau_1 * \omega_1 = \tau_3 * \omega_3$

$\frac{\tau_3}{\tau_1} = TR = \frac{\omega_1}{\omega_3}$

```
fig, ax = plt.subplots()
tr = np.zeros(len(kin['omega3']))
for i in range(len(tr)):
    if kin['omega1'][i] == 0 or kin['omega3'][i] == 0:
        tr[i] = 0
    else:
        tr[i] = kin['omega1'][i] / kin['omega3'][i]

ax.plot( (angs - np.pi/2) * 180/np.pi, tr)
ax.set_ylabel("Torque Ratio, Output/Input")
ax.set_xlabel("Angle of Travel, Deg")
ax.set_ylim((0, np.max(tr) * 1.2))
ax.set_title("Effective Torque Function, Pitch Linkage")
```

```
Text(0.5, 1.0, 'Effective Torque Function, Pitch Linkage')
```




```
# Plotting w/ Anim
fig, ax = plt.subplots()

curr = complex(0,0)
links = np.zeros(4, object)

linknames = ['G', 'link1', 'link2', 'link3']

i = 0
for n in range(4):
    l = linknames[n]
    prev = complex(curr)
    curr = curr + kin[l][i]
    if l == "G":
        linestyle = "--"
    else:
        linestyle = ""

    prev_plt = prev * np.exp(-1j * (ground_ang + np.pi/2))
    curr_plt = curr * np.exp(-1j * (ground_ang + np.pi/2))

    links[n] = ax.plot([np.real(prev_plt), np.real(curr_plt)],
              [np.imag(prev_plt), np.imag(curr_plt)],
              linestyle)[0]

def update(frame):
```

```
    curr = complex(0,0)

    linknames = ['G', 'link1', 'link2', 'link3']

    for n in range(4):
        l = linknames[n]
        prev = complex(curr)
        curr = curr + kin[l][frame]

        prev_plt = prev * np.exp(-1j * (ground_ang + np.pi/2))
        curr_plt = curr * np.exp(-1j * (ground_ang + np.pi/2))

        links[n].set_xdata([np.real(prev_plt), np.real(curr_plt)])
        links[n].set_ydata([np.imag(prev_plt), np.imag(curr_plt)])

    return links

ax.set_xlim(-1 * lengths['G']*1.4, lengths['G']*1.4)
ax.set_ylim(-1 * lengths['G']*1.4, lengths['G']*1.4)


ani = anim.FuncAnimation(fig = fig, func = update, frames = [i * 10 for i in range(int(resolu
ani.save("4barkinematics_pitch.gif", writer = "pillow")
plt.close()
```

```
HTML('<img src="./4barkinematics_pitch.gif">')
```

---

## Roll Link

Aim for Link3 Outputs Angles:

```
ankle_roll = [-30, 30]
```

Inputs:

Note that the angle 1 `lim` needs iterated to get limits similar to desired on the output link.

```
ground_x = 237
ground_y = 0
ground_ang = float(np.angle(ground_x + ground_y*1j))

lengths = {'G': float(np.abs(ground_x + ground_y*1j)), # Ground
```

```
            '1': 30, # Drive Link
            '2': 0, # Connector Link
            '3': 54, # Output Link
            }
lengths['2'] = float(np.abs(ground_x + (lengths['3'] - lengths['1'])*1j))

angles = {'G': 180 * np.pi/180, # Required to be 180 to solve. Map if you wan other angles
          '1': np.pi/2 + ground_ang}
omegas = {'G':0,
        '1': 2} # Rad/s
alphas = {'G':0,
          '1':0} # Rad/s
config = True

lim = [angles['1'] + i * np.pi/180 for i in [-60, +60]]

resolution = 360
```

Running:

```
kin = {
    'G': np.zeros(resolution,dtype=complex),
    'link1': np.zeros(resolution,dtype=complex),
    'omega1': np.zeros(resolution, dtype=float),
    'alpha1': np.zeros(resolution, dtype=float),
    'link2': np.zeros(resolution,dtype=complex),
    'omega2': np.zeros(resolution, dtype=float),
    'alpha2': np.zeros(resolution, dtype=float),
    'link3': np.zeros(resolution,dtype=complex),
    'omega3': np.zeros(resolution, dtype=float),
    'alpha3': np.zeros(resolution, dtype=float)
}

angs = np.linspace(lim[0], lim[1], resolution)

for i in range(len(angs)):
    angles['1'] = angs[i]
    kin_vals = kinematics(lengths, angles, omegas, alphas, config)

    kin['G'][i] = kin_vals[0]['G']

    kin['link1'][i] = kin_vals[0]['1']
    kin['omega1'][i] = kin_vals[1]['1']
    kin['alpha1'][i] = kin_vals[2]['1']

    kin['link2'][i] = kin_vals[0]['2']
    kin['omega2'][i] = kin_vals[1]['2']
    kin['alpha2'][i] = kin_vals[2]['2'][0]

    kin['link3'][i] = kin_vals[0]['3']
    kin['omega3'][i] = kin_vals[1]['3']
    kin['alpha3'][i] = kin_vals[2]['3'][0]
```

Analysis:

```
output_angles = [np.angle(-1 * a) for a in kin['link3']]
input_angles = [np.angle(a) - ground_ang for a in kin['link1']]

max_ang = max(output_angles)
min_ang = min(output_angles)

print("Max Output Angle: " + str(max_ang) + " rad = " + str(max_ang * 180/np.pi) + " deg")
print("Min Output Angle: " + str(min_ang) + " rad = " + str(min_ang * 180/np.pi) + " deg")
print("Input Travel: [" + str(input_angles[0] *180/np.pi - 90) + "deg, " + str(input_angles[
print("Output Travel: [" + str(min_ang * 180/np.pi - 90) + "deg, " + str(max_ang * 180/np.pi

print("Desired Output Travel: [" + str(ankle_roll[0]) + "deg, " + str(ankle_roll[1]) + "deg]"
```

```
Max Output Angle: 2.0923347995633605 rad = 119.8819533433316 deg
Min Output Angle: 1.0913768198582336 rad = 62.53128563628632 deg
Input Travel: [-60.0deg, 59.99999999999997deg]
```

```
    Output Travel: [-27.46871436371368deg, 29.881953343331602deg]
    Desired Output Travel: [-30deg, 30deg]
```

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

curr = complex(0,0)
links = np.zeros(4, object)

linknames = ['G', 'link1', 'link2', 'link3']

i = 0
for n in range(4):
    l = linknames[n]
    prev = complex(curr)
    curr = curr + kin[l][i]
    if l == "G":
        linestyle = "--"
    else:
        linestyle = ""

    prev_plt = prev * np.exp(-1j * (ground_ang))
    curr_plt = curr * np.exp(-1j * (ground_ang))

    links[n] = ax.plot([np.real(prev_plt), np.real(curr_plt)],
             [np.imag(prev_plt), np.imag(curr_plt)],
             linestyle)[0]

ax.set_xlim(-1 * lengths['G']*1.4, lengths['G']*1.4)
ax.set_ylim(-1 * lengths['G']*1.4, lengths['G']*1.4)
```

```
(-331.7999999999995, 331.7999999999995)
```

$$\tau_1 * \omega_1 = \tau_3 * \omega_3$$

$$\frac{\tau_3}{\tau_1} = TR = \frac{\omega_1}{\omega_3}$$

```
fig, ax = plt.subplots()
tr = np.zeros(len(kin['omega3']))
for i in range(len(tr)):
    if kin['omega1'][i] == 0 or kin['omega3'][i] == 0:
        tr[i] = 0
    else:
        tr[i] = kin['omega1'][i] / kin['omega3'][i]

ax.plot( (angs - np.pi/2) * 180/np.pi, tr)
ax.set_ylabel("Torque Ratio, Output/Input")
ax.set_xlabel("Angle of Travel, Deg")
ax.set_ylim((0, np.max(tr) * 1.2))
ax.set_title("Effective Torque Function, Roll Linkage")
```

```
Text(0.5, 1.0, 'Effective Torque Function, Roll Linkage')
```