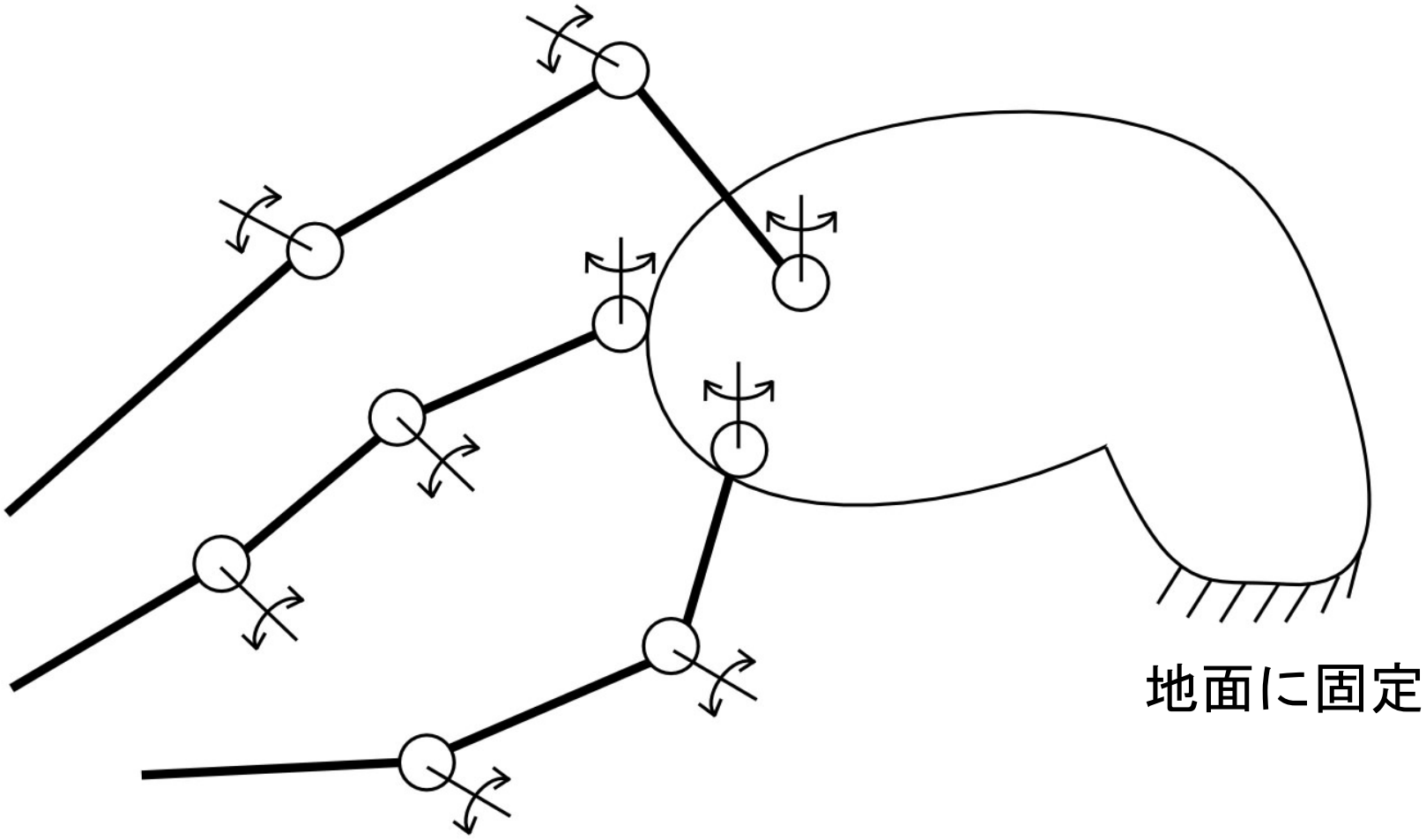
機構学
Part3：機構の自由度

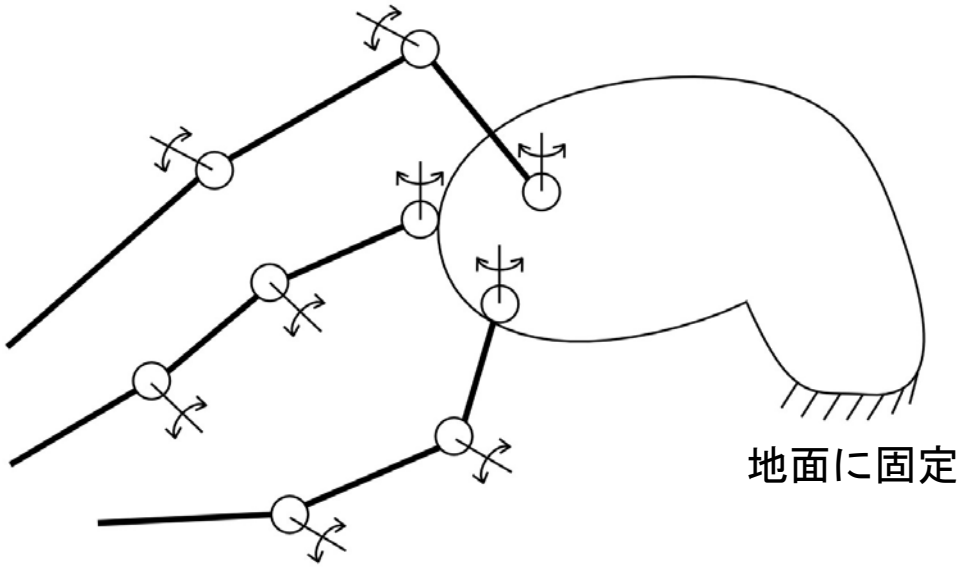
金子真

課題１

機構の自由度は？



課題１の答え



$$N = 10$$

$$J = 9$$

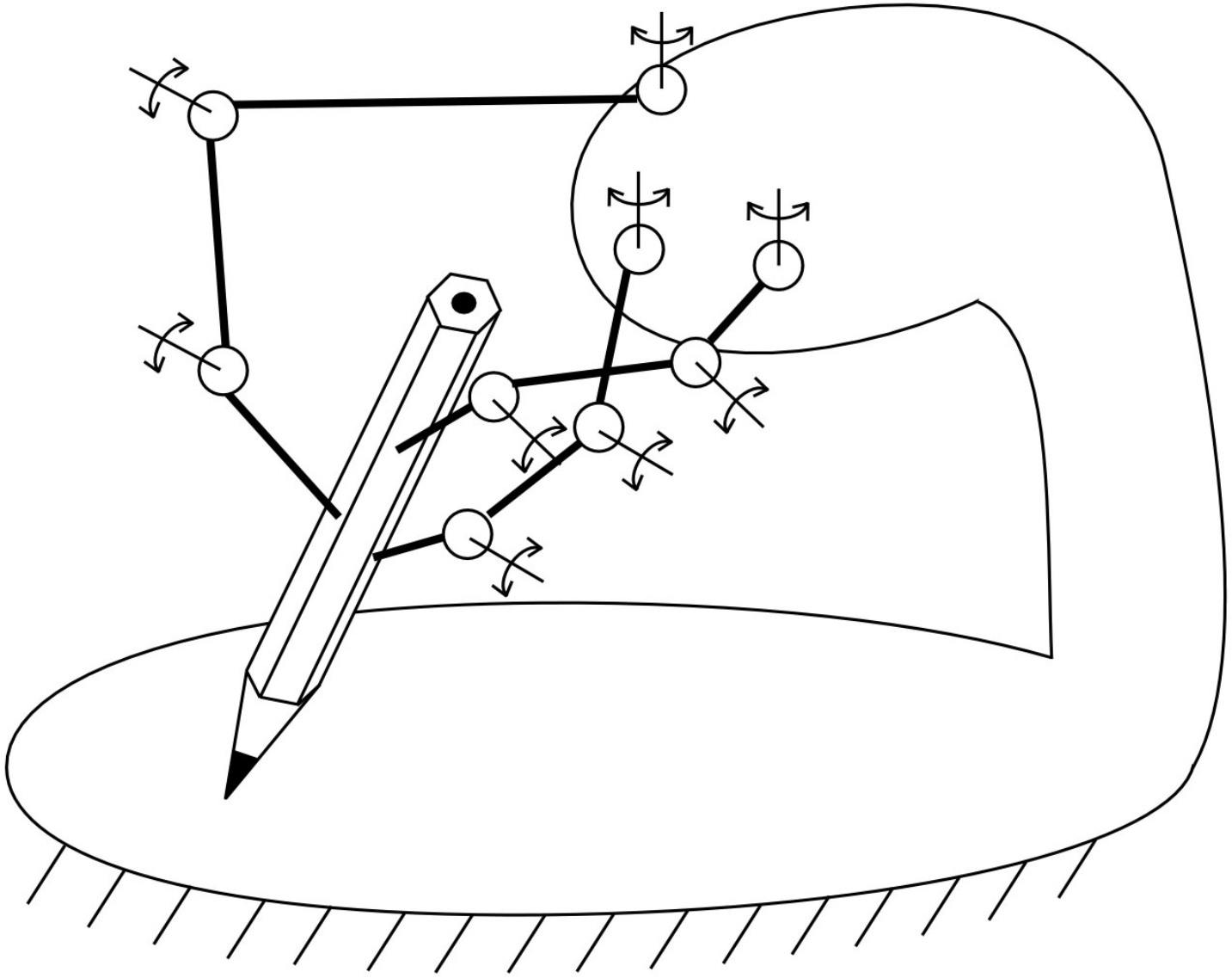
$$\sum f_i = 9$$

$$F = 6(N - J - 1) + \sum f_i$$

$$= 9$$

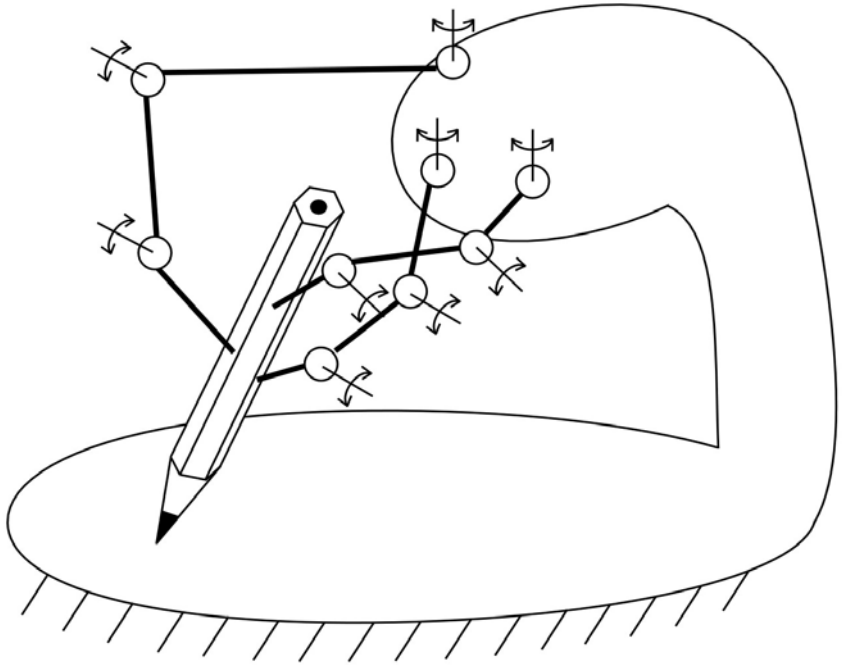
課題２

機構の自由度は？



地面に固定

課題３の答え



地面に固定

$$N = 11$$

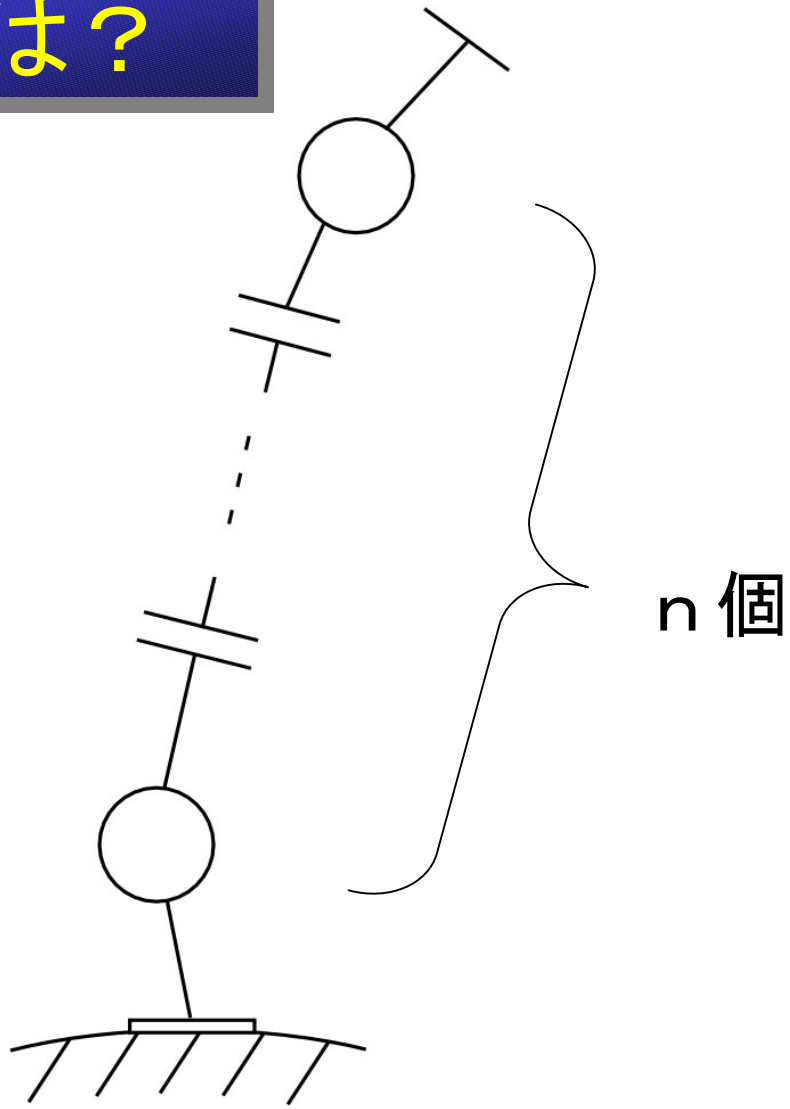
$$J = 13$$

$$\sum f_i = 9 + 3 \times 4 = 12$$

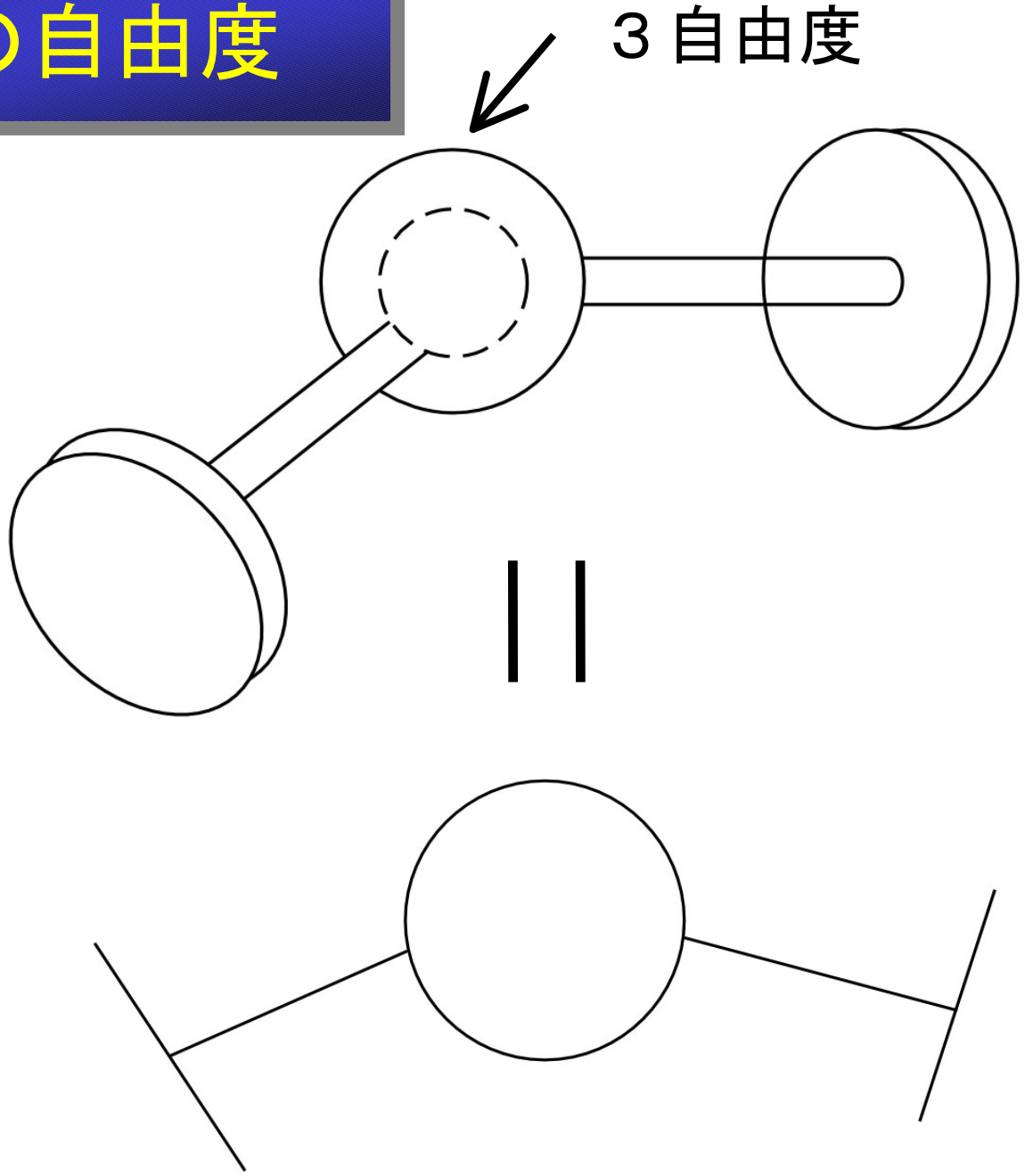
$$F = 6(N - J - 1) + \sum f_i$$

$$= 3$$

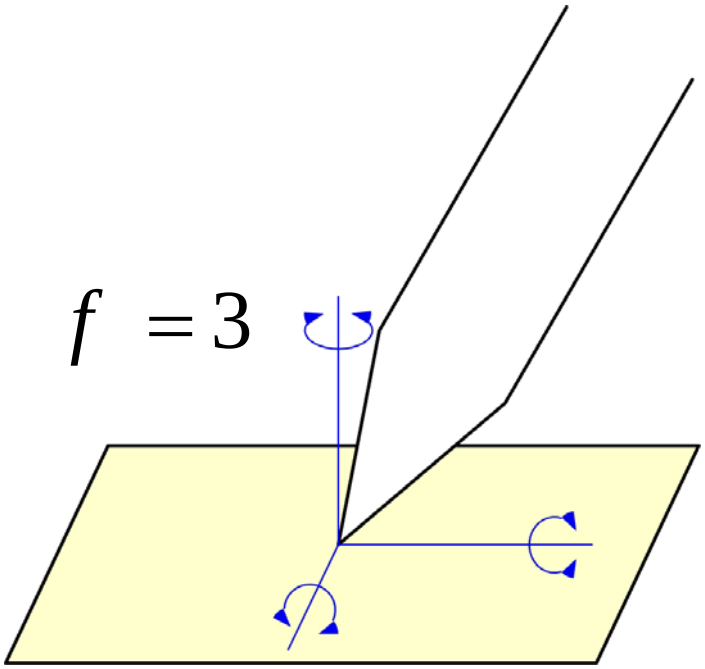
課題1：球関節がn個連なったらFkは？

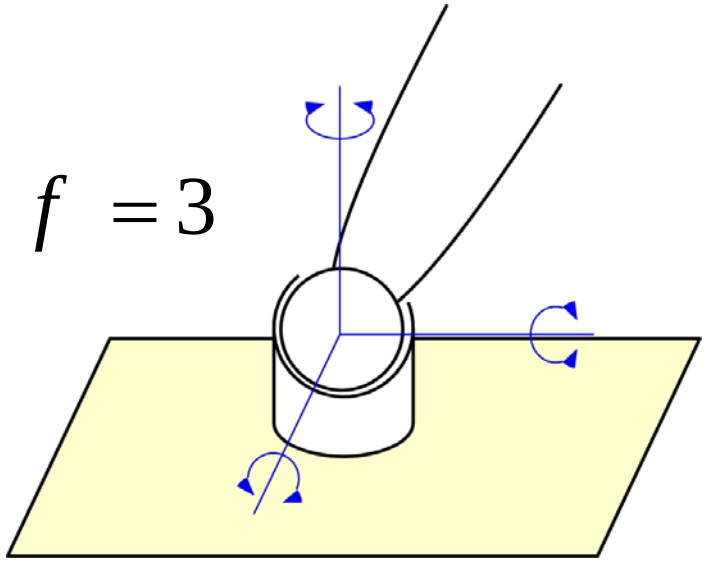


球関節の自由度

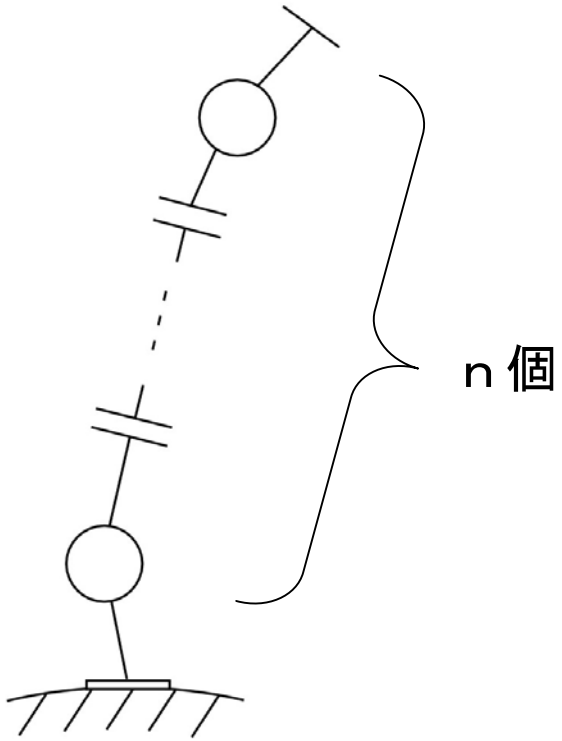


ロボットの足先と地面との自由度





課題０の答え



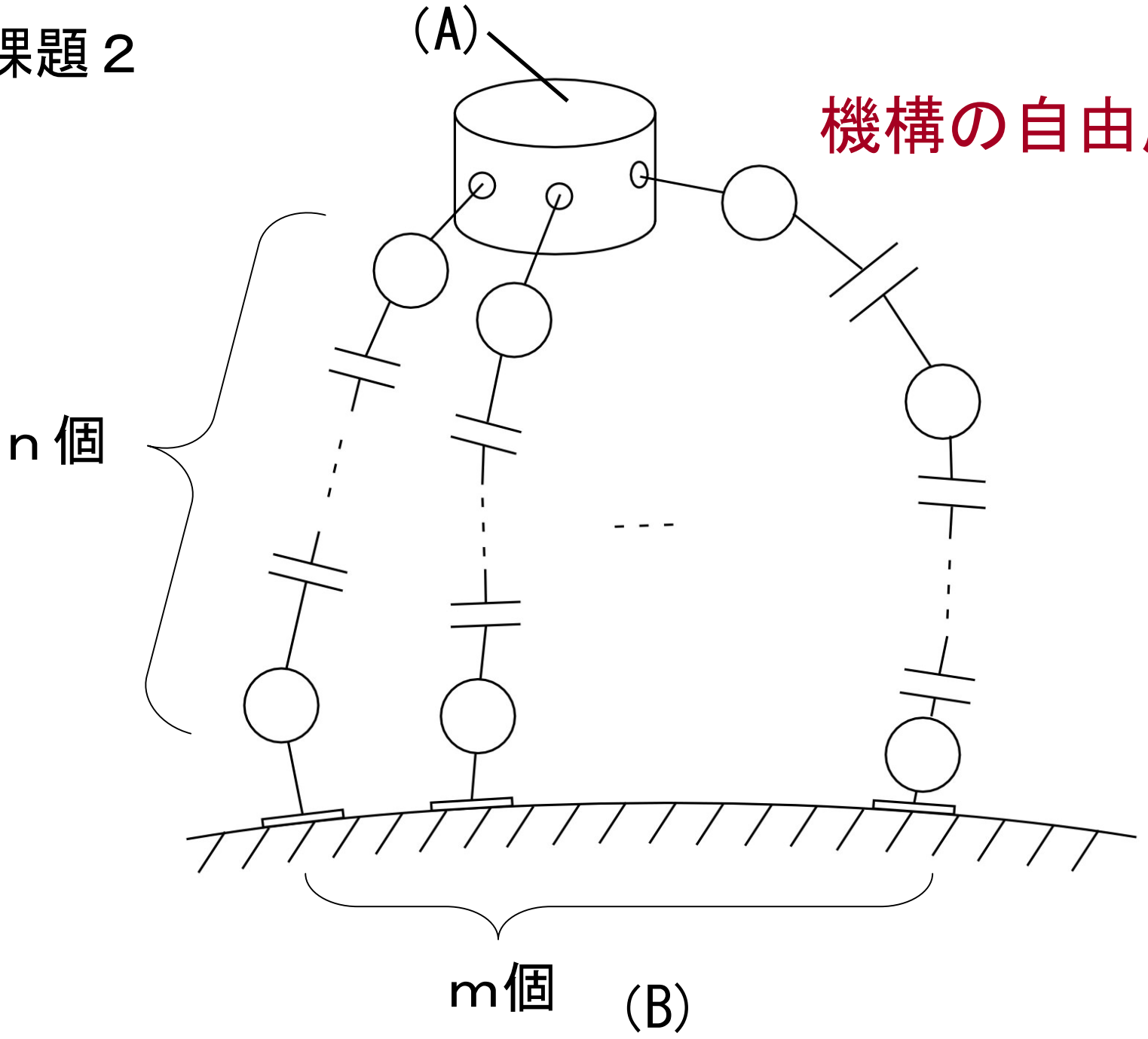
$$N = n + 1$$

$$J = n$$

$$\sum f_i = 3 \times n$$

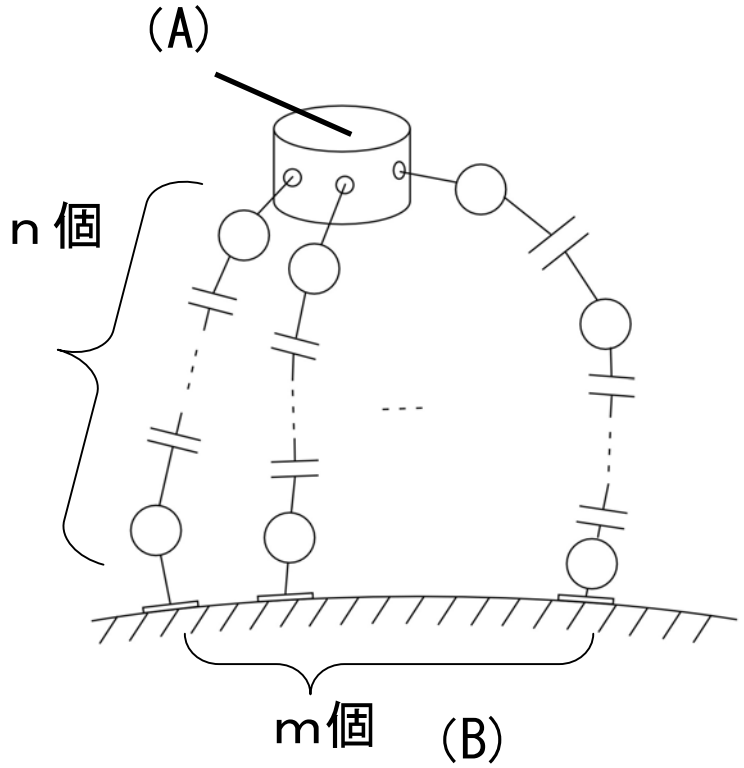
$$F = 6(N - J - 1) + \sum f_i = 3n$$

課題２



機構の自由度は？

課題２の答え



$$N = 2 + (n-1)m$$

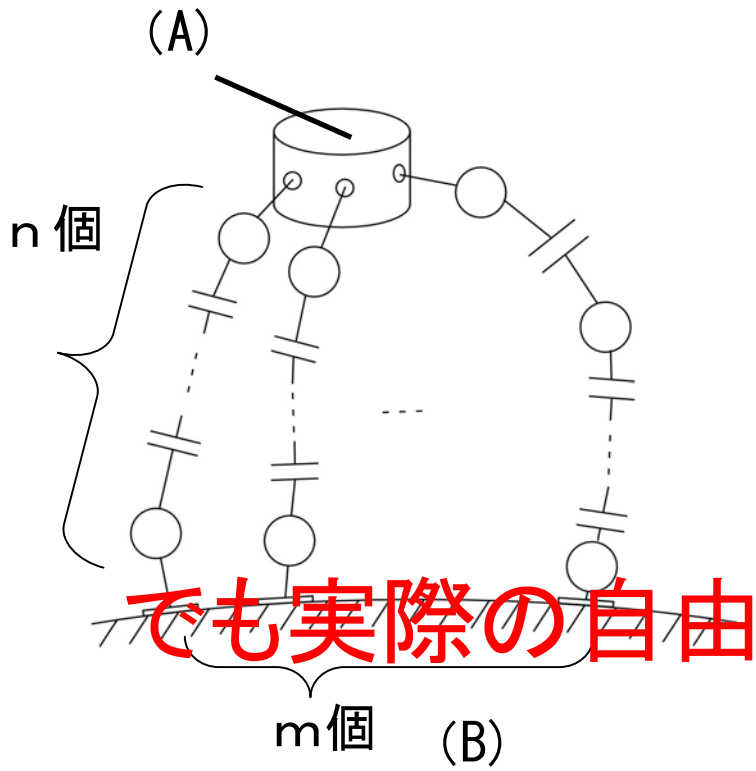
$$J = n \times m$$

$$F = 6(N - J - 1) + \sum f_i$$

$$= 6\{2 + (n-1)m - nm - 1\} + 3mn$$

$$= 6 - 6m + 3mn$$

課題２の答え



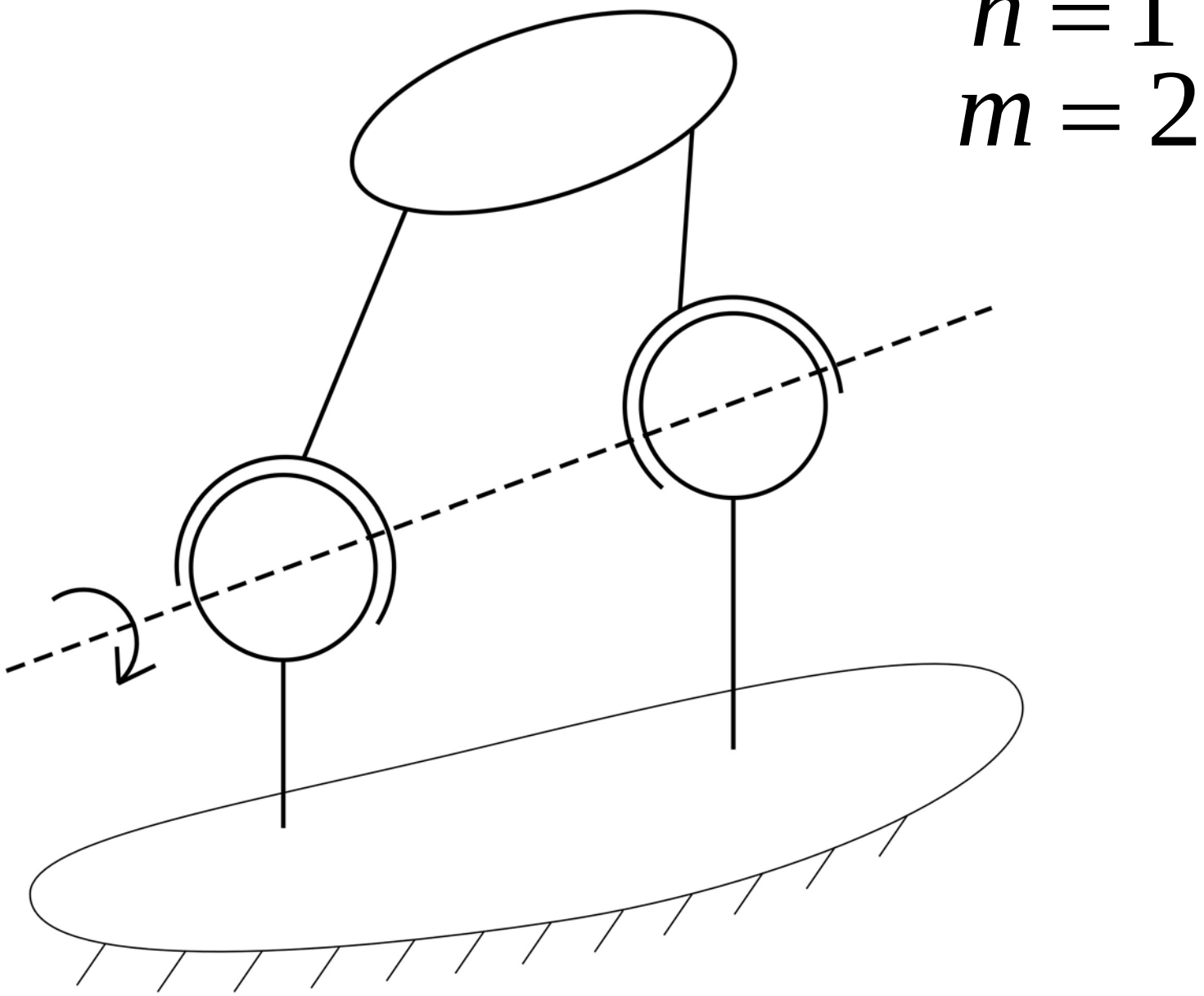
$$\left.\begin{aligned} n &= 1 \\ m &= 2 \end{aligned}\right\} \text{のとき}$$

$$N = 2 + (n-1)m = 2$$

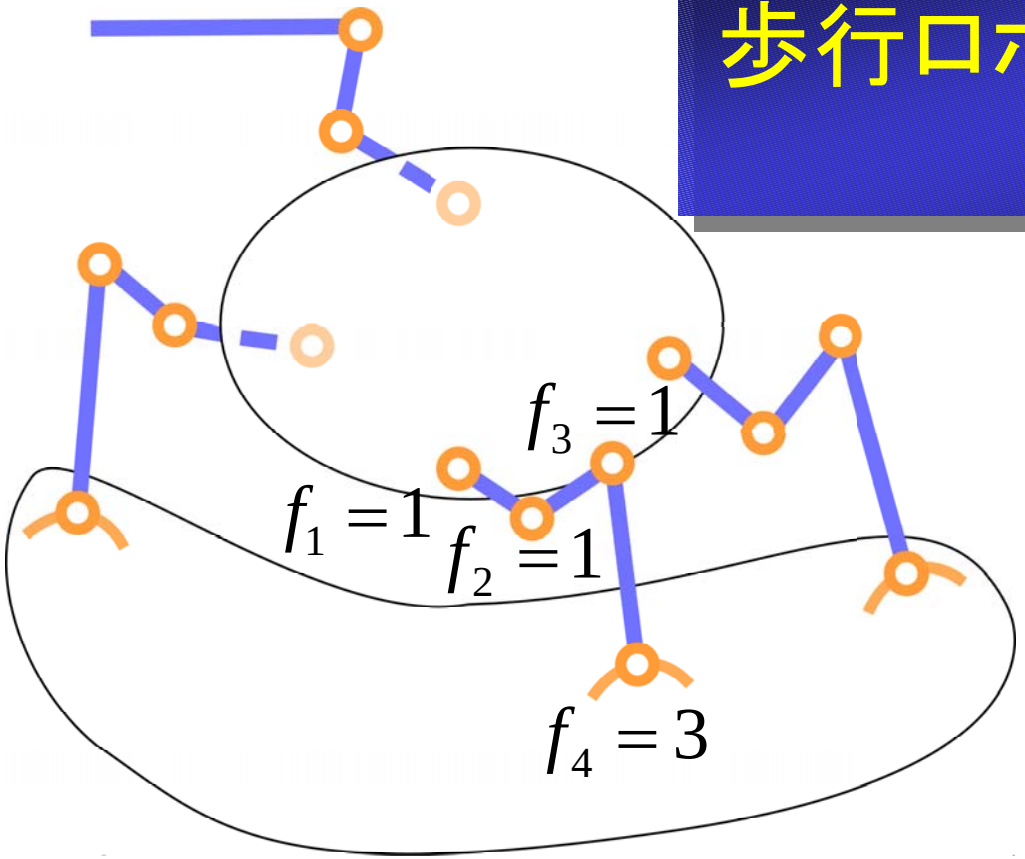
$$J = n \times m = 2$$

でも実際の自由度はゼロじゃない！

$$\begin{aligned} F &= 6(N - J - 1) + \sum f_i \\ &= 6(2 - 2 - 1) + 6 \\ &= 0 \end{aligned}$$


$n = 1$
$m = 2$

歩行ロボットの自由度
課題3



９自由度
の意味は？

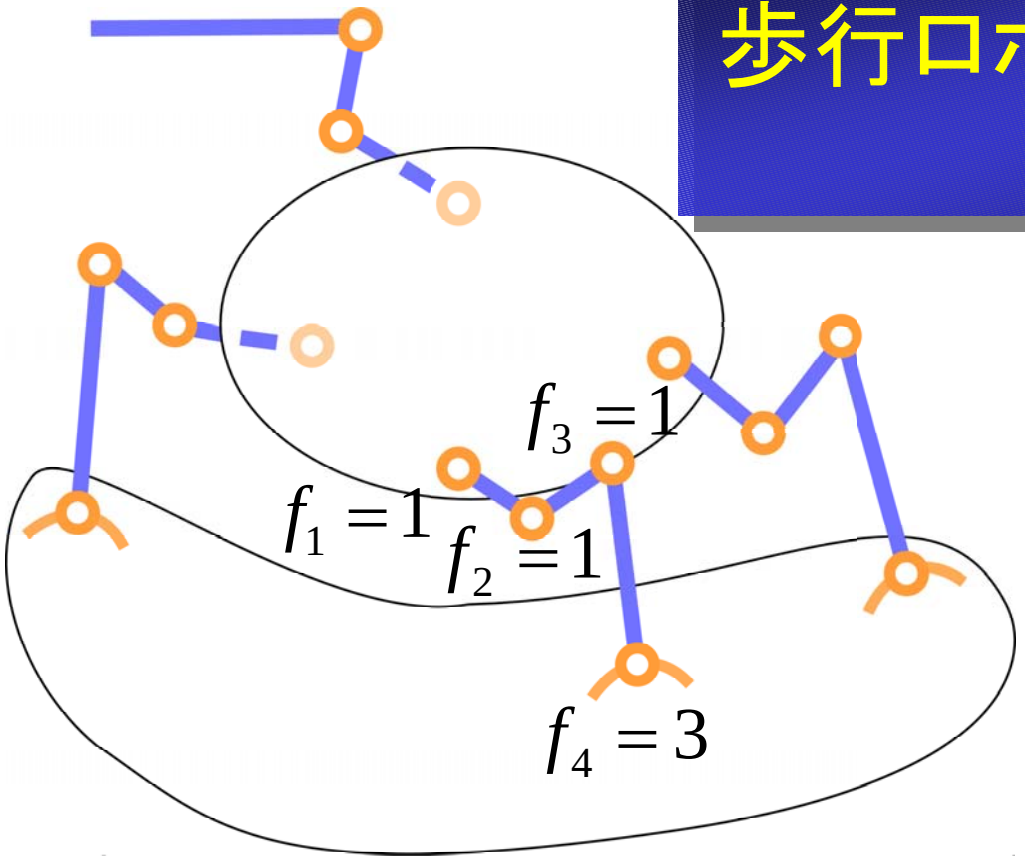
$$N = 14 \quad J = 4 \times 3 + 3 = 15$$

$$F_k = 6 \times (14 - 15 - 1) + \sum f_i$$

$$= -12 + (6 \times 3 + 3)$$

$$= 9$$

歩行ロボットの自由度
課題3

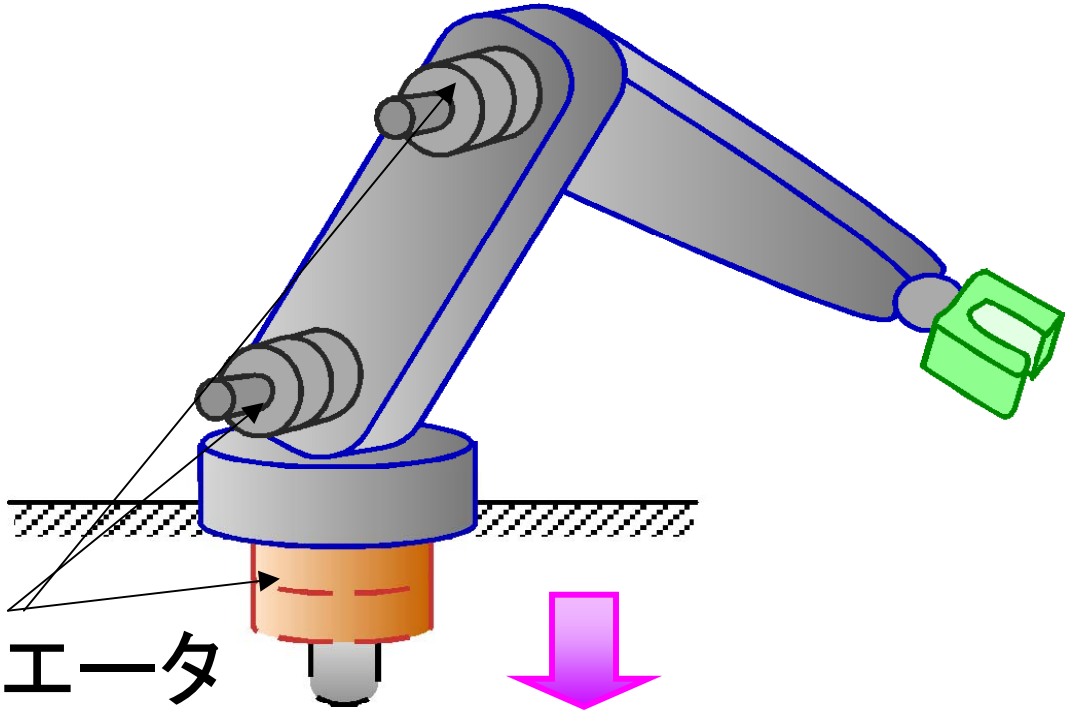


９自由度
の意味は？

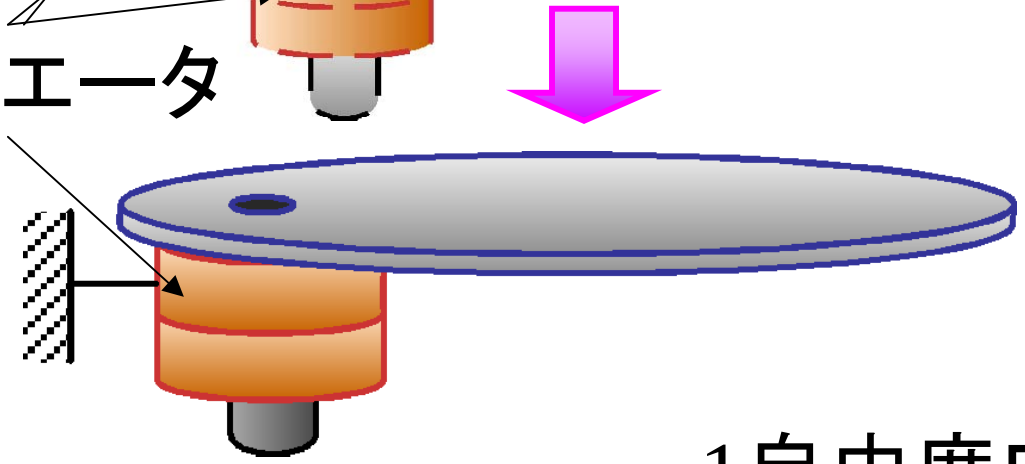
3は遊脚の自由度

6は胴体の位置(3)・姿勢(3)の自由度

能動自由度と受動自由度



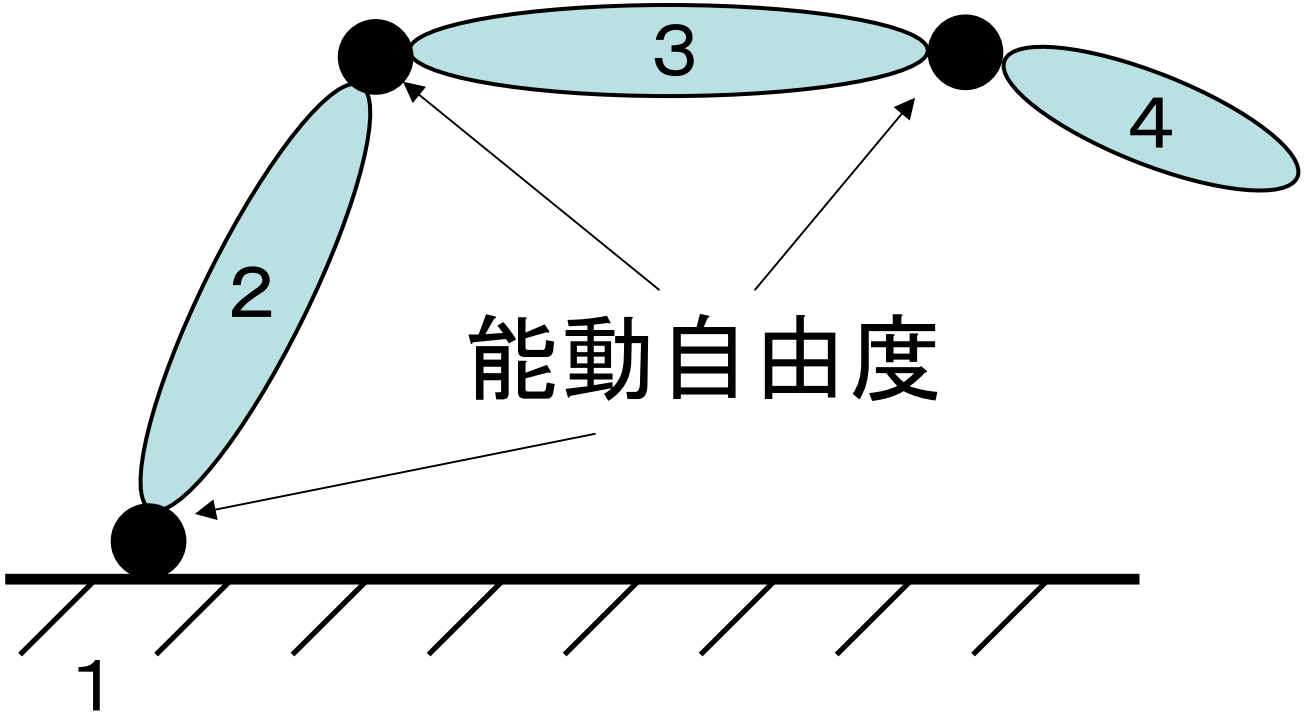
アクチュエータ



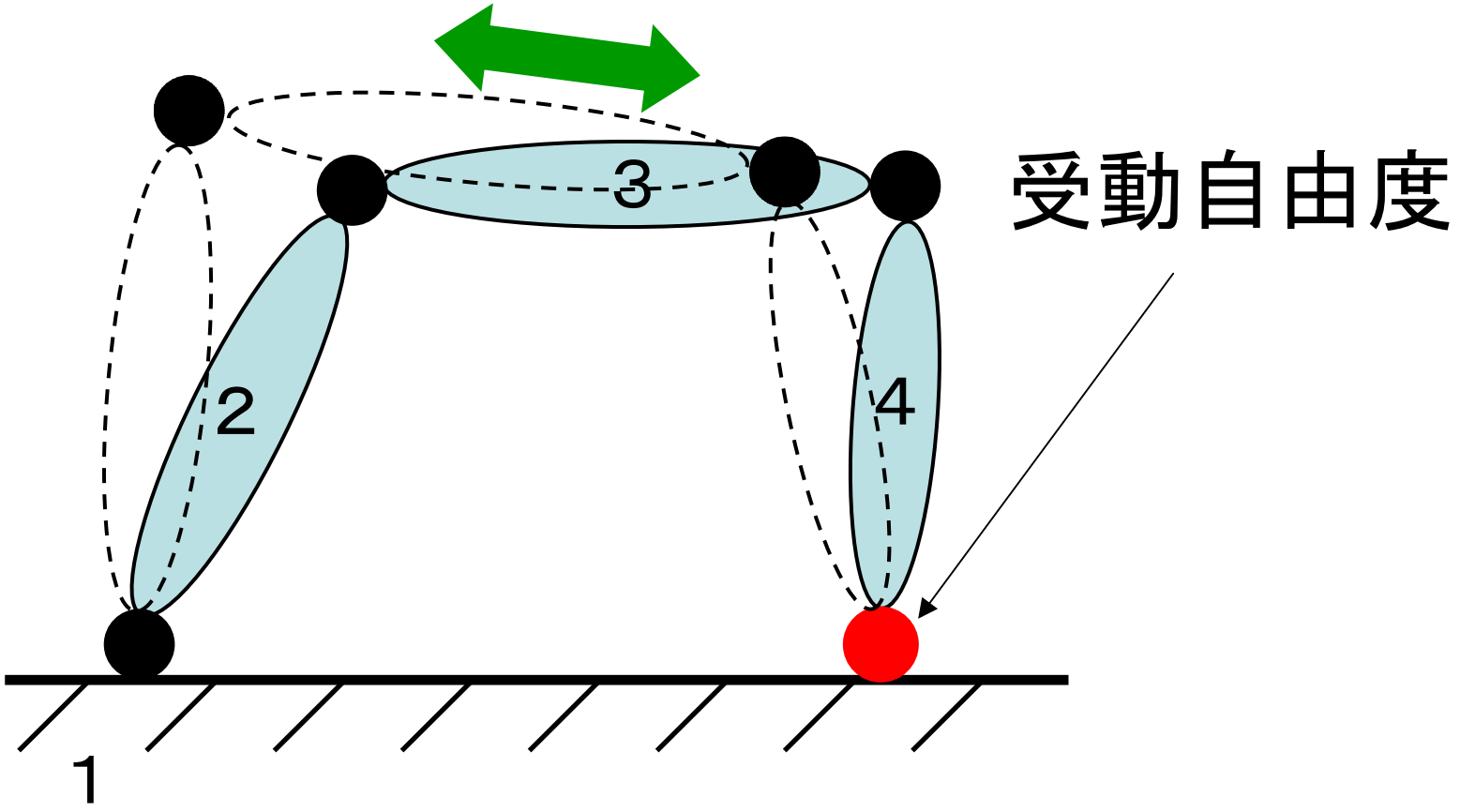
1自由度ロボット

能動自由度と受動自由度

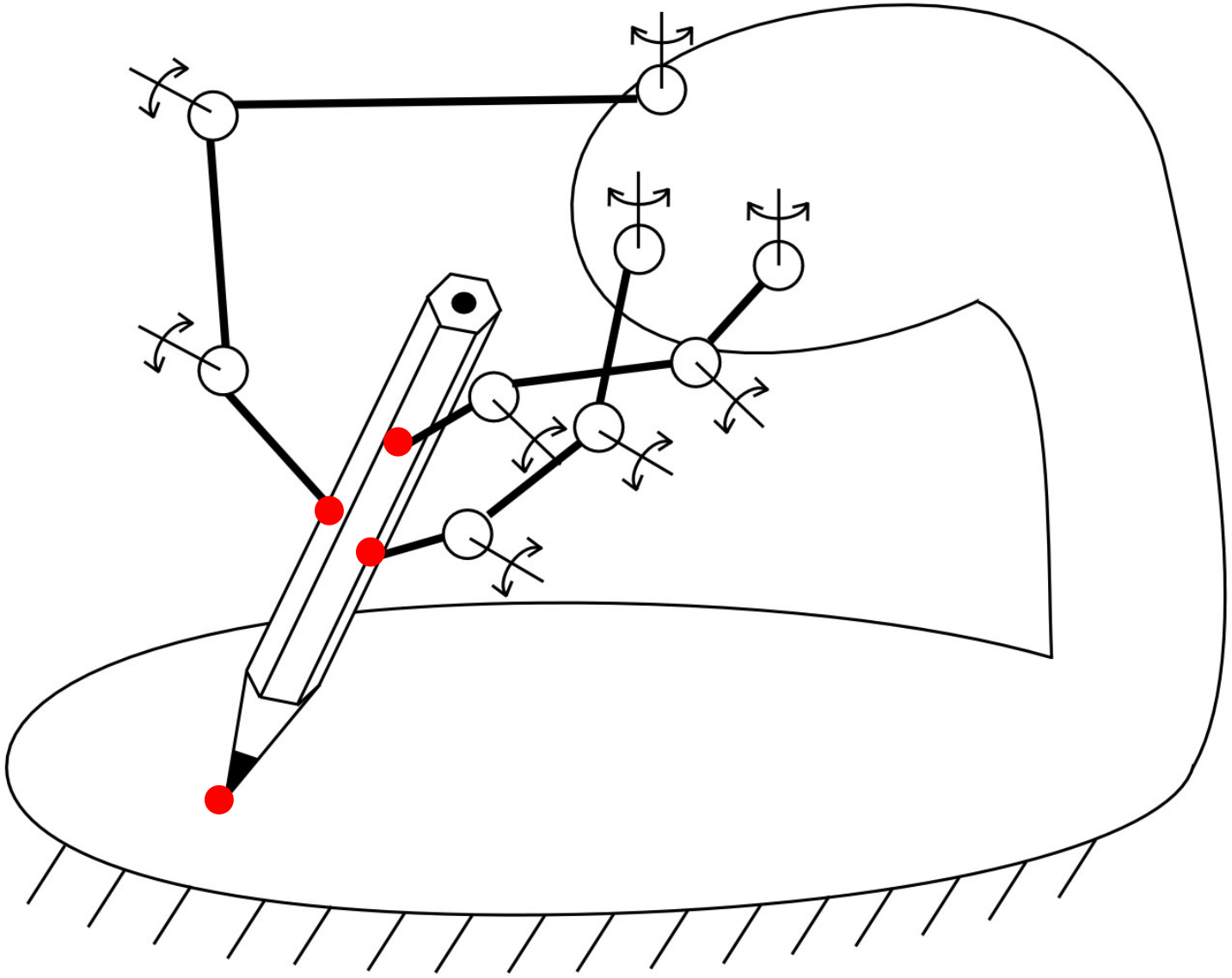
能動自由度：アクチュエータがついている
受動自由度：アクチュエータがついていない



能動自由度と受動自由度

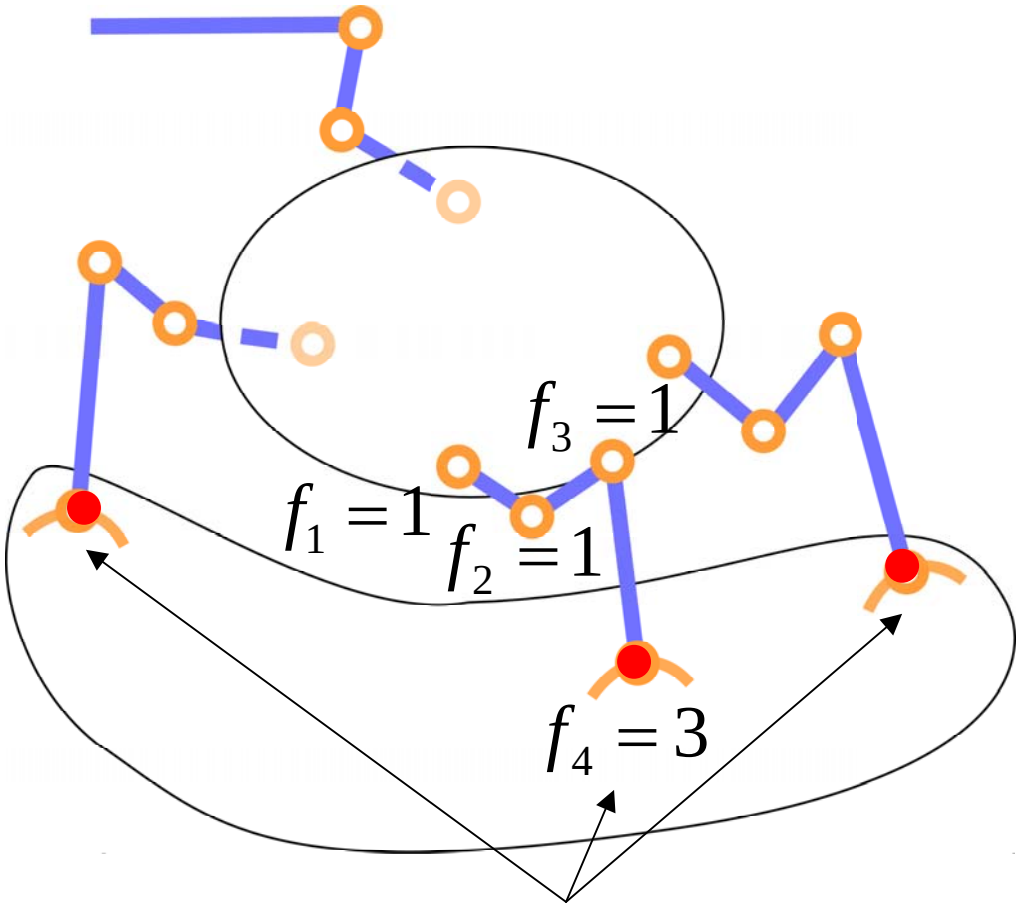


受動自由度● と能動自由度 ○

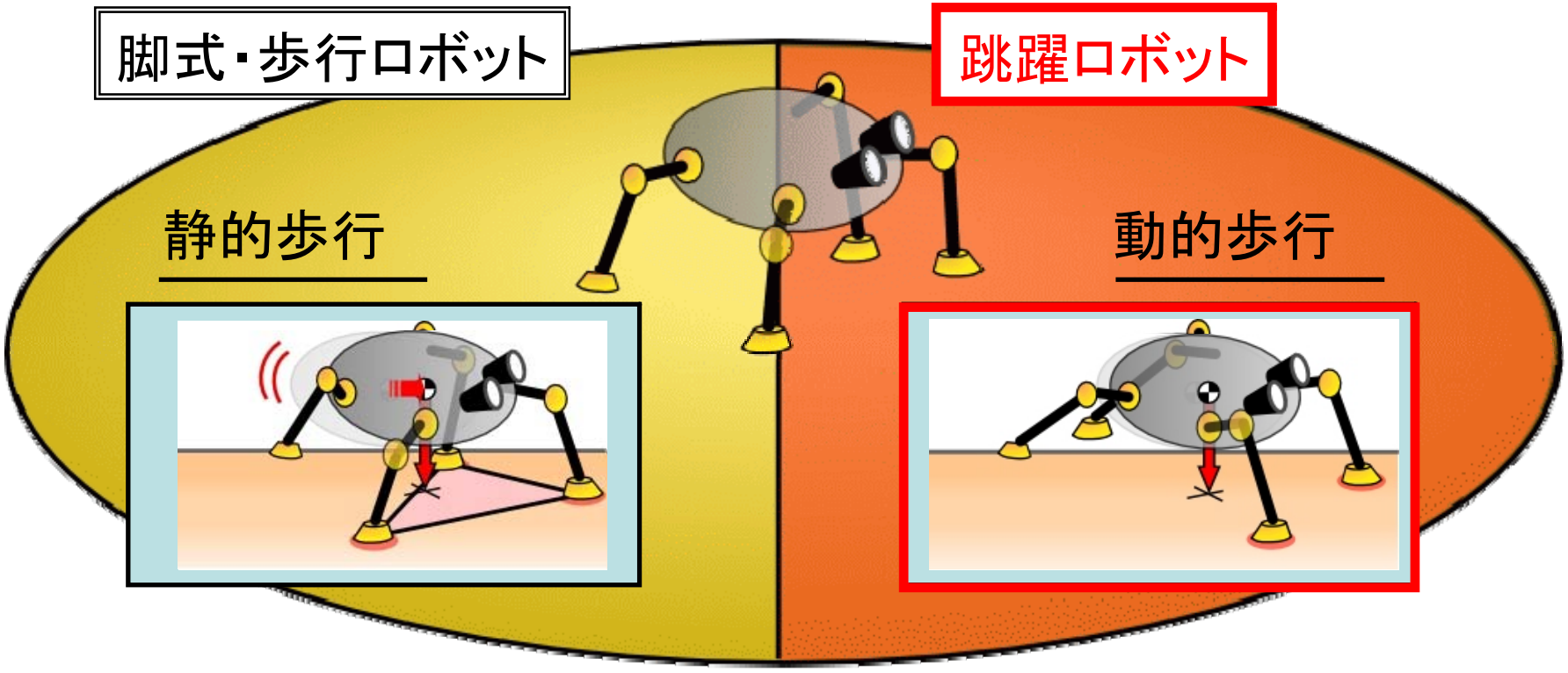


地面に固定

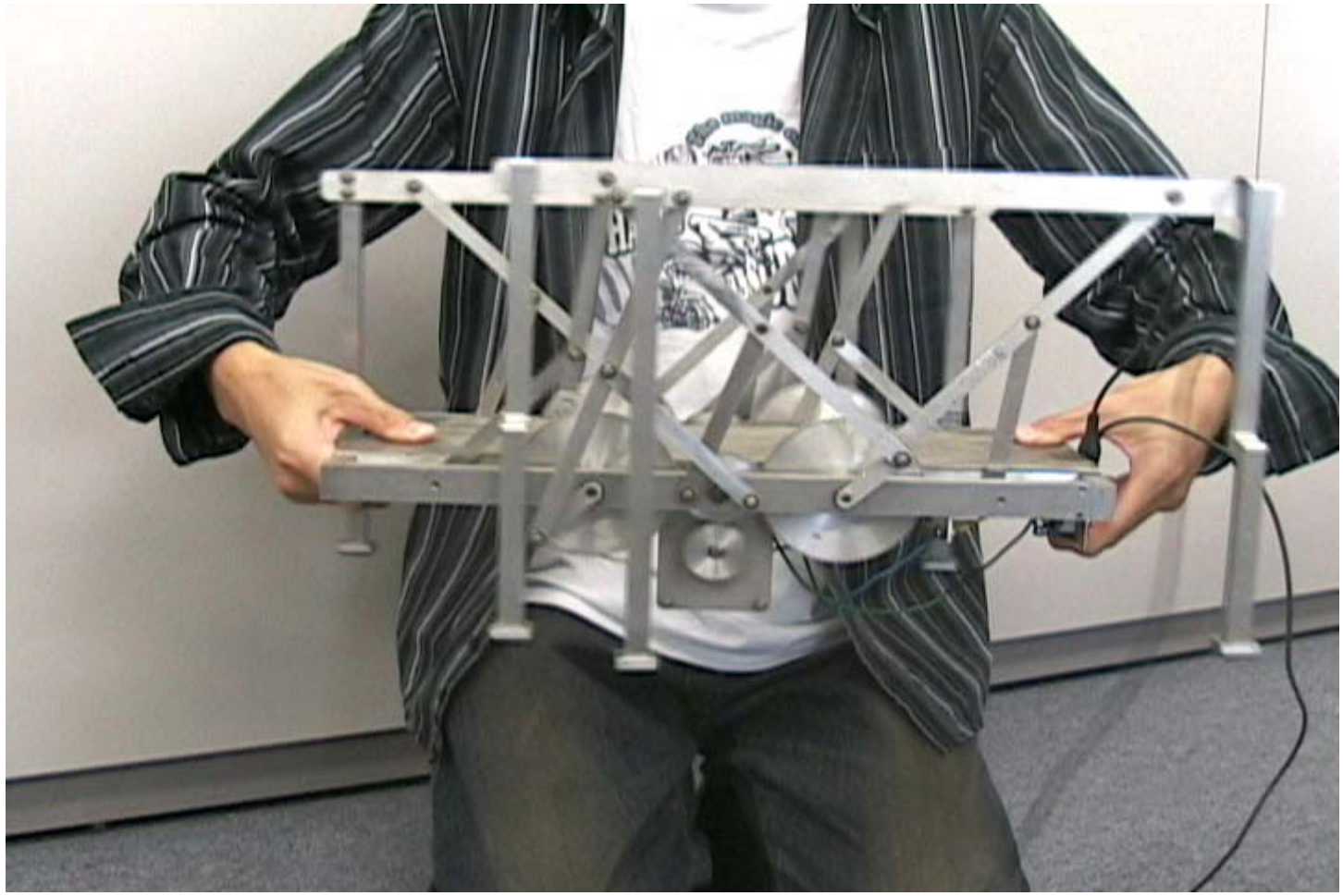
能動自由度と受動自由度



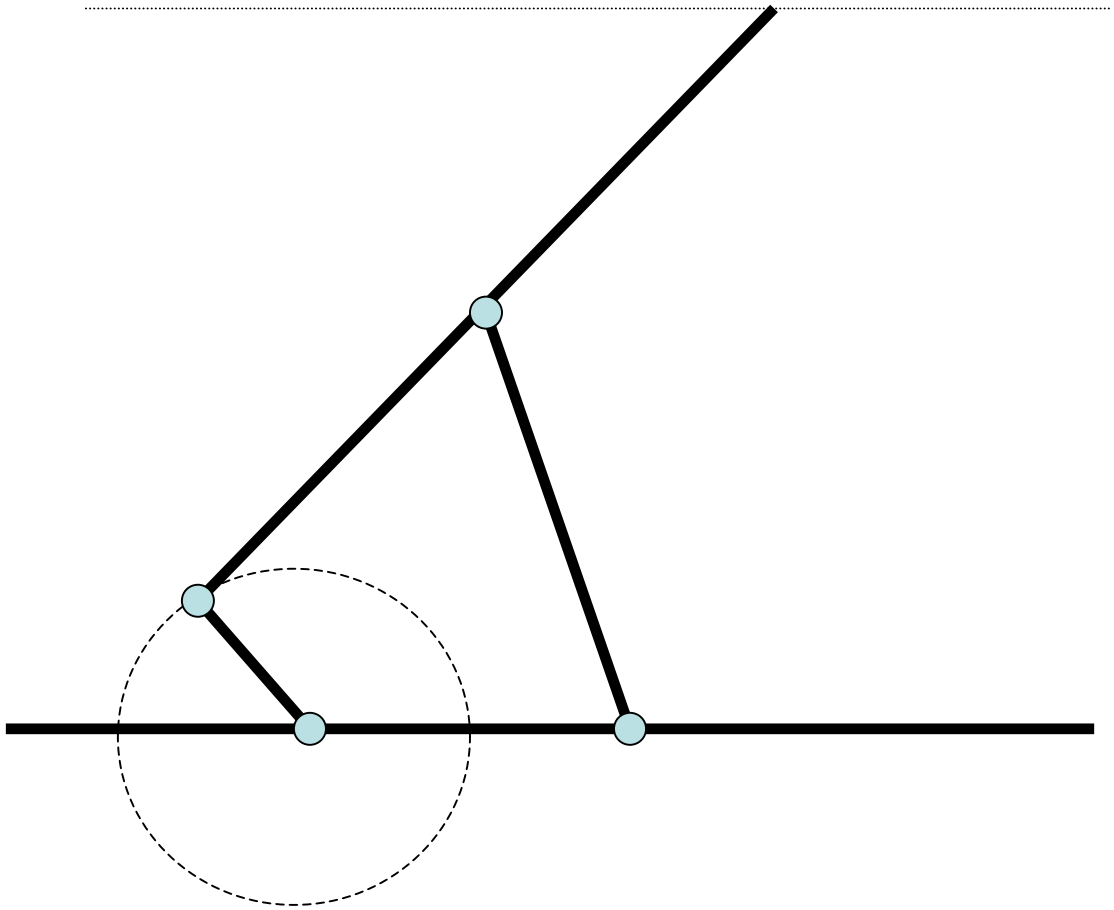
受動自由度

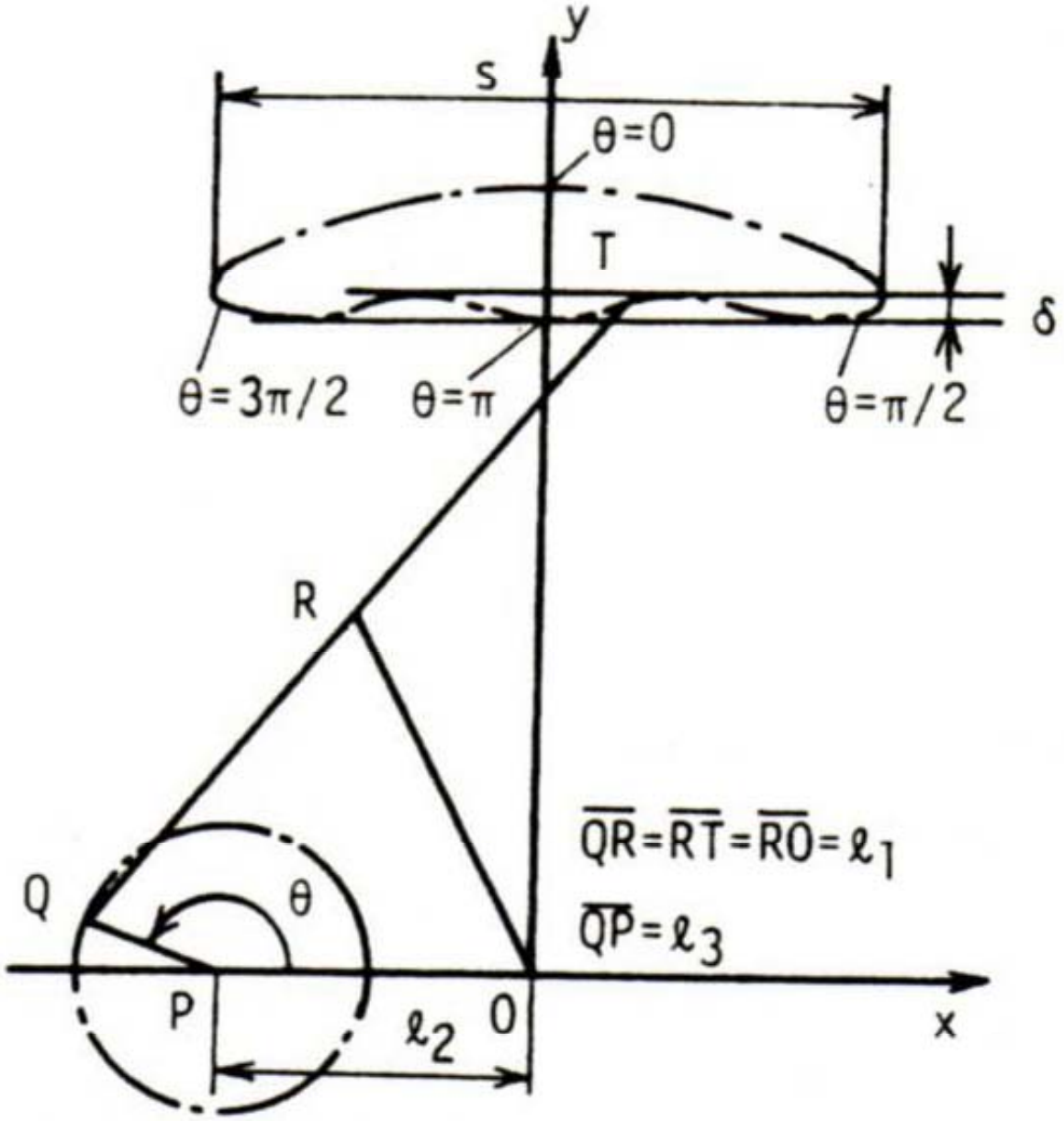

脚式・歩行ロボット
跳躍ロボット
静的歩行
動的歩行

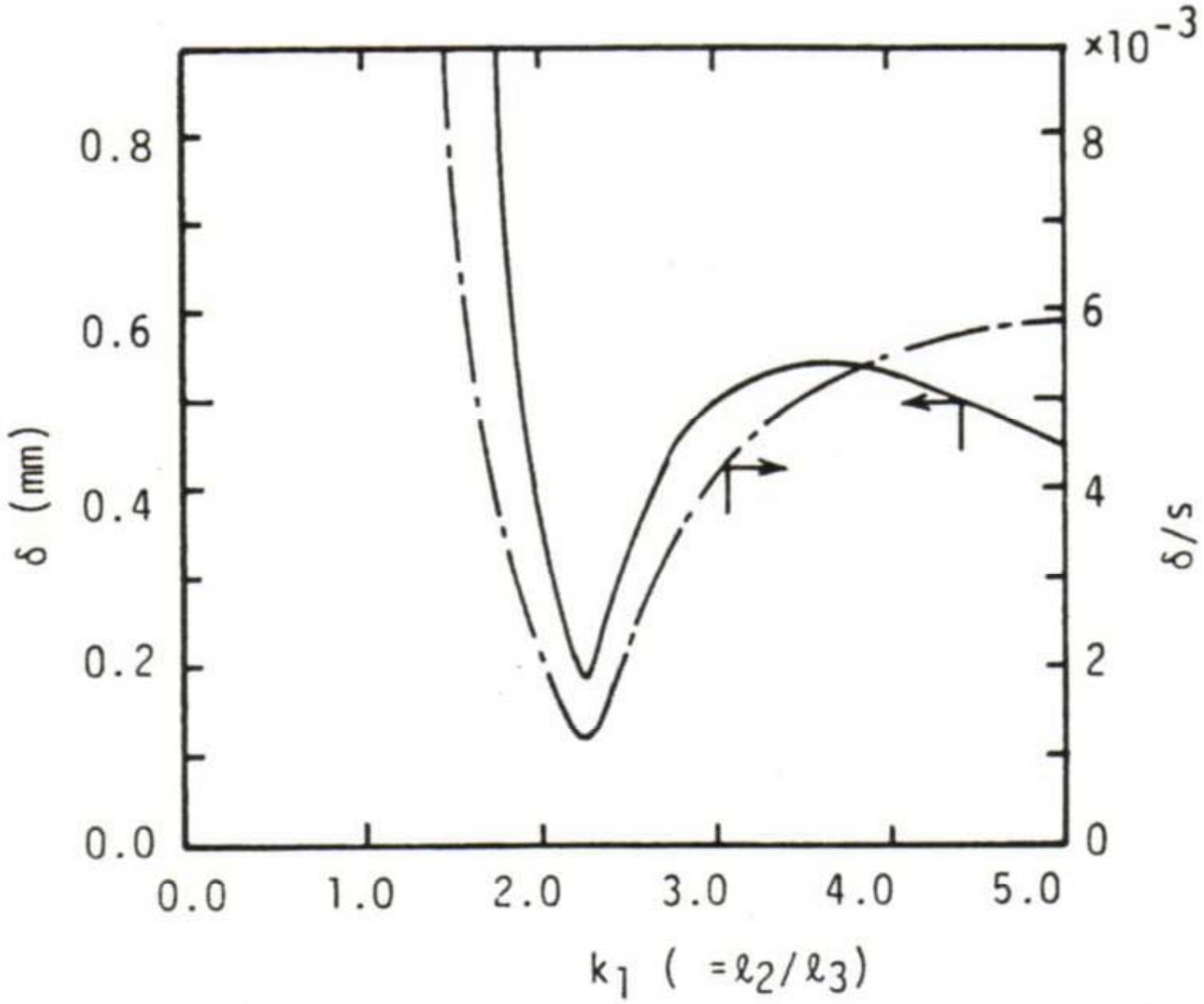
脚の動き

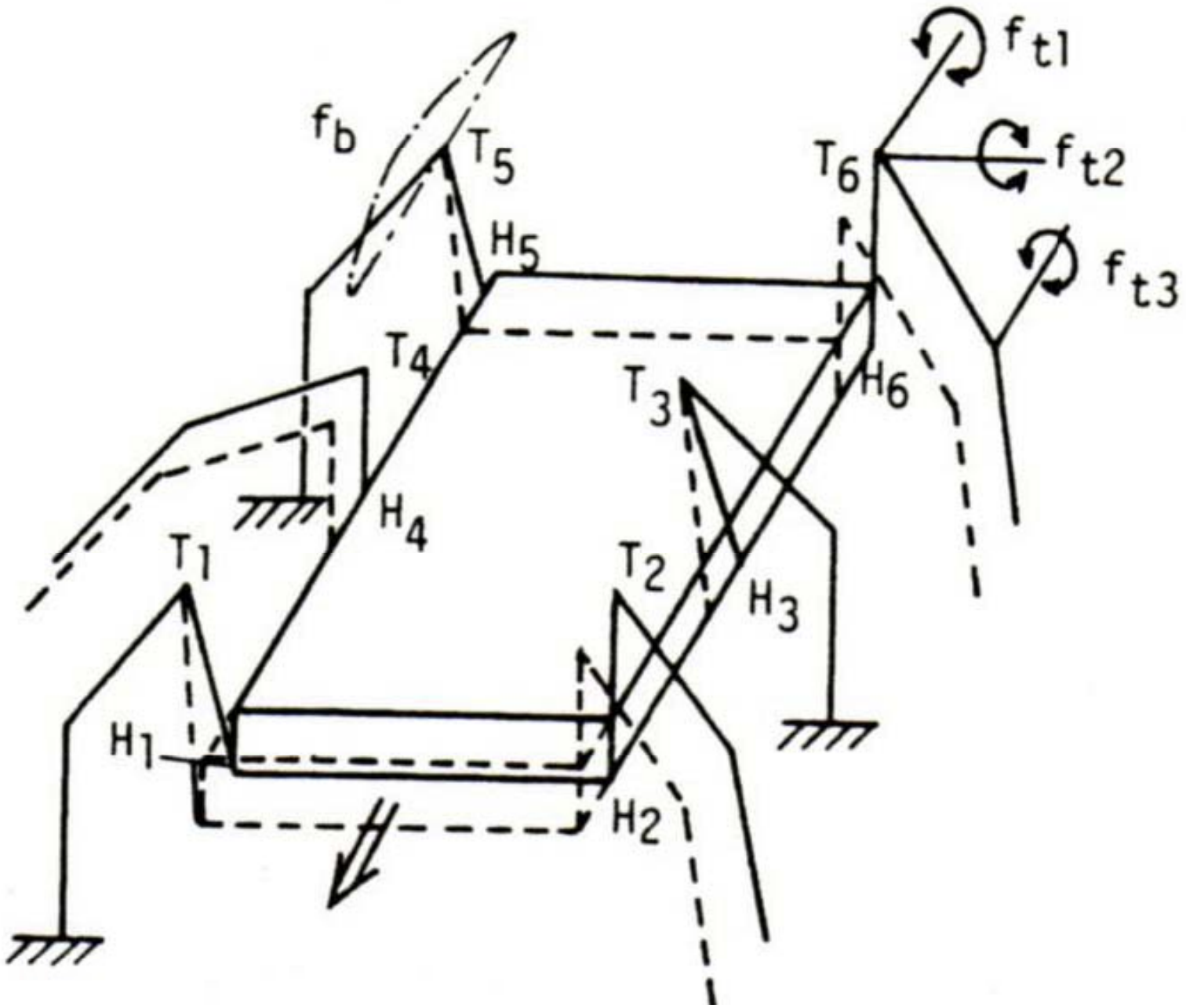


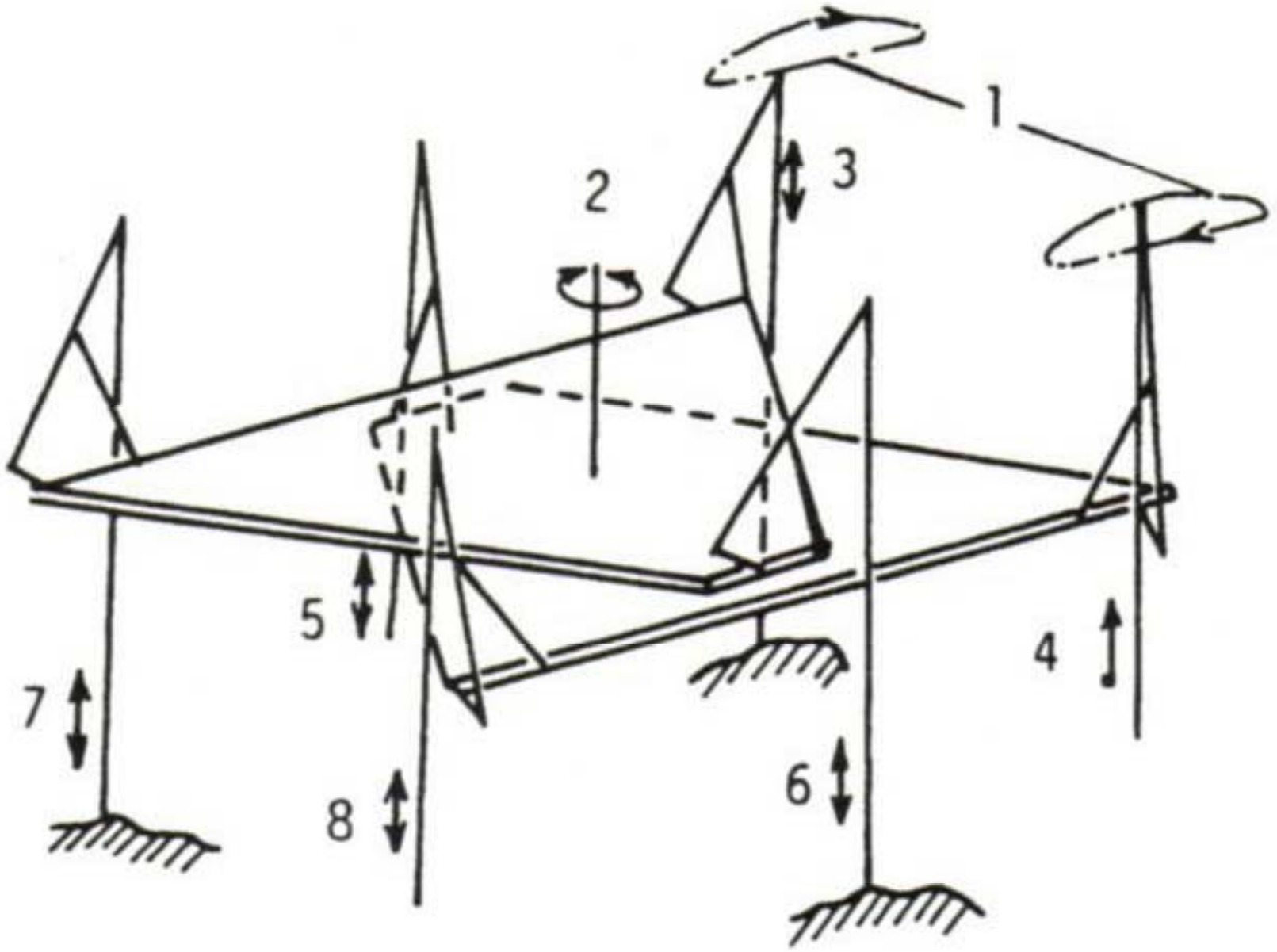
４節リンク機構

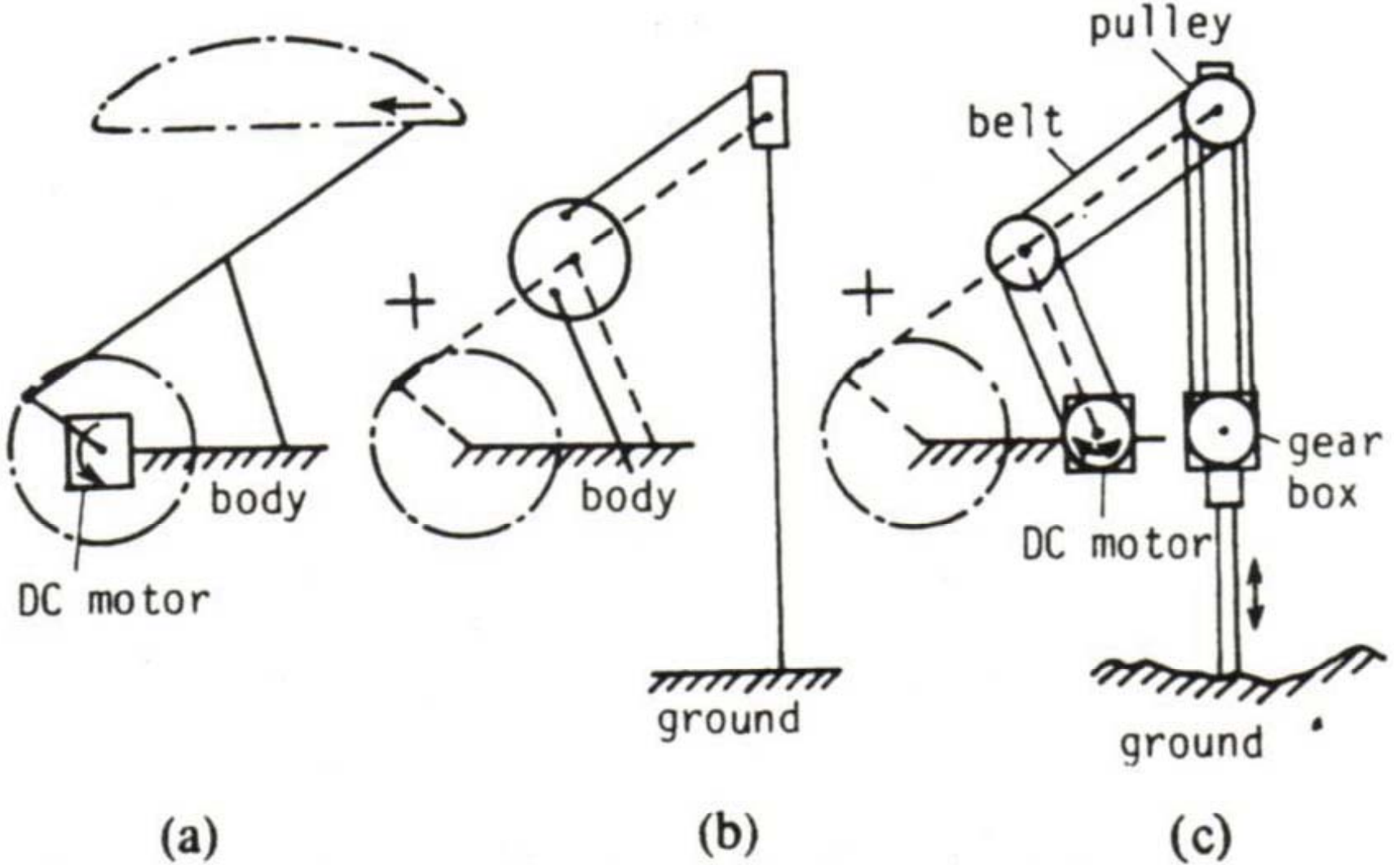



y
s
θ=0
T
δ
θ=3π/2
θ=π
θ=π/2
R
Q
θ
P
ℓ2
O
x
$\overline{QR}=\overline{RT}=\overline{RO}=\ell_1$
$\overline{QP}=\ell_3$

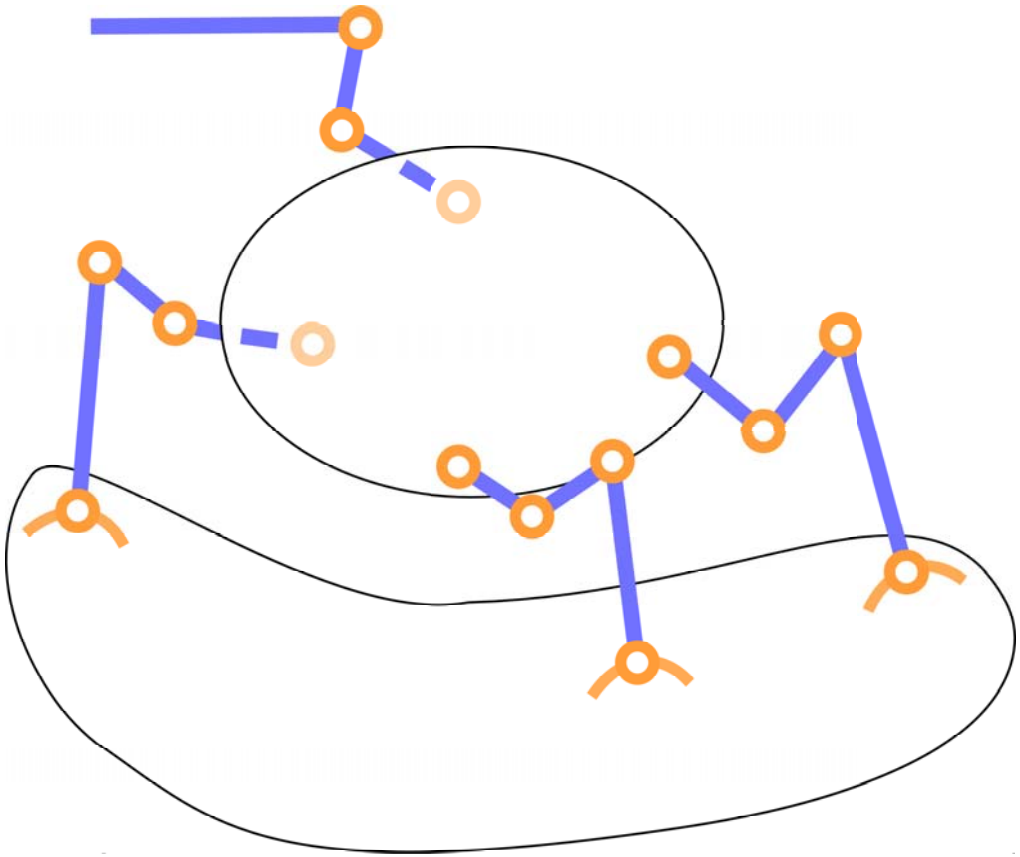

×10⁻³
0.8
0.6
0.4
0.2
0.0
δ (mm)
8
6
4
2
0
δ/s
0.0
1.0
2.0
3.0
4.0
5.0
k1 (=ℓ2/ℓ3)


f_{t1}
f_{t2}
f_{t3}
f_b
T_5
T_6
H_5
T_4
T_3
H_6
H_4
T_1
T_2
H_3
H_1
H_2

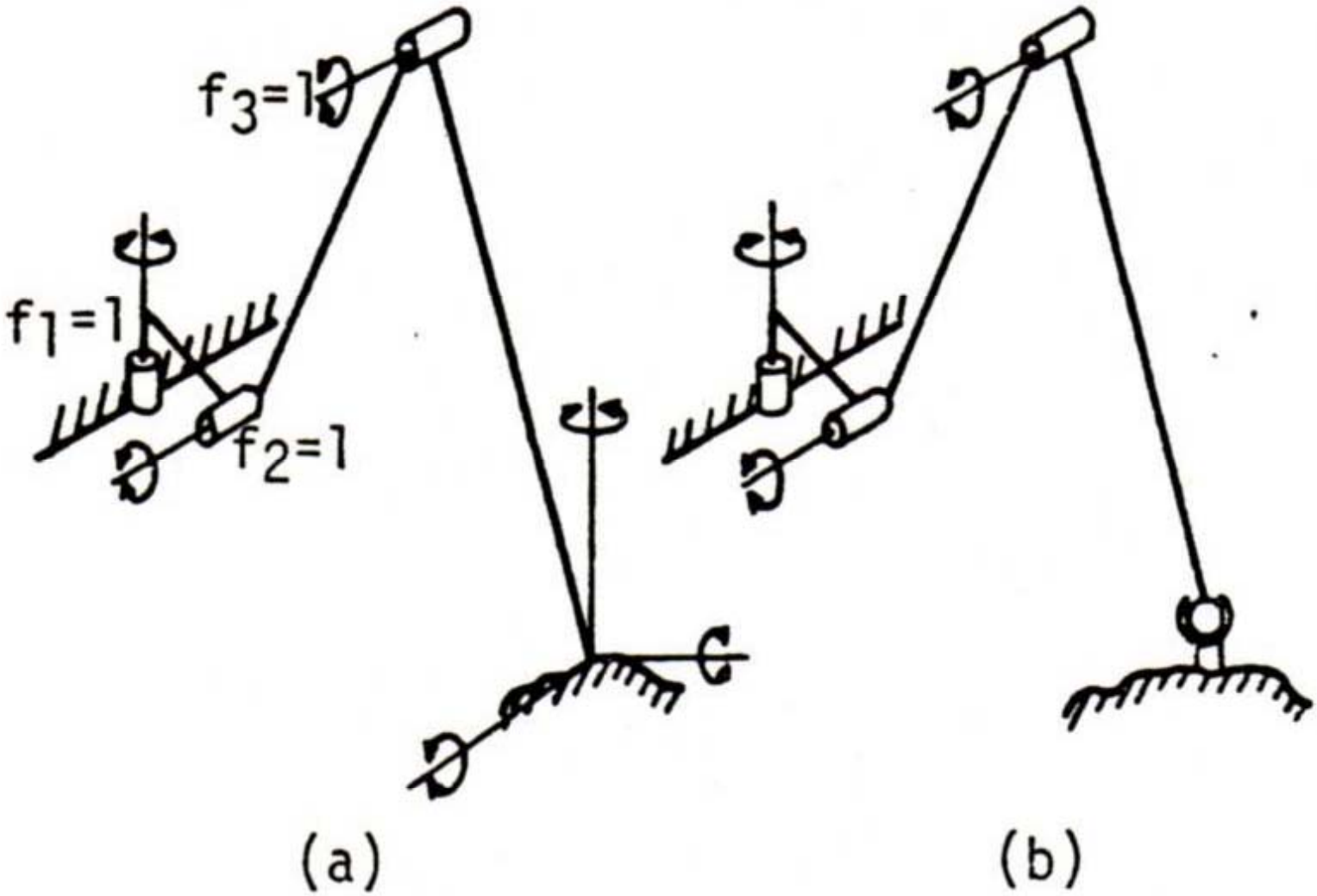

1
2
3
4
5
6
7
8


body
DC motor
body
ground
pulley
belt
gear
box
DC motor
ground
(a)
(b)
(c)

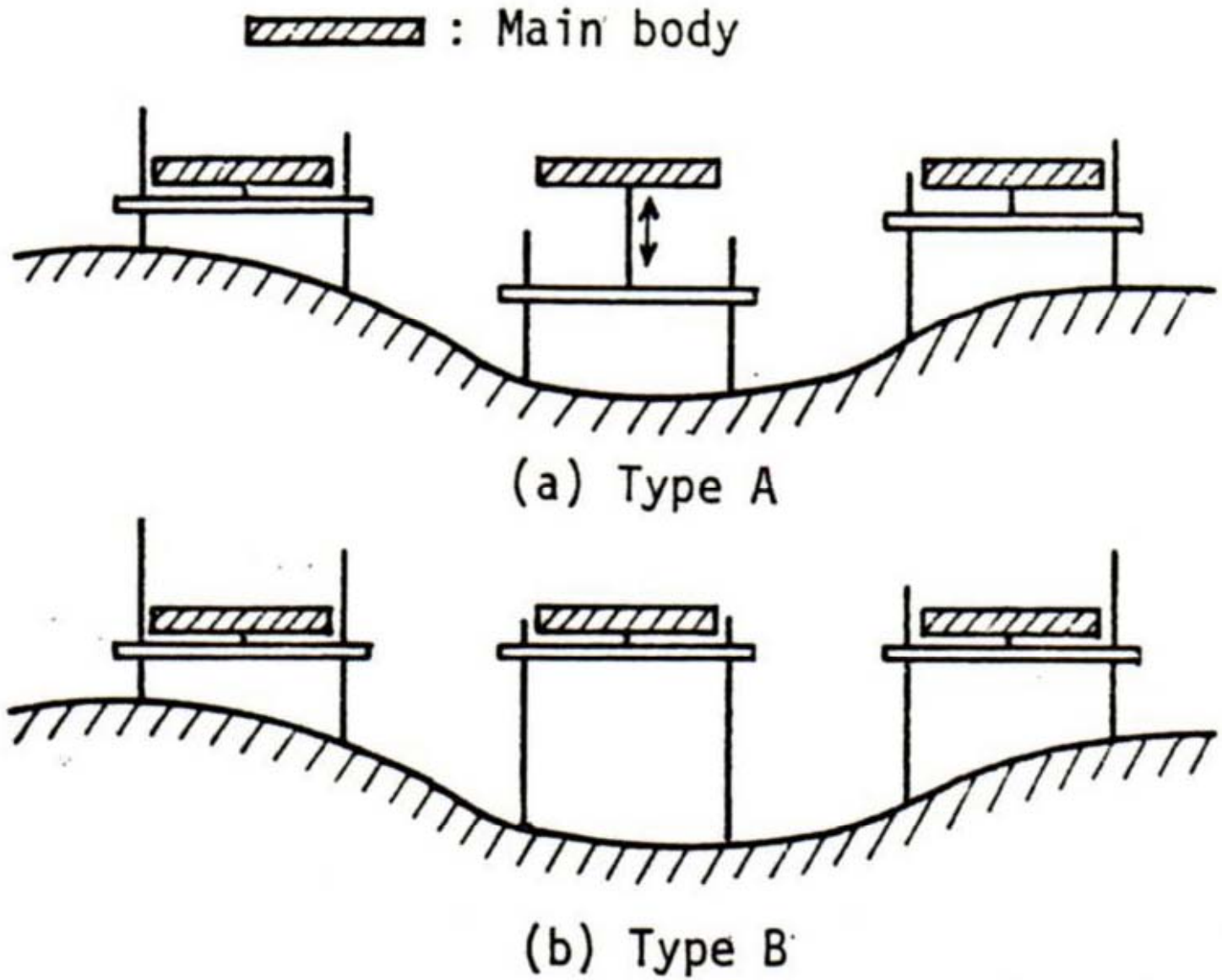
最低限の機能を有する4足歩行ロボットの最低能動自由度？



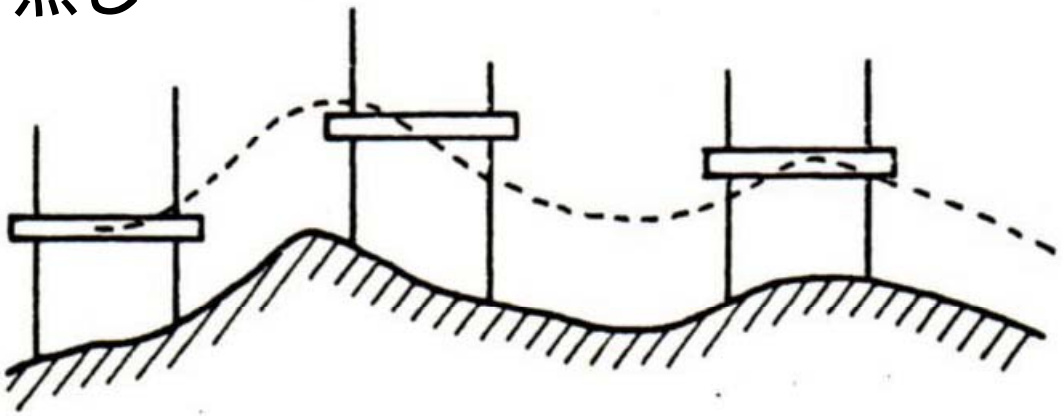
キャプション無し



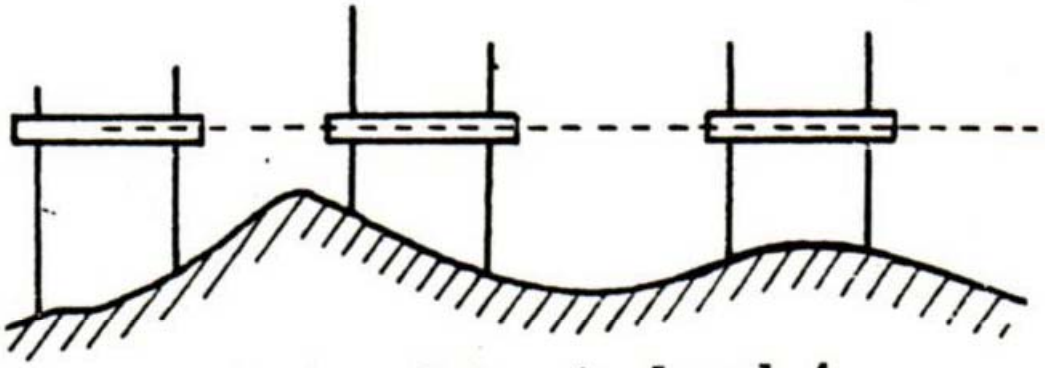
キャプション無し



キャプション無し

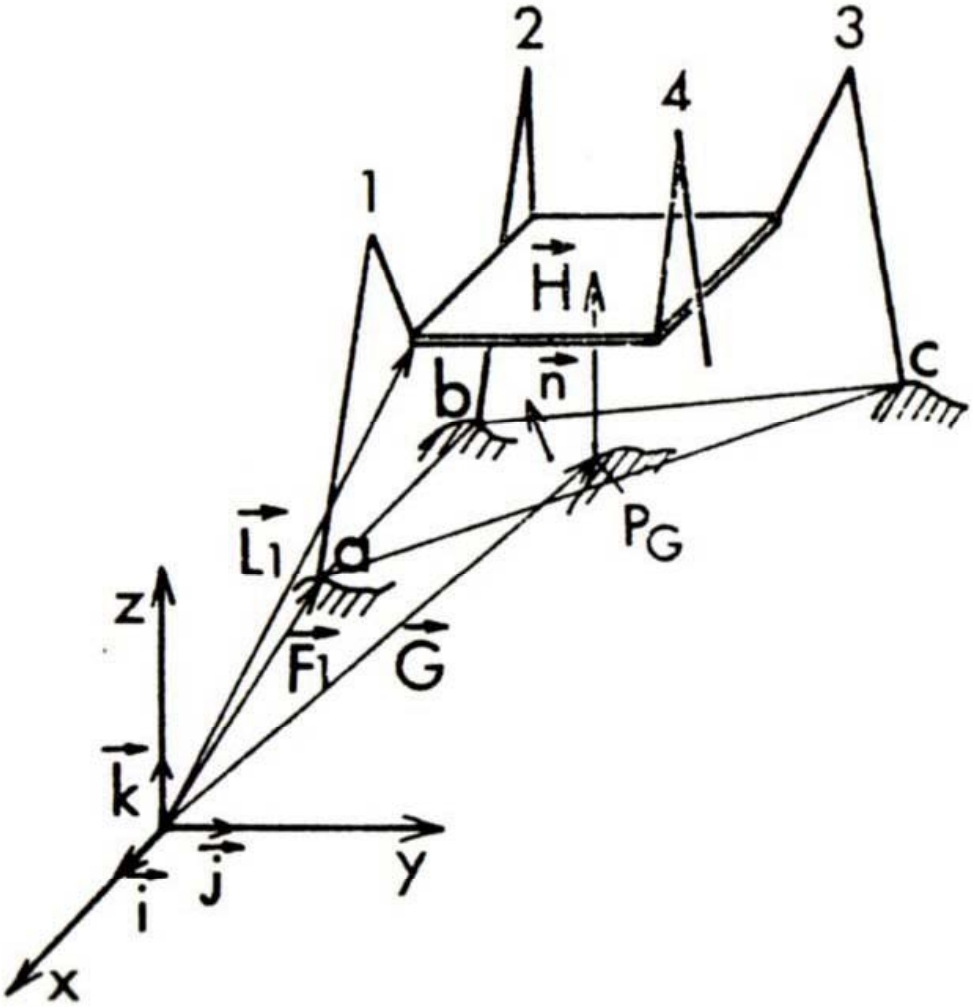


(a) Walking in level 3



(b) Walking in level 4

キャプション無し



キャプション無し