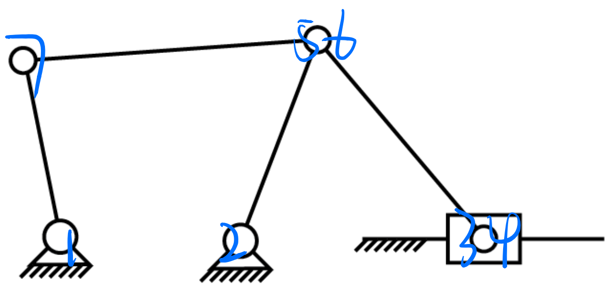
MAE 292 Spring 2020 Homework 4

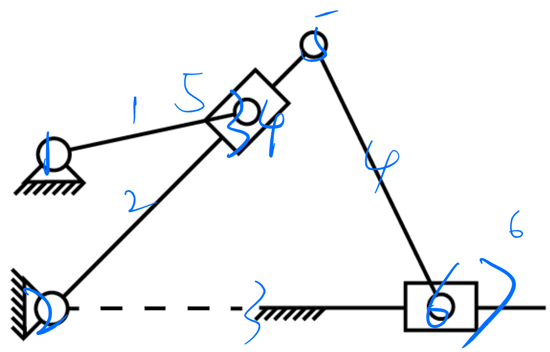
Due on May 14, 2020, at 11:59 PM

Problem 1: Analyze the mobility of following mechanisms (20 points)

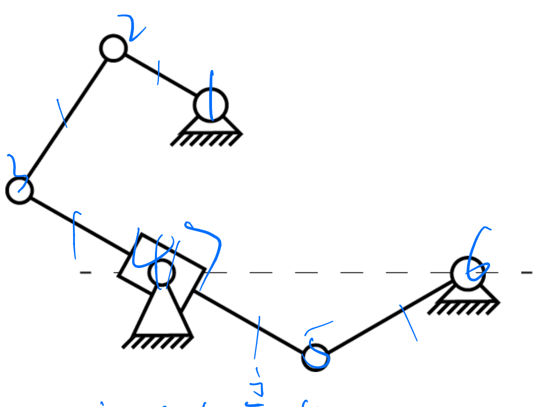
Part a



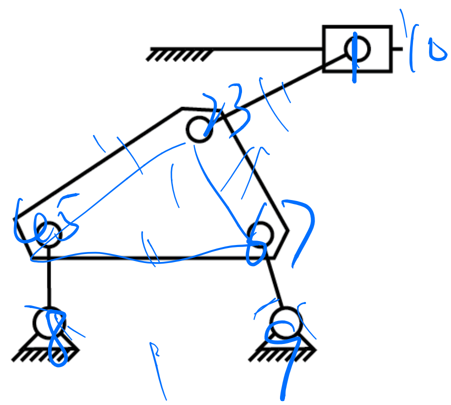
Part b



Part c



Part d



$M = \lambda(l - j - 1) + \sum_{1}^{j} f_i$

As for planar system: $\lambda = 3$, $f_i = 1$

$\Rightarrow M = 3(l-1) - 2j$.

Part a: $l = 6$ $j = 7$

$M = 3(6-1) - 2 \times 7$

$= 1$

DoF $= 1$

Part b: $l = 6$ $j = 7$

$M = 1$

DoF $= 1$

Part c $a = 6$ $j = 7$

$M = 1$

DoF $= 1$

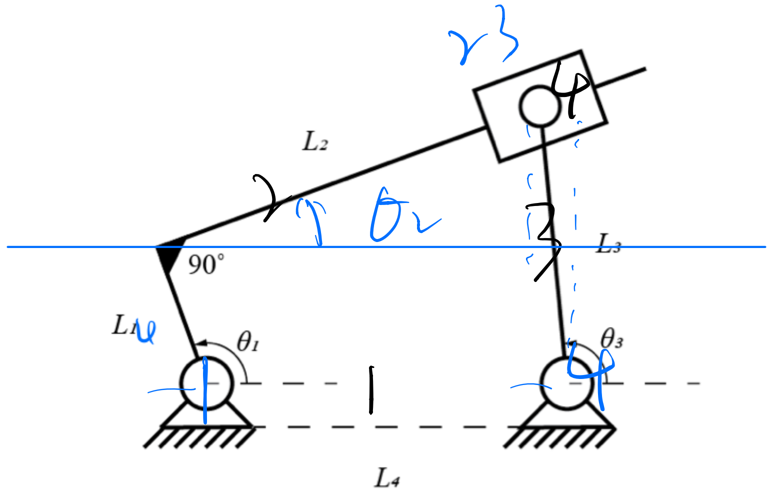
Part D $a = 8$ $j = 10$

$M = 3 \times (8-1) - 10 \times 2$

$= 1$

DoF $= 1$

Problem 2



(a)

joints $=4$

link $=4$

$M=3\times(4-1)-4\times 2=1$

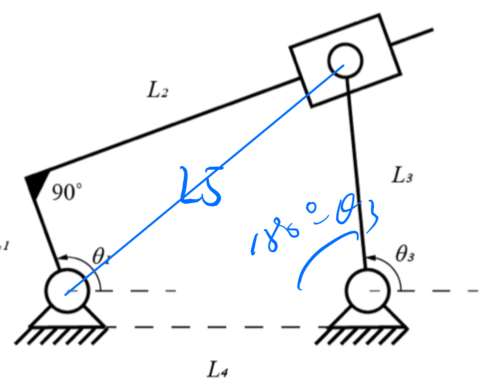
(b)
$$\begin{cases} L_1\cdot\cos\theta_1+L_2\cos\theta_2-L_3\cos\theta_3-L_4=0 \\ L_1\sin\theta_1+L_2\cdot\sin\theta_2-L_3\sin\theta_3=0 \end{cases}$$

$(180-\theta_1)+\theta_2=90^\circ \Rightarrow \theta_1=90^\circ+\theta_2$

$$\begin{cases} L_2\cos\theta_2=L_4+L_3\cos\theta_3-L_1\cos\theta_1 & ① \\ L_2\sin\theta_2=L_3\sin\theta_3-L_1\sin\theta_1 & ② \end{cases}$$

$①^2+②^2$

$$\Rightarrow L_2^2=L_4^2+2L_3L_4\cos\theta_3-2L_1L_4\cos\theta_1$$
$$+\cancel{L_3^2\cos^2\theta_3}-2L_1L_3\cos\theta_3\cos\theta_1$$
$$+\cancel{L_1^2\cos^2\theta_1}+\cancel{L_3^2\sin^2\theta_3}+\cancel{L_1^2\sin^2\theta_1}-2L_1L_3\sin\theta_1\sin\theta_3$$
$$=L_4^2+L_3^2+L_1^2+2(L_3L_4\cos\theta_3-L_1L_4\cos\theta_1)$$
$$-2L_1L_3\cos(\theta_1-\theta_3)$$



A: $L_2^2+L_1^2=L_5^2$

B: $L_5^2=L_3^2+L_4^2-2L_3L_4\cos(180^\circ-\theta_3)$

$$\Rightarrow L_2^2 = L_5^2 - L_1^2 = \cancel{L_3^2} + \cancel{L_4^2} + 2\cancel{L_3 L_4}\cos\theta_3 - L_1^2$$

$$= \cancel{L_4^2} + \cancel{L_3^2} + L_1^2 + 2L_3\cancel{L_4}\cos\theta_3 - 2L_1L_4\cos\theta_1 - 2L_1L_3\cos(\theta_1 - \theta_3)$$

$$L_1 - L_4\cos\theta_1 - L_3\cos(\theta_1 - \theta_3) = 0$$

$$\frac{L_1}{L_3} - \frac{L_4}{L_3}\cos\theta_1 - \cos(\theta_1 - \theta_3) = 0$$

Let, $D_1 = \frac{L_1}{L_3}$ $D_2 = \frac{L_4}{L_3}$

$$\Rightarrow D_1 - D_2 - \cos(\theta_1 - \theta_3) = 0.$$

(c)

Hw4P2b.m 〉 No Selection

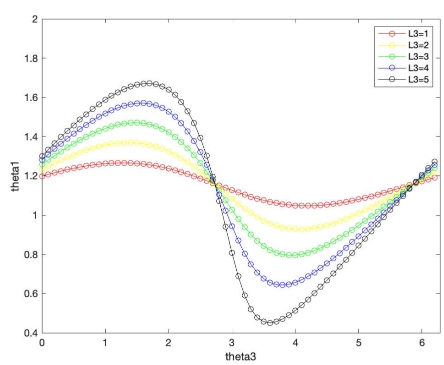
```
function fx = loop_closure_constraint(theta1, theta3, l1, l3, l4)
    l2 =
        squrt(l3^2+l4^2+l1^2+2*(l3*l4*cos(theta3)-l1*l4*cos(theta1))-2*l1*l3*cos
        (theta1-theta3));
     fx = [l1*cos(theta1) + l2*cos(theta1-pi/2) - l3*cos(theta3) - l4;
           l1*sin(theta1) + l2*sin(theta1-pi/2) - l3*sin(theta3)];
end
```

(d)

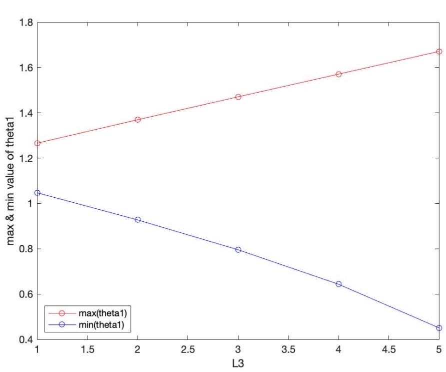
```
%%
%Problem2d
l1 = 4;
l4 = 10;
prompt = 'Please input the theta3 ';
theta3 = input(prompt);
for l3=[1:5]
    F = @(x) loop_closure_constraint(x, theta3, l1,  l3, l4);
    [x,fval] = fsolve(F, 0);
    theta1 = x;
end
```

Whole matlab code will be attached in HW4P2.m file.

(e)



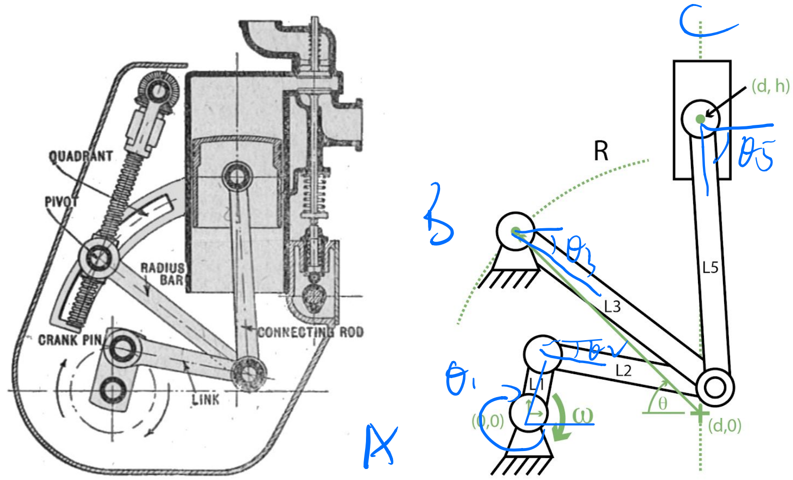
(f)



Problem 3: CAD and Simscape multibody (40 points)

Part 1: A variable stroke engine is shown to the left below and a schematic of the system is shown to the right below. Using the following parameters (dimensions are all in inches) construct a model of this system using simscape multibody or fsolve in matlab.

L_1	L_2	L_3	R	L_5	d	θ (deg.)
3	7	9	12.5	10	7	[35 - 70]



①

1. Plot the relationship between input angle and piston height for a range of stroke adjustment angles (θ), choose a reasonable range.

$\theta = \omega t$

2. Plot the vertical speed of the piston as a function of time, for a constant input angular speed $\omega = 1$.

A C

$(0,0) \to (d,h)$

3. Plot the total stroke length of the piston (max(h) - min(h)) as a function of θ.

x: $L_1 \cdot \cos\theta_1 + L_2\cos\theta_2 - L_5\cos\theta_5 - d = 0$

y: $L_1\sin\theta_1 + L_2\sin\theta_2 - L_5\sin\theta_5 + h = 0$

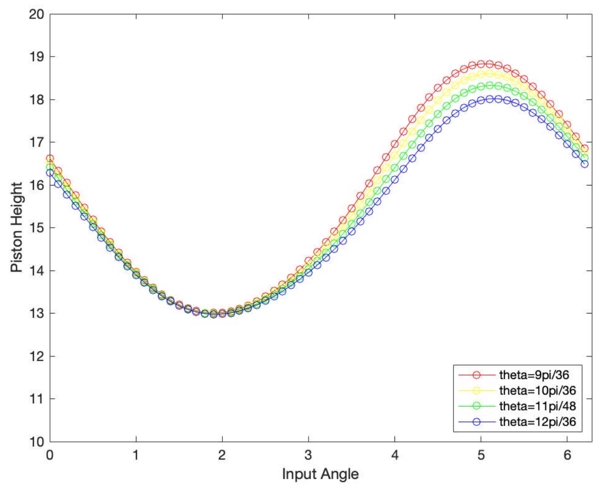
$35^\circ - 70^\circ \to (\frac{\pi}{4} \to \frac{\pi}{3})$

A → B.

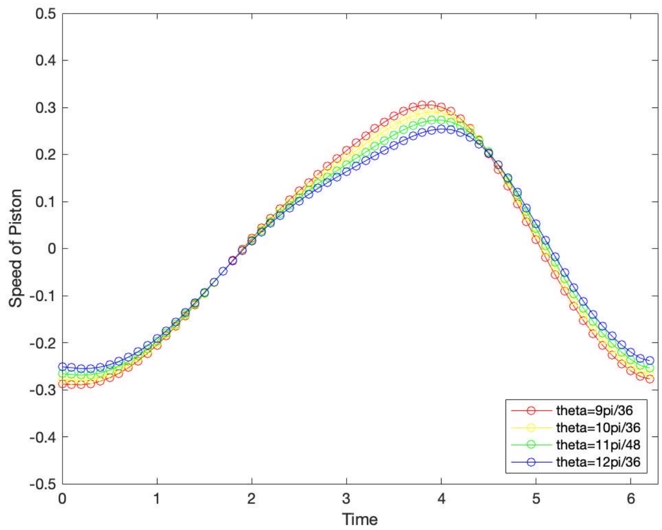
$x = L_1\sin\theta_1 + L_2\sin\theta_2 - L_3\sin\theta_3 - R\sin\theta = 0$

$y = L_3\cos\theta_3 - L_5\cos\theta_5 - R\cos\theta = 0$

$\frac{9\pi}{36}$ $\frac{10\pi}{36}$ $\frac{11\pi}{38}$ $\frac{12\pi}{36}$



② $\theta = wt = t$ $\quad v = \frac{dx}{dt}$.



Part2: Assemlebly
https://a360.co/362E0w6

③