

US4974836A

U.S. Patent Dec. 4, 1990

Sheet 1 of 8

4,974,830

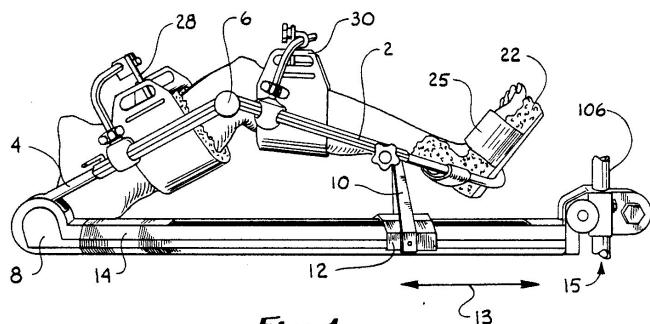
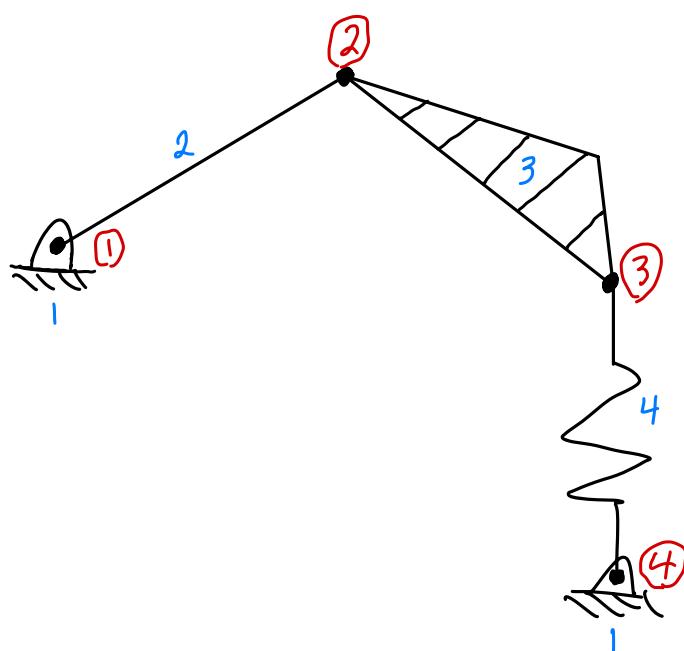
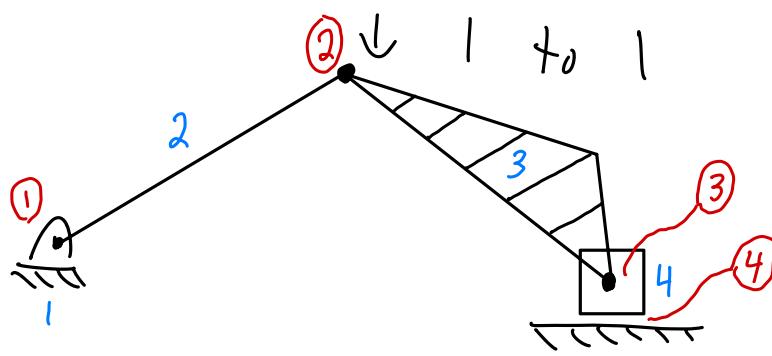


Fig. 1



4-bar

US 4,546,763

U.S. Patent Oct. 15, 1985

Sheet 3 of 3 4,546,763

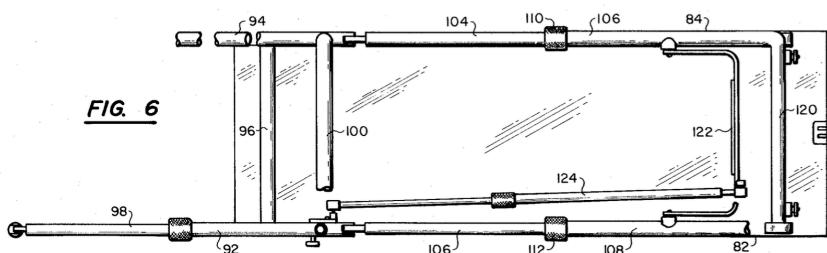


FIG. 6

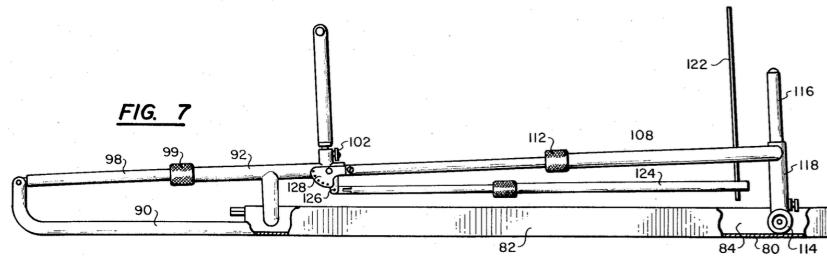
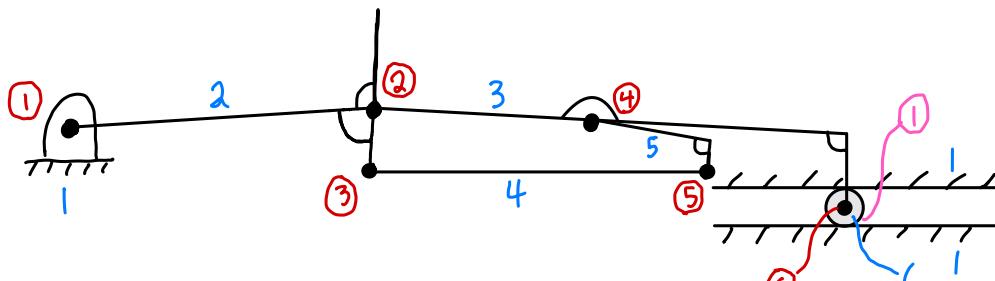
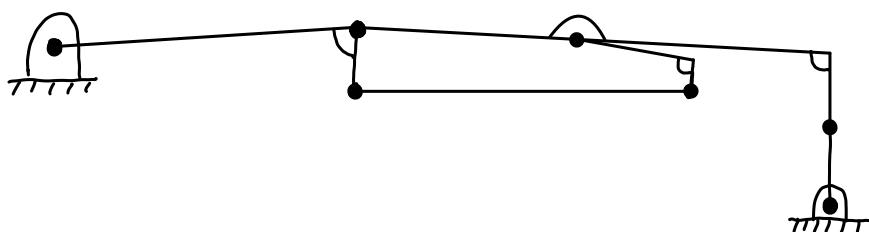


FIG. 7

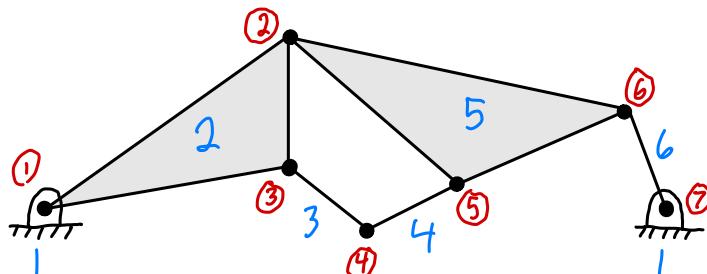


$$\begin{aligned} \text{DOF} &= 3(6-1) - 2(6) - 1 \\ &= 15 - 12 - 1 \\ &= 2 \end{aligned}$$

2 DOF



- One DOF for the major motion of the mechanism
- One DOF for the angle of the roller



$$\begin{aligned} \text{DOF} &= 3(7-1) - 2(7) - 0 \\ &= 15 - 14 \end{aligned}$$

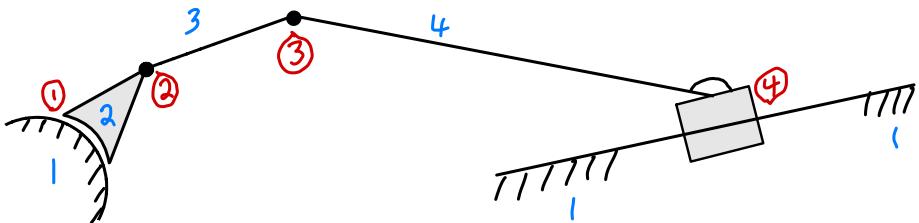
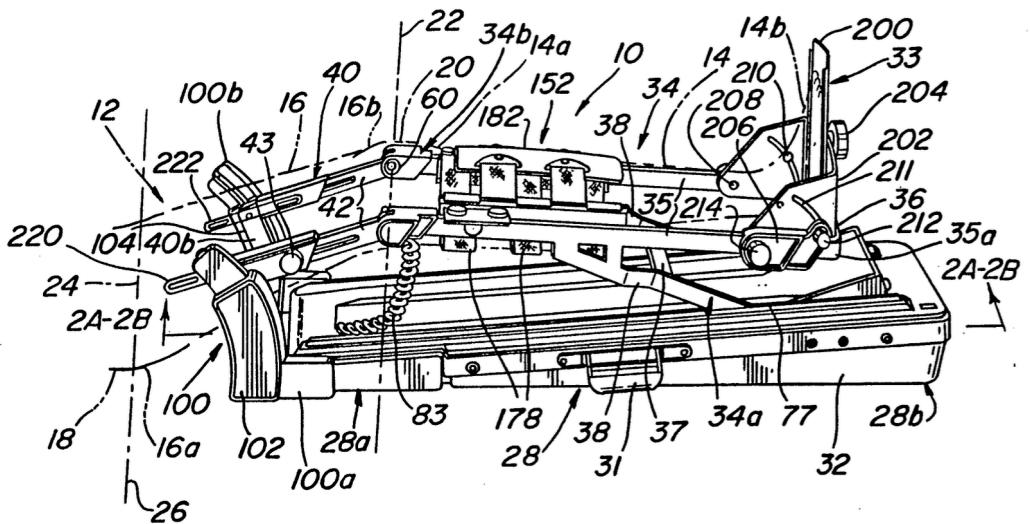
1 DOF

eliminated the roller because its angle is irrelevant, so one less DOF than the original

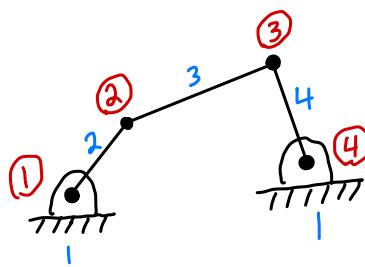
Watt 1

US 5,239,987 A

FIG. 1



$$\begin{aligned}
 \text{DOF} &= 3(4-1) - 2(4) \\
 &= 9 - 8 \\
 &\boxed{1 \text{ DOF}}
 \end{aligned}$$

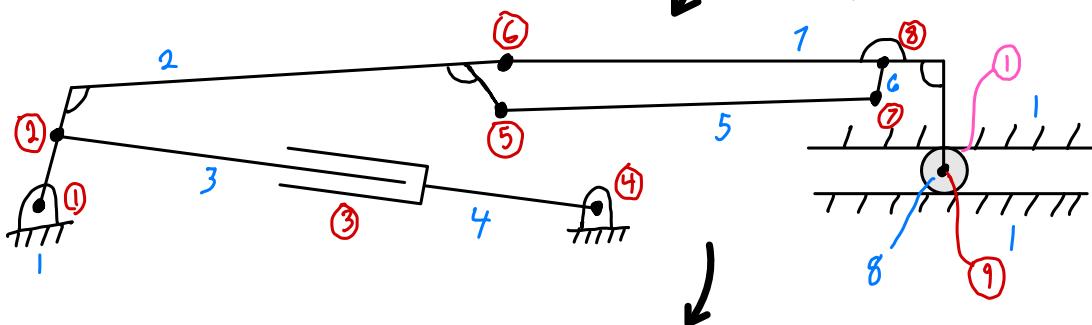
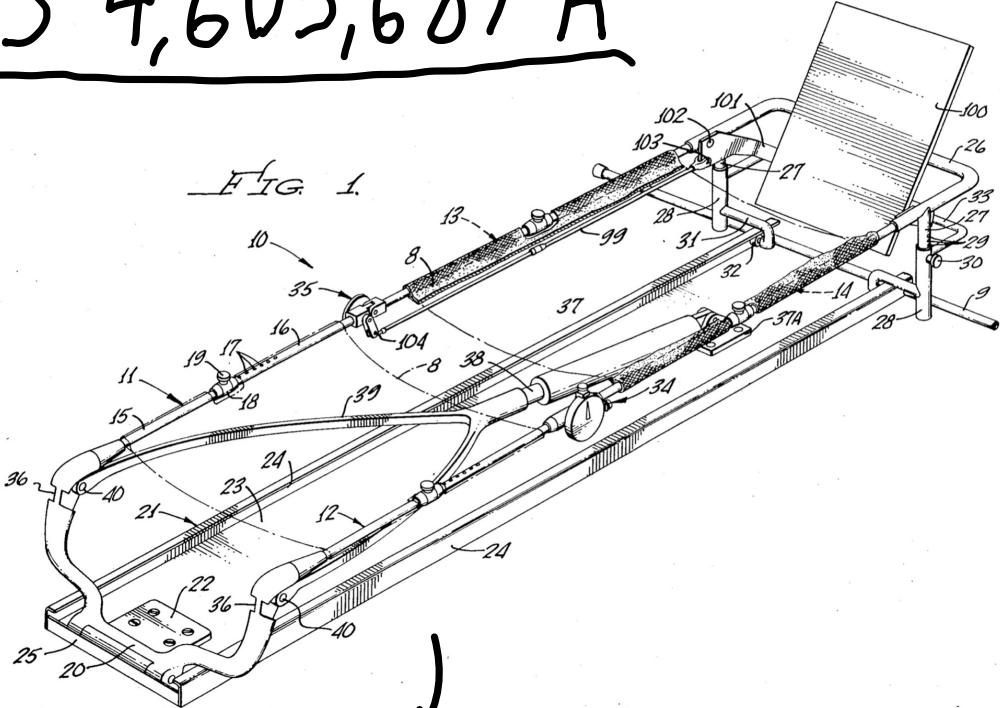


$$\begin{aligned}
 \text{DOF} &= 3(4-1) - 2(4) \\
 &= 9 - 8
 \end{aligned}$$

$$\boxed{1 \text{ DOF}}$$

4-bar

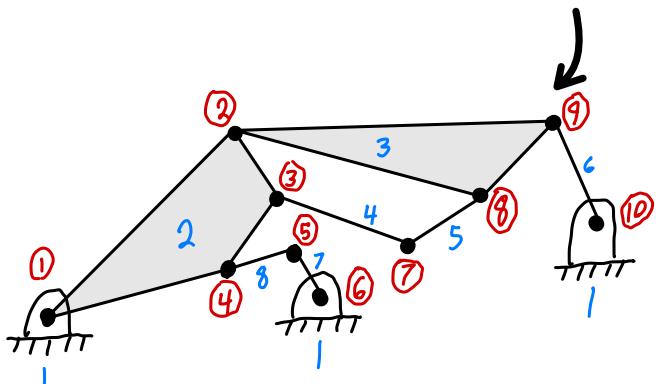
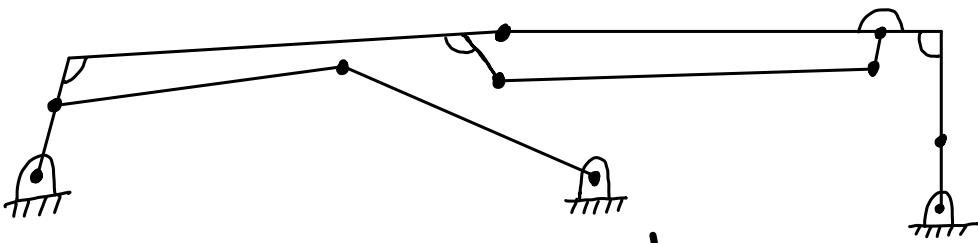
US 4,603,687 A



$$DOF = 3(8-1) - 2(9) - 1 \\ = 21 - 18 - 1$$

2 DOF

- One DOF for the major motion of the mechanism
 - One DOF for the angle of the roller

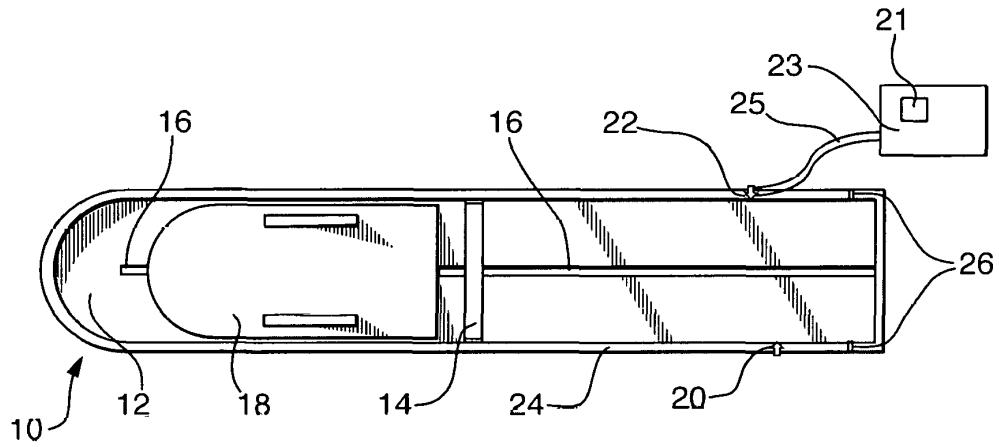


$$DOF = 3(8-1) - 2(10) - 0$$

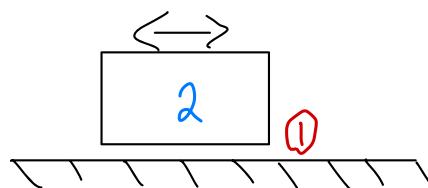
$$= 21 - 20$$

1 DOF

One less DOF
than the original
mechanism due to the
elimination of the roller
because its angle isn't
relevant



↓ 1 + 0 1 side view

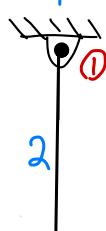


$$\text{DOF} = 3(2-1) - 2(1) - 0$$

$$= 3 - 2$$

1 DOF

↓ remove slider



$$\text{DOF} = 3(2-1) - 2(1) - 0$$

$$= 3 - 2$$

1 DOF

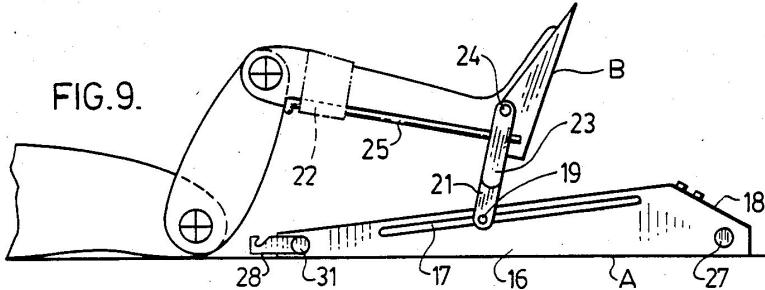
2-Bar

US 4,637,379 A

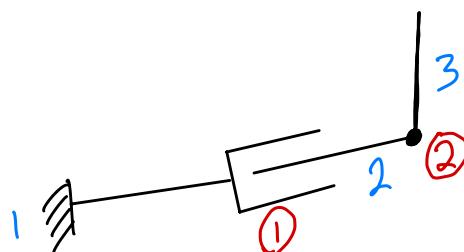
U.S. Patent Jan. 20, 1987

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4,637,379

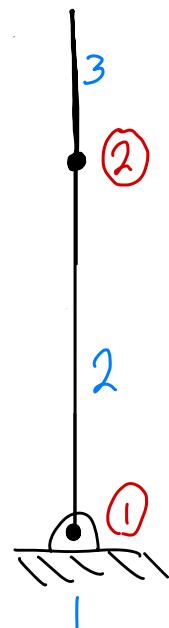


↓ 1 to 1



$$\begin{aligned} \text{DOF} &= 3(3-1) - 2(2) - 0 \\ &= 6 - 4 - 0 \\ &\boxed{2 \text{ DOF}} \end{aligned}$$

↓ remove slider

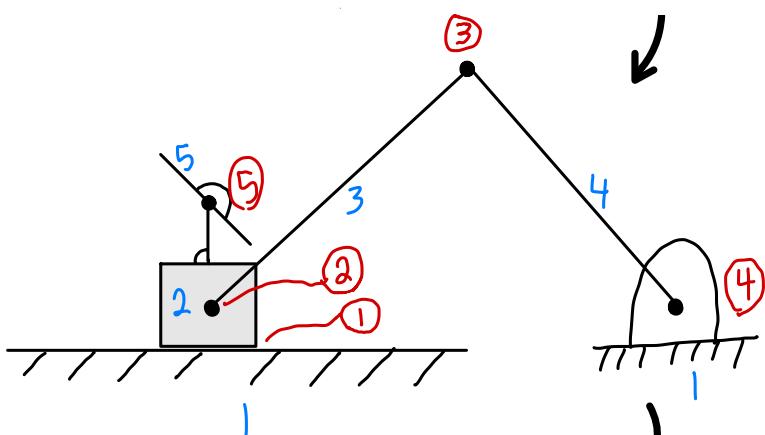
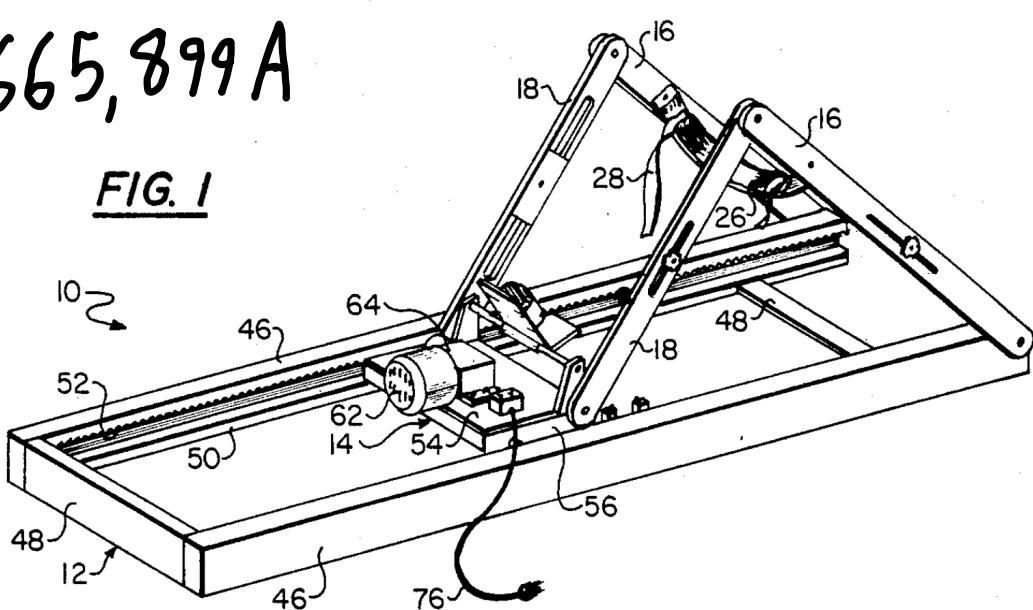


$$\begin{aligned} \text{DOF} &= 3(3-1) - 2(2) - 0 \\ &= 6 - 4 - 0 \\ &\boxed{2 \text{ DOF}} \end{aligned}$$

3-Bar

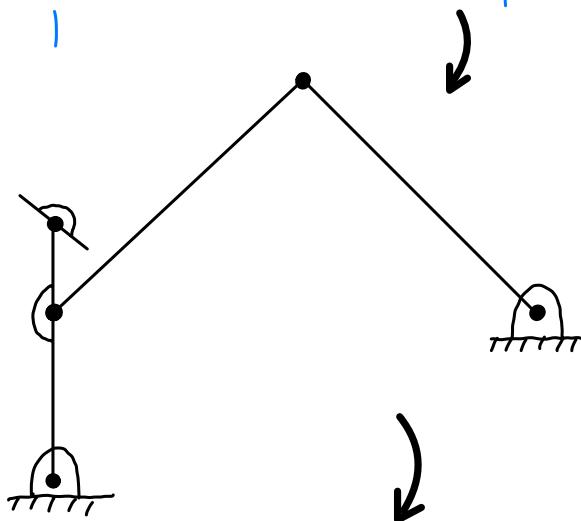
US 4,665,899 A

FIG. 1



$$\begin{aligned}
 \text{DOF} &= 3(5-1) - 2(5)-0 \\
 &= 12 - 10 \\
 &= \boxed{2 \text{DOF}}
 \end{aligned}$$

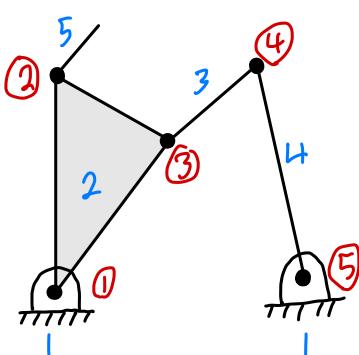
- one DOF for the major motion of the mechanism
- one for the tilt of the foot rest



$$\text{DOF} = 3(5-1) - 2(5)-0$$

$$= 12 - 10$$

$$= \boxed{2 \text{DOF}}$$



4-bar w/ extra link

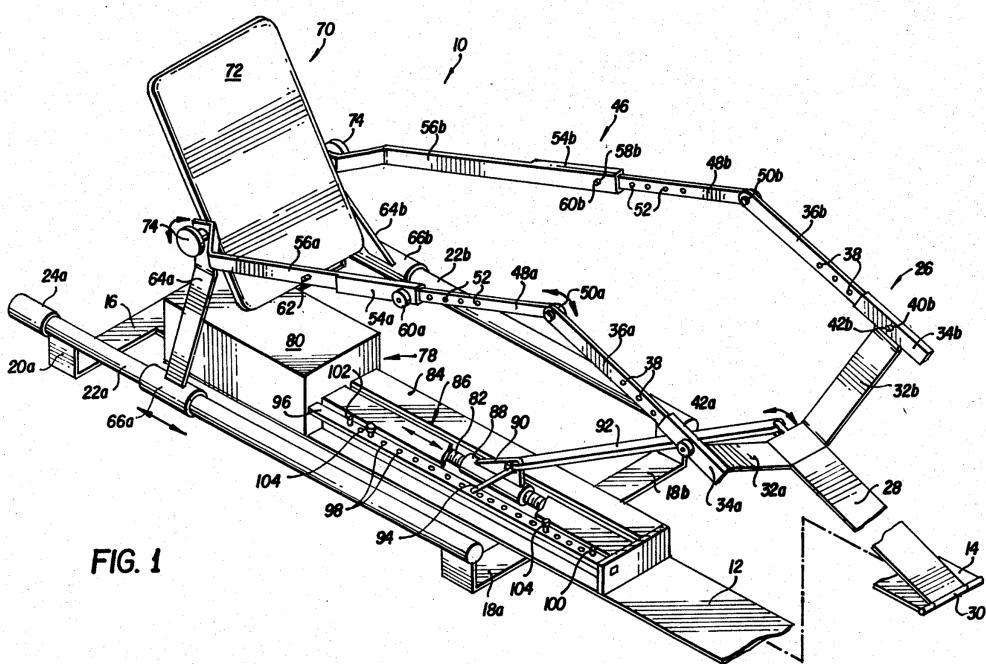
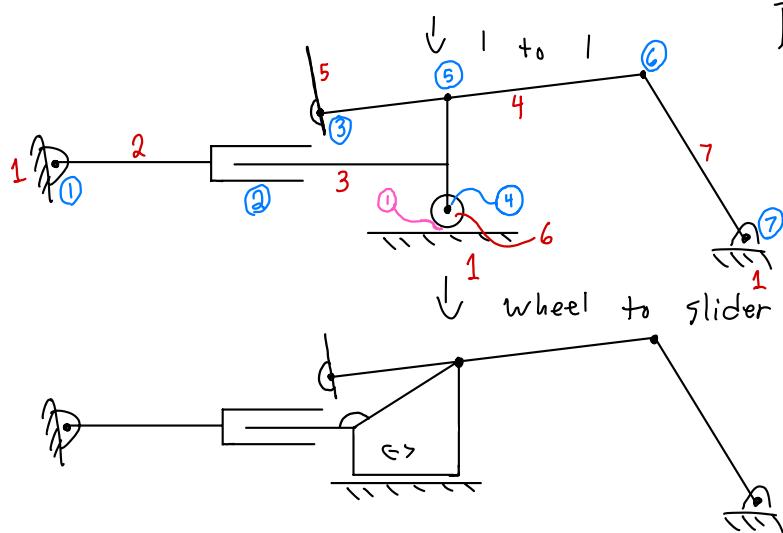
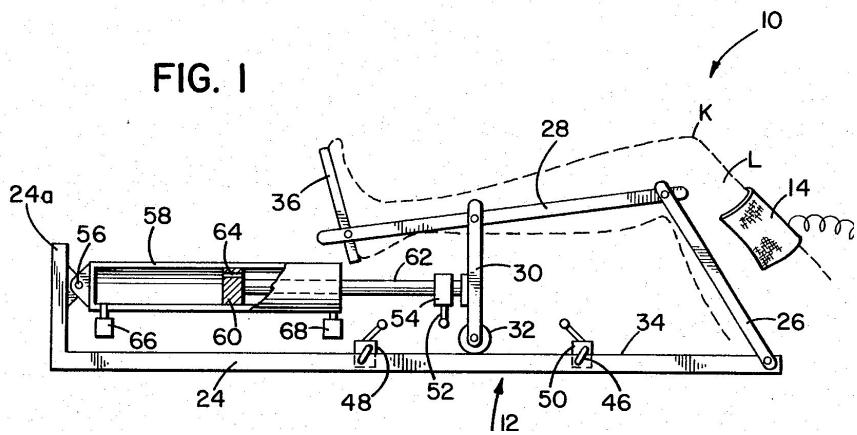


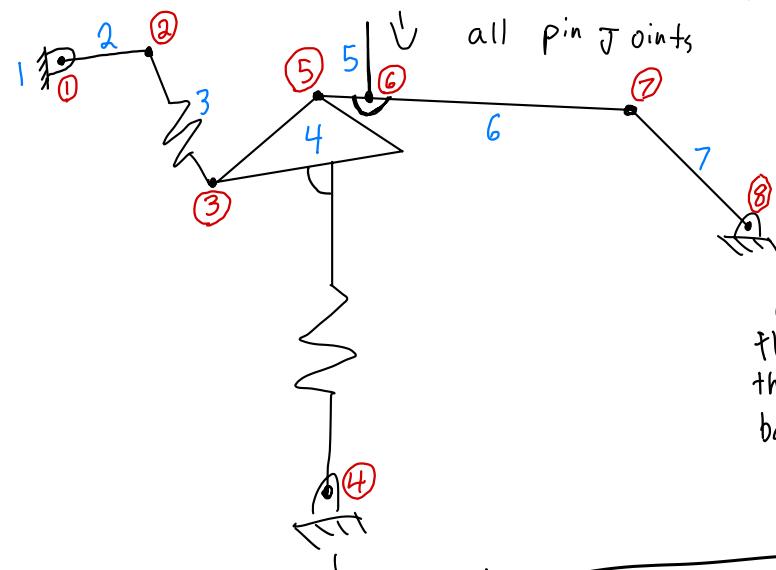
FIG. 1

US4509569A



$$\begin{aligned} \text{DOF} &= 3(n-1) - 2f_1 - f_2 \\ &= 3(7-1) - 2(7) - 1 \\ &= 18 - 14 - 1 \\ &\boxed{3 \text{ DOF}} \end{aligned}$$

One degree of freedom for the foot rest.
One degree of freedom for the major motion of the mechanism.
One degree of freedom for the roller.



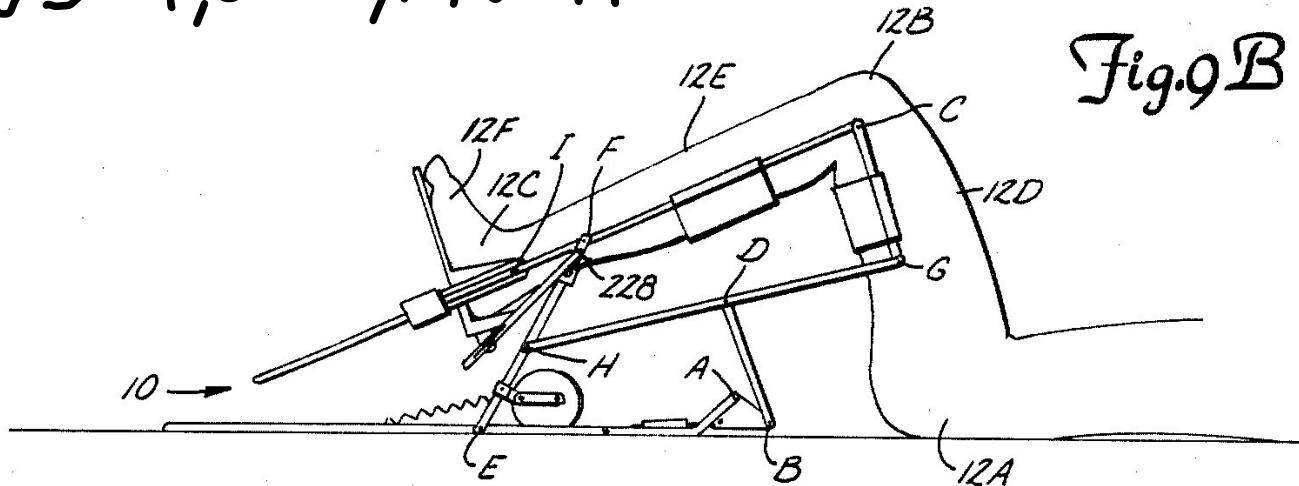
$$\begin{aligned} \text{DOF} &= 3(n-1) - 2f_1 - f_2 \\ &= 3(7-1) - 2(8) - 0 \\ &= 18 - 16 \end{aligned}$$

One less DOF than the original mechanism because the angle of the roller has been neglected

Watt II w/ extra link

US 4,566,440 A

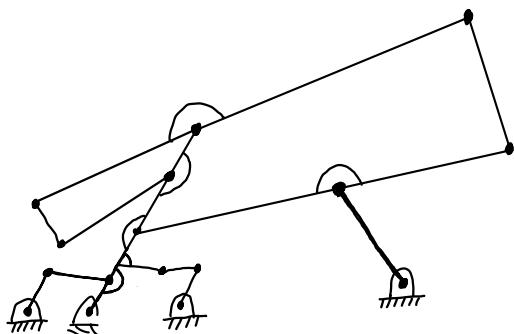
Fig. 9B



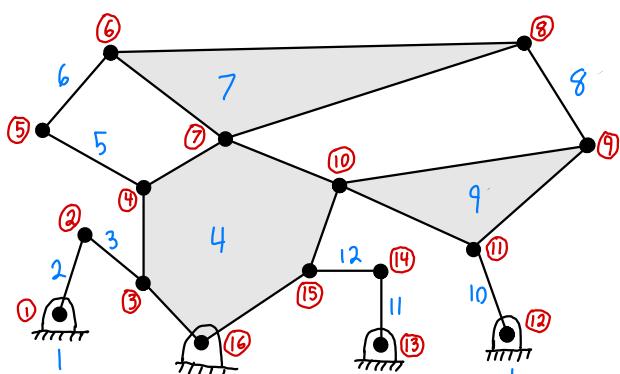
$$\begin{aligned} \text{DOF} &= 3(n-1) - 2f_1 - f_2 \\ &= 3(14-1) - 2(19) - 0 \\ &= 39 - 38 \end{aligned}$$

1 DOF

Convert sliders to dyads and remove immobile links



Redraw in easier to understand way

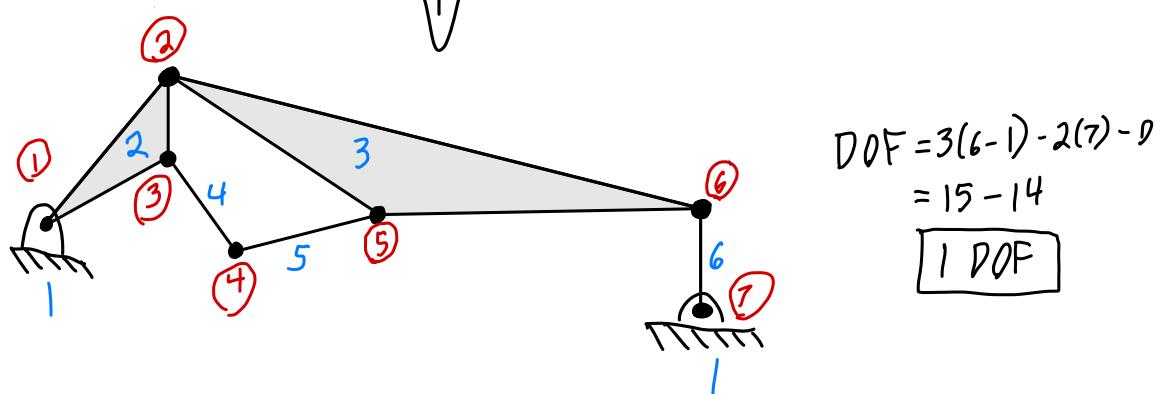
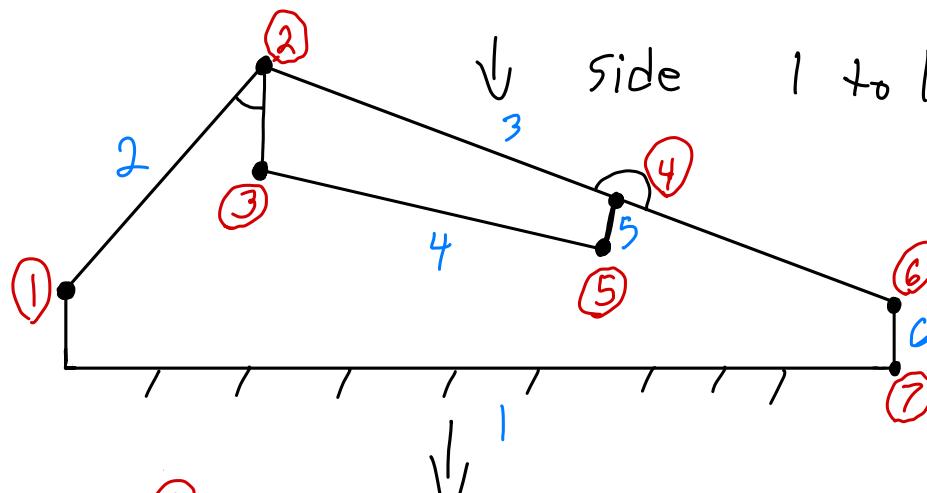
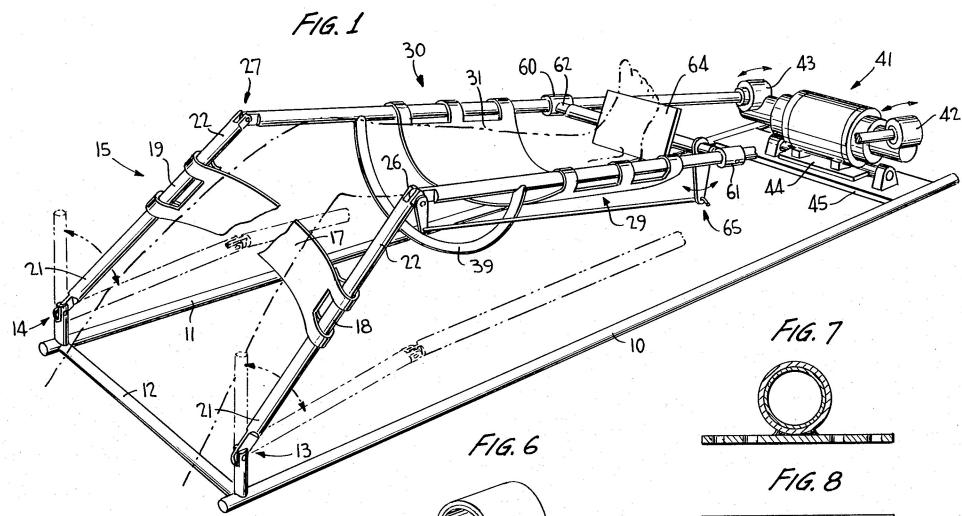


$$\begin{aligned} \text{DOF} &= 3(12-1) - 2(16) - 0 \\ &= 33 - 32 \end{aligned}$$

1 DOF

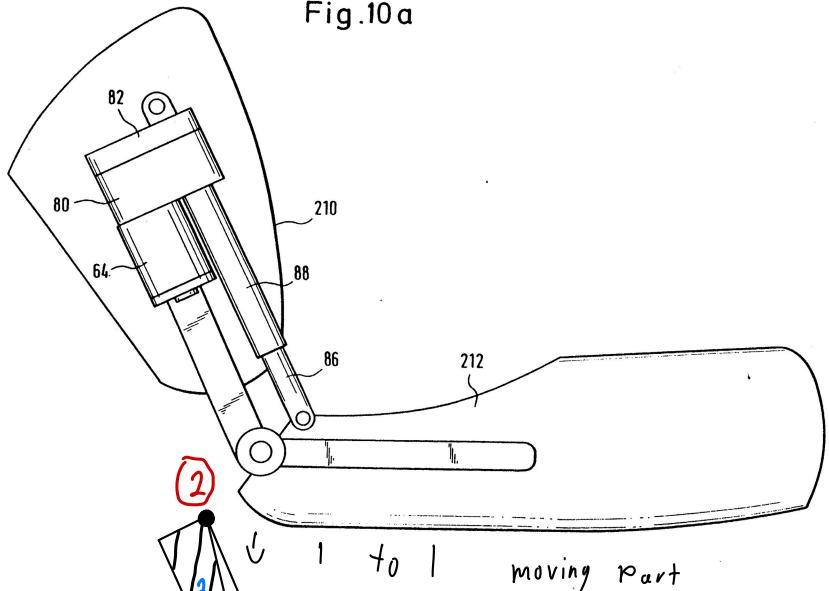
12 Bar linkage
At its heart is a Watt I with 3 other dyads tacked on

US4492222A



Watt I

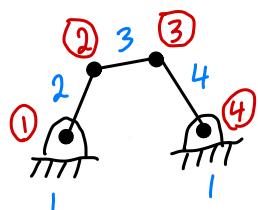
Fig. 10a



$$\begin{aligned} \text{DOF} &= 3(4-1) - 2(4) - 0 \\ &= 9 - 8 \end{aligned}$$

1 DOF

↓ remove slider



$$\begin{aligned} \text{DOF} &= 3(4-1) - 2(4) - 0 \\ &= 9 - 8 \end{aligned}$$

1 DOF

4-bar

US 5333604 A

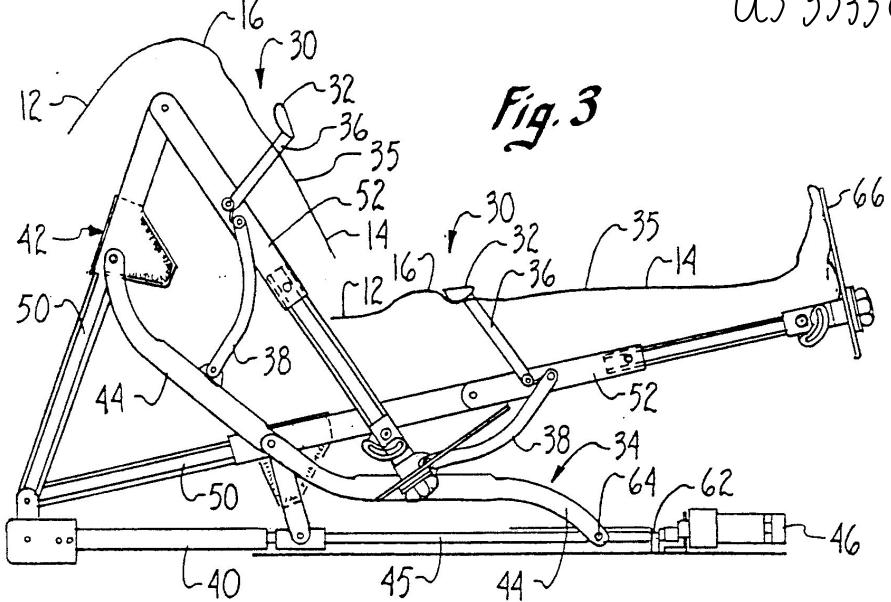
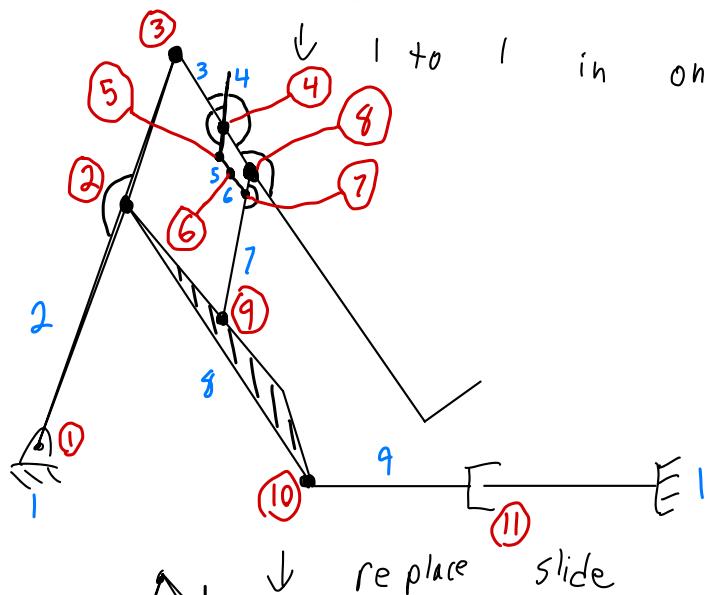
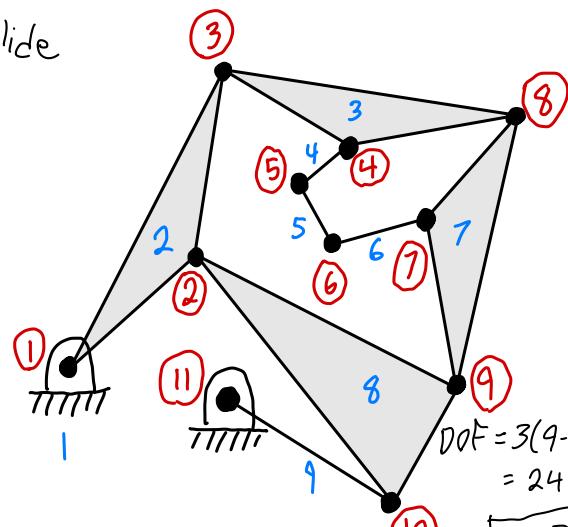
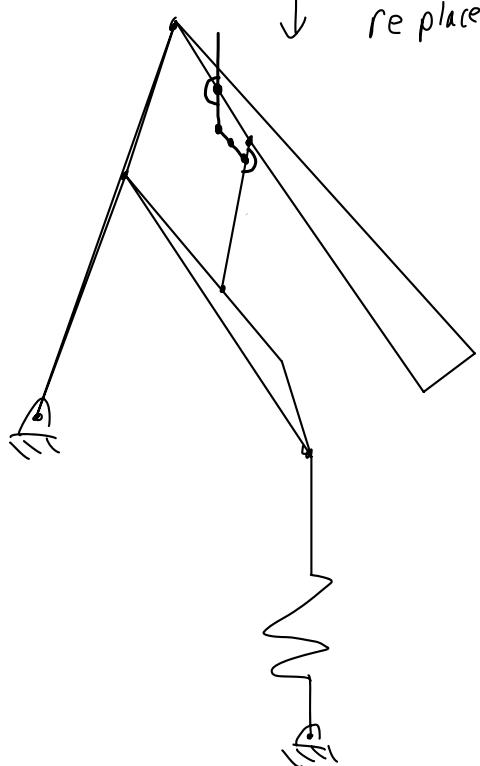


Fig. 3



$$\text{DOF} = 3(9-1) - 2(11) - 0 \\ = 24 - 22$$

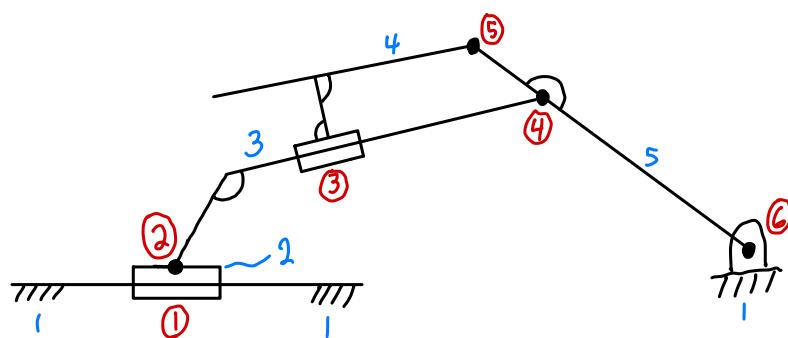
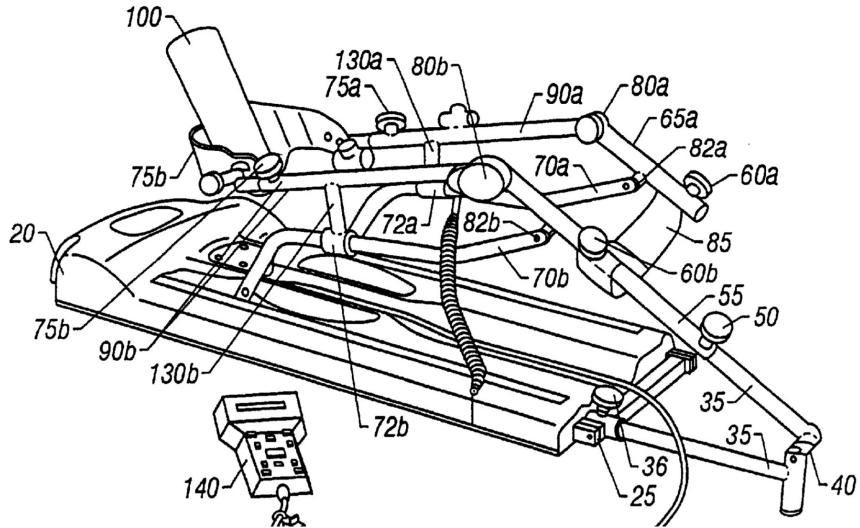
2 DOF



$$\text{DOF} = 3(9-1) - 2(11) - 0 \\ = 24 - 22$$

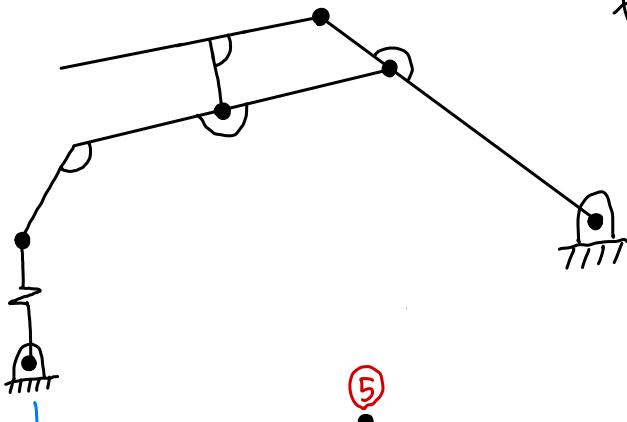
2 DOF

US 6,325,770 B1

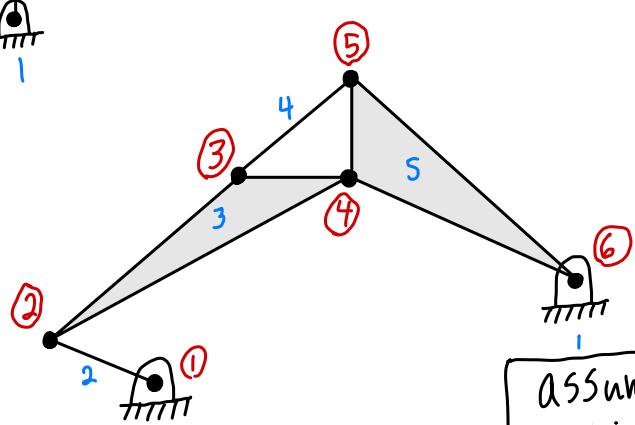


$$\text{DOF} = 3(5-1) - 2(6) - 0 \\ = 12 - 12 \\ \boxed{0 \text{ DOF}}$$

In practice
there must be enough
rotation allowed in joint 3
for the mechanism to move



$$\text{DOF} = 3(5-1) - 2(6) - 0 \\ = 12 - 12 \\ \boxed{0 \text{ DOF}}$$



assuming enough
slop in joint 3
its a Watt 1

WO 2011/119902 A1

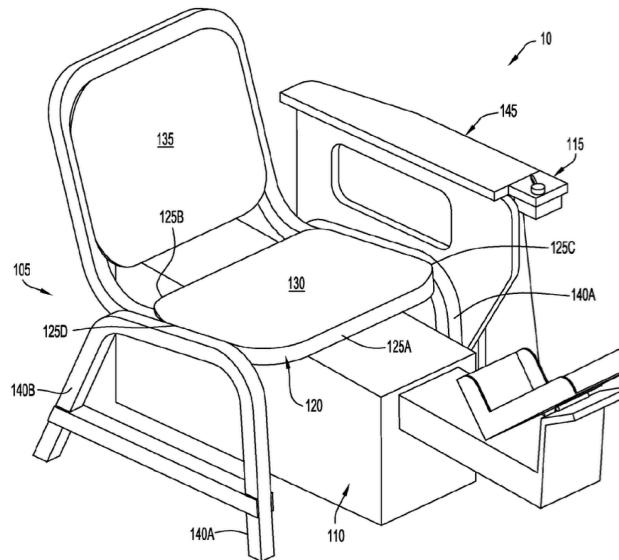
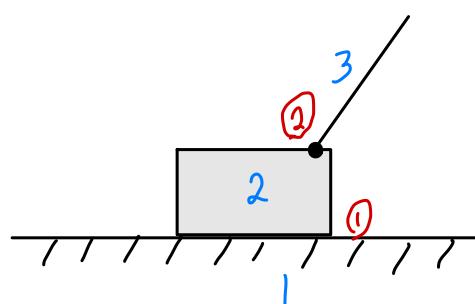


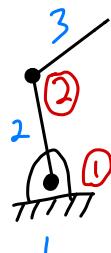
FIG.1A



$$DOF = 3(3-1) - 2(2) - 0$$

$$= 6 - 4 - 0$$

2 DOF



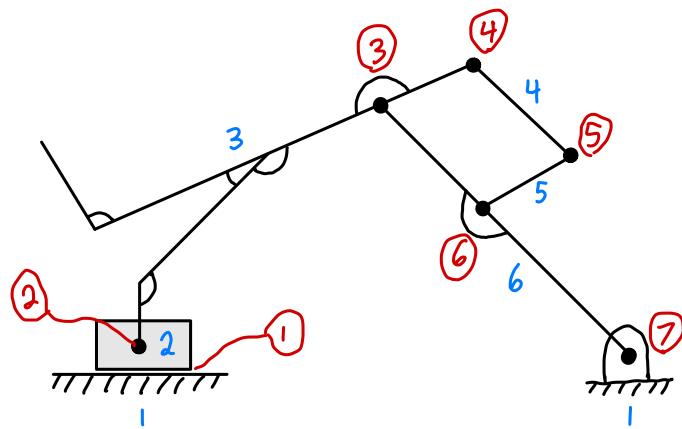
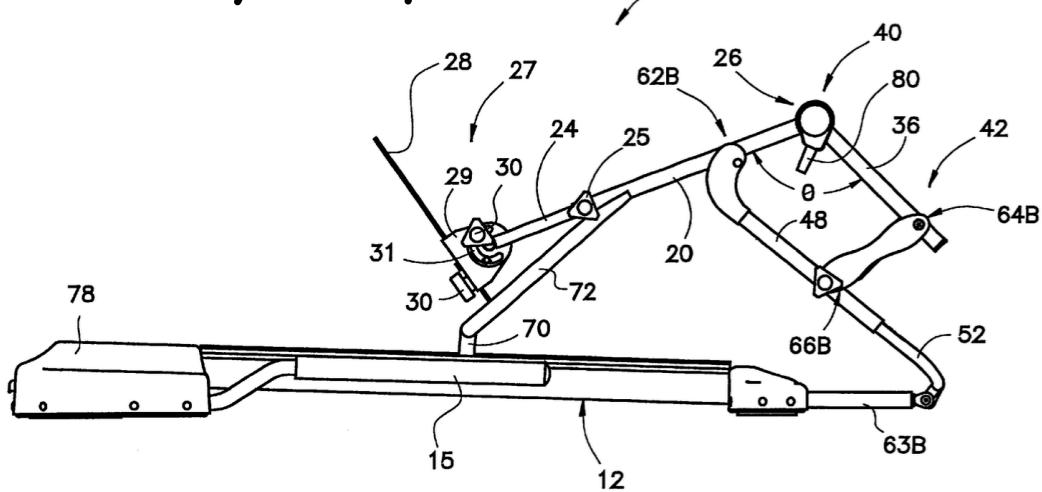
$$DOF = 3(3-1) - 2(2) - 0$$

$$= 6 - 4 - 0$$

2 DOF

3-Bar

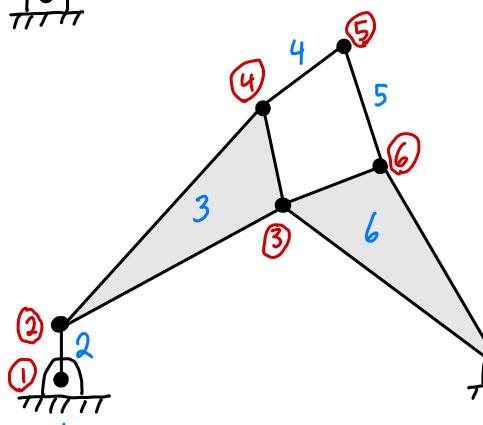
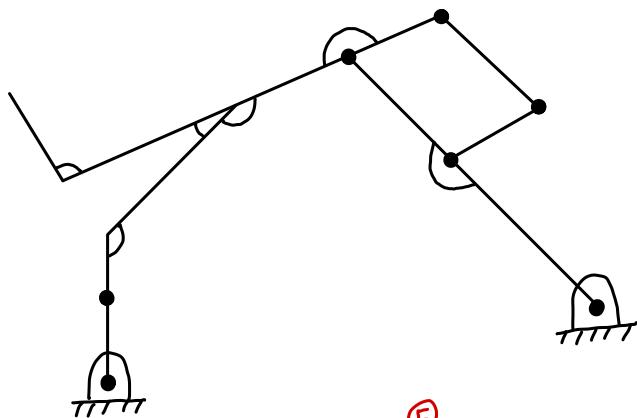
US 6,267,735 A



$$DOF = 3(6-1) - 2(7) - 0$$

$$= 15 - 14$$

1 DOF



$$DOF = 3(6-1) - 2(7) - 0$$

$$= 15 - 14$$

1 DOF

Watt I