

Design of Mechatronic systems

Spring 2026

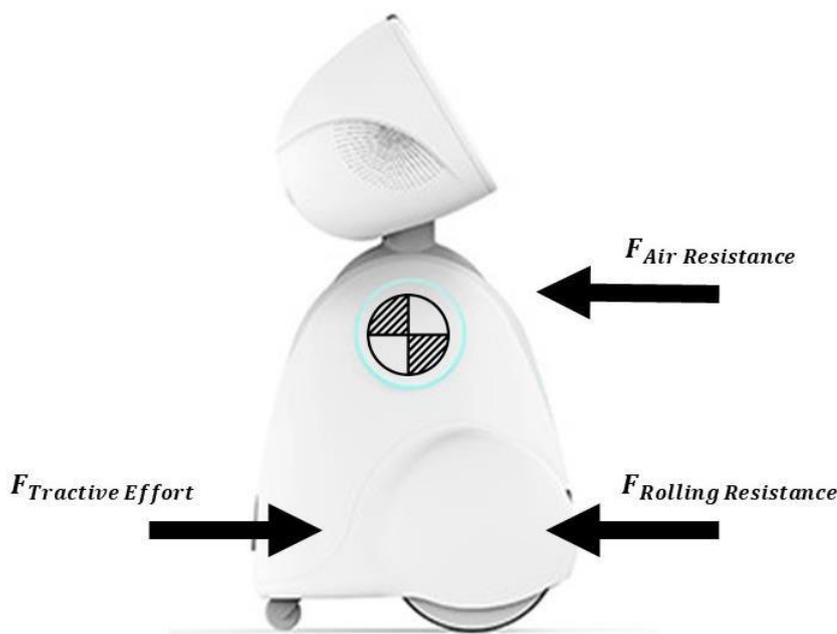
Mobile Robots Dynamics



Lab Objectives:

- I. Learn how to size an actuator for a mobile robot
- II. Learn how to check stability of a mobile robot
- III. Learn how to check the roll-over of the robot during acceleration and deceleration and cornering
- IV. Simulating a wheeled mobile robot on SOLIDWORKS Motion Analysis

↳ Mobile Robot Actuator Sizing:



$$\text{Tractive Effort} = T_m(\text{Motor Torque})/R_w(\text{Wheel Radius of the actuated Wheel})$$

$$\text{Rolling Resistance} = \mu_{rr}(\text{Coefficient of rolling resistance}) * mg$$

Air Resistance

$$= \frac{1}{2} * C_d(\text{Coefficient of Drag}) * \rho(\text{Air Density}) \\ * A_f(\text{Projected Frontal Area}) * V^2(\text{Robot Velocity})$$

↗ **Applying Newton's Second Law in Euler Form**

$$T_{motor} = T_R + J \theta$$

$$T_R = (F_{Air Resistance} + F_{Rolling Resistance}) * R_W$$

$$J = J_{motor} + J_{Eq Wheels} + J_{Eq Linear Mass}$$

θ Depends on motion requirements

↗ **Kinetic Energy of Linear mass = Kinetic Energy supplied by Motor**

$$\frac{1}{2} * m * V^2 = \frac{1}{2} * J_{Eq Linear Mass} * \theta^2$$

$$J_{Eq Linear Mass} = m * R_W^2$$

↗ **Traction Limit**

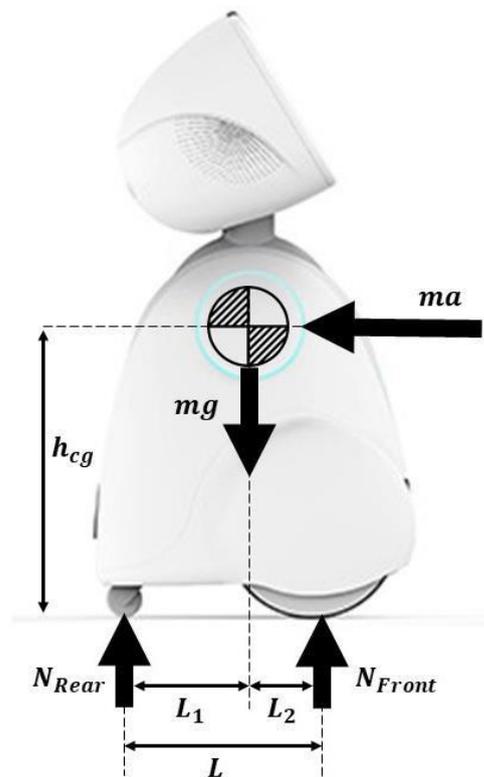
Maximum force the motor can generate to move the robot

Traction Effort Max

$$= N_{actuated Wheel}(\text{Reaction on the Actuated Wheel})$$

$$* \mu_f(\text{coefficient of friction between wheel tyre and ground})$$

↪ Stability in the Longitudinal Direction:



↪ Static Weight (While robot is stationary)

$$N_R = mg * \frac{L_2}{L}$$

$$N_F = mg * \frac{L_1}{L}$$

↪ Weight Transfer in the Longitudinal Direction

Taking the moment about the Front Wheel

$$N_R(\text{Reaction on the rear wheels}) * L = mg * L_2 + ma * h_{cg}$$

$$N_R = mg * \frac{L_2}{L} \text{ (Static Weight)} + \frac{ma * h_{cg}}{L} \text{ (Weight Transfer)}$$

Robot weight won't change

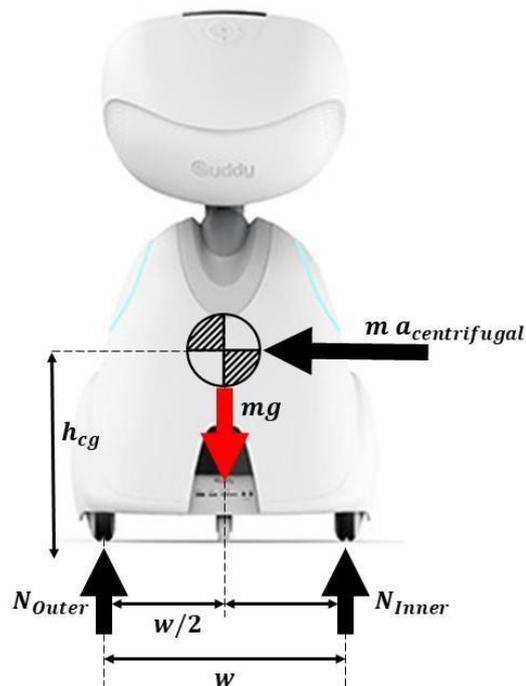
$$N_F = mg * \frac{L_1}{L} \text{ (Static Weight)} - \frac{ma * h_{cg}}{L} \text{ (Weight Transfer)}$$

↪ Longitudinal Roll over Condition

$$N_F = mg * \frac{L_1}{L} - \frac{ma * h_{cg}}{L} = 0$$

$$a = g \frac{L_1}{h_{cg}}$$

↪ Stability in the Lateral Direction:



↪ Static Weight (While robot is stationary)

$$N_{Outer} = mg * \frac{w/2}{w} = \frac{mg}{2}$$

$$N_{Outer} = mg * \frac{w/2}{w} = \frac{mg}{2}$$

↪ Weight Transfer in the Lateral Direction

Taking the moment about the Inner Wheel

$$N_o(\text{Reaction on the Outer wheels}) * w = mg * \frac{w}{2} + m \frac{V^2(\text{Robot Logitudinal Velocity})}{R(\text{Corner Radius})} * h_{cg}$$

$$N_{Outer} = \frac{mg}{2} (\text{Static Weight}) + \frac{m * V^2 h_{cg}}{w * R} (\text{Weight Transfer})$$

Robot weight won't change

$$N_{Inner} = \frac{mg}{2} (\text{Static Weight}) - \frac{m * V^2 h_{cg}}{w * R} (\text{Weight Transfer})$$

↪ Longitudinal Roll over Condition

$$N_{Inner} = \frac{mg}{2} - \frac{m * V^2 h_{cg}}{w * R} = 0 \quad V = \sqrt{\frac{g w R}{2 * h_{cg}}}$$