Problem 2

(a) $M = 3(l-1) - 2j \quad l=5 \quad j=5$

$M = 3\times4 - 10 = 2 \quad \therefore DoF = 2$

(b)
$$\begin{cases} x: l_1\cos\theta_1 + l_2\cos(\theta_1+\theta_2) + l_0 - l_3\cos(\theta_3) - l_4\cos(\theta_3+\theta_4) = 0 \\ y: l_1\sin\theta_1 + l_2\sin(\theta_1+\theta_2) - l_3\sin(\theta_3) - l_4\sin(\theta_3+\theta_4) = 0 \end{cases}$$

(c) Unlike 4-bar (DoF = 1), the 5-bar has 2 degrees of freedom, so we should certain two variables, for example the θ_1 and θ_3 as independene variables

① Define the range of θ_1 and θ_3

② Two for loop eg. to create 2 dimentional ranges, by the constain with fsolve, x_e, y_e can be certain. And the whole movement can be simulated.

Outlink of matlab

```
for θ1
    for θ3
        F = constainequation with θ1 and θ3
        fslove(F, 0)
    end
end
```

(d) ① certain the relationship, such as x_e, y_e, and also V_{xe}, V_{ye}, ($\sqrt{V_e^2+V_y^2} = V$) as the constaint F we need, with all variables and parameters as Problem 2c. However, the length through L_0 to L_4 change, which indeed increase the DoF of the whole system. We can use more layers "for loop" to "fslove" the extremum, but we also can use "fminsearch" and "fmincon" to optimizate.

② "fmincon" is a gradient based function to find minimum of constrainded nolinear multivarible.

$$\min f(x) \text{ such that } \begin{cases} c(X) \le 0 \\ Ceq(x) = 0 \\ A X \le b \\ Aeq \cdot X = beq \end{cases}$$

"fminsearch" find minimum of unconstrainded multivariable function using derivative-free method.

$$\min_{x} f(x)$$

③ Fminsearch do not need to know the gradient but it can't deal with explicit boundaries, and for large numbers of paramieters, it gets ineffiecient.

In this question, Fmincon is very suitable for bounded optimization, and thus are better given the leg requirement

ⓐ.

$AB: (x-\frac{a}{2})^2+(y+\frac{\sqrt{3}}{3}\frac{a}{2})^2=a^2$

$x^2+y^2-ax+\frac{\sqrt{3}}{3}ay-\frac{2}{3}a^2=0$

$\Rightarrow \rho^2-a\cos\theta\rho+\frac{\sqrt{3}}{3}a\sin\theta\rho-\frac{2}{3}a^2=0 \quad \theta\in(\frac{\pi}{2},\frac{7}{6}\pi)$

$AC: (x+\frac{a}{2})^2+(y+\frac{\sqrt{3}}{3}\frac{a}{2})^2=a^2 \qquad \theta\in(-\frac{\pi}{6},\frac{\pi}{2})$

$x^2+y^2+ax+\frac{\sqrt{3}}{3}ay-\frac{2}{3}a^2=0$

$\Rightarrow \rho^2-a\cos\theta\rho+\frac{\sqrt{3}}{3}a\sin\theta\rho-\frac{2}{3}a^2=0$

$BC: x^2+(y-\frac{2\sqrt{3}}{3}\cdot\frac{a}{2})^2=a^2 \qquad \theta\in(-\frac{5\pi}{6},-\frac{\pi}{6})$

$x^2+y^2+\frac{1}{3}a^2-\frac{2\sqrt{3}}{3}ay-a^2=0$

$\Rightarrow$

$\rho^2-\frac{2\sqrt{3}}{3}a\rho\sin\theta-\frac{2}{3}a^2=0$

ⓑ.