Wheeled Mobile Robots

Assignment 2

1. If the number of controllable degree of freedom is equal to the total degree of freedom, then system is called as a ___________

   ◯ mobile robot
   ◯ holonomic system
   ◯ nonholonomic system
   ◯ differential drive
   ◯ structure
   ◯ manipulator

   Correct answer is **holonomic system**

2. In a two fixed wheel (differential) drive mobile robot, the left side wheel angular velocity is 0.5 rad/s and the right side wheel angular velocity is 1.5 rad/s, both wheels are same size and the wheel radius is 10 cm. What will be the longitudinal velocity (u) of the robot with respect to the body frame?

   ◯ 0.2 m/s
   ◯ 0.1 m/s
   ◯ 2 m/s
   ◯ 1 m/s
   ◯ 0.05 m/s
   ◯ 0.025 m/s

   Correct answer is **0.1 m/s**

3. In a two fixed wheel (differential) drive mobile robot, the left side wheel angular velocity is 0.5 rad/s and the right side wheel angular velocity is 1.5 rad/s, both wheels are same size and the wheel radius is 10 cm. The wheels are placed along the $y-$axis of body frame and equal distance from the body frame. The distance between the wheel to wheel along $y-$axis is 40 cm. What will be the angular velocity (r) of the robot with respect to the body frame?

   ◯ -0.25 rad/s
   ◯ 0.25 rad/s
   ◯ -0.5 rad/s
   ◯ 0.5 rad/s
   ◯ -0.1 rad/s
   ◯ 0.1 rad/s

   Correct answer is **0.25 rad/s**

4. If the rank of the wheel configuration matrix of a wheeled mobile robot is less than three, then the system is called as a ___________

   ◯ mobile robot
   ◯ holonomic system
   ◯ nonholonomic system
   ◯ differential drive
   ◯ structure
   ◯ manipulator

   Correct answer is **nonholonomic system**

5. For a given mobile robot with four mecanum wheels, the wheel configuration matrix ($\mathbf{W}$) is $\frac{a}{4}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ -\frac{1}{d-l} & -\frac{1}{d-l} & \frac{1}{d-l} & \frac{1}{d-l} \end{bmatrix}$, if the robot is to move in a lateral direction (upwards), then what will be the right combination of these wheel angular velocities?

- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = \omega, \omega_4 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = -\omega, \omega_4 = -\omega$
- ◯ $\omega_1 = \omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = -\omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = \omega, \omega_3 = -\omega, \omega_4 = \omega$
- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = -\omega, \omega_4 = -\omega$

Correct answer is $\omega_1 = \omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = -\omega$

6. For a given mobile robot with four mecanum wheels, the wheel configuration matrix ($\mathbf{W}$) is $\frac{a}{4}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \\ -\frac{1}{d-l} & -\frac{1}{d-l} & \frac{1}{d-l} & \frac{1}{d-l} \end{bmatrix}$, if the robot is to rotate in the counter clockwise direction (upwards), then what will be the right combination of these wheel angular velocities?

- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = \omega, \omega_4 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = -\omega, \omega_4 = -\omega$
- ◯ $\omega_1 = \omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = -\omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = \omega, \omega_3 = -\omega, \omega_4 = \omega$
- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = -\omega, \omega_4 = -\omega$

Correct answer is $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = \omega, \omega_4 = \omega$

7. For a given mobile robot with three omni-directional wheels, the wheel configuration matrix ($\mathbf{W}$) is $\begin{bmatrix} 0 & -\frac{a\sqrt{3}}{3} & \frac{a\sqrt{3}}{3} \\ \frac{2a}{3} & -\frac{a}{3} & -\frac{a}{3} \\ \frac{a}{3l} & \frac{a}{3l} & \frac{a}{3l} \end{bmatrix}$, if the robot is to move in a lateral direction (upwards), then what will be the right combination of these wheel angular velocities?

- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = -\omega$
- ◯ $\omega_1 = \omega, \omega_2 = -\frac{\omega}{2}, \omega_3 = -\frac{\omega}{2}$
- ◯ $\omega_1 = \omega, \omega_2 = \frac{\omega}{2}, \omega_3 = \frac{\omega}{2}$
- ◯ $\omega_1 = 0, \omega_2 = -\omega, \omega_3 = \omega$
- ◯ $\omega_1 = 0, \omega_2 = \omega, \omega_3 = -\omega$

Correct answer is $\omega_1 = \omega, \omega_2 = -\frac{\omega}{2}, \omega_3 = -\frac{\omega}{2}$

8. For a given mobile robot with three omni-directional wheels, the wheel configuration matrix ($\mathbf{W}$) is $\begin{bmatrix} 0 & -\frac{a\sqrt{3}}{3} & \frac{a\sqrt{3}}{3} \\ \frac{2a}{3} & -\frac{a}{3} & -\frac{a}{3} \\ \frac{a}{3l} & \frac{a}{3l} & \frac{a}{3l} \end{bmatrix}$, if the robot is to move in a longitudinal direction (forward), then what will be the right combination of these wheel angular velocities?

- ◯ $\omega_1 = \omega, \omega_2 = \omega, \omega_3 = \omega$
- ◯ $\omega_1 = -\omega, \omega_2 = -\omega, \omega_3 = -\omega$
- ◯ $\omega_1 = \omega, \omega_2 = -\frac{\omega}{2}, \omega_3 = -\frac{\omega}{2}$
- ◯ $\omega_1 = \omega, \omega_2 = \frac{\omega}{2}, \omega_3 = \frac{\omega}{2}$
- ◯ $\omega_1 = 0, \omega_2 = -\omega, \omega_3 = \omega$
- ◯ $\omega_1 = 0, \omega_2 = \omega, \omega_3 = -\omega$

Correct answer is $\omega_1 = 0, \omega_2 = -\omega, \omega_3 = \omega$

9. For a given land-based mobile robot, the wheel configuration matrix is given as $\mathbf{W} \in \mathbb{R}^{m \times n}$ and $m > n$, then what will be the pseudo inverse, $\mathbf{W}^+ =$ ______ at what condition this is true? and when you will get an identity matrix?

   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| \neq 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$
   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| = 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$
   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| \neq 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| \neq 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| = 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| \neq 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$

   Correct answer is $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| \neq 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$

10. For a given land-based mobile robot, the wheel configuration matrix is given as $\mathbf{W} \in \mathbb{R}^{m \times n}$ and $m < n$, then what will be the pseudo inverse, $\mathbf{W}^+ =$ ______ at what condition this is true? and when you will get an identity matrix?

   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| \neq 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$
   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| = 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$
   - $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| \neq 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| \neq 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| = 0, \mathbf{W}^+\mathbf{W} = \mathbf{I}.$
   - $\mathbf{W}^+ = \left(\mathbf{W}^T\mathbf{W}\right)^{-1} \mathbf{W}^T, \left|\left(\mathbf{W}^T\mathbf{W}\right)\right| \neq 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$

   Correct answer is $\mathbf{W}^+ = \mathbf{W}^T \left(\mathbf{W}\mathbf{W}^T\right)^{-1}, \left|\left(\mathbf{W}\mathbf{W}^T\right)\right| \neq 0, \mathbf{W}\mathbf{W}^+ = \mathbf{I}.$

11. The Euler method is a first-order method, which means that the local error (error per step) is proportional to the square of the step size, and the global error (error at a given time) is proportional to the step size.

   - True
   - False

   Correct answer is **True**

12. There are less equations than unknowns (m¡n), then the solution is under-specified.

   - True
   - False

   Correct answer is **True**

13. If the given matrix $\mathbf{A} = \begin{bmatrix} 0.1 & 0.1 \\ 0 & 0 \\ 0.5 & -0.5 \end{bmatrix}$, what will be the Moore Penrose pseudo inverse matrix of $\mathbf{A}$?

   - $\mathbf{A}^+ = \begin{bmatrix} 5 & 0 & 1 \\ 5 & 0 & -1 \end{bmatrix}$
   - $\mathbf{A}^+ = \begin{bmatrix} 5 & 0 & 1 \\ -5 & 0 & 1 \end{bmatrix}$
   - $\mathbf{A}^+ = \begin{bmatrix} 0.5 & 0 & 0.1 \\ 0.5 & 0 & -0.1 \end{bmatrix}$

- ◯ $\mathbf{A}^{+} = \begin{bmatrix} 1 & 0 & 5 \\ 1 & 0 & -5 \end{bmatrix}$
- ◯ $\mathbf{A}^{+} = \begin{bmatrix} 1 & 0 & 5 \\ -1 & 0 & 5 \end{bmatrix}$
- ◯ $\mathbf{A}^{+} = \begin{bmatrix} 0.1 & 0 & 0.5 \\ 0.1 & 0 & -0.5 \end{bmatrix}$
- ◯ $\mathbf{A}^{+} = \begin{bmatrix} 0.1 & 0 & 0.5 \\ -0.1 & 0 & 0.5 \end{bmatrix}$

Correct answer is $\mathbf{A}^{+} = \begin{bmatrix} 5 & 0 & 1 \\ 5 & 0 & -1 \end{bmatrix}$