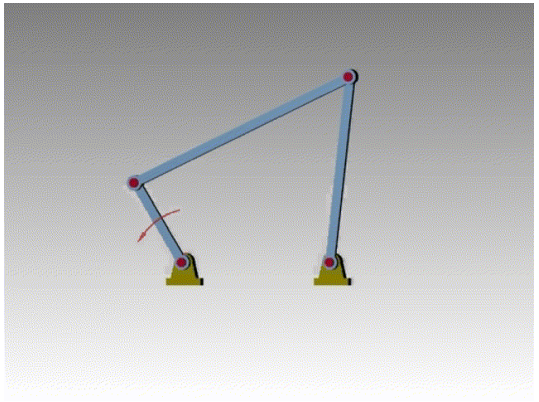
第3章 平面机构运动简图及其自由度

3.1 平面机构的组成

3.1.1 构件

构件：独立运动的单元体，由单个或多零件刚性构成。



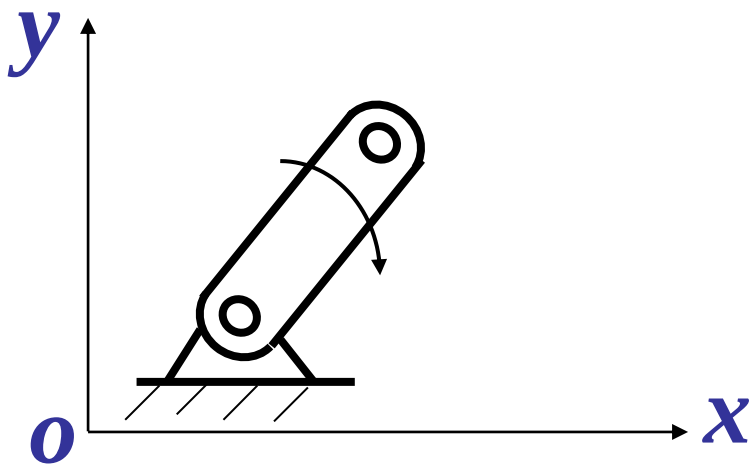
(1) 固定件 ---- 机架

(2) 原动件 ---- 主动件

(3) 从动件 ---- 运动输出构件

3.1.2 构件自由度和约束

自由度：构件的独立运动数



一个平面运动的构件有三个自由度

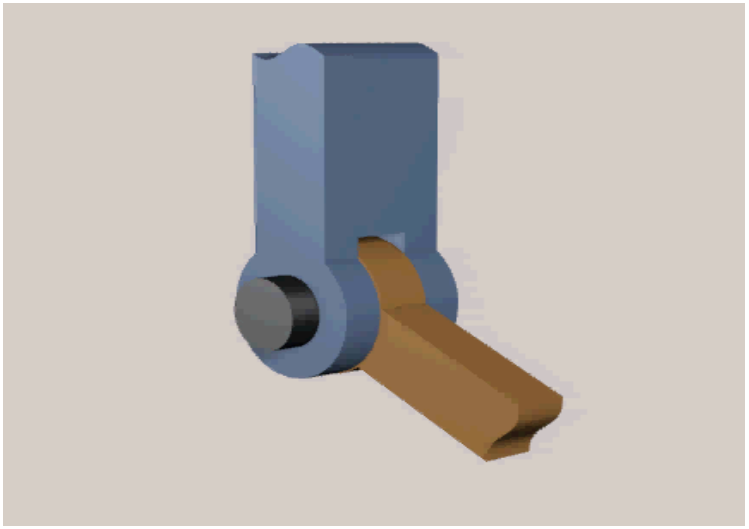
运动副：两个构件接触并能产生相对运动的连接

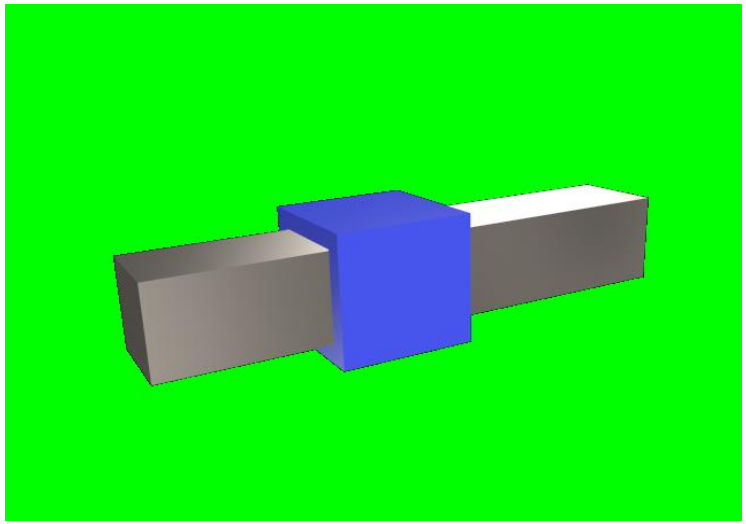
约束：对独立运动的限制，两个构件组成运动副后就彼此带来约束

3.1.3 运动副及其分类

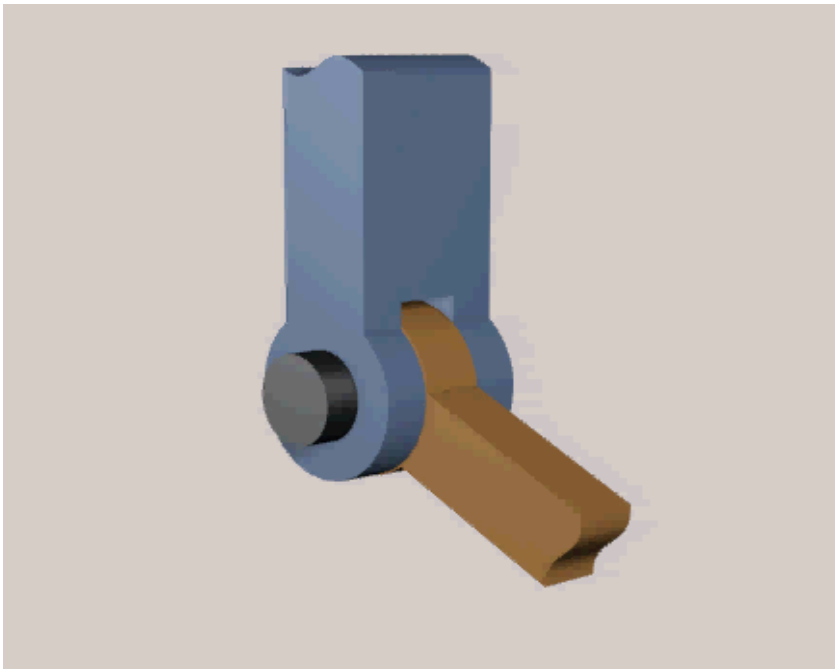
根据构件间的接触形式,运动副分:

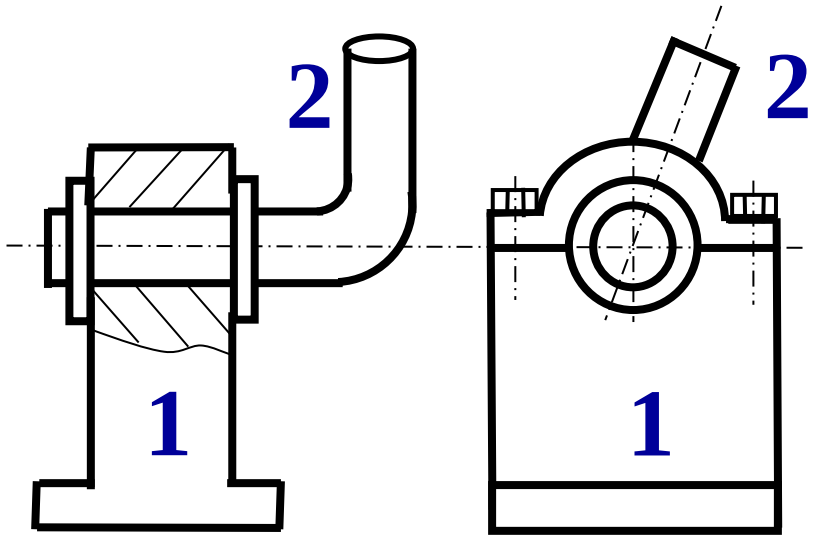
1.低副（面接触）
- 转动副(铰链)
- 移动副(导路)

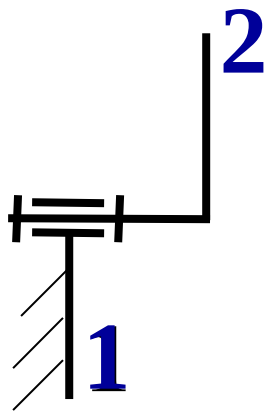


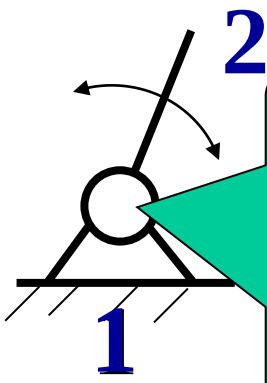


转动副

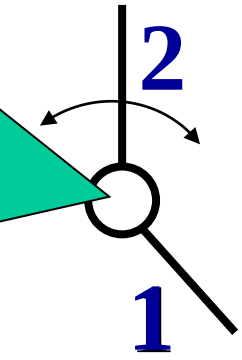








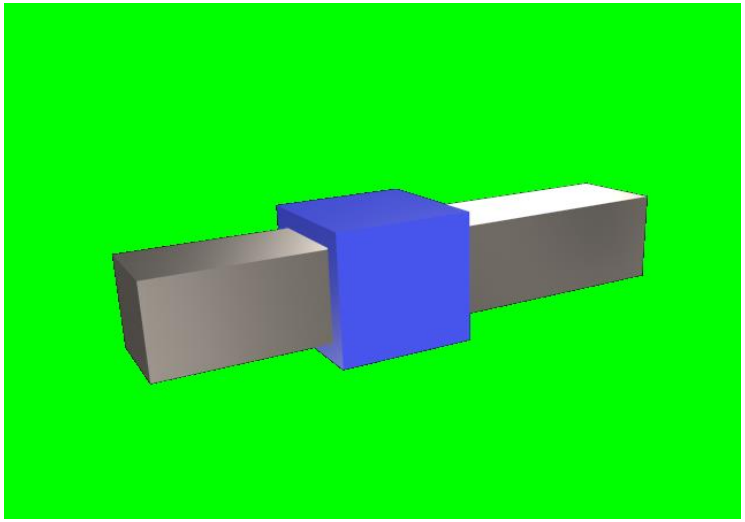
固定铰链

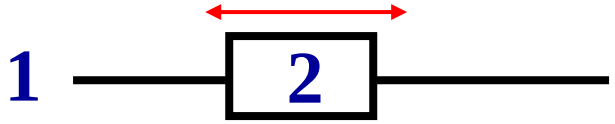


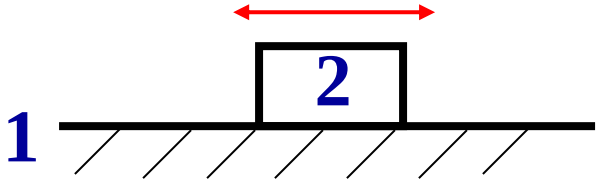
活动铰链

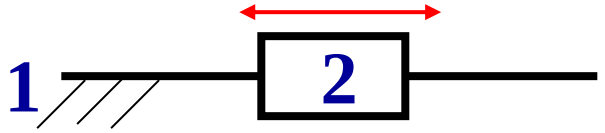
转动副对每个活动构件带来2个约束

移动副

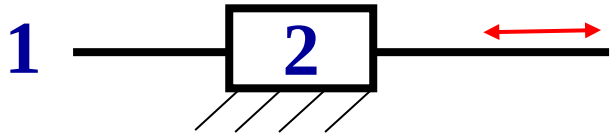






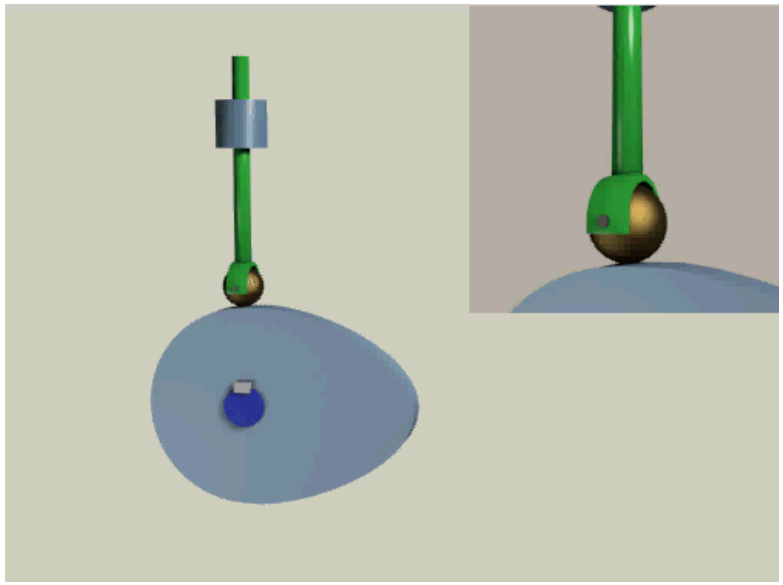


移动副对每个活动构件也带来2个约束

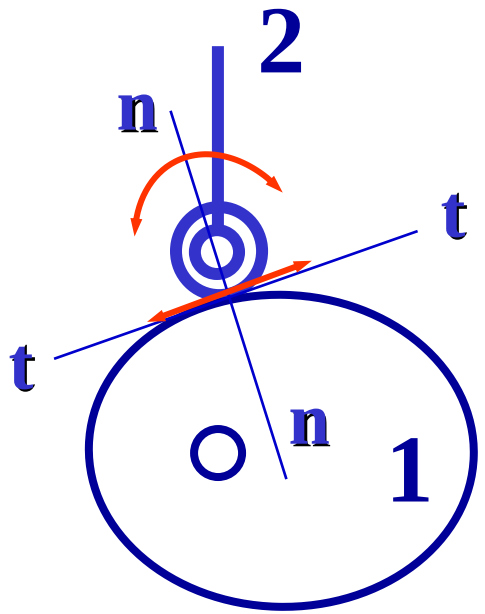


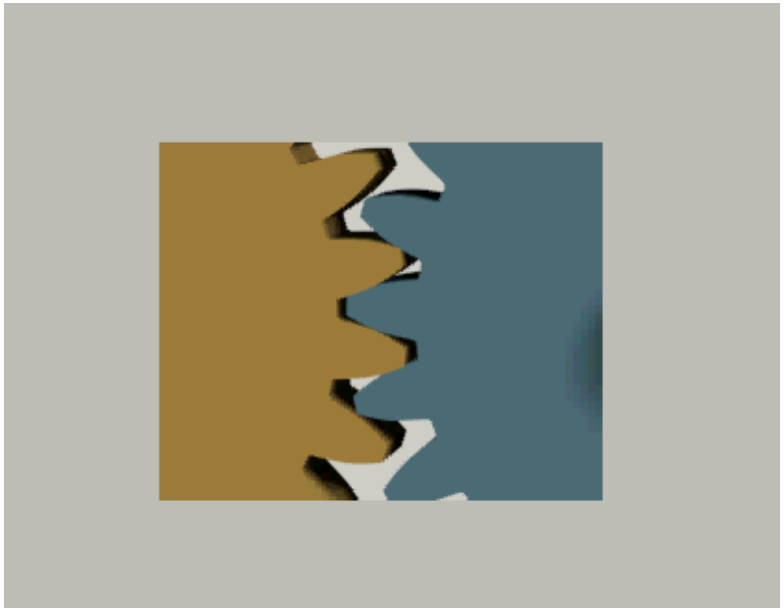
低副（转动副、移动副）对每个活动构件带来2个约束

2.高副(点、线接触)

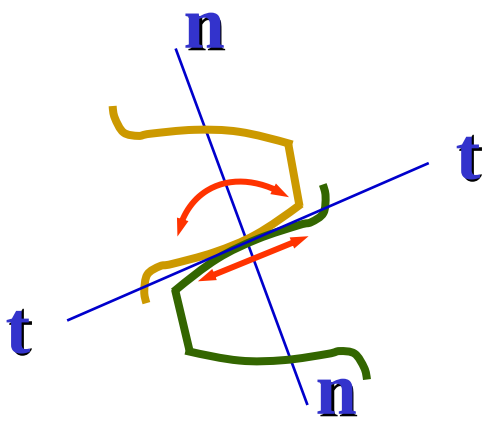


凸轮副





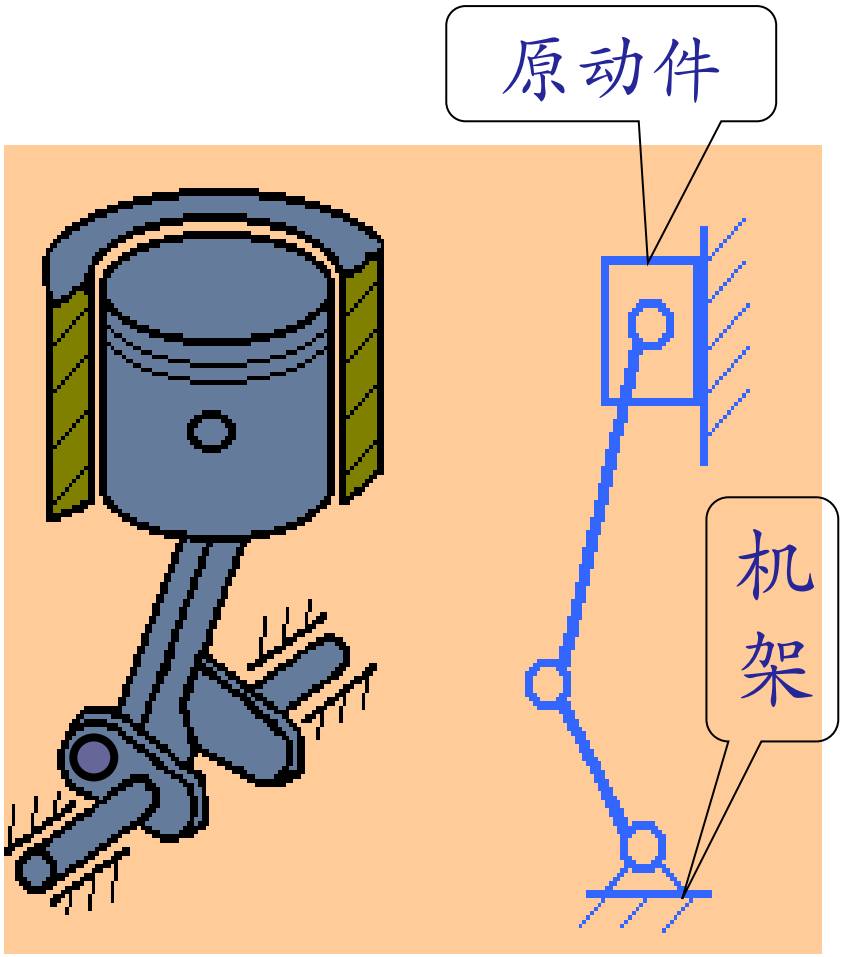
齿轮副



高副对每个活动构件带来1个约束

3.2 平面机构运动简图

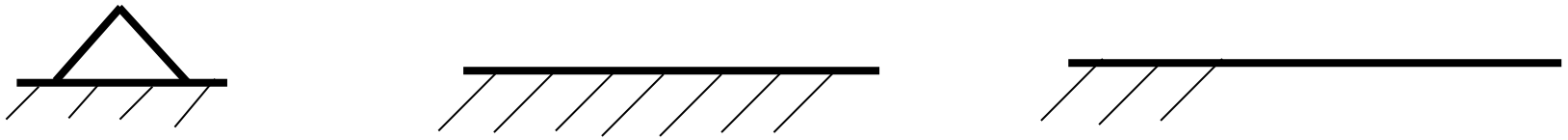
机构运动简图：不考虑与运动无关的结构，用简单的线条和符号表示各构件间相对运动关系。



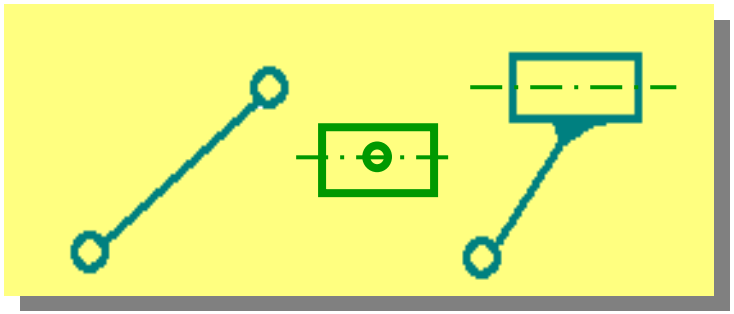
常见的机构运动简图符号：

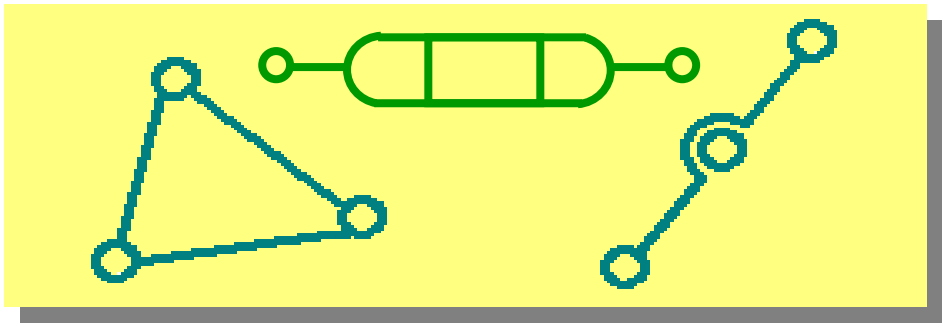
构件：

固定构件（机架）

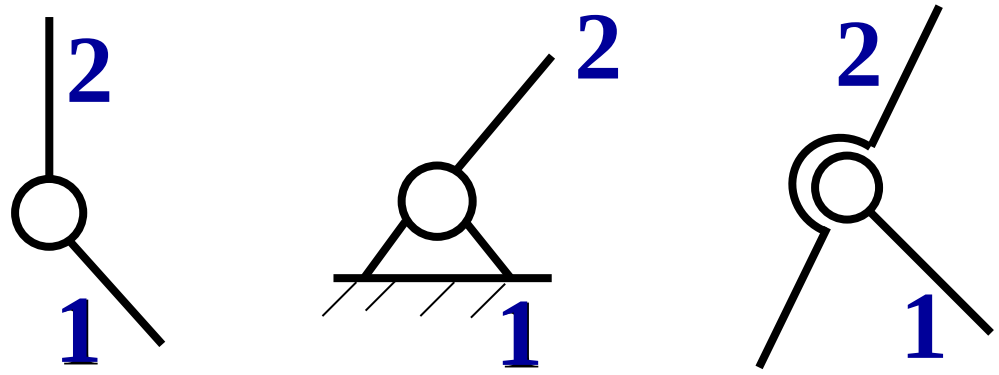


带有运动副的活动构件

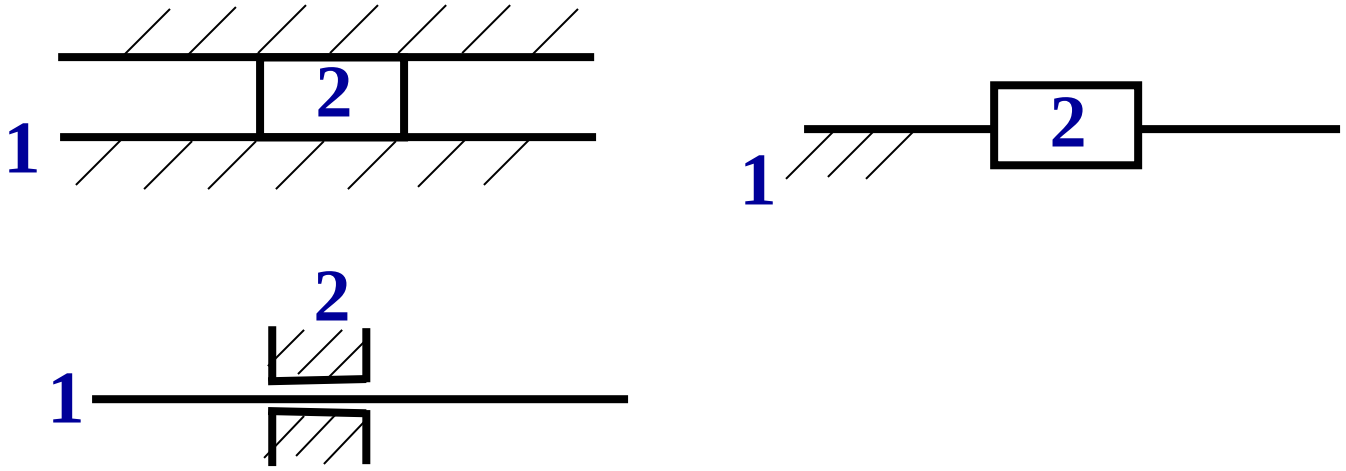




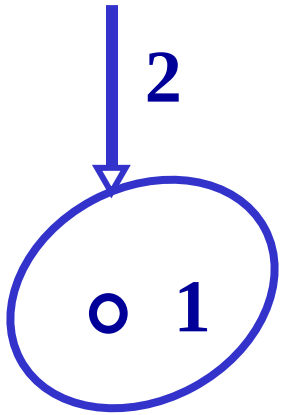
转动副（铰链）：



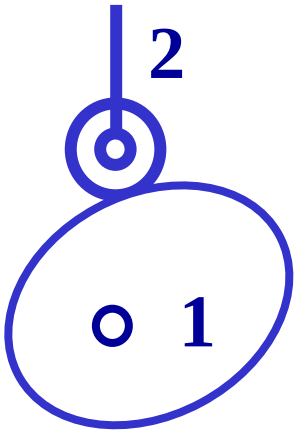
移动副:



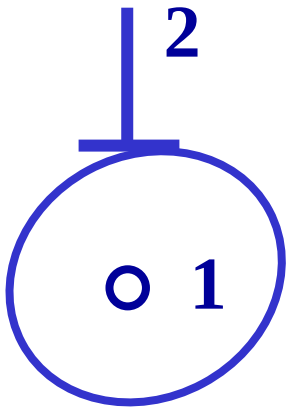
凸轮副:



尖顶从动件

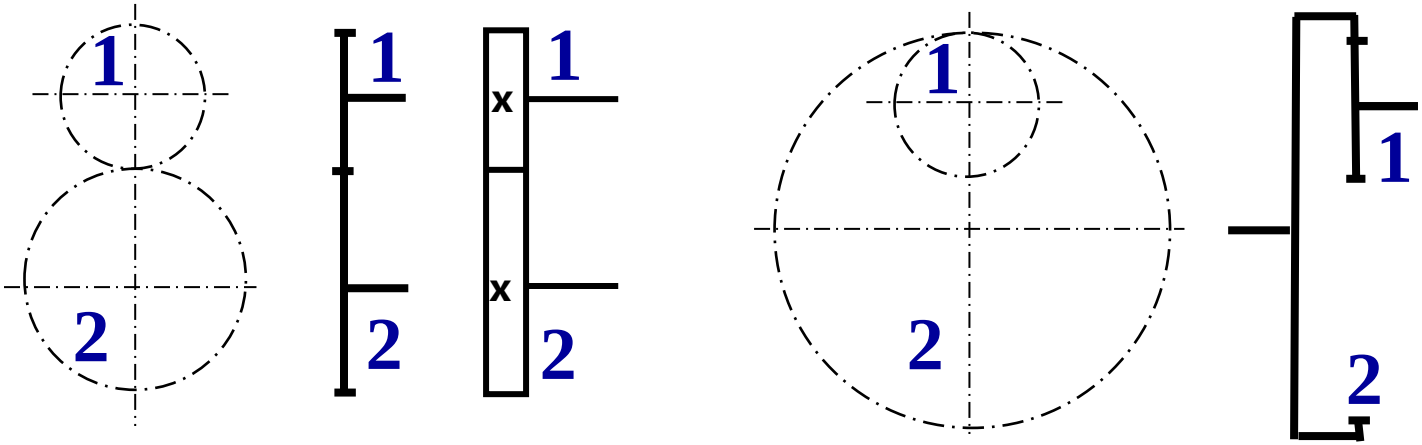


滚子从动件



平底从动件

齿轮副:



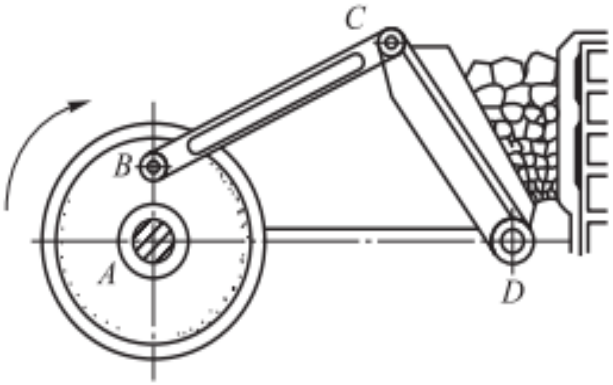
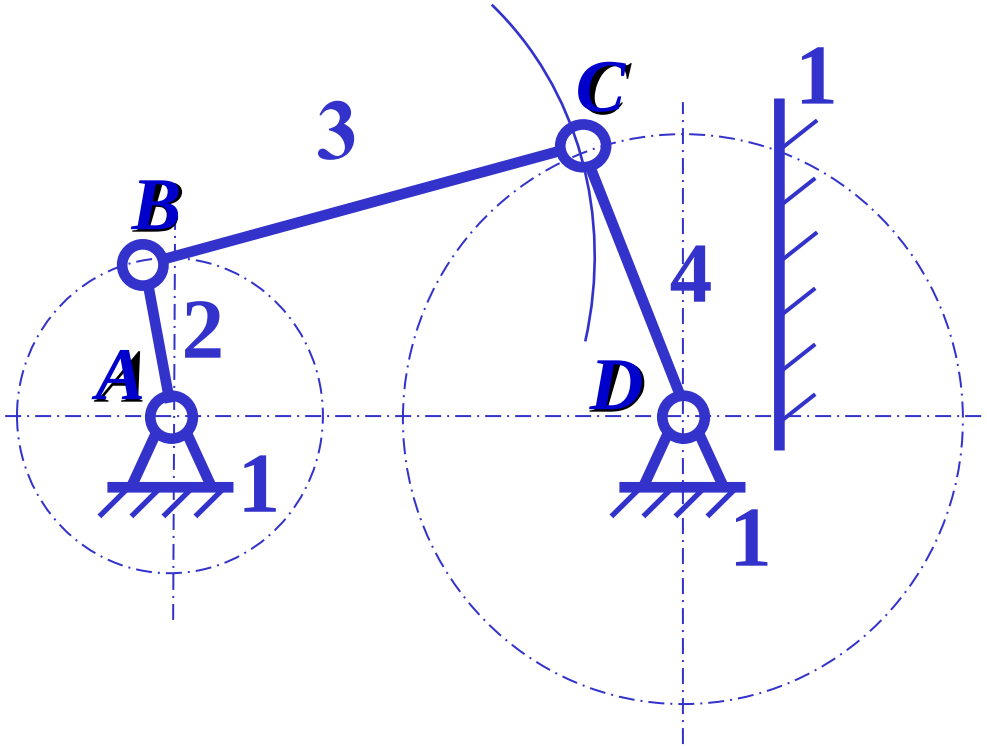


图 1-2　颚式矿石破碎机



破碎机运动简图

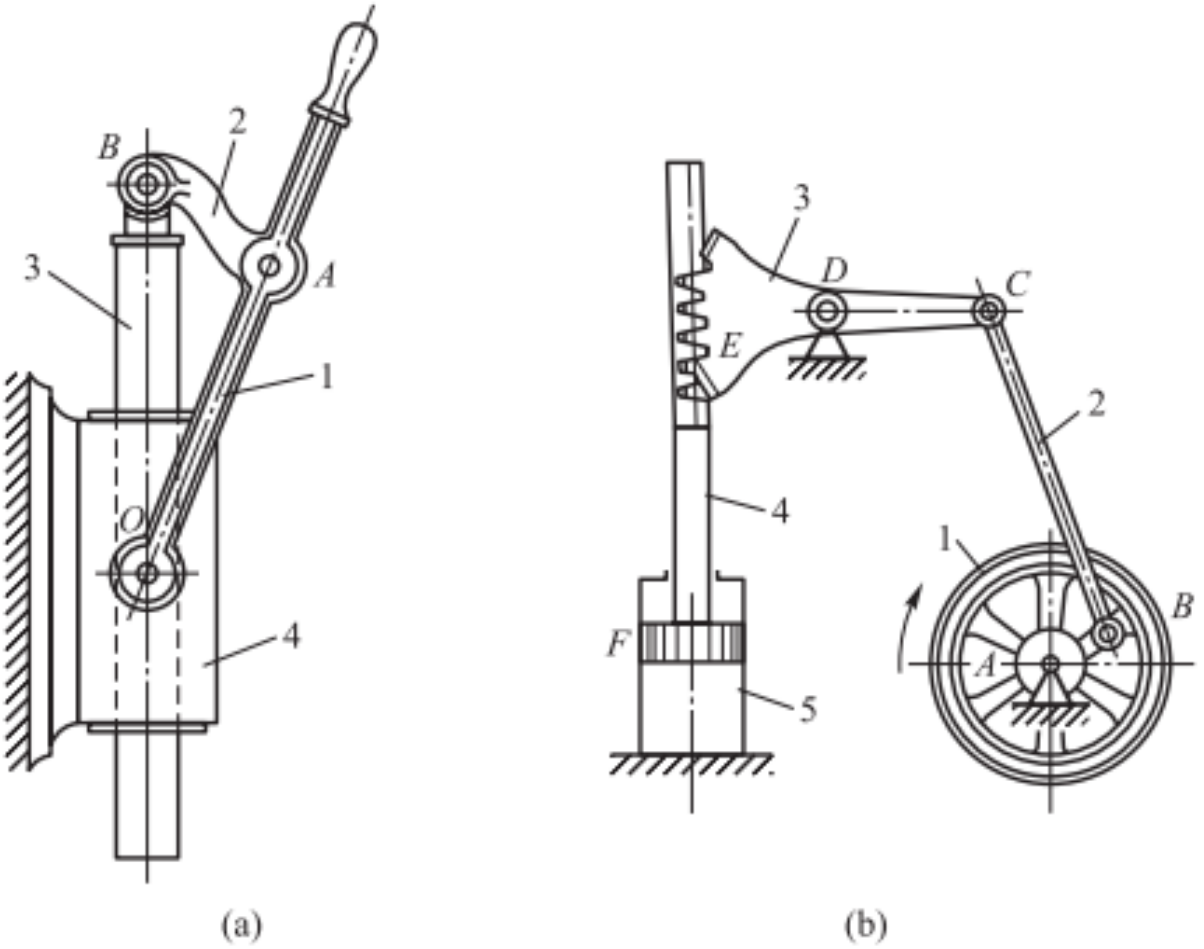


图 3-16　习题 3-5 图

3.3 平面机构的自由度

3.3.1 平面机构自由度计算公式

若机构中有N个构件，其中活动构件数为$n = N - 1$，构件自由度总数为$3n$个。

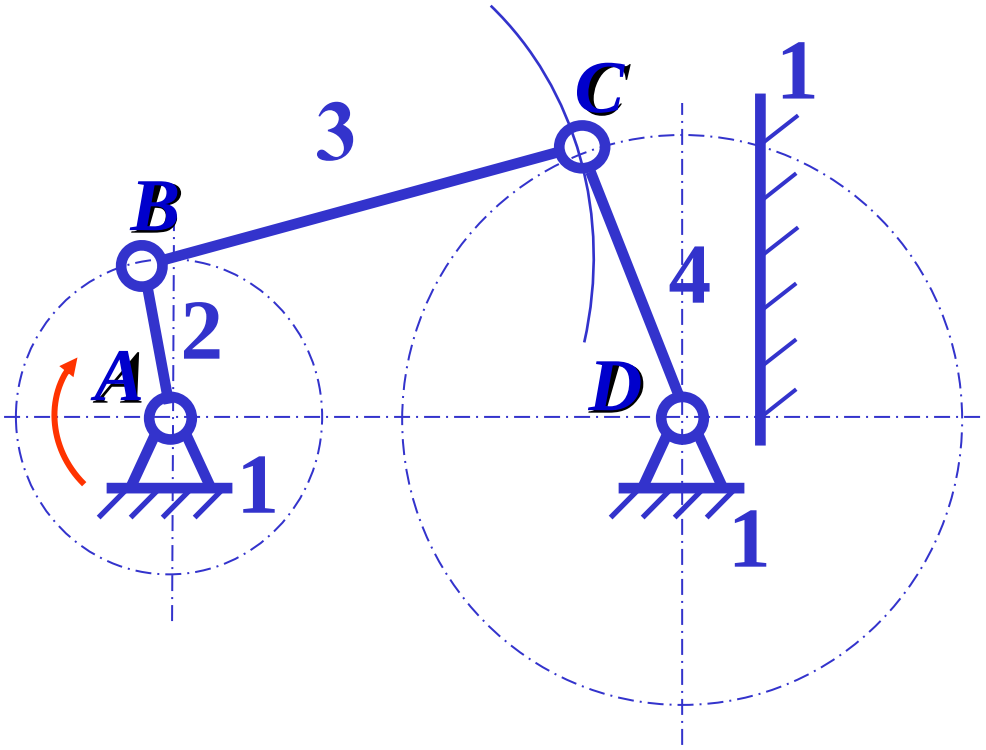
若机构中有p_L个低副，失去自由度为：$2p_L$

若机构中有p_H个高副，失去自由度为：p_H

则平面机构自由度为：$F = 3n - 2P_L - P_H$

要使机构具有确定的运动，必须使机构的原动件数等于机构的自由度数。

计算 例3-1 破碎机机构自由度



破碎机运动简图

构件数 N= 4

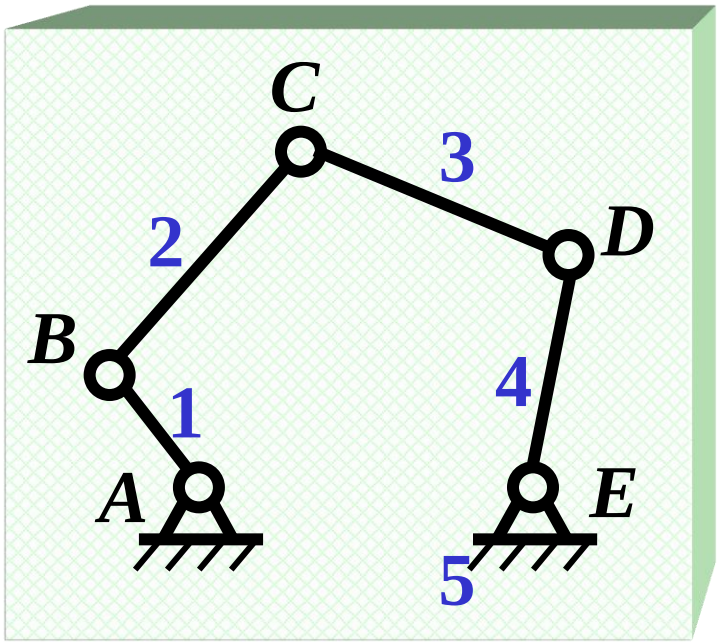
活动构件数 n=3

低副数 p_L=4

高副数 p_H=0

$$自由度数 F = 3\times3-2\times4-0=1$$

例2.



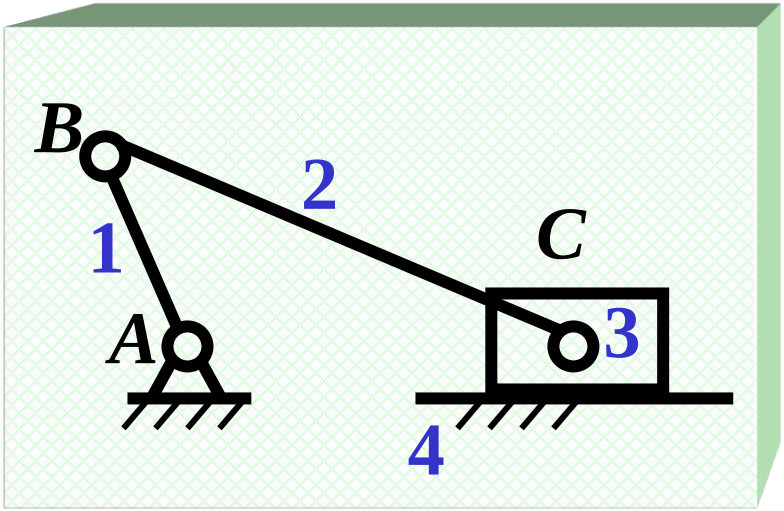
解：

$n=4,\ P_L=5,\ P_H=0$

$$F=3\times4-2\times5-0$$

$$=2$$

例3.

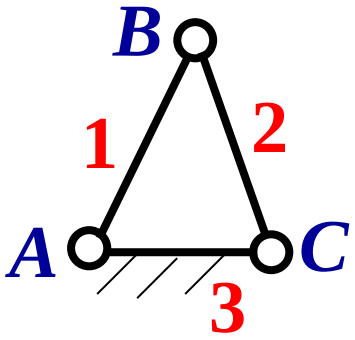


解：

$n=3,\ P_L=4,\ P_H=0$

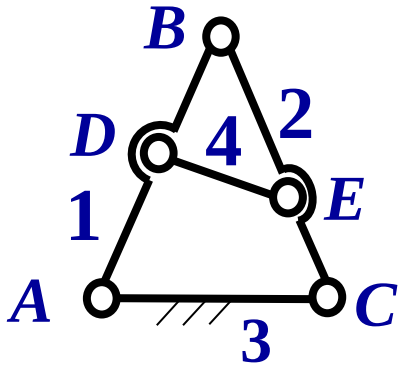
$$F=3\times3-2\times4-0$$

$$=1$$



$$F=3\times2-2\times3-0=0$$

刚性桁架

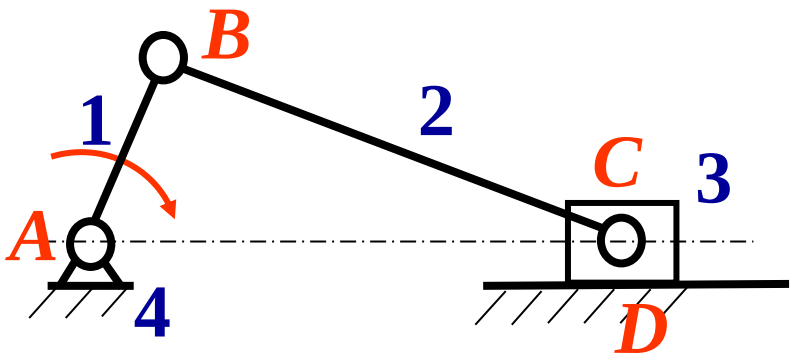


$$F=3\times3-2\times5-0=-1$$

超静定桁架

曲柄滑块机构

$$F=3\times3-2\times4-0=1$$

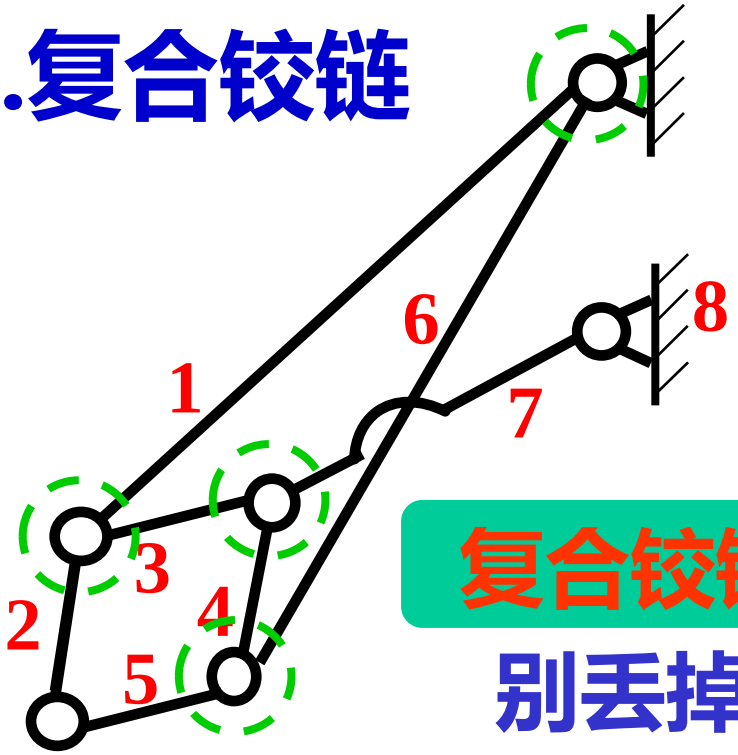


机构具有确定的运动的条件：

机构的原动件数等于机构的自由度数

3.3.2 计算机构自由度时应注意的问题

1.复合铰链



活动构件数$n=7$

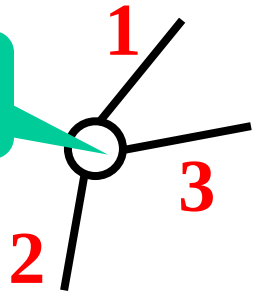
低副数$p_L=6$

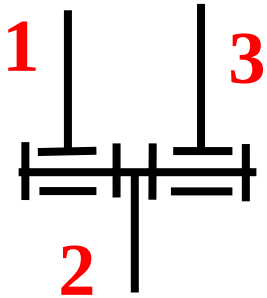
高副数$p_H=0$

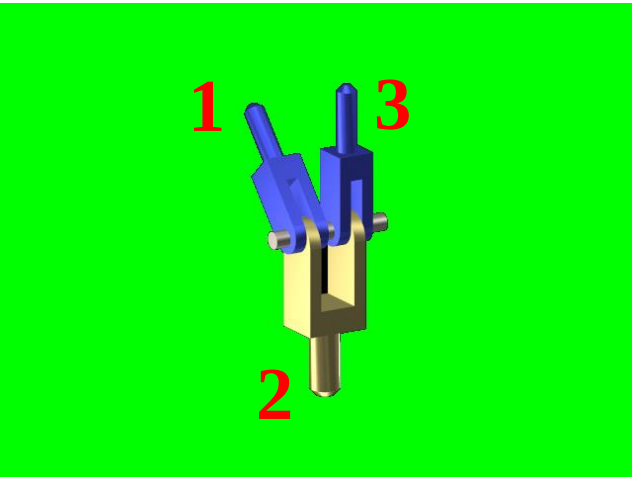
$$F=3\times7-2\times6-0=9$$

复合铰链

别丢掉





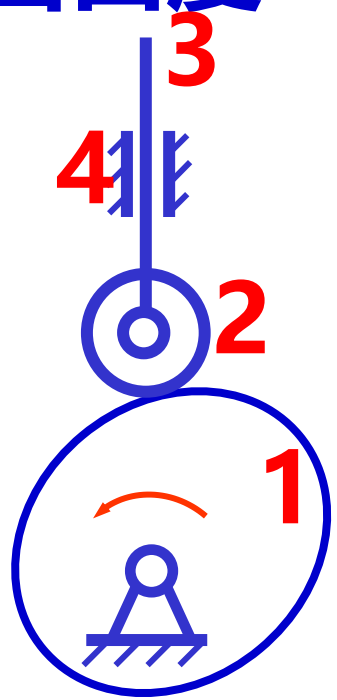


低副数$p_L=10$

高副数$p_H=0$

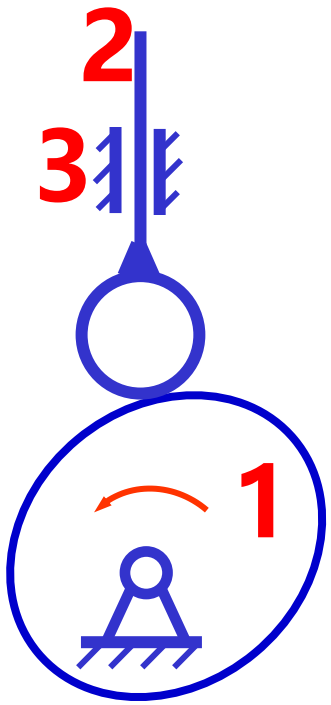
$$F=3\times7-2\times10-0=1$$

2. 局部自由度



$n=3,$
$p_L=3,$
$p_H=1$

$$F=3\times3-2\times3-1=2$$



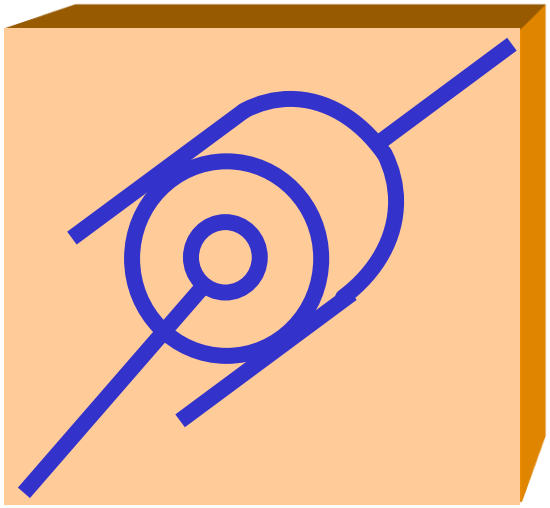
$n=2,$
$p_L=2,$
$p_H=1$

$$F=3\times2-2\times2-1=1$$

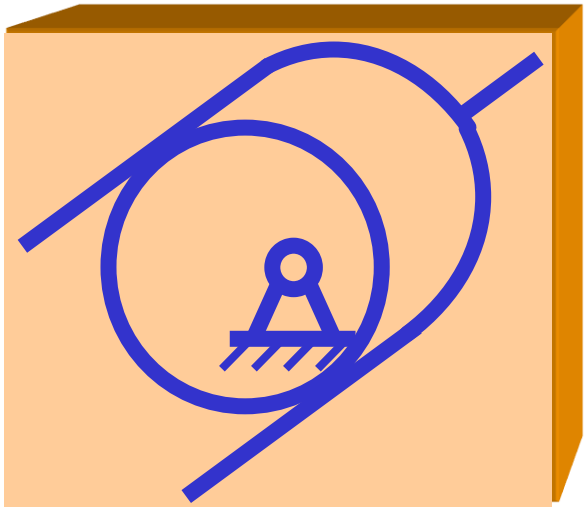
对整个机构的输入输出无影响的局部自由度应去掉, 视为滚子与从动件焊在一起

局部自由度要去掉

注：只有在小滚子处，且小滚子几何中心与转动中心重合，才是局部自由度。

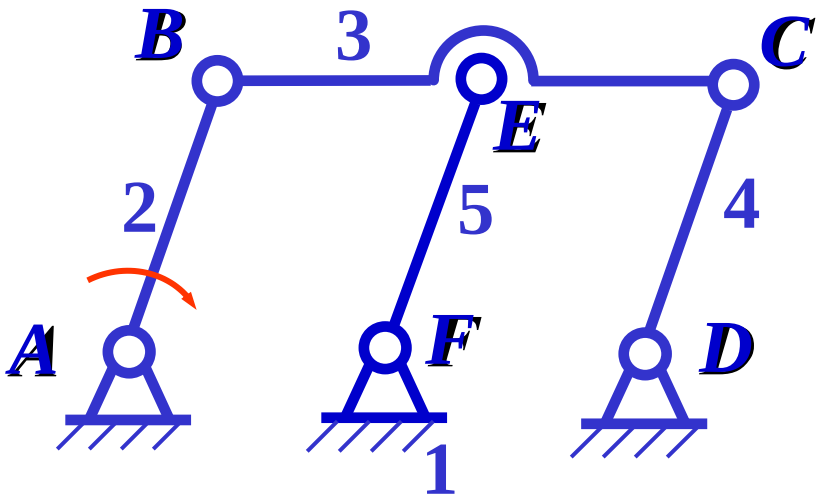


是



不是

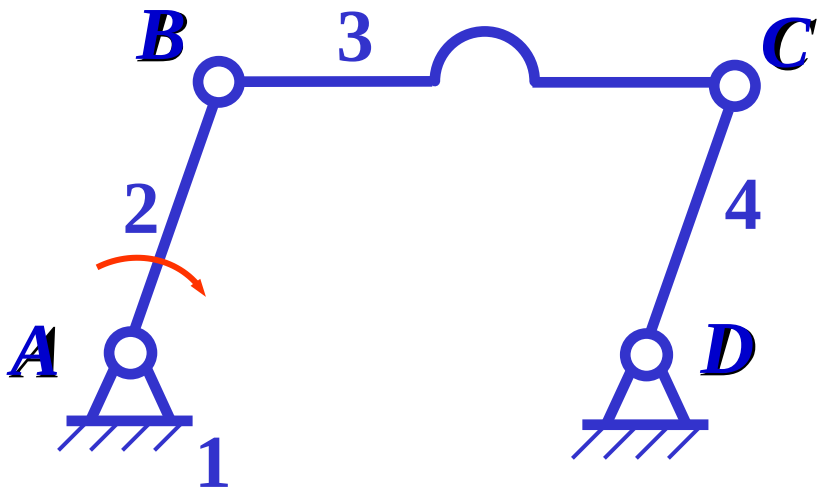
3. 虚约束　　对机构的运动不起作用的约束。



$n=4,\quad p_L=6,\quad p_H=0$

$$F=3\times4-2\times6-0=0$$

对机构运动不起作用的
虚约束要去掉

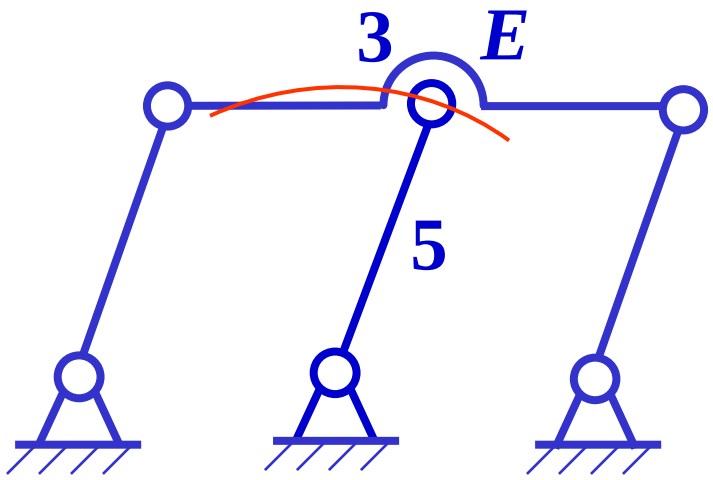


$n=3,\quad p_L=4,\quad p_H=0$

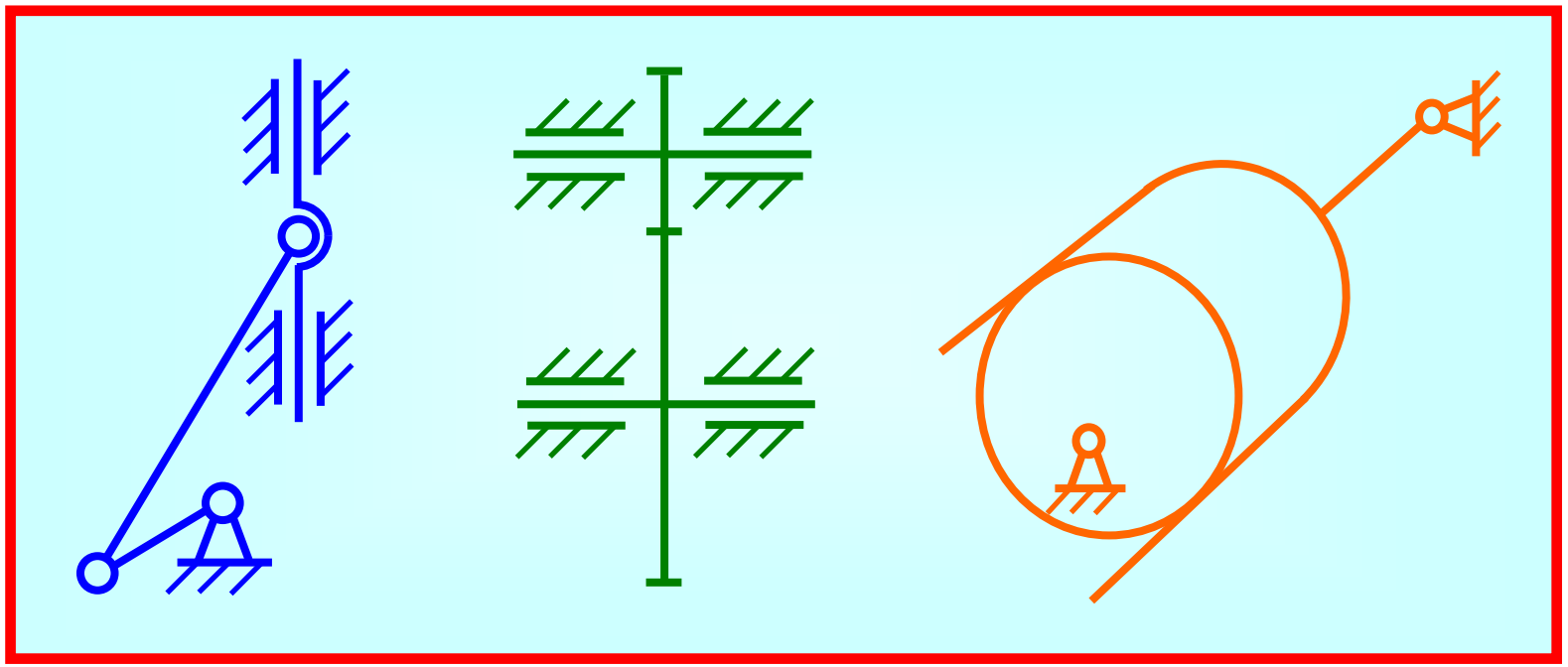
$$F=3\times3-2\times4-0=1$$

出现虚约束的情况：

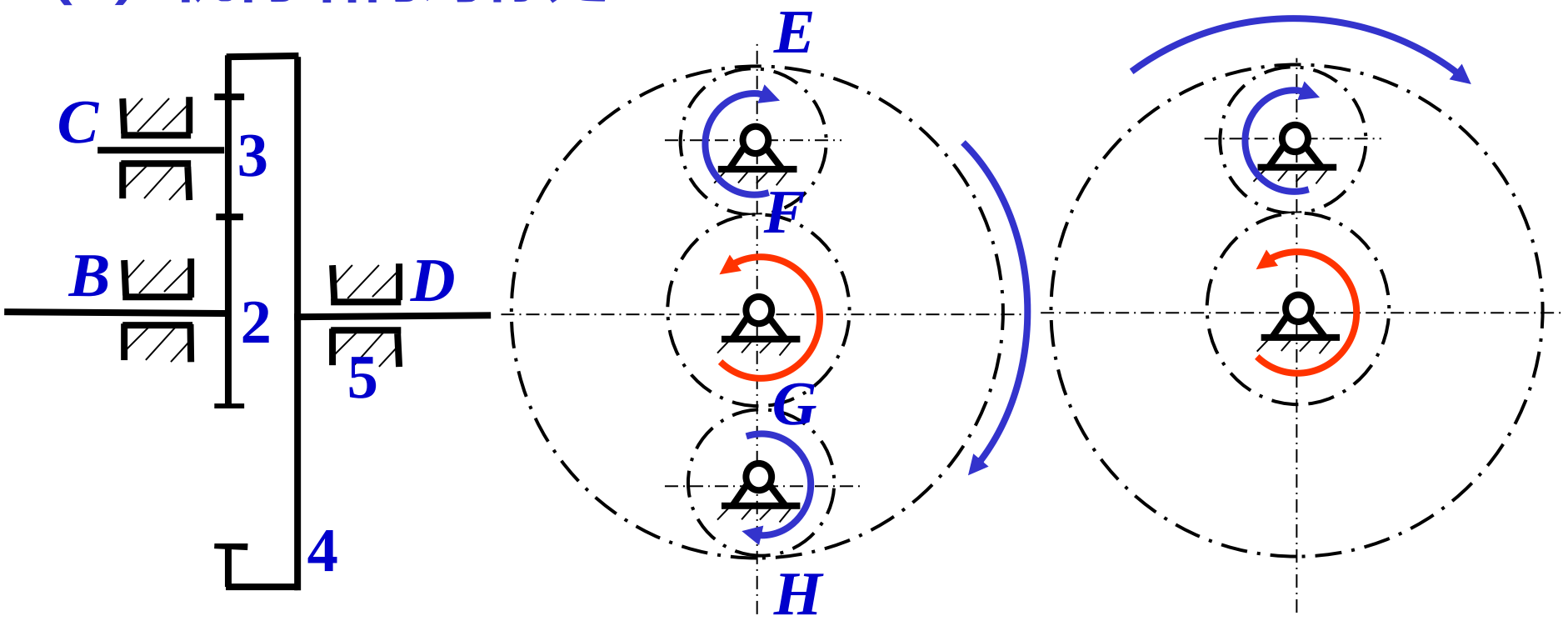
（1）两构件连接点轨迹重合处



(2) 两构件组成多个移动副，且导路平行；或组成多个转动副，且轴线重合，则只考虑一处约束，其它看作虚约束；若两构件组成多个高副，且公法线重合，也只考虑一处约束。如图所示：



(3) 机构结构对称处

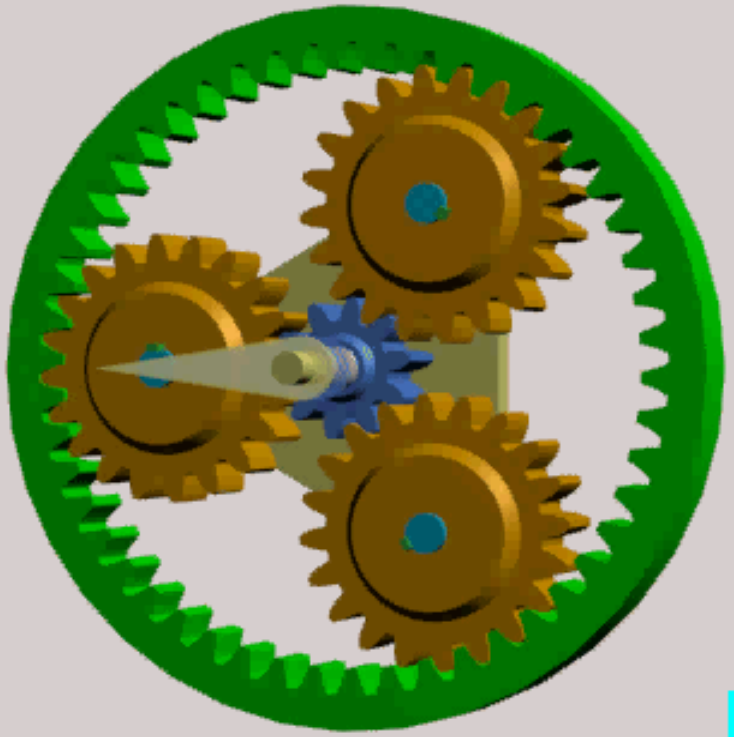


$n=4,\quad p_L=4,\quad p_H=4$

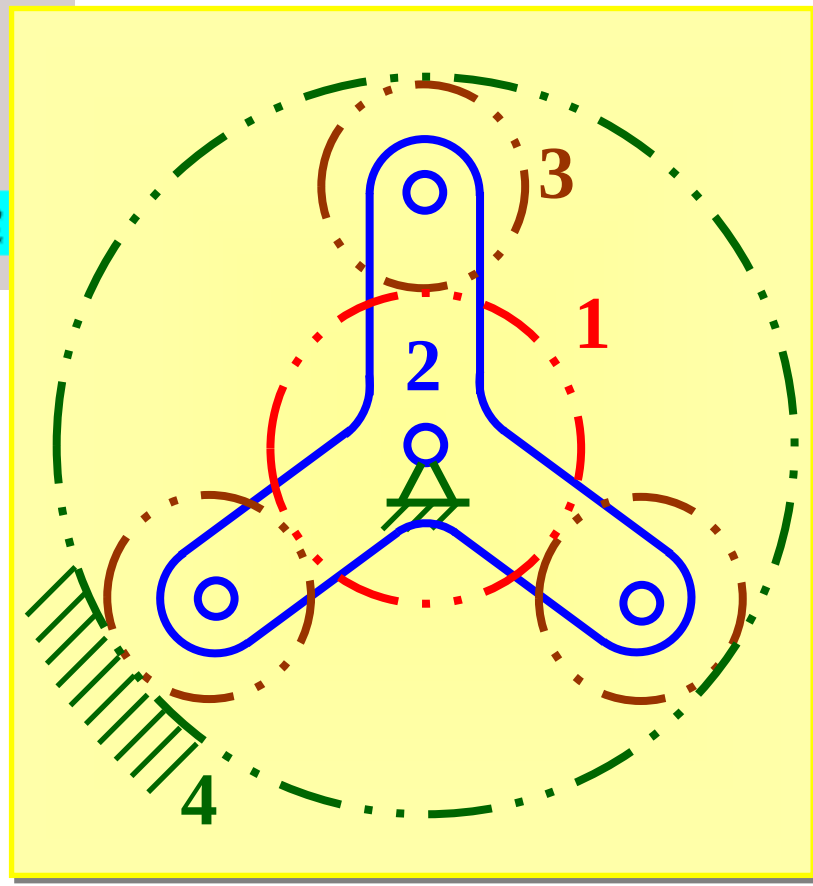
$$F=3\times4-2\times4-4=0$$

$n=3,\quad p_L=3,\quad p_H=2$

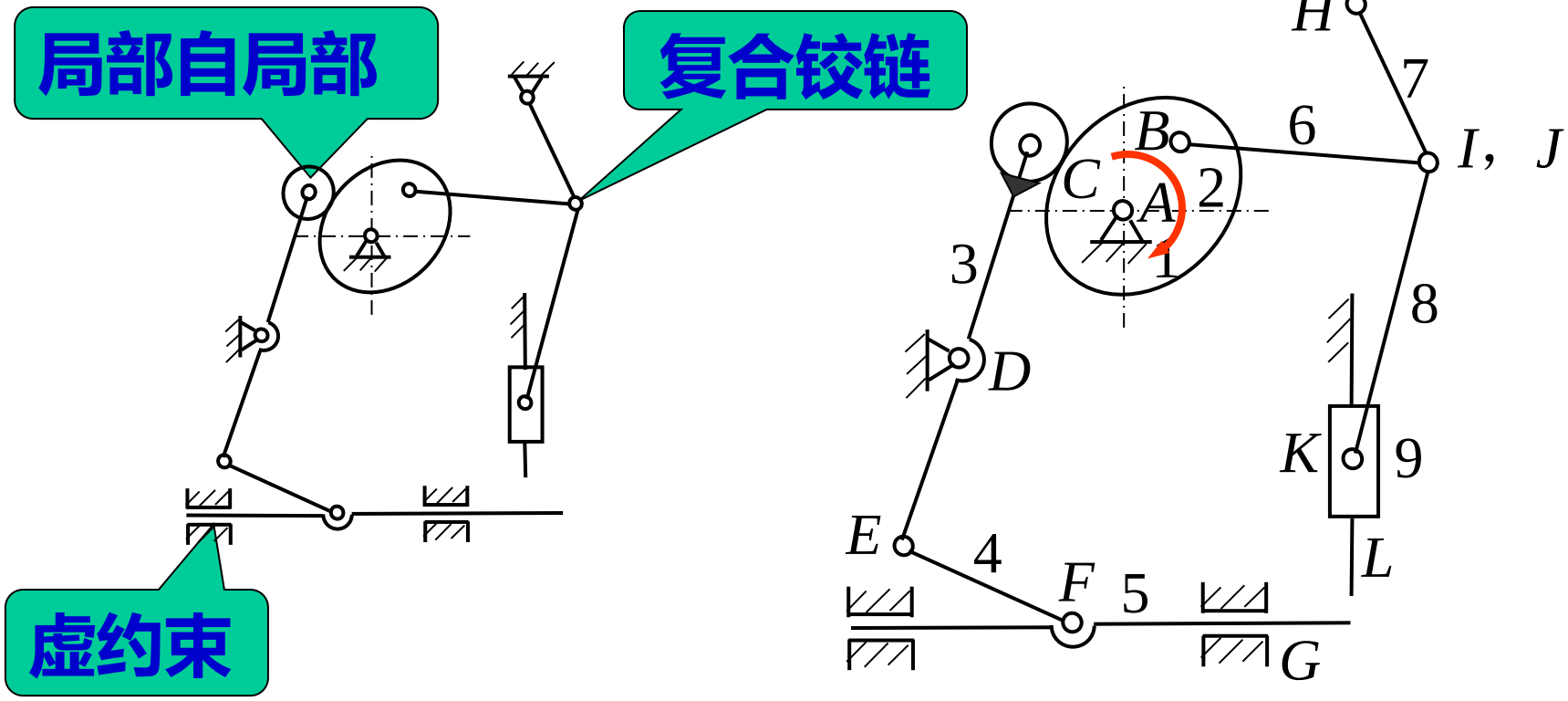
$$F=3\times3-2\times3-2=1$$



齿圈固定



例3-2 计算冲压机构的自由度。若有复合铰链、局部自由度、虚约束须指出。

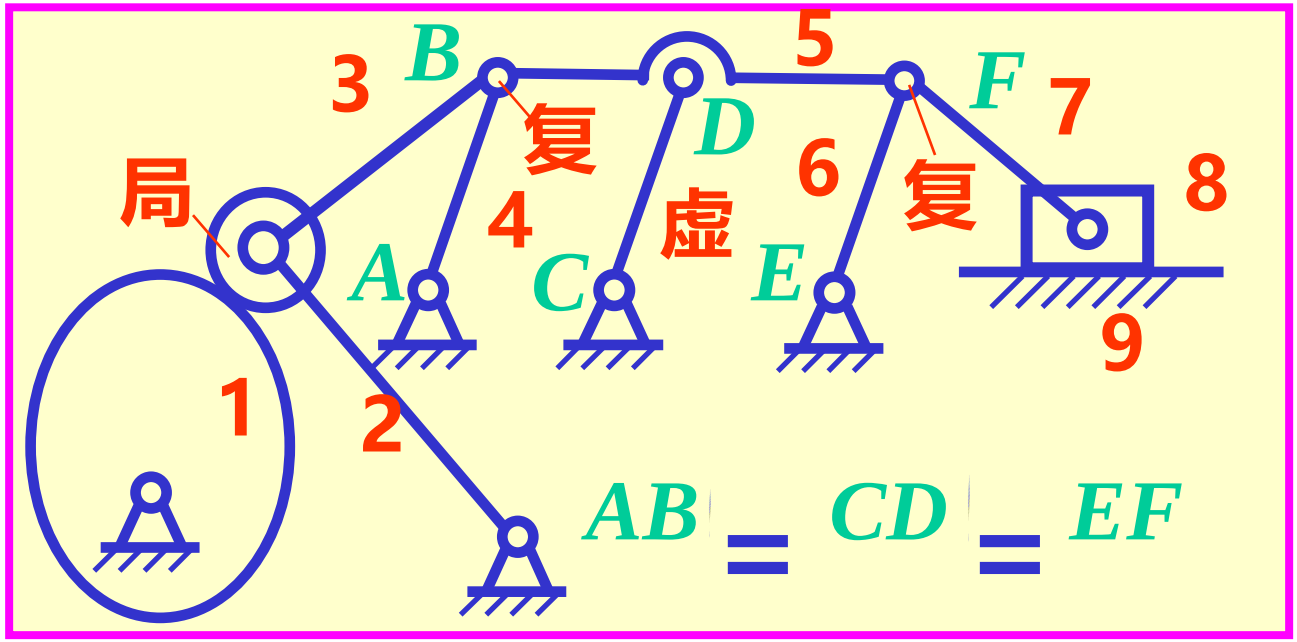


$n=8,\ p_L=11,\ p_H=1$

$$F=3\times8-2\times11-1=1$$

例1.计算下列机构的自由度。

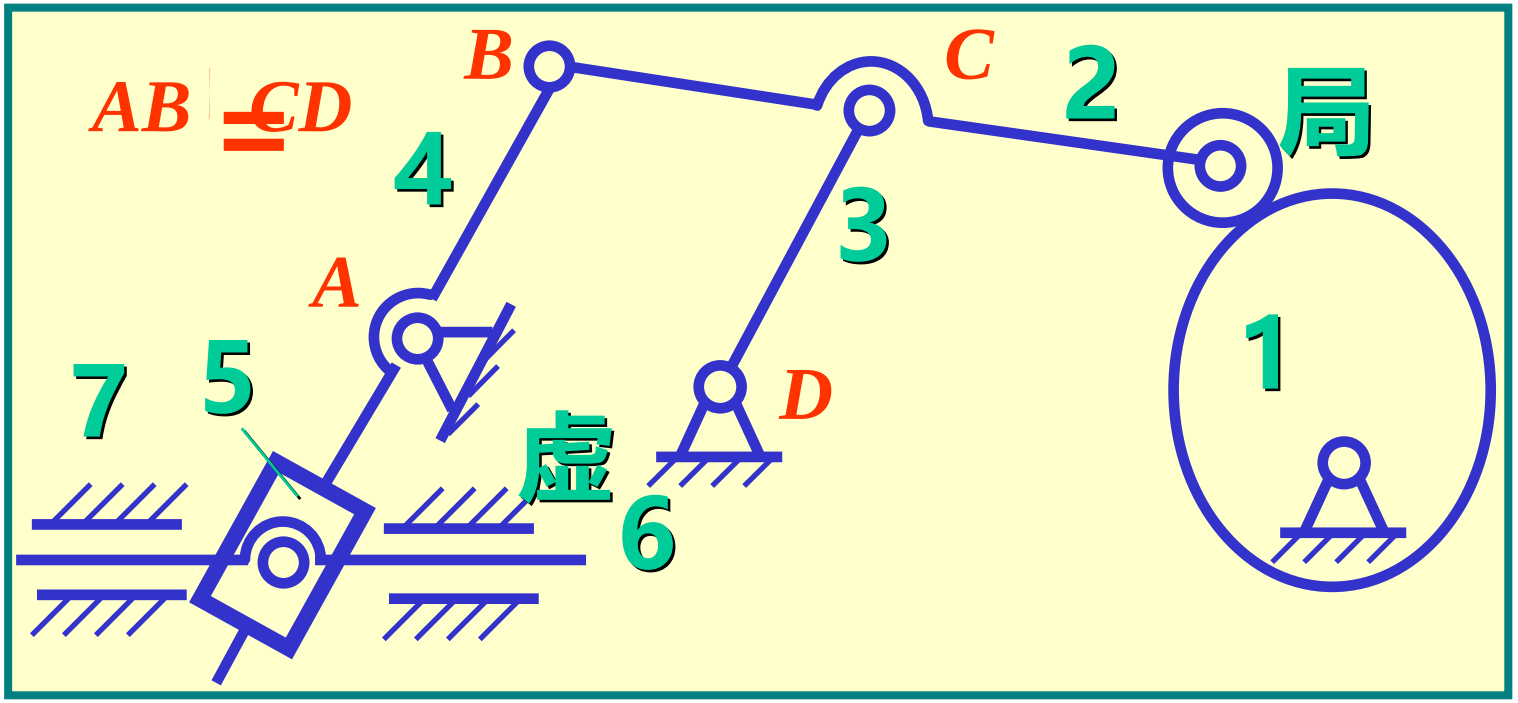
1）



解：$n=8,\quad P_{\mathrm{L}}=11,\quad P_{\mathrm{H}}=1$

$$F=3\times8-2\times11-1=1$$

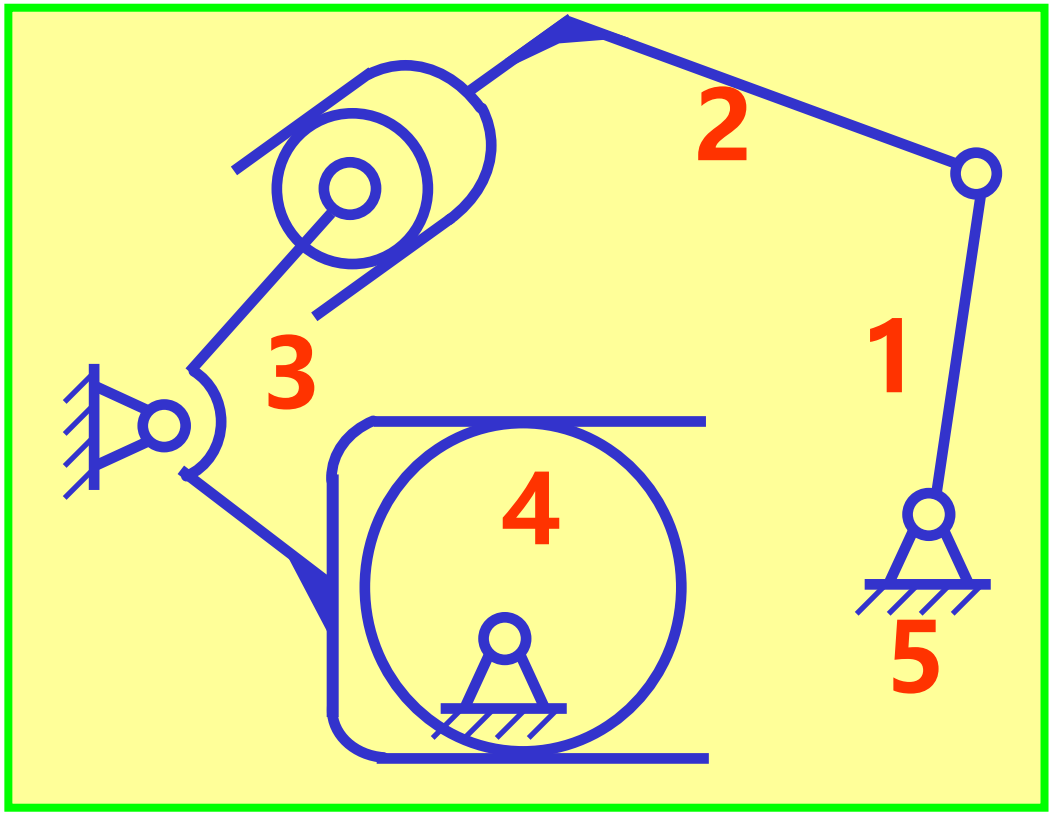
2)



解：$n=6,\quad P_L=8,\quad P_H=1$

$$F=3\times6-2\times8-1=1$$

3)

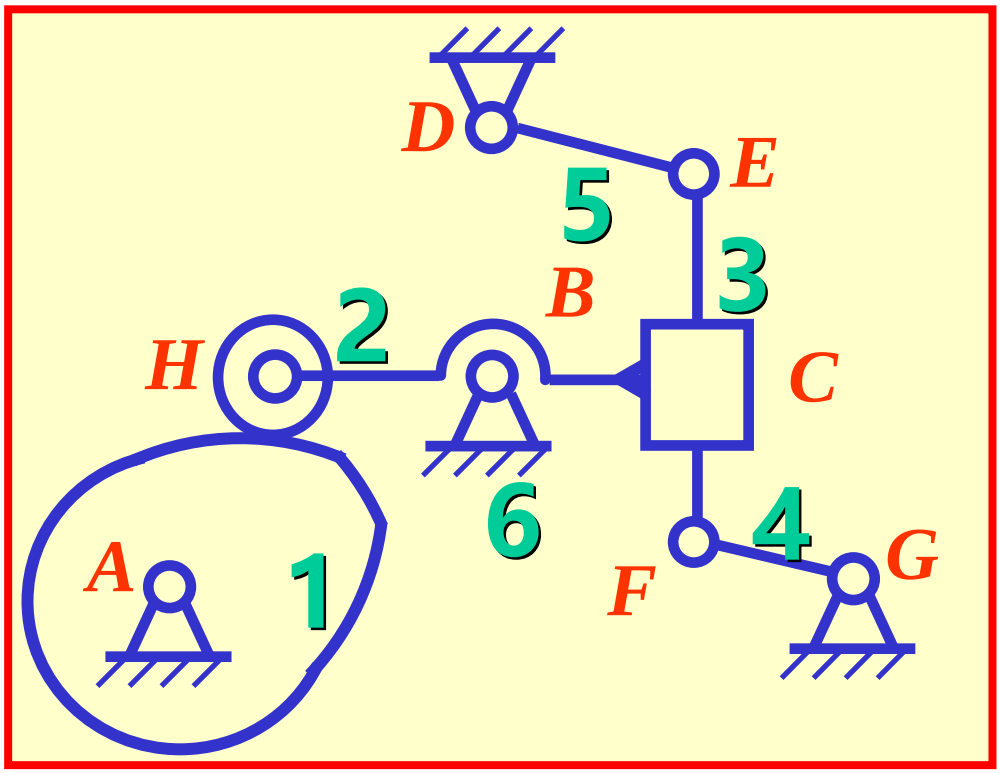


解：　n=4,　P_{L}=4,　P_{H}=2

$$F=3\times4-2\times4-2=2$$

例2.试判断下列机构运动是否确定，若不确定，如何改正?

1)



解：

$n=5,$

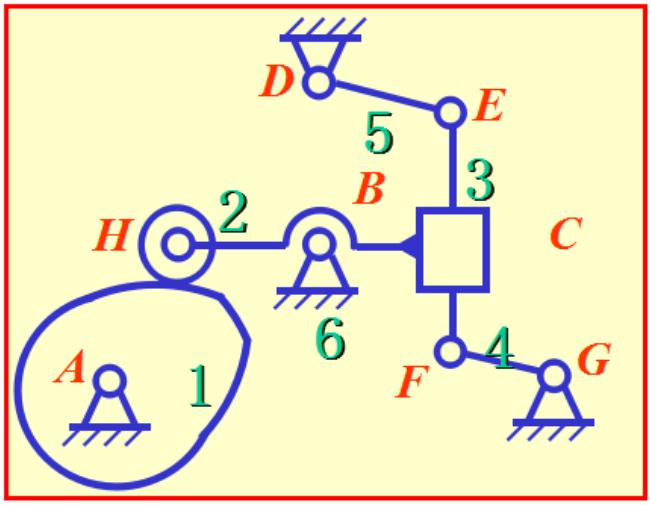
$P_L=7,$

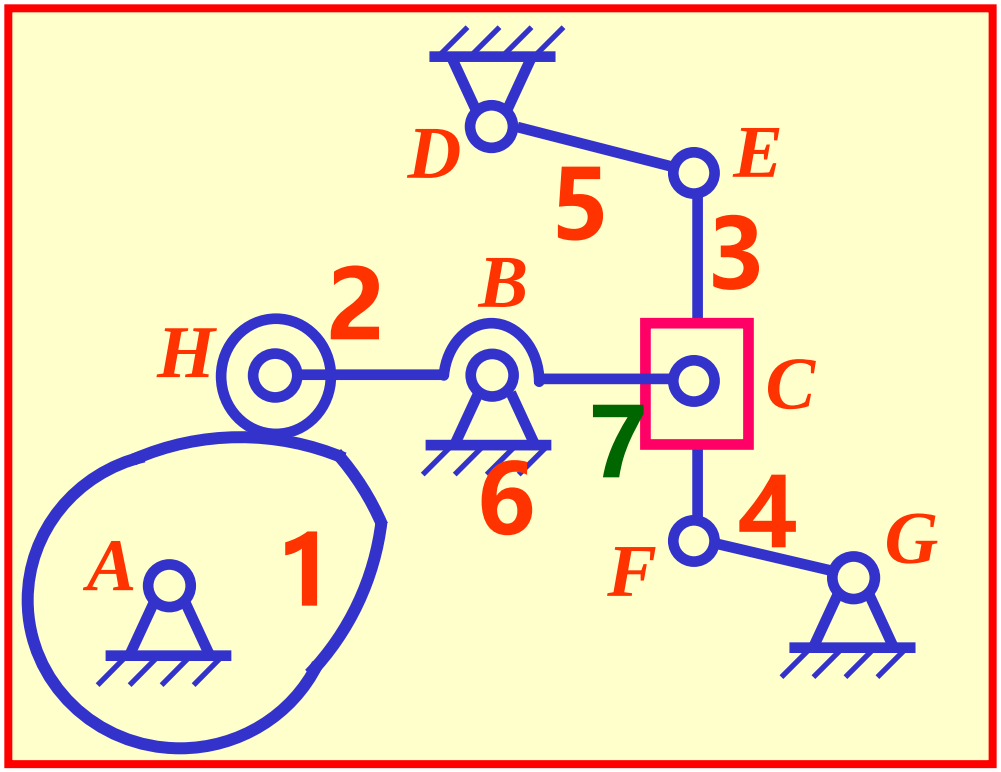
$P_H=1$

$$F=3\times5-2\times7-1=0$$

即：机构不能运动。

将C点改成如图：





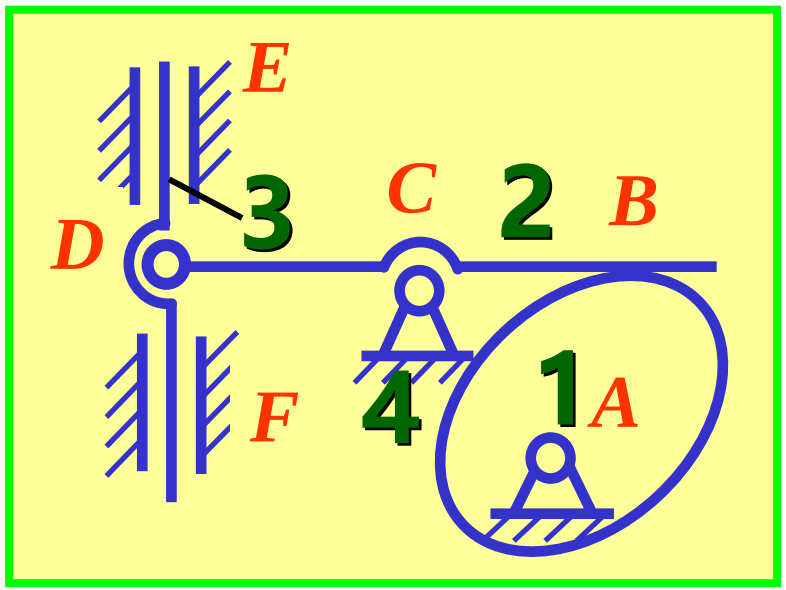
$n=6,$

$P_L=8,$

$P_H=1$

$$F=3\times6-2\times8-1=1$$

2)



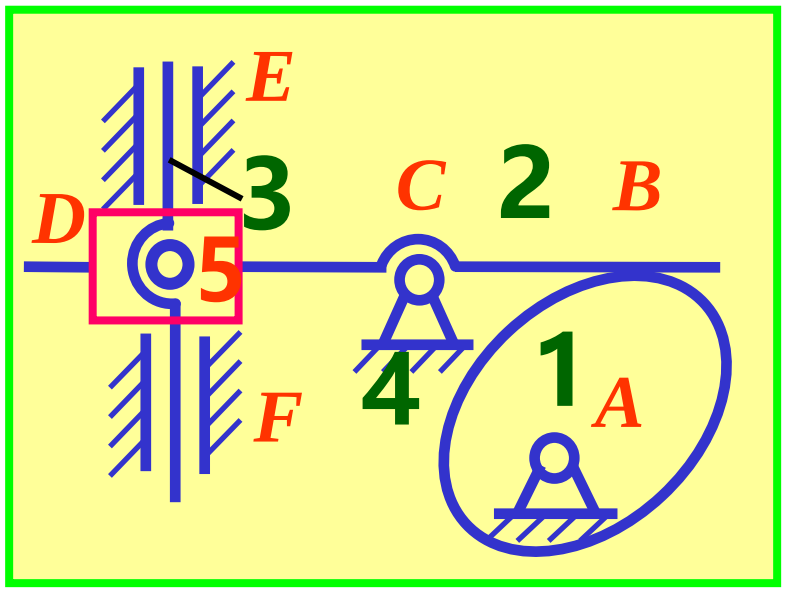
解：

$n=3,\ P_L=4,\ P_H=1$

$F=3\times3-2\times4-1=0$

即：机构不能运动。

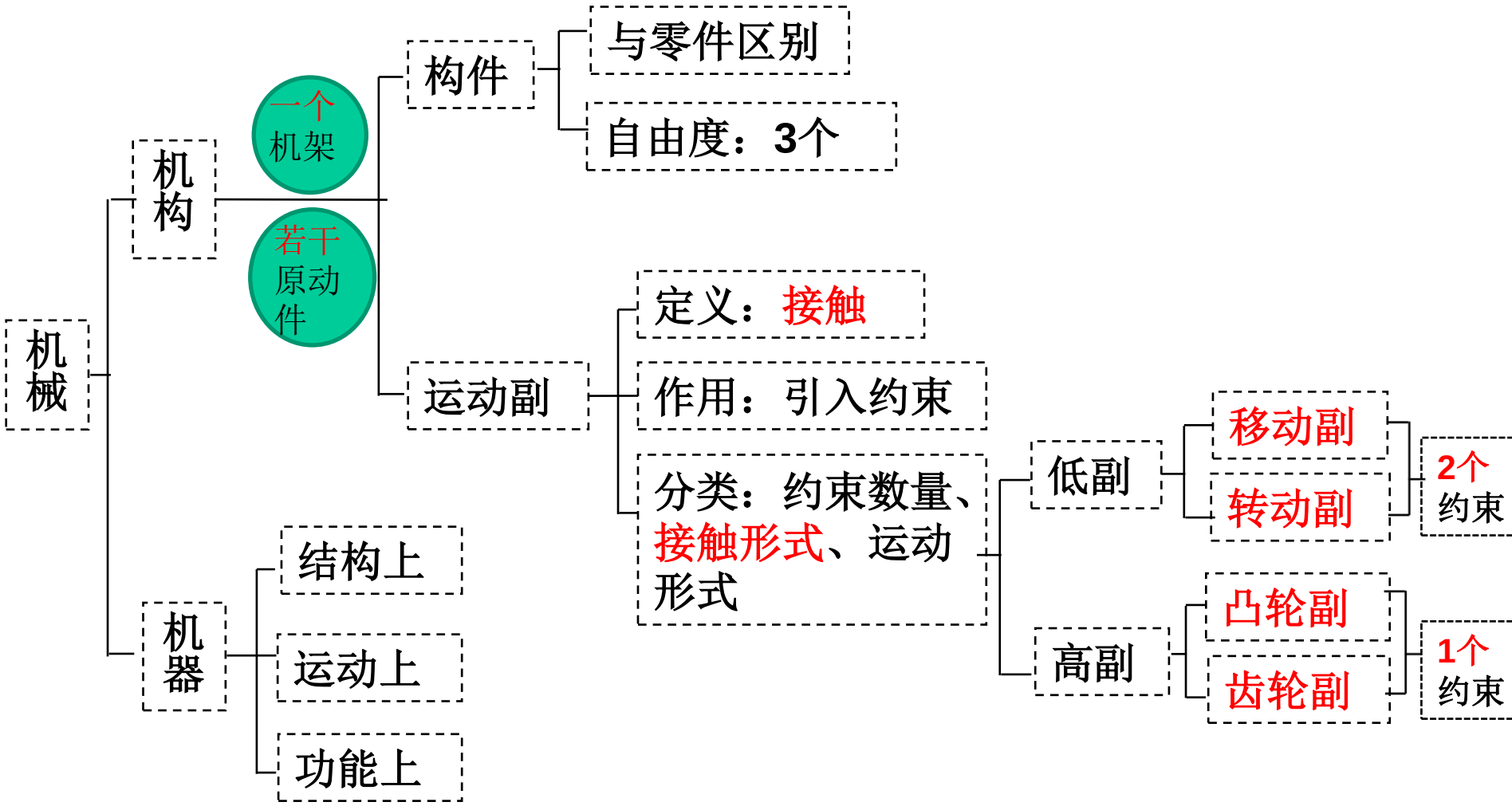
将D点改为如左图：

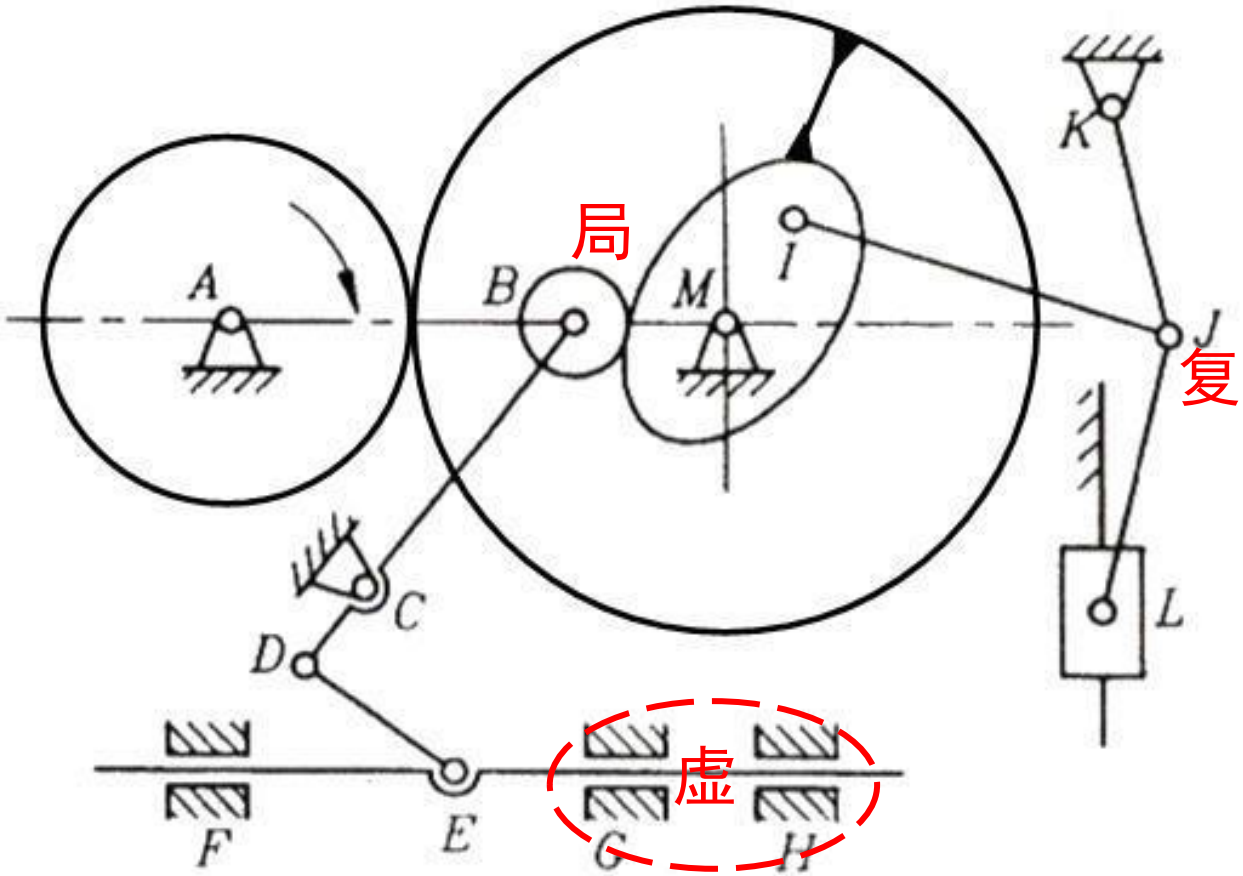


$n=4,\ P_L=5,\ P_H=1$

$F=3\times4-2\times5-1$

$=1$

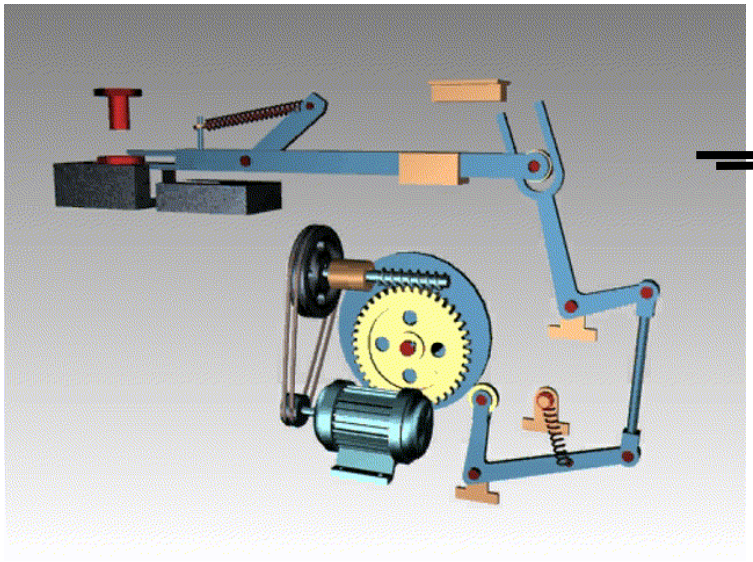

机械
机构
一个机架
若干原动件
构件
与零件区别
自由度：3个
运动副
定义：接触
作用：引入约束
分类：约束数量、接触形式、运动形式
低副
移动副
转动副
2个约束
高副
凸轮副
齿轮副
1个约束
机器
结构上
运动上
功能上

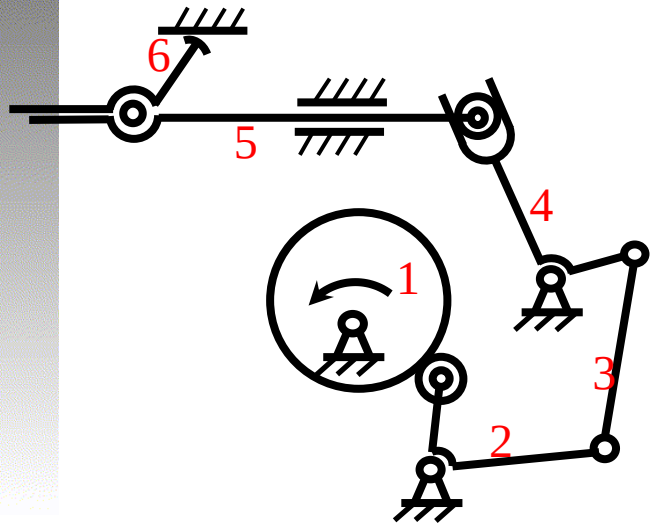


解：　$n=9$,　　$P_L=12$,　　$P_H=2$

$$F=3\times9-2\times12-2=1$$

【案例】画出下图自动卸料机的机构运动简图，并计算机构自由度。





解：　$n=6$，　$P_L=7$，　$P_H=3$

$$F=3\times6-2\times7-3=1$$