第八章

曲肱機械運動學
Kinematics of Crank-Engine.

六七、吸鎒變位、
Piston Displacement.

曲肱機械ニ於テ吸鎒行程ノ中央位置ト，吸鎒ノ或ル任意ノ位置トノ距離ヲ其ノ位置ニ於ケル吸鎒變位ト謂フ、

「第92圖」ニ於テ曲肱腕ガ OC ノ位置ニアルトキ曲肱栓 C ヲ中心トシ、接合棒ノ長サニ等シキ半徑ヲ以テ圓弧ヲ畫キ行程線ヲ B ニ於テ切リタリトスレバ、B ハ吸鎒ノ位置ナリ、思案點 DD′ ヨリ行程線上ニ DE 及ビ DE′ ヲ接合棒ノ長サニ等シクトレバ、E 及ビ E′ ハ吸鎒行程ノ兩端ナリ、M ヲ EE′ ノ中央トスレバ

吸鎒變位 ＝ MB.

今 x_p ＝ 吸鎒變位

r ＝ 曲肱腕ノ長サ

l ＝ 接合棒ノ長サ

$n = \frac{l}{r}$（之ヲ接合棒比ト謂フ）=4
Connecting-rod ratio.

θ ＝ 曲肱腕ト OD トノ狹ム角度

ϕ ＝ 接合棒ト行程線トノ角度

トスレバ

C ヨリ行程線ヘ垂線 CH ヲ引クトキハ

$$x_p = \mathrm{MB} = \mathrm{OH} + \mathrm{HB} - \mathrm{OM}$$

$$= r\cos\theta + l\cos\phi - l;$$

$$\therefore \quad x_p = r\{\cos\theta + n\cos\phi - n\} \text{ ....(1)}$$

$n = \infty$ ナルトキ $\phi = 0$;

$$\therefore \quad \cos\phi = 1.$$

$$x_p = r\cos\theta \text{ ....(2)}$$

$n = \infty$ ニシテ曲肱ノ角速度一様ナルトキハ吸鍔ハ單一弦運動 (Simple harmonic motion.) ヲナス、

三角形 OCB ニヨリ ϕ ト θ トノ關係ハ次ノ如シ、

$$\frac{\sin\phi}{\sin\theta} = \frac{r}{l} = \frac{1}{n};$$

$$\therefore \quad \sin\phi = \frac{1}{n}\sin\theta.$$

$$\sin\theta = n\sin\phi$$

$$\cos\theta = \sqrt{1 - n^2\sin^2\phi};$$

$$\cos\phi = \sqrt{1 - \frac{1}{n^2}\sin^2\theta}.$$

六八、吸鍔ノ速度、(Velocity of Pision.)

v_p = 吸鍔ノ速度

v_c = 曲肱栓ノ速度

ω = 曲肱ノ角速度 (常ニ $\omega r = v_c$ ナリ)

トスレバ

$$v_p = \frac{dx_p}{dt} = -r\left\{\sin\theta\frac{d\theta}{dt} + n\sin\phi\frac{d\phi}{dt}\right\};$$

$\sin\phi = \frac{1}{n}\sin\theta$; コレヲ t ニ就テ徵分シ $\frac{d\phi}{dt}$ ヲ求ムレバ

$$\frac{d\phi}{dt} = \frac{1}{n}\frac{\cos\theta}{\cos\phi}\frac{d\theta}{dt};$$

$$\therefore \quad v_p = -\omega r\{\sin\theta + \cos\theta\tan\phi\} \quad \cdots\cdots(3)$$

$$= -v_c\{\sin\theta + \cos\theta\tan\phi\} \quad \cdots\cdots(3')$$

$$\therefore \quad \frac{v_p}{v_c} = -\frac{\sin(\theta+\phi)}{\cos\phi} \quad \cdots\cdots(3'')$$

又 $\tan\phi = \frac{\sin\theta}{\sqrt{n^2 - \sin^2\theta}}$ ナルヲ以テ

(3')式ヨリ $$v_p = -v_c\left\{\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2-\sin^2\theta}}\right\} \quad \cdots\cdots(4)$$

$n = \infty$ ナルトキハ $\tan\phi = 0.$

故ニ式 (3') ニヨリ

$$v_p = -v_c\sin\theta \quad \cdots\cdots(5)$$

略近公式：―
Formula for approximation.

ϕ ヲ極小ナルモノト見做シ
$\cos\phi = 1.$

$\tan\phi \fallingdotseq \sin\phi$ 即チ $\tan\phi = \frac{1}{n}\sin\theta$;

トスルトキハ式 (3') ニヨリ

$$\boxed{v_p = -v_c\left\{\sin\theta + \frac{1}{2n}\sin 2\theta\right\}} \quad \cdots\cdots(6)$$

吸鍔速度ノ曲肱腕ニ對スル極式曲線及ビ吸鍔速度ノ吸鍔位置ニ對スル直交軸式曲線ハ既ニ第17項ニ於テ說明シタリ、(第17圖)之ヲ曲肱角ヲ橫距ニトリタル直交軸式ニテ表セバ、「第93圖」ニ示スガ如シ、

六九、吸鍔ノ加速度、
Acceleration of Piston.

茲ニ曲肱ハ一様ナル角速度ヲ以テ回轉スルモノト想定ス、即チ ω 或ハ v_c ハ共ニ定數ナリトス、

a_p ＝吸鍔ノ加速度

トスレバ
$$a_p = \frac{dv_p}{dt};$$

ナルヲ以テ第68項(4)式ニヨリ

$$a_p = \frac{d}{dt}\left[-v_c\left\{\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2-\sin^2\theta}}\right\}\right]$$

$$= -v_c\frac{d\theta}{dt}\left\{\cos\theta + \frac{\cos 2\theta}{\sqrt{n^2 \mp \sin^2\theta}} + \frac{\sin^2 2\theta}{4(n^2-\sin^2\theta)^{\frac{3}{2}}}\right\};$$

$$\therefore\quad a_p = -\frac{v_c^2}{r}\left\{\cos\theta + \frac{\cos^2\theta-\sin^2\theta}{\sqrt{n^2-\sin^2\theta}} + \frac{\sin^2\theta\cos^2\theta}{(n^2-\sin^2\theta)^{\frac{3}{2}}}\right\}\cdots(7a)$$

$$\because\quad \frac{d\theta}{dt} = \omega = \frac{v_c}{r}$$

$$= -\frac{v_c^2}{r}\left\{\cos\theta + \frac{n^2\cos 2\theta + \sin^4\theta}{(n^2-\sin^2\theta)^{\frac{3}{2}}}\right\}\cdots\cdots\cdots\cdots(7b)$$

$$= \frac{-v_c^2}{r}\left\{\cos\theta + \frac{\frac{\cos 2\theta}{n} + \frac{\sin^4\theta}{n^3}}{\left\{1-\left(\frac{\sin\theta}{n}\right)^2\right\}^{\frac{3}{2}}}\right\}\cdots\cdots\cdots\cdots(7c)$$

略近公式：―

吸鍔速度ノ略近公式(6)ヨリ

$$\frac{d}{dT}(v_p) = a_p = -v_c\frac{d}{dt}\left\{\sin\theta + \frac{1}{2n}\sin 2\theta\right\}$$

$$= -\frac{v_c^2}{r}\left\{\cos\theta + \frac{1}{n}\cos 2\theta\right\}\cdots\cdots\cdots\cdots(8).$$

$$\frac{d}{dT}\left(\frac{\sin 2\theta}{2\sqrt{n^2-\sin^2\theta}}\right) = \frac{d\theta}{dT}\left\{\frac{2\sqrt{n^2-\sin^2\theta}\,2\cos 2\theta + \frac{2\sin 2\theta\frac{1}{2}\times 2\sin\theta\cos\theta}{\sqrt{n^2-\sin^2\theta}}}{4(n^2-\sin^2\theta)}\right\}$$

七〇、吸鍔加速度ノ値及ビ線圖、

$n=4$ ナル場合ニ於テ各角度ニ對シテ吸鍔加速度ヲ計算シタル結果次ノ如シ、

曲肱角度	吸鍔加速度ノ精値	吸鍔加速度ノ略近値	誤差	誤差ノ最大加速度ニ對スル百分比
0	1·2500	1·2500	0	0
15	1·18387	1·18243	−0·00144	−0·15
30	0·99501	0·99102	−0·00399	−0·319
45	0·71121	0·70711	−0·00410	−0·328
60	0·37511	0·37500	−0·00011	−0·010
75	0·03678	0·04232	+0·00554	+0·443
90	−0·25820	−0·25000	+0·00820	+0·656
105	−0·48086	−0·47532	+0·00554	+0·443
120	−0·62489	−0·62500	−0·00011	−0·010
135	−0·70301	−0·70711	−0·00410	−0·328
150	−0·73703	−0·74102	−0·00399	−0·319
165	−0·74799	−0·74943	−0·00144	−0·115
180	−0·75000	−0·75000	0	0.

上表ニ於テ加速度ノ數値ハ $-\frac{v_c^2}{r}$ ヲ1トシテ表シ精値ハ公式(7*b*)又ハ(6*c*)ヨリ算定シ、略近値ハ公式(8)ヨリ算定セリ、

上表ヲ觀ルニ略近公式ヲ使用セル誤差ハ1%ヲ起ユル事ナキヲ知ル、

180°ヨリ360°ノ間ノ角度ニ對スル値ハ、上表ニアルモノヲ反對ニトレバ可ナリ、例ヘバ195°ニ對スルモノハ165°ニ對スルモノニ同ジ、

$n=4$ ナルトキノ吸鍔加速度ノ精値ヲ曲肱角度ニ對シテ畫キタル直交軸式曲線ハ「第93圖」ニ示セリ、

曲肱回轉ノ速度一様ニシテ $n=4$ ナルトキ、吸鍔加速度ハ思案點ニ於テ最大ニシテ約 76° 及ビ 284° ノトキ 0 ナリ、而シテ吸鍔速度ハ加速度 0 ナル點ニ於テ最大ニシテ思案點ニ於テ 0 ナリ、

七一、吸鍔加速度ヲ作圖ニ依リテ求ムル方法、—「クライン」氏ノ法、
Klein's Construction.

「第 94 圖」ニ於テ行程線 EDD′, 曲肱栓圓 DND′N′, 吸鍔位置 B ヲ記シ、接合棒ノ長サ BC ヲ以テ曲肱栓圓ヲ C ニ於テ切リ OC ヲ結ビ、之ヲ延長シテ B ニ於ケル行程線ニ垂線ナル BI ト I ニ於テ交ラシメ、又 BC ヲ延長シ O ニ於ケル行程線ニ垂線ナル ON ト Q ニ於テ交ラシム、

QI ヲ結ビ O ヲ過リ QI ニ平行ニ OJ ヲ引ケ、次ニ J ニ於テ BQ ニ垂線 JK ヲ引キ行程線ト K ニ於テ交ラシム、

然ルトキハ曲肱腕ノ角速度一様ナルトキハ

$$\text{所要ノ吸鍔加速度}\ a_p=\frac{\overline{\mathrm{OK}}}{\mathrm{OC}}\cdot\frac{v_c^2}{r}\ \cdots\cdots\cdots\cdots\cdots(9)$$

即チ半徑 OC ガ曲肱栓ノ法線加速度 $=\frac{v_c^2}{r}$ ヲ表ストキハ、OK ハ同比例尺ヲ以テ吸鍔加速度ヲ表ハスモノナリ、

〔證明〕 Q ヲ接合棒上ノ點ト見做シ此ノ點ニ就テ考フ Q ノ速度ヲ u ニテ表ハセバ

$$\frac{u}{v_c}=\frac{\mathrm{QI}}{\mathrm{CI}}$$

$$=\frac{\mathrm{OJ}}{\mathrm{OC}}\qquad\left(\because\ \begin{array}{c}\triangle\mathrm{CIQ}\ \text{ト}\ \triangle\mathrm{COJ}\\ \text{ハ相似ナルヲ以テ}\end{array}\right)$$

$$\therefore\quad u=v_c\frac{\mathrm{OJ}}{\mathrm{OC}}.$$

u ヲ BQ ト QN ト,ノ二ツノ方向ニ分チ、其ノ分速度ヲ夫々 u_2 及ビ u_1 トスレバ

$$\frac{u_1}{u}=\frac{OK}{OJ};\quad \left(\because\ \text{Q ノ速度ノ三角形ト, △ OJK トハ相似ナルヲ以テ}\right)$$

$$\therefore\quad u_1=v_c\frac{OJ}{OC}\cdot\frac{OK}{OJ}=v_c\frac{OK}{OC}.\qquad \therefore\quad u=v_c\frac{OJ}{OC}$$

然ルニ $$a_p=\frac{dv_p}{dt}=\frac{d}{dt}\left(v_c\frac{OQ}{OC}\right).$$

v_c ヲ定數ナリト想定セリ、而シテ OC ハ亦常數ナル故

$$a_p=\frac{v_c}{OC}\cdot\frac{d}{dt}(OQ);$$

$$=\frac{v_c}{OC}u_1;$$

然ルニ $u_1=v_c\dfrac{OK}{OC}$ ナルガ故ニ

$$\therefore\quad a_p=v_c^2\frac{OK}{OC^2};$$

$$\therefore\quad a_p=\frac{\overline{OK}}{OC}\,\frac{v_c^2}{r}.$$

此ノ作圖法ニ於テ曲肱ノ位置ガ行程線ト垂直ニ近キトキハ、I ハ甚ダシク遠隔ノ所ニアリテ實地上作圖困難ナリ,此ノトキニハ、次ノ如クスルヲ便トス、

互ニ相似ナル二ツノ三角形 CQI, CJO ニ於テ

$$\frac{QC}{CI}=\frac{CJ}{OC};$$

$$\therefore\quad \frac{QC}{CJ}=\frac{CI}{OC}.\ \dots\dots\dots\dots\dots\dots(1)$$

又二ツノ三角形 CQO, CBI ニ於テ

$$\frac{CI}{CB}=\frac{OC}{QC};$$

$$\therefore\qquad \frac{CI}{OC}=\frac{CB}{QC};\ \dotfill(II)$$

(I) ト (II) 式ヨリ

$$\frac{QC}{CJ}=\frac{BC}{QC};$$

即チ　　$\overline{QC}^2=\overline{CJ}\;\overline{CB}.$

此レニ由リテJノ位置ハI點ノ位置ヲ求メズ、CJ, CB ノ比例中項ガ QC ニ等シキ如ク之ヲ見出セバ可ナリ、其ノ方法ハ種々アレドモ、Klein (或ハ Kirsch) 氏ノ方法ニヨルヲ便ナリトス、

「第95圖」ニ於テ接合棒 CB ノ上ニ半圓 CRB ヲ畫キ、中心 C, 半徑 CQ ヲ以テ圓弧 QR ヲ畫キ、半圓ノ周トRニ於テ交ラシメ、R ヨリ CB ヘ垂線 RJ ヲ引ケバ、其ノ足ハ所要ノJ點ノ位置ナルコト明ラカナリ、

七二、接合棒ノ角速度及ビ角加速度、

接合棒ノ角速度ハ $\frac{d\phi}{dt}$ ニシテ角加速度ハ $\frac{d^2\phi}{dt^2}$ ナリ、

第67圖ニ述ベタル如ク

$$\sin\phi=\frac{1}{n}\sin\theta,$$

ナル故

$$\frac{d\phi}{dt}=\frac{1}{n}\frac{\cos\theta}{\sqrt{1-\frac{1}{n^2}\sin^2\theta}}\frac{d\theta}{dt};$$

$$=\frac{\cos\theta}{\sqrt{n^2-\sin^2\theta}}\,\omega.\ \dotfill(10)$$

$$\fallingdotseq \frac{1}{n}\,\omega\cos\theta. \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (11)$$

∵ $\frac{1}{n^2}\sin^2\theta =$ 極小値

又 $$\frac{d^2\phi}{dt^2} = \frac{d}{dt}\left\{\frac{\cos\theta}{\sqrt{n^2-\sin^2\theta}}\,\omega\right\};$$

$$= -\,\omega^2\frac{(n^2-1)\sin\theta}{(n^2-\sin^2\theta)^{\frac{3}{2}}} \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

又 $$\frac{d^2\phi}{dt^2} = \frac{1}{n}\,\omega\,(-\sin\theta)\,\frac{dt}{dt}$$

∵ $$\frac{d\phi}{dt} \fallingdotseq \frac{1}{n}\,\omega\cos\theta$$

$$= -\,\frac{1}{n}\,\omega^2\sin\theta \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (13).$$

EXERCISES.

1. Construct the centrodes of I and J for the mechanism shown in Fig. 8, when the link *a* is fixed.

2. The beams in a four-bar mechanism are of the following lengths *a* 1·4, *b* 1·9, *c* 2, *d* 1·2. Find the angular velocity of *b* when normal to *a*, having given the angular velocity of *d* as 2·3 radians per second.

3. The axes of two spur wheels in gear are 37 inches apart. One wheel rotates four times as fast as the other. Find the diameters of the pitch circles of the wheels.

Ans. 14·8 inches, 59·2 inches.

4. It is required to connect two shafts, whose axes are to be as nearly as possible 40 inches apart, by spur wheels so that the velocity ratio may be exactly 9 : 2. Find the number of teeth in each of the two wheels and the distance between the axes of the shafts, to the nearest hundredth of an inch, if the pitch of the teeth is $2\frac{1}{4}$ inches.

Ans. 20, 90, 39·39.

5. An epicyclic gear consists of three wheels, as shown in Fig. 58 (1). A is a dead wheel having 50 teeth. The arm P makes + 2, 499 revolutions in a certain time. Find the number of revolutions made by B in the same time when the number of teeth on B is (1) 50, (2) 51, and (3) 49.

Ans. (1) 0; (2) + 49; (3) − 51.

6. In the epicyclic bevel gear, shown in Fig. 63. the wheels

A and B have each 40 teeth, and the wheel C has 20 teeth; the shaft P rotates at the rate of 60 revolutions per minute about the axis of A and B; each wheel is free to rotate on its own spindle, and the wheel A rotates 30 times per minute in a direction opposite to the rotation of the shaft P. Find the speed and direction of the wheel B.

Ans. 240 rovolutions per minute in same direction as P.

7. Two pulleys are counected by a belt. The sum of the diameters of the pulleys is 36·6 inches and while the one makes 50 revolutions the other makes 200 revolutions. Find the diameters of the pulleys.

Ans. 29·2 inches; 7·4 inches.

8. A shaft running at 200 revolutions per minute carries a pulley 50 inches diameter, which drives a dynamo at 1,220 revolutions per minute by means of a belt $\frac{1}{4}$ inch thick. Allowing for the thickness of the belt and a slip of 4 per cent. determine the diameter of the pulley on the dynamo.

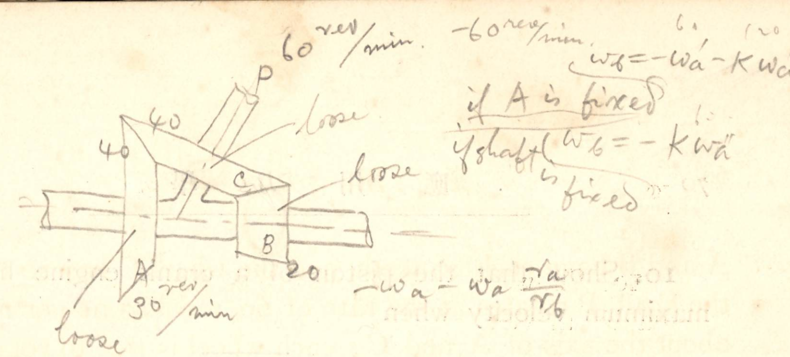
Ans. 7·79 inches.

9. A crank engine rotates uniformly at the speed of 120 revolutions per minute. Find the velocity and the acceleration of the piston when θ is 60°, and the accelerations at the dead points. The length of connecting rod is 9 feet and the length of the stroke is 4 feet.

Ans. $\theta =$ 60° { velocity 24·2 feet per second. acceleration 122·8 ft. per sec. per sec.

$\theta =$ 0°, acceleration 386·0 ft. per sec. per sec.

$\theta =$ 180°, acceleration 245·6 ft- per sec. per sec.



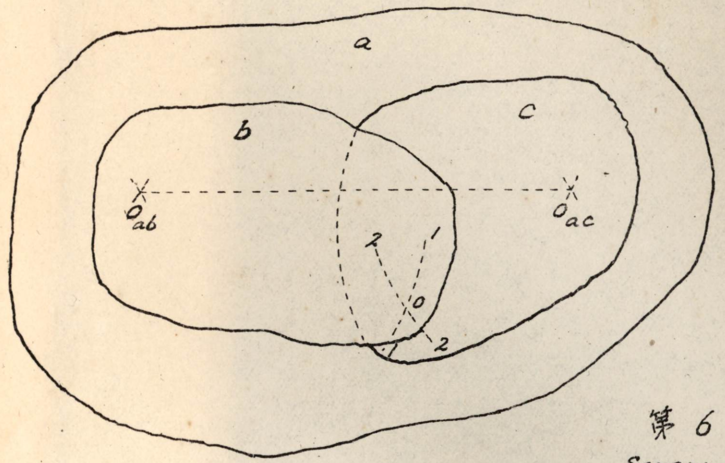
10. Show that the piston of a crank engine has the maximum velocity when

$$\theta = \cos^{-1} \frac{\pm\sqrt{n^2+8}-n}{4}$$

where n is the connecting-rod ratio.

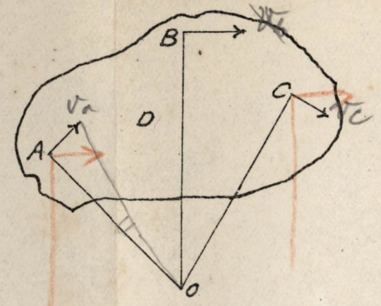
第 1 図

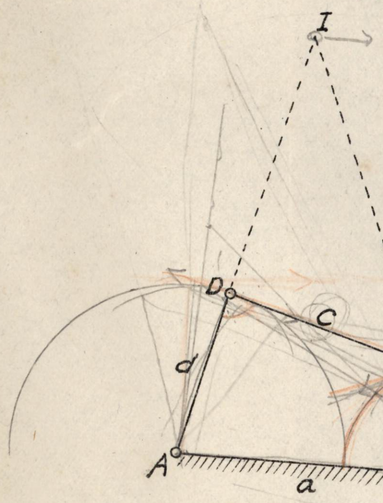
Instantane ous Centre.



第 2 図

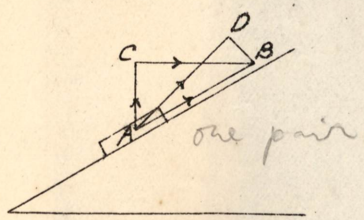
Position of instantane ous Centre.





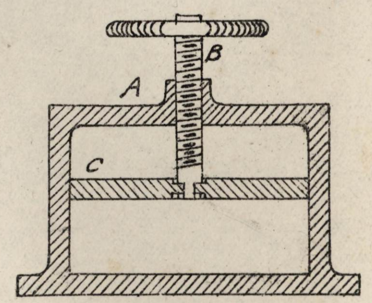
第 4 図

Inclined plane.



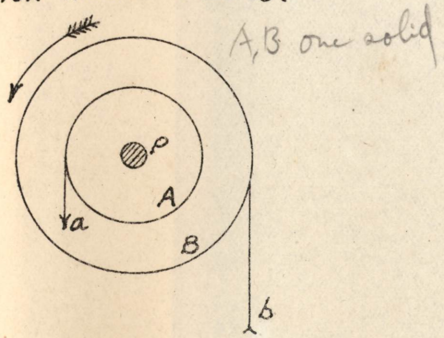
第 6 図

Screw press.



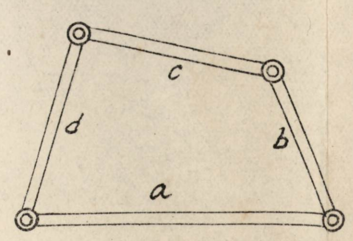
第 5 図

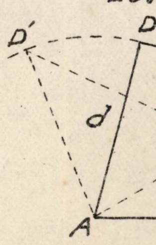
Screw wheel and ax le.



第 7 図

Crank chain.





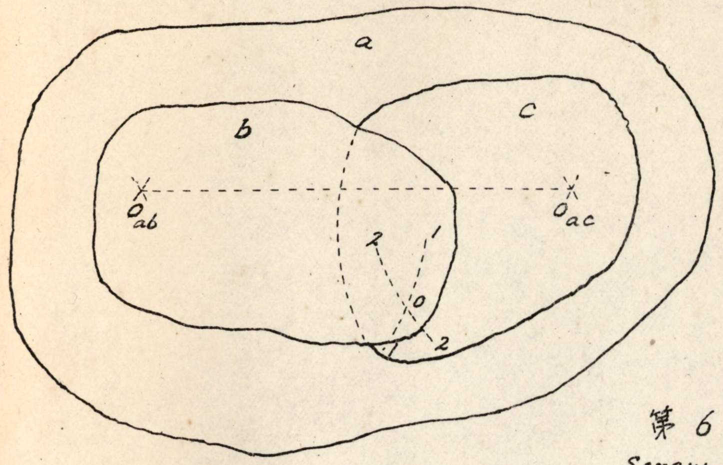
piston of a crank engine has the

$-_{1}\ \dfrac{\pm\sqrt{n^2+8}-n}{4}$

ing-rod ratio.

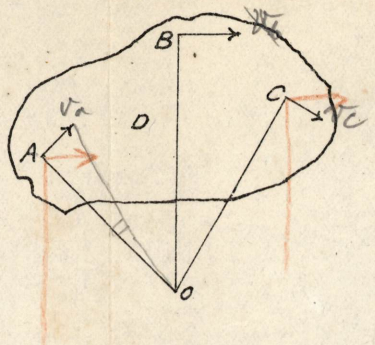
第1図

Instantaneous Centre.



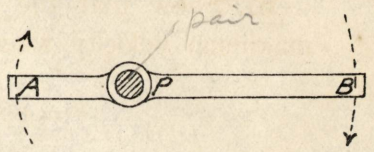
第2図

Position of instantaneous Centre.



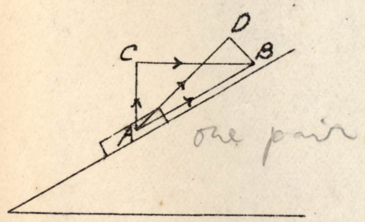
第3図

Lever.



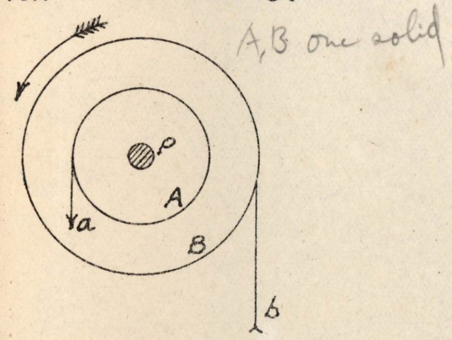
第4図

Inclined plane.



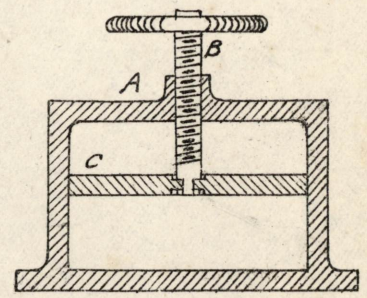
第5図

Screw wheel and axle.



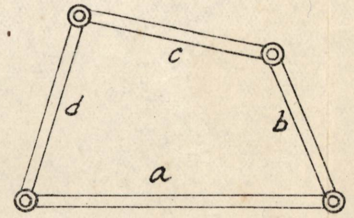
第6図

Screw Press.



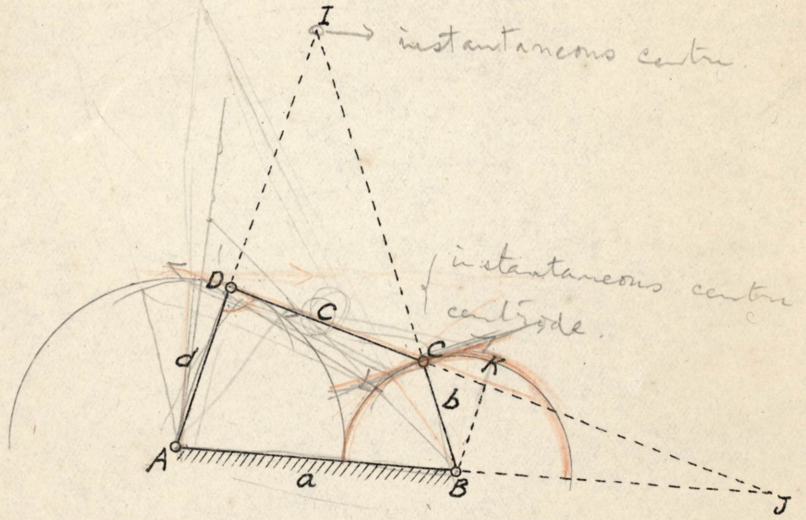
第7図

Crank chain.



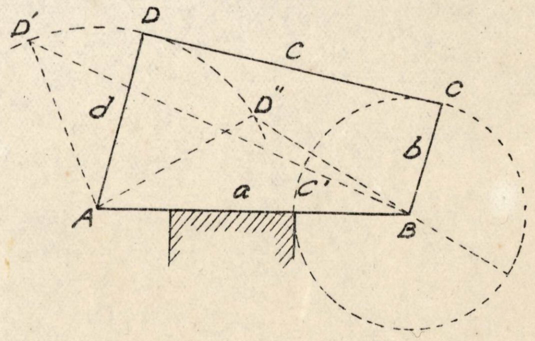
第8図

Crank Chain.



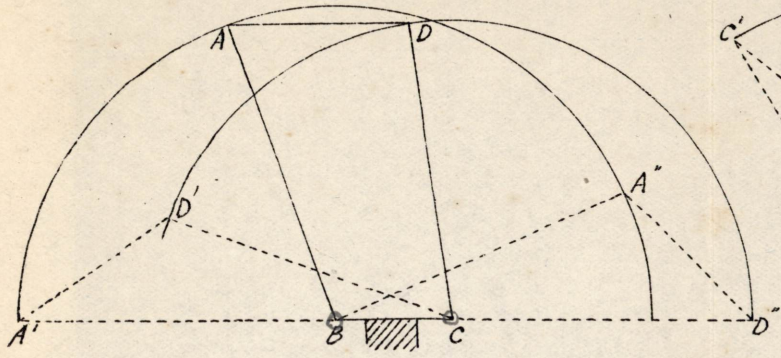
第9図

Lever Crank chain.



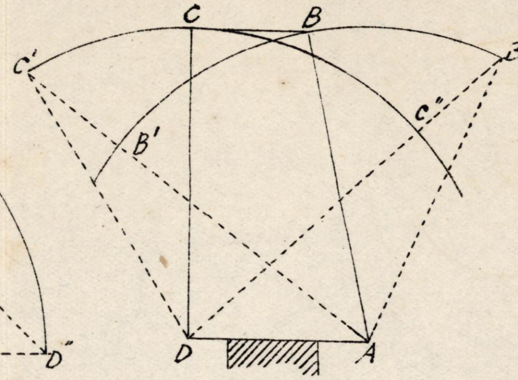
第10図

Double crank.



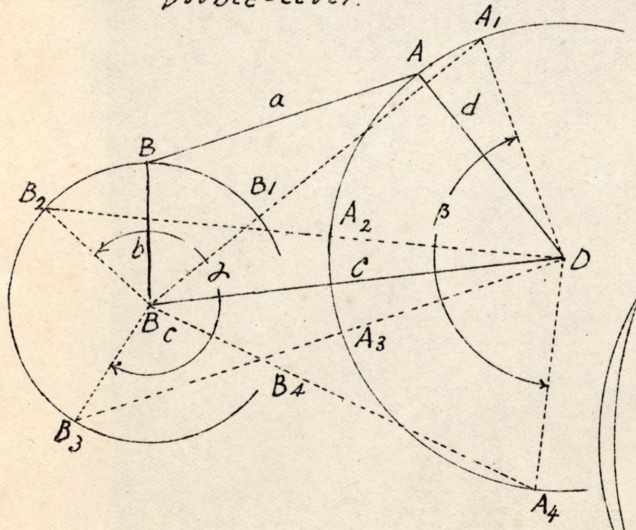
第11図

Double lever.



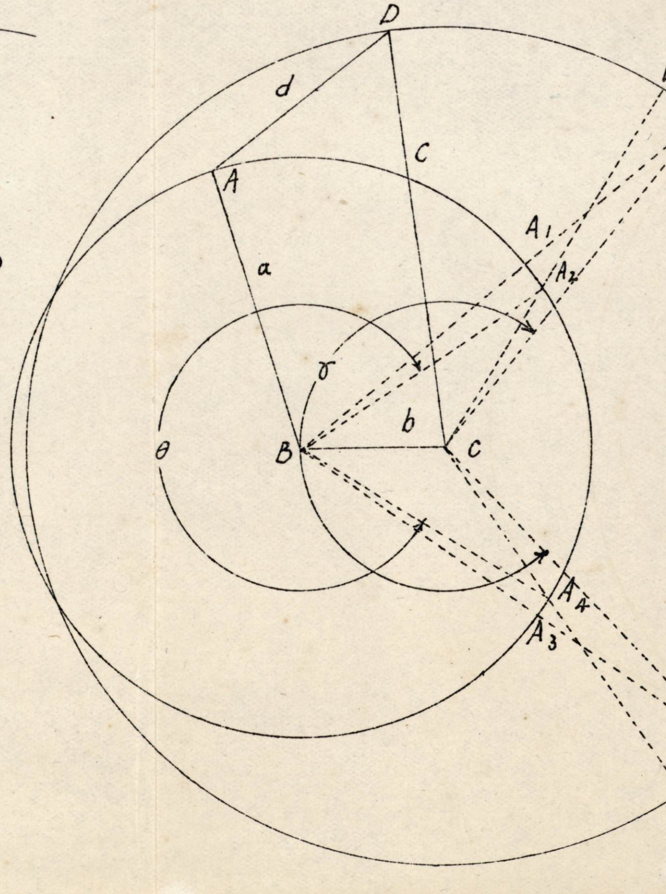
第12図ノ二

Double-lever.



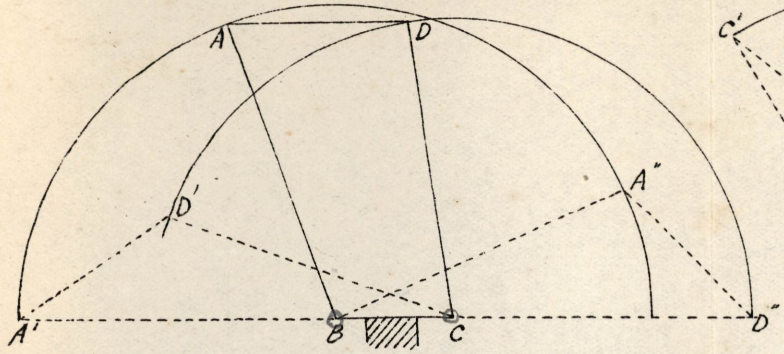
第12図ノ三

Double-lever.



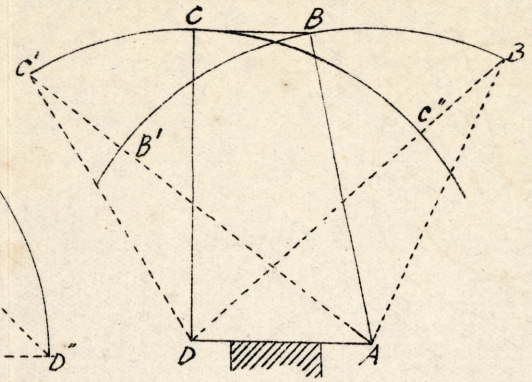
第10図

Double crank.



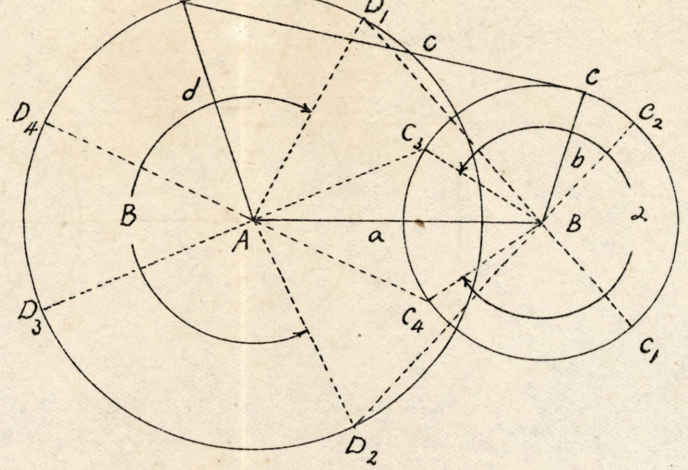
第11図

Double lever.



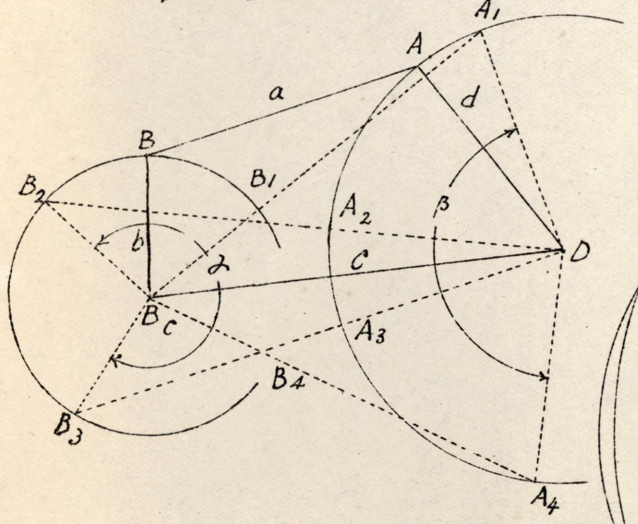
第12図ノ一

Double lever.



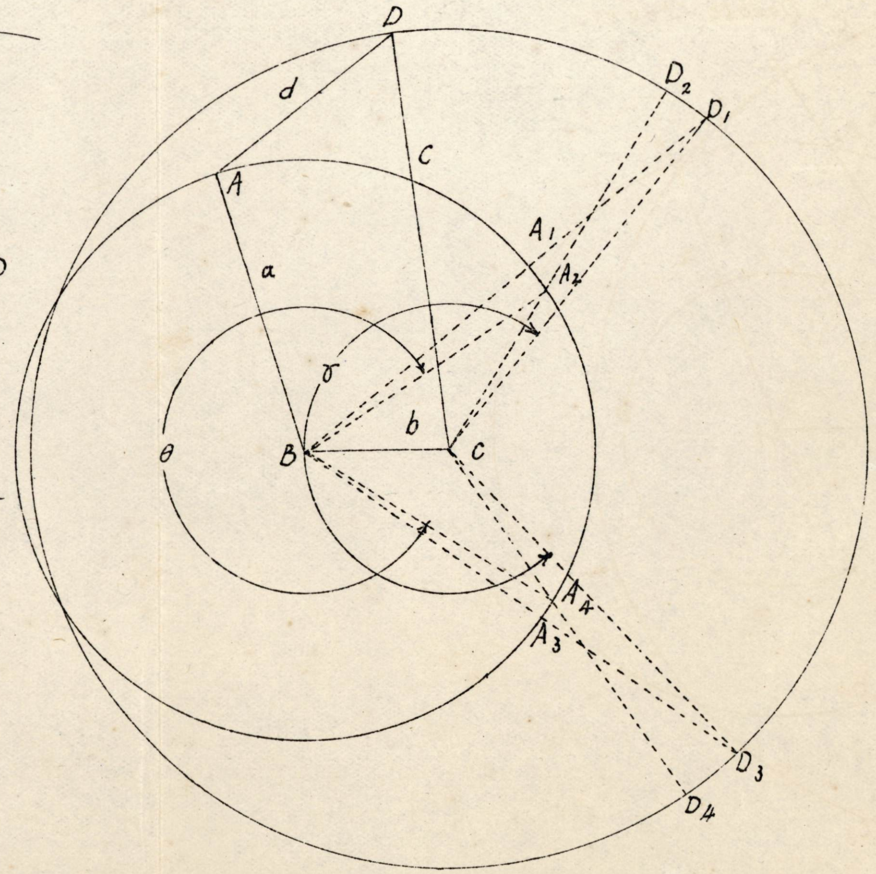
第12図ノ二

Double-lever.



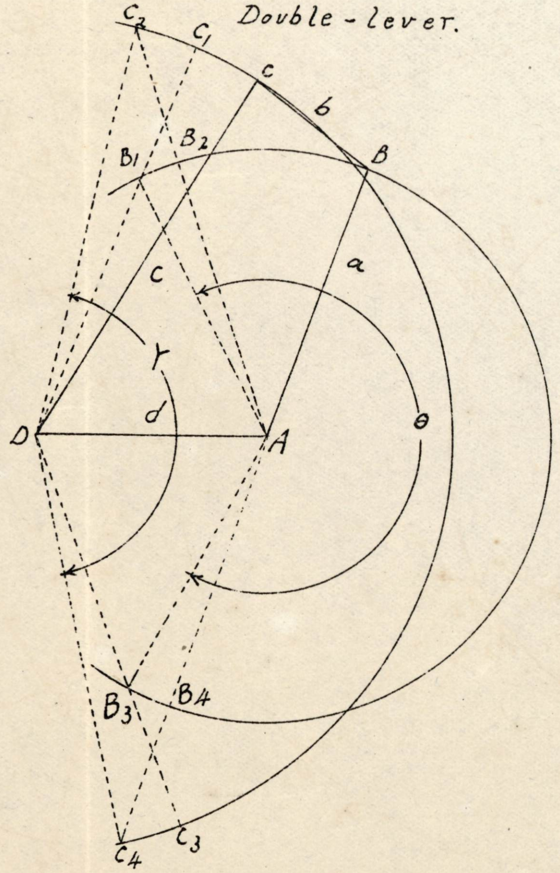
第12図ノ三

Double-lever.



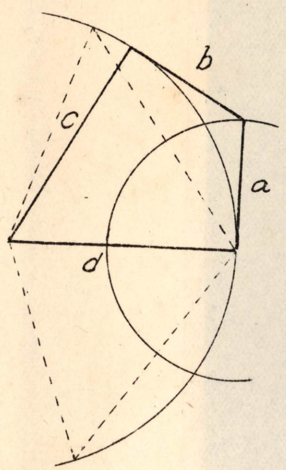
第12図ノ四

Double-lever.

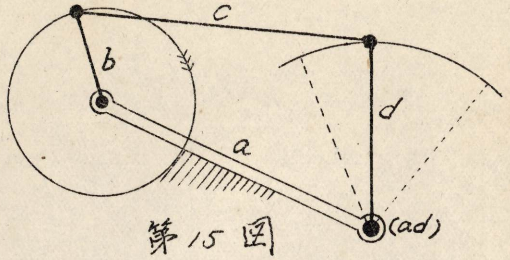


第13図,一

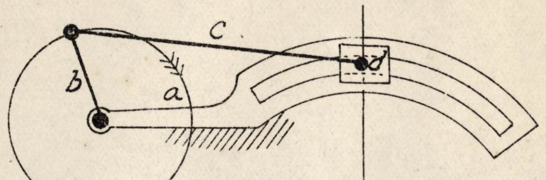
Lever-Crank.



第14図



第15図

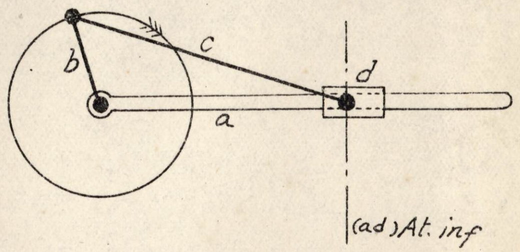


Slider crank Chain.

(piston)

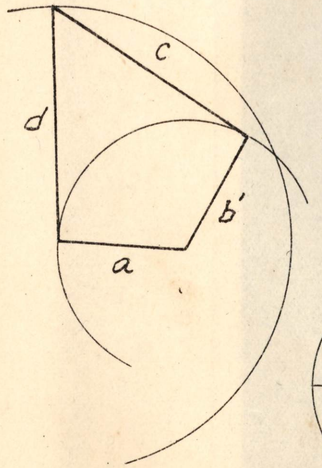
(ad)

第16図



第13図,二

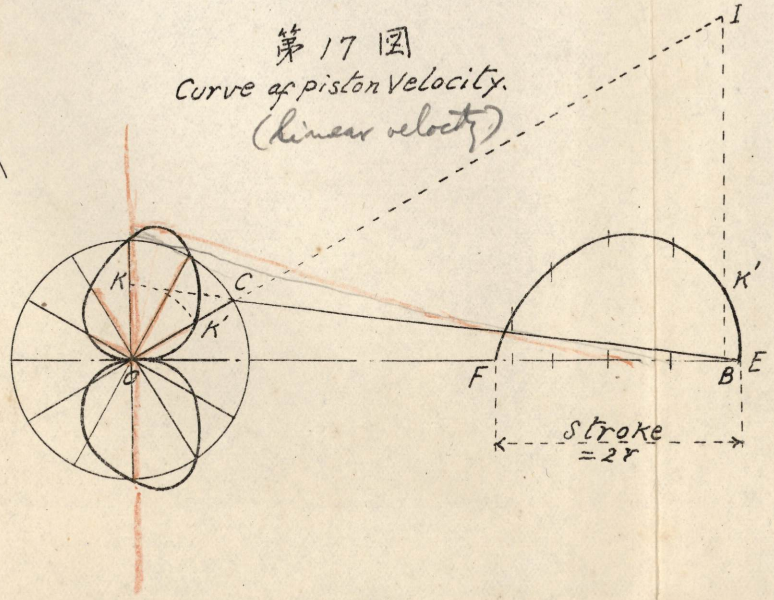
Double-Crank.



第17図

Curve of piston velocity.

(linear velocity)



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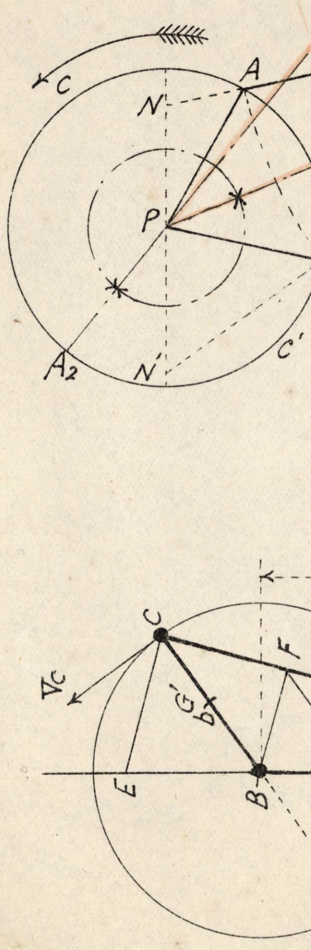
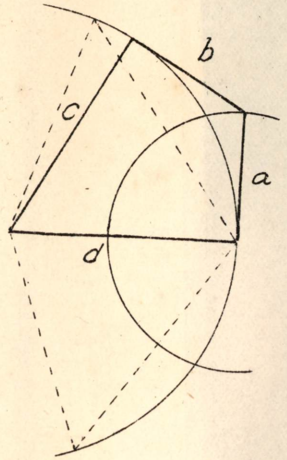
Qui



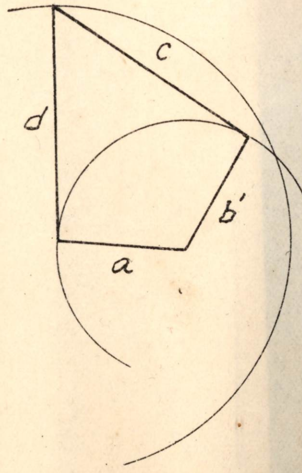
第13図、一

Lever-Crank.

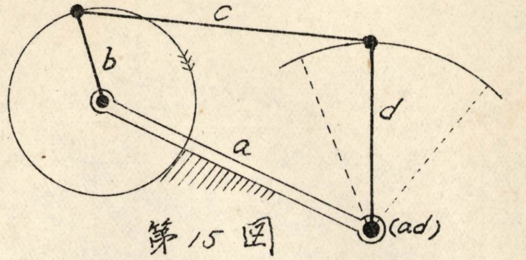


第13図、二

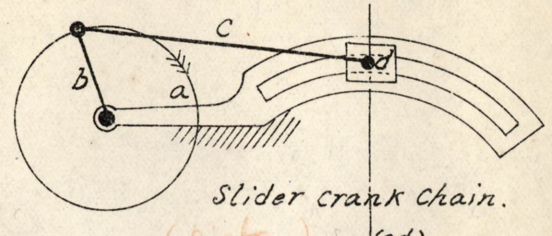
Double-Crank.



第14図



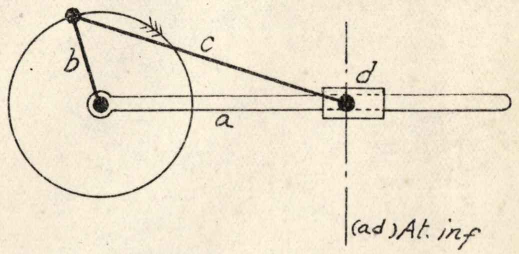
第15図



Slider crank Chain.

(piston) (ad)

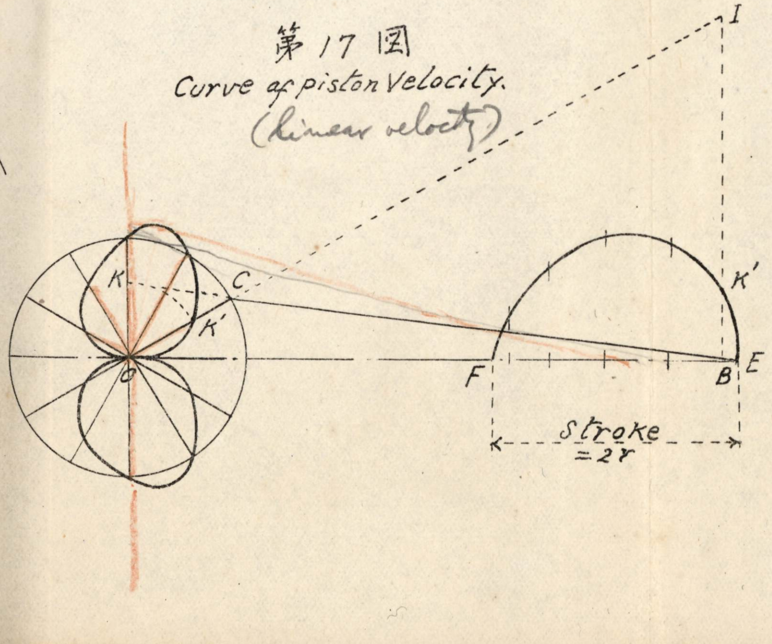
第16図



第17図

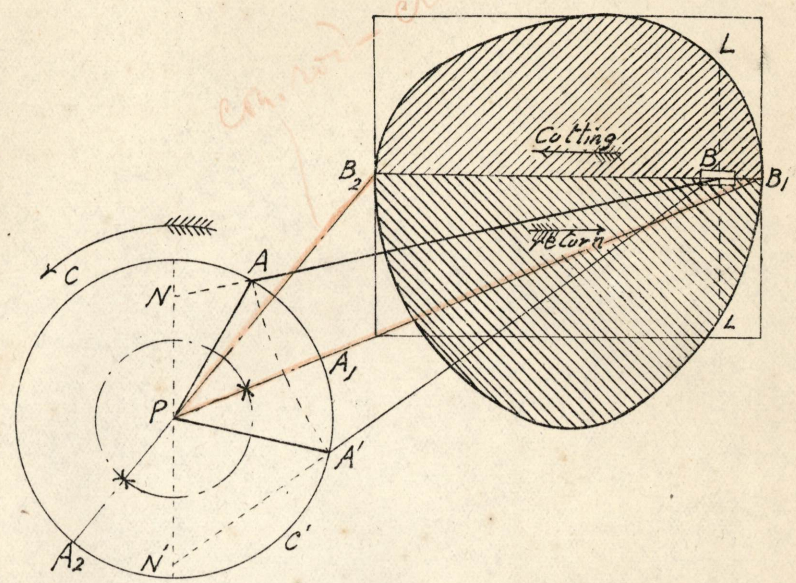
Curve of piston Velocity.

(linear velocity)

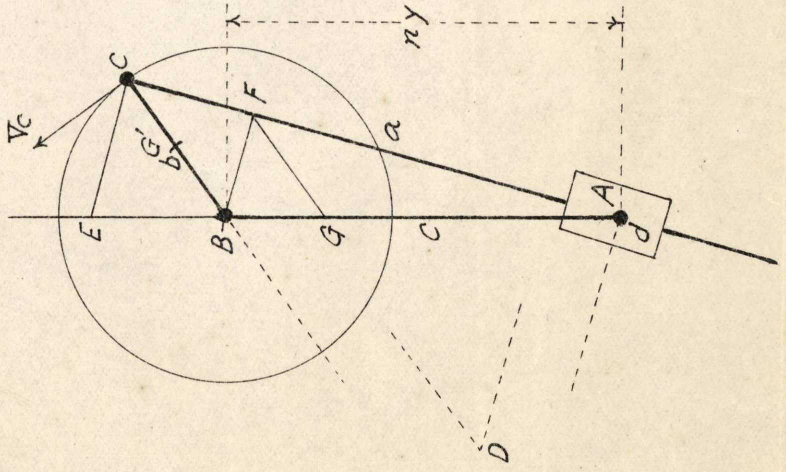


第18図

Quick return.

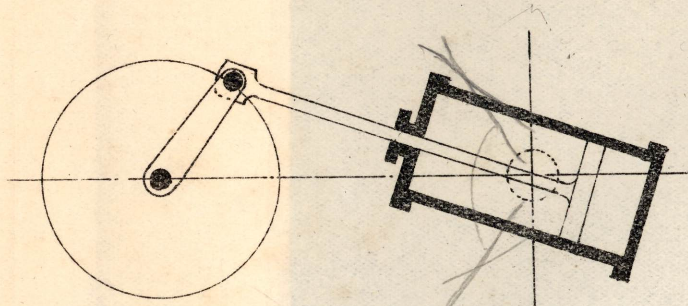


第19図、一



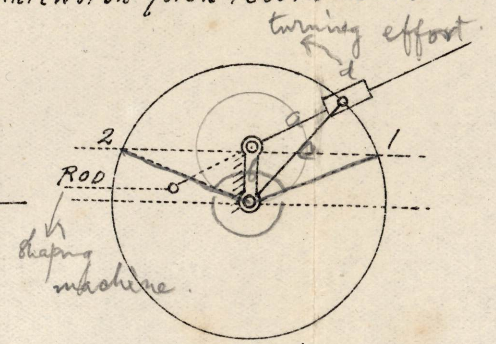
第19図ノ二

Oscillating Engine



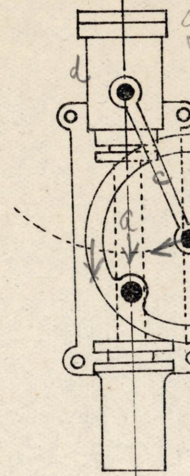
第21図ノ一

Whitworth quick return mechanism.



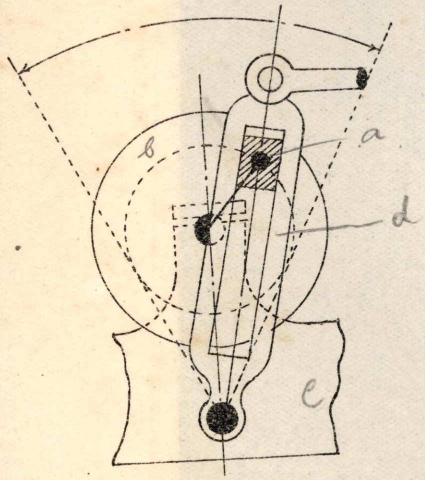
第23図

pendulum p

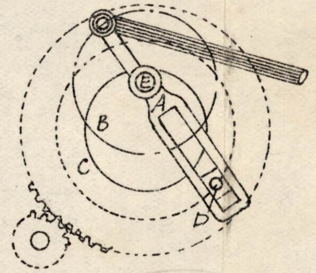


第19図ノ三

Quick return of Shaping machine.

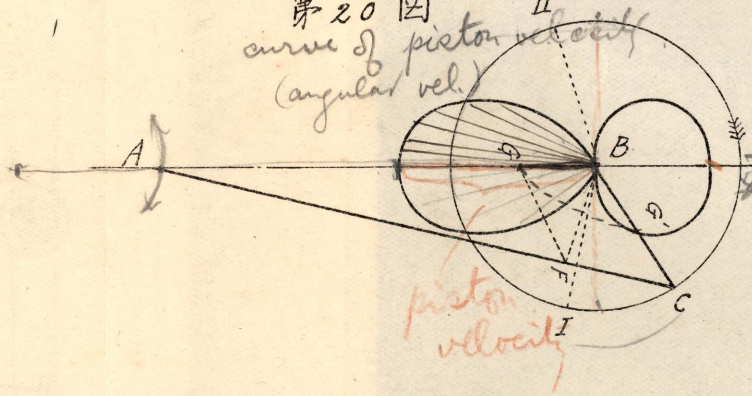


第21図ノ二

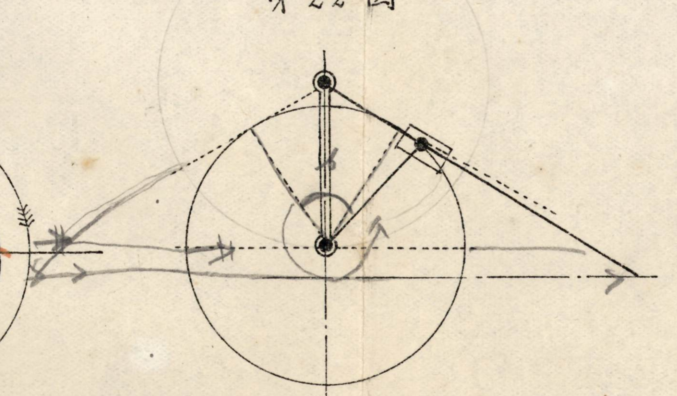


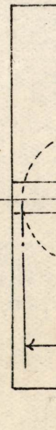
第20図

curve of piston velocity
(angular vel.)



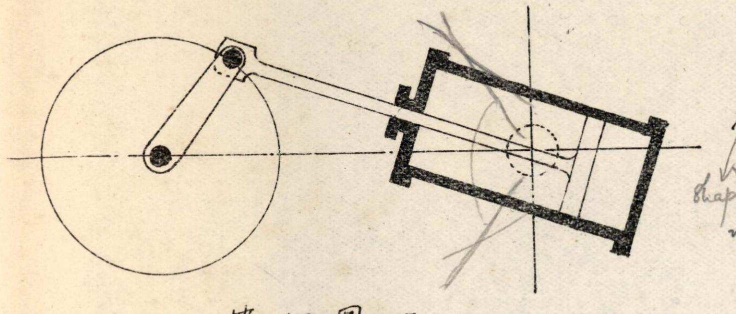
第22図





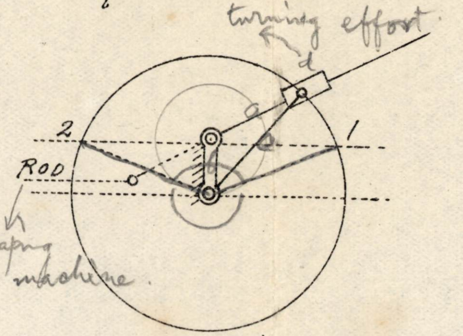
第19図ノ二

Oscillating Engine



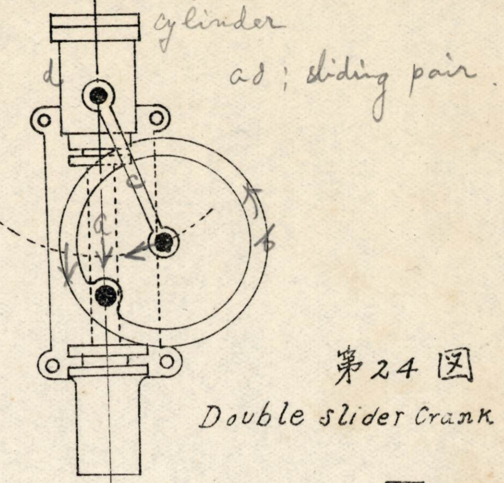
第21図ノ一

Whitworth quick return mechanism.



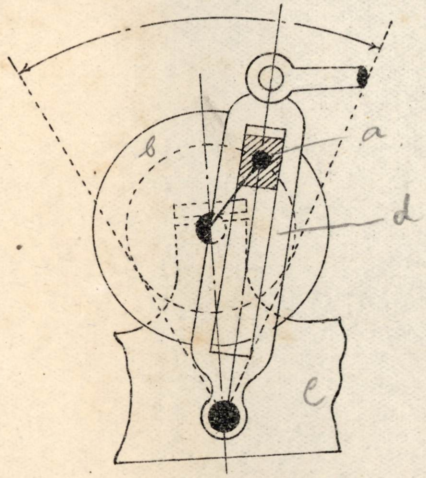
第23図

pendulum pump.

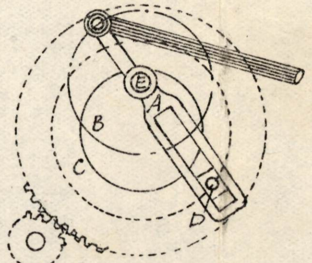


第19図ノ三

Quick return of shaping machine.

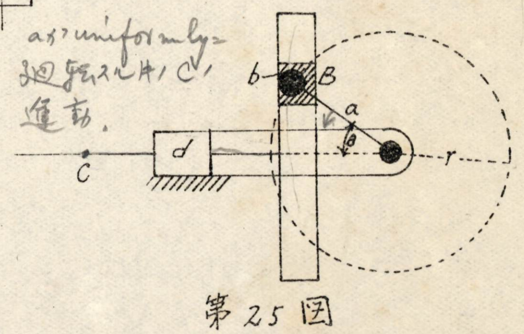


第21図ノ二

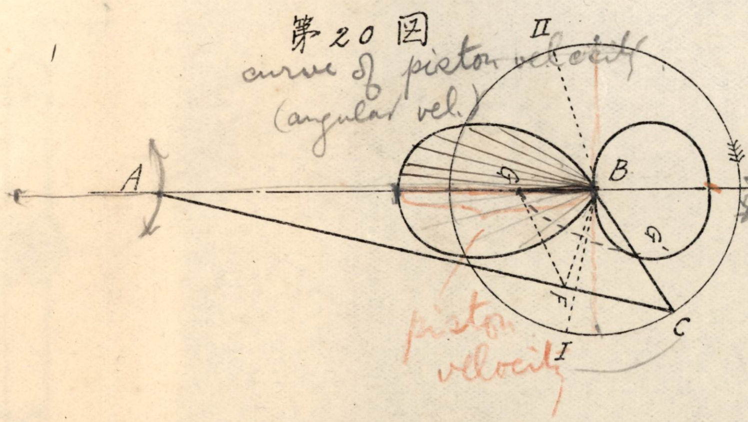


第24図

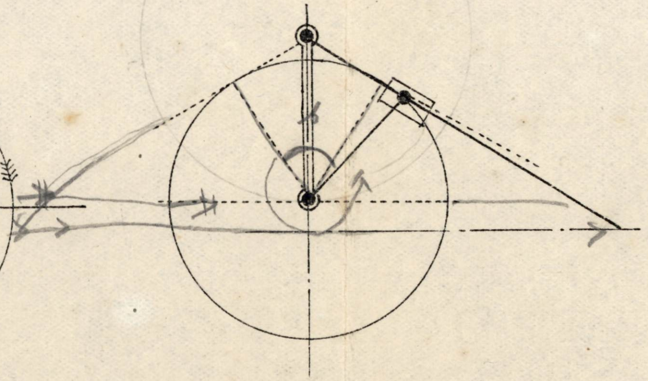
Double slider crank chain.



第20図

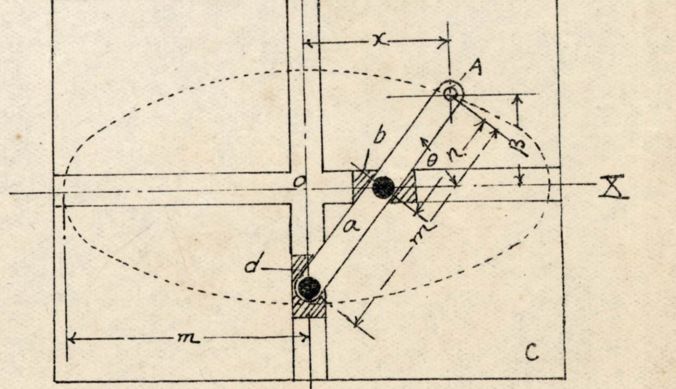


第22図



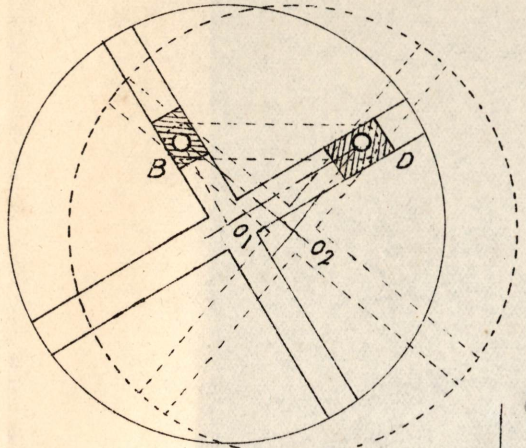
第25図

Elliptic trammel.



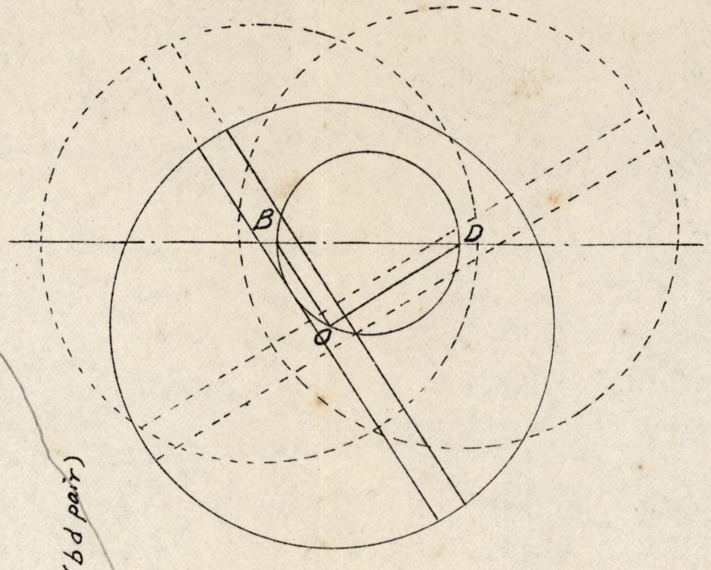
第26図ノ一

Oldham's Coupling.



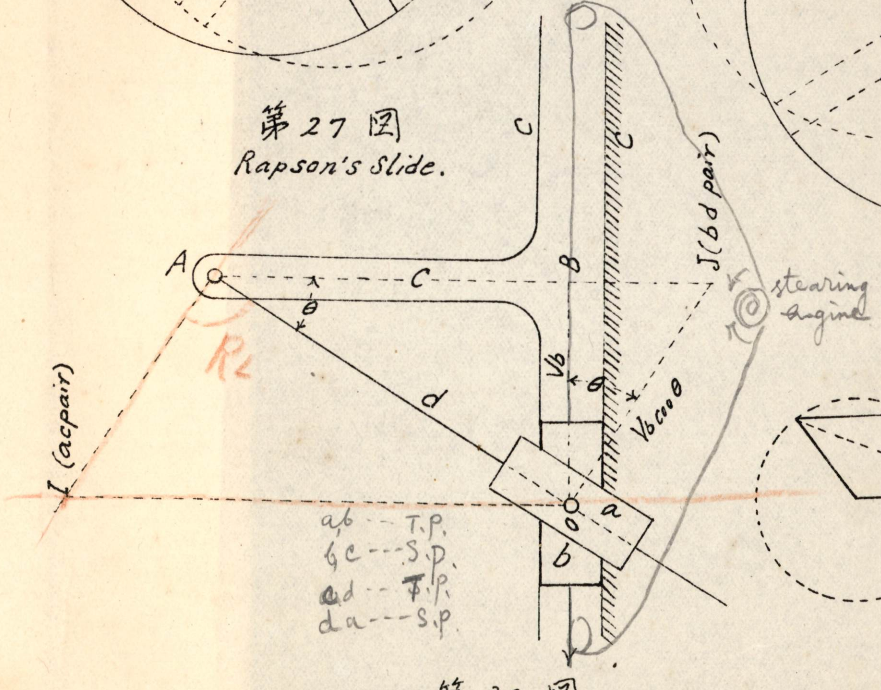
第26図ノ二

Oldham's Coupling.



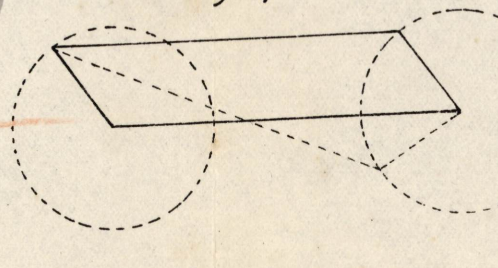
第27図

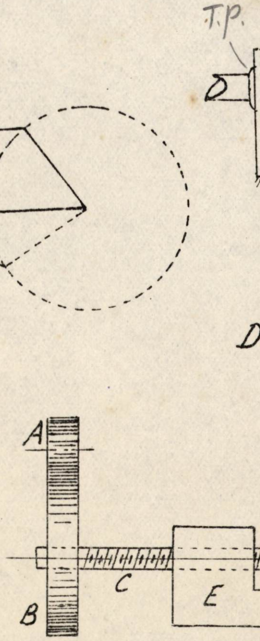
Rapson's Slide.



第28図

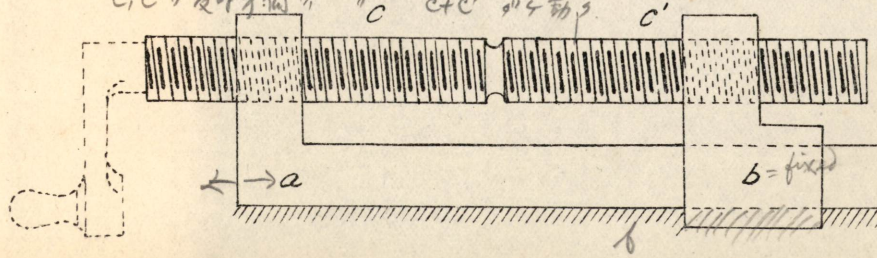
Change point.



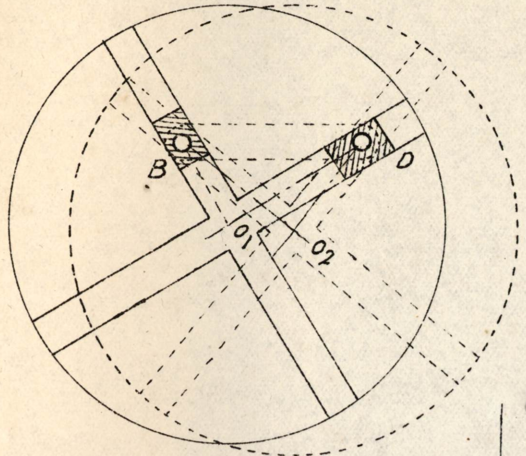


第30図

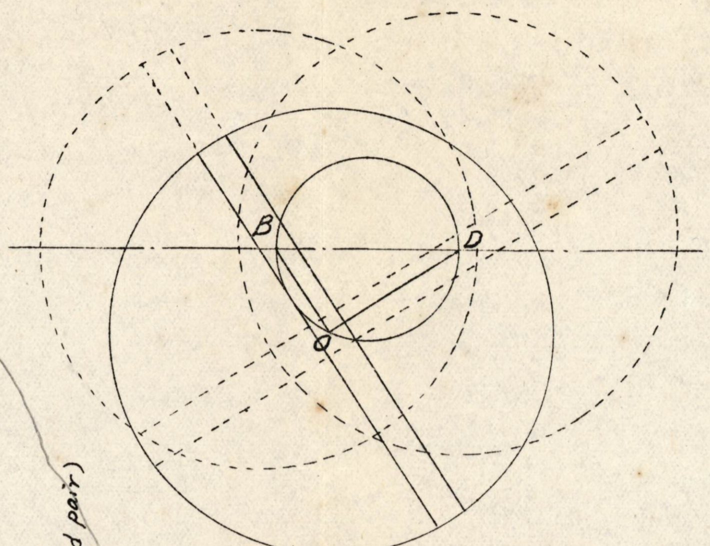
Differential Screw.



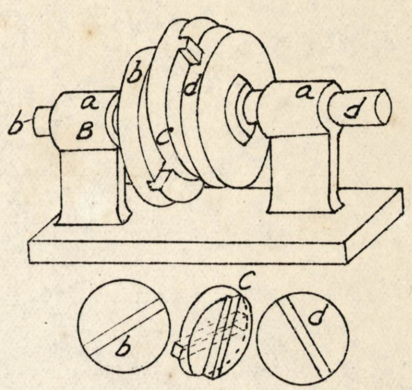
第26図,一
Oldham's Coupling.



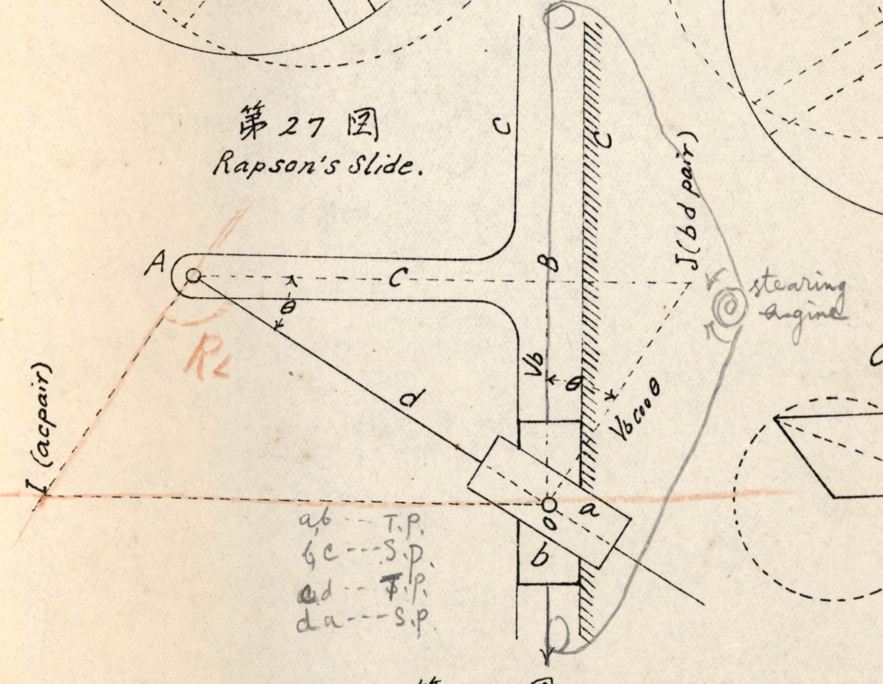
第26図,二
Oldham's Coupling.



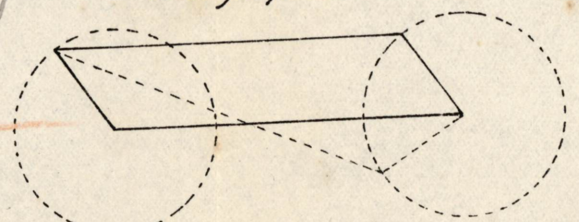
第26図,三
Oldham's Coupling.



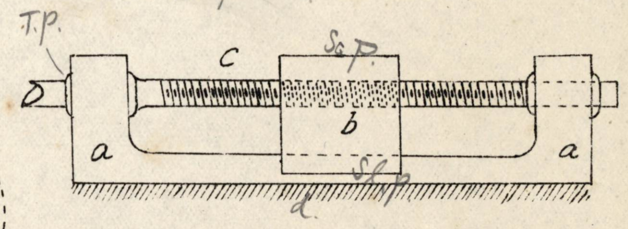
第27図
Rapson's Slide.



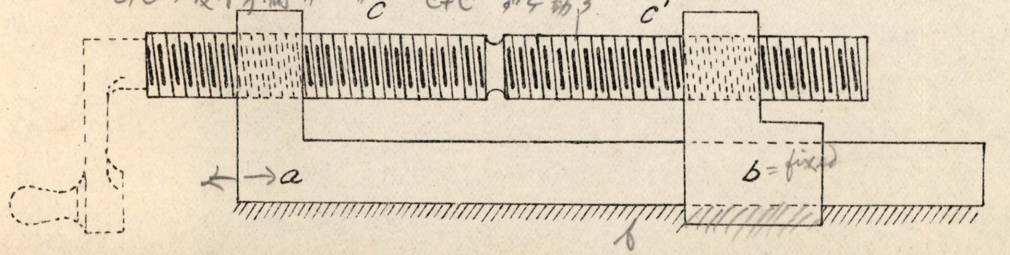
第28図
Change point.



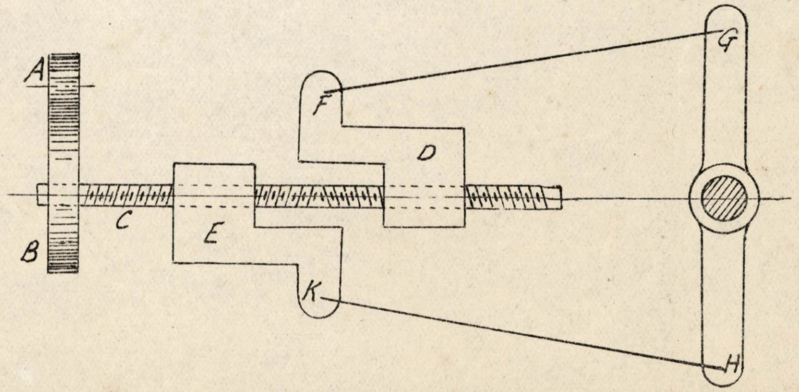
第29図
Screw chain.
3 pairs



第30図
Differential Screw.

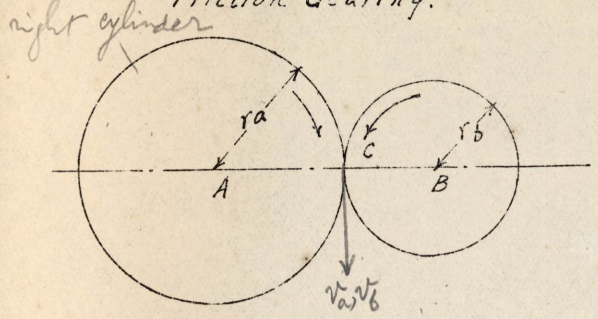


第31図
Differential Screw. (stearing gear)



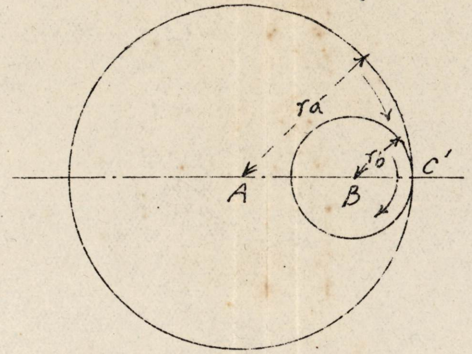
第32図ノ一

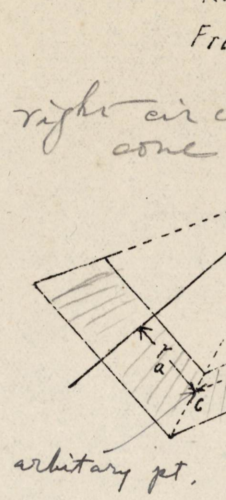
Rolling Contact.
Friction Gearing.



第32図ノ二

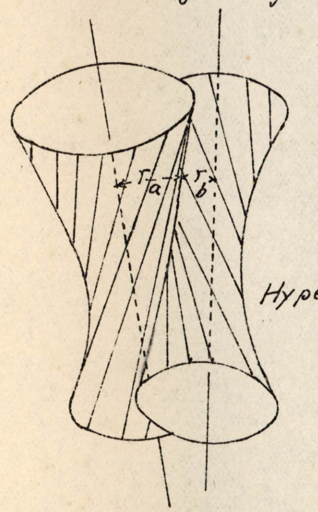
Rolling Contact.
Friction Gearing.



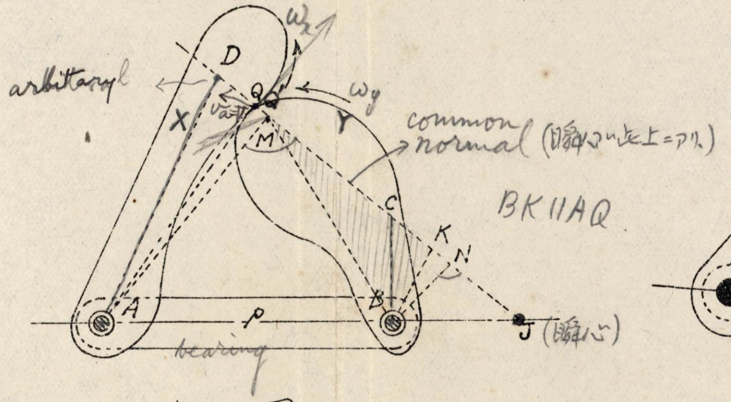


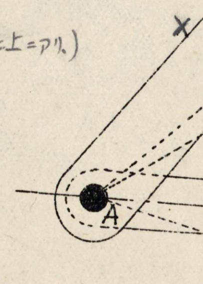
第34図

Friction gearing.

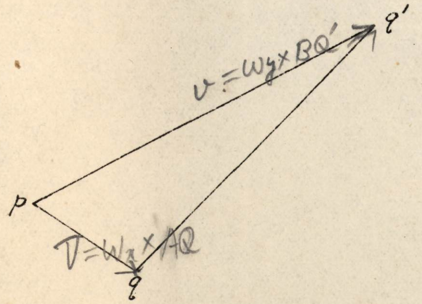


第35図ノ一

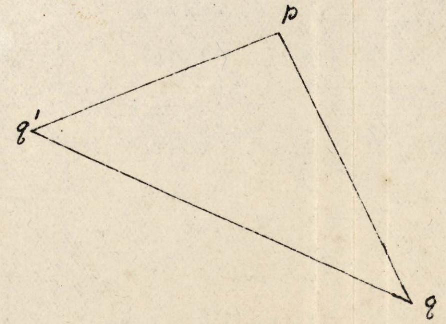


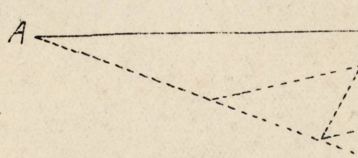


第36図ノ一

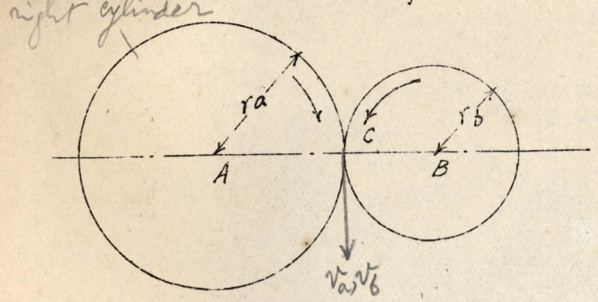


第36図ノ二

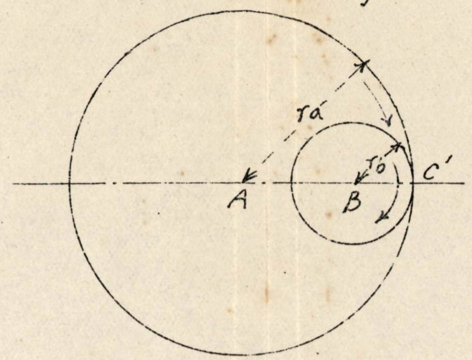




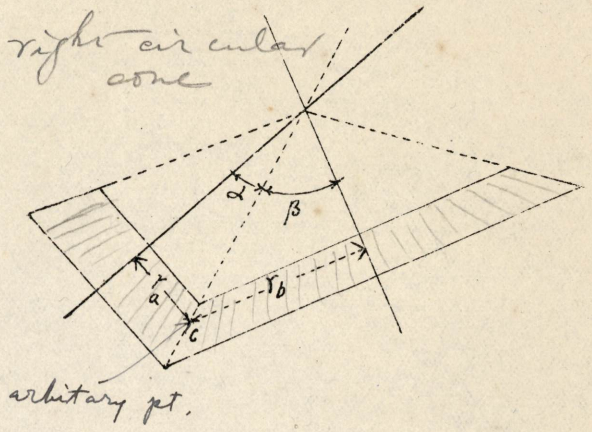
第32図，一
Rolling Contact.
Friction Gearing.



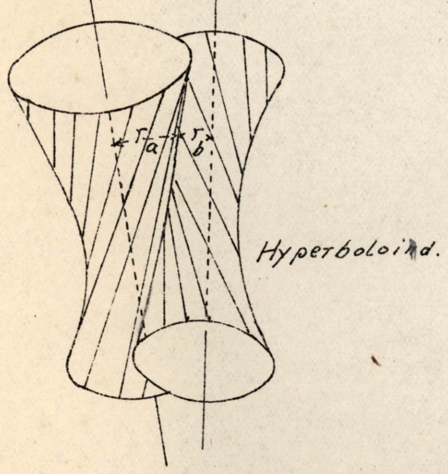
第32図，二
Rolling Contact.
Friction Gearing.



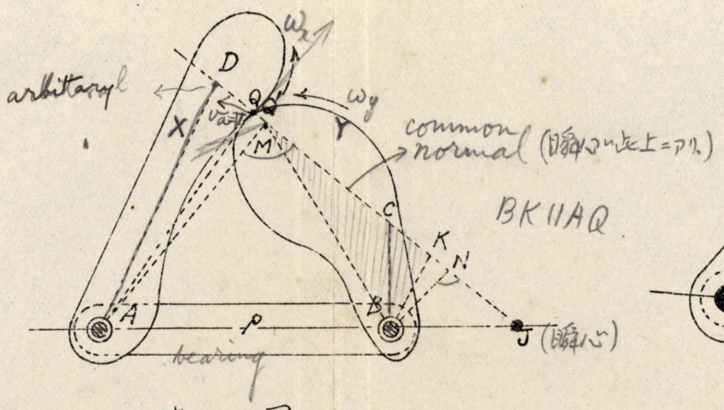
第33図
Rolling Contact.
Friction Gearing.



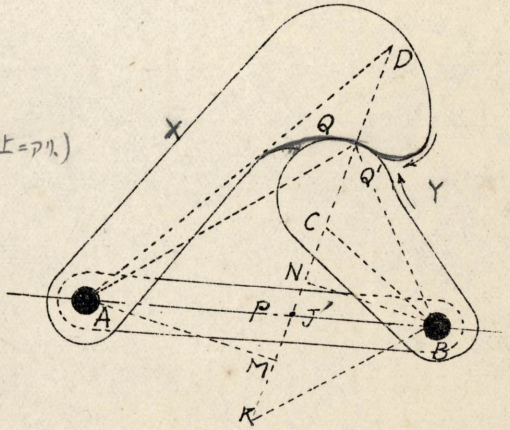
第34図
Friction gearing.



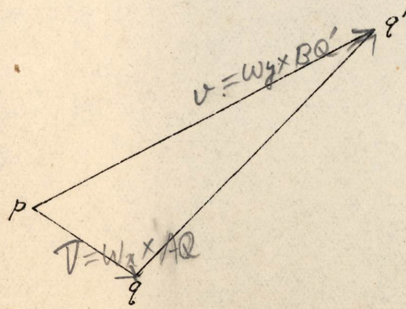
第35図，一



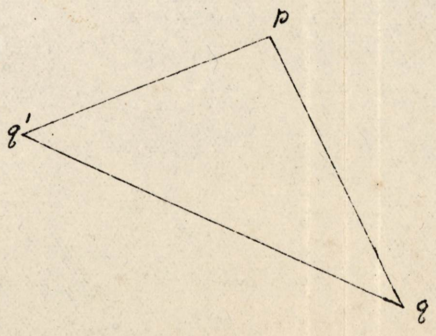
第35図，二



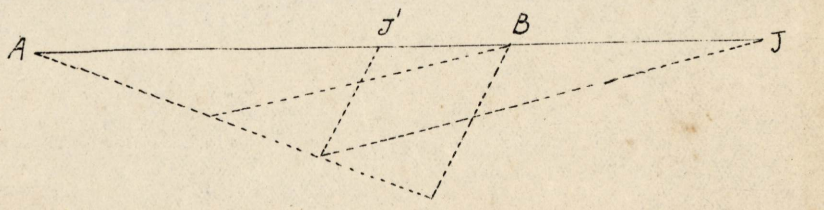
第36図，一



第36図，二

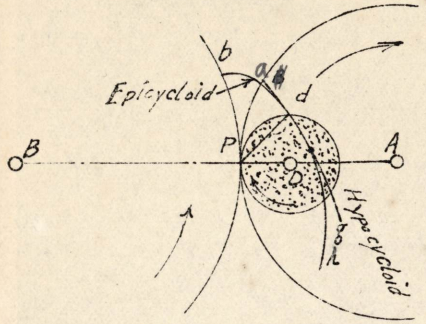


第37図



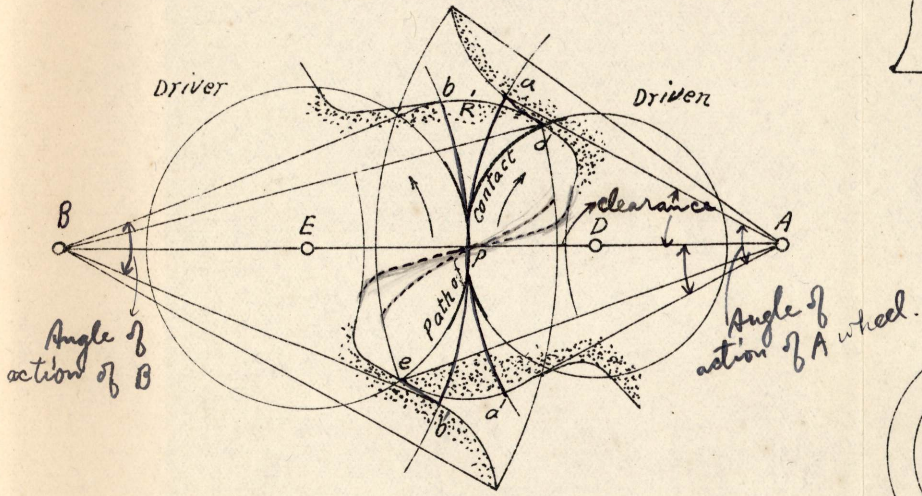
第38図

Cycloidal teeth.



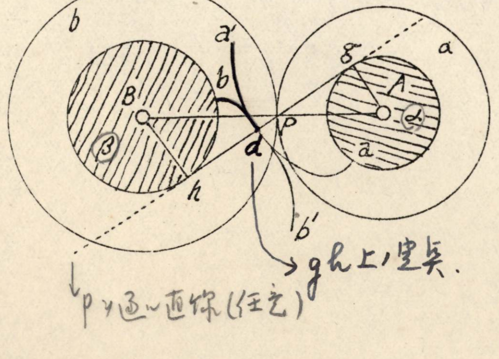
第39図

Dooble curve teeth.

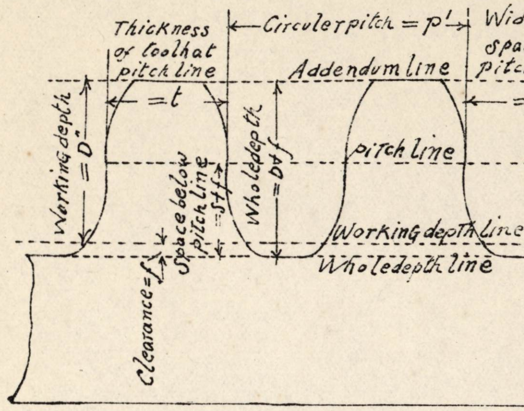


第40図

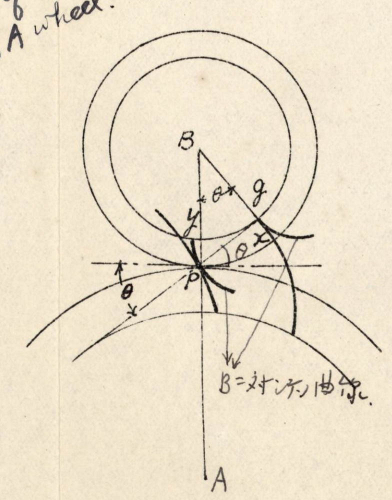
Involute teeth.

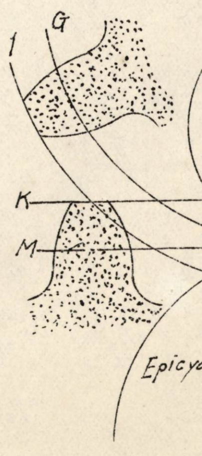


第41図 Ra

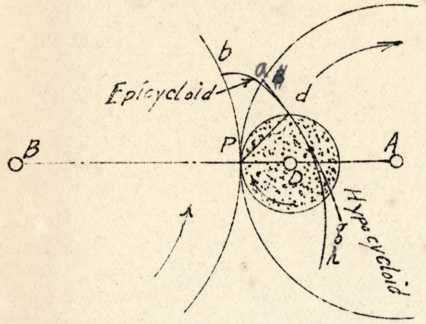


第42図

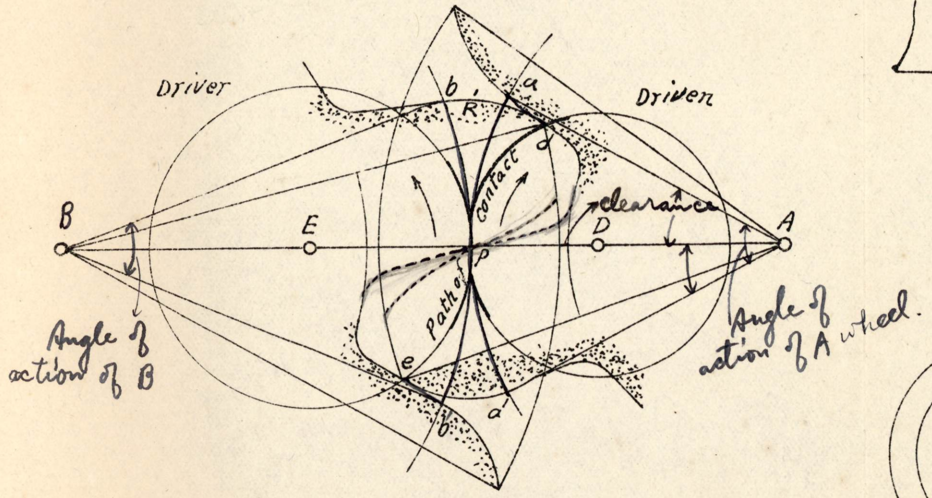




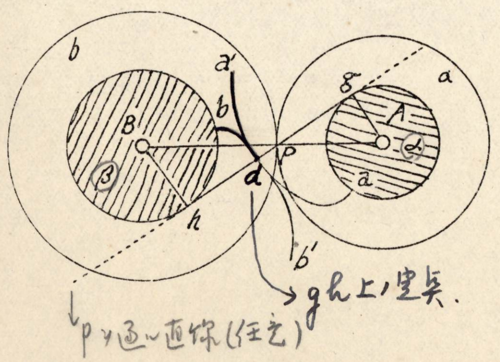
第38図
Cycloidal teeth.



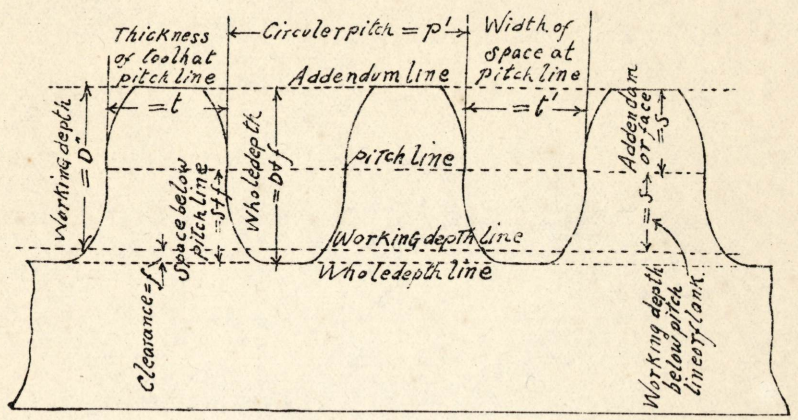
第39図
Dooble curve teeth.



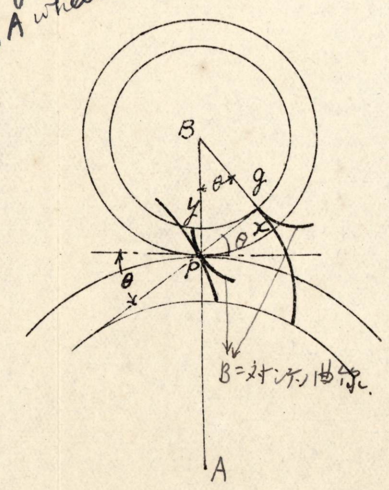
第40図
Involute teeth.



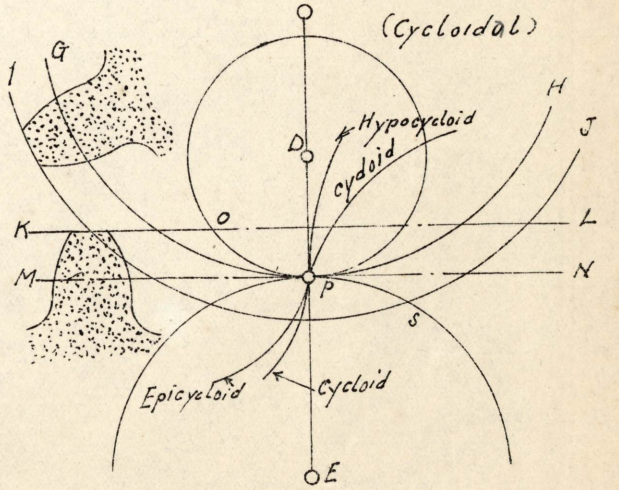
第41図 Rack (歯杆)



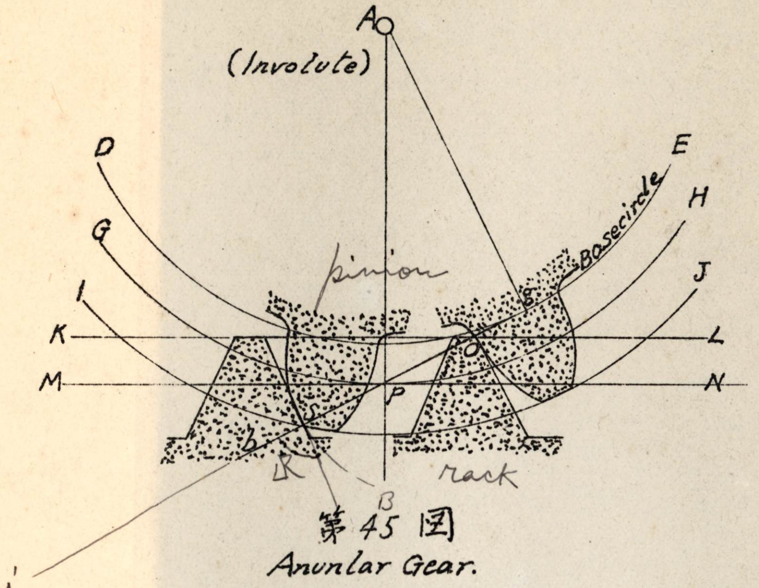
第42図



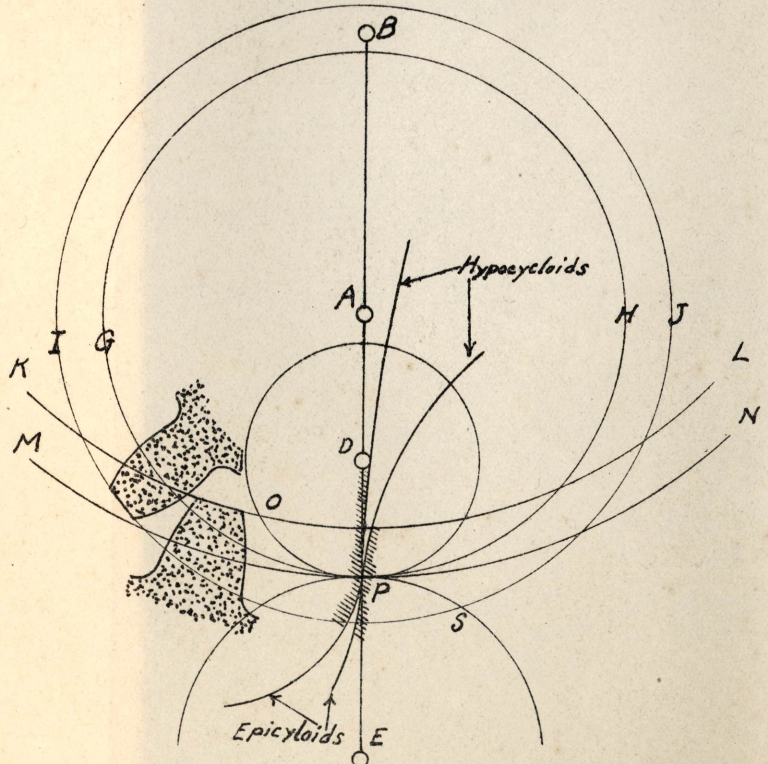
第43図
Rack and pinion.



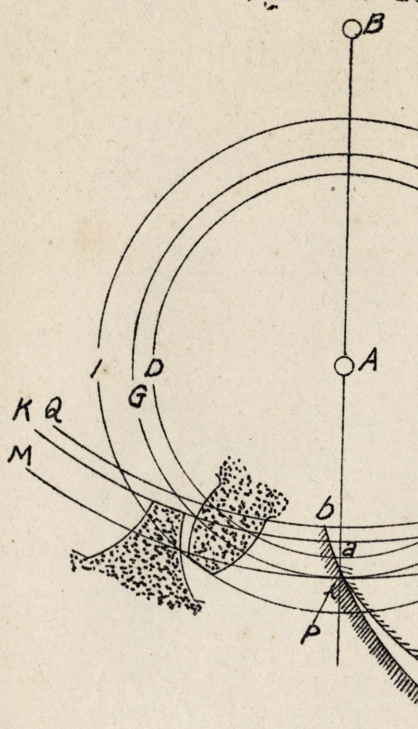
第44図
Rack and pinion.



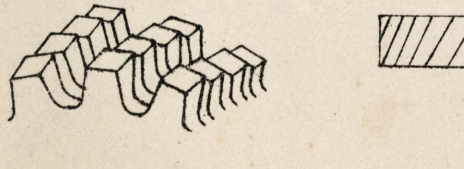
第45図
Anunlar Gear.



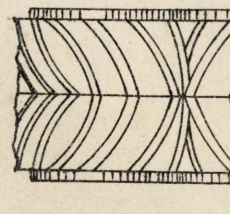
第46
Annular G



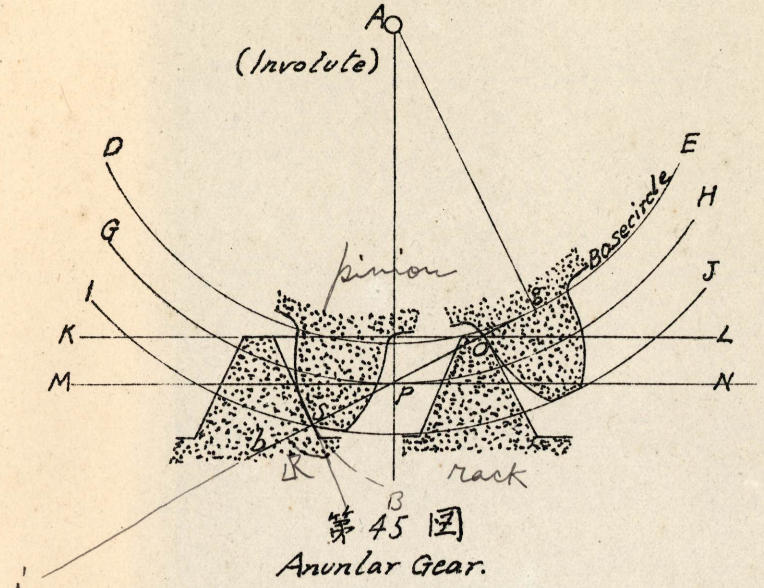
第47図
Stepped teeth.



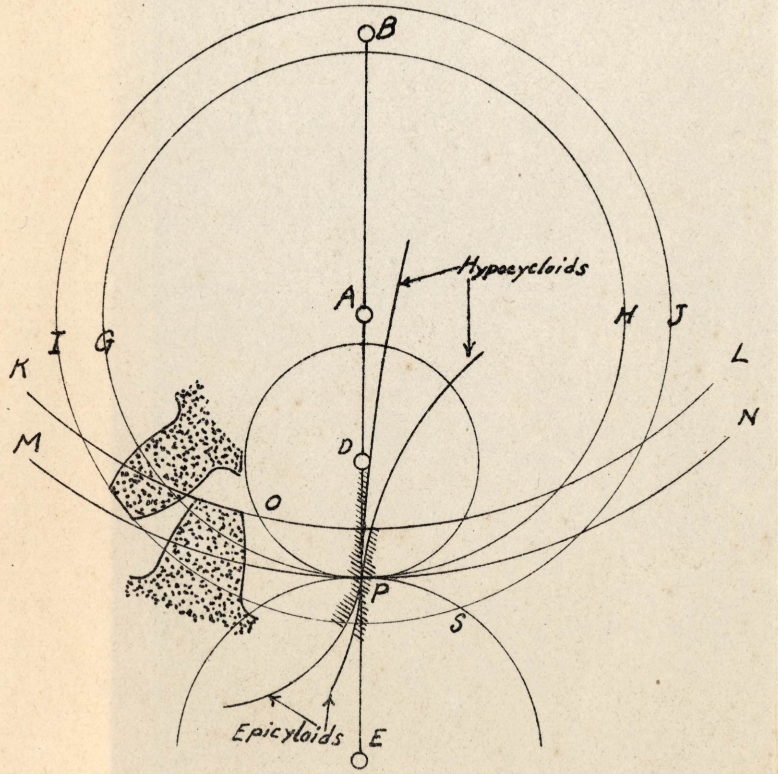
第49
Double herica



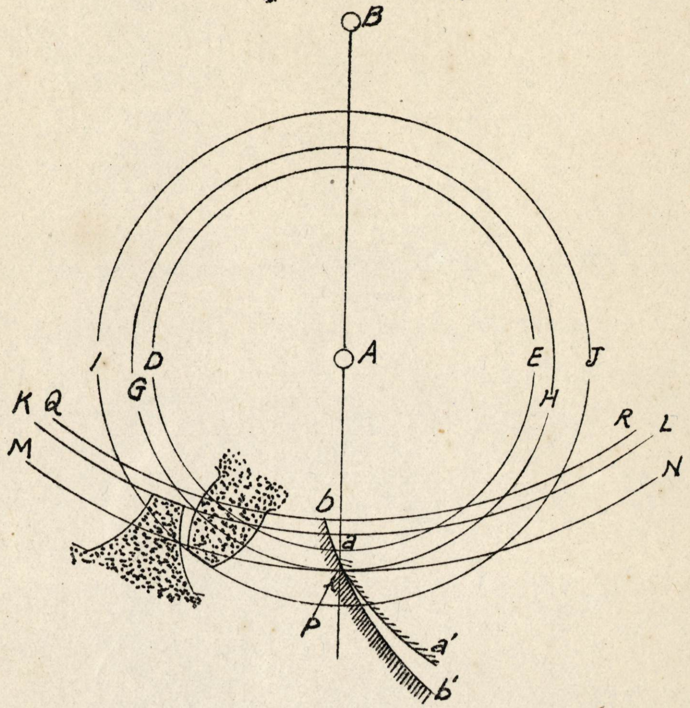
第44図
Rack and pinion.



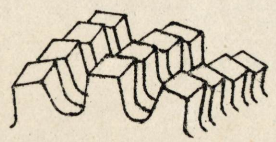
第45図
Anunlar Gear.



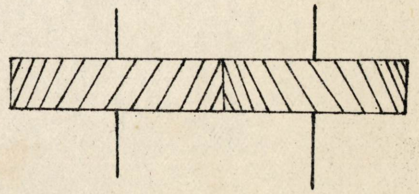
第46図
Annular Gear.



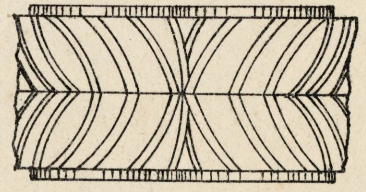
第47図
Stepped teeth.



第48図
Herical wheel.

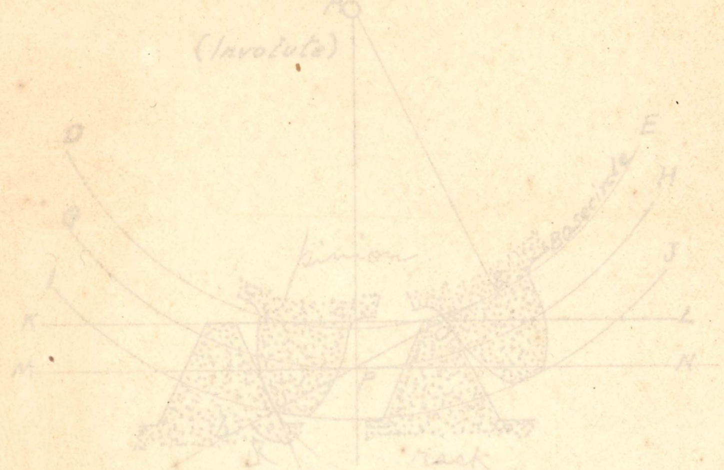


第49図
Double herical wheel.



第44図

Rack and pinion.

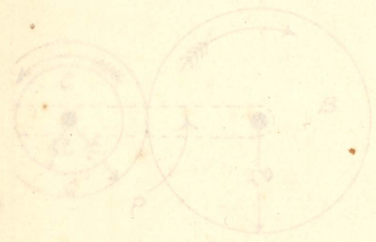


第45図

Annular Gear.

第58図

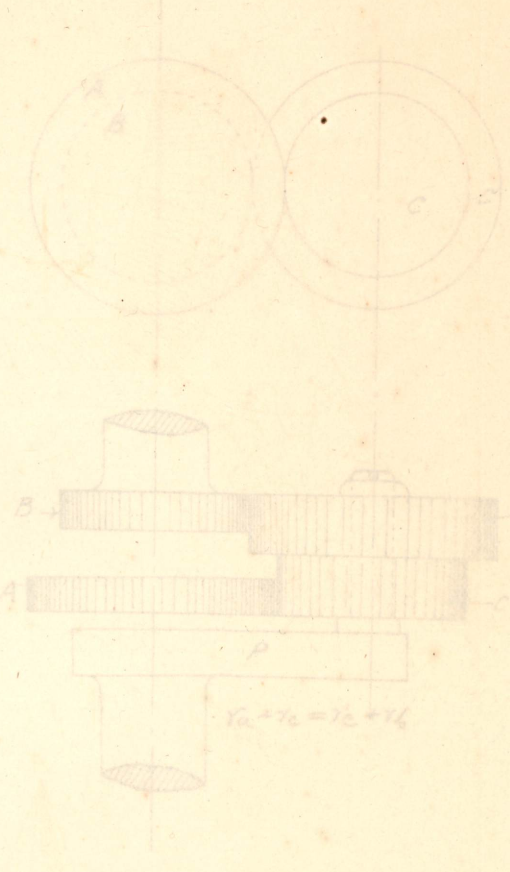
第59図



第60図

第61図

Reverted wheel train

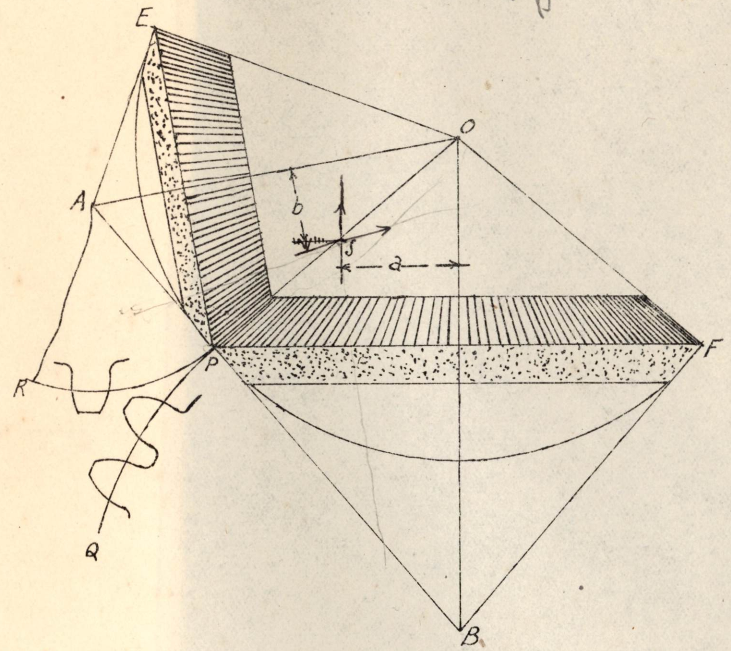


第62図

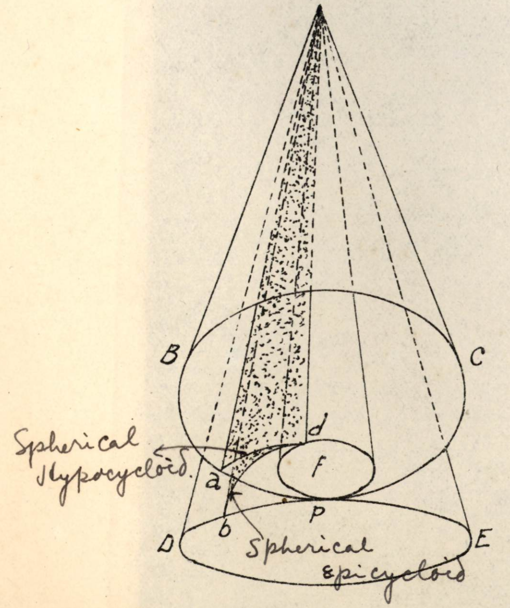
Reverted wheel train

第50図

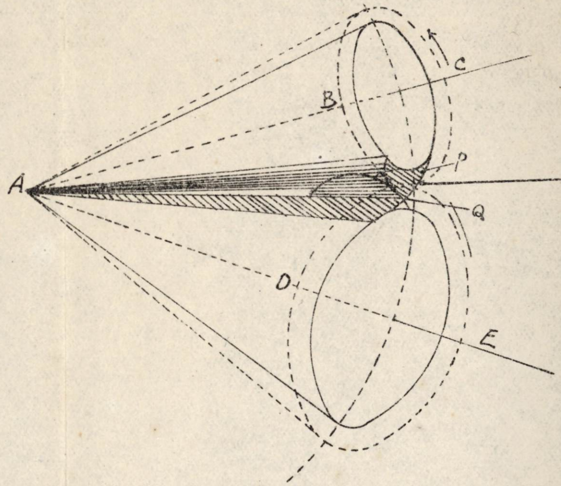
Bevel wheel.



第51図

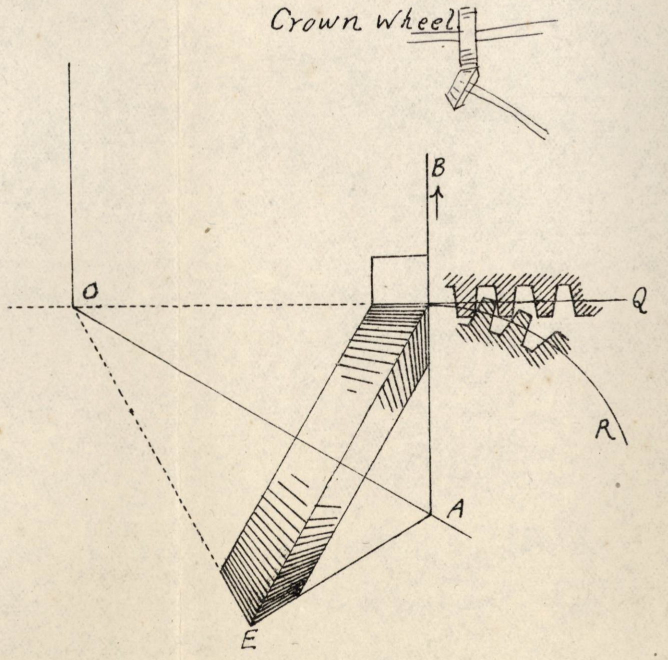


第52図



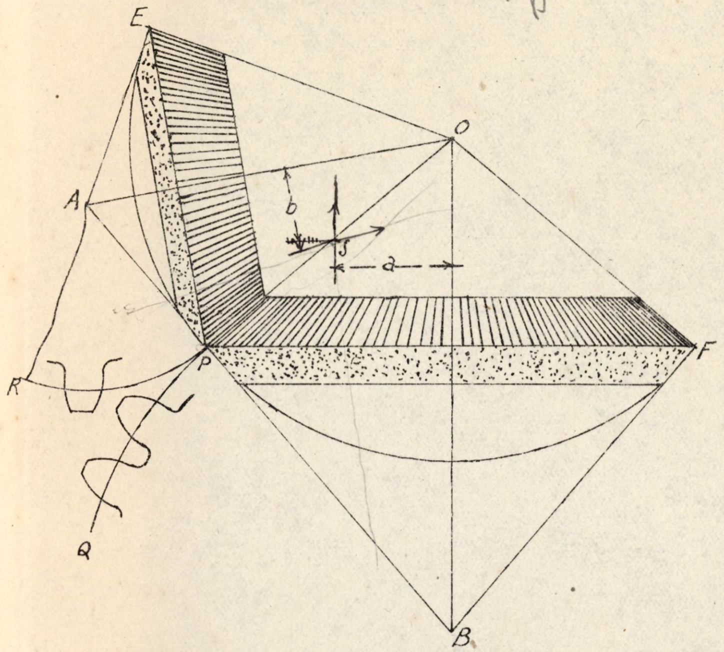
第53図

Crown wheel

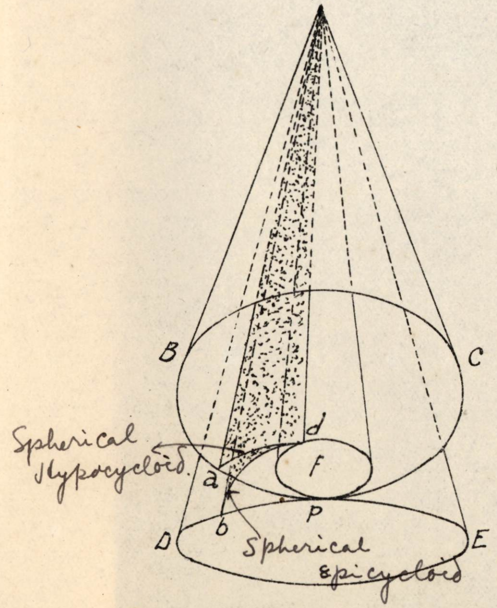


第50図

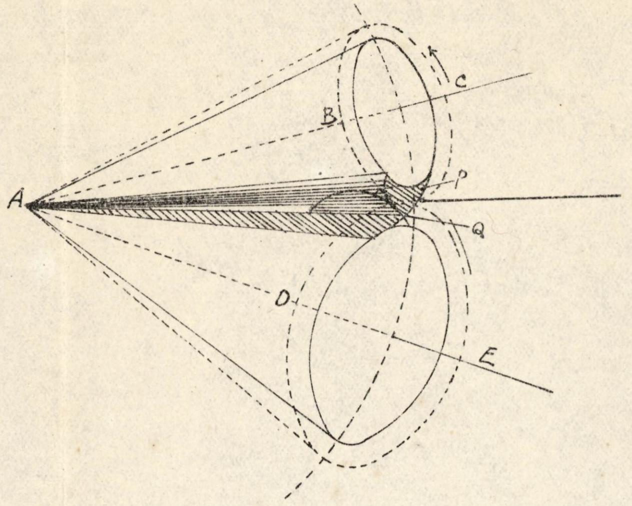
Bevel wheel.



第51図

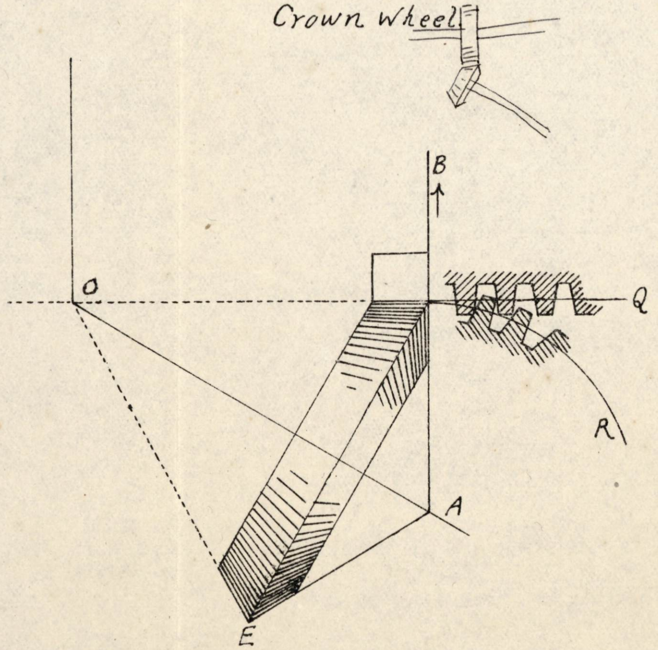


第52図



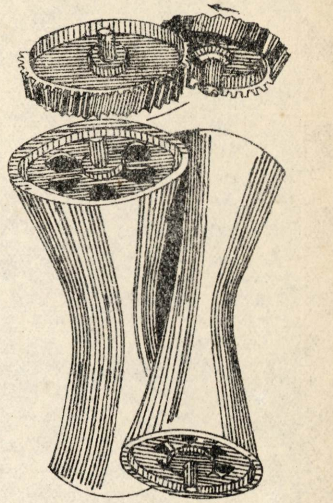
第53図

Crown wheel.



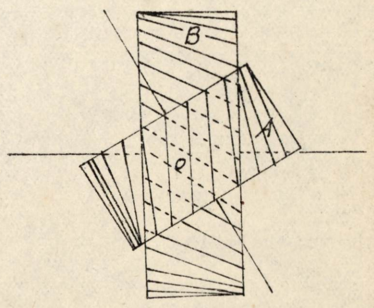
第54図

Skew Bevel wheel.

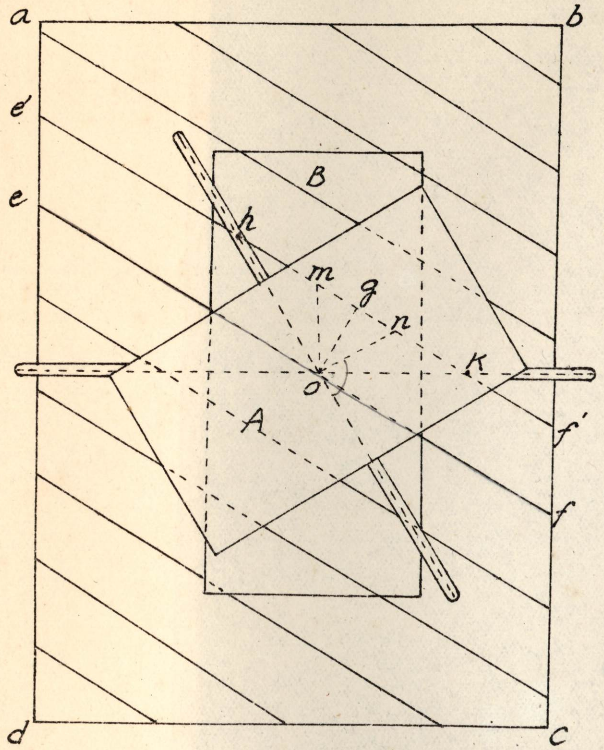


第55図

Screw gear.

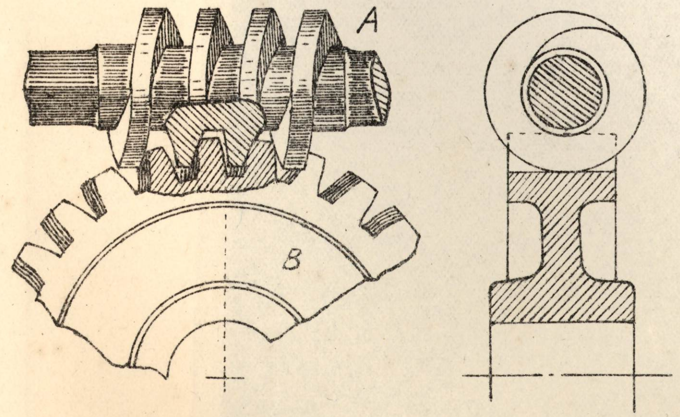


第56図



第57図

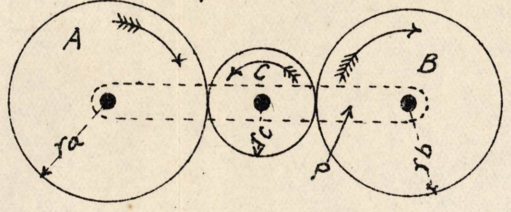
Worm and Worm Wheel.



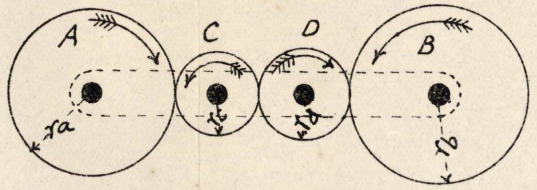
第58図, 一

Wheel train.

Simple wheel train.

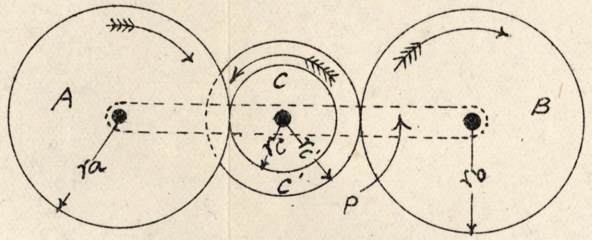


第58図, 二



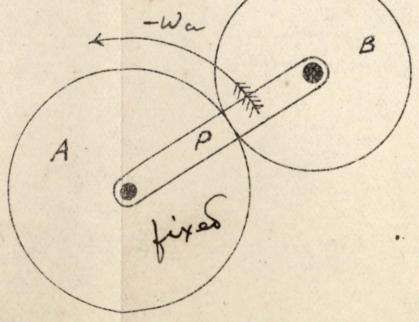
第59図

Compound wheel train.

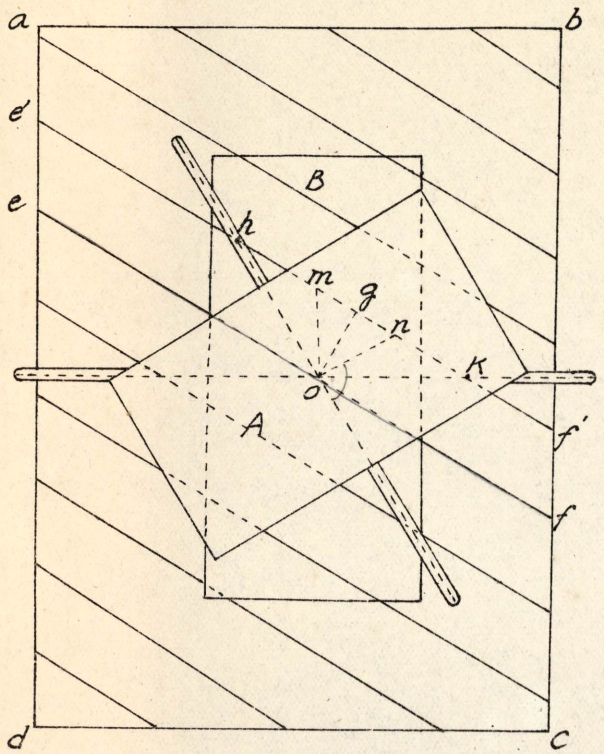


第60図

Epicyclic wheel train.

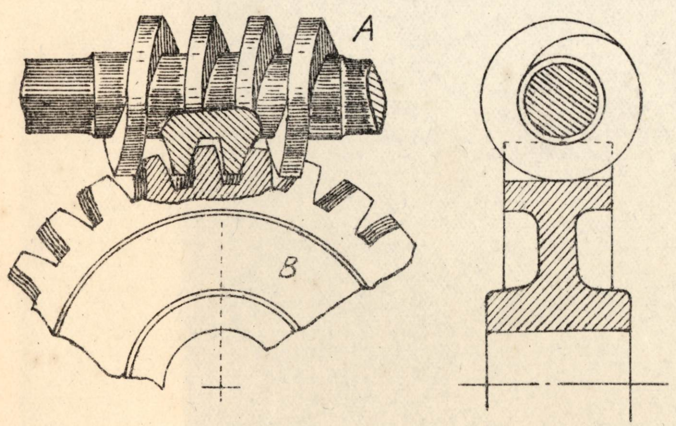


第56図



第57図

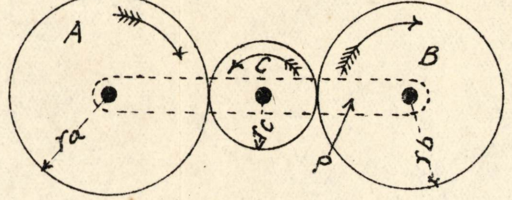
Worm and Worm Wheel.



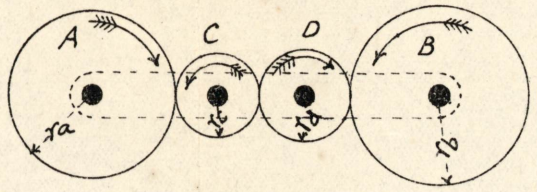
第58図，一

Wheel train.

Sinple wheel train.

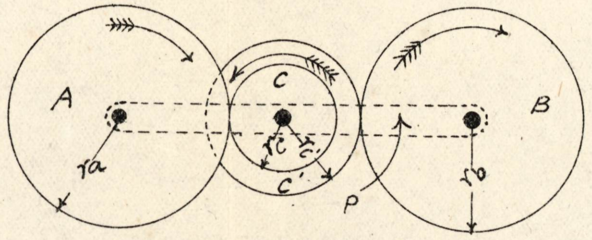


第58図，二



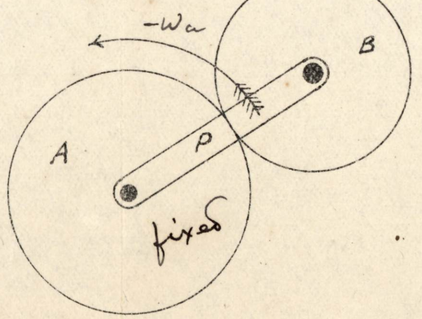
第59図

Compound wheel train.



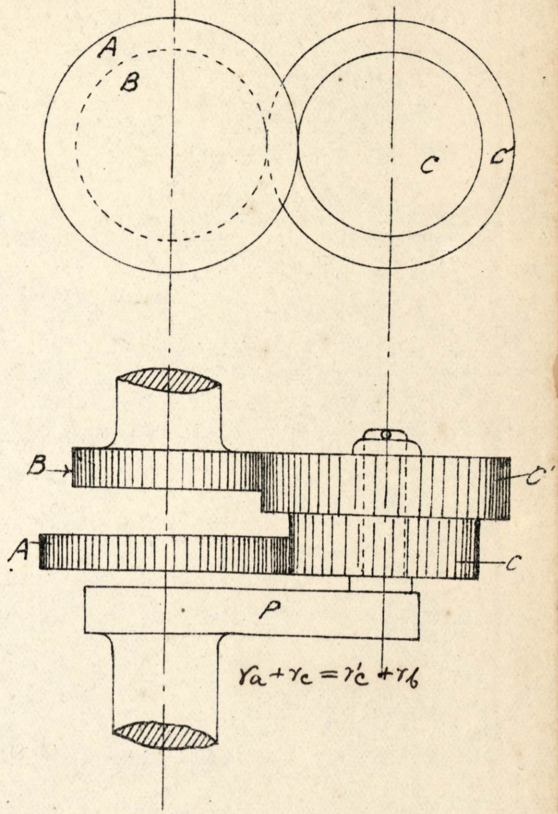
第60図

Epicyclic wheel train.



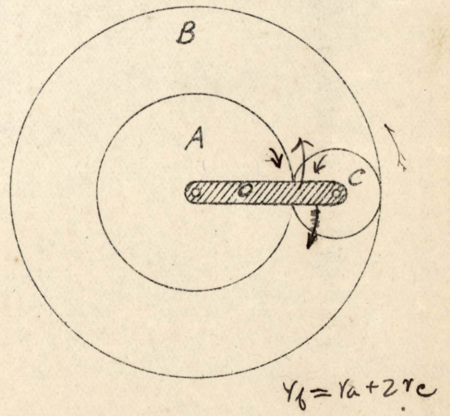
第61図

Reverted wheel train.

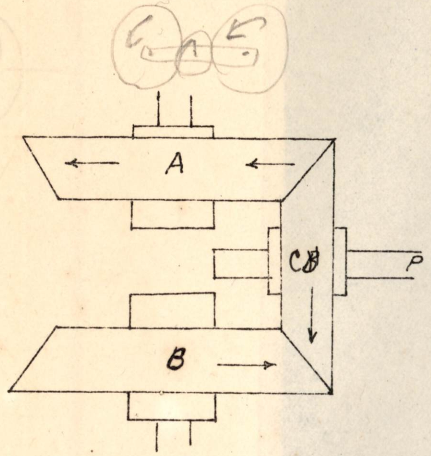


第62図

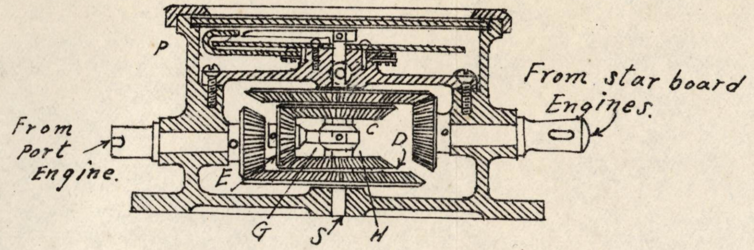
Reverted wheel train.



第63図

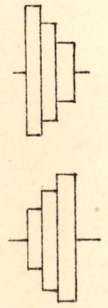


第64図

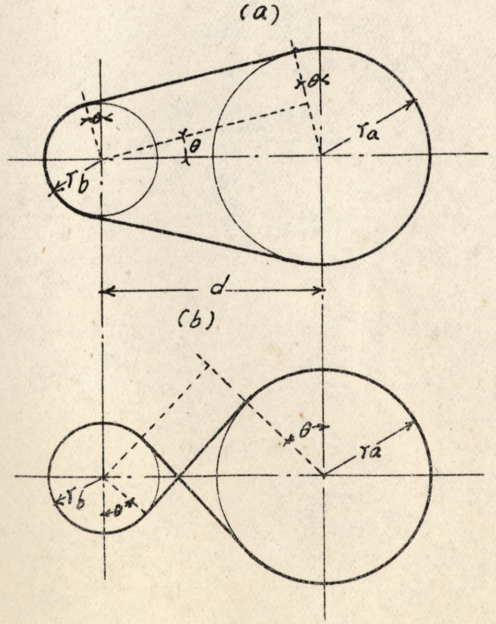


第66図

Stepped pulley.

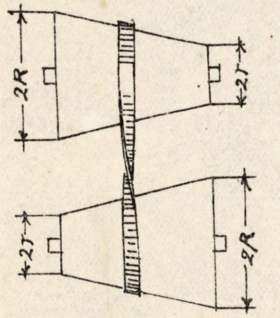


第67図



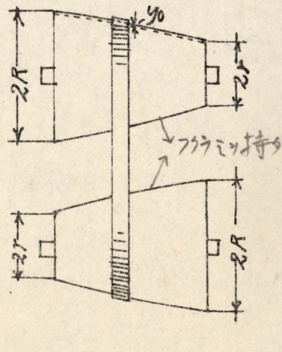
第68図

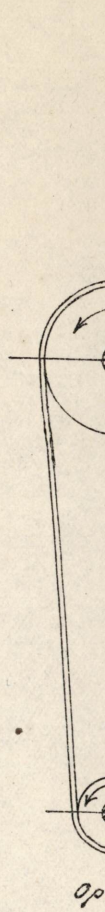
Cone pulley.



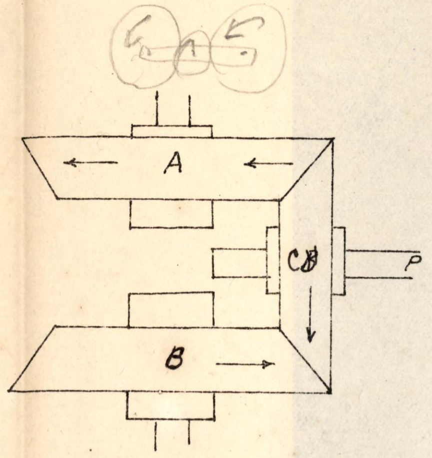
第69図

Cone pulley.

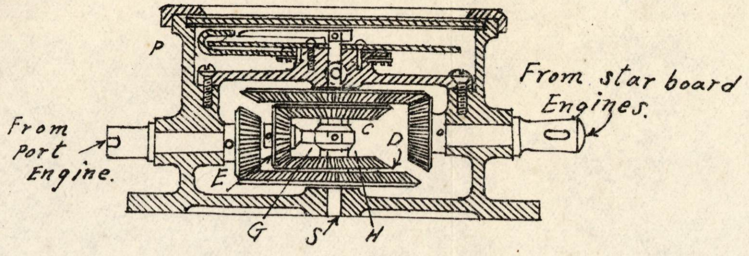




第63図

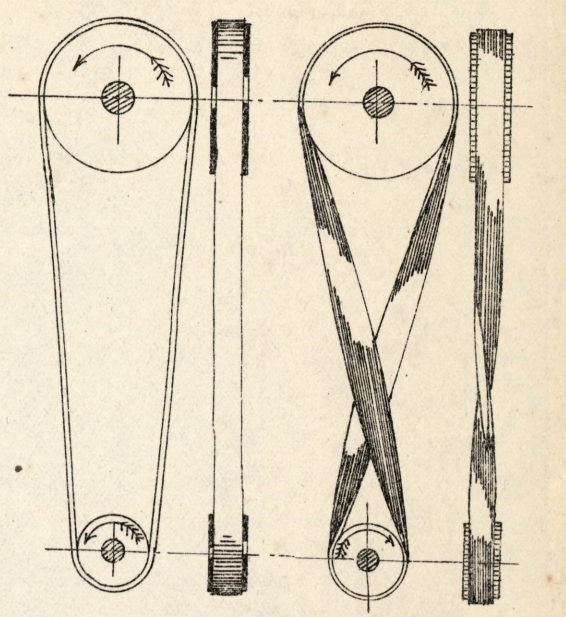


第64図



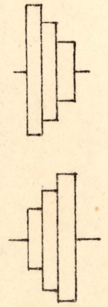
第65図

Belt gearing.

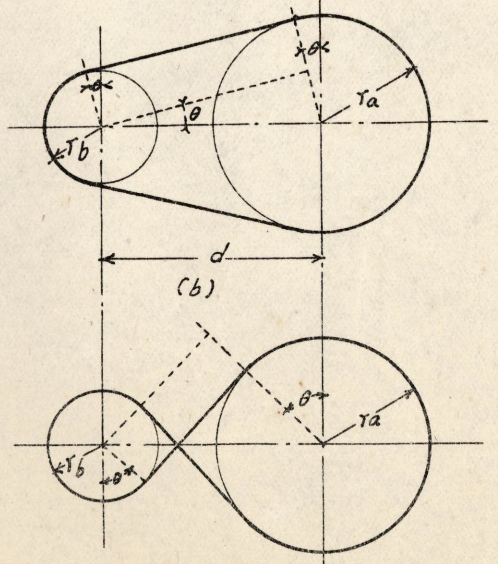


第66図

Stepped pulley.

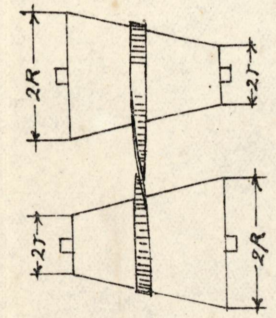


第67図



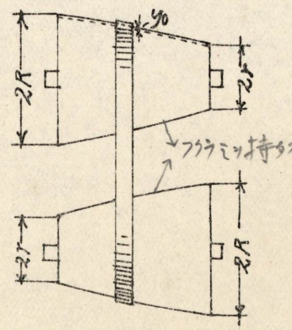
第68図

Cone pulley.

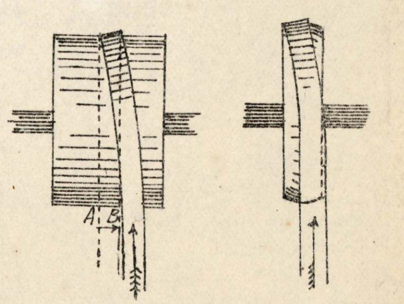


第69図

Cone pulley.



第70図



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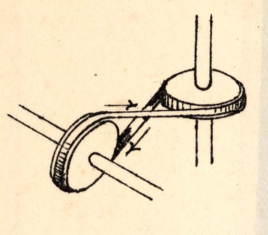

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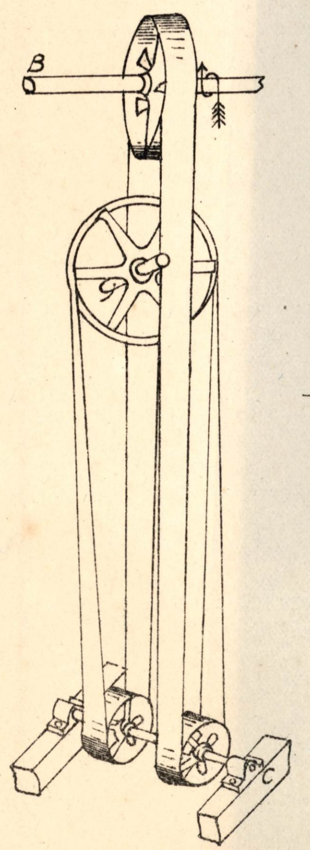
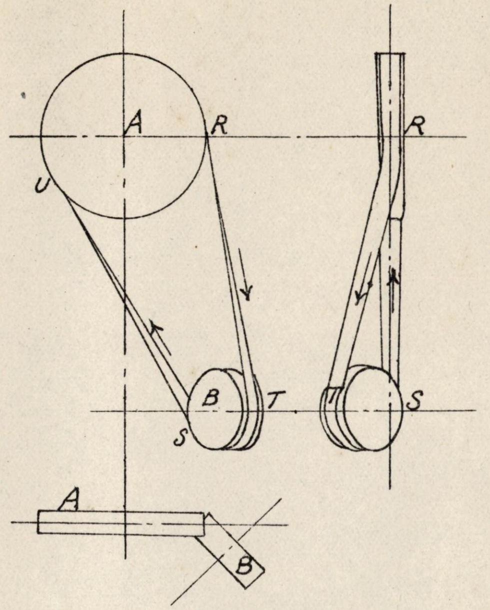
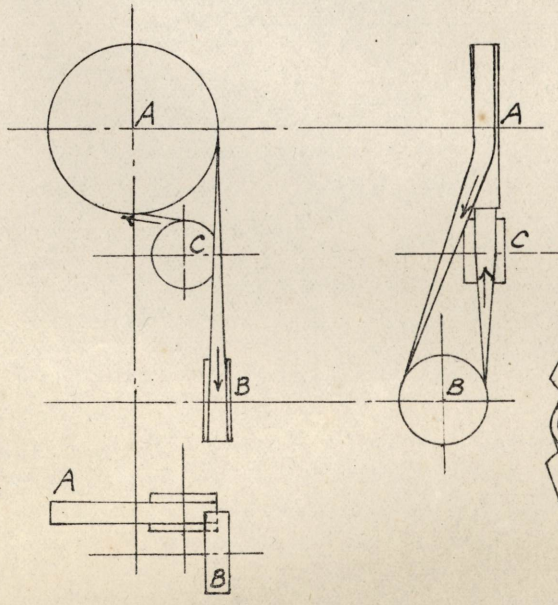


第73図



第74図



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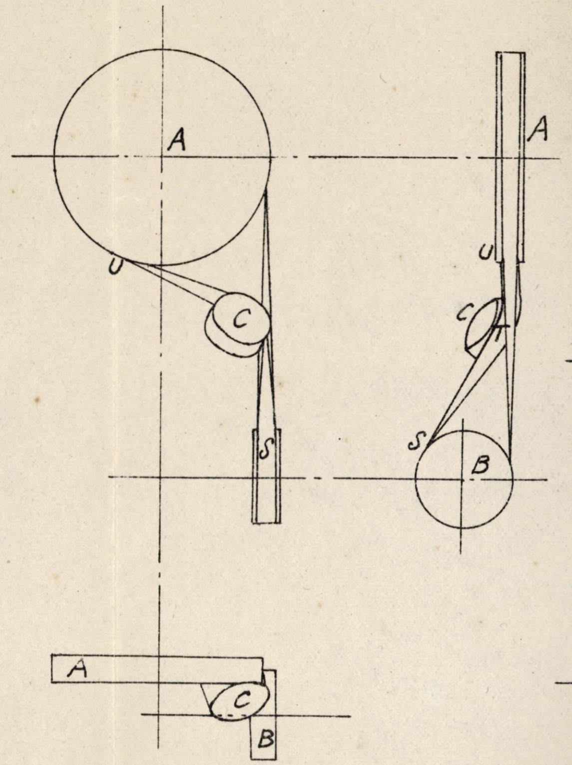

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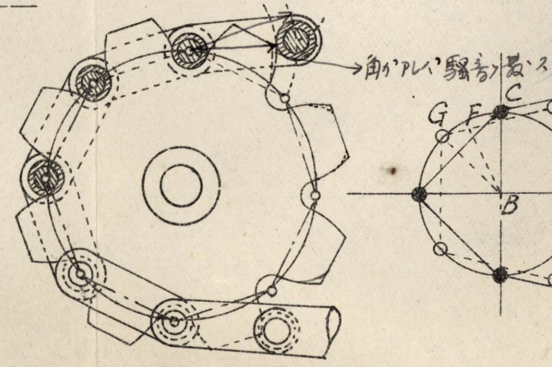

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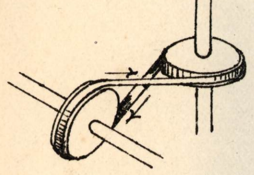

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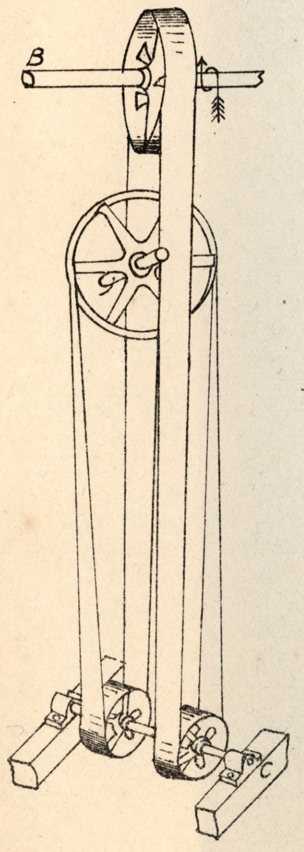

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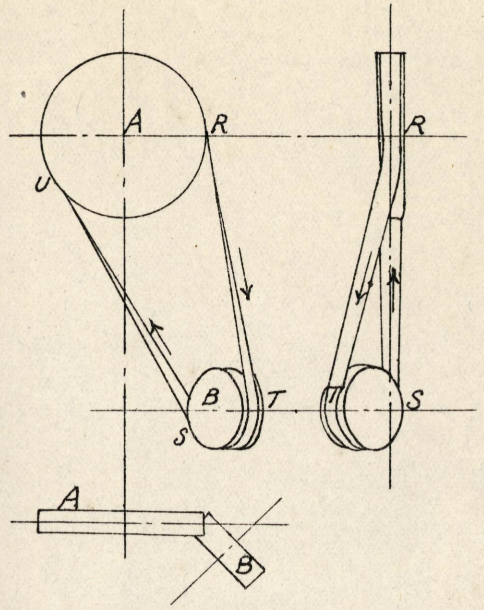

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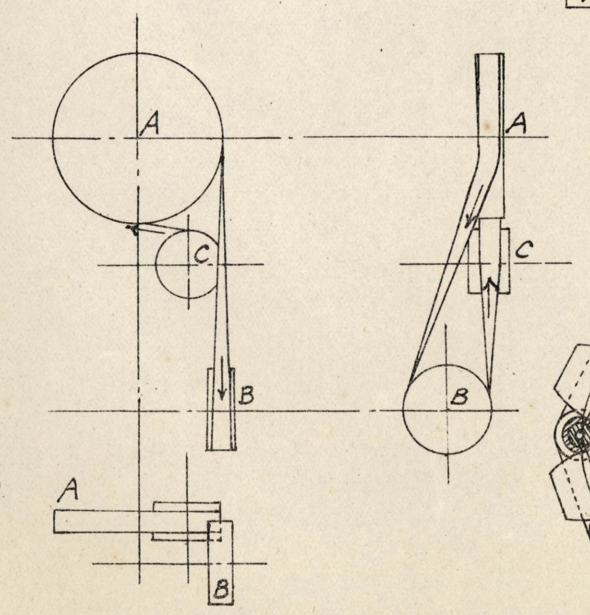

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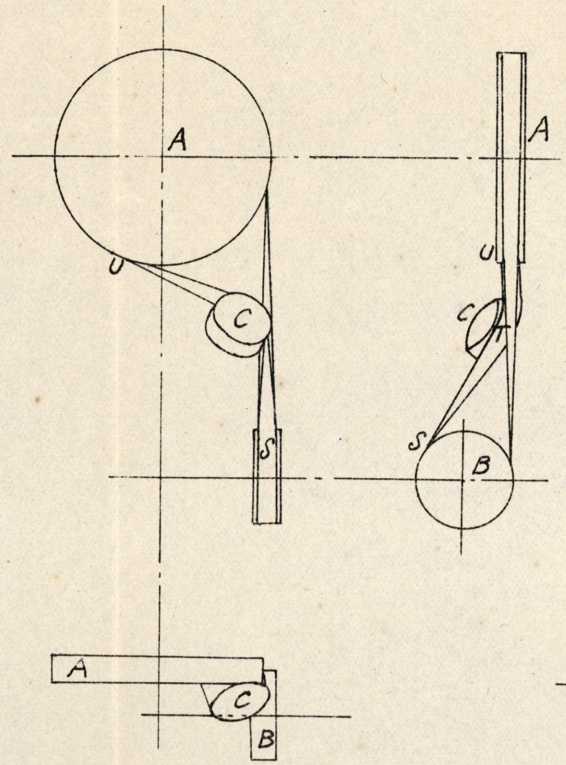
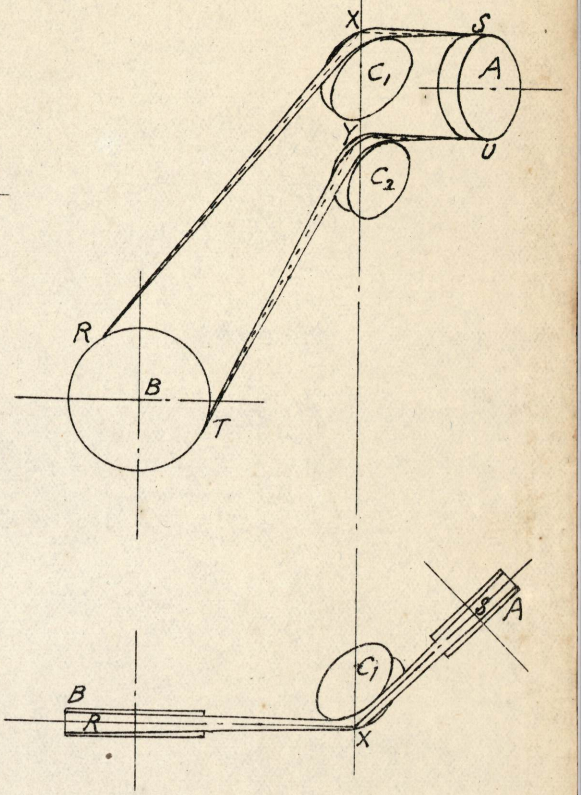


第76図



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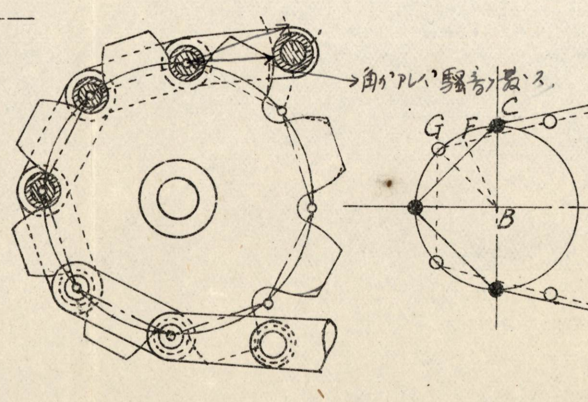
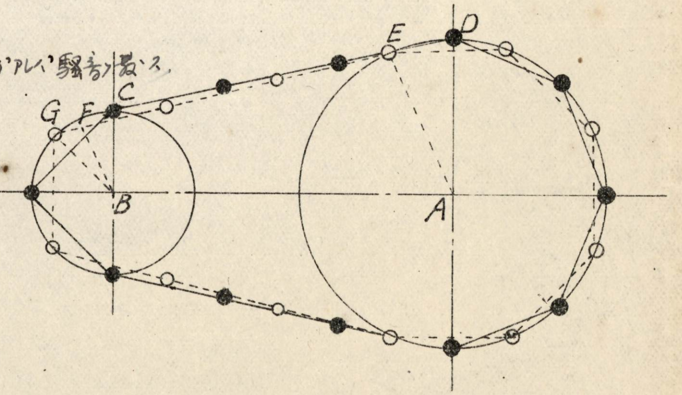
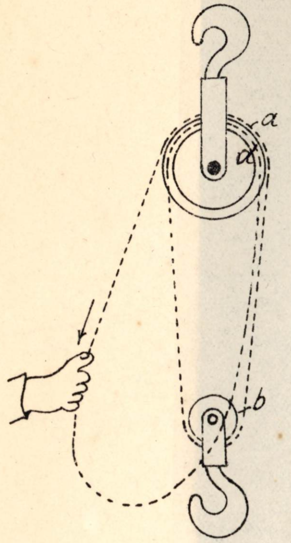


第78図



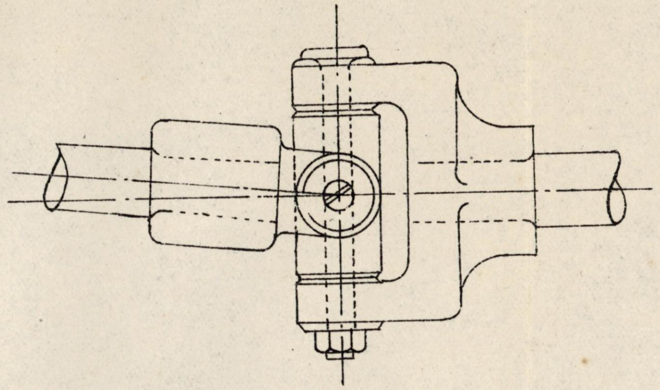
第79図

Differential pulley-block.

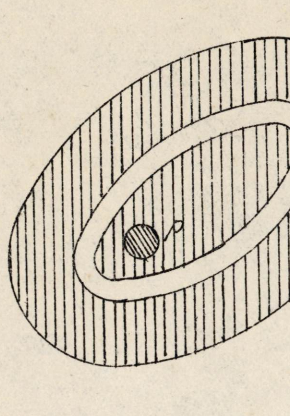


第81図

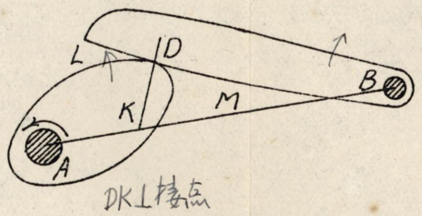
Hooke's Universal joint.



第84図

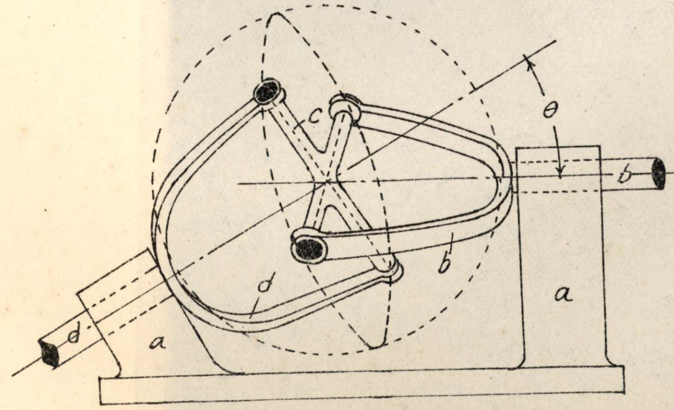


第82図



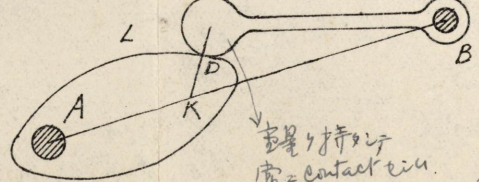
第80図

Hooke's Universol joint.



第83図

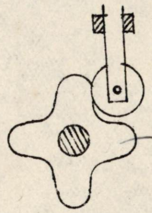
Cam train.



第85図

Lobe

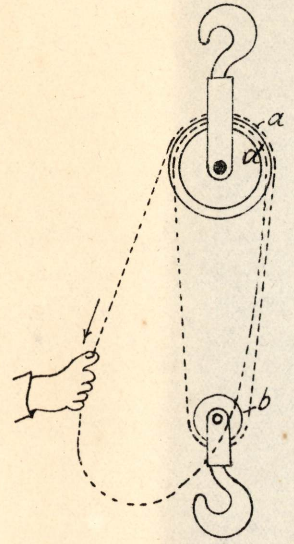
Whee



heart

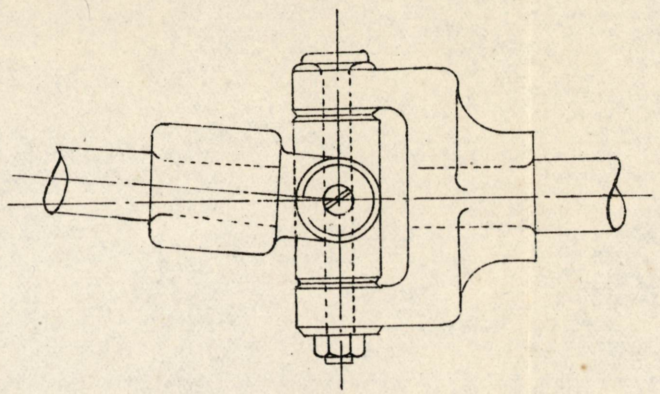
第79図

Differential pulley-block.

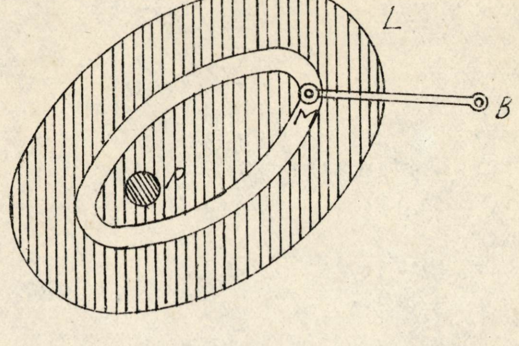


第81図

Hooke's Universal joint.

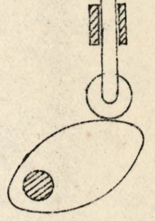


第84図



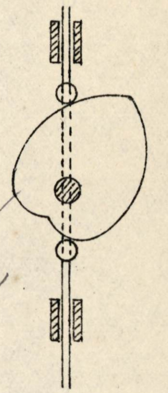
第85図ノ一

Cam.

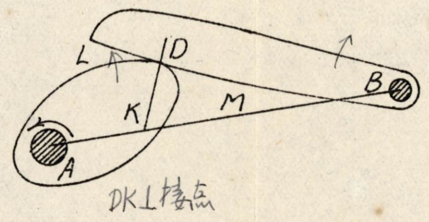


第85図ノ三

Cam.

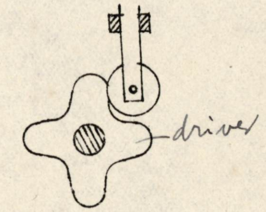


第82図



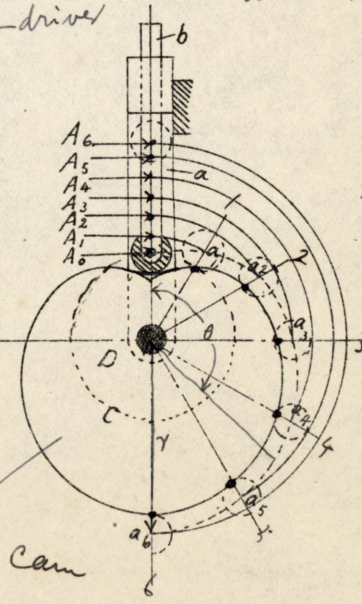
第85図ノ二

Lobed Wheel.



第86図

Cam.

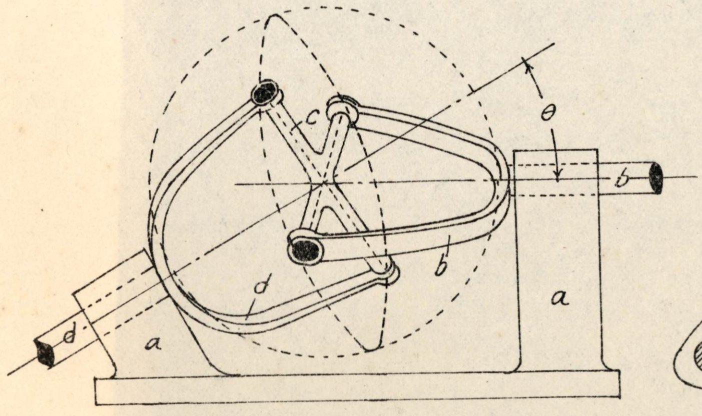


$Y = DA_0 + \frac{AA_6 \times \theta}{180}$

Archimedes' spiral

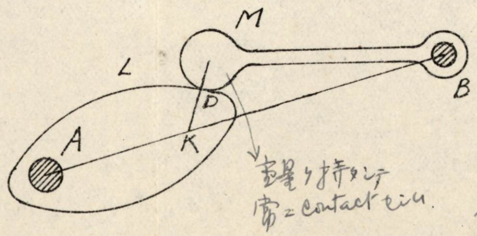
第80図

Hooke's Universal joint.



第83図

Cam train.

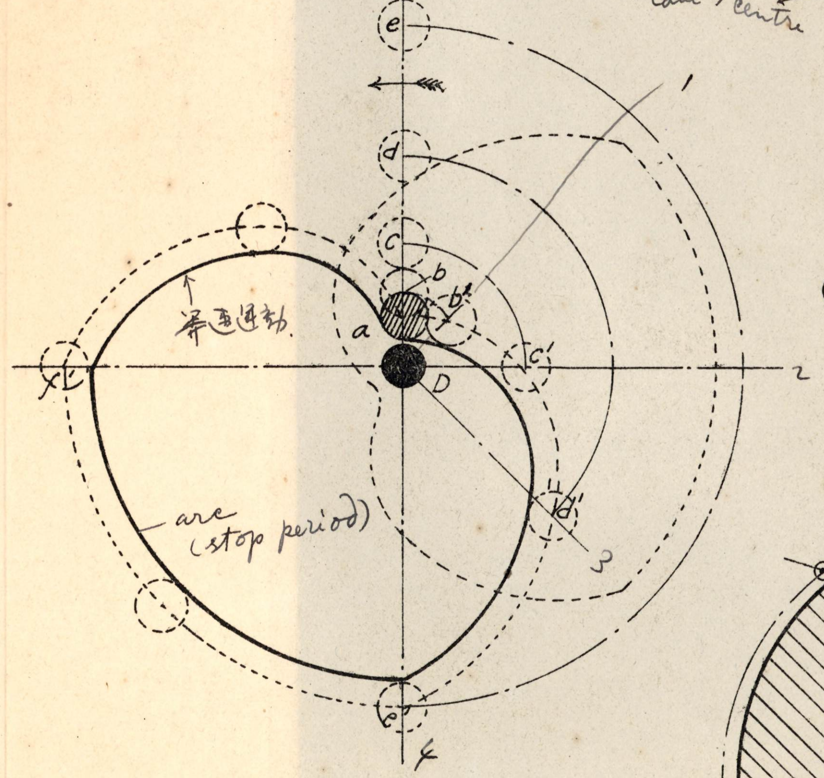


重量ヲ持タシテ

常ニcontactセシム

第87図

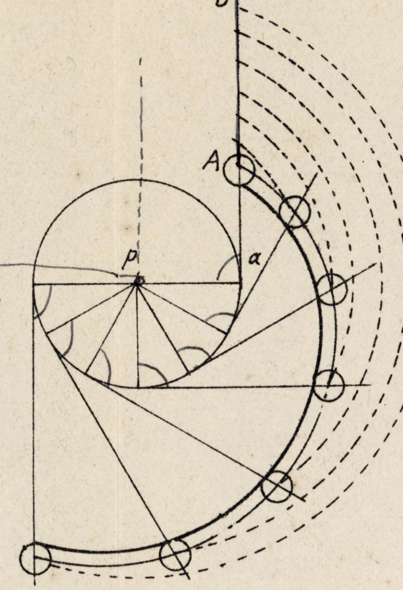
Cam.



第88図

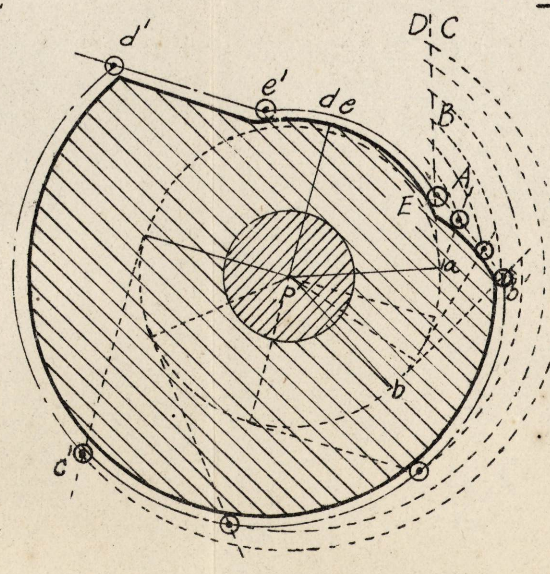
Cam.

同一中心線上ニ在ラザル場合



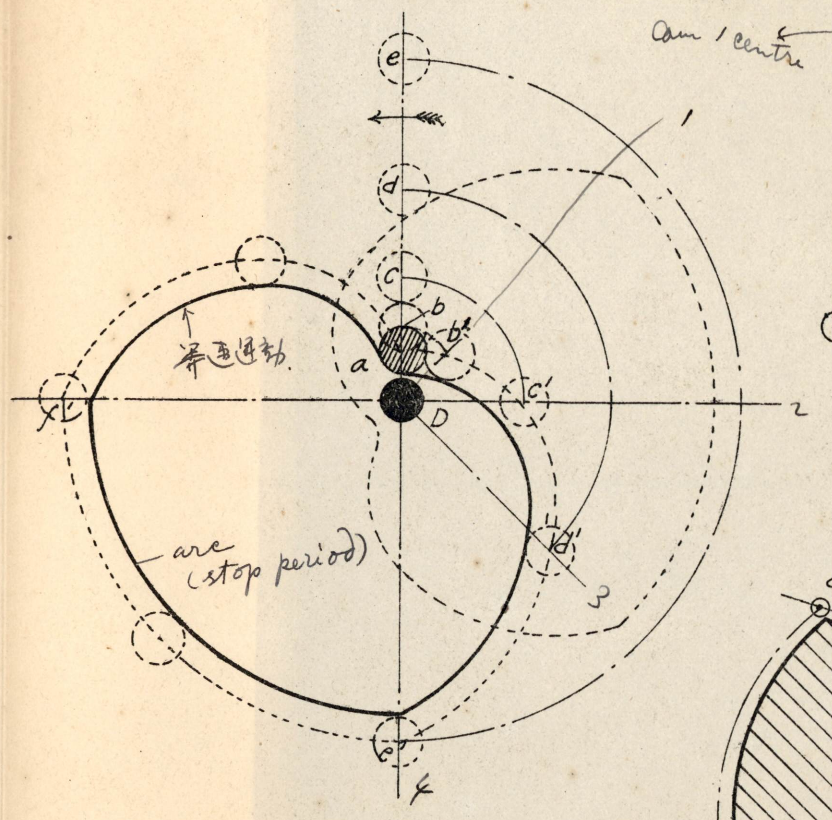
第89図

Cam.



第87図

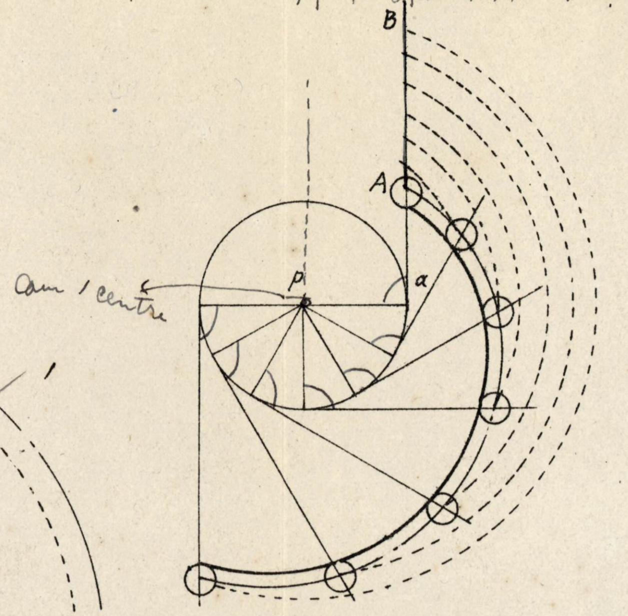
Cam.



第88図

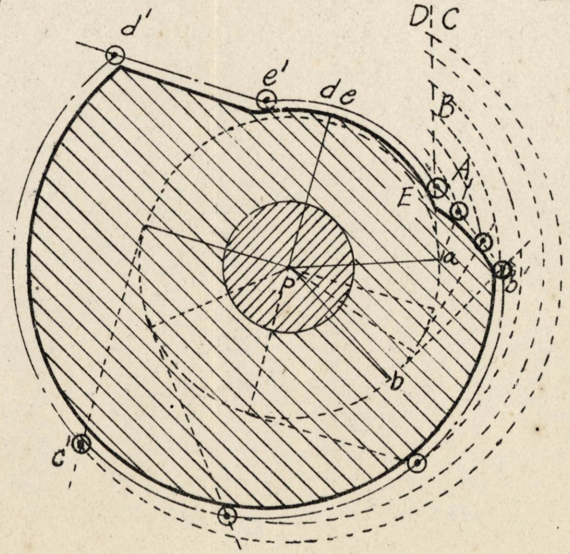
Cam.

同一中心線上ニ在ラザル場合



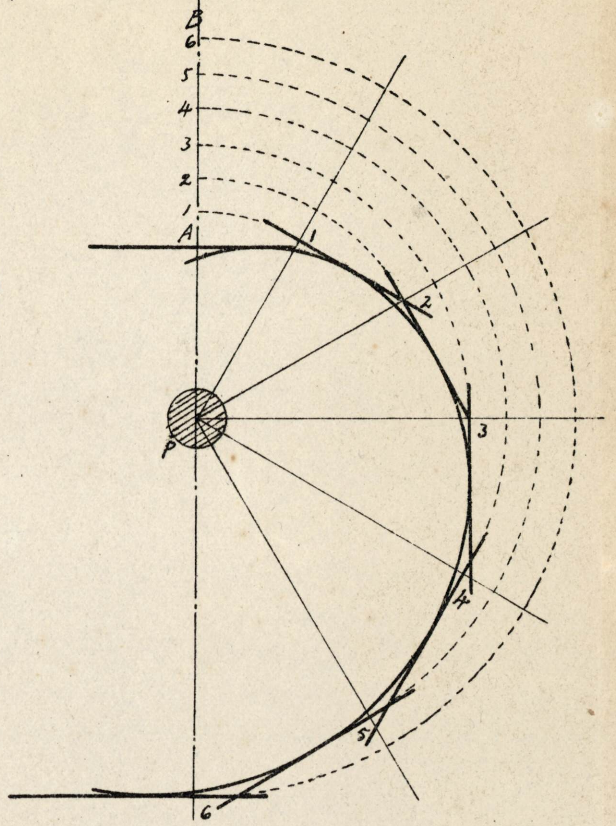
第89図

Cam.

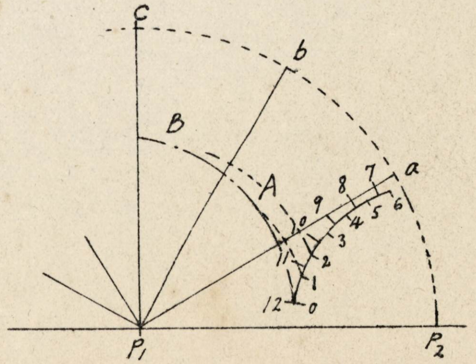


第90図

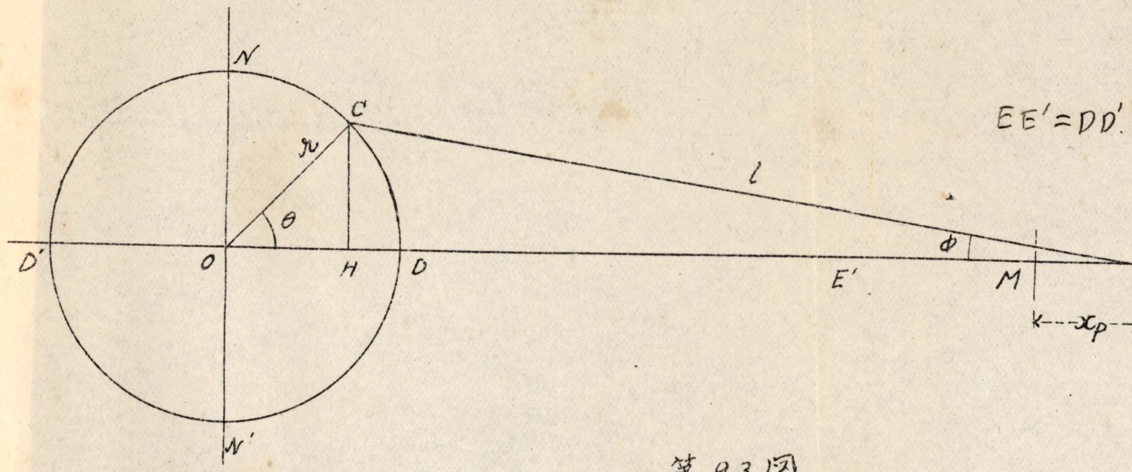
Cam.



第91図

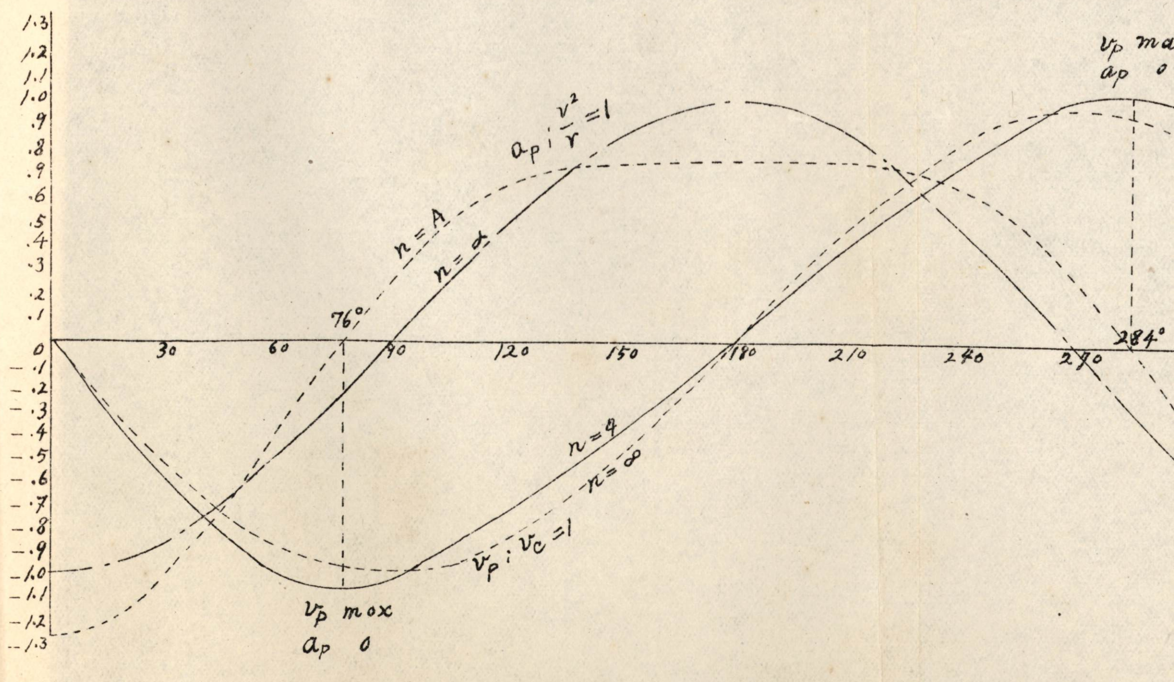


第92図

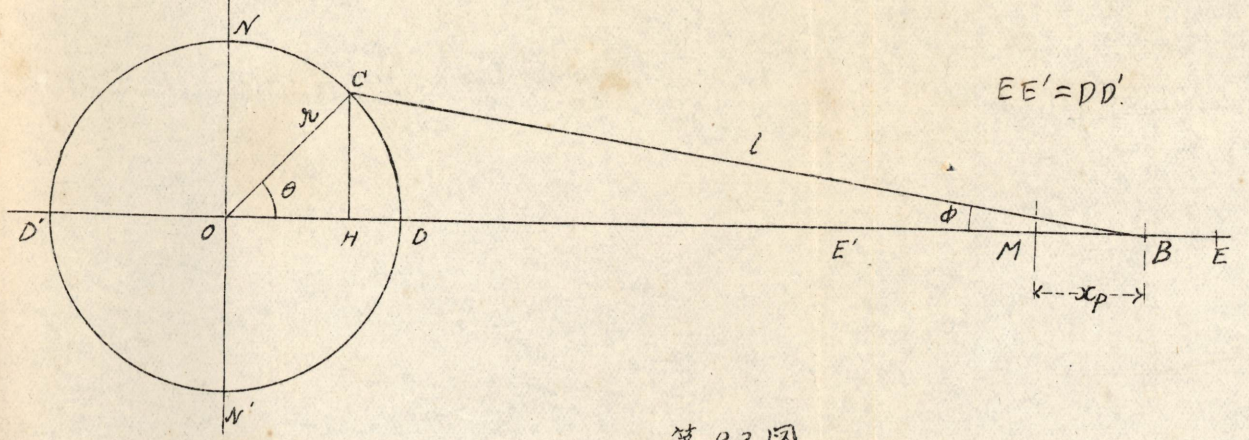


第93図

Curves of Velocity and acceleration of the piston.

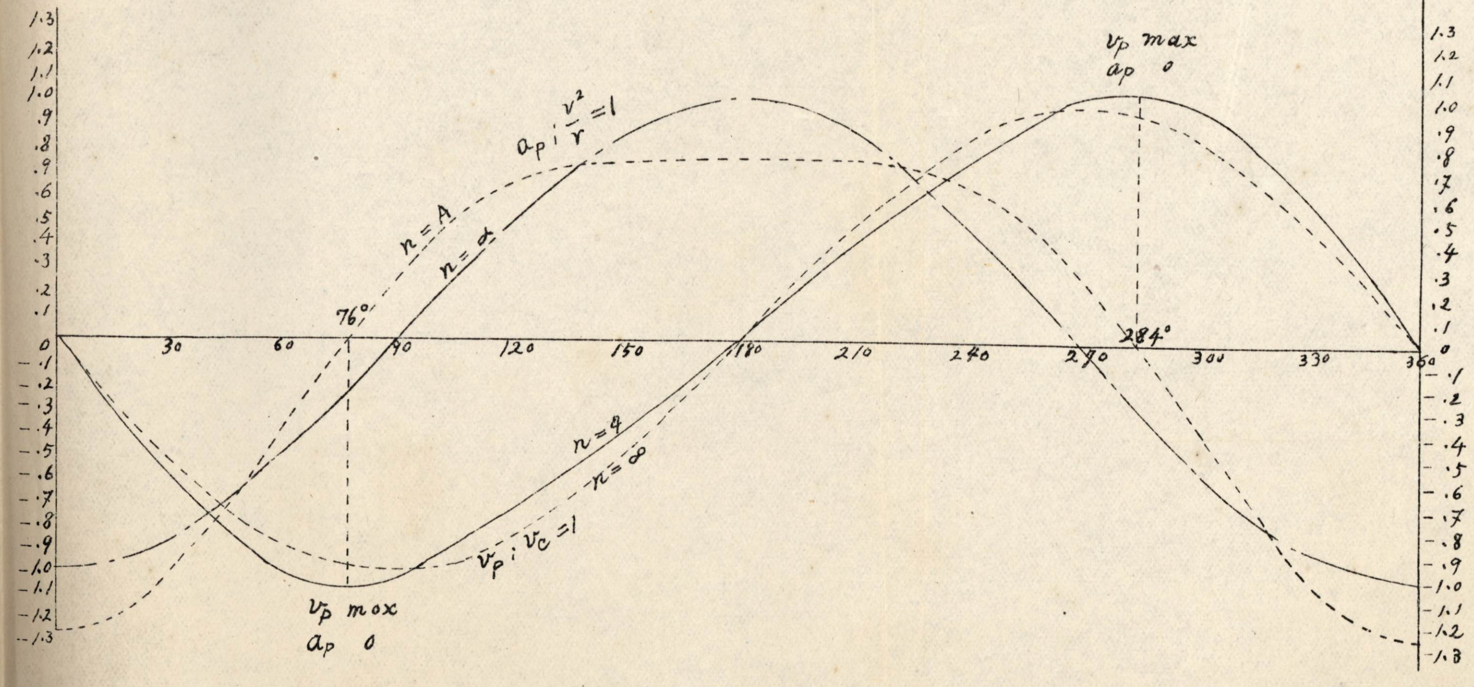


第92図

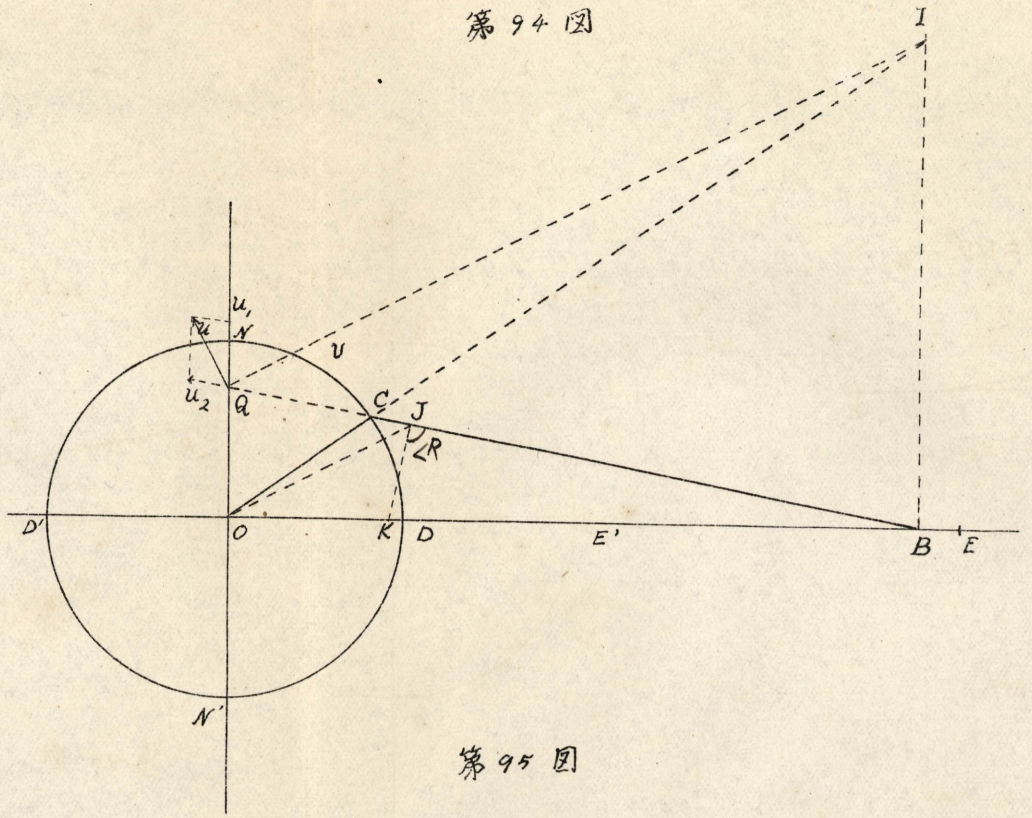


第93図

Curves of Velocity and acceleration of the piston.



第94図



第95図