MUZAFFARPUR INSTITUTE OF TECHNOLOGY, MUZAFFARPUR

COURSE FILE

OF

KINEMATICS OF MACHINERY

(021408)

FACULTY NAME:

SARVESH KUMAR YADAV

ASSISTANT PROFESSOR

DEPARTMENT OF MECHANICAL ENGINEERING

CONTENTS

Muzaffarpur Institute of Technology, Muzaffarpur

Department of Mechanical Engineering

Vision

• To strengthen the region through imparting superior quality technical education and research; which enables the fulfillment of industrial challenge and establish itself as a Centre of Excellence in the field of Mechanical Engineering.

Mission

• To build an academic environment of teaching and lifelong learning for students to make them competitive in context with advance technological, economical and ecological changes.

• To enable the students to enhance their technical skills and communications through research, innovation and consultancy projects.

• To share and explore the accomplishments through didactic, enlightenment, R & D programs with technical institution in India and abroad.

Mechanical Engineering Program Educational Objectives

- Graduates will spread and enhance their technical capability and proficiency through vital domain of economical, environmental and social concerns affiliated with the mankind and industry.
- Graduates will able to work professionally with modern methods in the area of Thermal, Mechanical System Design, Manufacturing, Measurement, Quality control and other interdisciplinary fields of concerns.
- Graduates will practice Mechanical engineering in sensible, flexible and ethical manner to benefit the society, industry and nation toward the rapidly changing global technical standards.
- Graduates will serve as ambassadors for engineering by their knowledge, creativity, imagination and innovation and set new extremes in their profession through lifelong learning.

Mechanical Engineering Student Outcomes

Mechanical Engineering Student Outcomes Students who complete the B.E. degree in ME will be able to:

1. An ability to apply the knowledge of mathematics, basic sciences and engineering concepts to solve the complex engineering problems.
2. The ability to conduct experiments and to critically analyze and interpret the experimental data to reach at substantial outcomes.
3. An ability to design systems, components, or processes to meet appropriate needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
4. An ability to identify, formulates, and solves the complex engineering problems.
5. An ability to function on multi-disciplinary teams that leads the multidisciplinary projects.
6. An understanding of professional and ethical responsibility.
7. An ability to communicate effectively with written, oral, and visual means.
8. An ability to understand the impact of engineering solutions in a global, environmental, economical and societal context.
9. An ability to recognize the need to engage in life-long learning.
10. An ability to attain knowledge of contemporary issues.

11. An ability to use the techniques, skills, and modern tools necessary for Mechanical engineering practice.

12. Possess ability to estimate costs, estimate quantities and evaluate materials for design and manufacturing purposes.

Course Description

This subject mainly deals with mechanisms of various machines which include position displacement velocity and acceleration that we come across in our day today life without giving much importance to Force or Mass. The subject also deals with graphical and analytical interpretation. The other chapters of interest are Velocity and Acceleration of mechanisms by Complex Numbers, Belt drive, gears, gear trains and mass balancing.

Course Outcomes:

ME021408.1: Study and analyze various types of inversion and find out different types of motion when corresponding link is fixed.

ME021408. 2: Develop the design concepts of different types of mechanism with lower pairs and higher pairs and its application.

ME021408.3: To analyze position, velocity and acceleration of links of different kinematics of mechanisms

ME021408.4: Study and analyze the gear profiles and gear trains.

ME021408.5: Understand the concept of braking and development of device to measure the power with help of dynamometers.

CO-PO MAPPING

Sr. No.	Course Outcome	PO
1	ME021408.1: Study and analyze various types of inversion and find out different types of motion when corresponding link is fixed.	PO1,PO2
2	ME021408.2: Develop the design concepts of different types of mechanism with lower pairs and higher pairs and its application.	PO3
3	ME021408.3: To analyze position, velocity and acceleration of links of different kinematics of mechanisms.	PO1,PO3
4	ME021408.4: Study and analyze the gear profiles and gear trains.	PO1,PO3
5	ME021408.5: Understand the concept of braking and development of device to measure the power with help of dynamometers.	PO1,PO3

Course Outcomes	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
ME021408.1: Study and analyze various types of inversion and find out different types of motion when corresponding link is fixed.	✓	✓										
ME021408.2: Develop the design concepts of different types of mechanism with lower pairs and higher pairs and its application.			✓									
ME021408.3:To analyze position, velocity and acceleration of links of different kinematics of	✓		✓									

mechanisms.												
ME021408.4: Study and analyze the gear profiles and gear trains.	✓		✓									
ME021408.5: Understand the concept of braking and development of device to measure the power with help of dynamometers.	✓		✓									

B. Tech. VI Semester (Mechanical)
ME- 021408 kinematics of Machinery

L T P/D Total		Max Marks:	100
3-1-0 4		Final Exams:	70 Marks
		Seasonal:	20 Marks
		Internals:	10 Marks.

UNIT-I

Basic Kinematic concepts: Links Kinematic pairs, Kinematic chains, Mechanism and inversions, single and double slider crank chains, straight line motion mechanisms.

Velocity and Acceleration in Mechanism: Relative velocity methods, instantaneous center of rotation, centroids, Kenomedy theorem of three centers, Acceleration diagram, acceleration center, Corriolis component.

UNIT-II

Friction Devices: Introduction to friction, belt, chain and rope drive, transmission of power through friction clutch, theory of shoe brakes band and block brakes.

UNIT-III

Fundamental Law of gearing: Classification of gears and basic terminology, Geometric and kinematic characteristics of involutes and cycloidal tooth profiles, undercutting and interference.

Gear Trains: Simple, compound and planetary, tooth load and torque.

UNIT-IV

Balancing: Balancing of revolving masses in the same plane by a single revolving mass balancing of several revolving masses in different planes by two revolving masses in suitable planes.

UNIT-V

Governors: Watt, Porter, Proell and Hartnell governors, effect of friction, controlling force, Governor Effect and power sensitivity and isochronisms.

GATE SYLLABUS

Kinematics of Machinery

Basic Kinematic concepts: Links Kinematic pairs, Kinematic chains, Mechanism and inversions, single and double slider crank chains, straight line motion mechanisms.

Velocity and Acceleration in Mechanism: Relative velocity methods, instantaneous center of rotation, centroids, Kenomedy theorem of three centers, Acceleration diagram, acceleration center, Corriolis component.

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MUZAFFARPUR INSTITUTE OF TECHANOLOGY, MUZAFFARPUR

Time Table (4th Semester) 2018

W.E.F 12/02/2018

Branch- Mechanical Engineering

Day	I	II	III	IV	1.20 to 2.00 PM	V	VI	VII
	10.00 to 10.50 AM	10.50 to 11.40 AM	11.40 to 12.30 PM	12.30 to 1.20 PM		2.00 to 2.50 PM	2.50 to 3.40 PM	3.40 to 4.30 PM
Monday		KOM (Room No 47)			RECESS			
Tuesday				KOM (Room No 47)		KOM T (Room No 15A)		
Wednesday	KOM (Room No 47)					KOM T (Room No 15A)		
Thursday								
Friday								
Saturday								

Sarvesh Kumar Yadav — **Principal**

In Charge — **MIT MUZAFFARP**

Student List

S.N	Name	Roll. No.
1	SUMAN BHARTI KESHAV	16M08
2	MUKUND KUMAR	16M52
3	ALOK ARAYA	16M19
4	VIKAS KUMAR BHARTI	16M31
5	RAJHANS KUMAR	16M20
6	SHASHI BHUSHAN KUMAR	16M69
7	NAWLESH KUMAR	16M05
8	ABHISHEK KUMAR	16M03
9	ANUBHAV SHRIVASTAVA	16M07
10	VISHAL KUMAR	16M58
11	MD AKRAM ALAM	16M02
12	SANDEEP RAHUL	16M51
13	ABHISHEK ANAND	16M12
14	RATAN KUMAR	16M64
15	RAUSHAN KUMAR	16M43
16	AVINASH KUMAR	16M32
17	SAURAV KUMAR	16M01
18	MITHUN KUMAR	16M22
19	MD TASLIM	16M19
20	KUMARI PAYAL	16M60
21	SHASHI KUMAR	16M24
22	VIVEK KUMAR	16M59
23	VISHWANATH KUMAR	16M34
24	PRINCE KUMAR	16M17
25	SHIWANGI KUMARI	16M68
26	KANHAIYA KUMAR	16M16
27	AMRIT RAJ	16M66
28	NANDAN KUMAR	16M65
29	KRISHNA KUMAR	16M71
30	RAHUL PRASAD	16M25
31	SHAILENDRA KUMAR	16M62
32	SHUBHAM	16M14
33	PIYUSH KUMAR	16M37
34	AMIT KUMAR	16M54
35	SHATRUDHAN KUMAR	16M23

36	NAVNEET DHANRAJ	16M18
37	RUPESH KUMAR	16M40
38	AVINASH RAJ	16M70
39	FAIZ ANWAR	16M38
40	PRABHAKAR KUMAR	16M55
41	VINOD KUMAR	16M47
42	KUMAR RAHUL	16M36
43	VISHAL KUMAR	16M61
44	VISHAL KUMAR	16M44
45	LALAN KUMAR	16M56
46	RAUSHAN KUMAR	16M41
47	VED PRAKASH	16M21
48	ANAND MOHAN SINGH	16M13
49	KANHAIYA KUMAR	16M35
50	TUSHAR VERMA	16M53
51	VISHAL KUMAR	16M27
52	UJJWAL KUMAR	16M06
53	RAHUL KUMAR	16M04
54	SONU KUMAR	16M63
55	SURENDRA KUMAR	16M15
56	MANOHAR KUMAR	16M26
57	ASHUTOSH KUMAR	16M11
58	NIDHI KUMARI GUPTA	16M49
59	ASHUTOSH KUMAR JHA	16M67
60	ASHUTOSH SINHA	
61	CHANDAN KUMAR	17(LE)M01
62	RAHUL RAY	17(LE)M02
63	SUDHANSHU KUMAR SHARMA	17(LE)M03
64	RAJEEV KUMAR	17(LE)M04
65	SANGAM KUMAR	17(LE)M05
66	KRISHNA KUMAR	17(LE)M06
67	ANKIT RANJAN	17(LE)M07
68	DHIRAJ KUMAR	17(LE)M08
69	GUDDU KUMAR	17(LE)M09
70	SUNNY KUMAR	17(LE)M10
71	RAKESH RAM	17(LE)M11
72	ANAND MOHAN JHA	17(LE)M12

COURSE PLAN

College Name	MIT MUZAFFARPUR
Batch	2018
Semester	4
Course code	021408
Course Name	Kinematics of Machinery
Coursr Credit	3
Branch	Mechanical
Sections	IV sem
Course Coordinator	Sarvesh Kumar Yadav
Lecture/Tutorial Per Week	4/0

1. **Scope and Objective of Course:**

This course introduces students to involve in kinematics study how a physical system might develop or alter over time and study the causes of those changes. In addition, Newton established the fundamental physical laws which govern dynamics in physics. By studying his system of mechanics, dynamics can be understood. In particular, kinematics is mostly related to Newton's second law of motion. However, all three laws of motion are taken into consideration, because these are interrelated in any given observation or experiment.

2. **Textbooks:**

   TB1: Theory of Machine by S S Ratan

   TB2: Theory of Machine by Sadhu Singh

3. **Reference Books:**

   RB1 Theory of Machines by R.S Khurmi

   RB2 Theory of Machine by R.K Bansal

Other readings and relevant websites

S.No.	**Link of Journals, Magazines, websites and Research Papers**
1.	https://www.journals.elsevier.com/mechanism-and-machine-theory
2.	https://www.journals.elsevier.com/mechanism-and-machine-theory/most-downloaded-articles
3.	https://www.journals.elsevier.com/mechanism-and-machine-theory/recent-articles
4.	https://www.sciencedirect.com/journal/mechanism-and-machine-theory

COURSE PLAN: Kinematics of Machinery

Part-A	Date of Lecture	**Lecture Plan**				
S.No		**Topic Name**	**Web Links for video lectures**	**Text Book / Reference Book / Other reading material**	**Periods**	**Page No**
1		Kinematic of Machinery				
1.1		**Introduction:**Basic Fudamental Of Kinematic Of Machinery	**https://www.youtube.com/watch?v=6coD3oOuhr8**	**TB1**	1	1-125
1.2		Velocity and acceleration in mechanism	http://nptel.ac.in	**TB1**	1	
1.3,1.4		Relative velocity method and instantaneous center method	http://nptel.ac.in	**TB1**	2	
1.5,1.6		Acceleration diagram	http://nptel.ac.in	**TB1**	2	
1.7,1.8		Coriolis component of acceleration	http://nptel.ac.in	**TB1**	2	
2		**Friction devices**				
2.1		Introduction of Friction Devices		**TB2**	1	167-185
2.2,2.3		Belt drive	https://www.youtube.com/watch?v=nMsB6Soz4Hc	**TB2**	2	
2.4		Clutch		**TB2**	1	
2.5		Shoe brakes	https://www.youtube.com/watch?v=P_m8CcIo7s4	**TB2**	1	189-213
2.6,2.7		Bank and block brakes	https://www.youtube.com/watch?v=CRSZwR-axzM	**TB2**	2	

3		**Fundamental law of gearing**				
3.1		Basic terminology of gears	http://nptel.ac.in	**TB1**	1	371-417
3.2		arc of contact and path of contact of involute gears	http://nptel.ac.in	**TB1**	1	
3.3		minimum number of teeth on the pinion to avoid interference	http://nptel.ac.in	**TB1**	1	
3.4		Gear trains-simple	http://nptel.ac.in	**RB1**	1	428--479
3.5,3.6		compound and planetary	http://nptel.ac.in	**RB1**	2	
3.7,3.8		tooth load and torque	http://nptel.ac.in	**RB1**	2	
3.9,3.10		Numerical Question		**RB2**	2	450-522
4		**Balancing**				
4.1		Introduction of Balancing	https://www.youtube.com/watch?v=svIjQtKF5AM	**TB1**	1	538-596
4.2,4.3		balancing of evolving masses in the same plane by a single revolving mass	https://www.youtube.com/watch?v=YoZgk1xlIW4	**TB1**	2	
4.4,4.5		Balancing of revolving masses in different planes by two revolving masses in suitable planes	https://www.youtube.com/watch?v=hAng12qWWpc	**TB1**	2	
4.6,4.7		Numerical Question		**TB1**	2	
5		**Governors**				
5.1		Introduction of Governors	http://nptel.ac.in	**RB2**	1	758-828
5.2		Watt Governor	http://nptel.ac.in	**RB2**	1	
5.3		Porter Governor	http://nptel.ac.in	**RB2**	1	
5.4		Proel & hartnell Governors	http://nptel.ac.in	**RB2**	1	
5.5		Effect of friction	http://nptel.ac.in	**RB2**	1	
5.6		controlling force	http://nptel.ac.in	**RB2**	1	
5.7		governor effort and power	http://nptel.ac.in	**RB2**	1	
5.7		sensitivity and isochronisms	http://nptel.ac.in	**RB1**	1	
5.8,5.9, 5.10		Numerical Question		**RB2**	3	

Part-B	Topics for Mid Semester Examination(Serial Numbers only)	1 to 2

Part-C	Assignment Numbers	Topics
1	Assignment #1	1

2	Assignment #2	2
3	Assignment #3	3
4	Assignment #4	4,5

5. Evaluation Scheme:

Component 1	Mid Semester Exam	20
Component 2	Assignment Evaluation	05
Component3	Attendance	05
Component 4**	End Term Examination**	70
	Total	**100**

Internal assessment is done through quiz tests, presentations, assignments and tutorial. Two sets of question papers are asked from each faculty and out of these two, without the knowledge of faculty, one question paper is chosen for the concerned examination. Examination rules and regulations are uploaded on the student's portal. Evaluation is a very transparent process and the answer sheets of sessional tests, internal assessment assignments are returned back to the students.

The components of evaluations along with their weightage followed by the University is given below

****** The End Term Comprehensive examination will be held at the end of semester. The mandatory requirement of 75% attendance in all theory classes is to be met for being eligible to appear in this component.

6. Syllabus:

Topics	**No of lectures**	**Weightage**
Velocity and acceleration in mechanism : - Relative velocity method and instantaneous center method - Acceleration diagram :Coriolis component of acceleration.	8	19%
Friction devices : - Belt drive - Clutch - Shoe brakes - Bank and block brakes.	7	17%
Fundamental law of gearing, basic terminology of gears, arc of contact and path of contact of involute gears, minimum number of teeth on the pinion to avoid interference, Gear trains-simple, compound and planetary, tooth load and torque.	10	24%
Balancing : balancing of evolving masses in the same plane by a single revolving mass – Balancing of	7	16%

revolving masses in different planes by two revolving masses in suitable planes.		
Governors : Watt, Porter, Proel&hartnell Governors, Effect of friction, controlling force, governor effort and power, sensitivity and isochronisms..	10	24%

7. This document is approved by:

Designation	**Name**	**Signature**
Course Coordinator	Sarvesh kumar yadav	
H.O.D	Dr. Vikas kumar	
Principal	Dr. J.N. Jha	
Date		

Lecture Plan: Kinematics of Machinery

Topic Name	Lecture Number	Date
Kinematic of Machinery		
Introduction: Basic Fudamental Of Kinematic Of Machinery	1	
Velocity and acceleration in mechanism	2	
Relative velocity method and instantaneous center method	3,4	
Acceleration diagram	5,6	
Coriolis component of acceleration	7,8	
Friction devices		
Introduction of Friction Devices	9	
Belt drive	10,11	
Clutch	12	
Shoe brakes	13	
Bank and block brakes	214,15	
Fundamental law of gearing		
Basic terminology of gears	16	
arc of contact and path of contact of involute gears	17	
minimum number of teeth on the pinion to avoid interference	18	
Gear trains-simple	19	
compound and planetary	20,21	
tooth load and torque	22,23	
Numerical Question	24,25	
Balancing		
Introduction of Balancing	26	
balancing of evolving masses in the same plane by a single revolving mass	27,28	
Balancing of revolving masses in different planes by two revolving masses in suitable planes	29,30	
Numerical Question	31,32	
Governors		
Introduction of Governors	33	
Watt Governor	34	
Porter Governor	35	
Proel & hartnell Governors	36	

Effect of friction	37	
controlling force	38	
governor effort and power	39	
sensitivity and isochronisms	40	
Numerical Question	41,42	

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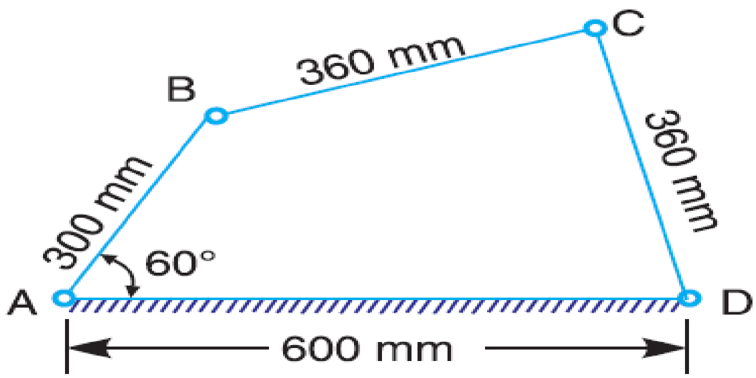
Mechanical Engineering Department

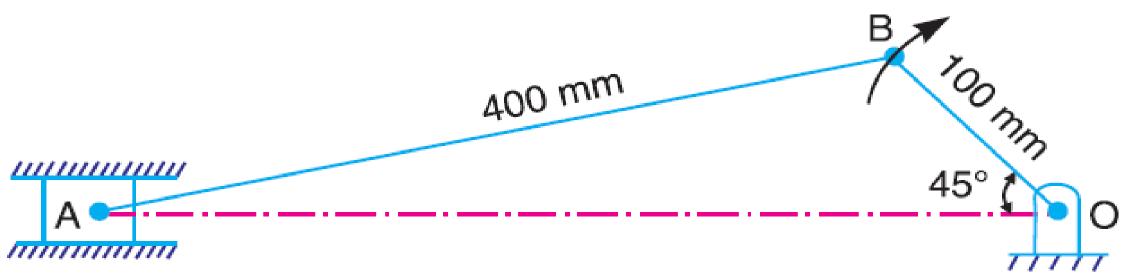
Kinematic Of Machine

ASSIGNMENT 1

Q1. In a pin jointed four bar mechanism, as shown in Fig. 6.9, AB = 300 mm, BC = CD = 360 mm, and AD = 600 mm. The angle BAD = 60°. The crank AB rotates uniformly at 100 r.p.m. Locate all the instantaneous centres and find the angular velocity of the link BC.

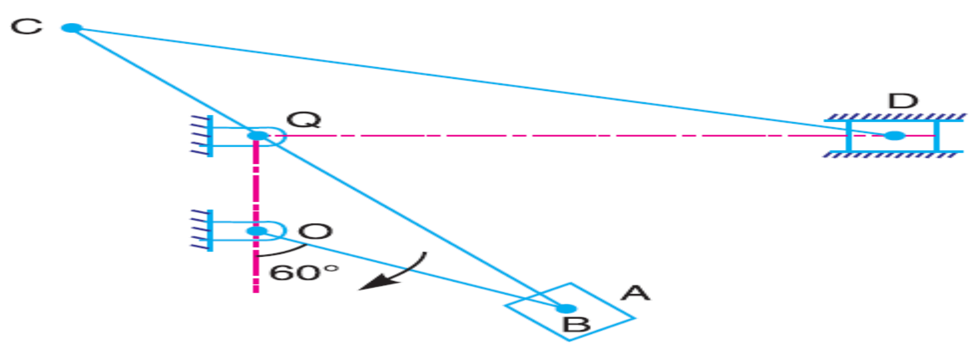


Q 2: Locate all the instantaneous centres of the slider crank mechanism as shown in Fig. The lengths of crank OB and connecting rod AB are 100 mm and 400 mm respectively. If the crank rotates clockwise with an angular velocity of 10 rad/s, find: **1.** Velocity of the slider A, and **2.** Angular velocity of the connecting rod AB.



Q 3:Figure shows a Whitworth quick return motion mechanism. The various dimensions in the mechanism are as follows:

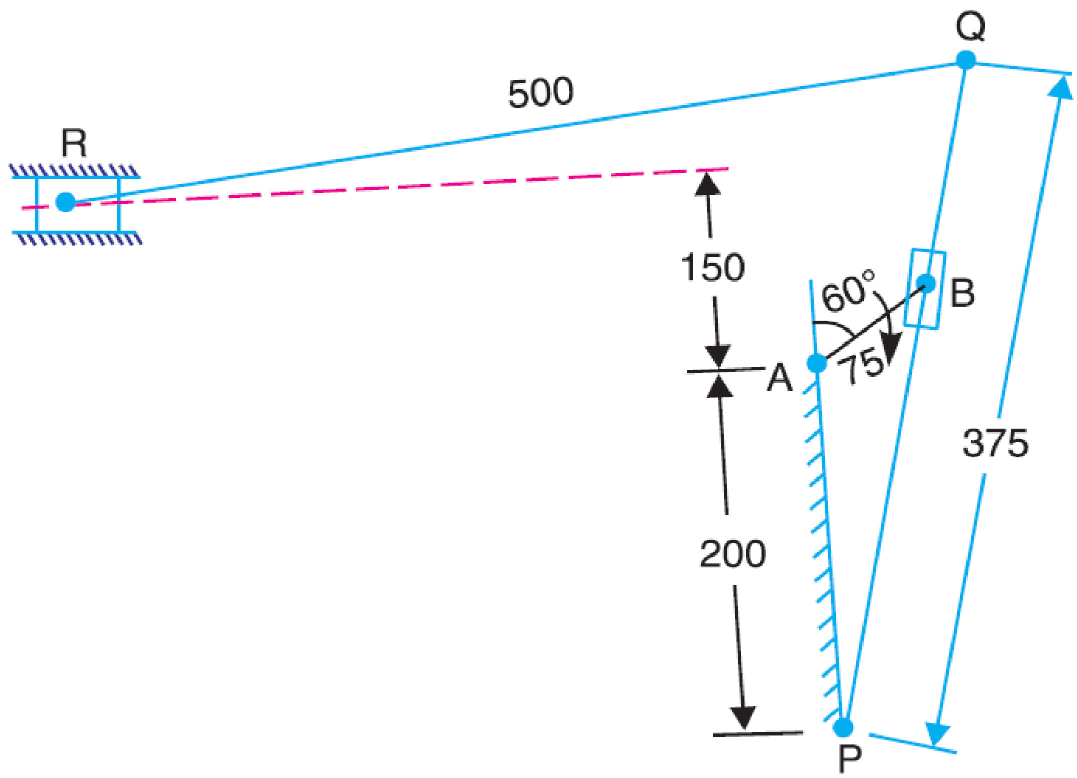
OQ = 100 mm; OA = 200 mm ; QC = 150 mm ; and CD = 500 mm. The crank OA makes an angle of 60° with the vertical and rotates at 120 r.p.m. in the clockwise direction. Locate all the instantaneous centres and find the velocity of ram D.



Q4*:* Four bar mechanism has the following dimensions :

DA = 300 mm ; CB = AB = 360 mm ; DC = 600 mm. The link DC is fixed and the angle ADC is 60°. The driving link DA rotates uniformly at a speed of 100 r.p.m. clockwise and the constant driving torque has the magnitude of 50 N-m. Determine the velocity of the point B and angular velocity of the driven link CB. Also find the actual mechanical advantage and the resisting torque if the efficiency of the mechanism is 70 per cent.

Q5: The driving crank AB of the quick-return mechanism, as shown in Fig., revolves at a uniform speed of 200 r.p.m. Find the velocity and acceleration of the tool-box R, in the position shown, when the crank makes an angle of 60° with the vertical line of centres PA. What is the acceleration of sliding of the block at B along the slotted lever PQ ?



All Dimensions in mm

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Kinematic Of Machine

ASSIGNMENT 2

Q1: The power is transmitted from a pulley 1 m diameter running at 200 r.p.m. to a pulley 2.25 m diameter by means of a belt. Find the speed lost by the driven pulley as a result of creep, if the stress on the tight and slack side of the belt is 1.4 MPa and 0.5 MPa respectively. The Young's modulus for the material of the belt is 100 MPa.

Q 2: Find the power transmitted by a belt running over a pulley of 600 mm diameter at 200 r.p.m. The coefficient of friction between the belt and the pulley is 0.25, angle of lap 160° and maximum tension in the belt is 2500 N.

Q 3: A shaft rotating at 200 r.p.m. drives another shaft at 300 r.p.m. and transmits 6 kW through a belt. The belt is 100 mm wide and 10 mm thick. The distance between the shafts is 4m. The smaller pulley is 0.5 m in diameter. Calculate the stress in the belt, if it is

1. An open belt drive, and
2. A cross belt drive. Take $\mu = 0.3$.

Q 4:A pulley is driven by a flat belt, the angle of lap being 120°. The belt is 100 mm wide by 6 mm thick and density1000 kg/m3. If the coefficient of friction is 0.3 and the maximum stress in the belt is not to exceed 2 MPa, find the greatest power which the belt can transmit and the corresponding speed of the belt.

Q5: In a flat belt drive the initial tension is 2000 N. The coefficient of friction between the belt and the pulley is 0.3 and the angle of lap on the smaller pulley is 150°. The smaller pulley has a radius of 200 mm and rotates at 500 r.p.m. Find the power in kW transmitted by the belt.

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Mechanical Engineering Department

Kinematic Of Machine

ASSIGNMENT 3

Q 1: A spur gear transmits 10 kW at a pitch line velocity of 10 m/s; driving gear has a diameter of 1.0 m. find the tangential force between the driver and the follower, and the transmitted torque respectively.

Q2: A fixed gear having 100 teeth meshes with another gear having 25 teeth, the centre lines of both the gears being joined by an arm so as to form an epicyclic gear train. The number of rotations made by the smaller gear for one rotation of the arm is

Q3:100 kW power is supplied to the machine through a gear box which uses an epicyclic gear train. The power is supplied at 100 rad/s. The speed of the output shaft of the gear box is 10 rad/s in a sense opposite to the input speed. What is the holding torque on the fixed gear of the train?

Q 4: A 20o full depth involute spur pinion of 4 mm module and 21 teeth is to transmit 15 kW at 960 rpm. Its face width is 25 mm.

(a): The tangential force transmitted (in N) is

(b) Given that the tooth geometry factor is 0.32 and the combined effect of dynamic load and allied factors intensifying the stress is 1.5; the minimum allowable stress (in MPa) for the gear material is

Q5 : The overall gear ratio in a 2 stage speed reduction gear box (with all spur gears) is 12. The input and output shafts of the gear box are collinear. The countershaft which is parallel to the input and output shafts has a gear (Z2 teeth) and pinion (Z3 = 15 teeth) to mesh with pinion (Z1 = 16 teeth) on the input shaft and gear (Z4 teeth) on the output shaft respectively. It was decided to use a gear ratio of 4 with 3 module in the first stage and 4 module in the second stage.

(a) Z2 and Z4 are

(b) The centre distance in the second stage is

Q 6: In an epicyclic gear train, an arm carries two gears A and B having 36 and 45 teeth respectively. If the arm rotates at 150 r.p.m. in the anticlockwise direction about the centre of the gear A which is fixed, determine the speed of gear B. If the gear A instead of being fixed, makes 300 r.p.m. in the clockwise direction, what will be the speed of gear B ?

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Mechanical Engineering Department

Kinematic Of Machine

ASSIGNMENT 4

Q1: All the arms of a Porter governor are 178 mm long and are hinged at a distance of 38 mm from the axis of rotation. The mass of each ball is 1.15 kg and mass of the sleeve is 20 kg. The governor sleeve begins to rise at 280 r.p.m. when the links are at an angle of 30° to the vertical. Assuming the friction force to be constant, determine the minimum and maximum speed of rotation when the inclination of the arms to the vertical is 45°.

Q 2: A Proell governor has all four arms of length 305 mm. The upper arms are pivoted on the axis of rotation and the lower arms are attached to a sleeve at a distance of 38 mm from the axis. The mass of each ball is 4.8 kg and are attached to the extension of the lower arms which are 102 mm long. The mass on the sleeve is 45 kg. The minimum and maximum radii of governor are 165 mm and 216 mm. assuming that the extensions of the lower arms are parallel to the governor axis at the minimum radius, find the corresponding equilibrium speeds.

Q 3:In a spring loaded Hartnell type governor, the extreme radii of rotation of the balls are 80 mm and 120 mm. The ball arm and the sleeve arm of the bell crank lever are equal in length. The mass of each ball is 2 kg. If the speeds at the two extreme positions are 400 and 420 r.p.m., find :

1. the initial compression of the central spring, and
2. the spring constant.

Q4: The following data refer to two cylinder locomotive with cranks at 90° :

Reciprocating mass per cylinder = 300 kg ; Crank radius = 0.3 m ; Driving wheel diameter = 1.8 m ; Distance between cylinder centre lines = 0.65 m ; Distance between the driving wheel central planes = 1.55 m. Determine :

1. the fraction of the reciprocating masses to be balanced, if the hammer blow is not to exceed 46 kN at 96.5 km. p.h. ;
2. the variation in tractive effort ; and
3. the maximum swaying couple.

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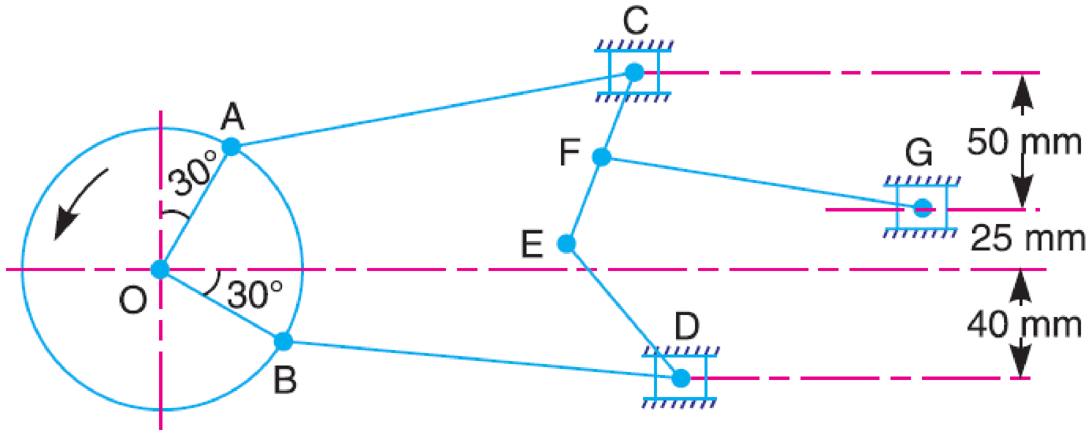
Kinematic Of Machine

Tutorial Sheet 1

Q1: In a slider crank mechanism, the length of crank *OB* and connecting rod *AB* are 125 mm and 500 mm respectively. The centre of gravity *G* of the connecting rod is 275 mm from the slider *A*. The crank speed is 600 r.p.m. clockwise. When the crank has turned 45° from the inner dead centre position, determine: 1. velocity of the slider *A*

2. Velocity of the point *G*, and 3. angular velocity of the connecting rod *AB*.Using Relative Velocity Method.

Q 2:In the mechanism, as shown in Fig. 7.32, OA and OB are two equal cranks at right angles rotating about O at a speed of 40 r.p.m. anticlockwise. The dimensions of the various links are as follows :



OA = OB = 50 mm; AC = BD = 175 mm ; DE = CE = 75 mm ; FG = 115 mm and EF = FC. Draw velocity diagram for the given configuration of the mechanism and find velocity of the slider G.

Q8: The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 r.p.m. The crank is 150 mm and the connecting rod is 600 mm long. Determine:

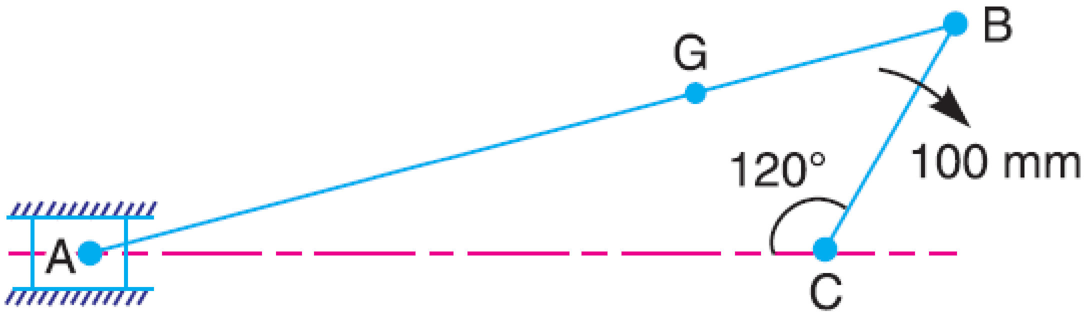
1. Linear velocity and acceleration of the midpoint of the connecting rod, and

2. Angular velocity and angular acceleration of the connecting rod, at a crank angle of 45° from inner dead centre position.

Q 9: An engine mechanism is shown in Fig. The crank CB = 100 mm and the connecting rod BA = 300 mm with centre of gravity G, 100 mm from B. In the position shown, the crankshaft has a speed of 75 rad/s and an angular acceleration of 1200 rad/s^2.

Find:

1. Velocity of G and angular velocity of AB, and
2. Acceleration of G and angular acceleration of AB.

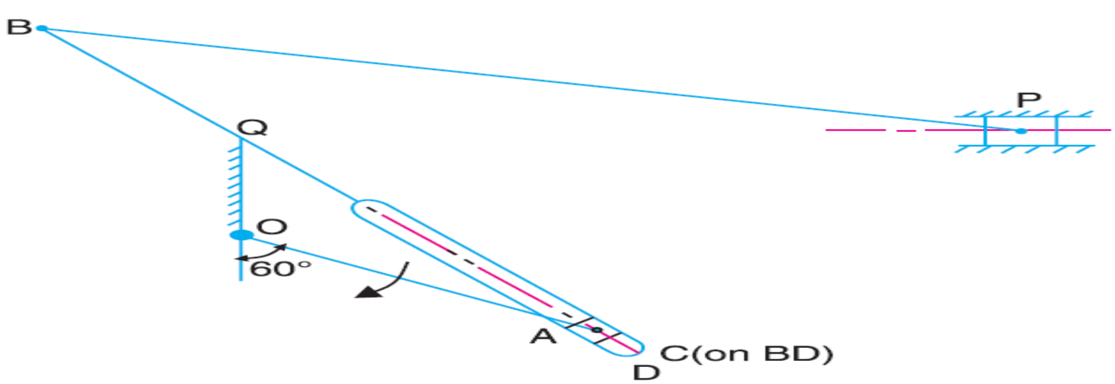


Q 4: In a Whitworth quick return motion mechanism, as shown in Fig. 7.39, the dimensions of various links are as follows :

OQ = 100 mm ; *OA* = 200 mm ; *BQ* = 150 mm and *BP* = 500 mm.

If the crank *OA* turns at 120 r.p.m. in clockwise direction and makes an angle of 120° with *OQ*, Find :

1. velocity of the block *P*, and 2. angular velocity of the slotted link *BQ*.



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Kinematic Of Machine

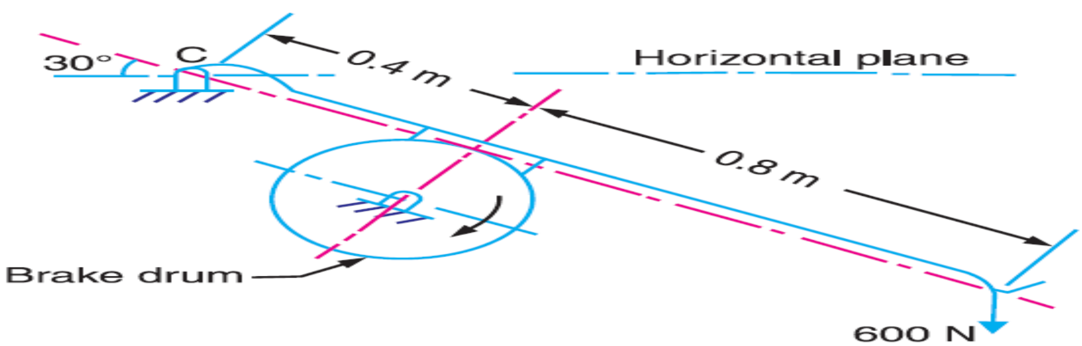
Tutorial Sheet 2

Q1: An open belt running over two pulleys 240 mm and 600 mm diameter connects two parallel shafts 3 meters apart and transmits 4 kW from the smaller pulley that rotates at 300 r.p.m. Coefficient of friction between the belt and the pulley is 0.3 and the safe working tension is 10N per mm width. Determine:

1. Minimum width of the belt,
2. Initial belt tension, and
3. Length of the belt required.

Q 2: Power is transmitted using a V-belt drive. The included angle of V-groove is 30°. The belt is 20 mm deep and maximum width is 20 mm. If the mass of the belt is 0.35 kg per meter length and maximum allowable stress is 1.4 MPa, determine the maximum power transmitted when the angle of lap is 140°. $\mu = 0.15$.

Q 3: A braking system has its braking lever inclined at an angle of 30° to the horizontal plane, as shown in Fig .The mass and diameter of the brake drum are 218 kg and 0.54 m respectively.



Q 4: A bicycle and rider of mass 100 kg are travelling at the rate of 16 km/h on a level road. A brake is applied to the rear wheel which is 0.9 m in diameter and this is the only resistance acting. How far will the bicycle travel and how many turns will it make before it comes to rest? The pressure applied on the brake is 100 N and $\mu = 0.05$.

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Kinematic Of Machine

Tutorial Sheet 3

Q 1: Two involutes gears of 20° pressure angle are in mesh. The number of teeth on pinion is 20 and the gear ratio is 2. If the pitch expressed in module is 5 mm and the pitch line speed is 1.2 m/s, assuming addendum as standard and equal to one module, find:

1. The angle turned through by pinion when one pair of teeth is in mesh; and

2. The maximum velocity of sliding.

Q 2: pinion having 18 teeth engages with an internal gear having 72 teeth. If the gears have involute profiled teeth with 20° pressure angle, module of 4 mm and the addenda on pinion and gear are 8.5 mm and 3.5 mm respectively, find the length of path of contact.

Q 3: Two mating gears have 20 and 40 involutes teeth of module 10 mm and 20° pressure angle. The addendum on each wheel is to be made of such a length that the line of contact on each side of the pitch point has half the maximum possible length. Determine the addendum height for each gear wheel, length of the path of contact, arc of contact and contact ratio.

Q 4: Determine the minimum number of teeth required on a pinion, in order to avoid interference which is to gear with,

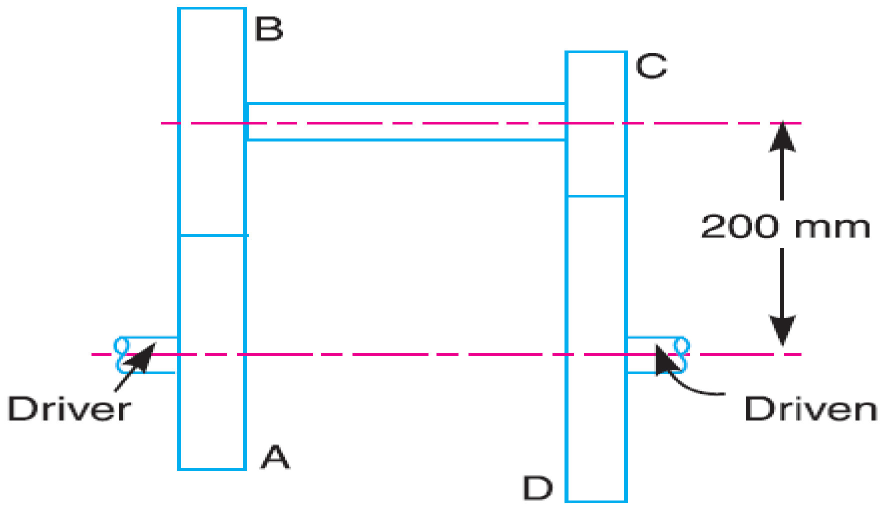
1. A wheel to give a gear ratio of 3 to 1; and

2. An equal wheel.

The pressure angle is 20° and a standard addendum of 1 module for the wheel may be assumed.

Q 5: A pinion of 20 involutes teeth and 125 mm pitch circle diameter drives a rack. The addendum of both pinion and rack is 6.25 mm. What is the least pressure angle which can be used to avoid interference? With this pressure angle, find the length of the arc of contact and the minimum number of teeth in contact at a time.

Q 6: The speed ratio of the reverted gear train, as shown in Fig. 13.5, is to be 12. The module pitch of gears A and B is 3.125 mm and of gears C and D is 2.5 mm. Calculate the suitable numbers of teeth for the gears. No gear is to have less than 24 teeth.


B
C
200 mm
Driver
Driven
A
D

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Kinematic Of Machine

Tutorial Sheet 4

Q 1: The following particulars refer to a Wilson-Hartnell governor:

Mass of each ball = 2 kg ; minimum radius = 125 mm ; maximum radius = 175 mm ; minimum speed = 240 r.p.m. ; maximum speed = 250 r.p.m. ; length of the ball arm of each bell crank lever = 150 mm; length of the sleeve arm of each bell crank lever = 100 mm ; combined stiffness of the two ball springs = 0.2 kN/m. Find the equivalent stiffness of the auxiliary spring referred to the sleeve.

Q 2: A Porter governor has equal arms each 250 mm long and pivoted on the axis of rotation. Each ball has a mass of 5 kg and the mass of the central load on the sleeve is 25 kg. The radius of rotation of the ball is 150 mm when the governor begins to lift and 200 mm when the governor is at maximum speed. Find the range of speed, sleeve lift, governor effort and power of the governor in the following cases:

1. When the friction at the sleeve is neglected, and
2. When the friction at the sleeve is equivalent to 10 N.

Q3:A shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radii 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitudes and angular positions.

<u>**Muzaffarpur institute of Technology**</u>

<u>**Mid-Term Exam 2017-18**</u>

Univ. Roll. No……………………………

Mid-Term Examination, 2017-18

Title of Paper: <u>**Kinematics of Machinery**</u> Paper Code: **(02 14×08)**

Time: **120** Min. Max. Marks: **20**

<u>**Section-A**</u>

<u>*Notes: Attempt All Questions.*</u> 1 x 5 = 5 marks

I. A slider sliding at 10cm/s on a link, which is rotating at 60 r.p.m. What is the magnitude of carioles acceleration component?

II. Find the degree of freedom of the given figure.

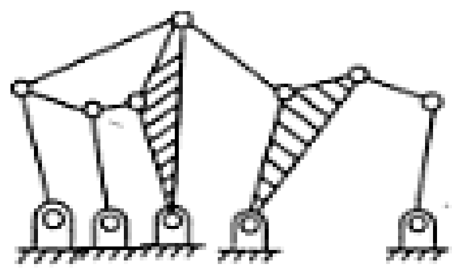

Fig-1

III. Differentiate giving examples:

a. Lower and higher pairs
b. Closed and unclosed pairs
c. Turning and rolling pairs

IV. Find the degree of freedom of the given figure-2.

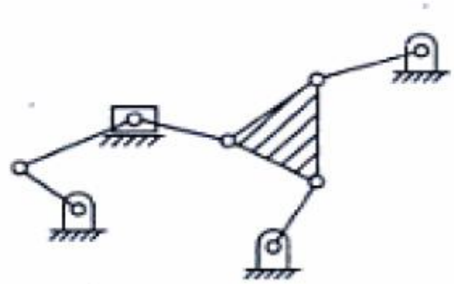

Fig-2

V. In a 4-bar mechanism, the lengths of driver crank, coupler and follower link are respectively 100mm, 250mm and 300mm. The fixed link-length is L_0. Find the values for L_0, so as to make it a Crank-crank mechanism.

Section-B

Notes: Attempt All Questions. 5 x 3 = 15 marks

I. **Fig.3** shows the layout of a quick return mechanism of the oscillating link type, for a special purpose machine. The driving crank BC is 30mm long and time ratio of the working stroke is to be 1.7. If the length of the working stroke of R is 120mm, determine the dimensions of AC and AP.

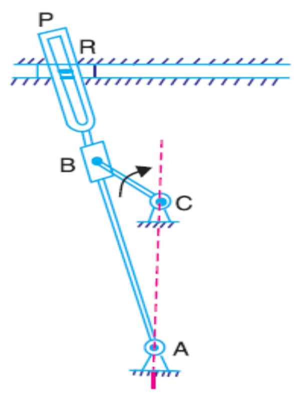

Fig-3

II. In the figure-4, the angular velocity of the crank OA is 600 r.p.m. Determine the linear velocity of the slider D and the angular velocity of the link BD, when the crank is inclined at an angle of 75° to the vertical. The dimensions of various links are: OA = 28 mm; AB = 44 mm; BC 49 mm; and BD = 46 mm. The centre distance between the centers of rotation O and C is 65 mm. The path of travel of the slider is 11 mm below the fixed point C. The slider moves along a horizontal path and OC is vertical.

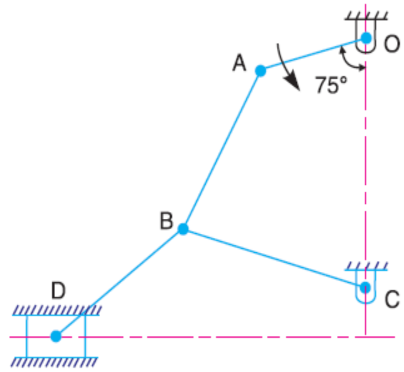

Fig-4

III. The dimensions and configuration of the four bar mechanism, shown in **fig-5**, are as follows: P_1A = 300mm; P_2B = 360mm; AB = 360mm, and P_1P_2 = 600mm. The angle $AP_1P_2 = 60^0$. The crank P_1A has an angular velocity of 10 rad/s and an angular acceleration of 30 rad/s^2, both clockwise. Determine the angular velocities and angular accelerations of P_2B, and AB and velocity and acceleration of the joint B.

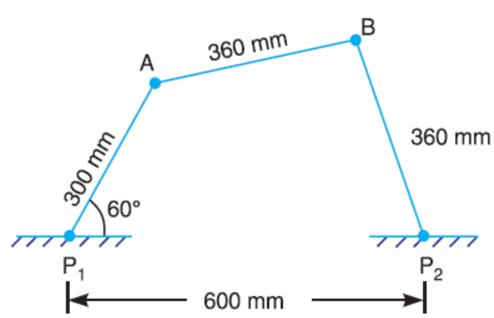

Fig-5

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Code : 021408

2013

KINEMATICS OF MACHINERY

Time : 3 hours *Full Marks* : 70

Instructions :

(i) The marks are indicated in the right-hand margin.

(ii) There are ***NINE*** *questions in this paper.*

(iii) Attempt ***FIVE*** *questions in all.*

(iv) Question No. ***1*** *is compulsory.*

(v) Any missing data may be assumed suitably.

1. Choose the correct option/Fill in the blanks (any *seven*) : 2×7=14

(a) Piston, piston rod and cross head of a steam engine

(i) constitute one link

(ii) constitute two links

(iii) constitute three links

(iv) do not conform to the concept of the link

(b) Which amongst the following constitutes higher pair?

(i) A ball and a socket joint

(ii) A toothed gearing

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(iii) Universal joint

(iv) Cycle wheels turning on their axles

(c) A —— is an assemblage of resistant bodies having no relative motion between them.

(d) The total number of instantaneous centres for a mechanism with n links is

(i) $n/2$

(ii) n

(iii) $(n-1)/2$

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(iv) $n(n-1)/2$

(e) The direction of linear velocity of any point on a link with respect to another point on the same link is —— to the line joining these points.

(f) The open-belt drive is used when the shafts are arranged —— and are to rotate in the —— directions.

(g) Which one of the following is a spring-controlled centrifugal governor?

(i) Pickering governor

(ii) Porter governor

(iii) Proell governor

(iv) Watt governor

(h) Two parallel and coplanar shafts are connected by

(i) spur gears

(ii) bevel gears

(iii) spiral gears

(iv) double-helical gears

(i) A —— is an imaginary circle which by pure rolling action gives the same motion as the actual gear.

(j) A system of several masses revolving in different planes of a shaft can be completely balanced by —— masses in —— planes.

2. *(a)* What do you mean by inversion of a mechanism? Draw any three inversions of a single-slider crank mechanism.

(b) "Peaucellier mechanism is a straight line generating mechanism." Prove this. 7+7

3. The crank of a slider crank mechanism is 150 mm and the connecting rod is 600 mm long. The crank makes 300 r.p.m. in the clockwise direction. When it has turned 45 degree from inner dead centre position, determine—

(a) acceleration of the midpoint of the connecting rod;

(b) angular acceleration of the connecting rod.

Use space diagram, velocity diagram and acceleration diagram. 14

4. *(a)* What are meant by slip and creep in a belt drive?

(b) A rope drive is required to transmit 1100 kW from a pulley 1·05 m in diameter running at 360 r.p.m. The safe pull in each rope is 2·2 kN and the mass of rope per meter of length is 1·35 kg. The angle of lap is 150 degree, the groove angle is 45 degree and the coefficient of friction between the rope and the groove is 0·3. How many ropes will be required if allowance is made for the centrifugal stress? 4+10

5. *(a)* Describe with a neat sketch, the working of a single-plate friction clutch.

(b) A cone clutch is to transmit 7·5 kW at 850 r.p.m. The cone has a face angle of 11 degree. The width of the face is half of the mean radius and the normal pressure between the contact faces is not to exceed 0·09 N/mm^2.

(Continued)

Assuming uniform wear and the coefficient of friction between contact faces as 0·2, find the main dimensions of the clutch and the axial force required to engage the clutch. 7+7

6. (a) State and prove the law of gearing. Show that involute profile satisfies the condition for correct gearing.

(b) Two involute gears of 20 degree pressure angle are in mesh. The number of teeth on pinion is 30 and the gear ratio is 2. The pitch expressed in module is 5 mm and the pitch line speed is 1·5 m/s. Assuming addendum on standard and equal to one module, find—

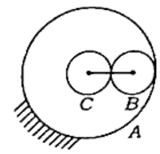
(i) the angle turned through by pinion when one pair of teeth is in mesh;

(ii) the maximum velocity of sliding. 7+7

7. (a) Explain with a sketch, the different types of gear trains depending upon the arrangement of wheels.

(b) An epicyclic gear consists of three wheels *A*, *B* and *C* as shown in figure below. Wheel *A* has 72 internal teeth, *C* has 32 external teeth.

The wheel *B* gears with both *A* and *C* and is carried on an arm which rotates about the centre of *A* at 18 r.p.m. If the wheel *A* is fixed, determine the speed of wheels *B* and *C*. 4+10



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8. All the arms of a Porter governor are 20 cm long. The lower and upper arms are pivoted to links of 4 cm and 3 cm respectively from the axis of rotation. Each ball weighs 4 kg and central load is 45 kg. If the force of friction of the mechanism corresponds to the weight of 3 kg of the sleeve and if the extreme radii of rotations are 10 cm and 12 cm, determine the range of speed of governor. 14

9. A shaft carries four masses in parallel planes *A*, *B*, *C* and *D* in the order along its length. The masses at *B* and *C* are 18 kg and 12·5 kg respectively and each has an eccentricity of 60 mm. The masses at *A* and *D* have

Question Bank

Paper: Kinematics of Machinery

Q.1 (a) Define and discuss: kinematic link, kinematic pair, and kinematic chain.

(b) Sketch and explain Whitworth quick return mechanism.

Q.2 (a) Describe Klein's construction with an example.

(b) The crank of a slider crank mechanism rotates clockwise at a constant speed of 300 rpm. The crank is 150 mm and connecting rod is 600 mm long. Determine 1. Linear velocity and acceleration of midpoint of connecting rod 2. Angular velocity and angular acceleration of the connecting rod, at a crank angle of 45o from inner dead centre position.

Q.3 : Enlist different type of gear train .Explain compound gear train with neat sketch .Also derive the equation of the velocity ratio for compound gear train.

Q.4: (An Epicyclic gear train is composed of fixed annular wheel "A" having 300 teeth. Meshing with A is wheel X which drives wheel Z through idle wheel Y, wheel Z being concentric with A. wheels X and Y are carried on an arm E which revolves clockwise at 120 rpm about the axis of A and Z. if the wheel X and Z have 50 and 80 teeth respectively .Determine the number of teeth on Y. and rpm of Y

Q.5 (a) Derive an expression for the length of path of contact for two involutes profile gear in mesh.

(b) A pair 20o involutes gears has module of 5 mm. the pinion has 20 teeth and gear has 60 teeth. Addendum on the pinion and gear wheel in terms of module is 1. Find the followings. (i) Number of pairs in contact (ii) Angle turned through by the pinion and gear wheel for one pair in contact.

Q 6: (i) Explain Primary and Secondary Unbalanced Force Due to Reciprocating Masses.

(ii) Explain the balancing of several masses rotating in same plane by Graphical Method.

Q 7: Four masses 150 kg, 200 kg, 100 kg and 250 kg are attached to a shaft revolving at radii 150mm, 200 mm, 100 mm and 250 mm ; in planes A, B, C and D respectively. The planes B, C and D are at distances 350 mm, 500 mm and 800 mm from plane A. The masses in planes B, C and D are at an angle 105o , 200o and 300o measured anticlockwise from mass in plane A. It is required to balance the system by placing the balancing masses in the planes P and Q which are midway between the planes A and B, and between C and D respectively. If the balancing masses revolve at radius 180 mm, find the magnitude and angular positions of the balance masses.

Q 8: What are the reasons for unbalance in rotating machine elements? Give two practical examples of rotating unbalances in systems.

Q 9: Explain the method of balancing a number of masses rotating in different planes.

Q.10: A statically balanced system need not to be dynamically balanced always. Justify the statement. Q
Q 11: A V-twin engine has the cylinder axes at right angles and connecting rod operate a common crank. The reciprocating mass per cylinder is 10 Kg and crank radius is 80mm.The length of connecting rod is 0.4m. Show that the engine may be balanced for primary forces by means of a revolving balance mass. If the engine speed is 600 rpm, what is the value of maximum resultant secondary force?

Kinematics of Machinery Notes

Introduction:

Definitions : Link or Element, Pairing of Elements with degrees of freedom, Grubler's criterion (without derivation), Kinematic chain, Mechanism, Mobility of Mechanism, Inversions, Machine.

Kinematic Chains and Inversions:

Kinematic chain with three lower pairs, Four bar chain, Single slider crank chain and Double slider crank chain and their inversions.

Mechanisms:

i) Quick returns motion mechanisms – Drag link mechanism, Whitworth mechanism and Crank and slotted lever mechanism

ii) Straight line motion mechanisms – Peacelier's mechanism and Robert's mechanism.

iii) Intermittent motion mechanisms – Geneva mechanism and Ratchet & Pawl mechanism.

iv) Toggle mechanism, Pantograph, Hooke's joint and Ackerman Steering gear mechanism.

Terminology and Definitions-Degree of Freedom, Mobility

Kinematics: The study of motion (position, velocity, acceleration). A major goal of understanding kinematics is to develop the ability to design a system that will satisfy specified motion requirements. This will be the emphasis of this class.

Kinetics: The effect of forces on moving bodies. Good kinematic design should produce good kinetics.

Mechanism: A system design to transmit motion. (Low forces)

Machine: A system designed to transmit motion and energy. (forces involved)

Basic Mechanisms: Includes geared systems, cam-follower systems and linkages (rigid links connected by sliding or rotating joints). A mechanism has multiple moving parts (for example, a simple hinged door does not qualify as a mechanism).

Examples of mechanisms: Tin snips, vise grips, car suspension, backhoe, piston engine, folding chair, windshield wiper drive system, etc.

Key concepts:

Degrees of freedom: The number of inputs required to completely control a system.

Examples: A simple rotating link. A two link system. A four-bar linkage. A five-bar linkage.

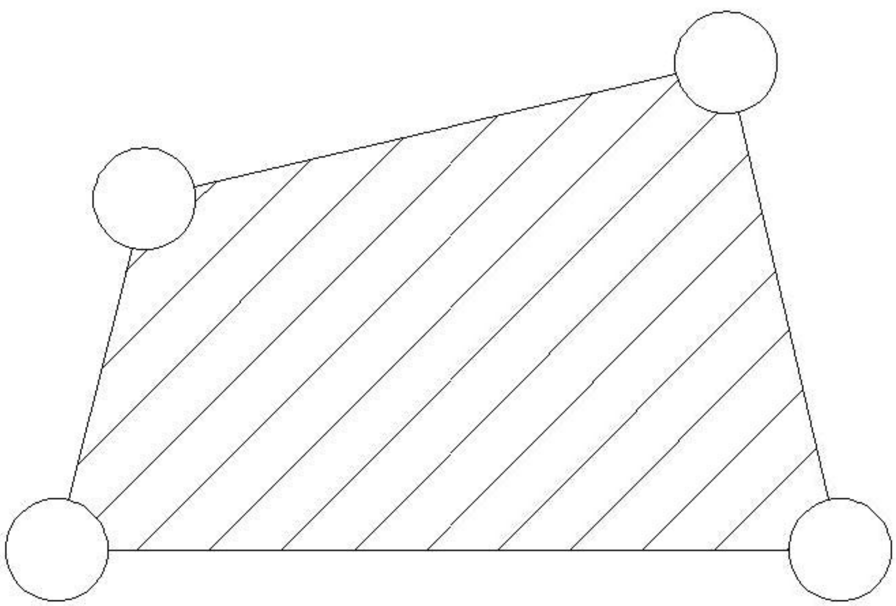
Types of motion: Mechanisms may produce motions that are pure rotation, pure translation, or a combination of the two. We reduce the degrees of freedom of a mechanism by restraining the ability of the mechanism to move in translation (x-y directions for a 2D mechanism) or in rotation (about the z-axis for a 2-D mechanism).

Link: A rigid body with two or more nodes (joints) that are used to connect to other rigid bodies. (WM examples: binary link, ternary link (3 joints), quaternary link (4 joints)

Joint: A connection between two links that allows motion between the links. The motion allowed may be rotational (revolute joint), translational (sliding or prismatic joint), or a combination of the two (roll-slide joint).

Kinematic chain: An assembly of links and joints used to coordinate an output motion with an input motion.

Link or element:



A mechanism is made of a number of resistant bodies out of which some may have motions relative to the others. A resistant body or a group of resistant bodies with rigid connections preventing their relative movement is known as a link.

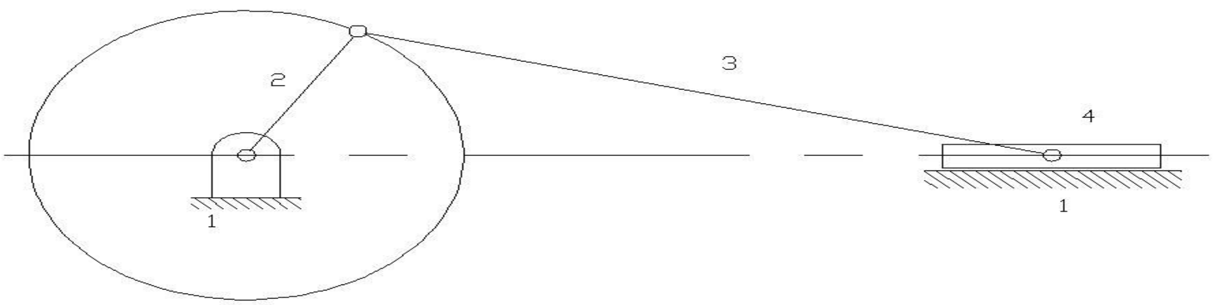
A link may also be defined as a member or a combination of members of a mechanism, connecting other members and having motion relative to them, thus a link may consist of one or more resistant bodies. A link is also known as kinematic link or an element.

Links can be classified into 1) Binary, 2) Ternary, 3) Quarternary, etc.

Kinematic Pair:

A Kinematic Pair or simply a pair is a joint of two links having relative motion between them.

Example:



In the above given Slider crank mechanism, link 2 rotates relative to link 1 and constitutes a revolute or turning pair. Similarly, links 2, 3 and 3, 4 constitute turning pairs. Link 4 (Slider) reciprocates relative to link 1 and it's a sliding pair.

Types of Kinematic Pairs:

Kinematic pairs can be classified according to

i) Nature of contact.

ii) Nature of mechanical constraint.

iii) Nature of relative motion.

i) Kinematic pairs according to nature of contact:

a) Lower Pair: A pair of links having surface or area contact between the members is known as a lower pair. The contact surfaces of the two links are similar.

Examples: Nut turning on a screw, shaft rotating in a bearing, all pairs of a slider-crank mechanism, universal joint.

b) Higher Pair: When a pair has a point or line contact between the links, it is known as a higher pair. The contact surfaces of the two links are dissimilar.

Examples: Wheel rolling on a surface cam and follower pair, tooth gears, ball and roller bearings, etc.

ii) Kinematic pairs according to nature of mechanical constraint.

a) Closed pair: When the elements of a pair are held together mechanically, it is known as a closed pair. The contact between the two can only be broken only by the destruction of at least one of the members. All the lower pairs and some of the higher pairs are closed pairs.

b) Unclosed pair: When two links of a pair are in contact either due to force of gravity or some spring action, they constitute an unclosed pair. In this the links are not held together mechanically.

Ex.: Cam and follower pair.

iii) Kinematic pairs according to nature of relative motion.

a) Sliding pair: If two links have a sliding motion relative to each other, they form a sliding pair. A rectangular rod in a rectangular hole in a prism is an example of a sliding pair.

b) Turning Pair: When on link has a turning or revolving motion relative to the other, they constitute a turning pair or revolving pair.

c) Rolling pair: When the links of a pair have a rolling motion relative to each other, they form a rolling pair. A rolling wheel on a flat surface, ball ad roller bearings, etc. is some of the examples for a Rolling pair.

d) Screw pair (Helical Pair): if two mating links have a turning as well as sliding motion between them, they form a screw pair. This is achieved by cutting matching threads on the two links. The lead screw and the nut of a lathe is a screw Pair

e) Spherical pair: When one link in the form of a sphere turns inside a fixed link, it is a spherical pair. The ball and socket joint is a spherical pair.

Degrees of Freedom:

An unconstrained rigid body moving in space can describe the following independent motions.

1. Translational Motions along any three mutually perpendicular axes x, y and z,
2. Rotational motions along these axes.

Thus a rigid body possesses six degrees of freedom. The connection of a link with another imposes certain constraints on their relative motion. The number of restraints can never be zero (joint is disconnected) or six (joint becomes solid).

Degrees of freedom of a pair is defined as the number of independent relative motions, both translational and rotational, a pair can have.

Degrees of freedom = 6 – no. of restraints.

To find the number of degrees of freedom for a plane mechanism we have an equation known as **Grubler's equation and is given by $F = 3 (n - 1) - 2 j1 - j2$**

F = Mobility or number of degrees of freedom

n = Number of links including frame.

j1 = Joints with single (one) degree of freedom.

J2 = Joints with two degrees of freedom.

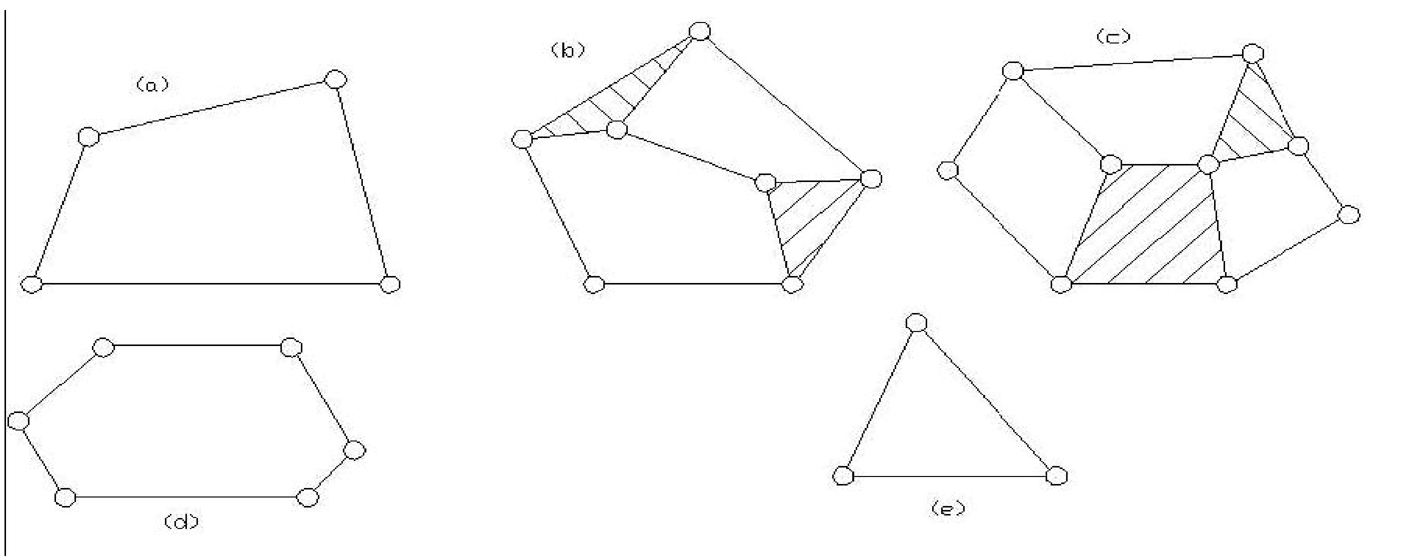
If F > 0, results in a mechanism with 'F' degrees of freedom.

F = 0, results in a statically determinate structure.

F < 0, results in a statically indeterminate structure.

Kinematic Chain:

A Kinematic chain is an assembly of links in which the relative motions of the links is possible and the motion of each relative to the others is definite (fig. a, b, and c.)



In case, the motion of a link results in indefinite motions of other links, it is a non-kinematic chain. However, some authors prefer to call all chains having relative motions of the links as kinematic chains.

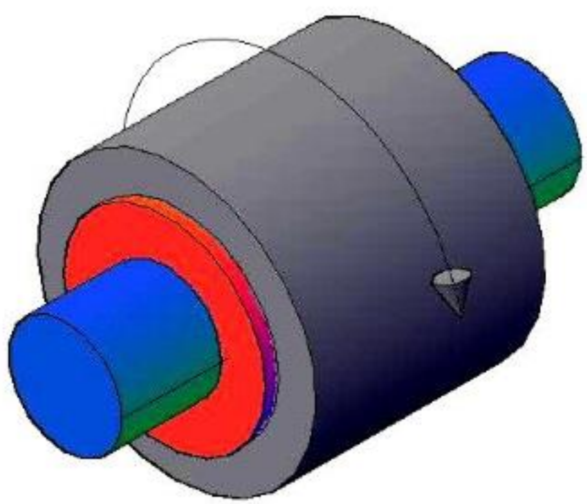
Linkage, Mechanism and structure:

A linkage is obtained if one of the links of kinematic chain is fixed to the ground. If motion of each link results in definite motion of the others, the linkage is known as mechanism. If one of the links of a redundant chain is fixed, it is known as a structure.To obtains constrained or definite motions of some of the links of a linkage, it is necessary to know how many inputs are needed. In some mechanisms, only one input is necessary that determines the motion of other links and are said to have one degree of freedom. In other mechanisms, two inputs may be necessary to get a constrained motion of the other links and are said to have two degrees of freedom and so on.

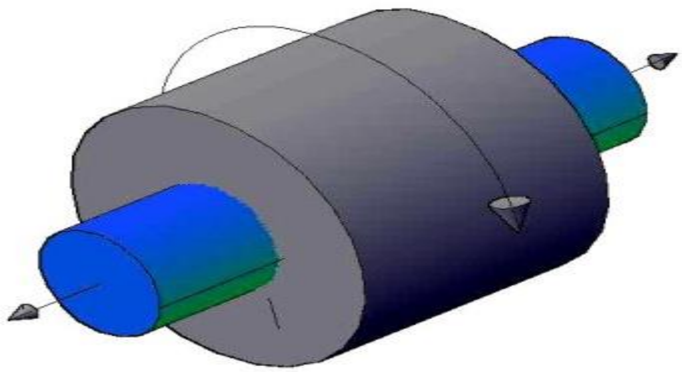
The degree of freedom of a structure is zero or less. A structure with negative degrees of freedom is known as a **Superstructure.**

The three main types of constrained motion in kinematic pair are,

1. **Completely constrained motion:** If the motion between a pair of links is limited to a definite direction, then it is completely constrained motion. E.g.: Motion of a shaft or rod with collars at each end in a hole as shown in fig.



2. Incompletely Constrained motion: If the motion between a pair of links is not confined to a definite direction, then it is incompletely constrained motion. E.g.: A spherical ball or circular shaft in a circular hole may either rotate or slide in the hole as shown in fig.



direction is not brought about by itself but by some other means, then it is known as successfully constrained motion. E.g.: Foot step Bearing

Machine:

It is a combination of resistant bodies with successfully constrained motion which is used to transmit or transform motion to do some useful work. E.g.: Lathe, Shaper, Steam Engine, etc.

Kinematic chain with three lower pairs

It is impossible to have a kinematic chain consisting of three turning pairs only. But it is possible to have a chain which consists of three sliding pairs or which consists of a turning, sliding and a screw pair. The figure shows a kinematic chain with three sliding pairs. It consists of a frame B, wedge C and a sliding rod A. So the three sliding pairs are, one between the wedge C and the frame B, second between wedge C and sliding rod A and the frame B.

1.3.Kutzbach criterion, Grashoff's law Kutzbach criterion:

Fundamental Equation for 2-D Mechanisms: $M = 3(L - 1) - 2J1 - J2$

Can we intuitively derive Kutzbach's modification of Grubler's equation? Consider a rigid link constrained to move in a plane. How many degrees of freedom does the link have? (3: translation in x and y directions, rotation about z-axis)

If you pin one end of the link to the plane, how many degrees of freedom does it now have?

Add a second link to the picture so that you have one link pinned to the plane and one free to move in the plane. How many degrees of freedom exist between the two links? (4 is the correct answer)

Pin the second link to the free end of the first link. How many degrees of freedom do you now have?

How many degrees of freedom do you have each time you introduce a moving link? How many degrees of freedom do you take away when you add a simple joint? How many degrees of freedom would you take away by adding a half joint? Do the different terms in equation make sense in light of this knowledge?

1.3.1 Grashoff's law:

Grashoff 4-bar linkage: A linkage that contains one or more links capable of undergoing a full rotation. A linkage is Grashoff if: S + L < P + Q (where: S = shortest link length, L = longest, P, Q = intermediate length links). Both joints of the shortest link are capable of 360 degrees of rotation in a Grashoff linkage. This gives us 4 possible linkages: crank-rocker (input rotates 360), rocker-crank-rocker (coupler rotates 360), rocker-crank (follower); double crank (all links rotate 360). Note that these mechanisms are simply the possible of a Grashoff mechanism.

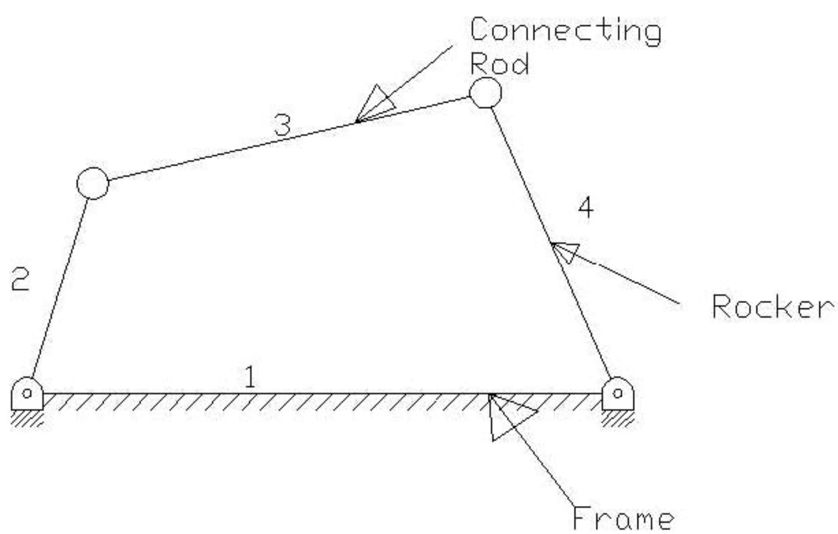
Non Grashoff 4 bar: No link can rotate 360 if: S + L > P + Q

Kinematic Inversions of 4-bar chain and slider crank chains:

Types of Kinematic Chain: 1) Four bar chain 2) Single slider chain 3) Double Slider chain

Four bar Chain:

The chain has four links and it looks like a cycle frame and hence it is also called quadric cycle chain. It is shown in the figure. In this type of chain all four pairs will be turning pairs.



Inversions:

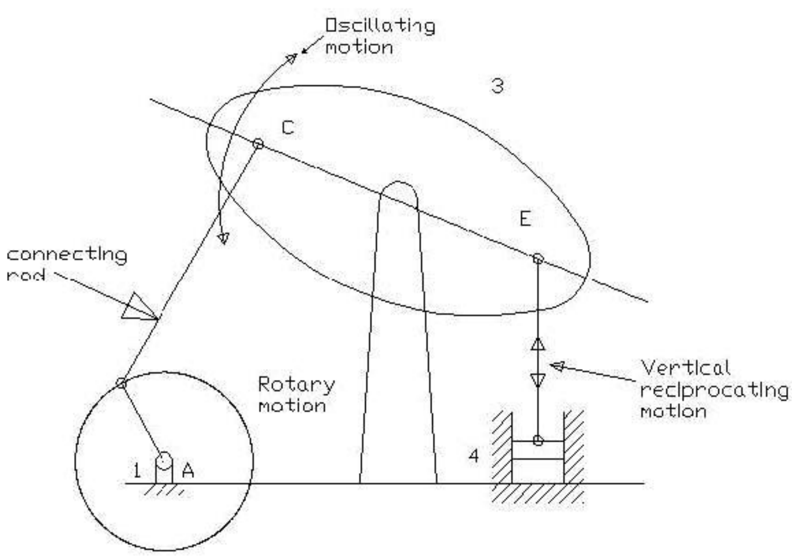
By fixing each link at a time we get as many mechanisms as the number of links, then each mechanism is called 'Inversion' of the original Kinematic Chain.

Inversions of four bar chain mechanism:

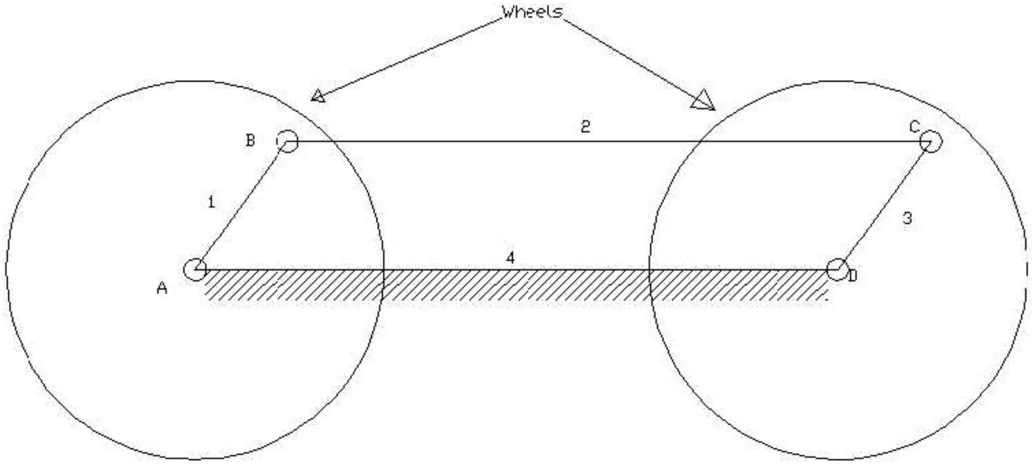
There are three inversions: 1) Beam Engine or Crank and lever mechanism. 2) Coupling rod of locomotive or double crank mechanism. 3) Watt's straight line mechanism or double lever mechanism.

Beam Engine:

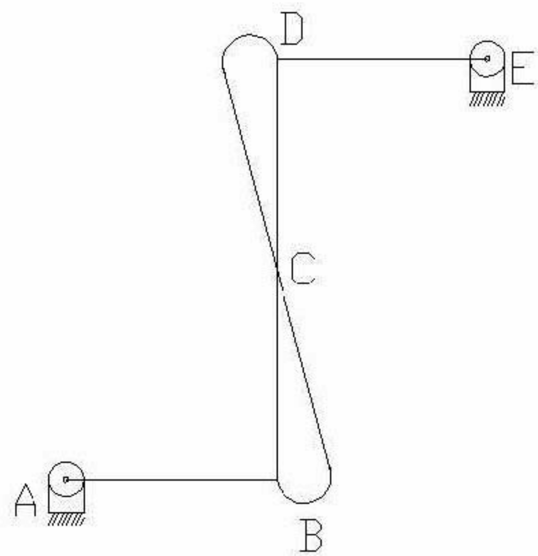
When the crank AB rotates about A, the link CE pivoted at D makes vertical reciprocating motion at end E. This is used to convert rotary motion to reciprocating motion and vice versa. It is also known as Crank and lever mechanism. This mechanism is shown in the figure below.



2. Coupling rod of locomotive: In this mechanism the length of link AD = length of link C. Also length of link AB = length of link CD. When AB rotates about A, the crank DC rotates about D. this mechanism is used for coupling locomotive wheels. Since links AB and CD work as cranks, this mechanism is also known as double crank mechanism. This is shown in the figure below. 3.



3. **Watt's straight line mechanism or Double lever mechanism:** In this mechanism, the links AB & DE act as levers at the ends A & E of these levers are fixed. The AB & DE are parallel in the mean position of the mechanism and coupling rod BD is perpendicular to the levers AB & DE. On any small displacement of the mechanism the tracing point 'C' traces the shape of number '8', a portion of which will be approximately straight. Hence this is also an example for the approximate straight line mechanism. This mechanism is shown below.



2. Slider cranks Chain:

It is a four bar chain having one sliding pair and three turning pairs. It is shown in the figure below the purpose of this mechanism is to convert rotary motion to reciprocating motion and vice versa.Inversions of a Slider cranks chain:

There are four inversions in a single slider chain mechanism. They are:

1) Reciprocating engine mechanism (1st inversion)

2) Oscillating cylinder engine mechanism (2 nd inversion)

3) Crank and slotted lever mechanism (2 nd inversion)

4) Whitworth quick return motion mechanism (3 rd inversion)

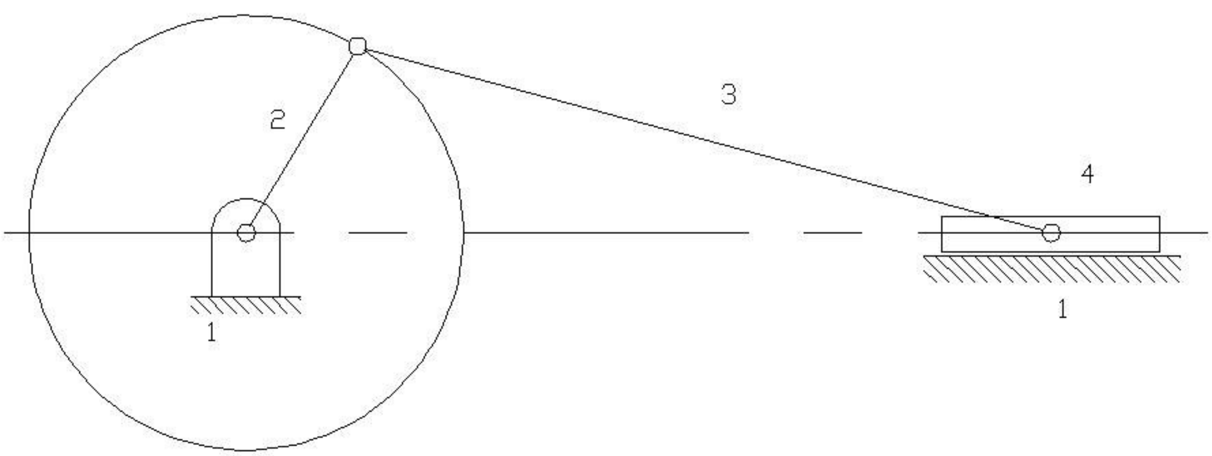
5) Rotary engine mechanism (3 rd inversion)

6) Bull engine mechanism (4 th inversion)

7) Hand Pump (4 th inversion)

1. Reciprocating engine mechanism:

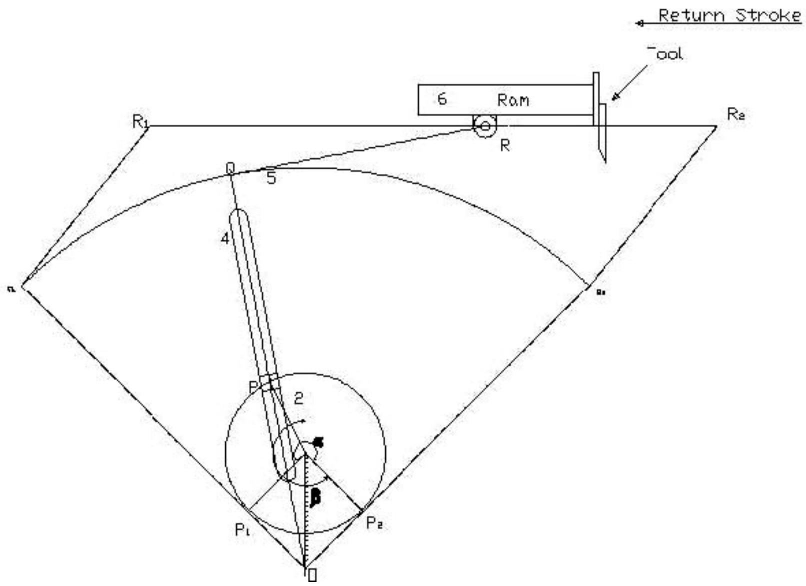
In the first inversion, the link 1 i.e., the cylinder and the frame is kept fixed. The fig below shows a reciprocating engine.



A slotted link 1 is fixed. When the crank 2 rotates about O, the sliding piston 4 reciprocates in the slotted link 1. This mechanism is used in steam engine, pumps, compressors, I.C. engines, etc.

2. Crank and slotted lever mechanism:

It is an application of second inversion. The crank and slotted lever mechanism is shown in figure below.



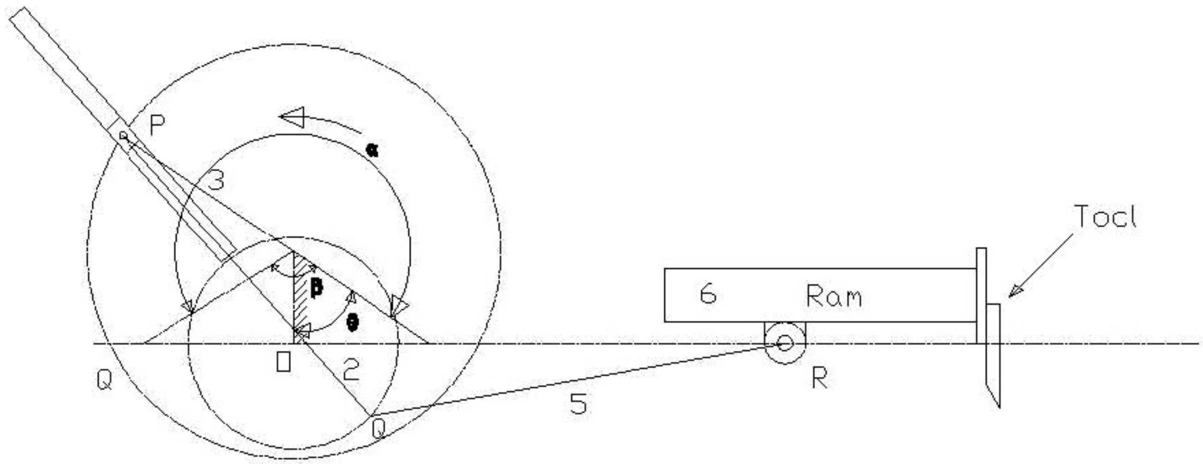
In this mechanism link 3 is fixed. The slider (link 1) reciprocates in oscillating slotted lever (link 4) and crank (link 2) rotates. Link 5 connects link 4 to the ram (link 6). The ram with the cutting tool reciprocates perpendicular to the fixed link 3. The ram with the tool reverses its direction of motion when link 2 is perpendicular to link 4. Thus the cutting stroke is executed during the rotation of the crank through angle α and the return stroke is executed when the crank rotates through angle β or 360 – α. Therefore, when the crank rotates uniformly, we get

Time to cutting = α = α

Time of return β 360 – α

This mechanism is used in shaping machines, slotting machines and in rotary engines.

1.4 . 1 Whitworth quick return motion mechanism:



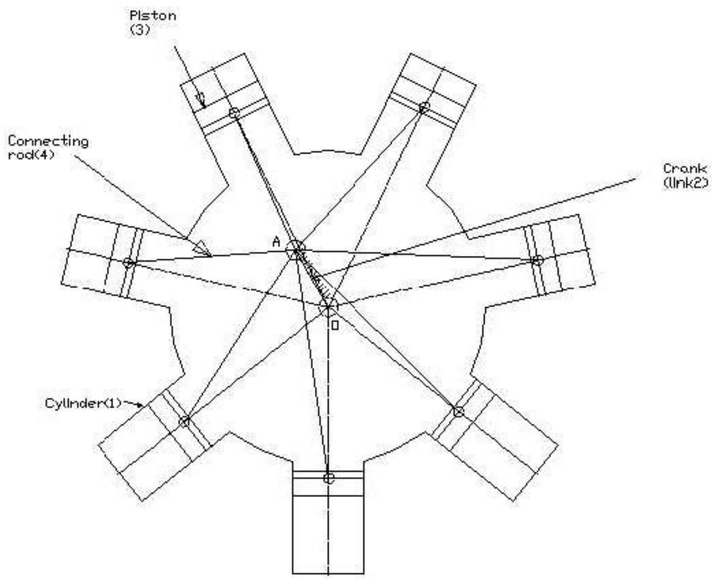
Third inversion is obtained by fixing the crank i.e. link 2. Whitworth quick return mechanism is an application of third inversion. This mechanism is shown in the figure below. The crank OC is fixed and OQ rotates about O. The slider slides in the slotted link and generates a circle of radius CP. Link 5 connects the extension OQ provided on the opposite side of the link 1 to the ram (link 6). The rotary motion of P is taken to the ram R which reciprocates. The quick return motion mechanism is used in shapers and slotting machines. The angle covered during cutting stroke from P1 to P2 in counter clockwise direction is α or 360 -2θ. During the return stroke, the angle covered is 2θ or β.

Therefore, Time to cutting = 360 -2θ = 180 – θ

Time of return 2θθ = α = α . β 360 – α

1. Rotary engine mechanism or Gnome Engine:

Rotary engine mechanism or gnome engine is another application of third inversion. It is a rotary cylinder V – type internal combustion engine used as an aero – engine. But now Gnome engine has been replaced by Gas turbines. The Gnome engine has generally seven cylinders in one plane. The crank OA is fixed and all the connecting rods from the pistons are connected to A. In this mechanism when the pistons reciprocate in the cylinders, the whole assembly of cylinders, pistons and connecting rods rotate about the axis O, where the entire mechanical power developed, is obtained in the form of rotation of the crank shaft. This mechanism is shown in the figure below.



2 **Double Slider Crank Chain:**

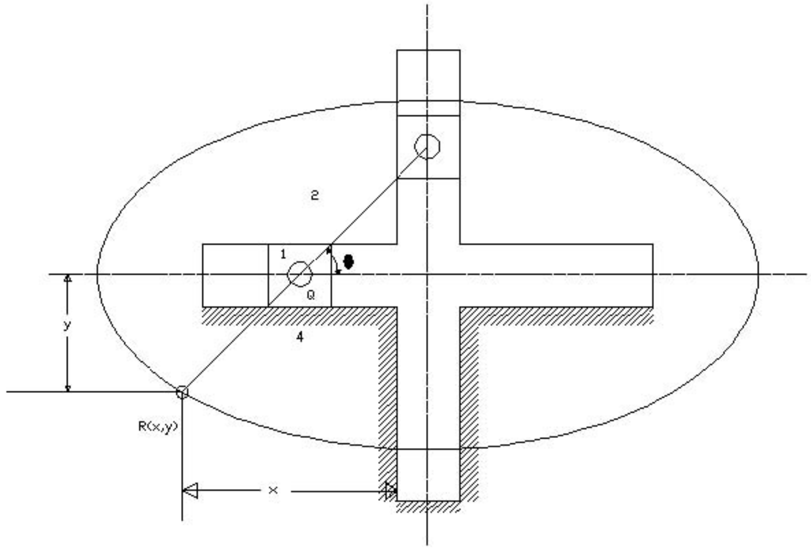
A four bar chain having two turning and two sliding pairs such that two pairs of the same kind are adjacent is known as double slider crank chain.

3 Inversions of Double slider Crank chain:

It consists of two sliding pairs and two turning pairs. They are three important inversions of double slider crank chain. 1) Elliptical trammel. 2) Scotch yoke mechanism. 3) Oldham's coupling.

4. Elliptical Trammel:

This is an instrument for drawing ellipses. Here the slotted link is fixed. The sliding blocks P and Q in vertical and horizontal slots respectively. The end R generates an ellipse with the displacement of sliders P and Q.



The co-ordinates of the point R are x and y. From the fig. cos θ = x.PR

and Sin θ = y. QR

Squaring and adding (i) and (ii) we get x2 + y2= cos2 θ + sin2 θ

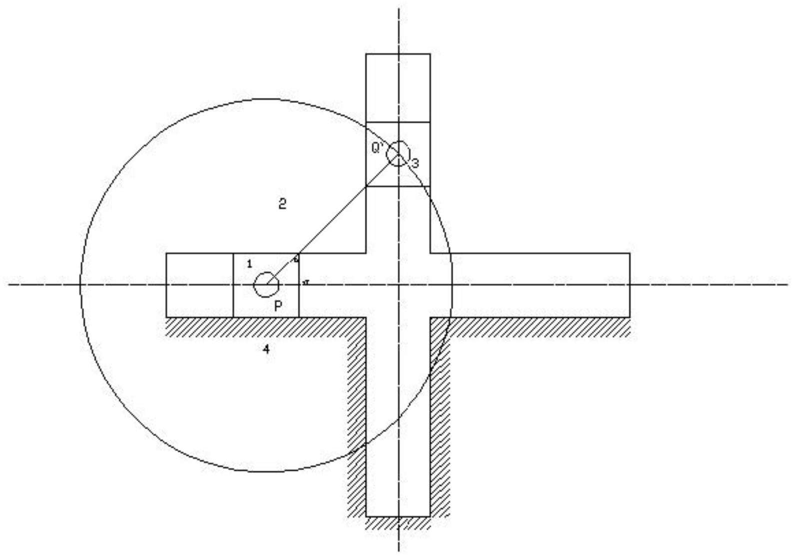
$X^2 + y^2 = 1$

The equation is that of an ellipse, hence the instrument traces an ellipse. Path traced by mid-point of

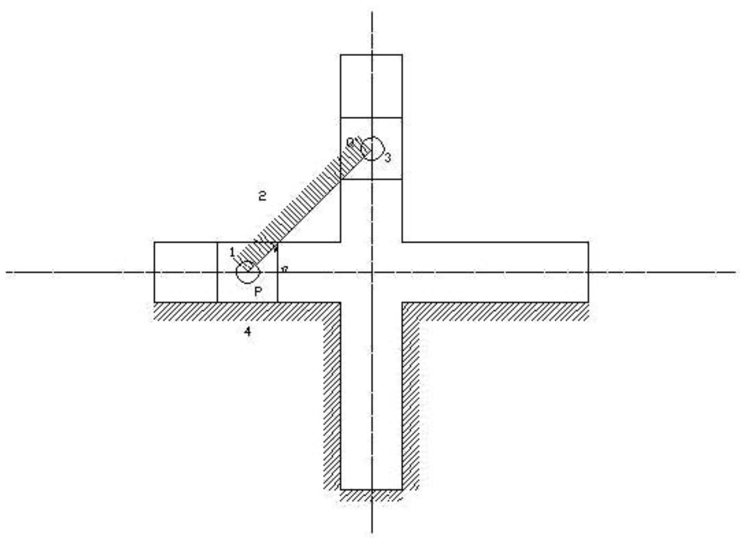
PQ is a circle. In this case, PR = PQ and so

It is an equation of circle with PR = QR = radius of a circle.

5. Scotch yoke mechanism: This mechanism, the slider P is fixed. When PQ rotates above P, the slider Q reciprocates in the vertical slot. The mechanism is used to convert rotary to reciprocating mechanism.



5. Oldham's coupling: The third inversion of obtained by fixing the link connecting the 2 blocks P & Q. If one block is turning through an angle, the frame and the other block will also turn through the same angle. It is shown in the figure below.



An application of the third inversion of the double slider crank mechanism is Oldham's coupling shown in the figure. This coupling is used for connecting two parallel shafts when the distance between the shafts is small. The two shafts to be connected have flanges at their ends, secured by forging. Slots are cut in the flanges. These flanges form 1 and 3. An intermediate disc having tongues at right angles and opposite sides is fitted in between the flanges. The intermediate piece forms the link 4 which slides or reciprocates in flanges 1 & 3. The link two is fixed as shown.

When flange 1 turns, the intermediate disc 4 must turn through the same angle and whatever angle 4 turns, the flange 3 must turn through the same angle. Hence 1, 4 & 3 must have the same angular velocity at every instant. If the distance between the axis of the shaft is x, it will be the diameter if the circle traced by the centre of the intermediate piece. The maximum sliding speed of each tongue along its slot is given by

$v = x\omega$ where, ω = angular velocity of each shaft in rad/sec v = linear velocity in m/sec

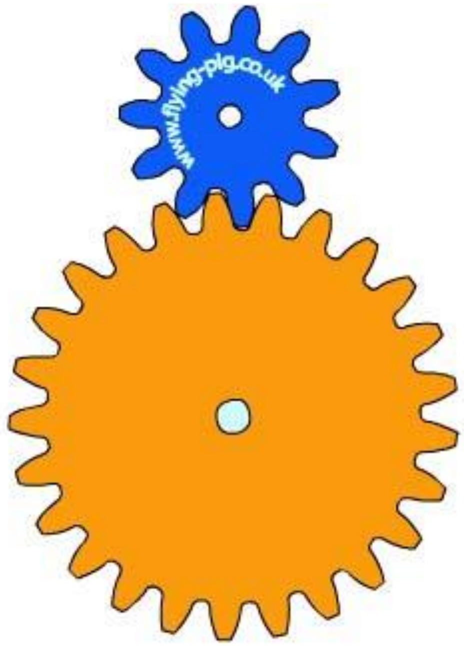
Mechanical Advantage, Transmission angle:

1. The mechanical advantage (MA) is defined as the ratio of output torque to the input torque. (or) Ratio of load to output.

2 Transmission angle.

3 The extreme values of the transmission angle occur when the crank lies along the line of frame.

GEARS AND TRAINS
4.1 Introduction
Gears are used to change speed in rotational movement.



In the example above the blue gear has eleven teeth and the orange gear has twenty five. To turn the orange gear one full turn the blue gear must turn 25/11 or 2.2727r turns. Notice that as the blue gear turns clockwise the orange gear turns anti-clockwise. In the above example the number of teeth on the orange gear is not divisible by the number of teeth on the blue gear. This is deliberate. If the orange gear had thirty three teeth then every three turns of the blue gear the same teeth would mesh together which could cause excessive wear. By using none divisible numbers the same teeth mesh Only every seventeen turns of the blue gear.

A **gear** is a rotating machine part having cut *teeth*, or *cogs*, which *mesh* with another toothed part in order to transmit torque. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, magnitude, and direction of a power source. The most common situation is for a gear to mesh with another gear; however a gear can also mesh a non-rotating toothed part, called a rack, there by producing translation instead of rotation. The gears in a transmission are analogous to the wheels in a pulley. An advantage of

gears is that the teeth of a gear prevent slipping. When two gears of unequal number of teeth are combined a mechanical advantage is produced, with both the rotational speeds and the torques of the two gears differing in a simple relationship.

In transmissions which offer multiple gear ratios, such as bicycles and cars, the term **gear**, as in first gear, refers to a gear ratio rather than an actual physical gear. The term is used to describe similar devices even when gear ratio is continuous rather than discrete, or when the device does not actually in any gears, as in a continuously variable transmission.

Fundamental Law of Gear-Tooth

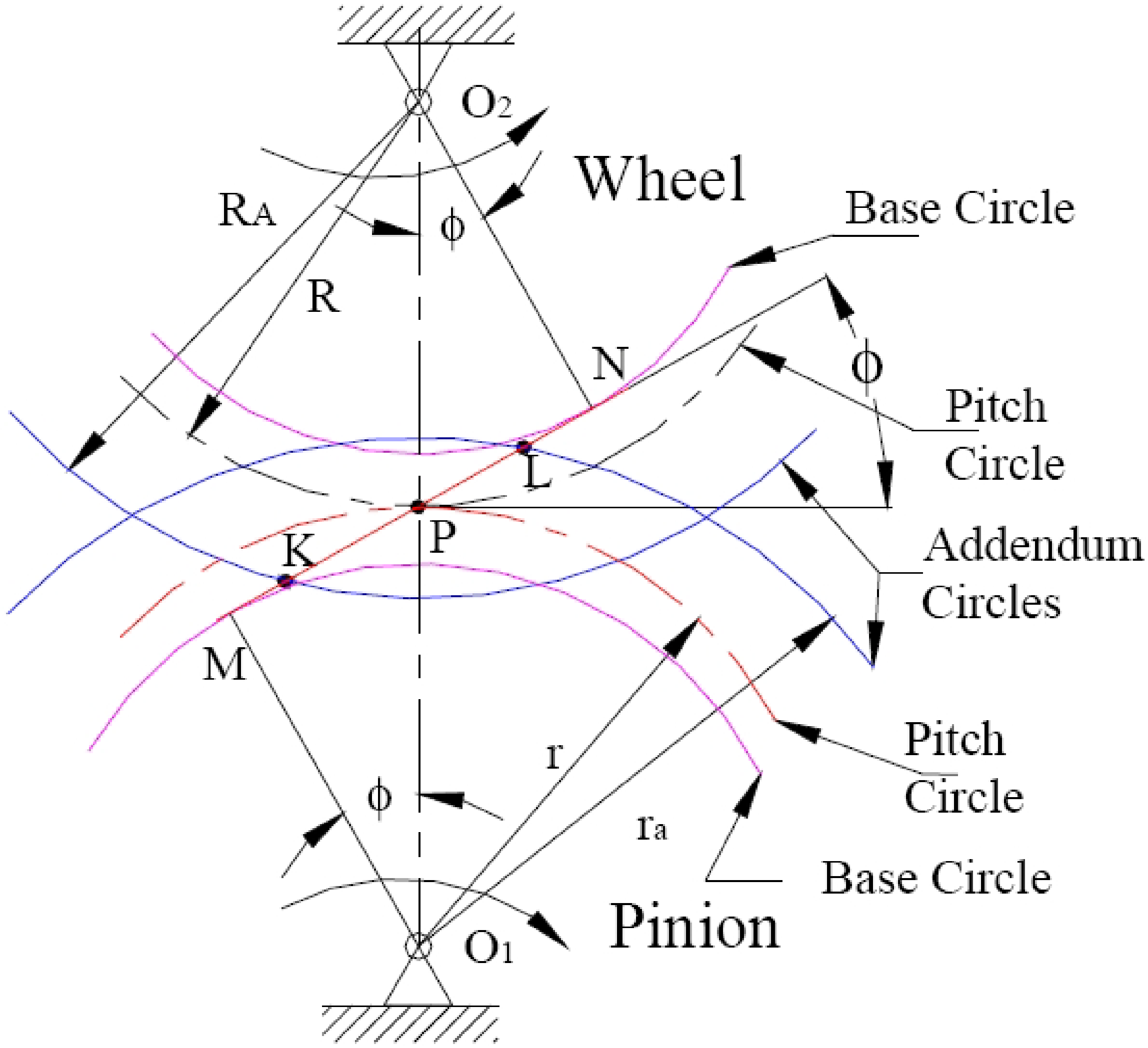
Pitch point divides the line between the line of centers and its position decides the velocity ratio of the two teeth. The above expression is the **fundamental law of gear-tooth action**. **Formation of teeth:**

Involutes teeth

Cycloidal teeth

Involute curve:

The curve most commonly use d for gear-tooth profiles is the involutes of a circle. This **involute curve** is the path traced by a point on a line as the line Rolls without slipping on the circumference of a circle. It may also be defined as a path traced by the end of a string, which is originally wrapped on a circle when the string is unwrapped from the circle. The circle from which the involute is derived is called the **base circle.**



Consider a pinion driving wheel as shown in figure. When the pinion rotates in clockwise, the contact between a pair of involute teeth begin sat *K*(on the near the base circle of pinion or the outer end of the tooth face on the wheel) and ends at *L*(outer end of the tooth face on the pinion or on the flank near the base circle of wheel). *MN* is the common normal at the point of contacts and the common tangent to the base circles. The point *K* is the intersection of the addendum circle of wheel and the common tangent. The point *L* is the intersection of the addendum circle of pinion and common tangent. The length of path of contact is the length of common normal cut-off by the addendum circles of the wheel and the pinion. Thus the length of part of contact is *KL* which is the sum of the parts of path of contacts *KP* and *PL*.Contact length *KP* is called as **path of approach** and contact length *PL* is called as **path of recess**.

Path of approach: KP

$$KP = KN - PN$$
$$= \sqrt{(R_A)^2 - R^2\cos^2\phi} - R\sin\phi$$

Path of recess: PL

$$PL = ML - MP$$
$$= \sqrt{(r_a)^2 - r^2\cos^2\phi} - r\sin\phi$$

Length of path of contact :

]

$$KL = KP + PL$$
$$= \sqrt{(R_A)^2 - R^2\cos^2\phi} + \sqrt{(r_a)^2 - r^2\cos^2\phi} - (R+r)\sin\phi$$

Arc of contact: Arc of contact is the path traced by a point on the pitch circle from the beginning to the end of engagement of a given pair of teeth. In Figure, the arc of contact is EPF or GPH. The arc GP is known as arc of approach and the arc PH is called arc of recess. The angles subtended by the arcs at O1arecalled angle of approach and angle of recess respectively.

Length of arc of approach = arc GP $= \dfrac{Lenght\ of\ path\ of\ approach}{\cos\phi} = \dfrac{KP}{\cos\phi}$

Length of arc of recess = arc PH $= \dfrac{Lenght\ of\ path\ of\ recess}{\cos\phi} = \dfrac{PL}{\cos\phi}$

Length of arc contact = arc GPH $= arc\ GP + arc\ PH$

$$= \frac{KP}{\cos\phi} + \frac{PL}{\cos\phi} = \frac{KL}{\cos\phi} = \frac{Length\ of\ path\ of\ contact}{\cos\phi}$$

Contact Ratio (or Number of Pairs of Teeth in Contact)

The contact ratio or the number of pairs of teeth in contact is defined as the ratio of the length of the arc of contact to the circular pitch.

$$Contat\,ratio = \frac{Length\ of\ the\ arc\ of\ \ contact}{P_C}$$

$$P_C = Circular\ \ pitch = \pi \times m \qquad \text{and} \qquad m = \text{Module.}$$

Continuous motion transfer requires **two pairs of teeth in contact at the ends of the path of contact**, though the reason one pair in contact in the middle of the path, as in Figure. The average number of teeth in contact is an important parameter-If it is tool ow due the use of inappropriate profile shift sort an excessive centre distance. The manufacturing in accuracies may lead to loss of kinematic continuity that is to impact, vibration and noise The average number of teeth in contact is also a guide to load sharing between teeth; it is termed the **contact ratio** The tooth tip of the pinion will then undercut the toot h on the wheel at the root and damages part of the involutes profile. This effect is known as interference, and occurs when the teeth are being cut and weakens the tooth at its root. In general, the phenomenon, when the tip of tooth undercuts the root on its mating gear is known as interference .Similarly, if there radius of the addendum circles of the wheel increases beyond O2M, then the tip of tooth on wheel will cause interference with the tooth on pinion. The points M and N are called interference points. Interference may be avoided if the path of the contact does not extend beyond interference points. The limiting value of the radius of the addendum circle of the pinion is O1N and of the wheel is O2M. The interference may only be prevented, if the point of contact between the two teeth is always on the involutes profiles and if the addendum circles of the two mating gears cut the Common tangent tooth base circles at the points of tangency.

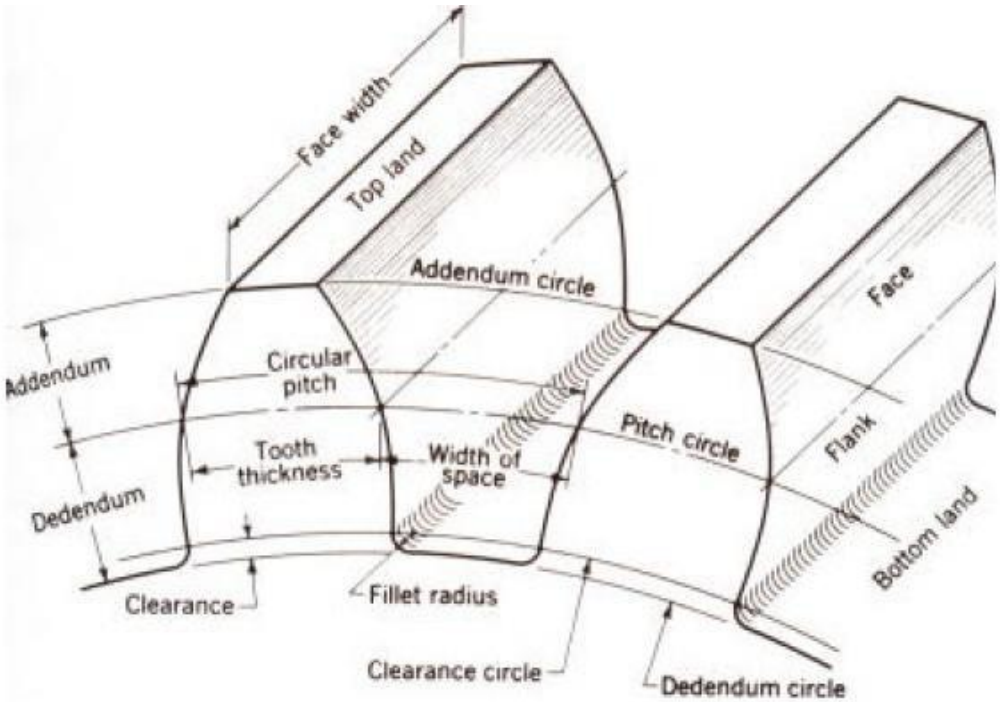
Methods to avoid Interference

1. Height of the teeth may be reduced.
2. undercut of the radial flank of the pinion.

3. Centre distance may be increased. It leads to increase in pressure angle.

4. By tooth correction, the pressure angle, centre distance and base circles remain unchanged, but Tooth thickness of gear will be greater than the pinion tooth thickness.

Spur Gear Terminology



Addendum: The radial distance between the Pitch Circle and the top of the teeth.

Arc of Action: Is the arc of the Pitch Circle between the beginning and the end of the Engagement of a given pair of teeth.

Arc of Approach: Is the arc of the Pitch Circle between the first points of contact of the gear Teeth and the Pitch Point.

Arc of Recession: That arc of the Pitch Circle between the Pitch Point and the last point of Contact of the gear teeth.

Backlash: Play between mating teeth.

Base Circle: The circle from which is generated the involute curve upon which the tooth profile is based.

Center Distance: The distance between centers of two gears.

Chordal Addendum: The distance between a chord, passing through the points where the Pitch Circle crosses the tooth profile, and the tooth top.

Chordal Thickness: The thickness of the tooth measured along a chord passing through the points where the Pitch Circle crosses the tooth profile.

Circular Pitch: Millimeter of Pitch Circle circumference per tooth

Circular Thickness: The thickness of the tooth measured along an arc following the Pitch Circle

Clearance: The distance between the top of a tooth and the bottom of the space into which it fits On the meshing gear.

Contact Ratio: The ratio of the length of the Arc of Action to the Circular Pitch.

Dedendum: The radial distance between the bottom of the tooth to pitch circle.

Diametral Pitch: Teeth per mm of diameter.

Face: The working surface of a gear tooth, located between the pitch diameter and the top of the tooth.

Face Width: The width of the tooth measured parallel to the gear axis.

Flank: The working surface of a gear tooth, located between the pitch diameter and the bottom of the teeth

Gear: The larger of two meshed gears. If both gears are the same size, they are both called "gears".

Line of Action: That line along which the point of contact between gear teeth travels, between the first point of contact and the last.

Module: Millimeter of Pitch Diameter to Teeth.

Pinion: The smaller of two meshed gears.

Pitch Circle: The circle, the radius of which is equal to the distance from the center of the gear to the pitch point.

Diametral pitch: Teeth per millimeter of pitch diameter.

Pitch Point: The point of tangency of the pitch circles of two meshing gears, where the Line of Centers cross the pitch circles.

Pressure Angle: Angle between the Line of Action and a line perpendicular to the Line of Centers.

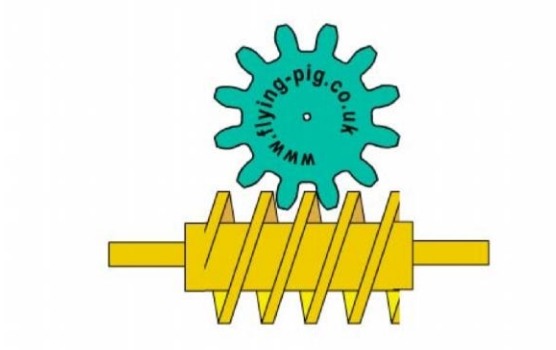
Root Circle: The circle that passes through the bottom of the tooth spaces.

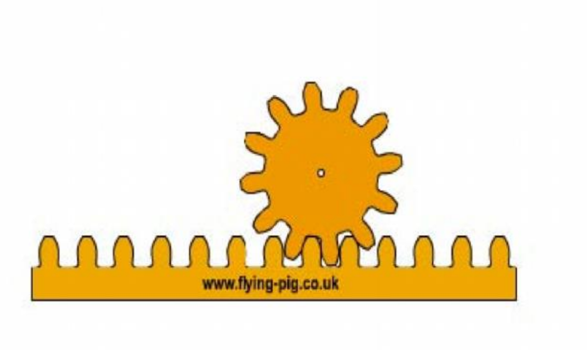
Root Diameter: The diameter of the Root Circle.

Working Depth: The depth to which a tooth extends to the space between teeth on the mating gear.

Worm, Rack and Pinion Gears

RACK AND PINION **WORM GEAR**





RACK AND PINION: The rack and pinion is used to convert between rotary and linear motion. The rack is the flat, toothed part, the pinion is the gear. Rack and pinion can convert from rotary to linear of from linear to rotary. The diameter of the gear determines the speed that the rack moves as the pinion turns. Rack and pinions are commonly used in the steering system of cars to convert the rotary motion of the steering wheel to the side to side motion in the wheels. Rack and pinion gears give a positive motion especially compared to the friction drive of a wheel in tarmac. In the rack and pinion railway a central rack between the two rails engages with a pinion on the engine allowing the train to be pulled up very steep slopes.

WORM GEAR: A worm is used to reduce speed. For each complete turn of the worm shaft the gear shaft advances only one tooth of the gear. In this case, with a twelve tooth gear, the speed is reduced by a factor of twelve. Also, the axis of rotation is turned by 90 degrees. Unlike ordinary gears, the motion is not reversible, a worm can drive a gear to reduce speed but a gear cannot drive a worm to increase it. As the speed is reduced the power to the drive increases correspondingly. Worm gears are a compact, efficient means of substantially decreasing speed and increasing power. Ideal for use with small electric motors.

Parallel axis gear trains:

Simple Gear Trains – A simple gear train is a collection of meshing gears where each gear is on its own axis. The train ratio for a simple gear train is the ratio of the number of teeth on the input gear to the number of teeth on the output gear. A simple gear train will typically have 2 or 3 gears and a gear ratio of 10:1 or less. If the train has 3 gears, the intermediate gear has no numerical effect on the train ratio except to change the direction of the output gear.

Compound Gear Trains – A compound gear train is a train where at least one shaft carries more than one gear. The train ratio is given by the ratio mV = (product of number of teeth on driver gears)/(product of number of teeth on driven gears). A common approach to the design of compound gear trains is to first determine the number of gear reduction steps needed (each step is typically smaller than 10:1 for size purposes). Once this is done, determine the desired ratio for each step, select a pinion size, and then calculate the gear size.

Reverted Gear Trains – A reverted gear train is a special case of a compound gear train. A reverted gear train has the input and output shafts in –line with one another. Assuming no idler gears are used, a reverted gear train can be realized only if the number of teeth on the input side of the train adds up to the same as the number of teeth on the output side of the train.

Epicyclic gear trains:

If the axis of the shafts over which the gears are mounted are moving relative to a fixed axis, the gear train is called the epicyclic gear train.

Reference Materials

4. **Textbooks:**

   TB1: Theory of Machine by S S Ratan

   TB2: Theory of Machine by Sadhu Singh

5. **Reference Books:**

   RB1 Theory of Machines by R.S Khurmi

   RB2 Theory of Machine by R.K Bansal

Other readings and relevant websites

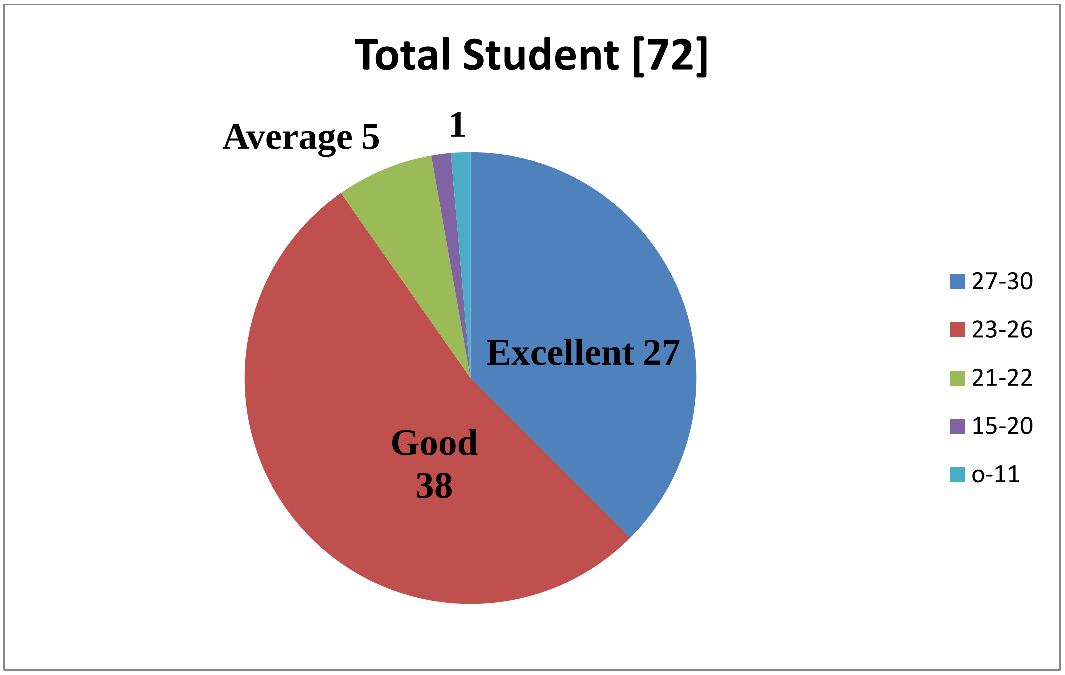
S.No.	**Link of Journals, Magazines, websites and Research Papers**
5.	https://www.journals.elsevier.com/mechanism-and-machine-theory
6.	https://www.journals.elsevier.com/mechanism-and-machine-theory/most-downloaded-articles
7.	https://www.journals.elsevier.com/mechanism-and-machine-theory/recent-articles
8.	https://www.sciencedirect.com/journal/mechanism-and-machine-theory

Kinematics of Machinery (Result):

S.N	Name	Roll. No.	Total Marks (30)
1	SUMAN BHARTI KESHAV	16M08	22
2	MUKUND KUMAR	16M52	25
3	ALOK ARAYA	16M19	29
4	VIKAS KUMAR BHARTI	16M31	23
5	RAJHANS KUMAR	16M20	24
6	SHASHI BHUSHAN KUMAR	16M69	27
7	NAWLESH KUMAR	16M05	29
8	ABHISHEK KUMAR	16M03	24
9	ANUBHAV SHRIVASTAVA	16M07	23
10	VISHAL KUMAR	16M58	24
11	MD AKRAM ALAM	16M02	22
12	SANDEEP RAHUL	16M51	28
13	ABHISHEK ANAND	16M12	27
14	RATAN KUMAR	16M64	28
15	RAUSHAN KUMAR	16M43	26
16	AVINASH KUMAR	16M32	28
18	MITHUN KUMAR	16M22	30
19	MD TASLIM	16M19	28
20	KUMARI PAYAL	16M60	24
21	SHASHI KUMAR	16M24	24
22	VIVEK KUMAR	16M59	29
23	VISHWANATH KUMAR	16M34	27
24	PRINCE KUMAR	16M17	24
25	SHIWANGI KUMARI	16M68	27
26	KANHAIYA KUMAR	16M16	25
27	AMRIT RAJ	16M66	23
28	NANDAN KUMAR	16M65	28
29	KRISHNA KUMAR	16M71	27
30	RAHUL PRASAD	16M25	28
31	SHAILENDRA KUMAR	16M62	23
32	SHUBHAM	16M14	27
33	PIYUSH KUMAR	16M37	24
34	AMIT KUMAR	16M54	24
35	SHATRUDHAN KUMAR	16M23	25
36	NAVNEET DHANRAJ	16M18	24

37	RUPESH KUMAR	16M40	26
38	AVINASH RAJ	16M70	27
39	FAIZ ANWAR	16M38	25
40	PRABHAKAR KUMAR	16M55	23
41	VINOD KUMAR	16M47	25
42	KUMAR RAHUL	16M36	27
43	VISHAL KUMAR	16M61	23
44	VISHAL KUMAR	16M44	25
45	LALAN KUMAR	16M56	23
46	RAUSHAN KUMAR	16M41	25
47	VED PRAKASH	16M21	24
48	ANAND MOHAN SINGH	16M13	28
49	KANHAIYA KUMAR	16M35	28
51	VISHAL KUMAR	16M27	20
52	UJJWAL KUMAR	16M06	34
53	RAHUL KUMAR	16M04	22
54	SONU KUMAR	16M63	24
55	SURENDRA KUMAR	16M15	23
57	ASHUTOSH KUMAR	16M11	22
58	NIDHI KUMARI GUPTA	16M49	25
59	ASHUTOSH KUMAR JHA	16M67	28
60	ASHUTOSH SINHA		23
61	CHANDAN KUMAR	17(LE)M01	27
62	RAHUL RAY	17(LE)M02	9
63	SUDHANSHU KUMAR SHARMA	17(LE)M03	27
64	RAJEEV KUMAR	17(LE)M04	23
65	SANGAM KUMAR	17(LE)M05	30
66	KRISHNA KUMAR	17(LE)M06	24
67	ANKIT RANJAN	17(LE)M07	24
68	DHIRAJ KUMAR	17(LE)M08	24
69	GUDDU KUMAR	17(LE)M09	23
70	SUNNY KUMAR	17(LE)M10	22
71	RAKESH RAM	17(LE)M11	23
72	ANAND MOHAN JHA	17(LE)M12	25

Kinematics of Machinery Result Analysis



Total Student [72]	Marks Obtained (30)	Performance
27	27-30	Excellent
38	23-26	Good
5	21-22	Average
1	15-20	Weak
1	0-11	Failed