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Task 1-a

Here, revolute joint parameters are shown as **q** and prismatic joint parameters are shown as **d**.
q is in degrees and **d** and other values are in meters.

- For Stanford-type Robot:
  Joint parameters are of the form: [q1,q2,d3]

```
-->Joint parameters: [  9.46232221 -18.20076026   0.23023432]
  Position of end effector: [0.45  0.075 0.1  ]
-->Joint parameters: [ -9.46232221 -18.20076026   0.23023432]
  Position of end effector: [ 0.45  -0.075  0.1  ]
-->Joint parameters: [-16.69924423 -29.88580023   0.05103986]
  Position of end effector: [ 0.25  -0.075  0.1  ]
-->Joint parameters: [ 16.69924423 -29.88580023   0.05103986]
  Position of end effector: [0.25  0.075 0.1  ]
```

- For PUMA-type Robot:
  Joint parameters are of the form: [q1,q2,q3]

```
-->Joint parameters: [  9.46232221  -2.0367282  -32.32806412]
  Position of end effector: [0.45  0.075 0.1  ]
-->Joint parameters: [ -9.46232221  -2.0367282  -32.32806412]
  Position of end effector: [ 0.45  -0.075  0.1  ]
-->Joint parameters: [ -16.69924423   23.09520685 -105.96201416]
  Position of end effector: [ 0.25  -0.075  0.1  ]
-->Joint parameters: [  16.69924423   23.09520685 -105.96201416]
  Position of end effector: [0.25  0.075 0.1  ]
```

- For SCARA-type Robot:
  Joint parameters are of the form: [q1,q2,d3]

```
-->Joint parameters: [-14.6965151   48.31767461  -0.15      ]
  Position of end effector: [0.45  0.075 0.1  ]
-->Joint parameters: [-33.62115951  48.31767461  -0.15      ]
  Position of end effector: [ 0.45  -0.075  0.1  ]
-->Joint parameters: [-75.23171135 117.06493423  -0.15      ]
  Position of end effector: [ 0.25  -0.075  0.1  ]
-->Joint parameters: [-41.83322288 117.06493423  -0.15      ]
  Position of end effector: [0.25  0.075 0.1  ]
```

Task 1-b

Here, A=(0.1,0.2)
B=(0.2,0.2)
C=(0.2,0.1)
D=(0.1,0.1)

For Stanford-type
-->Joint parameters: [6.34349488e+01 -3.38545148e+01 1.92582404e-02]
  Position of end effector: [0.1 0.2 0.1]
-->Joint parameters: [45.   -27.93835273   0.07015621]
  Position of end effector: [0.2 0.2 0.1]
-->Joint parameters: [2.65650512e+01 -3.38545148e+01 1.92582404e-02]
  Position of end effector: [0.2 0.1 0.1]
-->Joint parameters: [4.50000000e+01 -4.66861433e+01 -4.38447187e-02]
  Position of end effector: [0.1 0.1 0.1]

For PUMA-type
-->Joint parameters: [63.43494882   23.56277893 -114.83458749]
  Position of end effector: [0.1 0.2 0.1]
-->Joint parameters: [45.   22.24652717 -100.36975981]
  Position of end effector: [0.2 0.2 0.1]
-->Joint parameters: [26.56505118   23.56277893 -114.83458749]
  Position of end effector: [0.2 0.1 0.1]
-->Joint parameters: [45.   18.96379305 -131.29987279]
  Position of end effector: [0.1 0.1 0.1]

For SCARA-type
-->Joint parameters: [0.   126.86989765 -0.15   ]
  Position of end effector: [0.1 0.2 0.1]
-->Joint parameters: [-10.55009801 111.10019602 -0.15   ]
  Position of end effector: [0.2 0.2 0.1]
-->Joint parameters: [-36.86989765 126.86989765 -0.15   ]
  Position of end effector: [0.2 0.1 0.1]
-->Joint parameters: [-28.57005981 147.14011962 -0.15   ]
  Position of end effector: [0.1 0.1 0.1]

Task 1-c

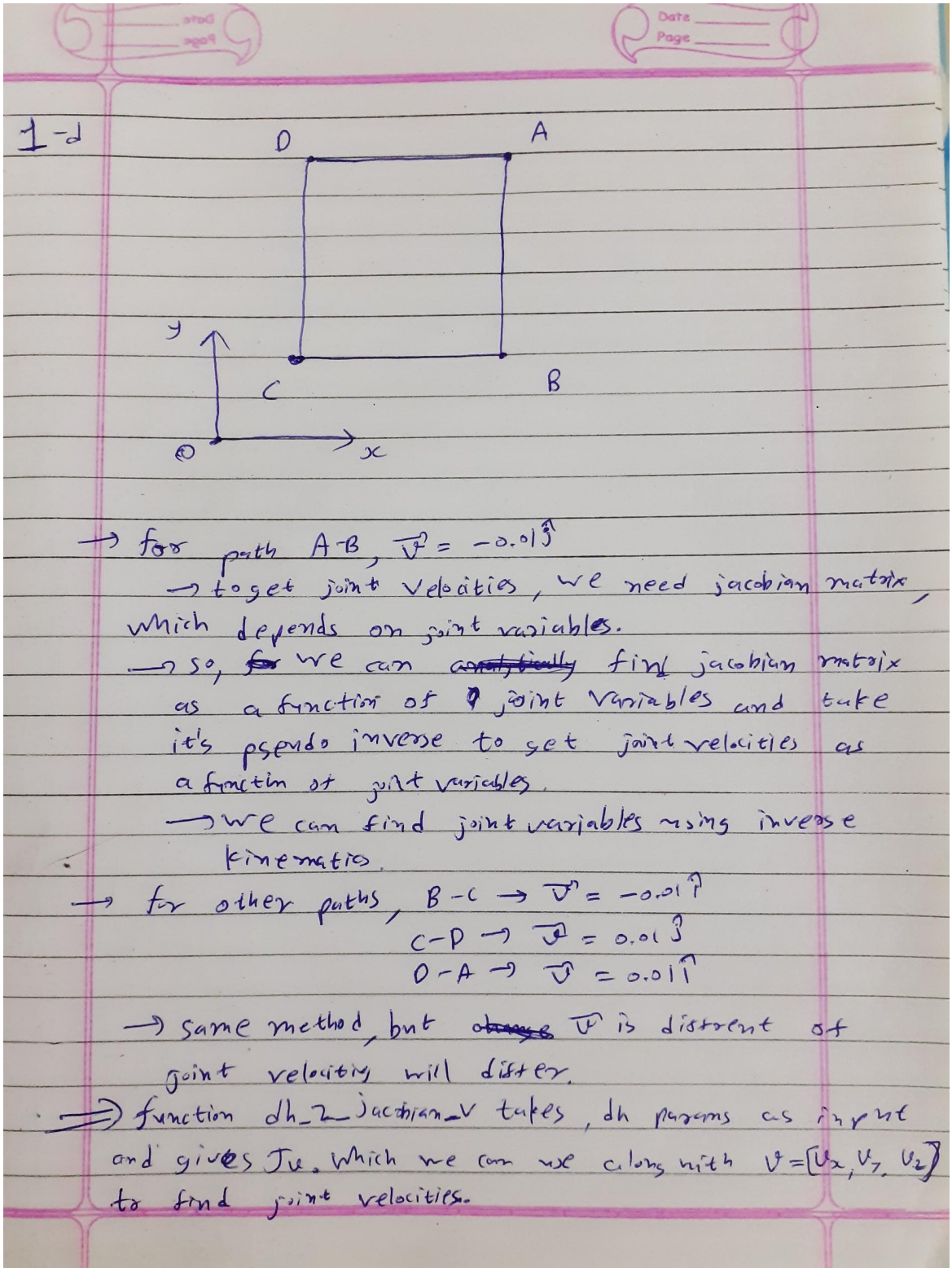
For Stanford-type
-->Joint parameters: [8.53076561 -20.34735591   0.18139309]
  Position of end effector: [0.4 0.06 0.1]
-->Joint parameters: [1.43209618 -20.5501612   0.17731721]
  Position of end effector: [0.4 0.01 0.1]
-->Joint parameters: [1.63657704 -23.1901278   0.13091994]
  Position of end effector: [0.35 0.01 0.1]
-->Joint parameters: [9.72757855 -22.89965963   0.13548671]
  Position of end effector: [0.35 0.06 0.1]

For PUMA-type
-->Joint parameters: [8.53076561 10.02177432 -60.73826047]
  Position of end effector: [0.4 0.06 0.1]
-->Joint parameters: [1.43209618 10.73046775 -62.5612579]
  Position of end effector: [0.4 0.01 0.1]
-->Joint parameters: [1.63657704 17.18320514 -80.74666588]
  Position of end effector: [0.35 0.01 0.1]
-->Joint parameters: [9.72757855 16.65895944 -79.11723814]
  Position of end effector: [0.35 0.06 0.1]

For SCARA-type
-->Joint parameters: [-27.47577049 72.0130722   -0.15   ]
  Position of end effector: [0.4 0.06 0.1]
-->Joint parameters: [-35.41392532 73.692043   -0.15   ]
  Position of end effector: [0.4 0.01 0.1]
-->Joint parameters: [-43.91349624 91.10014657 -0.15   ]
  Position of end effector: [0.35 0.01 0.1]
-->Joint parameters: [-35.02031676 89.49579063 -0.15   ]
  Position of end effector: [0.35 0.06 0.1]

Task 1-d

Here, joint velocities are in radian/s but the joint angles are in degrees. Joint velocities are in m/s and joint displacement (in the prismatic joint) are in meters.



- For Stanford-type

```
from A to B
-->Joint parameters: [  7.12501635 -20.41044552   0.18011626]
   position of end effector: [0.4  0.05 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02461538 -0.00100569 -0.00116248]]
-->Joint parameters: [  5.71059314 -20.46250378   0.17906876]
   position of end effector: [0.4  0.04 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02475248 -0.00081073 -0.00093225]]
-->Joint parameters: [  4.28915333 -20.5032705    0.17825226]
   position of end effector: [0.4  0.03 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02486016 -0.0006117  -0.00070052]]
-->Joint parameters: [  2.86240523 -20.53253945   0.1776681 ]
   position of end effector: [0.4  0.02 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02493766 -0.00040955 -0.00046765]]
from B to C
-->Joint parameters: [  1.46880071 -21.0312032    0.16797129]
   position of end effector: [0.39 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00065703 -0.00858333 -0.00933078]]
-->Joint parameters: [  1.50743576 -21.53420358   0.15865633]
   position of end effector: [0.38 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00069204 -0.00897893 -0.00929877]]
-->Joint parameters: [  1.5481577  -22.0606171    0.14937451]
   position of end effector: [0.37 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00072993 -0.00940096 -0.00926449]]
-->Joint parameters: [  1.59114027 -22.61202116   0.14012818]
   position of end effector: [0.36 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00077101 -0.00985165 -0.00922774]]
from C to D
-->Joint parameters: [  3.27048792 -23.16479527   0.13131352]
   position of end effector: [0.35 0.02 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[0.02847844 0.00058855 0.0005245 ]]
-->Joint parameters: [  4.89909245 -23.12275872   0.13196859]
   position of end effector: [0.35 0.03 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[0.02836305 0.00087801 0.0007854 ]]
-->Joint parameters: [  6.51980175 -23.06429112   0.13288379]
   position of end effector: [0.35 0.04 0.1 ]
```

velocity of end effector: [[0. 0.01 0.]]
velocity of joint variables: [[0.02820306 0.0011618 0.0010447]]
-->Joint parameters: [8.13010235 -22.98976777   0.13405729]
position of end effector: [0.35 0.05 0.1]
velocity of end effector: [[0. 0.01 0.]]
velocity of joint variables: [[0.028   0.00143818 0.00130189]]
from D to A
-->Joint parameters: [9.46232221 -22.34253825   0.14458839]
position of end effector: [0.36 0.06 0.1]
velocity of end effector: [[0.01 0. 0.]]
velocity of joint variables: [[-0.0045045   0.00950283 0.00912343]]
-->Joint parameters: [9.21102654 -21.81019577   0.15373258]
position of end effector: [0.37 0.06 0.1]
velocity of end effector: [[0.01 0. 0.]]
velocity of joint variables: [[-0.00427046 0.00908379 0.00916448]]
-->Joint parameters: [8.97262661 -21.30113027   0.16291646]
position of end effector: [0.38 0.06 0.1]
velocity of end effector: [[0.01 0. 0.]]
velocity of joint variables: [[-0.00405405 0.00869   0.00920283]]
-->Joint parameters: [8.74616226 -20.81394817   0.17213742]
position of end effector: [0.39 0.06 0.1]
velocity of end effector: [[0.01 0. 0.]]
velocity of joint variables: [[-0.00385356 0.00831963 0.0092387]]

- For PUMA-type

```
from A to B
-->Joint parameters: [  7.12501635  10.24685347 -61.31459799]
   position of end effector: [0.4  0.05 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02461538  0.00355392 -0.00911922]]
-->Joint parameters: [  5.71059314  10.4293939  -61.78379536]
   position of end effector: [0.4  0.04 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02475248  0.00282081 -0.00726307]]
-->Joint parameters: [  4.28915333  10.57038178 -62.14730456]
   position of end effector: [0.4  0.03 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02486016  0.00210277 -0.00542893]]
-->Joint parameters: [  2.86240523  10.67056494 -62.40620879]
   position of end effector: [0.4  0.02 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02493766  0.0013958  -0.0036107 ]]
from B to C
-->Joint parameters: [  1.46880071  12.25468261 -66.57177163]
   position of end effector: [0.39 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00065703  0.02541994 -0.06800654]]
-->Joint parameters: [  1.50743576  13.64911697 -70.3666411 ]
   position of end effector: [0.38 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00069204  0.02329756 -0.06455298]]
-->Joint parameters: [  1.5481577   14.92857466 -73.97838351]
   position of end effector: [0.37 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00072993  0.02139524 -0.06159239]]
-->Joint parameters: [  1.59114027  16.10392462 -77.43189156]
   position of end effector: [0.36 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[ 0.00077101  0.01965539 -0.05901409]]
from C to D
-->Joint parameters: [  3.27048792  17.13886236 -80.60731526]
   position of end effector: [0.35 0.02 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.02847844 -0.0010332   0.00324349]]
-->Joint parameters: [  4.89909245  17.06471085 -80.37493914]
   position of end effector: [0.35 0.03 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.02836305 -0.00155626  0.00486853]]
-->Joint parameters: [  6.51980175  16.96038035 -80.04934295]
   position of end effector: [0.35 0.04 0.1 ]
```

```
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.02820306 -0.00208707  0.00649775]]
-->Joint parameters: [  8.13010235  16.82535232 -79.63024019]
   position of end effector: [0.35 0.05 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.028      -0.00262824  0.00813284]]
from D to A
-->Joint parameters: [  9.46232221  15.54881444 -75.78270537]
   position of end effector: [0.36 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[-0.0045045  -0.02020715  0.05941996]]
-->Joint parameters: [  9.21102654  14.34079842 -72.30198837]
   position of end effector: [0.37 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[-0.00427046 -0.02198671  0.06214101]]
-->Joint parameters: [  8.97262661  13.02584276 -68.65394605]
   position of end effector: [0.38 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[-0.00405405 -0.02394908  0.06527815]]
-->Joint parameters: [  8.74616226  11.59172815 -64.81135263]
   position of end effector: [0.39 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[-0.00385356 -0.02615889  0.06895703]]
```

- For SCARA-type

```
from A to B
-->Joint parameters: [-29.14618209  72.54239688  -0.15      ]
   position of end effector: [0.4  0.05 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02880852  0.00838628  0.        ]]
-->Joint parameters: [-30.7765756   72.97433748  -0.15      ]
   position of end effector: [0.4  0.04 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02809915  0.00669334  0.        ]]
-->Joint parameters: [-32.3656476   73.30960186  -0.15      ]
   position of end effector: [0.4  0.03 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02736572  0.00501112  0.        ]]
-->Joint parameters: [-33.91195281  73.54871607  -0.15      ]
   position of end effector: [0.4  0.02 0.1 ]
   velocity of end effector: [[ 0.   -0.01  0.  ]]
   velocity of joint variables: [[-0.02660595  0.0033366   0.        ]]
from B to C
-->Joint parameters: [-37.24714506  77.43189156  -0.15      ]
   position of end effector: [0.39 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[-0.03130894  0.06393193  0.        ]]
-->Joint parameters: [-39.00516546  81.02520243  -0.15      ]
   position of end effector: [0.38 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[-0.03008476  0.0615536   0.        ]]
-->Joint parameters: [-40.69740297  84.49112133  -0.15      ]
   position of end effector: [0.37 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[-0.02900742  0.05947469  0.        ]]
-->Joint parameters: [-42.3314451   87.84517075  -0.15      ]
   position of end effector: [0.36 0.01 0.1 ]
   velocity of end effector: [[-0.01  0.    0.  ]]
   velocity of joint variables: [[-0.02804937  0.05764076  0.        ]]
from C to D
-->Joint parameters: [-42.21081927  90.96261438  -0.15      ]
   position of end effector: [0.35 0.02 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.03007866 -0.00320045  0.        ]]
-->Joint parameters: [-40.46761055  90.73340601  -0.15      ]
   position of end effector: [0.35 0.03 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.03076324 -0.00480039  0.        ]]
-->Joint parameters: [-38.68646484  90.41253318  -0.15      ]
   position of end effector: [0.35 0.04 0.1 ]
```

```
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.03140314 -0.00640017  0.        ]]
-->Joint parameters: [-36.86989765  90.          -0.15      ]
   position of end effector: [0.35 0.05 0.1 ]
   velocity of end effector: [[0.   0.01 0.  ]]
   velocity of joint variables: [[ 0.032 -0.008  0.   ]]
from D to A
-->Joint parameters: [-33.65702572  86.23869586  -0.15      ]
   position of end effector: [0.36 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[ 0.02435766 -0.05772434  0.        ]]
-->Joint parameters: [-32.2274681   82.87698928  -0.15      ]
   position of end effector: [0.37 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[ 0.02555976 -0.05966045  0.        ]]
-->Joint parameters: [-30.72595548  79.39716419  -0.15      ]
   position of end effector: [0.38 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[ 0.026874   -0.06185612  0.        ]]
-->Joint parameters: [-29.14519042  75.78270537  -0.15      ]
   position of end effector: [0.39 0.06 0.1 ]
   velocity of end effector: [[0.01 0.   0.  ]]
   velocity of joint variables: [[ 0.02833225 -0.06437162  0.        ]]
```

Task 1-e

- For Stanford-type

```
-->Joint parameters: [  8.53076561 -13.88699366   0.16665333]
  Position of end effector: [0.4  0.06 0.15]
  Position of end effector after adding wrist: [0.4  0.06 0.1 ]
-->Joint parameters: [  1.43209618 -14.03203244   0.16243181]
  Position of end effector: [0.4  0.01 0.15]
  Position of end effector after adding wrist: [0.4  0.01 0.1 ]
-->Joint parameters: [  1.63657704 -15.93922205   0.11414283]
  Position of end effector: [0.35 0.01 0.15]
  Position of end effector after adding wrist: [0.35 0.01 0.1 ]
-->Joint parameters: [  9.72757855 -15.72755722   0.11891733]
  Position of end effector: [0.35 0.06 0.15]
  Position of end effector after adding wrist: [0.35 0.06 0.1 ]
```

- For PUMA-type

```
-->Joint parameters: [  8.53076561  19.67308009 -67.12014752]
  Position of end effector: [0.4  0.06 0.15]
  Position of end effector after adding wrist: [0.4  0.06 0.1 ]
-->Joint parameters: [  1.43209618  20.39330012 -68.85066511]
  Position of end effector: [0.4  0.01 0.15]
  Position of end effector after adding wrist: [0.4  0.01 0.1 ]
-->Joint parameters: [  1.63657704  27.31791134 -86.51426677]
  Position of end effector: [0.35 0.01 0.15]
  Position of end effector after adding wrist: [0.35 0.01 0.1 ]
-->Joint parameters: [  9.72757855  26.72515491 -84.90542426]
  Position of end effector: [0.35 0.06 0.15]
  Position of end effector after adding wrist: [0.35 0.06 0.1 ]
```

- For SCARA-type

```
-->Joint parameters: [-27.47577049  72.0130722   -0.1       ]
  Position of end effector: [0.4  0.06 0.15]
  Position of end effector after adding wrist: [0.4  0.06 0.1 ]
-->Joint parameters: [-35.41392532  73.692043    -0.1       ]
  Position of end effector: [0.4  0.01 0.15]
  Position of end effector after adding wrist: [0.4  0.01 0.1 ]
-->Joint parameters: [-43.91349624  91.10014657  -0.1       ]
  Position of end effector: [0.35 0.01 0.15]
  Position of end effector after adding wrist: [0.35 0.01 0.1 ]
-->Joint parameters: [-35.02031676  89.49579063  -0.1       ]
  Position of end effector: [0.35 0.06 0.15]
  Position of end effector after adding wrist: [0.35 0.06 0.1 ]
```

Task 1-f

- For Stanford-type

```
-->Joint parameters: [  8.53076561 -13.88699366   0.16665333]
   Euler angles: -180.0 76.11301 -171.46923
   Position of end effector after adding wrist: [0.4  0.06 0.1 ]
   orientation of end effector after adding wrist:
[[ 1. -0. -0.]
 [-0. -1.  0.]
 [-0. -0. -1.]]
-->Joint parameters: [  1.43209618 -14.03203244   0.16243181]
   Euler angles: -180.0 75.96797 -178.5679
   Position of end effector after adding wrist: [0.4  0.01 0.1 ]
   orientation of end effector after adding wrist:
[[ 1.  0. -0.]
 [ 0. -1.  0.]
 [ 0. -0. -1.]]
-->Joint parameters: [  1.63657704 -15.93922205   0.11414283]
   Euler angles: -180.0 74.06078 -178.36342
   Position of end effector after adding wrist: [0.35 0.01 0.1 ]
   orientation of end effector after adding wrist:
[[ 1.  0.  0.]
 [ 0. -1.  0.]
 [-0. -0. -1.]]
-->Joint parameters: [  9.72757855 -15.72755722   0.11891733]
   Euler angles: -180.0 74.27244 -170.27242
   Position of end effector after adding wrist: [0.35 0.06 0.1 ]
   orientation of end effector after adding wrist:
[[ 1.  0.  0.]
 [ 0. -1.  0.]
 [-0. -0. -1.]]
```

- For PUMA-type

```
-->Joint parameters: [  8.53076561  19.67308009 -67.12014752]
  Euler angles: -42.55293 90.0 98.53077
  Position of end effector after adding wrist: [0.4  0.06 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1. -0.  0.]
   [-0. -1.  0.]
   [-0. -0. -1.]]
-->Joint parameters: [  1.43209618  20.39330012 -68.85066511]
  Euler angles: -41.54264 90.0 91.4321
  Position of end effector after adding wrist: [0.4  0.01 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1. -0.  0.]
   [-0. -1.  0.]
   [-0. -0. -1.]]
-->Joint parameters: [  1.63657704  27.31791134 -86.51426677]
  Euler angles: -30.80364 90.0 91.63658
  Position of end effector after adding wrist: [0.35 0.01 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1.  0. -0.]
   [ 0. -1.  0.]
   [-0. -0. -1.]]
-->Joint parameters: [  9.72757855  26.72515491 -84.90542426]
  Euler angles: -31.81973 90.0 99.72758
  Position of end effector after adding wrist: [0.35 0.06 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1.  0. -0.]
   [ 0. -1.  0.]
   [-0. -0. -1.]]
```

- For SCARA-type

```
-->Joint parameters: [-27.47577049  72.0130722   -0.1       ]
  Euler angles: 0.0 180.0 -135.4627
  Position of end effector after adding wrist: [0.4  0.06 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1.  0.  0.]
   [ 0. -1.  0.]
   [ 0. -0. -1.]]
-->Joint parameters: [-35.41392532  73.692043    -0.1       ]
  Euler angles: 0.0 180.0 -141.72188
  Position of end effector after adding wrist: [0.4  0.01 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1. -0.  0.]
   [-0. -1.  0.]
   [ 0. -0. -1.]]
-->Joint parameters: [-43.91349624  91.10014657  -0.1       ]
  Euler angles: 0.0 180.0 -132.81335
  Position of end effector after adding wrist: [0.35 0.01 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1. -0.  0.]
   [-0. -1.  0.]
   [ 0. -0. -1.]]
-->Joint parameters: [-35.02031676  89.49579063  -0.1       ]
  Euler angles: 0.0 180.0 -125.52453
  Position of end effector after adding wrist: [0.35 0.06 0.1 ]
  orientation of end effector after adding wrist:
  [[ 1. -0.  0.]
   [-0. -1.  0.]
   [ 0. -0. -1.]]
```

Task 2-a

For pill picking, one thing that we need to ensure is that the pill should not be broken which picking. A hard gripper might be easier to make/use but chances are that it might just break the pill.

So, a soft gripper will be more suitable for this task (https://youtu.be/gI0tzsO8xwc). Another advantage of using a soft gripper is that we need not calculate exactly how much we need to actuate the gripper to just hold the object and not break it.

A compliant gripper may also work as it can also pick fragile objects without breaking them (https://youtu.be/SEPlKdzYpCM).

Task 2-b

After reviewing the mentioned grippers, the soft robotic gripper and universal gripper seemed suitable for pill picking task.

For the soft robotic gripper, the main advantage is that there is no need of having sensors on the gripper to hold the object just enough.

(octopus-inspired soft robot: https://youtu.be/X0XGure7mak)

For the universal gripper, even though we know the exact size of the pill, it's orientation will be arbitrary. So, use of universal gripper make sense as we need not worry about the orientation of the pill. There is a gripper called Universal Jamming Gripper, which is a soft bag which can change it's shape easily in normal condition. But after reducing the pressure, the bag quickly becomes hard with the shape that it had recently.

(Universal Jamming Gripper: https://youtu.be/Rna03llJjf8)

(DIY Universal Jamming Gripper: https://youtu.be/3OjhoVuAQkQ)

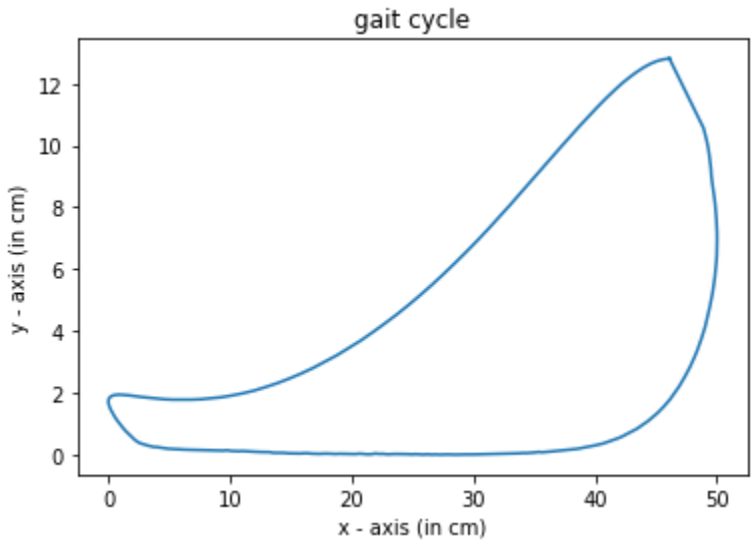
Task 3-a

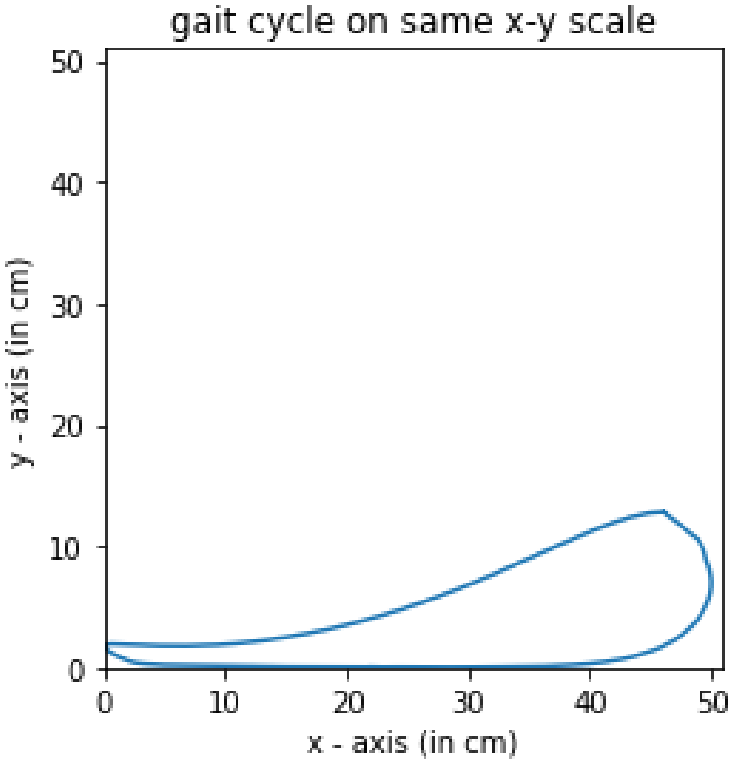
My hip-to-knee distance is 45cm and knee-to-ankle distance is also 45cm. So, $l1 = l2 = 0.45$. for planer 2R elbow manipulator.

- Step length:
  - A step length is the distance between the initial contect of one foot and the initial contact of the other foot.
- Step height:
  - While the leg is swinging, the maximum height it reaches is called step height.
- Gait trajectory:
  - Gait trajectory is the path the ankle takes while walking. This is also called as gait cycle. Which is divided into two parts. Stance plase and Swing phase.
    - During Stance phase, the foot is always in contact with the ground. It is 60% of full gait cycle.
    - During Swing phase, the foot is swinging and the other leg is in Stance phase. It is 40% of the full gait cycle.

  (Gait Cycle & Gait Analysis: https://youtu.be/1u6d1CX7o9c)

Task 3-b



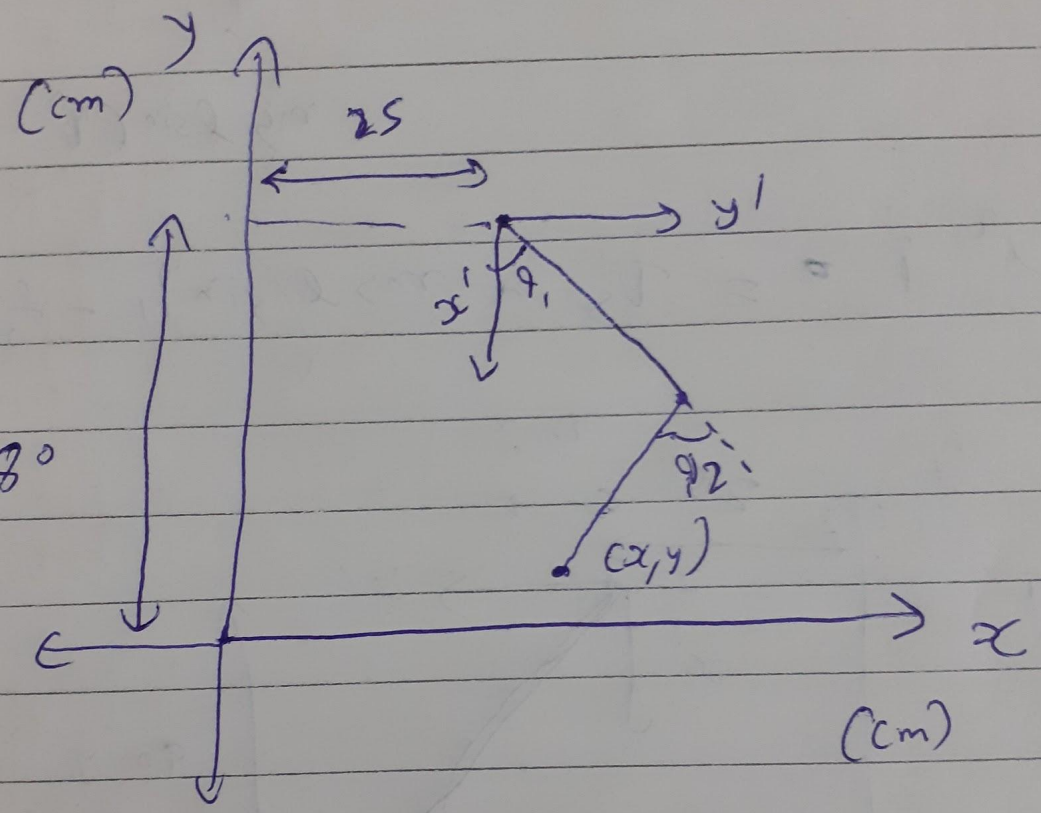


Task 3-c

As the output file is too large it is on the github named “Task-3c.txt”.
All the angles are in degrees and the positions are in cm.

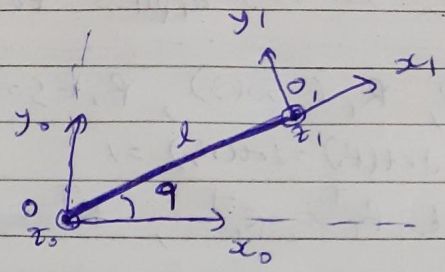
A typo in image below: it is *Task 3c.*

Task-3b



$$x' = 80 - y'$$
$$y' = x' - 25$$

4-a. D-H parameters for a robot with single revolute joint and a single link of length l.



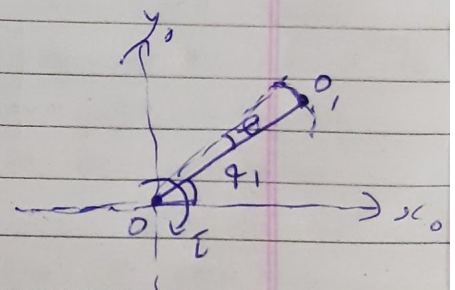
D-H Parameters:-

Link	θ_i	d_i	a_i	α_i
1	q^*	0	l	0

4-b → ~~for some~~ say, $q = q_1$, ~~the~~ is the equilibrium position.

→ Say the ~~arm~~ is rotated by an angle θ.

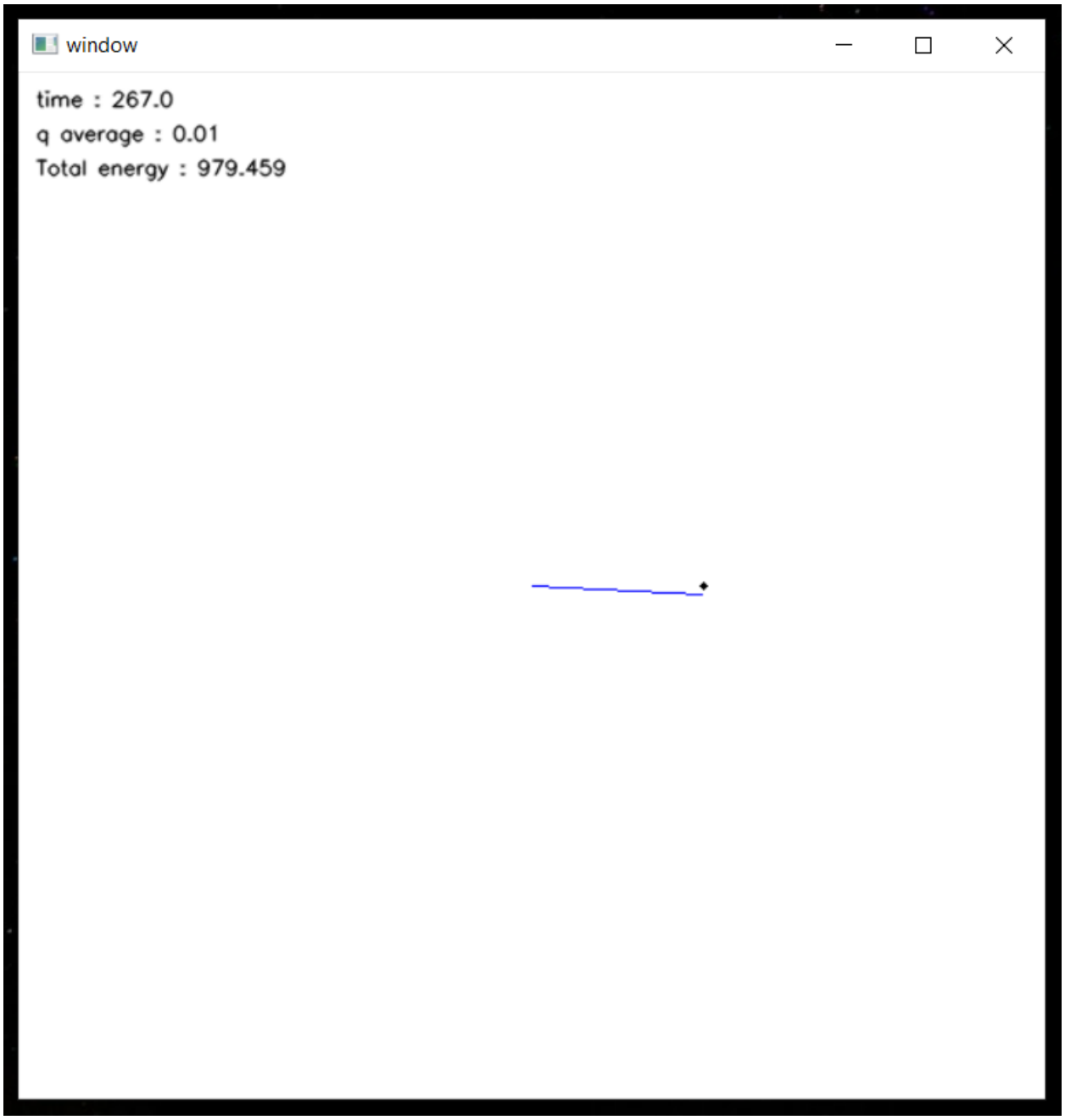
→ for it to behave like a torsional spring the joint O_1 should apply a torque of, $\boxed{T = -k\theta}$, where, k is torsional stiffness.



$\therefore T = -k(q - q_1)$ where, q is the angle of arm.

→ T and q both can change as a function of time.

Task 4-c



A screenshot of the python simulation. For initial angle q1=0.1 radians. And zero initial angular velocity.

Mid-Sem

5. Yes, all the joint axes are aligned with their respective z-axis. (for Revolute joint, z-axis is the axis of rotation and for Prismatic joint, z-axis is the axis along which the distance changes / axis of translation)

6. No, origins may not be at the center of the joint. In some cases, origin may be outside the Robot's body. (in open space)

7. Yes.

$$H = \begin{bmatrix} R_{11} & R_{12} & R_{13} & d_1 \\ R_{21} & R_{22} & R_{23} & d_2 \\ R_{31} & R_{32} & R_{33} & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$R = [R_{ij}]$ $i,j = 1 \text{ to } 3$ (Rotation)

$d = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \end{bmatrix}$ (translation)

8. Yes, the rotation matrices can be multiplied together according to the sequence or order in which the rotations were done, to get an overall matrix that represents the combined rotation.

⇒ say, we applied a rotation R_1, then on new (rotated) frame we applied R_2, The combined rotation matrix, $R = R_1 * R_2$

9. Yes, any rotation matrix is orthogonal and have a determinant of 1.

→ A composite rotation matrix is a rotation matrix, so this applies to it as well.

→ say, $R_1 \in SO(3)$, $R_2 \in SO(3)$ ~~(small proof)~~

$\therefore \det(R_1) = \det(R_2) = 1$ (small proof)

and $R_1^T = R_1^{-1}$, $R_2^T = R_2^{-1}$

→ $R = R_1 \cdot R_2 \Rightarrow \det(R) = \det(R_1)\det(R_2)$

$= 1 \cdot 1$

$= 1$

→ $R^T = R_2^T R_1^T = R_2^{-1} R_1^{-1} = (R_1 R_2)^{-1} = R^{-1}$