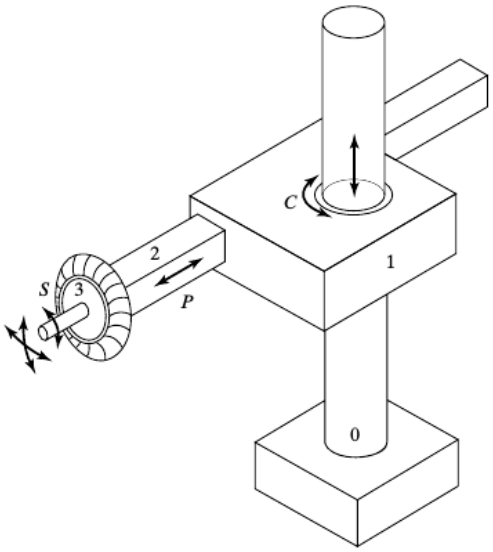
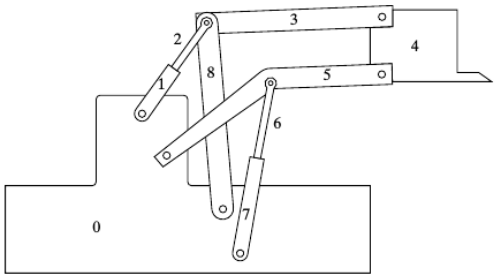
ME 380
Kinematics and Machine Dynamics
Midterm I

1. [30 points] This question is concerned with finding the degrees of freedom of linkages.

   (a) [10 points] Find the number of degrees of freedom for the spatial linkage below. This open- loop kinematic chain includes cylindrical, prismatic, and spherical joints.



   (b) [10 points] The linkage depicted below is a schematic representation of a piece of construction machinery. It has two hydraulic cylinders (links 1 and 2, and links 6 and 7), which may be considered cylindrical pairs. The other pairs are revolute joints. Find the number of degrees of freedom if this linkage is treated as a planar linkage.



   (c) [10 points] Indicate the conditions that must be met for the planar linkage assumption to be valid in part (b).

2. [30 points] Consider the linkage shown in Figure 1. Let $l_1 = |O_1A|$, $l_2 = |AB|$, $l_2' = |AC|$, $l_5 = |DE|$, $l_6 = |O_2F|$, and $l_7 = |FE|$, $l_7' = |CF|$. Answer the following questions about this mechanism.

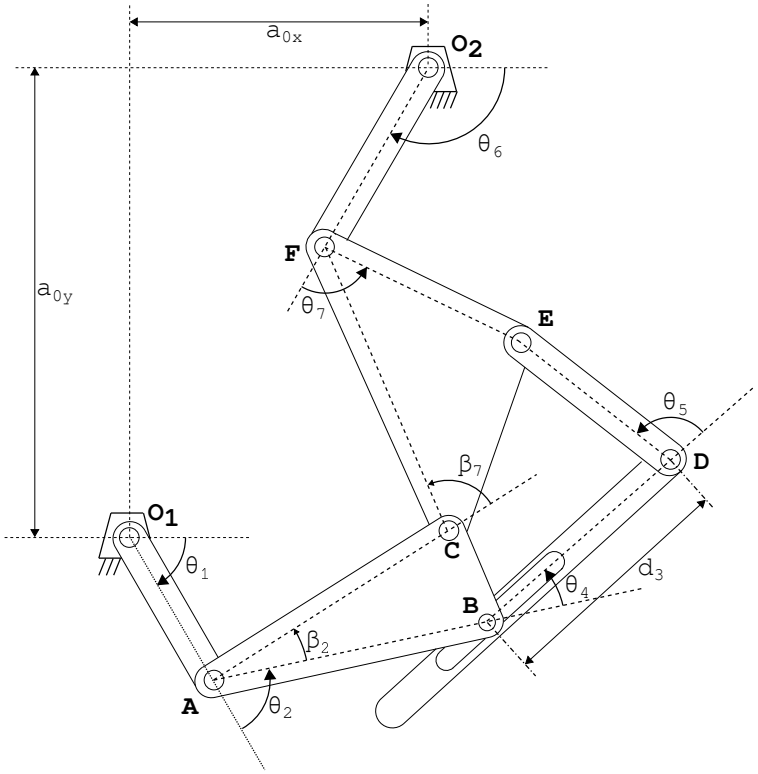


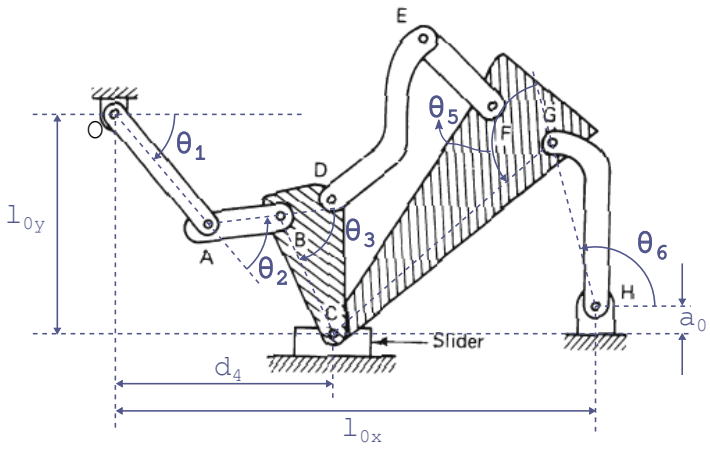
Figure 1: `Fourbar with inverted slider`

(a) [10 points] Compute the mobility of this linkage.

(b) [20 points] Analytically derive the loop equations in terms of the variables $(\theta_1, \theta_2, d_3, \theta_4, \theta_5, \theta_6, \theta_7)$ and the various constants a_{0x}, a_{0y}, l_1 through l_7, and β_2, β_7.

3. [40 points] Consider the linkage shown in the figure below. Answer the following questions related to this mechanism.

Quantity	Endpoints	Length [mm]
l_1	$\|OA\|$	100
l_2	$\|AB\|$	50
l_3	$\|BC\|$	90
l_5	$\|GC\|$	200
l_6	$\|HG\|$	125
l_{0x}	shown	350
l_{0y}	shown	160
a_0	shown	15



(a) [7 points] Compute the mobility of this linkage and identify the various sub-components of this mechanism as various simpler mechanisms we have discussed in class.

(b) [13 points] Derive the position-level loop equations for this mechanism.

(c) [20 points] Use vector cross product method to solve for the position-level kinematics at an instant when $\theta_1 = -\frac{5\pi}{16}$ rad and $d_4 = 175$ mm. (solve for θ_2, θ_3, θ_5, and θ_6).