

# Homework 1

## Introduction to Robotics

1. What are the degrees of freedom of a standard, four-wheel, hand-pushed lawnmower? Why are you still able to mow your entire lawn?
2. What are the maximum degrees of freedom for objects driving on the plane?
3. (a) Calculate the angle between vectors  $(\cos 45^\circ, -\sin 45^\circ, 0)^T$  and  $(\sin 45^\circ, \cos 45^\circ, 0)^T$ .  
(b) Provide a third vector that forms a coordinate system with the other two.
4. (a) Write out the entries of a rotation matrix  ${}^A_B R$  assuming basis vectors  $X_A, Y_A, Z_A$ , and  $X_B, Y_B, Z_B$ .  
(b) Express  $\hat{X}_B = [0, 1, 0]^T$  in frame  $\{A\}$ .  
(c) Write out the entries of rotation matrix  ${}^B_A R$ .
5. Consider a tri-cycle with two independent standard wheels in the rear and the steerable, actuated front-wheel. Assume  $r$  to be the radius of the front wheel and  $l$  be the distance between the front and rear axle. Chose a suitable coordinate system and use  $\phi$  as the steering wheel angle and wheel-speed  $\dot{\omega}$  (only the steered front-wheel is driven). Provide the forward kinematics of the mechanism.