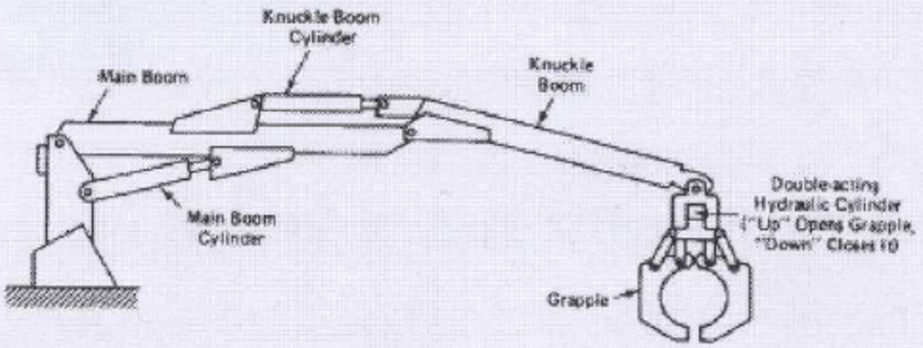
Question 1: Determine the number of degrees of freedom of the following mechanisms using Gruebler's equation.

a) solution a)



- 13 links
- 13 revolute
- 3 prismatic

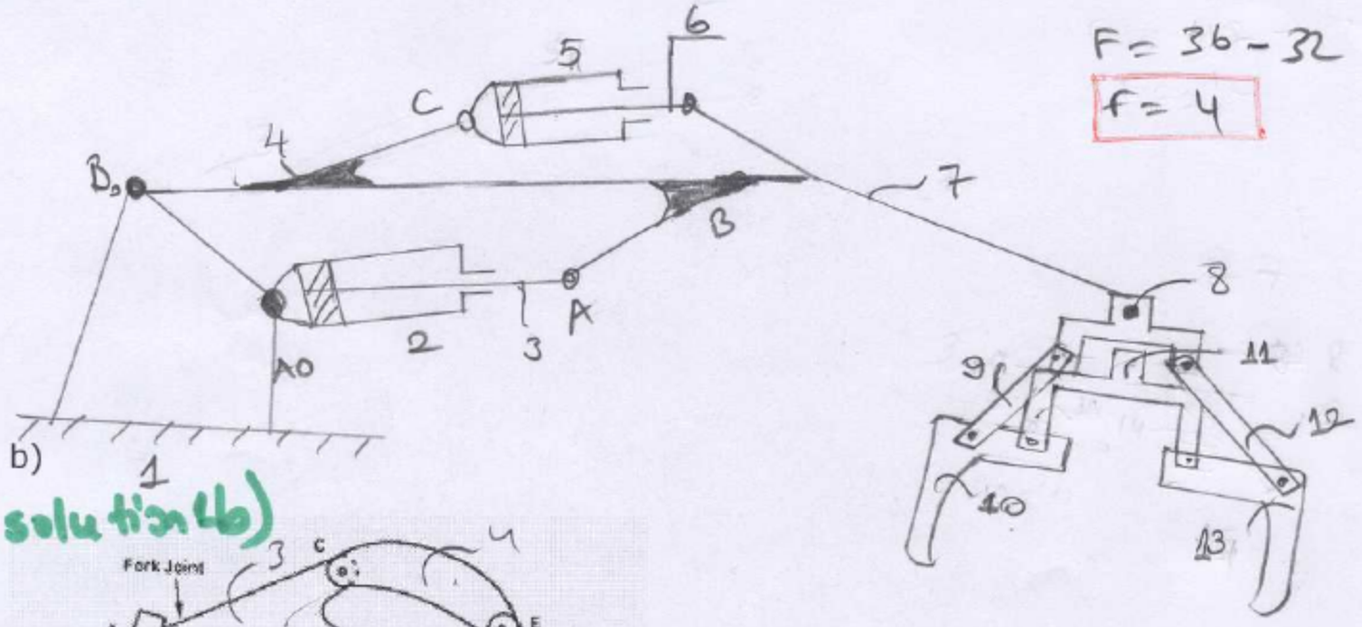
$F = 3(n-1) - 2f_1$ (revolute - f_1, prismatic - f_2)

$F = 3(13-1) - 2(13) - 2(3)$

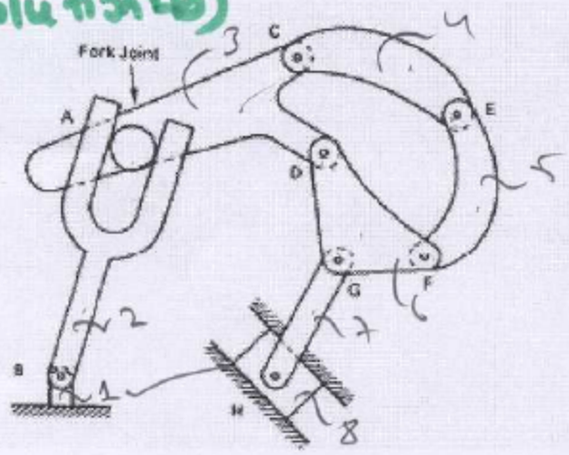
$F = 36 - 32$

$F = 4$

b)



solution b)



- 8 links
- 7 revolute
- 1 prismatic
- 1 pin insolt (2 dof joint)

$f = 3(n-1) - 2f_1 - f_2$

$f = 3(8-1) - 2(7) - 2(1) - 1(1)$

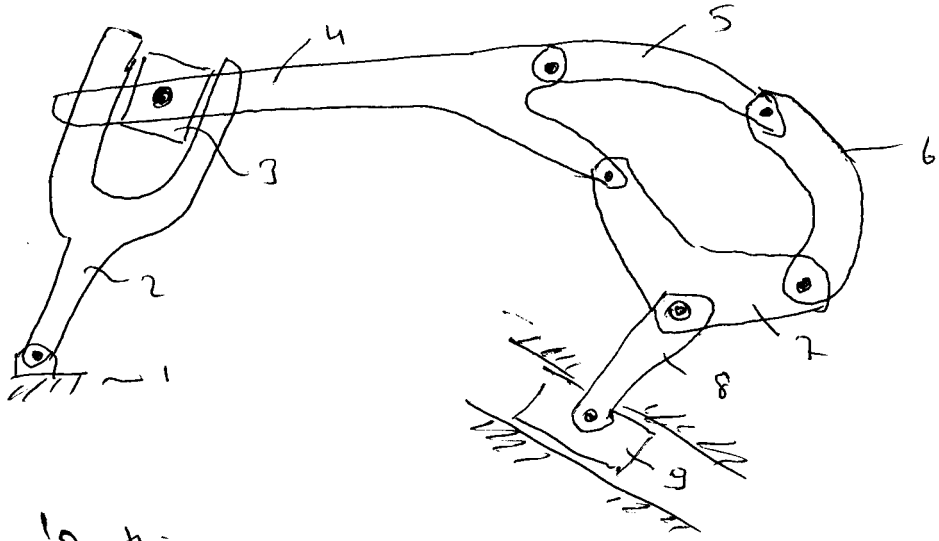
(revolute, prismatic, pin slot)

$F = 21 - 14 - 2 - 1$

$F = 21 - 17 = 4$ dof

1) b) Alternative solution

As suggested in Erdman pages 27-28, due to kinematic equivalence "pin-in-slot" joint can be replaced by two lower pair joints (2 revolute and 2 prismatic joint) and 2 link.

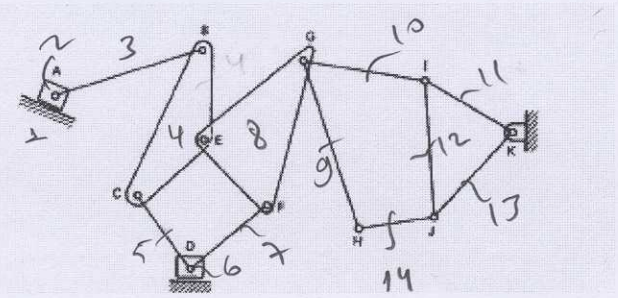


In this case

- n = 9 links
- 8 revolute joints
- 2 prismatic joints

$$F = 3(n-1) - 2f_1$$
$$= 3(9-1) - 2(8) - 2(2)$$
$$= 24 - 16 - 4 = 4 \text{ dof}$$

c) Solution c)



- 14 links
- 16 revolute
- 2 prismatic

$F = 3(n-1) - 2f_1 - f_2$

$F = 3(14-1) - 2(18)$

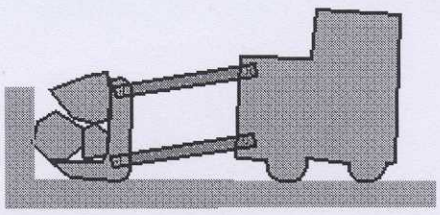
$f = 39 - 36$

$F = 3$

Question 2: Identify the type of linkages (four-bar, slider-crank, etc.) for the following mechanisms.

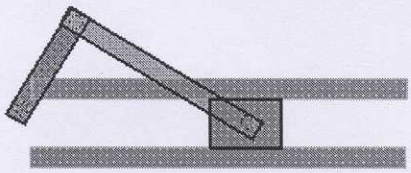
Solutions 2.)

a)



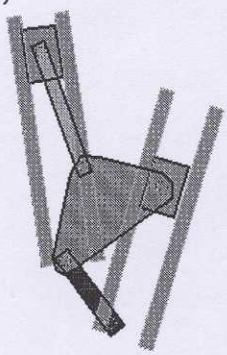
→ A (parallelogram) four bar linkage,

b)



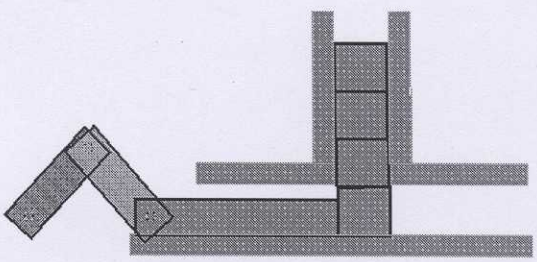
→ A slider_crank mechanism.

c)



→ A slider-crank mechanism with multiple sliders.

d)

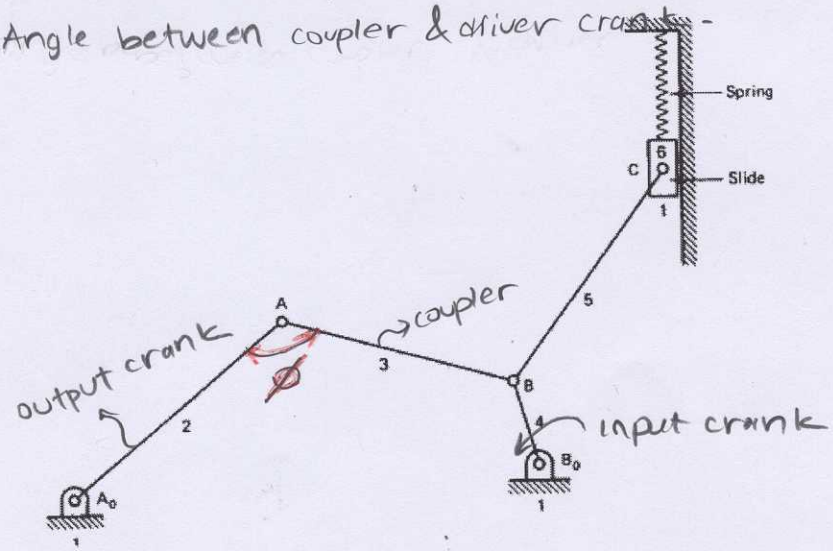


→ A slider crank mechanism

Question 3: Determine the transmission angles for the following mechanisms:

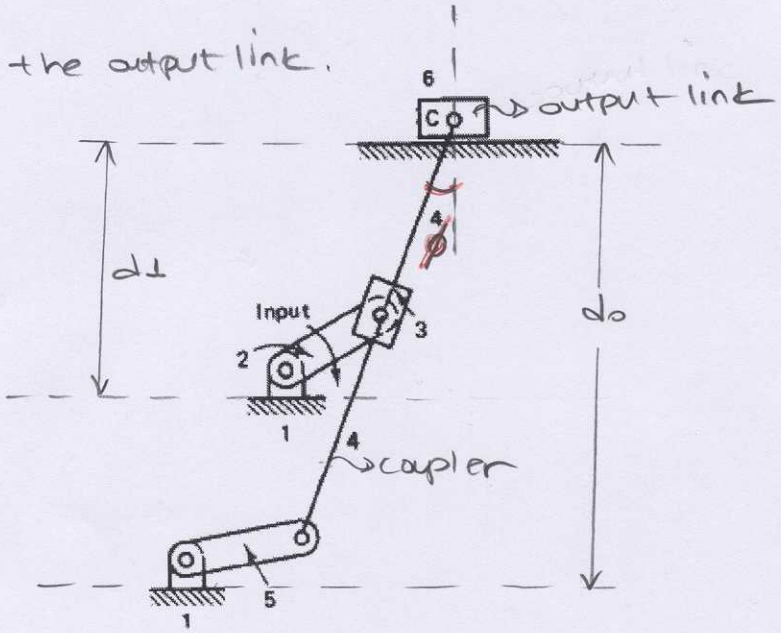
a) 6-bar mechanism where link 6 is the input and link 2 is the output.

Solution 3-a)
Transmission angle : Angle between coupler & driver crank

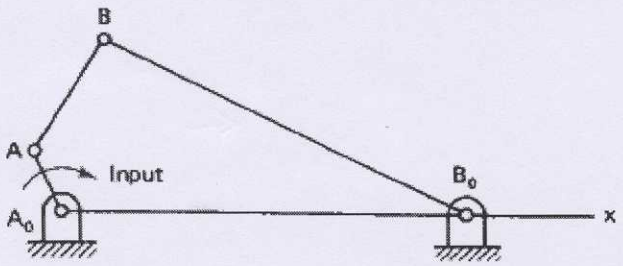


b) The two quick – return shaper mechanism where link 2 is the input and link 6 is the output.

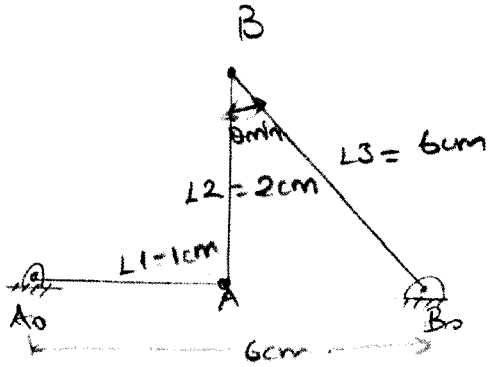
Solution 3b.) Link 6 is the output link.



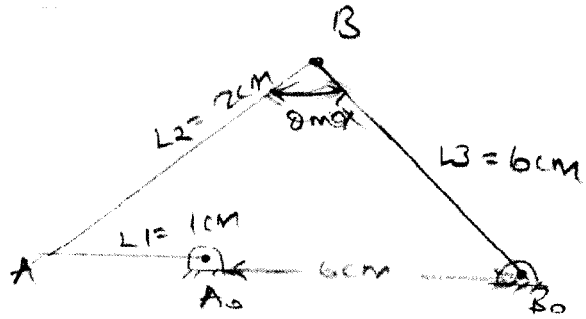
c) Determine the maximum and minimum transmission angles for the following four-bar linkage with dimensions: A_0B_0 = 6 cm, A_0A = 1 cm, AB = 2 cm, BB_0 = 6 cm.



Solution 3c)



Minimum value of transmission angle /



Maximum value of transmission angle

$A_0B_0 = 6cm$

$A_0A = 1cm$

$AB = 2cm$

$BB_0 = 6cm$

For min. transmission angle:

$$\cos\phi_{min} = \frac{(AB)^2 + (BB_0)^2 - (AB_0)^2}{2(AB)(BB_0)} = \frac{2^2 + 6^2 - 5^2}{2 \cdot 2 \cdot 6} = \frac{4+36-25}{24} = \frac{15}{24}$$

$$\phi_{min} = \arccos\left(\frac{15}{24}\right) = 0,8957 \text{ rad}$$

$$\phi_{min} = 51,3178°$$

For max. transmission angle:

$$\cos\phi_{max} = \frac{(AB)^2 + (BB_0)^2 - (AB_0)^2}{2(AB)(BB_0)} = \frac{7^2 + 6^2 - 7^2}{2 \cdot 2 \cdot 6} = \frac{4+36-49}{24} = -\frac{9}{24}$$

$$\phi_{max} = \arccos\left(-\frac{9}{24}\right) = 1.95 \text{ rad}$$

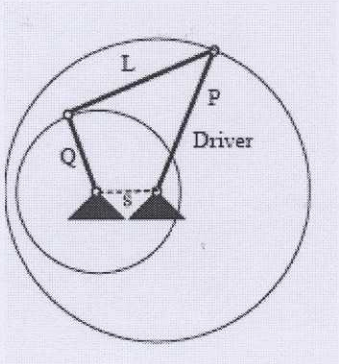
$$\phi_{max} = 112°$$

Question 4: Classify the following four-bar linkages according to Grashof criterion.

a) solution.4)

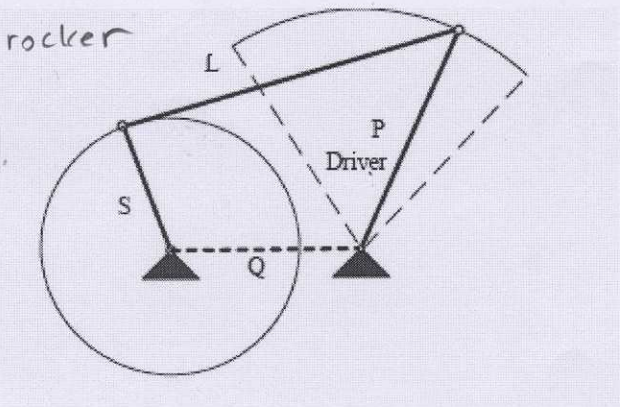
L+S < P+Q

This is a drang link since shortest link is the ground link(s)



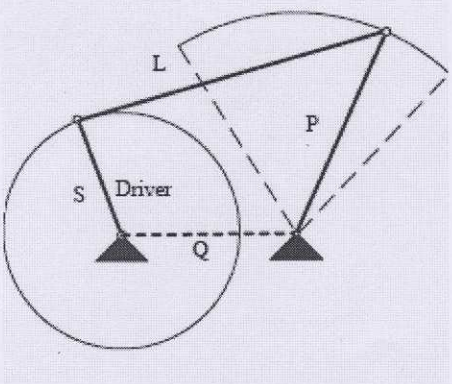
b) L+S < P+Q

This is a crank-rocker since shortest link is the output link(s).



c) L+S < P+Q

This is a crank rocker since shortest link is the output link(s).



d) L+S < P+Q

This is a double rocker since shortest link is the coupler.