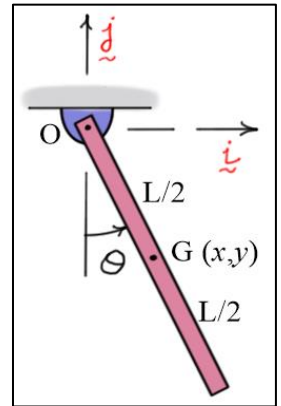


# Multibody Dynamics

## Exercises #6

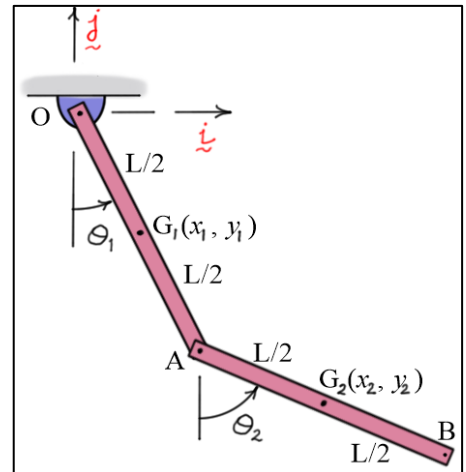
1. The figure shows a pendulum made of a single slender bar of mass  $m$  and length  $L$ . Using Lagrange's equations, complete the following.



a) Formulate the equation of motion of the pendulum using  $\theta$  as the only generalized coordinate.

b) Formulate equations of motion of the pendulum using the set of dependent generalized coordinates  $(x, y, \theta)$ . Then differentiate the constraint equations to form second-order ordinary differential equations. There should be **five** equations in all.

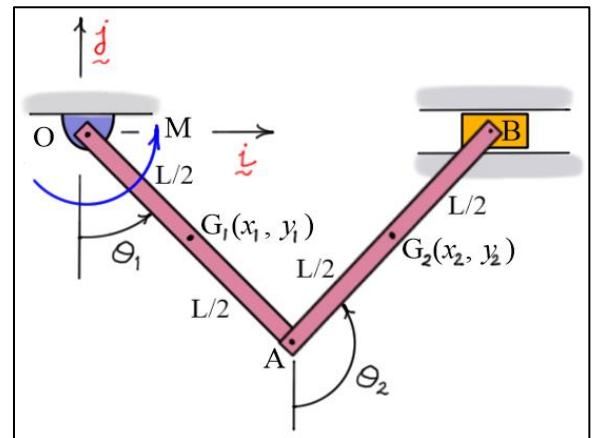
2. The figure shows a double pendulum made of two slender bars each having mass  $m$  and length  $L$ . Using Lagrange's equations, complete the following.



a) Formulate equations of motion of the pendulum using  $\theta_1$  and  $\theta_2$  as generalized coordinates.

b) Formulate equations of motion of the pendulum using the set of constrained generalized coordinates  $(x_1, y_1, \theta_1)$  and  $(x_2, y_2, \theta_2)$ . Then differentiate the constraint equations to form second-order ordinary differential equations. There should be **ten** equations in all.

3. The figure shows a slider-crank mechanism driven by a motor torque  $M$ . Each slender bar has mass  $m$  and length  $L$ . Assume the mass of the slider is negligible and treat the system as a constrained double pendulum.



a) Using results from 2(a), formulate equations of motion of the slider-crank mechanism using the set of constrained generalized coordinates  $(\theta_1, \theta_2)$ . Then differentiate the constraint equation to form a second-order ordinary differential equation. There should be **three** equations in all.

b) Using results from 2(b), formulate equations of motion of the slider-crank mechanism using the set of constrained generalized coordinates  $(x_1, y_1, \theta_1)$  and  $(x_2, y_2, \theta_2)$ . Then differentiate the constraint equations to form second-order ordinary differential equations. There should be **eleven** equations in all.