# Chapter 2.3 through 2.5, Configuration Space

**Latest Submission Grade 100%**

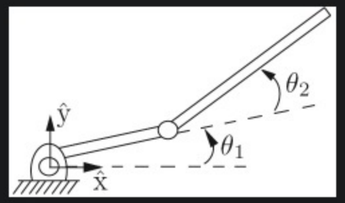
**1.** The tip coordinates for the two-link planar 2R robot of figure below are given by

1 / 1 point

$x = \cos\theta_1 + 2\cos(\theta_1 + \theta_2)$

$y = \sin\theta_1 + 2\sin(\theta_1 + \theta_2)$

(In other words, link 1 has length 1 and link 2 has length 2.) The joint angles have no limits.




Which of the following best describes the shape of the robot's workspace (the set of locations the endpoint can reach)?

- ○ A circle and its interior.
- ○ A circle only (not including the interior).
- ◉ Annulus or ring (the area between two concentric bounding circles).

Correct
The endpoint can never get closer than a distance 1 from the origin.

**2.** The chassis of a mobile robot moving on a flat surface can be considered as a planar rigid body. Assume that the chassis is circular, and the mobile robot moves in a square room. Which of the following could be a mathematical description of the C-space of the chassis while it is confined to the room? (See Chapter 2.3.1 for related discussion.)

1 / 1 point

- ◉ $[a,b] \times [a,b] \times S^1$
- ○ $[a,b] \times \mathbb{R}^1 \times S^1$
- ○ $[a,b] \times [a,b] \times \mathbb{R}^1$
- ○ $\mathbb{R}^2 \times S^1$

Correct

**3.** Which of the following is a possible mathematical description of the C-space of a rigid body in 3-dimensional space?

1 / 1 point

- ○ $\mathbb{R}^3 \times S^3$
- ○ $\mathbb{R}^3 \times T^3$
- ○ $\mathbb{R}^3 \times T^2 \times S^1$
- ◉ $\mathbb{R}^3 \times S^2 \times S^1$

Correct
This follows from the reasoning in Chapter 2.1 when we counted the degrees of freedom of a rigid body. $\mathbb{R}^3$ is for the placement of the first point, $S^2$ is for the placement of the second point on the surface of a sphere, and $S^1$ is for the placement of the third point on a circle.

4. Referring back to Question 1, let $T = T_{sb}$ be considered as a transformation operator consisting of a rotation about $\hat{x}$ by $-90^\circ$ and a translation along $\hat{y}$ by 2 units. Calculate $T_1 = TT_{sa}$, and think of $T_{sa}$ as the representation of the initial configuration of {a} relative to {s}, $T$ as a transformation operation, and $T_1$ as the new configuration of {a} after performing the transformation. Are the rotation axis $\hat{x}$ and translation axis $\hat{y}$ of the transformation $T$ properly considered to be expressed in the frame {s} or the frame {a}? 1 / 1 point

- (•) The frame {s}.
- ( ) The frame {a}.

Correct

5. Referring back to Question 1, use $T_{sb}$ to change the representation of the point $p_b = (1, 2, 3)^T$ (in {b} coordinates) to {s} coordinates. All elements of this vector should be integers. 1 / 1 point

**Enter your vector in the answer box (just modify the vector already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[1,2,3] for $\begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$.

```
1  [1,5,-2]
```

Run
Reset

Correct

Good job!

6. Referring back to Question 1, choose a point p represented by $p_s = (1, 2, 3)^T$ in {s} coordinates. Calculate $q = T_{sb}p_s$. Is q a representation of p in {b} coordinates? 1 / 1 point

- ( ) Yes
- (•) No

Correct

7. Referring back to Question 1, a twist $\mathcal{V}$ is represented in {s} as $\mathcal{V}_s = (3, 2, 1, -1, -2, -3)^T$. What is its representation $\mathcal{V}_b$? All elements of this vector should be integers. 1 / 1 point

**Enter your vector in the answer box (just modify the vector already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[1,2,3,4,5,6] for $\begin{bmatrix} 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{bmatrix}$.

```
1  [1,-3,-2,-3,-1,5]
```

Run
Reset

Correct

Good job!

8. Referring back to Question 1, calculate the matrix logarithm $[S]\theta$ of $T_{sb}$. Write the rotation amount $\theta$ in radians with at least 2 decimal places. 1 / 1 point

8. Referring back to Question 1, calculate the matrix logarithm $[S]\theta$ of $T_{ab}$. Write the rotation amount $\theta$ in radians with at least 2 decimal places. 1 / 1 point

```
2.0943951023931957
```

Run
Reset

Correct
Good job!

9. Calculate the matrix exponential corresponding to the exponential coordinates of rigid-body motion $\mathcal{S}\theta = (0, 1, 2, 3, 0, 0)^T$. The maximum allowable error for any matrix element is 0.01, so give enough decimal places where necessary. 1 / 1 point

**Enter your matrix in the answer box (just modify the matrix already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[[1.11,2.22,3.33],[4.44,5.55,6.66],[7.77,8.88,9.99]] for $\begin{bmatrix} 1.11 & 2.22 & 3.33 \\ 4.44 & 5.55 & 6.66 \\ 7.77 & 8.88 & 9.99 \end{bmatrix}$.

```
[[-0.61727288, -0.78368982,  0.35184491,  1.05553472],[ 0.78368982, -0.2938183, 0.6466
```

Run
Reset

Correct
Good job!

10. Referring back to Question 1, use $T_{ab}$ to change the representation of the wrench $\mathcal{F}_b = (1, 0, 0, 2, 1, 0)^T$ (in {b} coordinates) to {s} coordinates. All elements of this vector should be integers. 1 / 1 point

**Enter your vector in the answer box (just modify the vector already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[1,2,3] for $\begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$.

```
[-1, 0,-4, 2, 0,-1]
```

Run
Reset

Correct
Good job!

11. Use the function `TransInv` in the given software to calculate the inverse of the homogeneous transformation matrix 1 / 1 point

$$T = \begin{bmatrix} 0 & -1 & 0 & 3 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

All elements of this matrix should be integers.

**Enter your matrix in the answer box (just modify the matrix already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[[1,2,3],[4,5,6],[7,8,9]] for $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$.

```
[[ 0,  1,  0,  0],
 [-1,  0,  0,  3],
 [ 0,  0,  1, -1],
```

Run

**13.** Use the function `ScrewToAxis` in the given software to calculate the normalized screw axis representation $\mathcal{S}$ of the screw described by a unit vector $\hat{s} = (1, 0, 0)$ in the direction of the screw axis, located at the point $p = (0, 0, 2)$, with pitch $h = 1$. All elements of this vector should be integers. 1 / 1 point

**Enter your vector in the answer box (just modify the vector already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[1,2,3] for $\begin{bmatrix} 1 \\ 2 \\ 3 \end{bmatrix}$.

```
[1,0,0,1,2,0]
```

Run
Reset

**Correct**

Good job!

**14.** Use the function `MatrixExp6` in the given software to calculate the homogeneous transformation matrix $T \in SE(3)$ corresponding to the matrix exponential of 1 / 1 point

$$[\mathcal{S}]\theta = \begin{bmatrix} 0 & -1.5708 & 0 & 2.3562 \\ 1.5708 & 0 & 0 & -2.3562 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \end{bmatrix}.$$

All elements of this matrix should be integers.

**Enter your matrix in the answer box (just modify the matrix already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[[1,2,3],[4,5,6],[7,8,9]] for $\begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{bmatrix}$.

```
[[0,-1,0,3],[1,0,0,0],[0,0,1,1],[0,0,0,1]]
```

Run
Reset

**Correct**

Good job!

**15.** Use the function `MatrixLog6` in the given software to calculate the matrix logarithm $[\mathcal{S}]\theta \in se(3)$ of the homogeneous transformation matrix 1 / 1 point

$$T = \begin{bmatrix} 0 & -1 & 0 & 3 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 \end{bmatrix}.$$

The maximum allowable error for any matrix element is 0.01, so give enough decimal places where necessary.

**Enter your matrix in the answer box (just modify the matrix already shown there) and click "Run." Your answer will not be evaluated until you submit the quiz.**

[[1.11,2.22,3.33],[4.44,5.55,6.66],[7.77,8.88,9.99]] for $\begin{bmatrix} 1.11 & 2.22 & 3.33 \\ 4.44 & 5.55 & 6.66 \\ 7.77 & 8.88 & 9.99 \end{bmatrix}$.

```
[[ 0,          -1.57079633,  0,          2.35619449],
 [ 1.57079633,  0,          0,         -2.35619449],
 [ 0,           0,          0,          1         ],
 [ 0,           0,          0,          0         ]]
```

Run
Reset

**Correct**

Good job!