REFERENCE ANSWER

for

EXERCISE BOOK

of

《Mechanisms and Machine Theory》

TRG of Machinery Theory and Design

College of Mechanical Engineering

Fuzhou University

2003

Name________________Class_____Student No.___________Date____________

2-1 Draw the kinematic diagrams of the mechanisms shown in Fig2-1.

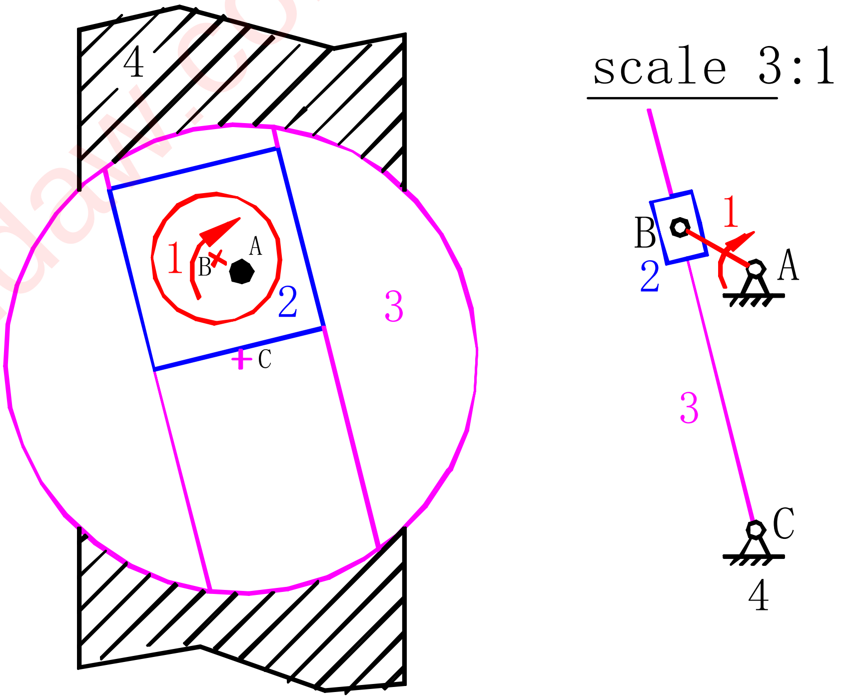

Fig2-1(a)

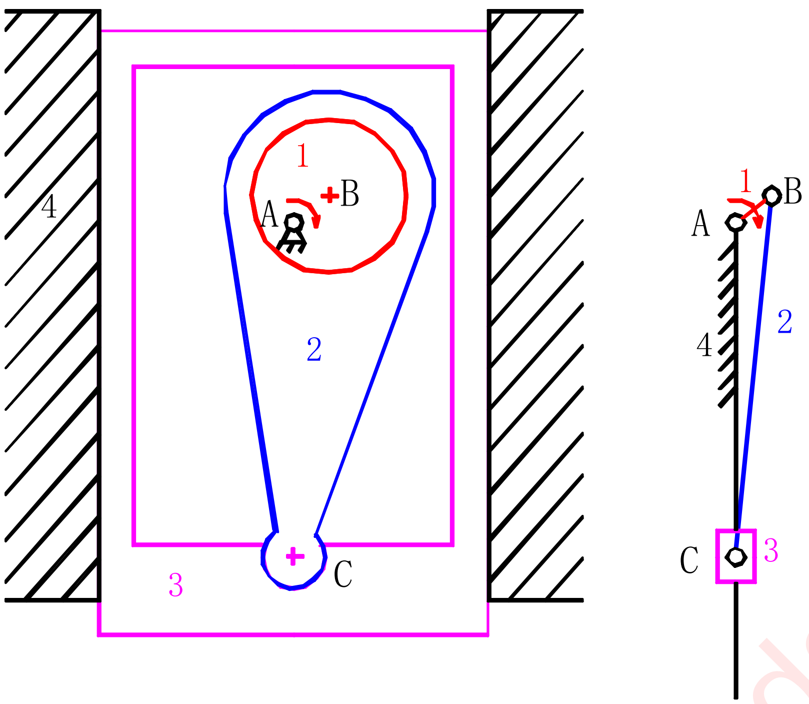

Fig2-1(b)

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2-2 Draw the kinematic diagrams of the mechanisms shown in Fig2-2.

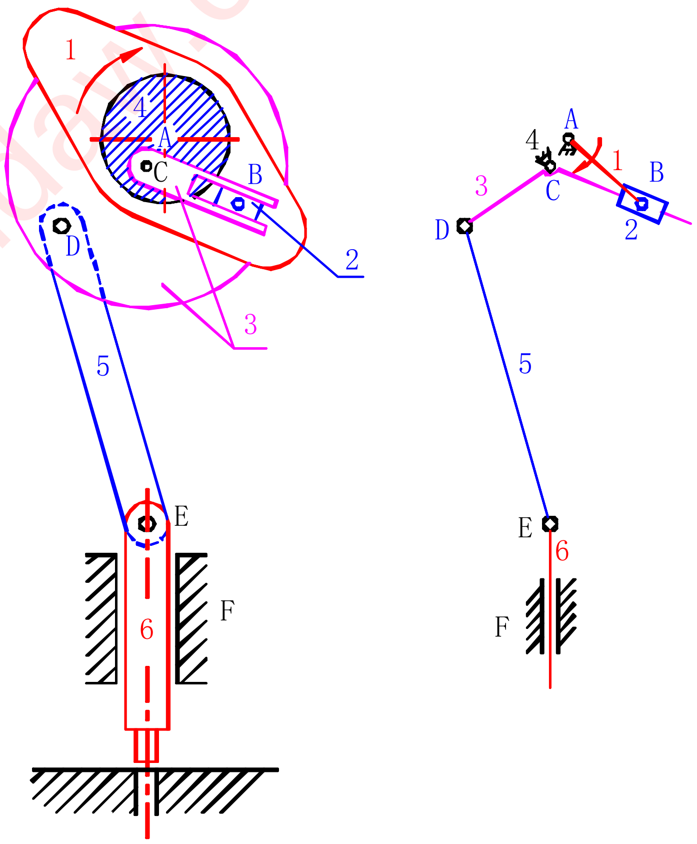

Fig2-2(a)

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2-3 Draw the kinematic diagram of the mechanism shown in Fig2-3.

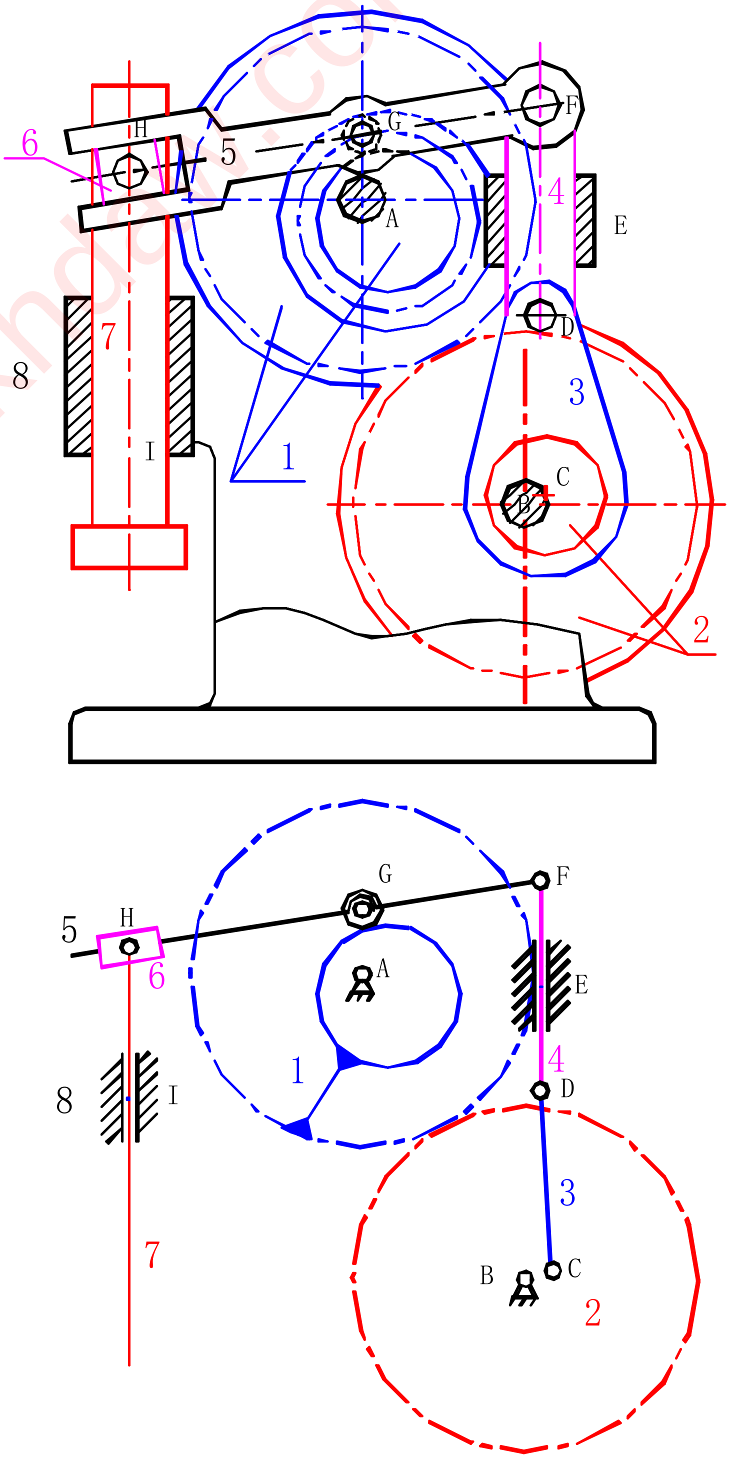

Fig2-3

Name________________Class_____Student No.__________Date___________

2-4 Calculate the degree of freedom of the mechanisms shown in Fig2-4,and point out what should be paid attention to during the calculation .

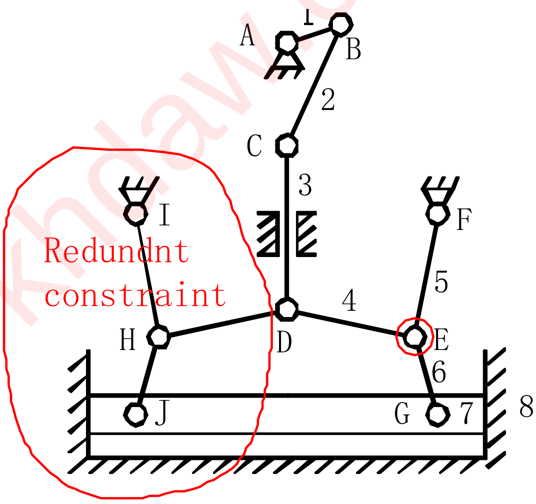

Fig2-4(a)

解：

(a) 左右为对称结构，设左侧为虚约束。

(b) E 为杆 4、5、6 的复合铰链。(c) 滑块 7 与机架 8 间为移动副。

$F=3n-2P_L-P_h=3\times7-2\times10=1$

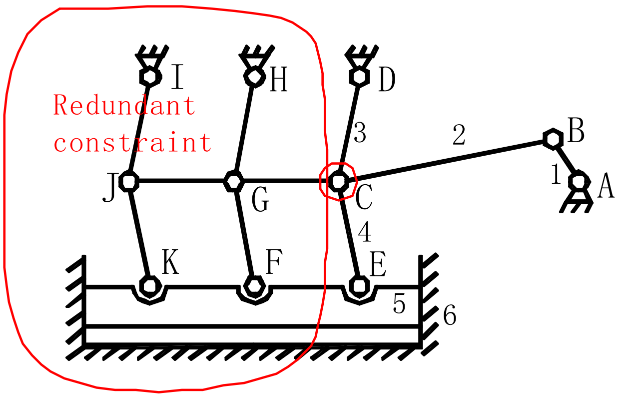

Fig2-4(b)

解：

(1)红线内的构件为重复结构，构成虚约束。

(2)去掉以上构件后，C 仍为构件 2、3、4 的复合铰链。

(3)滑块 5 与机架 6 之间为移动副。

$F= 3n-2P_L-P_h =3\times5-2\times7=1$

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2-5 Calculate the degree of freedom of the mechanisms shown in Fig2-5,and point out what should be paid attention to during the calculation .

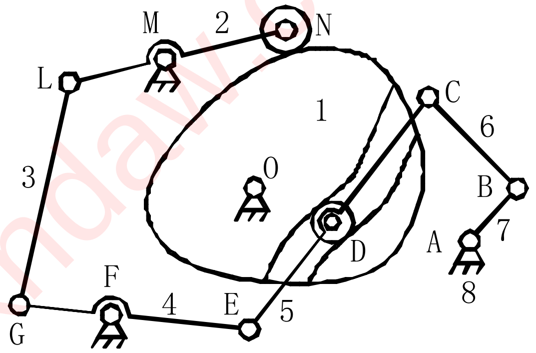

Fig2-5(a)

解：

(a) 两个滚子有局部自由度。

(b) 滚子 D 与凸轮 1 之间只能算一个高副。

$F=3n-2P_L-P_h=3\times7-2\times9-2=1$

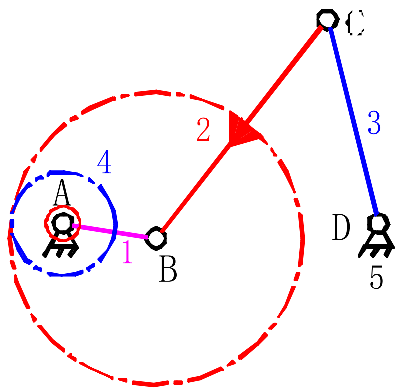

Fig2-5(b)

解：

(1) 杆件 BC 与齿轮 2 焊接在一起。 (2) A 为齿轮 4、杆件 1 和机架 5 的复合铰链。

$F=3n-2P_L-P_h=3\times4-2\times5-1=1$

常见错误：认为 B 是复合铰链，而不认为 A 是复合铰链。

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2-6 Calculate the degree of freedom of the mechanisms shown in Fig2-6,and point out what should be paid attention to during the calculation .

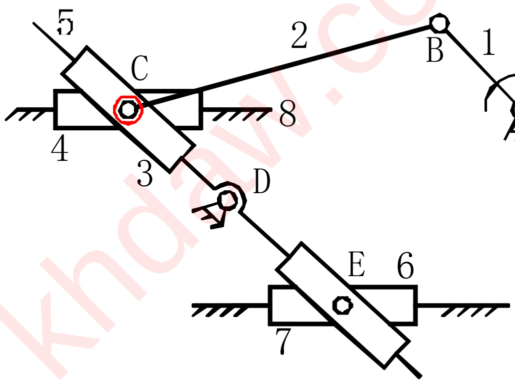

Fig2-6(a)

解：

(a) C 为构件 2、3、4 的复合铰链。

(b) C 处有两个转动副和两个移动副。 E 处有一个转动副和两个移动副。

$F=3n-2P_L-P_h=3\times7-2\times10=1$

注意：E 不是复合铰链！

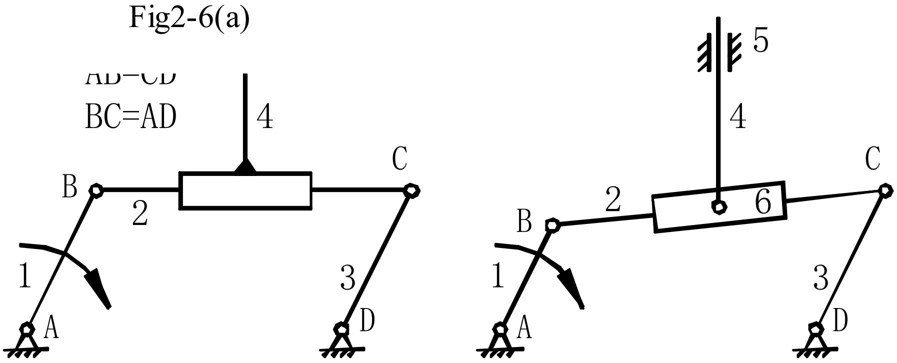

Fig2-6(b)

解：

当构件尺寸任意时，构件 2 作平面复杂运动，而杆 4 与机架间组成移动副，所以杆 4 仅作平动。因此，构件 2 和构件 4 之间有相对转动。因此，应该有构件 6，并且构件 4 和 6 之间有转动副，如右图所示。

当 AB＝CD 且 BC＝AD 时，杆 2 仅作平动。杆 4 与机架间组成移动副，所以杆 4 也仅作平动。这样，构件 2 和构件 4 之间就没有相对转动，只有相对移动。即：构件 4 和构件 6 之间就没有相对转动了，因此，可将构件 6 与构件 4 焊接起来（去掉构件 6），如左图所示。

然而，在计算机构自由度时，应该按一般尺寸情况下进行分析，即：应该按照右图情况来分析机构的自由度。

$F=3n-2P_L-P_h=3\times5-2\times7=1$

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2-7 The kinematic diagram of an engine mechanism is given in Fig2-7.

(1) Calculate the degree of freedom of the mechanism, and point out what should be paid attention to during the calculation.

(2) Make the structural analysis for the mechanism.

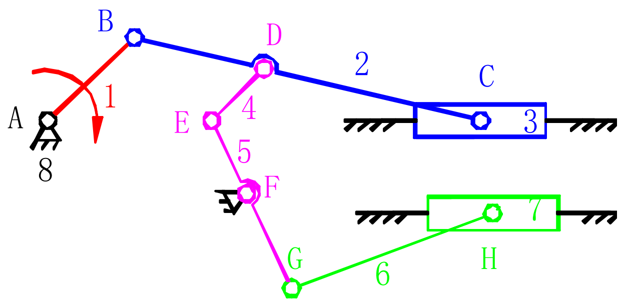
(3) Make the structural analysis for the mechanism when link EFG is regarded as the driver.

Note: During structural analysis, list the assembly order of Assur groups, the type of group, the grade of group, the grade of the mechanism, the link serial numbers, the inner pair and the outer pairs of each group in each mechanism.

解：

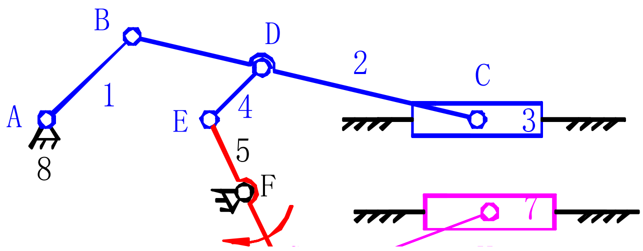
（1） $F=3n-2P_L-P_h=3\times7-2\times10=1$

（2） 当 AB 为原动件时，



	类型	杆号	内副	外副
第一杆组	RRP	2, 3	转C_{2-3}	B, 移C_{3-8}
第二杆组	RRR	4, 5	E	F, D
第三杆组	RRP	6, 7	转H_{6-7}	G, 移H_{7-8}

（3）当 EFG 为原动件时，



类型	杆号	内副	外副
III级杆组	1, 2, 3, 4	B, D, 转C	A, E, 移C_{3-8}
RRP	6, 7	转H	G, 移H_{7-8}

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2-8 Make the structural analysis for the mechanism shown in Fig2-8.

(a) When link 1 is regarded as the driver.

(b) When link 5 is regarded as the driver.

Note: During structural analysis, list the assembly order of Assur groups, the type of group, the grade of group, the grade of the mechanism, the link serial numbers, the inner pair and the outer pairs of each group in each mechanism.

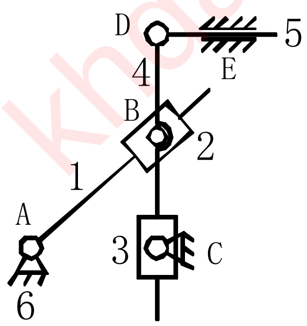
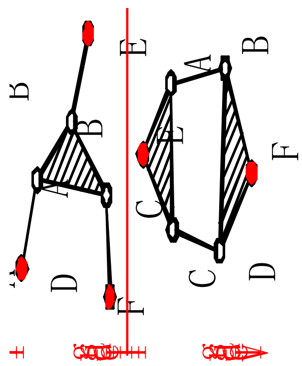
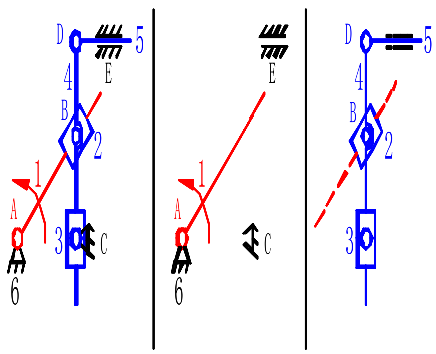


Fig2-8

解：

(a) 当 1 为原动件时



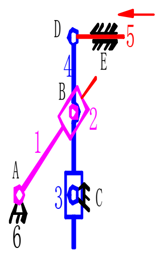


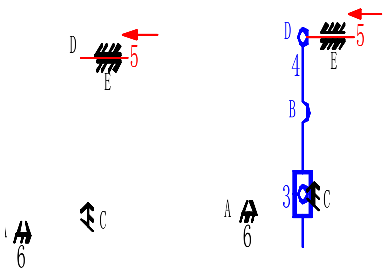
杆件 2, 3, 4 和 5 组成一个三级 Assur group.

(b) 当 5 为原动件时

杆件 3 和 4 组成第一个 RPR Assur group.

杆件 1 和 2 组成第二个 RPR Assur group





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2-9 The schematic diagram of a punch machine designed by someone is shown in Fig2-9. This machine should be able to transform a continuous rotation of gear 1 into a translation of the punch 4. Can the machine work properly? If it can't ,please rectify it.

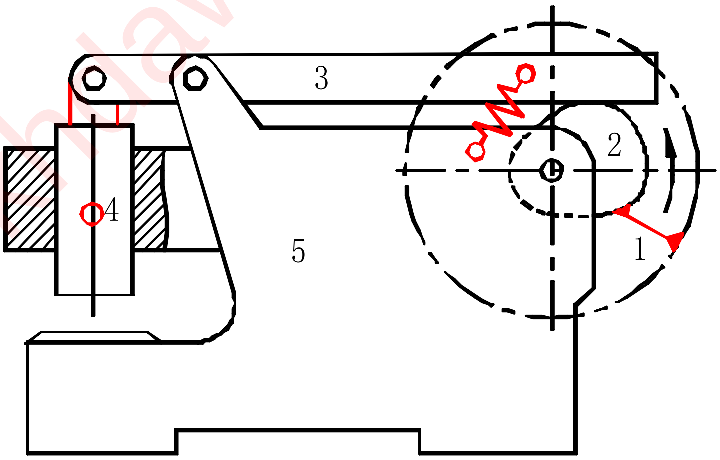

Fig2-9

解：不能正常工作。

改正如图(或者改成题目 2-3 构件 5、6、7 的连接)

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2-10 The schematic diagram of a mechanism designed by someone is shown in Fig2-10. This mechanism should be able to transform a continuous rotation of link1 into an oscillation of link4. Can the mechanism work properly? If it can't ,please rectify it.

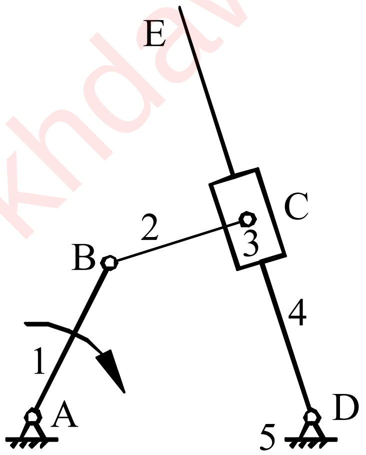
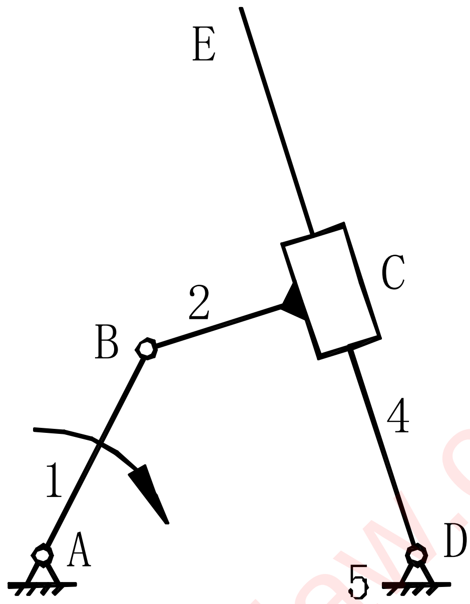
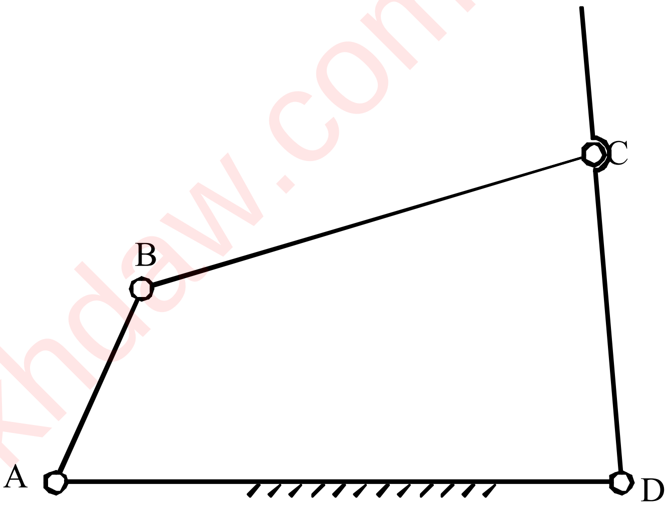
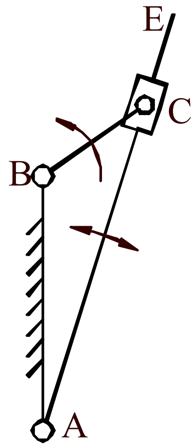


Fig2-10

解：不能正常工作。
改正后




B
C
A
D


E
C
B
A

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3-1 Locate all instant centres of mechanisms in the position shown in Fig3-1.

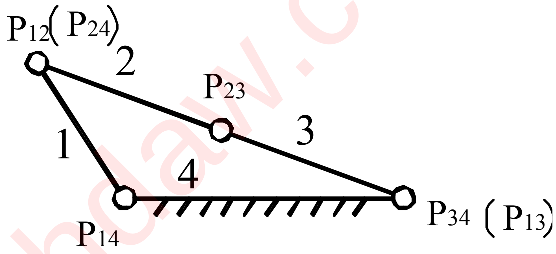

Fig3-1(a)

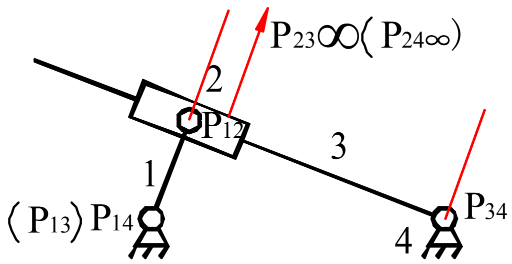

Fig3-1(b)

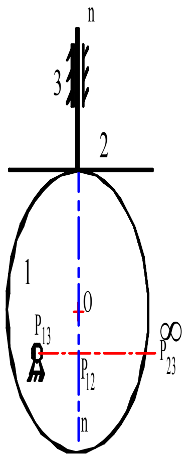

Fig3-1(c)

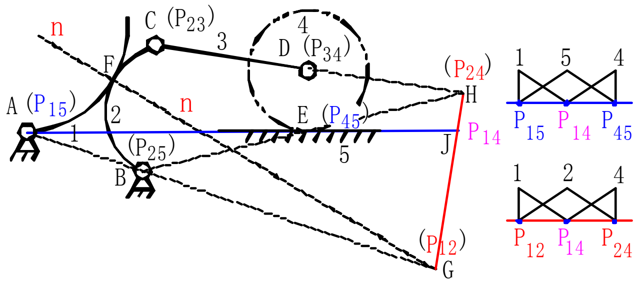

Fig3-1(d)

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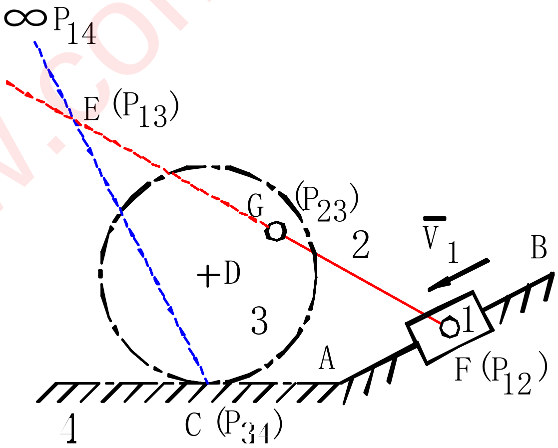

Fig3-1(e)

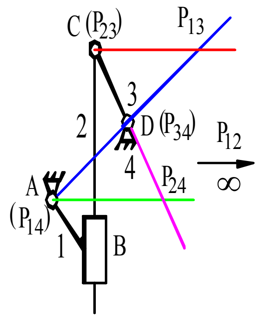

Fig3-1(f)

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3-2 In the position shown in Fig3-2, determine the ratio ω_3/ω_1 of the angular velocity of gear 3 to that of gear 1, using the method of instant centres.

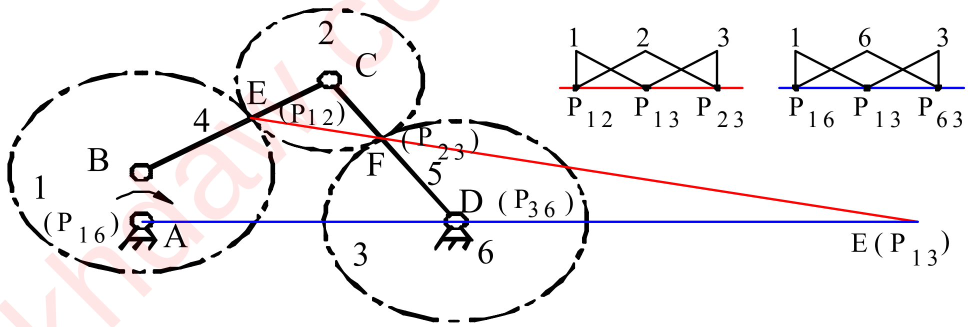

Fig3-2

解：

P_{13} 是构件 1 和 3 的瞬心，等速重合点，

所以$\omega_1 L_{AE} = \omega_3 L_{DE}$

$\omega_3/\omega_1 = L_{AE}/L_{DE}$

3-3 In the position shown in Fig3-3, determine the ratio ω_2/ω_1 of the angular velocity of follower 2 to that of cam 1, using the method of instant centres.

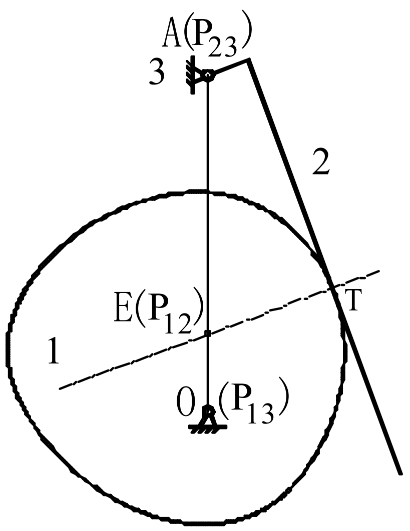

Fig3-3

解：

E（P_{12}）是构件 1 和 2 的瞬心，等速重合点，

所以$\omega_1 L_{OE} = \omega_2 L_{AE}$

$\omega_2/\omega_1 = L_{OE}/L_{AE}$

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3-4 In the pivot four-bar linkage shown in Fig3-4, ω_1= 10rad/sec. Using the method of instant centres,

(a) Find the velocity of point C in the position shown in the figure.

(b) In the position shown in the figure, locate the point E on the line BC (or its extension) which has the minimum velocity among all points of line BC and its extension, and then calculate its velocity.

(c) draw two positions of the crank AB when V_C=0.

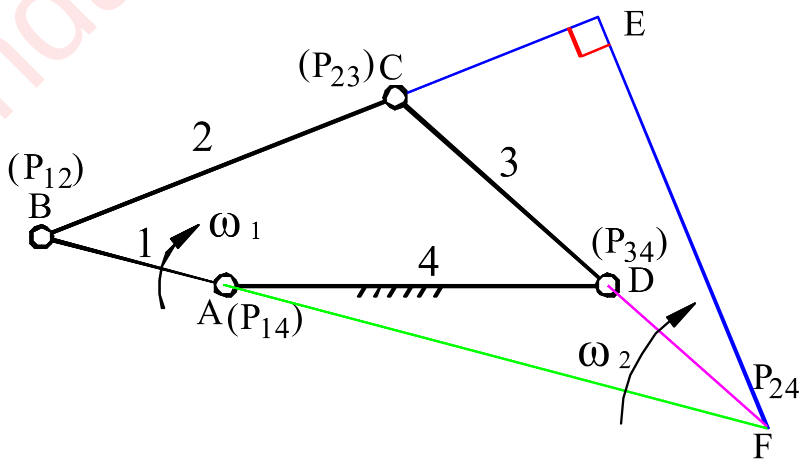
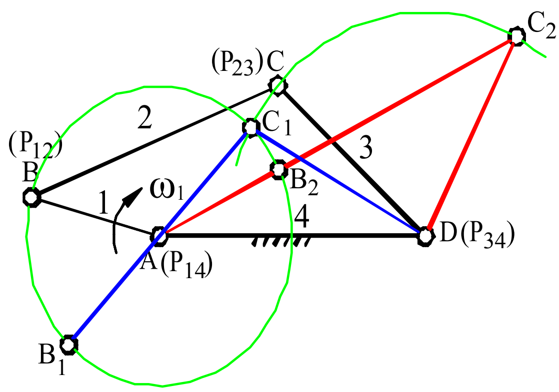


Fig3-4

解：

（a）$V_{B1}= \omega_1 L_{AB}=V_{B2}= \omega_2 L_{FB}$ ，所以 $V_C= V_{C2}= \omega_2 L_{FC}= \omega_1 L_{AB} L_{FC}/L_{FB}$

(b)$V_E=\omega_2 L_{FE}$。



(c) V_C=0 所对应的曲柄 AB 的两个位置:

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3-5 In the six-bar mechanism shown in Fig3-5, $X_A=0$, $Y_A=0$, $X_D=450mm$, $Y_D=0$, $L_{AB}=150mm$, $L_{BC}=400mm$, $L_{DC}=350mm$, $\angle CDE=30°$, $L_{DE}=150mm$, $L_{EF}=400mm$. The crank AB rotates at a constant speed 10rad/sec. Write a main program to analyze the output motion of the point F when the driver AB rotates from 0° to 360° with a step size of 5°..

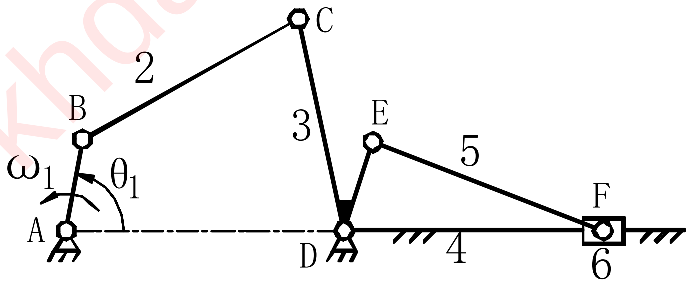

Fig3-5

解：

```
FOR I=0 TO 360 STEP 5
      CALL   LINK(0, 0, 0, 0, 0, 0, I*PI/180, 10, 0, 150,
                      XB, YB, VBX, VBY, ABX, ABY)
      CALL   RRR(450, 0, 0, 0, 0, 0, XB, YB, VBX,VBY,
                      ABX,ABY,350,400,Q3,W3,E3,Q2,W2,E2)
      CALL   LINK(450, 0, 0, 0, 0, 0, Q3-PI/6, W3, E3,
                     150, XE, YE, VEX, VEY, AEX, AEY)
      CALL   RRP(1, 0, 400, XE, YE, VEX, VEY, AEX,
                     AEY, Q5, W5, E5)
      CALL LINK(XE,YE,VEX,VEY,AEX,AEY,Q5,W5,
                     E5, 400, XF, YF, VFX, VFY, AFX, AFY)
       PRINT I, XF, YF, VFX, VFY, AFX, AFY
NEXT   I
```

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3-6 In the mechanism shown in Fig3-6, $X_A=0$, $Y_A=0$, $X_D=200mm$, $Y_D=0$, $L_{AB}=80mm$, $L_{CD}=60mm$ and $L_{BE}=380mm$. The crank AB rotates at a constant speed of 10rad/sec. Write a main program to analyze the output motion of the point E when the driver AB rotates from 0° to 360° with a step size of 5°.

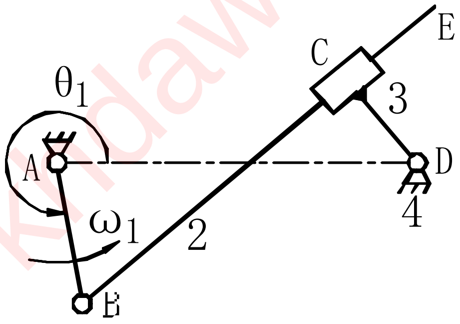
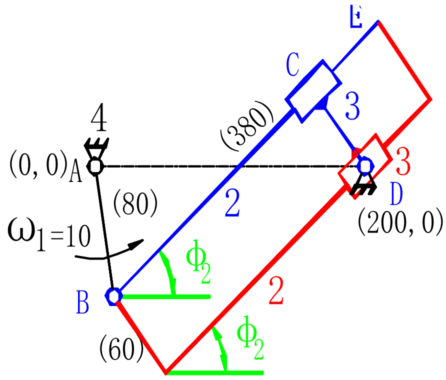


Fig3-6




```
FOR I=0 TO 360 STEP 5
    CALL  LINK(0, 0, 0, 0, 0, 0, I*PI/180, 10, 0, 80,
                XB, YB, VBX, VBY, ABX, ABY)
    CALL  RPR(1, XB, YB, VBX, VBY, ABX, ABY,
                200, 0, 0, 0, 0, 0, 60, Q2, W2, E2)
    CALL  LINK(XB, YB, VBX, VBY, ABX, ABY, Q2,
               W2, E2, 380, XE, YE, VEX, VEY, AEX, AEY)
     PRINT I, XE, YE, VEX, VEY, AEX, AEY
NEXT I
```

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3-7 . In the mechanism shown in Fig3-7, $X_G=Y_G=0$, $X_B=-42$, $Y_B=39$, $X_D=70$, $Y_D=75$, $L_{BA}=34mm$, $L_{GF}=24mm$, $L_{FE}=95mm$, $L_{EC}=69mm$, $L_{DC}=48mm$, $\angle EFG=90°$. The crank BA rotates at a constant speed of 10 rad/sec. Write a main program to analyze the output motion of the point C when the driver BA rotates from 0° to 360° with a step size of 5°.

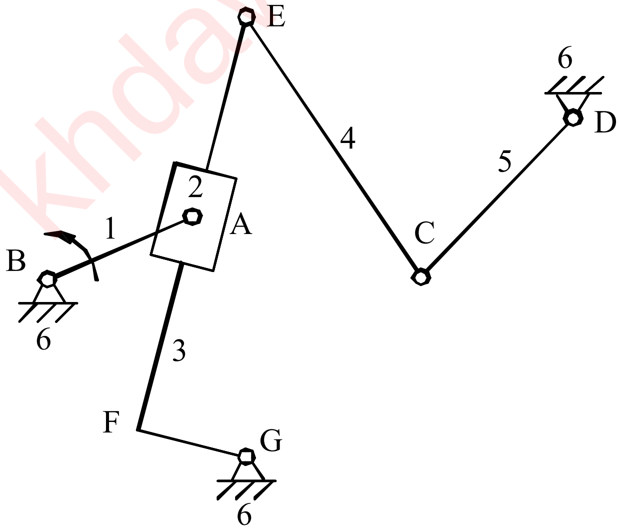

Fig3-7

```
FOR I=0 TO 360 STEP 5
    CALL    LINK(-42, 39, 0, 0, 0, 0, I*PI/180, 10, 0, 34,
                  XA, YA, VAX, VAY, AAX, AAY)
    CALL    RPR(-1, 0, 0, 0, 0, 0, 0, XA, YA, VAX, VAY,
                AAX, AAY, 24, QFE, W3, E3)
    CALL    LINK(0, 0, 0, 0, 0, 0, QFE+PI/2, W3, E3, 24,
               XF, YF, VFX, VFY, AFX, AFY)
    CALL    LINK(XF, YF, VFX, VFY, AFX, AFY, QFE, W3, E3,
               95, XE, YE, VEX, VEY, AEX, AEY)
    CALL    RRR(XE, YE, VEX, VEY, AEX, AEY, 70, 75, 0, 0,
               0, 0, 69, 48,QEC, W4, E4, QDC, W5, E5)
    CALL    LINK(70, 75, 0, 0, 0, 0, QDC, W5, E5, 48, XC, YC,
                VCX, VCY, ACX, ACY)
     PRINT I, XC, YC, VCX, VCY, ACX, ACY
NEXT I
```

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3-8 In the six-bar mechanism shown in Fig3-8, X_B=0, Y_B=0, X_F=37.2, Y_F=17.5, Y_C=28.8, L_{FE}=16.8mm, L_{EC}=39.2mm, L_{CD}=20.633mm, L_{DE}=36.4mm, ∠BGA=90°, L_{BG}=9mm, L_{GA}=58mm. The crank FE rotates clockwise at a constant speed of 10 rad/sec. Write a main program to analyze the output motion of the point A.when the driver FE rotates from 360° to 0° with a step size of -5°.

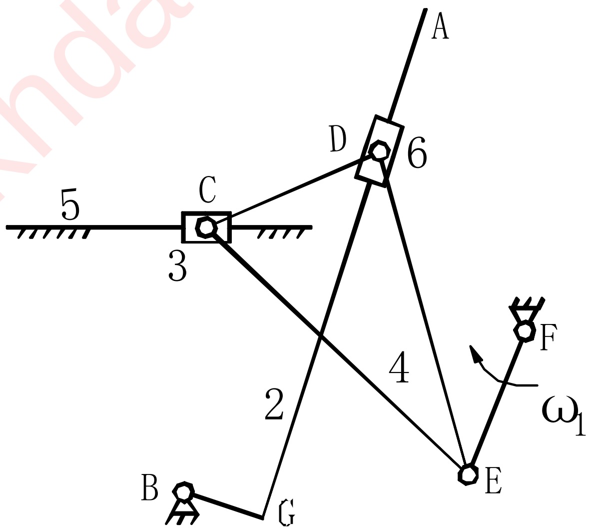

Fig3-8

```
For I = 360 To 0 Step -5
Call LINK(37.2, 17.5, 0, 0, 0, 0, 16.8, I*PI/180, 10, 0, XE, YE, VEX, VEY, AEX, AEY)
Call RRP(-1, 28.8, XE, YE, VEX, VEY, AEX, AEY, 39.2, QEC, W4, E4, XC)
Call LINK(XE, YE, VEX, VEY, AEX, AEY, QEC-QCED, W4,E4,XD,YD, VDX, VDY, ADX, ADY)
Call RPR(1, 0, 0, 0, 0, 0, 0, XD, YD, VDX, VDY, ADX, ADY, LBG, QGA, W2, E2)
Call LINK(0, 0, 0, 0, 0, 0, LBG, 3 * PI / 2 + QGA, W2, E2, XG, YG, VGX, VGY, AGX, AGY)
Call LINK(XG, YG, VGX, VGY, AGX, AGY, LGA, QGA, W2, E2, XA, YA, VAX, VAY, AAX, AAY)
Print I, XA, YA, VAX, VAY, AAX, AAY
Next I
```

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4-1 Determine the type of the pivot four-bar linkages whose dimensions are shown in Fig4-1.

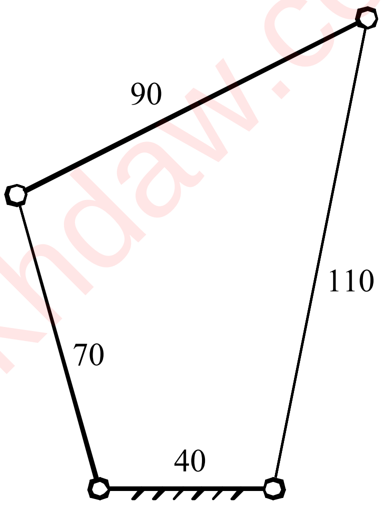

Fig4-1(a)

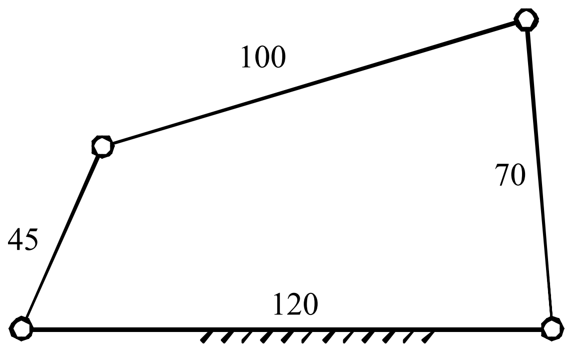

Fig4-1(b)

双曲柄机构

曲柄摇杆机构

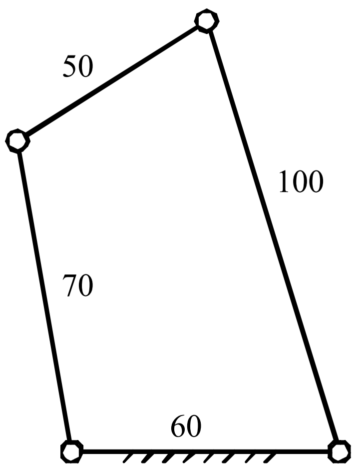

Fig4-1(c)

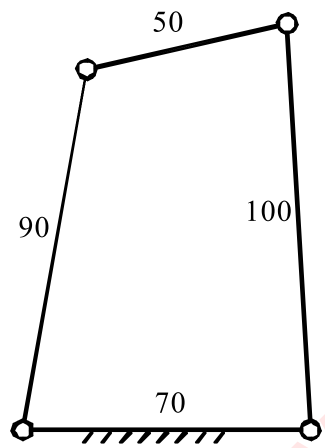

Fig4-1(d)

双摇杆机构

双摇杆机构

Name______________Class_____Student No.___________Date____________

4-2 In the revolute four-bar mechanism shown in Fig4-2

(1) Find the pressure angle α and the transmission angle γ of the mechanism in the position shown in the figure.

(2) Find the angular stroke ψ_{max} of the link DC.

(3) Find the crank acute angle θ between the two limiting positions.

(4) Find the maximum pressure angle α_{max} and the minimum transmission angle γ_{min}.

(5) Is there dead-point during the whole cycle of the motion when the link DC is regarded as the driver? If there is, when? And draw the dead-point positions of the mechanism.

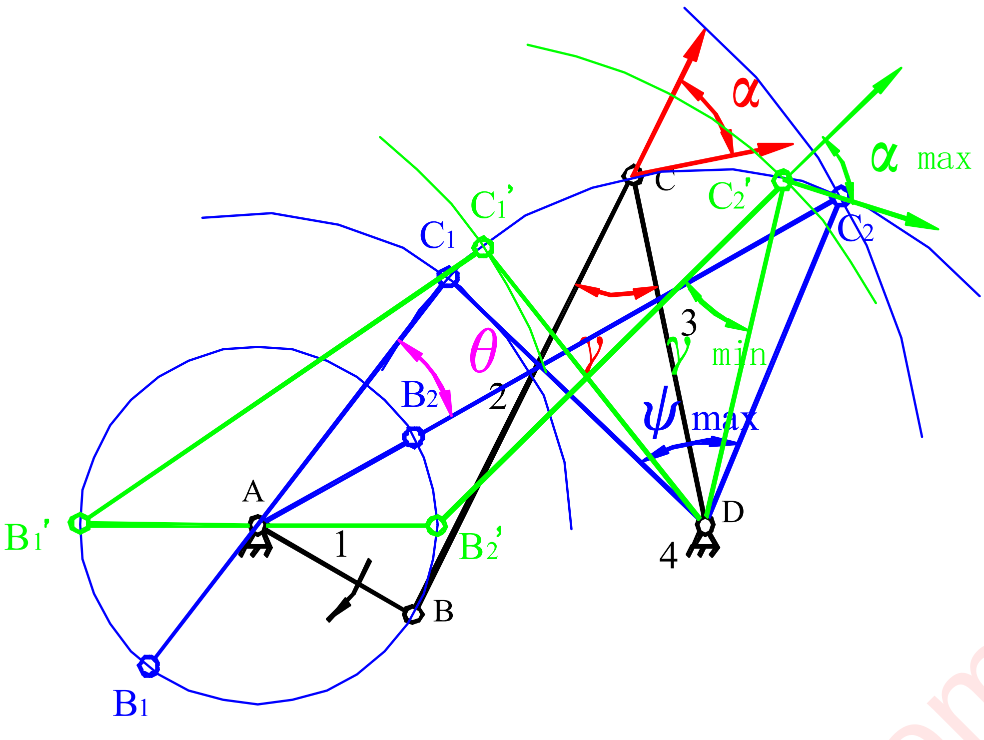

Fig4-2

(5)当 DC 为原动件时，此机构有死点位置。
死点位置为图中 AB_1C_1D 和 AB_2C_2D。

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4-3 Design an offset slider-crank mechanism ABC in which the crank AB is the driver. The maximum pressure angle α_{max}=30°. Find the stroke H of the slider and the crank acute angle θ between the two limiting positions.

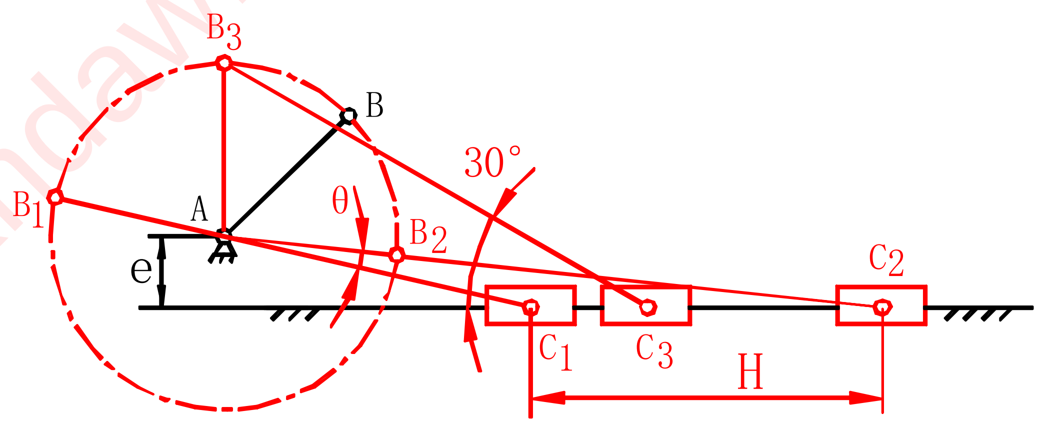
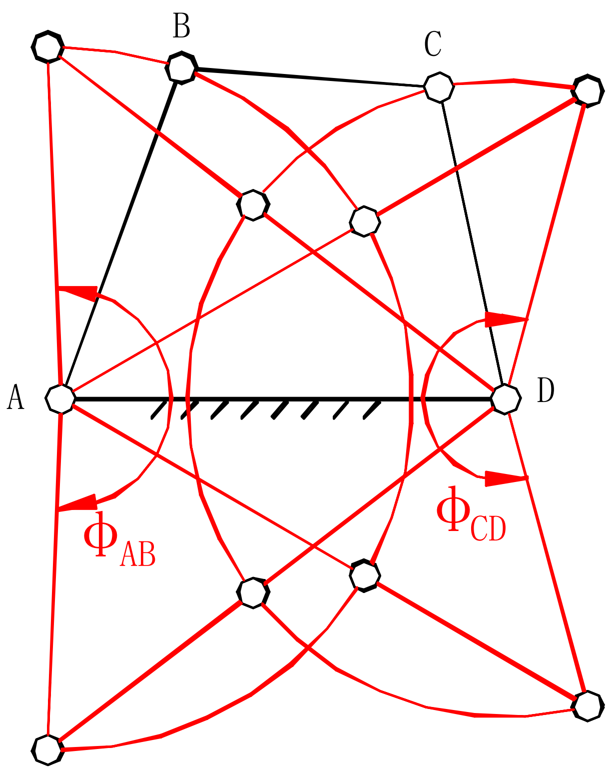


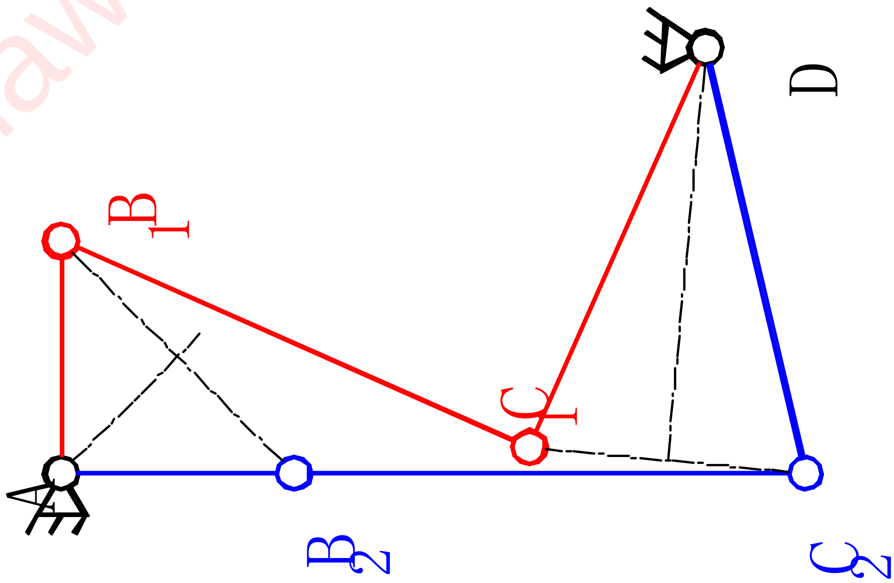
Fig4-3

4-4 Determine the angular strokes of the rockers AB and CD shown in Fig4-4, respectively, using graphical method.



Name______________Class______Student No.___________Date____________

4-5 In Fig4-5 there are two positions, B_1C_1 and B_2C_2, of the coupler BC of a revolute four-bar linkage ABCD. The link AB is a driver. The pressure angle α at the first position is 0°. The second position of the mechanism is a toggle position. Design the linkage and write out the drawing steps briefly.



解:

a) 链点 A 必在 B_1B_2 的垂直平分线上。

b) 类似的，铰链点 D 必在 C_1C_2 的垂直平分线上。

c) AB 为原动件时，机构在第一位置的压力角为 0^o 得到 $B_1C_1 \perp C_1D$。

d) 机构的第二位置为一死点位置得到 A, B_2, C_2 三点共线。

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4-6 In a crank-slider mechanism, two sets of corresponding positions of the slider and a line segment AE on the crank ABE are shown in Fig4-6. The position C_1 of the slider is its left limiting position. Find the first position B_1 of the revolute B and write out the drawing steps briefly.

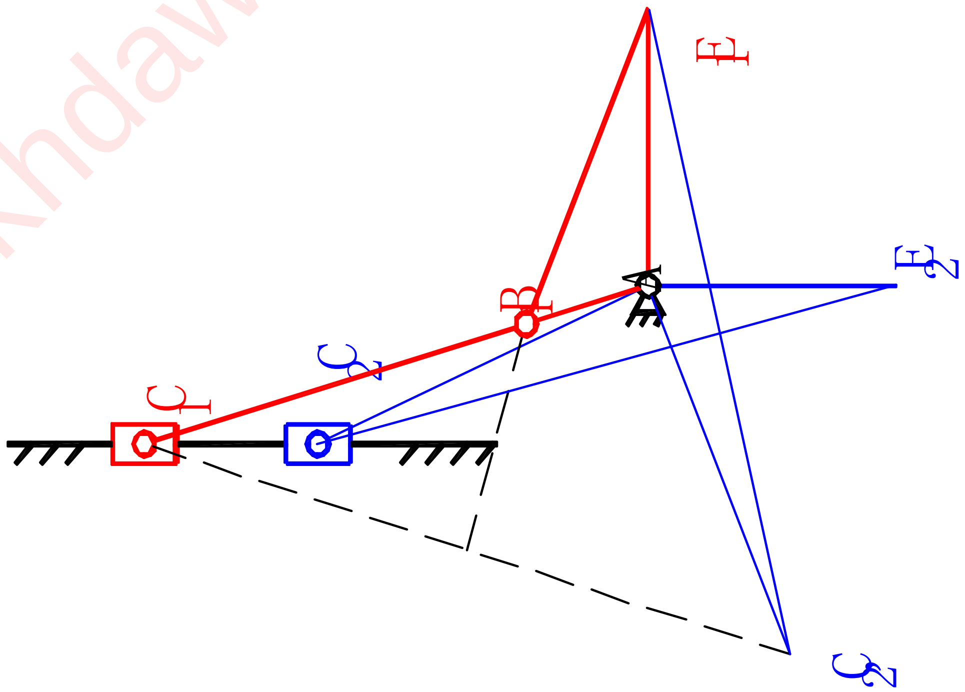

Fig4-6

解：

作$\Delta AC_2'E_1 \cong \Delta AC_2E_2$，且字母旋向相同，得 C_2'。因 C_1 为滑块的极限位置之一，所以 B_1 点在 AC_1 连线上。

作 C_1C_2'的中垂线与 AC_1 交于待定活动铰链点 B 的第一个位置点 B_1。

Name______________Class_____Student No.__________Date____________

4-7 In a revolute four-bar linkage ABCD, side link AB is the driver. Two sets of corresponding positions of the side link CD and a line segment CE on the coupler CBE are shown in Fig4-7. The first position of the linkage is also a dead point. Find the second position B_2 of the revolute B and write out the drawing steps briefly.

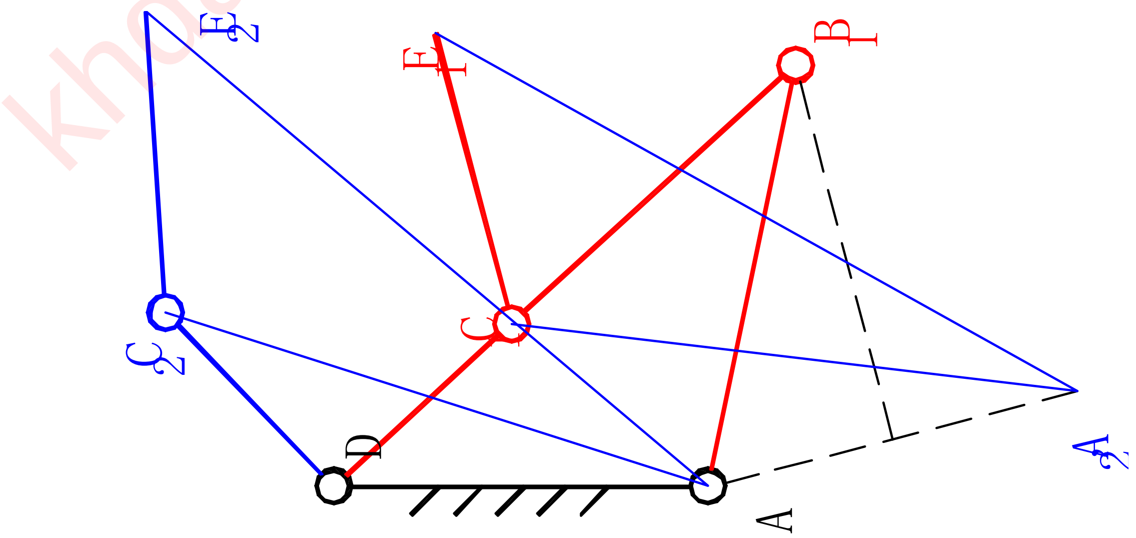

Fig4-7

解：

作ΔA**2**'C**1**E**1**≅ΔAC**2**E**2**，得 A**2**'点。因 AB 为原动件且机构第一位置为死点，所以 B**1** 点在 DC**1** 的延长线上。

作 AA**2**' 的中垂线与 DC**1** 的延长线交于待定活动铰链点 B 的第一个位置点 B**1**。

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4-8 In a crank-rocker linkage ABCD, side link AB is the driver. Two positions of the rocker CD are shown in Fig4-8. At the first position , the pressure angle of the linkage is zero. Position DC_2 is one of the limit positions of the rocker. Find the first position B_1 of the revolute B and write out the drawing steps briefly.

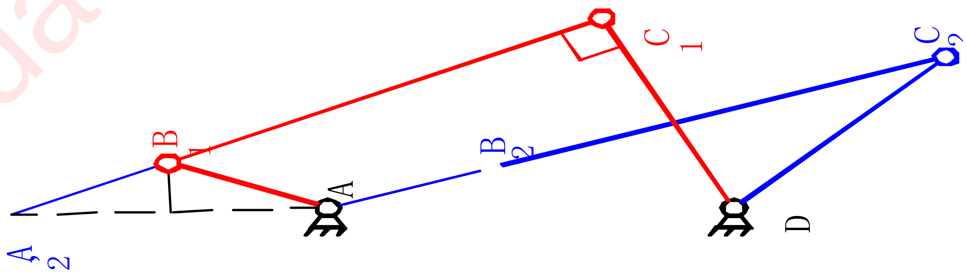

Fig4-8

解:

因 A 点在 C**2**B**2** 延长线上，故在 C**1**B**1** 延长线上截取 C**1**A**2**'=C**2**A，得 A**2**'点。作 AA**2**'的中垂线与 C**1**B**1** 交于待定活动铰链点 B 的第一个位置点 B**1**。

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4-9 In an offset slider-crank mechanism ABC, two sets of corresponding positions of the crank AB and a point F on the slider are shown in Fig4-9. When the crank AB is located at position AB_1, the slider reaches its left limit position. Find the first position C_1 of the revolute C on the slider and write out the drawing steps briefly.

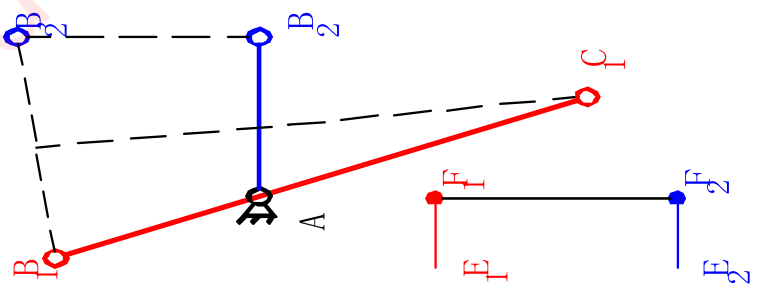

Fig4-9

解：

作 B2B2’ //=F**1**F**2**，得 B**2**’点因为第一位置是滑块的左极限位置,故 C**1** 在 B**1**A 的延长线上.

作 B**1**B**2**’的中垂线,交 B**1**A 的延长线于待定活动铰链点 C 的第一个位置点 C**1**。

作 C**1**C**2**=F**1**F**2**，得 C2 点。

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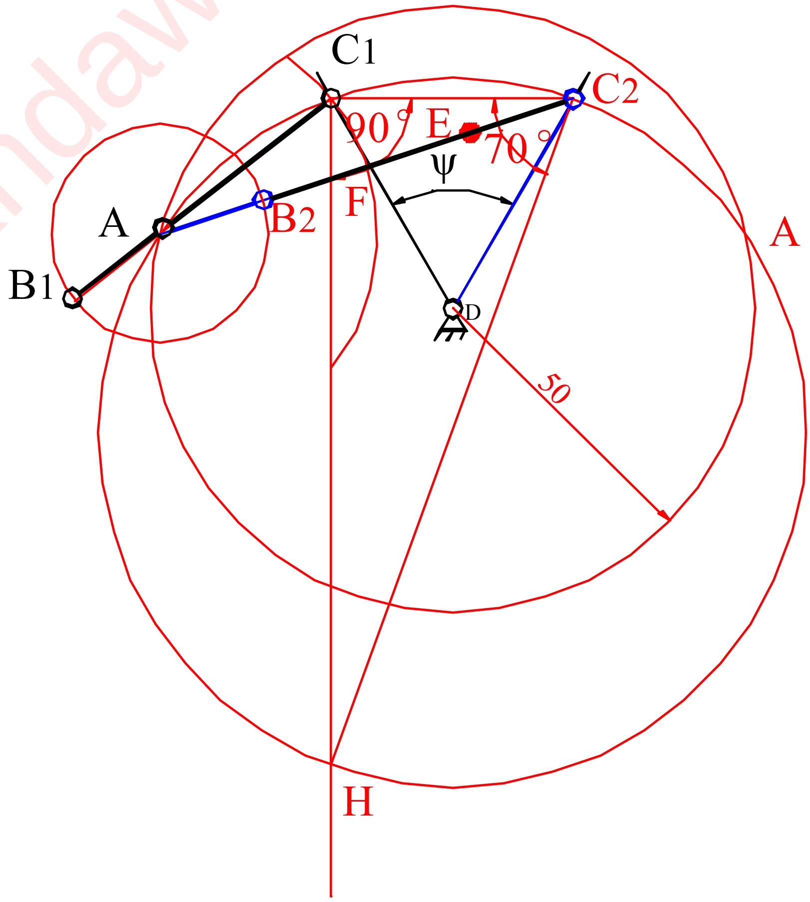
4-10 In a crank-rocker mechanism ABCD, the coefficient of travel speed variation(k) is 1.25, when crank AB rotate constantly. The angular stroke of rocker DC $\psi=60^{o}$ .The length of the rocker DC is 40mm. The length of the frame AD is 50mm. Design the mechanism and write out the drawing steps briefly.



解：（取比例尺μℓ=0. 001m/mm）

$$\theta = 180^{0} \times \frac{k-1}{k+1} = 180^{0} \times \frac{1.25-1}{1.25+1} = 20^{0}$$

取 DC1=DC**2=40mm**，作直角三角形 C1C2H,其中∠C1C2H=90º － θ=70º

作三角形 C1C2H 的外接圆，以 D 点为圆心，以 50mm 为半径作圆，两圆的交点为铰链点 A。

连接 AC1、AC2,以 A 点为圆心，以（AC2 －AC1）/ 2 为半径作圆得铰链点 B,AB=17.98mmBC=53.72mm

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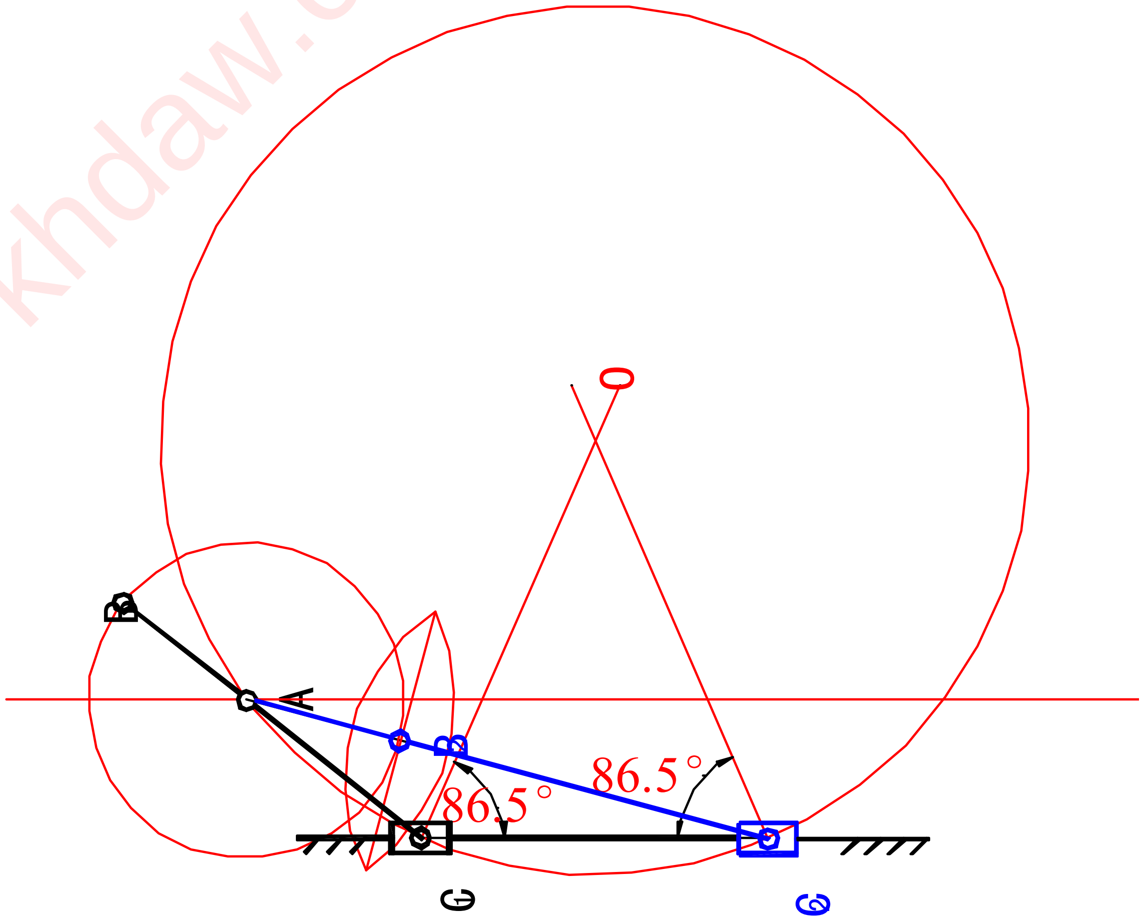
4-11 In an offset slider-crank mechanism, the offset e is 20mm. The coefficient of travel speed variation k is 1.3. The working stroke H of the slider is 50mm. Design the offset slider-crank mechanism



解： （取比例尺μℓ=0. 001m/mm）

$$\theta = 180^0 \times \frac{k-1}{k+1} = 180^0 \times \frac{1.3-1}{1.3+1} = 23.5^0$$

作C1C2=50mm,作等腰三角形OC1C2其中∠0C1C2=∠0C2C1=90º－θ=86.5º，以O为圆心，以OC1为半径作圆

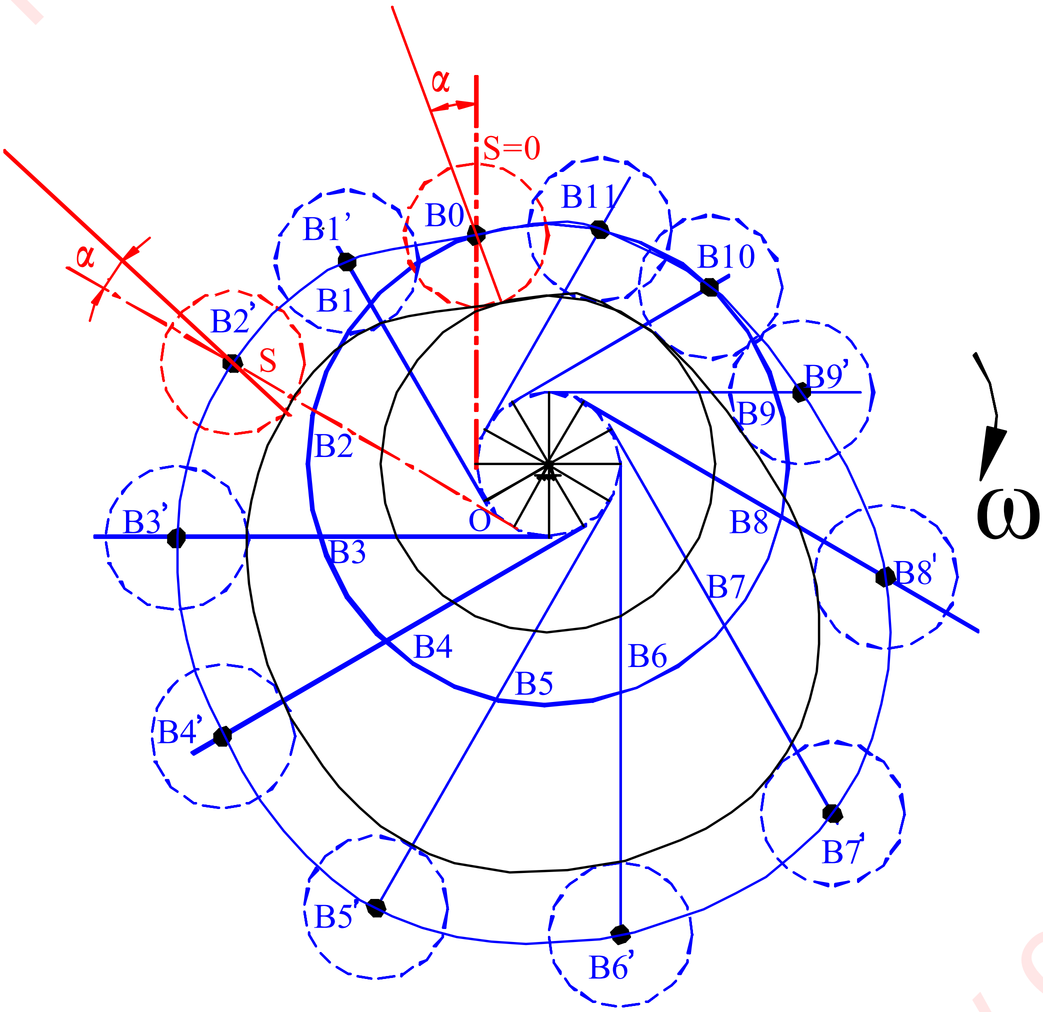
作一与C1C2平行且距离为20mm的直线，此直线与圆O的交点为铰链点A

以A为圆心，以（AC2－AC1）/2为半径作圆A得到铰链点B。BC=55.06mm,AB=22.83mm.

Name______________Class_____Student No.___________Date____________

5-1 A plate cam with positive-offset translating roller follower has the following motion: a rise through lift h=40mm with a sine acceleration motion curve during δ_0=150°, δ_S=30°, a return with a 3-4-5 polynomial motion curve during δ_0'=120°, and δ_S'=60°. The cam rotates clockwise. And r_P=40mm. r_R=12mm, e=12mm and r_C=25mm. Construct the pitch curve and the cam contour graphically with a scale of 1:1. Label in red the centerline of the follower, S, the roller and α when δ = 60° and δ = 0°.

δ	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
S(mm)	0	7.86	15.72	23.58	31.44	40	40	35.86	20	4.14	0	0	0



Name______________Class_____Student No.___________Date____________

5-2 A plate cam with translating offset roller follower has the same motion curve and dimensions as exercise5-1 has. Write a program to calculate the co-ordinates of the pitch curve, the cam contour and the locus of the center of the milling cutter, α and ρ_B.

```
SET WINDOW -100,120,-100,60
LET M=-1
LET N=+1
LET RP=40
LET E=12
LET RR=12
LET RC=25
LET H=40
LET DELTA0=150*PI/180
LET DELTAS=30*PI/180
LET DELTA01=120*PI/180
LET DELTAS1=60*PI/180
LET S0=SQR(RP^2-E^2)

BOX CIRCLE -RP,RP,-RP,RP
BOX CIRCLE -E,E,-E,E

FOR I=0 TO 360 STEP .005
     LET DELTA=I*PI/180
     IF DELTA<=DELTA0 THEN
         LET DD=DELTA/DELTA0
         LET S=H*(DD-1/2/PI*SIN(2*PI*DD))
         LET S1=H/DELTA0*(1-COS(2*PI*DD))
         LET S11=2*PI*H/DELTA0^2*SIN(2*PI*DD)
    ELSEIF DELTA<=(DELTA0+DELTAS) THEN
         LET S=H
         LET S1=0
         LET S11=0
    ELSEIF DELTA<=(DELTA0+DELTAS+DELTA01) THEN
         LET D4=(DELTA-DELTA0-DELTAS)/DELTA01
         LET S=H*(1-10*D4^3+15*D4^4-6*D4^5)
         LET S1=-H/DELTA01*(30*D4^2-60*D4^3+30*D4^4)
```

```
        LET S11=-H/DELTA01^2*(60*D4-180*D4^2+120*D4^3)
    ELSE
        LET S=0
        LET S1=0
        LET S11=0
    END IF
    LET XB=M*((S0+S)*SIN(DELTA)+N*E*COS(DELTA))
    LET YB=(S0+S)*COS(DELTA)-N*E*SIN(DELTA)
    LET XB1=M*(S1*SIN(DELTA)+(S0+S)*COS(DELTA)-N*E*SIN(DELTA))
    LET YB1=S1*COS(DELTA)-(S0+S)*SIN(DELTA)-N*E*COS(DELTA)
    LET KB=SQR(XB1^2+YB1^2)
    LET XT=XB+M*RR*YB1/KB
    LET YT=YB-M*RR*XB1/KB
    LET XC=XT-M*RC*YB1/KB
    LET YC=YT+M*RC*XB1/KB

    LET ALAFA=ARCTAN(ABS(S1-N*E)/(S0+S))
    LET
LOUB=((S0+S)^2+(S1-N*E)^2)^1.5/(-(S0+S)*(S11-S0-S)+(S1-N*E)*(2*S1-N*E))

    PLOT XB,YB
    PLOT XT,YT
    PLOT XC,YC

NEXT I
END
```

Name______________Class_____Student No.__________Date___________

5-3 In the plate cam with translating offset roller follower as shown in Fig5-1, GH and IJ are two arcs with center at O. Indicate radius of prime circle r_P, offset e, cam angle for rise δ_0, cam angle for outer dwell δ_S, cam angle for return δ_0', cam angle for inner dwell δ_S' and lift h. In the position shown in Fig5-1, indicate pressure angle α, displacement S and the corresponding cam angle δ.

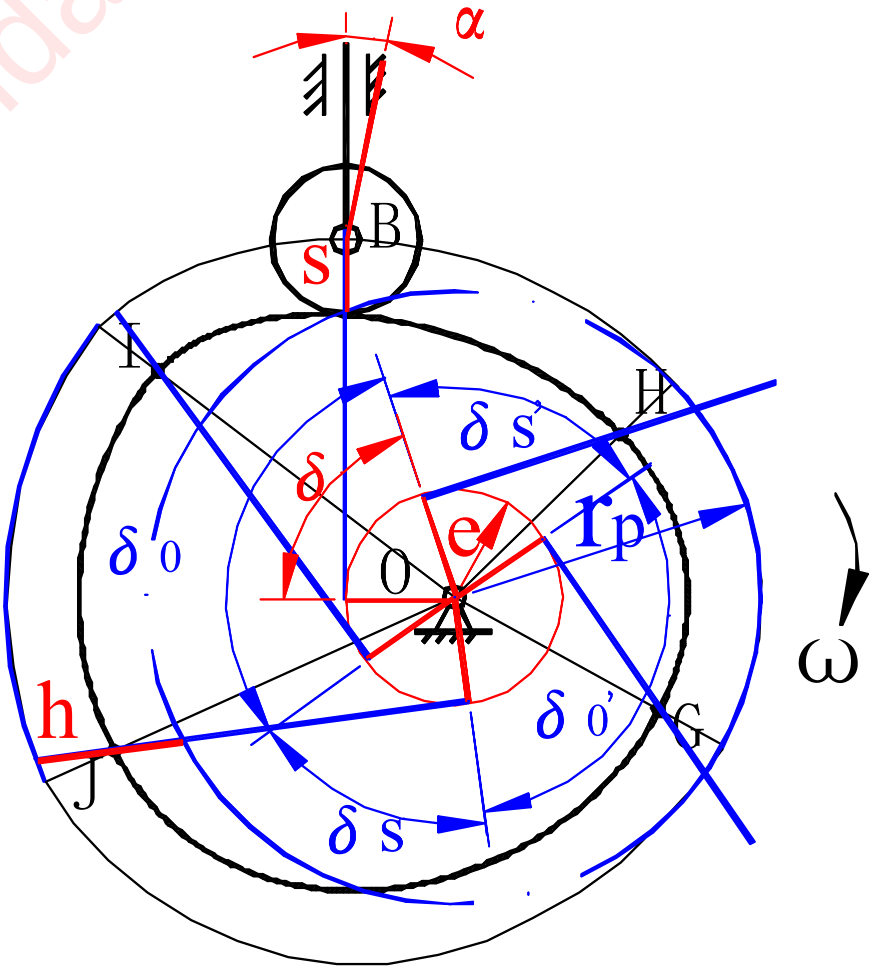


Fig5-1

Name______________Class_____Student No.__________Date____________

5-4 In the plate cam with translating offset roller follower as shown in Fig5-2, EA, AB and BCD are three arcs with center at O, N and P, respectively. Indicate radius of prime circle r_P, offset e, cam angle for rise δ_0, cam angle for outer dwell δ_S, cam angle for return δ_0', cam angle for inner dwell δ_S' and indicate lift h ,pressure angle α, displacement S and the corresponding cam angle δ in the position shown in Fig5-2,.

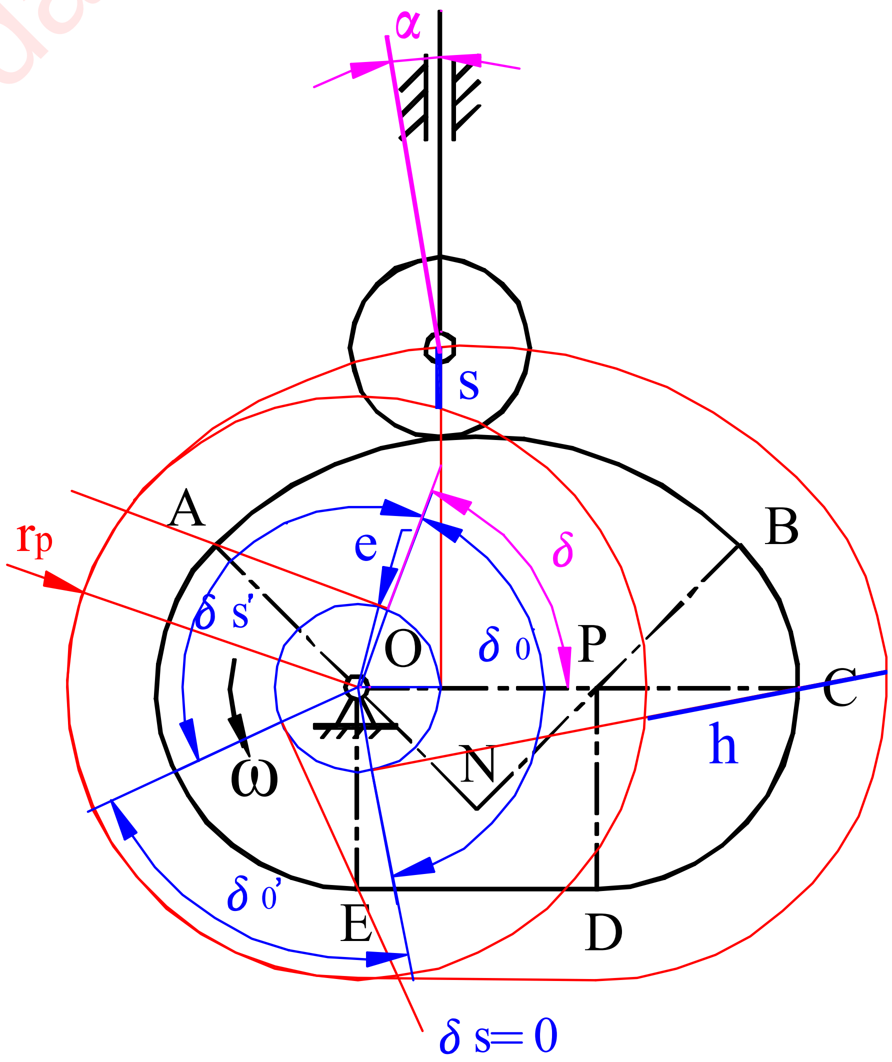
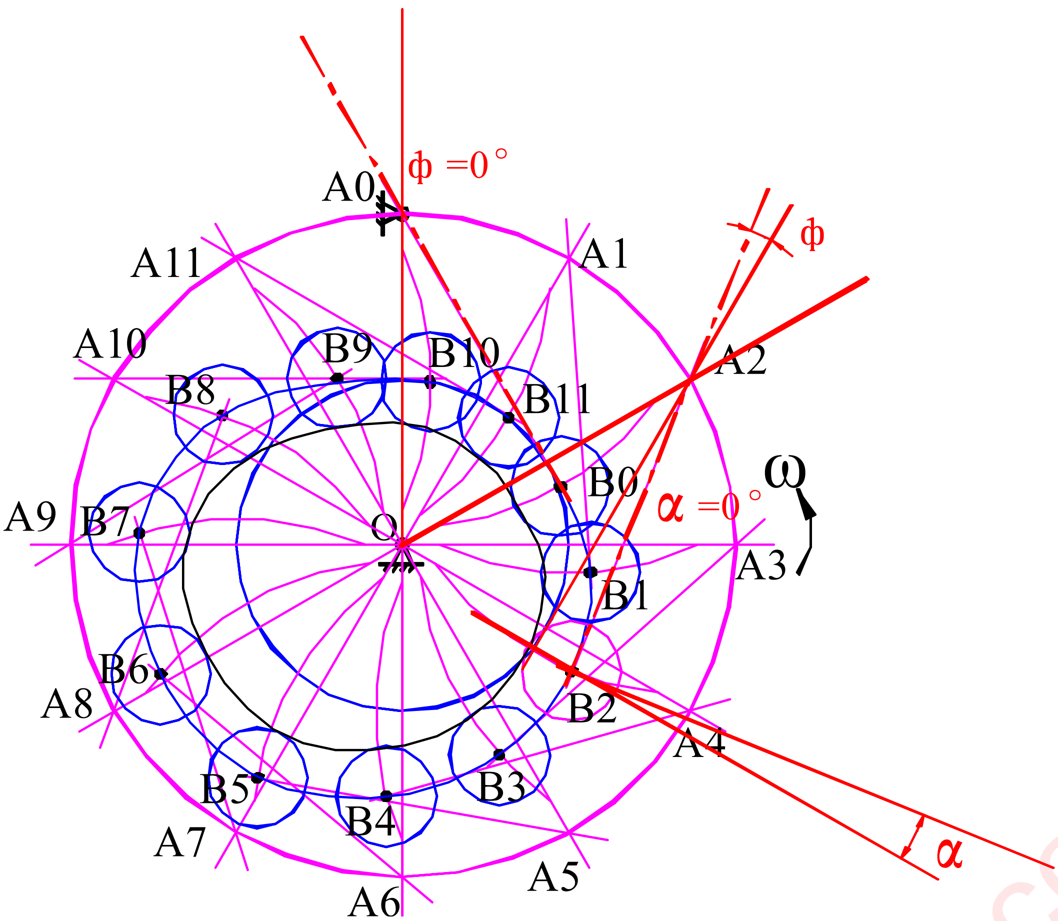


Fig5-2

Name______________Class_____Student No.__________Date____________

5-5 A plate cam with an oscillating roller follower similar to that in Fig.5-36 of textbook is to have the following motion: an angular lift $\phi_{MAX}=20°$ with a sine acceleration motion curve during $\delta_0=150°$, $\delta_S=30°$, a return with a 3-4-5 polynomial motion curve during $\delta_0'=120°$ and $\delta_S'=60°$. The given dimensions are: $r_P=40mm$, $L_{OA}=80mm$, $L_{AB}=76mm$, $r_R=12mm$ and $r_C=16mm$. Construct the pitch curve and the cam contour graphically with a scale of 1:1. Label in red ink the frame OA, ϕ, centreline AB of the follower, the roller and α corresponding to δ=60° and δ=0°.

δ	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
φ	0°	3.93°	7.86°	11.79°	15.72°	20°	20°	17.93°	10°	2.07°	0°	0°	0°



Name______________Class_____Student No.__________Date___________

5-6 A plate cam with an oscillating roller follower has the same motion curve and dimensions as exercise5-5 has. Write a program to calculate the co-ordinates of the pitch curve, the cam contour and the locus of the center of the milling cutter, the pressure angle α and the radius of curvature ρ_B of the pitch curve.

```
SET WINDOW -100,120,-100,60
LET M=+1
LET N=+1
LET RP=40
LET RR=12
LET RC=16
LET H=20
LET LOA=80
LET LAB=76
LET DELTA0=150*PI/180
LET DELTAS=30*PI/180
LET DELTA01=120*PI/180
LET DELTAS1=60*PI/180
LET S0=ARCTAN(SQR((2*LOA*LAB)^2-(LOA^2+LAB^2-RP^2)^2)/(LOA^2+LAB^2-RP^2))

BOX CIRCLE -RP,RP,-RP,RP

FOR I=0 TO 360 STEP .005
     LET DELTA=I*PI/180
     IF DELTA<=DELTA0 THEN
         LET DD=DELTA/DELTA0
         LET S=H*(DD-1/2/PI*SIN(2*PI*DD))
         LET S1=H/DELTA0*(1-COS(2*PI*DD))
         LET S11=2*PI*H/DELTA0^2*SIN(2*PI*DD)
    ELSEIF DELTA<=(DELTA0+DELTAS) THEN
         LET S=H
         LET S1=0
         LET S11=0
    ELSEIF DELTA<=(DELTA0+DELTAS+DELTA01) THEN
         LET D4=(DELTA-DELTA0-DELTAS)/DELTA01
         LET S=H*(1-10*D4^3+15*D4^4-6*D4^5)
         LET S1=-H/DELTA01*(30*D4^2-60*D4^3+30*D4^4)
```

```
        LET S11=-H/DELTA01^2*(60*D4-180*D4^2+120*D4^3)
    ELSE
        LET S=0
        LET S1=0
        LET S11=0
    END IF
    LET XB=M*(LOA*SIN(DELTA)+N*LAB*SIN(S0+S-N*DELTA))
    LET YB=LOA*COS(DELTA)-LAB*COS(S0+S-N*DELTA)
    LET XB1=M*(LOA*COS(DELTA)+N*LAB*COS(S0+S-N*DELTA)*(S1-N))
    LET YB1=-LOA*SIN(DELTA)+LAB*SIN(S0+S-N*DELTA)*(S1-N)
    LET KB=SQR(XB1^2+YB1^2)
    LET XT=XB+M*RR*YB1/KB
    LET YT=YB-M*RR*XB1/KB
    LET XC=XT-M*RC*YB1/KB
    LET YC=YT+M*RC*XB1/KB

    LET ALAFA=ARCTAN(ABS(LAB*(1-N*S)-LOA*COS(S0+S))/(LOA*SIN(S0+S)))
    LET K=(1-N*S)*(2-N*S)*COS(S0+S)+S11*SIN(S0+S)
    LET
LOUB=(LOA^2+LAB^2*(1-N*S1)^2-2*LOA*LAB*(1-N*S1)*COS(S0+S))^1.5/(LOA^2+LAB^2*
(1-N*S1)^3-LOA*LAB*K)

    PLOT XB,YB
    PLOT XT,YT
    PLOT XC,YC

NEXT I
END
```

Name______________Class_____Student No.__________Date___________

5-7 In the plate cam mechanism with oscillating roller follower, the cam is a circle with center at C. Indicate radius of prime circle r_P, cam angle for rise δ_0, cam angle for outer dwell δ_S, cam angle for return δ_0', cam angle for inner dwell δ_S' and angular lift ϕ_{max}. In the position shown in Fig5-4, indicate pressure angle α, angular displacement of follower ϕ and the corresponding cam angle δ.

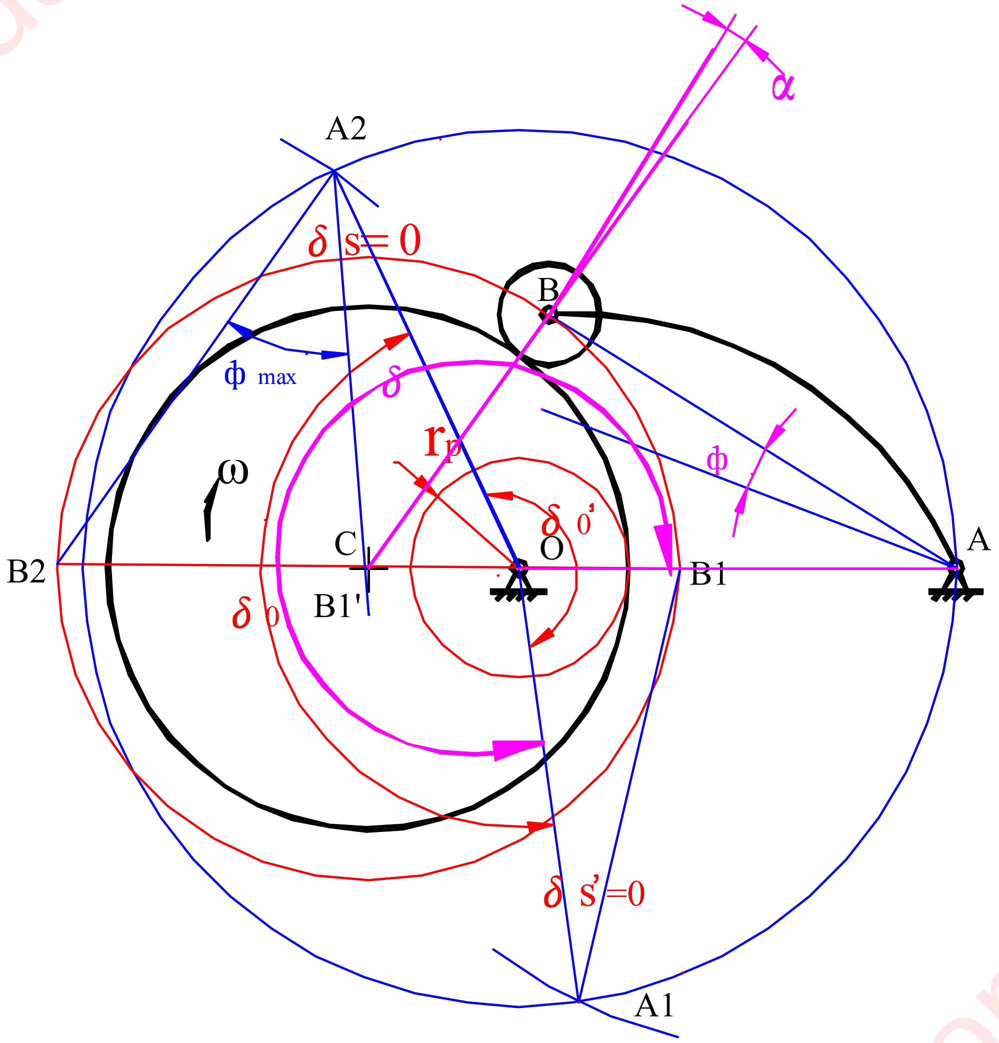
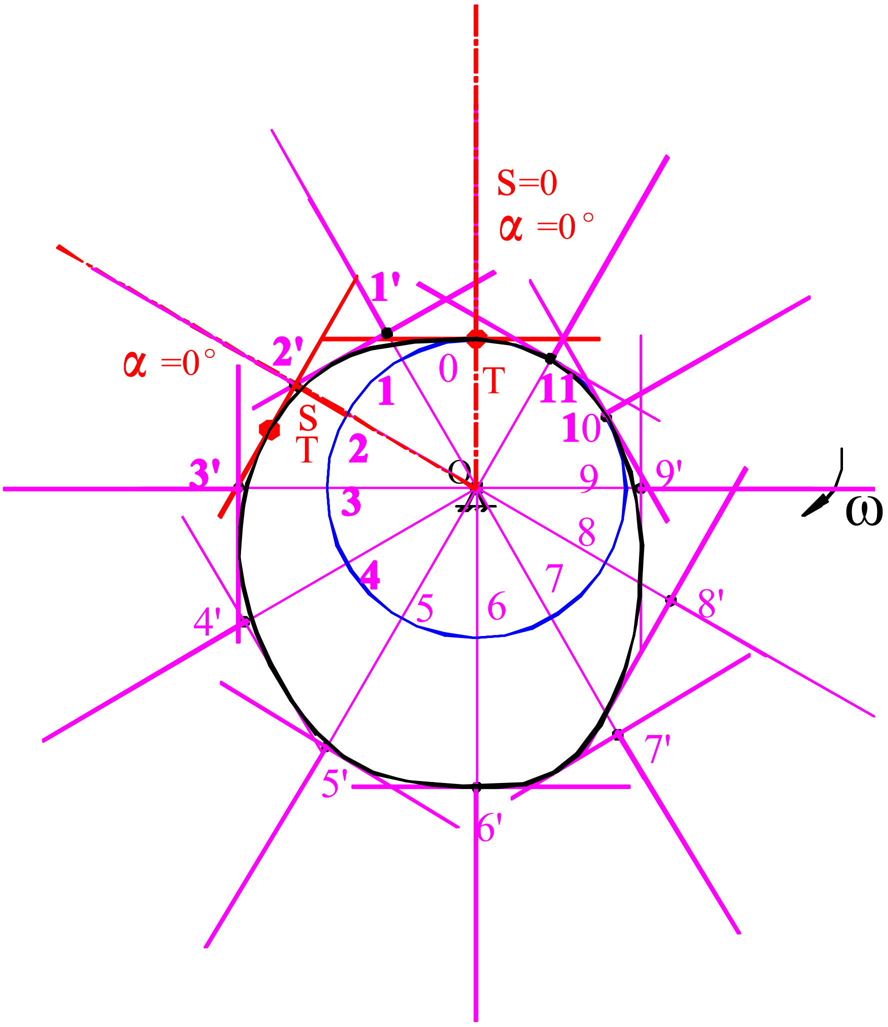


Fig5-4

Name______________Class_____Student No.__________Date____________

5-8 A plate cam with a translating flat-faced follower has the following motion: a rise through lift h=40mm with a sine acceleration motion curve during δ_0=150°, δ_S=30°, a return with a 3-4-5 polynomial motion curve during δ_0'=120° and δ_S'=60°. The cam rotates clockwise. And r_P=40mm. r_C=20mm. Construct the pitch curve and the cam contour graphically with a scale of 1:1. Label in red the follower centerline, S, the flat face, the tangent point T between the cam contour and α when δ=60° and δ=0°.

δ	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
S(mm)	0	7.86	15.72	23.58	31.44	40	40	35.86	20	4.14	0	0	0



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5-9 A plate cam with a translating flat-faced follower has the same motion curve and dimensions as exercise5-8 has. Write a program to calculate the co-ordinates of the pitch curve??, the cam contour and the locus of the center of the milling cutter and ρ_T.

```
LET M=-1
LET RP=40
LET H=40
LET RC=20
LET DELTA0=150*PI/180
LET DELTAS=30*PI/180
LET DELTA01=120*PI/180

SET WINDOW -90,90,-90,40
BOX CIRCLE -RP,RP,-RP,RP

FOR I= 0 TO 360 STEP 0.5
    LET DELTA=I*PI/180
    IF DELTA<=DELTA0 THEN
       LET D2=DELTA/DELTA0
       LET S=H*(D2-1/2/PI*SIN(2*PI*D2))
       LET S1=H/DELTA0*(1-COS(2*PI*D2))
       LET S11=2*PI*H/DELTA0^2*SIN(2*PI*D2)
    ELSEIF DELTA<=(DELTA0+DELTAS) THEN
       LET S=H
       LET S1=0
       LET S11=0
    ELSEIF DELTA<=(DELTA0+DELTAS+DELTA01) THEN
       LET D4=(DELTA-DELTA0-DELTAS)/DELTA01
       LET S=H*(1-10*D4^3+15*D4^4-6*D4^5)
       LET S1=-H/DELTA01*(30*D4^2-60*D4^3+30*D4^4)
       LET S11=-H/DELTA01^2*(60*D4-180*D4^2+120*D4^3)
    ELSE
       LET S=0
       LET S1=0
       LET S11=0
    END IF
```

```
    LET XB=M*(RP+S)*SIN(DELTA)
    LET YB=(RP+S)*COS(DELTA)
    LET XT=M*((RP+S)*SIN(DELTA)+S1*COS(DELTA))
    LET YT=(RP+S)*COS(DELTA)-S1*SIN(DELTA)
    LET XB11=+LOA*SIN(DELTA)+LAB*SIN(Q0+Q-DELTA)*(Q1-1)^2
            -LAB*COS(Q0+Q-DELTA)*Q11
    LET YB11=-LOA*COS(DELTA)+LAB*COS(Q0+Q-DELTA)*(Q1-1)^2
              +LAB*SIN(Q0+Q-DELTA)*Q11
    LET XT1=M*(S1*SIN(DELTA)+(RP+S)*COS(DELTA)+S11*COS(DELTA)-S1*SIN(DELTA))
    LET YT1=S1*COS(DELTA)-(RP+S)*SIN(DELTA)-(S11*SIN(DELTA)+S1*COS(DELTA))
    LET XC=XT-M*RC*YT1/SQR(YT1^2+XT1^2)
    LET YC=YT+M*RC*XT1/SQR(YT1^2+XT1^2)
    LET LOUT=RP+S+S11

    PLOT XB,YB
    PLOT XT,YT
NEXT I
END
```

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6-1 A pair of standard involute spur gears have a module of 5mm, pressure angle α=20°, center distance a=350mm, transmission ratio i_{12} =9/5. Calculate the numbers of teeth (Z_1 and Z_2), reference diameters (d_1 and d_2), addendum diameters (d_{a1} and d_{a2}), base diameters (d_{b1} and d_{b2}), tooth thickness s, spacewidth e, pressure angles on the addendum circles (α_{a1} and α_{a2}), the radii of curvatures of tooth profile on the reference circles (ρ_1 and ρ_2), and the radii of curvatures of tooth profile on the addendum circles (ρ_{a1} and ρ_{a2})..

解：

$$\left\{\begin{aligned} a &= \frac{d_1' + d_2'}{2} = 350mm \\ i_{12} &= \frac{d_2'}{d_1'} = \frac{9}{5} \end{aligned}\right. \Rightarrow \left\{\begin{aligned} d_1' &= 250mm \\ d_2' &= 450mm \end{aligned}\right.$$

$$d_1 = d_1' = 250mm$$

$$d_2 = d_2' = 450mm$$

$$z_1 = \frac{d_1}{m} = \frac{250}{5} = 50mm$$

$$z_2 = \frac{d_2}{m} = \frac{450}{5} = 90mm$$

$$d_{a1} = d_1 + 2h_a = d_1 + 2h_a^* m = 250 + 2*1*5 = 260mm$$

$$d_{a2} = d_2 + 2h_a = d_2 + 2h_a^* m = 450 + 2*1*5 = 460mm$$

$$d_{b1} = d_1 \cos\alpha = 250 * \cos 20^o = 234.92\ mm$$

$$d_{b2} = d_2 \cos\alpha = 450 * \cos 20^o = 422.86\ mm$$

$$s = e = \frac{p}{2} = \frac{\pi m}{2} = \frac{\pi * 5}{2} = 7.854mm$$

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6-2 How many teeth would an external standard involute spur gear has when its dedendum circle and its base circle coincide? Which one is bigger as the number of teeth increases ?

解：

$$d_a = d_b$$

$$d - 2h_a = d\cos\alpha$$

$$z - h_a^* = z\cos\alpha$$

$$z - h_a^* = z\cos\alpha$$

$$1 - \frac{2h_a^*}{z} = \cos\alpha$$

$$z = \frac{2h_a^*}{1-\cos\alpha} = \frac{2*1}{1-\cos 20^o} = 33.16$$

$$z \geq 34$$

If Z increases, then da is bigger.

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6-3 In Fig6-1 there are a pair of involute profiles C_1 and C_2 with the common normal n-n passing through the contact point K.

1) Draw the two base circles and two pitch circles. Label the theoretical line of action N_1N_2 and actual line of action B_1B_2. Label the working pressure angle α' and pressure angle α_K at the point K. Label the actual working section DG of the profile C_2.

2) Find out point M_2 on the profile C_2 that will engage with point M_1 on the profile 1.

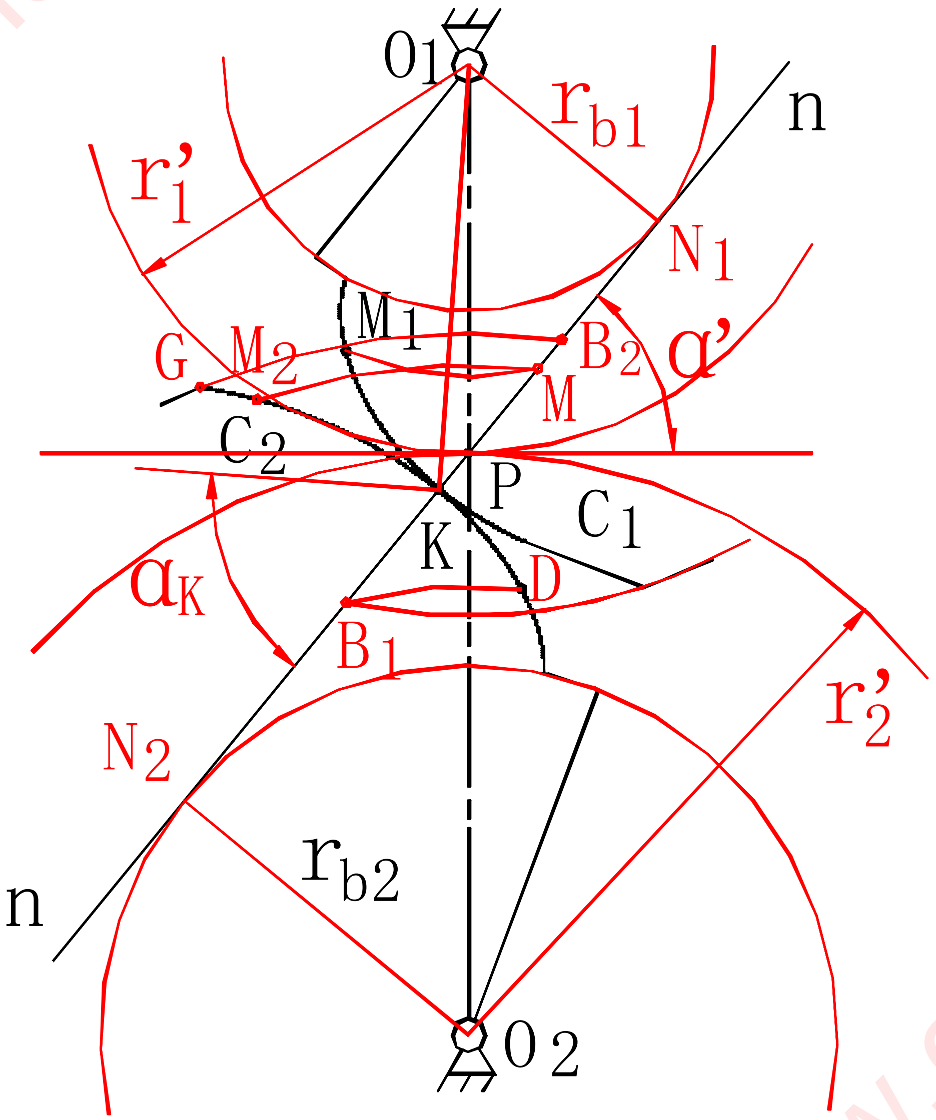

Fig6-1

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6-4 In Fig6-2 there are a pair of involute pinion and rack with their pitch circle and pitch line. Determine graphically the actual line of action B_1B_2, the actual working section EF on the tooth profile of the pinion and the actual working section GH on the tooth profile of the rack.

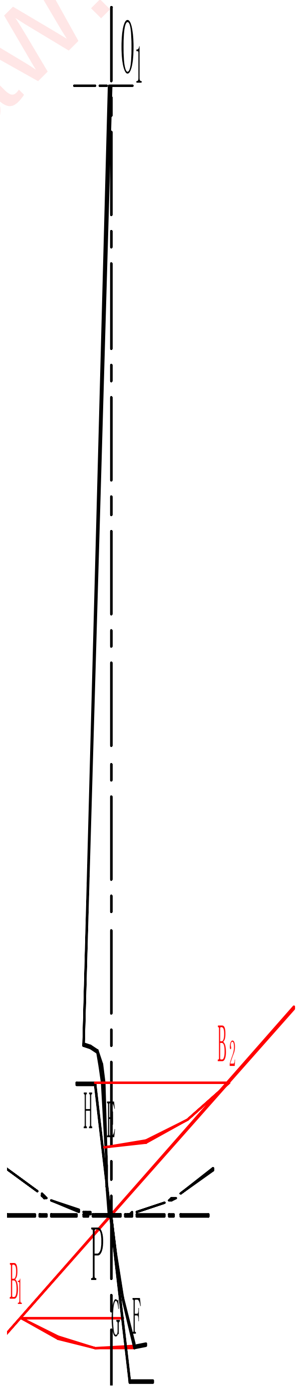

Fig6-2

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6-5 In a pair of external spur gears Z_1=10, Z_2=27, m=10mm, α=20°, ha*=1, c*=0.25, working center distance a'=185mm. Neither gear has cutter interference.

(1) What type of corrected gear pair does it belong to? Why?

(2) Calculate the ranges of modification coefficients x_1 and x_2, respectively.

(3) When x_1=0.5, calculate r_{a2}, r_{b2}, S_2, α_{a2}, and ρ_{a2} for gear 2.

解：（1）

$$a=\frac{m(z_1+z_2)}{2}=\frac{10\times(10+27)}{2}=185mm$$

$$a\cos\alpha=a'\cos\alpha'$$

$$\alpha'=20^0$$

$$inv\alpha'=\frac{2(x_1+x_2)\tan\alpha}{z_1+z_2}+inv\alpha$$

$x_1+x_2=0$为等变位齿轮

（2）

$$x_1\ge h_a^*-\frac{z_1\sin^2\alpha}{2}=1-\frac{10\times\sin^2 20^0}{2}=0.42$$

$$x_2\le -0.42$$

（3）

$$x_1=0.5$$

$$x_2=-0.5$$

$$r_{f1}=r_1-(h_a^*+c^*)m+x_1m=\frac{mz_1}{2}-(h_a^*+c^*)m+x_1m$$

$$=\frac{10\times10}{2}-(1+0.25)*\ 10+0.5*10=42.5mm$$

$$r_{a2}=a'-r_{f1}-c^*m=185-42.5-0.25\times10=140mm$$

$$r_{b2}=r_2\cos\alpha=\frac{mz_2}{2}\cos 20^0=\frac{10\times27}{2}\cos 20^0=126.86mm$$

$$s_2=\left(\frac{\pi}{2}+2x_2\tan\alpha\right)m=\left(\frac{\pi}{2}+2\times(-0.5)\tan 20^0\right)\times10=12.07mm$$

$$\alpha_{a2}=\arccos\frac{r_{b2}}{r_{a2}}=\arccos\frac{126.86}{140}=25.02^0=25^0 01' 20''$$

$$\rho_{a2}=\sqrt{r_{a2}^2-r_{b2}^2}=\sqrt{140^2-126.86^2}=59.22mm$$

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6-6 In a pair of external spur gears ,Z_1=20, Z_2=40, m=2mm, (ha*=1, c*=0.25,) α=20°, d_{f1}=37.0mm, S_2=2.413652185mm.

(1) Calculate the modification coefficients x_1 and x_2

(2) What type of corrected gear pair does it belong to? Why?

(3) Calculate r_{b1}, r_{a1}, α_{a1}, ρ_{a1}, S_1, and ρ_1 of gear 1.

解：（1）

$$r_{f1} = r_1 - \left(h_a^* + c^*\right)m + x_1 m = \frac{mz_1}{2} - \left(h_a^* + c^*\right)m + x_1 m = \frac{37.0}{2} = 18.5$$

$$x_1 = 0.5$$

$$s_2 = \left(\frac{\pi}{2} + 2x_2 \tan\alpha\right)m = 2.413652185mm$$

$$x_2 = -0.5$$

（2）

$\because x_1 + x_2 = 0 \therefore$ 为等变位齿轮

（3）

$$r_1 = \frac{mz_1}{2} = 20mm$$

$$r_{b1} = r_1 \cos\alpha = 20 \times \cos 20^0 = 18.79mm$$

$$r_{f2} = r_2 - \left(h_a^* + c^*\right)m + x_2 m = \frac{mz_2}{2} - \left(h_a^* + c^*\right)m + x_2 m$$

$$= \frac{2\times 40}{2} - (1+0.25)\times 2 - 0.5\times 2 = 36.5mm$$

$\because$ 这一对齿轮为等变位齿轮

$$\therefore d' = a = \frac{m}{2}\left(z_1 + z_2\right) = 60mm$$

$$r_{a1} = a' - r_{f2} - c^* m = 60 - 36.5 - 0.25\times 2 = 23mm$$

$$\alpha_{a1} = \arccos\frac{r_{b1}}{r_{a1}} = \arccos\frac{18.79}{23} = 35.22^0 = 35^0 13' 07''$$

$$\rho_{a1} = \sqrt{r_{a1}^2 - r_{b1}^2} = \sqrt{23^2 - 18.79^2} = 13.26mm$$

$$S_1 = \left(\frac{\pi}{2} + 2x_1 \tan\alpha\right)m = \left(\frac{\pi}{2} + 2\times 0.5\tan 20^0\right)\times 2 = 3.87mm$$

$$\rho_1 = \sqrt{r_1^2 - r_{b1}^2} = \sqrt{20^2 - 18.79^2} = 6.85mm$$

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6-7 There are a pair of external standard spur gears in a shaping machine with $Z_1=17$, $Z_2=118$, $m=5$mm, $\alpha=20°$, $h_a^*=1$, $c^*=0.25$. The pinion is worn out and the gear is worn to such an extent that the tooth thickness is decreased by 0.75mm. The gear is to be repaired by addendum modification and a new pinion is to be manufactured to mesh with the repaired gear.

(1) What is the minimum modification coefficient of the new pinion if the original frame is still used?

(2) When $x_1=0.3$, calculate r_{a1}, r_{f1}, S_1, α_{a1}, ρ_{a1}, and ε_α.

解：（1）

$$s_2=\left(\frac{\pi}{2}+2x_2\tan\alpha\right)m=\frac{\pi}{2}m-0.75$$

$$x_2=-0.21\Rightarrow x_{2\max}=-0.21$$

$$\because a=a' \therefore \text{此对齿轮为等变位齿轮}$$

$$x_1+x_2=0\Rightarrow x_{1\min}=0.21$$

（2）

$$x_1=0.3\Rightarrow x_2=-0.3$$

$$r_1=\frac{mz_1}{2}=42.5mm$$

$$r_2=\frac{mz_2}{2}=295mm$$

$$r_{b1}=r_1\cos\alpha=42.5\times\cos20^0=39.94mm$$

$$r_{b2}=r_2\cos\alpha=295\times\cos20^0=277.21mm$$

$$r_{f1}=r_1-\left(h_a^*+c^*\right)m+x_1m=42.5-(1+0.25)\times5+0.3\times5=37.75mm$$

$$r_{f2}=r_2-\left(h_a^*+c^*\right)m+x_2m=\frac{mz_2}{2}-\left(h_a^*+c^*\right)m+x_2m$$

$$=\frac{5\times118}{2}-(1+0.25)\times5-0.3\times5=287.25mm$$

$$\because \text{这一对齿轮为等变位齿轮} \therefore a'=a=\frac{m}{2}\left(z_1+z_2\right)=337.5mm$$

$$r_{a1}=a'-r_{f2}-c^*m=337.5-287.25-0.25\times5=49mm$$

$$r_{a2}=a'-r_{f1}-c^*m=337.5-37.75-0.25\times5=298.5mm$$

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$$\alpha_{a1} = \arccos\frac{r_{b1}}{r_{a1}} = \arccos\frac{39.94}{49} = 35.40^0 = 35^0 24'09''$$

$$\alpha_{a2} = \arccos\frac{r_{b2}}{r_{a2}} = \arccos\frac{277.21}{298.5} = 21.77^0 = 21^0 46'14''$$

$$\rho_{a1} = \sqrt{r_{a1}^2 - r_{b1}^2} = \sqrt{49^2 - 39.94^2} = 28.39mm$$

$$S_1 = \left(\frac{\pi}{2} + 2x_1 \tan\alpha\right)m = \left(\frac{\pi}{2} + 2\times 0.3\tan 20^0\right)\times 5 = 8.95mm$$

$$\varepsilon_\alpha = \frac{1}{2\pi}\left[z_1\left(\tan\alpha_{a1} - \tan\alpha'\right) + z_2\left(\tan\alpha_{a2} - \tan\alpha'\right)\right]$$

$$= \frac{1}{2\pi}\left[17\times\left(\tan 35.40^0 - \tan 20^0\right) + 118\times\left(\tan 21.77^0 - \tan 20^0\right)\right]$$

$$= 1.60$$

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6-8 In the gear train shown in Fig6-3, both gear pairs must have the same working center distance. Z_1=27, Z_2=60, $Z_{2'}$=63, Z_3=25, (ha*=1, c*=0.25,)m=5mm. The gear pair 2' and 3 is a corrected gear pair with reference center distance. The modification coefficient x_2 of the gear 2 is zero.

(1) What type of corrected gear pair should the gear pair 1 and 2 be? Give the brief reason.

(2) Is the gear 2 a standard gear? Why?

(3) Calculate x_1, S_1, r_{b1}, r_{f1}, α_{a1}, and ρ_{a1}.

解:

（1）

$$a'_{2'3}=a_{2'3}=\frac{m\left(z_{2'}+z_3\right)}{2}=\frac{5\times\left(63+25\right)}{2}=220mm$$

$$\alpha'_{2'3}=20^0$$

$$a'_{12}=a'_{2'3}=220mm, a_{12}=\frac{m\left(z_1+z_2\right)}{2}=217.5mm$$

$$\alpha'_{12}=\arccos\frac{a_{12}\cos\alpha}{a'_{12}}=21.72^0=21^0 43'12''$$

$$x_1+x_2=\frac{\left(inv\alpha'_{12}-inv\alpha\right)\cdot\left(z_1+z_2\right)}{2\tan\alpha}$$

$$=\frac{\left(0.019258-0.014904\right)\cdot\left(z_1+z_2\right)}{2\tan\alpha}=0.52$$

齿轮1和齿轮2为一对正传动齿轮。

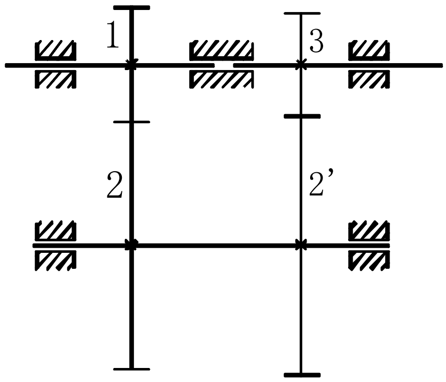

Fig6-3

（2）齿轮 2 不是标准齿轮。

$$\because a'_{12}=220mm>a_{12}=\frac{m\left(z_1+z_2\right)}{2}=217.5mm$$

齿轮 2 的齿全高与标准齿轮不同。

（3）

$$x_1=0.52-x_2=0.52$$

$$S_1=\left(\frac{\pi}{2}+2x_1\tan\alpha\right)m=\left(\frac{\pi}{2}+2\times0.52\times\tan 20^0\right)\times5=9.75mm$$

$$r_1=\frac{mz_1}{2}=67.5mm$$

$$r_{b1}=r_1\cos\alpha=67.5\times\cos 20^0=63.43mm$$

$$r_{f1}=r_1-\left(h_a^*+c^*\right)m+x_1m=67.5-(1+0.25)\times 5+0.52\times 5=63.85mm$$

$$r_2=\frac{mz_2}{2}=150mm$$

$$r_{b2}=r_2\cos\alpha=150\times\cos 20^0=140.95mm$$

$$r_{f2}=r_2-\left(h_a^*+c^*\right)m+x_2m$$

$$=150-(1+0.25)\times 5+0\times 5=143.75mm$$

$$r_{a1}=a_{12}'-r_{f2}-c^*m=220-143.75-0.25\times 5=75mm$$

$$\alpha_{a1}=\arccos\frac{r_{b1}}{r_{a1}}=32.25^0=32^0 14'58''$$

$$\rho_{a1}=\sqrt{r_{a1}^2-r_{b1}^2}=\sqrt{75^2-63.43^2}=40.02mm$$

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6-9 The parameters of a pair of external spur gear such as m, Z_1, i_{12}, α, h_a^*, c^*, S_1, and r_{f2}.s are known: Write all formulae to calculate ε_α according to calculation step.

解：

$$z_2 = i_{12} z_1$$

$$r_1 = \frac{m z_1}{2}, r_2 = \frac{m z_2}{2}$$

$$r_{b1} = r_1 \cos\alpha, r_{b2} = r_2 \cos\alpha$$

$$r_{f2} = r_2 - \left(h_a^* + c^*\right) m + x_2 m \Rightarrow x_2$$

$$S_1 = \left(\frac{\pi}{2} + 2x_1 \tan\alpha\right) m \Rightarrow x_1$$

$$r_{f1} = r_1 - \left(h_a^* + c^*\right) m + x_1 m$$

$$inv\alpha' = \frac{2\left(x_1 + x_2\right)\tan\alpha}{z_1 + z_2} + inv\alpha \Rightarrow \alpha'$$

$$a = \frac{m}{2}\left(z_1 + z_2\right), a' = \frac{a\cos\alpha}{\cos\alpha'}$$

$$r_{a1} = a' - r_{f2} - c^* m, r_{a2} = a' - r_{f1} - c^* m$$

$$\alpha_{a1} = \arccos\frac{r_{b1}}{r_{a1}}, \alpha_{a2} = \arccos\frac{r_{b2}}{r_{a2}}$$

$$\varepsilon_\alpha = \frac{1}{2\pi}\left[z_1\left(\tan\alpha_{a1} - \tan\alpha'\right) + z_2\left(\tan\alpha_{a2} - \tan\alpha'\right)\right]$$

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6-10 In a pair of standard external helical gears Z_1 =20, Z_2 =40, m_n =8mm, α_n =20°, h_{an}^*=1，？？ c^*=0.25, B=30mm, a=250mm. Find the helix angle β, total contact ratio ε_γ and the virtual numbers of teeth Z_{v1}, Z_{v2}.

解：

$$\beta = \arccos\frac{m_n\left(z_1+z_2\right)}{2a} = \arccos\frac{8\times\left(20+40\right)}{2\times 250} = 16.26^0 = 16^0 15'37''$$

$$\alpha_t' = arctg\frac{\tan\alpha_n}{\cos\beta} = 20.76^0 = 20^0 45'49''$$

$$r_1 = \frac{m_n z_1}{2\cos\beta} = 83.333mm, r_2 = \frac{m_n z_2}{2\cos\beta} = 166.667mm$$

$$r_{b1} = r_1\cos\alpha = 78.31mm, r_{b2} = r_2\cos\alpha = 156.62mm$$

$$r_{a1} = r_1 + h_{an}^* m_n = 91.333mm, r_{a2} = r_2 + h_{an}^* m_n = 174.667m$$

$$\alpha_{at1} = \arccos\frac{r_{b1}}{r_{a1}} = 30.97^0, \alpha_{at2} = \arccos\frac{r_{b2}}{r_{a2}} = 26.27^0$$

$$\varepsilon_\alpha = \frac{1}{2\pi}\left[z_1\left(\tan\alpha_{at1} - \tan\alpha_t'\right) + z_2\left(\tan\alpha_{at2} - \tan\alpha_t'\right)\right]$$

$$= 1.433$$

$$\varepsilon_\beta = \frac{B\sin\beta}{\pi m_n} = 0.334$$

$$\varepsilon_\gamma = \varepsilon_\alpha + \varepsilon_\beta = 1.77$$

$$z_{v1} = \frac{z_1}{\cos^3\beta} = 22.61$$

$$z_{v2} = \frac{z_2}{\cos^3\beta} = 45.21$$

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6-11 A pair of standard external helical gears with transmission ratio i≈3.5 is to be designed. According to the strength calculation, m_n=2.5mm, a_{min}=111.5mm. Find a integral center distance a and corresponding Z_1, Z_2, the helix angle β .

解：

$$\text{取}a = 115mm$$

$$\text{初选}\beta = 15^0$$

$$z_1 = \frac{2a\cos\beta}{m_n(1+i)} = \frac{2\times115\times\cos15^0}{2.5\times4.5} = 19.74$$

$$\text{取}z_1 = 20$$

$$z_2 = 70$$

$$\beta = \arccos\frac{m_n(z_1+z_2)}{2a} = \arccos\frac{2.5\times(20+70)}{2\times115} = 11.97^0 = 11^0 58' 07''$$

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6-12 The number of the teeth of a standard worm wheel Z_2 is 40, reference diameter d_2=320mm. It meshes with a single-threaded worm.

(1) Determine module of the worm gear on the mid-plane m_{t2} and m_{x1};

(2) Determine axial pitch p_{x1} and lead l of the worm;

(3) Choose reference diameter of worm;

(4) Calculate lead angle λ_1 of the worm;

(5) Calculate center distance a without modification.

解：

（1）

$$m_{t2} = \frac{d_2}{z_2} = 8mm$$

$$m_{x1} = m_{t2} = 8mm$$

（2）

$$p_{x1} = \pi m_{x1} = 15.13mm$$

$$l = p_{x1} = 15.13mm$$

（3）

$$d_1 = 80mm$$

（4）

$$\lambda_1 = arctg\frac{m_{x1} z_1}{d_1} = arctg\frac{8}{80} = 5.71^0 = 5^0 42' 38''$$

（5）

$$a = \frac{d_1}{2} + \frac{d_2}{2} = 40 + 160 = 200mm$$

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6-13 In a pair of straight bevel gears Z_1 =15, Z_2 =30, m=5mm, h_a^*=1, c^*=0.2, $\sum$ =90° .Calculate d_1, d_2, d_{a1}, d_{a2}, d_{f1}, d_{f2}, δ_1, δ_2, δ_{a1}, δ_{a2}, δ_{f1}, δ_{f2}, R, Z_{v1} and Z_{v2} when bottom clearance is constant.

解：

$$\delta_2 = arctg(\frac{z_2}{z_1}) = arctg\,2 = 63.43^0 = 63^0 26'20''$$

$$\delta_1 = 90^o - \delta_2 = 26.57^0 = 26^0 33'40''$$

$$d_1 = mz_1 = 5*15 = 75mm$$

$$d_2 = mz_2 = 5*30 = 150mm$$

$$d_{a1} = d_1 + 2h_a^* m\cos\delta_1 = 83.944mm$$

$$d_{a2} = d_2 + 2h_a^* m\cos\delta_2 = 154.316mm$$

$$d_{f1} = d_1 - 2(h_a^* + c^*)m\cos\delta_1 = 64.267\,mm$$

$$d_{f2} = d_2 - 2(h_a^* + c^*)m\cos\delta_2 = 144.633mm$$

$$R = \frac{1}{2}\sqrt{d_1^2 + d_2^2} = 83.85\,mm$$

$$\theta_a = \theta_f = arctg(\frac{h_f}{R}) = arctg(\frac{(h_a^* + c^*)m}{R}) = 4.09^0 = 4^0 5'34''$$

$$\delta_{a1} = \delta_1 + \theta_a = 30.66^0 = 30^0 39'14''$$

$$\delta_{a2} = \delta_2 + \theta_a = 68.52^0 = 67^0 31'54''$$

$$\delta_{f1} = \delta_1 - \theta_f = 22.48^0 = 22^0 28'6''$$

$$\delta_{f2} = \delta_2 - \theta_f = 59.34^0 = 59^0 20'46''$$

$$z_{v1} = \frac{z_1}{\cos\delta_1} = 16.77$$

$$z_{v2} = \frac{z_2}{\cos\delta_2} = 67.07$$

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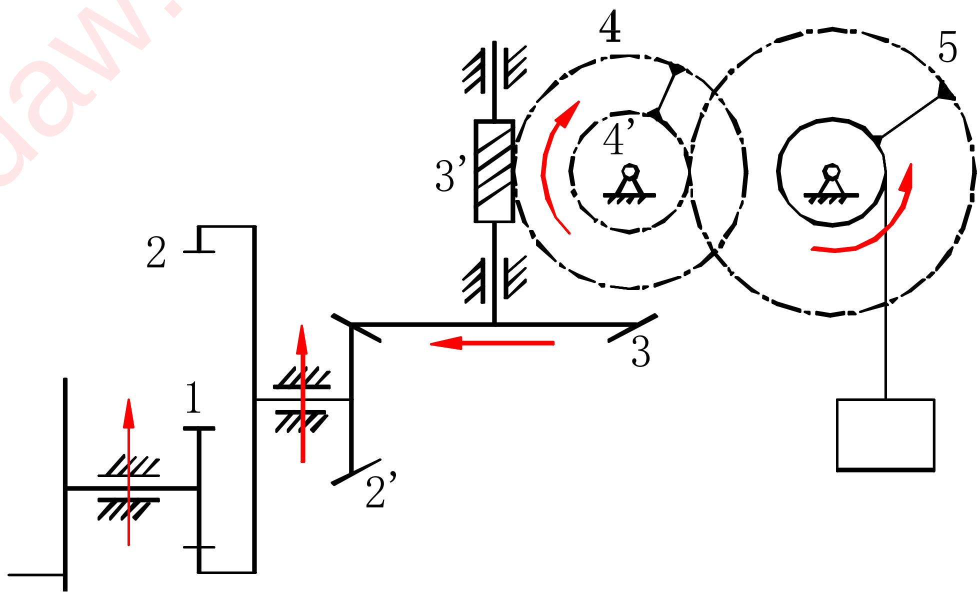
7-1 A hoist is shown in Fig7-1. The teeth numbers of all the gears is listed as follows, Z_1=20, Z_2=50, $Z_{2'}$=15, Z_3=30, $Z_{3'}$=1, Z_4=40, $Z_{4'}$=18, Z_5=52. Find the train ratio i_{15} and point out the rotating direction of the handle to raise the weight.



解：

$$i_{15}=\frac{Z_2Z_3Z_4Z_5}{Z_1Z_{2'}Z_{3'}Z_{4'}}=\frac{50*30*30*52}{20*15*1*18}=\frac{1300}{3}=433.3$$

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7-2 The gear train in a clock is shown in Fig7-2. S, M and H denote the pointers of second, minute and hour, respectively. ?All gears in Fig7-2 are standard spur gears. In this gear train $Z_1=Z_{2'}=8$, $Z_2=64$, $Z_{3'}=12$, $Z_{4'}=15$. If the modules of gear 4 and gear 5 are equal, find the numbers of teeth Z_3, Z_4, and Z_5.

解：

$$\because i_{13}=\frac{z_2\bullet z_3}{z_1\bullet z_2'}=\frac{n_S}{n_M}=60$$

$$\therefore z_3=\frac{60z_1\bullet z_2'}{z_2}=\frac{60*8*8}{64}=60$$

$$i_{3'5}=\frac{z_4\bullet z_5}{z_3'\bullet z_4'}=\frac{n_M}{n_H}=12$$

$$\because m_4=m_5$$

$$\therefore m_{3'}=m_4=m_{4'}=m_5$$

$$\because a_{3'4}=a_{4'5}$$

$$\therefore z_{3'}+z_4=z_{4'}+z_5$$

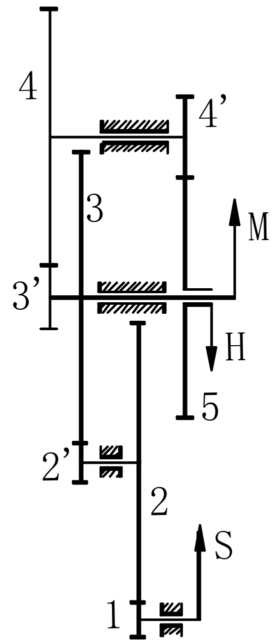

Fig7-2

$$\begin{cases} z_4=48 \\ z_5=45 \end{cases}$$

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7-3 Shown in Fig7-3 is a gear train in which gear 3 engages with gears 2 and 4 simultaneously. What kind of gear train is it? If Z_1=34, Z_2=Z_3=20, Z_4=74, find the train ratio i_{1H}.

解：1,4,2——3,H 组成一差动轮系，得：

$$i_{14}^{H}=\frac{n_1-n_H}{n_4-n_H}=-\frac{z_2\bullet z_3\bullet z_4}{z_1\bullet z_2\bullet z_3}=-\frac{37}{17}$$

$$\because n_4=0$$

$$\therefore i_{1H}=\frac{n_1}{n_H}=1+\frac{37}{17}=\frac{54}{17}$$

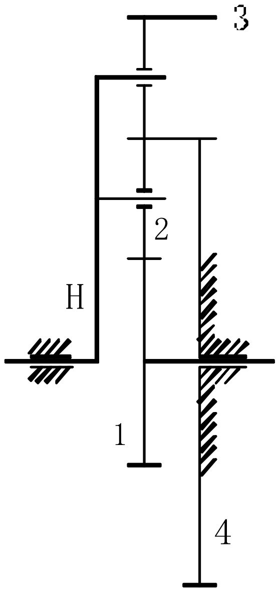

Fig7-3

Name______________Class_____Student No.__________Date____________

7-4 In a differential gear train shown in Fig7-4 , Z_1=15, Z_2=25, $Z_{2'}$=20, Z_3=60, n_1=200 r/min, n_3=50 r/min. Find both the magnitude and the direction of n_H when

(1) n_1 and n_3 are in the same direction;

(2) n_1 and n_3 are in the opposite directions.

解：此轮系为一差动轮系

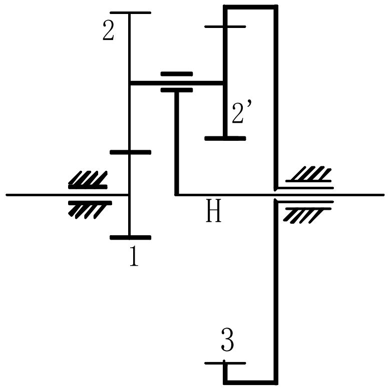

Fig7-4

$$i_{13}^{H}=\frac{n_1-n_H}{n_3-n_H}=-\frac{z_2\bullet z_3}{z_1\bullet z_{2}^{'}}=-\frac{25*60}{15*20}=-5$$

(1)

$$n_1=200r/\min，\ n_3=50r/\min$$

$$n_H=\frac{n_1+5n_3}{6}=\frac{200+5*50}{6}=75r/\min$$

$\therefore H$的转速为75r/min,方向与1轮转向相同。

（2）

$$n_1=200r/\min，\ n_3=-50r/\min$$

$$n_H=\frac{n_1+5n_3}{6}=\frac{200-5*50}{6}=-8.33r/\min$$

$\therefore H$的转速为8.33r/min,方向与1轮转向相反。

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7-5 In the combined gear train shown in Fig7-5, Z_1=36, Z_2=60, $Z_{2'}$=23, Z_3=49, $Z_{3'}$=69, Z_4=31, Z_5=131, Z_6=94, Z_7=36, Z_8=167, n_1=3549 r/min. Find both the magnitude and the direction of n_H.

解：

1,2,2’,3 组成一定轴轮系，得

$$i_{14}=\frac{n_1}{n_3}=\frac{z_2\bullet z_3}{z_1\bullet z_{2'}}=\frac{60*49}{36*23}$$

$$\therefore n_3=\frac{6*507*23}{70}$$

$$n_3^{'}=n_3$$

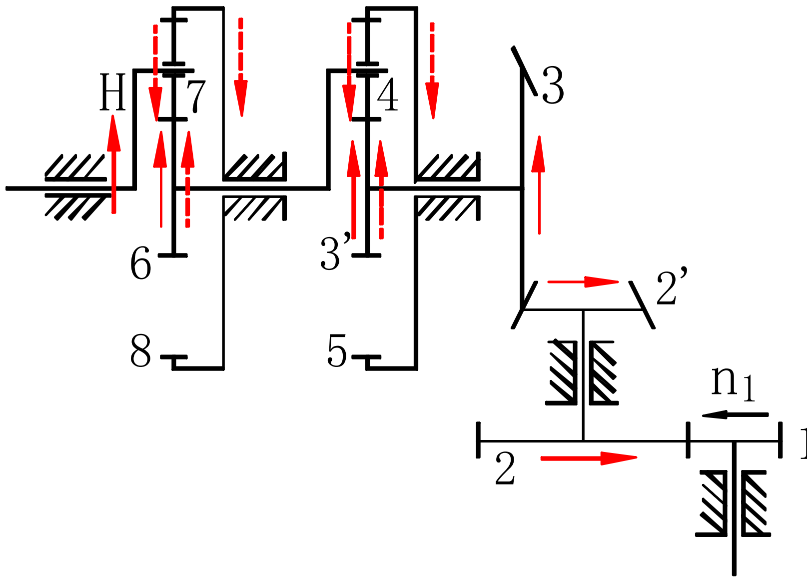

Fig7-5

3’,4,5,6 组成一行星轮系，得：

$$i_{3'5}^{6}=\frac{n_{3'}-n_6}{n_5-n_6}=-\frac{z_5}{z_{3'}}$$

$$=-\frac{131}{69}$$

$$\because n_5=0\ \therefore n_6=\frac{69}{200}n_3^{'}$$

6,7,8,H组成一行星轮系，得：

$$i_{68}^{H}=\frac{n_6-n_H}{n_8-n_H}=-\frac{z_8}{z_6}=-\frac{167}{94}$$

$$\because n_8=0$$

$$\therefore n_H=\frac{94}{261}n_6$$

$$\therefore n_H=\frac{94}{261}*\frac{69}{200}*\frac{6*507*23}{70}=1.77r/\min$$

转向如图所示。

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7-6 In the combined gear train shown in Fig7-6, Z_1=20, Z_2=25, Z_3=15, $Z_{1'}$=30, Z_4=70, $Z_{4'}$=60, n_H=110 r/min. Find both the magnitude and the direction of n_1.

解：

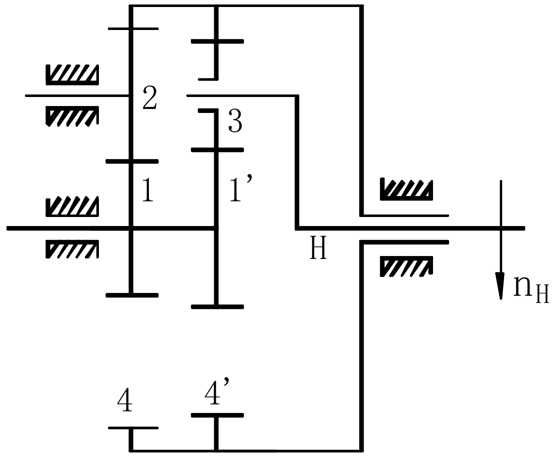

Fig7-6

$1',4',3,H$组成一差动轮系

$$i_{1'4'}^{H}=\frac{n_{1'}-n_H}{n_{4'}-n_H}=-\frac{z_{4'}}{z_{1'}}=-\frac{60}{30}=-$$

$$n_{1'}=-2n_{4'}+3n_H=-2n_{4'}+330$$

$$n_1=n_{1'}$$

$$n_4=n_{4'}$$

$1,2,4$组成定轴轮系

$$i_{14}=\frac{n_1}{n_4}=\frac{z_4\cdot z_2}{z_2\cdot z_1}=\frac{z_4}{z_1}=\frac{7}{2}$$

$$\therefore n_1=210r/\min$$

$$n_4=60r/\min$$

$$n_{1'}=-2n_{4'}+3n_H=-2\times60+330$$

$$=210r/\min$$

1轮转向与n_H的转向相同。

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7-7 In the combined gear train shown in Fig7-7, $Z_1= Z_5= Z_6=17$, $Z_2=27$, $Z_{2'}=18$, $Z_3=34$, $Z_4=51$. $n_1=110$ r/min. Find both the magnitude and the direction of n_6.

解：

1,3,2—2′,6 组成一差动轮系，得

$$i_{13}^{6}=\frac{n_1-n_6}{n_3-n_6}=-\frac{z_2 \bullet z_3}{z_1 \bullet z_2^{'}}$$

$$=-\frac{27*34}{17*18}=-3$$

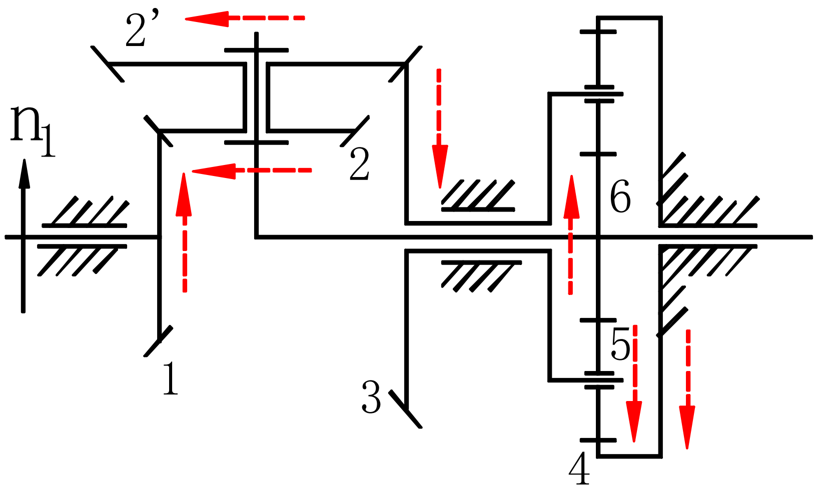

Fig7-7

6,4,5,3 组成一行星轮系，得：

$$i_{46}^{3}=\frac{n_4-n_3}{n_6-n_3}=-\frac{z_6}{z_4}$$

$$=-\frac{17}{51}=-\frac{1}{3}$$

$$\because n_4=0$$

$$\therefore n_3=\frac{n_6}{4}$$

$$\therefore i_{16}=\frac{n_1}{n_6}=\frac{13}{4}=3.25$$

$$n_6=\frac{n_1}{3.25}=\frac{110}{3.25}=33.85r/\min$$

转向1轮转向相同。

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7-8 In a gear train shown in Fig7-8 , Z_1=6, Z_2= $Z_{2'}$ =25, Z_3=57, Z_4=56. Find the train ratio i_{14}.

解：

1,3,2,H组成一行星轮系，得：

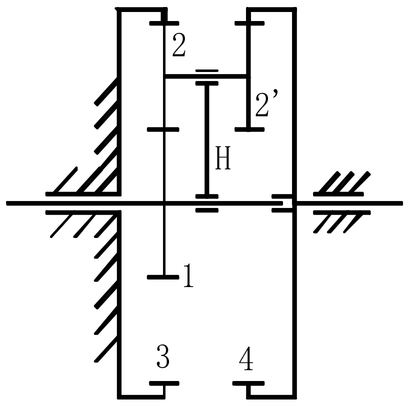

Fig7-8

$$i_{13}^H = \frac{n_1 - n_H}{n_3 - n_H} = -\frac{z_2 \cdot z_3}{z_1 \cdot z_2} = -\frac{57}{6} = -\frac{19}{2}$$

$$\because n_3 = 0$$

$$\therefore n_H = \frac{2}{21} n_1$$

1,4,2—2′,H 组成一差动轮系，得：

$$i_{14}^H = \frac{n_1 - n_H}{n_4 - n_H} = -\frac{z_2 \cdot z_4}{z_1 \cdot z_2'}$$

$$\because z_2 = z_2'$$

$$\therefore i_{14}^H = -\frac{56}{6} = -\frac{28}{3}$$

$$i_{14} = \frac{n_1}{n_4} = -588$$

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7-9 In the gear train shown in Fig7-9, Z_2=15, n_{MH}=12rpm, n_H=－2rpm. Calculate Z_{1}.

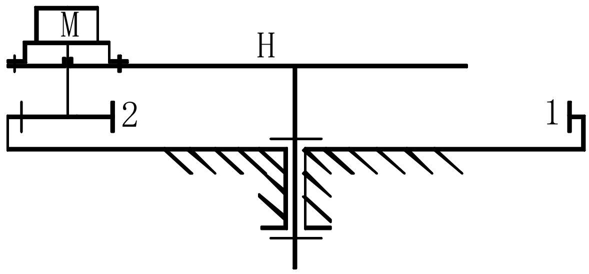

Fig7-9

解：

给整个机构以$-n_H$

得一定轴轮系：

$$i_{12}^H = \frac{n_1 - n_H}{n_2 - n_H} = \frac{z_2}{z_1} = \frac{15}{z_1}$$

$$= \frac{n_1 - n_H}{n_M^H} = \frac{2}{12}$$

$$\therefore z_1 = 90$$

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7-10 In the gear train shown in Fig.7-10, Z_1=20 and i_{1H}=4.5. All the gears are standard spur gears with h_a^*=1.

（1）Determine the numbers of teeth Z_2 and Z_3 and the number of planet gears k.??

（2）If the mechanical efficiency of every pair of gears is η=0.9, find the mechanical efficiency of the gear train η_{1H}.

解：

（1）1,3,2,H 组成一行星轮系，得：

$$i_{13}^H = \frac{n_1 - n_H}{n_3 - n_H} = -\frac{z_3}{z_1}$$

$$\because n_3 = 0, i_{1H} = 4.5$$

$$\therefore \frac{n_1}{n_H} = 1 + \frac{z_3}{z_1} = 4.5$$

$$z_3 = 70$$

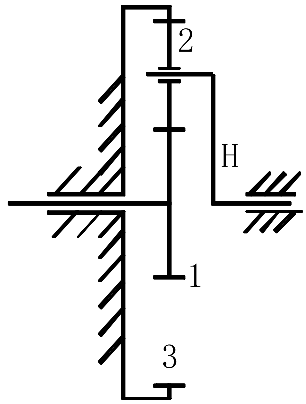

Fig7-10

$$a_{12} = r_3 - r_2$$

由于所有齿轮皆为标准齿轮且1、2，2、3之间相互啮合

$$\therefore \frac{m(z_1 + z_2)}{2} = \frac{m(z_3 - z_2)}{2}$$

$$z_2 = \frac{z_3 - z_1}{2} = 25$$

$$k = \frac{z_1 + z_3}{N} = \frac{90}{N}$$

$$\because (z_1 + z_2)\sin\frac{180^0}{k} > z_2 + 2h_a^*$$

$$\therefore k < 4.9$$

（2）

$$N_1^H = N_1\left(1 - i_{H1}\right) = M_1\varpi_1\left(1 - i_{H1}\right) \approx 0.78 M_1\varpi_1 > 0$$

$$\eta_{1H} = \frac{N_1 - N_f}{N_1} = 1 - \left|1 - i_{H1}\right|\left(1 - \eta_{13}^H\right)$$

$$\eta_{13}^H =$$

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9-1 In the cam-linkage shown in Fig9-1, the driving rotary block 1 rotates continuously. By designing the contour of the fixed cam correctly, the sliding block 4 can be given a predetermined motion.

(1)Analyze the motion transmission route and draw its structural block diagram.
(2)Identify the combination pattern of the combined mechanism.

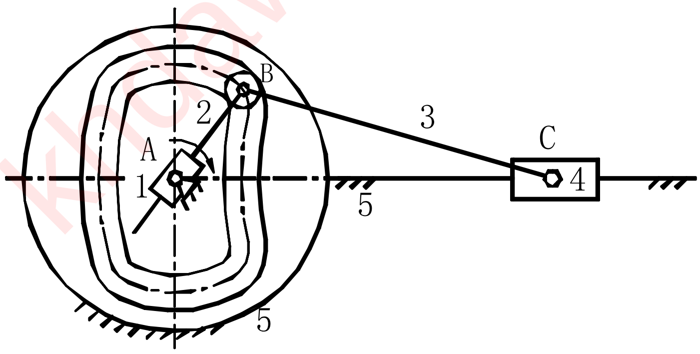
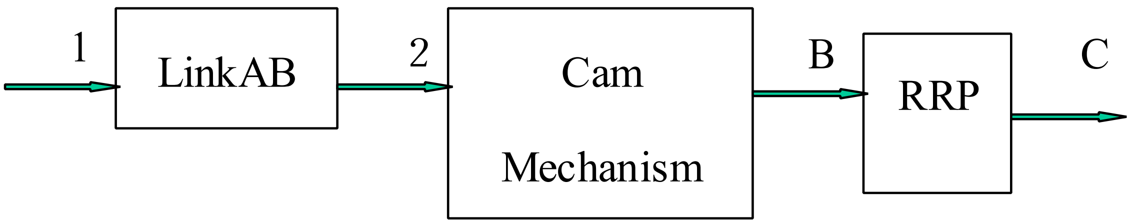


Fig9-1

解：（1）



（2）此机构为串联机构。

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9-2 In the combined gear train shown in Fig9-2, the gear 1 is the driver, the link 6 is an output.

(1) Analyze the motion transmission route and draw its structural block diagram.

(2) Identify the combination pattern of the combined mechanism.

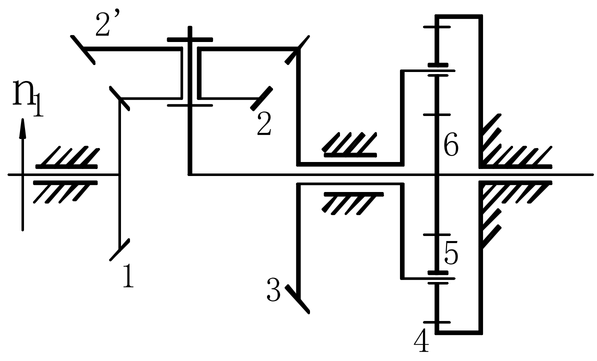
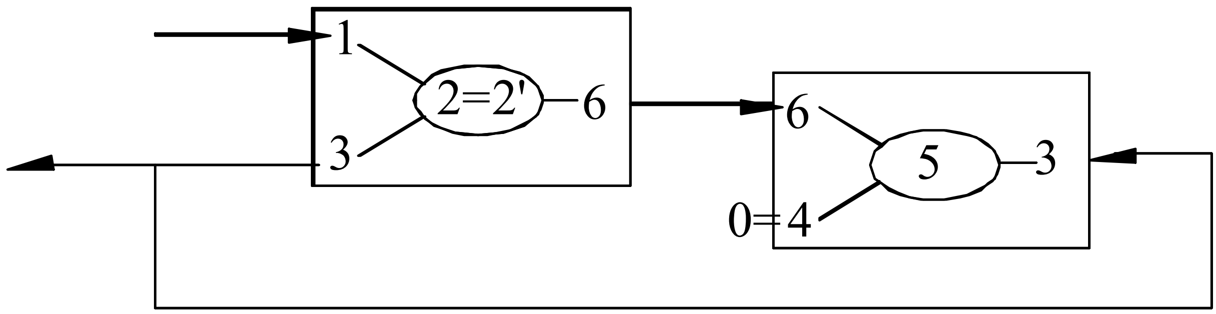


Fig9-2

解：（1）



（2）所以此组合机构为反馈式的。

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9-3 In the gear-linkage shown in Fig9-3, the crank AB is a driver. The output pinion 4 is located on the shaft A.

(1) Analyze the motion transmission route and draw its structural block diagram.

(2) Identify the combination pattern of the combined mechanism.

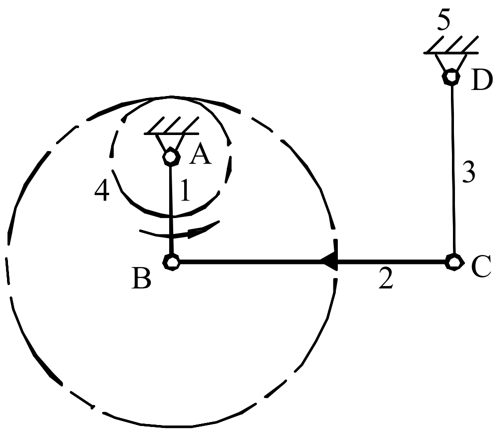
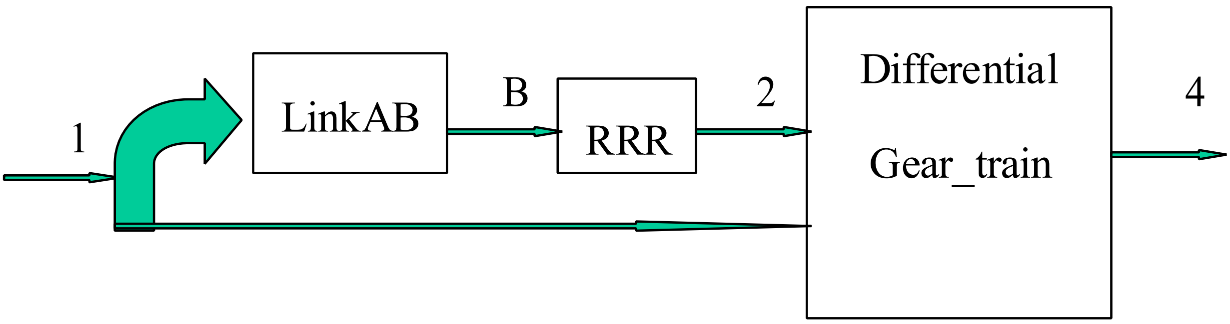


Fig9-3

解：（1）



（2）所以此组合机构为并联的。

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9-4 In the kinematic chain shown in Fig.9-4, if the driver is the link 3 instead of the gear 1, while the gear 5 is still an output gear.

(1) Analyze the motion transmission route and draw its structural block diagram.

(2) Identify the combination pattern of the combined mechanism.

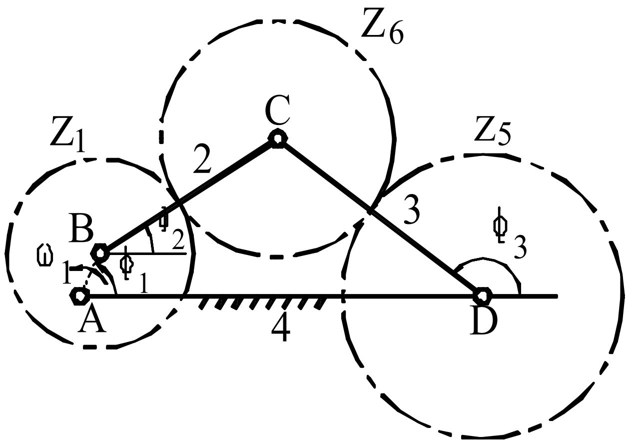
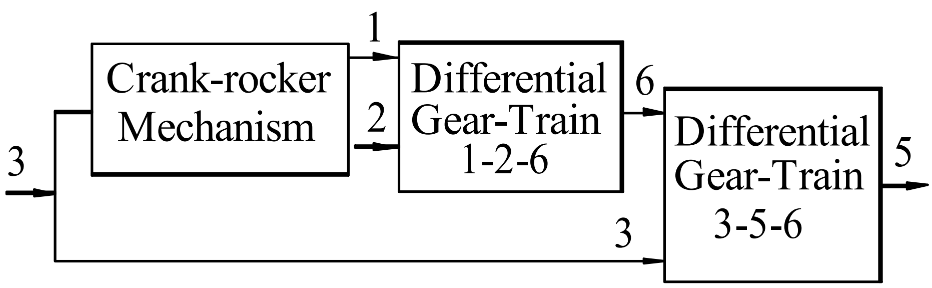


Fig9-4

解：

（1）



（2）所以此组合机构为并联的。

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10-1 There are four imbalances in a disk-like rotor shown in Fig10-1. The masses, rotating radii and angular orientations are listed as follows, m_1=8kg, m_2=10kg, m_3=8kg and m_4=7kg, r_1=10mm, r_2=10mm, r_3=15mm and r_4=20mm. The rotor is to be balanced by removing a mass m_C at a rotating radius of 25mm. Find the magnitude m_C and its location angle θ_C.

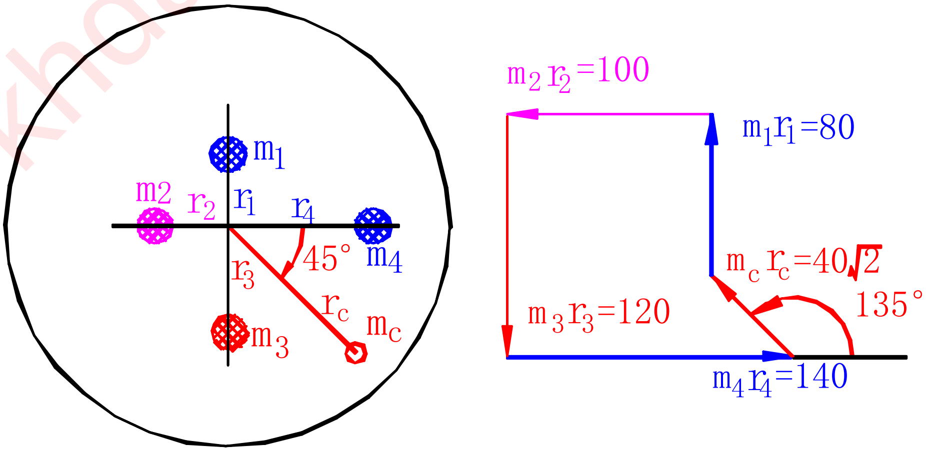

Fig10-1

解：如图所示得

$$m_c r_c = 40\sqrt{2} Kg \cdot mm$$

$$\because r_c = 25mm$$

$$\therefore m_c = 40\sqrt{2} / 25 = 2.26Kg$$

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10-2 Among the following rotors shown in Fig10-1, rotors a, b, c, d____are statically balanced, rotors ____b, c,______ are dynamically balanced.

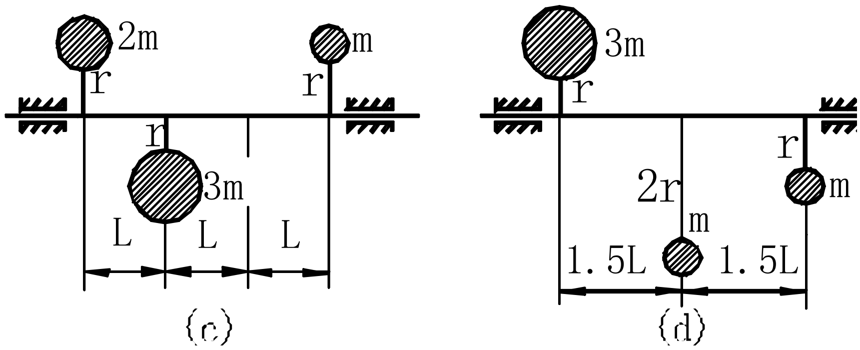

Fig10-2

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10-3 On a circular rotating disk shown in Fig10-3, there are two circular holes. d_1=40mm, d_2=50mm. The rotating radiis of the hole centers r_1 r_2 are 100mm and 140mm, respectively. The location of the two holes are shown in Fig10-3. The disk is to be balanced by drilling the third hole. The rotating radius of the third hole center is to be r_3=150mm. Find the diameter d_3 and its location angle θ_3.

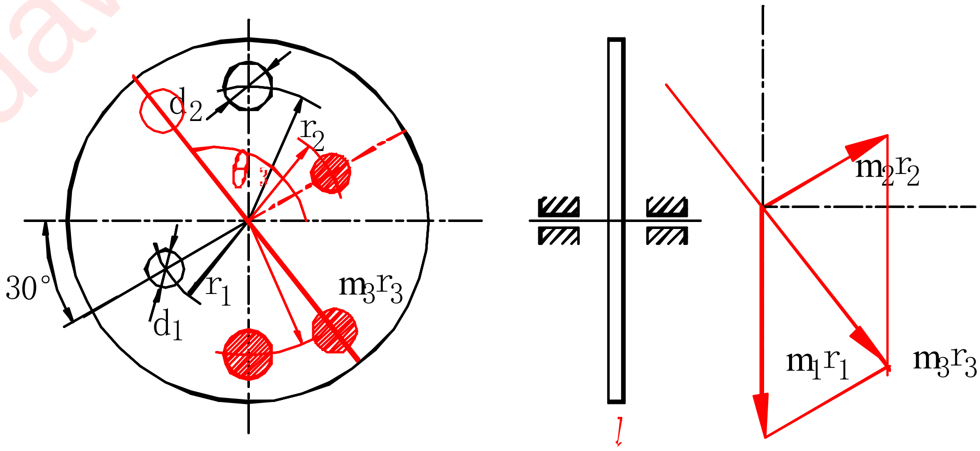

Fig10-3

解：如图所示，在 1、2 两位置挖孔相当于在圆盘对应位置有两个配重。

$$m_1 r_1 = \rho \frac{\pi}{4} d_1^2 l = \rho \frac{\pi}{4} l d_1^2 = 1600 \rho \frac{\pi}{4} l = 1600c$$

$$m_2 r_2 = \rho \frac{\pi}{4} d_2^2 l = \rho \frac{\pi}{4} l d_2^2 = 2500 \rho \frac{\pi}{4} l = 1600c$$

c为一常数。

$$m_3 r_3 = \sqrt{\left(\sum \mathrm{m_i} r_i \cos\theta_i\right)^2 + \left(\sum \mathrm{m_i} r_i \sin\theta_i\right)^2}$$

$$= \sqrt{(1600c \cos 30^o + 2500c \cos 270^o)^2 + (1600c \sin 30^o + 2500c \sin 270^o)^2}$$

$$= 2193c$$

$$d_3 = \sqrt{2193} = 46.83mm$$

$$\theta_3 = tg^{-1}\left(\frac{-\sum m_i r_i \sin\theta_i}{-\sum m_i r_i \cos\theta_i}\right) = tg^{-1}\left(\frac{17}{-8\sqrt{3}}\right) = -50.82^0$$

$$\because -\sum m_i r_i \sin\theta_i > 0, -\sum m_i r_i \cos\theta_i < 0$$

$$\theta_3 = 129.18^0 = 129^0 10' 58''$$

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10-4 Four unbalanced masses m_1, m_2, m_3 and m_4 is on four transverse planes spaced equally and parallel. Their mass-radius products are listed as follows: m_1r_1=3kgmm, m_2r_2=2kgmm, m_3r_3=5kgmm, and m_4r_4=4kgmm. Their locations are shown in Fig10-4. Suppose the system is to be balanced fully by two balancing mass-radius products, P_{b1} and P_{b3}, on the planes I and III, respectively. Determine the amounts and angular locations of the two balancing mass-radius products.

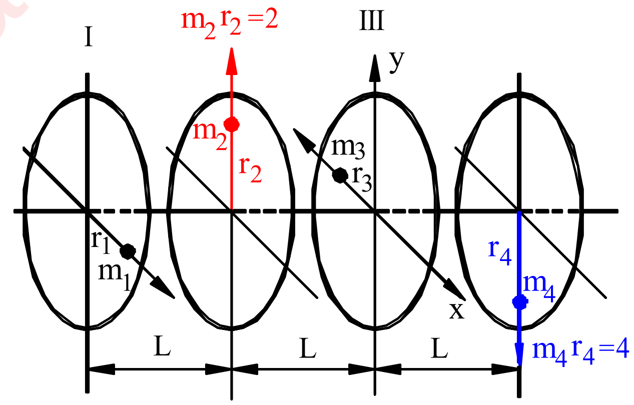
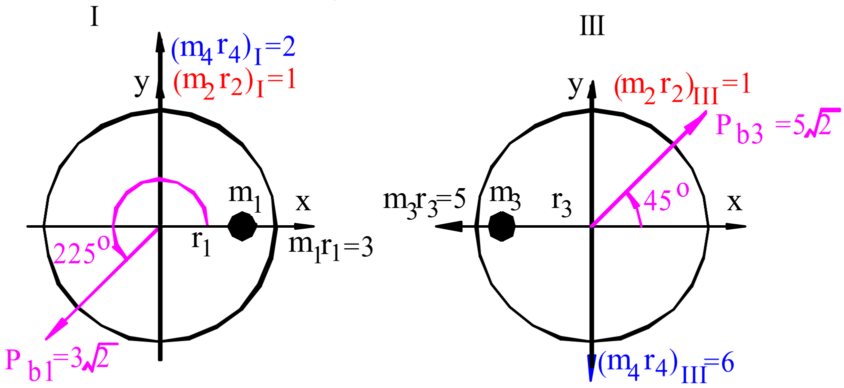


Fig10-4



解：将各质径积分别用 I 和 III 面上的两个质径积来平衡得到结果如图所示。

$$得到P_{b1} = 3\sqrt{2}Kg \cdot mm$$

位于x轴成225^0位置处。

$$P_{b3} = 5\sqrt{2}Kg \cdot mm$$

位于x轴成45^0位置处。

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10-5 On the non-disk rigid rotor shown in Fig10-5, there are four unbalanced masses. Their masses, rotating radii and angular locations are listed as follows: m_1=10kg, m_2=15kg, m_3=20kg and m_4=10kg, r_1=40mm, r_2=30mm, r_3=20mm and r_4=30mm and θ_1=120°, θ_2=240°, θ_3=300° and θ_4=30°. $L_{12}=L_{23}=L_{34}$. The system is to be balanced dynamically by adding a mass m_A on the balancing plane A at a rotating radius r_A of 50mm and removing a mass m_B on the balancing plane B at a rotating radius r_B of 60mm. Determine the magnitudes (m_A and m_B) and angular locations (θ_A and θ_B) of the required masses.

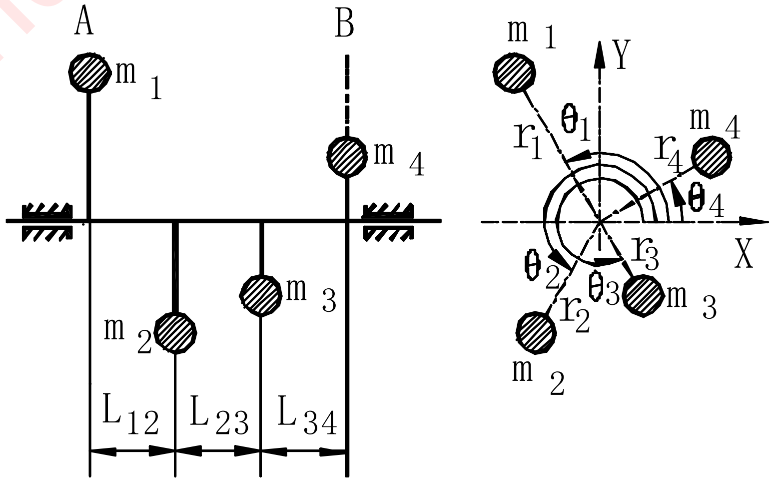
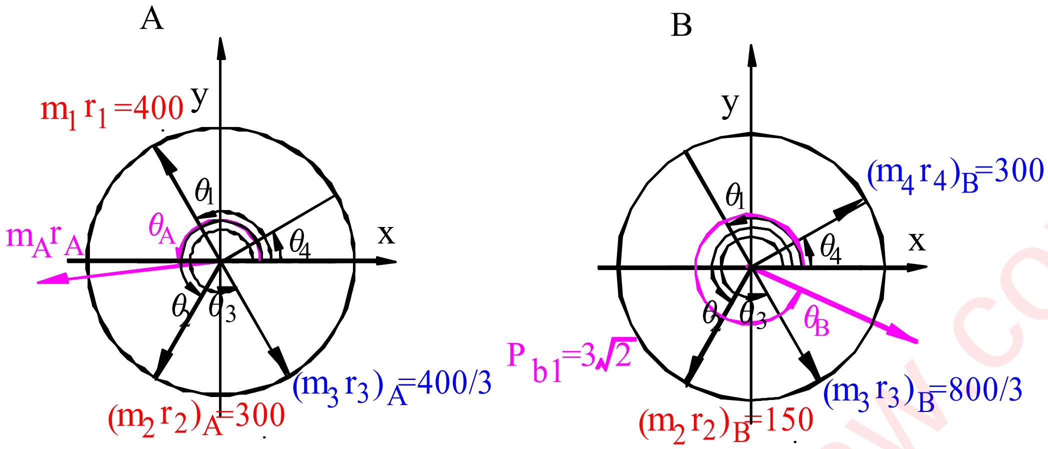


Fig10-5

解：将各质径积分别用 A 和 B 面上的两个质径积来平衡得到结果如图所示。



$$m_A r_A = \sqrt{\left(\sum(m_i r_i)_A \cos\theta_i\right)^2 + \left(\sum(m_i r_i)_A \sin\theta_i\right)^2}$$

$$= \sqrt{\begin{array}{l}(400\cos120^o + 300\cos240^o + \frac{400}{3}\cos300^o)^2 \\ +(400\sin120^o + 300\sin240^o + \frac{400}{3}\sin300^o)^2\end{array}}$$

$$= \sqrt{(-283.33)^2 + (-28.86)^2} = 284.80 Kg\cdot mm$$

$$m_A = 5.70 Kg$$

$$\theta_A = tg^{-1}\left(\frac{\sum(m_i r_i)_A \sin\theta_i}{\sum(m_i r_i)_A \cos\theta_i}\right) = tg^{-1}(\frac{-28.86}{-283.33}) = 5.82^0$$

$$\because \sum(m_i r_i)_A \sin\theta_i < 0, \sum(m_i r_i)_A \cos\theta_i < 0$$

$$\theta_A = 185.82^0 = 185^0 48' 58''$$

$$\theta_B = tg^{-1}\left(\frac{\sum(m_i r_i)_B \sin\theta_i}{\sum(m_i r_i)_B \cos\theta_i}\right) = tg^{-1}(\frac{-210.84}{318.14}) = -33.53^0$$

$$\because \sum(m_i r_i)_B \sin\theta_i < 0, \sum(m_i r_i)_B \cos\theta_i > 0$$

$$\theta_A = 326.47^0 = 326^0 27' 59''$$

$$m_B r_B = \sqrt{\left(\sum(m_i r_i)_B \cos\theta_i\right)^2 + \left(\sum(m_i r_i)_B \sin\theta_i\right)^2}$$

$$= \sqrt{\begin{array}{l}(150\cos240^o + \frac{800}{3}\cos300^o + 300\cos30^o)^2 \\ +(150\sin240^o + \frac{800}{3}\sin300^o + 300\sin30^o)^2\end{array}}$$

$$= \sqrt{(318.14)^2 + (-210.84)^2} = 381.67 Kg\cdot mm$$

$$m_B = 6.36 Kg$$

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11-1 A slider-crank mechanism driven by a pair of gears is shown in Fig11-1. $Z_1=20$, $Z_2=60$. The moment of inertia of the pinion 1 about its center of mass A is $J_1=0.15\text{kgm}^2$. The moment of inertia of the gear 2 about its center of mass B is $J_2=1.8\text{kgm}^2$. The length of the crank BC is 100mm. The mass of coupler CD is $m_3=10$kg. Its center of mass is located at the middle of CD. Its moment of inertia about its center of mass is $J_3=1\text{kgm}^2$. The mass of slider 4 is $m_4=5$kg. The resistant force F_4 acts on slider 4. $F_4=25$kN. Take the pinion 1 as the equivalent link. Find the equivalent resistant moment of force M_r of F_4 and the equivalent moment of inertia J of the whole mechanism in the position shown in the following diagram.

解：

$$i_{12}=\frac{\varpi_1}{\varpi_2}=\frac{z_2}{z_1}=\frac{60}{20}$$

$$\varpi_2=\frac{\varpi_1}{3}$$

$$\varpi_3=0$$

$$v_{C4}=l_{BC}\cdot\varpi_2$$

$$=\frac{l_{BC}\cdot\varpi_1}{3}$$

$$v_{C3}=\frac{l_{BC}\cdot\varpi_1}{3}$$

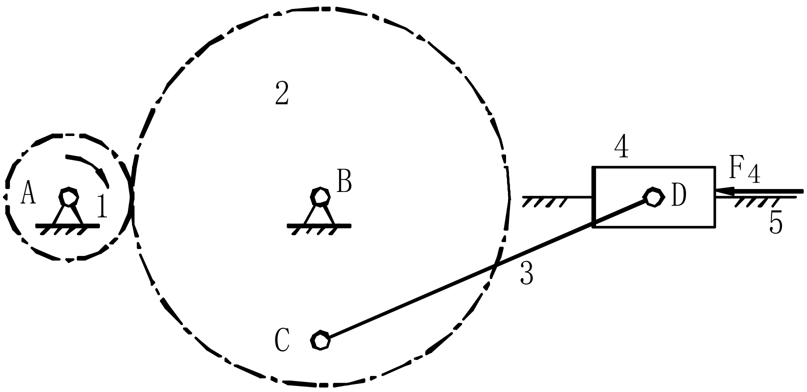

Fig11-1

$$M_r=F_4\left(\frac{v_4}{\omega_1}\right)=F_4\cdot\frac{l_{BC}}{3}=25*\frac{100}{3}=833.33N\cdot m$$

$$J=\sum_{i=1}^{n}\left[m_i\left(\frac{v_{C_i}}{\omega_1}\right)^2+J_{C_i}\left(\frac{\omega_i}{\omega_1}\right)^2\right]$$

$$=J_1+J_2\left(\frac{\varpi_2}{\varpi_1}\right)^2+J_3\left(\frac{\varpi_3}{\varpi_1}\right)^2+m_3\left(\frac{v_{C3}}{\varpi_1}\right)^2+m_4\left(\frac{v_{C4}}{\varpi_1}\right)^2$$

$$=0.15+1.8\times\left(\frac{1}{3}\right)^2+0+10\times\left(\frac{l_{BC}}{3}\right)^2+5\times\left(\frac{l_{BC}}{3}\right)^2$$

$$=0.15+1.8\times\left(\frac{1}{3}\right)^2+10\times\left(\frac{0.1}{3}\right)^2+5\times\left(\frac{0.1}{3}\right)^2=0.367Kg\cdot m^2$$

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11-2 A planetary gear train with two planets is shown in Fig11-2. The module of all the gears is m. The numbers of teeth are Z_1, Z_2, and Z_3, respectively. The moments of inertia of the links (about their centers of mass) are J_1, J_2, and J_H. The mass of a planet is m_2. (All gears are standard gears.) The resistant moment of force M_H acts on the planet carrier H. Take gear 1 as the equivalent link. Find the equivalent resistant moment of force M_r of M_H and the equivalent moment of inertia J of the whole gear train.

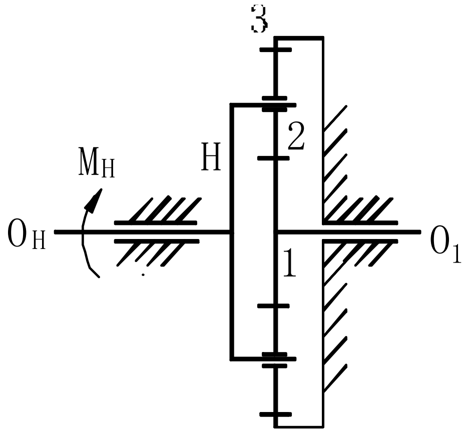

Fig11-2

解：1,2,3,H 组成一行星轮系，得：

$$\because \frac{m(z_3 - z_2)}{2} = \frac{m(z_1 + z_2)}{2}$$

$$\therefore z_3 = 2z_2 + z_1$$

$$i_{13}^H = \frac{n_1 - n_H}{n_3 - n_H} = -\frac{z_3}{z_1}$$

$$\because n_3 = 0$$

$$\therefore \frac{n_H}{n_1} = \frac{z_1}{z_1 + z_3} = \frac{\varpi_H}{\varpi_1}$$

$$= \frac{z_1}{2(z_1 + z_2)}$$

$$v_{C2} = \frac{m(z_1 + z_2)}{2} \cdot \varpi_H$$

$$\frac{v_{C2}}{\varpi_1} = \frac{m(z_1 + z_2)}{2} \cdot \frac{z_1}{z_1 + z_3} = \frac{mz_1}{4}$$

$$\varpi_2 = \frac{v_{C2}}{mz_2 / 2}$$

$$\frac{\varpi_2}{\varpi_1} = \frac{m(z_1 + z_2)}{2} \cdot \frac{z_1}{z_1 + z_3} \cdot \frac{2}{mz_2}$$

$$= \frac{z_1}{z_1 + z_3} \cdot \frac{z_1 + z_2}{z_2} = \frac{z_1}{2z_2}$$

$$M_r = M_H\left(\frac{\omega_H}{\omega_1}\right) = M_H \cdot \frac{z_1}{z_1 + z_3}$$

$$= M_H \cdot \frac{z_1}{2\left(z_1 + z_2\right)}$$

$$J = \sum_{i=1}^{n}\left[m_i\left(\frac{v_{C_i}}{\omega_1}\right)^2 + J_{C_i}\left(\frac{\omega_i}{\omega_1}\right)^2\right]$$

$$= J_1 + J_2\left(\frac{\varpi_2}{\varpi_1}\right)^2 + J_H\left(\frac{\varpi_H}{\varpi_1}\right)^2 + 2m_2\left(\frac{v_{C2}}{\varpi_1}\right)^2$$

$$= J_1 + J_2\left(\frac{z_1}{2z_2}\right)^2 + J_H\left(\frac{z_1}{2\left(z_1 + z_2\right)}\right)^2 + 2m_2\left(\frac{mz_1}{4}\right)^2$$

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11-3 The resistant moment M_r of a machine on the equivalent link is a given function of the rotating angle ϕ as shown in Fig11-3. The angular period of moment ϕ_T is 2π. The input moment M_d is constant.

(1) Calculate the input moment M_d.

(2) Calculate the maximum increment of work ΔWmax.

(3) The average speed is n_m =620 r/min. The allowable coefficient of speed fluctuation [δ] is 0.01. Masses and moments of inertia of all the links are neglected. Find the minimum moment of inertia of the flywheel J_F on the equivalent link.

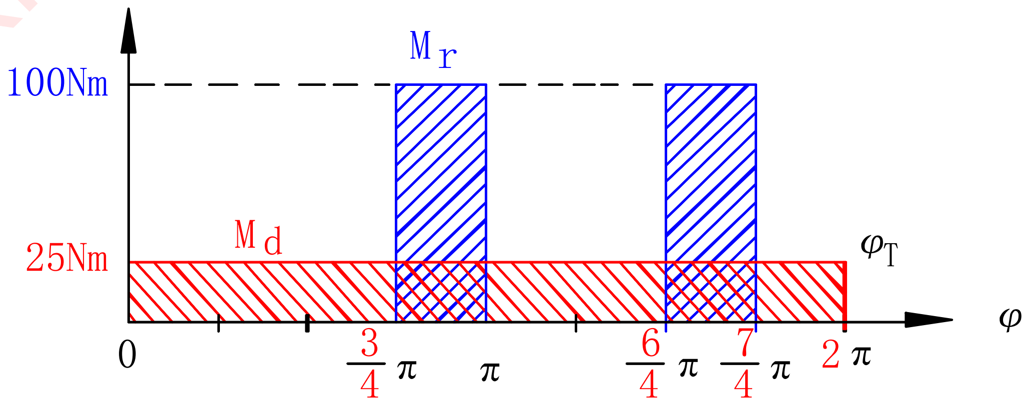

Fig11-3

解：

（1）

$$2\pi M_d = \int_0^{2\pi} M_r d\varphi = \frac{\pi}{2} \cdot M_r = \frac{\pi}{2} \times 100 N \cdot m$$

$$M_d = 25(N \cdot m)$$

（3） 动量变化图如下图所示：

由图可见

$$\varphi = \frac{3\pi}{4} \Rightarrow W = W_{max} = \frac{75}{4}\pi$$

$$\varphi = \frac{7\pi}{4} \Rightarrow W = W_{max} = -\frac{25}{4}\pi$$

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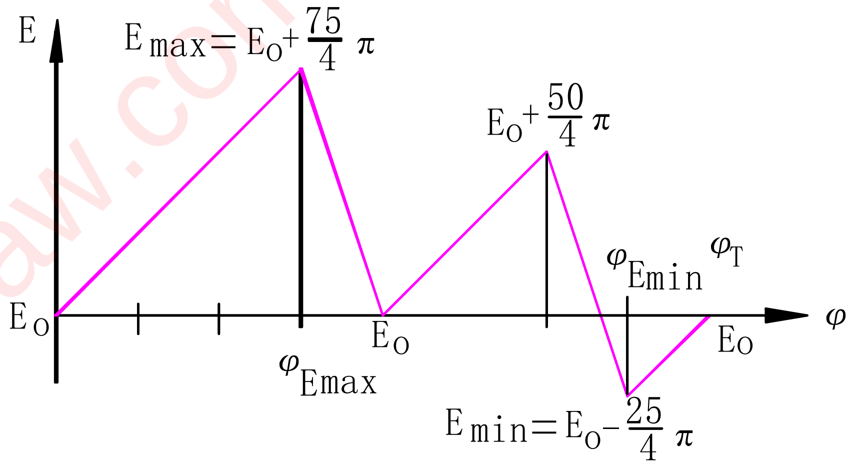

$$\therefore \Delta W_{\max} = W_{\max} - W_{\min} = \frac{75}{4}\pi - \left(-\frac{25}{4}\pi\right) = 25\pi = 78.54 N \cdot m$$

（3）

$$\varpi_m = \frac{2\pi n_m}{60} = \frac{\pi n_m}{30}$$

$$J_F = \frac{\Delta W_{\max}}{\varpi_m^2[\delta]} = \frac{\Delta W_{\max}}{\left(\frac{\pi n_m}{30}\right)^2[\delta]} = \frac{78.54 \times 900}{\pi^2 \times 620^2 \times 0.01} = 1.86 Kg \cdot m^2$$

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Ex.11-4 In a mechanical system running at a periodic and stable speed, a rotating link is selected as an equivalent link. The equivalent input moment M_d and the equivalent resistant moment M_r on the equivalent link are given functions of the rotating angle ϕ as shown in Fig11-4. The works of the some phases are: F_2=1000Nm, F_3=800Nm, F_4=700Nm, F_5=1000Nm, F_6=900Nm, F_7=400Nm, respectively. Therefore, F_1=_400_Nm. The maximum increment of work ΔW_{max}=_1100_Nm. If the equivalent moment of inertia J_e is constant, then the maximum speed of the equivalent link will take place at _g_, the minimum speed of the equivalent link will take place at _c_.

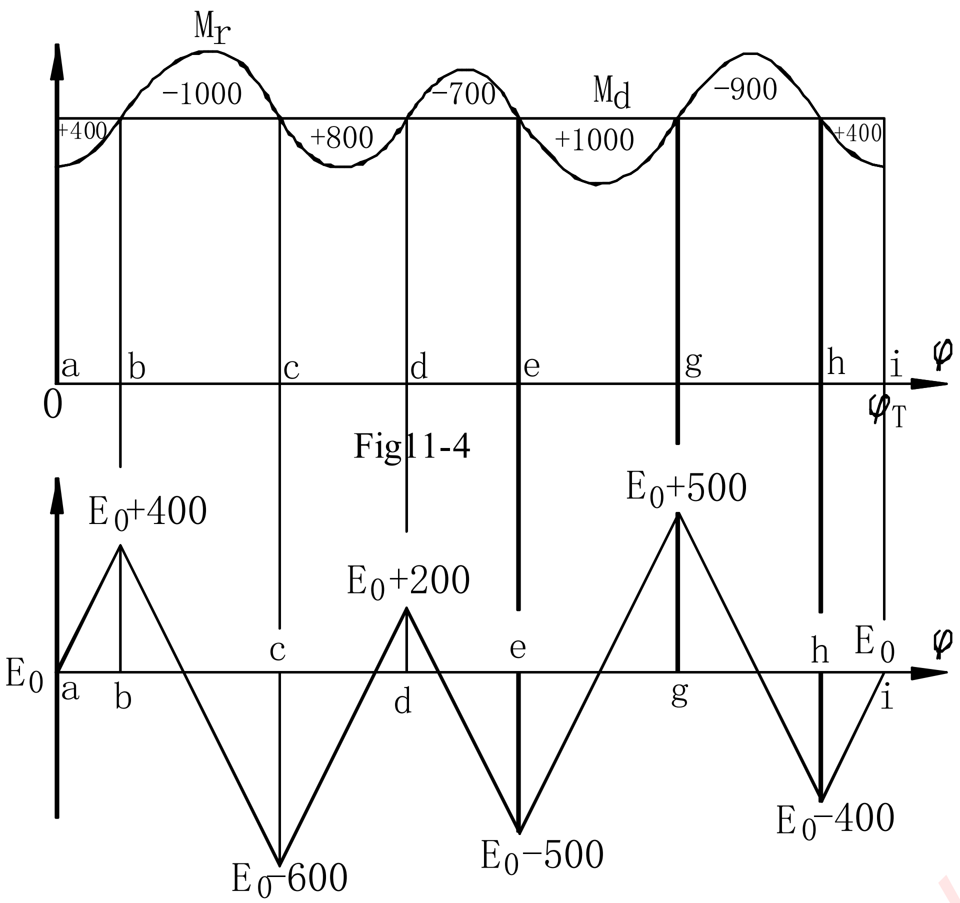
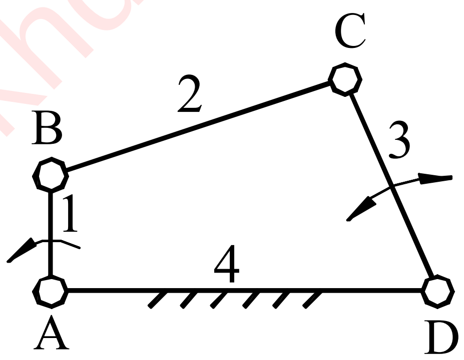


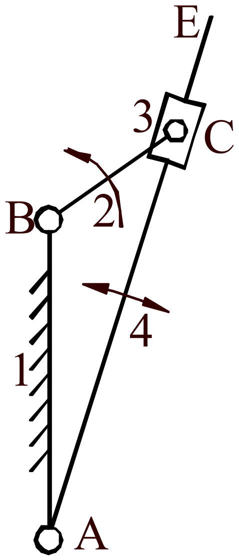
Fig11-4

Name______________Class_____Student No.__________Date____________

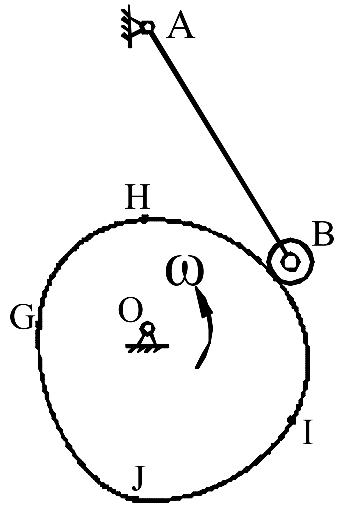
12-1 List and draw the schematic diagrams of four mechanisms which have less than 4 links and can transform a continuous rotation into an oscillation. Give name of each mechanism.



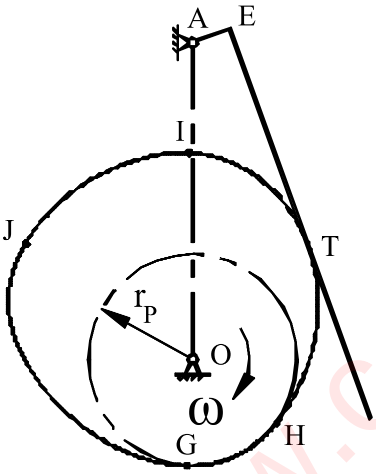
曲柄摇杆机构



摆动导杆机构



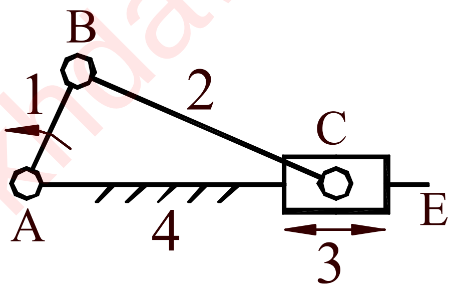
滚子摆动从动件盘形凸轮机构



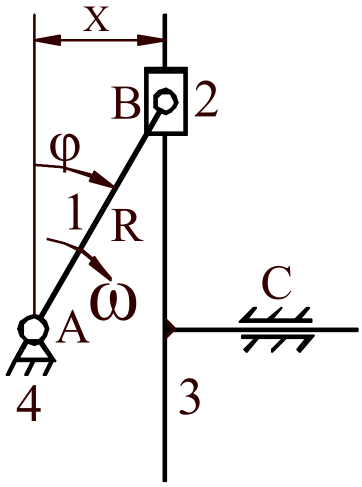
平底摆动从动件盘形凸轮机构

Name______________Class_____Student No.___________Date____________

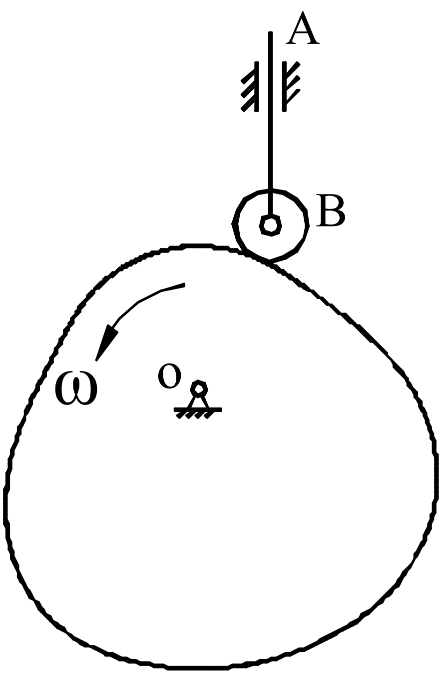
12-2 List and draw the schematic diagrams of four mechanisms which have less than 4 links and can transform a continuous rotation into a translation back and forth. Give name of each mechanism.



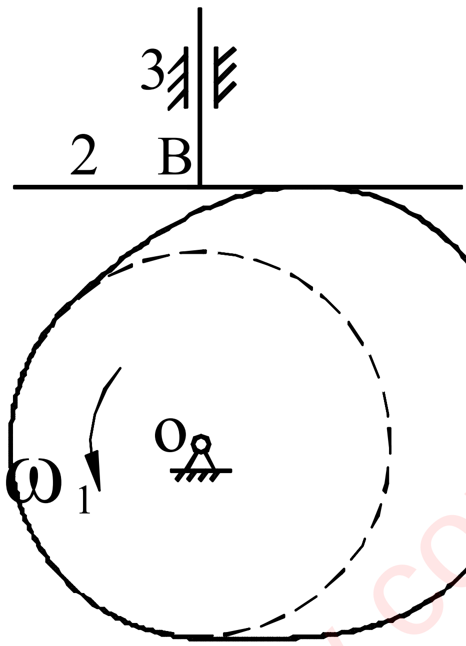
曲柄滑块机构



正弦机构



偏置滚子直动从动件盘形凸轮机构



对心平底直动从动件盘形凸轮机构