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UPSC ENGINEERING SERVICES EXAMINATION

MECHANICAL ENGINEERING

ESE SUBJECTWISE
CONVENTIONAL SOLVED PAPER-II

COMPLETE SOLUTIONS WITH EXPLANATIONS I THOROUGHLY REVISED AND UPDATED

MECHANICAL ENGINEERING

ESE SUBJECTWISE

CONVENTIONAL SOLVED PAPER-II

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PREFACE

Engineering Services Exam (ESE) is one of most coveted exams written by engineering students aspiring for reputed posts in the country. As all the senior engineering posts come under the Government of India, ESE is conducted by the Union Public Services Commission (UPSC), and therefore the standards to clear this exam too are very high. To clear the ESE, a candidate needs to clear three stages – ESE Prelims, ESE Mains and Personality Test.

It is not mere hard work that helps a student succeed in an examination like ESE that witnesses lakhs of aspirants competing neck to neck to move one step closer to their dream job. It is hard work along with smart work that lets an ESE aspirant fulfil his dream.

After detailed interaction with students preparing for ESE, IES Master has come up with this book which is a one-stop solution for mechanical engineering students aspiring to crack this most prestigious engineering exam. The book includes previous years' solved conventional questions segregated topic-wise along with detailed explanation to all questions. This book will also help ESE aspirants get an idea about the pattern and weightage of questions asked in ESE.

IES Master feels immense pride in bringing out this book with utmost care to build upon the exam preparedness of a student up to the UPSC standards. The credit for flawless preparation of this book for mechanical engineering students aspiring for ESE goes to the entire team of IES Master Publication. Teachers, students, and professional engineers are welcome to share their suggestions to make this book more valuable.

Mr. Kanchan Kumar Thakur

Director – IES Master

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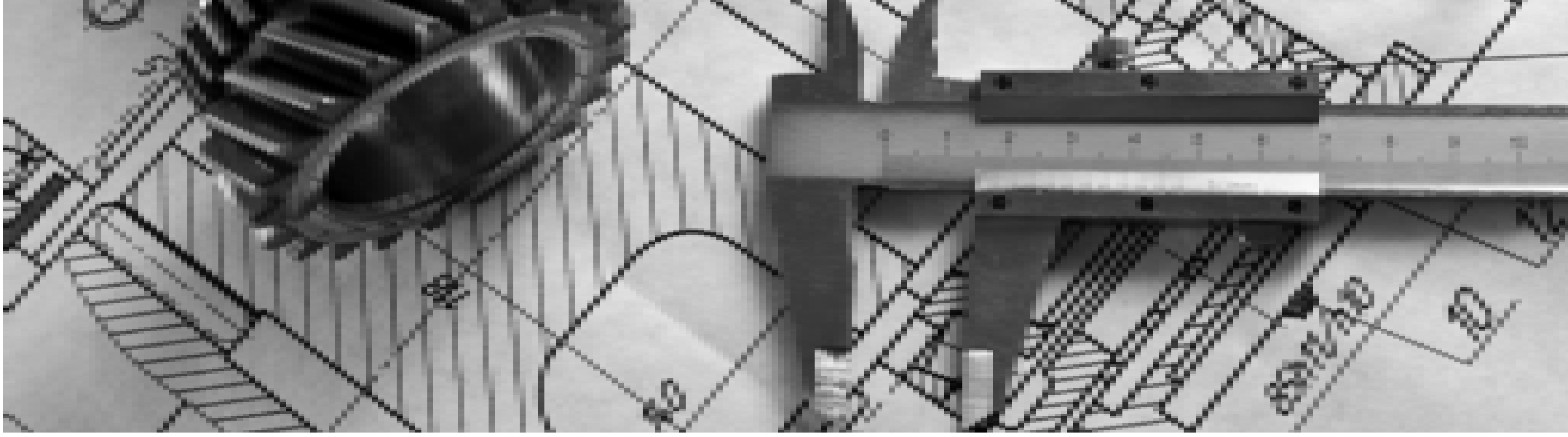

UNIT 1 THEORY OF MACHINES

SYLLABUS

Type of Kinematics Pair, Mobility, Inversion, Kinematics Analysis, Velocity and Acceleration Analysis of Planar Mechanisms, CAMs with Uniform Acceleration and Retardation, Cycloidal Motion, Oscillating Followers, Vibrations-Free and Forced Vibrations of Undamped and Damped SDOF Systems, Transibility Ratio, Vibration Isolation, Critical Speed of Shafts. Gears-Geometry of Tooth Profiles, Law of Gearing, Involute Profile, Interference, Helical, Spiral and Worm Gears. Gear Trains-Simple, Compound and Epicyclic. Dynamic Analysis-Slider Crank Mechnisms, Turning Moment Computation, Balancing of Revolving and Reciprocating Masses. Gyroscopes-Effect of Gyroscopic couple on Automobiles, Ships and Aircraft, Governors.

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CHAPTER 1
Mechanism

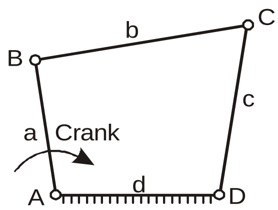
Q–1: Explain Grashof's linkage. Explain the inversions of this linkage. ***[4 Marks ESE–2015]***

Sol : A very important consideration when designing a mechanism is to ensure that the input crank can make a complete revolution. Mechanisms in which no link makes a complete revolution would not be useful in such applications. Grashof's law states that for a planar four-bar linkage, the sum of the shortest and longest link lengths cannot be greater than the sum of the remaining two link lengths if there is to be continuous relative rotation between two members. Let the longest link has length *l*, the shortest link has length s, and the other two links have lengths p and q. In this notation. Grashof's law states that one of the links, in particular the shortest link, will rotate continuously relative to the other three links if and only if

$$s + l \le p + q$$

If this inequality is not satisfied, no link will make a complete revolution relative to another.

By fixing different links one by one in a mechanism, different mechanisms are obtained. This process of getting different mechanism is called inversion of mechanisms. The relative motion between the links remain same irrespective of any link fixed.



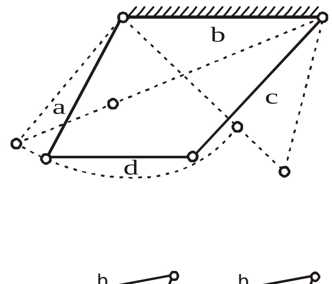
1. Inversion of Four Bar Chain

Consider a 4-bar mechanism shown in the figure.

The length of four links are a, b, c and d as shown in figure.

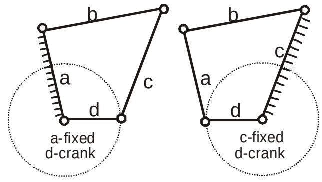
(a) Shortest length link *'d'* is fixed *i.e. d < b*, c,a.

- Sum of shortest and longest link length is less than sum of rest two.
- In above conditions both *'a'* and *'c'* can make full revolution and *'b'* also make full revolution relative to fixed link *'d'*. This type of mechanism is called as crank-crank, or double cranks or rotatory-rotatory or drag-crank mechanism.



(b) Link adjacent to Shortest *(a* or *c)* is fixed

- Both the cases, *'d'* makes complete revolution.
- But link *'b'* oscilates.
- This mechanism is called as crank-rocker or crank-lever or rotatory-oscilatory mechanism.



(c) Fix link 'b' opposite to shortest link

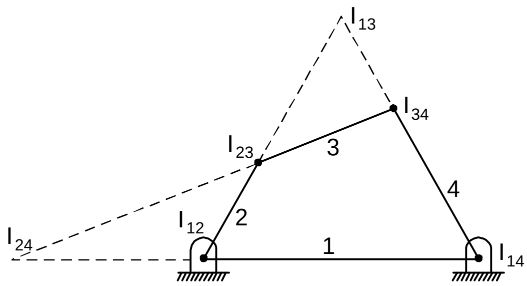
- Here links adjacent to shortest *i.e. 'a'* and *'c'* can oscilate only. This mechanism is called as double rocker or double lever or oscilating-oscilating mechanism as *Class-II* of mechanism when sum of shortest and longest links is more than sum of rest two.

Q–2: ***Draw a crank rocker mechanism and identify all instantaneous centres.*** ***[4 Marks ESE–2014]***

Sol : For crank-rocker mechanism, the Grashof law should be satisfied. i.e. “Sum of length of largest link and smallest link should be less than the sum of rest two intermediate length links.” Hence atleast one link of four bar chain is crank if Grashof law is satisfied.

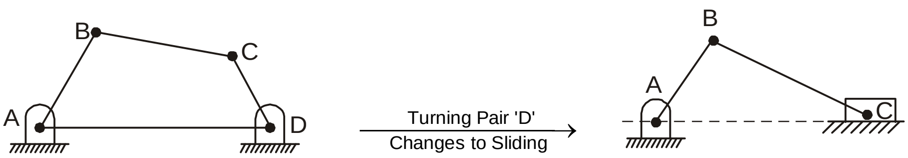
To get crank rocker mechanism, the link adjacent to shortest should be fixed as shown below i.e. link ‘1’ or ‘3’ should be fixed.

All instantaneous centres are marked on figure.



Q–3: ***One of the turning pairs of a four-bar chain is replaced by a sliding pair. Draw the inversions by fixing different links. Give one application for each of the mechanism.*** ***[10 Marks ESE–2013]***

Sol : When one of the turning pair of four bar chain is replaced by sliding pair, the mechanism is called sliding pair mechanism.



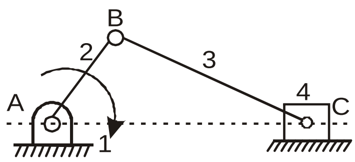
Various inversion of sliding pair mechanism.

We know that in 4-bar mechanism a turning pair can be replaced by a sliding pair and resultant mechanism is called as slider-crank mechanism as shown in figure. The various inversions of slider crank mechanism are,

(a) First Inversion

(a) Fixing link ‘1’.

(b) Link-2 as crank i.e., complete revolutions.

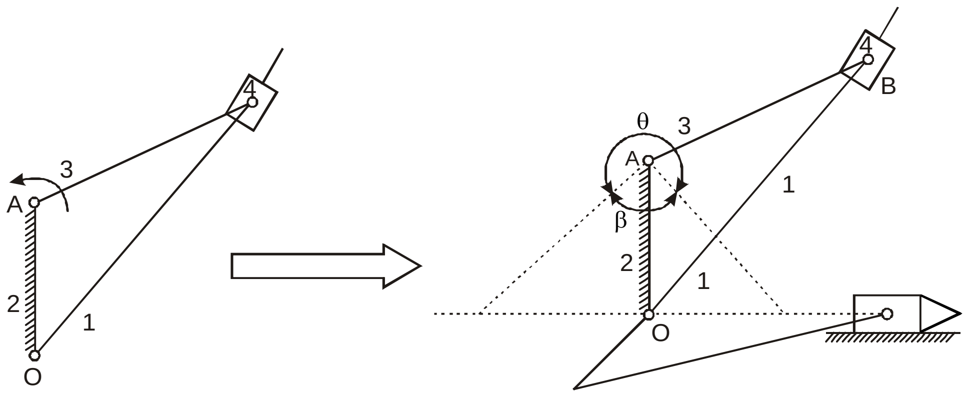


Applications

- **Reciprocating Compressor :** Hence crank-2 is driver and piston-4 is follower.
- **Reciprocating Engine :** Here piston-4 is driver and crank-2 is follower.

(b) Second Inversion

Now fix link-2 and link-3 along with slider rotates. This makes the link-1 to oscilate as shown below.



Applications

- Whitworth Quick Return mechanism
- Rotatory Engine

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Whitworth Quick Return Mechanism

- During rotation of anlge ‘θ’, metal cutting occure.
- During rotation of along β, the return stroke occure.

  So in order to minimise the total cutting time, the return stroke is fast.

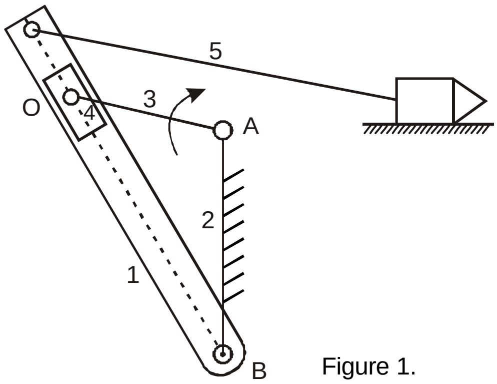


Figure 1.

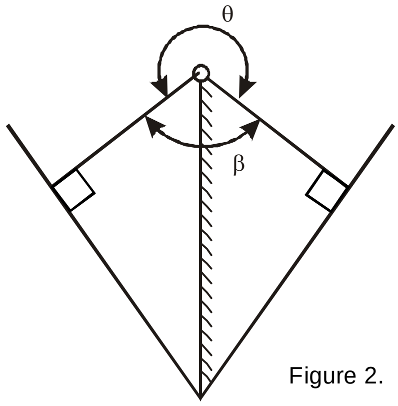


Figure 2.

The quick return ratio of this mechanism is,

$$\frac{\theta}{\beta}. = \frac{\text{Cutting time}}{\text{Return time}}$$

Crank and Slotted Lever Mechanim

- Crank (link-3) rotates about *A* and link-2 is fixed.

  From Fig. 2 it is clear that the time of forward stroke is proportional to angle ‘θ’ and time of return stroke is proportional to angle ‘β’.

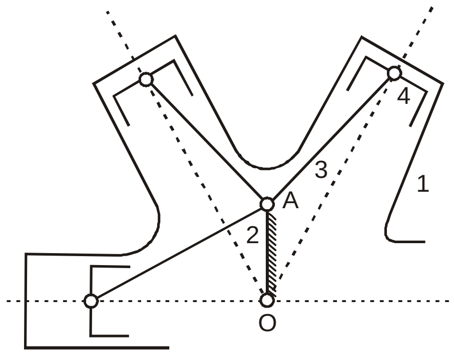
$$\therefore \qquad \frac{\text{Forward stroke time}}{\text{Return stroke time}} = \left(\frac{\theta}{\beta}\right)$$

Difference between Slotted-lever and Whitworth Mechanism

- Output is same i.e., slow forward and fast return stroke used in metal cutting (shaper).
- Attachment of link-5 to link-1. In whitworth it is attached with beyond point *B* and in slotted lever it is opposite of this.

Rotatory Engine

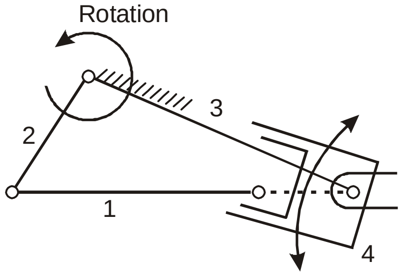
In this engine, link ‘3’ rotates about *A* and link ‘1’ *i.e.* body of engine rotates about ‘O’ and piston ‘4’ reciprocates in cylinder *i.e.*, in link 1.



(c) Third inversion

Here link ‘3’ is fixed and link ‘2’ rotates (*i.e.*, crank) and link ‘4’ oscilates.

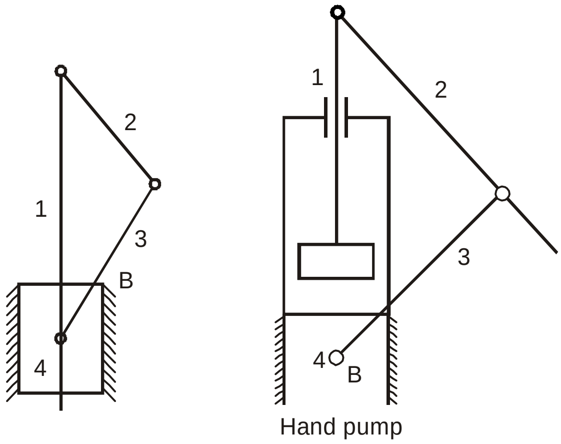
Oscillating Cylinder Engine



Here link-2 rotates (*i.e.*, crank) and cylinder-4 oscillates. The piston is fixed at the end of link 1 which reciprocates in cylinder.

(d) Fourth Inversion

Now the link-4 (slider) is fixed as shown in figure.

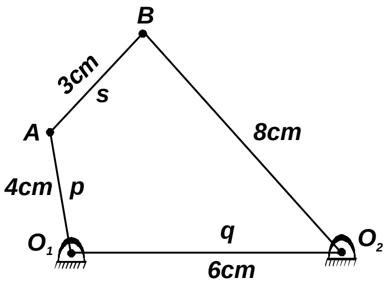


Hand pump

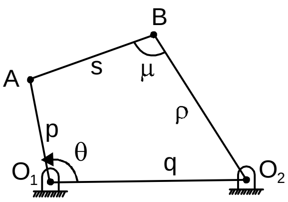
The example is Hand pump.

- Link-3-oscilLates about B.
- Link-1-reciprocates along the axes of link-1 (fixed).

Q–4: Determine the maximum and minimum transmission angle of the mechanism shown which is driven by member O_1A. ***[2 Marks ESE–2012]***



Sol :



Class of mechanism,

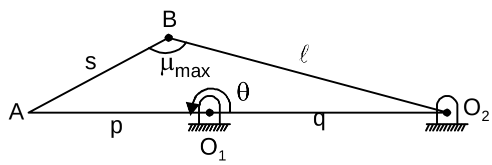
$\because$ $(\ell + s) > (p + q)$

$(8 + 3) > (4 + 6)$

$11 > 10$

Hence the mechanism is class II and is a double rocker mechanism. So in this mechanism,

(i) Maximum transmission angle 'μ' occure when θ is 180°



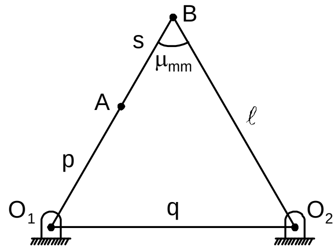
$$\therefore \quad \cos\mu_{max} = \frac{s^2 + \ell^2 - (p+q)^2}{2s\ell}$$

$$= \frac{3^2 + 8^2 - (4+6)^2}{2 \times 3 \times 8}$$

$$= \frac{9 + 64 - 100}{48} = -\frac{27}{48} = -0.5625$$

$$\mu_{max} = 124.229°$$

(ii) Minimum angle of transmission occures when links ‘p’ and ‘s’ are collinear as shown below.



$$\therefore \quad \cos\mu_{min} = \frac{(p+s)^2+\ell^2-q^2}{2(p+s)\cdot\ell}$$

$$= \frac{7^2+8^2-6^2}{2\times7\times8}$$

$$= 0.6875$$

$$\therefore \quad \mu_{min} = 46.567°$$

Q–5: ***A crank and slotted lever Quick Return Motion Mechanism used in a shaping machine has a distance of 200 mm between the centre of oscillation ‘A’ of the slotted lever and the centre of rotation ‘B’ of the crank. The radius of the crank BC is 100 mm.***

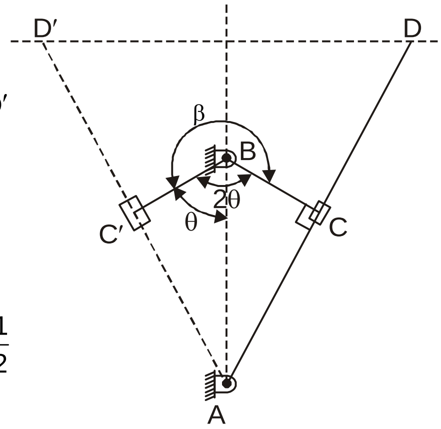
(i) Show on a diagram the extreme positions of the lever AD during one complete rotation of the crank.

(ii) Find the ratio of the time of cutting to the time of the return stroke. [2 Marks ESE–2011]

Sol : Distance between fixed centers, AB = 200 mm

Radius of crank, BC = 100 mm

In extreme positions, the angle ∠BCA is right angle. So AD and AD′ are extreme positions of slotted link AD.



The ratio of cutting to return stroke time,

$$= \frac{2\beta}{2\theta} = \frac{\beta}{\theta}$$

∴ In right angle triangle ABC

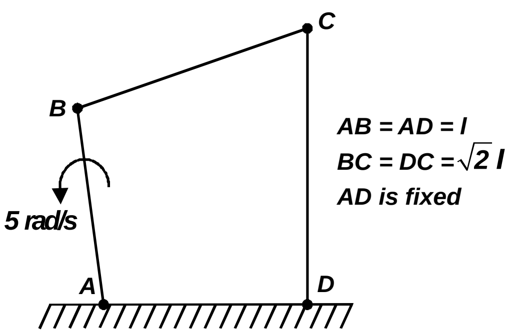
$$\cos\theta = \frac{BC}{AB} = \frac{100}{200} = \frac{1}{2}$$

$$\therefore \quad \theta = \frac{\pi}{3}$$

$$\beta = \pi - \theta = \frac{2}{3}\pi$$

$$\therefore \quad \text{Time ratio} = \frac{\frac{2\pi}{3}}{\frac{\pi}{3}} = 2$$

Q–6:



The driver link AB of a four bar mechanism is rotated at 5.0 rad/s in counter clockwise direction as shown in the above figure. Located and indicate the Instantaneous Centre (I.C.) of the coupler BC with respect to fixed link AD at an instant when ∠BAD = 180°. Find angular velocity of the coupler using I.C. method only. [2 Marks ESE–2010]

Sol : The schematic of four bar mechanism when angle BAD = 180°

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