		OR			
9		Explain with sketches the different types of cams and followers.	L2	CO1 CO3	10 M
		UNIT-V			
10	a)	Derive natural frequency of free longitudinal vibrations.	L2	CO1 CO5	5 M
	b)	A vibrating system consists of a mass of 200 kg, a spring of stiffness 80 N/mm and a damper with damping coefficient of 800 N/m/s. Determine the frequency of vibration of the system.	L3	CO1 CO5	5 M
		OR			
11		Explain and Draw Turning moment diagram of steam engine.	L2	CO1 CO4	10 M

Code: 23ME3403

II B.Tech - II Semester – Regular Examinations - MAY 2025

THEORY OF MACHINES
(MECHANICAL ENGINEERING)

Duration: 3 hours Max. Marks: 70

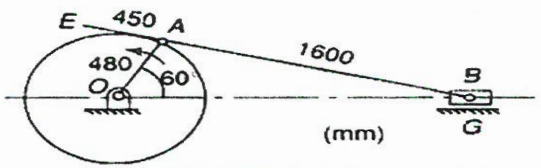
Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	What is the degree of freedom of a mechanism?	L2	CO1
1.b)	Classify different types of constrained motion?	L2	CO1
1.c)	What is the Coriolis component of acceleration?	L2	CO1 CO2
1.d)	State kennedy's theorem.	L1	CO1 CO2
1.e)	Explain about interference.	L2	CO1 CO3
1.f)	Explain about a Gear train.	L2	CO1 CO3
1.g)	Explain about Dynamic balancing.	L2	CO1 CO4
1.h)	What is pressure angle in Cam?	L2	CO1 CO4
1.i)	Explain about coefficient of fluctuation of energy.	L2	CO1 CO5
1.j)	What is damping coefficient?	L2	CO1 CO5

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Classify kinematic pairs with a neat sketch.	L2	CO1	6 M
	b)	Sketch any two inversions of single slider crank chain.	L2	CO1	4 M
OR					
3	a)	Explain any one of the approximate straight line mechanisms.	L2	CO1	5 M
	b)	What is a Hook's joint and where is it used?	L2	CO1	5 M
UNIT-II					
4		In a four bar chain ABCD, AD is fixed and is 150 mm long. The crank AB is 40mm 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. Calculate the angular velocity of link CD when angle BAD = 60° by instantaneous center method.	L3	CO1 CO2	10 M
OR					
5		For configuration of slider-crank mechanism shown, calculate acceleration of Slider B. 	L3	CO1 CO2	10 M

			BL	CO	Max. Marks
UNIT-III					
6	a)	Classify different types of gear trains.	L2	CO1 CO3	6 M
	b)	State law of gearing.	L2	CO1 CO3	4 M
OR					
7		An aeroplane flying at 240 km/hr turns towards the left and completes a quarter circle of 60 m radius. The mass of the rotary engine and the propeller of the plane is 450 kg with a radius of gyration of 320 mm. The engine speed is 2000 rpm clockwise when viewed from the rear. Determine the gyroscopic couple on the aircraft and state its effect.	L3	CO1 CO4	10 M
UNIT-IV					
8		A shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radii 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitudes and angular positions.	L3	CO1 CO4	10 M

Code: 23ME3403

PVP 23

II B.Tech-I Semester-Regular / Supplementary Examinations-

May 2025

Theory of Machines

(MECHANICAL ENGINEERING)

Duration: 3 hours **Max. Marks: 70**

Note: 1. This question paper contains Two Parts A and B
2. Part-A contains 10 short answer questions. Each question carries 2 Marks
3. Part-B contains 5 essay questions with an internal choice from each unit. Each question carries 10 Marks

Answer the following questions.

SCHEME OF EVALUATION

Question No	Concept to cover	BL	CO	Marks	Total Marks
1.a)	Definition of degree of freedom of a mechanism	L2	1	1 Mark	2 Marks
	example			1 Mark	
1.b)	Constrined motion types	L2	1	1 Mark	2 Marks
	Names with example			1 Mark	
1.c)	Coriolis component of acceleration	L2	1,2	1 Mark	2 Marks
				1 Mark	
1.d)	Kennedy's theorem	L2	1,2	1 Mark	2 Marks
	equation			1 Mark	
1.e)	Interference with figure	L2	1,3	2 Marks	2 Marks
1.f)	Gear train types	L2	1,3	2 Marks	2 Marks
1.g)	Dynamic balancing explanation	L2	1,4	2 Marks	2 Marks
1.h)	Pressure angel in cam definition and representation	L2	1,4	2 Marks	2 Marks
1.i)	Definition of coefficient of fluctuation of energy	L2	1,5	2 Marks	2 Marks
1.j)	Damping coefficient	L2	1,5	2 Mark	2 Marks
PART-B					
UNIT-1					
2.a	Classification of kinematic pairs	L2	1	4 Mark	10 Marks
	Neat sketch explanation	L2	1	2 Marks	
2.b	Inversions of single slider crank chain with neat sketch	L2	1	4 Marks	

OR					
3.a	Any type of approximate straight line mechanism with neat sketch	L2	1	5 Marks	10 Marks
3.b	Hook's joint purpose and application	L2	1	5 Marks	
UNIT-II					
4.	Instantaneous method representation using the given details	L2	1,2	7 Marks	10 Marks
	Calculation of angular velocity of link CD	L2	1,2	3 Marks	
OR					
5.	Velocity and acceleration of given problem	L2	1,2	8 Marks	10 Marks
	Acceleration of slider B	L2	1,2	2 Marks	
UNIT-III					
6. a.	Gear trains types	L2	1,3	2 Marks	10 Marks
	Explanation of each-type	L2	1,3	4 Marks	
6.b	Law of gearing explanation and Figure representation	L2	1,3	4 Marks	
OR					
7.	Representation of the problem with given data	L3	1,4	2 Marks	10 Marks
	Determination of gyroscopic couple	L2	1,4	6 Marks	
	Explanation of couple effect in statement	L2	1,4	2 Marks	
UNIT-IV					
8.	Representation of masses with angle	L3	1,4	2 Marks	10 Marks
	Determination of balancing mass	L3	1,4	4 Marks	
	Determination of position of balancing mass	L3	1,4	4 Marks	
OR					
9.	Different types of cams and followers	L2	1,3	5 Marks	10 Marks
	With figure explanation	L2	1,3	5 Marks	
UNIT-V					
10. a)	Natural frequency definition under free longitudinal vibration	L2	1,5	5 Marks	10 Marks
10.b)	Given problem data representation and natural	L3`	1,5	5 Marks	

	frequency formula and substitution				
(OR)					
11.	Turning moment diagram representation	L2	1,4	5 Marks	10 Marks
	And explanation of turning moment diagram of steam engine	L2	1,4	5 Marks	

Code: 20ME3302

PVP 23

II B.Tech-I Semester-Regular / Supplementary Examinations-

DECEMBER 2023

MATERIAL SCIENCE AND METALLURGY

(MECHANICAL ENGINEERING)

Duration: 3 hours **Max. Marks: 70**

Note: 1. This question paper contains Two Parts A and B
2. Part-A contains 10 short answer questions. Each question carries 2 Marks
3. Part-B contains 5 essay questions with an internal choice from each unit. Each question carries 10 Marks

Answer the following questions.

PART-A

1. a) ***What is the degree of freedom of a mechanism ? L2 CO1 2 Marks***

Ans) The degree of freedom (DOF) of a mechanism, also known as its mobility, represents the number of independent parameters or inputs required to fully define the position or motion of a system

1.b) Classify different types of constrained motion L2 CO1 2 Marks

Ans) There are three types of constrained motions. They are listed below:

Completely Constrained Motion
Partially or Successfully Constrained Motion
Incompletely Constrained Motion.
Completely Constrained Motion
Completely constrained motion is defined as the type of motion where the motion of the pair is limited to only one direction.
Successfully Constrained Motion
Partially or successfully constrained motion is the kind of motion that can be in more than one direction without the influence of any external force.
Incompletely Constrained Motion
Incompletely constrained motion is the type of motion where the motion between a pair can take place in more than just one direction.

1.c) What is the Coriolis component of acceleration L2 CO1,2 2 Marks

Ans).The Coriolis component of acceleration is a tangential acceleration that arises when a point on one rotating link slides along another link

1.d) what is the kennedy theorem L2 CO1,2 2 Marks

Ans) Kennedy's theorem, also known as the "Three Centers in Line Theorem" or the "Aronhold-Kennedy Theorem of Three Centers," states that if three bodies have relative motion, their three instantaneous centers of velocity are collinear

1.e) Expalin about interference? L2 CO1, 3 2 Marks

Ans) Interference in gears occurs when the tooth tips of one gear contact the non-involute portion of the mating gear, causing potential damage or failure

1.f) Explain about a Gear train L2 CO1, 3 2 Marks

Ans) A gear train is a system of two or more gears that work together to transmit rotational motion and torque.

Types of Gear Trains:
Simple Gear Train
ompound Gear Train
Epicyclic Gear Train
Reverted Gear Train

1.g) Explain about dynamic balancing L2 CO1, 4 2 Marks

Ans) Dynamic balancing is a process of balancing rotating machinery to reduce vibration and improve performance. It involves measuring and correcting unbalance in rotating parts while they are in motion, ensuring that forces and moments are distributed evenly around the axis of rotation

1. *h) What is pressure angle in Cam? L2 CO1, 4 2 Marks*

Ans) In cam mechanisms, the pressure angle is the angle between the normal to the pitch curve (or the cam profile) and the instantaneous direction of the follower's motion. This angle is crucial because it represents the steepness of the cam profile and varies with the follower's movement.

1.i) Explain about coeeficient of fluctuation of energy L2 CO1, 5 2 Marks

Ans) The coefficient of fluctuation of energy (CFE) is a measure of how much the energy of a system, like a flywheel, fluctuates during a cycle. It's calculated as the ratio of the maximum fluctuation of energy to the total work done per cycle.

1.j) What is damping coefficent? L2 CO1, 5

Ans) A damping coefficient, often denoted by "c," is a parameter that quantifies the amount of energy dissipation in a system due to damping forces, such as friction or air resistance

PART-B

UNIT-I

2. a. Classify kinematic pairs with a neat sketch. L2, CO1 6M

Ans)

Kinematic Pair:

A kinematic pair is a connection between two physical objects that imposes constraints on their relative movement.

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), the pair is known as kinematic pair.

Types of kinematic pairs:

Kinematic Pairs according to Nature of Relative Motion

(a) Sliding Pair If two links have a sliding motion relative to each other, they form a sliding pair.

A rectangular rod in a rectangular hole in a prism is a sliding pair [Fig. 1.8(a)].

(b) Turning Pair When one link has a turning or revolving motion relative to the other, they constitute a turning or revolving pair [Fig. 1.8(b)].

In a slider-crank mechanism, all pairs except the slider and guide pair are turning pairs. A circular shaft revolving inside a bearing is a turning pair.

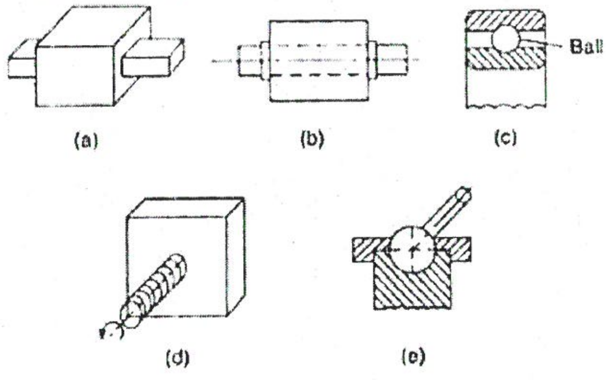


Fig. 1.8

(c) Rolling Pair When the links of a pair have a rolling motion relative to each other, they form a rolling pair, e.g., a rolling wheel on a flat surface, ball and roller bearings, etc. In a ball bearing [Fig. 1.8(c)], the ball and the shaft constitute one rolling pair whereas the ball and the bearing is the second rolling pair.

(d) Screw Pair (Helical Pair) If two mating links have a turning as well as sliding motion between them, they from a screw pair. This is achieved by cutting matching threads on the two links.

The lead screw and the nut of a lathe is a screw pair [Fig. 1.8(d)].

(e) Spherical Pair When one link in the form of a sphere turns inside a fixed link, it is a spherical pair.

The ball and socket joint is a spherical pair [Fig. 1.8(e)].

Kinematic Pairs according to Nature of Contact

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

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

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

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

Kinematic Pairs according to Nature of Mechanical Constraint

(a) Closed Pair When the elements of a pair are held together mechanically, it is known as a closed pair. The two elements are geometrically identical; one is solid and full and the other is hollow or open. The latter not only envelops the former but also encloses it. The contact between the two can be broken only by destruction of at least one of the members.

All the lower pairs and some of the higher pairs are closed pairs. A cam and follower pair (higher pair) shown in Fig. 1.7(a) and a screw pair (lower pair) belong to the closed pair category.

(b) Unclosed Pair When two links of a pair are in contact either due to force of gravity or some spring action, they constitute an unclosed pair. In this, the links are not held together mechanically, e.g., cam and follower pair of Fig. 1.7(b).

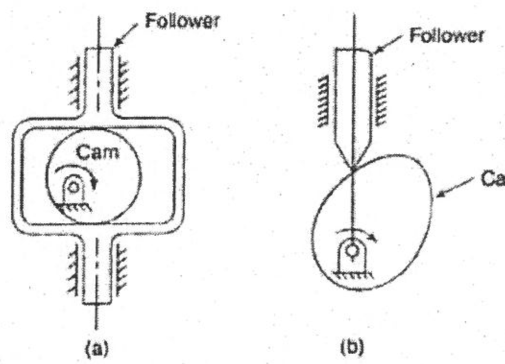


Fig. 1.7

2.b) Sketch any two inversions of single slider crank chains. L2 CO1 4M

1. *Pendulum pump or Bull engine*. In this mechanism, the inversion is obtained by fixing the cylinder or link 4 (*i.e.* sliding pair), as shown in Fig. 5.23. In this case, when the crank (link 2) rotates, the connecting rod (link 3) oscillates about a pin pivoted to the fixed link 4 at *A* and the piston attached to the piston rod (link 1) reciprocates. The duplex pump which is used to supply feed water to boilers have two pistons attached to link 1, as shown in Fig. 5.23.

2. ***Oscillating cylinder engine.*** The arrangement of oscillating cylinder engine mechanism, as shown in Fig. 5.24, is used to convert reciprocating motion into rotary motion. In this mechanism, the link 3 forming the turning pair is fixed. The link 3 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 *A*.

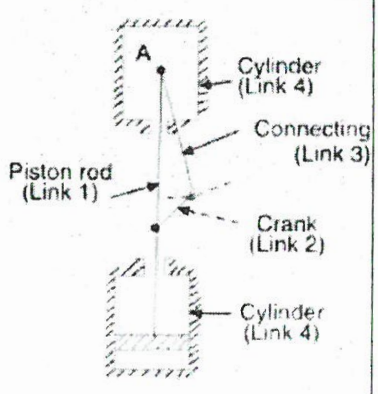


Fig. 5.23. Pendulum pump.

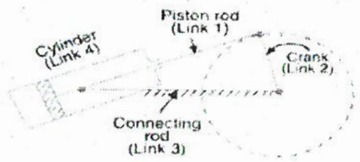


Fig. 5.24. Oscillating cylinder engine.

3. ***Rotary internal combustion engine or Gnome engine.*** Sometimes back, rotary internal combustion engines were used in aviation. But now-a-days gas turbines are used in its place. It consists of seven cylinders in one plane and all revolves about fixed centre *D*, as shown in Fig. 5.25, while the crank (link 2) is fixed. In this mechanism, when the connecting rod (link 4) rotates, the piston (link 3) reciprocates inside the cylinders forming link 1.

Note: Any two types are accepted

OR

3. Explain any one of the approximate straight line mechanisms. L2, CO1 5M

Ans)

The approximate straight line motion mechanisms are the modifications of the four-bar chain mechanisms. Following mechanisms to give approximate straight line motion, are important from the subject point of view :

1. ***Watt's mechanism.*** It is a crossed four bar chain mechanism and was used by Watt for his early steam engines to guide the piston rod in a cylinder to have an approximate straight line motion.

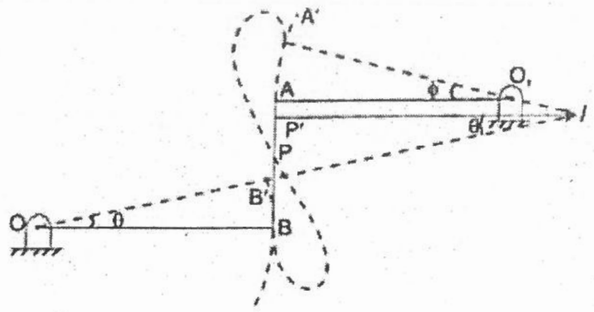


Fig. 9.6. Watt's mechanism.

$$\text{arc } B B' = \text{arc } A A' \quad \text{or} \quad OB \times \theta = O_1A \times \phi \qquad ...(i)$$

$$\therefore \quad OB / O_1A = \phi / \theta$$

Also $A'P' = IP' \times \phi$, and $B'P' = IP' \times \theta$

$$\therefore \quad A'P' / B'P' = \phi / \theta \qquad ...(ii)$$

From equations (*i*) and (*ii*),

$$\frac{OB}{O_1A} = \frac{A'P'}{B'P'} = \frac{AP}{BP} \quad \text{or} \quad \frac{O_1A}{OB} = \frac{PB}{PA}$$

Thus, the point *P* divides the link *A B* into two parts whose lengths are inversely proportional to the lengths of the adjacent links.

Grasshopper Mechanism

- In this mechanism, the centers O and O1 are fixed. The link OA oscillates about O through an angle AOA1 which causes the pin P to move along a circular arc with O1 as center and O1P as radius.

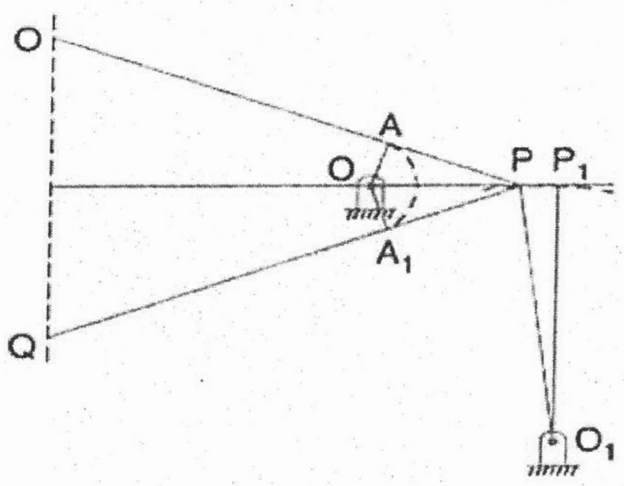


Fig. 2.7 Grasshopper Mechanism

- For small angular displacements of OP on each side of the horizontal, the point Q on the extension of the link PA traces out an approximately a straight path QQ'. if the lengths are such that

$$OA = \frac{AP^2}{AQ}$$

Note: any approximate straight line mechanism is accepted

3 b) What is a Hook's joint and where is it used? L2 CO1 5M

A Hooke's joint is used to connect two shafts, which are intersecting at a small angle, as shown in Fig. 9.18. The end of each shaft is forked to U-type and each fork provides two bearings

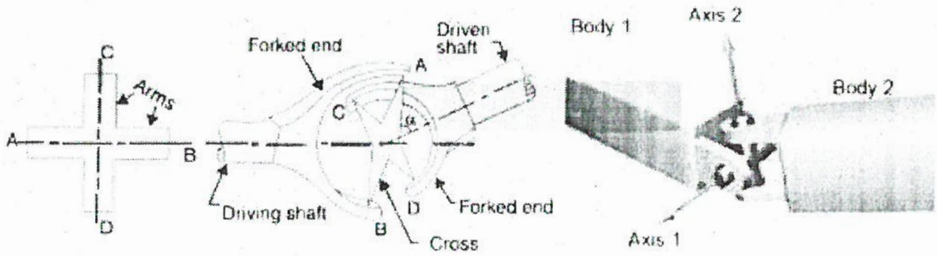


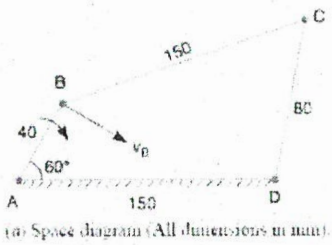
Fig. 9.18. Universal or Hooke's joint

for the arms of a cross. The arms of the cross are perpendicular to each other. The motion is transmitted from the driving shaft to driven shaft through a cross. The inclination of the two shafts may be constant, but in actual practice it varies, when the motion is transmitted. The main application of the Universal or Hooke's joint is found in the transmission from the gear box to the differential or back axle of the automobiles. It is also used for transmission of power to different spindles of multiple drilling machine. It is also used as a knee joint in milling machines.

UNIT-II

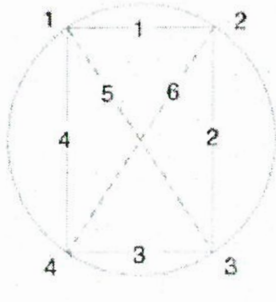
4. *In a four bar chain ABCD, AD is fixed and is 150 mm long. The crank AB is 40mm long and rotates at 120 r.p.m. clockwise, while the link CD =80 mm oscillates about D. BC and AD are of equal length. Calculate the angular velocity of link CD when angle BAD =60 by instantaneous center method L2, CO2 10M*

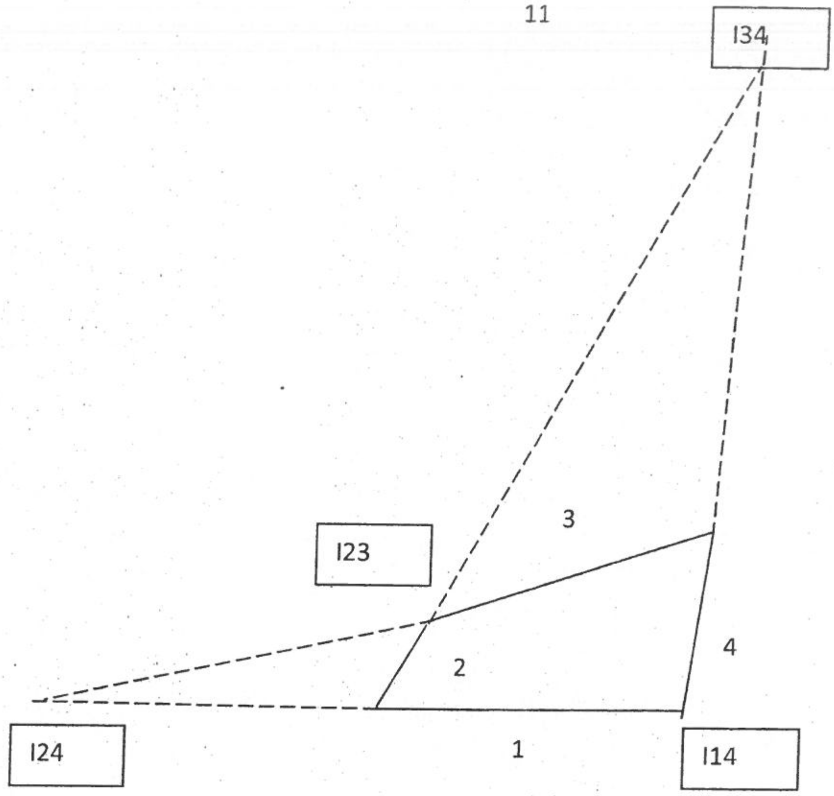
- **Ans)**



(a) Space diagram (All dimensions in mm).

$N_{BA} = 120$ r.p.m





From the given data:

- $AB = 40\,\text{mm}$
- $BC = AD = 150\,\text{mm}$
- $CD = 80\,\text{mm}$
- $\angle BAD = 60^\circ$

Since AB is rotating at $\omega_{AB} = 4\pi\,\text{rad/s}$, the linear velocity of point B relative to A:

$$V_B = \omega_{AB} \times AB = 4\pi \times 40 = 160\pi\,\text{mm/s} \approx 502.65\,\text{mm/s}$$

Direction of V_B: perpendicular to AB (due to pure rotation), clockwise.

- Link 1: Fixed (AD)
- Link 2: Crank AB
- Link 3: Coupler BC
- Link 4: CD

Finding Instantaneous Center I_{13}

- I_{13} lies at the intersection of:
  - The perpendicular to V_B at B (since B is on link AB, rotating)
  - The perpendicular to V_C at C (since C is on link CD, rotating)

We know from IC method:

$$\frac{V_B}{V_C} = \frac{I_{13}C}{I_{13}B}$$

But we can also write:

$$V_B = \omega_{BC} \times I_{13}B$$

$$V_C = \omega_{CD} \times CD$$

From velocity ratio:

$$\frac{\omega_{BC} \times I_{13}B}{\omega_{CD} \times CD} = \frac{I_{13}C}{I_{13}B} \Rightarrow \omega_{CD} = \frac{\omega_{BC} \times I_{13}B^2}{CD \times I_{13}C}$$

This is complex algebraically, so we simplify by **applying geometry** to find the triangle positions when angle BAD = 60°.

$$\frac{V_B}{V_C} = \frac{IC - C}{IC - B} \Rightarrow \frac{\omega_{AB} \cdot AB}{\omega_{CD} \cdot CD} = \frac{IC - C}{IC - B}$$

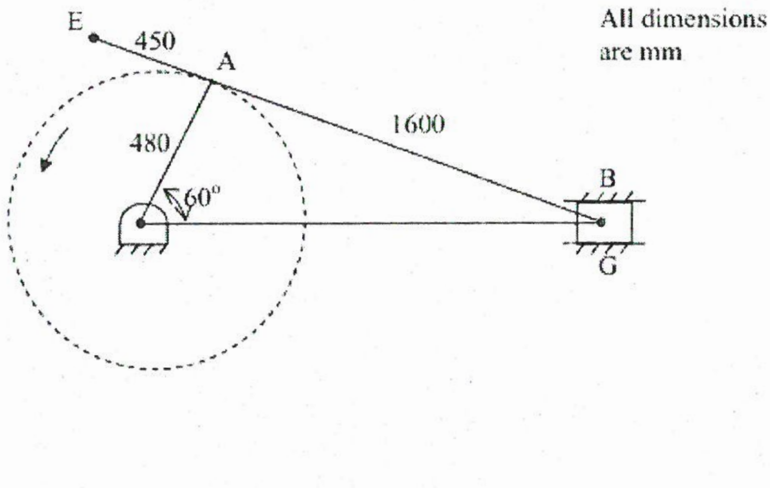
- $IC - B = 100\,\text{mm}$
- $IC - C = 60\,\text{mm}$

Then:

$$\frac{4\pi \cdot 40}{\omega_{CD} \cdot 80} = \frac{60}{100} \Rightarrow \omega_{CD} = \frac{4\pi \cdot 40 \cdot 100}{80 \cdot 60} = \frac{16000\pi}{4800} = \frac{100\pi}{30} \approx 10.47\,\text{rad/s}$$

OR

5. ***For configuration of slider-crank mechanism shown, calculate acceleration slider B.*** ***L2, CO2 10M***



Step 1: Draw configuration diagram.

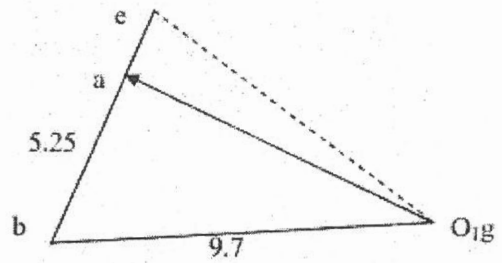
Step 2: Find velocity of A with respect to O.

$V_a = \omega_{OA} \times OA$

$V_a = 20 \times 0.48$

$V_a = 9.6$ m/s

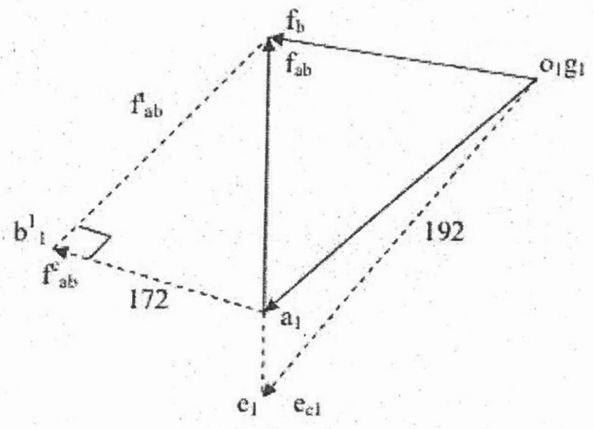
Step 4: Draw velocity vector diagram.



Step 4:

Sl. No.	Link	Magnitude	Direction	Sense
1.	OA	$f^c_{aO} = \omega^2_{OA} r = 192$	Parallel to OA	→ O
2.	AB	$f^c_{ab} = \omega^2_{ab} r = 17.2$ f^t_{ab} –	Parallel to AB ⊥r to AB	→ A –
3.	Slider B	–	Parallel to Slider	–

Step 5: Draw the acceleration diagram choosing a suitable scale.



- Mark o_1g_1 (zero acceleration point)
- Draw $\overline{o_1g_1}$ = C acceleration of OA towards 'O'.
- From a_1 draw $a_1b'_1 = 17.2\ m/s^2$ towards 'A' from b'_1 draw a line $\perp^r$ to AB.
- From o_1g_1 draw a line along the slider B to intersect previously drawn line at b_1, $\overline{a_1b_1} = f_{ab}$

  $\overline{g_1b_1} = f_b = 72\ m/s^2$.
- Extend $\overline{a_1b_1} = \overline{a_1e_1}$ such that $\frac{\overline{a_1b_1}}{AB} = \frac{\overline{A_1R_1}}{AE}$.
- Join e_1 to δ_1g_1. $\overline{g_1e_1} = f_e = 236\ m/s^2$.
- $\alpha_{ab} = \frac{f'_{ab}}{AB} = \frac{\overline{b_1b_1}}{AB} = \frac{167}{1.6} = 104\ rad/sec^2$ (CCW).

Answers:

$f_b = 72\ m/sec^2$

UNIT-III

6.Classift different types of gear trains L2, CO1-3 6 M

Following are the different types of gear trains, depending upon the arrangement of wheels :

1. Simple gear train, **2.** Compound gear train, **3.** Reverted gear train, and **4.** Epicyclic gear train.

In the first three types of gear trains, the axes of the shafts over which the gears are mounted are fixed relative to each other. But in case of epicyclic gear trains, the axes of the shafts on which the gears are mounted may move relative to a fixed axis.

Simple Gear train:

When there is only one gear on each shaft, as shown in Fig. 13.1, it is known as ***simple gear train***. The gears are represented by their pitch circles.

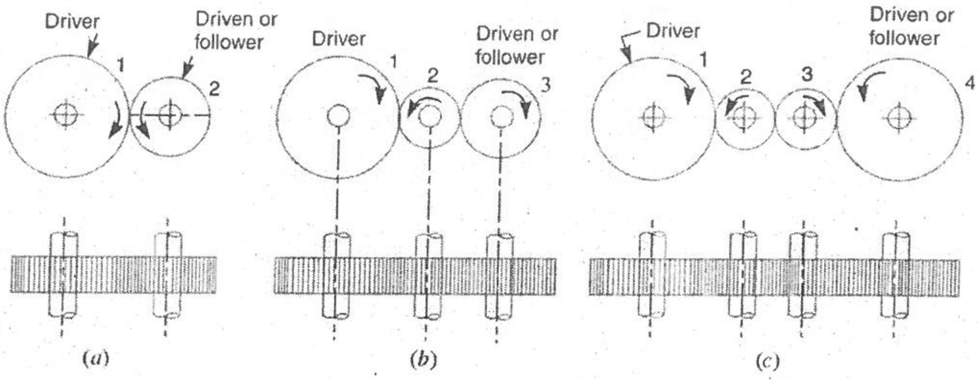


Fig. 13.1. Simple gear train.

$$\frac{N_1}{N_2} \times \frac{N_2}{N_3} = \frac{T_2}{T_1} \times \frac{T_3}{T_2} \quad \text{or} \quad \frac{N_1}{N_3} = \frac{T_3}{T_1}$$

$$\text{Speed ratio} = \frac{\text{Speed of driver}}{\text{Speed of driven}} = \frac{\text{No. of teeth on driven}}{\text{No. of teeth on driver}}$$

$$\text{Train value} = \frac{\text{Speed of driven}}{\text{Speed of driver}} = \frac{\text{No. of teeth on driver}}{\text{No. of teeth on driven}}$$

Compound gear train:

When there are more than one gear on a shaft, as shown in Fig. 13.2, it is called a ***compound train of gear***.

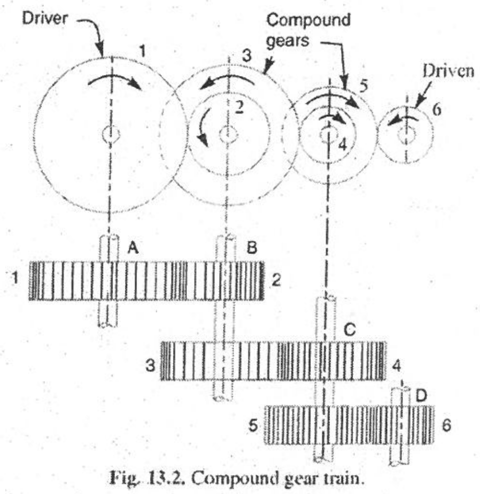


Fig. 13.2. Compound gear train.

$$\text{Speed ratio} = \frac{\text{Speed of the first driver}}{\text{Speed of the last driven or follower}}$$

$$= \frac{\text{Product of the number of teeth on the drivens}}{\text{Product of the number of teeth on the drivers}}$$

Reverted Gear Train

When the axes of the first gear (*i.e.* first driver) and the last gear (*i.e.* last driven or follower) are co-axial, then the gear train is known as ***reverted gear* train** as shown in Fig. 13.4.

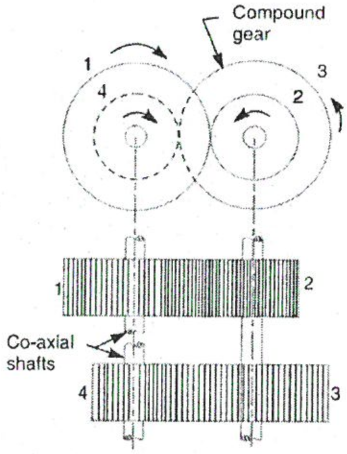


Fig. 13.4. Reverted gear train.

$$\frac{N_1}{N_4} = \frac{T_2 \times T_4}{T_1 \times T_3}$$

EpicyclicGearTrain

We have already discussed that in an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train is shown in Fig. 13.6, where a gear A and the arm C have a common axis at O_1 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at O_2, about which the gear B can rotate. If the arm is fixed, the gear train is simple and gear A can drive gear B or *vice- versa*, but if gear A is fixed and the arm is rotated about the axis of gear A (*i.e.* O_1), then the gear B is forced to rotate *upon* and *around* gear A. Such a motion is called **epicyclic** and the gear trains arranged in such a manner that one or more of their members move upon and around another member are known as ***epicyclic gear trains*** (***epi.*** means upon and ***cyclic*** means around). The epicyclic gear trains may be ***simple*** or ***compound***.

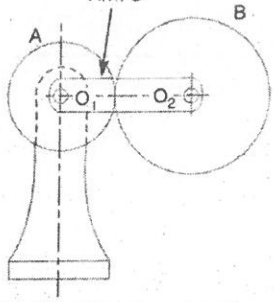
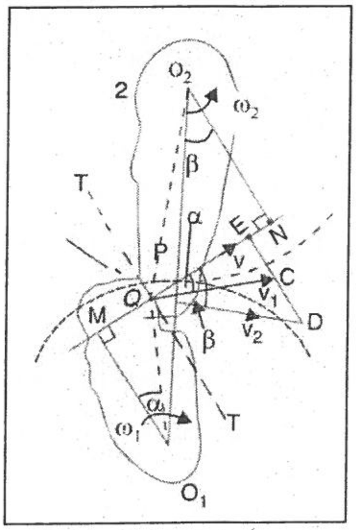


Fig. 13.6. Epicyclic gear train.

6. State law of gearing L2 CO1, CO3 4 Marks

Consider the portions of the two teeth, one on the wheel 1 (or pinion) and the other on the wheel 2, as shown by thick line curves in Fig. 12.6. Let the two teeth come in contact at point Q, and the wheels rotate in the directions as shown in the figure.



Let $T\,T$ be the common tangent and MN be the common normal to the curves at the point of contact Q. From the centres O_1 and O_2, draw O_1M and O_2N perpendicular to MN. A little consideration will show that the point Q moves in the direction QC, when considered as a point on wheel 1, and in the direction QD when considered as a point on wheel 2.

Let v_1 and v_2 be the velocities of the point Q on the wheels 1 and 2 respectively. If the teeth are to remain in contact, then the components of these velocities along the common normal MN must be equal.

$$\therefore \quad v_1 \cos\alpha = v_2 \cos\beta$$

or

$$(\omega_1 \times O_1Q)\cos\alpha = (\omega_2 \times O_2Q)\cos\beta$$

$$(\omega_1 \times O_1Q)\frac{O_1M}{O_1Q} = (\omega_2 \times O_2Q)\frac{O_2N}{O_2Q} \quad \text{or} \quad \omega_1 \times O_1M = \omega_2 \times O_2N$$

$$\therefore \quad \frac{\omega_1}{\omega_2} = \frac{O_2N}{O_1M} \quad \ldots(i)$$

Also from similar triangles O_1MP and O_2NP,

$$\frac{O_2N}{O_1M} = \frac{O_2P}{O_1P} \quad \ldots(ii)$$

Combining equations (*i*) and (*ii*), we have

$$\frac{\omega_1}{\omega_2} = \frac{O_2N}{O_1M} = \frac{O_2P}{O_1P} \quad \ldots(iii)$$

From above, we see that the angular velocity ratio is inversely proportional to the ratio of the distances of the point P from the centres O_1 and O_2, or the common normal to the two surfaces at the point of contact Q intersects the line of centres at point P which divides the centre distance inversely as the ratio of angular velocities.

Therefore in order to have a constant angular velocity ratio for all positions of the wheels, the point P must be the fixed point (called pitch point) for the two wheels. In other words, ***the common normal at the point of contact between a pair of teeth must always pass through the pitch point.*** This is the fundamental condition which must be satisfied while designing the profiles for the teeth of gear wheels. It is also known as ***law of gearing.***

OR

7. An aeroplane flying at 240 km/hr turns towards the left and completes a quarter circle of 60 m radius. The mass of the rotary engine and the propeller of the plane is 450 kg with a radius of gyration of 320 mm. The engine speed is 2000 rpm clockwise when viwered from the rear. Determine the gyroscopic couple on the airplane ands state its effect 13 *CO 1,4 10M*

Given : R = 60 m ; v = 240 km/hr = $\frac{240 \times 1000}{3600}$ = 66.67 m/s ; m = 450 kg ; k = 0.32 m

N = 2000 r.p.m. or $\omega = 2\pi N/60 = 2\pi \times 2000/60 = 209.43$ rad/s

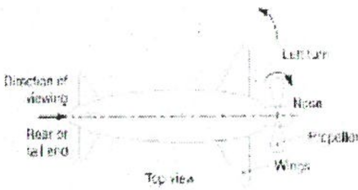
Mass moment of inertia of the rotor, $I = m\,k^2 = 450\,(0.32)^2 = 46.08$ kg-m^2

Angular velocity of precession, $\omega_p = \frac{v}{R} = \frac{66.67}{60} = 1.11$ rad/s

Gyroscopic couple, $C = I\omega\,\omega_p = 46.08 \times 209.43 \times 1.11 = 10712.09$ N-m

Effect

When the aero-plane turns towards left, the effect of the gyroscopic couple is to lift the nose upwards and tail downwards.



When the engine or propeller rotates in clockwise direction when viewed from the rear or tail end and the aeroplane takes a right turn, the effect of the reactive gyroscopic couple will be to dip the nose and raise the tail of the aeroplane.

UNIT-IV

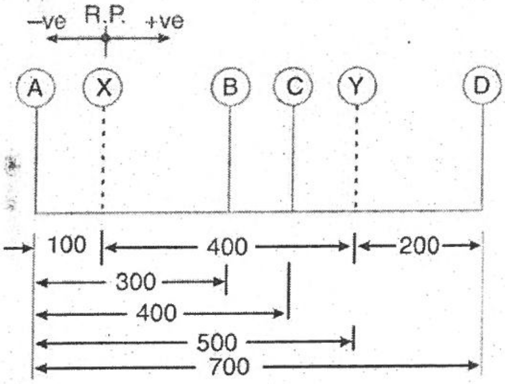
8. **A shaft carries four masses A, B, C, and D with magnitudes 200 kg, 300 kg, 400 kg, and 200 kg respectively. They revolve at radii of 80 mm, 70 mm, 60 mm, and 80 mm in planes measured from A at 300 mm, 400 mm, and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70°, and C to D 120°. Balancing masses are to be placed in planes X and Y. The distance between planes A and X is 100 mm, between X and Y is 400 mm, and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, find their magnitude and angular positions. L3 CO 1,4 10 Marks**

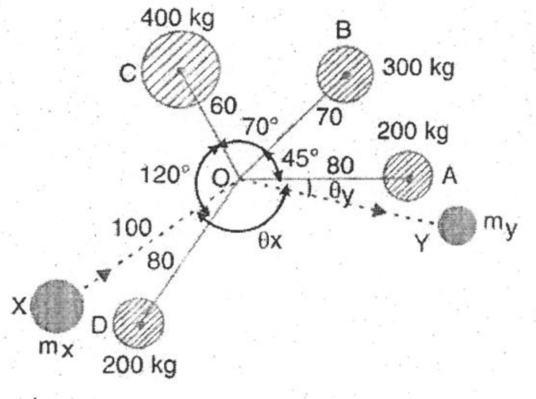
Solution. Given : $m_A = 200$ kg ; $m_B = 300$ kg ; $m_C = 400$ kg ; $m_D = 200$ kg ; $r_A = 80$ mm $= 0.08$m ; $r_B = 70$ mm $= 0.07$ m ; $r_C = 60$ mm $= 0.06$ m ; $r_D = 80$ mm $= 0.08$ m ; $r_X = r_Y = 100$ mm $= 0.1$ m

Let m_X = Balancing mass placed in plane *X*, and

m_Y = Balancing mass placed in plane *Y*.

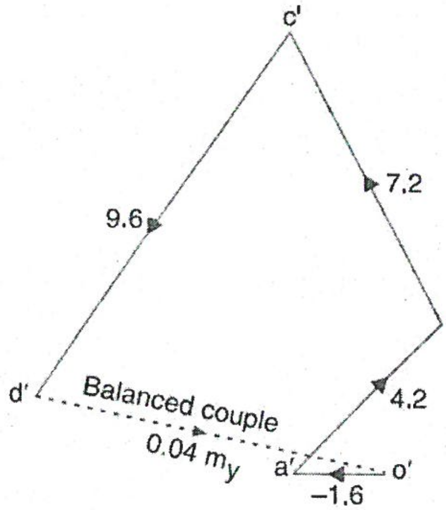
Plane (1)	*Mass (m)* kg (2)	*Radius (r)* m (3)	*Cent.force* $\div \omega^2$ (m.r) kg-m (4)	*Distance from Plane x(l)* m (5)	*Couple* $\div \omega^2$ (m.r.l) kg-m^2 (6)
A	200	0.08	16	– 0.1	– 1.6
X(R.P.)	m_X	0.1	0.1 m_X	0	0
B	300	0.07	21	0.2	4.2
C	400	0.06	24	0.3	7.2
Y	m_Y	0.1	0.1 m_Y	0.4	0.04 m_Y
D	200	0.08	16	0.6	9.6



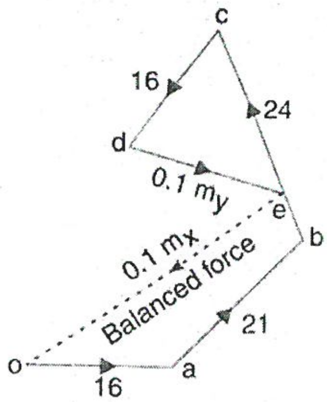


All dimensions in mm.

(*a*) Position of planes. (*b*) Angular position of masses.



(c) Couple polygon.



(d) Force polygon.

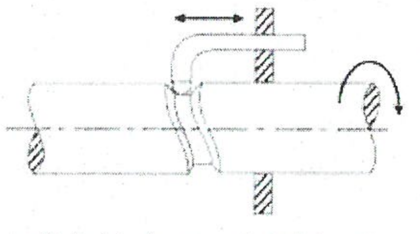
$$0.1\, m_X = \text{vector } eo = 35.5 \text{ kg-m} \quad \text{or} \quad m_X = 355 \text{ kg } \textbf{Ans.}$$

The angular position of the mass m_X is obtained by drawing Om_X in Fig. 21.8 (*b*), parallel to vector *eo*. By measurement, the angular position of m_X is $\theta_X = 145°$ in the clockwise direction from mass m_A (*i.e.* 200 kg). **Ans.**

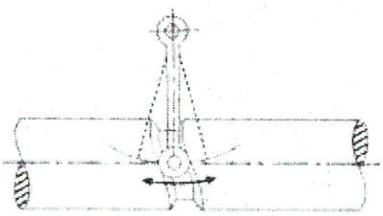
9. Explain with sketches the different types of cams and followers L2, CO1-3 10M

Classification of Cams

Though the cams may be classified in many ways, yet the following two types are important from the subject point of view :



(a) Cylindrical cam with reciprocating follower.



(b) Cylindrical cam with oscillating follower.

1. ***Radial or disc cam.*** In radial cams, the follower reciprocates or oscillates in a direction perpendicular to the cam axis. The cams as shown in Fig. 20.1 are all radial cams.

2. ***Cylindrical cam.*** In cylindrical cams, the follower reciprocates or oscillates in a direction parallel to the cam axis. The follower rides in a groove at its cylindrical surface. A cylindrical grooved cam with a reciprocating and an oscillating follower is shown in Fig. 20.2 (*a*) and (*b*) respectively.

Classification of follower:

The followers may be classified as discussed below :

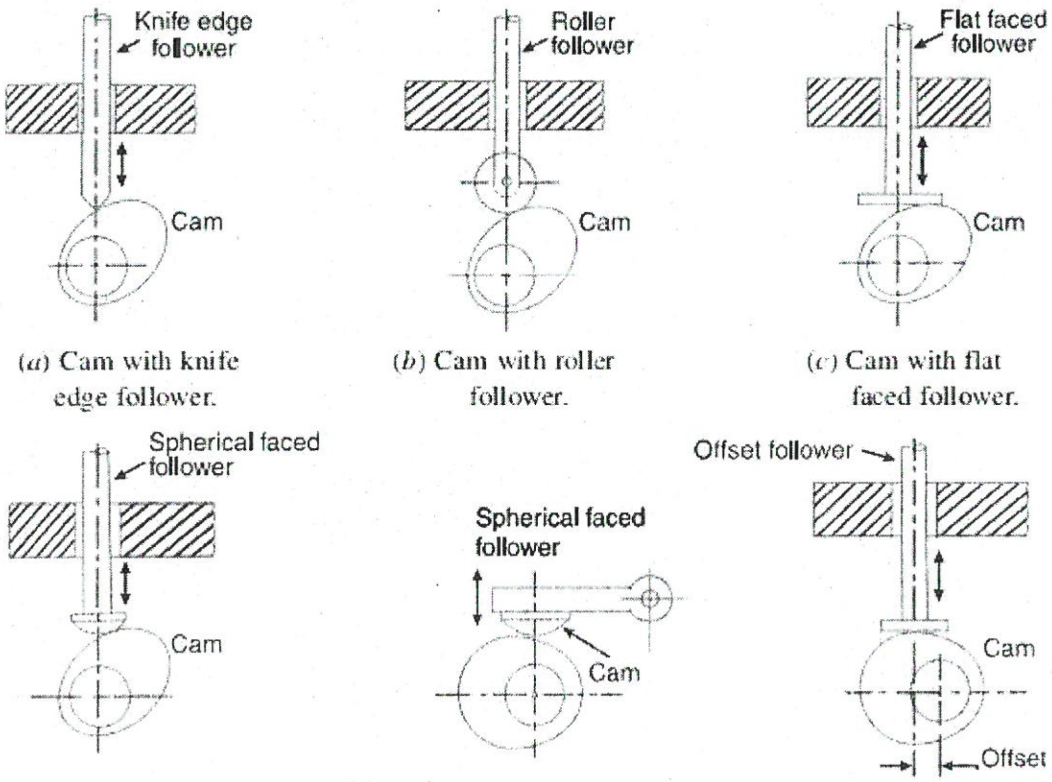
1. ***According to the surface in contact.*** The followers, according to the surface in contact, are as follows :

(*a*) ***Knife edge follower.*** When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower, as shown in Fig. 20.1 (*a*). The sliding motion takes place between the contacting surfaces (*i.e.* the knife edge and the cam surface). It is seldom used in practice because the small area of contacting surface results in excessive wear. In knife edge followers, a considerable side thrust exists between the follower and the guide.

(*b*) ***Roller follower.*** When the contacting end of the follower is a roller, it is called a roller follower, as shown in Fig. 20.1 (*b*). Since the rolling motion takes place between the contacting surfaces (*i.e.* the roller and the cam), therefore the rate of wear is greatly reduced. In roller followers also the side thrust exists between the follower and the guide. The roller followers are extensively used where more space is available such as in stationary gas and oil engines and aircraft engines.

(*c*) ***Flat faced or mushroom follower.*** When the contacting end of the follower is a perfectly flat face, it is called a flat-faced follower, as shown in Fig. 20.1 (*c*). It may be noted that the side thrust between the follower and the guide is much reduced in case of flat faced followers. The only side thrust is due to friction between the contact surfaces of the follower and the cam. The relative motion between these surfaces is largely of sliding nature but wear may be reduced by off-setting the axis of the follower, as shown in Fig. 20.1 (*f*) so that when the cam rotates, the follower also rotates about its own axis. The flat faced followers are generally used where space is limited such as in cams which operate the valves of automobile engines.

(*d*) ***Spherical faced follower.*** When the contacting end of the follower is of spherical shape, it is called a spherical faced follower, as shown in Fig. 20.1 (*d*). It may be noted that when a flat-faced follower is used in automobile engines, high surface stresses are produced. In order to minimise these stresses, the flat end of the follower is machined to a spherical shape.



(*a*) Cam with knife edge follower. (*b*) Cam with roller follower. (*c*) Cam with flat faced follower.

(*d*) Cam with spherical faced follower. (*e*) Cam with spherical faced follower. (*f*) Cam with offset follower.

Fig. 20.1. Classification of followers.

2. *According to the motion of the follower.* The followers, according to its motion, are of the following two types:

(*a*) ***Reciprocating or translating follower.*** When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower. The followers as shown in Fig. 20.1 (*a*) to (*d*) are all reciprocating or translating followers.

(*b*) ***Oscillating or rotating follower.*** When the uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower, it is called oscillating or rotating follower. The follower, as shown in Fig 20.1 (*e*), is an oscillating or rotating follower.

3. *According to the path of motion of the follower.* The followers, according to its path of motion, are of the following two types:

(*a*) ***Radial follower.*** When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower. The followers, as shown in Fig. 20.1 (*a*) to (*e*), are all radial followers.

(*b*) ***Off-set follower.*** When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower. The follower, as shown in Fig. 20.1 (*f*), is an off-set follower.

UNIT-V

10 a) Derive natural frequency of free longitudinal vibrations. L2 CO1, CO5 5 Marks

1. ***Free or natural vibrations.*** When no external force acts on the body, after giving it an initial displacement, then the body is said to be under ***free or natural vibrations.*** The frequency of the free vibrations is called ***free or natural frequency.***

3. *Rayleigh's method*

In this method, the maximum kinetic energy at the mean position is equal to the maximum potential energy (or strain energy) at the extreme position. Assuming the motion executed by the vibration to be simple harmonic, then

$$x = X \sin \omega t \qquad \ldots (i)$$

where x = Displacement of the body from the mean position after time t seconds, and

X = Maximum displacement from mean position to extreme position.

Now, differentiating equation (*i*), we have

$$\frac{dx}{dt} = \omega \times X \cos \omega . t$$

Since at the mean position, $t = 0$, therefore maximum velocity at the mean position,

$$v = \frac{dx}{dt} = \omega . X$$

∴ Maximum kinetic energy at mean position

and maximum potential energy at the extreme position

$$= \left(\frac{0 + s.X}{2} \right) X = \frac{1}{2} \times s.X^2 \qquad \ldots (iii)$$

Equating equations (*ii*) and (*iii*),

$$\frac{1}{2} \times m.\omega^2.X^2 = \frac{1}{2} \times s.X^2 \quad \text{or} \quad \omega^2 = \frac{s}{m}, \text{ and } \omega = \sqrt{\frac{s}{m}}$$

∴ Time period, $$t_p = \frac{2\pi}{\omega} = 2\pi \sqrt{\frac{s}{m}} \qquad \ldots \text{(Same as before)}$$

and natural frequency, $$f_n = \frac{1}{t_p} = \frac{\omega}{2\pi} = \frac{1}{2\pi} \sqrt{\frac{s}{m}} \qquad \ldots \text{(Same as before)}$$

Note : In all the above expressions, ω is known as **natural circular frequency** and is generally denoted by ω_n.

UNIT-V

10. B. ***A longitudinal system consists of a mass of 200 kg, a spring of stiffness 80 N/mm and a damper with damping coeeeficient of 800 N/m/s. Determine the frequency of vibration of the system.L3, CO1 5 5M***

The natural frequency of a spring-mass system is given by,

$f_n = \frac{\omega_n}{2\pi}$ and $\omega_n = \sqrt{\frac{k}{m}}$

where k = spring stiffness (N/m) and m = mass of the body (kg)

<u>Calculation:</u>

<u>Given:</u>

Mass of body (m) = 200 kg, spring stiffness (k) = 80 N/mm = 80 × 10^3 N/m

The natural frequency of vibration is:

$$\omega_n = \sqrt{\frac{k}{m}}$$

$$\omega_n = \sqrt{\frac{80 \times 10^3}{200}} = \sqrt{400} = 20\ rad/s$$

OR

11. Explain and Draw Turning moment diagram of steam engine . L3, CO5 10M

Ans) The turning moment diagram (also known as crankeffort 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.

A turning moment diagram for a single cylinder double acting steam engine is shown in Fig. 16.1. The vertical ordinate represents the turning moment and the horizontal ordinate represents the crank angle.

We have discussed in Chapter 15 (Art. 15.10.) that the turning moment on the crankshaft,

$$T = F_P \times r\left(\sin\theta + \frac{\sin 2\theta}{2\sqrt{n^2 - \sin^2\theta}}\right)$$

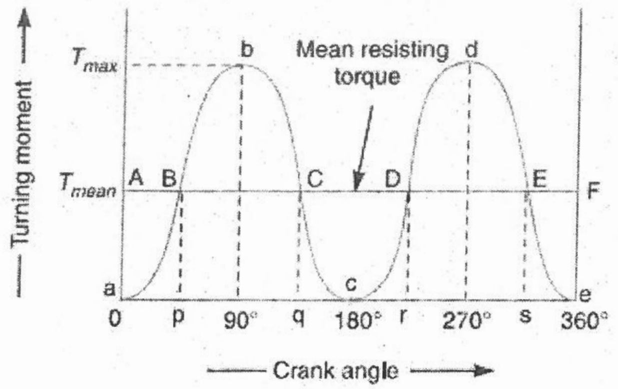


Fig. 16.1. Turning moment diagram for a single cylinder, double acting steam engine.

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.

From the above expression, we see that the turning moment (T) is zero, when the crank angle (θ) is zero. It is maximum when the crank angle is 90° and it is again zero when crank angle is 180°. This is shown by the curve abc in Fig. 16.1 and it represents the turning moment diagram for outstroke. The curve cde is the turning moment diagram for instroke and is somewhat similar to the curve abc. Since the work done is the product of the turning moment and the angle turned, therefore the area of the turning moment diagram represents the work done per revolution. In actual practice, the engine is assumed to work against the mean resisting torque, as shown by a horizontal line AF. The height of the ordinate aA represents the mean height of the turning moment diagram. Since it is assumed that the work done by the turning moment per revolution is equal to the work done against the mean resisting torque, therefore the area of the rectangle aAFe is proportional to the work done against the mean resisting torque.