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Novi Sad 22-24 June 2012

Correlation of GeoGebra and CAD software in the analysis of cycloid meshing

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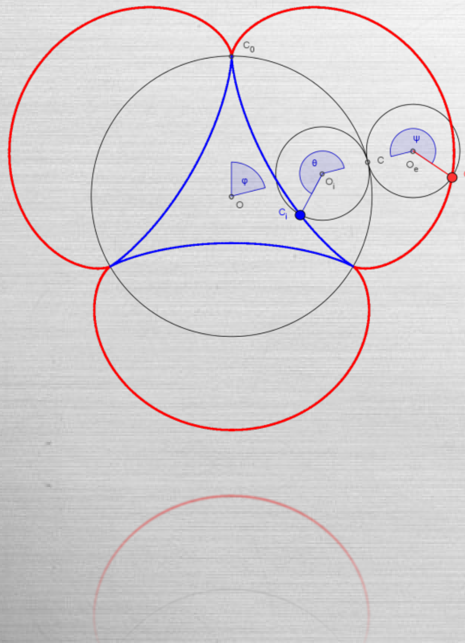
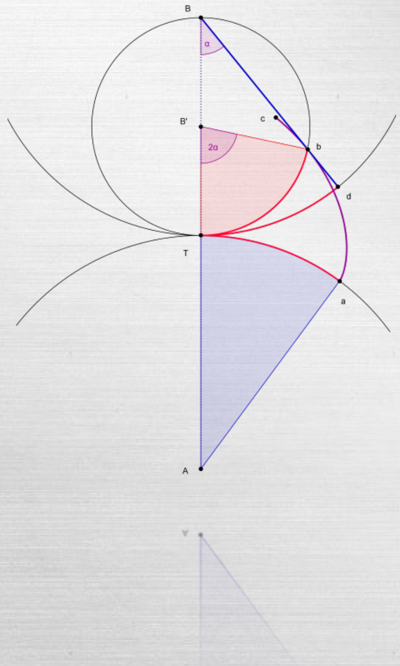
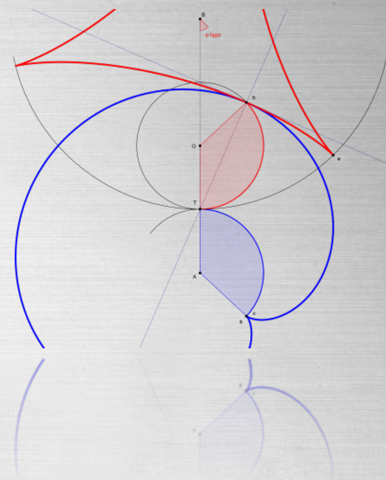
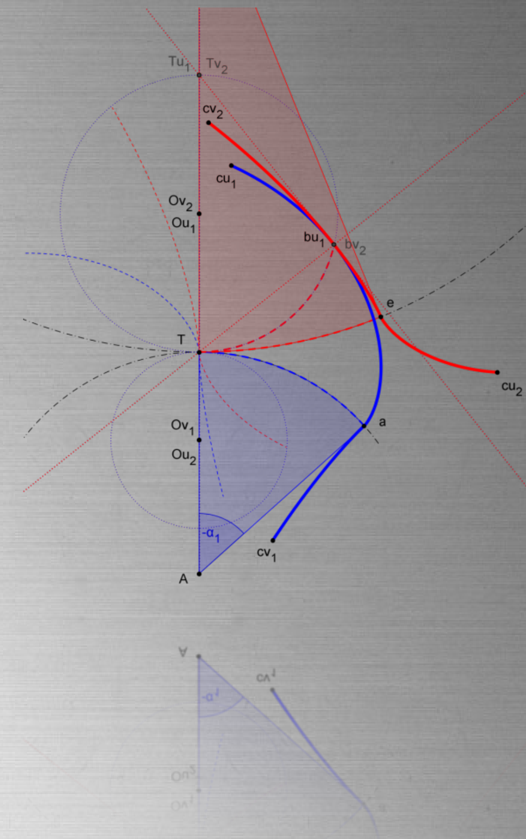


C_0
C
C_i
C_e
O_i
O_e
O
φ
θ
ψ



B
α
B'
c
b
2α
d
T
a
A





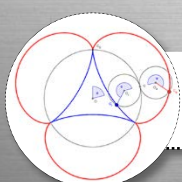
Tu_1
Tv_2
cv_2
cu_1
Ov_2
Ou_1
bu_1
bv_2
e
T
cu_2
a
Ov_1
Ou_2
$-\alpha_1$
cv_1
A

CONTENT

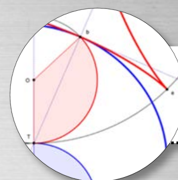
Content

1 Introduction

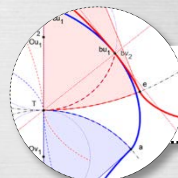
2 The problem



3 Cycloid Laboratory



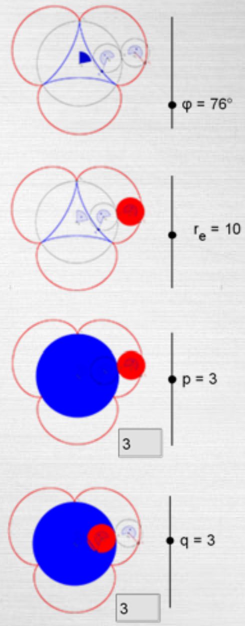
4 Cycloid meshing

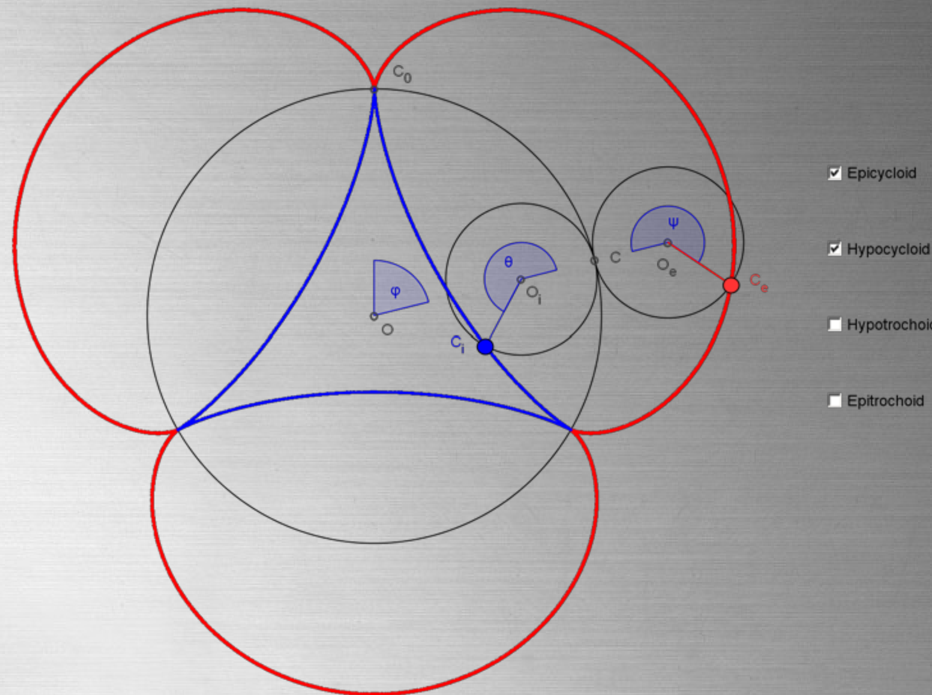


5 Cycloid Gearing

6 Questions

..: Problems in engineering education
..: Innovations in engineering education

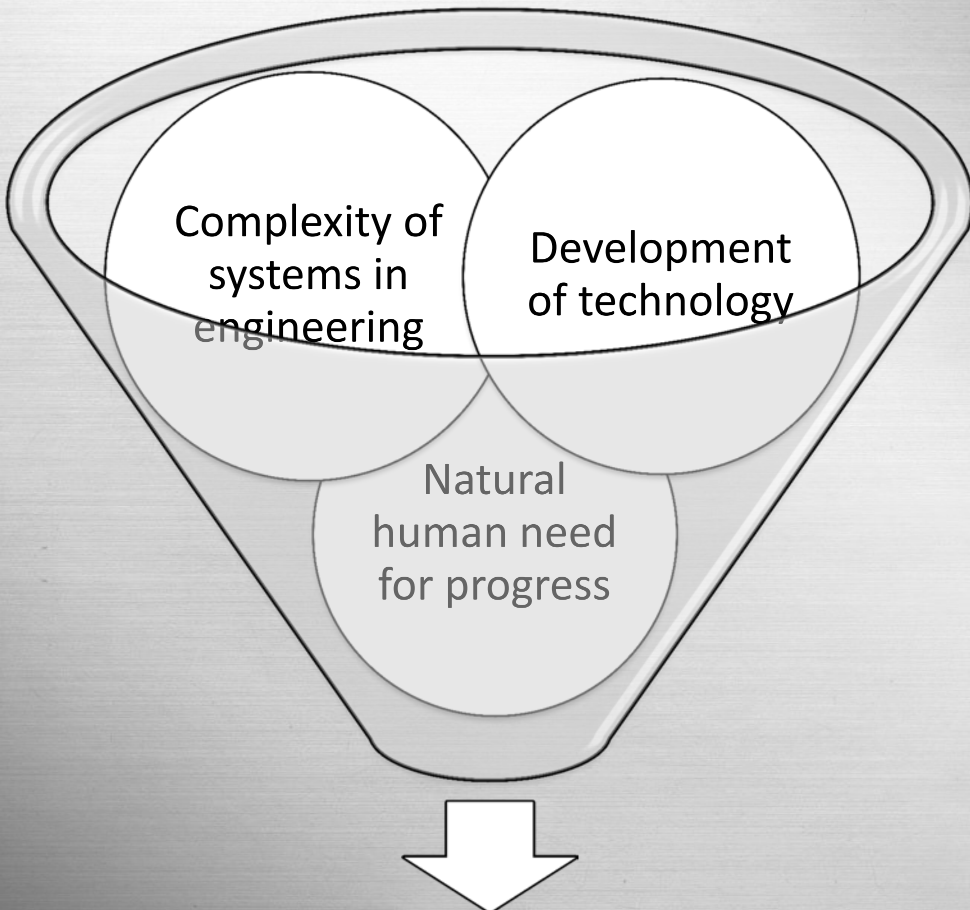




Part 1

INTRODUCTION

Introduction
Problems in engineering education

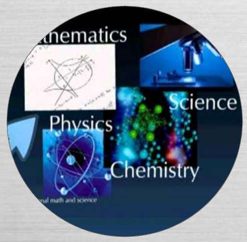


Multidisciplinary approach

Low interest for studying engineering

Development of new methods in education

Innovations in engineering education



Virtual and Augmented reality

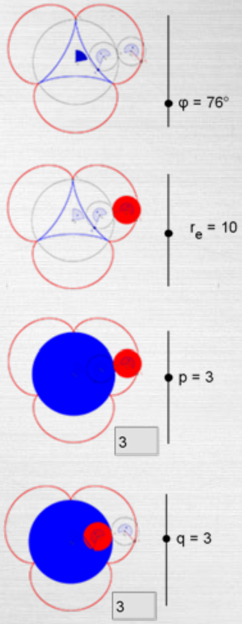
Blended learning

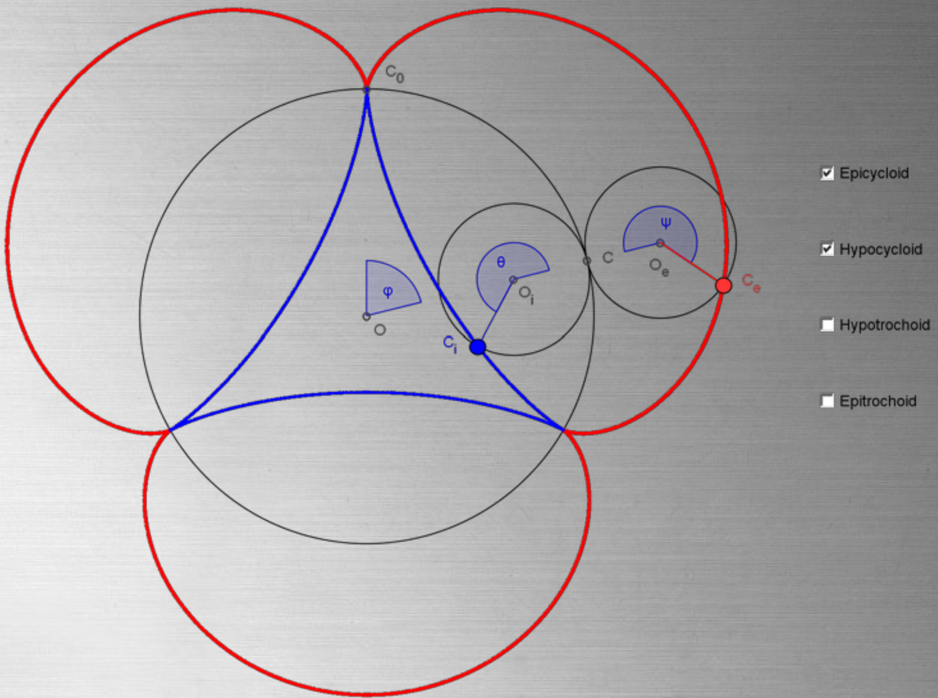
Multi-disciplinary Approach

Video games

Applicative software

..: Motivation
..: Basic knowledge
- Theory of mechanisms
- Basic Math
- Application software





Part 2

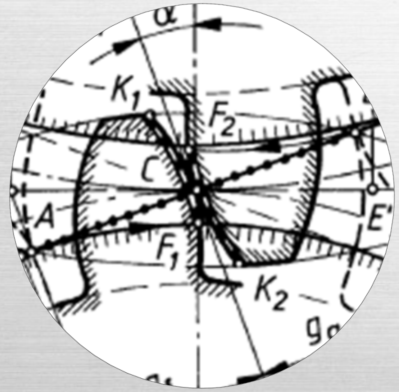
THE PROBLEM

The problem
Motivation

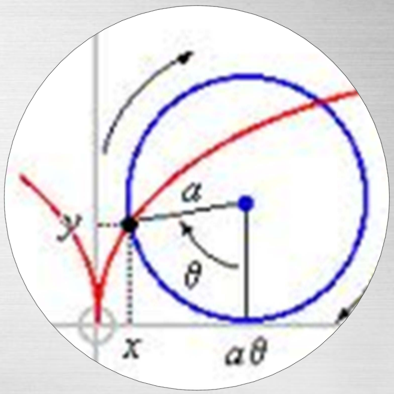
- Actuality of the graduation papers
  - Higher complexity of the assignments
  - New problems
  - Problems from real world
- Introducing new teaching methods
  - Multidisciplinary approach
  - Efficiency of acquainted knowledge
- Why cycloid meshing?
  - Frequently applied in practice
  - Basic theoretical experiment
  - Richness of different solutions
  - Complex example
  - Adequate with non classical methods of learning
  - Suitable for analysis in GeoGebra laboratory
  - Demanding CAD model

The 18-by-10-foot multimedia wall in the Collaborative Visualization Environment (CoVE) will be used in the new Professional Master's Degree in Applied Systems Engineering

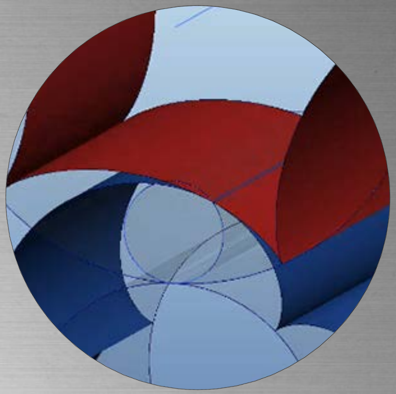
The problem
Basic knowledge



Theory of mechanisms
Pedagogical view
Basic theory



Basic Math
Trigonometry
Analytic geometry in plane
Cycloids

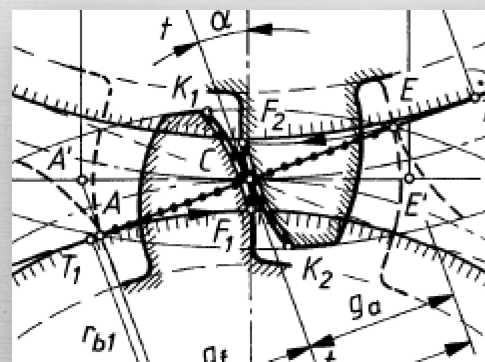


Application software
Math
CAD

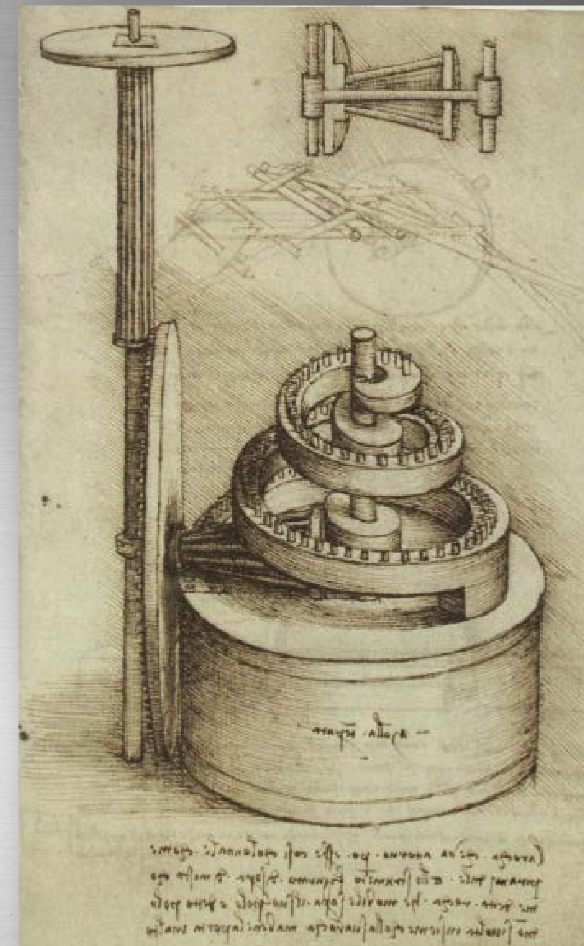
The problem
Theory of mechanisms

- Pedagogical view
  - Part of few core subjects of study during all four years
  - Students usually have learning problems
  - Teachers have teaching difficulties
  - Long and rich history
  - Science literature is not adequate for secondary level
  - School books are not enough

Antikythera mechanism, early 1st century BC



Roloff Matek Maschinenelemente, 2007



Leonardo da Vinci Madrid Codices I, 1493

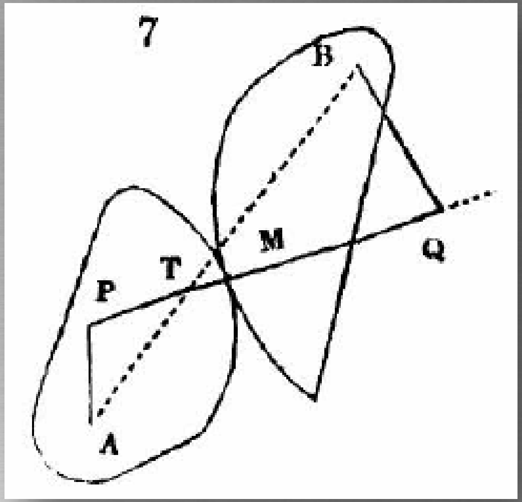
The problem
Theory of mechanisms

- Basic theory

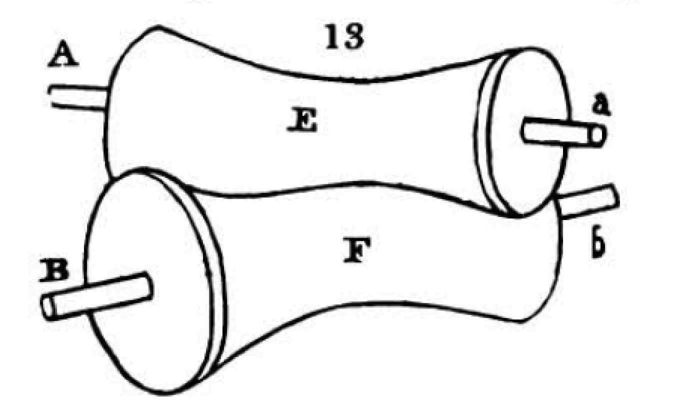
Communication of Motion by Contact

1. *In the communication of motion by contact*
   - *the angular motions of the pieces are inversely as the segments into which the common normal divides the line of centers*
2. *In rolling contact*
   - *the point of contact is always in the line of centers*
   - *the angular velocities are inversely as the segments into which the point of contact divides the line of centers*
   - *if the velocity ratio is constant, the segments must be constant, and the curves become circles, revolving round their centers, and whose radii are the segments*

Willis, Principles of Mechanism, 1841.



by Sliding Contact



by Rolling Contact

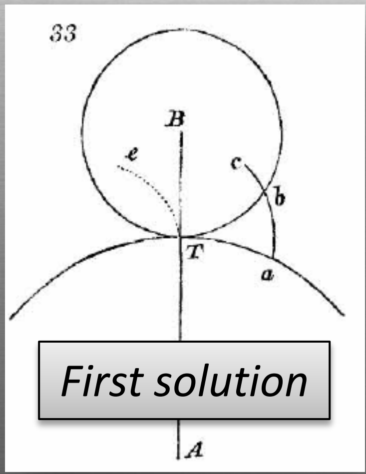
The problem
Theory of mechanisms

- Basic theory

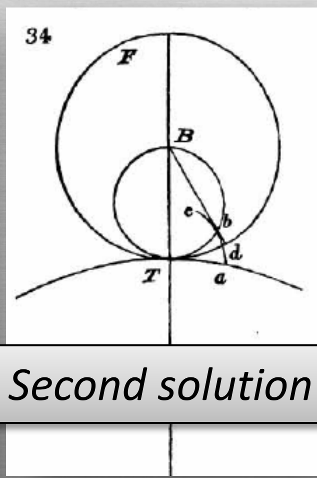
Willis, Principles of Mechanism, 1841.

Communication of Motion by Sliding Contact

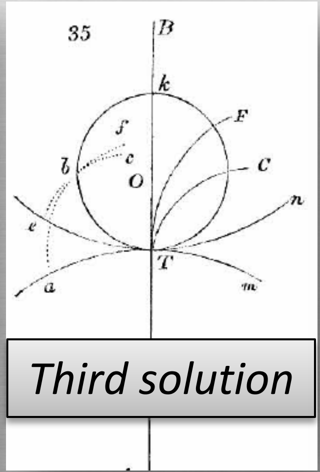
1. The axes being supposed parallel
2. The angular velocities are in the inverse ratio of the segments into which the normal of the curves, at the point of contact, divides the line of centers
3. Any curve then being assumed for the edge of one revolving piece
4. If we can assign such a form to the edge of another revolving piece that the common normal of the two curves shall divide the line of centers in a fixed point, in all positions of contact, then will these curves preserve a constant angular velocity ratio



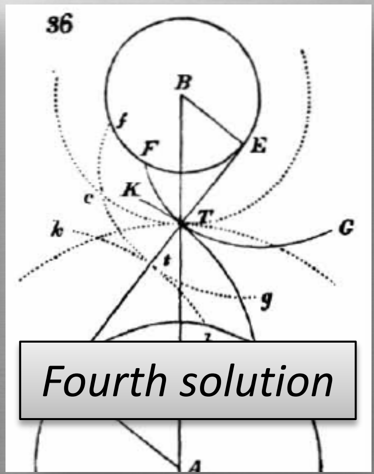
First solution



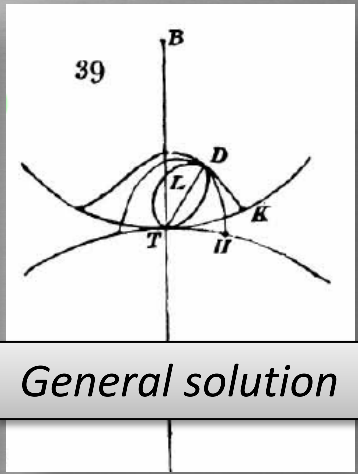
Second solution



Third solution



Fourth solution



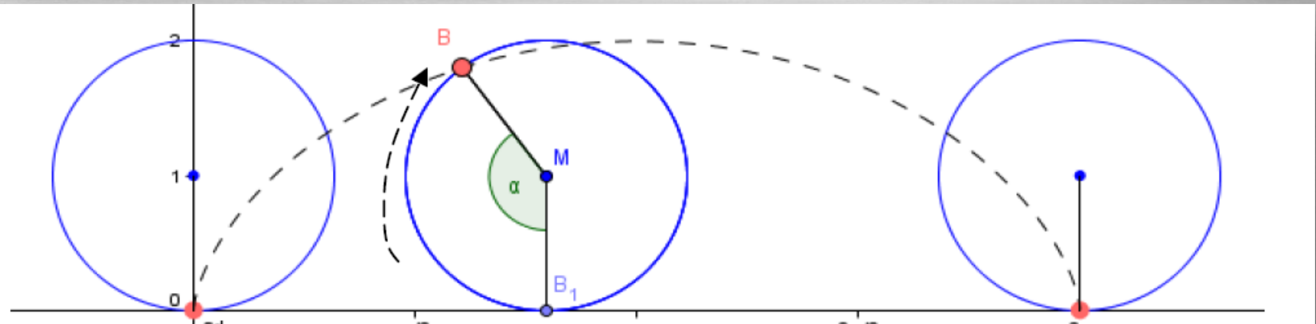
General solution

The problem
Basic Math

- Trigonometry, Analytic geometry in plane
- Both are parts of the curriculum
- Cycloid

$$x = r(t - \sin t)$$
$$y = r(1 - \cos t)$$

- Although, parametric equations of the curves are not part of the curriculum by the use of GeoGebra students except them easily
- It is known that the so-called mechanical curves are not the subject of study at the secondary level. However, by the use of GeoGebra, analysis of these curves is qualitatively possible and acceptable for students

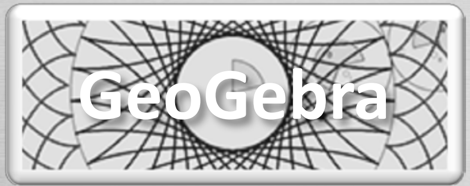


Position of the circle and the point B for t=0

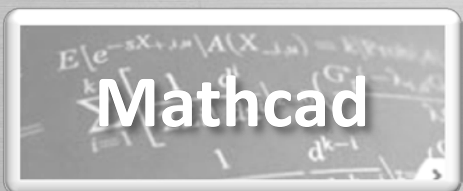
Position of the circle and the point B for t=α

Position of the circle and the point B for t=2π

The problem
Application software



GeoGebra is an interactive geometry, algebra, and calculus application, intended for teachers and students



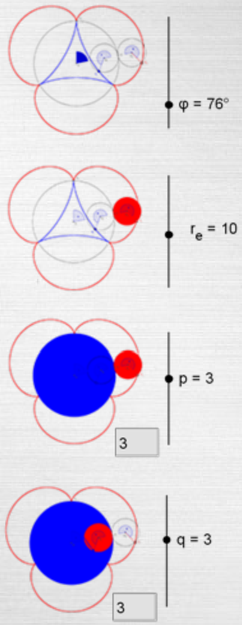
Mathcad is computer software primarily intended for the verification, validation, documentation and re-use of engineering calculations

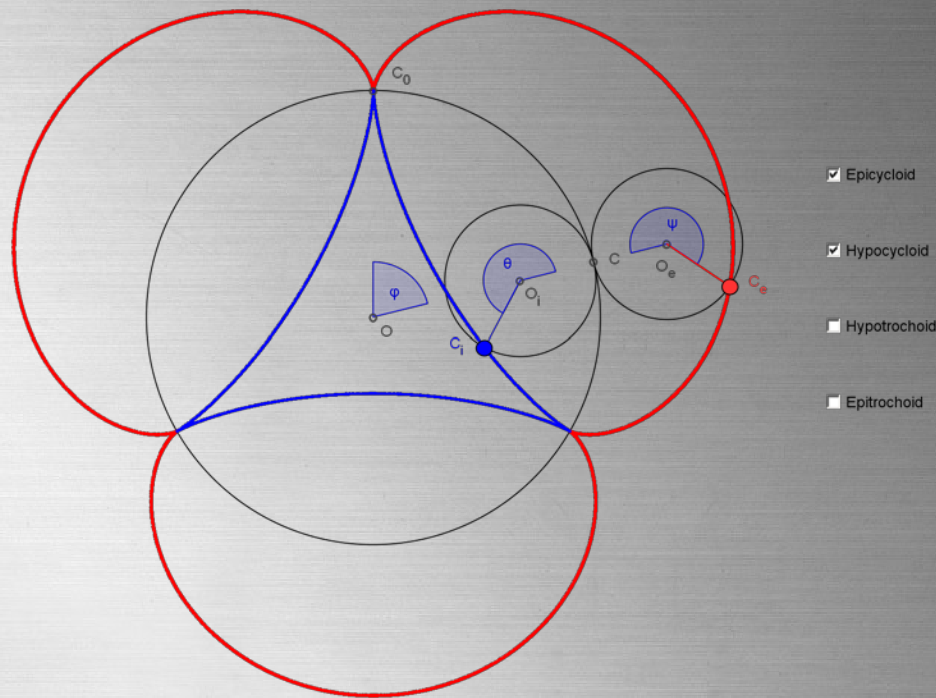
Math softwere

Creo Elements/Pro (formerly Pro/ENGINEER) parametric, integrated 3D CAD/CAM/CAE solution for design and manufacturing

CAD softwere

..: with GeoGebra
..: Examples
..: Conclusion



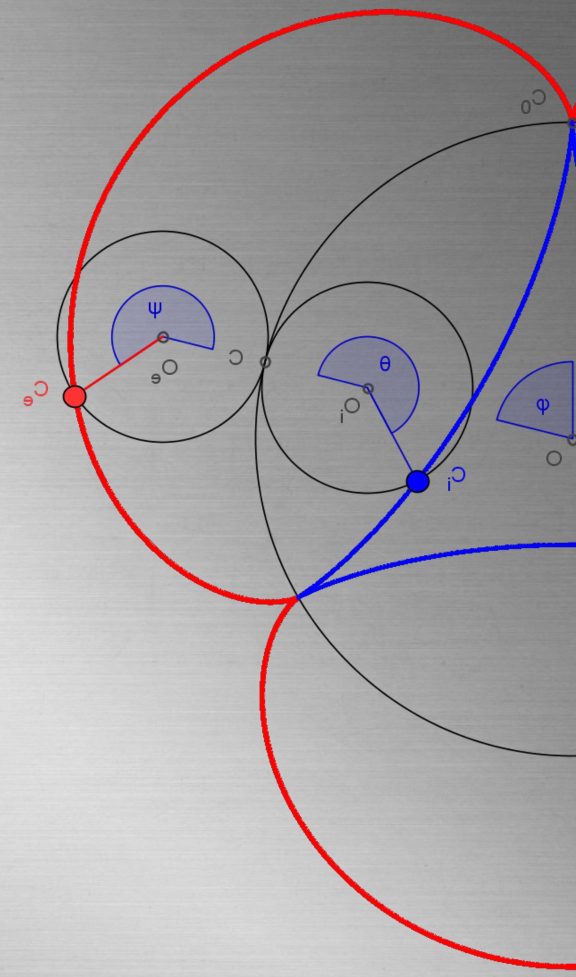


Part 3

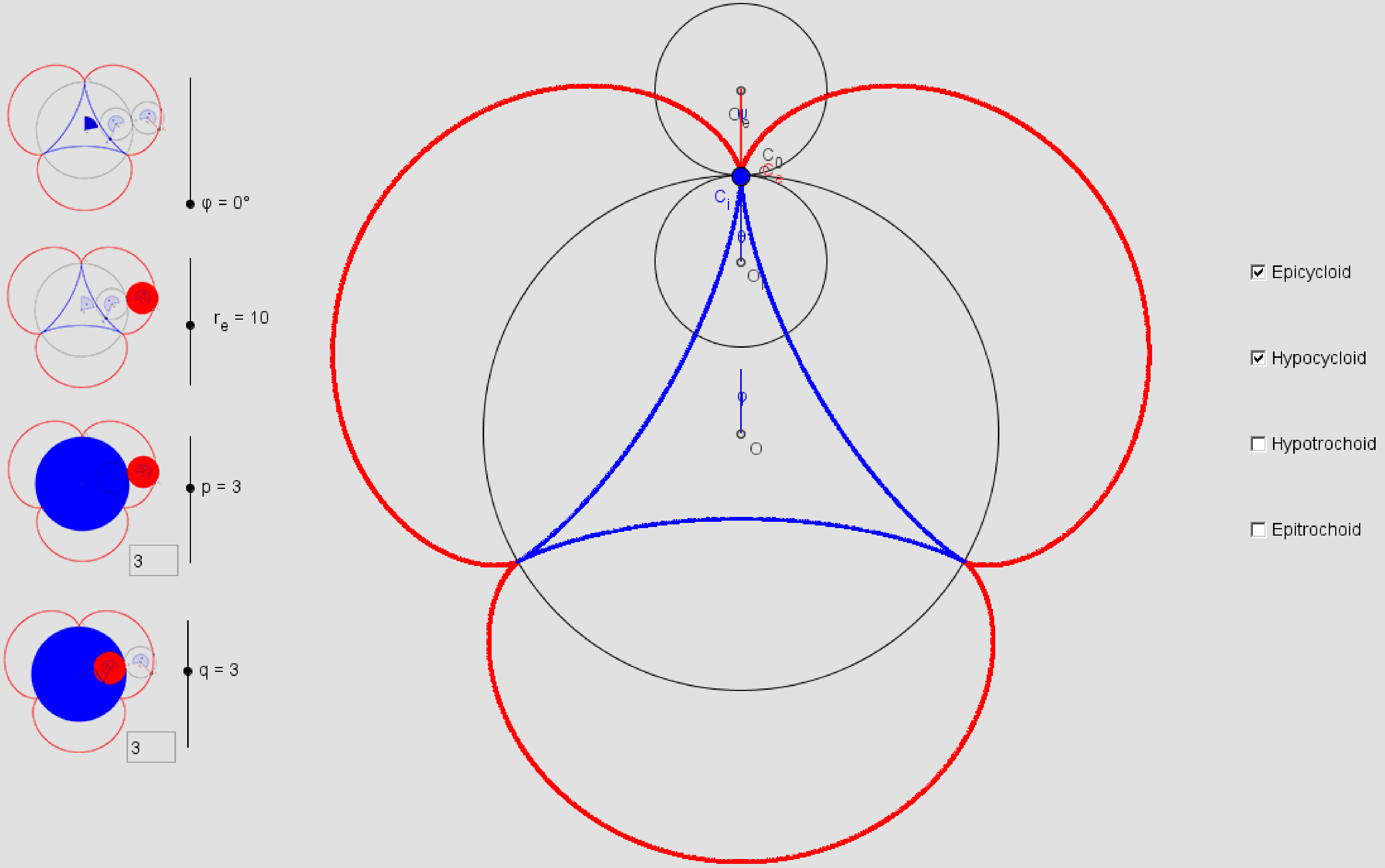
CYCLOID LABORATORY

Cycliod Laboratory
with GeoGebra

- When a straight line rolls along a stationary circle a point on the line traces a curve called an ***involute***
- When a circle rolls along a stationary straight line a point on the circumference of the circle traces a curve called a ***cycloid***
- When a circle rolls along another circle then a point on the circumference of the rolling circle traces out a curve called an ***epicycloid***
  (if the rolling circle rolls on the outside of the stationary circle)
- or a ***hypocycloid***
  (if the rolling circle rolls on the inside of the stationary circle).
- In all these cases of rolling circles points not on the circumference trace curves called ***trochoids***

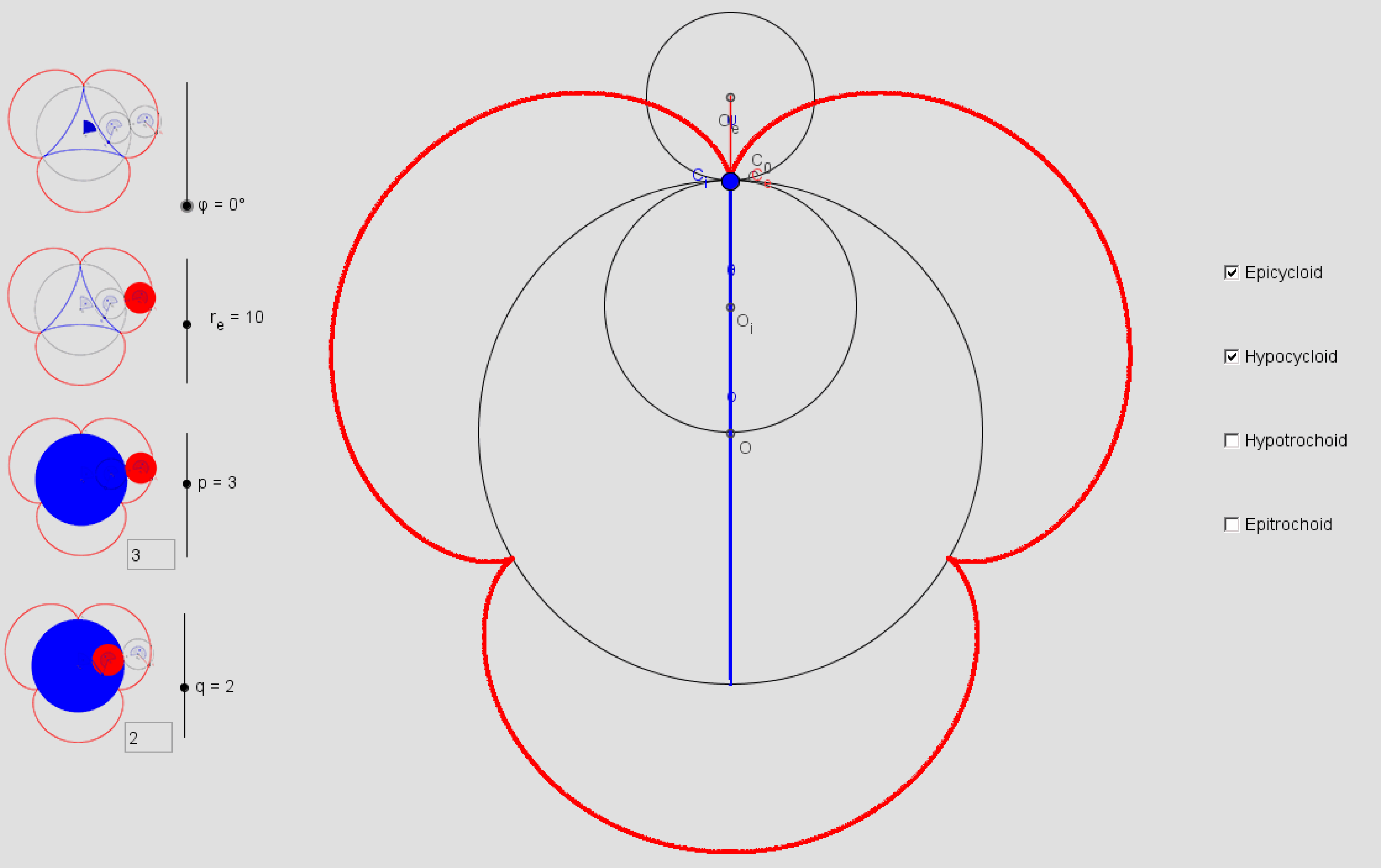


Example 1



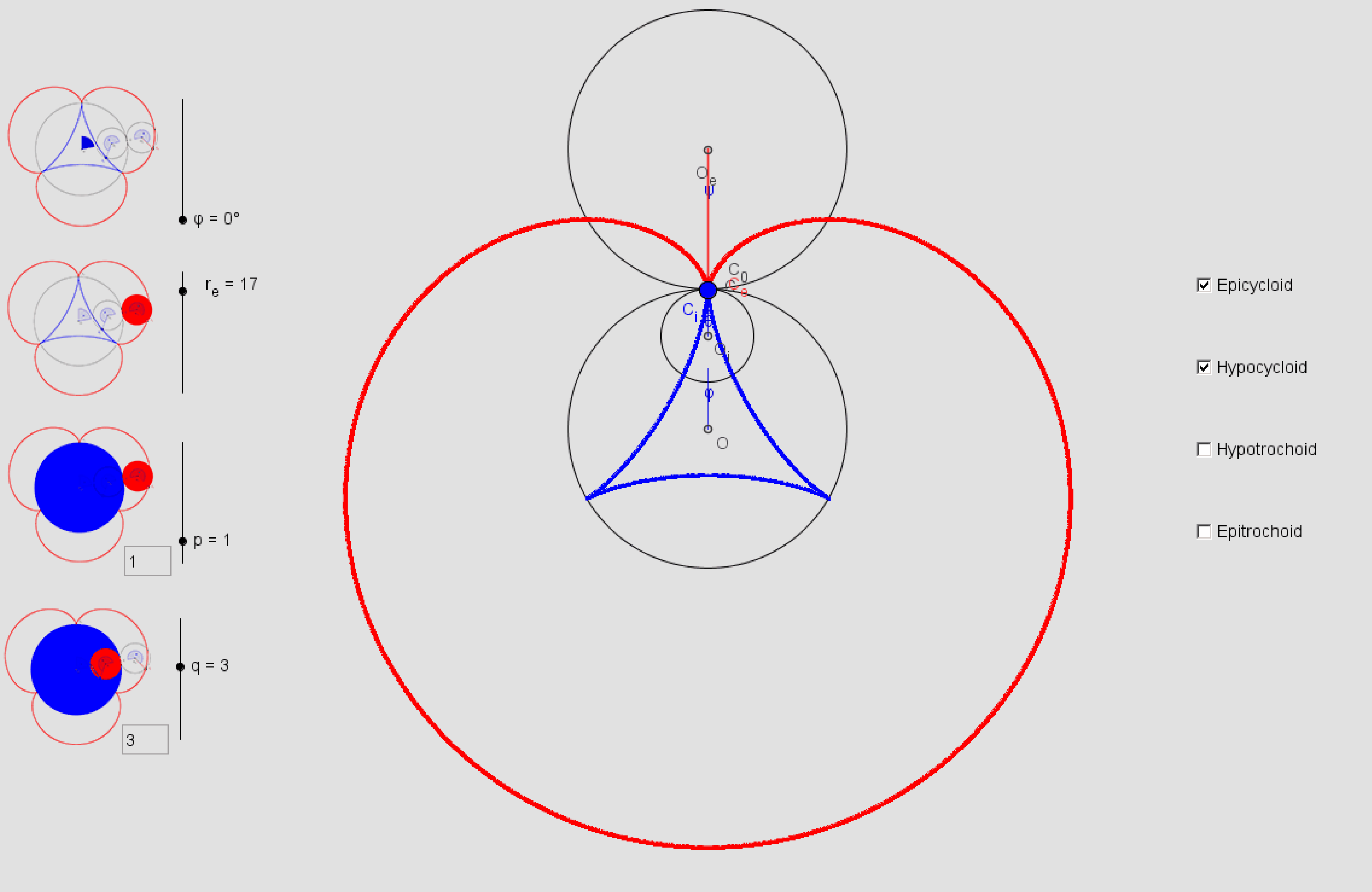
φ = 0°
r_e = 10
p = 3
3
q = 3
3
O_e
C_o
C_i
O_i
O
Epicycloid
Hypocycloid
Hypotrochoid
Epitrochoid

Example 2

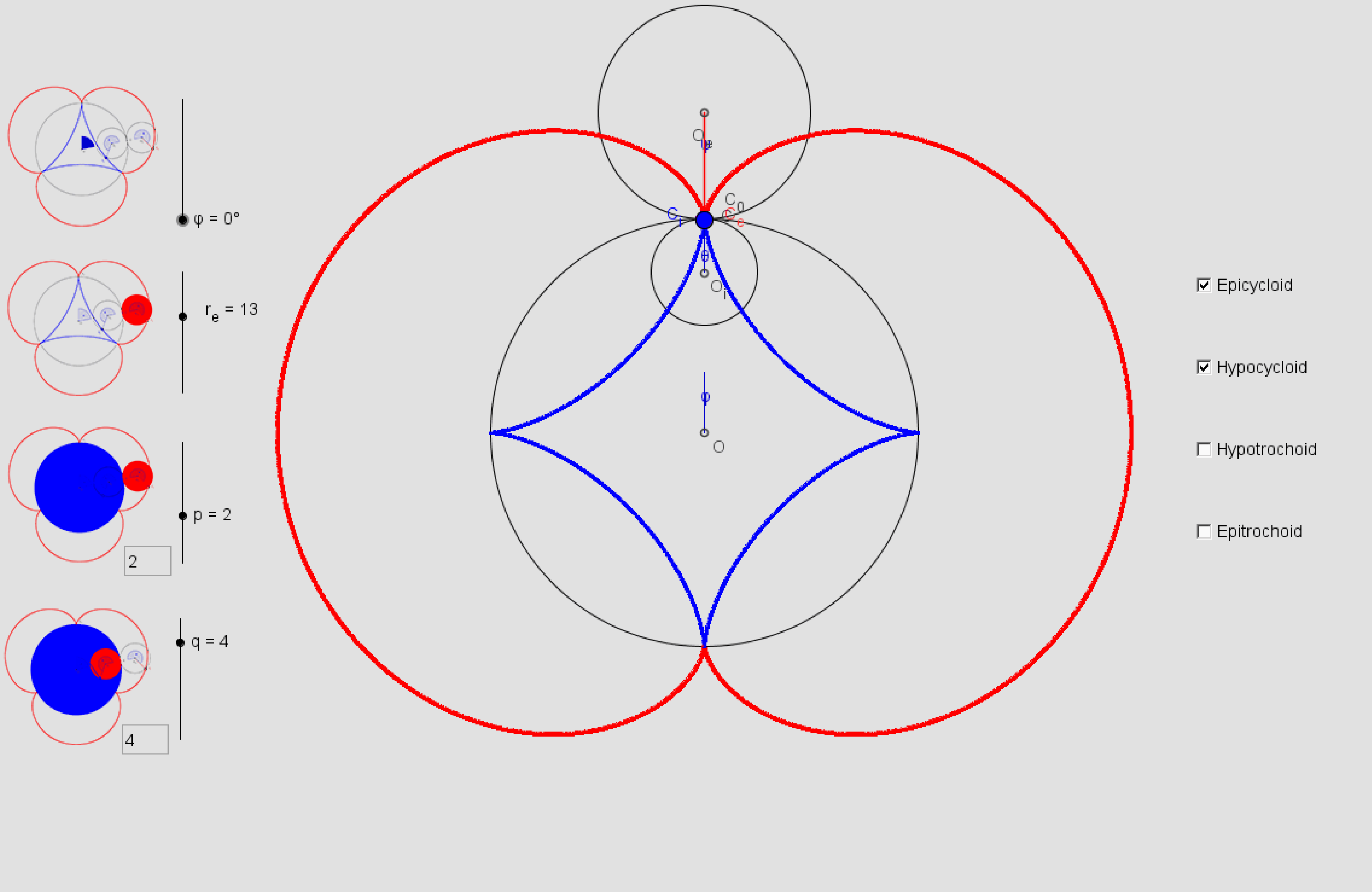


φ = 0°
r_e = 10
p = 3
3
q = 2
2
O_e
C_i
C_e
O_i
O
Epicycloid
Hypocycloid
Hypotrochoid
Epitrochoid

Example 3


φ = 0°
r_e = 17
p = 1
1
q = 3
3
Epicycloid
Hypocycloid
Hypotrochoid
Epitrochoid
O_e
C_0
C_i
O

Example 4

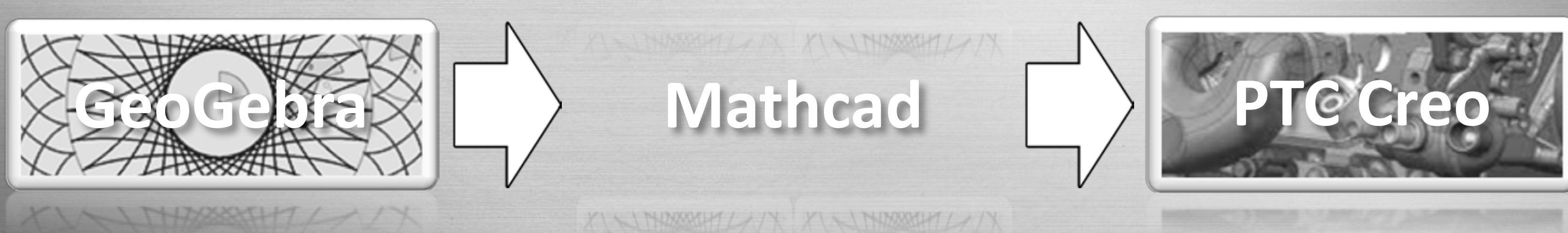

φ = 0°
r_e = 13
p = 2
2
q = 4
4
Epicycloid
Hypocycloid
Hypotrochoid
Epitrochoid
O

Cycliod Laboratory
Conclusion

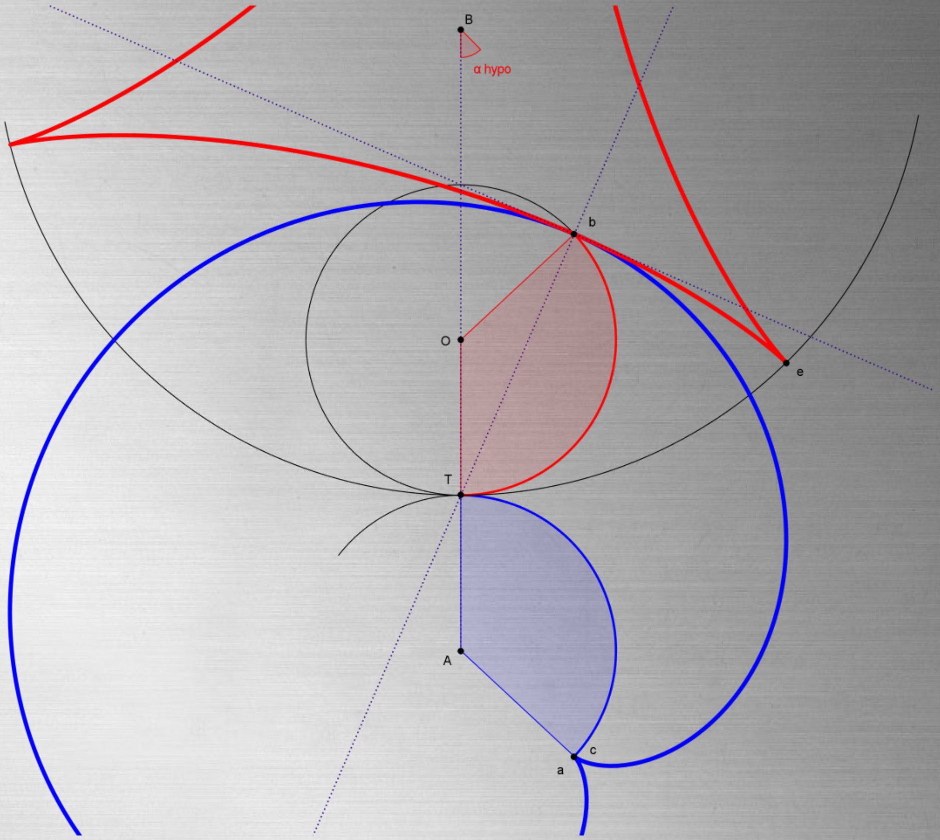
- The aim of GeoGebra laboratory is for student to
  - To spot kinematic connections
  - To spot trajectory of the fixed point
  - To grasp the mining of the ratio
  - To grasp the correlation between the given ratio and the form of the curve
  - To grasp the mining of proportions being integers

Cycliod Laboratory
Conclusion

- The aim of GeoGebra laboratory is for student to
  - To spot kinematic connections
  - To spot trajectory of the fixed point
  - To grasp the mining of the proportions
  - To grasp the correlation between the proportions and the form of the curve
  - To grasp the mining of proportions being integers



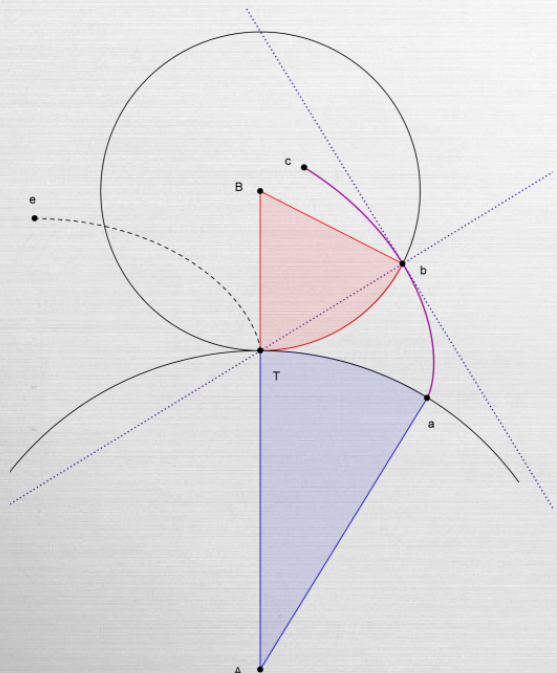
..: First Solution
..: Second Solution
..: Third Solution
..: Application



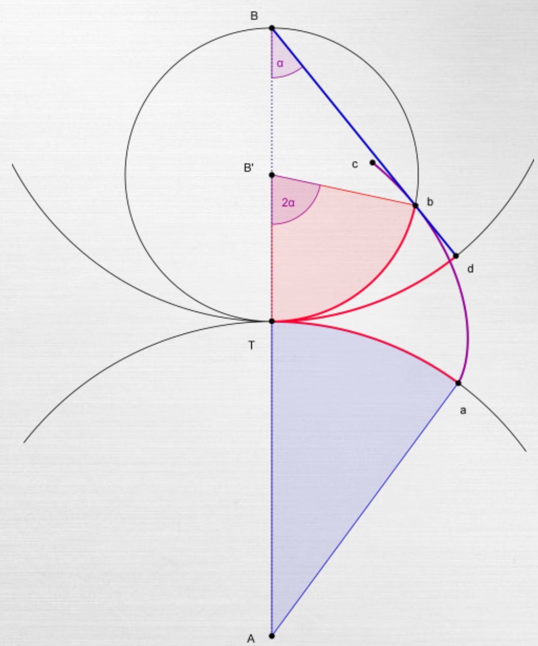
Part 4

CYCLOID MESHING

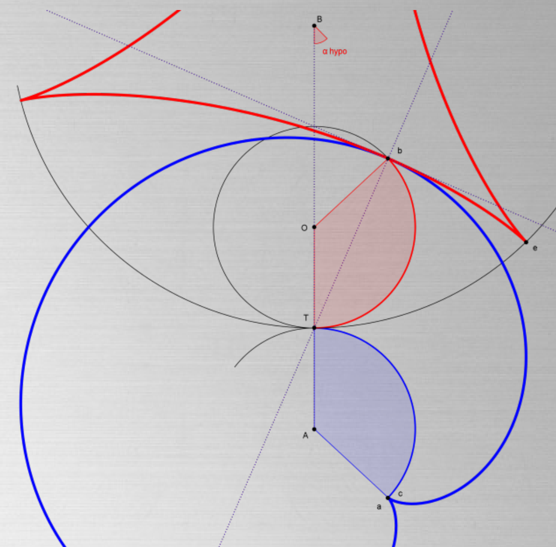
Cycloid meshing



First Solution



Second Solution



Third Solution

Willis, Principles of Mechanism, 1841.

First Solution

β = 0°

r1 = 10

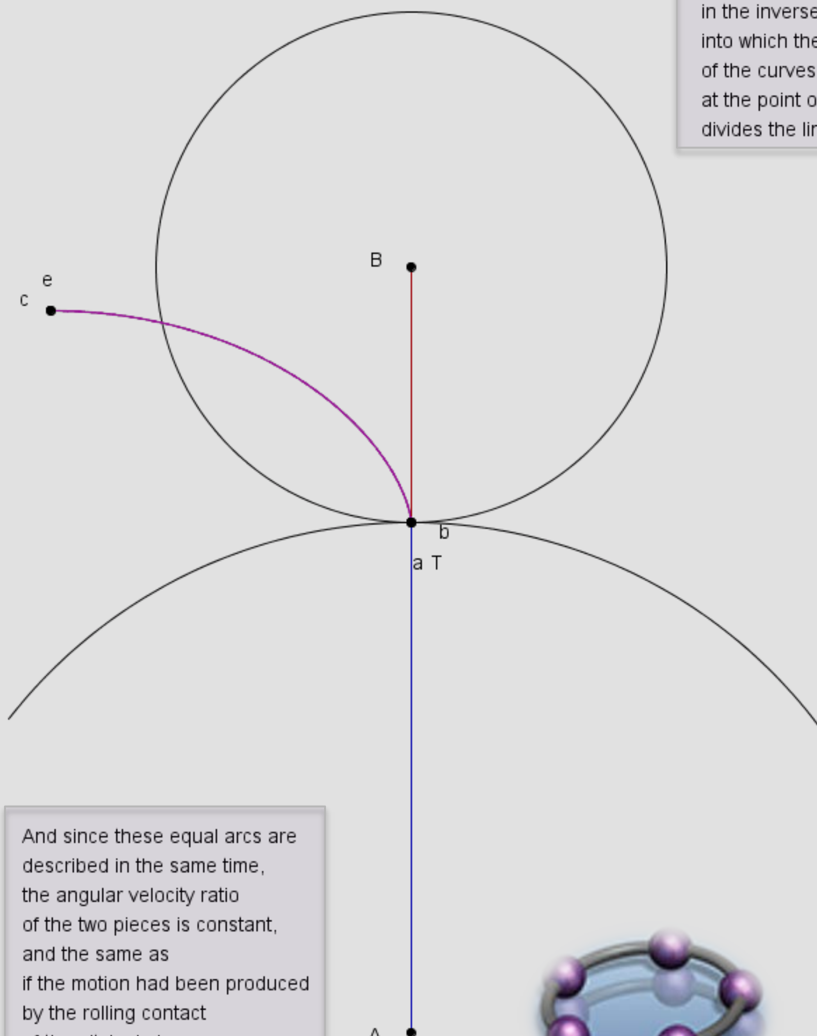
r2 = 5

☑ Comment 1 ☑ Comment 2 ☑ Comment 3

Let A, B be the centers of motion,
AB the line of centers divided as usual, in T,
in the inverse proportion of the angular velocities;
describe through T the respective pitch circles,
and let abc be a portion of an epicycloid
whose base is the pitch circle aT,
and whose describing circle
has the same diameter as the pitch circle Tb,
and let b a pin
whose diameter is exceedingly small,
so that it may be considered as
a mathematical line.
Then if the curve abc be cut out of a thin plate,
and caused to turn round the center A,
and the pin b carried by a piece capable of
turning round the center B,
the motion communicated from
the edge to the pin will fulfil
the required conditions.

If the curve move into
any other position abc
driving the pin to b,
the arc Ta will be equal to Tb;
for Tb is an arc of the describing circle,
and therefore, if it were made to roll on Ta,
the point b would trace
an epicycloidal arc coinciding with ba;
and the point b would coincide with a.
But the arcs Ta, Tb are also those described by
the two pitch circles respectively,
in moving from T to the second position;

And since these equal arcs are
described in the same time,
the angular velocity ratio
of the two pieces is constant,
and the same as
if the motion had been produced
by the rolling contact
of the pitch circle.



The axes being supposed parallel,
it appears, that in sliding contact,
the angular velocities are
in the inverse ratio of the segments
into which the normal
of the curves,
at the point of contact,
divides the line of centers.

The common normal
of the two curves
shall divide the line of centers
in a fixed point,
in all positions of contact,
then will these curves preserve
a constant
angular velocity ratio.

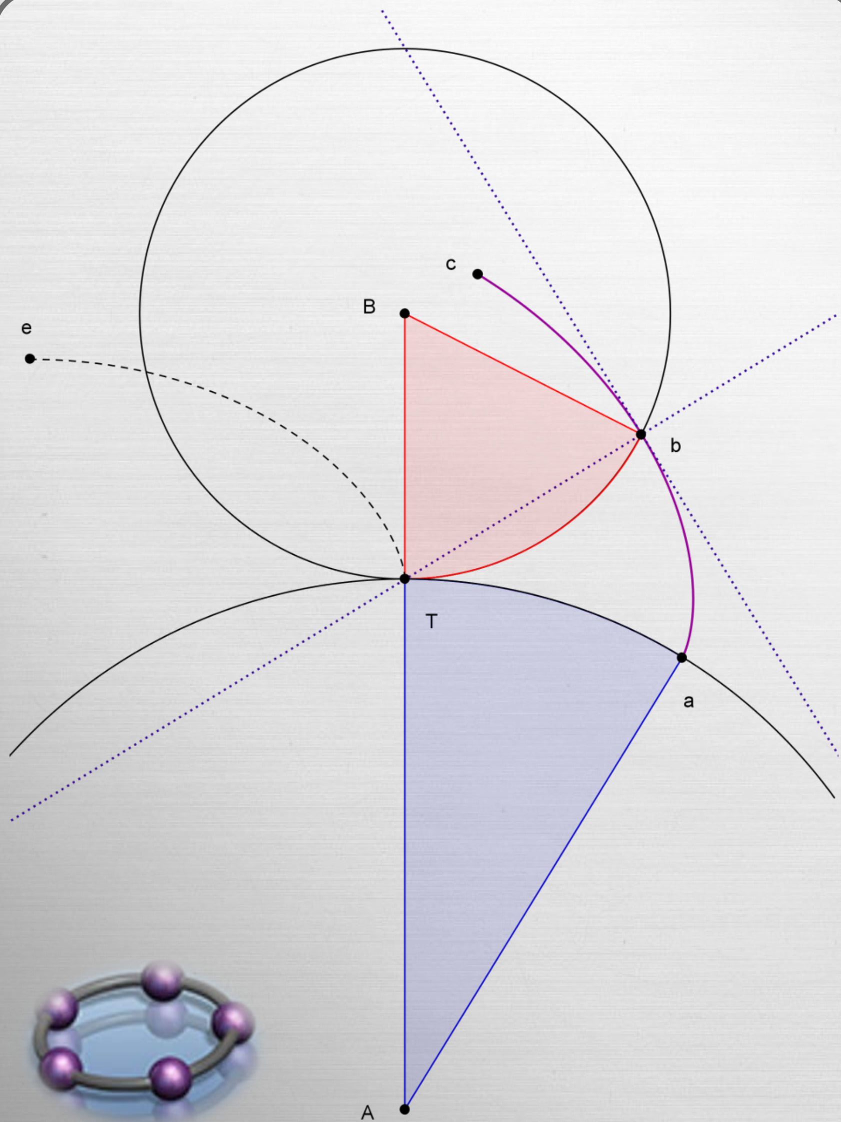
By the known property of the epicycloid,
the normal to any point b
passes through
the point of contingence T
of its describing circle
and its base circle.

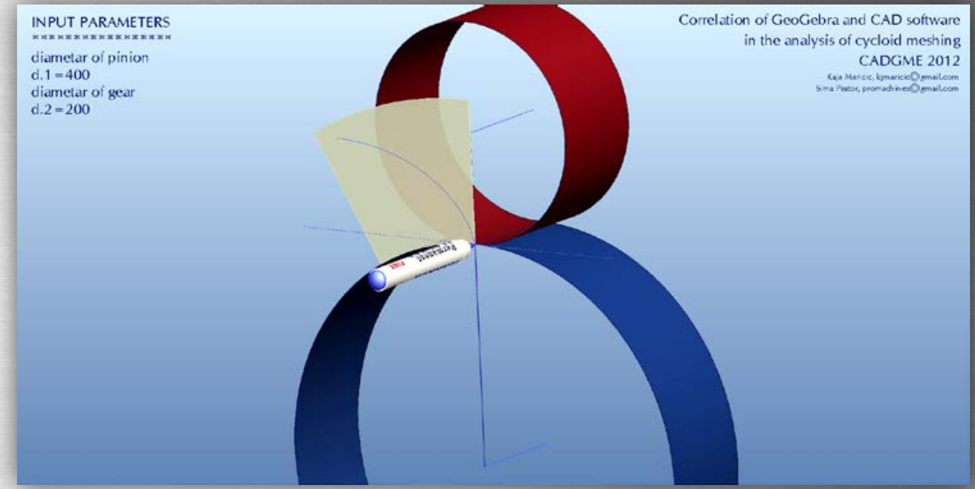
The angular velocity ratio
of the circles
will be constant
and equal to
the inverse ratio
of their radii

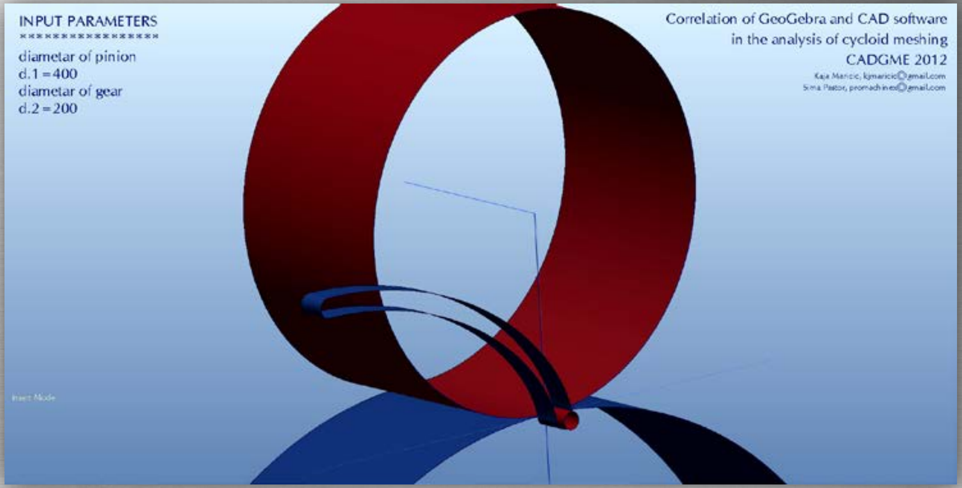
Otherwise, by the known property of the epicycloid,
the normal to any point b passes through
the point of contingence T
of its describing circle and its base circle.

But these latter circles are
the two pitch circles of the combination;
and since the normal of the curve ab
at the point of the contact
is thus shown to pass through a constant point T
of the line of centers,
the angular velocity ratio of the circles
will be constant and equal
to the inverse ratio of their radii.

First Solution







Second Solution

$\beta = 0°$

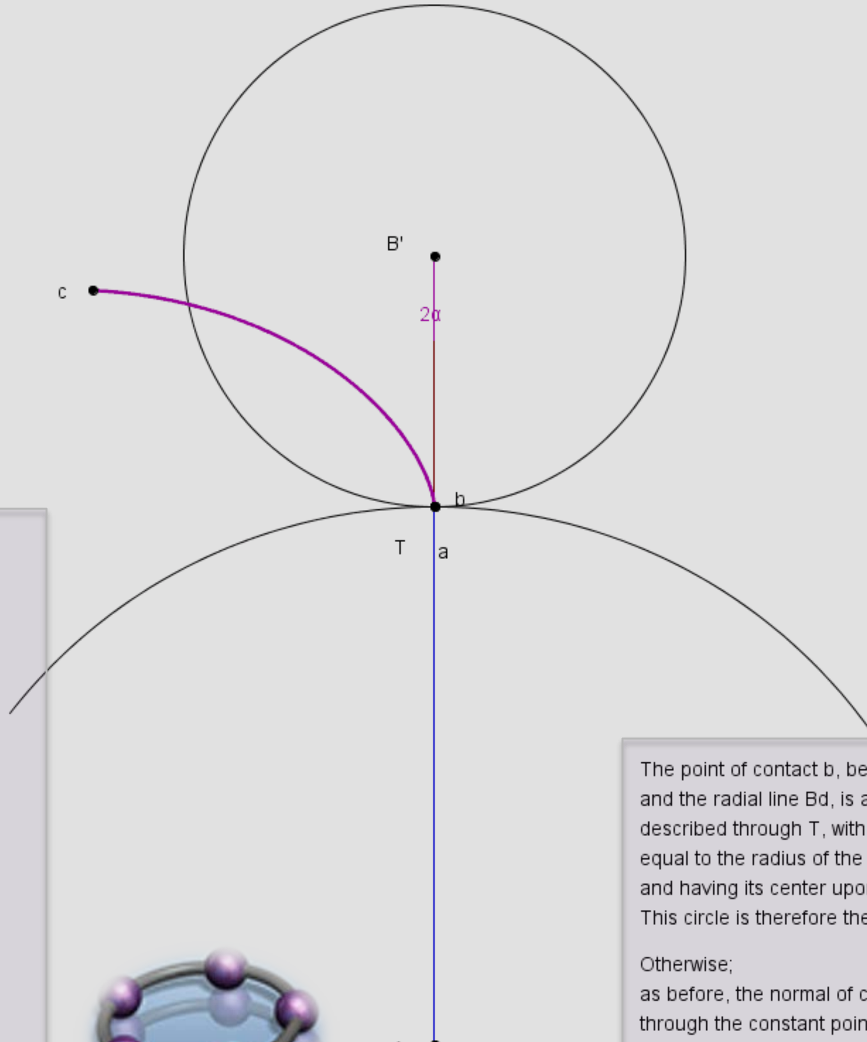
r1 = 15

r2 = 7

☑ Comment 1

☑ Comment 2

☑ Comment 3



Let abc be an arc of an epicycloid
whose describing circle is TbB,
of half the diameter
of the pitch circle TdF.
From the center B draw a radial line
through the describing point b,
meeting the circle in d;
then will this line touch
the epicycloid in b.

Let motion
be communicated by contact from
the curved edge abc,
which revolves round A,
to the radial line Bbd,
which revolves round B;

In moving
to any other position of contact abc, Bbd; Ta, Td,
will be the arcs simultaneously described by
the two pitch circles.

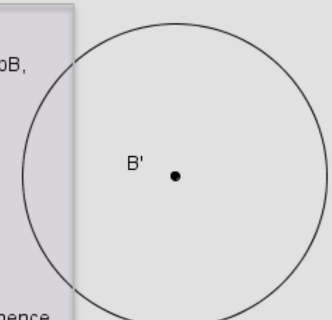
Now α is an angle at
the circumference of the circle TbB,
and α an angle at
the center of the circle TdF;
thereforeTb measures an angle double of Td.
Also
the radius of Tb is half that of Td;
therefore
the arc Tb = Td.

Again,TbB is the describing circle
of the epicycloid abc,
and Ta its base,
therefore Tb = Ta.

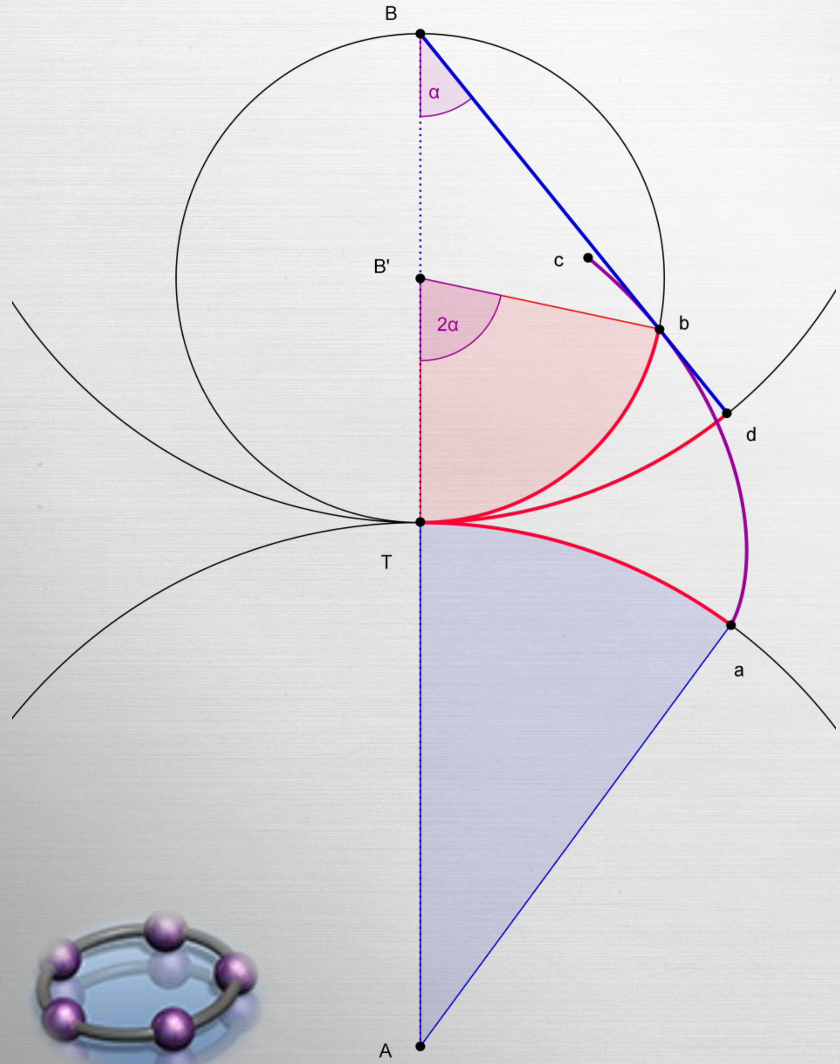
whence Td = Ta,
that is, the arcs of the pitch circle
described from the beginning of the motion
are equal, and conquendy
the angular velocity ratio constant, and
the same as would be obtained
by the rolling contact
of the pitch circles.

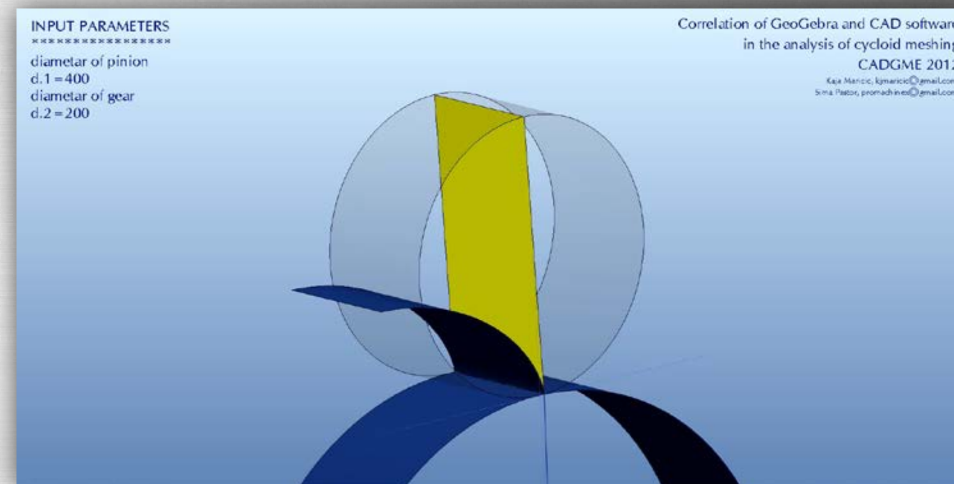
The point of contact b, between the curve ac
and the radial line Bd, is always situated in the circle TbB,
described through T, with a diameter
equal to the radius of the pitch circle of the radial line,
and having its center upon the line of centers.
This circle is therefore the locus of contact.

Otherwise;
as before, the normal of contact at b passes
through the constant point T of the line of centers, and
therefore divides it into a pair of constant segments; whence
by Art. 75
the angular velocity ratio is constant.



Second Solution





Third Solution

$\beta = 0°$

$p = 4$

$q = 4$

$r_e = 13$

☑ Comment 1

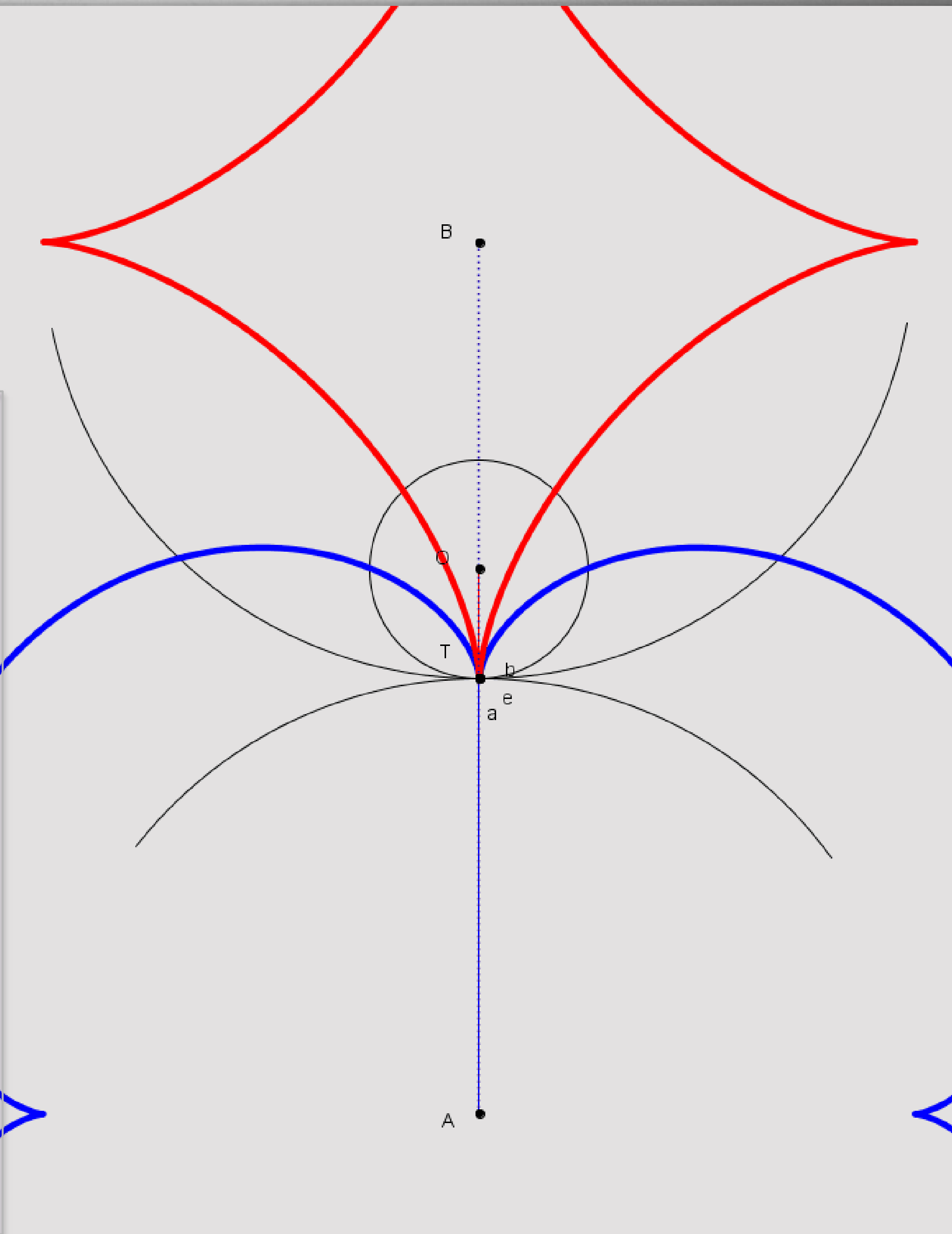
☑ Comment 2

But these are the arcs respectively
described by the two pitch circles in moving
from the first position to the second;
therefore, as before,
the angular velocity ratio is constant
and equal to that which would be obtained
by the rolling contact
of the pitch circles.

Otherwise; as before,
the constancy of the angular velocity ratio
may be shown from the known property of
the curves by which
the normal from the point b
passes through T.

This third solution includes the two former ones,
for it is known that if the diameter of
the describing circle of an hypocycloid
be made equal to the radius of the base,
the hypocycloid becomes a straight line
coinciding with a diameter of the latter;
and thus the second solution is obtained.

Also, if the describing circle of the hypocycloid
equal the circle of the base,
the hypocycloid is reduced to a point
in its circumference,
and thus the first solution is obtained.



A and B being, as before, the centers of motion,
and T the point of contingence of the pitch circles.

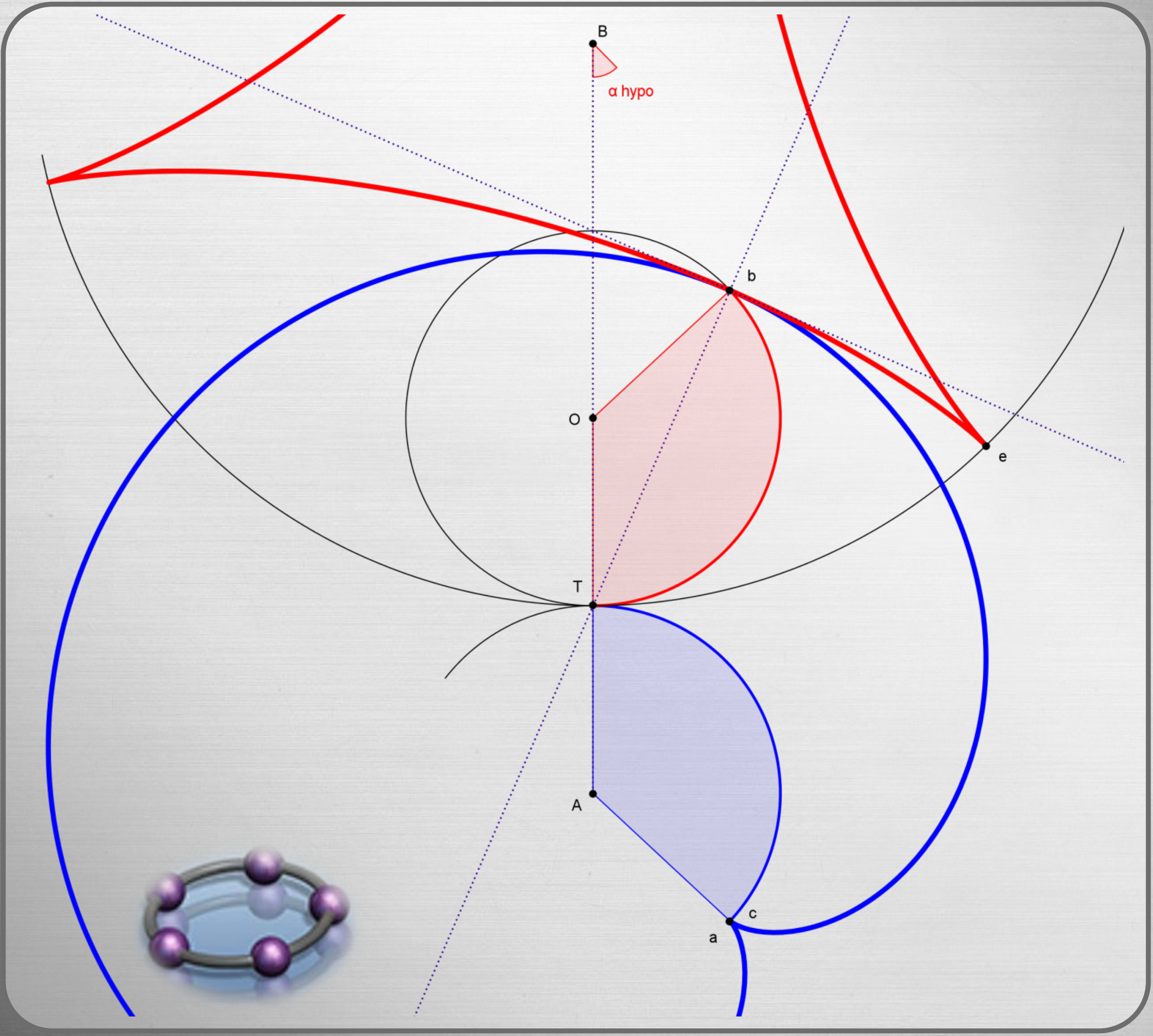
Let a describing circle r_e be taken of any diameter,
and with it describe an epicycloid abc_0 by rolling
on the outside of the pitch circle $r_0$epi,
and an hypocycloid ebf_0 by rolling
on the inside of the pitch circle $r_0$hypo.

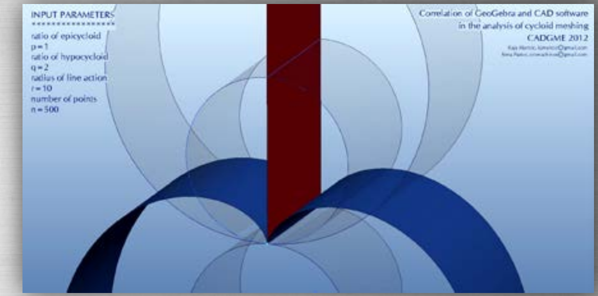
Let these curves be cut out and made to
revolve in contact, round their
respective centers of motion A and B,
until they come into a
new position where abc is the epicycloid
and ebf the hypocycloid.

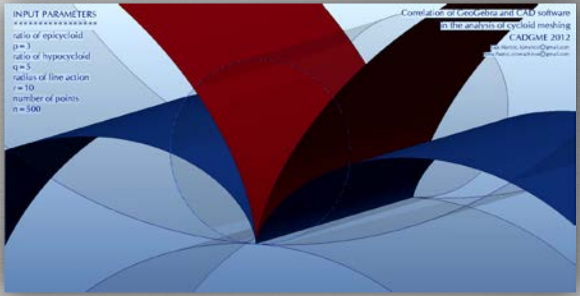
By the known properties of thc curves
they will have their common point b
in the circumference of the
describing circle r_e, when its center O
is on the line of centers,
and they will also have
a common tangent there.

Also, if the describing circle r_i were
to roll upon $r_0$hypo from its present position,
it would describe the curve be
with the point b,
and this point would come to e;
therefore
the arc Tb is equal to the arc Te,
and similarly,
the arc Tb is equal to the arc Ta;Te = Ta.

Third Solution

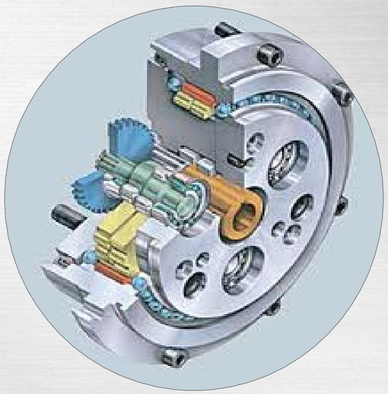






Cycloid Meshing
Application

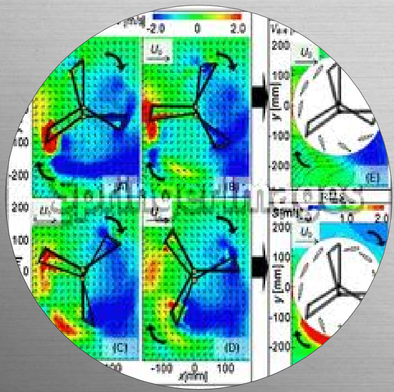
Cycloidal drives



Cycloidal gears

Cycloid
hydraulic motor

MEMS



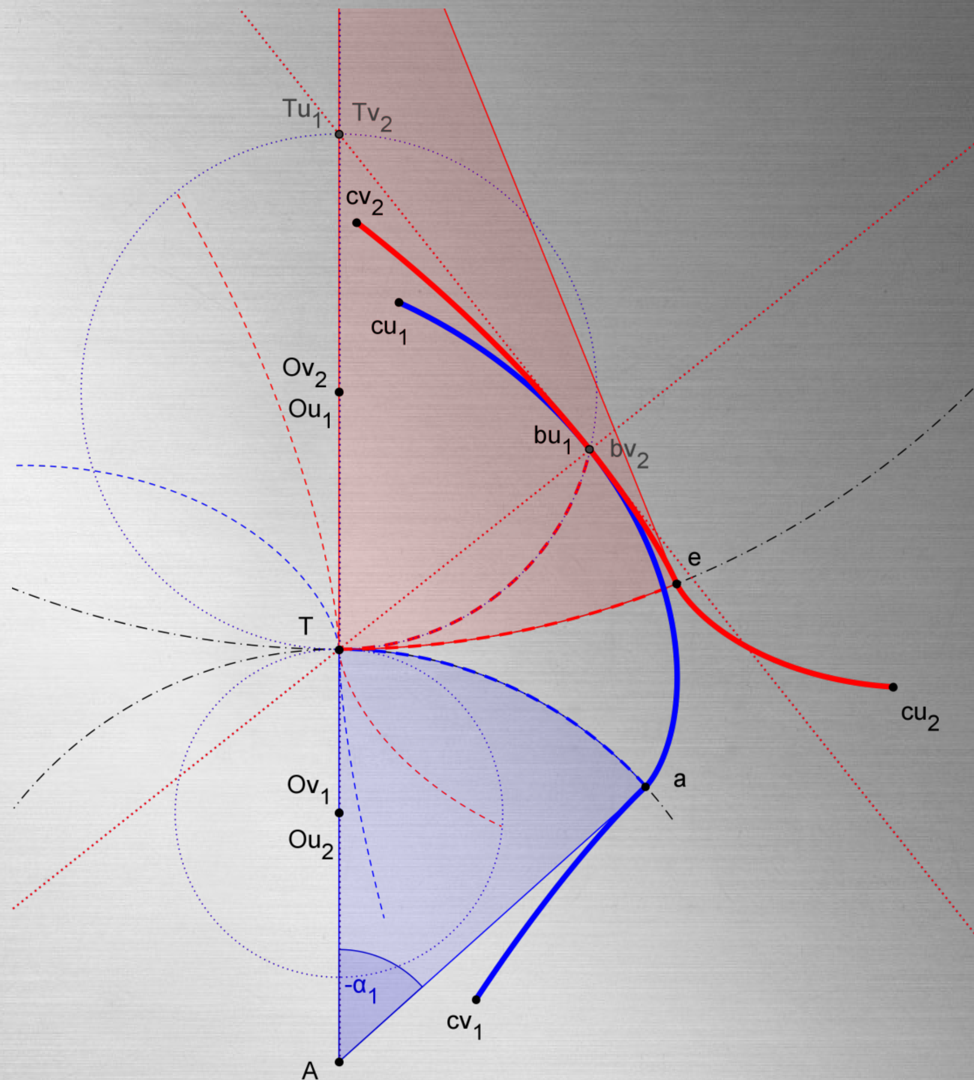
Cycloidal propeller

Cycloidal flow meters

Wankel rotary engine

The Reuleaux polygon

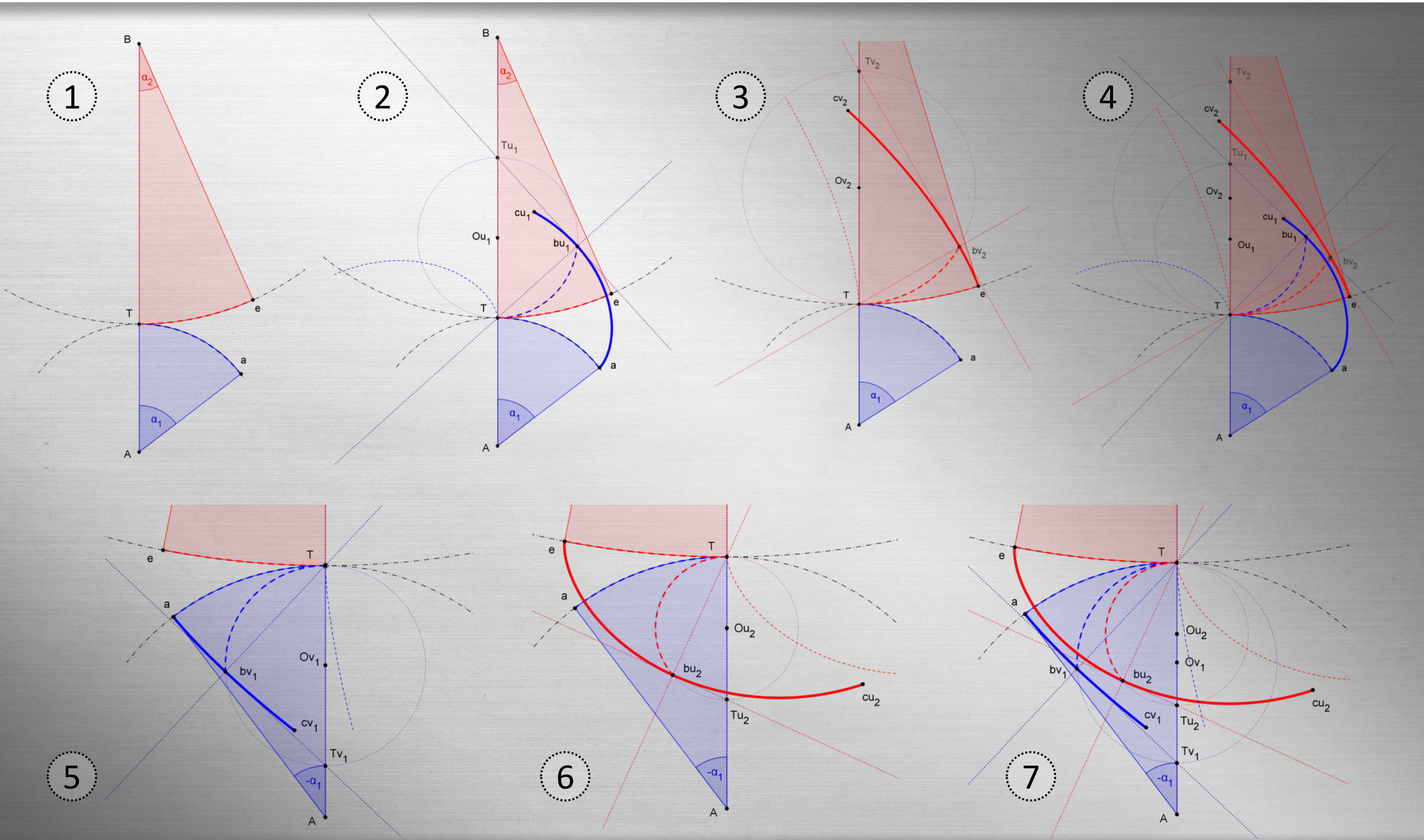
..: GeoGebra Laboratory
..: PTC Creo CAD Assembly



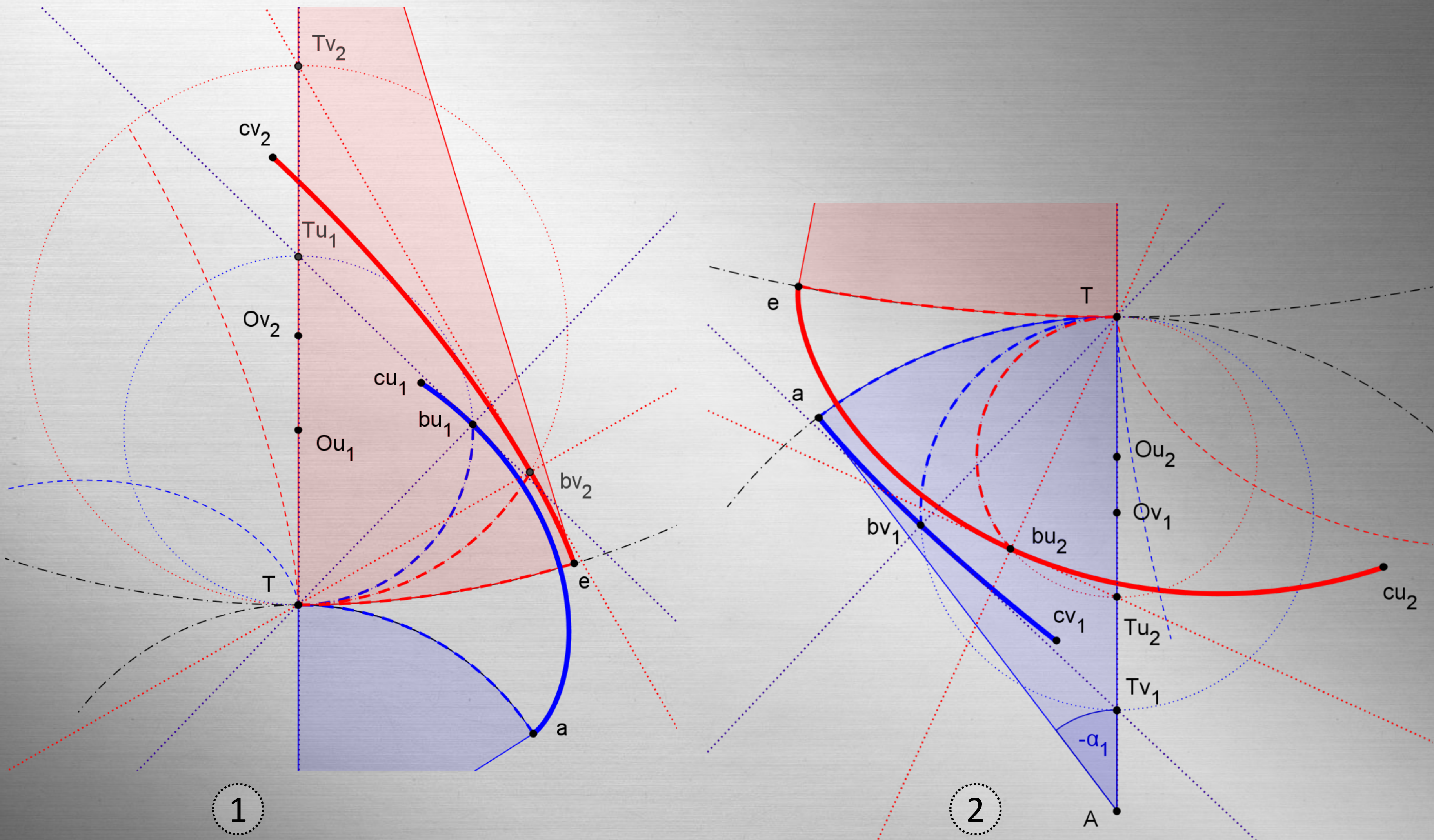
Part 5

CYCLOID GEARING

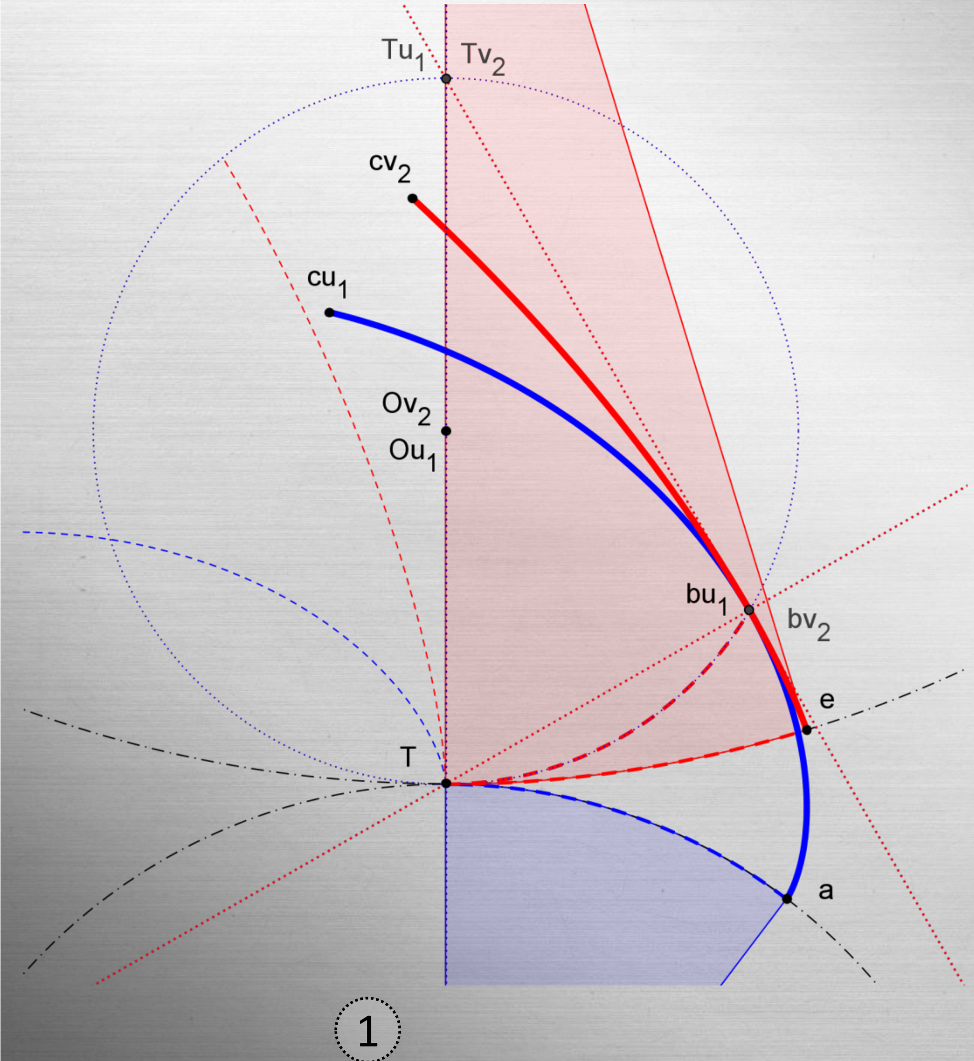
Cycloid Gearing
GeoGebra Laboratory

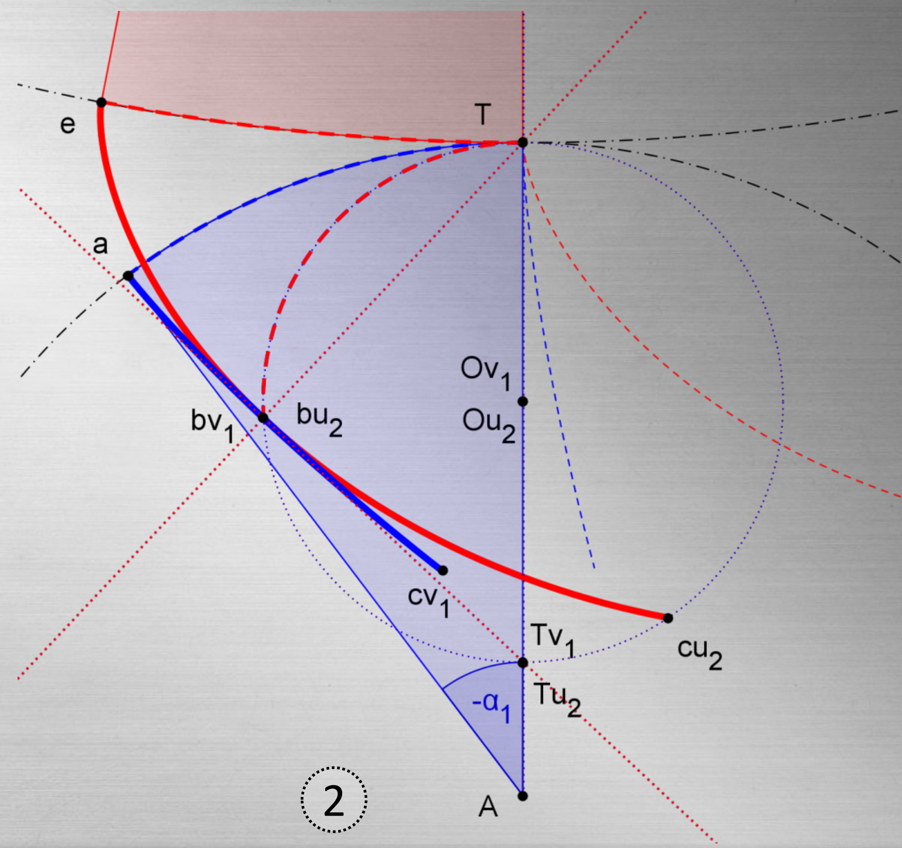


Cycloid Gearing
GeoGebra Laboratory

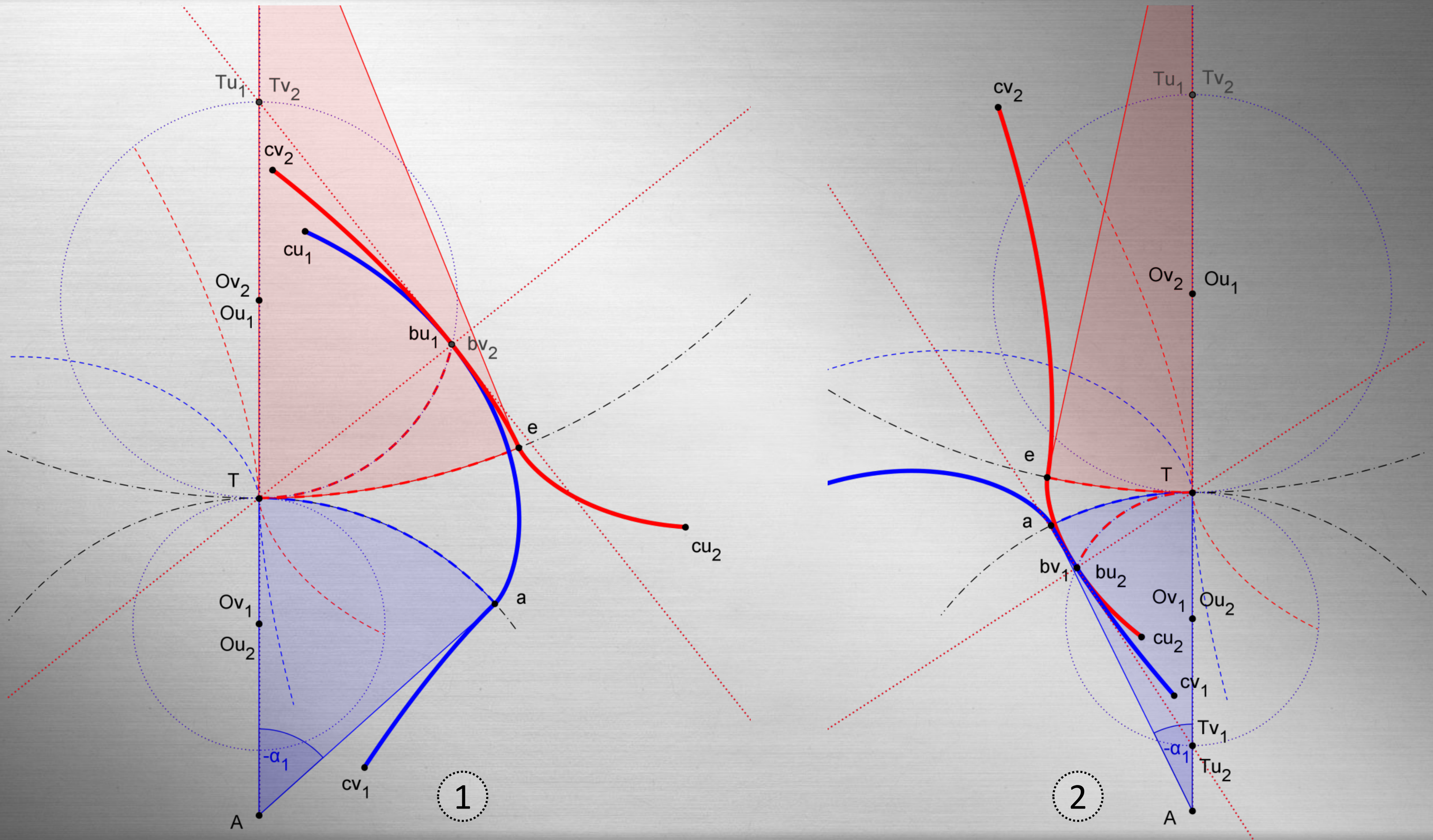


Cycloid Gearing
GeoGebra Laboratory

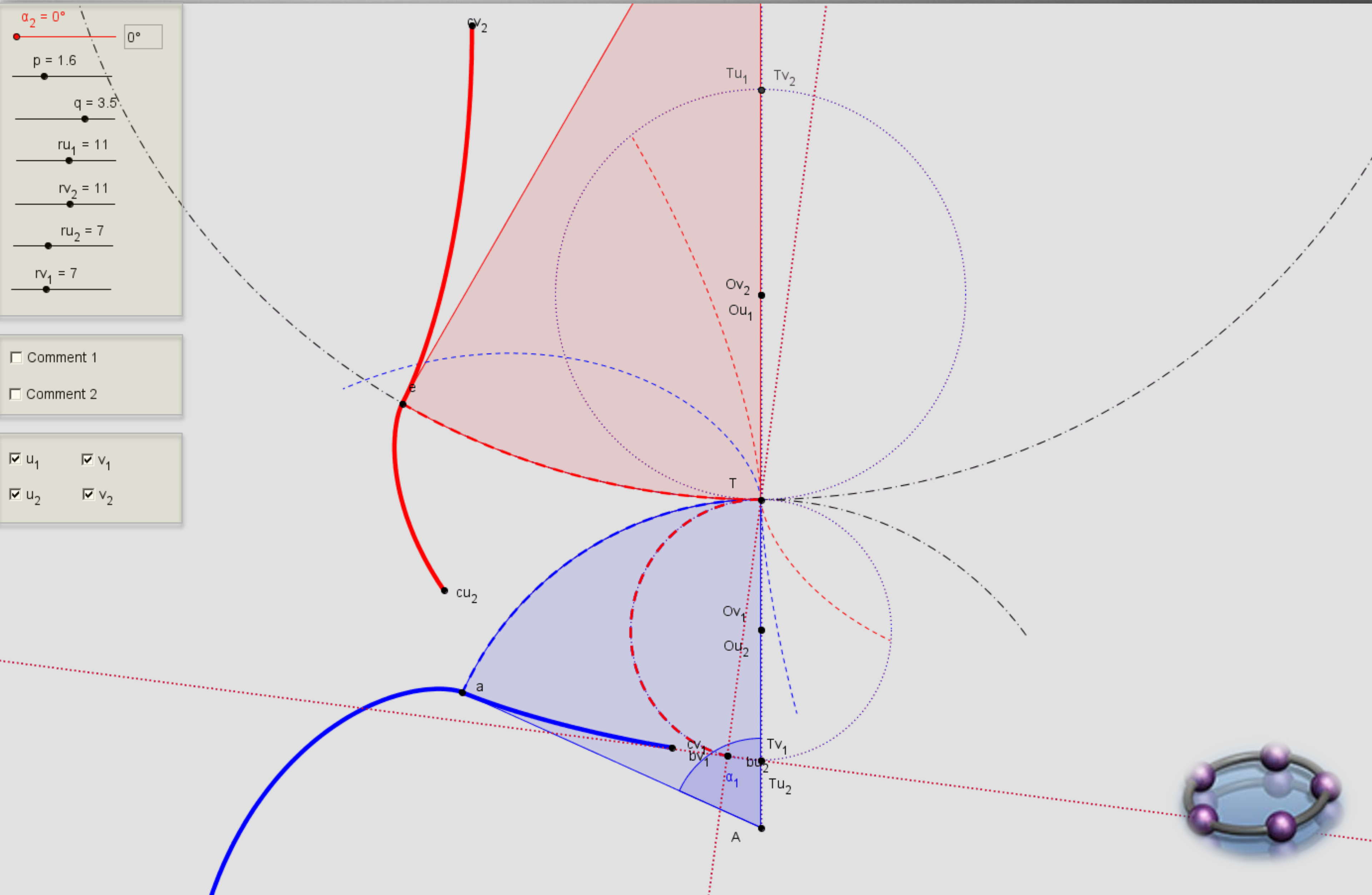




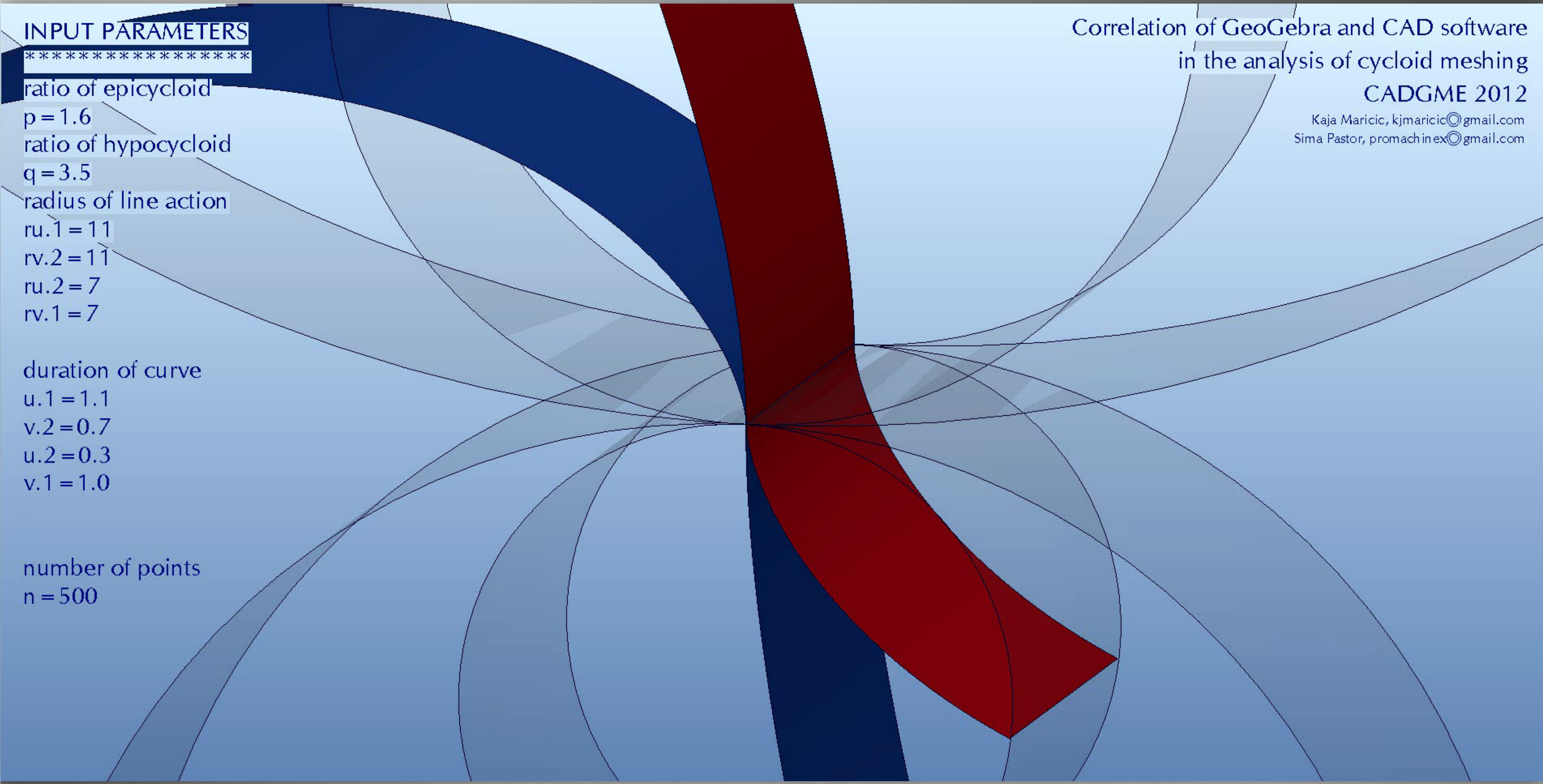
Cycloid Gearing
GeoGebra Laboratory



Cycloid Gearing



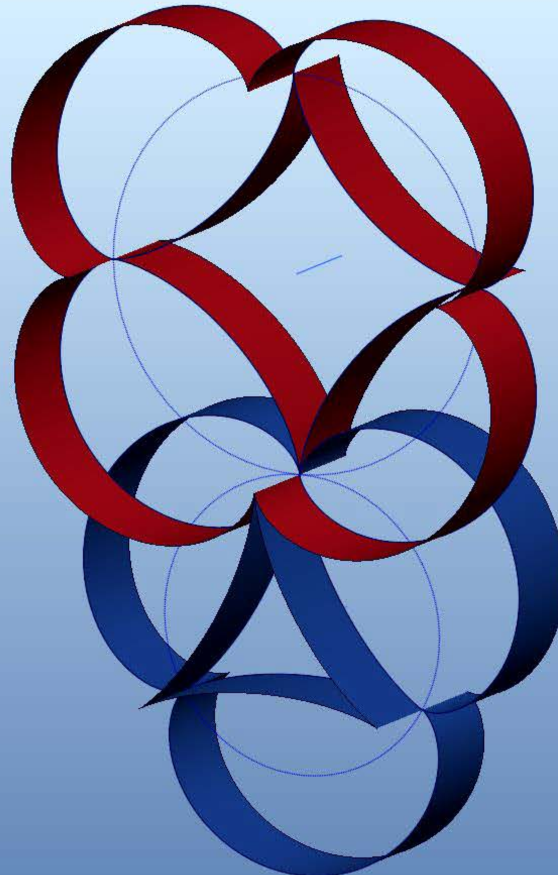
Cycliod Gearing
PTC Creo CAD Assembly



Cycliod Gearing
PTC Creo CAD Assembly

INPUT PARAMETERS
****
ratio of epicycloid
up = 3.0
ratio of hypocycloid
vq = 4.0
radius of line action
ru.1 = 10
rv.2 = 10
ru.2 = 10
rv.1 = 10
duration of curve
u.1 = 6.3
v.2 = 6.3
u.2 = 6.3
v.1 = 6.3
number of points
n = 500

OUTPUT PARAMETERS
****
diameter of circle
d.1 = 60.0
d.2 = 80.0
ratio of epicycloid
vp = 3.0
ratio of hypocycloid
uq = 4.0



Correlation of GeoGebra and CAD software
in the analysis of cycloid meshing
CADGME 2012

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Sima Pastor, promachinex@gmail.com

Thank you!

Questions...

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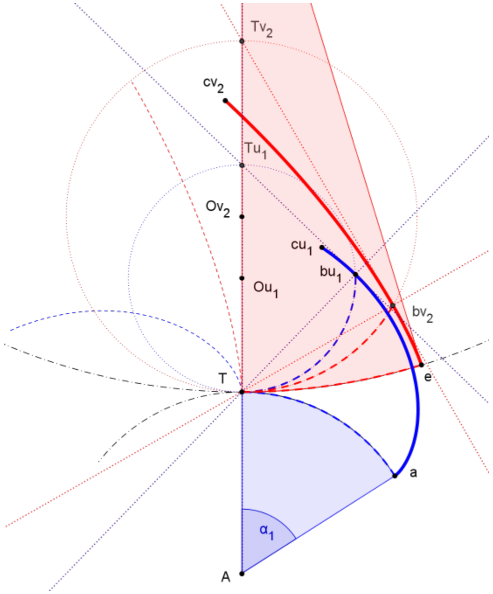

CADGME 2012
Novi Sad, Serbia
22-24 June 2012

Correlation of GeoGebra and CAD software
in the analysis of cycloid meshing, Maricic, Pastor