In Pursuit of Excellence	**Course and Faculty Details**	SESSION-2019-2020
		SEM-6TH

Faculty Details

Name of the Faculty: Pravesh Chandra

Designation: Assistant Professor

Department: Mechanical Engineering

Course Details

Name of the Programme: B.Tech.

Batch: 2017-2021

Branch: Mechanical Engineering

Section: 2019-20

Name of Subject: THEORY OF MACHINE

Code: RME 602

Category of Course: Core

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In Pursuit of Excellence	**Index**	SESSION-2019-2020 SEM-6TH

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Course Outcome Attainment	
Practical Course File	
Course Scheme& Exam Scheme	
Course Syllabus as per University	
Syllabus Adopted by the Program	
Course Outcome of Practical	
List of Experiment as per University	
List of Experiment with enhancement by The Institute	
Schedule of Practical List Performed	
Class Notes with Real-world examples (In Separate File)	
PPT (if any)	

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MORADABAD INSTITUTE OF TECHNOLOGY

Vision and Mission of the Institute

Vision

To develop industry ready professionals with values and ethics for global needs.

Mission

M1: To impart education through outcome based pedagogic principles.

M2: To provide conducive environment for personality development, training and entrepreneurial skills.

M3: To induct high professional ethics and accountability towards society in students.

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Vision

To develop competent and skilled Mechanical Engineers having moral values and ethics for the fulfillment of fast changing global needs.

Mission

M1: To nurture continuous enhancement in teaching learning process for imparting strong fundamental knowledge of core, engineering science, and interdisciplinary subjects to students.

M2: To provide state-of-the-art laboratories for providing hand-on experience of technology, and to provide platforms for leadership and overall personality development.

M3: To develop strong mentor-mentee relationship for the professional and personal growth of students and also to inculcate moral values and ethics for serving the society.

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Program Education Objectives

PEO 1: To prepare students for successful careers in industry that meet the needs of Indian and multinational companies.

PEO 2: To develop the ability among students to synthesize data and technical concepts for application to product design.

PEO 3: To provide opportunity for students to work as part of teams on multidisciplinary projects.

PEO 4: To provide students with a sound foundation in the mathematical, scientific and engineering fundamentals necessary to formulate, solve and analyze engineering problems and to prepare them for graduate studies.

PEO 5: To promote student awareness of the life-long learning and to introduce them to professional ethics and codes of professional practice.

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Program Outcomes

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization for the solution of complex engineering problems.

2. Problem analysis: Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, and cultural, societal, and environmental considerations.

4. Conduct investigations of complex problems: Use research based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions.

5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools, including prediction and modeling to complex engineering activities, with an understanding of the limitations.

6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

10. Communication: Communicate effectively on complex engineering activities with the engineering community and with the society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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After completing their graduation, students of Mechanical Engineering will be able to –

PSO1: Identify and solve problems of thermal engineering, strength of materials, fluid mechanics, refrigeration & air conditioning, design, dynamics of machines, mathematics and engineering science.

PSO2: Get fundamental knowledge and hand-on experience of different manufacturing processes, material testing techniques and CAD/CAM tooling to apply in various industries.

PSO3: Learn quality and industrial management concepts, communication and soft skills along with other interdisciplinary subjects such as programming language, electrical engineering and basic electronics to enhance their employability.

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In Pursuit of Excellence	**Academic Calendar**	SESSION-2019-2020 SEM-6^{TH}

Moradabad Institute of Technology

Ramganga Vihar Phase – II, Moradabad

Date: 16-01-2020

ACADEMIC CALENDAR

Even Semester **Session: 2019 – 2020**

S. No.	Particulars	Date	Responsibility
1.	**Time Table** (a) Display on Notice Boards (b) Distribution to concerned Teachers	 18 Jan 2020 18 Jan 2020	O.C. Time Table
2.	Distribution of Students' lists to teachers	18 Jan 2020	Concerned HODs /O.C. Class
3.	Blow up submission to HODs	18 Jan 2020	Concerned Teachers
4.	**Registrations** (a) 2nd and 4th Semester (b) 6th and 8th Semester (b) List of unregistered students to various department (c) Notifying unregistered students for getting registered at the earliest (through class O.Cs, / Faculty)	 20 Jan 2020 21 Jan 2020 27 Jan 2020 29 Jan 2020	 Concerned Teachers OS Academic Concerned HODs
5.	**Commencement of Classes** (a) 2nd and 4th Semester (b) 6th and 8th Semester	 21 Jan 2020 22 Jan 2020	HODs and Concerned Teachers
6.	Announcement of Test series dates	30 Jan 2020	Dean Academics
7.	Procurement of stationary & materials for Test Series for full semester (a) Requirement (b) Actual Procurement	 10 Feb 2020 15 Feb 2020	Convener Test Series Committee O.S. Academics
8.	(a) Short attendance compilation before Class Test-1 (b) Information to parents (c) Undertaking form handed over to students (b) Collection of undertaking form	20 Feb 2020 21 Feb 2020 21 Feb 2020 22 Feb 2020	O.C. Class
9.	1st Test Series	24, 25 and 26 Feb 2020	
	Announcement of Test Series schedule, Invigilation Programme, Seating arrangement etc.	18 Feb 2020	Class Test Committee
	After completion of Test Series (a) Evaluation of test copies & showing of copies to students (b) Report of poor performance of students to class OCs (c) Submission of test copies in Nodal Centre	 29 Feb 2020 29 Feb 2020 29 Feb 2020	 Concerned Teachers Concerned Teachers Concerned Teachers
10.	(a) Last date for submission of examination forms to office (b) Submission of forms to University	06 March 2020** 07 March 2020**	OS Academic to take timely action as per University directions.

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11.	Mid Semester break	09 March to 11 March 2020	
12.	Announcement of dues list and its last date for clearing dues (Current semester)	25 March 2020	Accounts/ OS Academic
13.	(a)Short attendance compilation before Class Test-2 (b) Information to parents (c)Undertaking form handed over to students (b)Collection of undertaking form	01 April 2020 03 April 2020 03 April 2020 04 April 2020	O.C. Class
14.	**2nd Test Series**	**07, 08 and 09 April 2020**	
	Announcement of Test Series schedule, Invigilation Programme, Seating arrangement etc.	03 April 2020	Class Test Committee
	After completion of Test Series (a) Evaluation of test copies & showing of copies to students (b) Report of poor performance of students to class OCs (c)) Submission of test copies in Nodal Centre	 13 April 2020 13 April 2020 13 April 2020	 Concerned Teachers Concerned Teachers Concerned Teachers
15.	Filling of student feedback forms for current semester	22 April 2020	Concerned HODs
16.	Requirement of additional Faculty (to be conveyed to Director) (for even semester)	30 April 2020	Concerned HODs
17.	(a) Floating the electives for even semester (b) Last date for students choice	22 April 2020 23 April 2020	Concerned HODs
18.	Date up to which final attendance is to be counted	26 April 2020	Concerned teachers
19.	Submission of consolidated list of shortage of attendance to Director and information to Parents	27 April 2020	Class O.Cs
20.	**3rd Test Series**	**28,29,30 April 2020**	
	Announcement of Test Series schedule, Invigilation Programme, Seating arrangement etc.	23 April 2020	Class Test Committee
	After completion of Test Series (a) Evaluation of test copies & showing of copies to students (b) Report of poor performance of students to class OCs (c)) Submission of test copies in Nodal Centre	 04 May 2020 04 May 2020 04 May 2020	Concerned Teacher Concerned Teachers Concerned Teachers
21.	**Submission of sessional marks:** (a) Meeting of Dean Academics, , all HODs and Director regarding attendance and performance of students.	05 May 2020	Dean Academics
	(b) Checking of Teachers' Records by HODs	06 May 2020	Concerned HODs
	(c) Finalization of sessional marks	08 May 2020	Concerned Teachers
	(d) Submission of Award list after final checking and uploading to OS Academics for further necessary action	As per date announced by AKTU	HODs Concerned Teachers
22.	**Theory Examinations:** (a) Collection of Admit Cards / Roll Nos. from University (b) Preparation of Roll lists (c) Collection of stationery such as copies, practical copies drawing sheets, graph paper etc. from University. (c) Procurement of stationery and other materials locally as necessary.	As per AKTU schedule	OS Academics to take appropriate actions as per University directions.

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23.	**Practical Examinations:**	As per AKTU schedule	Concerned HODs
	(a) Appointment of Internal Examiners	3 days before the practical exam schedule	Concerned HODs
	(b) Obtaining list of panel of External Examiners from AKTU & preparation of schedule of practical examination.	As per AKTU schedule	OS Academics
	(d) Dispatch of letters/contacting the external examiners	Within 2 days of list obtained from AKTU	HODs and concerned teachers
24.	**Preparation for Even Semester** (a) Load Distribution by Department (b) Submission to O.C. Time Table	15 May 2020 16 May 2020	Concerned Coordinators O.C. Time Table
25.	Registration for odd semester (2020 – 21)	To be announced**	OS Academic

****May be revised as per AKTU Schedule.**

16-01-2020
Dean Academics

Director

Copy to:

1. Chairman
2. Secretary
3. P.A. to Director for Director's folder
4. All HODs
5. DOSW
6. Controller of Examination
7. O.C. Time Table
8. Registrar
9. All Faculty Members through HODs
10. O.S. Academics
11. A.S. Examinations
12. Account Section
13. T & P Cell
14. Librarian
15. Convener Test Series

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STUDY AND EVALUATION SCHEME

B-Tech. Mechanical Engineering

YEAR: 3rd / SEMESTER-VI

S. No.	Subject Code	Subject Name	Department	L-T-P	Theory / Lab Marks	SESSIONAL		Total	Credit
						Test	Assignment / Attendance		
1	RAS601	Industrial Management	Applied Science	3--0--0	70	20	10	100	3
2	RUC601/ RAS602	Cyber Security/ Sociology	Applied Science	3--0--0	70	20	10	100	3
3	RME601	Fluid Machinery	Core Deptt.	3--0--0	70	20	10	100	3
4	RME602	Theory of Machines	Core Deptt.	3--1--0	70	20	10	100	4
5	RME603	Machine Design-II	Core Deptt.	3--0--0	70	20	10	100	3
6	RME061-064	Deptt. Elective Course-2	Core Deptt.	3--1--0	70	20	10	100	4
7	RME651	Fluid Machinery Lab	Core Deptt.	0--0--2	50		50	100	1
8	RME652	Theory of Machines Lab	Core Deptt.	0--0--2	50		50	100	1
9	RME653	Design and Simulation Lab II	Core Deptt.	0--0--2	50		50	100	1
10	RME654	Refrigeration & Air-conditioning	Core Deptt.	0--0--2	50		50	100	1
TOTAL								1000	24

DEPTT ELECTIVE COURSE-2

1. **RME061 Refrigeration & Air-conditioning**
2. **RME062 Production Planning and Control**
3. **RME063 Mechanical Vibration**
4. **RME064 Reliability Engineering**

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THEORY OF MACHINES

L:T:P
3: 1: 0

Unit I 8

Introduction, mechanisms and machines, kinematics and kinetics, types of links, kinematic pairs and their classification, types of constraint, degrees of freedom of planar mechanism, Grubler's equation, mechanisms, inversion of four bar chain, slider crank chain and double slider crank chain.

Velocity analysis:
Introduction, velocity of point in mechanism, relative velocity method, velocities in four bar mechanism, instantaneous center .

Acceleration analysis:
Introduction, acceleration of a point on a link, acceleration diagram, Corioli's component of acceleration, crank and slotted lever mechanism,.

Unit II 8

Cams
Introduction, classification of cams and followers, cam profiles for knife edge, roller and flat faced followers for uniform velocity, uniform acceleration,

Gears and gear trains
Introduction, classification of gears, law of gearing, tooth forms and their comparisons, systems of gear teeth, length of path of contact, contact ratio, minimum number of teeth on gear and pinion to avoid interference, simple, compound, reverted and planetary gear trains, sun and planet gear train.

Unit III 8

Force analysis:
Static force analysis of mechanisms, D'Alembert's Principle, dynamics of rigid link in plane motion, dynamic force analysis of planar mechanisms, piston force and crank effort. Turning

moment on crankshaft due to force on piston, Turning moment diagrams for single cylinder double acting steam engine, four stroke IC engine and multi-cylinder engines, Fluctuation of speed, Flywheel.

Unit IV 8

Balancing
:
Introduction,static balance, dynamic balance, balancing of rotating masses,two plane balancing, graphical and analytical methods, balancing of reciprocating masses,

Governors:
Introduction, types of governors, characteristics of centrifugal governors, gravitycontrolled and spring controlled centrifugal governors, hunting of centrifugal governors, inertia

governors. Effort and Power of governor

Unit V 8

Brakes and dynamometers:
Introduction, Law of friction and types of lubrication, types of brakes, effect of braking on rear and front wheels of a four wheeler, dynamometers, belt transmission dynamometer, torsion dynamometer, hydraulic dynamometer

Text/Reference Books:

1. Kinematics and dynamics of machinery: Wilson and Sadler, Third edition, Pearson.
2. Theory of Mechanisms and Machines: AmitabhaGhosh and Ashok kumarMallik, Third Edition Affiliated East-West Press.
3. Theory of Machines and Mechanisms: Joseph Edward Shigley and John Joseph Uicker, Jr. Oxford University Press
4. Kinematics and dynamics of machinery: R L Norton, McGraw Hill
5. Theory of Mchines: S.S. Rattan, McGraw Hill
6. Theory of Mchines: Thomas Bevan, CBS Publishers.

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Syllabus

Unit I

Introduction, mechanisms and machines, kinematics and kinetics, types of links, kinematic pairs and their classification, types of constraint, degrees of freedom of planar mechanism, Grubler's equation, mechanisms, inversion of four bar chain, slider crank chain and double slider crank chain.

Velocity analysis:

Introduction, velocity of point in mechanism, relative velocity method, velocities in four bar mechanism, instantaneous center .

Acceleration analysis:

Introduction, acceleration of a point on a link, acceleration diagram, Corioli's component of acceleration, crank and slotted lever mechanism,.

Unit II

Cams

Introduction, classification of cams and followers, cam profiles for knife edge, roller and flat faced followers for uniform velocity, uniform acceleration,

Gears and gear trains

Introduction, classification of gears, law of gearing, tooth forms and their comparisons, systems of gear teeth, length of path of contact, contact ratio, minimum number of teeth on gear and pinion to avoid interference, simple, compound, reverted and planetary gear trains, sun and planet gear train.

Unit III

Force analysis:

Static force analysis of mechanisms, D'Alembert's Principle, dynamics of rigid link in plane motion, dynamic force analysis of planar mechanisms, piston force and crank effort. Turning moment on crankshaft due to force on piston, Turning moment diagrams for single cylinder double acting steam engine, four stroke IC engine and multi-cylinder engines, Fluctuation of speed, Flywheel.

Unit IV

Balancing:

Introduction,static balance, dynamic balance, balancing of rotating masses, two plane balancing, graphical and analytical methods, balancing of reciprocating masses,

Governors:

Introduction, types of governors, characteristics of centrifugal governors, gravity controlled and spring controlled centrifugal governors, hunting of centrifugal governors, inertia governors. Effort and Power of governor

Unit V

Brakes and dynamometers:

Introduction, Law of friction and types of lubrication, types of brakes, effect of braking on rear and front wheels of a four wheeler, dynamometers, belt transmission dynamometer, torsion dynamometer, hydraulic dynamometer

Text/Reference Books:

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6. Theory of Mchines: Thomas Bevan, CBS Publishers.

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COURSE OUTCOMES

Once the student has successfully completed this course, he/she will be able:

RME 602.1	Students will able to do velocity and acceleration analysis of four bar and slider crank mechanism.
RME 602.2	Students will be able to compute the problems of the simple, compound and epicylic gear train.
RME 602.3	Analyze dynamic force analysis of slider crank mechanism and design of flywheel.
RME 602.4	Analyse analytical and graphical methods for calculating balancing of rotary and reciprocating masses. balancing of reciprocating and rotary masses.
RME 602.5	Compute frictional losses, torque transmission of mechanical systsms.

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In Pursuit of Excellence	**Course Delivery Method**	SESSION-2019-2020
		SEM-6TH

Name of Subject: Theory of Machine Subject Code: RME-602

Branch: Mechanical Engineering

Course Plan

Delivery Methods: Chalk & Talk, Power Point Presentation, Tutorials, Video Lectures, Analogy, solving Numericals /Design exercises, assignments, seminar, Brainstorming, Group Discussion/Interactive session, Delivery through Simulation Software/CAD Tools, Mini Project, Quiz

Coverage of

Unit 1 by: - Chalk & Talk, Power Point Presentation, Tutorials, Video Lectures, solving numerical, assignments, seminar.

Unit 2 by: - Google meet, Google classroom, Power Point Presentation, Tutorials, Video Lectures, solving Numericals /Design exercises, assignments.

Unit 3 by: - Google meet, Google classroom, Power Point Presentation, Tutorials, Video Lectures, solving Numericals, assignments.

Unit 4 by: - Google meet, Google classroom, Power Point Presentation, Tutorials, Video Lectures, solving Numericals, assignments, Power Point Presentation, Tutorials, Video Lectures, solving Numericals, assignments

Unit 5 by: - Google meet, Google classroom , Power Point Presentation, Tutorials,. Video Lectures, solving Numericals, assignments.

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In Pursuit of Excellence	**Video Lectures**	SESSION-2019-2020
		SEM-6^{TH}

S. No	TOPIC	Video Lecture Link
1	**Velocity Analysis**	https://youtu.be/m_HX5VPL9BY https://youtu.be/DxCMrDjCvhU https://youtu.be/yiNP5RipCEQ https://youtu.be/vYSgQBnen8o
2	**Acceleration Analysis**	https://youtu.be/OufAsw5X3t8 https://youtu.be/SfZXoFdxFN0 https://youtu.be/i6r3hQCwhUA
3	**CAM and follower**	https://youtu.be/UPEBKCBLiLo https://youtu.be/wSs77iq59UM
4	**Gear and Gear trains**	https://youtu.be/m5y378c3Bqw https://youtu.be/QvdogUvSgzM https://youtu.be/ee6if1ZnG68 https://youtu.be/8UEC0FQ4LOg

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In Pursuit of Excellence	Mapping	SESSION-2019-2020 SEM-6TH

Mapping of Course Outcomes with POs & PSOs:

CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
RME 602.1	3	3	3	1	2	2	-	-	-	1	1	1
RME 602.2	3	3	3	1	2	1	-	-	-	1	1	1
RME 602.3	3	3	3	2	2	1	-	-	-	1	1	1
RME 602.4	3	2	2	1	1	1	-	-	-	1	1	1
RME 602.5	3	3	3	1	3	2	-	-	-	1	1	1
RME 602	3	2.8	2.8	1.2	2	1.4	-	-	-	1	1	1

CO	PSO1	PSO2	PSO3
KME 603.1	3	1	
KME 603.2	3	1	
KME 603.3	3	1	
KME 604.4	3	1	
KME 605.5	3	1	
KME 603	3	1	

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In Pursuit of Excellence	**Time Table**	SESSION-2019-2020 SEM-6TH

TIME / DAY	9.00-10.00 am	10.00-11.00am	11.00 - 12.00 Noon	12.00-01.00pm	01.00-2.00pm	2.00-3.00pm	3.00-4.00pm	4.00-5.00pm
MON				**5.GV.01(L) B.VOC 1ST B B-304**	L			
TUE			**5.GV.01(L) B.VOC 1ST B B-304**		U	RME 551, 5TH E3, D-402		
WED	**5.GV.01(L) B.VOC 1ST B B-304**		RME 501 (L) 5TH E D-304		N			
THU		RME 501 (L) 5TH E D-304		**5.GV.01(L) B.VOC 1ST B B-304**	C	RME 551, 5TH E2, D-402		
FRI	RME 551, 5TH E1, D-402			RME 501 (L) 5TH E D-304	H			
SAT	KWS 101 (P), 1ST C1 G-101							

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	Lecture Plan & Course Coverage	SESSION-2019-2020 SEM-6TH
In Pursuit of Excellence		

Total Period: 45

Sr. No.	No. of Periods	Topics/Sub Topics	Reference Books	CO Covered	Planned Date	Coverage Date	Sign
1	1	Introduction, mechanisms and machines	4,5,6	CO1	24/01/19	24/01/20	
2	1	kinematics and kinetics, types of links	4,5,6	CO1	24/01/19	25/01/20	
3	1	kinematic pairs and their classification,	4,5,6	CO1	25/01/19	27/01/20	
4	1	types of constraint, degrees of freedom of planar mechanism	4,5,6	CO1	31/01/20	31/01/20	
5	1	Grubler's equation, mechanisms	4,5,6	CO1	21/01/20	3/02/20	
6	1	inversion of four bar chain	4,5,6	CO1	03/02/20	07/20/20	
7	1	slider crank chain and double slider crank chain.	5	CO1	07/02/20	12/02/20	
8	1	Introduction, velocity of point in mechanism	5	CO1	12/02/20	14/02/20	
9	1	relative velocity method	5	CO1	14/02/20	17/02/20	
10	1	velocities in four bar mechanism,	5	CO1	17/02/20	19/02/20	
11	1	Problems on four bar mechanism by Releative Velocity Method	4,5	CO1	02/03/20	02/03/20	
12	2	Problems on Slider crank mechanism by Releative velocity Method	4,6	CO1	03/03/20	03/03/20	
13	1	instantaneous center Method	4,5,6	CO1	18/03/20	18/03/20	
14	1	Problems on four bar mechanism by I-Centre Method	4,6	CO1	19/03/20	19/03/20	
15	1	Problems on Slider crank mechanism by I-Centre Method	4,5	CO1	20/03/20	20/03/20	
16	1	Introduction, acceleration of a point on a link	4,5,6	CO1	20/03/20	21/03/20	
17	1	acceleration diagram	4,5,6	CO1	21/03/20	23/3/20	
18	1	Corioli's component of acceleration,	4,5,6	CO1	23/03/20	28/3/20	
19	1	crank and slotted lever mechanism,.	4,5,6	CO1	04/04/20	4/04/20	
20	1	Introduction, classification of cams and followers	4,5,6	CO2	04/04/20	08/04/20	
21	1	cam profiles for knife edge	4,5,6	CO2	08/04/20	10/04/20	

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22	1	roller and flat faced followers for uniform velocity	4,5,6	CO2	16/04/20	16/04/20	
23	2	roller and flat faced followers for uniform acceleration,	4,5,6	CO2	16/04/20	18/04/20	
24	1	Introduction, classification of gears	4,5,6	CO2	18/04/20	21/04/20	
25	1	law of gearing	4,6	CO2	21/04/20	24/04/20	
26	1	tooth forms and their comparisons	4,6	CO2	24/04/20	28/4/20	
27	1	systems of gear teeth,	4,6	CO2	28/04/20	07/05/20	
28	1	length of path of contact	4,6	CO2	07/05/20	09/05/20	
29	1	contact ratio,	4,6	CO2	09/05/20	14/05/20	
30	1	minimum number of teeth on gear and pinion to avoid interference,	4,6	CO2	19/05/20	19/05/20	
31	2	simple, compound, reverted and planetary gear trains	4,6	CO2	21/05/20	21/05/20	
32	1	Simple gear trains	4,6	CO2	21/05/20	28/05/20	
33	2	Compound gear trains,Tabular Method for solving Gear .	4,6	CO2	28/05/20	02/06/20	
34	2	planetary gear trains .sun and planet gear train	4,6	CO2	06/06/20	06/06/20	
36	2	Ratio method for calculating Gear Trains Problems	4,6	CO2	07/06/20	07/06/20	

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In Pursuit of Excellence	**Lecture Plan** & **Course Coverage**	SESSION-2019-2020 SEM-6TH

Total Period: 45

Sr. No.	No. of Periods	Topics/Sub Topics	Reference Books	CO Covered	Planned Date	Coverage Date	Sign
1	1	Introduction, static balance, dynamic balance	4,5,6	CO4	20/1/19	20/1/19	✓
2	1	Balancing of rotating masses in single plan graphical methods	4,5,6	CO4	4/2/19	4/2/19	✓
3	1	Balancing of rotating masses in single plan analytical methods	4,5,6	CO4	8/2/19	8/2/19	✓
4	1	Balancing of rotating masses two plane graphical methods	4,5,6	CO4	13/2/19	13/2/19	✓
5	1	Balancing of rotating masses two plane analytical methods	4,5,6	CO4	18/2/19	18/2/19	✓
6	1	Balancing of rotating masses different plane graphical methods	4,5,6	CO4	25/2/19	25/2/19	✓
7	1	Balancing of reciprocating masses	5,6	CO4	27/2/19	27/2/19	✓
8	1	Primary and secondary unbalancing	5,6	CO4	3/3/19	3/3/19	✓
9	1	Partial balancing of unbalance force	5,6	CO4	5/3/19	5/3/19	✓
10	1	Variation of tractive force, swaying couple and hammer blow	5,6	CO4	17/3/19	17/3/19	✓
11	1	Introduction, types of governors and its function, inertia governors	4,5,6	CO4	19/3/19	19/3/19	✓
12	1	Term used in governor, characteristics of centrifugal governors, centrifugal governor its numerical	4,5,6	CO4	23/3/19	23/3/19	✓
13	1	Characteristics of gravity controlled governors, its numerical	4,5,6	CO4	25/3/19	25/3/19	✓
14	1	Characteristics of hartnell centrifugal governors governors, its numerical	4,5,6	CO4	27/3/19	27/3/19	✓
15	1	Characteristics of spring controlled centrifugal governors governors, its numerical	4,5,6	CO4	30/3/19	30/3/19	✓
16	1	Hunting of centrifugal governors	4,5,6	CO4	01/4/19	01/4/19	✓
17	1	Effort and Power of watt governor	4,5,6	CO4	03/3/19	03/4/19	✓
18	1	Effort and Power of porter governor	4,5,6	CO4	08/4/19	08/4/19	✓
19	1	Effort and Power of proell governor	4,5,6	CO4	13/4/19	13/4/19	✓
20	1	Introduction, Law of friction and types of lubrication	4,5,6	CO5	15/4/19	15/4/19	✓

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21	1	Types of brakes with applications, material for brake lining	4,6	CO5	17/4/19	17/4/19	
22	1	Effort and torque of Single block brake	4,6	CO5	20/4/19	20/4/19	
23	1	Effort and torque of pivioted block brake	4,6	CO5	22/4/19	22/4/19	
24	1	Effort and torque of simple band brake	4,6	CO5	24/4/19	24/4/19	
25	1	Effort and torque of differential band brake	4,6	CO5	27/4/19	27/4/19	
26	1	Effort and torque of internal expanding brake	4,6	CO5	29/4/19	29/4/19	
27	1	Effect of braking on rear and front wheels of a four wheeler	4,6	CO5	01/5/19	1/5/19	
28	1	Dynamometers, and its types with applications	4,6	CO5	01/5/19	1/5/19	
29	1	Classification of absorption type dynamometer, work done, torque and power in prony brake dynamometer	4,6	CO5	04/5/19	04/5/19	
30	1	work done, torque and power in rope brake dynamometer	4,6	CO5	4/5/19	4/5/19	
31	1	Classification of transmission type dynamometer, work done, torque and power in belt transmission dynamometer	4,6	CO5	4/5/19	4/5/19	
32	1	Torsion dynamometer, work done, torque and power in torsion dynamometer	4,6	CO5	8/5/19	6/5/19	
33	1	Static force analysis of mechanisms	5,6	CO3	6/5/19	6/5/19	
34	1	D'Alembert's Principle, velocity and acceleration of reciprocating part of engine	5,6	CO3	8/5/19	8/5/19	
35	1	Analytical method for Velocity and acceleration of pistion and angular Velocity and angular acceleration of connecting rod	5,6	CO3	11/5/19	11/5/19	
36	1	Force on reciprocating part neglecting weight of connecting rod	5,6	CO3	13/5/19	13/5/19	
37	1	Equivalent dynamical system, Equivalent dynamical system for two masses by graphical method.	5,6	CO3	15/5/19	15/5/19	
38	1	Correction couple for dynamical Equivalent system	5,6	CO3	20/5/19	20/5/19	
39	1	Inertia force for reciprocating part with or without considering weight of engine	5,6	CO3	29/5/19	29/5/19	
40	1	Turning moment on crankshaft due to force on piston	5,6	CO3	1/6/19	1/6/19	
41	1	Turning moment diagrams for single cylinder double acting steam engine, four stroke IC engine and multi-cylinder engines	5,6	CO3	3/6/19	3/6/19	

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42	1	Fluctuation of speed, energy, determination of max & min Fluctuation of speed, energy	5,6	CO3	10/6/19	10/6/19	[signature]
43	1	Coefficient of Fluctuation of energy	5,6	CO3	12/6/19	12/6/19	[signature]
44	1	Flywheel, Coefficient of Fluctuation of speed	5,6	CO3	15/6/19	15/6/19	[signature]
45	1	Energy stored in flywheel, dimension of flywheel rim	5,6	CO3	17/6/19	17/6/19	[signature]

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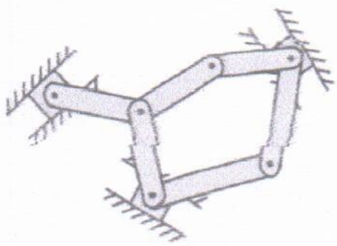
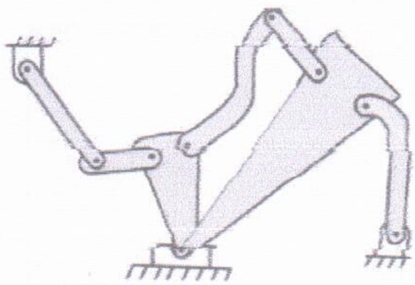
In Pursuit of Excellence	**Tutorial -1** **CO-1**	SESSION-2019-2020 SEM- 6th RME -602

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Pair and mechanism				

Q1. Find the no. of revolute pairs and degree of freedom of the following mechanism.



Q2. What is the DOF of the mechanism shown in figure below.



Q3. Calculate the DOF of the mechanism shown below.

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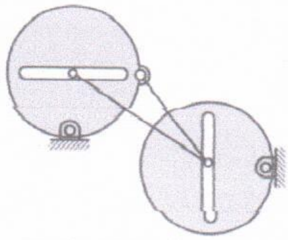
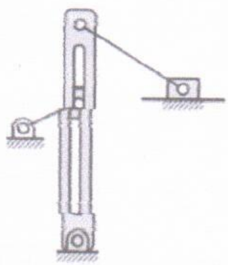


Q4. Calculate the numbers of lower pairs and DOF of the mechanism shown below.



Q5. Calculate the DOF of the mechanism shown.

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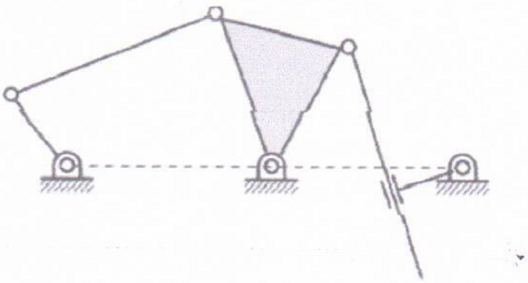
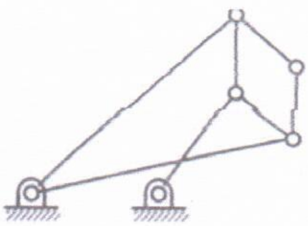


Q6. Figure below is an example of--------- DOF . Choose right option.



a. 0
b. 1
c. 3
d. 5

Q7. The screw pair has DOF ---------and is a ----------- pair?

a. 1, Higher
b. 2, Lower
c. 2, Higher
d. 1, Lower

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Q8. An over constrained mechanism has--------------- DOF?

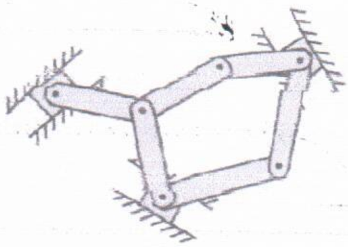
a. 0

b. 1

c. Negative

d. At least one

Q9. Find the no. of revolute pairs and DOF Of the following mechanism.



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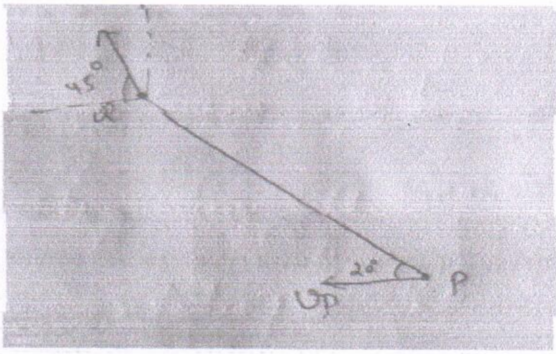
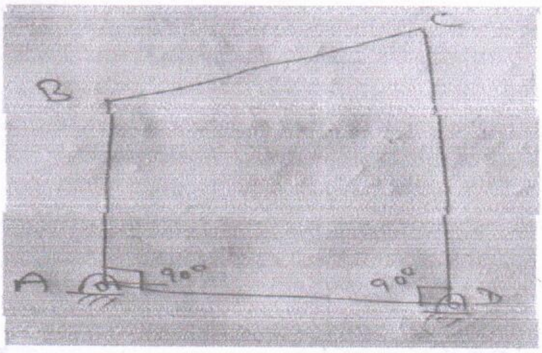
In Pursuit of Excellence	**Tutorial -2**	SESSION-2019-2020 SEM- 6^{th} RME-602

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	I-Centre method				

Q1. A rigid link PQ is 2 m long and oriented at 20^0 to the horizontal as shown in figure. Dtermine the magnitude of v_p (in m/s) at this instant.



Q2. For the four bar linkage shown in figure .The Angular velocity of link AB is 1 rad/sec. The length of CD is 1.5 times the length of AB in the configuration shown. Determine the Angular velocity of link CD (in rad /sec).



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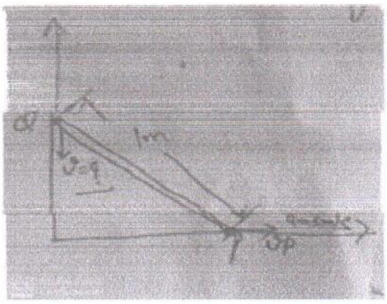
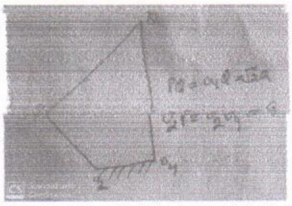
Q3. A rigid rod of length 1 m is resting at an angle of 45^0 as shown in figure. The end P is dragged with a velocity of 5 m/s to the right. At the instant shown , Determine the Magnitude of velocity v (in m/s) of point Q as it moves along the wall without losing contact.



Q4. The input link O_2P of a four bar linkagewith angular velocity 2 rad/sec in CCW as shown in figure. Determine the angular velocity of coupler PQ in rad/sec at any instant when $<O_4O_2P = 180^0$.



Q5. A slider crank mechanism with crank radius 60mm and connecting rod length 240 mm is shown in figure. The crank is rotating with uniform angular velocity of 10 rad/sec (CCW) for the given configuration determine the speed in m/s of the slider.

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In Pursuit of Excellence	**Tutorial – 3**	SESSION-2019-2020
		SEM 6th
		RME-602

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	***Mechanism and Velocity Analysis***				

Q1. State and Prove Angular velocity ratio Theorm.

Q2. State the Aronhold-Kennedy's theorem as applicable to instantaneous centres of rotation of three bodies.

Q3. Explain in brief: Instantaneous centre of rotation and types of ICs.

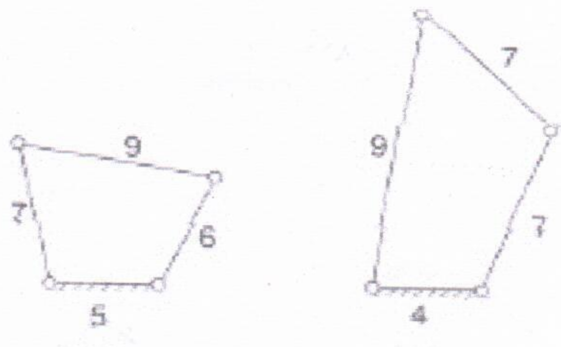
Q4. What do you understand by Degree of freedom? For a plane mechanism derive an expression for Grubler's equation.

Q5. Discuss the inversion of double slider crank mechanism.

Q6. Differentiate between lower pair and higher pair with an example.

Q7. What do you mean by instantaneous Centre? Explain properties of it.

Q8. Figure shows some four link mechanism in which the figure indicate the dimensions in standard units of length. Indicate the type of each mechanism whether crank rocker or double crank or double rocker.



(a) (b)

Q9. Explain inversions of single slider crank mechanism.

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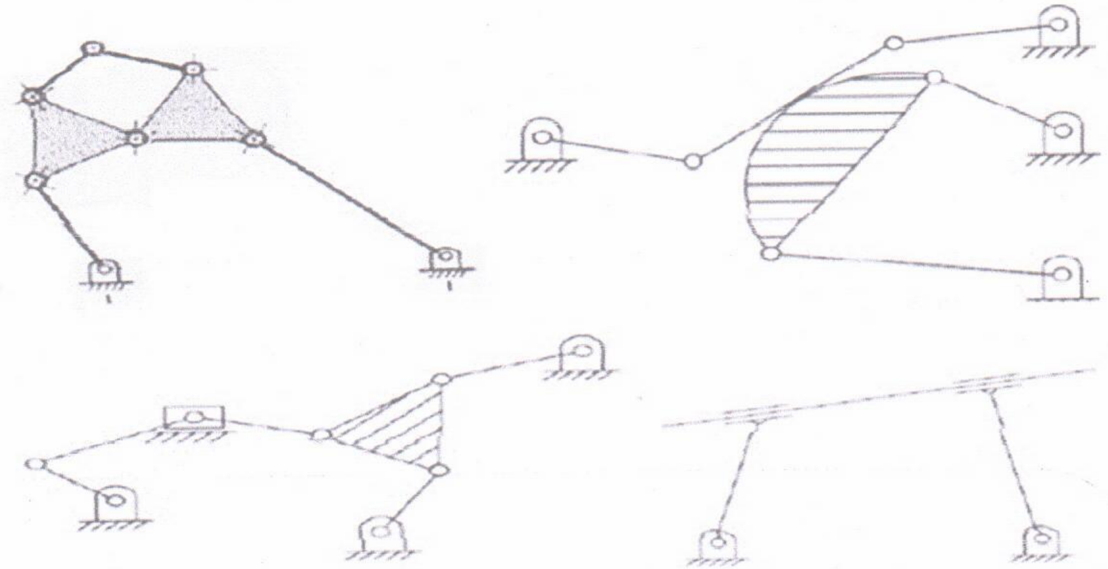
Q10. Determine the degree of freedom of following cases :



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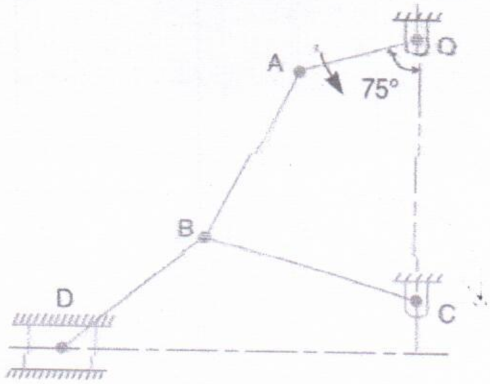
In Pursuit of Excellence	**Tutorial -4**	SESSION-2019-2020
		SEM- 6th
		RME-602

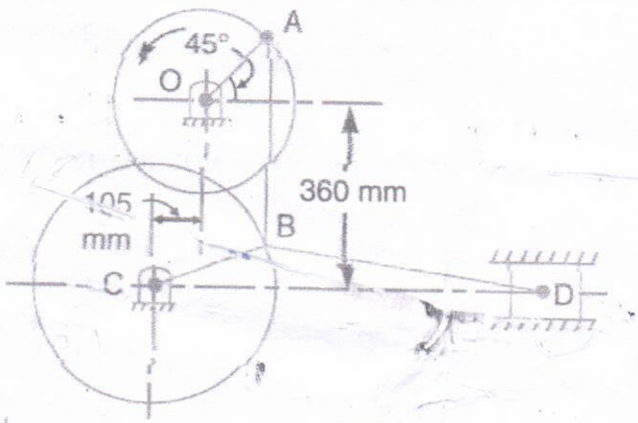
Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Velocity Analysis (Relative Velocity Method)				

Q1. In Fig, 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 centres 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.



Q2. In the toggle mechanism, as shown in Fig. , the slider D is constrained to move on a horizontal path. The crank OA is rotating in the counter-clockwise direction at a speed of 180 r.p.m. The dimensions of various links are as follows : OA = 180 mm ; CB = 240 mm ; AB = 360 mm ; and BD = 540 mm.

For the given configuration, find : 1. Velocity of slider D, 2. Angular velocity of links AB, CB and BD;



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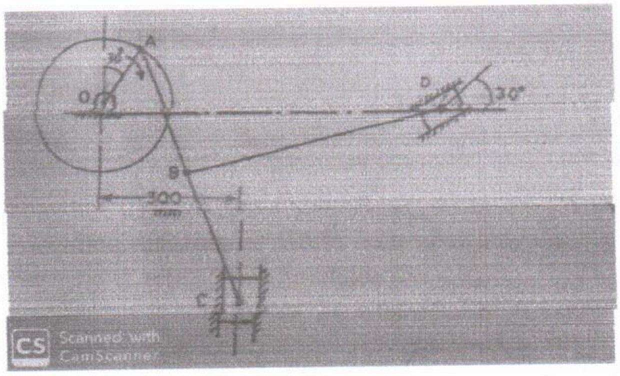
Q3. In the mechanism shown in figure OA = 300 mm, AB = 600 mm, AC = 1200 mm and BD = 1200 mm. OD is horizontal at the instant shown and OA rotates at 200 r.p.m, CW direction. Find:

(i) Velocities Of C and D

(ii) Angular velocities of links AC and BD



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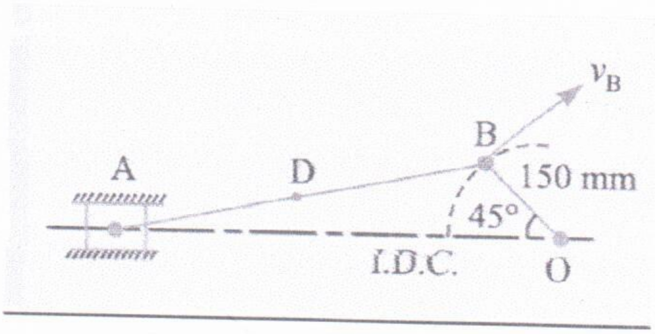
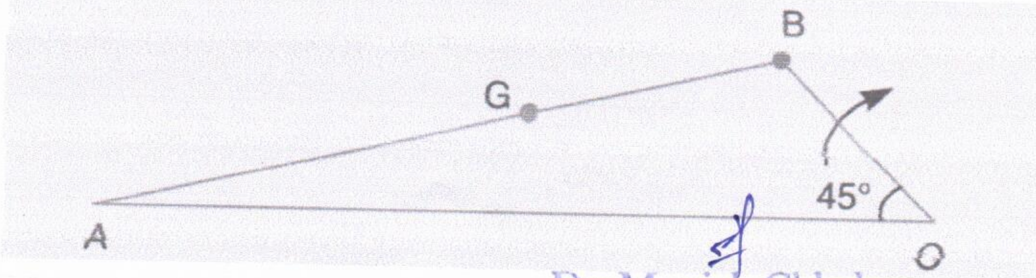
	Tutorial -5	SESSION-2019-2020
In Pursuit of Excellence		SEM- 6th
		RME-602

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date		Sign
			Batch A	Batch B	
1.	1	Acceleration Analysis			

Q1. 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.



Q2. The engine mechanism shown in Fig. has crank OB = 50 mm and length of connecting rod AB=225 mm. The centre of gravity of the rod is at G which is 75 mm from B. The engine speed is 200 r.p.m. For the position shown, in which OB is turned 45° from OA, Find 1. the velocity of G and the angular velocity of AB, and 2. the acceleration of G and angular acceleration of AB.



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Q3. In a pin jointed four bar mechanism ABCD, the lengths of various links are as follows: AB = 25 mm ; BC = 87.5 mm ; CD = 50 mm and AD = 80 mm. The link AD is fixed and the angle BAD = 135°. If the velocity of B is 1.8 m/s in the clockwise direction, find 1. velocity and acceleration of the mid point of BC, and 2. angular velocity and angular acceleration of link CB and CD.

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In Pursuit of Excellence	**Tutorial-6**	SESSION-2019-2020 SEM-6TH

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Rotating balancing				

1. A shaft carries four rotating masses A, B, C and D along its axis. The mass A may be assumed concentrated at a radius 200mm, B at 260mm and D at 170mm. the mass of B,C and D are 32kg, 52kg, 42kg respectively. The planes of revolution of B and C are 300mm apart. The angle between B and C is 90° and B and D is 210° and C and D is 120°. determine
   (i) The magnitude and angular position of mass A,
   (ii) The position of planes A and D
2. Four masses A,B,C and D are completely balanced. Masses C and D makes angle of 90° and 195° respectively with B in same sense. The rotating masses have following properties:

   M_b = 25kg R_a =150mm
   M_c = 40 kg R_b =200mm
   M_d = 35kg R_c =100mm R_d =180mm

   Planes B and C are 250mm apart. Determine:
   (i) The magnitude of mass A and its angular position.
   (ii) The position of planes A and D

3. Four masses A,B,C and D are completely balanced. The planes in which masses revolve are spaced 700mm apart. The rotating masses have following properties:

   M_b = 12kg R_a =110mm
   M_c = 07 kg R_b =140mm
   M_d = 05kg R_c =210mm R_d =160mm

   Determine the magnitude of mass A and relative angular positions of all masses so that the shaft is in completely balance.
4. A shaft is supported in bearings 1.8 m apart and projects 0.45 m beyond bearings at each end. The shaft carries three pulleys one at each end and one at the middle of its length. The mass of end pulleys is 48 kg and 20 kg and their centre of gravity are 15 mm and 12.5mm respectively from the shaft axis. The centre pulley has a mass of 56 kg and its centre of gravity is 15 mm from the shaft axis. If the pulleys are arranged so as to give static balance, determine: **1.** relative angular positions of the pulleys, and **2.** dynamic forces produced on the bearings when the shaft rotates at 300 r.p.m.

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In Pursuit of Excellence	**Tutorial-7**	SESSION-2019-2020
		SEM-6TH

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Reciprocating balancing				

1. A single cylinder reciprocating engine has speed 240 r.p.m., stroke 300 mm, mass of reciprocating parts 50 kg, mass of revolving parts at 150 mm radius 37 kg. If two third of the reciprocating parts and all the revolving parts are to be balanced, find: **1.** The balance mass required at a radius of 400 mm, and **2.** The residual unbalanced force when the crank has rotated 60° from top dead centre.
2. An inside cylinder locomotive has its cylinder centre lines 0.7 m apart and has a stroke of 0.6 m. The rotating masses per cylinder are equivalent to 150 kg at the crank pin, and the reciprocating masses per cylinder to 180 kg. The wheel centre lines are 1.5 m apart. The cranks are at right angles. The whole of the rotating and 2/3 of the reciprocating masses are to be balanced by masses placed at a radius of 0.6 m. Find the magnitude and direction of the balancing masses.
3. The three cranks of a three cylinder locomotive are all on the same axle and are set at 120°. The pitch of the cylinders is 1 metre and the stroke of each piston is 0.6 m. The reciprocating masses are 300 kg for inside cylinder and 260 kg for each outside cylinder and the planes of rotation of the balance masses are 0.8 m from the inside crank. If 40% of the reciprocating parts are to be balanced, find : **1.** the magnitude and the position of the balancing masses required at a radius of 0.6 m ; and the hammer blow per wheel when the axle makes 6 r.p.s.

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In Pursuit of Excellence	**Tutorial-8**	SESSION-2019-2020 SEM-6TH

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Governor				

1. The arms of a Porter governor are each 250 mm long and pivoted on the governor axis. The mass of each ball is 5 kg and the mass of the central sleeve is 30 kg. The radius of rotation of the balls is 150 mm when the sleeve begins to rise and reaches a value of 200 mm for maximum speed. Determine the speed range of the governor. If the friction at the sleeve is equivalent of 20 N of load at the sleeve, determine how the speed range is modified.
2. A Proell governor has equal arms of length 300 mm. The upper and lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 80 mm long and parallel to the axis when the radii of rotation of the balls are 150 mm and 200 mm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. Determine the range of speed of the governor.
3. A Hartnell governor having a central sleeve spring and two right-angled bell crank levers moves between 290 r.p.m. and 310 r.p.m. for a sleeve lift of 15mm. The sleeve arms and the ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine: 1. loads on the spring at the lowest and the highest equilibrium speeds, and 2. stiffness of the spring.

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In Pursuit of Excellence	**Tutorial-9**	SESSION-2019-2020 SEM-6TH

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	brakes				

1. 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 $\mu = 0.05$.

2. A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brake provides a braking torque of 225 N-m. One end of the band is attached to a fulcrum pin of the lever and the other end to a pin 100 mm from the fulcrum. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0 .25, find the operating force when the drum rotates in the (a) anticlockwise direction, and (b) clockwise direction.

3. A car moving on a level road at a speed 50 km/h has a wheel base 2.8 metres, distance of C.G. from ground level 600 mm, and the distance of C.G. from rear wheels 1.2 metres. Find the distance travelled by the car before coming to rest when brakes are applied, 1. to the rear wheels, 2. to the front wheels, and 3. to all the four wheels. The coefficient of friction between the tyres and the road may be taken as 0.6.

4. A vehicle moving on a rough plane inclined at 10° with the horizontal at a speed of 36 km/h has a wheel base 1.8 metres. The centre of gravity of the vehicle is 0.8 metre from the rear wheels and 0.9 metre above the inclined plane. Find the distance travelled by the vehicle before coming to rest and the time taken to do so when 1. The vehicle moves up the plane, and 2. The vehicle moves down the plane. The brakes are applied to all the four wheels and the coefficient of friction is 0.5.

(Ganesh Chetry)
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In Pursuit of Excellence	Tutorial-10	SESSION-2019-2020
		SEM-6TH

Sr. No.	No. of Periods	Topics/Sub Topics	Coverage Date			Sign
			Batch A	Batch B		
1.	1	Brake & dynamometer				

1. The wheel base of a car is 3 metres and its centre of gravity is 1.2 metres ahead the rear axle and 0.75 m above the ground level. The coefficient of friction between the wheels and the road is 0.5. Determine the maximum deceleration of the car when it moves on a level road, if the braking force on all the wheels is the same and no wheel slip occurs.
2. In a laboratory experiment, the following data were recorded with rope brake: Diameter of the flywheel 1.2 m; diameter of the rope 12.5 mm; speed of the engine 200 r.p.m.; dead load on the brake 600 N; spring balance reading 150 N. Calculate the brake power of the engine.
3. The essential features of a transmission dynamometer are shown in Fig. 19.35. A is the driving pulley which runs at 600 r.p.m. B and C are jockey pulleys mounted on a, horizontal beam pivoted at D, about which point the complete beam is balanced when at rest. E is the driven pulley and all portions of the belt between the pulleys are vertical. A, B and C are each 300 mm diameter and the thickness and weight of the belt are neglected. The length DF is 750 mm. Find : **1.** the value of the weight W to maintain the beam in a horizontal position when 4.5 kW is being transmitted, and **2.** the value of W, when the belt just begins to slip on pulley A. The coefficient of friction being 0.2 and maximum tension in the belt 1.5 kN.

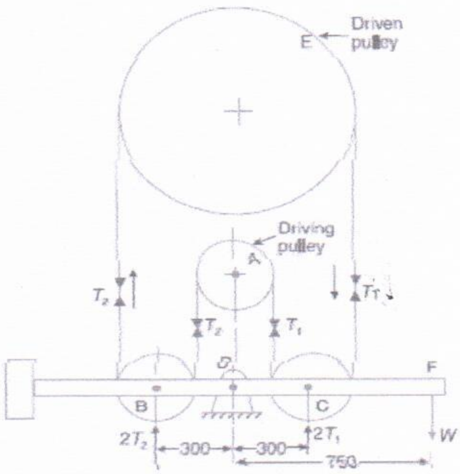

Fig. 19.35. All dimensions in mm.

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In Pursuit of Excellence	Assignment -1	SESSION-2019-2020
		SEM-6TH

1. If the crank and the connecting rod are 300 mm and 1 m long respectively and the crank rotates at a constant speed of 200 r.p.m., determine:1. The crank angle at which the maximum velocity occurs, and 2. Maximum velocity of the piston.

2. The crank-pin circle radius of a horizontal engine is 300 mm. The mass of the reciprocating parts is 250 kg. When the crank has travelled 60° from I.D.C., the difference between the driving and the back pressures is 0.35 N/mm2. The connecting rod length between centres is 1.2 m and the cylinder bore is 0.5 m. If the engine runs at 250 r.p.m. and if the effect of piston rod diameter is neglected, calculate : 1. pressure on slide bars, 2. thrust in the connecting rod, 3. tangential force on the crank-pin, and 4. turning moment on the crank shaft.

3. A connecting rod is suspended from a point 25 mm above the centre of small end, and 650 mm above its centre of gravity, its mass being 37.5 kg. When permitted to oscillate, the time period is found to be 1.87 seconds. Find the dynamical equivalent system constituted of two masses, one of which is located at the small end centre.

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In Pursuit of Excellence	**Assignment -2**	SESSION-2019-2020
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1. The following data relate to a connecting rod of a reciprocating engine:

   Mass = 55 kg; Distance between bearing centres = 850 mm; Diameter of small end bearing = 75 mm; Diameter of big end bearing = 100 mm; Time of oscillation when the connecting rod is suspended from small end = 1.83 s; Time of oscillation when the connecting rod is suspended from big end = 1.68 s.

   Determine: 1. the radius of gyration of the rod about an axis passing through the centre of gravity and perpendicular to the plane of oscillation; 2. the moment of inertia of the rod about the same axis; and 3. the dynamically equivalent system for the connecting rod, constituted of two masses, one of which is situated at the small end centre.

2. A connecting rod of an I.C. engine has a mass of 2 kg and the distance between the centre of gudgeon pin and centre of crank pin is 250 mm. The C.G. falls at a point 100 mm from the gudgeon pin along the line of centres. The radius of gyration about an axis through the C.G. perpendicular to the plane of rotation is 110 mm. Find the equivalent dynamical system if only one of the masses is located at gudgeon pin.
   If the connecting rod is replaced by two masses, one at the gudgeon pin and the other at the crank pin and the angular acceleration of the rod is 23 000 rad/s2 clockwise, determine the correction couple applied to the system to reduce it to a dynamically equivalent system.

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In Pursuit of Excellence	**Assignment -3**	SESSION-2020-2021 SEM-6TH

1. The mass of flywheel of an engine is 6.5 tonnes and the radius of gyration is 1.8 metres. It is found from the turning moment diagram that the fluctuation of energy is 56 kN-m. If the mean speed of the engine is 120 r.p.m., find the maximum and minimum speeds.
2. The turning moment diagram for a petrol engine is drawn to the following scales : Turning moment, 1 mm = 5 N-m ; crank angle, 1 mm = 1°. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295, 685, 40, 340, 960, 270 mm2. The rotating parts are equivalent to a mass of 36 kg at a radius of gyration of 150 mm. Determine the coefficient of fluctuation of speed when the engine runs at 1800 r.p.m.
3. The turning moment diagram for a multicylinder engine has been drawn to a scale 1 mm = 600 N-m vertically and 1 mm = 3° horizontally. The intercepted areas between the output torque curve and the mean resistance line, taken in order from one end, are as follows : + 52, – 124, + 92, – 140, + 85, – 72 and + 107 mm2, when the engine is running at a speed of 600 r.p.m. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, find the necessary mass of the flywheel of radius 0.5 m.

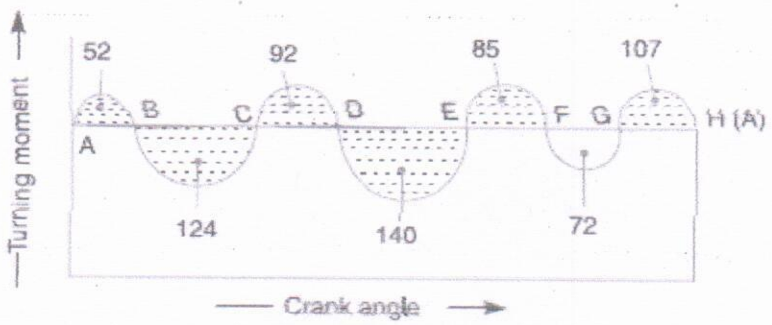

Fig. 16.7

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In Pursuit of Excellence	**Assignment -4**	SESSION-2020-2021
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1. A shaft fitted with a flywheel rotates at 250 r.p.m. and drives a machine. The torque of machine varies in a cyclic manner over a period of 3 revolutions. The torque rises from 750 N-m to 3000 N-m uniformly during 1/2 revolution and remains constant for the following revolution. It then falls uniformly to 750 N-m during the next 1/2 revolution and remains constant for one revolution, the cycle being repeated thereafter. Determine the power required to drive the machine and percentage fluctuation in speed, if the driving torque applied to the shaft is constant and the mass of the flywheel is 500 kg with radius of gyration of 600 mm.

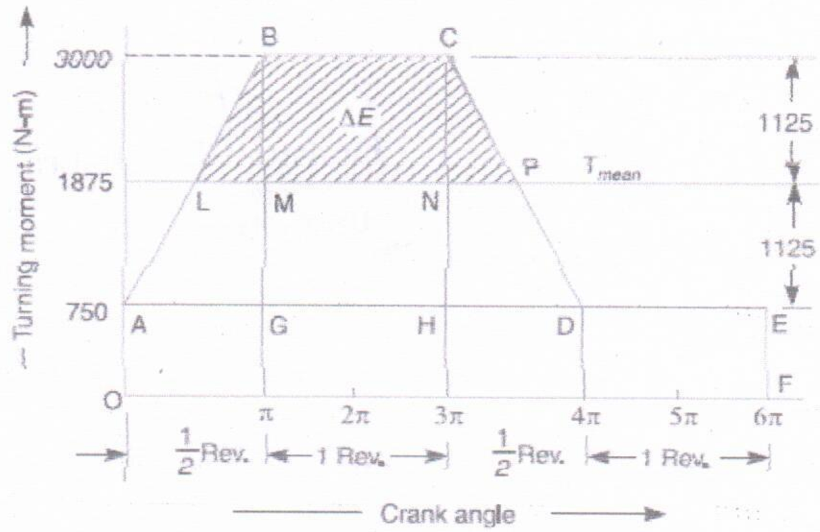

Fig. 16.8

2. *A single cylinder, single acting, four stroke gas engine develops 20 kW at 300 r.p.m. The work done by the gases during the expansion stroke is three times the work done on the gases during the compression stroke, the work done during the suction and exhaust strokes being negligible. If the total fluctuation of speed is not to exceed ± 2 per cent of the mean speed and the turning moment diagram during compression and expansion is assumed to be triangular in shape, find the moment of inertia of the flywheel.*

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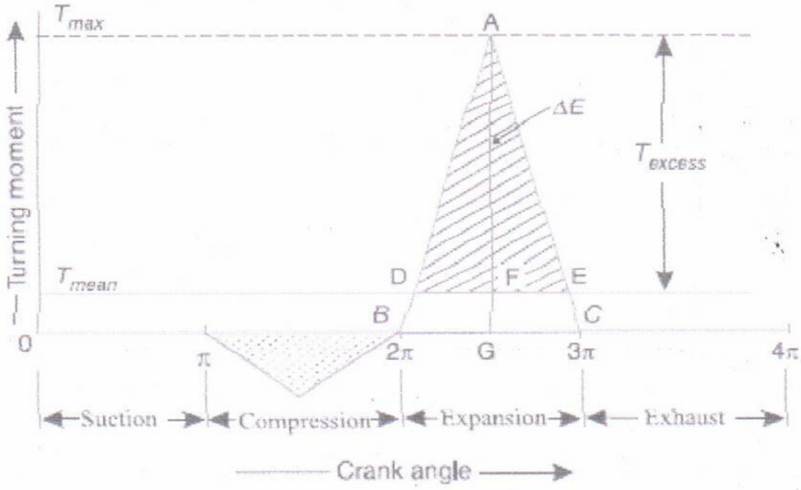

Fig. 16.11

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In Pursuit of Excellence	**ASSIGNMENT - 5**	SESSION-2019-2020 SEM-6TH

Home Assignments

1. Explain clearly the terms 'static balancing' and 'dynamic balancing'. State the necessary conditions to achieve them.
2. Discuss how a single revolving mass is balanced by two masses revolving in different planes
3. Explain the method of balancing of different masses revolving in the same plane.
4. How the different masses rotating in different planes are balanced ?
5. A four mass system having 200kg, 250kg, 150kg, 100 kg revolve at radius 100mm, 120mm, 250mm, 300mm respectively. The angle between successive masses is 45°, 70° and 140°. Find the position and magnitude of balanced masses by graphical and analytical method if radius of rotation is 350mm.
6. A rotating shaft carries four unbalanced masses having magnitude 20kg, 15kg, 17kg and 14kg revolving at radii 60mm, 80mm, 100mm and 60mm respectively. The m2, m3 and m4 revolve in plane 100mm, 180mm and 300mm respectively from the plane of mass m1 are angularly located at 65°, 145° and 270°respectively, measured in anticlockwise direction from the mass m1 looking from the mass end of the shaft. The shaft is to be dynamically balanced by two masses, both located at 70mm radii and revolving in plane midway between m1 & m2 and m3 & m4. Determine the magnitude of balancing masses and their respectively angular position.
7. A shaft is supported between bearing 2.0m apart and extended 0.5m beyond bearing at each end. The shaft carries 3 pulleys one at each end and one at the middle of its length. The masses of end pulleys are 50kg and 25kg and their centre of gravity are 20mm and 15mm respectively from the axis of shaft. The centre pulley has a mass of 60 kg and its centre of gravity is 20mm from the axis of shaft. If the pulleys are arranged so as to give the static balance. Determine:
   (i) The relative angular position of the pulleys, and
   (ii) The dynamics forces produced on the bearings when the shaft rotates at 340 r.p.m.
8. A shaft carries four masses in parallel planes A, B, C and D in this 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 an eccentricity of 80 mm. The angle between the masses at B and C is 100° and that between the masses at B and A is 190°, both being measured in the same direction. The axial distance between the planes A and B is 100 mm and that between B and C is 200 mm. If the shaft is in complete dynamic balance, determine : **1.** The magnitude of the masses at A and D ; **2.** the distance between planes A and D ; and **3.** the angular position of the mass at D.
9. A shaft has three eccentrics, each 75 mm diameter and 25 mm thick, machined in one piece with the shaft. The central planes of the eccentric are 60 mm apart. The distance of the centres from the axis of rotation are 12 mm, 18 mm and 12 mm and their angular positions are 120° apart. The density of metal is 7000 kg/m3. Find the amount of out-of-balance force and couple at 600 r.p.m. If the shaft is balanced by adding two masses at a radius 75 mm and at distances of 100 mm from the central plane of the middle eccentric, find the amount of the masses and their angular positions.

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In Pursuit of Excellence	**ASSIGNMENT -6**	SESSION-2019-2020
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1. Write a short note on primary and secondary balancing.
2. Explain why only a part of the unbalanced force due to reciprocating masses is balanced by revolving mass.
3. Derive the following expressions, for an uncoupled two cylinder locomotive engine : (*a*) Variation is tractive force ; (*b*) Swaying couple ; and (*c*) Hammer blow.
4. 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
5. The following data apply to an outside cylinder uncoupled locomotive : Mass of rotating parts per cylinder = 360 kg ; Mass of reciprocating parts per cylinder = 300 kg ; Angle between cranks = 90° ; Crank radius = 0.3 m ; Cylinder centres = 1.75 m ; Radius of balance masses = 0.75 m ; Wheel centres = 1.45 m. If whole of the rotating and two-thirds of reciprocating parts are to be balanced in planes
of the driving wheels, find : **1.** Magnitude and angular positions of balance masses, **2.** Speed in kilometres per hour at which the wheel will lift off the rails when the load on each driving wheel is 30 kN and the diameter of tread of driving wheels is 1.8 m, and Swaying couple at speed arrived at in **(2)** above.
6. A four cylinder vertical engine has cranks 150 mm long. The planes of rotation of the first, second and fourth cranks are 400 mm, 200 mm and 200 mm respectively from the third crank and their reciprocating masses are 50 kg, 60 kg and 50 kg respectively. Find the mass of the reciprocating parts for the third cylinder and the relative angular positions of the cranks in order that the engine may be in complete primary balance.
7. A four crank engine has the two outer cranks set at 120° to each other, and their reciprocating masses are each 400 kg. The distance between the planes of rotation of adjacent cranks are 450 mm, 750 mm and 600 mm. If the engine is to be in complete primary balance, find the reciprocating mass and the relative angular position for each of the inner cranks. If the length of each crank is 300 mm, the length of each connecting rod is 1.2 m and the speed of rotation is 240 r.p.m., what is the maximum secondary unbalanced force ?
8. The cranks and connecting rods of a 4-cylinder in-line engine running at 1800 r.p.m. are 60 mm and 240 mm each respectively and the cylinders are spaced 150 mm apart. If the cylinders are numbered 1 to 4 in sequence from one end, the cranks appear at intervals of 90° in an end view in the order 1-4-2-3. The reciprocating mass corresponding to each cylinder is 1.5 kg. Determine : **1.** Unbalanced primary and secondary forces, if any, and **2.** Unbalanced primary and secondary couples with reference to central plane of the engine.

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In Pursuit of Excellence	**ASSIGNMENT - 7**	SESSION-2019-2020 SEM-6^{TH}

1. What is the function of a governor ? How does it differ from that of a flywheel ?
2. *State the different types of governors. What is the difference between centrifugal and* inertia type governors ? Why is the former preferred to the latter ?
3. Explain the term height of the governor. Derive an expression for the height in the case of a Watt governor. What are the limitations of a Watt governor ?
4. What are the effects of friction and of adding a central weight to the sleeve of a Watt governor ?
5. Define and explain the following terms relating to governors :
   1. Stability, 2. Sensitiveness, 3. Isochronism, and 4. Hunting.

6. Explain the terms and derive expressions for 'effort' and 'power' of a Porter governor.
7. Prove that the sensitiveness of a Proell governor is greater than that of a Porter governor.
8. 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 minimum and maximum speeds and range of speed of the governor.

9. In an engine governor of the Porter type, the upper and lower arms are 200mm and 250 mm respectively and pivoted on the axis of rotation. The mass of the central load is 15 kg, the mass of each ball is 2 kg and friction of the sleeve together with the resistance of the operating gear is equal to a load of 25 N at the sleeve. If the limiting inclinations of the upper arms to the vertical are 30° and 40°, find, taking friction into account, range of speed of the governor.

10. Porter governor has all four arms 250 mm long. The upper arms are attached on the axis of rotation and the lower arms are attached to the sleeve at a distance of 30 mm from the axis. The mass of each ball is 5 kg and the sleeve has a mass of 50 kg. The extreme radii of rotation are 150 mm and 200 mm. Determine the range of speed of the governor.

11. 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°.

12. A governor of the Proell type has each arm 250 mm long. The pivots of the upper and lower arms are 25 mm from the axis. The central load acting on the sleeve has a mass of 25 kg and the each rotating ball has a mass of 3.2 kg. When the governor sleeve is in mid-position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 175 mm. The vertical height of the governor is 200 mm. If the governor speed is 160 r.p.m. when in mid-position, find : 1. length of the extension link; and 2. tension in the upper arm.

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13. 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.

14. 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.

15. The upper arms of a Porter governor has lengths 350 mm and are pivoted on the axis of rotation. The lower arms has lengths 300 mm and are attached to the sleeve at a distance of 40 mm from the axis. Each ball has a mass of 4 kg and mass on the sleeve is 45 kg. Determine the equilibrium speed for a radius of rotation of 200 mm and find also the effort and power of the governor for 1 per cent speed change.

16. The radius of rotation of the balls of a Hartnell governor is 80 mm at the minimum speed of 300 r.p.m. Neglecting gravity effect, determine the speed after the sleeve has lifted by 60 mm. Also determine the initial compression of the spring, the governor effort and the power. The particulars of the governor are given below:
Length of ball arm = 150mm ; length of sleeve arm = 100mm ; mass of each ball = 4 kg ; and stiffness of the spring = 25 N/mm.

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In Pursuit of Excellence	**ASSIGNMENT - 8**	SESSION-2019-2020
		SEM-6^{TH}

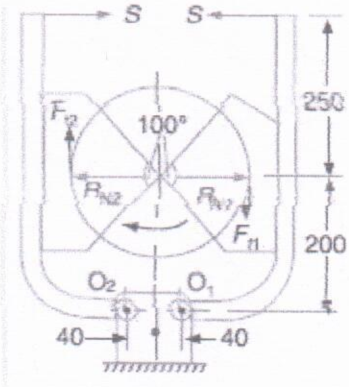
1. Distinguish between brakes and dynamometers.
2. Discuss the various types of the brakes.
3. Show that, in a band and block brake, the ratio of the maximum and minimum tensions in the brake straps is

$$\frac{T_0}{T_n}=\left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n$$

where $T0$ = Maximum tension,
Tn = Minimum tension
μ = Coefficient of friction between the blocks and drum, and
2θ = Angle subtended by each block at the centre of the drum.

4. Describe with the help of a neat sketch the principles of operation of an internal expanding shoe.
Derive the expression for the braking torque.
5. What are the leading and trailing shoes of an internal expanding shoe brake ?

5. A double shoe brake, as shown in Fig. 19.10, is capable of absorbing a torque of 1400 N-m. The diameter of the brake drum is 350 mm and the angle of contact for each shoe is 100°. If the coefficient of friction between the brake drum and lining is 0.4 ; find **1.** the spring force necessary to set the brake ; and **2.** The width of the brake shoes, if the bearing pressure on the lining material is not to exceed 0.3 N/mm2.



All dimensions in mm
Fig. 19.10

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In Pursuit of Excellence	**ASSIGNMENT - 9**	SESSION-2019-2020 SEM-6TH

1. What is the difference between absorption and transmission dynamometers ? What are torsion dynamometers ?

2. Describe the construction and operation of a prony brake or rope brake bsorption dynamometer.

3. Describe with sketches one form of torsion dynamometer and explain with detail the calculations involved in finding the power transmitted

4. A simple band brake operates on a drum of 600 mm in diameter that is running at 200 r.p.m. The coefficient of friction is 0.25. The brake band has a contact of 270°, one end is fastened to a fixed pin and the other end to the brake arm 125 mm from the fixed pin. The straight brake arm is 750 mm long and placed perpendicular to the diameter that bisects the angle of contact.

1. What is the pull necessary on the end of the brake arm to stop the wheel if 35 kW is being absorbed ? What is the direction for this minimum pull ?

2. What width of steel band of 2.5 mm thick is required for this brake if the maximum tensile stress is not to exceed 50 N/mm2 ?

5. In a winch, the rope supports a load W and is wound round a barrel 450 mm diameter. A differential band brake acts on a drum 800 mm diameter which is keyed to the same shaft as the barrel. The two ends of the bands are attached to pins on opposite sides of the fulcrum of the brake lever and at distances of 25 mm and 100 mm from the fulcrum. The angle of lap of the brake band is 250° and the coefficient of friction is 0.25. What is the maximum load W which can be supported by the brake when a force of 750 N is applied to the lever at a distance of 3000 mm from the fulcrum ?

6. A band and block brake, having 14 blocks each of which subtends an angle of 15° at the centre, is applied to a drum of 1 m effective diameter. The drum and flywheel mounted on the same shaft has a mass of 2000 kg and a combined radius of gyration of 500 mm. The two ends of the band are attached to pins on opposite sides of the brake lever at distances of 30 mm and 120 mm from the fulcrum. If a force of 200 N is applied at a distance of 750 mm from the fulcrum, find:

1. maximum braking torque, **2.** angular retardation of the drum, and **3.** time taken by the system to come to rest from the rated speed of 360 r.p.m.

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In Pursuit of Excellence	ASSIGNMENT - 10	SESSION-2019-2020
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1. Define 'inertia force' and 'inertia torque'.

2. How are velocity and acceleration of the slider of a single slider crank chain determined analytically?

3. Derive an expression for the inertia force due to reciprocating mass in reciprocating engine, neglecting the mass of the connecting rod.

4. What is the difference between piston effort, crank effort and crank-pin effort?

5. Discuss the method of finding the crank effort in a reciprocating single acting, single cylinder petrol engine.

6. The inertia of the connecting rod can be replaced by two masses concentrated at two points and connected rigidly together. How to determine the two masses so that it is dynamically equivalent to the connecting rod ? Show this.

7. Given acceleration image of a link. Explain how dynamical equivalent system can be used to determine the direction of inertia force on it.

8. Describe the graphical and analytical method of finding the inertia torque on the crankshaft of a horizontal reciprocating engine.

9. Derive an expression for the correction torque to be applied to a crankshaft if the connecting rod of a reciprocating engine is replaced by two lumped masses at the piston pin and the crank pin respectively.

10. The crank and connecting rod of a steam engine are 0.3 m and 1.5 m in length. The crank rotates at 180 r.p.m. clockwise. Determine the velocity and acceleration of the piston when the crank is at 40 degrees from the inner dead centre position. Also determine the position of the crank for zero acceleration of the piston.

11. In a slider crank mechanism, the length of the crank and connecting rod are 150 mm and 600 mm respectively. The crank position is 60° from inner dead centre. The crank shaft speed is 450 r.p.m. (clockwise). Using analytical method, determine: 1. Velocity and acceleration of the slider, and 2. Angular velocity and angular acceleration of the connecting rod.

12. A vertical double acting steam engine has a cylinder 300 mm diameter and 450 mm stroke and runs at 200 r.p.m. The reciprocating parts has a mass of 225 kg and the piston rod is 50 mm diameter. The connecting rod is 1.2 m long. When the crank has turned through 125° from the top dead centre, the steam pressure above the piston is 30 kN/m2 and below the piston is 1.5 kN/m2. Calculate the effective turning moment on the crank shaft.

13. The crank and connecting rod of a petrol engine, running at 1800 r.p.m.are 50 mm and 200 mm respectively. The diameter of the piston is 80 mm and the mass of the reciprocating parts is 1 kg. At a point during the power stroke, the pressure on the piston is 0.7 N/mm2, when it has moved 10 mm from the inner dead centre. Determine : **1.** Net load on the gudgeon pin, **2.** Thrust in the connecting rod, **3.** Reaction between the piston and cylinder, and **4.** The engine speed at which the above values become zero.

14. A vertical petrol engine 100 mm diameter and 120 mm stroke has a connecting rod 250 mm long. The mass of the piston is 1.1 kg. The speed is 2000 r.p.m. On the expansion stroke with a crank 20° from top dead centre, the gas pressure is 700 kN/m2.

Determine:**1.** Net force on the piston, **2.** Resultant load on the gudgeon pin,

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In Pursuit of Excellence	**List of Students**	SESSION-2019-2020 SEM-6TH

Moradabad Institute of Technology

Ram Ganga Vihar, Phase-II, Moradabad

3RD Year 6TH Semester Batch 2017

Mechanical Engineering Section E

S.No.	Roll No.	Name of Students
1.	1708240001	AATIF KHAN
2.	1708240002	ABDUL KABIR
3.	1708240003	ABHINAV GUPTA
4	1708240004	ABHINAV KUMAR
5.	1708240005	ABHISHEK CHANDRA
6.	1708240006	ADITYA SHARMA
7.	1708240007	AISHVARYA KRISHN
8.	1708240008	AKSHAT DABAS
9.	1708240010	AMAN AGARWAL
10.	1708240011	AMBESH KUMAR PAL
11.	1708240012	ANAS BEIG
12.	1708240013	ANKIT KUMAR GANGWAR
13.	1708240014	ANUJ
14.	1708240015	ANURAG JOSHI
15.	1708240016	ANURAG VASHISHTH
16.	1708240017	ARYAN KUMAR
17.	1708240018	ASHEESH KUMAR
18.	1708240019	ASHUTOSH BHARDWAJ
19.	1708240020	ASHUTOSH KUMAR
20.	1708240021	AYUSH KUMAR
21.	1708240022	AYUSH KUMAR
22.	1708240023	HIMANSHU YADAV
23.	1708240025	KSHITIZ SHIVAM
24.	1708240026	LALIT KUMAR
25.	1708240027	LUCKY KUNAR
26.	1708240028	MANJEET SINGH
27.	1708240030	MOHAMMAD AQIB
28.	1708240031	MOHAMMAD SALMAN
29.	1708240032	MOHAMMAD ZAKI
30.	1708240033	MOHAMMAD AMAAN KHAN
31.	1708240035	MOHD. SAMAD KHAN
32.	1708240036	NITIN TOMAR
33.	1708240037	NITISH PANDEY
34.	1708240038	OSKAR POURYA
35.	1708240039	PRASHANT CHAUDHARY
36.	1708240040	PRATEEK KUMAR
37.	1708240041	RAJVEER SAINI

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38.	1708240042	RASHI
39.	1708240043	RISHABH GOEL
40.	1708240044	RITIK CHANDRA
41.	1708240045	ROHAN SHARMA
42.	1708240046	SAMBHAV SHARMA
43.	1708240047	SANDEEP SHARMA
44.	1708240048	SARTHAK DIXIT
45.	1708240049	SHASHI PRAKASH
46.	1708240050	SHIVAM KUMAR
47.	1708240051	SIDDHANT SHARMA
48.	1708240052	SIDDHARTHA RAJA
49.	1708240053	SIRAJ AHMAD
50.	1708240054	SOURABH KUMAR
51.	1708240055	SUBHASH CHANDRA PANDEY
52.	1708240057	SUNEEL KUMAR
53.	1708240058	TUSHAR GUPTA
54.	1708240059	VIVEK GUPTA
55.	1708240060	VIVEK KUMAR
56.	1708240061	YOGENDRA PAL SINGH
57.	1708240062	ZAEEM UL SAJJAD
58.	1608240066	RAJAT SAINI
59.	1608240067	RAJNISH CHAUHAN
60.	1808240901	GAURAV RATHAUR
61.	1808240902	SHUBHAM

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In Pursuit of Excellence	**Record of Monthly Attendance**	SESSION-2019-2020 SEM-6TH

Attendance Register. Dates From: 21-01-2020 to 15-02-2020						
	Section: E					
Paper Code - RME-602	Course: B.Tech	Year: 3rd				
S. No.	Name	Roll Number	(P)	(A)	Tot.	Tot. (%age)
1	Rajat Saini	1608240066	9	9	18	50
2	Rajnish Chauhan	1608240067	9	9	18	50
3	Aatif Khan	1708240001	8	11	19	42.11
4	Abdul Kabir	1708240002	9	10	19	47.37
5	Abhinav Gupta	1708240003	18	1	19	94.74
6	Abhinav Kumar	1708240004	6	13	19	31.58
7	Abhishek Chandra	1708240005	14	5	19	73.68
8	Aditya Sharma	1708240006	5	14	19	26.32
9	Aishvarya Krishn	1708240007	7	12	19	36.84
10	Akshat Dabas	1708240008	11	8	19	57.89
11	Aman Agarwal	1708240010	1	18	19	5.26
12	Ambesh Kumar Pal	1708240011	15	4	19	78.95
13	Anas Beig	1708240012	8	11	19	42.11
14	Ankit Kumar Gangwar	1708240013	13	6	19	68.42
15	Anuj	1708240014	10	9	19	52.63
16	Anurag Joshi	1708240015	16	3	19	84.21
17	Anuurag Vashishth	1708240016	12	7	19	63.16
18	Aryan Kumar	1708240017	2	17	19	10.53
19	Asheesh Kuumar	1708240018	7	12	19	36.84
20	Ashutosh Bhardwaj	1708240019	14	5	19	73.68
21	Ashutosh Kumar	1708240020	12	7	19	63.16
22	Ayush Kumar	1708240021	13	6	19	68.42
23	Ayush Kumar	1708240022	16	3	19	84.21
24	Himanshu Yadav	1708240023	16	3	19	84.21
25	Kshitiz Shivam	1708240025	9	10	19	47.37
26	Lalit Kumar	1708240026	8	11	19	42.11
27	Lucky Kumar	1708240027	16	3	19	84.21
28	Manjeet Singh	1708240028	7	12	19	36.84

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	29	Mohammad Aqib	1708240030	12	7	19	63.16
	30	Mohammad Salman	1708240031	13	6	19	68.42
	31	Mohammad Zaki	1708240032	12	7	19	63.16
	32	Mohd Amaan Khan	1708240033	15	4	19	78.95
	33	Mohd Samad Khan	1708240035	7	9	16	43.75
	34	Nitin Tomar	1708240036	15	3	18	83.33
	35	Nitish Pandey	1708240037	13	5	18	72.22
	36	Oskar Pourya	1708240038	14	4	18	77.78
	37	Prashant Chaudhary	1708240039	17	1	18	94.44
	38	Prateek Kumar	1708240040	9	9	18	50
	39	Rajveer Saini	1708240041	12	6	18	66.67
	40	Rashi	1708240042	13	5	18	72.22
	41	Rishabh Goel	1708240043	16	2	18	88.89
	42	Ritik Chandra	1708240044	12	6	18	66.67
	43	Rohan Sharma	1708240045	15	3	18	83.33
	44	Sambhav Sharma	1708240046	14	4	18	77.78
	45	Sandeep Sharma	1708240047	12	6	18	66.67
	46	Sarthak Dixit	1708240048	10	8	18	55.56
	47	Shashi Prakash	1708240049	14	4	18	77.78
	48	Shivam Kumar	1708240050	15	3	18	83.33
	49	Siddhant Sharma	1708240051	11	7	18	61.11
	50	Siddhartha Raja	1708240052	13	5	18	72.22
	51	Siraj Ahmad	1708240053	13	5	18	72.22
	52	Sourabh Kumar	1708240054	6	12	18	33.33
	53	Subhash Chandra Pandey	1708240055	15	3	18	83.33
	54	Suneel Kumar	1708240057	11	7	18	61.11
	55	Tushar Gupta	1708240058	10	8	18	55.56
	56	Vivek Gupta	1708240059	15	3	18	83.33
	57	Vivek Kumar	1708240060	13	5	18	72.22
	58	Yogendra Pal Singh	1708240061	10	8	18	55.56
	59	Zaeemul Sajjad	1708240062	10	8	18	55.56
	60	Gaurav Rathor	1808240901	11	7	18	61.11
	61	Shubham Shukla	1808240902	10	8	18	55.56

Attendance Register. Dates From: 18-02-2020 to 14-03-2020							
Paper Code - RME-602							
• Course: B.Tech • Year: 3rd • Section: E | Staff Name: Atul Sharma							
S. No.	Name	Student Id	Roll Number	(P)	(A)	Tot.	Tot. (%age)
1	Rajat Saini	1640454	1608240066	4	11	15	26.67
2	Rajnish Chauhan	1640023	1608240067	5	10	15	33.33
3	Aatif Khan	1740093	1708240001	12	3	15	80

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4	Abdul Kabir	1740277	1708240002	11	4	15	73.33
5	Abhinav Gupta	1740133	1708240003	14	1	15	93.33
6	Abhinav Kumar	1740223	1708240004	11	4	15	73.33
7	Abhishek Chandra	1740052	1708240005	11	4	15	73.33
8	Aditya Sharma	1740181	1708240006	11	4	15	73.33
9	Aishvarya Krishn	1740310	1708240007	9	6	15	60
10	Akshat Dabas	1740067	1708240008	10	5	15	66.67
11	Aman Agarwal	1740117	1708240010	11	4	15	73.33
12	Ambesh Kumar Pal	1740329	1708240011	11	4	15	73.33
13	Anas Beig	1740264	1708240012	10	5	15	66.67
14	Ankit Kumar Gangwar	1740106	1708240013	14	1	15	93.33
15	Anuj	1740125	1708240014	10	5	15	66.67
16	Anurag Joshi	1740317	1708240015	12	3	15	80
17	Anuurag Vashishth	1740239	1708240016	13	2	15	86.67
18	Aryan Kumar	1740319	1708240017	6	9	15	40
19	Asheesh Kuumar	1740167	1708240018	12	3	15	80
20	Ashutosh Bhardwaj	1740328	1708240019	11	4	15	73.33
21	Ashutosh Kumar	1740201	1708240020	11	4	15	73.33
22	Ayush Kumar	1740014	1708240021	8	7	15	53.33
23	Ayush Kumar	1740076	1708240022	10	5	15	66.67
24	Himanshu Yadav	1740286	1708240023	13	2	15	86.67
25	Kshitiz Shivam	1740189	1708240025	13	2	15	86.67
26	Lalit Kumar	1740279	1708240026	7	8	15	46.67
27	Lucky Kumar	1740234	1708240027	9	6	15	60
28	Manjeet Singh	1740188	1708240028	7	8	15	46.67
29	Mohammad Aqib	1740080	1708240030	13	2	15	86.67
30	Mohammad Salman	1740141	1708240031	13	2	15	86.67
31	Mohammad Zaki	1740109	1708240032	13	2	15	86.67
32	Mohd Amaan Khan	1740259	1708240033	12	3	15	80
33	Mohd Samad Khan	1740330	1708240035	10	3	13	76.92
34	Nitin Tomar	1740015	1708240036	6	9	15	40
35	Nitish Pandey	1740065	1708240037	13	2	15	86.67
36	Oskar Pourya	1740253	1708240038	11	4	15	73.33
37	Prashant Chaudhary	1740070	1708240039	10	5	15	66.67
38	Prateek Kumar	1740178	1708240040	10	5	15	66.67
39	Rajveer Saini	1740099	1708240041	7	8	15	46.67
40	Rashi	1740124	1708240042	9	6	15	60
41	Rishabh Goel	1740006	1708240043	13	2	15	86.67
42	Ritik Chandra	1740053	1708240044	11	4	15	73.33
43	Rohan Sharma	1740185	1708240045	10	5	15	66.67
44	Sambhav Sharma	1740232	1708240046	9	6	15	60
45	Sandeep Sharma	1740337	1708240047	10	5	15	66.67
46	Sarthak Dixit	1740059	1708240048	12	3	15	80
47	Shashi Prakash	1740288	1708240049	8	7	15	53.33
48	Shivam Kumar	1740017	1708240050	10	5	15	66.67

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49	Siddhant Sharma	1740215	1708240051	11	4	15	73.33
50	Siddhartha Raja	1740127	1708240052	10	5	15	66.67
51	Siraj Ahmad	1740299	1708240053	13	2	15	86.67
52	Sourabh Kumar	1740230	1708240054	2	13	15	13.33
53	Subhash Chandra Pandey	1740258	1708240055	11	4	15	73.33
54	Suneel Kumar	1740157	1708240057	9	6	15	60
55	Tushar Gupta	1740268	1708240058	9	6	15	60
56	Vivek Gupta	1740300	1708240059	11	4	15	73.33
57	Vivek Kumar	1740007	1708240060	11	4	15	73.33
58	Yogendra Pal Singh	1740107	1708240061	13	2	15	86.67
59	Zaeemul Sajjad	1740312	1708240062	9	6	15	60
60	Gaurav Rathor	2184004	1808240901	11	4	15	73.33
61	Shubham Shukla	2184018	1808240902	10	5	15	66.67

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Set-1

Moradabad Institute of Technology
Department of Mechanical Engineering
SESSIONAL TEST 1

Course: B.Tech.
Session: 2019-20
Subject: Theory of Machines
Max. Marks: 20

Semester: 6th
Section: E
Subject Code: RME 602
Time: 1:15 hr.

Q.NO.:	1	2	3	4	5	6
CO NO.:	CO-1	CO-4	CO-1	CO-4	CO-1	CO-4

Section -A

Each question carries 2 marks:

1. Determine the degree of freedom of linkages shown.

2. How the different masses rotating in different planes are balanced? Explain with Fig. with different condition.

Section –B

Each question carries 3 marks:

3. Differentiate between :
   (i) Kinematic chain and Mechanism.
   (ii) Lower pair and Higher pair.
   (iii) fully constraint motion and successfully constrained motion.

4. Derive the following expressions, for an uncoupled two cylinder locomotive engine :
   (*a*) Variation is tractive force : (*b*) Swaying couple : and (*c*) Hammer blow.

Section –C

Each question carries 5 marks:

5. What is instantaneous centre of rotation? Locate all the I-centres of slider crank Mechanism.

6. A shaft is supported between bearing 2.0 m apart and extended 0.5 m beyond bearing at each end. The shaft carries 3 pulleys one at each end and one at the middle of its length. The masses of end pulleys are 50 kg and 25 kg and their centre of gravity are 20 mm and 15 mm respectively from the axis of shaft. The centre pulley has a mass of 60 kg and its centre of gravity is 20 mm from the axis of shaft. If the pulleys are arranged so as to give the static balance. Determine:

   (i) The relative angular position of the pulleys, and

   (ii) The dynamics forces produced on the bearings when the shaft rotates at 340 r.p.m.

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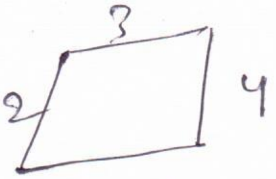
Moradabad - 244001

CT-1 Solution

Ans-1. $f = 3(n-1) - 2j - h$
$= 3 \times 6 - 2 \times 8 = 2$

(b) $f = 3 \times 4 - 2 \times 6$
$= 12 - 12 = 0.$

Ans 2 → → ~~Consti~~ kinematic chain →
(i) Combination of links.



mechanism →
if one link is fixed in the kinematic chain then the ~~mechanism~~ is kinematic chain is called mechanism which are capable of
(ii) motion.

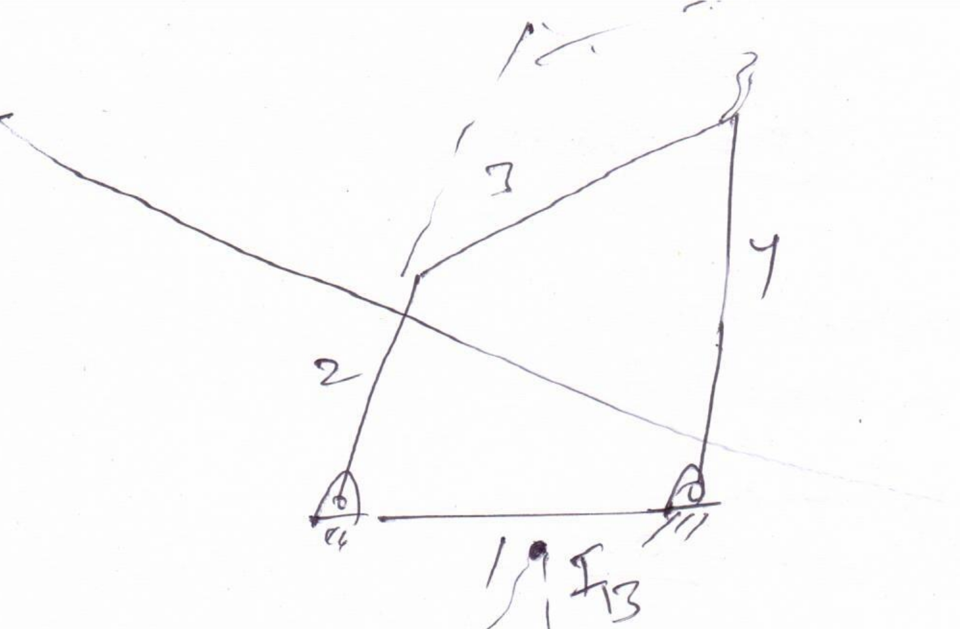
~~Ans~~ Lower Pair → Surface Contact b/w the pair.

Higher pair → point Contact b/w the pairs.

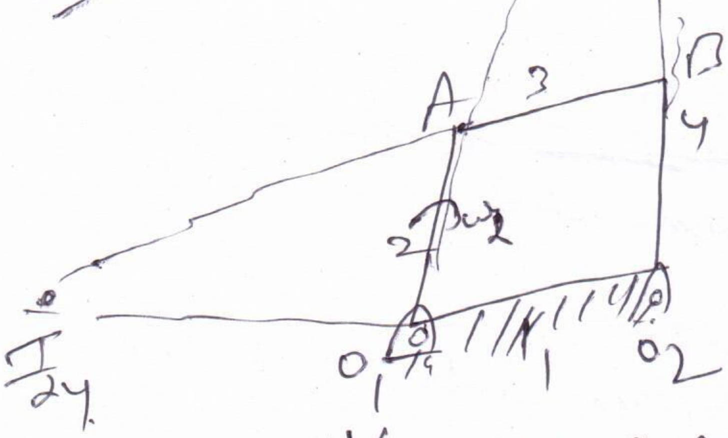
(iii) Fully Constrained motion :→ when motion b/w the pair is limited to a definite direction irrespective of direction of force, and motion is said to be fully Constrained motion.

Successfully Constrained motion :
when the motion b/w Elements, forming a pair is such that Constrained motion is not completely by itself, ~~but~~ but by some other means, then motion is said to be Successfully Constraining motion

Ans



Ans



$V_2 = \omega_2 \times O_1A$

$V_2 = I_{13}A \times O_1A$.

So, $\omega_2 \times O_1A = I_{13}A \times O_1A$

$$\omega_2 = \frac{I_{13}A \times O_1A}{O_1A}$$ Ans

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Moradabad Institute of Technology
Department of Mechanical Engineering
SESSIONAL TEST II

Set-1

Course: B.Tech.
Session: 2019-20
Subject: Theory of Machines

Semester: 6^{th}
Section: E
Subject Code: RME
602

Max. Marks: 20 **Time: 1:15 hr.**

Q.NO.:	**1**	**2**	**3**	**4**	**5**	**6**
CO NO.:	CO-1	CO-4	CO-1	CO-4	CO-1	CO-5

Section -A

Each question carries 2 marks:

1. State and Prove Angular-velocity ratio Theorem.

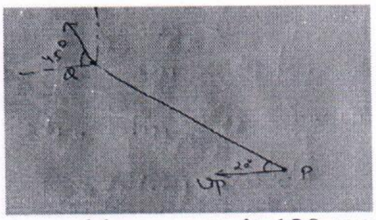
2. Define following terms in governor:

(a) Stability (b) Sensitiveness (c) Isochronism (d) hunting

Section –B

Each question carries 3 marks:

3. A rigid link PQ is 2 m long and oriented at 20^0 to the horizontal as shown in figure. Determine the magnitude of vp (in m/s) at this instant. ***Using I-centre method***



4. In porter governor, the upper and lower arm is 120 mm and 190 mm respectively and pivoted at axis of rotation. The central load is 20 kg and mass of fly-ball is 3kg. The limiting inclination of upper arm from axis of rotation is 30^o and 45^o. Find, Range of speed of the governor when taking friction as 20 N.

Section –C

Each question carries 5 marks:

5. The engine mechanism shown in Fig. has crank OB = 50 mm and length of connecting rod AB=225 mm. The centre of gravity of the rod is at G which is 75 mm from B. The engine speed is 200 r.p.m. For the position shown, in which OB is turned 45° from OA, Find 1. the velocity of G and the angular velocity of AB, and 2. the acceleration of G and angular acceleration of AB using relative velocity method

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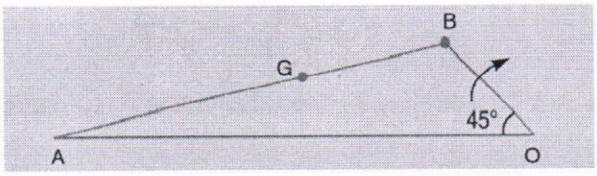
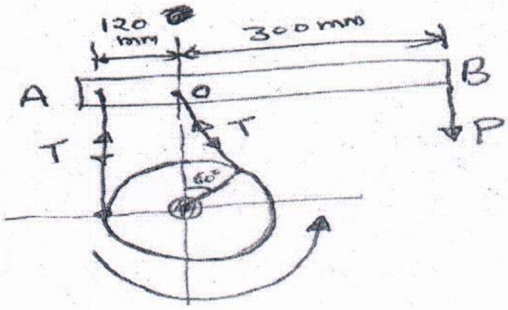


6. In simple band brake as shown in fig., shaft carry a flywheel of mass 400kg and moment of inertia is 81 kg-m^2. The flywheel rotates at 300 rpm. If coefficient of friction is 0.2 and dia. of wheel is 240 mm. Find:

(a) Torque due to load of 100 N

(b) Numbers of turns before it is brought to rest

(c) Time required bringing it to rest.



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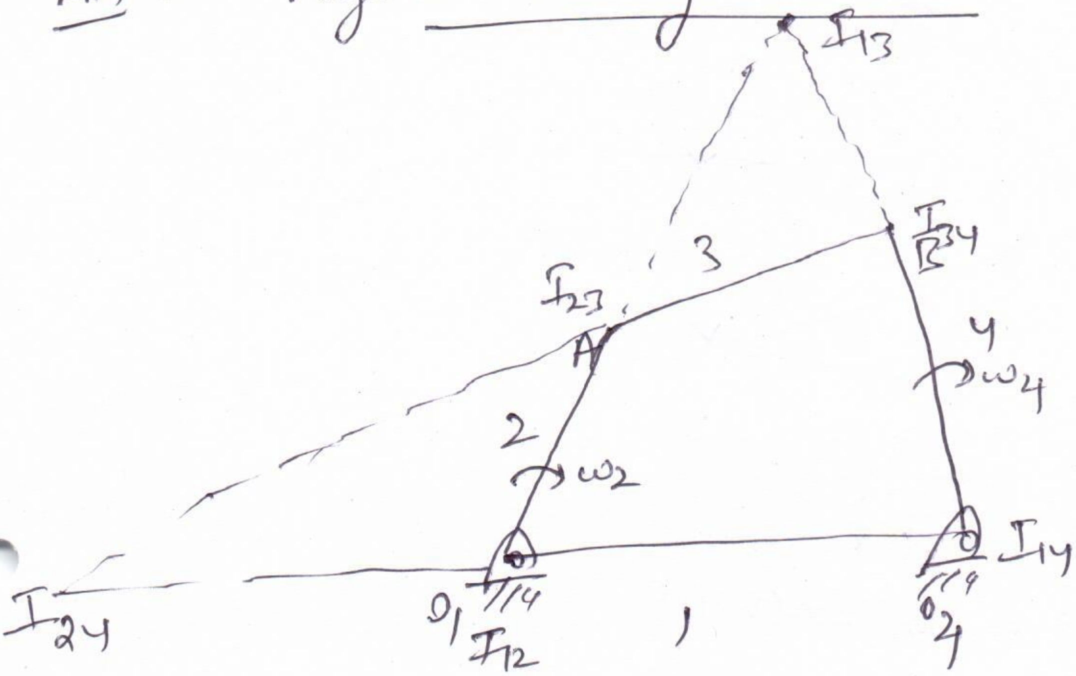
CT-2 Solution

Ans: Angular-Velocity Ratio theorem



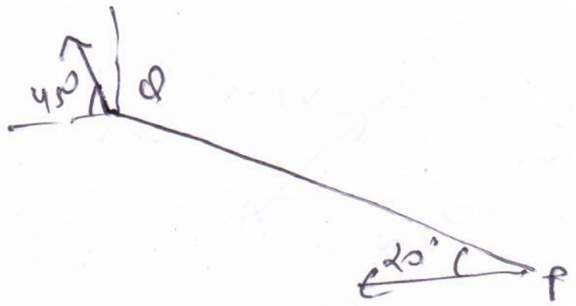
$$V_{I_{24}} = \omega_2 \times O_1A$$

$$V_{I_{24}} = \omega_4 \times I_{24}-I_{14}$$

So $\omega_2 \times O_1A = \omega_4 \times I_{24}-I_{14}$

$$\boxed{\frac{\omega_2}{\omega_4} = \frac{I_{24}-I_{14}}{O_1A}}$$ — Angular-velocity ratio theorem

Ans 3



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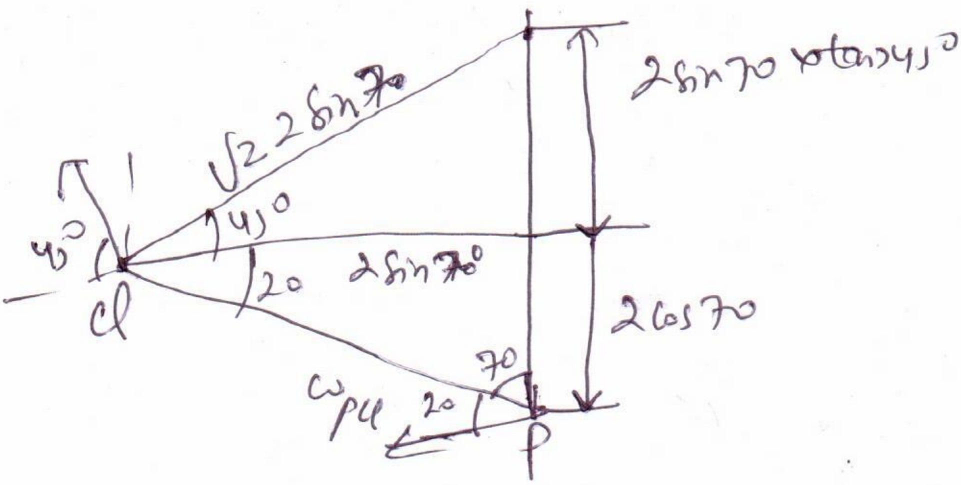


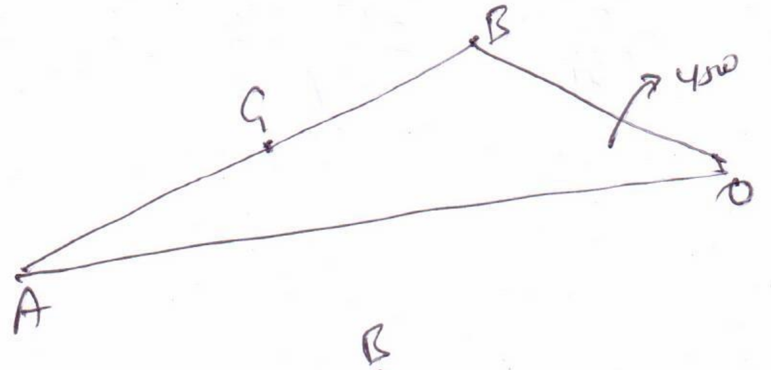
$$\omega_{pq} = \frac{V_p}{P I_{pq}} = \frac{V_q}{Q \cdot I_{pq}}$$

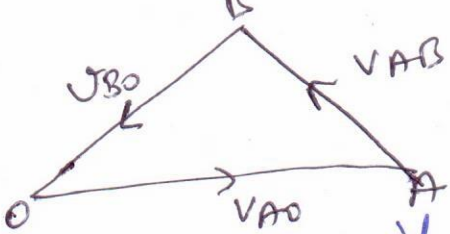
$$P \cdot I_{pq} = 2\cos 70 + 2\sin 70 \times \tan 45^\circ$$

$$Q \cdot I_{pq} = \sqrt{2} \times 2 \sin 70$$

$$\frac{V_p}{2.56} = \frac{1}{2.66} \quad \text{or } V_p = \frac{2.56}{2.66} = 0.96 \text{ m/s.}$$

Ans





– velocity triangle

In Pursuit of Excellence	**Class Test Attendance**	SESSION-2019-2020 SEM-6TH

	THEORY OF MACHINE (RME 602)						**CT 1 MARKS and attendence**		
S.No.	**Roll No.**	**Name of Students**	**Q1 (CO-1)**	**Q2 (CO-4)**	**Q3 (CO-1)**	**Q4 (CO-4)**	**Q5 (CO-1)**	**Q6 (CO-4)**	**TOTAL (20)**
			2	**2**	**3**	**3**	**5**	**5**	
1.	1708240001	AATIF KHAN							D
2.	1708240002	ABDUL KABIR							D
3.	1708240003	ABHINAV GUPTA	0	2	3	3	1	2	**11**
	1708240004	ABHINAV KUMAR							D
5.	1708240005	ABHISHEK CHANDRA	1	2	2	3	2	1	**11**
6.	1708240006	ADITYA SHARMA							D
7.	1708240007	AISHVARYA KRISHN							D
8.	1708240008	AKSHAT DABAS	0	2	3	2.5	0	0	**7.5**
9.	1708240010	AMAN AGARWAL							D
10.	1708240011	AMBESH KUMAR PAL	0	1	2.5	2	4	1	**10.5**

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11.	1708240 012	ANAS BEIG							D
12.	1708240 013	ANKIT KUMAR GANGWAR	1	2	2	2.5	1	2	**10.5**
13.	1708240 014	ANUJ							D
14.	1708240 015	ANURAG JOSHI	1	1.5	2	2.5	1	2	**10**
15.	1708240 016	ANURAG VASHISHTH							D
16.	1708240 017	ARYAN KUMAR							D
17.	1708240 018	ASHEESH KUMAR							D
18.	1708240 019	ASHUTOSH BHARDWAJ	1	1.5	1			0	**3.5**
19.	1708240 020	ASHUTOSH KUMAR	1	2	2	3	1		**9**
20.	1708240 021	AYUSH KUMAR							D
21.	1708240 022	AYUSH KUMAR	1		1	3			**5**
22.	1708240 023	HIMANSHU YADAV	1	1.5	2	1		0	**5.5**
23.	1708240 025	KSHITIZ SHIVAM							D
24.	1708240 026	LALIT KUMAR							D
25.	1708240 027	LUCKY KUNAR	1		2	1.5	0	0	**4.5**
26.	1708240 028	MANJEET SINGH							D
27.	1708240 030	MOHAMMAD AQIB							D
28.	1708240	MOHAMMAD							D

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	031	SALMAN							
29.	1708240 032	MOHAMMAD ZAKI							D
30.	1708240 033	MOHAMMAD AMAAN KHAN	1	2	3	2.5	4	2	**14.5**
31.	1708240 035	MOHD. SAMAD KHAN							D
32.	1708240 036	NITIN TOMAR	1	2	2	2.5	0.5		**8**
33.	1708240 037	NITISH PANDEY							D
34.	1708240 038	OSKAR POURYA	1	1.5	2	0	0	0	**4.5**
35.	1708240 039	PRASHANT CHAUDHARY	1	0	2	3	4		**10**
36.	1708240 040	PRATEEK KUMAR							D
37.	1708240 041	RAJVEER SAINI	0	1	0	0			**1**
38.	1708240 042	RASHI	1	2	3	2.5	4	1	**13.5**
39.	1708240 043	RISHABH GOEL	1	1.5	3	3	5	1	**14.5**
40.	1708240 044	RITIK CHANDRA	0				0		**0**
41.	1708240 045	ROHAN SHARMA	0		1			0.5	**1.5**
42.	1708240 046	SAMBHAV SHARMA							D
43.	1708240 047	SANDEEP SHARMA							D
44.	1708240 048	SARTHAK DIXIT							D
45.	1708240 049	SHASHI PRAKASH	1		2.5		0	1	**4.5**

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46.	1708240 050	SHIVAM KUMAR	1		1	1	0	0	**3**
47.	1708240 051	SIDDHANT SHARMA	0	1.5	2	2.5	1	1	**8**
48.	1708240 052	SIDDHARTHA RAJA							D
49.	1708240 053	SIRAJ AHMAD							D
50.	1708240 054	SOURABH KUMAR							D
51.	1708240 055	SUBHASH CHANDRA PANDEY	1	0	2		2	1	**6**
52.	1708240 057	SUNEEL KUMAR							D
53.	1708240 058	TUSHAR GUPTA							D
54.	1708240 059	VIVEK GUPTA	0		1	1	0	0	**2**
55.	1708240 060	VIVEK KUMAR							D
56.	1708240 061	YOGENDRA PAL SINGH							D
57.	1708240 062	ZAEEM UL SAJJAD							D
58.	1608240 066	RAJAT SAINI							D
59.	1608240 067	RAJNISH CHAUHAN							D
60.	1808240 901	GAURAV RATHAUR	0		1.5	1	0		**2.5**
61.	1808240 902	SHUBHAM							0

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Paper Code: RME-602 - (Theory of Machines), Course - B.Tech, Sem - 6, Section - E

Sessional Name: CT-02 (Even Sem)

S. No.	Student Id	Roll No.	Name	Max. Marks						Total	Per.
				Q.1	Q.2	Q.3	Q.4	Q.5	Q.6		(%)
				2	2	3	3	5	5	20	
1	1640454	1608240066	Rajat Saini	1	2	1	2	4	2.5	12.5	62.5
2	1640023	1608240067	Rajnish Chauhan	2	2	2	2	2	2.5	12.5	62.5
3	1740093	1708240001	Aatif Khan	2	2	3	2	4	2.5	15.5	77.5
4	1740277	1708240002	Abdul Kabir	1	2	2	3	4	2.5	14.5	72.5
5	1740133	1708240003	Abhinav Gupta	2	2	2	3	5	4	18	90
6	1740223	1708240004	Abhinav Kumar	2	2	2	2	5	2.5	15.5	77.5
7	1740052	1708240005	Abhishek Chandra	2	2	2	2	4	2.5	14.5	72.5
8	1740181	1708240006	Aditya Sharma	2	2	2	2	3	2.5	13.5	67.5
9	1740310	1708240007	Aishvarya Krishn	2	2	2	2	3	2.5	13.5	67.5
10	1740067	1708240008	Akshat Dabas	2	2	2	3	3	2.5	14.5	72.5
11	1740117	1708240010	Aman Agarwal	2	2	1	2	4	2.5	13.5	67.5
12	**1740329**	**1708240011**	**Ambesh Kumar Pal**	**2**	**2**	**3**	**2.5**	**0**	**5**	**9.5**	**47.5**
13	**174026**	**17082400**	**Anas Beig**	**1**	**2**	**2**	**2**	**0**	**0**	**4**	**20**

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	4	12									
14	1740106	1708240013	Ankit Kumar Gangwar	2	2	2	2	3	2.5	13.5	67.5
15	1740125	1708240014	Anuj	2	2	1	1.5	2	2.5	11	55
16	1740317	1708240015	Anurag Joshi	1	2	3	2	4	2.5	14.5	72.5
17	1740239	1708240016	Anuurag Vashishth	2	2	2	3	5	2.5	16.5	82.5
18	1740319	1708240017	Aryan Kumar	2	2	2	2	3	2.5	13.5	67.5
19	1740167	1708240018	Asheesh Kuumar	1	2	2	2	3	2.5	12.5	62.5
20	1740328	1708240019	Ashutosh Bhardwaj	1	2	2	2	3	2.5	12.5	62.5
21	1740201	1708240020	Ashutosh Kumar	2	2	2	2	3	2.5	13.5	67.5
22	1740014	1708240021	Ayush Kumar	2	2	2	2	3	2.5	13.5	67.5
23	1740076	1708240022	Ayush Kumar	2	2	2	2	3	2.5	13.5	67.5
24	1740286	1708240023	Himanshu Yadav	1	2	2	2	3	2.5	12.5	62.5
25	1740189	1708240025	Kshitiz Shivam	2	1.5	2	2	3	2.5	13	65
26	1740279	1708240026	Lalit Kumar	2	2	2	2	2	2.5	12.5	62.5
27	1740234	1708240027	Lucky Kumar	2	2	2	1.5	3	2.5	13	65
28	1740188	1708240028	Manjeet Singh	1	2	1	2	2	2.5	10.5	52.5
29	1740080	1708240030	Mohammad Aqib	2	2	3	3	4	4.5	18.5	92.5
30	1740141	1708240031	Mohammad Salman	1	2	3	3	3	3.5	15.5	77.5

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31	1740109	1708240032	Mohammad Zaki	1	2	2	3	4	4.5	16.5	82.5
32	1740259	1708240033	Mohd Amaan Khan	2	2	2	3	5	2.5	16.5	82.5
33	1740330	1708240035	Mohd Samad Khan	2	2	2	2.5	3	2.5	14	70
34	1740015	1708240036	Nitin Tomar	2	2	2	3	4	2.5	15.5	77.5
35	1740065	1708240037	Nitish Pandey	1	2	2	2	4	2.5	13.5	67.5
36	1740253	1708240038	Oskar Pourya	1	2	1	2	4	2.5	12.5	62.5
37	1740070	1708240039	Prashant Chaudhary	2	2	2	3	5	3.5	17.5	87.5
38	1740178	1708240040	Prateek Kumar	2	2	2	3	4	2.5	15.5	77.5
39	**1740099**	**1708240041**	**Rajveer Saini**	**1**	**2**	**1**	**2.5**	**3**	**2.5**	**7**	**35**
40	1740124	1708240042	Rashi	1	2	2	3	3	3	14	70
41	1740006	1708240043	Rishabh Goel	2	2	2	3	5	4	18	90
42	1740053	1708240044	Ritik Chandra	2	2	2	2	4	2.5	14.5	72.5
43	1740185	1708240045	Rohan Sharma	2	2	3	3	0	2.5	12.5	62.5
44	1740232	1708240046	Sambhav Sharma	2	2	2	2	4	2.5	14.5	72.5
45	1740337	1708240047	Sandeep Sharma	2	2	2	2	3	2.5	13.5	67.5
46	1740059	1708240048	Sarthak Dixit	2	2	2	2	2	2.5	12.5	62.5
47	**1740288**	**1708240049**	**Shashi Prakash**	**1**	**2**	**2**	**2.5**	**0**	**4**	**8.5**	**42.5**
48	174001	17082400	Shivam Kumar	2	2	2	2	3	2.	13.5	67.

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	7	50							5		5
49	1740215	1708240051	Siddhant Sharma	2	2	2	2	2	4.5	14.5	72.5
50	1740127	1708240052	Siddhartha Raja	1	2	2	3	1	4.5	13.5	67.5
51	1740299	1708240053	Siraj Ahmad	2	2	2	2	0	0	8	40
52	1740230	1708240054	Sourabh Kumar	2	2	2	2	2	2.5	12.5	62.5
53	1740258	1708240055	Subhash Chandra Pandey	2	2	0	2	4	2.5	12.5	62.5
54	1740157	1708240057	Suneel Kumar							-	-
55	**1740268**	**1708240058**	**Tushar Gupta**	**1**	**2**	**2**	**2**	**3**	**2.5**	**6.5**	**32.5**
56	1740300	1708240059	Vivek Gupta	2	2	2	2	3	2.5	13.5	67.5
57	1740007	1708240060	Vivek Kumar	2	2	3	2	3	4	16	80
58	1740107	1708240061	Yogendra Pal Singh	2	2	2	2	3	2.5	13.5	67.5
59	1740312	1708240062	Zaeemul Sajjad	2	2	2	2	2	2.5	12.5	62.5
60	2184004	1808240901	Gaurav Rathor	2	2	2	2	3	2.5	13.5	67.5
61	2184018	1808240902	Shubham Shukla	2	2	3	2	0	5	14	70

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In Pursuit of Excellence	**List of Students having short attendance**	SESSION-2019-2020 SEM-6TH

1	1608240066	RAJAT SAINI
2	1608240067	RAJNISH CHAUHAN
3	1708240001	AATIF KHAN
4	1708240002	ABDUL KABIR
5	1708240004	ABHINAV KUMAR
6	1708240006	ADITYA SHARMA
7	1708240007	AISHVARYA KRISHN
8	1708240010	AMAN AGARWAL
9	1708240012	ANAS BEIG
10	1708240014	ANUJ
11	1708240016	ANURAG VASHISHTH
12	1708240017	ARYAN KUMAR
13	1708240018	ASHEESH KUMAR
14	1708240021	AYUSH KUMAR
15	1708240025	KSHITIZ SHIVAM
16	1708240026	LALIT KUMAR
17	1708240028	MANJEET SINGH
18	1708240030	MOHAMMAD AQIB
19	1708240031	MOHAMMAD SALMAN
20	1708240032	MOHAMMAD ZAKI
21	1708240035	MOHD. SAMAD KHAN
22	1708240037	NITISH PANDEY
23	1708240040	PRATEEK KUMAR
24	1708240046	SAMBHAV SHARMA
25	1708240047	SANDEEP SHARMA
26	1708240048	SARTHAK DIXIT
27	1708240052	SIDDHARTHA RAJA
28	1708240053	SIRAJ AHMAD
29	1708240054	SOURABH KUMAR
30	1708240057	SUNEEL KUMAR
31	1708240058	TUSHAR GUPTA
32	1708240060	VIVEK KUMAR
33	1708240061	YOGENDRA PAL SINGH
34	1708240062	ZAEEM UL SAJJAD

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In Pursuit of Excellence	**Class Test Marks**	SESSION-2019-2020
		SEM-6TH

Mechanical Engineering **Section E**

THEORY OF MACHINE (RME 602)

CT-1

S.No.	Roll No.	Name of Students	CT-1 (20)
1	1608240066	RAJAT SAINI	D
2	1608240067	RAJNISH CHAUHAN	D
3	1708240001	AATIF KHAN	D
4	1708240002	ABDUL KABIR	D
5	1708240003	ABHINAV GUPTA	11
6	1708240004	ABHINAV KUMAR	D
7	1708240005	ABHISHEK CHANDRA	11
8	1708240006	ADITYA SHARMA	D
9	1708240007	AISHVARYA KRISHN	D
10	1708240008	AKSHAT DABAS	7.5
11	1708240010	AMAN AGARWAL	D
12	1708240011	AMBESH KUMAR PAL	10.5
13	1708240012	ANAS BEIG	D
14	1708240013	ANKIT KUMAR GANGWAR	10.5
15	1708240014	ANUJ	D
16	1708240015	ANURAG JOSHI	10
17	1708240016	ANURAG VASHISHTH	D
18	1708240017	ARYAN KUMAR	D
19	1708240018	ASHEESH KUMAR	D
20	1708240019	ASHUTOSH BHARDWAJ	3.5
21	1708240020	ASHUTOSH KUMAR	9
22	1708240021	AYUSH KUMAR	D

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23	1708240022	AYUSH KUMAR	5
24	1708240023	HIMANSHU YADAV	5.5
25	1708240025	KSHITIZ SHIVAM	D
26	1708240026	LALIT KUMAR	D
27	1708240027	LUCKY KUNAR	4.5
28	1708240028	MANJEET SINGH	D
29	1708240030	MOHAMMAD AQIB	D
30	1708240031	MOHAMMAD SALMAN	D
31	1708240032	MOHAMMAD ZAKI	D
32	1708240033	MOHAMMAD AMAAN KHAN	14.5
33	1708240035	MOHD. SAMAD KHAN	D
34	1708240036	NITIN TOMAR	8
35	1708240037	NITISH PANDEY	D
36	1708240038	OSKAR POURYA	4.5
37	1708240039	PRASHANT CHAUDHARY	10
38	1708240040	PRATEEK KUMAR	D
39	1708240041	RAJVEER SAINI	1
40	1708240042	RASHI	13.5
41	1708240043	RISHABH GOEL	14.5
42	1708240044	RITIK CHANDRA	0
43	1708240045	ROHAN SHARMA	1.5
44	1708240046	SAMBHAV SHARMA	D
45	1708240047	SANDEEP SHARMA	D
46	1708240048	SARTHAK DIXIT	D
47	1708240049	SHASHI PRAKASH	4.5
48	1708240050	SHIVAM KUMAR	3
49	1708240051	SIDDHANT SHARMA	8
50	1708240052	SIDDHARTHA RAJA	D
51	1708240053	SIRAJ AHMAD	D
52	1708240054	SOURABH KUMAR	D
53	1708240055	SUBHASH CHANDRA PANDEY	6
54	1708240057	SUNEEL KUMAR	D
55	1708240058	TUSHAR GUPTA	D
56	1708240059	VIVEK GUPTA	2
57	1708240060	VIVEK KUMAR	D

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58	1708240061	YOGENDRA PAL SINGH	D
59	1708240062	ZAEEM UL SAJJAD	D
60	1808240901	GAURAV RATHAUR	2.5
61	1808240902	SHUBHAM SHUKLA	0

Mechanical Engineering **Section E**

THEORY OF MACHINE (RME 602)

CT-2

S.No.	Roll No.	Name of Students	CT-2 (20)
1	1608240066	RAJAT SAINI	15
2	1608240067	RAJNISH CHAUHAN	15
3	1708240001	AATIF KHAN	18
4	1708240002	ABDUL KABIR	18
5	1708240003	ABHINAV GUPTA	19
6	1708240004	ABHINAV KUMAR	18
7	1708240005	ABHISHEK CHANDRA	19
8	1708240006	ADITYA SHARMA	17
9	1708240007	AISHVARYA KRISHN	17
10	1708240008	AKSHAT DABAS	18
11	1708240010	AMAN AGARWAL	17
12	1708240011	AMBESH KUMAR PAL	18
13	1708240012	ANAS BEIG	14
14	1708240013	ANKIT KUMAR GANGWAR	19
15	1708240014	ANUJ	17
16	1708240015	ANURAG JOSHI	19
17	1708240016	ANURAG VASHISHTH	19
18	1708240017	ARYAN KUMAR	16
19	1708240018	ASHEESH KUMAR	17
20	1708240019	ASHUTOSH BHARDWAJ	18
21	1708240020	ASHUTOSH KUMAR	18
22	1708240021	AYUSH KUMAR	17
23	1708240022	AYUSH KUMAR	18
24	1708240023	HIMANSHU YADAV	17
25	1708240025	KSHITIZ SHIVAM	17
26	1708240026	LALIT KUMAR	16

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27	1708240027	LUCKY KUNAR	18
28	1708240028	MANJEET SINGH	18
29	1708240030	MOHAMMAD AQIB	19
30	1708240031	MOHAMMAD SALMAN	19
31	1708240032	MOHAMMAD ZAKI	19
32	1708240033	MOHAMMAD AMAAN KHAN	19
33	1708240035	MOHD. SAMAD KHAN	16
34	1708240036	NITIN TOMAR	18
35	1708240037	NITISH PANDEY	17
36	1708240038	OSKAR POURYA	17
37	1708240039	PRASHANT CHAUDHARY	19
38	1708240040	PRATEEK KUMAR	17
39	1708240041	RAJVEER SAINI	17
40	1708240042	RASHI	19
41	1708240043	RISHABH GOEL	19
42	1708240044	RITIK CHANDRA	17
43	1708240045	ROHAN SHARMA	17
44	1708240046	SAMBHAV SHARMA	17
45	1708240047	SANDEEP SHARMA	17
46	1708240048	SARTHAK DIXIT	17
47	1708240049	SHASHI PRAKASH	18
48	1708240050	SHIVAM KUMAR	18
49	1708240051	SIDDHANT SHARMA	19
50	1708240052	SIDDHARTHA RAJA	19
51	1708240053	SIRAJ AHMAD	14
52	1708240054	SOURABH KUMAR	16
53	1708240055	SUBHASH CHANDRA PANDEY	18
54	1708240057	SUNEEL KUMAR	16
55	1708240058	TUSHAR GUPTA	16
56	1708240059	VIVEK GUPTA	18
57	1708240060	VIVEK KUMAR	18
58	1708240061	YOGENDRA PAL SINGH	18
59	1708240062	ZAEEM UL SAJJAD	17
60	1808240901	GAURAV RATHAUR	18
61	1808240902	SHUBHAM SHUKLA	17

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In Pursuit of Excellence	**List of Weak Students** (Action taken for Improvement)	SESSION-2019-2020
		SEM-6TH

S.No.	Name of Students	Action Taken
1708240012	ANAS BEIG	• Extra classes were taken • Providing notes and important questions Test conducted separately • A question bank based on the previous years' question papers, is provided to the students for better preparation.
1608240066	RAJAT SAINI	
1708240053	SIRAJ AHMAD	
1608240067	RAJNISH CHAUHAN	
1808240902	SHUBHAM SHUKLA	
1708240054	SOURABH KUMAR	
1708240017	ARYAN KUMAR	
1608240004	AKASH GAUTAM	

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In Pursuit of Excellence	**List of Bright Students** (Action taken for enhancing performance)	SESSION-2019-2020
		SEM-6TH

S.No.	Name of Students	Action taken to enhance the performance
1	ABHINAV GUPTA	Extra material related to GATE exam provided on topic Gears, Velocity Analysis, Vibration. Questions of competitive exam level regularly taught to students. Students are encouraged to enhance their skills by joining NPTEL/MOOC or any other
2	MOHAMMAD ZAKI	
3	ABHISHEK CHANDRA	
4	RASHI	
5	PRASHANT CHAUDHARY	
6	MOHAMMAD SALMAN	
7	MOHAMMAD AMAAN KHAN	
8	ANURAG VASHISHTH	
9	RISHABH GOEL	
10	MOHAMMAD AQIB	
11	SIDDHARTHA RAJA	
12	SIDDHANT SHARMA	

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In Pursuit of Excellence	**Previous Year Question Papers**	SESSION-2019-2020
		SEM-6TH

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Printed Pages: 04 Subject Code:NME502

Paper Id: 140519 Roll No:

BTECH
(SEM V) THEORY EXAMINATION 2018-19
KINEMATICS OF MACHINE

Time: 3 Hours *Total Marks:100*

Notes: *Assume any Missing Data.*

SECTION A

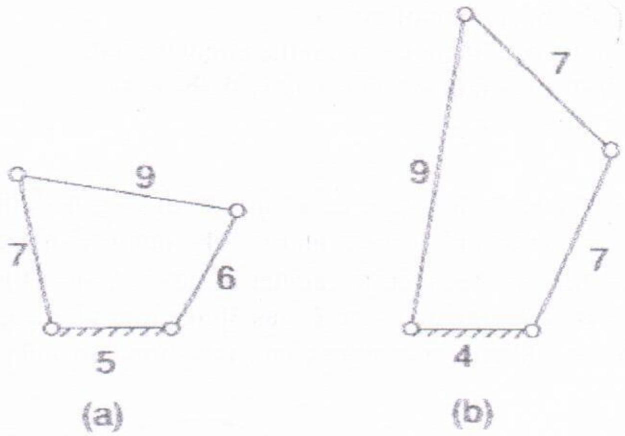
1. Attempt *all* questions in brief. **2 x10 = 20**

a. What is degree of freedom of a mechanism? Explain its importance in brief

b. Two gears having an angular velocity ratio of 3: 1 are mounted on shafts whose centers are 136 mm apart. If the module of the gears is 4 mm, how many teeth are there on each gear?

c. Explain why Ackerman steering gear mechanism is preferred over Davis steering gear mechanism in practice.

d. Figure shows some four link mechanism in which the figure indicate the dimensions in standard units of length .Indicate the type of each mechanism whether crank-rocker or double crank or double rocker.



e. What do you mean by instantaneous Centre? Explain properties of it.

f. In what way a mechanism differs from a machine? Explain with example.

g. Why is a cycloidal motion programme the most suitable for high-speed cams?

h. Draw the polar diagram depicting the salient features of driven shaft speed

i. What do you understand by the term 'interference' as applied to gears?

j. Which of the two assumptions-uniform intensity of pressure or uniform rate of wear, would you make use of in designing friction clutch and why?

SECTION B

2. Attempt any *three* of the following: **10 x 3 = 30**

a. The two shafts of a Hooke's coupling have their axes inclined at 20^0. The shaft *A* revolves at a uniform speed of 1000 rpm. The shaft *B* carries a flywheel of mass 30 kg. If the radius of gyration of the flywheel is 100 mm, find the maximum torque in shaft *B*.

b. Attempt both parts:

I. Explain the working of Hart mechanism with suitable diagram and prove that it will produce straight line motion.

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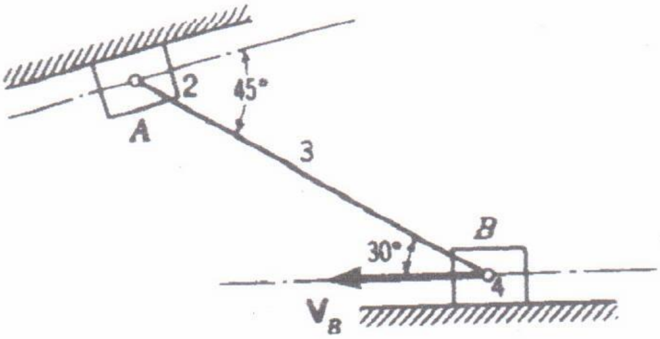
II. The velocity of point B of the linkage shown in the figure is 40 m/s. Find the velocity of point A and angular velocity of link 3



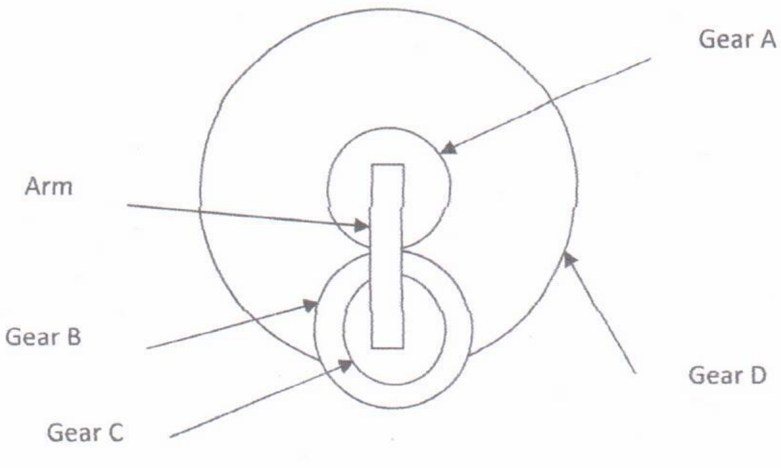
c. The following data relate to a symmetrical circular cam operating a flat-faced follower:

Minimum radius of the cam 40 mm
Lift -24 mm
Angle of lift =75°
Nose radius = 8 mm
Speed of the cam = 420 rpm

Determine the main dimensions of the cam and the acceleration of the follower at:

(i) the beginning of the lift
(ii) the end of contact with the circular flank
(iii) the beginning of contact with the nose
(iv) the apex of nose.

d. Figure shows an epicyclic gear train in which gear A drives the internal gear D through compound gears B and C. The number of teeth on gear A is 20 and center distance between the center of gears A and B is 300 mm. If module of all gears is 10 mm and gear C has 30 teeth, find the speed of gear D. The arm rotates at 600 rpm in counter clockwise direction and gear A is fixed.



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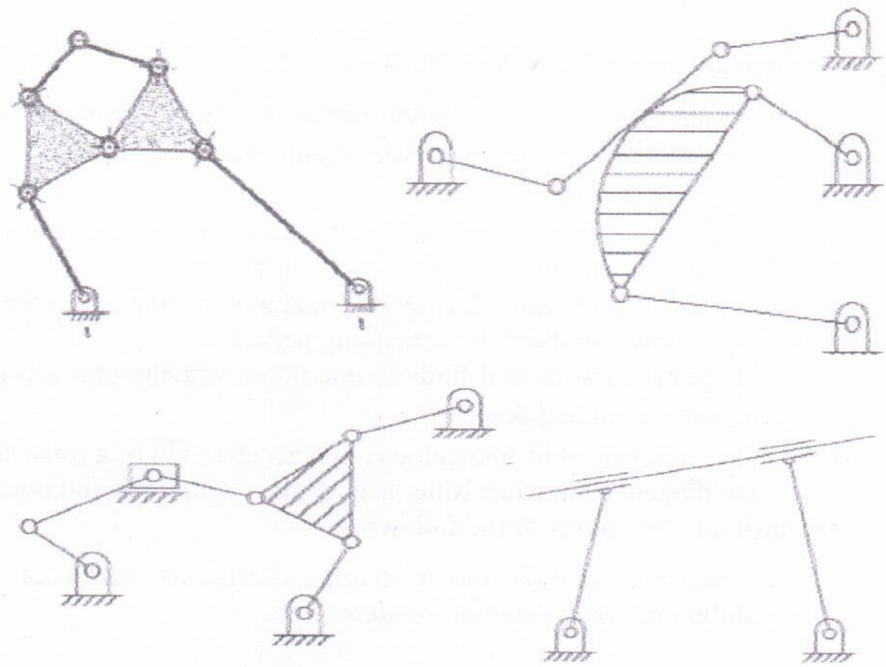
e. Determine the degree of freedom of following cases:



SECTION C

3. Attempt any *two* parts of the following: 5 x 2 = 10

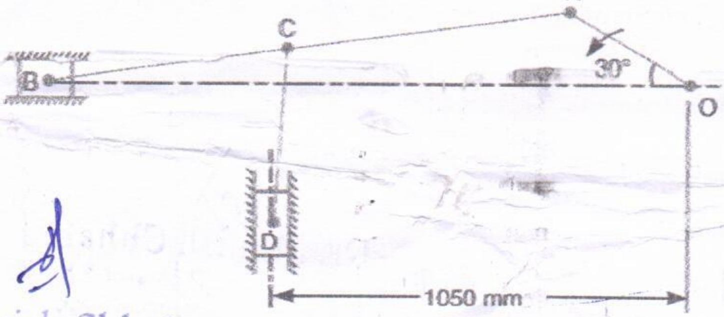
(a) Explain Kennedy's theorem. Also prove that if three bodies are in relative motion with respect to one another, the three-relative instantaneous center of velocity are collinear.

(b) What do you mean by kinematic inversion of mechanism? Explain inversions of double slider chain with neat diagrams.

(c) In a slider crank mechanism, the lengths of the crank and the connecting rod are 200 mm and 800 mm respectively. Locate all I-centers of the mechanism for the position of the crank when it has turned 30^0 from the outer dead center. Also find the velocity of slider and the angular velocity of the connecting rod, if the crank rotates at 40 rad/sec.

4. Attempt any *one* part of the following: 10 x 1 = 10

(a) *In the mechanism, as shown in Figure, the crank OA rotates at 20 r.p.m.* anticlockwise and gives motion to the sliding blocks B and D. The dimensions of the various links are OA = 300 mm; AB = 1200 mm; BC = 450 mm and CD = 450 mm. For the given configuration, Determine : **1.** velocities of sliding at B and D, **2.** Angular velocity of CD, **3.** linear acceleration of D, and **4.** angular acceleration of CD.



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(b) Determine the lengths of the links of a four-bar linkage to generate $y = \log_{10} x$ in the interval $1 \leq x \leq 10$. The length of the smallest link is 5 cm. Use three accuracy points with Chebyshev' spacing.

5. Attempt any *one* part of the following: **10 x 1 = 10**

(a) A cam with 30 mm minimum radius is rotating clockwise at 1200 rpm to give the following motion to a knife edged follower:

Lift = 25 mm
Follower rises during 120^0 cam rotation with constant acceleration motion
Follower to dwell for 60^0 cam rotation
Follower to return during 90^0 rotation with constant velocity
Follower to dwell for remaining period

Draw cam profile and find the maximum velocity and acceleration of follower during ascent and descent.

(b) Derive relations to find velocity and acceleration of a roller follower moving on the tangent cam, when roller is in contact with flank and nose.

6. Attempt any *two* parts of the following: **5 x 2 = 10**

(a) State and prove the law of gearing. Derive an expression for the velocity of sliding between a pair of involute teeth.

(b) Attempt any two of the following:

I. Pressure angle and its importance in case of geared drive
II. Difference between involute and cycloidal profile teeth
III. Different methods to prevent interference in gears

(c) Two mating involute gears of 20^0 pressure angle have a gear ratio of 2. The number of teeth on pinion is 20 and speed is 250 rpm. Take module as 12 mm.

If the addendum on each wheel is such that the path of approach and path of recess on each side are half of the maximum possible length each. Find:

- Addendum for pinion and gear
- Length of arc of contact
- Maximum velocity of sliding

7. Attempt any *two* parts of the following: **5 x 2 = 10**

(a) Derive an expression to calculate the power lost in collar bearing assuming uniform wear theory.

(b) Derive the relation between tension on tight and side of V-belt.

(c) An open belt drive running over two pulleys of diameter 200 mm and 600 mm connects two parallel shafts placed at a distance of 2.5 m. The smaller pulley rotates at 300 rpm and transmits 7.5 kW. The coefficient of friction is 0.3. Determine:

I. Length of belt
II. Initial Tension

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Printed pages: 03 Sub Code: NME502

Paper Id: | 4 | 0 | 4 | 7 | Roll No

B.TECH
(SEM V) THEORY EXAMINATION 2017-18
KINEMATICS OF MACHINES

Time: 3 Hours *Total Marks: 100*

Note: 1. Attempt all Sections. If require any missing data: then choose suitably.

SECTION A

1. Attempt *all* questions in brief. **2 x10= 20**

a. Explain the terms: Lower pair, higher pair, Kinematic chain, and Inversion.

b. Determine the mobility (degrees of freedom) of the mechanism shown in Fig.1

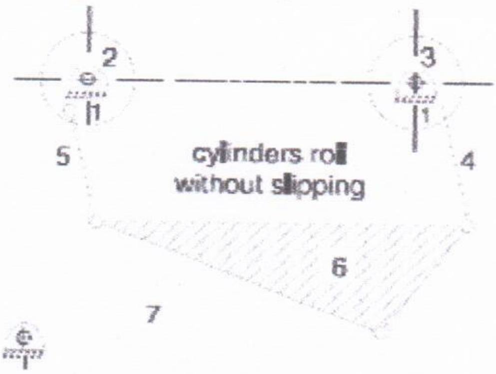

Fig.1

c. Explain, with the help of a neat sketch, the space centrode and body centrode.

d. Explain how the coriolis component of acceleration arises when a point is rotating about some other fixed point and at the same time its distance from the fixed point varies.

e. Give a neat sketch of the straight line motion 'Hart mechanism

f. Which of the two assumptions-uniform intensity of pressure or uniform rate of wear

g. Explain the phenomena of 'slip' and 'creep' in a belt drive.

h. Distinguish between brakes and dynamometers.

i. Define the following terms as applied to cam with a neat sketch:
(*a*) Base circle, (*b*) Pitch circle, (*c*) Pressure angle, and (*d*) Stroke of the follower.

j. State and prove the law of gearing.

SECTION B

2. Attempt any *three* of the following: **10x3 = 30**

a. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centers is 240 mm and the length of the driving crank is 120 mm. Find the inclination of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke. If the length of the slotted bar is 450 mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever.

b. Locate all the instantaneous centers for the crossed four bar mechanism as shown in Fig.2. The dimensions of various links are: $CD = 65$ mm; $CA = 60$ mm; $DB = 80$ mm; and $AB = 55$ mm. Find the angular velocities of the links AB and DB, if the crank CA rotates at 100 r.p.m. in the anticlockwise direction.

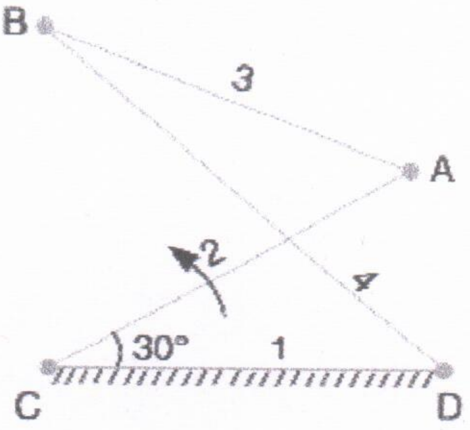

Fig.2

c. In a quick return mechanism, as shown in Fig.3, the driving crank OA is 60 mm long and rotates at a uniform speed of 200 r.p.m. in a clockwise direction. For the position shown, find

1. Velocity of the ram R
2. Acceleration of the ram R, and
3. Acceleration of the sliding block A along the slotted bar CD.

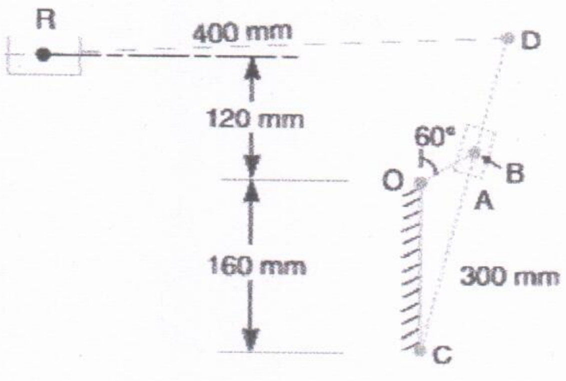

Fig.3

d. A conical pivot bearing 150 mm in diameter has a cone angle of 120°. If the shaft supports an axial load of 20 kN and the coefficient of friction is 0.03, find the power lost in friction when the shaft rotates at 200 r.p.m., assuming 1.Uniform pressure and 2. Uniform wear

e. A simple band brake is operated by a lever of length 500 mm. The brake drum has a diameter of 500 mm and the brake band embraces 5/8 of the circumference. One end of the band is attached to the fulcrum of the lever while the other end is attached to a pin on the lever 100 mm from the fulcrum. If the effort applied to the end of the lever is 2 kN and the coefficient of friction is 0.25, find the maximum braking torque on the drum.

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SECTION C

3. Attempt any *one* part of the following: **10 x 1 = 10**

(a) A toggle press mechanism, as shown in Fig.4, has the dimensions of various links as follows : $OP = 50$ mm ; $RQ = RS = 200$ mm ; $PR = 300$ mm. Find the velocity of S when the crank OP rotates at 60 r.p.m. in the anticlockwise direction. If the torque on P is 115 N-m, what pressure will be exerted at S when the overall efficiency is 60 percent.

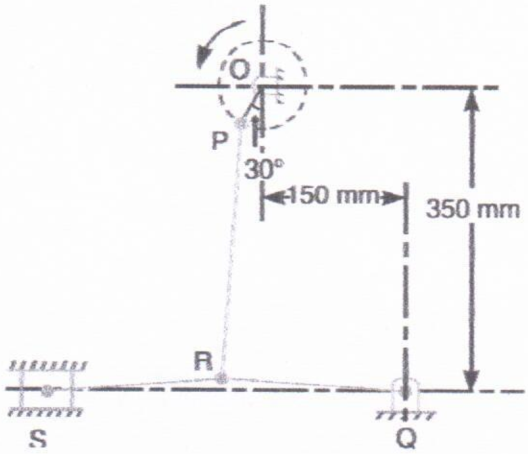

Fig.4

(b) State and prove the 'Aronhold Kennedy's Theorem' of three instantaneous centres.

4. Attempt any *one* part of the following: **10 x1 = 10**

(a) Draw the acceleration diagram of a slider crank mechanism.

(b) A Hooke's joint connects two shafts whose axes intersect at 150°. The driving shaft rotates uniformly at 120 r.p.m. The driven shaft operates against a steady torque of 150 N-m and carries a flywheel whose mass is 45 kg and radius of gyration 150 mm. Find the maximum torque which will be exerted by the driving shaft.

5. Attempt any *one* part of the following: **10 x 1 = 10**

(a) In a screw jack, the helix angle of thread is α and the angle of friction is φ. Show that its efficiency is maximum, when $2\alpha = (90° - \varphi)$.

(b) What is the difference between absorption and transmission dynamometers? What are torsion dynamometers?

6. Attempt any *one* part of the following: **10x 1 = 10**

(a) Draw the profile of a cam with oscillating roller follower for the following motion :

(*a*) Follower to move outwards through an angular displacement of 20° during 120° of cam rotation.

(*b*) Follower to dwell for 50° of cam rotation.

(*c*) Follower to return to its initial position in 90° of cam rotation with uniform acceleration and retardation.

(*d*) Follower to dwell for the remaining period of cam rotation.

The distance between the pivot centre and the roller centre is 130 mm and the distance between the pivot centre and cam axis is 150 mm. The minimum radius of the cam is 80 mm and the diameter of the roller is 50 mm.

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(b) Draw the displacement, velocity and acceleration diagrams for a follower when it moves with simple harmonic motion. Derive the expression for velocity and acceleration during outstroke and return stroke of the follower.

7. Attempt any *one* part of the following: **10 x1 = 10**

(a) A compound epicyclic gear is shown diagrammatically in Fig.5. The gears *A*, *D* and *E* are free to rotate on the axis *P*. The compound gear *B* and *C* rotate together on the axis *Q* at the end of arm *F*. All the gears have equal pitch. The number of external teeth on the gears *A*, *B* and *C* are 18, 45 and 21 respectively. The gears *D* and *E* are annular gears. The gear *A* rotates at 100 r.p.m. in the anticlockwise direction and the gear *D* rotates at 450 r.p.m. clockwise. Find the speed and direction of the arm and the gear *E*.

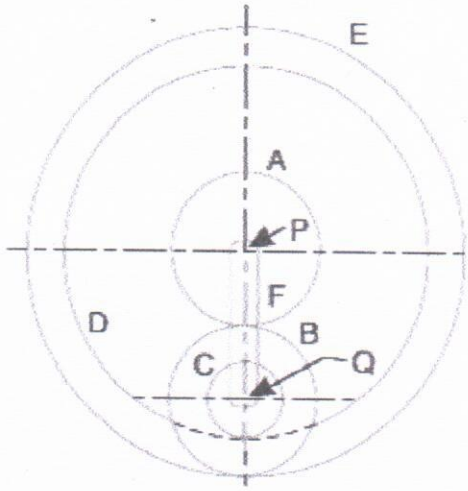

Fig.5

(b) Explain briefly the differences between simple, compound, and epicyclic gear trains. What are the special advantages of epicyclic gear trains?

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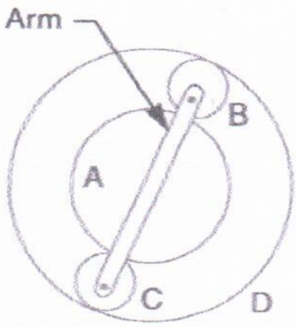
6. **Attempt any *one* part of the following:** 10 x 1 = 10

(a) Define the following with respect to Gear: Pressure angle, Pitch point, Circular Pitch, Backlash and Contact Ratio

(b) An epicyclic train of gears is arranged as shown in figure. How many revolutions does the arm, to which the pinions B and C are attached, make: **1.** when A makes one revolution clockwise and D makes half a revolution anticlockwise, and **2.** when A makes one revolution clockwise and D is stationary? The number of teeth on the gears A and D are 40 and 90 respectively.



7. **Attempt any *one* part of the following:** 10 x 1 = 10

(a) Derive the condition for maximum power transmission by a belt drive considering the effect of centrifugal tension.

(b) An open belt drive connects two pulleys 1.2 m and 0.5 m diameter, on parallel shafts 4 meter apart. The mass of the belt is 0.9 kg per meter length and the maximum tension is not to exceed 2000 N. The coefficient of friction is 0.3. The 1.2 m pulley, which is the driver, runs at 200 r.p.m. Due to belt slip on one of the pulleys, the velocity of the driven shaft is only 450 r.p.m. Calculate the torque on each of the two shafts, the power transmitted, and power lost in friction. What is the efficiency of the drive?

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Sub Code: NME502

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B. TECH
(SEM V) THEORY EXAMINATION 2019-20
KINEMATICS OF MACHINES

Time: 3 Hours *Total Marks: 100*

Note: Attempt all Sections. If require any missing data; then choose suitably.

SECTION A

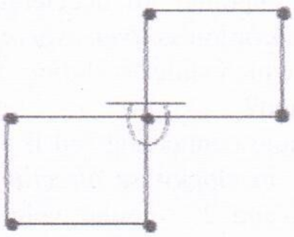
1. Attempt *all* questions in brief. **2 x 10 = 20**

a. How do you classify the kinematic pairs?
b. State the *Aronhold-Kennedy's* theorem as applicable to instantaneous centres of rotation of three bodies.
c. What do you mean by kinematic synthesis of mechanism?
d. What is the function of Hooke's joint?
e. Explain any four terminology of cam profile.
f. Differentiate between Radial follower and Off-set follower.
g. Define fundamental law of gearing.
h. Differentiate between involute and cycloidal profile of gear tooth.
i. What do you mean by creep of belt?
j. What is the function of clutch?

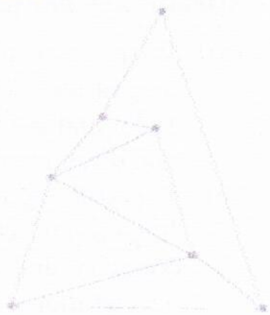
SECTION B

2. Attempt any *three* of the following: **10 x 3 = 30**

a. Find the degrees of freedom of the following Mechanisms:


(i)


(ii)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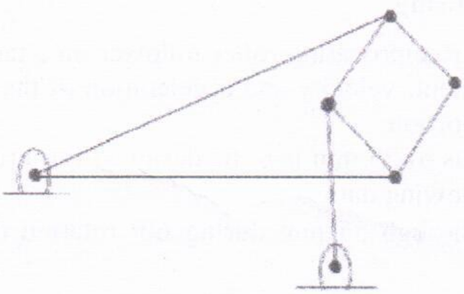
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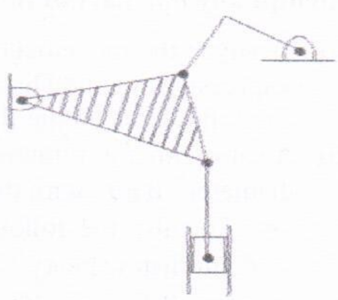
(v)

b. Two shafts are connected by a Hooke's joint. The driving shaft revolves uniformly at 500 r.p.m. If the total permissible variation in speed of the driven shaft is not to exceed ± 6% of the mean speed, find the greatest permissible angle between the centre lines of the shafts.

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c. Deduce the expression for displacement, velocity and acceleration when the follower moves with simple harmonic motion and also draw the velocity and acceleration profile.

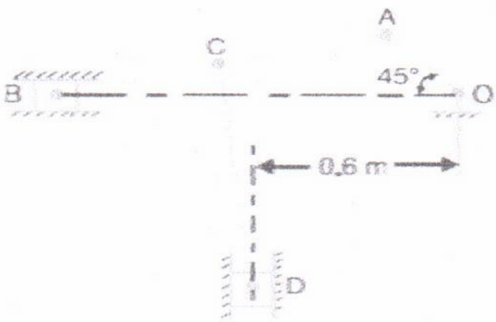
d. Define interference in gears. Derive an expression for minimum number of teeth required on a wheel in order to avoid interference.

e. A conical pivot supports a load of 20 kN, the cone angle is 120° and the intensity of normal pressure is not to exceed 0.3 N/mm^2. The external diameter is twice the internal diameter. Find the outer and inner radii of the bearing surface. If the shaft rotates at 200 r.p.m. and the coefficient of friction is 0.1, find the power absorbed in friction. Assume uniform pressure.

SECTION C

3. Attempt any *one* part of the following: 10 x 1 = 10

(a) The lengths of various links of a mechanism, as shown in figure, are, OA = 0.3 m, AB = 1 m, CD = 0.8 m, and AC = CB. Determine, for the given configuration, the velocity of the slider D if the crank OA rotates at 60 r.p.m. in the clockwise direction. Also find the angular velocity of the link CD. Use instantaneous centre method.



(b) Draw the Kinematic link diagram of Crank & Slotted lever QRMM, and hence, also deduct an expression for its stroke length.

4. Attempt any *one* part of the following: 10 x 1 = 10

(a) What do you understand by Coriolis component of acceleration? Show that magnitude of Coriolis component of acceleration is $2v\omega$, where v is velocity of slider and ω is angular velocity of link in which slider is sliding. How is the sense and direction of this acceleration determined?

(b) A petrol engine has a stroke of 120 mm and connecting rod is 3 times the crank length. The crank rotates at 1500 r.p.m. in clockwise direction. Determine: 1. Velocity and acceleration of the piston, and 2. Angular velocity and angular acceleration of the connecting rod, when the piston had travelled one-fourth of its stroke from I.D.C.

5. Attempt any *one* part of the following: 10 x 1 = 10

(a) Analyze the movement of a Reciprocating roller follower on a tangent cam. Find expression for the Displacement, velocity and acceleration of the follower, when the follower is on the flank portion.

(b) A cam with a minimum radius of 25 mm is to be designed for a roller follower of diameter 16 mm with the following data:

- To raise the follower through 35 mm during 60° rotation of the cam with uniform velocity
- Dwell for next 40° of cam rotation
- Descending of the follower during next 90° of the cam rotation with uniform acceleration and deceleration.
- Dwell during the rest of the cam rotation

Draw the profile of the cam if Radial follower (Line of stroke of follower passes *through the axis of the cam shaft*).

Printed Pages—7 **EME502**

(Following Paper ID and Roll No. to be filled in your Answer Book)

PAPER ID : 2102 **Roll No.** | | | | | | | | | | |

B.Tech.

(SEM. V) ODD SEMESTER THEORY EXAMINATION 2012-13

THEORY OF MACHINES—I

Time : 3 Hours *Total Marks : 100*

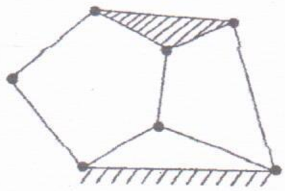
Note : *(1) Attempt* ***ALL*** *questions.*

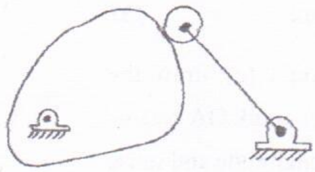
(2) All questions carry marks as shown against each.

1. Answer any **four** parts of the following :— **(5×4=20)**

(a) (i) What is the difference between higher and lower pairs ? **(1)**

(ii) Ascertain the degree of freedom for the two mechanisms shown : **(4)**





(b) Draw a sketch of one inversion of slider-crank mechanism in which the crank is made stationary. Describe the use and special features of this mechanism. **(5)**

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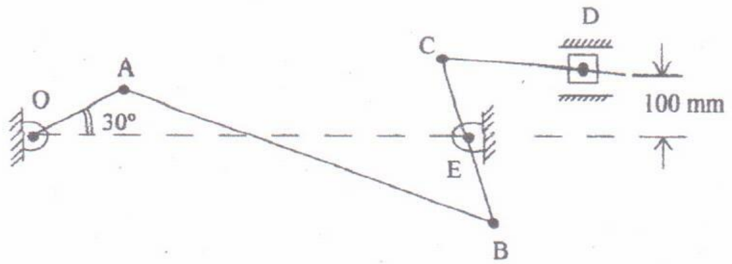
(c) A mechanism is shown below. It has following dimensions :



OA = 200 mm, AB = 1·5 metres, BC = 600 mm, CD = 500 mm, BE = 400 mm, OE = 1·35 metres.

Locate all instantaneous centres for this mechanism. **(5)**

(d) If in the mechanism shown in question 1 (c), crank OA rotates clockwise at 120 rpm; find the angular velocity of link CD by drawing a velocity diagram. **(5)**

(e) For the mechanism shown in question 1 (c), draw the acceleration diagram assuming that the crank OA rotates clockwise at 120 r.p.m. Ascertain the magnitude and sense of the acceleration of slider D. **(5)**

(f) Draw a sketch and explain the working of Oldham's coupling. **(5)**

2. Attmept any **two** parts out of the following :— **(10×2=20)**

(a) What do you understand by Coriolis component acceleration ? Under what circumstances, is it produced ? Show that the magnitude of Coriolis component acceleration is 2 $w.V_{pq}$, where the symbols have their usual meaning. How is the sense and direction of this acceleration determined ? **(10)**

(b) Describe HART's exact straight line mechanism with proof that it generates an exact straight line. In what respects is this mechanism considered superior to PEAUCELLIER's mechanism ? **(10)**

(c) A Hooke's joint connects two shafts whose axes intersect at 150°. The driving shaft rotates uniformly at 120 r.p.m. The driven shaft carries a flywheel of mass = 45 kg and radius of gyration of 150 mm. Find the maximum torque which will be exerted by the driving shaft. **(10)**

3. Attempt any **two** parts out of the following :— **(10×2=20)**

(a) (i) Draw a sketch of a single plate clutch and label its various parts. Why is "uniform wear theory" adopted for calculating the power which may be transmitted through this clutch ? **(5)**

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(ii) A thrust shaft of a ship has 6 collars of 600 mm external diameter and 300 mm internal diameter. The total thrust is 100 kN. If $\mu = 0 \cdot 12$ and speed of rotation of shaft is 90 r.p.m., find the power loss due to friction. Assume uniform pressure on thrust bearing surfaces. (5)

(b) (i) Differentiate between a FLAT BELT, a V-Belt and a TIMING belt. (3)

(ii) A shaft rotating at 90 r.p.m. is to transmit 10·5 kW to another shaft by a (weightless) flat belt of 11·5 cm width and 12 mm thickness by open belting arrangement. The driven shaft is to run at 225 r.p.m. The distance between shaft centres is 2·75 metres. Smaller pulley dia = 60 cm. Calculate the stress in belt, assuming μ to be 0·25. (7)

(c) (i) Differentiate between brakes and dynamometers. Name some common brakes. (3)

(ii) Show that for a band and block brake, the ratio of tensions is given by the expression

$$\left(\frac{1+\mu \tan\theta}{1-\mu \tan\theta}\right)^n$$, where the symbols have their usual meaning. (7)

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4. Answer any **two** parts of the following :— **(10×2=20)**

(a) Draw the profile of a cam with roller reciprocating follower. Axis of the follower passes through axis of the cam. Roller diameter is 5 mm and minimum radius of cam equals 20 mm. Total lift is 25 mm. The cam has to lift the follower with S.H.M. during 180° of cam rotation and then allow the follower to drop with uniform velocity during remaining 180° of cam rotation.

Determine the maximum velocity and maximum acceleration on the outward stroke. Cam rotates at uniform r.p.m. of 100 r.p.m. **(10)**

(b) In a symmetrical tangent cam with roller reciprocating follower, the minimum radius of cam is 25 mm. Roller diameter equals 25 mm. Angle of ascent is 60° and total lift is 12·5 mm. Cam shaft speed is 100 rad/sec.

Determine :—

(i) Main dimensions of cam, and

(ii) Velocity and acceleration of the follower at the beginning and end of lift.

There is no dwell period between ascent and descent.

(10)

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(c) Analyse the movement of a flat faced mushroom follower on a circular arc cam. Find expressions for the velocity and acceleration of the follower, when the follower is on the flank portion and also when the follower is on the nose portion of the cam.

Complete your analysis by drawing graphs of stroke, velocity and acceleration of follower versus angle of cam rotation. **(10)**

5. Answer any **two** of the following :— **(10×2=20)**

(a) (i) *What do* you understand by the term epicycloid, hypocycloid and involute ? **(3)**

(ii) Draw a base circle of 40 mm radius and construct the exact profile of an involute teeth (one side only) on it. The details of the construction may be explained step by step.

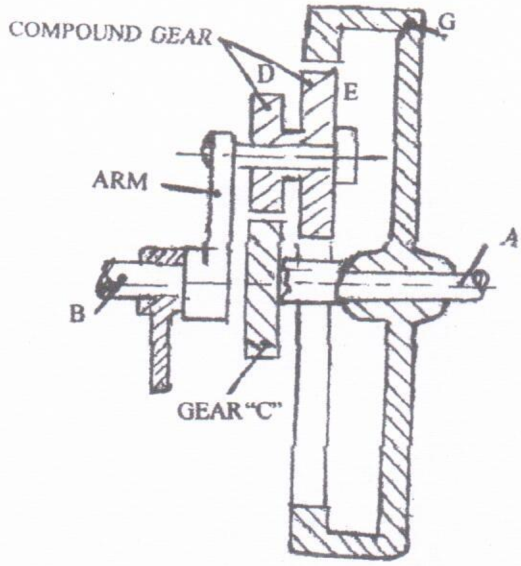
What are the properties of the involute curve, which make it suitable for adoption as gear-tooth profile ? **(5)**

(iii) What is the importance of pressure-angle in gears ? **(2)**

(b) A pair of gears, having 40 and 20 teeth respectively, are rotating in mesh, the speed of smaller being 2000 r.p.m. Determine the velocity of sliding between the gear teeth faces at the point of engagement, at the pitch point and at the point of disengagement if the smaller gear is the driver. Assume that the gear teeth are 20° *involute* form. Assume further that addendum length is 5 mm and the module is also 5 mm.

Also find the angle through which the pinion turns while any pair of teeth remain in contact. **(10)**

(c) Two shafts A and B are coaxial as shown. A gear C (50 teeth) is rigidly mounted on shaft A. A compound gear D.E. gears with 'C' and an internal gear 'G'. D has 20 teeth and E has 35 teeth. Gear G is fixed and is concentric with shaft axis. Compound gear DE is mounted on a pin which projects from an arm keyed to shaft B. All gears have same module. If shaft A rotates at 110 rpm (CW), find the speed of shaft B. **(10)**



In Pursuit of Excellence	**QUESTION BANK**	SESSION-2020-2021
		SEM-6^{TH}

THEORY OF MACHINE (KME-603)

UNIT -1

Q1. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240 mm and the length of the driving crank is 120 mm. Find the inclina-tion of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke.If the length of the slotted bar is 450 mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever.

Q2. Identify the kinematic chains to which the following mechanisms belong :1. Steam engine mechanism ; 2. Beam engine ; 3. Whitworth quick return motion mechanism; 4. Elliptical trammels.

Q3. In a pin jointed four bar mecha-nism, as shown in Fig. 6.9, AB = 300 mm, BC = CD = 360 mm, and AD = 600 mm. The angle BAD = 60°. The crankAB rotates uniformly at 100 r.p.m. Locate all the instantaneous centres and find the angular velocity of the link BC.

Q4. Locate all the instantaneous centres of the slider crank mechanism as shownin 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.

Q5. Write the relation between the number of instantaneous centres and the number of links in a mechanism.

Q6. What do you understand by the instantaneous centre of rotation (centro) in kinematic of machines? Answer briefly.

Q7. In a four bar chain ABCD, AD is fixed and is 150 mm long. The crank AB is 40 mm long and rotates at 120 r.p.m. clockwise, while the link CD = 80 mm oscillates about D. BC and AD are of equal length. Find the angular velocity of link CD when angle BAD = 60°.

Q8. The crank and connecting rod of a theoretical steam engine are 0.5 m and 2 m long respectively. The crank makes 180 r.p.m. in the clockwise direction. When it has turned 45° from the inner dead centre position, determine: 1. velocity of piston, 2. angular velocity of connecting rod, 3. velocity of point E on the connecting rod 1.5 m from the gudgeon pin, 4. velocities of rubbing at the pins of the crank shaft, crank and crosshead when the diameters of their pins are

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50 mm, 60 mm and 30 mm respectively, 5. position and linear velocity of any point G on the connecting rod which has the least velocity relative to crank shaft.

Q9. A 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.

Q10. In a slider crank mechanism, the length of crank OB and connecting rod A B 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 A B.

Q11. In a four bar chain ABCD , link AD is fixed and the crank A B rotates at 10 radians per second clockwise. Lengths of the links are A B = 60 mm ; BC = CD = 70 mm ; DA = 120 mm. When angle DAB = 60° and both B and C lie on the same side of AD, find 1. angular velocities (magnitude and direction) of BC and CD ; and 2. angular acceleration of BC and CD.

Q12. In a quick return mechanism, as shown in Fig. 8.43, the driving crank OA is 60 mm long and rotates at a uniform speed of 200 r.p.m. in a clockwise direction. For the position shown, find 1. velocity of the ram R ; 2. acceleration of the ram R, and 3. acceleration of the sliding block A along the slotted bar CD.

Q13. Explain how the coriolis component of acceleration arises when a point is rotating about some other fixed point and at the same time its distance from the fixed point varies.

Q14. Sketch a quick return motion of the crank and slotted lever type and explain the procedure of drawing the velocity and acceleration diagram, for any given configuration of the mechanism.

Q15. Draw the acceleration diagram of a slider crank mechanism.

UNIT -2

Q1. A disc cam is to give uniform motion to a knife edge follower during out stroke of 50 mm during the first half of the cam revolution. The follower again returns to its original position with uniform motion during the next half of the revolution. The minimum radius of the cam is 50 mm and the diameter of the cam shaft is 35 mm. Draw the profile of the cam when 1. the axis of follower passes through the axis of cam shaft, and 2. the axis of follower is offset by 20 mm from the axis of the cam shaft.

Q2. A cam operating a knife-edged follower has the following data :

(a) Follower moves outwards through 40 mm during 60° of cam rotation.

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(b) Follower dwells for the next 45°.

(c) Follower returns to its original position during next 90°.

(d) Follower dwells for the rest of the rotation.

The displacement of the follower is to take place with simple harmonic motion during both the outward and return strokes. The least radius of the cam is 50 mm. Draw the profile of the cam when 1. the axis of the follower passes through the cam axis, and 2. the axis of the follower is offset 20 mm towards right from the cam axis. If the cam rotates at 300 r.p.m., determine maximum velocity and acceleration of the follower during the outward stroke and the return stroke.

Q3. A cam rotating clockwise with a uniform speed is to give the roller follower of 20 mm diameter with the following motion :

(a) Follower to move outwards through a distance of 30 mm during 120° of cam rotation ;

(b) Follower to dwell for 60° of cam rotation ;

(c) Follower to return to its initial position during 90° of cam rotation ; and

(d) Follower to dwell for the remaining 90° of cam rotation.

The minimum radius of the cam is 45 mm and the line of stroke of the follower is offset 15 mm from the axis of the cam and the displacement of the follower is to take place with simple harmonic motion on both the outward and return strokes. Draw the cam profile.

Q4. A cam with 30 mm as minimum diameter is rotating clockwise at a uniform speed of 1200 r.p.m. and has to give the following motion to a roller follower 10 mm in diameter:

(a) Follower to complete outward stroke of 25 mm during 120° of cam rotation with equal uniform acceleration and retardation ;

(b) Follower to dwell for 60° of cam rotation ;

(c) Follower to return to its initial position during 90° of cam rotation with equal uniform acceleration and retardation ;

(d) Follower to dwell for the remaining 90° of cam rotation.

Draw the cam profile if the axis of the roller follower passes through the axis of the cam. Determine the maximum velocity of the follower during the outstroke and return stroke and also the uniform acceleration of the follower on the out stroke and the return stoke.

Q5. Write short notes on cams and followers.

Q6. Define the following terms as applied to cam with a neat sketch :- (a) Base circle, (b) Pitch circle, (c) Pressure angle, and (d) Stroke of the follower.

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Q7. What are the different types of motion with which a follower can move?

Q8. Draw the displacement, velocity and acceleration diagrams for a follower when it moves with simple harmonic motion. Derive the expression for velocity and acceleration during outstroke and return stroke of the follower.

Q9. Why a roller follower is preferred to that of a knife-edged follower?

Q10. Explain with sketches the different types of cams and followers.

UNIT -2

Q1. The pitch circle diameter of the smaller of the two spur wheels which mesh externally and have involute teeth is 100 mm. The number of teeth are 16 and 32. The pressure angle is 20° and the addendum is 0.32 of the circular pitch. Find the length of the path of contact of the pair of teeth.

Q2. A pair of gears, having 40 and 30 teeth respectively are of 25° involute form. The addendum length is 5 mm and the module pitch is 2.5 mm. If the smaller wheel is the driver and rotates at 1500 r.p.m., find the velocity of sliding at the point of engagement and at the point of disengagement.

Q3. Two gears of module 4mm have 24 and 33 teeth. The pressure angle is 20° and each gear has a standard addendum of one module. Find the length of arc of contact and the maximum velocity of sliding if the pinion rotates at 120 r.p.m.

Q4. The number of teeth in gears 1 and 2 are 60 and 40 ; module = 3 mm ; pressure angle = 20° and addendum = 0.318 of the circular pitch. Determine the velocity of sliding when the contact is at the tip of the teeth of gear 2 and the gear 2 rotates at 800 r.p.m.

Q5. Two mating gears have 20 and 40 involute teeth of module 10 mm and 20° pressure angle. If the addendum on each wheel is such that the path of contact is maximum and interference is just avoided, find the addendum for each gear wheel, path of contact, arc of contact and contact ratio.

Q6. A 20° involute pinion with 20 teeth drives a gear having 60 teeth. Module is 8 mm and addendum of each gear is 10 mm. 1. State whether interference occurs or not. Give reasons. 2. Find the length of path of approach and arc of approach if pinion is the driver.

Q7. Explain the terms : (i) Module, (ii) Pressure angle, and (iii) Addendum.

Q8. State and prove the law of gearing. Show that involute profile satisfies the conditions for correct gearing.

Q9. Prove that for two involute gear wheels in mesh, the angular velocity ratio does not change if the centre distance is increased within limits, but the pressure angle increases.

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Q10. Derive an expression for the length of the arc of contact in a pair of meshed spur gears.

Q11. Derive an expression for minimum number of teeth required on a pinion to avoid interference when it gears with a rack.

Q12. Show that, in a pair of spiral gears connecting inclined shafts, the efficiency is maximum when the spiral angle of the driving wheel is half the sum of the shaft and friction angles.

Q13. Two parallel shafts, about 600 mm apart are to be connected by spur gears.One shaft is to run at 360 r.p.m. and the other at 120 r.p.m. Design the gears, if the circular pitch is to be 25 mm.

Q14. 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?

Q15. Two parallel shafts are to be connected by spur gearing. The approximate distance between the shafts is 600 mm. If one shaft runs at 120 r.p.m. and the other at 360 r.p.m., find the number of teeth on each wheel, if the module is 8 mm. Also determine the exact distance apart of the shafts.

Q16. What do you understand by 'gear train'? Discuss the various types of gear trains.

Q17. Explain briefly the differences between simple, compound, and epicyclic gear trains. What are the special advantages of epicyclic gear trains ?

Q18. How the velocity ratio of epicyclic gear train is obtained by tabular method?

Q19. What are the various types of the torques in an epicyclic gear train ?

Q20. Explain with a neat sketch the 'sun and planet wheel.'

UNIT-3 (PART-1)

1. Define 'inertia force' and 'inertia torque'.
2. How are velocity and acceleration of the slider of a single slider crank chain determined analytically?
3. Derive an expression for the inertia force due to reciprocating mass in reciprocating engine, neglecting the mass of the connecting rod.
4. What is the difference between piston effort, crank effort and crank-pin effort?
5. *Discuss the method of finding the crank effort in a reciprocating single acting, single cylinder* petrol engine.
6. The inertia of the connecting rod can be replaced by two masses concentrated at two points and connected rigidly together. How to determine the two masses so that it is dynamically equivalent to the connecting rod ? Show this.
7. Given acceleration image of a link. Explain how dynamical equivalent system can be used to determine the direction of inertia force on it.
8. Describe the graphical and analytical method of finding the inertia torque on the crankshaft of a horizontal reciprocating engine.

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9. Derive an expression for the correction torque to be applied to a crankshaft if the connecting rod of a reciprocating engine is replaced by two lumped masses at the piston pin and the crank pin respectively.

10. The crank and connecting rod of a steam engine are 0.3 m and 1.5 m in length. The crank rotates at 180 r.p.m. clockwise. Determine the velocity and acceleration of the piston when the crank is at 40 degrees from the inner dead centre position. Also determine the position of the crank for zero acceleration of the piston.

11. In a slider crank mechanism, the length of the crank and connecting rod are 150 mm and 600 mm respectively. The crank position is 60° from inner dead centre. The crank shaft speed is 450 r.p.m. (clockwise). Using analytical method, determine: 1. Velocity and acceleration of the slider, and 2. Angular velocity and angular acceleration of the connecting rod.

12. A vertical double acting steam engine has a cylinder 300 mm diameter and 450 mm stroke and runs at 200 r.p.m. The reciprocating parts has a mass of 225 kg and the piston rod is 50 mm diameter. The connecting rod is 1.2 m long. When the crank has turned through 125° from the top dead centre, the steam pressure above the piston is 30 kN/m2 and below the piston is 1.5 kN/m2. Calculate the effective turning moment on the crank shaft.

13. The crank and connecting rod of a petrol engine, running at 1800 r.p.m.are 50 mm and 200 mm respectively. The diameter of the piston is 80 mm and the mass of the reciprocating parts is 1 kg. At a point during the power stroke, the pressure on the piston is 0.7 N/mm2, when it has moved 10 mm from the inner dead centre. Determine : **1.** Net load on the gudgeon pin, **2.** Thrust in the connecting rod, **3.** Reaction between the piston and cylinder, and **4.** The engine speed at which the above values become zero.

14. A vertical petrol engine 100 mm diameter and 120 mm stroke has a connecting rod 250 mm long. The mass of the piston is 1.1 kg. The speed is 2000 r.p.m. On the expansion stroke with a crank 20° from top dead centre, the gas pressure is 700 kN/m2. Determine:
1. Net force on the piston, **2.** Resultant load on the gudgeon pin, **3.** Thrust on the cylinder walls, and **4.** Speed above which, other things remaining same, the gudgeon pin load would be reversed in direction.

15. If the crank and the connecting rod are 300 mm and 1 m long respectively and the crank rotates at a constant speed of 200 r.p.m., determine:1. The crank angle at which the maximum velocity occurs, and 2. Maximum velocity of the piston.

16. The crank-pin circle radius of a horizontal engine is 300 mm. The mass of the reciprocating parts is 250 kg. When the crank has travelled 60° from I.D.C., the difference between the driving and the back pressures is 0.35 N/mm2. The connecting rod length between centres is 1.2 m and the cylinder bore is 0.5 m. If the engine runs at 250 r.p.m. and if the effect of piston rod diameter is neglected, calculate : 1. pressure on slide bars, 2. thrust in the connecting rod, 3. tangential force on the crank-pin, and 4. turning moment on the crank shaft.

17. A connecting rod is suspended from a point 25 mm above the centre of small end, and 650 mm above its centre of gravity, its mass being 37.5 kg. When permitted to oscillate, the time period is found to be 1.87 seconds. Find the dynamical equivalent system constituted of two masses, one of which is located at the small end centre.

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UNIT-3(PART-2)

1. Draw the turning moment diagram of a single cylinder double acting steam engine.

2. Explain precisely the uses of turning moment diagram of reciprocating engines.

3. Explain the turning moment diagram of a four stroke cycle internal combustion engine.

4. Discuss the turning moment diagram of a multicylinder engine.

5. Explain the terms 'fluctuation of energy' and 'fluctuation of speed' as applied to flywheels.

6. Define the terms 'coefficient of fluctuation of energy' and 'coefficient of fluctuation of speed', in the

case of flywheels.

7. What is the function of a flywheel? How does it differ from that of a governor?

8. Prove that the maximum fluctuation of energy,

$$\Delta E = E \times 2CS$$

where E = Mean kinetic energy of the flywheel, and

CS = Coefficient of fluctuation of speed.

16. The flywheel of a steam engine has a radius of gyration of 1 m and mass 2500 kg. The starting torque of the steam engine is 1500 N-m and may be assumed constant. Determine: **1.** the angular acceleration of the flywheel, and **2.** the kinetic energy of the flywheel after 10 seconds from the start.

17. A horizontal cross compound steam engine develops 300 kW at 90 r.p.m. The coefficient of fluctuation of energy as found from the turning moment diagram is to be 0.1 and the fluctuation of speed is to be kept within ± 0.5% of the mean speed. Find the weight of the flywheel required, if the radius of gyration is 2 metres.

18. During forward stroke of the piston of the double acting steam engine, the turning moment has the maximum value of 2000 N-m when the crank makes an angle of 80° with the inner dead centre. During the backward stroke, the maximum turning moment is 1500 N-m when the crank makes an angle of 80° with the outer dead centre. The turning moment diagram for the engine may be assumed for simplicity to be represented by two triangles.

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19. If the crank makes 100 r.p.m. and the radius of gyration of the flywheel is 1.75 m, find the coefficient of fluctuation of energy and the mass of the flywheel to keep the speed within ± 0.75%of the mean speed. Also determine the crank angle at which the speed has its minimum and maximum values.

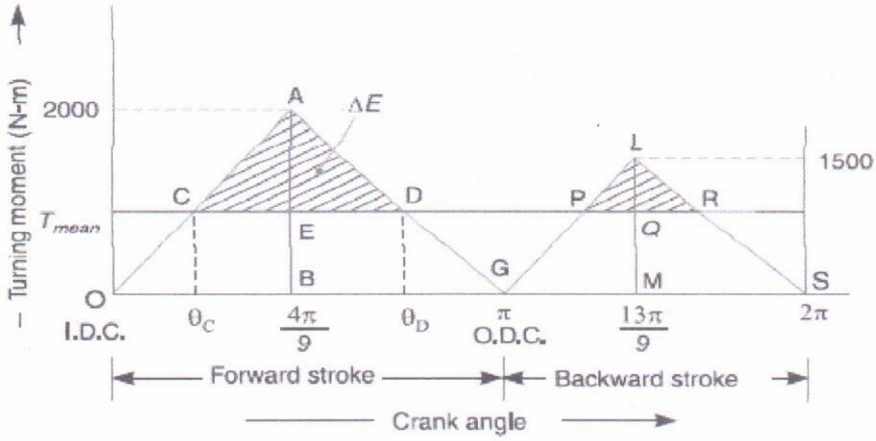
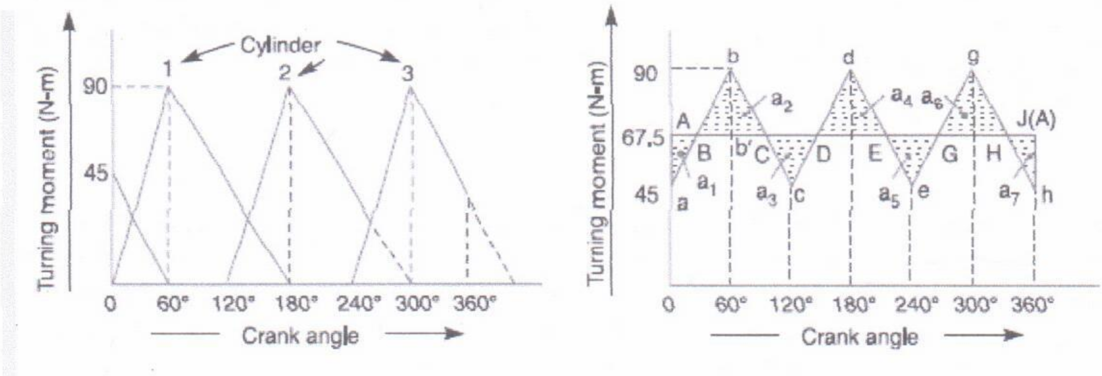


Fig. 16.9

20. A three cylinder single acting engine has its cranks set equally at 120° and it runs at 600 r.p.m. The torque-crank angle diagram for each cycle is a triangle for the power stroke with a maximum torque of 90 N-m at 60° from dead centre of corresponding crank. The torque on the return stroke is sensibly zero. Determine : **1.** power developed. **2.** coefficient of fluctuation of speed, if the mass of the flywheel is 12 kg and has a radius of gyration of 80 mm, **3.** coefficient of fluctuation of energy, and 4. maximum angular acceleration of the flywheel.



(a) (b)

Fig. 16.10

21. The turning moment diagram for a four stroke gas engine may be assumed for simplicity to be represented by four triangles, the areas of which from the line of zero pressure are as follows :

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Suction stroke = 0.45 × 10–3 m2; Compression stroke = 1.7 × 10^{-3} m2; Expansion stroke = 6.8 × 10^{-3} m2; Exhaust stroke = 0.65 × 10^{-3} m2. Each m2 of area represents 3 MN-m of energy. Assuming the resisting torque to be uniform, find the mass of the rim of a flywheel required to keep the speed between 202 and 198 r.p.m. The mean radius of the rim is 1.2 m.

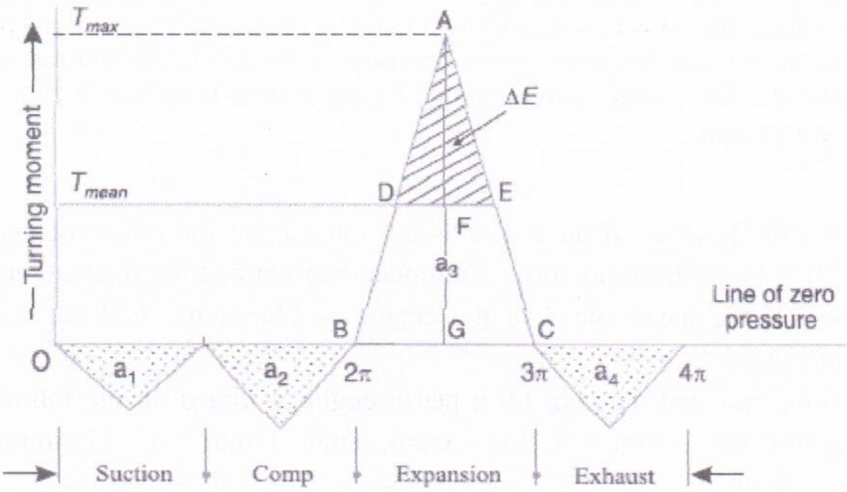

Fig. 16.12

22. The turning moment diagram for a multi-cylinder engine has been drawn to a scale of 1 mm to 500 N-m torque and 1 mm to 6° of crank displacement. The intercepted areas between output torque curve and mean resistance line taken in order from one end, in sq. mm are – 30, + 410, – 280, + 320, – 330, + 250, – 360, + 280, – 260 sq. mm, when the engine is running at 800 r.p.m.

    The engine has a stroke of 300 mm and the fluctuation of speed is not to exceed ± 2% of the mean speed. Determine a suitable diameter and cross-section of the flywheel rim for a limiting value of the safe centrifugal stress of 7 MPa. The material density may be assumed as 7200 kg/m3. The width of the rim is to be 5 times the thickness.

23. The following data relate to a connecting rod of a reciprocating engine:

Mass = 55 kg; Distance between bearing centres = 850 mm; Diameter of small end bearing = 75 mm; Diameter of big end bearing = 100 mm; Time of oscillation when the connecting rod is suspended from small end = 1.83 s; Time of oscillation when the connecting rod is suspended from big end = 1.68 s.

Determine: 1. the radius of gyration of the rod about an axis passing through the centre of gravity and perpendicular to the plane of oscillation; 2. the moment of inertia of the rod about the same axis; and 3. the dynamically equivalent system for the connecting rod, constituted of two masses, one of which is situated at the small end centre.

24. A connecting rod of an I.C. engine has a mass of 2 kg and the distance between the centre of gudgeon pin and centre of crank pin is 250 mm. The C.G. falls at a point 100 mm from the gudgeon pin along the line of centres. The radius of gyration about an axis through the C.G. perpendicular to the plane of rotation is 110 mm. Find the equivalent dynamical system if only one of the masses is located at gudgeon pin.
If the connecting rod is replaced by two masses, one at the gudgeon pin and the other at the crank pin and the angular acceleration of the rod is 23 000 rad/s2 clockwise, determine the correction couple applied to the system to reduce it to a dynamically equivalent system.

25. The mass of flywheel of an engine is 6.5 tonnes and the radius of gyration is 1.8 metres. It is found from the turning moment diagram that the fluctuation of energy is 56 kN-m. If the mean speed of the engine is 120 r.p.m., find the maximum and minimum speeds.

26. The turning moment diagram for a petrol engine is drawn to the following scales : Turning moment, 1 mm = 5 N-m ; crank angle, 1 mm = 1°. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295, 685, 40, 340, 960, 270 mm2. The rotating parts are equivalent to a mass of 36 kg at a radius of gyration of 150 mm. Determine the coefficient of fluctuation of speed when the engine runs at 1800 r.p.m.

27. The turning moment diagram for a multicylinder engine has been drawn to a scale 1 mm = 600 N-m vertically and 1 mm = 3° horizontally. The intercepted areas between the output torque curve and the mean resistance line, taken in order from one end, are as follows : + 52, – 124, + 92, – 140, + 85, – 72 and + 107 mm2, when the engine is running at a speed of 600 r.p.m. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, find the necessary mass of the flywheel of radius 0.5 m.

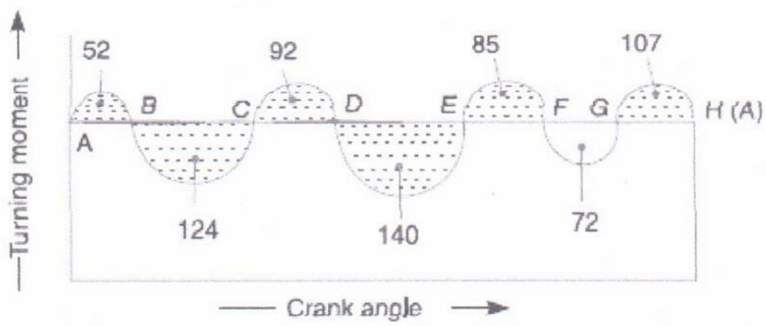

Fig. 16.7

28. A shaft fitted with a flywheel rotates at 250 r.p.m. and drives a machine. The torque of machine varies in a cyclic manner over a period of 3 revolutions. The torque rises from 750 N-m to 3000 N-m uniformly during 1/2 revolution and remains constant for

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the following revolution. It then falls uniformly to 750 N-m during the next 1/2 revolution and remains constant for one revolution, the cycle being repeated thereafter. Determine the power required to drive the machine and percentage fluctuation in speed, if the driving torque applied to the shaft is constant and the mass of the flywheel is 500 kg with radius of gyration of 600 mm.

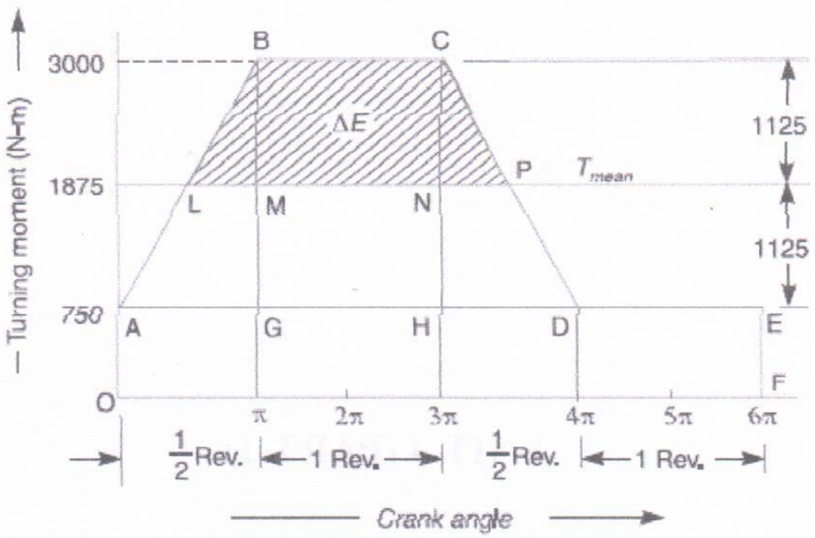

Fig. 16.8

29. *A single cylinder, single acting, four stroke gas engine develops 20 kW at 300 r.p.m. The work done by the gases during the expansion stroke is three times the work done on the gases during the compression stroke, the work done during the suction and exhaust strokes being negligible. If the total fluctuation of speed is not to exceed ± 2 per cent of the mean speed and the turning moment diagram during compression and expansion is assumed to be triangular in shape, find the moment of inertia of the flywheel.*

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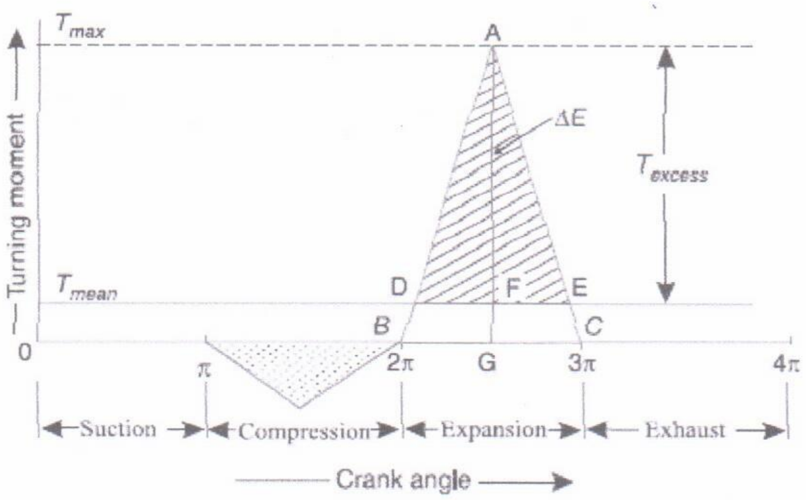

Fig. 16.11

UNIT-4 (PART-1)

5. Explain clearly the terms 'static balancing' and 'dynamic balancing'. State the necessary conditions to achieve them.
6. Discuss how a single revolving mass is balanced by two masses revolving in different planes
7. Explain the method of balancing of different masses revolving in the same plane.
8. How the different masses rotating in different planes are balanced ?
9. A shaft carries four rotating masses A, B, C and D along its axis. The mass A may be assumed concentrated at a radius 200mm, B at 260mm and D at 170mm. the mass of B,C and D are 32kg, 52kg, 42kg respectively. The planes of revolution of B and C are 300mm apart. The angle between B and C is 90° and B and D is 210° and C and D is 120°. determine
   (iii) The magnitude and angular position of mass A,
   (iv) The position of planes A and D
10. Four masses A,B,C and D are completely balanced. Masses C and D makes angle of 90° and 195° respectively with B in same sense. The rotating masses have following properties:

    $M_b = 25kg$ $R_a = 150mm$
    $M_c = 40\ kg$ $R_b = 200mm$
    $M_d = 35kg$ $R_c = 100mm$ $R_d = 180mm$

    Planes B and C are 250mm apart. Determine:
    (iii) The magnitude of mass A and its angular position.
    (iv) The position of planes A and D

11. Four masses A,B,C and D are completely balanced. The planes in which masses revolve are spaced 700mm apart. The rotating masses have following properties:

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M_b = 12kg R_a =110mm
M_c = 07 kg R_b =140mm
M_d = 05kg R_c =210mm R_d =160mm

Determine the magnitude of mass A and relative angular positions of all masses so that the shaft is in completely balance.

12. A shaft is supported in bearings 1.8 m apart and projects 0.45 m beyond bearings at each end. The shaft carries three pulleys one at each end and one at the middle of its length. The mass of end pulleys is 48 kg and 20 kg and their centre of gravity are 15 mm and 12.5mm respectively from the shaft axis. The centre pulley has a mass of 56 kg and its centre of gravity is 15 mm from the shaft axis. If the pulleys are arranged so as to give static balance, determine: **1.** relative angular positions of the pulleys, and **2.** dynamic forces produced on the bearings when the shaft rotates at 300 r.p.m.
13. A four mass system having 200kg, 250kg, 150kg, 100 kg revolve at radius 100mm, 120mm, 250mm, 300mm respectively. The angle between successive masses is 45°, 70° and 140°. Find the position and magnitude of balanced masses by graphical and analytical method if radius of rotation is 350mm.
14. A rotating shaft carries four unbalanced masses having magnitude 20kg, 15kg, 17kg and 14kg revolving at radii 60mm, 80mm, 100mm and 60mm respectively. The m2, m3 and m4 revolve in plane 100mm, 180mm and 300mm respectively from the plane of mass m1 are angularly located at 65°, 145° and 270°respectively, measured in anticlockwise direction from the mass m1 looking from the mass end of the shaft. The shaft is to be dynamically balanced by two masses, both located at 70mm radii and revolving in plane midway between m1 & m2 and m3 & m4. Determine the magnitude of balancing masses and their respectively angular position.
15. A shaft is supported between bearing 2.0m apart and extended 0.5m beyond bearing at each end. The shaft carries 3 pulleys one at each end and one at the middle of its length. The masses of end pulleys are 50kg and 25kg and their centre of gravity are 20mm and 15mm respectively from the axis of shaft. The centre pulley has a mass of 60 kg and its centre of gravity is 20mm from the axis of shaft. If the pulleys are arranged so as to give the static balance. Determine:
    (iii) The relative angular position of the pulleys, and
    (iv) The dynamics forces produced on the bearings when the shaft rotates at 340 r.p.m.
16. A shaft carries four masses in parallel planes A, B, C and D in this 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 an eccentricity of 80 mm. The angle between the masses at B and C is 100° and that between the masses at B and A is 190°, both being measured in the same direction. The axial distance between the planes A and B is 100 mm and that between B and C is 200 mm. If the shaft is in complete dynamic balance, determine : **1.** The magnitude of the masses at A and D ; **2.** the distance between planes A and D ; and **3.** the angular position of the mass at D.
17. A shaft has three eccentrics, each 75 mm diameter and 25 mm thick, machined in one piece with the shaft. The central planes of the eccentric are 60 mm apart. The distance of the centres from the axis of rotation are 12 mm, 18 mm and 12 mm and their angular positions are 120° apart. The density of metal is 7000 kg/m3. Find the amount of out-of-

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balance force and couple at 600 r.p.m. If the shaft is balanced by adding two masses at a radius 75 mm and at distances of 100 mm from the central plane of the middle eccentric, *find the amount of the masses and their angular positions.*

UNIT-4 (PART-2)

4. Write a short note on primary and secondary balancing.
5. Explain why only a part of the unbalanced force due to reciprocating masses is balanced by revolving mass.
6. Derive the following expressions, for an uncoupled two cylinder locomotive engine : (*a*) Variation is tractive force ; (*b*) Swaying couple ; and (*c*) Hammer blow.

7. 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
8. The following data apply to an outside cylinder uncoupled locomotive : Mass of rotating parts per cylinder = 360 kg ; Mass of reciprocating parts per cylinder = 300 kg ; Angle between cranks = 90° ; Crank radius = 0.3 m ; Cylinder centres = 1.75 m ; Radius of balance masses = 0.75 m ; Wheel centres = 1.45 m. If whole of the rotating and two-thirds of reciprocating parts are to be balanced in planes
   of the driving wheels, find : **1.** Magnitude and angular positions of balance masses, **2.** Speed in kilometres per hour at which the wheel will lift off the rails when the load on each driving wheel is 30 kN and the diameter of tread of driving wheels is 1.8 m, and Swaying couple at speed arrived at in **(2)** above.
9. A four cylinder vertical engine has cranks 150 mm long. The planes of rotation of the first, second and fourth cranks are 400 mm, 200 mm and 200 mm respectively from the third crank and their reciprocating masses are 50 kg, 60 kg and 50 kg respectively. Find the mass of the reciprocating parts for the third cylinder and the relative angular positions of the cranks in order that the engine may be in complete primary balance.
10. A four crank engine has the two outer cranks set at 120° to each other, and their reciprocating masses are each 400 kg. The distance between the planes of rotation of adjacent cranks are 450 mm, 750 mm and 600 mm. If the engine is to be in complete primary balance, find the reciprocating mass and the relative angular position for each of the inner cranks. If the length of each crank is 300 mm, the length of each connecting rod is 1.2 m and the speed of rotation is 240 r.p.m., what is the maximum secondary unbalanced force ?
11. The cranks and connecting rods of a 4-cylinder in-line engine running at 1800 r.p.m. are 60 mm and 240 mm each respectively and the cylinders are spaced 150 mm apart. If the cylinders are numbered 1 to 4 in sequence from one end, the cranks appear at intervals of 90° in an end view in the order 1-4-2-3. The reciprocating mass corresponding to each cylinder is 1.5 kg. Determine : **1.** Unbalanced primary and secondary forces, if any, and **2.** Unbalanced primary and secondary couples with reference to central plane of the engine.

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12. A single cylinder reciprocating engine has speed 240 r.p.m., stroke 300 mm, mass of reciprocating parts 50 kg, mass of revolving parts at 150 mm radius 37 kg. If two third of the reciprocating parts and all the revolving parts are to be balanced, find: **1.** The balance mass required at a radius of 400 mm, and **2.** The residual unbalanced force when the crank has rotated 60° from top dead centre.
13. An inside cylinder locomotive has its cylinder centre lines 0.7 m apart and has a stroke of 0.6 m. The rotating masses per cylinder are equivalent to 150 kg at the crank pin, and the reciprocating masses per cylinder to 180 kg. The wheel centre lines are 1.5 m apart. The cranks are at right angles. The whole of the rotating and 2/3 of the reciprocating masses are to be balanced by masses placed at a radius of 0.6 m. Find the magnitude and direction of the balancing masses.
14. The three cranks of a three cylinder locomotive are all on the same axle and are set at 120°. The pitch of the cylinders is 1 metre and the stroke of each piston is 0.6 m. The reciprocating masses are 300 kg for inside cylinder and 260 kg for each outside cylinder and the planes of rotation of the balance masses are 0.8 m from the inside crank. If 40% of the reciprocating parts are to be balanced, find : **1.** the magnitude and the position of the balancing masses required at a radius of 0.6 m ; and the hammer blow per wheel when the axle makes 6 r.p.s.

UNIT-4 (PART-3)

5. What is the function of a governor ? How does it differ from that of a flywheel ?
6. State the different types of governors. What is the difference between centrifugal and inertia type governors ? Why is the former preferred to the latter ?
7. Explain the term height of the governor. Derive an expression for the height in the case of a Watt governor. What are the limitations of a Watt governor ?
8. What are the effects of friction and of adding a central weight to the sleeve of a Watt *governor* ?
5. Define and explain the following terms relating to governors :
   1. Stability, 2. Sensitiveness, 3. Isochronism, and 4. Hunting.
6. Explain the terms and derive expressions for 'effort' and 'power' of a Porter governor.
7. Prove that the sensitiveness of a Proell governor is greater than that of a Porter governor.
8. 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 minimum and maximum speeds and range of speed of the governor.

9. The arms of a Porter governor are each 250 mm long and pivoted on the governor axis. The mass of each ball is 5 kg and the mass of the central sleeve is 30 kg. The radius of rotation of the balls is 150 mm when the sleeve begins to rise and reaches a value of 200 mm for maximum speed. Determine the speed range of the governor. If the friction at the sleeve is equivalent of 20 N of load at the sleeve, determine how the speed range is modified.
10. A Proell governor has equal arms of length 300 mm. The upper and lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 80 mm long and parallel to the axis when the radii of rotation of the balls are 150

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mm and 200 mm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. Determine the range of speed of the governor.

11. A Hartnell governor having a central sleeve spring and two right-angled bell crank levers moves between 290 r.p.m. and 310 r.p.m. for a sleeve lift of 15mm. The sleeve arms and the ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine : **1.** loads on the spring at the lowest and the highest equilibrium speeds, and **2.** stiffness of the spring.

12. In an engine governor of the Porter type, the upper and lower arms are 200mm and 250 mm respectively and pivoted on the axis of rotation. The mass of the central load is 15 kg, the mass of each ball is 2 kg and friction of the sleeve together with the resistance of the operating gear is equal to a load of 25 N at the sleeve. If the limiting inclinations of the upper arms to the vertical are 30° and 40°, find, taking friction into account, range of speed of the governor.

13. Porter governor has all four arms 250 mm long. The upper arms are attached on the axis of rotation and the lower arms are attached to the sleeve at a distance of 30 mm from the axis. The mass of each ball is 5 kg and the sleeve has a mass of 50 kg. The extreme radii of rotation are 150 mm and 200 mm. Determine the range of speed of the governor.

14. 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°.

15. A governor of the Proell type has each arm 250 mm long. The pivots of the upper and lower arms are 25 mm from the axis. The central load acting on the sleeve has a mass of 25 kg and the each rotating ball has a mass of 3.2 kg. When the governor sleeve is in mid-position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 175 mm. The vertical height of the governor is 200 mm. If the governor speed is 160 r.p.m. when in mid-position, find : **1.** length of the extension link; and **2.** tension in the upper arm.

16. 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.

17. 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.

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18. The upper arms of a Porter governor has lengths 350 mm and are pivoted on the axis of rotation. The lower arms has lengths 300 mm and are attached to the sleeve at a distance of 40 mm from the axis. Each ball has a mass of 4 kg and mass on the sleeve is 45 kg. Determine the equilibrium speed for a radius of rotation of 200 mm and find also the effort and power of the governor for 1 per cent speed change.

19. The radius of rotation of the balls of a Hartnell governor is 80 mm at the minimum speed of 300 r.p.m. Neglecting gravity effect, determine the speed after the sleeve has lifted by 60 mm. Also determine the initial compression of the spring, the governor effort and the power. The particulars of the governor are given below:
Length of ball arm = 150mm ; length of sleeve arm = 100mm ; mass of each ball = 4 kg ; and stiffness of the spring = 25 N/mm.

UNIT-5 (PART-1)

Distinguish between brakes and dynamometers.

2. Discuss the various types of the brakes.

3. Show that, in a band and block brake, the ratio of the maximum and minimum tensions in the brake straps is

$$\frac{T_0}{T_n} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n$$

where $T0$ = Maximum tension,

Tn = Minimum tension

μ = Coefficient of friction between the blocks and drum, and

2θ = Angle subtended by each block at the centre of the drum.

4. Describe with the help of a neat sketch the principles of operation of an internal expanding shoe.

Derive the expression for the braking torque.

5. What are the leading and trailing shoes of an internal expanding shoe brake ?

5. A double shoe brake, as shown in Fig. 19.10, is capable of absorbing a torque of 1400 N-m. The diameter of the brake drum is 350 mm and the angle of contact for each shoe is 100°. If the coefficient of friction between the brake drum and lining is 0.4 ; find **1.** the spring force necessary to set the brake ; and **2.** The width of the brake shoes, if the bearing pressure on the lining material is not to exceed 0.3 N/mm2.

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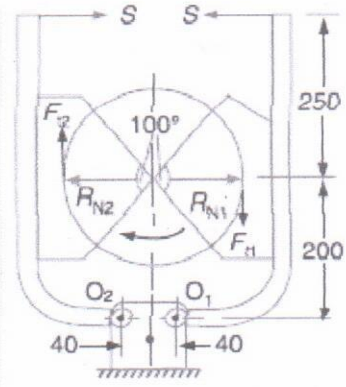

All dimensions in mm.
Fig. 19.10

5. 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 $\mu = 0.05$.

6. A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brake provides a braking torque of 225 N-m. One end of the band is attached to a fulcrum pin of the lever and the other end to a pin 100 mm from the fulcrum. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0 .25, find the operating force when the drum rotates in the (a) anticlockwise direction, and (b) clockwise direction.

7. A car moving on a level road at a speed 50 km/h has a wheel base 2.8 metres, distance of C.G. from ground level 600 mm, and the distance of C.G. from rear wheels 1.2 metres. Find the distance travelled by the car before coming to rest when brakes are applied, 1. to the rear wheels, 2. to the front wheels, and 3. to all the four wheels. The coefficient of friction between the tyres and the road may be taken as 0.6.

8. A vehicle moving on a rough plane inclined at 10° with the horizontal at a speed of 36 km/h has a wheel base 1.8 metres. The centre of gravity of the vehicle is 0.8 metre from the rear wheels and 0.9 metre above the inclined plane. Find the distance travelled by the vehicle before coming to rest and the time taken to do so when 1. The vehicle moves up the plane, and 2. The vehicle moves down the plane. The brakes are applied to all the four wheels and the coefficient of friction is 0.5.
9. The wheel base of a car is 3 metres and its centre of gravity is 1.2 metres ahead the rear axle and 0.75 m above the ground level. The coefficient of friction between the wheels

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and the road is 0.5. Determine the maximum deceleration of the car when it moves on a level road, if the braking force on all the wheels is the same and no wheel slip occurs.

UNIT-5 (PART-2)

1. What is the difference between absorption and transmission dynamometers ? What are torsion dynamometers ?

2. Describe the construction and operation of a prony brake or rope brake bsorption dynamometer.

3. Describe with sketches one form of torsion dynamometer and explain with detail the calculations involved in finding the power transmitted

4.A simple band brake operates on a drum of 600 mm in diameter that is running at 200 r.p.m. The coefficient of friction is 0.25. The brake band has a contact of 270°, one end is fastened to a fixed pin and the other end to the brake arm 125 mm from the fixed pin. The straight brake arm is 750 mm long and placed perpendicular to the diameter that bisects the angle of contact.

1. What is the pull necessary on the end of the brake arm to stop the wheel if 35 kW is being absorbed ? What is the direction for this minimum pull ?

2. What width of steel band of 2.5 mm thick is required for this brake if the maximum tensile stress is not to exceed 50 N/mm2 ?

9. In a winch, the rope supports a load W and is wound round a barrel 450 mm diameter. A differential band brake acts on a drum 800 mm diameter which is keyed to the same shaft as the barrel. The two ends of the bands are attached to pins on opposite sides of the fulcrum of the brake lever and at distances of 25 mm and 100 mm from the fulcrum. The angle of lap of the brake band is 250° and the coefficient of friction is 0.25. What is the maximum load W which can be supported by the brake when a force of 750 N is applied to the lever at a distance of 3000 mm from the fulcrum ?

6. A band and block brake, having 14 blocks each of which subtends an angle of 15° at the centre, is applied to a drum of 1 m effective diameter. The drum and flywheel mounted on the same shaft has a mass of 2000 kg and a combined radius of gyration of 500 mm. The two ends of the band are attached to pins on opposite sides of the brake lever at distances of 30 mm and 120 mm from the fulcrum. If a force of 200 N is applied at a distance of 750 mm from the fulcrum, find:

1. maximum braking torque, **2.** angular retardation of the drum, and **3.** time taken by the system to come to rest from the rated speed of 360 r.p.m.

7. In a laboratory experiment, the following data were recorded with rope brake:
Diameter of the flywheel 1.2 m; diameter of the rope 12.5 mm; speed of the engine 200 r.p.m.; dead load on the brake 600 N; spring balance reading 150 N. Calculate the brake power of the engine.

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8. The essential features of a transmission dynamometer are shown in Fig. 19.35. A is the driving pulley which runs at 600 r.p.m. B and C are jockey pulleys mounted on a, horizontal beam pivoted at D, about which point the complete beam is balanced when at rest. E is the driven pulley and all portions of the belt between the pulleys are vertical. A, B and C are each 300 mm diameter and the thickness and weight of the belt are neglected. The length DF is 750 mm. Find : **1.** the value of the weight W to maintain the beam in a horizontal position when 4.5 kW is being transmitted, and **2.** the value of W, when the belt just begins to slip on pulley A. The coefficient of friction being 0.2 and maximum tension in the belt 1.5 kN.

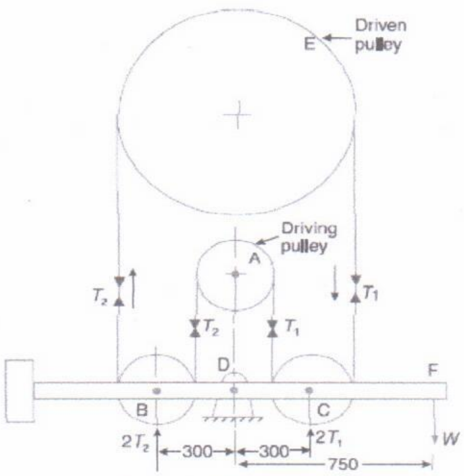

Fig. 19.35. All dimensions in mm.

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In Pursuit of Excellence	QUESTION BANK	SESSION-2019-2020 SEM-6TH

THEORY OF MACHINE (RME-602)

UNIT -1

Q1. In a crank and slotted lever quick return motion mechanism, the distance between the fixed centres is 240 mm and the length of the driving crank is 120 mm. Find the inclina-tion of the slotted bar with the vertical in the extreme position and the time ratio of cutting stroke to the return stroke.If the length of the slotted bar is 450 mm, find the length of the stroke if the line of stroke passes through the extreme positions of the free end of the lever.

Q2. Identify the kinematic chains to which the following mechanisms belong :1. Steam engine mechanism ; 2. Beam engine ; 3. Whitworth quick return motion mechanism; 4. Elliptical trammels.

Q3. In a pin jointed four bar mecha-nism, as shown in Fig. 6.9, AB = 300 mm, BC = CD = 360 mm, and AD = 600 mm. The angle BAD = 60°. The crankAB rotates uniformly at 100 r.p.m. Locate all the instantaneous centres and find the angular velocity of the link BC.

Q4. Locate all the instantaneous centres of the slider crank mechanism as shownin 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.

Q5. Write the relation between the number of instantaneous centres and the number of links in a mechanism.

Q6. What do you understand by the instantaneous centre of rotation (centro) in kinematic of machines? Answer briefly.

Q7. In a four bar chain ABCD, AD is fixed and is 150 mm long. The crank AB is 40 mm long and rotates at 120 r.p.m. clockwise, while the link CD = 80 mm oscillates about D. BC and AD are of equal length. Find the angular velocity of link CD when angle BAD = 60°.

Q8. The crank and connecting rod of a theoretical steam engine are 0.5 m and 2 m long respectively. The crank makes 180 r.p.m. in the clockwise direction. When it has turned 45° from the inner dead centre position, determine: 1. velocity of piston, 2. angular velocity of connecting rod, 3. velocity of point E on the connecting rod 1.5 m from the gudgeon pin, 4. velocities of rubbing at the pins of the crank shaft, crank and crosshead when the diameters of their pins are

50 mm, 60 mm and 30 mm respectively, 5. position and linear velocity of any point G on the connecting rod which has the least velocity relative to crank shaft.

Q9. A 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.

Q10. In a slider crank mechanism, the length of crank OB and connecting rod A B 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 A B.

Q11. In a four bar chain ABCD , link AD is fixed and the crank A B rotates at 10 radians per second clockwise. Lengths of the links are A B = 60 mm ; BC = CD = 70 mm ; DA = 120 mm. When angle DAB = 60° and both B and C lie on the same side of AD, find 1. angular velocities (magnitude and direction) of BC and CD ; and 2. angular acceleration of BC and CD.

Q12. In a quick return mechanism, as shown in Fig. 8.43, the driving crank OA is 60 mm long and rotates at a uniform speed of 200 r.p.m. in a clockwise direction. For the position shown, find 1. velocity of the ram R ; 2. acceleration of the ram R, and 3. acceleration of the sliding block A along the slotted bar CD.

Q13. Explain how the coriolis component of acceleration arises when a point is rotating about some other fixed point and at the same time its distance from the fixed point varies.

Q14. Sketch a quick return motion of the crank and slotted lever type and explain the procedure of drawing the velocity and acceleration diagram, for any given configuration of the mechanism.

Q15. Draw the acceleration diagram of a slider crank mechanism.

UNIT -2

Q1. A disc cam is to give uniform motion to a knife edge follower during out stroke of 50 mm during the first half of the cam revolution. The follower again returns to its original position with uniform motion during the next half of the revolution. The minimum radius of the cam is 50 mm and the diameter of the cam shaft is 35 mm. Draw the profile of the cam when 1. the axis of follower passes through the axis of cam shaft, and 2. the axis of follower is offset by 20 mm from the axis of the cam shaft.

Q2. A cam operating a knife-edged follower has the following data :

(a) Follower moves outwards through 40 mm during 60° of cam rotation.

(b) Follower dwells for the next 45°.

(c) Follower returns to its original position during next 90°.

(d) Follower dwells for the rest of the rotation.

The displacement of the follower is to take place with simple harmonic motion during both the outward and return strokes. The least radius of the cam is 50 mm. Draw the profile of the cam when 1. the axis of the follower passes through the cam axis, and 2. the axis of the follower is offset 20 mm towards right from the cam axis. If the cam rotates at 300 r.p.m., determine maximum velocity and acceleration of the follower during the outward stroke and the return stroke.

Q3. A cam rotating clockwise with a uniform speed is to give the roller follower of 20 mm diameter with the following motion :

(a) Follower to move outwards through a distance of 30 mm during 120° of cam rotation ;

(b) Follower to dwell for 60° of cam rotation ;

(c) Follower to return to its initial position during 90° of cam rotation ; and

(d) Follower to dwell for the remaining 90° of cam rotation.

The minimum radius of the cam is 45 mm and the line of stroke of the follower is offset 15 mm from the axis of the cam and the displacement of the follower is to take place with simple harmonic motion on both the outward and return strokes. Draw the cam profile.

Q4. A cam with 30 mm as minimum diameter is rotating clockwise at a uniform speed of 1200 r.p.m. and has to give the following motion to a roller follower 10 mm in diameter:

(a) Follower to complete outward stroke of 25 mm during 120° of cam rotation with equal uniform acceleration and retardation ;

(b) Follower to dwell for 60° of cam rotation ;

(c) Follower to return to its initial position during 90° of cam rotation with equal uniform acceleration and retardation ;

(d) Follower to dwell for the remaining 90° of cam rotation.

Draw the cam profile if the axis of the roller follower passes through the axis of the cam. Determine the maximum velocity of the follower during the outstroke and return stroke and also the uniform acceleration of the follower on the out stroke and the return stoke.

Q5. Write short notes on cams and followers.

Q6. Define the following terms as applied to cam with a neat sketch :- (a) Base circle, (b) Pitch circle, (c) Pressure angle, and (d) Stroke of the follower.

Q7. What are the different types of motion with which a follower can move?

Q8. Draw the displacement, velocity and acceleration diagrams for a follower when it moves with simple harmonic motion. Derive the expression for velocity and acceleration during outstroke and return stroke of the follower.

Q9. Why a roller follower is preferred to that of a knife-edged follower?

Q10. Explain with sketches the different types of cams and followers.

UNIT -2

Q1. The pitch circle diameter of the smaller of the two spur wheels which mesh externally and have involute teeth is 100 mm. The number of teeth are 16 and 32. The pressure angle is 20° and the addendum is 0.32 of the circular pitch. Find the length of the path of contact of the pair of teeth.

Q2. A pair of gears, having 40 and 30 teeth respectively are of 25° involute form. The addendum length is 5 mm and the module pitch is 2.5 mm. If the smaller wheel is the driver and rotates at 1500 r.p.m., find the velocity of sliding at the point of engagement and at the point of disengagement.

Q3. Two gears of module 4mm have 24 and 33 teeth. The pressure angle is 20° and each gear has a standard addendum of one module. Find the length of arc of contact and the maximum velocity of sliding if the pinion rotates at 120 r.p.m.

Q4. The number of teeth in gears 1 and 2 are 60 and 40 ; module = 3 mm ; pressure angle = 20° and addendum = 0.318 of the circular pitch. Determine the velocity of sliding when the contact is at the tip of the teeth of gear 2 and the gear 2 rotates at 800 r.p.m.

Q5. Two mating gears have 20 and 40 involute teeth of module 10 mm and 20° pressure angle. If the addendum on each wheel is such that the path of contact is maximum and interference is just avoided, find the addendum for each gear wheel, path of contact, arc of contact and contact ratio.

Q6. A 20° involute pinion with 20 teeth drives a gear having 60 teeth. Module is 8 mm and addendum of each gear is 10 mm. 1. State whether interference occurs or not. Give reasons. 2. Find the length of path of approach and arc of approach if pinion is the driver.

Q7. Explain the terms : (i) Module, (ii) Pressure angle, and (iii) Addendum.

Q8. State and prove the law of gearing. Show that involute profile satisfies the conditions for correct gearing.

Q9. Prove that for two involute gear wheels in mesh, the angular velocity ratio does not change if the centre distance is increased within limits, but the pressure angle increases.

Q10. Derive an expression for the length of the arc of contact in a pair of meshed spur gears.

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Q11. Derive an expression for minimum number of teeth required on a pinion to avoid interference when it gears with a rack.

Q12. Show that, in a pair of spiral gears connecting inclined shafts, the efficiency is maximum when the spiral angle of the driving wheel is half the sum of the shaft and friction angles.

Q13. Two parallel shafts, about 600 mm apart are to be connected by spur gears.One shaft is to run at 360 r.p.m. and the other at 120 r.p.m. Design the gears, if the circular pitch is to be 25 mm.

Q14. 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?

Q15. Two parallel shafts are to be connected by spur gearing. The approximate distance between the shafts is 600 mm. If one shaft runs at 120 r.p.m. and the other at 360 r.p.m., find the number of teeth on each wheel, if the module is 8 mm. Also determine the exact distance apart of the shafts.

Q16. What do you understand by 'gear train'? Discuss the various types of gear trains.

Q17. Explain briefly the differences between simple, compound, and epicyclic gear trains. What are the special advantages of epicyclic gear trains ?

Q18. How the velocity ratio of epicyclic gear train is obtained by tabular method?

Q19. What are the various types of the torques in an epicyclic gear train ?

Q20. Explain with a neat sketch the 'sun and planet wheel.'

UNIT-3 (PART-1)

1. Define 'inertia force' and 'inertia torque'.
2. How are velocity and acceleration of the slider of a single slider crank chain determined analytically?
3. Derive an expression for the inertia force due to reciprocating mass in reciprocating engine, neglecting the mass of the connecting rod.
4. What is the difference between piston effort, crank effort and crank-pin effort?
5. Discuss the method of finding the crank effort in a reciprocating single acting, single cylinder petrol engine.
6. The inertia of the connecting rod can be replaced by two masses concentrated at two points and connected rigidly together. How to determine the two masses so that it is dynamically equivalent to the connecting rod ? Show this.
7. Given acceleration image of a link. Explain how dynamical equivalent system can be used to determine the direction of inertia force on it.
8. Describe the graphical and analytical method of finding the inertia torque on the crankshaft of a horizontal reciprocating engine.
9. Derive an expression for the correction torque to be applied to a crankshaft if the connecting rod of a reciprocating engine is replaced by two lumped masses at the piston pin and the crank pin respectively.

10. The crank and connecting rod of a steam engine are 0.3 m and 1.5 m in length. The crank rotates at 180 r.p.m. clockwise. Determine the velocity and acceleration of the piston when the crank is at 40 degrees from the inner dead centre position. Also determine the position of the crank for zero acceleration of the piston.

11. In a slider crank mechanism, the length of the crank and connecting rod are 150 mm and 600 mm respectively. The crank position is 60° from inner dead centre. The crank shaft speed is 450 r.p.m. (clockwise). Using analytical method, determine: 1. Velocity and acceleration of the slider, and 2. Angular velocity and angular acceleration of the connecting rod.

12. A vertical double acting steam engine has a cylinder 300 mm diameter and 450 mm stroke and runs at 200 r.p.m. The reciprocating parts has a mass of 225 kg and the piston rod is 50 mm diameter. The connecting rod is 1.2 m long. When the crank has turned through 125° from the top dead centre, the steam pressure above the piston is 30 kN/m2 and below the piston is 1.5 kN/m2. Calculate the effective turning moment on the crank shaft.

13. The crank and connecting rod of a petrol engine, running at 1800 r.p.m.are 50 mm and 200 mm respectively. The diameter of the piston is 80 mm and the mass of the reciprocating parts is 1 kg. At a point during the power stroke, the pressure on the piston is 0.7 N/mm2, when it has moved 10 mm from the inner dead centre. Determine : **1.** Net load on the gudgeon pin, **2.** Thrust in the connecting rod, **3.** Reaction between the piston and cylinder, and **4.** The engine speed at which the above values become zero.

14. A vertical petrol engine 100 mm diameter and 120 mm stroke has a connecting rod 250 mm long. The mass of the piston is 1.1 kg. The speed is 2000 r.p.m. On the expansion stroke with a crank 20° from top dead centre, the gas pressure is 700 kN/m2. Determine:
1. Net force on the piston, **2.** Resultant load on the gudgeon pin, **3.** Thrust on the cylinder walls, and **4.** Speed above which, other things remaining same, the gudgeon pin load would be reversed in direction.

15. If the crank and the connecting rod are 300 mm and 1 m long respectively and the crank rotates at a constant speed of 200 r.p.m., determine:1. The crank angle at which the maximum velocity occurs, and 2. Maximum velocity of the piston.

16. The crank-pin circle radius of a horizontal engine is 300 mm. The mass of the reciprocating parts is 250 kg. When the crank has travelled 60° from I.D.C., the difference between the driving and the back pressures is 0.35 N/mm2. The connecting rod length between centres is 1.2 m and the cylinder bore is 0.5 m. If the engine runs at 250 r.p.m. and if the effect of piston rod diameter is neglected, calculate : 1. pressure on slide bars, 2. thrust in the connecting rod, 3. tangential force on the crank-pin, and 4. turning moment on the crank shaft.

17. A connecting rod is suspended from a point 25 mm above the centre of small end, and 650 mm above its centre of gravity, its mass being 37.5 kg. When permitted to oscillate, the time period is found to be 1.87 seconds. Find the dynamical equivalent system constituted of two masses, one of which is located at the small end centre.

UNIT-3(PART-2)

1. Draw the turning moment diagram of a single cylinder double acting steam engine.

2. Explain precisely the uses of turning moment diagram of reciprocating engines.

3. Explain the turning moment diagram of a four stroke cycle internal combustion engine.

4. Discuss the turning moment diagram of a multicylinder engine.

5. Explain the terms 'fluctuation of energy' and 'fluctuation of speed' as applied to flywheels.

6. Define the terms 'coefficient of fluctuation of energy' and 'coefficient of fluctuation of speed', in the

case of flywheels.

7. What is the function of a flywheel? How does it differ from that of a governor?

8. Prove that the maximum fluctuation of energy,

$$\Delta E = E \times 2CS$$

where E = Mean kinetic energy of the flywheel, and

CS = Coefficient of fluctuation of speed.

16. The flywheel of a steam engine has a radius of gyration of 1 m and mass 2500 kg. The starting torque of the steam engine is 1500 N-m and may be assumed constant. Determine: **1.** the angular acceleration of the flywheel, and **2.** the kinetic energy of the flywheel after 10 seconds from the start.

17. A horizontal cross compound steam engine develops 300 kW at 90 r.p.m. The coefficient of fluctuation of energy as found from the turning moment diagram is to be 0.1 and the fluctuation of speed is to be kept within ± 0.5% of the mean speed. Find the weight of the flywheel required, if the radius of gyration is 2 metres.

18. During forward stroke of the piston of the double acting steam engine, the turning moment has the maximum value of 2000 N-m when the crank makes an angle of 80° with the inner dead centre. During the backward stroke, the maximum turning moment is 1500 N-m when the crank makes an angle of 80° with the outer dead centre. The turning moment diagram for the engine may be assumed for simplicity to be represented by two triangles.

19. If the crank makes 100 r.p.m. and the radius of gyration of the flywheel is 1.75 m, find the coefficient of fluctuation of energy and the mass of the flywheel to keep the speed within ± 0.75%of the mean speed. Also determine the crank angle at which the speed has its minimum and maximum values.

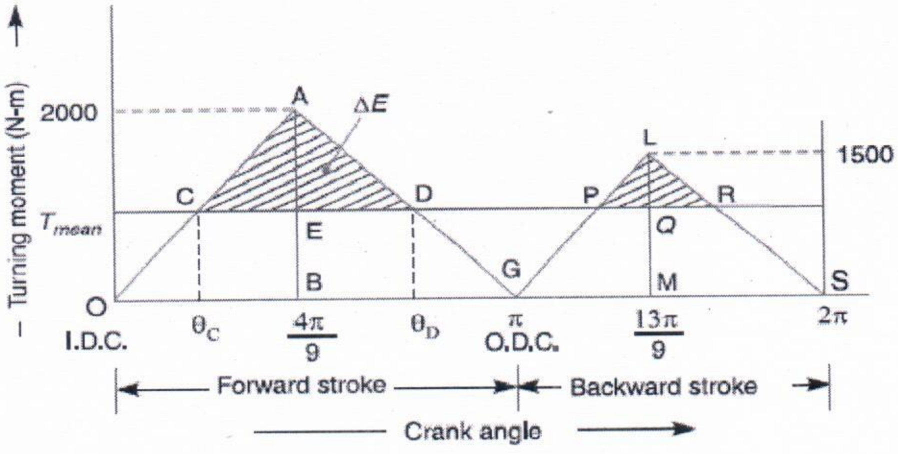

Fig. 16.9

20. A three cylinder single acting engine has its cranks set equally at 120° and it runs at 600 r.p.m. The torque-crank angle diagram for each cycle is a triangle for the power stroke with a maximum torque of 90 N-m at 60° from dead centre of corresponding crank. The torque on the return stroke is sensibly zero. Determine : **1.** power developed. **2.** coefficient of fluctuation of speed, if the mass of the flywheel is 12 kg and has a radius of gyration of 80 mm, **3.** coefficient of fluctuation of energy, and 4. maximum angular acceleration of the flywheel.

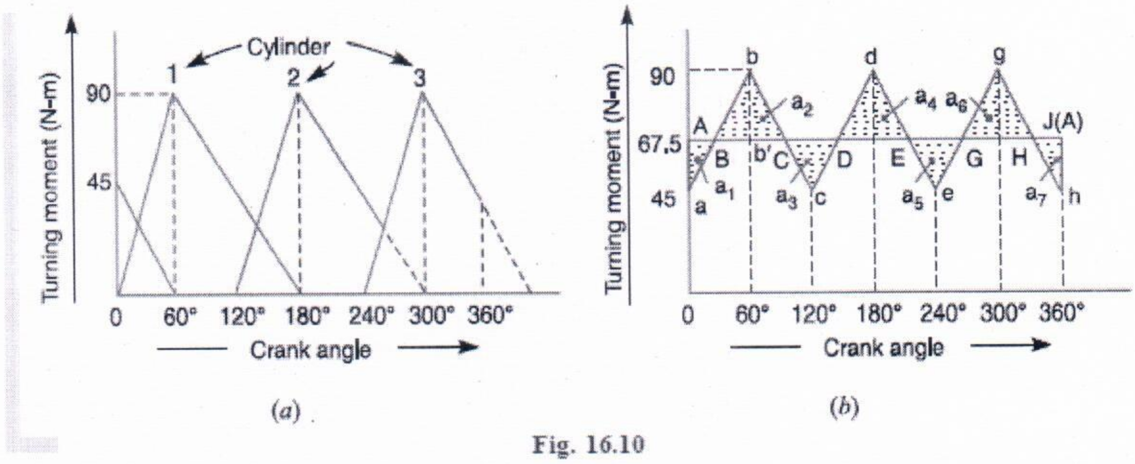

Fig. 16.10

21. The turning moment diagram for a four stroke gas engine may be assumed for simplicity to be represented by four triangles, the areas of which from the line of zero pressure are as follows :

Suction stroke = 0.45 × 10–3 m2; Compression stroke = 1.7 × 10^{-3} m2; Expansion stroke = 6.8 × 10^{-3} m2; Exhaust stroke = 0.65 × 10^{-3} m2. Each m2 of area represents 3 MN-m of energy. Assuming the resisting torque to be uniform, find the mass of the rim of a flywheel required to keep the speed between 202 and 198 r.p.m. The mean radius of the rim is 1.2 m.

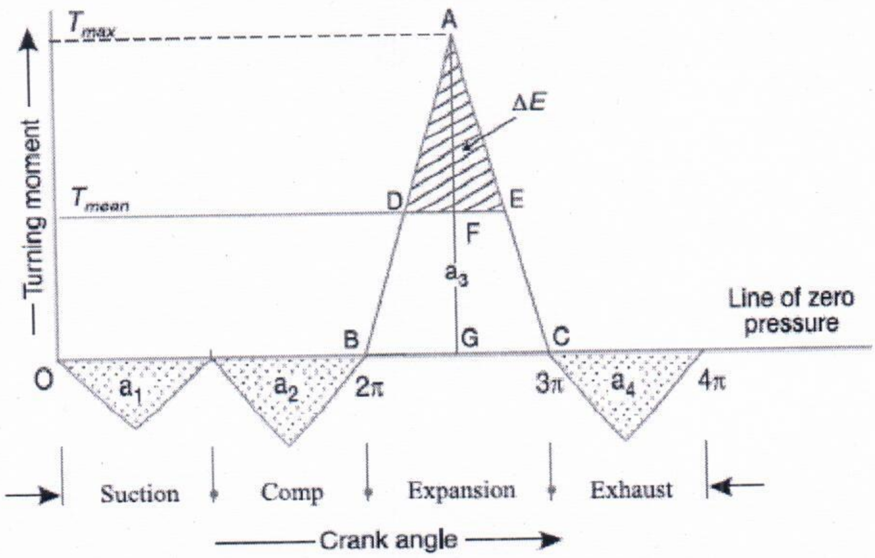

Fig. 16.12

22. The turning moment diagram for a multi-cylinder engine has been drawn to a scale of 1 mm to 500 N-m torque and 1 mm to 6° of crank displacement. The intercepted areas between output torque curve and mean resistance line taken in order from one end, in sq. mm are – 30, + 410, – 280, + 320, – 330, + 250, – 360, + 280, – 260 sq. mm, when the engine is running at 800 r.p.m.

    The engine has a stroke of 300 mm and the fluctuation of speed is not to exceed ± 2% of the mean speed. Determine a suitable diameter and cross-section of the flywheel rim for a limiting value of the safe centrifugal stress of 7 MPa. The material density may be assumed as 7200 kg/m3. The width of the rim is to be 5 times the thickness.

23. The following data relate to a connecting rod of a reciprocating engine:

Mass = 55 kg; Distance between bearing centres = 850 mm; Diameter of small end bearing = 75 mm; Diameter of big end bearing = 100 mm; Time of oscillation when the connecting rod is suspended from small end = 1.83 s; Time of oscillation when the connecting rod is suspended from big end = 1.68 s.

Determine: 1. the radius of gyration of the rod about an axis passing through the centre of gravity and perpendicular to the plane of oscillation; 2. the moment of inertia of the rod about the same axis; and 3. the dynamically equivalent system for the connecting rod, constituted of two masses, one of which is situated at the small end centre.

24. A connecting rod of an I.C. engine has a mass of 2 kg and the distance between the centre of gudgeon pin and centre of crank pin is 250 mm. The C.G. falls at a point 100 mm from the gudgeon pin along the line of centres. The radius of gyration about an axis through the C.G. perpendicular to the plane of rotation is 110 mm. Find the equivalent dynamical system if only one of the masses is located at gudgeon pin.

If the connecting rod is replaced by two masses, one at the gudgeon pin and the other at the crank pin and the angular acceleration of the rod is 23 000 rad/s2 clockwise, determine the correction couple applied to the system to reduce it to a dynamically equivalent system.

25. The mass of flywheel of an engine is 6.5 tonnes and the radius of gyration is 1.8 metres. It is found from the turning moment diagram that the fluctuation of energy is 56 kN-m. If the mean speed of the engine is 120 r.p.m., find the maximum and minimum speeds.
26. The turning moment diagram for a petrol engine is drawn to the following scales : Turning moment, 1 mm = 5 N-m ; crank angle, 1 mm = 1°. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295, 685, 40, 340, 960, 270 mm2. The rotating parts are equivalent to a mass of 36 kg at a radius of gyration of 150 mm. Determine the coefficient of fluctuation of speed when the engine runs at 1800 r.p.m.
27. The turning moment diagram for a multicylinder engine has been drawn to a scale 1 mm = 600 N-m vertically and 1 mm = 3° horizontally. The intercepted areas between the output torque curve and the mean resistance line, taken in order from one end, are as follows : + 52, – 124, + 92, – 140, + 85, – 72 and + 107 mm2, when the engine is running at a speed of 600 r.p.m. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, find the necessary mass of the flywheel of radius 0.5 m.

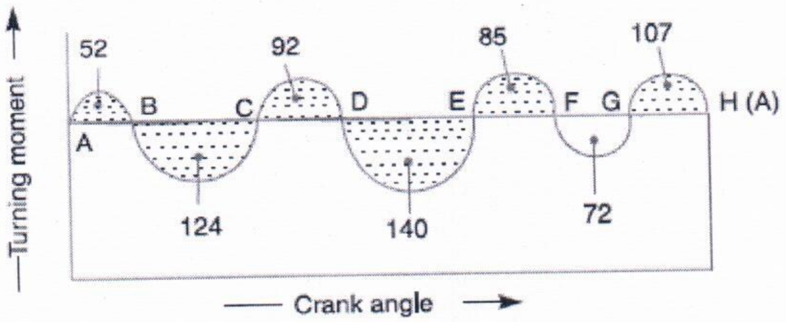

Fig. 16.7

28. A shaft fitted with a flywheel rotates at 250 r.p.m. and drives a machine. The torque of machine varies in a cyclic manner over a period of 3 revolutions. The torque rises from 750 N-m to 3000 N-m uniformly during 1/2 revolution and remains constant for the following revolution. It then falls uniformly to 750 N-m during the next 1/2 revolution and remains constant for one revolution, the cycle being repeated thereafter. Determine the power required to drive the machine and percentage fluctuation in speed, if the driving torque applied to the shaft is constant and the mass of the flywheel is 500 kg with radius of gyration of 600 mm.

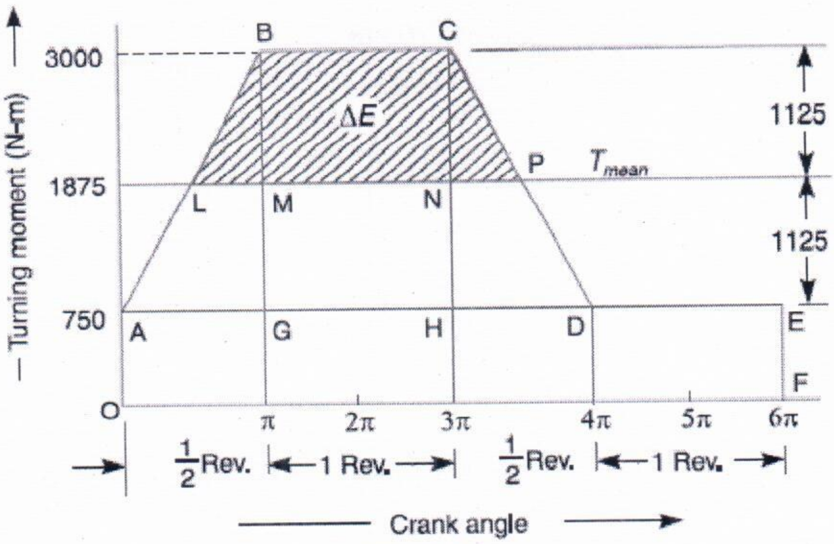

Fig. 16.8

29. *A single cylinder, single acting, four stroke gas engine develops 20 kW at 300 r.p.m. The work done by the gases during the expansion stroke is three times the work done on the gases during the compression stroke, the work done during the suction and exhaust strokes being negligible. If the total fluctuation of speed is not to exceed ± 2 per cent of the mean speed and the turning moment diagram during compression and expansion is assumed to be triangular in shape, find the moment of inertia of the flywheel.*

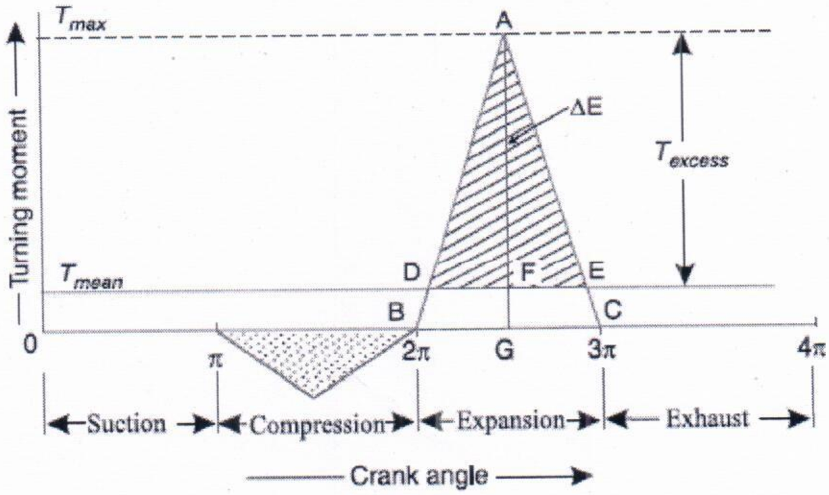

Fig. 16.11

UNIT-4 (PART-1)

5. Explain clearly the terms 'static balancing' and 'dynamic balancing'. State the necessary conditions to achieve them.
6. Discuss how a single revolving mass is balanced by two masses revolving in different planes
7. Explain the method of balancing of different masses revolving in the same plane.
8. How the different masses rotating in different planes are balanced ?
9. A shaft carries four rotating masses A, B, C and D along its axis. The mass A may be assumed concentrated at a radius 200mm, B at 260mm and D at 170mm. the mass of B,C and D are 32kg, 52kg, 42kg respectively. The planes of revolution of B and C are 300mm apart. The angle between B and C is 90^o and B and D is 210^o and C and D is 120^o. determine
   (iii) The magnitude and angular position of mass A,
   (iv) The position of planes A and D
10. Four masses A,B,C and D are completely balanced. Masses C and D makes angle of 90^o and 195^o respectively with B in same sense. The rotating masses have following properties:

    $M_b = 25$kg $\quad$ $R_a = 150$mm
    $M_c = 40$ kg $\quad$ $R_b = 200$mm
    $M_d = 35$kg $\quad$ $R_c = 100$mm $\quad$ $R_d = 180$mm

    Planes B and C are 250mm apart. Determine:
    (iii) The magnitude of mass A and its angular position.
    (iv) The position of planes A and D

11. Four masses A,B,C and D are completely balanced. The planes in which masses revolve are spaced 700mm apart. The rotating masses have following properties:

    $M_b = 12$kg $\quad$ $R_a = 110$mm
    $M_c = 07$ kg $\quad$ $R_b = 140$mm
    $M_d = 05$kg $\quad$ $R_c = 210$mm $\quad$ $R_d = 160$mm

    Determine the magnitude of mass A and relative angular positions of all masses so that the shaft is in completely balance.
12. A shaft is supported in bearings 1.8 m apart and projects 0.45 m beyond bearings at each end. The shaft carries three pulleys one at each end and one at the middle of its length. The mass of end pulleys is 48 kg and 20 kg and their centre of gravity are 15 mm and 12.5mm respectively from the shaft axis. The centre pulley has a mass of 56 kg and its centre of gravity is 15 mm from the shaft axis. If the pulleys are arranged so as to give static balance, determine: **1.** relative angular positions of the pulleys, and **2.** dynamic forces produced on the bearings when the shaft rotates at 300 r.p.m.
13. A four mass system having 200kg, 250kg, 150kg, 100 kg revolve at radius 100mm, 120mm, 250mm, 300mm respectively. The angle between successive masses is 45^o, 70^o and 140^o. Find the position and magnitude of balanced masses by graphical and analytical method if radius of rotation is 350mm.
14. A rotating shaft carries four unbalanced masses having magnitude 20kg, 15kg, 17kg and 14kg revolving at radii 60mm, 80mm, 100mm and 60mm respectively. The m2, m3 and

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m4 revolve in plane 100mm, 180mm and 300mm respectively from the plane of mass m1 are angularly located at 65°, 145° and 270°respectively, measured in anticlockwise direction from the mass m1 looking from the mass end of the shaft. The shaft is to be dynamically balanced by two masses, both located at 70mm radii and revolving in plane midway between m1 & m2 and m3 & m4. Determine the magnitude of balancing masses and their respectively angular position.

15. A shaft is supported between bearing 2.0m apart and extended 0.5m beyond bearing at each end. The shaft carries 3 pulleys one at each end and one at the middle of its length. The masses of end pulleys are 50kg and 25kg and their centre of gravity are 20mm and 15mm respectively from the axis of shaft. The centre pulley has a mass of 60 kg and its centre of gravity is 20mm from the axis of shaft. If the pulleys are arranged so as to give the static balance. Determine:
    (iii) The relative angular position of the pulleys, and
    (iv) The dynamics forces produced on the bearings when the shaft rotates at 340 r.p.m.
16. A shaft carries four masses in parallel planes A, B, C and D in this 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 an eccentricity of 80 mm. The angle between the masses at B and C is 100° and that between the masses at B and A is 190°, both being measured in the same direction. The axial distance between the planes A and B is 100 mm and that between B and C is 200 mm. If the shaft is in complete dynamic balance, determine : **1.** The magnitude of the masses at A and D ; **2.** the distance between planes A and D ; and **3.** the angular position of the mass at D.
17. A shaft has three eccentrics, each 75 mm diameter and 25 mm thick, machined in one piece with the shaft. The central planes of the eccentric are 60 mm apart. The distance of the centres from the axis of rotation are 12 mm, 18 mm and 12 mm and their angular positions are 120° apart. The density of metal is 7000 kg/m3. Find the amount of out-of-balance force and couple at 600 r.p.m. If the shaft is balanced by adding two masses at a radius 75 mm and at distances of 100 mm from the central plane of the middle eccentric, find the amount of the masses and their angular positions.

UNIT-4 (PART-2)

4. Write a short note on primary and secondary balancing.
5. Explain why only a part of the unbalanced force due to reciprocating masses is balanced by revolving mass.
6. Derive the following expressions, for an uncoupled two cylinder locomotive engine : (*a*) Variation is tractive force ; (*b*) Swaying couple ; and (*c*) Hammer blow.
7. 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

8. The following data apply to an outside cylinder uncoupled locomotive : Mass of rotating parts per cylinder = 360 kg ; Mass of reciprocating parts per cylinder = 300 kg ; Angle between cranks = 90° ; Crank radius = 0.3 m ; Cylinder centres = 1.75 m ; Radius of balance masses = 0.75 m ; Wheel centres = 1.45 m. If whole of the rotating and two-thirds of reciprocating parts are to be balanced in planes of the driving wheels, find : **1.** Magnitude and angular positions of balance masses, **2.** Speed in kilometres per hour at which the wheel will lift off the rails when the load on each driving wheel is 30 kN and the diameter of tread of driving wheels is 1.8 m, and Swaying couple at speed arrived at in **(2)** above.
9. A four cylinder vertical engine has cranks 150 mm long. The planes of rotation of the first, second and fourth cranks are 400 mm, 200 mm and 200 mm respectively from the third crank and their reciprocating masses are 50 kg, 60 kg and 50 kg respectively. Find the mass of the reciprocating parts for the third cylinder and the relative angular positions of the cranks in order that the engine may be in complete primary balance.
10. A four crank engine has the two outer cranks set at 120° to each other, and their reciprocating masses are each 400 kg. The distance between the planes of rotation of adjacent cranks are 450 mm, 750 mm and 600 mm. If the engine is to be in complete primary balance, find the reciprocating mass and the relative angular position for each of the inner cranks. If the length of each crank is 300 mm, the length of each connecting rod is 1.2 m and the speed of rotation is 240 r.p.m., what is the maximum secondary unbalanced force ?
11. The cranks and connecting rods of a 4-cylinder in-line engine running at 1800 r.p.m. are 60 mm and 240 mm each respectively and the cylinders are spaced 150 mm apart. If the cylinders are numbered 1 to 4 in sequence from one end, the cranks appear at intervals of 90° in an end view in the order 1-4-2-3. The reciprocating mass corresponding to each cylinder is 1.5 kg. Determine : **1.** Unbalanced primary and secondary forces, if any, and **2.** Unbalanced primary and secondary couples with reference to central plane of the engine.
12. A single cylinder reciprocating engine has speed 240 r.p.m., stroke 300 mm, mass of reciprocating parts 50 kg, mass of revolving parts at 150 mm radius 37 kg. If two third of the reciprocating parts and all the revolving parts are to be balanced, find: **1.** The balance mass required at a radius of 400 mm, and **2.** The residual unbalanced force when the crank has rotated 60° from top dead centre.
13. An inside cylinder locomotive has its cylinder centre lines 0.7 m apart and has a stroke of 0.6 m. The rotating masses per cylinder are equivalent to 150 kg at the crank pin, and the reciprocating masses per cylinder to 180 kg. The wheel centre lines are 1.5 m apart. The cranks are at right angles. The whole of the rotating and 2/3 of the reciprocating masses are to be balanced by masses placed at a radius of 0.6 m. Find the magnitude and direction of the balancing masses.
14. The three cranks of a three cylinder locomotive are all on the same axle and are set at 120°. The pitch of the cylinders is 1 metre and the stroke of each piston is 0.6 m. The reciprocating masses are 300 kg for inside cylinder and 260 kg for each outside cylinder and the planes of rotation of the balance masses are 0.8 m from the inside crank. If 40% of the reciprocating parts are to be balanced, find : **1.** the magnitude and the position of the balancing masses required at a radius of 0.6 m ; and the hammer blow per wheel when the axle makes 6 r.p.s.

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UNIT-4 (PART-3)

5. What is the function of a governor ? How does it differ from that of a flywheel ?
6. State the different types of governors. What is the difference between centrifugal and inertia type governors ? Why is the former preferred to the latter ?
7. Explain the term height of the governor. Derive an expression for the height in the case of a Watt governor. What are the limitations of a Watt governor ?
8. What are the effects of friction and of adding a central weight to the sleeve of a Watt governor ?
5. Define and explain the following terms relating to governors :
   1. Stability, 2. Sensitiveness, 3. Isochronism, and 4. Hunting.
6. Explain the terms and derive expressions for 'effort' and 'power' of a Porter governor.
7. Prove that the sensitiveness of a Proell governor is greater than that of a Porter governor.
8. 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 minimum and maximum speeds and range of speed of the governor.

9. The arms of a Porter governor are each 250 mm long and pivoted on the governor axis. The mass of each ball is 5 kg and the mass of the central sleeve is 30 kg. The radius of rotation of the balls is 150 mm when the sleeve begins to rise and reaches a value of 200 mm for maximum speed. Determine the speed range of the governor. If the friction at the sleeve is equivalent of 20 N of load at the sleeve, determine how the speed range is modified.
10. A Proell governor has equal arms of length 300 mm. The upper and lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 80 mm long and parallel to the axis when the radii of rotation of the balls are 150 mm and 200 mm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. Determine the range of speed of the governor.
11. A Hartnell governor having a central sleeve spring and two right-angled bell crank levers moves between 290 r.p.m. and 310 r.p.m. for a sleeve lift of 15mm. The sleeve arms and the ball arms are 80 mm and 120 mm respectively. The levers are pivoted at 120 mm from the governor axis and mass of each ball is 2.5 kg. The ball arms are parallel to the governor axis at the lowest equilibrium speed. Determine : **1.** loads on the spring at the lowest and the highest equilibrium
    speeds, and **2.** stiffness of the spring.

12. In an engine governor of the Porter type, the upper and lower arms are 200mm and 250 mm respectively and pivoted on the axis of rotation. The mass of the central load is 15 kg, the mass of each ball is 2 kg and friction of the sleeve together with the resistance of the operating gear is equal to a load of 25 N at the sleeve. If the limiting inclinations of the upper arms to the vertical are 30° and 40°, find, taking friction into account, range of speed of the governor.

13. Porter governor has all four arms 250 mm long. The upper arms are attached on the axis of rotation and the lower arms are attached to the sleeve at a distance of 30 mm from the axis. The mass of each ball is 5 kg and the sleeve has a mass of 50 kg. The extreme radii of rotation are 150 mm and 200 mm. Determine the range of speed of the governor.

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14. 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°.

15. A governor of the Proell type has each arm 250 mm long. The pivots of the upper and lower arms are 25 mm from the axis. The central load acting on the sleeve has a mass of 25 kg and the each rotating ball has a mass of 3.2 kg. When the governor sleeve is in mid-position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 175 mm. The vertical height of the governor is 200 mm. If the governor speed is 160 r.p.m. when in mid-position, find : **1.** length of the extension link; and **2.** tension in the upper arm.

16. 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.

17. 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.

18. The upper arms of a Porter governor has lengths 350 mm and are pivoted on the axis of rotation. The lower arms has lengths 300 mm and are attached to the sleeve at a distance of 40 mm from the axis. Each ball has a mass of 4 kg and mass on the sleeve is 45 kg. Determine the equilibrium speed for a radius of rotation of 200 mm and find also the effort and power of the governor for 1 per cent speed change.

19. The radius of rotation of the balls of a Hartnell governor is 80 mm at the minimum speed of 300 r.p.m. Neglecting gravity effect, determine the speed after the sleeve has lifted by 60 mm. Also determine the initial compression of the spring, the governor effort and the power. The particulars of the governor are given below:
Length of ball arm = 150mm ; length of sleeve arm = 100mm ; mass of each ball = 4 kg ; and stiffness of the spring = 25 N/mm.

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Distinguish between brakes and dynamometers.

2. Discuss the various types of the brakes.

3. Show that, in a band and block brake, the ratio of the maximum and minimum tensions in the brake straps is

$$\frac{T_0}{T_n} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n$$

where $T0$ = Maximum tension,

Tn = Minimum tension

μ = Coefficient of friction between the blocks and drum, and

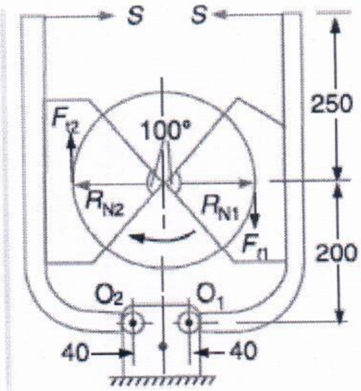
2θ = Angle subtended by each block at the centre of the drum.

4. Describe with the help of a neat sketch the principles of operation of an internal expanding shoe.

Derive the expression for the braking torque.

5. What are the leading and trailing shoes of an internal expanding shoe brake ?

5. A double shoe brake, as shown in Fig. 19.10, is capable of absorbing a torque of 1400 N-m. The diameter of the brake drum is 350 mm and the angle of contact for each shoe is 100°. If the coefficient of friction between the brake drum and lining is 0.4 ; find **1.** the spring force necessary to set the brake ; and **2.** The width of the brake shoes, if the bearing pressure on the lining material is not to exceed 0.3 N/mm2.



All dimensions in mm.

Fig. 19.10

5. 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 μ = 0.05.

6. A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brake provides a braking torque of 225 N-m. One end of the

band is attached to a fulcrum pin of the lever and the other end to a pin 100 mm from the fulcrum. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0 .25, find the operating force when the drum rotates in the (a) anticlockwise direction, and (b) clockwise direction.

7. A car moving on a level road at a speed 50 km/h has a wheel base 2.8 metres, distance of C.G. from ground level 600 mm, and the distance of C.G. from rear wheels 1.2 metres. Find the distance travelled by the car before coming to rest when brakes are applied, 1. to the rear wheels, 2. to the front wheels, and 3. to all the four wheels. The coefficient of friction between the tyres and the road may be taken as 0.6.

8. A vehicle moving on a rough plane inclined at 10° with the horizontal at a speed of 36 km/h has a wheel base 1.8 metres. The centre of gravity of the vehicle is 0.8 metre from the rear wheels and 0.9 metre above the inclined plane. Find the distance travelled by the vehicle before coming to rest and the time taken to do so when 1. The vehicle moves up the plane, and 2. The vehicle moves down the plane. The brakes are applied to all the four wheels and the coefficient of friction is 0.5.
9. The wheel base of a car is 3 metres and its centre of gravity is 1.2 metres ahead the rear axle and 0.75 m above the ground level. The coefficient of friction between the wheels and the road is 0.5. Determine the maximum deceleration of the car when it moves on a level road, if the braking force on all the wheels is the same and no wheel slip occurs.

UNIT-5 (PART-2)

1. What is the difference between absorption and transmission dynamometers ? What are torsion dynamometers ?
2. Describe the construction and operation of a prony brake or rope brake bsorption dynamometer.
3. Describe with sketches one form of torsion dynamometer and explain with detail the calculations involved in finding the power transmitted
4.A simple band brake operates on a drum of 600 mm in diameter that is running at 200 r.p.m. The coefficient of friction is 0.25. The brake band has a contact of 270°, one end is fastened to a fixed pin and the other end to the brake arm 125 mm from the fixed pin. The straight brake arm is 750 mm long and placed perpendicular to the diameter that bisects the angle of contact.

1. What is the pull necessary on the end of the brake arm to stop the wheel if 35 kW is being absorbed ? What is the direction for this minimum pull ?

2. What width of steel band of 2.5 mm thick is required for this brake if the maximum tensile stress is not to exceed 50 N/mm2 ?

9. In a winch, the rope supports a load W and is wound round a barrel 450 mm diameter. A differential band brake acts on a drum 800 mm diameter which is keyed to the same shaft

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as the barrel. The two ends of the bands are attached to pins on opposite sides of the fulcrum of the brake lever and at distances of 25 mm and 100 mm from the fulcrum. The angle of lap of the brake band is 250° and the coefficient of friction is 0.25. What is the maximum load W which can be supported by the brake when a force of 750 N is applied to the lever at a distance of 3000 mm from the fulcrum ?

6. A band and block brake, having 14 blocks each of which subtends an angle of 15° at the centre, is applied to a drum of 1 m effective diameter. The drum and flywheel mounted on the same shaft has a mass of 2000 kg and a combined radius of gyration of 500 mm. The two ends of the band are attached to pins on opposite sides of the brake lever at distances of 30 mm and 120 mm from the fulcrum. If a force of 200 N is applied at a distance of 750 mm from the fulcrum, find:
1. maximum braking torque, **2.** angular retardation of the drum, and **3.** time taken by the system to come to rest from the rated speed of 360 r.p.m.

7. In a laboratory experiment, the following data were recorded with rope brake:
Diameter of the flywheel 1.2 m; diameter of the rope 12.5 mm; speed of the engine 200 r.p.m.; dead load on the brake 600 N; spring balance reading 150 N. Calculate the brake power of the engine.

8. The essential features of a transmission dynamometer are shown in Fig. 19.35. A is the driving pulley which runs at 600 r.p.m. B and C are jockey pulleys mounted on a, horizontal beam pivoted at D, about which point the complete beam is balanced when at rest. E is the driven pulley and all portions of the belt between the pulleys are vertical. A, B and C are each 300 mm diameter and the thickness and weight of the belt are neglected. The length DF is 750 mm. Find : **1.** the value of the weight W to maintain the beam in a horizontal position when 4.5 kW is being transmitted, and **2.** the value of W, when the belt just begins to slip on pulley A. The coefficient of friction being 0.2 and maximum tension in the belt 1.5 kN.

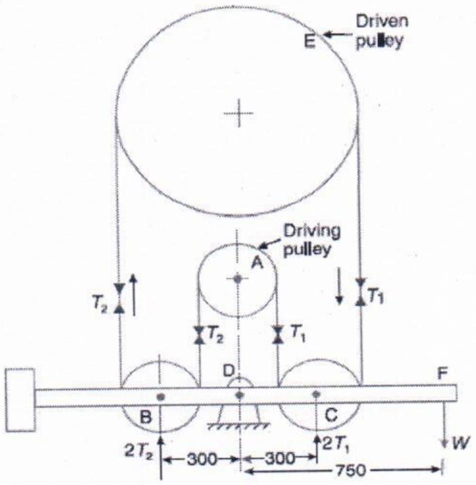

Fig. 19.35. All dimensions in mm.

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In Pursuit of Excellence	**Final Internal Marks**	SESSION-2019-2020
		SEM-6TH

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Moradabad Institute of Technology

Ram Ganga Vihar, Phase-II, Moradabad

3RD Year 6TH Semester Batch 2017

Mechanical Engineering **Section E**

THEORY OF MACHINE (RME 602)

S.No.	Roll No.	Name of Students	CT-1 (20)	CT-2 (20)	BEST 1 (20)	AT. (5)	TUTE (5)	TOTAL (30)
1.	1708240001	AATIF KHAN	D	16	16	5	5	26
2.	1708240002	ABDUL KABIR	D	15	15	4	5	24
3.	1708240003	ABHINAV GUPTA	11	18	18	5	5	28
4	1708240004	ABHINAV KUMAR	D	16	16	4	4	24
5.	1708240005	ABHISHEK CHANDRA	11	15	15	5	5	25
6.	1708240006	ADITYA SHARMA	D	14	14	4	4	22
7.	1708240007	AISHVARYA KRISHN	D	14	14	4	4	22
8.	1708240008	AKSHAT DABAS	7.5	15	15	5	4	24
9.	1708240010	AMAN AGARWAL	D	14	14	4	4	22
10.	1708240011	AMBESH KUMAR PAL	10.5	15	15	5	5	25
11.	1708240012	ANAS BEIG	D	7	7	4	3	14
12.	1708240013	ANKIT KUMAR GANGWAR	10.5	14	14	5	5	24
13.	1708240014	ANUJ	D	11	11	4	4	19
14.	1708240015	ANURAG JOSHI	10	15	15	5	5	25
15.	1708240016	ANURAG VASHISHTH	D	17	17	5	5	27
16.	1708240017	ARYAN KUMAR	D	14	14	4	3	21
17.	1708240018	ASHEESH KUMAR	D	13	13	4	4	21
18.	1708240019	ASHUTOSH BHARDWAJ	3.5	13	13	5	4	22
19.	1708240020	ASHUTOSH KUMAR	9	14	14	5	5	24
20.	1708240021	AYUSH KUMAR	D	14	14	4	4	22
21.	1708240022	AYUSH KUMAR	5	14	14	4	4	22
22.	1708240023	HIMANSHU YADAV	5.5	13	13	5	5	23
23.	1708240025	KSHITIZ SHIVAM	D	13	13	4	4	21
24.	1708240026	LALIT KUMAR	D	13	13	4	4	21
25.	1708240027	LUCKY KUNAR	4.5	13	13	4	4	21
26.	1708240028	MANJEET SINGH	D	11	11	4	4	19
27.	1708240030	MOHAMMAD AQIB	D	19	19	5	5	29
28.	1708240031	MOHAMMAD SALMAN	D	16	16	5	5	26
29.	1708240032	MOHAMMAD ZAKI	D	17	17	5	5	27
30.	1708240033	MOHAMMAD AMAAN KHAN	14.5	17	17	4	5	26
31.	1708240035	MOHD. SAMAD KHAN	D	14	14	4	4	22
32.	1708240036	NITIN TOMAR	8	16	16	4	4	24
33.	1708240037	NITISH PANDEY	D	14	14	4	4	22
34.	1708240038	OSKAR POURYA	4.5	13	13	4	4	21
35.	1708240039	PRASHANT CHAUDHARY	10	18	18	5	5	28
36.	1708240040	PRATEEK KUMAR	D	16	16	4	4	24
37.	1708240041	RAJVEER SAINI	1	12	12	4	4	20
38.	1708240042	RASHI	13.5	14	14	4	5	23
39.	1708240043	RISHABH GOEL	14.5	18	18	4	5	27
40.	1708240044	RITIK CHANDRA	0	15	15	4	4	23
41.	1708240045	ROHAN SHARMA	1.5	13	13	4	4	21
42.	1708240046	SAMBHAV SHARMA	D	15	15	4	5	24
43.	1708240047	SANDEEP SHARMA	D	14	14	4	5	23
44.	1708240048	SARTHAK DIXIT	D	13	13	4	4	21
45.	1708240049	SHASHI PRAKASH	4.5	12	12	4	5	21
46.	1708240050	SHIVAM KUMAR	3	14	14	4	4	22
47.	1708240051	SIDDHANT SHARMA	8	15	15	5	5	25
48.	1708240052	SIDDHARTHA RAJA	D	14	14	5	5	24
49.	1708240053	SIRAJ AHMAD	D	8	8	4	3	15
50.	1708240054	SOURABH KUMAR	D	13	13	4	4	21
51.	1708240055	SUBHASH CHANDRA PANDEY	6	13	13	5	4	22
52.	1708240057	SUNEEL KUMAR	D	AB	0	4	4	8

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53.	1708240058	TUSHAR GUPTA	D	13	13	4	4	21
54.	1708240059	VIVEK GUPTA	2	14	14	4	4	22
55.	1708240060	VIVEK KUMAR	D	16	16	4	4	24
56.	1708240061	YOGENDRA PAL SINGH	D	14	14	4	4	22
57.	1708240062	ZAEEM UL SAJJAD	D	13	13	4	4	21
58.	1608240066	RAJAT SAINI	D	13	13	4	4	21
59.	1608240067	RAJNISH CHAUHAN	D	13	13	4	4	21
60.	1808240901	GAURAV RATHAUR	2.5	14	14	4	4	22
61.	1808240902	SHUBHAM	0	14	14	4	4	22

(Pravesh Chandra)

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In Pursuit of Excellence	**Course outcome Attainment**	SESSION-2019-2020
		SEM-6TH

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Course Name	Theory of Machine
Course Code	RME602
Batch	2017 2021
Semester	6
Session	2019 2020
L:T:P	3.1.0

CO Attainment Gap

Course Code	CO	CO Targets	CO Attainment	CO Attainment Gap (Target - Attainment)
RME602	CO1	45	37.26	7.74
	CO2	45	39.21	5.79
	CO3	45	39.21	5.79
	CO4	45	38.73	6.27
	CO5	45	38.89	6.11

If Gap > 0 : Target not attained
If Gap ≤ 0 : Target attained

Closure of Quality Loop

Course Code	CO	CO Targets	CO Attainment Gap	Action proposed to bridge the gap where targets are not achieved	Modification of targets where Achieved
RME602	CO1	45	7.74	Contact hours will be increases for covering velocity and acceleration analysis.	
	CO2	45	5.79	some videos and examples for gear will be added in lectures and assignment in next offering of course.	
	CO3	45	5.79	More practice question will be added for Dynamic anlysis and Flywheel.	
	CO4	45	6.27	Mor practice will be added for brake and dyanometer.	
	CO5	45	6.11	Contact hours will be increases for covering Balancing Problems.	

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Theory of Machines

(Course Code:KME 603)

Department of Mechanical Engineering
MIT Moradabad,

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Course Outcomes

At the end of the course, students will be able to,

- ✓ **CO1: Describe** the concepts of machines, mechanisms and related terminologies.
- ✓ **CO2: Identify** the mechanisms and predict their motions in mechanical components.
- ✓ **CO3: Analyze** planar mechanism for displacement, velocity and acceleration analytically and graphically.
- ✓ **CO4: Analyze** various motion transmission elements like gears, gear trains and cams.
- ✓ **CO5: Utilize** analytical, mathematical and graphical aspects of kinematics of machines for effective design.

2021

TEXT BOOKS

- ✓ **Theory of Machines,** Rattan S.S, Tata McGraw-Hill Publishing Company.
- ✓ **Theory of Machines,** Sadhu Singh
- ✓ **Theory of Machines,** by R S Khurmi

REFERENCE BOOKS:

- ✓ **"Theory of Machines & Mechanisms"**, J.J. Uicker, , G.R. Pennock, J.E. Shigley. OXFORD 3rd Ed.

Further Reference:

- ✓ *National Programme on Technology Enhanced Learning (NPTEL)*
  http://nptel.ac.in/courses/112104121/1

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Kinematics of Machines

UNIT 1: Introduction to Kinematics of Machines

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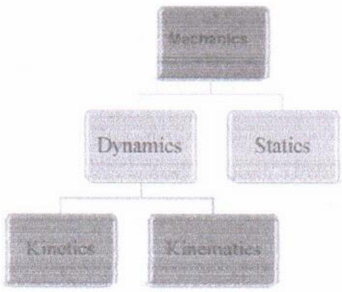
1.45



CONT....

STATICS

- It deals with the analysis of stationary systems. But time is not considered.

DYNAMICS

- It deals with the systems that change with time.

MECHANICS

- *The branch of scientific analysis that deals* with motions, time and forces is called mechanics.
- It is divided in to two parts statics and dynamics.

CONT....

KINEMATICS

- It is the study of motion, quite apart from the forces which produce that motion.
- It is the study of position, displacement, rotation, speed, velocity and acceleration.

KINETICS

- It is the study of motion and its causes

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Introduction: Definitions: Link or element, kinematic pairs, Degrees of freedom, Grubler's criterion (without derivation), Kinematic chain, Mechanism, Structure, Mobility of Mechanism, Inversion, Machine.

Kinematic Chains and Inversions: Inversions of Four bar chain; Single slider crank chain and Double slider crank chain

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Classification of Motion

- *Continuous rotation motion*

- Linear motion / Rectilinear Motion / *translatory motion*

- Intermittent motion

- Angular Oscillations

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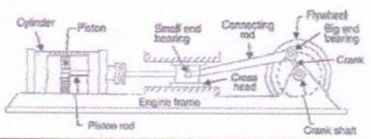
Terminologies

Machine

- Device for transferring and/or transforming motion and force (power) from **source (Input)** to the **load (output).**

or

- *A machine is a device which receives energy in some available form and utilizes to do some work.*



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Basic Definitions

- *Link or element*
- Kinematic pair
- Kinematic chain
- Mechanism, Machine & Structure
- Degrees of freedom (DOF)
- Grubler's criterion
- Inversion

Kinematic Chains and Inversions

- *Inversions of Four bar chain*
- Single slider crank chain and
- Double slider crank chain

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Basic Definitions

Link/Element → Kinematic Pair/Joint → Kinematic Chain → Mechanism → Machine

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Types of Links

- **Rigid link :** Link which does not undergo any deformation while transmitting motion.
- **Flexible link:** Link which is partly deformed in a manner not to affect the transmission of motion.

  e.g.: belts, ropes, chains and wires
- **Fluid link:** A link formed by having a fluid in a receptacle and the motion is transmitted through the fluid by pressure.

  e.g.: hydraulic presses, jacks and brakes.

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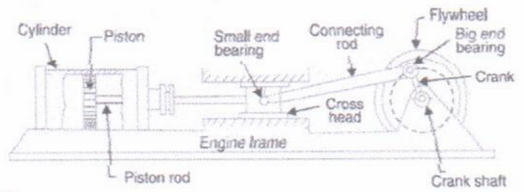
Kinematic Link or Element

Each part of a machine, which moves relative to some other part, is known as a ***kinematic link (or simply link) or element.***



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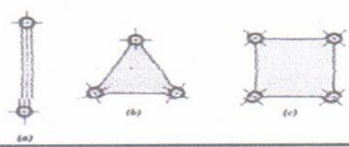
Classification of Links

- **Unary Link** : Link with one Node (bucket of an excavator)
- **Binary link :** Link connected to other links at two points
- **Ternary link:** Link connected to other links at three points
- **Quaternary link:** Link connected to other links at four points



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Structure

An assembly of a no. of resistant bodies (members) having **no relative motion between them** and meant for carrying loads having straining action.

Examples: A railway bridge, a roof truss, machine frames, etc.

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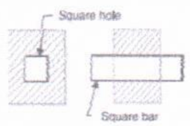
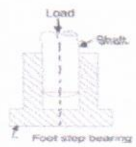
Kinematic Pair

The two links or elements of a machine, when in contact with each other, are said to form a pair. If the *relative motion between them is completely or successfully constrained* (*i.e. in a definite* direction)



Completely constrained



Successfully constrained

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Difference Between a Machine and a Structure

- The parts of a machine move relative to one another, whereas the members of a structure do not move relative to one another
- A machine transforms the available energy into some useful work, whereas in a structure no energy is transformed into useful work
- The links of a machine may transmit both power and motion, while the members of a structure transmit forces only (load bearing member).

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Constrained Motions

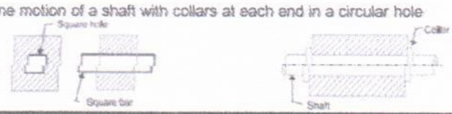
1. Completely constrained motion

When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion.

Example:

✓The motion of a square bar in a square hole

✓The motion of a shaft with collars at each end in a circular hole



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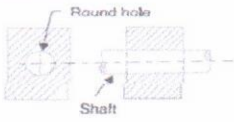
2. Incompletely constrained motion

When the motion between a pair can take place in more than one direction, then it can be an incompletely constrained motion.

E.g.: A circular bar or shaft in a circular hole

It may either rotate or slide in a hole. These both motions have no relationship with the other (automobile wheel).



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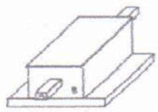
Classification of Kinematic Pairs

According to the **type of relative motion between the elements**

1. Sliding pair / Prismatic pair (P)



DOF = 1

When the two elements of a pair are connected in such a way that one can only slide relative to the other, has a completely constrained motion.

E.g.: The piston and cylinder, Cross-head and guides of a *reciprocating steam engine, ram and its guides in shaper,* tail stock on the lathe bed

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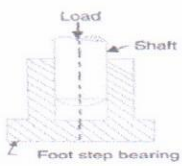
3. Successfully constrained motion

When the motion between the elements, forming a pair, is such that the *constrained motion is not completed by itself, but by some other means*

E.g.: Shaft in a foot-step bearing, I C engine valve, Piston inside an cylinder.



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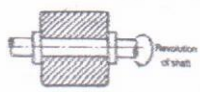
2. Turning Pair / Revolute Pair (R)

When the two elements of a pair are connected in such a way that one can only turn or revolve about a fixed axis of another link

Examples Lathe spindle supported in head stock.

cycle wheels turning over their axles.



DOF = 1

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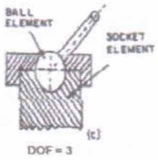
3. Spherical pair (S)

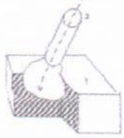
When the two elements of a pair are connected in such a way that one element turns or swivels about the other fixed element.

Eg: The ball and socket joint.

Attachment of a car mirror.

Pen stand.





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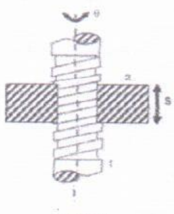
4. Screw pair

When the two elements of a pair are connected in such a way that one element can turn about the other by screw threads.

Examples:

- The lead screw of a lathe with nut
- Bolt with a nut



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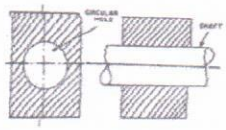
DOF = 1

5. Cylindrical pair

If the relative motion between the pairing elements is the combination of turning and sliding, then it is called as cylindrical pair.



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DOF = 2

6. Rolling Pair

When the two elements of a pair are connected in such a way that one rolls over another fixed link.

E.g.: Ball and roller bearings, railway wheel rolling over a fixed rail

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DOF = 1

Belt and pulley

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Classification of Kinematic Pairs

According to the type / nature of contact between the elements / links.

1. Lower pair

When the two elements of a pair have a **surface contact,** and the surface of one element slides or rolls over the surface of the other.

E.g. sliding pairs, turning pairs and screw pairs form lower pairs.

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Classification of Kinematic Pairs

According to the Mechanical arrangement.

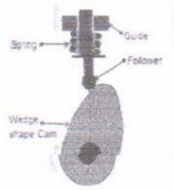
1. Self closed pair

When the two elements of a pair are ***connected together mechanically*** *in such a* way that only required relative motion occurs.

E.g. Lower pairs are self closed pair.

2. Force - closed pair

When the two elements of a pair are **not connected mechanically** but **are kept in contact by the action of** ***external forces***, the pair is said to be a force-closed pair.



E.g.: Cam and follower

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Classification of Kinematic Pairs

According to the type / nature of contact between the elements / links.

2. Higher pair

When the two elements of a pair have a **line or point contact,** and the motion between the two elements is partly turning and partly sliding.

E.g.: toothed gearing, belt and rope drives, ball and roller bearings and cam and follower.

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Kinematic Pairs

- **Lower pair**
  - Sliding pairs
  - Turning pairs
  - Screw pairs
- **Higher pair**
  - Rolling pair
- **Self closed pair**
- **Force - closed pair**

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- Based on the possible motions (Few Important Types only)

Name of Pair	Letter Symbol	D.O.F
1. Revolute / Turning Pair	R	1
2. Prismatic / Sliding Pair	P	1
3. Helical / Screw Pair	H	1
4. Cylindrical Pair	C	2
5. Spherical / Globular Pair	S (or) G	3
6. Flat / Planar Pair	E	3

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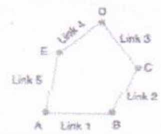
Kinematic Chain

When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (*i.e. completely or successfully constrained motion*), it is called a *kinematic chain.*

Or

Assembly of links (Kinematic link / element) and Kinematic pairs to transmit required / specified output motion(s) for given input motion(s)



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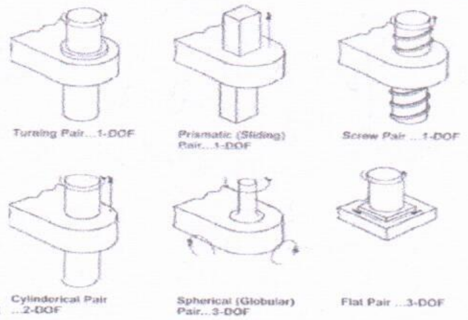

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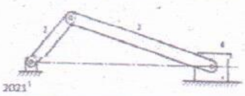
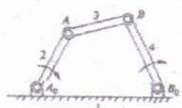
Mechanism

- When one of the links of a kinematic chain is fixed, the chain is known as **mechanism.**
- It may be used for transmitting or transforming motion

e.g. printing machine, windshield wiper, robot arms

- A mechanism may be regarded as a machine in which each part is reduced to the simplest form to transmit the required motion.





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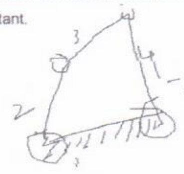
Degrees of Freedom (DOF) / Mobility of a Mechanism

Number of independent coordinates, required to describe / specify the configuration or position of all the links of the mechanism, with respect to the fixed link at any given instant.



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Grubler's Criterion / Equation

Grubler's mobility equation

$M = 3(n-1) - 2J_1 - J_2$

M = Mobility or Total no. of DOF

n = Total no. of links in a mechanism

J_1 = No. of joints having 1 DOF

J_2 = No. of joints having 2 DOF

If, M>0, It gives mechanism with M DOF

M=0, it gives a statically determinate structure

M<0, it gives statically indeterminate structure.

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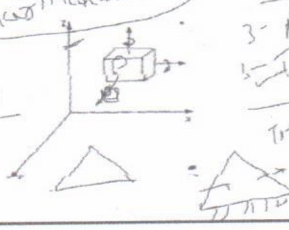
Degrees of freedom (DOF)

In a kinematic pair, depending on the constraints imposed on the motion, the links may loose some of the six degrees of freedom.



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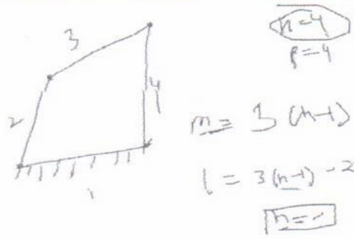

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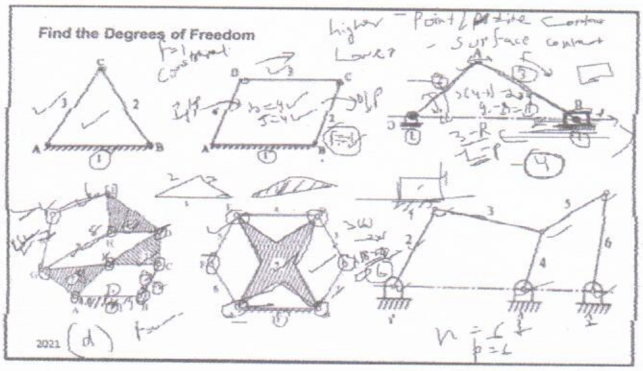

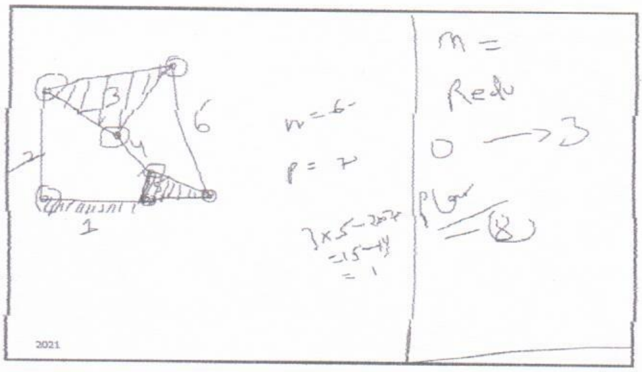

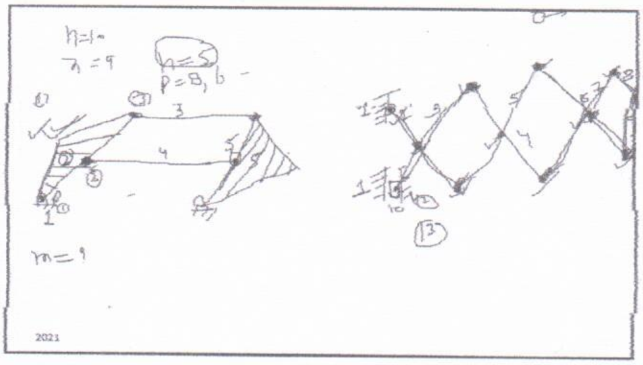

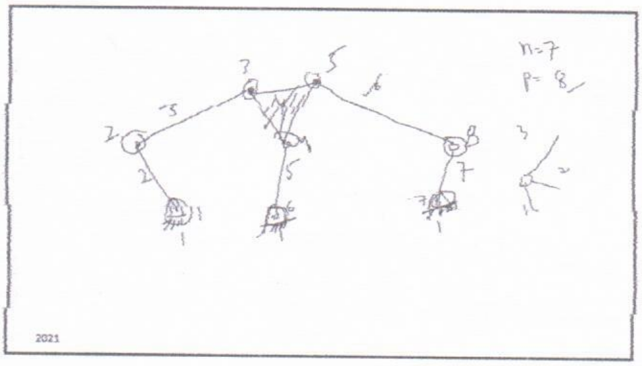

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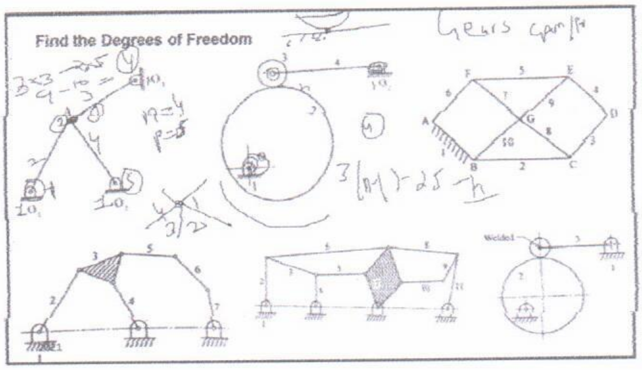

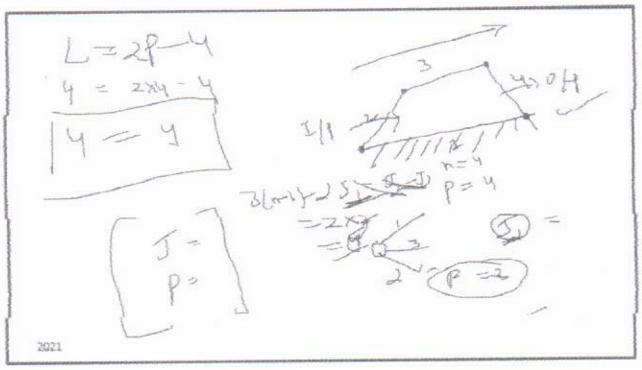

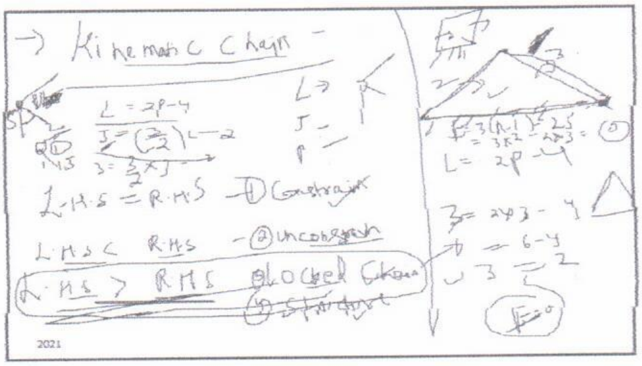

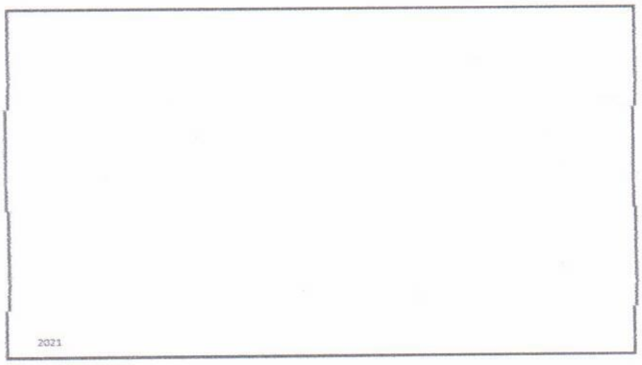

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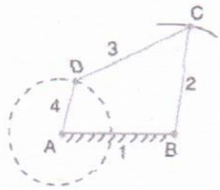
Inversion of Mechanism

- A mechanism is one in which one of the links of a kinematic chain is fixed.
- Different mechanisms can be obtained by fixing different links of the same kinematic chain.



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Types of Kinematic Chains

1. Four bar chain or quadric cyclic chain — 4-R chain — R–R–R–R
2. Single slider crank chain — 3 R–1 P Chain — R–R–R–P
3. Double slider crank chain — 2 R – 2 P Chain — R–R–P–P

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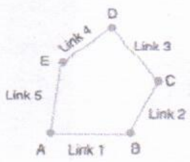
Kinematic Chain

When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (*i.e. completely* or successfully constrained motion).



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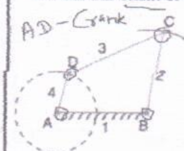
1. Four bar chain or quadric chain

AD – Crank



- Four bar chain (mechanism) is the simplest and the basic kinematic chain and consists of four rigid links
- Each of them forms a *turning pair at A, B, C and D.*

The link that makes a complete revolution is called a **crank**

- The four links may be of different lengths. $S+L > P+Q$ → R-R
- According to **Grashof 's law** for a four bar mechanism, "the sum of the shortest and longest link lengths should not be greater than the sum of the remaining two link lengths" if there is to be continuous relative motion between the two links. $S+L \leq P+Q$

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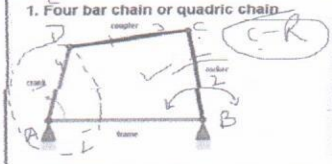
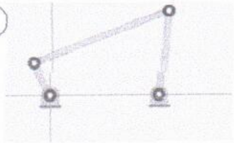
1. Four bar chain or quadric chain



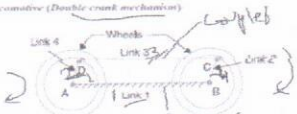


- The shortest link, will make a complete revolution relative to the other three links **crank or driver.** In Fig., AD (link 4) is a crank.
- link BC (link 2) which makes a partial rotation or oscillates is known as **lever** or **rocker or follower**
- link CD (link 3) which connects the crank and lever is called **connecting rod or coupler.**
- The fixed link AB (link 1) is known as **frame of the mechanism.**

2021 **The mechanism transforms rotary motion into oscillating motion.**

Inversions of Four Bar Chain

1. *Coupling rod of a locomotive (Double crank mechanism)*



- In this mechanism, the links AD and BC (having equal length) act as cranks and are connected to the respective wheels.
- The link CD acts as a coupling rod.
- The link AB is fixed in order to maintain a constant centre to centre distance between them.

2021 **Purpose: Transmitting rotary motion from one wheel to the other wheel.**

Inversions of Four Bar Chain

Coupling rod of a locomotive (Double crank mechanism)

Beam engine (crank and lever mechanism)

Watt's indicator mechanism (Double lever mechanism).

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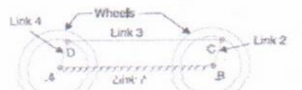

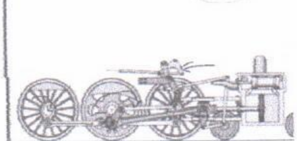

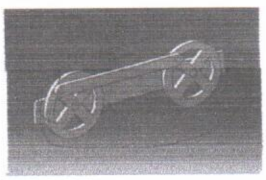

2021 *Coupling rod of a locomotive (Double crank mechanism)*

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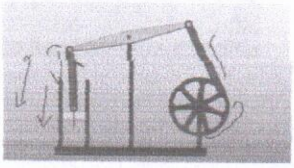
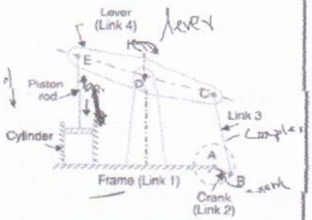
Beam engine (crank and lever mechanism)

- When the crank AB rotates about the fixed pointA.
- The lever oscillates about another fixed point D.
- The end E of lever is connected to a piston rod which reciprocates in a cylinder.





2021 **Purpose of this mechanism is to convert rotary motion into reciprocating motion.**

Single Slider Crank Chain & Inversion

2021

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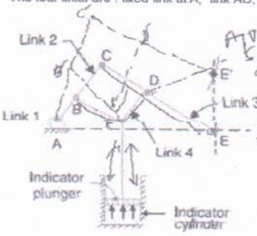
3. Watt's indicator mechanism (Double lever mechanism)

Watt's straight line mechanism

The four links are : fixed link at A, link AC, link CE and link BFD. Links CE and BFD act as levers.



On displacement of the mechanism, the tracing point ***E*** *at the end of the link CE traces out approximately a straight line.*

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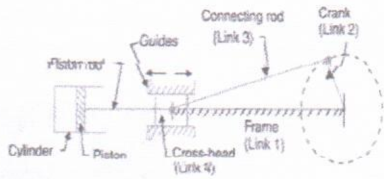
2. Single Slider Crank Chain



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Inversions of Single Slider Crank Chain

Pendulum pump or Bull engine

Oscillating cylinder engine

Rotary internal combustion or Gnome engine

Crank and slotted lever quick return motion mechanism.

Whitworth quick return motion mechanism.

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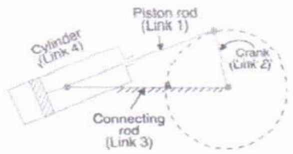
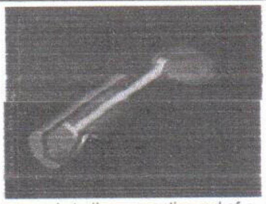
Oscillating cylinder engine





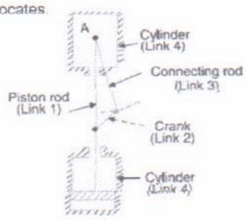
Link 3 forming the turning pair is fixed and it corresponds to the connecting rod of a reciprocating steam engine mechanism.

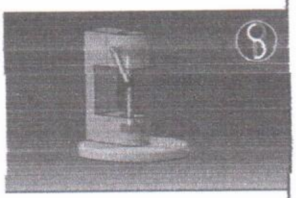
When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at

2021

Pendulum Pump or Bull Engine

When the crank (link 2) is given a rotary motion, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at *A. The piston* attached to the piston rod (link 1) reciprocates.





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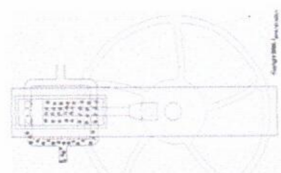
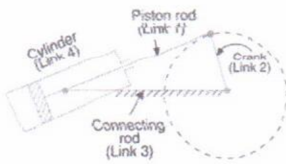
Oscillating cylinder engine





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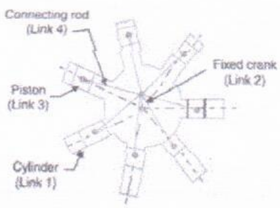
Rotary internal combustion engine

Gnome engine



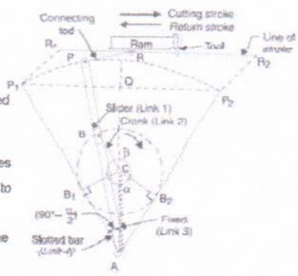
It consists of seven cylinders in one plane all revolve about fixed centre *D*.

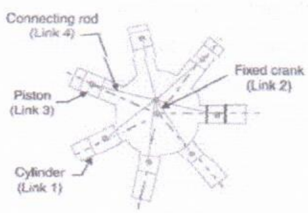
Cylinders form link 1, Crank (link 2) is fixed. When the connecting rod (link4) rotates, the piston (link 3) reciprocates inside the cylinder.

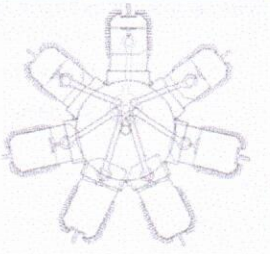
Crank and slotted lever quick return motion mechanism.

A mechanism used in shaping and slotting *machines, where the metal is cut intermittently.*

- Link AC (i.e. link 3) is fixed.
- Crank CB revolves with uniform angular speed about the fixed center C.
- Sliding block attached to the crank pin at **B** slides along the slotted bar AP, thus causing AP to oscillate about the pivoted point A.
- Short link PR transmits the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R_1R_2

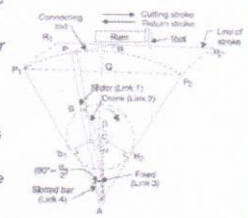






Radial Engine

- The forward or cutting stroke occurs when the crank rotates from the position CB_1 to CB_2 (or through an angle β) in the clockwise direction.
- The return stroke occurs when the crank rotates from the position CB_2 to CB_1 (or through angle α) in the clockwise direction.



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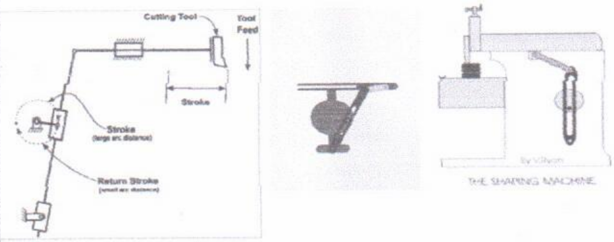

Crank and slotted lever quick return motion mechanism.

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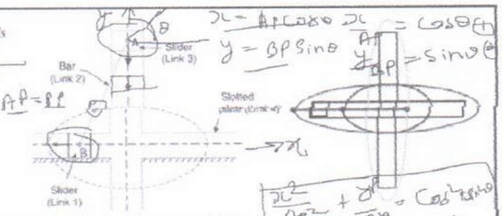
Elliptical trammels



$x = AP\cos\theta$, $\frac{x}{AP} = \cos\theta$

$y = BP\sin\theta$, $\frac{y}{BP} = \sin\theta$

$\frac{x^2}{AP^2} + \frac{y^2}{BP^2} = 1$

- This inversion is obtained by fixing the slotted plate (link 4).
- fixed plate or link 4 has two straight grooves cut in it, at right angles to each other.
- link 1 and link 3, are known as sliders and form sliding pairs with link 4.
- link AB (link 2) is a bar which forms turning pair with links 1 and 3.
- When the links 1 and 3 slide along their respective grooves, any point on the link 2 such as **P** traces out an ellipse on the surface of link 4

Double Slider Crank Chain

R–R–P–P
R–P–R–P

Inversions of Double Slider Crank Chain

Elliptical trammels

Scotch yoke mechanism

Oldham's coupling

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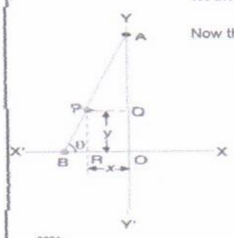
Show that AP and BP are the semi-major axis and semi-minor axis of the ellipse.



OX and OY as horizontal and vertical axes

let the link BA is inclined at an angle θ with the horizontal,

Now the co-ordinates of the point P on the link BA will be

$$x = PQ = AP\cos\theta, \text{ and } y = PR = BP\sin\theta$$

$$\frac{x}{AP} = \cos\theta; \text{ and } \frac{y}{BP} = \sin\theta$$

Squaring and adding,

$$\frac{x^2}{(AP)^2} + \frac{y^2}{(BP)^2} = \cos^2\theta + \sin^2\theta = 1$$

This is the equation of an ellipse

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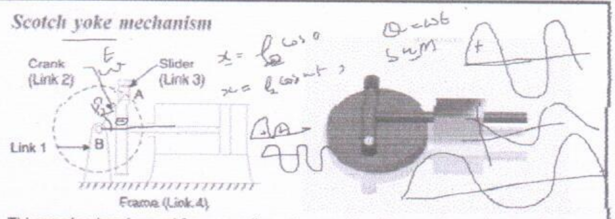
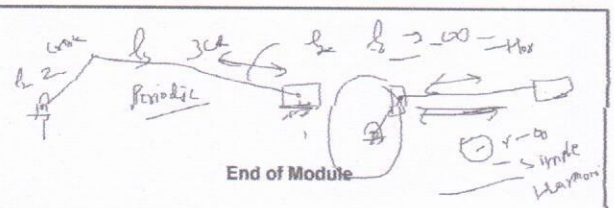
Scotch yoke mechanism



- This mechanism is used for converting rotary motion into a reciprocating motion.
- The inversion is obtained by fixing either the link 1 or link 3. link 1 is fixed.
- *In this mechanism, when the link 2 (crank) rotates about B as centre, the link 4* (frame) reciprocates.
- ~~The~~ fixed link 1 guides the frame.



End of Module

2021

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INVERSION OF 4 BAR CHAIN MECHANISM

TOPICS

INVERSION:

CLASSIFICATION OF INVERSION:

INVERSION OF FOUR BAR CHAIN

GRASHOF'S LAW

S+L<P+Q	S+L=P+Q	S+L>P+Q
IF S IS FIXED CRANK-CRANK MECHANISM	PARALLELOGRAM LINKAGE	DOUBLE ROCKER
IF S IS COUPLER DOUBLE ROCKER MECHANISM	DELTOID LINKAGE	
IF S IS ADJACENT TO FIXED LINK CRANK-ROCKER MECHANISM	IF L IS FIXED CRANK-ROCKER MECHANISM	

S : LENGTH OF SHORTEST LINK

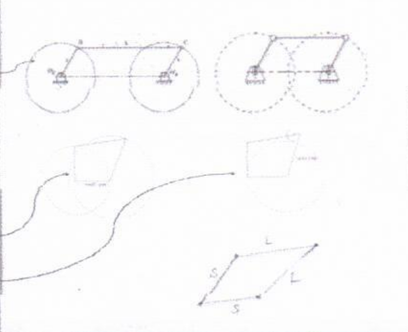
L : LENGTH OF LONGEST LINK

P&Q : ANOTHER TWO LINK

INVERSION

- WHEN DIFFERENT LINKS OF A KINEMATIC CHAIN ARE USED AS A FRAME, RELATIVE MOTION OF LINKS ARE NOT ALTERED, HOWEVER, THE ABSOLUTE MOTION OF SUCH A MECHANISM IS DRASTICALLY CHANGED.
- THE PROCESS OF CHOOSING DIFFERENT LINKS OF A CHAIN FOR FRAME IS CALLED " KINEMATIC INVERSION".
- THEREFORE, IF A MECHANISM HAS "N" NUMBER OF LINKS, WE CAN OBTAIN "N" NUMBER OF INVERSIONS.
- THE BEHAVIOUR AND APPEARANCE OF SUCH MECHANISM IS DIFFERENT. EACH MECHANISM THUS OBTAINED IS CALLED *AN "INVERSION OF KINEMATIC CHAIN"*

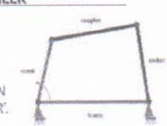
S+L=P+Q

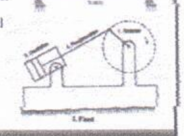


FOUR BAR CHAIN

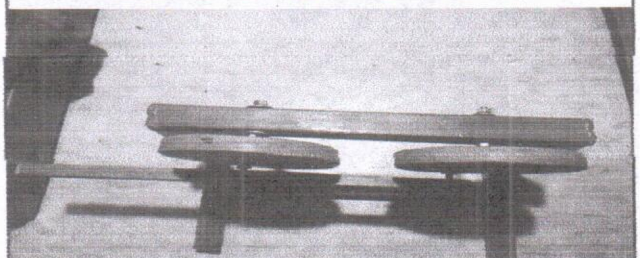
SOME IMPORTED TERMS NEED TO BE CLEARED AS AN ENGINEER

- **CRANK** : LINK WHICH IS PERMITTED TO COMPLETE THE FULL ROTATION IS TERMED AS 'CRANK'.
- **ROCKER** : LINK WHICH IS PERMITTED TO OSCILLATE BETWEEN SPECIFIED LIMIT BUT NOT TO ROTATION IS TERMED AS 'ROCKER'.
- **FRAME** : LINK WHICH WE WOULD ASSUME TO BE STATIC WHI DESIGNING.
- **COUPLER** : LINK WHICH JOINTS ROCKER AND CRANK AND RECIPROCATES WITHIN THE LIMIT.





LOCOMOTIVE MECHANISM (S+L=P+Q)



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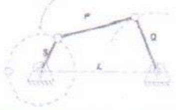
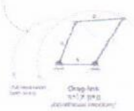
S+L<P+Q (FIRST MECHANISM)

- IF OTHER THEN SHORTEST LINK IS FIXED CRANK-ROCKER MECHANISM IS OBTAINED
- ONE LINK OSCILLATES WITHIN THE LIMIT
- KNOWN AS CLASS FIRST MECHANISM
- IF SHOREST LINK IS FIXED CRANK-CRANK MECHANISM CAN BE OBTAINED KNOWN AS DOUBLE-CRANK MECHANISM,ROTARY-ROTARY CONVERSION AND DRAG-CRANK MECHANISM





Q. The lengths of the links of a 4-bar linkage with revolute pairs only are p,q,r and s units. Given that p < q < r < s. which of these links should be the fixed one, for obtaining a 'double crank' mechanism?
(a) link of length p (b) link of length q (c) link of length r (d) link of length s

Q. In a four-bar linkage, S denotes the shortest link length, L is the longest link length, P and Q are the lengths of other two links. At least one of the three moving links will rotate by 360° if
(A) S L P Q

Q. A 4-bar mechanism with all revolute pairs has link lengths lf = 20 mm, lin = 40 mm, lco = 50 mm and lout = 60 mm. The suffixes 'f', 'in', 'co' and 'out' denote the fixed link, the input link, the coupler and output link respectively. Which one of the following statements is true about the input and output links?
(A) Both links can execute full circular motion
(B) Both links cannot execute full circular motion
(C) Only the output link cannot execute full circular motion
(D) Only the input link cannot execute full circular motion

S+L>P+Q

- CLASS SECOND MECHANISM
- ALWAYS GIVE DOUBLE ROTOR MECHANISM
- NEVER GIVE CRANK MECHANISM WHICH MEANS THERE WOULD BE NO RORATING MOTION OF ANY LINK

THANK YOU !!

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REDUNDANT DEGREE OF FREEDOM

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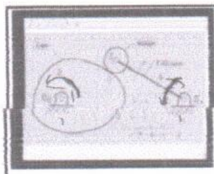


n = 4
1-2 — R
2-3 — h
3-4 — R
1-4 — R

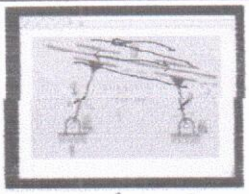
F = 3
h = 1

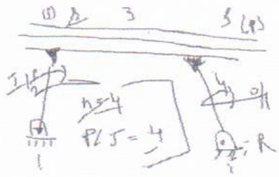
$F = 3(n-1) - 2j - h$
$= 3\times3 - 2\times3 - 1$
$= 9 - 6 - 1$

$F_r = 1$

$F_{eff} = 3(n-1) - 2j - h - F_r$

F = 3 − 1 = 2





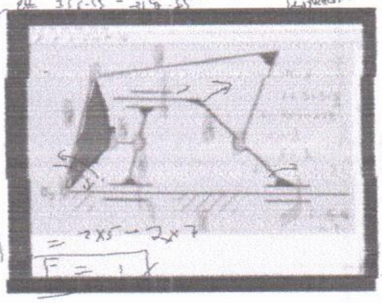
due to link − 3

n = 4
P/J = 4

1-2 — R
2-3 → P
3-4 → P
1-4 — R

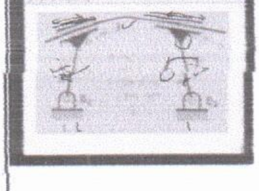
$F = 3(n-1) - 2j$
$= 3\times3 - 2\times4$
$= 9 - 8$
$= 1$

$F = 3(n-1) - 2j - h - F_r$ → redundant pair



n = 6
P = 8 − 1 = 7
F = −1

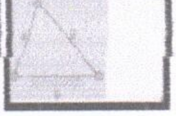
$3\times5 - 2\times7$
$= 15 - 14$
$= 1$



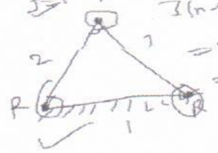
n = 4
J = 4

F = 1

1-2 — R
2-3 — P
3-4 — P
1-4 — R



F = 0
n = 3



n = 3
J = 3

$3(n-1) - 2j$
$= 3\times2 - 2\times3$
$= 6 - 6$
$= 0$

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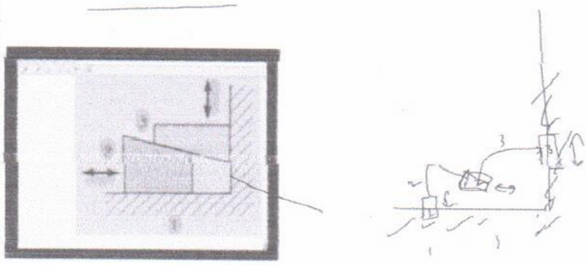

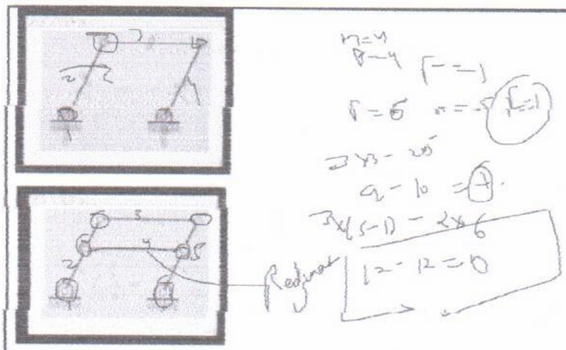

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DYNAMICS OF MACHINES

INTRODUCTION

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9/6/2021

Sub-divisions of Theory of Machines

1. Kinematics.

   It is that branch of Theory of Machines which deals with the relative motion between the various parts of the machines.

2. Dynamics.

   It is that branch of Theory of Machines which deals with the forces and their effects, while acting upon the machine parts in motion.

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Introduction

The subject Theory of Machines may be defined as that branch of Engineering-science, which deals with the **study of relative motion** between the various parts of a machine, **and forces** which act on them.

The knowledge of this subject is very essential for an engineer in designing the various parts of a machine.

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Sub-divisions of Theory of Machines

3. Kinetics.

   It is that branch of Theory of Machines which deals with the inertia forces which arise from the combined effect of the mass and motion of the machine parts.

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Sub-divisions of Theory of Machines

The Theory of Machines may be sub-divided into the following four branches :

1. Kinematics.
2. Dynamics.
3. Kinetics.
4. Statics.

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Sub-divisions of Theory of Machines

4. Statics.

   It is that branch of Theory of Machines which deals with the forces and their effects while the machine parts are at rest. The mass of the parts is assumed to be negligible.

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3

DYNAMICS OF MACHINES

Unit I
FORCE ANALYSIS

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Inertia force

A force equal in magnitude but opposite in direction and collinear with the impressed force producing the acceleration, is known as inertia force.

Inertia force = – m x a

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Static force analysis

When the inertia forces due to the mass of the machine components are neglected, then the analysis of the mechanism is known as static force analysis.

Condition for static equilibrium

- The vector sum of all the forces acting on the system is equal to zero.

$\sum F = 0$

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Inertia torque

The inertia torque is an imaginary torque, which when applied upon the rigid body, *brings it in equilibrium position. It is equal to* the accelerating couple in magnitude but opposite in direction.

Inertia Torque = -I x α

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Dynamic force analysis

When the inertia forces are considered in the analysis of the mechanism, the analysis is known as dynamic force analysis.

Condition for dynamic equilibrium

- The vector sum of all the forces acting on the system is equal to zero.

$\sum F = 0$

- The vector sum of the moments of all the forces about any arbitrary axis is equal to zero.

$\sum M = 0$

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D-Alembert's principle

D-Alembert's principle states that, the inertia forces and toques, and the external forces and torques, acting on a body together result in statically equilibrium.

$\sum F = 0$ and $\sum M = 0$

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Dynamic Analysis in reciprocating engines

The velocity and acceleration of the reciprocating parts of the steam engine or internal combustion engine may be determined by graphical method or analytical method.

The velocity and acceleration, by graphical method, may be determined by one of the following constructions:

1. Klien's construction,
2. Ritterhaus's construction, and
3. Bennett's construction.

Dynamic Analysis in reciprocating engines - Analytical Method

Let

l = Length of connecting rod between the centres,

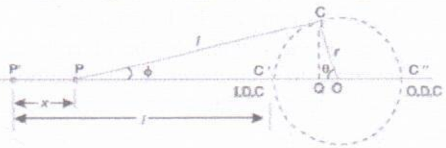
r = Radius of crank or crank pin circle,

θ = Inclination of crank to the line of stroke PO

n = Ratio of length of connecting rod to the radius of crank = l/r.

Dynamic Analysis in reciprocating engines - Analytical Method

Consider the motion of a crank and connecting rod of a reciprocating steam engine as shown in Figure.



Dynamic Analysis in reciprocating engines - Analytical Method

Velocity of the piston

From the geometry of Fig.

$$x = P'P = OP' - OP = (P'C' + C'O) - (PQ + QO)$$

$$= (l + r) - (l\cos\phi + r\cos\theta) \quad \ldots \left[\because PQ = l\cos\phi, \text{ and } QO = r\cos\theta\right]$$

$$= r(1-\cos\theta) + l(1-\cos\phi) = r\left[(1-\cos\theta) + \frac{l}{r}(1-\cos\phi)\right]$$

$$= r[(1-\cos\theta) + n(1-\cos\phi)] \quad \ldots(i)$$

Dynamic Analysis in reciprocating engines - Analytical Method

Let OC be the crank and PC the connecting rod. Let the crank rotates with angular velocity of rad/s and the crank turns through an angle θ from the inner dead centre (briefly written as I.D.C).

Let x be the displacement of a reciprocating body P from I.D.C. after time t seconds, during which the crank has turned through an angle θ.

Dynamic Analysis in reciprocating engines - Analytical Method

From triangles CPQ and CQO,

$$CQ = l\sin\phi = r\sin\theta \text{ or } l/r = \sin\theta/\sin\phi$$

$$\therefore \quad n = \sin\theta/\sin\phi \text{ or } \sin\phi = \sin\theta/n \quad \ldots(ii)$$

We know that, $\cos\phi = (1-\sin^2\phi)^{\frac{1}{2}} = \left(1 - \frac{\sin^2\theta}{n^2}\right)^{\frac{1}{2}}$

Expanding the above expression by binomial theorem, we get

$$\cos\phi = 1 - \frac{1}{2}\times\frac{\sin^2\theta}{n^2} + \ldots \quad \ldots\text{(Neglecting higher terms)}$$

or

$$1 - \cos\phi = \frac{\sin^2\theta}{2n^2} \quad \ldots(iii)$$

Dynamic Analysis in reciprocating engines - Analytical Method

Substituting the value of $(1 - \cos\phi)$ in equation (i), we have

$$x = r\left[(1-\cos\theta) + n \times \frac{\sin^2\theta}{2n^2}\right] = r\left[(1-\cos\theta) + \frac{\sin^2\theta}{2n}\right] \quad \ldots(iv)$$

Differentiating equation (iv) with respect to θ,

$$\frac{dx}{d\theta} = r\left[\sin\theta + \frac{1}{2n} \times 2\sin\theta.\cos\theta\right] = r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right) \quad \ldots(v)$$

$(\because 2\sin\theta\cos\theta = \sin 2\theta)$

$\therefore$ Velocity of P with respect to O or velocity of the piston P,

$$v_{PO} = v_P = \frac{dx}{dt} = \frac{dx}{d\theta} \times \frac{d\theta}{dt} = \frac{dx}{d\theta} \times \omega$$

...($\because$ Ratio of change of angular velocity $= d\theta/dt = \omega$)

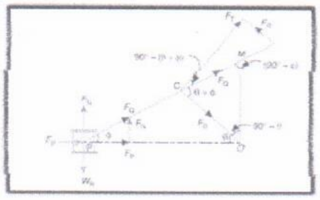
Substituting the value of $dx/d\theta$ from equation (v), we have

$$v_{PO} = v_P = \omega r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right) \quad \ldots(vi)$$

Forces on the Reciprocating Parts of an Engine

1. Piston effort

It is the net force acting on the piston or crosshead pin, along the line of stroke. It is denoted by F_P.



Dynamic Analysis in reciprocating engines - Analytical Method

Acceleration of the piston

Since the acceleration is the rate of change of velocity, therefore acceleration of the piston P,

$$a_P = \frac{dv_P}{dt} = \frac{dv_P}{d\theta} \times \frac{d\theta}{dt} = \frac{dv_P}{d\theta} \times \omega$$

Differentiating equation (vi) with respect to θ,

$$\frac{dv_P}{d\theta} = \omega r\left[\cos\theta + \frac{\cos 2\theta \times 2}{2n}\right] = \omega r\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

Substituting the value of $\frac{dv_P}{d\theta}$ in the above equation, we have

$$a_P = \omega r\left[\cos\theta + \frac{\cos 2\theta}{n}\right] \times \omega = \omega^2 r\left[\cos\theta + \frac{\cos 2\theta}{n}\right] \quad \ldots(vii)$$

The inertia force due to the acceleration of the reciprocating parts, opposes the force on the piston due to the difference of pressures in the cylinder on the two sides of the piston. On the other hand, the inertia force due to retardation of the reciprocating parts, helps the force on the piston. Therefore,Piston effort,

Dynamic Analysis in reciprocating engines - Analytical Method

Notes: 1. When crank is at the inner dead centre (I.D.C.), then $\theta = 0°$.

$$\therefore \quad a_P = \omega^2 r\left[\cos 0° + \frac{\cos 0°}{n}\right] = \omega^2 r\left(1 + \frac{1}{n}\right)$$

2. When the crank is at the outer dead centre (O.D.C.), then $\theta = 180°$.

$$\therefore \quad a_P = \omega^2 r\left[\cos 180° + \frac{\cos 2 \times 180°}{n}\right] = \omega^2 r\left(-1 + \frac{1}{n}\right)$$

As the direction of motion is reversed at the outer dead centre, therefore changing the sign of the above expression,

$$a_P = \omega^2 r\left[1 - \frac{1}{n}\right]$$

Piston effort, F_P = Net load on the piston $\mp$ Inertia force

$= F_L \mp F_I$ ...(Neglecting frictional resistance)

$= F_L \mp F_I - R_F$ ...(Considering frictional resistance)

where R_F = Frictional resistance.

The –ve sign is used when the piston is accelerated, and +ve sign is used when the piston is retarded.

In a double acting reciprocating steam engine, net load on the piston,

$$F_L = p_1 A_1 - p_2 A_2 = p_1 A_1 - p_2 (A_1 - a)$$

where p_1, A_1 = Pressure and cross-sectional area on the back end side of the piston,

p_2, A_2 = Pressure and cross-sectional area on the crank end side of the piston,

a = Cross-sectional area of the piston rod.

Notes: 1. If 'p' is the net pressure of steam or gas on the piston and D is diameter of the piston, then

Net load on the piston, F_L = Pressure × Area $= p \times \frac{\pi}{4} \times D^2$

2. In case of a vertical engine, the weight of the reciprocating parts assists the piston effort during the downward stroke (i.e. when the piston moves from top dead centre to bottom dead centre) and opposes during the upward stroke of the piston (i.e. when the piston moves from bottom dead centre to top dead centre).

$\therefore$ Piston effort, $F_P = F_L \mp F_I \pm W_R - R_F$

$$F_I = m_R \cdot a_R = m_R\, \omega^2 r\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

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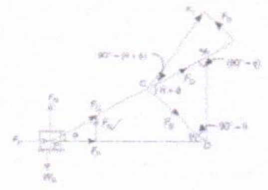
Forces on the Reciprocating Parts of an Engine

2. Force acting along the connecting rod, F_Q



$$F_Q = \frac{F_P}{\cos\phi}$$

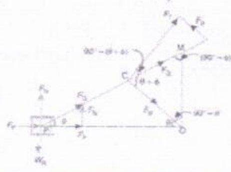
We know that $\cos\phi = \sqrt{1 - \frac{\sin^2\phi}{n^2}}$

$$\therefore \quad F_Q = \frac{F_P}{\sqrt{1 - \frac{\sin^2\theta}{n^2}}}$$

Forces on the Reciprocating Parts of an Engine

3. Thrust on the sides of the cylinder walls (or) normal reaction on the guide bars, F_N

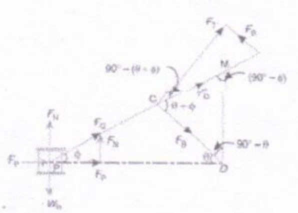
$$F_N = F_Q \sin\phi = \frac{F_P}{\cos\phi} \times \sin\phi = F_P \tan\phi$$



Forces on the Reciprocating Parts of an Engine

4. Crank-pin effort, F_T

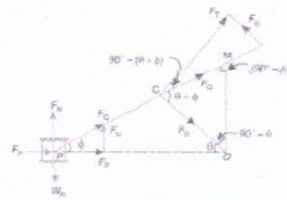
$$F_T = F_Q \sin(\theta + \phi) = \frac{F_P}{\cos\phi} \times \sin(\theta + \phi)$$



Forces on the Reciprocating Parts of an Engine

5. Thrust on crank shaft bearings, F_B

$$F_B = F_Q \cos(\theta + \phi) = \frac{F_P}{\cos\phi} \times \cos(\theta + \phi)$$

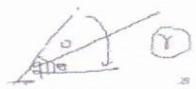


Forces on the Reciprocating Parts of an Engine

6. Crank effort or turning moment or torque on the crank shaft.

The product of the crankpin effort (F_T) and the crank pin radius (r) is known as crank effort or turning moment or torque on the crank shaft.

$T = F \times r$



Crank effort, $T = F_T \times r = \frac{F_P \sin(\theta + \phi)}{\cos\phi} \times r$

$$= \frac{F_P (\sin\theta\cos\phi + \cos\theta\sin\phi)}{\cos\phi} \times r$$

$$= F_P \left(\sin\theta + \cos\theta \times \frac{\sin\phi}{\cos\phi} \right) \times r$$

$$= F_P (\sin\theta + \cos\theta\tan\phi) \times r$$

We know that $l \sin\phi = r \sin\theta$

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

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

$$\therefore \quad \tan\phi = \frac{\sin\phi}{\cos\phi} = \frac{\sin\theta}{n} \times \frac{n}{\sqrt{n^2 - \sin^2\theta}} = \frac{\sin\theta}{\sqrt{n^2 - \sin^2\theta}}$$

$$T = F_P \left\{ \sin\theta + \frac{\cos\theta\sin\theta}{\sqrt{n^2 - \sin^2\theta}} \right\} \times r$$

$$T = F_P \times r \left(\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2 - \sin^2\theta}} \right)$$

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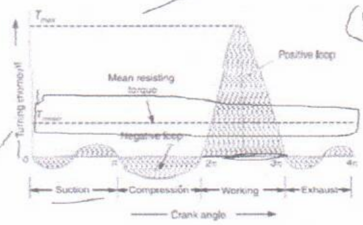
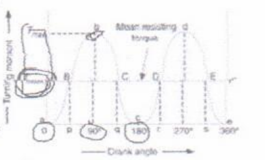
Turning moment diagram

The turning moment diagram (also known as crank effort diagram) is the graphical representation of the turning moment or crank-effort for various positions of the crank. It is plotted on cartesian co-ordinates, in which the turning moment is taken as the ordinate and *crank angle as abscissa.*

Turning moment diagram – IC engine



Turning moment diagram – Single cylinder engine



Turning moment diagram for a single cylinder, double acting steam engine.

where F_P = Piston effort,
r = Radius of crank,
n = Ratio of the connecting rod length and radius of crank, and
θ = Angle turned by the crank from inner dead centre.

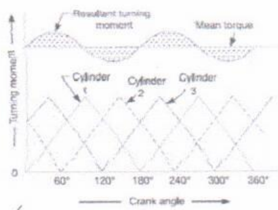
Fluctuation of Energy

The variations of energy above and below the mean resisting torque line are called fluctuations of energy.

The difference between the maximum and the minimum energies is known as maximum fluctuation of energy.

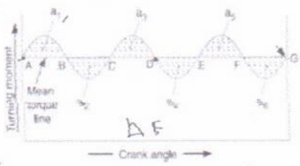
Maximum fluctuation of energy, E = Maximum energy – Minimum energy

Turning moment diagram – Multi cylinder engine



Determination of Maximum Fluctuation of Energy

Let the energy in the flywheel at A = E



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Coefficient of Fluctuation of Energy

It may be defined as the ratio of the maximum fluctuation of energy to the work done per cycle.

C_E = Maximum fluctuation of energy / Work done per cycle

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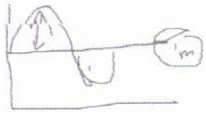
Flywheel

A flywheel used in machines serves as a reservoir, which stores energy during the period when the supply of energy is more than the requirement, and releases it during the period when the requirement of energy is more than the supply.



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Work done per cycle

The work done per cycle (in N-m or joules) may be obtained by using the following two relations :

1. Work done per cycle $= T_{mean} \times \theta$

where T_{mean} = Mean torque, and

θ = Angle turned (in radians), in one revolution.

$= 2\pi$, in case of steam engine and two stroke internal combustion engines

$= 4\pi$, in case of four stroke internal combustion engines.

The mean torque (T_{mean}) in N-m may be obtained by using the following relation :

$$T_{mean} = \frac{P \times 60}{2\pi N} = \frac{P}{\omega}$$

where P = Power transmitted in watts,

N = Speed in r.p.m.

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Coefficient of Fluctuation of Speed

The difference between the maximum and minimum speeds during a cycle is called the maximum fluctuation of speed. The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed.

$$C_s = \frac{N_1 - N_2}{N} = \frac{2(N_1 - N_2)}{N_1 + N_2}$$

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Work done per cycle

2. The work done per cycle may also be obtained by using the following relation :

$$\text{Work done per cycle} = \frac{P \times 60}{n}$$

where n = Number of working strokes per minute,

$= N$, in case of steam engines and two stroke internal combustion engines.

$= N/2$, in case of four stroke internal combustion engines.

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Energy Stored in a Flywheel

Energy stored, $E = mk^2\omega^2C_S = mv^2C_S$

m = Mass of the flywheel in kg,

k = Radius of gyration of the flywheel in metres

C_s = Coefficient of Fluctuation of Speed

v = Mean linear velocity

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N = Mean speed during the cycle in r.p.m. $= \frac{N_1 + N_2}{2}$,

ω = Mean angular speed during the cycle in rad/s $= \frac{\omega_1 + \omega_2}{2}$

C_s = Coefficient of fluctuation of speed. $= \frac{N_1 - N_2}{N}$ or $\frac{\omega_1 - \omega_2}{\omega}$

$K.E = \frac{1}{2} \times I \times \omega^2$

ω_1 – max

ω_2 – min

$\Delta E = K.E_{max} - K.E_{min}$

$= \frac{1}{2} I (\omega_1)^2 - \frac{1}{2} I (\omega_2)^2$

$= \frac{1}{2} I [(\omega_1)^2 - (\omega_2)^2]$

$= \frac{1}{2} I (\omega_1 + \omega_2)(\omega_1 - \omega_2)$

$= I \omega (\omega_1 - \omega_2)$

$= I \omega^2 \left(\frac{\omega_1 - \omega_2}{\omega}\right) \Rightarrow I \omega^2 C_s$

$\Delta E = I \omega^2 C_s$

$I = mk^2$

$\Delta E = mk^2 \omega^2 C_s$

Flywheel in Punching Press

The function of a flywheel in an engine is to reduce thefluctuations of speed, when the load on the crankshaft is constant and the input torque varies during the cycle. The flywheel can also be used to perform the same function when the torque is constant and the load varies during the cycle. Such an application is found in punching press or in a riveting machine.

Dimensions of the Flywheel Rim

Tensile stress or hoop stress, $\sigma = \rho R^2 \omega^2 = \rho v^2$

ρ = Density of rim material in kg/m³,

N = Speed of the flywheel in r.p.m.,

ω = Angular velocity of the flywheel in rad/s,

v = Linear velocity at the mean radius in m/s

$= \omega R = \pi DN/60$

Dynamics of Cam follower mechanism

Cam Dynamics

Cam dynamics is the study of cam follower systems with considering the dynamic forces and torques developed in it.

Types of cam systems

1. Rigid body cam systems
2. Elastic body cam systems

Dimensions of the Flywheel Rim

Mass of the rim, m = Volume × density = ρ DA

If the cross-section of the rim is a rectangular, then

$A = b \times t$

where b = Width of the rim, and

t = Thickness of the rim.

Dynamics of Cam follower mechanism

Rigid cam system

If the members of the cam system are fairly rigid and their speed is moderate, then the analysis of such a cam system is known as analysis of rigid cam system.

Elastic cam system

If the members of the cam system are elastic and their speed is very high, then the analysis of such a cam system is known as analysis of elastic cam system

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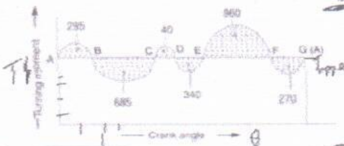
The turning moment diagram for a petrol engine is drawn to the following scales : Turning moment, 1 mm = 5 N-m ; crank angle, 1 mm = 1°. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295, 685, 40, 340, 960, 270 mm2. The rotating parts are equivalent to a mass of radius of gyration of 150 mm. Determine the coefficient of fluctuation of speed when the engine runs at 1800 r.p.m.



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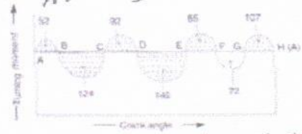
The turning moment diagram for a multicylinder engine has been drawn to a scale 1 mm = 600 N-m vertically and 1 mm = 3" horizontally. The intercepted areas between the output torque curve and the mean resistance line, taken in order from one end, are as follows : + 52, − 124, + 92, − 140, + 85, − 72 and + 107 mm2, when the engine is running at a speed of 600 r.p.m. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, find the necessary mass of the flywheel of radius 0.5 m.



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Total Energy at A = E

$E_B = E + 295$ – max

$E_D = E + 295 - 685 + 40 = E - 350$

$E_E = E_D - 340 \Rightarrow E - 690$ – (min)

$E_F = E_E + 960 \Rightarrow E + 270$

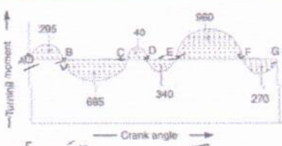
$E_G = E_F - 270 = $ Energy at A

– Max. Fluctuation of Energy (ΔE)

$\Delta E = $ max. Energy – min Energy

$(E + 295) - (E - 690) \Rightarrow 985 \text{ mm}^2 \times \frac{\pi}{36}$

$= 86$ N-m



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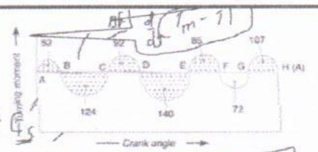
$\Delta E = I\omega^2 C_s$

$\Delta E = mk^2\omega^2 C_s$



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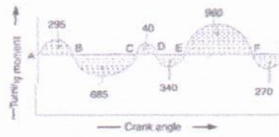
$\Delta E = 86$ N-m or J

$\Delta E = I\omega^2 C_s$

$86 = mk^2\omega^2 C_s$

$86 = 36 \times (0.15)^2 \times 188^2 \times C_s$

$\omega = \frac{2\pi N}{60}$



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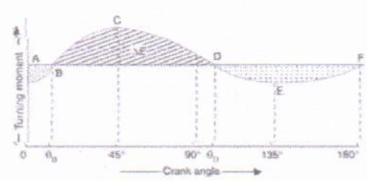
The turning moment curve for an engine is represented by the equation, T = (20 000 + 9500 sin 2 − 5700 cos 2) N-m, where is the angle moved by the crank from inner dead centre. If the resisting torque is constant,

[illegible] fluctuation of speed is not exceed 1% of mean speed which is 180 r.p.m; and 3. Angular acceleration of the flywheel when the crank has turned through 45° from inner dead centre.



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Centrifugal governors

- Pendulum type
  - Watt governor
- Loaded type
  - Dead weight governors
    - Porter governor
    - Proell governor
  - Spring controlled governors
    - Hartnell governor
    - Hartung governor
    - Wilson-Hartnell governor
    - Pickering governor

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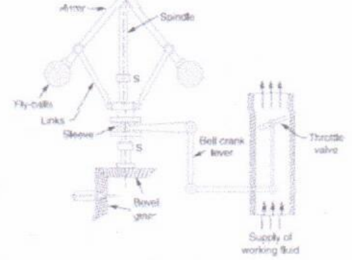

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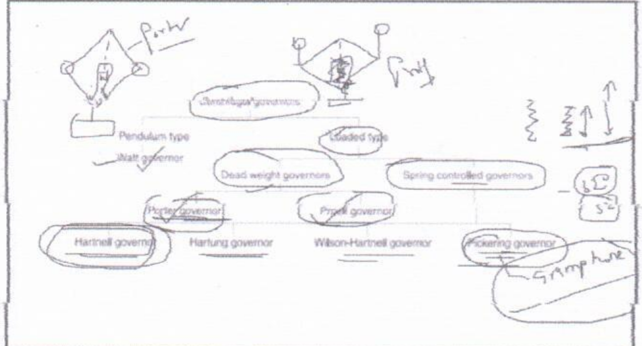
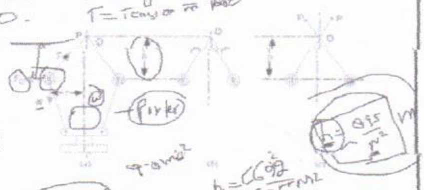
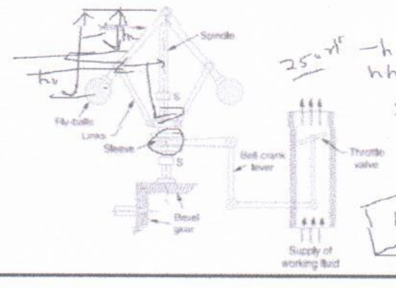
Terms Used in Governors

- 1. *Height of a governor.* It is the vertical distance from the centre of the ball to a point where the axes of the arms (or arms produced) intersect on the spindle axis. It is usually denoted by *h*.
- 2. *Equilibrium speed.* It is the speed at which the governor balls, arms etc., are in complete equilibrium and the sleeve does not tend to move upwards or downwards.
- 3. *Mean equilibrium speed.* It is the speed at the mean position of the balls or the sleeve.
- 4. *Maximum and minimum equilibrium speeds.* The speeds at the maximum and minimum radius of rotation of the balls, without tending to move either way are known as maximum and minimum equilibrium speeds respectively.
- 5. *Sleeve lift.* It is the vertical distance which the sleeve travels due to change in equilibrium speed.



Watt Governor





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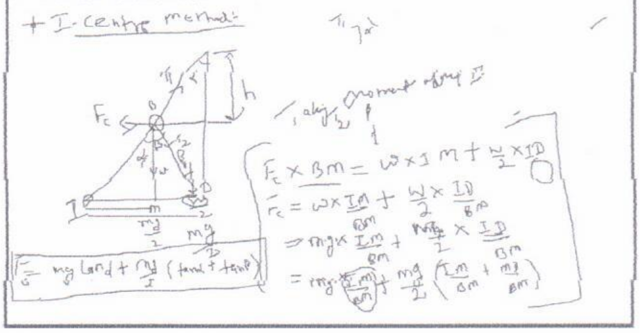
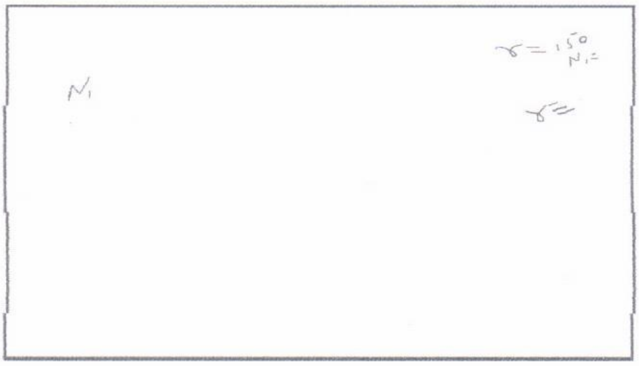
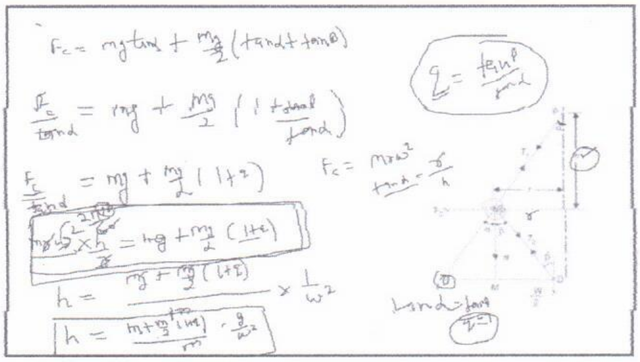
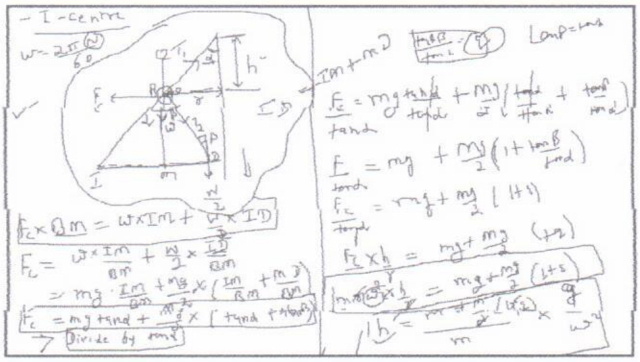
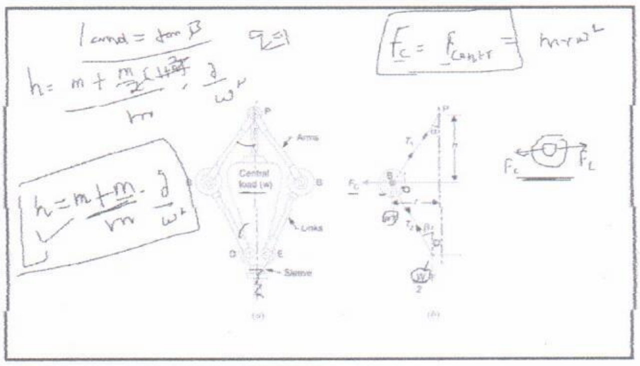
Porter Governor



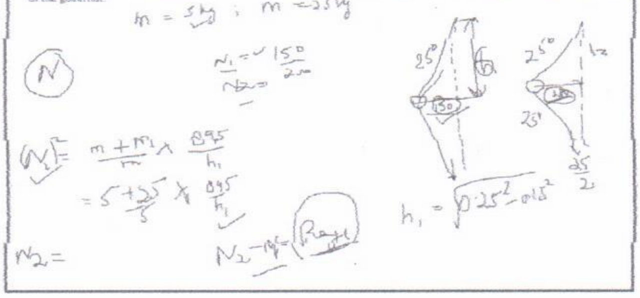


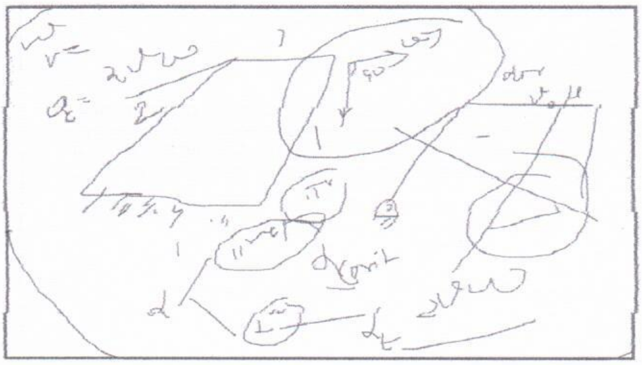


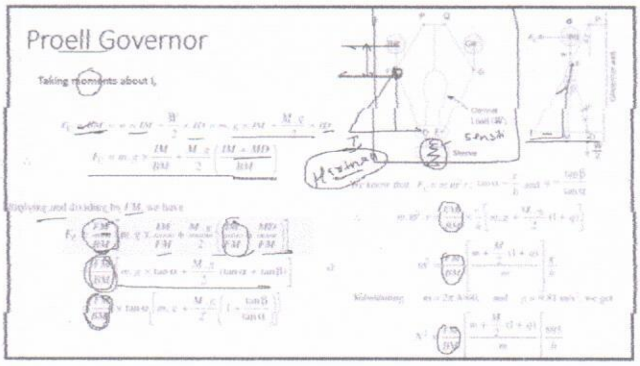




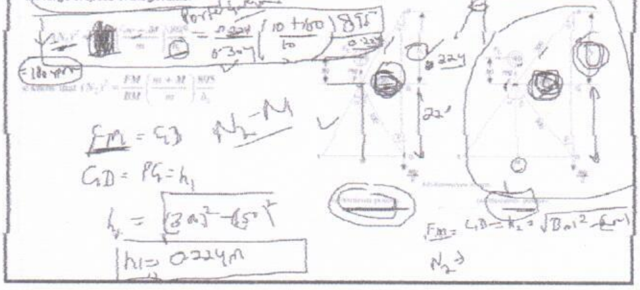
A Porter governor has equal arms each 250 mm long and pivoted on the axis of rotation. Each ball has a mass of 5 kg and the mass of the central load on the sleeve is 25 kg. The radius of rotation of the ball is 150 mm when the governor begins to lift and 200 mm when the governor is at maximum speed. Find the minimum and maximum speeds and range of speed of the governor.







A Proell governor has equal arms of length 300 mm. The upper and lower ends of the arms are pivoted on the axis of the governor. The extension arms of the lower links are each 80 mm long and parallel to the axis when the radii of rotation of the balls are 150 mm and 200 mm. The mass of each ball is 10 kg and the mass of the central load is 100 kg. Determine the range of speed of the governor



In an engine governor of the Porter type, the upper and lower arms are 200 mm and 250 mm respectively and pivoted on the axis of rotation. The mass of the central load is 15 kg, the mass of each ball is 2 kg and friction of the sleeve together with the resistance of the operating gear is equal to a load of 25 N at the sleeve. If the limiting inclinations of the upper arms to the vertical are 30° and 40°, find, taking friction into account, range of speed of the governor

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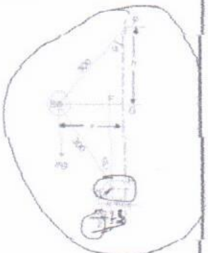
The arms of a Porter governor are 300 mm long. The upper arms are pivoted on the axis of rotation. The lower arms are attached to a sleeve at a distance of 40 mm from the axis of rotation. The mass of the load on the sleeve is 70 kg and the mass of each ball is 10 kg. Determine the equilibrium speed when the radius of rotation of the balls is 200 mm. If the friction is equivalent to a load of 20 N at the sleeve, what will be the range of speed for this position



Hunting

- A governor is said to be hunt if the speed of the engine fluctuates continuously above and below the mean speed. This is caused by a too sensitive governor which changes the fuel supply by a large amount when a small change in the speed of rotation takes place.

Sensitiveness of Governors

- sensitiveness is defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed.

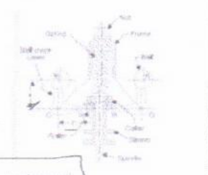
Let N_1 = Minimum equilibrium speed,

N_2 = Maximum equilibrium speed, and

N = Mean equilibrium speed = $\frac{N_1 + N_2}{2}$

Sensitiveness of the governor $= \frac{N_2 - N_1}{N} = \frac{2(N_2 - N_1)}{N_1 + N_2} = \frac{2(\omega_2 - \omega_1)}{\omega_1 + \omega_2}$

Hartnell Governor



For the minimum position i.e. when the radius of rotation changes from r to r_1,

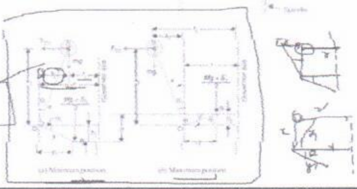
$$\frac{h_1}{y} = \frac{a_1}{x} = \frac{r - r_1}{x}$$

Similarly, for the maximum position i.e. when the radius of rotation changes from r to r_2,

$$\frac{h_2}{y} = \frac{a_2}{x} = \frac{r_2 - r}{x}$$

$$\frac{h_1 + h_2}{y} = \frac{r_2 - r_1}{x} \quad \text{or} \quad \frac{h}{y} = \frac{r_2 - r_1}{x}$$

$$h = (r_2 - r_1)\frac{y}{x}$$



(a) Minimum position. (b) Maximum position.

Isochronous Governors

$$(N_1)^2 = \frac{m + \frac{M}{2}(1 + q)}{m} \times \frac{895}{h_1}$$

$$(N_2)^2 = \frac{m + \frac{M}{2}(1 + q)}{m} \times \frac{895}{h_2}$$

Now for minimum position, taking moments about point O, we get

$$\frac{M \cdot g + S_1}{2} \times y_1 = F_{C1} \times x_1 - m \cdot g \times a_1$$

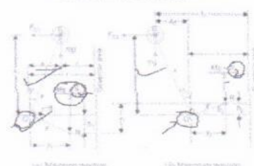
$$M \cdot g + S_1 = \frac{2}{y_1}(F_{C1} \times x_1 - m \cdot g \times a_1)$$

Again for maximum position, taking moments about point O, we get

$$\frac{M \cdot g + S_2}{2} \times y_2 = F_{C2} \times x_2 + m \cdot g \times a_2$$

$$M \cdot g + S_2 = \frac{2}{y_2}(F_{C2} \times x_2 + m \cdot g \times a_2)$$

$$S_2 - S_1 = \frac{2}{y_2}(F_{C2} \times x_2 + m \cdot g \times a_2) - \frac{2}{y_1}(F_{C1} \times x_1 - m \cdot g \times a_1)$$



(a) Minimum position. (b) Maximum position.

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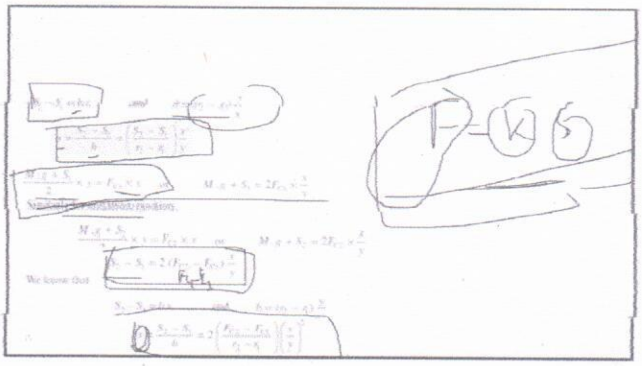
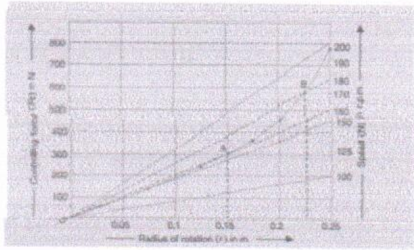


The range of equilibrium speeds for the governor is obtained by drawing lines from the origin through the two points A (when r = 0.15 m) and B (when r = 0.225 m)
on the controlling force curve.
From the graph, we see that these lines intersect the speed scale at approximately 160 r.p.m. and 180 r.p.m.

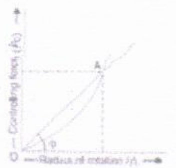


Controlling Force

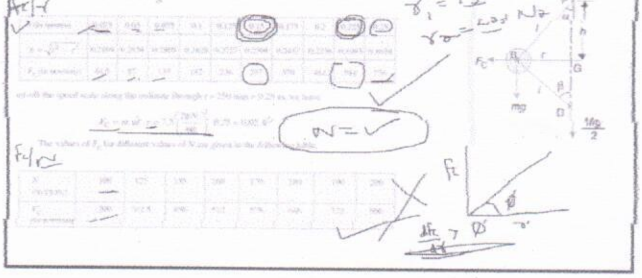
$$F_C = m\omega^2 r = m\left(\frac{2\pi N}{60}\right)^2 r$$

$$N^2 = \frac{1}{m}\left(\frac{60}{2\pi}\right)^2\left(\frac{F_C}{r}\right) = \frac{1}{m}\left(\frac{60}{2\pi}\right)^2(\tan\phi)$$

$$N = \frac{60}{2\pi}\left(\frac{\tan\phi}{m}\right)^{1/2}$$



In a Porter governor, the length of each arm is 300 mm and all the arms are pivoted on the axis of rotation. The mass of each ball is 7.5 kg and the mass of the sleeve is 45 kg. The extreme radii of rotation are 150 mm and 225 mm. Draw the controlling force curve and set-off a speed scale along the ordinate corresponding to a radius of 250 mm.



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