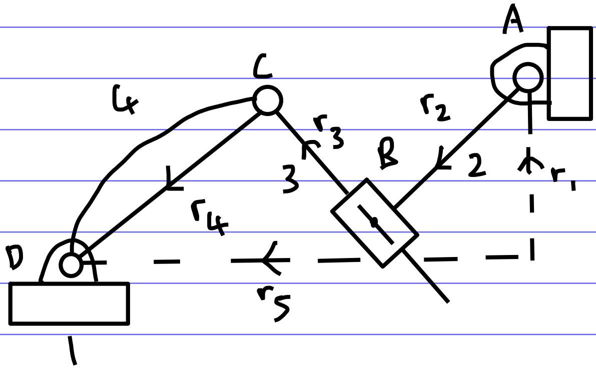
6.1)



Vector loop closure equation:

$$\underset{\sim}{r_1} + \underset{\sim}{r_2} + \underset{\sim}{r_3} + \underset{\sim}{r_4} = \underset{\sim}{r_5}$$

$$r_1\underset{\sim}{j} + r_2(\cos\theta_2\underset{\sim}{i} + \sin\theta_2\underset{\sim}{j}) + r_3(\cos\theta_3\underset{\sim}{i} + \sin\theta_3\underset{\sim}{j}) + r_4(\cos\theta_4\underset{\sim}{i} + \cos\theta_4\underset{\sim}{j}) = -r_5\underset{\sim}{i}$$

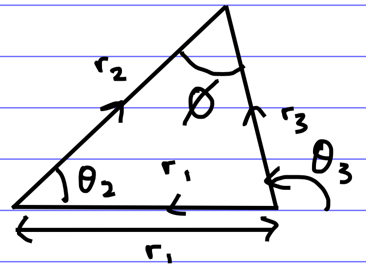
x component:

$$-r_5 = r_2\cos\theta_2 + r_3\cos\theta_3 + r_4\cos\theta_4 \quad -(1)$$

Y component:

$$r_1 + r_2\sin\theta_2 + r_3\sin\theta_3 + r_4\sin\theta_4 = 0 \quad -(2)$$

6.2)



Vector loop closure equation:

$$r_1 + r_2 = r_3$$

$$-r_1 \underset{\sim}{i} + r_2(\cos\theta_2 \underset{\sim}{i} + \sin\theta_2 \underset{\sim}{j}) = r_3(\cos\theta_3 \underset{\sim}{i} + \sin\theta_3 \underset{\sim}{j})$$

Position analysis

x component:

$$r_1 + r_3\cos\theta_3 = r_2\cos\theta_2$$

y component:

$$r_3\sin\theta_3 = r_2\sin\theta_2$$

Unknowns: r_2 and r_3

Velocity analysis:

x component:

$$\dot{r}_3\cos\theta_3 - r_3 w_3\sin\theta_3 = \dot{r}_2\cos\theta_2 - r_2 w_2\sin\theta_2$$

y component:

$$\dot{r}_3\sin\theta_3 + r_3 w_3\cos\theta_3 = \dot{r}_2\sin\theta_2 + r_2 w_2\cos\theta_2$$

Since $w_3 = w_2$, the unknowns are $\dot{r}_2$ and $\dot{r}_3$.

Acceleration analysis:

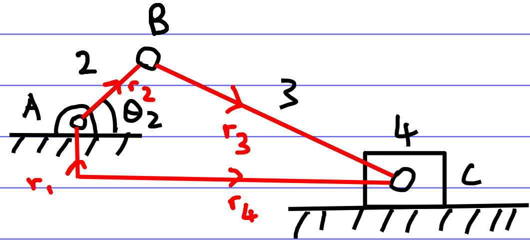
x component:

$$\ddot{r}_3\cos\theta_3 - \dot{r}_3 w_3\sin\theta_3 - (\dot{r}_3 w_3\sin\theta_3 + r_3\alpha_3\sin\theta_3 + r_3 w_3^2\cos\theta_3)$$
$$= \ddot{r}_2\cos\theta_2 - \dot{r}_2 w_2\sin\theta_2 - (\dot{r}_2 w_2\sin\theta_2 + r_2\alpha_2\sin\theta_2 + r_2 w_2^2\cos\theta_2)$$

$$\ddot{r}_3\cos\theta_3 - r_3\alpha_3\sin\theta - 2\dot{r}_3 w_3\sin\theta_3 - r_3 w_3^2\cos\theta_3$$
$$= \ddot{r}_2\cos\theta_2 - r_2\alpha_2\sin\theta_2 - 2\dot{r}_2 w_2\sin\theta_2 - r_2 w_2^2\cos\theta_2$$

Since $\alpha_3 = \alpha_2 = 0$, the unknowns are $\ddot{r}_2$ and $\ddot{r}_3$.

6.3)



Vector loop closure equation:

$$\underset{\sim}{r_1} + \underset{\sim}{r_2} + \underset{\sim}{r_3} = \underset{\sim}{r_4}$$

$$r_1 \underset{\sim}{j} + r_2(\cos\theta_2 \underset{\sim}{i} + \sin\theta_2 \underset{\sim}{j}) + r_3(\cos\theta_3 \underset{\sim}{i} + \sin\theta_3 \underset{\sim}{j}) = r_4 \underset{\sim}{i}$$

x component:

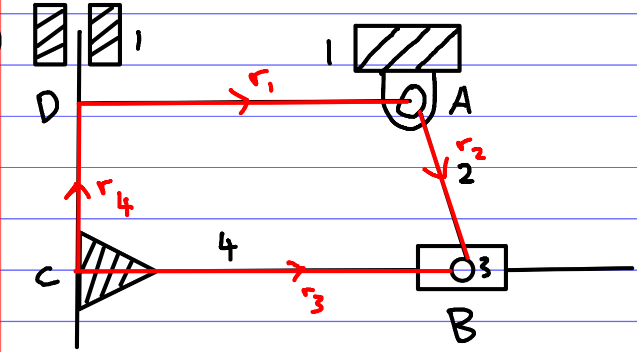
$$r_2 \cos\theta_2 + r_3 \cos\theta_3 = r_4$$

y component:

$$r_1 + r_2 \sin\theta_2 + r_3 \sin\theta_3 = 0$$

r_1, r_2 and r_3 are constants, while θ_2 is an input, hence the unknowns are θ_3 and r_4.

6.4)



Vector loop closure equation:

$$r_4 + r_1 + r_2 = r_3$$

$$r_4 \underset{\sim}{j} + r_1 \underset{\sim}{i} + r_2 \left(\cos\theta \underset{\sim}{i} + \sin\theta \underset{\sim}{j}\right) = r_3 \underset{\sim}{i}$$

x component:

$r_1 + r_2 \cos\theta = r_3 \quad -(1)$

y component

$r_4 + r_2 \sin\theta = 0 \quad -(2)$

r_1, r_2 are constants and θ_2 is an input and the unknowns are r_3 and r_4.