PVP 23

Code: 23ME3403

II B.Tech - II Semester – Regular / Supplementary Examinations APRIL 2026

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.

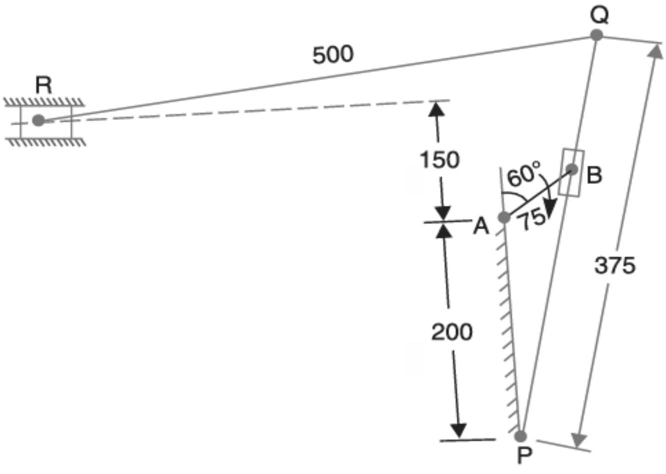
BL – Blooms Level CO – Course Outcome

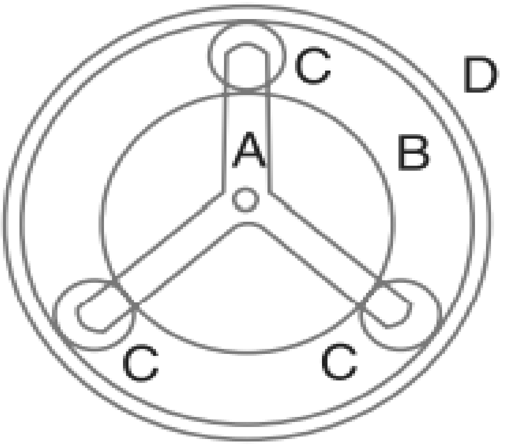
PART – A

		BL	CO
1.a)	What is kinematic inversion?	L2	CO1
1.b)	Give the application of straight line mechanisms.	L2	CO3
1.c)	Define Radial Component of acceleration. What is its direction?	L2	CO2
1.d)	Define Centrode and Axode.	L2	CO2
1.e)	Explain about the Involute teeth profile.	L2	CO3
1.f)	How does the gyroscopic effect influence the stability of an airplane during a turn?	L2	CO4
1.g)	Derive the condition for balancing of single rotating mass.	L3	CO4
1.h)	Define radial cam.	L2	CO3
1.i)	What is vibration isolation and transmissibility?	L2	CO5
1.j)	Define coefficient of fluctuation of energy.	L2	CO4

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Explain the different constrained motions with suitable examples.	L2	CO1	5 M

	b)	Differentiate Mechanism and Machines.	L2	CO1	5 M
OR					
3	a)	Compare Peaucellier and Scott Russell mechanisms.	L2	CO3	5 M
	b)	Describe Watt's linkage and identify the specific point on the coupler that traces an approximate straight line.	L2	CO3	5 M
UNIT-II					
4	PQRS is a four bar chain with link PS fixed. The lengths of the links are PQ = 62.5 mm; QR = 175 mm; RS = 112.5 mm; and PS = 200 mm. The crank PQ rotates at 10 rad/s clockwise. Draw the velocity and acceleration diagrams when angle QPS = 60° and Q and R lie on the same side of PS. Find the angular velocity and angular acceleration of links QR and RS.		L3	CO2	10M
OR					
5	The driving crank AB of the quick-return mechanism, as shown in Fig. revolves at a uniform speed of 200 r.p.m. Find the velocity and acceleration of the tool-box R, in the position shown, when the crank makes an angle of 60° with the vertical line of centres PA. What is the acceleration of sliding of the block at B along the slotted lever PQ?  All dimensions in mm.		L3	CO2	10M
UNIT-III					
6	a)	Explain interference and undercutting in involute gears.	L2	CO3	5 M

	b)	Compare involute and cycloidal gear profiles. Discuss advantages and disadvantages.	L2	CO3	5 M
OR					
7		In an epicyclic gear of the 'sun and planet' type shown in Fig. the pitch circle diameter of the internally toothed ring is to be 224 mm and the module 4 mm. When the ring D is stationary, the spider A, which carries three planet wheels C of equal size, is to make one revolution in the same sense as the sunwheel B for every five revolutions of the driving spindle carrying the sunwheel B. Determine suitable numbers of teeth for all the wheels.  	L3	CO3	10M
UNIT-IV					
8		Four masses m_1, m_2, m_3 and m_4 are 250 kg, 350 kg, 240 kg and 280 kg respectively. The corresponding radii of rotation are 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively and the angles between successive masses are 45°, 75° and 135°. Find the position and magnitude of the balance mass required, if its radius of rotation is 0.2 m.	L3	CO4	10M
OR					
9		Draw a cam profile to drive an radial roller follower to the specifications given below : (i) Follower to move outwards during the first 120° rotation of the cam ; (ii) Follower to return to its initial position during next 120° rotation of the cam ;	L3	CO3	10M

	(iii) Follower to dwell during the next 120° of cam rotation. Lift of the follower = 50 mm; Minimum radius of cam = 40 mm ; Radius of roller = 10 mm ; The inward and outward strokes take place with simple harmonic motion.			
UNIT-V				
10	The long shaft 55 mm diameter and 3.2 metres long is simply supported at the ends and carries three loads of 1000 N, 1500 N and 750 N at 1 m, 2 m and 2.5 m from the left support. The Young's modulus for shaft material is 200 GN/m^2. Find the frequency of transverse vibration.	L3	CO5	10M
OR				
11	A multi-cylinder engine is to run at a speed of 600 r.p.m. On drawing the turning moment diagram to a scale of 1 mm = 250 N-m and 1 mm = 3°, the areas above and below the mean torque line in mm^2 are : +160, –172, +168, –191, +197, –162 The speed is to be kept within ± 1% of the mean speed of the engine. Calculate the necessary moment of inertia of the flywheel. Determine the suitable dimensions of a rectangular flywheel rim if the breadth is twice its thickness. The density of the cast iron is 7250 kg/m^3 and its hoop stress is 6 MPa. Assume that the rim contributes 92% of the flywheel effect.	L3	CO4	10M

Scheme of Evaluation

Code: 23ME3403 THEORY OF MACHINES

PART-A.

1. (a). Definition of kinematic inversion – 2m

1. (b). Any two applications of straight line mechanisms – 2m

1. (c) Definition of Radial component of acceleration – 1m
Direction " " – 1m

1. (d). Definition of centrode – 1m
Definition of Axode – 1m

1. (e). Definition of involute teeth profile – 2m

1. (f). Gyroscopic effect of any one turn – 2m

1. (g). condition for balancing of single rotating mass – 2m
$(\Sigma F = 0)$

1. (h). Definition/Diagram of radial cam – 2m

1 (i). Vibration isolation – 1m
Transmissibility – 1m

1 (j). Definition/formula of Coefficient of fluctuation of energy – 2m

PART-B

UNIT – 1

2. (a). Definitions of 3 Constrained Motions – 3m
examples – 2m

(b) Any 3 differences between mechanism and Machine – 5m

(OR)

3. (a) Any 3 differences between peaucellier and Scott Russel mechanisms – 5m

(b) Diagram of watt linkage – 3m
Explanation – 2m

UNIT – 2

Given data – 2m

4. Configuration diagram of 4 bar mechanism – 3m
velocity diagram – 2m
Acceleration diagram – 2m
calculation – 1m

(OR)

5. Given data - 2m
Configuration diagram - 3m
Velocity diagram - 2m
Acceleration diagram - 2m
Calculation - 1m

UNIT-3

6.(a). Definition of interference - 2m
Definition of Undercutting - 2m
diagram - 1m

(B) Any 3 differences of cycloidal and involute teeth - 5m

(OR)

7. Given data - 2m
Table of motions - 5m
Calculation - 3m

UNIT-4

8. Given data - 2m
Position/force vector diagram - 4m
Calculation of angle - 2m
Calculation of mass - 2m

(OR)

9. Given data - 2m
Displacement diagram of follower - 4m
Cam profile - 4m

UNIT-5

10. Given data - 2m
Calculation of deflections - 6m (2m each)
Calculation of natural frequency - 2m

(OR)

11. Given data - 2m
Calculation of ΔE - 4m
Calculation of moment of inertia - 2m
Calculation of dimensions of flywheel - 2m

II B.Tech – II Semester – Regular Examinations – April 2026

THEORY OF MACHINES (23ME3403)

KEY and Scheme of evaluation

PART – A

1. a) The process of fixing different links of the same kinematic chain to produce distinct mechanisms is known as kinematic inversion.

1. b) *Machine tools* - Used in devices like shaper machine and slotting machine to produce straight-line cutting motion.
Pumps and engines - Employed in mechanisms such as the reciprocating pump and steam engine where pistons need linear motion.
Automobile steering systems - Used in approximate straight-line mechanisms like the Davis steering gear and Ackermann steering mechanism.
Printing and textile machinery - For guiding components in a straight path during operations like printing or weaving.
Measuring instruments - To ensure precise linear displacement in devices requiring accurate motion.
Linkages in engineering systems - Used in mechanisms such as the Peaucellier–Lipkin linkage to convert rotary motion into exact straight-line motion.

1. c) The radial component of acceleration is the part of an object's acceleration that points along the radius of its path in curved motion. he radial component of acceleration is always directed toward the center of curvature.

1. d) A *centrode* is the locus (path) of the instantaneous center of rotation of a rigid body during its motion. An *axode* is the three-dimensional counterpart of a centrode. It is the locus of the instantaneous axis of rotation of a rigid body in space during motion.

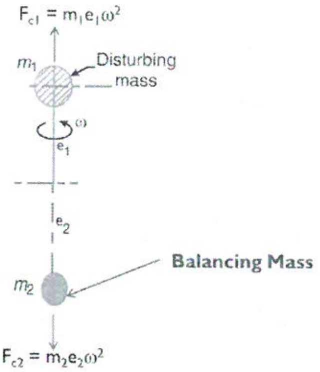
1. e) An involute is defined as the locus of a point on a straight line which rolls without slipping on the circumference of a circle. Also, it is the path traced out by the end of a piece of taut cord being unwound from the circumference of a circle. The circle on which the straight-line rolls or from which the cord is unwound is known as the base circle.

1. f) Steering is the turning of a complete aeroplane in a curve towards left or right, while it moves forward.

A. Rotor of the aeroplane moving in clockwise when viewed from tail
    i) Left turn – Nose raises
    ii) Right turn – Nose dips

B. Rotor of the aeroplane moving in counter clockwise when viewed from tail
    i) Left turn – Nose dips
    ii) Right turn – Nose raises

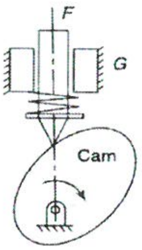
1. g) Consider a disturbing mass m_1 attached to a shaft rotating at ω rad/s. Let e_1 be the radius of rotation of the mass m_1 (i.e. distance between the axis of rotation of the shaft and the centre of gravity of the mass m_1). The unbalanced force $F_{c1} = m_1 e_1 w^2$
In order to counter act, a balancing mass (m_2) may be attached in the same plane of rotation as that of disturbing mass (m_1) such that the centrifugal forces due to the two masses are equal and opposite.



$$m_1 e_1 w^2 = m_2 e_2 w^2$$

$$m_1 e_1 = m_2 e_2$$

1. h) A cam in which the follower moves radially from the centre of rotation of the cam is known as a radial or a disc cam. Radial cams are very popular due to their simplicity and compactness.



1. i) Vibration isolation is the process of reducing or preventing the transmission of vibrations from a source (like a machine) to another system (like its support or surroundings).

Transmissibility is a measure of how much vibration is transmitted through a system. It is defined as the ratio of output vibration to input vibration.

1. j) It is defined as the ratio of the maximum fluctuation of energy to the work done/cycle.

$$C_E = \frac{\text{Maximum fluctuation of energy}}{\text{Work done/cycle}}$$

PART – B

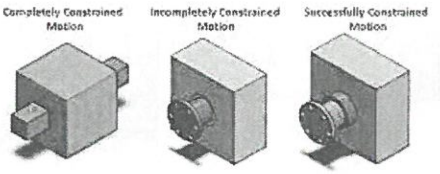
UNIT – I

2. a)

Incompletely constrained motion: When the motion between a pair can take place in more than one direction, it is said to be incompletely constrained motion.

Partially or successfully constrained motion: When the constrained motion between a pair is not completed by itself but by some other means, it is said to be successfully constrained motion.

Completely constrained motion: When the motion between a pair takes place in a definite direction irrespective of the direction of force applied, then the motion is said to be completely constrained motion.



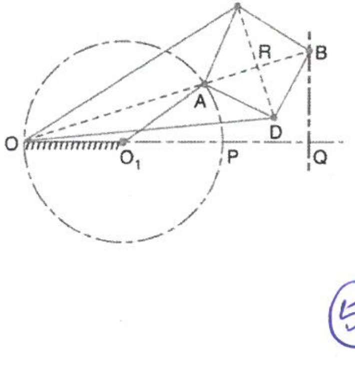
b)

Mechanism	Machine
A mechanism is an assemblage of links, the motion to one of them producing definite motion to others.	A machine is an assemblage of links having relative motion and capable of transforming available energy into certain useful work.
A mechanism is not necessarily a machine. It is meant to produce definite motion between various links constituting it.	A machine is constituted of a mechanism or a number of mechanisms meant for transmitting energy to do useful work.
A mechanism is a part of a machine.	A machine is a practical development of any mechanism
Example: an indicator – to draw P-V diagram a watch – energy is stored in winding spring to move the hands	Example: steam engine, hoist etc.

OR

3. a)

Peaucellier mechanism:



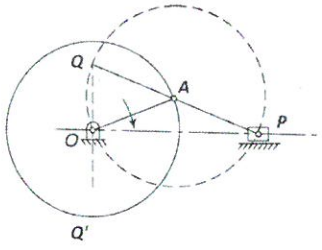
- A type of exact straight-line mechanism
- Converts rotary motion into perfect straight-line motion
- Works based on a geometric principle called inversion of points
- Consists of a linkage of 8 bars (Peaucellier–Lipkin linkage)

⑤

- Produces a true straight line, not approximate
- More complex in construction

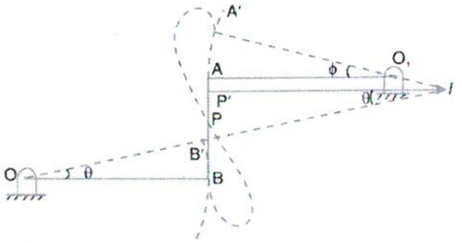
Scott Russell's mechanism:

- Also used to generate straight-line motion
- Produces an exact straight line (not approximate)
- Based on the principle of perpendicular link motion
- Consists of fewer links (simpler, typically 4 links)
- One link slides while another rotates
- Simpler and more compact than Peaucellier



b)

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.



In Fig., OBAO$_1$ is a crossed four bar chain in which O and O$_1$ are fixed. In the mean position of the mechanism, links OB and O$_1$A are parallel and the coupling rod AB is perpendicular to O$_1$A and OB. The tracing point P traces out an approximate straight line over certain positions of its movement, if $\frac{PB}{PA} = \frac{O_1A}{OB}$. This may be proved as follows:

A little consideration will show that in the initial mean position of the mechanism, the instantaneous centre of the link BA lies at infinity. Therefore, the motion of the point P is along the vertical line BA. Let OB'A'O$_1$ be the new position of the mechanism after the links OB and O$_1$A are displaced through an angle θ and φ respectively. The instantaneous centre now lies at I. Since the angles θ and φ are very small, therefore

$$arc\, BB' = arc\, AA'$$

or
$$OB \times \theta = O_1A \times \varphi \qquad \text{(i)}$$

$$\therefore \frac{OB}{O_1A} = \frac{\varphi}{\theta}$$

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

$$\Rightarrow \frac{A'P'}{B'P'} = \frac{\varphi}{\theta} \qquad \text{(ii)}$$

From equations (i) and (ii),

⑥

$$\frac{OB}{O_1A} = \frac{A'P'}{B'P'} = \frac{AP}{BP}$$

$$\Rightarrow \frac{O_1A}{OB} = \frac{BP}{AP}$$

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

UNIT – II

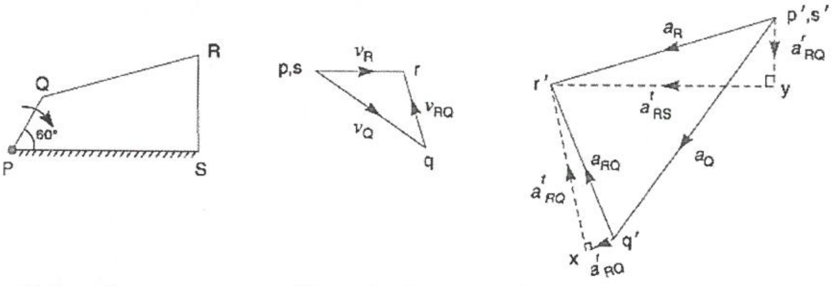
4.

Solution. Given : $\omega_{QP} = 10$ rad/s; $PQ = 62.5$ mm $= 0.0625$ m ; $QR = 175$ mm $= 0.175$ m ; $RS = 112.5$ mm $= 0.1125$ m ; $PS = 200$ mm $= 0.2$ m

We know that velocity of Q with respect to P or velocity of Q,

$$v_{QP} = v_Q = \omega_{QP} \times PQ = 10 \times 0.0625 = 0.625 \text{ m/s}$$

...(Perpendicular to PQ)



(*a*) Space diagram. (*b*) Velocity diagram. (*c*) Acceleration diagram.

vector $pq = v_{QP} = v_Q = 0.625$ m/s

v_{RQ} = vector $qr = 0.333$ m/s, and $v_{RS} = v_R$ = vector $sr = 0.426$ m/s

We know that angular velocity of link QR,

$$\omega_{QR} = \frac{v_{RQ}}{RQ} = \frac{0.333}{0.175} = 1.9 \text{ rad/s (Anticlockwise)} \textbf{ Ans.}$$

$$\omega_{RS} = \frac{v_{RS}}{SR} = \frac{0.426}{0.1125} = 3.78 \text{ rad/s (Clockwise)} \textbf{ Ans.}$$

We know that radial component of the acceleration of Q with respect to P (or the acceleration of Q),

$$a^r_{QP} = a_{QP} = a_Q = \frac{v^2_{QP}}{PQ} = \frac{(0.625)^2}{0.0625} = 6.25 \text{ m/s}^2$$

Radial component of the acceleration of R with respect to Q,

$$a^r_{RQ} = \frac{v^2_{RQ}}{QR} = \frac{(0.333)^2}{0.175} = 0.634 \text{ m/s}^2$$

and radial component of the acceleration of R with respect to S (or the acceleration of R).

$$a_{RS}^{r} = a_{RS} = a_{R} = \frac{v_{RS}^{2}}{SR} = \frac{(0.426)^2}{0.1125} = 1.613 \text{ m/s}^2$$

We know that angular acceleration of link QR.

$$\alpha_{QR} = \frac{a_{RQ}^{t}}{QR} = \frac{4.1}{0.175} = 23.43 \text{ rad/s}^2 \text{ (Anticlockwise) } \textbf{Ans.}$$

and angular acceleration of link RS,

$$\alpha_{RS} = \frac{a_{RS}^{t}}{SR} = \frac{5.3}{0.1125} = 47.1 \text{ rad/s}^2 \text{ (Anticlockwise) } \textbf{Ans.}$$

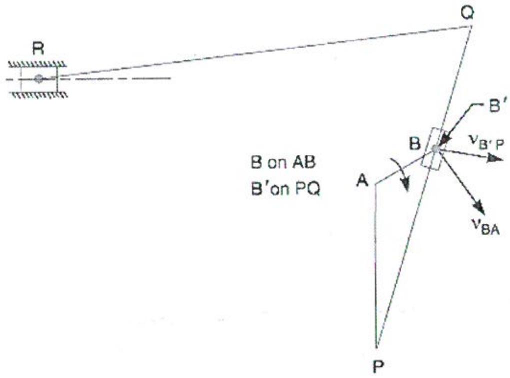
OR

5.

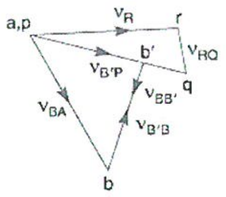
Solution. Given : $N_{BA} = 200$ r.p.m. or $\omega_{BA} = 2\,\pi \times 200/60 = 20.95$ rad/s ; $AB = 75$ mm $= 0.075$ m

We know that velocity of B with respect to A,

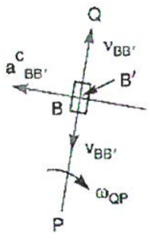
$$v_{BA} = \omega_{BA} \times AB = 20.95 \times 0.075 = 1.57 \text{ m/s} \qquad \text{...(Perpendicular to } AB\text{)}$$



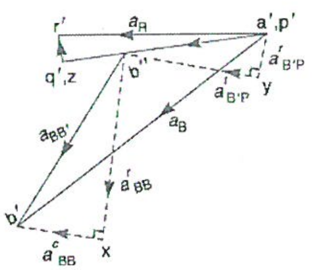
(*a*) Space diagram.



(*b*) Velocity diagram.



(*c*) Direction of coriolis component.



(*d*) Acceleration diagram.

By measurement, we find that velocity of the tool-box R,

$$v_R = \text{vector } ar = 1.6 \text{ m/s } \textbf{Ans.}$$

We also find that velocity of B' with respect to B,

$$v_{B'B} = \text{vector } bb' = 1.06 \text{ m/s}$$

Velocity of B' with respect to P,

$$v_{B'P} = \text{vector } pb' = 1.13 \text{ m/s}$$

Velocity of R with respect to Q,

$$v_{RQ} = \text{vector } qr = 0.4 \text{ m/s}$$

Velocity of Q with respect to P,

$$v_{QP} = \text{vector } pq = 1.7 \text{ m/s}$$

∴ Angular velocity of the link PQ,

$$\omega_{PQ} = \frac{v_{QP}}{OP} = \frac{1.7}{0.375} = 4.53 \text{ rad/s} \qquad \ldots(\because PQ = 0.375 \text{ m})$$

We know that the radial component of the acceleration of B with respect to A,

$$a^r_{BA} = \omega^2_{BA} \times AB = (20.95)^2 \times 0.075 = 32.9 \text{ m/s}^2$$

Coriolis component of the acceleration of the slider B with respect to coincident point B'.

$$a^c_{BB'} = 2\omega v = 2\omega_{QP} \times v_{BB'} = 2 \times 4.53 \times 1.06 = 9.6 \text{ m/s}^2$$

$$\ldots(\because \omega = \omega_{QP}, \text{ and } v = v_{BB'})$$

Radial component of the acceleration of R with respect to Q,

$$a^r_{RQ} = \frac{v^2_{RQ}}{QR} = \frac{(0.4)^2}{0.5} = 0.32 \text{ m/s}^2$$

Radial component of the acceleration of B' with respect to P,

$$a^r_{B'P} = \frac{v^2_{B'P}}{PB'} = \frac{(1.13)^2}{0.248} = 5.15 \text{ m/s}^2$$

...(By measurement, $PB' = 248$ mm $= 0.248$ m)

By measurement, we find that

$$a_R = \text{vector } ar' = 22 \text{ m/s}^2 \textbf{ Ans.}$$

By measurement, we find that the acceleration of sliding of the block B along the slotted lever PQ

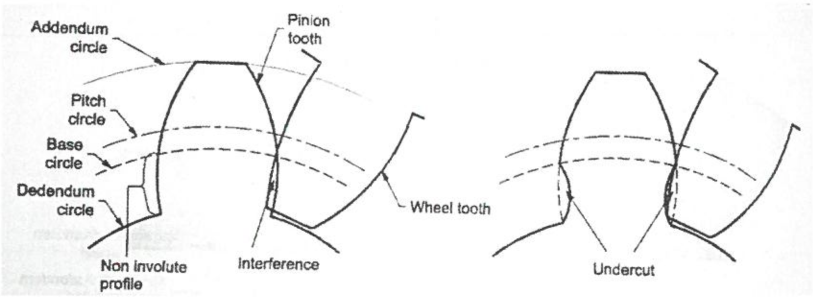
$$= a_{BB'} = \text{vector } b''x = 18 \text{ m/s}^2 \textbf{ Ans.}$$

UNIT – III

6. a)

The non-involute flank portion of the driving gear is transmitting motion in conjunction with the involute face portion of the driver gear. Obviously the two profiles are not conjugate and hence interference occurs. The effect of interference is to dig the non-involute portion of the tooth profile.

A gear having its material removed in this manner is known as undercutting.



b)

Cycloidal teeth	**Involute teeth**
Pressure angle varies from maximum at the beginning of engagement, reduces to zero at the pitch point and again increases to maximum at the end of engagement resulting in less smooth running of the gears.	Pressure angle is constant throughout the engagement of teeth. This results in smooth running of the gears.
It involves double curve for the teeth, epicycloid and hypocycloid. This complicates the manufacture.	It involves single curve for the teeth resulting in simplicity of manufacturing and of tools.
Owing to difficulty to manufacture, these are costlier.	These are simple to manufacture and thus are cheaper.
Exact centre distance is required to transmit a constant velocity ratio.	A little variation in the centre distance does not affect the velocity ratio.
Phenomenon of interference does not occur at all.	Interference can occur if the condition of minimum number of teeth on a gear is not followed.
The teeth have spreading flanks and thus are stronger.	The teeth have radial flanks and thus are weaker as compound to cycloidal form for the same pitch.
In this, a convex flank always has contact with a concave face resulting in less wear.	Two convex surfaces are in contact and thus there is more wear.

OR

7. **a)**

Solution. Given : $d_D = 224$ mm ; $m = 4$ mm ; $N_A = N_B / 5$

Let T_B, T_C and T_D be the number of teeth on the sun wheel B, planet wheels C and the internally toothed ring D. The table of motions is given below :

Step No.	*Conditions of motion*	*Revolutions of elements*			
		Spider A	*Sun wheel B*	*Planet wheel C*	*Internal gear D*
1.	Spider A fixed, sun wheel B rotates through + 1 revolution (*i.e.* 1 rev. anticlockwise)	0	+ 1	$-\frac{T_B}{T_C}$	$-\frac{T_B}{T_C} \times \frac{T_C}{T_D} = -\frac{T_B}{T_D}$
2.	Spider A fixed, sun wheel B rotates through + x revolutions	0	$+x$	$-x \times \frac{T_B}{T_C}$	$-x \times \frac{T_B}{T_D}$
3.	Add + y revolutions to all elements	$+y$	$+y$	$+y$	$+y$
4.	Total motion	$+y$	$x+y$	$y - x \times \frac{T_B}{T_C}$	$y - x \times \frac{T_B}{T_D}$

We know that when the sun wheel B makes + 5 revolutions, the spider A makes + 1 revolution. Therefore, from the fourth row of the table,

$$y = +1\ ;\ \text{and}\ x + y = +5$$

$$\therefore \quad x = 5 - y = 5 - 1 = 4$$

Since the internally toothed ring D is stationary, therefore from the fourth row of the table,

$$y - x \times \frac{T_B}{T_D} = 0$$

or

$$1 - 4 \times \frac{T_B}{T_D} = 0$$

$$\therefore \quad \frac{T_B}{T_D} = \frac{1}{4} \quad \text{or} \quad T_D = 4\,T_B \qquad \ldots(i)$$

We know that $T_D = d_D / m = 224 / 4 = 56$ Ans.

$\therefore \quad T_B = T_D / 4 = 56 / 4 = 14$ Ans. ...[From equation (i)]

Let d_B, d_C and d_D be the pitch circle diameters of sun wheel B, planet wheels C and internally toothed ring D respectively. Assuming the pitch of all the gears to be same, therefore from the geometry of Fig. 13.13,

$$d_B + 2\,d_C = d_D$$

Since the number of teeth are proportional to their pitch circle diameters, therefore

$$T_B + 2\,T_C = T_D \quad \text{or} \quad 14 + 2\,T_C = 56$$

$\therefore \quad T_C = 21$ Ans.

UNIT – IV

8.

Given: m_1=250kg, m_2=350kg, m_3=240kg, m_4=280kg, r_1=0.2m, r_2=0.15m, r_3=0.25m, r_4=0.3m, θ_1=0, θ_2=45, θ_3=60, θ_4=75

$$\sum F_X = (250 \times 0.2 \times \cos 0) + (350 \times 0.15 \times \cos 45) - (240 \times 0.25 \times \cos 60) - (280 \times 0.3 \times \cos 75) = 35.38$$

$$\sum F_Y = (250 \times 0.2 \times \sin 0) + (350 \times 0.15 \times \sin 45) + (240 \times 0.25 \times \sin 60) - (280 \times 0.3 \times \sin 75) = 7.95$$

$0.2 m_b \cos\theta_b = 35.38$ (1)

$0.2 m_b \sin\theta_b = 7.95$ (2)

$(2) \div (1) \rightarrow \theta_b = 13.8$ (Position of the balancing mass

Balancing mass, $m_b = 182.16\ kg$

OR

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UNIT – V

10.

Solution. Given : d = 55 mm = 0.055m ; l =3.2m, W_1 = 1000 N ; W_2 = 1500 N ; W_3 = 750 N; E = 200 GN/m^2 = 200 × 10^9 N/m^2

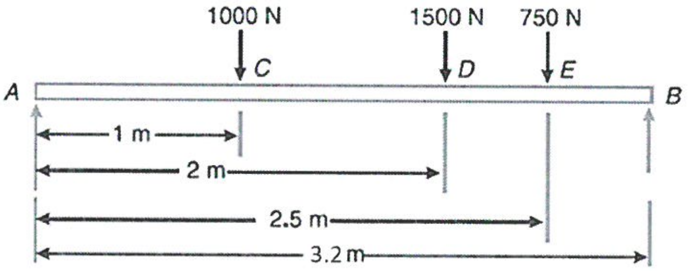
The shaft carrying the loads is shown in Fig.

We know that moment of inertia of the shaft,

$$I = \frac{\pi}{64} \times d^4 = \frac{\pi}{64}(0.055)^4 = 0.449 \times 10^{-6}\,\mathrm{m}^4$$

and the static deflection due to a point load W,

$$\delta = \frac{Wa^2b^2}{3EIl}$$



∴ Static deflection due to a load of 1000 N,

$$\delta_1 = \frac{1000 \times 1^2 \times 2.2^2}{3 \times 200 \times 10^9 \times 0.449 \times 10^{-6} \times 3.2} = 5.61 \times 10^{-3} m$$

Similarly, static deflection due to a load of 1500 N,

$$\delta_2 = \frac{1500 \times 2^2 \times 1.2^2}{3 \times 200 \times 10^9 \times 0.449 \times 10^{-6} \times 3.2} = 10.02 \times 10^{-3} m$$

and static deflection due to a load of 750 N,

$$\delta_3 = \frac{750 \times 2.5^2 \times 0.7^2}{3 \times 200 \times 10^9 \times 0.449 \times 10^{-6} \times 3.2} = 2.66 \times 10^{-3} m$$

We know that frequency of transverse vibration,

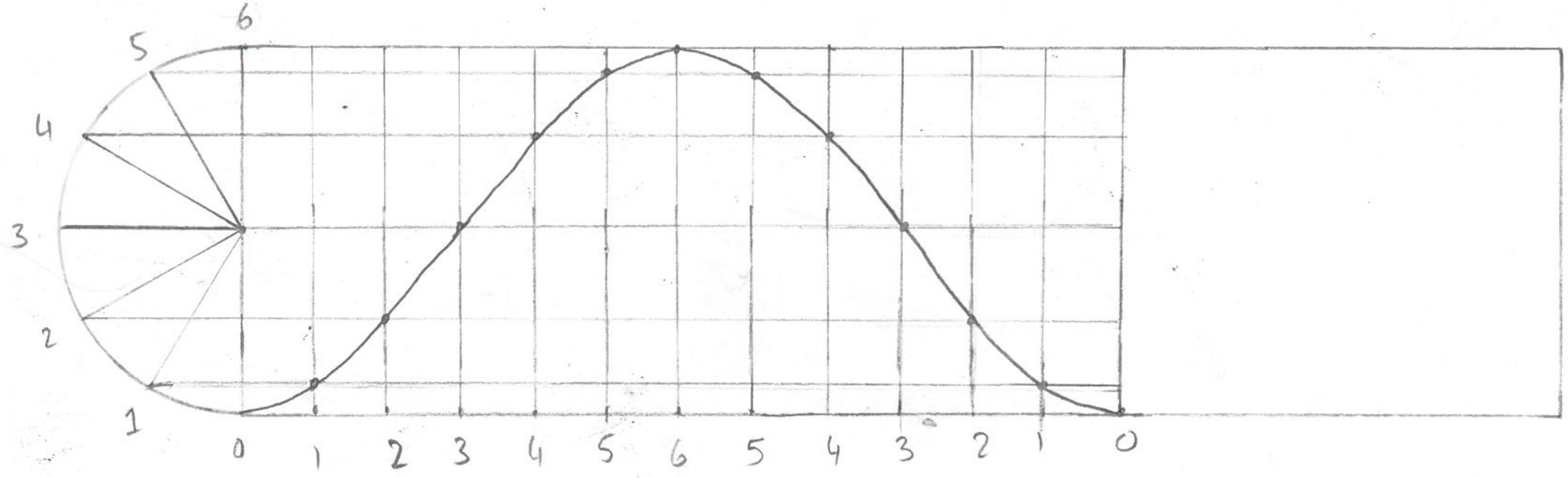
$$f_n = \frac{0.4985}{\sqrt{\delta_1 + \delta_2 + \delta_3}} = 0.135\ Hz$$

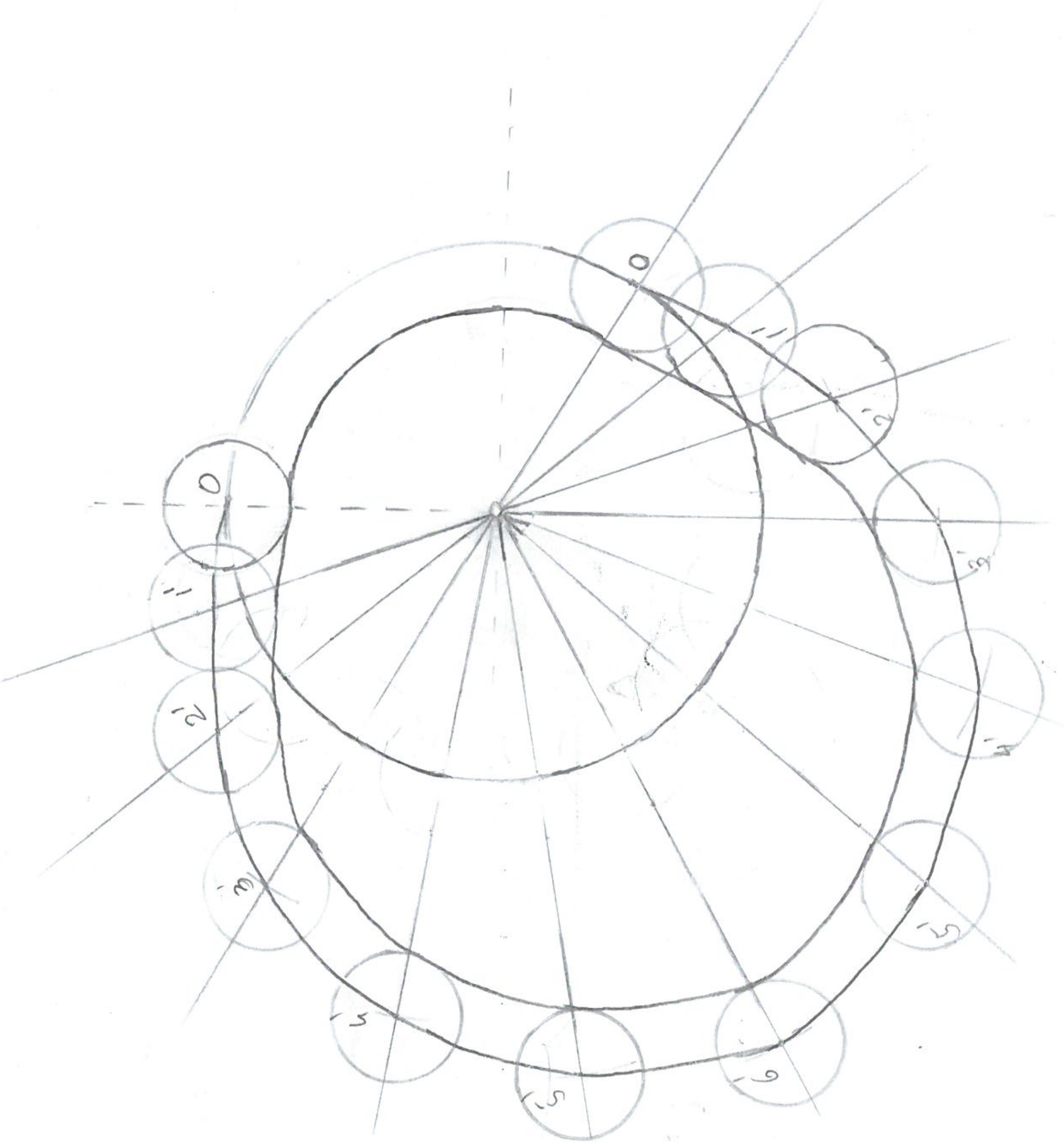
OR

9. Given data : $\phi_a = 120°$, $\phi_r = 120°$, $\phi_d = 120°$

$h = 50mm$, $r_c = 40mm$; $r_r = 10mm$

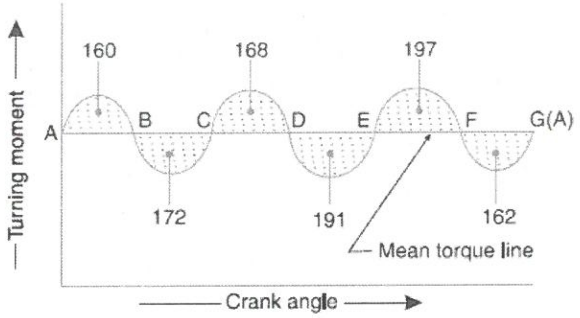
Scale
1cm = 20°.




0
1'
2'
3'
4'
5'
6'
0
1'
2'
3'
4'
5'

11.

Solution. Given : $N = 600$ r.p.m. or $\omega = 2\pi \times 600/60 = 62.84$ rad /s; $\rho = 7250$ kg/m^3; $\sigma = 6$ MPa $= 6 \times 10^6$ N/m^2



Since the fluctuation of speed is ± 1% of mean speed, therefore, total fluctuation of speed,

$$\omega_1 - \omega_2 = 2\%\ \omega = 0.02\ \omega$$

and coefficient of fluctuation of speed,

$$C_S = \frac{\omega_1 - \omega_2}{\omega} = 0.02$$

Let the total energy at $A = E$. Therefore from Fig., we find that

$$\text{Energy at } B = E + 160$$

$$\text{Energy at } C = E + 160 - 172 = E - 12$$

$$\text{Energy at } D = E - 12 + 168 = E + 156$$

$$\text{Energy at } E = E + 156 - 191 = E - 35 \qquad \text{. . . (Minimum energy)}$$

$$\text{Energy at } F = E - 35 + 197 = E + 162 \qquad \text{. . . (Maximum energy)}$$

$$\text{Energy at } G = E + 162 - 162 = E = \text{Energy at } A$$

We know that maximum fluctuation of energy,

$$\Delta E = \text{Maximum energy} - \text{Minimum energy}$$

$$= (E + 162) - (E - 35) = 197 \text{ mm}^2$$

$$= 197 \times 13.1 = 2581 \text{ N-m}$$

We also know that maximum fluctuation of energy (ΔE),

$$2581 = I.\omega^2.C_S = I \times (62.84)^2 \times 0.02 = 79\ I$$

$$\therefore \qquad I = 2581/79 = 32.7 \text{ kg-m}^2 \textbf{ Ans.}$$

We know that hoop stress (σ),

$$6 \times 10^6 = \rho.v^2 = 7250\ v^2 \quad \text{or} \quad v^2 = 6 \times 10^6/7250 = 827.6$$

$$\therefore \qquad v = 28.8 \text{ m/s}$$

We know that $\quad v = \pi DN/60, \quad$ or $\quad D = v \times 60 / \pi N = 28.8 \times 60/\pi \times 600 = 0.92$ m

Now, let us find the mass (m) of the flywheel rim. Since the rim contributes 92% of the flywheel effect, therefore maximum fluctuation of energy of rim,

$$\Delta E_{rim} = 0.92 \times \Delta E = 0.92 \times 2581 = 2375 \text{ N-m}$$

We know that maximum fluctuation of energy of rim (ΔE_{rim}),

$$2375 = m.v^2.C_S = m \times (28.8)^2 \times 0.02 = 16.6\ m$$

∴ $m = 2375/16.6 = 143$ kg

Also $m = \text{Volume} \times \text{density} = \pi\, D.A\,.\rho = \pi\, D.b.t.\rho$

∴ $143 = \pi \times 0.92 \times 2\,t \times t \times 7250 = 41\,914\,t^2$

$t^2 = 143 / 41\,914 = 0.0034\ \text{m}^2$

or $t = 0.0584$ m = 58.4 mm **Ans.**

and $b = 2\,t = 116.8$ mm **Ans.**