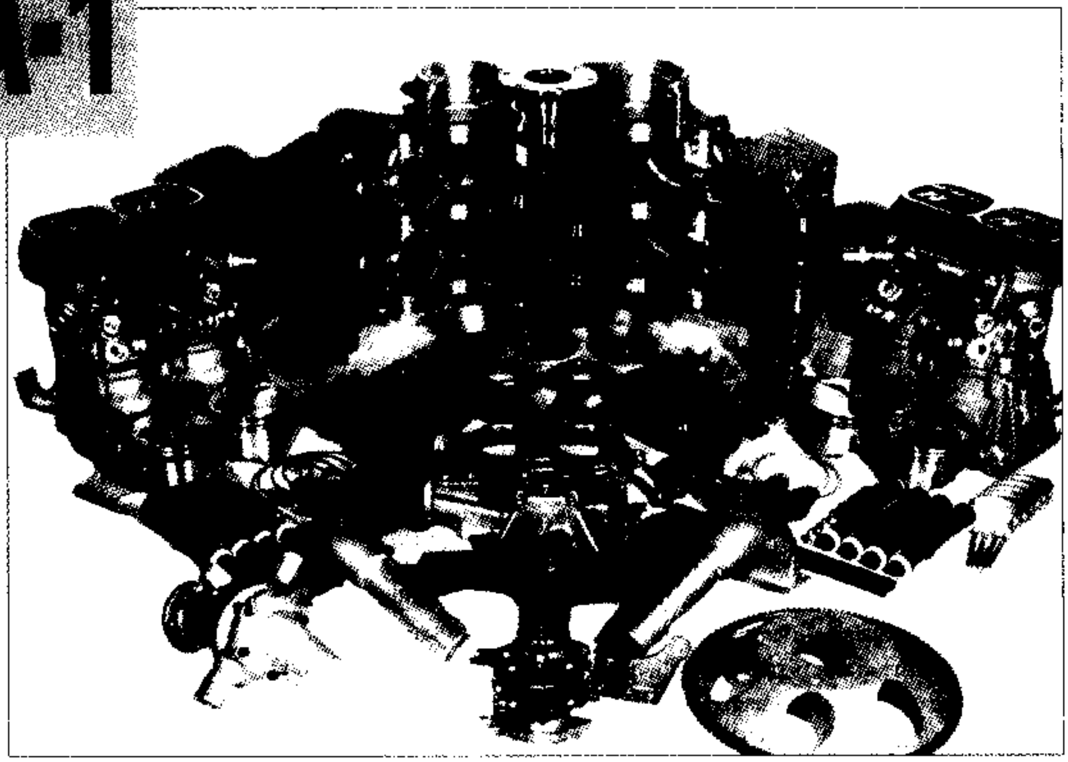
A-1



MACHINE THEORY LABORATORY PRACTICE

Experiment 1 To draw the displacement, velocity and acceleration curves for a slider–crank mechanism.

Apparatus Slider-crank apparatus, graph sheet.

Theory The displacement of a slider–crank mechanism, when the crank has rotated by θ from inner dead centre is:

$$x = r\left[(1 - \cos\theta) + \left\{n - \left(n^2 - \sin^2\theta\right)^{0.5}\right\}\right]$$

Velocity,

$$v = \omega r\left[\sin\theta + \frac{\sin 2\theta}{2n}\right]$$

Acceleration,

$$f = \omega^2 r\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

The slider–crank apparatus shown in Fig.1. consists of the frame *F* in which the slider *S* moves in a slot. The graduated wheel *W* replaces the crank *OC*. The wheel and the slider are connected by the connecting rod *C*. When the crank *OC* is rotated the slider moves to and fro in a linear motion. The motion of the slider can be read on a scale attached to the frame on the side of the slot.

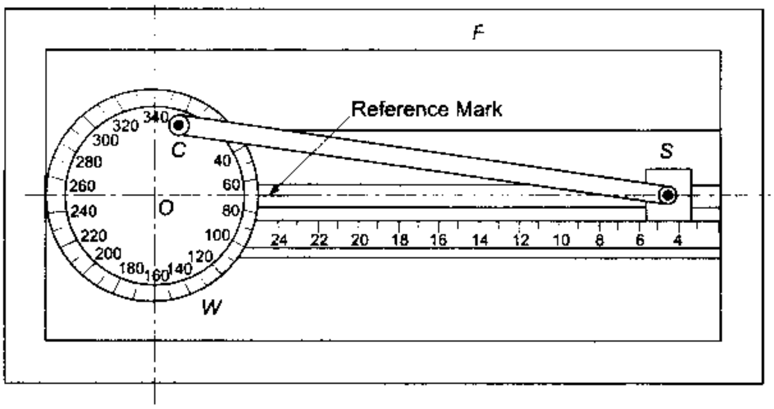


Fig.1 Slider–crank mechanism

Procedure

1. Bring the wheel and the slider to the respective reference marks.
2. For a given angle of rotation of the crank, note down the displacement of the slide.
3. Plot a graph between slider displacement and the crank rotation.
4. Assume that the crank is rotating with a uniform angular speed of 1 rad/s.
5. Convert the crank rotation angle into time and plot the slider displacement v's time.
6. By graphical differentiation, determine the velocity time graph.
7. By differentiation twice, determine the acceleration time graph.
8. Calculate the results with the theoretical values.

Observations Crank radius, $r =$ mm

Length of connecting rod, $l =$ mm

Sl. No.	Crank rotation, θ		Time t	Displacement, x mm		Velocity, v mm/s		Acceleration, f mm/s^2	
	deg	rad	s	measured	theoretical	measured	theoretical	measured	theoretical

Calculations

$$n = \frac{l}{r}$$

$$w = 1 \text{ rad/s}$$

$$\theta = 30°; \quad x = \text{mm}$$

$$v = \text{mm/s}; \quad f = \text{mm/s}^2$$

Sources of error

1. Clearance in the joints of the mechanism.
2. Inaccurate graduations.

Graphical differentiation Draw the mechanism for a number of different crank positions by taking 30° crank intervals. With the extreme right-hand position of the slider chosen as the starting point, lay off the displacement of the slider. Draw tangents at the middle of the crank angle interval on the displacement diagram. Choose a convenient point as the pole below the displacement diagram. From this point, draw lines parallel to the tangents to intersect the vertical axis. Draw horizontal lines from these points. Also project the lines from the points chosen on the displacement diagram to intersect the respective horizontal lines. Join the points of intersection by a smooth curve to get the velocity diagram. Now draw tangents on the velocity diagram and repeat the above procedure to get the acceleration diagram.

Experiment 2

To determine the ratio of times for the crank and slotted lever quick-return mechanism.

Apparatus Crank and slotted lever mechanism, graph sheet.

Theory The crank and slotted lever mechanism is shown in Fig.2. It consists of a graduated disc A on which the crank rotation can be measured. The slotted lever *B* is hinged at *O*, and carries a slider *C*. The slotted lever is hinged to an oscillating link *D*, which slides horizontally in link *E* and its other end is attached to the ram *F* on which the cutting tool is mounted.

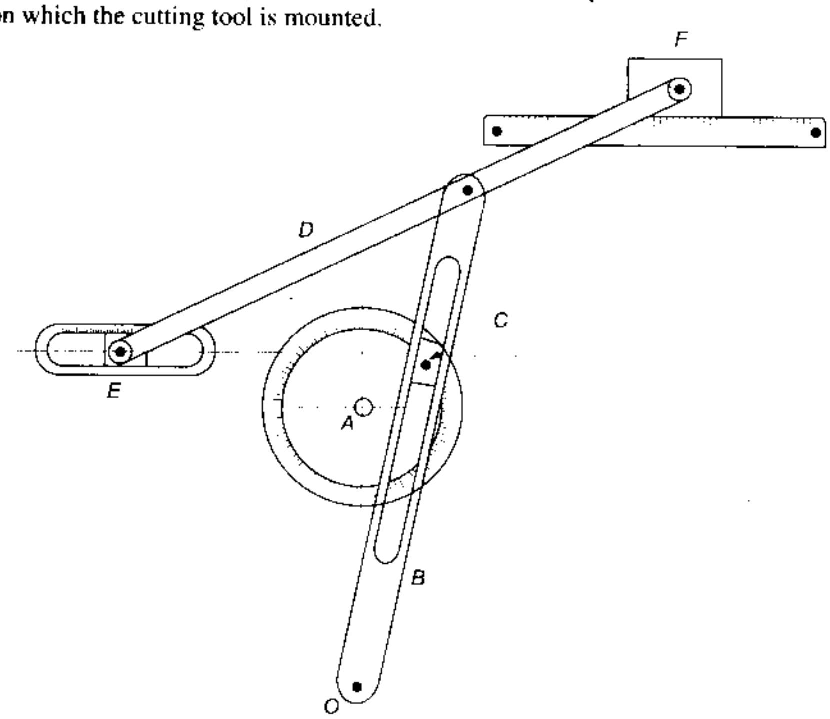


Fig.2 Crank and slotted lever apparatus

$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\alpha}{360° - \alpha}$$

where α is the angle of cutting.

Let $OA = d;\quad OB = r;\quad OD = l$

$$\alpha = 2\left[90^\circ + \sin^{-1}\left(\frac{r}{d}\right)\right]$$

$$\frac{\text{Maximum velocity during return}}{\text{Maximum velocity during cutting}} = \frac{d+r}{d-r}$$

Procedure

1. Bring the crank and the ram to zero positions.
2. For the given crank angle of rotation, note down the displacement of the ram.
3. Plot the crank rotation v's displacement of the ram.
4. Assume the crank to be rotating at an angular speed of 1 rad/s.
5. Plot the displacement–time graph.
6. By graphical differentiation, determine the velocity–time graph.
7. From the velocity–time graph, determine the maximum velocities during cutting and return.
8. Determine the angle of cutting and angle of return.
9. Determine the ratio of time of cutting and time of return, and the ratio of maximum velocities during return and cutting.
10. Draw the theoretical velocity diagram and calculate the theoretical ratio of velocities. Observations

Length of crank, r = mm

Length of link OA, d = mm

Length of slotted lever OD, l = mm

Angle of forward stroke, α =

Sl. No.	Crank rotation, θ		Time	Ram displacement mm	Ram velocity mm/s
	deg	rad	s		

Calculations

$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{t_c}{t_r} = \frac{\alpha}{360^\circ - \alpha}$$

From graph, $\frac{t_c}{t_r} =$

$$\frac{\text{Maximum return velocity}}{\text{Maximum cutting velocity}} = \frac{v_r}{v_c} = \frac{d+r}{d-r}$$

From graph, $\frac{v_r}{v_c} =$

Theoretical ratio, $\frac{v_r}{v_c} =$

Precautions

1. The slider and slotted lever should be lubricated to decrease friction.
2. Displacement and crank rotation should be measured accurately.

Sources of error

1. Effect of clearances in the joints.
2. Errors during graphical differentiation.

Experiment 3

To determine the ratio of times and tool velocities of Whitworth type quick-return mechanism.

Apparatus Whitworth quick-return mechanism, graph sheets.

Theory The Whitworth quick-return mechanism shown in Fig.3 consists of a graduated disc on which rotation of crank can be measured. The displacement of the tool can be read from the scale attached to the ram.

$$\frac{\text{Time of cutting}}{\text{Time of return}} = \frac{\alpha}{360° - \alpha}$$

where a is the angle of cutting.

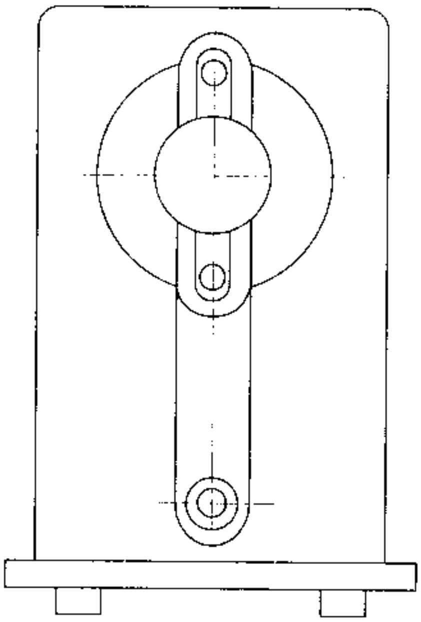


Fig.3 Witworth quick return mechanism apparatus

Procedure

1. Bring the crank and ram to zero positions.
2. For the given crank angle of rotation, note down the displacement of the ram.
3. Plot the crank rotation v's displacement of ram.
4. Assuming the crank to be rotating at 1 rad/s, plot the displacement–time graph.
5. By graphical differentiation, determine the velocity–time graph.

6. Determine the angles of cutting and return strokes.
7. Calculate the ratio of cutting angle and angle of return strokes.
8. Draw the theoretical velocity diagram and calculate the ratio of velocities.

Observations

Length of crank OA, r = mm

AB = mm

PB = mm

Sl. No.	Crank rotation, θ		Time	Ram displacement, mm	Ram velocity mm/s
	deg	rad	s		

Calculations

Cutting angle, $\alpha = \dfrac{\text{Angle of cutting}}{\text{Angle of return}}$

$$\frac{t_c}{t_r} = \frac{\alpha}{360° - \alpha}$$

From graph, $\dfrac{t_c}{t_r} =$

Theoretical velocity of ram = mm/s

Precautions

1. The slider and slotted lever should be lubricated to decrease friction.
2. Displacement and crank rotation should be measured accurately.

Sources of error

1. Effect of clearances in the joints.
2. Errors during graphical differentiation.

Experiment 4 To determine the ratio of angular speed of shafts of a Hooke universal joint.

Apparatus Hooke's joint.

Theory The Hooke joint is shown in Fig.4. It has the provision for measuring the angle of rotation of the driving and the driven shafts. The angle between the driving and driven shafts can also be varied and measured.

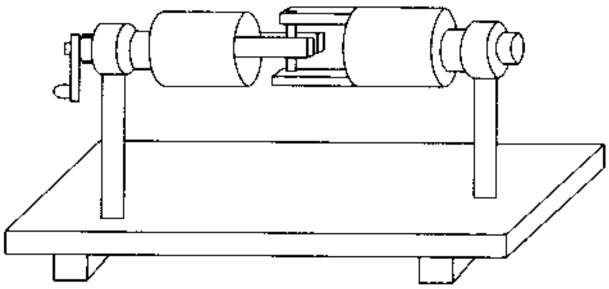


Fig.4 Hooke's joint apparatus

Let α = angle between the axes of the two shafts
θ = angle turned through by the driving shaft
ϕ = angle turned through by the driven shaft
ω_1 = angular velocity of the driving shaft
ω_2 = angular velocity of the driven shaft.

Then $$\frac{\omega_1}{\omega_2} = \frac{1 - \cos^2\theta \sin^2\alpha}{\cos\alpha}$$

Angular acceleration $$= \frac{-\omega_1^2 \cos\alpha \sin^2\alpha \sin 2\theta}{\left(1 - \cos^2\theta \sin^2\alpha\right)^2}$$

Procedure

1. Adjust the angle between the shafts to be 15°.
2. Set the angles of driving and driven shafts to be equal to zero degree.
3. Rotate the driving shaft through equal intervals of 30° and note down the corresponding angles of the driven shaft.
4. Change the angle between the shafts to 30°, 45°, 60° and 90°, etc., and repeat the experiment.
5. Calculate the ratio of incremental angles turned through by the driving and the driven shafts.
6. Calculate the theoretical values and compare.

Observations

Sl. No.	$\alpha = 15°$				$\alpha = 30°$			
	θ	ϕ	ω_1/ω_2		θ	ϕ	ω_1/ω_2	
			Exp.	Theor.			Exp.	Theor.

Calculations

$$\frac{\omega_1}{\omega_2} = \frac{1-\cos^2\theta\sin^2\alpha}{\cos\alpha} =$$

Also
$$\frac{\omega_1}{\omega_2} = \frac{\Delta\theta}{\Delta\phi} =$$

Precautions

1. Lubricate all moving parts to minimize friction.
2. All angles should be measured carefully.

Sources of error

1. Clearance in the joints.
2. Errors in graduations.

Experiment 5 To determine the coefficient of friction between a flat belt and a pulley.

Apparatus Flat belt and pulley, weights.

Theory The flat belt and pulley system consists of a flat belt and a pulley mounted on bearings. The angle of contact is 180° (Fig.5).

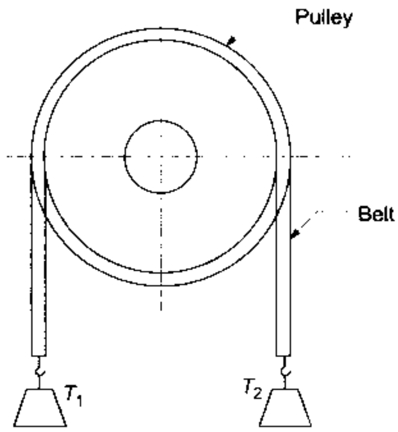


Fig.5 Belt and pulley

The coefficient of friction is given by,

$$\mu = \left(\frac{1}{\theta}\right)\ln\left(\frac{T_1}{T_2}\right)$$

where θ = angle of arc of contact in radians

T_1 = tension on the tight side of the belt

T_2 = tension on the slack side of the belt

Procedure

1. Note the angle of contact of the belt.
2. Hang some weight on one side of the belt.

3. Put some weight on the other side of the belt. Increase the weight till the belt just starts slipping on tapping the pulley slightly.
4. Note down the values of tight and slack side tensions.
5. Vary the tension on the tight side and repeat the experiment.
6. Calculate the coefficient of friction between the belt and the pulley.

Observations

Material of belt =
Material of pulley =

Sl. No.	T_1	T_2	Angle of contact		Coefficient of friction
	kg	kg	deg	rad	

Calculations

$$\text{Coefficient of friction,} \quad \mu = \left(\frac{1}{\theta}\right) \ln\left(\frac{T_1}{T_2}\right)$$
$$=$$

Precautions

1. Tapping of the pulley should be done mildly with a pencil.
2. Weights should be increased in small steps.
3. Weights should be added slowly without jerks.

Sources of error

1. Worn out old belt.
2. Rusted pulley surface.
3. Friction in pulley bearings.
4. Inaccurate weights.

Experiment 6 To determine the moment of inertia of a plane disc by using a gyroscope.

Apparatus Gyroscope, plane disc, stop watch, graph sheet and weights.

Theory The gyroscope (Fig.6) consists of an electric motor supported within a ring mounted on ball bearings which is carried on a cradle attached to a vertical shaft with ball bearings. A disc is mounted coaxially to the armature. A loading arm carrying a counterpoise and hanger is attached to the ring. The heavy base is of mild steel and has a vertical shaft. It has four levelling screws and a spirit level mounted to the base for levelling. A brass angular scale is fitted to the cradle which enables the angle of the tilt of loading arm to be found when the precession is arrested by stopping the rotation of cradle. Knowing the time for one revolution, the angular velocity of precession can be determined.

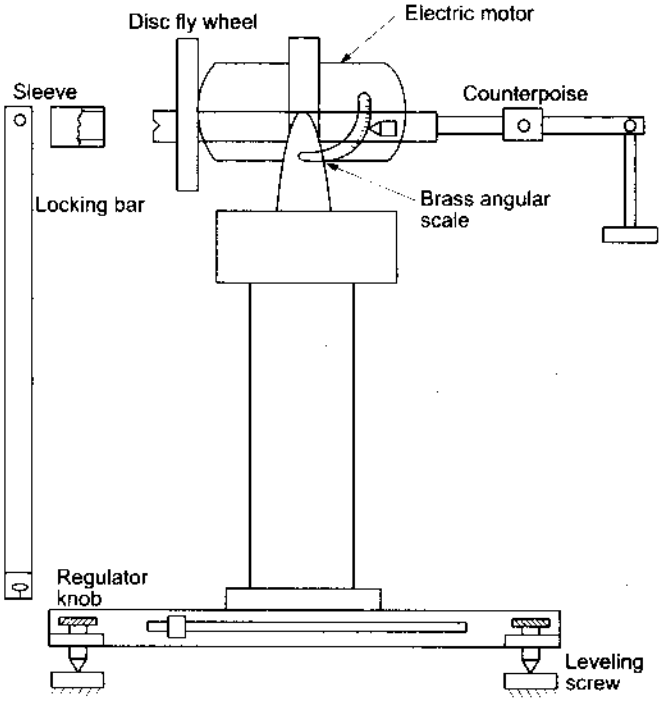


Fig.6 Gyroscope apparatus

The torque, $T = I_p \, \omega \omega_p$

where $\omega = \dfrac{2\pi n}{60}$ rad/s

$\omega_p = \dfrac{2\pi}{t_p}$

t_p = time for one revolution in the horizontal plane

Procedure

1. Set the instrument perfectly horizontal by four levelling screws and the spirit level.
2. Switch on the motor and obtain the desired speed by changing the variable resistance.
3. Determine the motor speed by a tachometer or a strobometer.
4. Move the counterpoise to keep the loading arm horizontal so as to show zero on angular brass scale.
5. Put the hanger with known weight at the end of the loading arm.
6. Note the time for one revolution.
7. Keeping the speed constant, increase the load, thus the torque, to find out corresponding angular speed of precession.
8. Change the motor speed and repeat the experiment.
9. Plot the graph between torque and speed of precession.
10. Calculate the value of moment of inertia of the disc.

Observations

Lever arm = mm

Sl. No.	Motor speed, n_1, rpm				Motor speed, n_2, rpm			
	Weight, W	Torque, T	Time for one revolution T_0	ω_p, $2\pi/t_p$	Weight, W	Torque T	Time for one revolution T_0	ω_p, $2\pi/t_p$
	N	N mm	s	rad/s	N	N mm	s	rad/s

Calculations

Torque, $T =$ N mm

Angular speed, $\omega = \dfrac{2\pi n}{60}$ rad/s =

Speed of precession, $\omega_p = \dfrac{2\pi}{t_p}$

Moment of inertia, $I_p = \dfrac{T}{\omega\omega_p} =$

Precautions

1. The motor speed should be kept constant by a voltage stabilizer.
2. The gyroscope should be levelled properly.
3. The time should be measured accurately.

Sources of error

1. Fluctuations in motor speed.
2. Inaccuracies in measuring time.
3. Personal errors.

Experiment 7 To determine the forces on the spring and stiffness of a Hartnell governor.

Apparatus Hartnell governor, weighing balance, scale and graph sheet.

Theory The Hartnell governor (Fig.7) consists of two bell crank levers hinged in the frame at *A*. The levers carry balls at *B* on the vertical arm and a roller *C* in a fork at the other end. These rollers press against the sleeve *D* which compresses the spring *E* from the bottom. The compression varies with different positions of the sleeve. The initial force in the spring is controlled by the nut *F*. The speed of rotation can be varied by the electric motor and the voltage regulator.

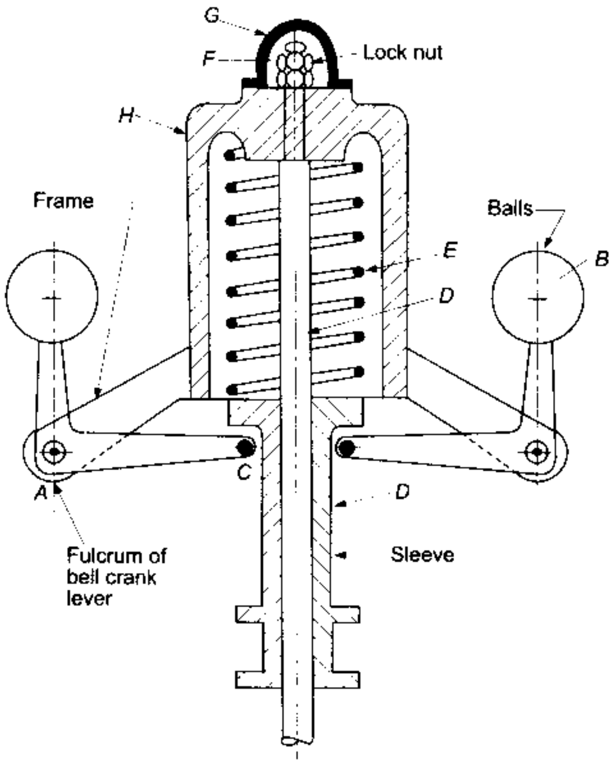


Fig.7

The spring stiffness is given by,

$$k = 2\left(\frac{a^2}{b^2}\right)\left[\frac{F_1 - F_2}{r_1 - r_2}\right]$$

where a, b = vertical and horizontal arms of the bell crank lever, respectively.

r_1, r_2 = radii of the balls at the maximum and minimum speeds, respectively.

$F_1 = m r_1 \omega_1^2$

$F_2 = m r_2 \omega_2^2$

m = mass of the ball

$\omega = \frac{2\pi n}{60}$ rad/s

n = speed in rpm.

The compression of the spring, $\delta = \frac{(r_1 - r_2)\,b}{a}$

The radii r_1 and r_2 can be determined by plotting a graph between the displacement of the sleeve from the mean position and the radii of the balls. The motor speed may be measured by a tachometer of a strobometer.

Procedure

1. Plot a graph between the displacement of the sleeve from the mean position and the radii of the balls.
2. Determine the mass of the balls and the length of the arms of the bell crank lever.

3. Start the motor and adjust the speed so that the balls run at the innermost position. Note the sleeve position and from the graph determine the ball radius r_2.
4. Increase the speed and adjust its speed so that the balls run at the outermost position. Again note down the sleeve position and determine the ball radius r_1.
5. Calculate the forces F_1 and F_2.
6. Calculate the spring stiffness k.

Observations

Sleeve position					
Radius of ball, mm					

Mass of ball, $m =$ kg
Lever arm length:

$a =$ mm
$b =$ mm

Sl. No.	Motor speed, n rpm	Ball radius, r mm	$F = mr\omega^2$ N	Spring stiffness k, N/mm

Calculations

Spring force, $F =$
Spring stiffness, $k =$

Precautions

1. Change the speed of the motor slowly.
2. Measure the speed of the motor accurately.
3. Use a constant voltage transformer to keep the speed constant.

Sources of error

1. Friction between the sleeve and the shaft.
2. Friction between the lever roller and the sleeve.
3. Friction at the lever fulcrum.

Experiment 8 To study the motion of the follower for the given cam and to determine the displacement, velocity and acceleration at every point.

Apparatus Cam and follower, graph sheets.

Theory The cam and follower apparatus (Fig.8) consists of a cam with roller follower (or as may be available). The angle of rotation of the cam and follower displacement can be read from the graduations marked on the cam and follower scale.

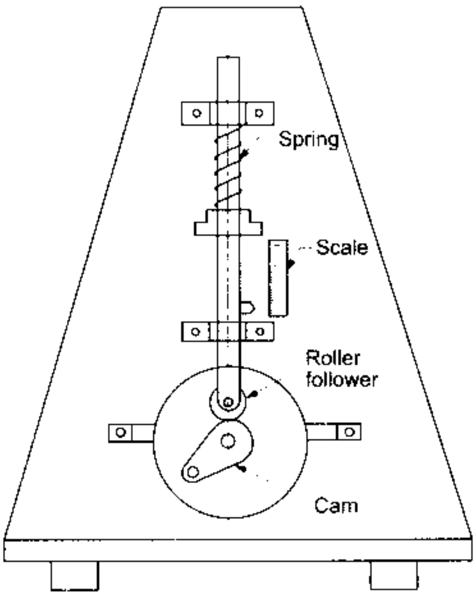


Fig.8 Cam apparatus

The cam may be moving with SHM, uniform acceleration and deceleration, or any other type of motion. The various formulae for the displacement, velocity and acceleration may be seen from Chapter 8.

Procedure

1. Bring the cam and follower to zero positions.
2. Rotate the cam slowly and note down the angle of rotation of the cam at regular intervals and the corresponding displacement of the follower.
3. Plot a graph between displacement of follower and the angle of rotation of the cam.
4. Plot the velocity and acceleration diagrams by graphical differentiation.
5. Determine the maximum velocity and acceleration during ascent and descent.

Observations

Diameter of roller follower = mm

Base circle diameter of cam = mm

Maximum lift = mm

Sl. No.	Angle of rotation of cam, deg	Displacement of follower, mm

Maximum velocity = mm/s
Maximum acceleration = mm/s^2

Precautions

1. Cam should be rotated slowly and gradually.
2. Cam and roller bearings should be lubricated to reduce friction.

Sources of error

1. Lateral shift in the roller follower and the cam.
2. Effect of clearances in the roller and cam spindles.
3. Effect of elasticity of the links.

Experiment 9 To study the working of Oldham's coupling.

Apparatus Oldham's coupling, graph sheet.

Theory Oldham's coupling apparatus (Fig.9) consists of two shafts having flanges at their ends. The flanges have rectangular slots cut in their middle. An intermediate piece having tongues on both sides perpendicular to each other is used to connect the two flanges. The shafts carrying flanges are mounted on sliding blocks, which enables to change the centre distance between the shafts as desired. The angle of rotation of the flanges and the displacement of the tongue can be measured from the graduated scales. Assuming the speed of rotation of the shafts to be 1 rad/s, we can plot the displacement–time graph. From this graph, we can find the velocity by graphical differentiation.

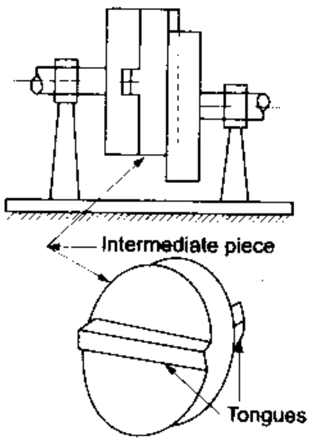


Fig.9 Oldham's coupling

Maximum sliding speed of each tongue along its slot

= Peripheral velocity of centre of disc along its circular path

= Distance between the axes of the shafts × Angular velocity of each shaft.

Procedure

1. Fix some centre distance between the two shafts.
2. Bring the graduated flange to zero position and note the position of the tongue.

3. Give some known angular rotation to the flange and note the displacement of the tongue.
4. Increase the angular rotation of the flange at regular intervals and note the corresponding displacement of the tongue.
5. Change the centre distance between the shafts and repeat the experiment.
6. Plot displacement of tongue v's angle of rotation of the flange.
7. Assuming angular velocity to be 1 rad/s, plot the displacement–time graph.
8. Determine the velocity – time graph by graphical differentiation.
9. Calculate the theoretical velocity of sliding of the tongue and compare with experimental results.

Observations

Sl. No.	Center distance between shafts, c = mm			
	Angle of rotation of flange, θ, deg	Time = $\pi\theta/180$ s	Displacement of tongue, x, mm	Sliding speed of tongue, v, mm/s

Calculations

Centre distance between shafts, c = mm

Angular speed of shafts = 1 rad/s

Maximum sliding speed of tongue, $v = c$ mm/s

From graph, v = mm/s

Precautions

1. Lubricate the tongue to reduce friction.
2. Fix the shaft bearing firmly after changing the centre distance.
3. Measure the angle of flange rotation accurately.

Sources of error

1. Error in the measurement of centre distance.
2. Error in graphical differentiation.

Experiment 10 To determine the speed ratio of a gear train.

Apparatus Spur gear train, string, weights, metre rod, stop watch.

Theory The simple spur gear train is shown in Fig.10. Pulley *D* is mounted on the shaft for gear *A* and pulley *E* on the shaft for gear *C*.

For a simple gear train, the speed ratio is given by,

$$i = \frac{n_i}{n_o} = \frac{z_o}{z_i}$$

where suffixes i and o represent input and output, respectively.

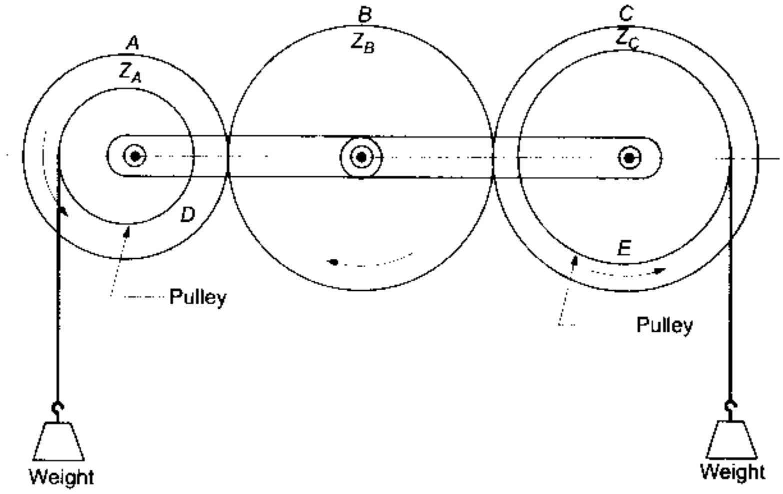


Fig.10 Simple gear train

If the diameters of pulleys D and E are same, then the speed ratio can be determined by measuring the distances moved by the strings in a given time.

Procedure

1. Put some weights on the string attached to pulley E.
2. Add weights on the hanger attached to string passing over pulley D.
3. Increase the weight till it starts moving.
4. For the given distance moved by the weight on pulley E, determine the distance moved down by the weight on pulley D in the same time.
5. Calculate the speed ratio by dividing the distance moved by the weight on pulley D to the distance moved by weight on pulley E.
6. Calculate the theoretical speed ratio and compare.

Observations

Diameter of pulley $D =$ mm

Diameter of pulley $E =$ mm

Number of teeth, $z_i =$

Number of teeth, $z_o =$

Sl. No.	Distance moved by weight on pulley D, x_1, mm	Distance moved by weight on pulley E, x_o, mm	Speed ratio x_o/x_1

Calculations

$$\text{Theoretical speed ratio} = \frac{z_o}{z_i}$$

Precautions

1. Lubricate the gears and their bearings to reduce friction.
2. Measure the distances accurately.
3. The pulley strings should be of same diameter.

Sources of error

1. Friction in the gear teeth and their bearings.
2. Error in distance measurements.

Experiment 11

To verify the two fundamental laws of balancing by using rotating masses, when

(a) all the masses are rotating in the same plane, and
(b) all the masses are rotating in different planes.

Apparatus Dynamic balancing apparatus for rotating masses.

Theory (a) When all the masses are rotating in the same plane, the following equation results for the equilibrium of the system:

$$\sum_{i=1}^{n} W_i r_i \exp(j\phi_1) + W_b r_b \exp(j\theta) = 0 \tag{1}$$

where W_i = weight of the rotating mass
r_i = radius of i^{th} mass from the centre of rotation
ϕ = angular displacement of the ith mass from the reference axis
W_b = weight of the balancing mass
r_b = radius of the balancing mass from the centre of rotation
θ = angular displacement of the balancing mass from the reference axis.

For a single mass, we have

$$W_1 r_1 \exp(j\phi_1) = -W_b r_b \exp(j\theta) \tag{2}$$

From (2), we get

$$\cos\phi_1 = -\cos\theta$$
$$\sin\phi_1 = -\sin\theta$$

or

$$\theta = \pi + \phi_1 \tag{3}$$

This implies that weight W_b must be added opposite to the weight W_1. After determining the angle θ, we must determine the product $W_b\, r_b$ from the following:

$$W_1 r_1 = W_b r_b \tag{4}$$

So, there are two alternatives that we may choose. One of them is to choose the value of r_b and calculate the weight W_b of the balancing mass. The other one is to choose the weight W_b and calculate the distance r_b. The first alternative is preferred because the distances on the disc are fixed. For many rotating masses in the same plane, their resultant has to be determined.

(b) When the masses rotate in different planes, then taking moments about the centre of rotation of balancing mass W_{b2}, we have

$$\sum_{i=1}^{n} W_i r_i \exp(j\phi_i) + \sum_{i=1}^{2} W_{bi} r_{bi} \exp(j\theta_1) = 0 \quad (5)$$

and

$$\sum_{i=1}^{n} W_i r_i l_i \exp(j\phi_i) + W_{b1} r_{b1} l \exp(j\theta_1) = 0 \quad (6)$$

where l_i = axial distance of rotating mass W_i from the balancing mass W_{b2}

l = axial diatance of balancing mass W_{b1} from W_{b2}

θ = angle of rotation from first rotating mass

ϕ_i = angle of rotating mass W_i from W_1

Equations (5) and (6) can be solved simultaneously to determine the unknowns.

Experimental setup

The dynamic balancing apparatus for rotating masses is shown in Fig.11. It is intended for primary balancing. It consists of a rectangular steel frame suspended by four springs from a strong steel stand. On rectangular frame, two blocks with ball bearings are mounted which support a steel shaft carrying four balanced discs equally spaced. One of the discs is grooved and this is connected to a balanced 220 volts, A.C. electric motor by V-belt so that the whole system can be rotated. In all the four discs, circumferential slots are provided at four different radii. A number of steel pieces to act as balancing masses are included and these pieces can be attached in the slots of the discs by means of screwed rods and nuts. The discs are marked with radial lines and numbered to read the angular positions of the balancing masses. By attaching the balancing weights to the circumferential slots of the discs at different positions, various combinations of out of balance conditions can be obtained either in one plane or two planes. By switching on the motor and making the system rotate, the out of balance state can be clearly observed due to vibrations and oscillations set up in the system. Now the distance between discs, positions of balancing weights, their magnitude, etc. can be noted and a solution can be obtained analytically or graphically to have balance condition. According to this solution, balancing weights can be attached to the discs at suitable places and the motor can be started. Now the system can be observed, free from oscillations and vibrations and thus illustrating the theory of balancing.

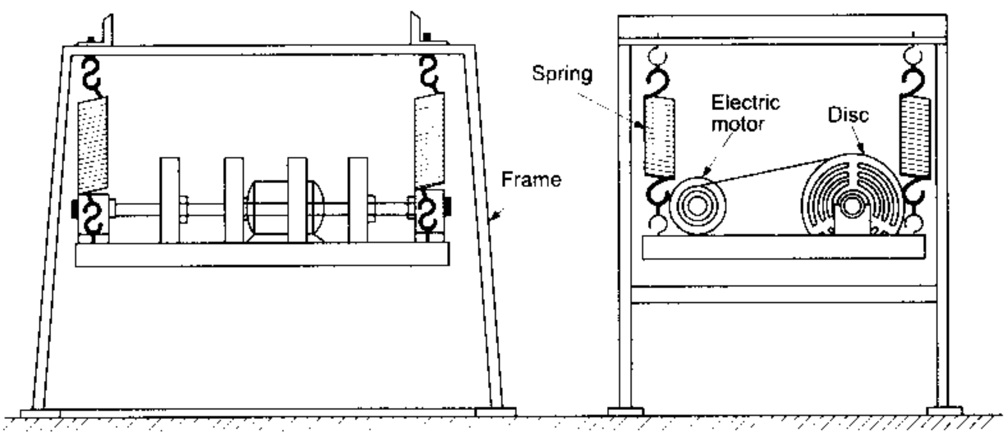


Fig.11 Rotating masses apparatus

Procedure

1. Start the motor and check that the apparatus is completely balanced, i.e. the platform should not oscillate. As the motor is started the platform starts vibrating due to transient vibrations, which die out after some time.
2. Fix a known weight in the circumferential slot of any disc, preferably the middle one, at the known distance. Balance the platform by fixing the four different balancing masses at different distances from the centre of rotation of discs.
3. Verify the law $Wr = W_b r_b$ and $\theta = \pi + \phi_1$ by noting the distances and the weight of all the masses.
4. Fix three known weights in the circumferential slots of the same disc at three different or same distance from centre of rotation and balance the platform by fixing the balancing weight. Note down the weight and distances of all the masses. Change to a different balancing weight placed at different distance to balance the platform. Take four different readings. Verify the first law of balancing. Draw the force polygon for any one of the readings.
5. Fix a known weight in the circumferential slot of the same disc at a known distance from the centre of rotation of the disc. Select the two balancing weights and fix them in the slots of two different discs and balance the platform. Note down the axial and radial distances of the weights and the value of weight fixed in the slot. Take four different readings for different balancing weights with different axial and radial distances. Verify the second law of balancing.
6. Fix two known weights in the circumferential slots of any of the two different discs at a known axial and radial distances with some angular displacement. Now fix the balancing weights in the remaining two discs. Put the balancing weights in the circumferential slots at a suitable radial distance so that the platform is balanced. Note down the value of weights and the axial and radial distances. Take four readings for different balancing weights at different radial distances. Verify the second law of balancing. Draw the vector diagram.

Precautions

1. Weights should be securely tightened to the discs.
2. Take readings after the system has stabilized.
3. Initial check on the apparatus being completely balanced should be made.

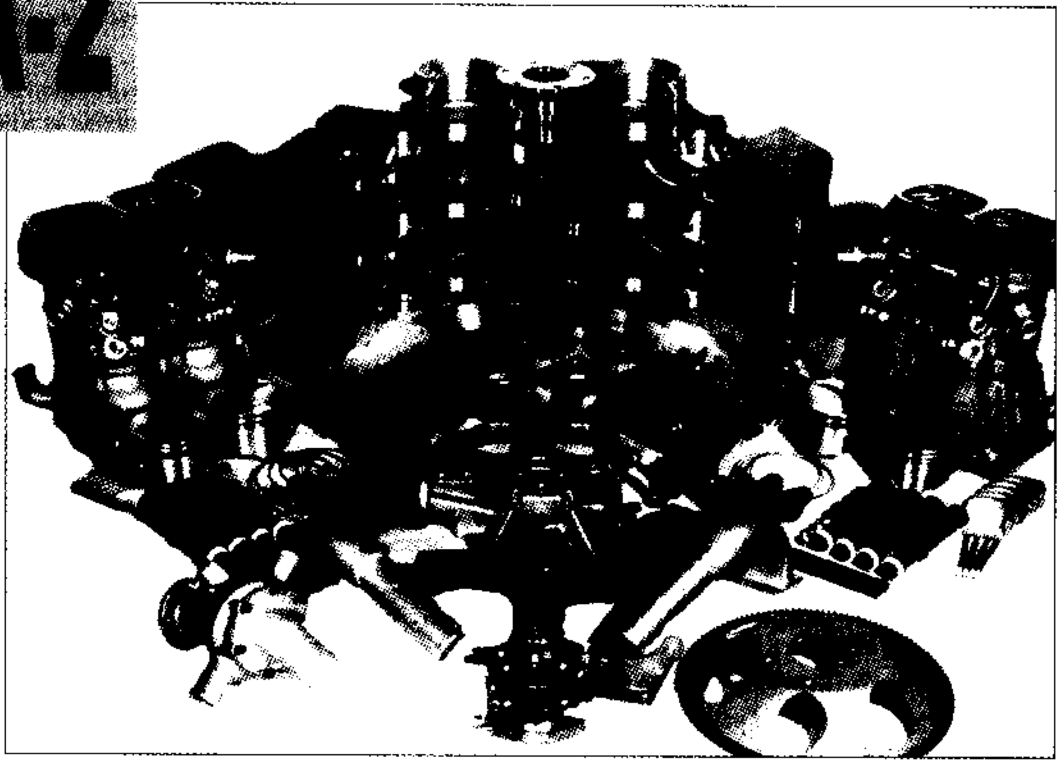
Observations

Sl. No.	Unbalance			Balancing weights		
	Weight	Axial distance	Radial distance	Weight	Axial distance	Radial distance
	W_1 W_2 W_3			W_{b1} W_{b2} W_{b3}		

Sources of error

1. Error in fixing the weights at an angular position.
2. Error in the value of weights.
3. Error in judging the balanced platform.

A-2



GLOSSARY OF TERMS

Mechanisms

Machine It is a contrivance which transforms energy available in one form or another to do the desired work.

Element It is a part of machine which has been manufactured without the operation of assembling.

Link It is a resistant body or assembly of resistant bodies, which constitute part or parts of a machine, connecting other parts which have motion relative to it.

Rigid link A link is called rigid, when it does not undergo any deformation while transmitting motion, for example a connecting rod, a crank etc.

Flexible link It is a link which while transmitting motion is partly deformed in a manner not to affect transmission of motion, for example, belts and springs.

Floating link It is not connected to the frame.

Fluid link It is formed by having fluid in a receptacle.

Binary link A link having connections at two points.

Ternary link A link having connections at three or more points.

Kinematic pair It is a movable joint of two links which are in contact so that the relative motion between the two links is constrained.

Lower pair It is formed by two links having surface contact while in motion. The relative motion is purely turning or sliding, for example, a universal joint, an automobile steering gear, a shaft revolving in a bearing, a straight line motion mechanism, etc.

Higher pair It is formed by two links having point or line contact while in motion. The relative motion being the combination of sliding and turning, for example a belt, a rope, a chain, gears, cams, ball and roller bearings.

Sliding pair When two links are so connected that one is constrained to have sliding motion relative to another, they form a sliding pair, for example, cross-head and guides.

Turning pair When two links are so connected that one is constrained to turn or revolve about a fixed axis of another link, they form a turning pair, for example a crankshaft turning in a bearing.

Rolling pair When two links are so connected that one is constrained to work in another link which is fixed, they form a rolling pair, for example ball and roller bearings.

Screw (or helical) pair When one element turns about the other element by means of threads, they form a screw pair. The relative motion is a combination of sliding and turning, for example, a bolt and nut, the lead screw of a lathe.

Spherical pair When one element in the form of a sphere turns about the fixed element, they form a spherical pair, for example a ball and socket joint.

Closed pair When two elements are held together mechanically, forms a closed pair lower pair is a closed pair. Screw pair and spherical pair are closed pairs.

Open (or unclosed) pair When two elements are not held together mechanically, they form an open pair. A cam and follower is an open pair.

Kinematic chain When kinematics pairs are so connected that the last link is joined to the first link to transmit a definite constrained motion, they form a kinematic chain. For a kinematics chain, $L = 2P - 4 = 2(J + 2)/3$, where L = number of links, P = number of pairs and J = number of joints.

Mechanism It is an assemblage of a number of rigid links so formed and connected that they move upon each other with a definite relative motion. A mechanism is formed by fixing one of the links of a kinematics chain.

Simple mechanism It is one which has upto four links, for example cams, gears, the beam engine and the elliptical trammel.

Compound mechanism It is one which has more than four links.

Degrees of freedom Degrees of freedom of a mechanism are the number of inputs a mechanism must have in order to fulfill a useful engineering purpose. It may be defined as the number of independent relative motions, a pair can have. $F = 6$ - number of restraints.

Gruebler criterion This criteria states the degrees of freedom of a mechanism, as follows: $F = 3(L - 1) - 2g - h$, where F = degrees of freedom, L = number of links, g = number of lower pairs, h = number of higher pairs.

Structure A mechanism is called a structure if $F = 0$.

Constrained mechanism It is one for which $F = 1$.

Grashof criteria This criteria states that for a mechanism $(l + s) < (a + b)$, where l, s = length of the longest and shortest link respectively and a, b = length of other links.

Plane mechanism It is a mechanism having all the links in the same plane.

Spatial mechanism It is a mechanism having links in different planes.

Complex mechanism It is formed by the inclusion of ternary or higher order floating link to a simple mechanism.

Kinematics of machines It deals with the study of relative motion of parts of which the machines are constituted, neglecting consideration of forces producing it.

Dynamics of machines It deals with the study of motion of a machine under the forces acting on different parts of the machine.

Resistant body It is one which does not suffer appreciable distortion or change in physical form by the forces acting on it. Resistant bodies need not be rigid, such as springs, belts, fluids, etc.

Completely constrained motion It is one in which the motion takes place in a definite direction, for example a rectangular bar moving in a rectangular hole, a shaft with collars at each end rotating in a round hole.

Partially constrained motion It is one in which the constrained motion is not completed by itself but by some other means, for example, a foot step bearing and the rotor of a vertical turbine.

Incomplete constrained motion It is one in which the links are so connected that motion can take place in more than one direction, for example a circular bar moving in a round hole.

Inversion of a mechanism Different mechanisms formed by fixing different links of the same kinematic chain are known as inversions of each other. The inversions of four bar chain are the beam engine, the engine indicator and the coupled wheels of locomotives. The inversions of slider–crank chain are the pendulum pump, the oscillating cylinder engine, the crank and slotted lever type quick-return motion, the Whitworth mechanism and the Gnome engine. Inversions of double slider crank chain are the donkey pump, Oldham's coupling and the elliptical trammel.

Instantaneous centre A link or rigid body as a whole may be considered to be rotating about an imaginary centre or a given centre at a given instant which has zero velocity. Then the link is at rest at this point which is known as the instantaneous centre or centre of rotation. Number of instantaneous centres, $N = n(n-1)/2$, where n = number of links.

Kennedy's theorem of three centres This theorem states that if three bodies have relative motion with respect to each other, their relative instantaneous centres lie on a straight line.

Primary instantaneous centre It is one which is either fixed or permanent.

Secondary instantaneous centre It is one which is neither fixed nor permanent.

Angular velocity ratio theorem This theorem states that the ratio of the angular velocities of any two bodies moving in a constrained system is inversely proportional to the ratio of the distances of their common instantaneous centre from their centre of rotation.

Total acceleration of a point in a rigid link The total acceleration of end B with respect to end A of a rigid link AB is the vector sum of the radial (centripetal) and normal (tangential) accelerations, that is,

$$\vec{f}_{ba} = \omega^2 \cdot \overrightarrow{AB} + \alpha \cdot \overrightarrow{AB}$$

Acceleration centre The acceleration centre of a link is one which has zero acceleration.

Klein's construction It is a graphical procedure of drawing the acceleration diagram for a reciprocating engine, that is a slider–crank mechanism.

Coriolis acceleration If the distance between the two points does not remain fixed and the second point slides, the total acceleration will contain an additional component of acceleration, known as coriolis acceleration. Coriolis component of acceleration is equal to $2v\omega$, where v is the sliding velocity and ω the angular speed. The direction of Coriolis acceleration is such as to rotate the slider velocity vector in the same sense as the angular velocity of the link.

Motion of slider–crank mechanism

Displacement,

$$x = r\cos\theta + l\left[1 - \left(\frac{\sin\theta}{n}\right)^2\right]^{1/2}$$

where $n = l/r$,

l = length of connecting rod,

r = radius of crank,

θ = crank angle.

Velocity of piston,

$$v_p = -r\omega\left[\frac{\sin\theta + \sin 2\theta}{2n\left[1 - \left(\frac{\sin\theta}{n}\right)^2\right]^{1/2}}\right]$$

Acceleration,

$$f_p = -r\omega^2\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

Lower pairs

Pantagraph It is a mechanism in which a point describes a path similar to another point. It is used for tracing a curve on a magnified or reduced scale.

Straight line motion mechanisms Peaucellier, Hart and Scott–Russel are for accurate straight line and Grasshopper, Watt and Tchebicheff are for approximate straight line motion.

Engine pressure indicators Simplex, Crosby, Richard, Thompson and Dobbie-McInnes are engine pressure indicators.

Automobile steering gear mechanisms The two steering gears for automobiles are Davis and Ackermann. The later is most commonly used. For correct steering $\cot\phi - \cot\theta = b/l$, where ϕ = outer turning angle and θ = inner turning angle.

The steering mechanism automatically adjusts the values of the inner and outer turning angles. For Davis gear, $\tan\alpha = b/2l$, $b/l = 0.4$ to 0.5 and for Ackermann gear, $\tan\alpha = (\sin\phi - \sin\theta)/(\cos\theta + \cos\phi - 2)$ and b/l is nearly 0.455. b = distance between the pivots of front axle and l = wheel base.

Hooke's coupling It is used in the propeller shaft of an automobile. The ratio of the angular speeds of the driven to the driving shafts is $\cos\alpha/\left(1 - \sin^2\alpha\cos^2\theta\right)$, where α is the angle between the axes of the two shafts and θ is the angle turned through by the driving shaft. If ϕ is the angle turned through by the driven shaft, then $\tan\theta = \cos\alpha \cdot \tan\phi$. The maximum ratio of angular speeds is $1/\cos\alpha$ at $\theta = 0°$ and $180°$. The minimum ratio is $\cos\alpha$ at $\theta = 90°$ and $270°$.

Angular acceleration of driven shaft $= -\omega_a^2\cos\alpha\sin^2\alpha\sin 2\theta/\left(1 - \sin^2\alpha\cos^2\theta\right)^2$.

For acceleration to be maximum or minimum, $\cos 2\theta \cong 2\sin^2\alpha/\left(2 - \sin^2 a\right)$.

Belts Belts are used for power transmission. The two types of belts are flat and V-belts. The velocity ratio is inversely proportional to the pulley diameters. The length of cross-belt is more than the open belt length. The slip between the belt and the pulley decreases the speed ratio. The ratio of tight side to slack side tensions is equal to exp $(\mu\theta)$, where μ is the coefficient of friction between the belt and pulley and θ is the angle of arc of contact. For the v-belt, the virtual coefficient of friction is $\mu/\sin\alpha$, where α is the pulley semi-groove angle. Initial tension is half of the sum of the tight and slack side tensions. The centrifugal tension in the belt decreases the power transmission capacity of the belt.

Speed ratio, $\frac{N_2}{N_1} = \frac{D_1+t}{D_2+t}$ and percentage slip, $s = s_1 + s_2 - 0.01 s_1 s_2$.

Length of open belt, $L_0 = \frac{\pi(D_1+D_2)}{2} + \phi(D_2 - D_1) + 2C\cos\phi$, where $\sin\phi = \frac{D_2-D_1}{2C}$.

Length of cross belt, $L_c = (\pi + 2\phi)\frac{(D_1+D_2)}{2} + 2C\cos\phi$, where $\sin\phi = \frac{D_1+D_2}{2C}$.

Centrifugal tension, $T_c = \frac{wv^2}{g}$, where w = weight of belt per unit length.

For maximum power to be transmitted, $T_c = \frac{T_1}{2}$ or $\frac{T_1+T_c}{3}$.

Power transmitted, $P = \frac{(T_1-T_2)v}{1000}$ kW

Pitch surface It is an imaginary surface around the pulley to which the neutral section of the belt is tangential. The radius of this surface is the effective radius of the pulley.

Fast pulley It is one which transmits power.

Loose pulley It is one which does not transmit power.

Idler pulley It is free to rotate on its axis and is used to increase the tension in the belt, taking up stretch in the belt and increasing the angle of contact of the two pulleys.

Crowning of pulleys The convex shape given to the rim of the pulley is called crowning. It prevents the belt from running off the pulley by making the belt run in the centre of the pulley width.

Slip It is the relative motion between the belt and the pulley due to insufficient friction.

Creep It is due to the unequal stretching of the belt on the tight and slack sides. It leads to partial slip and reduced peripheral speed of driven pulley than the driving pulley.

$$\text{Creep of belt} = \frac{T_1 - T_2}{btE}$$

Brakes They are used to decrease the speed of a moving body or to stop it when desired. The brakes are of the following types: block and shoe brake, band brake, band and block brake and internal expanding shoe brake. Railway bogies use block and shoe brake whereas automobiles use internal expanding shoe brake. To stop a moving body, both the translational and rotational kinetic energies have to be absorbed.

Dynamometers It is a device to measure the power being transmitted by a prime mover. Dynamometers are of the following types: Prony (rope) brake, belt transmission and torsion dynamometers.

Governors The function of a governor is to keep the speed of a prime mover constant by adjusting the input. It regulates the speed over a number of cycles of the prime mover. Governors may be classified as follows:-

1. Centrifugal governors (a) simple Watt (pendulum type) (b) loaded (i) dead weight type—Porter, Proell (ii) spring controlled type—Hartnell, Wilson-Hartnell, Gravity and spring control, Hartung and Pickering.
2. Inertia governor.

   For simple Watt governor, height of governor, $h = (g/\omega^2)\,[(W + W_1/2)/(w + W_1/3)]$ where W = weight of ball, W_1 = total weight of arm, ω = angular speed.

   For Porter governor, $h = (g/\omega^2)\,[(W + w_0)/w_0]$, where W = dead weight, and w_0 = weight of ball.

Controlling force A single force replacing all the forces which tries to pull the ball in a radially inward direction is known as the controlling force.

Quality of a governor It is ascertained by the sensitiveness, stability, effort and power.

Sensitiveness It is defined as the ratio of the range of speed to mean speed.

Stability A governor is said to be stable when for each speed within the working range, there is only one radius of rotation of the governor balls at which the governor is in equilibrium.

Isochronism A governor is termed as isochronous when the equilibrium speed is constant for all radii of rotation of the balls within the working range.

Hunting It is a condition in which the speed of the engine controlled by the governor fluctuates continuously above and below the mean speed.

Effort of governor It is the average force that acts on the sleeve for a given percentage change of speed (generally 1%).

Power of a governor It is defined as the work done on the sleeve for a given percentage change of speed. Thus power is the product of the effort and the displacement of the sleeve.

Cam A cam may be defined as a rotating or a reciprocating element of a mechanism which imparts a rotating, reciprocating or oscillating motion to another element termed as follower.

Basic circle It is the circle with the least radius of the cam such that the lift of the follower is zero over this circle.

Lift It is the difference between the maximum distance of the lowest point of the follower from the axis of rotation of the cam and the least radius.

Angle of ascent It is the angle moved by the cam, from the instant the follower begins to rise, till it reaches the highest position.

Angle of dwell It is the angle through which the cam rotates during the period in which the follower remains in the highest position.

Angle of descent It is the angle during which the follower returns to its initial position.

Angle of action It is the total angle moved by the cam from the beginning of ascent to the termination of descent.

Pressure angle It is the angle between the line of motion of the follower and a line normal to the cam profile at the point of contact.

The trace point It is a reference point on the follower for the purpose of tracing the cam profile. In the case of a roller follower, it is the centre of the roller and in the case of knife edge follower, the knife edge.

Pitch curve It is the path of the trace point.

The prime circle It is the smallest circle drawn to the pitch curve from the centre of rotation of the cam.

The cam angle It is the angle of rotation of the cam for a definite displacement of the follower.

The pitch point It is the point on the cam pitch curve having the maximum pressure angle.

The pitch circle It is the circle with centre as the centre of the cam axis and radius such that it passes through the pitch point.

The cam profile It is the actual working contour or curve of the cam.

Motion of the follower The motion of the follower may be simple harmonic type, uniform acceleration and deceleration and cycloidal type.

Undercutting It is the condition of the constructed cam profile that has an inadequate curvature to produce correct follower movement. To avoid undercutting in a convex curve, the radius of curvature of pitch curve should be greater than the radius of the roller follower.

Follower motion

1. Simple harmonic motion: $y = 0.5s(1 - \cos\theta)$, s = lift, θ = angle turned through.

   $v = 0.5s\,\omega \sin\theta$, $v_{max} = s\omega/2$; $f = 0.5s\omega^2 \cos\theta$, $f_{max} = s\omega^2/2$.

2. Uniform acceleration and deceleration: $v = ft$, $y = 0.5ft^2$, $v_{max} = 2\omega s/\theta$; $f = 4\omega^2 s/\theta$.

   Cycloidal motion: $y = (s/\pi)[\pi\theta/\theta_1 - 0.5\sin(2\pi\theta/\theta_1)]$

   $v = (s\omega/\theta_1)[1 - \cos(2\pi\theta/\theta_1)]$, $v_{max} = 2s\omega/\theta_1$

   $f = (2\pi s\omega^2/\theta_1^2)[\sin(2\pi\theta/\theta_1)]$

   Maximum pressure angle = 25 to 35°.

Gears

Spur gear It is a cylindrical gear with tooth traces that are straight lines parallel to the gear axis. They are used for connecting shafts whose axes are parallel.

Rack It is a spur gear of infinite diameter.

Helical gear It is a cylindrical gear with teeth that are inclined at an angle to the gear axis.

Herringbone gear It is a gear with half of its width cut with tooth helix in one direction and the other half in the opposite direction.

Straight bevel gear It is a gear with tooth traces that are straight line generators of the cone. They are used for connecting shafts with axes intersecting generally at 90°.

Spiral bevel gears These are gears with tooth traces that are curved and oblique lines.

Hypoid gears They are similar to spiral bevel gears. They are used for connecting shafts whose axes are non-intersecting and non-parallel.

Worm gears They are used for connecting shafts with axes that are perpendicular and non-intersecting. They are used for high speed reductions, of the order of 100 : 1.

Terminology of gears

Pitch circle diameter It is the diameter of a circle which would produce the same motion as the toothed gear wheel by pure rolling action.

Base circle It is the circle from which involute form is generated.

Pitch surface It is the surface of the disc which the toothed gear has replaced at the pitch circle.

Pitch point It is the pitch of the tangency or the point of contact of the two pitch circles of the mating gears.

Circular pitch It is the distance measured along the circumference of the pitch circle from a point on one tooth to a corresponding point on the adjacent tooth.

Base pitch It is equal to circular pitch $\times \cos\phi$, where ϕ = pressure angle of the gear tooth profile.

Diametral pitch It is expressed as the number of teeth per unit pitch circle diameter.

$$\text{Circular pitch} \times \text{Diametral pitch} = \pi$$

Module It is expressed as the length of the pitch circle diameter per unit number of teeth.

Addendum It is the radial height of the tooth above pitch circle.

Addendum circle It is a circle bounding the top of the teeth.

Dedendum It is the radial depth of a tooth below the pitch circle.

Dedendum circle It is a circle passing through the roots of all the teeth.

Clearance It is the radial height difference between addendum and dedendum of teeth.

Face It is the part of the tooth surface lying below the pitch surface.

Backlash It is the minimum distance between the non-driving side of a tooth and adjacent side of the mating tooth at the pitch circle.

Profile It is the curve forming face and flank.

Tooth thickness It is the arc distance measured along the pitch circle from its intercept with one flank to its intercept with the other flank of the same tooth.

Face width It is the width of the gear tooth measured axially along the pitch surface.

Top land It is the surface of the top of the tooth.

Tooth fillet It is the radius that connects the root circle to the profile of the tooth.

Tooth space It is the width of the space between two teeth measured on the pitch circle.

Pressure angle It is the angle between the common normal at the point of contact and the common tangent at the pitch point. The pressure angle is either 14.5° or 20°.

Path of contact It is the locus of the point of contact of two mating teeth from the beginning of engagement to the end of engagement. It is a straight line.

Path of approach It is the portion of the path of contact from the beginning of engagement to the pitch point.

Angle of approach It is the angle turned by gears during the path of approach.

Path of recess It is the portion of the path of contact from the pitch point to the end of engagement of the two mating teeth.

Angle of recess It is the angle turned through during path of recess.

Arc of contact It is the locus of a point on the pitch circle, from the beginning of engagement to the end of engagement of pair of teeth in mesh.

Minimum number of teeth to avoid interference, $z = 2/\sin^2\phi$. For $\phi = 20°$, $z = 17$

Law of gearing This law states that the common normal at the point of contact always passes through a fixed point (pitch point) on the line joining the centres of rotation.

For constant angular velocity ratio of gearing, the common normal at the point of contact divides the line joining the centres of rotation in the inverse ratio of the angular velocities.

Velocity of sliding It is equal to the sum of the angular speeds of the driving and driven gears multiplied by the distance of the point of contact from the pitch point.

Involute The involute of a circle is the curve traced by the end of a thread as it is unwound from a stationary cylinder. $\text{inv}(\phi) = \tan\phi - \phi$.

Base circle diameter It is equal to pitch circle diameter $x \cos\phi$.

Cycloid It is the locus of a point on the circumference of a circle which rolls without slipping on a fixed straight line.

Interference It is the portion of a gear tooth below the base circle that cut as a radial line and not an involute curve. Therefore, if contact should occur below the base circle, non-conjugate action would result, leading to interference. Interference can be avoided by undercutting, making stub teeth, increasing the pressure angle and cutting the gears with long and short addendum gear teeth.

Helical gears

Helix angle It is the angle between a line drawn through one of the teeth and the centre line of the shaft on which the gear is mounted.

Normal circular pitch (p_n) It is the distance between corresponding points of adjacent teeth as measured in a plane perpendicular to the helix. It is the perpendicular distance between two adjacent teeth. $p_n = p_t \cos\beta$, $P_n = P_t/\cos\beta$.

Comparison between involute and cycloidal gears.

Characteristic	Involute gears	Cycloidal gears
1. Pressure angle	Constant throughout the engagement	Varies from commencement to end
2. Easie of manufacture	Easy to manufacture	Difficult to manufacture
3. Centre distance	Do not require exact centre distance	Requires exact centre distance
4. Interference	May occur	No interference
5. Strength	Less	More
6. Wear	More	Less
7. Running	Smooth	Less smooth

Transverse circular pitch (p_t) It is the distance measured in a plane perpendicular to the shaft axis between the corresponding points of adjacent teeth. $p_t = \pi d/z$, $P_t = z/d$.

Axial pitch (p_x) It is the distance measured in a plane parallel to the shaft axis between corresponding points of adjacent teeth. $p_x = p_t \cot\beta$.

Lead It is the distance measured parallel to the axis to represent the distance advanced by each tooth per revolution.

Lead angle It is the acute angle between the tangent to the helix and a plane perpendicular to the axis of cylinder.

Virtual (or formative or equivalent) number of teeth (z_v) The number of teeth of the equivalent spur gear in the normal plane is called the virtual number of teeth.

$z_v = z/\cos^3\beta$, β = helix angle; normal module, $m_n = m_t \cos\beta$, $\tan\phi_n = \tan\phi_t \cos\beta \cdot P_t$, $p_t = P_n$, $p_n = \pi$.

Bevel gears

Pitch cone It is the pitch surface of a bevel gear in a gear pair.

Cone centre It is the apex of the pitch cone.

Pitch cone radius It is the length of the pitch cone element.

Pitch angle (d) It is the angle that the pitch line makes with the axis of the gear.

Reference cone angle It is the angle between the axis and the reference cone generator containing the root cone generator.

Tip (or face) angle It is the angle between the tip cone generator and the axis of the gear.

Root (or cutting) angle It is the angle between the root cone generator and the axis of the gear.

Back cone It is an imaginary cone the elements of which are perpendicular to the elements of the pitch cone at the larger end of the tooth.

Gear diameter It is the diameter of the largest pitch circle.

Virtual number of teeth It is the number of teeth on an imaginary spur gear laid out on a pitch radius equal to the back cone radius. $z_v = z/\cos\delta$

Crown gears It is a gear pair for which pitch cone angle is 90°.

Miter gears These are two bevel gears of the same size having a pitch cone angle of 90°.

Worm gears

Axial diametral pitch It is the quotient of the number π by the axial pitch.

Diametral quotient (q) It is the ratio of the reference diameter to the axial module. $q = d/m$.

Axial Module (m_x) It is the quotient of the axial pitch by the number π.

Axial circular pitch (p_x) It is the distance, measured parallel to the axis of the worm, between two consecutive corresponding profiles.

Lead (p_z) It is the distance between two consecutive intersections of a helix and a straight generator of the cylinder on which it lies.

Length of the worm It is the length of the toothed part of the worm measured parallel to the axis on the reference cylinder.

Gear ratio It is the quotient of the number of teeth on the wheel divided by the number of threads on the worm.

Torus It is the surface of revolution generated by the rotation of a circle around an axis external to this circle and situated in its plane.

Gorg It is part of the tip surface in the form of a portion of a torus with the same middle circle diameter as the reference torus.

Tooth width It is the distance between two planes perpendicular to the axis containing the circles of intersection of the reference torus and the lateral faces of the teeth.

Width angle In the generating circle of the reference torus, the angle at the centre included between the points of intersection of this circle with the lateral faces of the teeth is called width angle.

Lead angle It is the angle between a tangent to the pitch helix and the plane of rotation of the worm.

$$\tan\gamma = \frac{p_z}{(\pi d_w)} = \frac{v_g}{v_w};\ p_z = z_w p_x;\ p_n = p_x\cos\gamma;\ m_x = \frac{m_n}{\tan\gamma}$$

Efficiency, $$\eta = \frac{(\cos\alpha_n - \mu\tan\gamma)}{(\cos\alpha_n + \mu\cot\gamma)}$$

Gear trains

Simple gear train A simple gear is one in which each shaft carries only one gear. $N_1/N_{n+1} = z_{n+1}/z_1$.

Compound gear train A compound gear train is one in which all the intermediate shafts carry two gears and the first and last shaft carry only one gear.

$$\frac{N_1}{N_4} = \left(\frac{z_2}{z_1}\right)\cdot\left(\frac{z_4}{z_3}\right)$$

Reverted gear train A reverted gear train is one in which the first and the last gears are on the same shaft.

$$d_1 + d_2 = d_3 + d_4;\ \frac{N_1}{N_4} = \left(\frac{z_2}{z_1}\right)\cdot\left(\frac{z_4}{z_3}\right)$$

Epicyclic gear train The axis of rotation of one or more of the gears is carried on an arm which is free to revolve about the axis of rotation of one of the other gears in the train. The speed ratio of these gear trains can be found either by the relative velocity method or by the tabular (or algebraic) method.

Inertia force in mechanisms

Dynamical equivalent system Two systems are said to be dynamically equivalent to one another, if by application of equal forces, equal linear and angular accelerations are produced in the two systems. For two masses m_1 and m_2 having accelerations a_1 and a_2 respectively, the conditions for dynamically equivalent system are:

$$m = m_1 + m_2;\ m_1 a_1 = m_2 a_2;\quad \text{and}\quad mK_G^2 = m_1 a_1^2 + m_2 a_2^2$$

where K_G = radius of gyration about the centre of graving and $K_G^2 = a_1 a_2$.

Dynamics of reciprocating parts Let R = weight of reciprocating parts, then accelerating force for reciprocating parts = $(R/g)fp$; $\sin\phi = \sin\theta/n$.

Thrust in connecting rod, $Q = P/\cos\phi$. P = piston effort.

Reaction of guide bar, $S = P\tan\phi$; Crank pin effort, $T = Q\sin(\theta + \phi)$

Force in crank, $W = Q\cos(\theta + \phi)$

Crank effort $= Tr = Pr[\sin\theta + \sin 2\theta/\{2(n^2 - \sin^2\theta)^{1/2}\}]$

Flywheel The function of a flywheel is to decrease the variation of speed during one cycle by storing up energy during the working stroke of the engine and releasing it during the idle stroke. Fluctuation of energy $= 5.589 \times 10^{-4} WK^2(N_1 + N_2)(N_1 - N_2)$, where W = weight of flywheel and K its radius of gyration.

Gyroscopic and precessional motion

Precessional motion It is the motion in which the plane of rotation varies from instant to instant.

Axis of spin It is the axis about which the body revolves.

Gyroscopic effect It is the combined effect of the plane of spin, the plane of precession and the plane of gyroscopic couple. The axis of spin, couple and precession are mutually perpendicular.

Axis of precession It is the third axis about which a body revolves and is perpendicular to both the axis of spin and that of the couple.

Gyroscope It is a body which while spinning about an axis is free to move in other directions under the action of external forces.

Gyroscopic Couple of a plane Disc = Iww_p, where I = moment of inertia of the disc, w = spinning angular velocity and w_p = angular speed of precession.

Balancing

1. Balancing of a single rotating mass shall require a single mass to balance it rotating in the same plane. $Bb = Mr$

2. Balancing of a single rotating mass by a balanced mass rotating in a different plane parallel to the plane of the unbalanced mass shall require two balancing masses, which can either be arranged in two different planes on the side of the plane of rotation of the unbalanced mass or on the opposite side of the plane of rotation of the unbalanced mass.

$$B_1 b_1 = \frac{Mra_2}{d} \quad \text{or} \quad B_2 b_2 = \frac{Mra_1}{d}$$

where d = distance between the planes.

3. For the balancing of several masses rotating in the same plane, the force polygon must close. If the force polygon does not close then the closing side of the polygon taken in the reverse order gives the resultant in magnitude and direction. The balancing mass must be placed at a convenient radius opposite to the resultant force. $\Sigma Mr = 0$.
4. For the balancing of number of masses rotating in different planes, the force polygon and the couple polygon must close.

$$\Sigma Mr = 0 \quad \text{and} \quad \Sigma Mra = 0$$

a = distance from the reference plane.

5. For the balancing of reciprocating parts, the primary and secondary forces must be balanced. The frequency of the secondary forces is double the frequency of the primary forces. The primary forces are generally balanced partially. For resultant unbalanced primary force to be minimum, the balancing should be 50% but generally $2/3^{rd}$ of the primary forces are balanced. This gives rise to swaying couple and hammer blow.

$$F_p = R\omega^2 r\cos\theta,\ F_s = R(2\omega)^2\left(\frac{r^2}{4l}\right)\cos 2\omega t,\ c = \frac{Bb}{Rr}$$

6. For the balancing of connecting rod of an engine, $2/3^{rd}$ of its mass is considered to be rotating at the crank pin and $1/3^{rd}$ reciprocating along with the gudgeon pin.

Swaying couple It is the couple produced due to unbalanced parts of the primary disturbing forces acting at a distance between the line of stroke of the cylinders.

$$C = (1-c)R\omega^2 ra\sqrt{2} \text{ at } 45° \quad \text{and} \quad 1350$$

Hammer blow It is the maximum value of the unbalanced vertical force or the balance weights. It is counterbalanced by the self weight of the engine and acts on the rails. Hammer blow = $Bb\omega^2$ at 90° and 270°, where B = balance mass of reciprocating parts alone. To avoid lifting of wheels from the rails, $\omega = [Mg/Bb]^{1/2}$, where Mg = dead load on each wheel. Net pressure on rails = $Mg \pm Bb\omega^2$.

Balancing of in-line engines

(a) Two-cylinder engines Primary forces are automatically balanced. Primary couples, secondary forces and couples have to be balanced. Equivalent radius of crank for secondary forces is $r^2/4l$ and equivalent fraquency is 2ω.

(b) Four-cylinder engine Primary forces and couples are automatically balanced. Secondary force is to be balanced and secondary couple is zero.

Balancing of V-Engines Both the resultant primary and secondary forces are to be balanced.

Friction

Flat pivot Frictional moment, $M = (2/3)\mu WR$ for uniform pressure and 0.5 μWR for uniform rate of wear. Intensity of pressure = $W/(\pi R^2)$.

Conical pivot $M = (2/3)(\mu/\sin\alpha)WR$ for uniform pressure and (1/2) $(\mu/\sin\alpha)WR$ for uniform rate of wear, α = semi-cone angle.

Flat collar

$$M = \left(\frac{2}{3}\right)\mu W \frac{(r_1^3 - r_2^3)}{(r_1^2 - r_2^2)} \text{ for uniform pressure}$$

$$= \mu W \frac{(r_1 + r_2)}{2} \text{ for uniform rate of wear}$$

Intensity of pressure, $$p = \frac{W}{\pi\,(r_1^2 - r_2^2)}$$

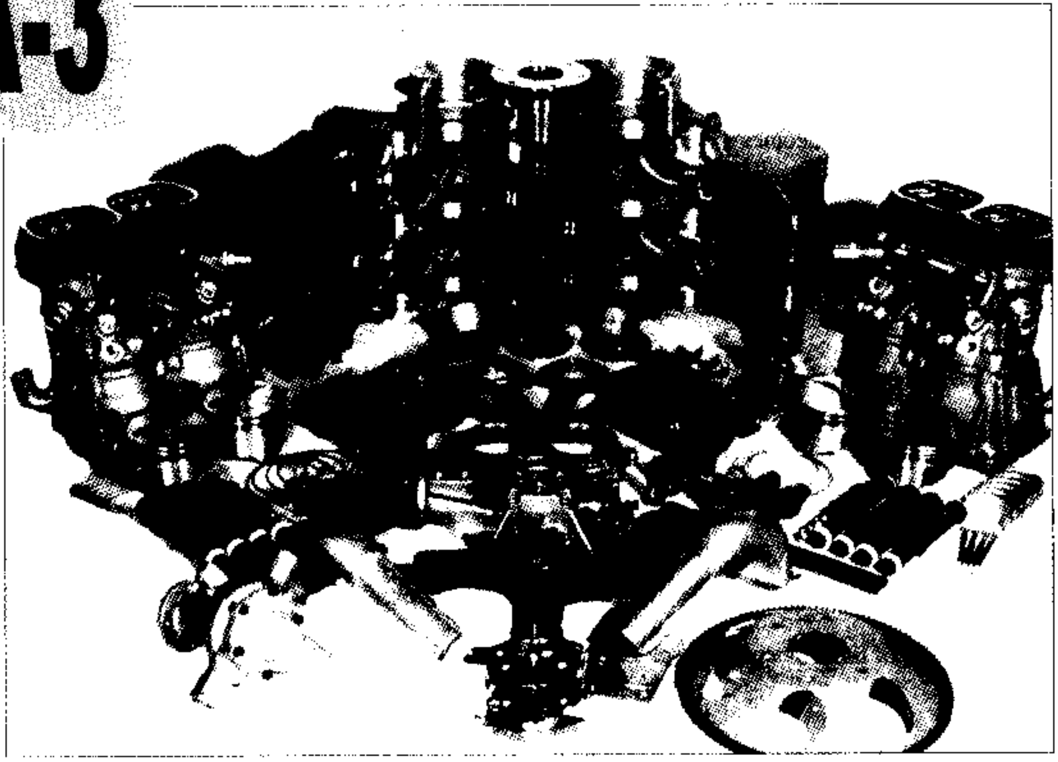
Conical collar

$$M = (2/3)(\mu/\sin\alpha)W(r_1^3 - r_2^3)/(r_1^2 - r_2^2) \text{ for uniform pressure}$$

$$= (1/2)(\mu/\sin\alpha)W(r_1 + r_2) \text{ for uniform rate of wear}$$

$$p = W/\pi(r_1^2 - r_2^2)$$

A-3



MULTIPLE CHOICE QUESTIONS

1. The purpose of a link is to

   (a) transmit motion (b) guide other links (c) act as a support (d) all of the above

2. A kinematic chain requires at least

   (a) 2 links and 3 turning pairs (b) 3 links and 4 turning pairs
   (c) 4 links and 4 turning pairs (d) 5 links and 4 turning pairs

3. The total number of instantaneous centres for a mechanism of n links are

   (a) $n(n-1)/2$ (b) n (c) $n-1$ (d) $n/2$

4. Which of the following is a lower pair?

   (a) ball and socket (b) piston and cylinder
   (c) cam and follower (d) (a) and (b) above

5. The quick-return mechanism is used in

   (a) milling machine (b) broaching machine
   (c) grinding machine (d) slotter

6. The centre of gravity of a link in any mechanism would experience

   (a) zero acceleration (b) linear acceleration
   (c) angular acceleration (d) both angular and linear accelerations

7. A kinematic chain becomes a mechanism when

   (a) when first link is fixed (b) any one link is fixed
   (c) all links are fixed (d) none of the links are fixed

8. A slider crank mechanism consists of the following number of turning and sliding pairs

   (a) 1, 3 (b) 2, 2 (c) 3, 1 (d) 4, 0

9. The coriolis component of acceleration is encountered in

   (a) four-bar mechanism (b) lower pairs
   (c) higher pairs (d) Whitworth quick-return motion

10. The coriolis component of acceleration exists whenever a point moves along a path that has

    (a) linear displacement (b) rotational motion
    (c) tangential acceleration (d) centripetal acceleration

11. The number of links in a pantograph mechanism is equal to

    (a) 2 (b) 3 (c) 4 (d) 5

12. The automobile steering gear is an example of

    (a) higher pair (b) sliding pair (c) turning pair (d) lower pair

13. A typewriter constitutes a

    (a) machine (b) structure (c) mechanism (d) inversion

14. In automobiles, the power is transmitted from gear box to differential through

    (a) bevel gears (b) knuckle joint (c) Hooke's joint (d) universal joint

15. A mechanism has 7 links with all binary pairs except one which is a ternary pair. The number of instantaneous centres of this mechanism are

    (a) 14 (b) 21 (c) 28 (d) 42

16. The direction of the linear velocity of any point on the kinematic link relative to any other point on the same kinematic link is

    (a) parallel to the line joining the points
    (b) perpendicular to the line joining the points
    (c) at 45° to the line joining the points
    (d) dependent on the angular speed of rotation of the link

17. Two kinematic links have absolute angular velocities of ω_1 (clockwise) and ω_2 (counter-clockwise). The angular velocity of link 1 relative to link 2, is

    (a) $\omega_1 + \omega_2$ (b) $\omega_1 - \omega_2$ (c) $\omega_2 - \omega_1$ (d) $\omega_1\omega_2$

18. The total acceleration of B relative to A is

(a) $\left[\left(\omega_{AB}^2 \times AB\right)^2 + (\alpha \times AB)^2\right]^{1/2}$

(b) $\omega_{AB}^2 \times AB + \alpha \times AB$

(c) $\left[\omega_{AB} \times AB^2 + \alpha \times AB^2\right]^{1/2}$

(d) $\left[(\omega_{AB} \times AB)^2 + (\alpha \times AB)^2\right]^{1/2}$

19. The total acceleration of B relative to A is inclined to AB at an angle tangent of which is given by

(a) α/ω^2 (b) α/ω (c) ω^2/α (d) ω/α

20. The velocity of slider–crank mechanism is given by

(a) $(\omega L/2)[\sin\theta + (L/4l)\sin 2\theta]$

(b) $\left(\omega^2 L/2\right)[\sin\theta + (L/2l)\sin 2\theta]$

(c) $(\omega L/2)[\cos\theta + (L/4l)\cos 2\theta]$

(d) $\left(\omega^2 L/2\right)[\cos\theta + (L/2l)\cos 2\theta]$

where L = length of stroke, l = length of connecting rod

ω = angular speed of crank, θ = crank angle

21. The linear acceleration of piston of a reciprocating engine is

(a) $\omega^2 r\,[\cos\theta + \cos 2\theta/2n]$ (b) $\omega^2 r\,[\cos\theta + \cos 2\theta/n]$

(c) $\omega^2 r\,[\sin\theta + \sin 2\theta/2n]$ (d) $\omega^2 r[\sin\theta + \sin 2\theta/n]$

where $n = l/r$

22. The angular velocity of the connecting rod of a reciprocating engine is approximately given by

(a) $\omega\cos\theta/n$ (b) $\omega\sin\theta/n$ (c) $\omega\cos\theta/2n$ (d) $\omega\sin\theta/2n$

23. The angular acceleration of the connecting rod of a reciprocating engine is approximately given by

(a) $\omega^2\cos\theta/n$ (b) $\omega^2\sin\theta/n$ (c) $\omega^2\cos\theta/2n$ (d) $\omega^2\sin\theta/2n$

24. Klein's construction is used mainly to determine the

(a) linear velocity of the piston (b) linear acceleration of the piston

(c) linear displacement of the piston (d) all of the above

25. A slider slides along a straight link with uniform velocity v and the link rotates about a point with uniform angular speed ω. The Coriolis component of acceleration of a point on the slider at a distance r from the centre of rotation is

(a) v^2/r parallel to link (b) ωr perpendicular to link

(c) $2\omega v$ perpendicular to link (d) v w parallel to link

26. The Coriolis component of acceleration occurs in

(a) slider–crank mechanism (b) Scotch–yoke mechanism

(c) oscillating cylinder mechanism (d) four-bar chain

27. The direction of the Coriolis component of acceleration is
    (a) along the surface of sliding
    (b) perpendicular to the surface of sliding in the direction of angular speed
    (c) perpendicular to the surface of sliding in the direction opposite to the direction of angular speed
    (d) inclined to the surface of sliding depending on the magnitude of normal and tangential accelerations

28. Scott–Russel mechanism for generating straight has
    (a) four lower kinematic turning pairs
    (b) two lower kinematic turning pairs and one lower kinematic sliding pair
    (c) one lower kinematic turning pair and two lower kinematic sliding pairs
    (d) two lower kinematic turning pairs and two lower kinematic sliding pairs

29. Watt mechanism is capable of generating
    (a) approximate straight line (b) exact straight line
    (c) approximate circular path (d) exact circular path

30. The pitch point on a cam is
    (a) any point on the pitch curve
    (b) the point on cam pitch curve having the maximum pressure angle
    (c) any point on pitch circle
    (d) a point at a distance equal to pitch circle radius from the centre

31. In its simplest form, a cam mechanism consists of following number of links
    (a) 1 (b) 2 (c) 3 (d) 4

32. The type of follower used in automobiles is
    (a) knife-edge (b) roller
    (c) mushroom with flat-face (d) mush-room with spherical face

33. The minimum radius circle drawn to the cam profile is called
    (a) prime circle (b) base circle (c) pitch circle (d) pitch curve

34. The reference point on the follower for the purpose of laying the cam profile is known as
    (a) pitch point (b) trace point (c) roller centre (d) cam centre

35. The pressure angle of a cam is defined as the angle between the line of motion of the follower and the
    (a) tangent on the pitch curve (b) normal on the pitch curve
    (c) tangent on the cam profile (d) normal on the cam profile

36. The cam profile and pitch curves are same for
    (a) roller follower (b) knife-edge follower
    (c) mushroom follower (d) flat-faced follower.

37. The size of the cam depends upon
    (a) base circle (b) prime circle (c) pitch circle (d) pitch curve

38. The point on the cam with maximum pressure angle is called the

(a) pitch point (b) trace point (c) cam centre (d) roller centre

39. Pressure angle of a cam is directly proportional to

(a) base circle diameter (b) pitch circle diameter
(c) prime circle diameter (d) lift of cam

40. The throw of a cam is the maximum lift of the follower from

(a) base circle (b) pitch circle (c) prime circle (d) pitch curve

41. For a cam and follower in simple harmonic motion, the maximum velocity is

(a) $\pi\omega s/2\theta$ (b) $\pi\omega s/\theta$ (c) $\pi\omega s/4\theta$ (d) $\pi\omega s/3\theta$

where s = lift.

42. For a cam and follower in simple harmonic motion, the maximum acceleration is

(a) $(\pi\omega/\theta)^2\,(s/2)$ (b) $(\pi\omega/\theta)^2 s$ (c) $(\pi\omega/\theta)^2(s/4)$ (d) $2s(\pi\omega/\theta)^2$

43. For a uniformly accelerated cam, the maximum velocity is

(a) $2(\omega s/\theta)$ (b) $0.5(\omega s/\theta)$ (c) $(\omega s/\theta)$ (d) $4(\omega s/\theta)$

44. For a uniformly accelerated cam, the maximum acceleration is

(a) $2(\omega/\theta)^2 s$ (b) $0.5(\omega/\theta)^2 s$ (c) $4(\omega/\theta)^2 s$ (d) $0.25(\omega/\theta)^2 s$

45. When a ship travels in sea, which of the following effects is more dangerous

(a) steering (b) pitching (c) rolling (d) all of the above

46. The gyroscopic acceleration of a disc rotating at speed w and uniform acceleration is

(a) $d\omega/dt$ (b) $\omega d\theta/dt$ (c) $r\omega^2$ (d) $r\, d\omega/dt$

47. The gyroscopic couple acting on a disc of moment of inertia I, rotating with speed w and speed of precession ω_p,is given by

(a) $I\omega^2\omega_p$ (b) $I\omega\omega_p^2$ (c) $I\omega\omega_p$ (d) $I\omega^2\omega_p^2$

48. The total reaction of ground on wheels of a vehicle due to gyroscopic couple and centrifugal force while negotiating curve is

(a) increased on inner wheels and decreased on outer wheels
(b) decreased on inner wheels and increased on outer wheels
(c) decreased on all the wheels
(d) increased on all the wheels

49. The axes of spin, precession and gyroscopic couple are contained in

(a) one plane (b) two planes perpendicular to each other
(c) two parallel planes (d) three planes perpendicular to one another

50. The gyroscopic couple is introduced in a ship whose spin axis is parallel to starboard, when it is

(a) rolling (b) pitching
(c) pitching or rolling (d) neither pitching nor rolling

51. The centrifugal tension in belts
    (a) reduces power transmission
    (b) increases power transmission
    (c) does not affect power transmission
    (d) increases or decreases power transmission depending on speed

52. In case of a flat belt drive with T as the maximum permissible tension, v as linear speed of belt, ω as weight per metre length of belt, the maximum permissible speed is given by
    (a) $T = \omega v^2/g$ (b) $T = 2\omega v^2/g$ (c) $T = 3wv^2/2g$ (d) $T = \sqrt{3}wv^2/2g$

53. With the same set of pulleys, belt and centre distance, the maximum power transmitted by
    (a) across belt is more than an open belt
    (b) across belt is less than an open belt
    (c) cross and open belts is the same
    (d) cross and open belts depends upon pulley diameters

54. The ratio of tensions in the tight and slack sides of a belt drive is
    (a) $\mu\theta$ (b) $\exp(\mu\theta)$ (c) $1/\mu\theta$ (d) $\exp(1/\mu\theta)$

55. If the percentage slip is same on both the driving and driven pulleys, then the speed ratio will
    (a) increase (b) decrease (c) remain same (d) be unpredictable

56. The crowning of pulleys is done to
    (a) make the belt run in the centre of the pulley face width
    (b) strengthen the pulley
    (c) give better shape to pulley
    (d) decrease slip

57. Considering centrifugal tension in a belt, the maximum linear velocity of belt is proportional to
    (a) cube root of maximum tension (b) square root of maximum tension
    (c) maximum tension (d) reciprocal of maximum tension

58. If the initial tension in the belt is increased then the power transmitted by the belt
    (a) reduces (b) increases (c) remains same (d) depends on speed

59. The initial tension in the belt due to centrifugal tension, for the same power to be transmitted
    (a) increases (b) decreases (c) remains same (d) depends on speed

60. The maximum tension in the belt, for limiting friction conditions, occurs at
    (a) starting (b) stopping (c) maximum power speed (d) specified speed

61. The apparent coefficient of friction for V-belts is
    (a) $\mu/\cos\beta$ (b) $\mu\cos\beta$ (c) $\mu\sin\beta$ (d) $\mu/\sin\beta$
    where β = semi-angle of pulley groove.

62. For maximum power to be transmitted by belt drive, the ratio of centrifugal tension to permissible tension is
    (a) 1 / 2 (b) 1 / 3 (c) 2 / 3 (d) 1 / 4

63. For maximum power to be transmitted by belt drive, the ratio of centrifugal tension to effective tight side tension is

(a) 1 / 2 (b) 1 / 3 (c) 2 / 3 (d) 1 / 4

64. If the ratio of the tensions on tight and slack sides of a belt drive is increased by 20%, the power is

(a) increased by 20% (b) decreased by 20% (c) unaffected (d) unpredictable

65. The net effect of creep in belts is to

(a) increase the speed of driven pulley (b) decrease the speed of driven pulley
(c) increase the power output (d) decrease the power output

66. The following dynamometer is widely used for absorption of wide range of power at wide range of speed

(a) hydraulic (b) belt transmission (c) rope brake (d) electric generator

67. The equivalent coefficient of friction for a block brake is

(a) $4\mu \sin\theta/(\sin\theta + \theta)$ (b) $4\mu \sin(\theta/2)/[\sin(\theta/2) + \theta/2]$
(c) $4\mu \sin(\theta/2)/(\sin\theta + \theta)$ (d) $\mu \sin\theta/(\sin\theta + \theta)$

68. The equivalent radius of a block brake is

(a) $4r \sin\theta/(\sin\theta + \theta)$ (b) $4r \sin\theta/2/(\sin\theta/2 + \theta/2)$
(c) $4r \sin\theta/2/(\sin\theta + \theta)$ (d) $r \sin\theta/(\sin\theta + \theta)$

where r = drum radius.

69. The ratio of tensions on the tight side to slack side of multi-block brake is

(a) $(1 - n\mu \tan\theta)/(1 + n\mu \tan\theta)$ (b) $(1 + n\mu \tan\theta)/(1 - n\mu \tan\theta)$
(c) $[(1 + \mu \tan\theta)/(1 - \mu \tan\theta)]^n$ (d) $[(1 - \mu \tan\theta)/(1 + \mu \tan\theta)]^n$

70. The stopping distance for a vehicle by applying brakes when all the four wheels are sliding as compared to when all the four wheels are in a limiting state of sliding is

(a) more (b) less (c) same (d) unpredictable

71. The stopping distance for a four wheel vehicle is

(a) unaltered by an increase in weight of vehicle
(b) decreases with increase of coefficient of friction
(c) directly proportional to square of velocity of vehicle
(d) all of the above

72. Dynamometer is a device used on a prime mover for measuring

(a) torque developed (b) power developed
(c) power absorbed (d) all of the above

73. Which of the following is an absorption dynamometer?

(a) Prony brake dynamometer (b) rope brake dynamometer
(c) Froude's hydraulic dynamometer (d) all of the above

74. Which of the following is a transmission dynamometer?

(a) torsion dynamometer (b) belt dynamometer
(c) hydraulic dynamometer (d) Prony brake dynamometer

75. The flywheel influences the
    (a) variation of load demand on prime mover
    (b) mean speed of the prime mover
    (c) cyclic variation in speed of the prime mover
    (d) mean torque developed by the prime mover

76. If mean speed of the prime mover is increased then the coefficient of fluctuation of speed will
    (a) increase (b) decrease (c) remains same (d) unpredictable

77. The maximum fluctuation of energy of flywheel is directly proportional to
    (a) coefficient of fluctuation of speed (b) square of angular speed of flywheel
    (c) moment of inertia of flywheel (d) all of the above

78. The height of Watt's governor is proportional to
    (a) speed (N) (b) N^2 (c) $1/N$ (d) $1/N^2$

79. In a Hartnell governor, if the stiffness of spring is increased, the governor will
    (a) become more sensitive (b) become less sensitive
    (c) remain unaffected (d) start hunting

80. The function of a governor is to
    (a) reduce the speed fluctuations during a cycle
    (b) maintain the prime mover speed within prescribed limits
    (c) not to influence the speed of the prime mover
    (d) not to control the variation in load on the prime mover

81. The following governor is spring loaded
    (a) Watt governor (b) Porter governor
    (c) Proel governor (d) Hartnell governor

82. The gravity controlled governor is
    (a) Hartnell governor (b) Pickering governor
    (c) Hartung governor (d) Proel governor

83. The height of a Watt's governor is
    (a) ω^2/g (b) g/ω^2 (c) $g\omega^2$ (d) $2g\omega^2$

84. The Proel governor as compared to Porter governor, at same speed
    (a) is more sensitive (b) requires smaller size
    (c) has less lift (d) all of the above

85. The sensitivity of a governor due to frictional resistance at the sleeve
    (a) increases (b) decreases (c) remains same (d) depends on speed

86. The spring loaded governors as compared to gravity controlled governors
    (a) can operate at higher speeds (b) are more compact and smaller in size
    (c) are capable of being fixed at any inclination (d) all of the above

87. If the ball masses of a governor occupy a definite specified position for each speed, it is said to be

(a) stable (b) hunting (c) isochronous (d) sensitive

88. If the ball masses of a governor have same equilibrium speed for all the radii of rotation, it is said to be

(a) stable (b) hunting (c) isochronous (d) sensitive

89. Isochronous governor is

(a) more sensitive (b) less stable (c) isochronous (d) less sensitive

90. Governor effort is defined as the force applied for

(a) 1% change in speed (b) 2% change in speed
(c) 5% change in speed (d) the total range of speed

91. Governor which is hunting is

(a) more sensitive (b) less sensitive (c) more stable (d) less stable

92. Governor power is defined as the product of governor effort and

(a) sleeve lift
(b) reciprocal of sleeve lift
(c) difference of radii of rotation for maximum and minimum speeds
(d) square of sleeve lift

93. The surface of the gear tooth below the pitch surface is called

(a) addendum portion (b) dedendum portion (c) flank (d) face

94. The path of contact in involute gears is

(a) a straight line (b) involute path (c) curved path (d) circle

95. For two meshing gears, their

(a) number of teeth must be same (b) addendum must be same
(c) dedendum must be same (d) module must be same

96. A reverted gear train is one in which the

(a) direction of rotation of first and last gear is the same
(b) direction of rotation of first and last gear is opposite
(c) first and last gear are on the same shaft
(d) first and last gear are essentially on separate but parallel shafts

97. The type of gears used to connect two parallel coplanar shafts are

(a) spur gears (b) bevel gears (c) spiral gears (d) worm gears

98. The type of gears used to connect two intersecting coplanar shafts are

(a) spur gears (b) straight bevel gears
(c) helical gears (d) spiral gears

99. The type of gears used to connect two non-parallel and non-intersecting shafts are

(a) spur gears (b) bevel gears (c) worm gears (d) spiral gears

100. The circular pitch of a spur gear is defined as
(a) $\pi d/z$ (b) d/z (c) z/d (d) $z/\pi d$
where d = pitch circle diameter and z = number of teeth.

101. The diametral pitch of a spur gear is defined as
(a) $\pi d/z$ (b) d/z (c) z/d (d) $z/\pi d$

102. The module of a spur gear is defined as
(a) $\pi d/z$ (b) d/z (c) z/d (d) $z/\pi d$

103. Choose the correct relationship.
(a) $pP = \pi$ (b) $p/P = \pi$ (c) $P/p = \pi$ (d) $pP = 1/\pi$

104. Module of a spur gear teeth is
(a) $1/P$ (b) $1/p$ (c) P/π (d) p/π

105. The range of pressure angle for spur gears is
(a) 10 to 14° (b) 14.5 to 20° (c) 21 to 25° (d) 26 to 30°

106. Choose the correct statement for involute profile in regard to pressure angle.
(a) It has minimum value when contact begins (b) It has maximum value when contact ends
(c) It remains same for all points of contact (d) The interference is zero

107. In case of cycloidal tooth profile gears
(a) the pressure angle is always constant through the contact
(b) the path of contact is a straight line
(c) the variation in centre distance affects the angular speed ratio
(d) interference is more

108. The involute function in terms of pressure angle ϕ is
(a) $\tan\phi - \phi$ (b) $\tan^{-1}\phi$ (c) $\tan^{-1}\phi - 1$ (d) $\phi - \tan\phi$

109. The minimum number of teeth for involute rack of 20° pressure angle is
(a) 17 (b) 24 (c) 32 (d) 34

110. Path of contact in case of cycloidal tooth profile gears is a
(a) straight line (b) circle (c) complex curve (d) parabola

111. To connect hour hand to minute hand in a clock mechanism, we use
(a) epicyclic gear train (b) reverted gear train
(c) simple gear train (d) all of the above

112. In a gear train, where the axes of gears have motions, is called
(a) simple gear train (b) compound gear train
(c) epicyclic gear train (d) reverted gear train

113. In case of reciprocating engines the ratio of primary to secondary forces is

(a) $\cos\theta / \cos 2\theta$ (b) $\cos\theta / (n \cos 2\theta)$
(c) $n \cos\theta / \cos 2\theta$ (d) $\cos^2\theta / \cos 2\theta$

114. Partial balancing in locomotives results in

(a) hammer blow (b) variation in tractor effort
(c) swaying couple (d) all of the above

115. In reciprocating engines, primary forces are

(a) completely balanced (b) partially balanced
(c) can not be balanced (d) balanced by secondary forces

116. In case of locomotives, the effect of hammer blow is counteracted by

(a) flanges of the tyres of the wheels (b) balancing weights
(c) inside section of the rails (d) dead weight of the engine

117. Hammer blow in locomotives results in

(a) pulsating torque (b) tendency to lift wheels from rails
(c) uneven speed (d) variable horizontal force

118. Swaying couple results due to

(a) primary disturbing force (b) secondary disturbing force
(c) partial balancing (d) hammer blow

119. Inertia force acts

(a) perpendicular to the accelerating force
(b) along the direction of the accelerating force
(c) opposite to the direction of the accelerating force
(d) in any direction with respect to accelerating force

120. If the balance mass is to be placed in a plane parallel to the plane of the unbalance mass then the minimum number of balance masses required are

(a) one (b) two (c) three (d) four

121. The frequency of secondary force as compared to that of primary force is

(a) half (b) twice (c) four times (d) sixteen times

122. If the ratio of the length of the connecting rod to the crank radius increases then

(a) the primary force increases (b) the primary force decreases
(c) the secondary force increases (d) the secondary force decreases

123. The resultant unbalanced force is minimum in reciprocating engines when the part of the reciprocating mass balanced by rotating masses are

(a) 1 / 3 (b) 1 / 2 (c) 2 / 3 (d) 3 / 4

124. In partial balancing of locomotives, the maximum variation of tractive effort is

(a) $(2/3)Mr\omega^2$ (b) $(\sqrt{2}/3)Mr\omega^2$ (c) $(3/\sqrt{2})Mr\omega^2$ (d) $(3/2)Mr\omega^2$

125. Which of the following is a constant acceleration cam?

(a) Simple harmonic motion (b) circular arc (c) polynomial (d) parabola

126. The arm *OA* of an epicyclic gear train shown in Fig.1 revolves counter-clockwise about *O* with an angular velocity of 4 rad/s. Both gears are of same size. The angular velocity of gear *C*, if the sun gear *B* is fixed, is

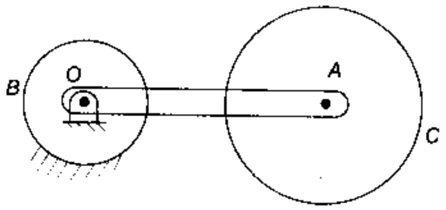


Fig.1

(a) 4 rad/s (b) 8 rad/s (c) 10 rad/s (d) 12 rad/s

127. Figure 2 shows a quick return mechanism. The crank *OA* rotates clockwise uniformly. *OA* = 2 cm, *OO* = 4 cm. The ratio of time for forward motion to that for return motion is

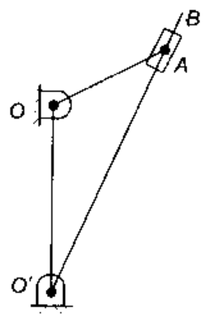


Fig.2

(a) 0.5 (b) 2.0 (c) 12 (d) 1

128. A rod of length 1 m is sliding in a corner as shown in Fig.3. At an instant when the rod makes an angle of 60 deg with the horizontal plane, the velocity of point *A* on the rod is 1 m/s. The angular velocity of the rod at this instant is

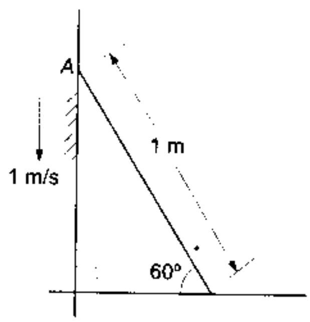


Fig.3

(a) 2 rad/s (b) 1.5 rad/s (c) 0.5 rad/s (d) 0.75 rad/s

129. *AB* and *CD* are two uniform and identical bars of mass 10 kg each, as shown in Fig.4. The hinges at *A* and *B* are frictionless. The assembly is released from rest and motion occurs in the vertical plane. At the instant that the hinge *B* passes the point *B*, the angle between the two bars will be:

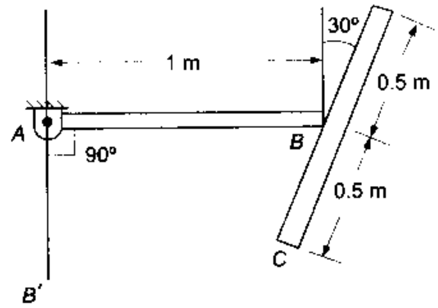


Fig.4

(a) 60° (b) 37.4° (c) 30° (d) 45°

130. In a plate cam mechanism with reciprocating roller follower, the follower has a constant acceleration in the case of

(a) cycloidal motion (b) simple harmonic motion

(c) parabolic motion (d) 3-4-5 polynomial motion

131. The number of degrees of freedom of a five link mechanism with five revolving pairs shown in Fig.5 is

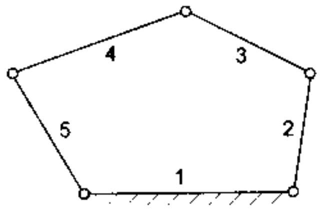


Fig.5

(a) 3 (b) 4 (c) 2 (d) 1

132. Which type of governor is preferred for gramophones?

(a) Porter (b) Pickering (c) Watt (d) Hartnell

133. The cam follower used in automobiles is

(a) roller type (b) mush room type (c) spherical type (d) knife-edge type

134. In the four-bar chain shown in Fig.6, links 2 and 4 have equal length. the point P on the coupler 3 will generate a / an

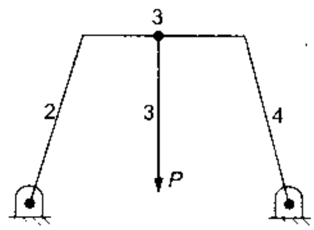


Fig.6

(a) ellipse (b) parabola (c) approximately straight line (d) circle

135. The sensitivity dh/dN of a given Porter Governor shown in Fig.7, where h is the height of the pin point A from the sleeve and N is the rpm, is proportional to

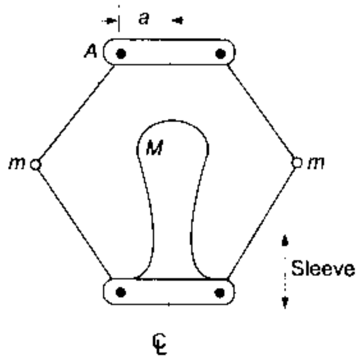


Fig.7

(a) N^2 (b) N^3 (c) $1/N^2$ (d) $1/N^3$

136. A point on a connecting link (excluding end points) of a double slider crank mechanism traces a

(a) straight line path (b) hyperbolic path (c) parabolic path (d) elliptical path

137. The mechanism shown in Fig.8 represents

(a) Hart's mechanism (b) Toggle mechanism
(c) Watt's mechanism (d) Beam engine mechanism

138. There are six gears A, B, C, D, E, F in a compound train. The number of teeth in the gears are 20, 60, 30, 80, 25, and 75, respectively. The ratio of the angular speeds of the driven (F) to the driver (A) of the drive is

(a) 1 / 24 (b) 1 / 8 (c) 4 / 15 (d) 12

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

(a) 3 (b) 4 (c) 5 (d) 6

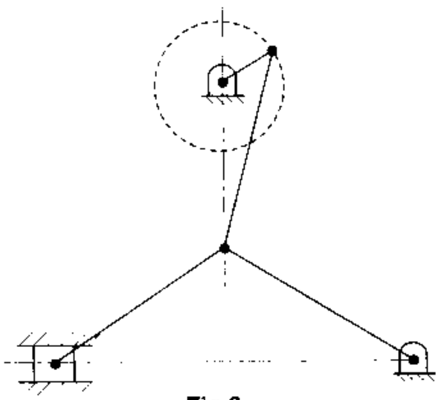


Fig.8

140. Balancing of a rigid rotor can be achieved by appropriately placing weights in

(a) a single plane (b) two planes (c) three planes (d) four planes

141. Which one of the following is a higher pair?

(a) belt and pulley (b) turning pair (c) screw pair (d) sliding pair

142. Which of the following are the inversions of double slider crank mechanism?

1. Oldham coupling 2. Whitworth quick-return mechanism
3. Beam engine mechanism 4. Elliptic trammel mechanism

Select the correct answer from the codes given below:

(a) 1 and 2 (b) 1 and 4 (c) 1, 2 and 4 (d) 2, 3 and 4

143. A body in motion will be subjected to Coriolis acceleration when that body is

(a) in plane rotation with variable velocity
(b) in plane translation with variable velocity
(c) in plane motion which is a resultant of plane translation and rotation
(d) restrained to rotate while sliding over another body

144. The Whitworth quick-return mechanism is formed in a slider–crank chain when the

(a) the coupler link is fixed (b) the longest link is fixed
(c) the slider is a fixed link (d) the smallest link is a fixed link

145. A bicycle remains stable in running through a bend because of

(a) gyroscopic action (b) Coriolis acceleration
(c) centrifugal action (d) radius of curved path

146. The connection between the piston and cylinder in a reciprocating engine corresponds to

(a) completely constrained kinematic pair
(b) incompletely constrained kinematic pair
(c) successfully constrained kinematic pair
(d) single link

147. Static balancing is satisfactory for low speed rotors but with increasing speeds, dynamic balancing becomes necessary. This is because, the

(a) unbalanced couple are caused only at higher speeds
(b) unbalanced forces are not dangerous at higher speeds
(c) effects of unbalance are proportional to the square of the speed
(d) effects of unbalance are directly proportional to the speed

148. Consider the following statements:

1. A round bar in a round hole forms a turning pair.
2. A square bar in a square hole forms a sliding pair.
3. A vertical shaft in a footstep bearing forms a successful constraint.

Of these statements,

(a) 1 and 2 are correct (b) 2 and 3 are correct
(c) 1 and 3 are correct (d) 1, 2 and 3 are correct

149. A system of masses rotating in different parallel planes is in dynamic balance if the resultant

(a) force is equal to zero
(b) couple is equal to zero
(c) force and the resultant couple are both equal to zero
(d) force is numerically equal to the resultant couple, but neither of them need necessarily be zero

150. Given that θ = angle through which the axis of the outer forward wheel turns; ϕ = angle through which the axis of the inner forward wheel turns; a = distance between the pivots of front axle and b = wheel base.

For correct steering, centre lines of the axes of four wheels of an automobile should meet at a common point. This condition will be satisfied if

(a) $\cos\theta - \cos\phi = a/b$ (b) $\cot\theta - \cot\phi = a/b$
(c) $\cos\theta + \cos\phi = a/b$ (d) $\tan\theta + \tan\phi = a/b$

151. A fixed gear having 200 teeth is in mesh with another gear having 50 teeth. The two gears are connected by an arm. The number of turns made by the smaller gear for one revolution of arm about the centre of the bigger gear is

(a) 2 (b) 3 (c) 4 (d) 5

152. An involute pinion and gear are in mesh. If both have the same size of addendum, then there will be an interference between the

(a) tip of the gear tooth and flank of pinion (b) tip of the pinion and flank of the gear
(c) flanks of both pinion and gear (d) tip of both gear and pinion

153. The sensitivity of an isochronous governor is

(a) zero (b) one (c) two (d) infinity

154. When the primary direct crank of a reciprocating engine is positioned at 30° clockwise, the secondary reverse crank for balancing will be at

(a) 30° counter-clockwise (b) 60° counter-clockwise
(c) 30° clockwise (d) 60° clockwise

155. A statically-balanced system is shown in Fig.9. Two equal weights W, each with an eccentricity e, are placed on opposite sides of the axis in the same axial plane. The axial distance between them is a. The total dynamic reaction at the supports will be

(a) zero (b) $(W/g)\omega^2 e(a/L)$ (c) $(W/g)\omega e^2(a/L)$ (d) $(W/g)\omega^2 e(L/a)$

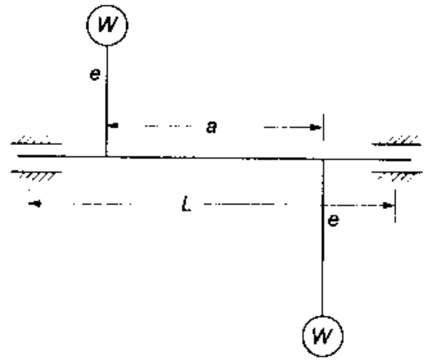


Fig.9

156. A reverted gear train is one in which the output shaft and input shaft

(a) rotate in opposite directions (b) are co-axial
(c) are at right angles to each other (d) are at an angle to each other

157. In the case of an involute toothed gear, the involute starts from

(a) the addendum circle (b) the dedendum circle
(c) the pitch circle (d) the base circle

158. In the epicyclic gear train shown in Fig.10, A is fixed. A has 100 teeth and B has 20 teeth.

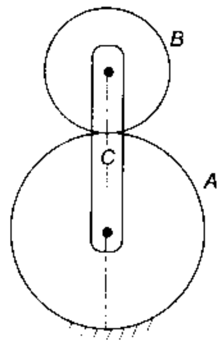


Fig.10

If the arm C makes three revolutions, the number of revolutions made by B will be

(a) 12 (b) 15 (c) 18 (d) 24

159. Which one of the following equations is valid with reference to the Fig.11?

(a) $\omega^2 = (W/w)(g/h)$

(b) $\omega^2 = [(W + w)/w](g/h)^{1/2}$

(c) $\omega^2 = [w/(W + w)](h/g)^{1/2}$

(d) $\omega^2 = [(W + w)/w](g/h)$

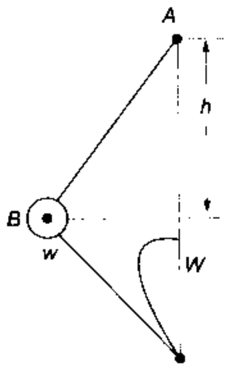


Fig.11

160. Which of the following statements are correct?

1. For constant velocity ratio transmission between two gears, the common normal at the point of contact must always pass through a fixed point on the line joining the centres of rotation of the gears.
2. For involute gears, the pressure angle changes with change in centre distance between gears.
3. The velocity ratio of compound gear train depends upon the number of teeth of the input and output gears only.
4. Epicyclic gear trains involve rotation of at least one gear axis about some other gear axis.

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1, 3 and 4 (c) 1, 2 and 4 (d) 2, 3 and 4

161. A compound train consisting of spur, bevel and spiral gears is shown in Fig.12, along with the teeth numbers marked against the wheels. The over-all speed ratio of the train is

(a) 8 (b) 2 (c) 1 / 2 (d) 1 / 8

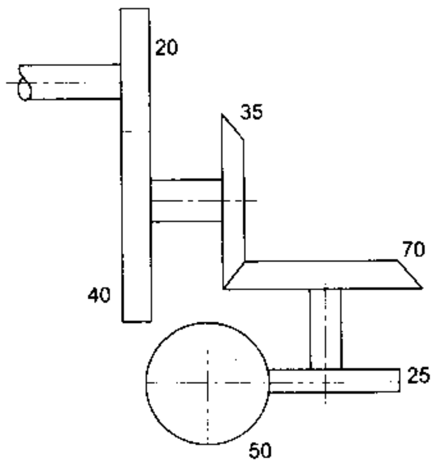


Fig.12

162. Which of the folowing statements hold good for a multicollar thrust bearing carrying an axial thrust of W units?

1. Friction moment is independent of the number of collars.
2. The intensity of pressure is affected by the number of collars.
3. Coefficient of friction of the bearing surface is affected by the number of collars.

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 1 and 3 (c) 2 and 3 (d) 1, 2 and 3

163. The centre of gravity of the coupler link in a four-bar mechanism would experience

(a) no acceleration (b) only linear acceleration
(c) only angular acceleration (d) both linear and angular acceleration

164. Which of the following pairs are correctly matched?

1. Lead screw nut —— Phosphor bronze 2. Piston —— Cast iron
3. Cam —— EN–31 steel 4. Lead screw —— Wrought iron

Select the correct answer using the codes given below:

(a) 2, 3 and 4 (b) 1, 3 and 4 (c) 1, 2 and 4 (d) 1, 2 and 3

165. Which one of the following is true for involute gears?

(a) Interference is inherently absent
(b) The variation in centre distance of shafts increases radial force
(c) A convex flank is always in contact throughout the teeth engagement
(d) The pressure angle is constant throughout the teeth engagement

166. The gear train usually employed in clocks is a

(a) reverted gear train (b) simple gear train
(c) sun and planet gear (d) differential gear

167. Consider the following statements regarding the differential of an automobile:

1. The speed of the crown wheel will always be the mean of the speeds of the two road wheels.
2. The road wheel speeds are independent of the number of teeth on the planet.
3. The difference between the speeds of the road wheels depends on the number of teeth on the planets.
4. The ratio of the speeds of the road wheels depends upon the number of teeth on the gear wheels attached to them and on the crown wheel.

Of these statements

(a) 1 and 2 are correct (b) 3 and 4 are correct
(c) 1 and 4 are correct (d) 2 and 4 are correct

168. A single epicyclic gear train is shown in Fig.13. Wheel A is stationary. If the number of teeth on *A* and *B* are 120 and 45 respectively, then when *B* rotates about its own axis at 100 rpm.

The speed of *C* would be

(a) 20 rpm (b) $27^3/11$ rpm (c) $19^7/11$ rpm (d) 100 rpm

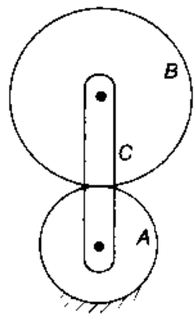


Fig.13

169. A rotor which is balanced statically but not dynamically is supported on two bearings L apart, and at high speeds of the rotor, dynamic reaction on the left bearing is R. The right side of the bearing is shifted to a new position $2L$ apart from the left bearing. At the same rotor speed, dynamic reaction on the left bearing in the new arrangement will

(a) remain same as before (b) becomes equal to $2R$
(c) becomes equal to $R/2$ (d) becomes equal to $R/4$

170. Consider the following statements regarding a high speed in- line engine with identical reciprocating parts with cranks spaced to give equal firing intervals:

1. All harmonic forces, except those which are multiples of half the number of cylinders, are balanced.
2. Couples are balanced if the engine is symmetrical about a plane normal to the axis of the crankshaft.
3. In a four cylinder in-line engine, second and fourth harmonic forces are unbalanced whereas in a six cylinder in-line engine, second, fourth and sixth harmonic forces are unbalanced.

Of these statements

(a) 1, 2 and 3 are correct (b) 1 and 3 are correct (c) 1 and 2 are correct (d) 2 and 3 are correct

171. In the statements, 'an eccentric mass rotating at 3000 rpm will create X times more unbalanced forces than 50% of the same mass rotating at 300 rpm', X stands for

(a) 10 (b) 50 (c) 100 (d) 200

172. In the given Fig.14, $ABCD$ is a four-bar mechanism. At the instant shown, AB and CD are vertical and BC is horizontal. Here AB is shorter than CD by 300 mm and AB is rotating at 5 rad/s and CD is rotating at 2 rad/s. The length of AB is

(a) 100 mm (b) 200 mm (c) 300 mm (d) 500 mm

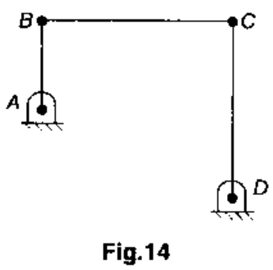


Fig.14

173. The two link system, shown in Fig.15 is constrained to move with planar motion.

It possesses

(a) 2-degree of freedom (b) 3-degree of freedom
(c) 4-degree of freedom (d) 6-degree of freedom

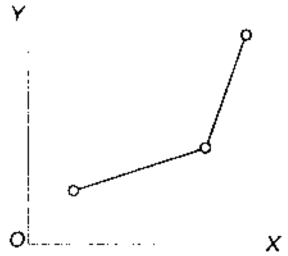


Fig.15

174. Two co-axial rotors having moments of inertia I_1, I_2 and angular speeds ω_1 and ω_2 respectively are engaged together. The loss of energy during engagement is equal to

(a) $I_1 I_2 (\omega_1 - \omega_2)^2 / 2 (I_1 + I_2)$ (b) $I_1 I_2 \left(\omega_1^2 - \omega_2^2\right)^2 / 2 (I_1 + I_2)$
(c) $2 I_1 I_2 (\omega_1 - \omega_2)^2 / (I_1 + I_2)$ (d) $\left(I_1 \omega_1^2 + I_2 \omega_2^2\right) / (I_1 + I_2)$

175. A spring controlled governor is found unstable. It can be made stable by

(a) increasing the spring stiffness (b) decreasing the spring stiffness
(c) increasing the ball weight (d) decreasing the ball weight

176. In a circular arc cam with roller follower, the acceleration in any position of the lift would depend only upon

(a) total lift, total angle of lift, minimum radius of cam and cam speed
(b) radius of the circular arc, cam speed, location of centre of circular arc and roller diameter
(c) weight of cam follower linkage, spring stiffness and cam speed
(d) total lift, centre of gravity of the cam and cam speed

177. The Klein's method of construction for reciprocating engine mechanism

(a) is a simplified version of instantaneous centre method
(b) utilises a quadrilateral similar to the diagram of mechanism for reciprocating engine
(c) enables determination of Corioli's component
(d) is based on the acceleration diagram

178. With reference to the mechanism shown in Fig.16, the relation between F and P is

(a) $F = (1/2) P \tan\alpha$ (b) $F = P \tan\alpha$ (c) $P = 2F \tan\alpha$ (d) $F = 2P \tan\alpha$

179. In the Fig.17, crank *AB* is 150 mm long and is rotating at 10 rad/s and *C* is vertically above *A*.

Length *CA* equals 240 mm and *C* is a swivel trunion through which *BD* (400 mm) slides. If *ABCD* becomes a vertical line during its motion, the angular velocity of the swivel trunion at that instant will be

(a) zero (b) (100 / 25) rad/s (c) (100 / 15) rad/s (d) (100 / 10) rad/s

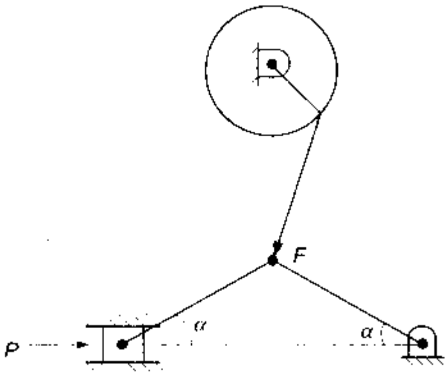


Fig.16

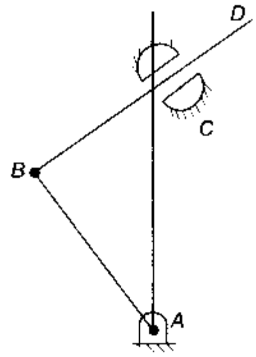


Fig.17

180. In order to draw the acceleration diagram, it is necessary to determine the Coriolis component of acceleration in the case of

(a) crank and slotted lever quick return mechanism
(b) slider crank mechanism
(c) four bar mechanism
(d) pantograph

181. What is the correct sequence of the following steps in engine analysis?

1. Vibration analysis
2. Inertia force analysis
3. Balancing analysis
4. Velocity and acceleration analysis

Select the correct answer using the codes given below:

(a) 2, 4, 1 and 3 (b) 2, 4. 3 and 1 (c) 4, 2, 3 and 1 (d) 4, 2, 1 and 3

182. If μ is the actual coefficient of friction in a belt moving in grooved pulley and the groove angle is 2α, the virtual coefficient of friction will be

(a) $\mu / \sin\alpha$ (b) $\mu / \cos\alpha$ (c) $\mu \sin\alpha$ (d) $\mu \cos\alpha$

83. A thin circular disc is rotating with a uniform linear speed, along a straight path on a plane surface. Consider the following statements in this regard:

1. All points on the disc have the same velocity
2. The centre of the disc has zero acceleration
3. The centre of the disc has centrifugal acceleration
4. The point on the disc making contact with the plane surface has zero acceleration

Of these statements

(a) 1 and 4 are correct (b) 3 and 4 are correct
(c) 3 alone is correct (d) 2 alone is correct

184. An elliptic trammel is shown in Fig.18. Associated with the motion of the mechanism are fixed and moving centrodes. It can be established analytically or graphically that the moving centrode is a circle with radius and centre respectively of

(a) l and O (b) $l/2$ and B (c) $l/2$ and C (d) $l/2$ and D

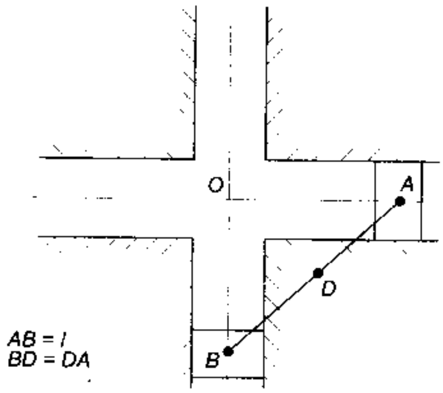


Fig.18

185. Given that T_1 and T_2 are the tensions on the tight and slack sides of the belt respectively, the initial tension of the belt taking into account centrifugal tension T_c, is equal to

(a) $(T_1 + T_2 + T_c)/3$ (b) $(T_1 + T_2 + 2T_c)/2$
(c) $(T_1 + T_2 + 3T_c)/3$ (d) $(T_1 - T_2 + 3T_c)/3$

186. Given that W = weight of load handled, W_r = weight of rope and f = aceleration, the additional load in ropes of a hoist during starting is given by

(a) $F_a = [(W - W_r)/g]f$ (b) $F_a = [(W + W_r)/g]f$
(c) $F_a = (W/g)f$ (d) $F_a = (W_r/g)f$

187. When a shaft transmits power through gears, the shaft experiences

(a) torsional stresses only
(b) bending stresses only
(c) constant bending and varying torsional stresses
(d) varying bending and constant torsional stresses

188. Which one of the following is an open pair?

(a) a ball and socket joint (b) a journal bearing
(c) a lead screw and nut (d) a cam and follower

189. In the mechanism *ABCD* shown in Fig.19, the fixed link denoted as 1, crank *AB* as 2, rocker *BD* as 3, swivel trunion at *C* as 4. The instantaneous centre I_{41} is at

(a) the centre of swivel trunion
(b) the intersection of line *AB* and a perpendicular to *BD* at *C*
(c) infinity along *AC*
(d) infinity perpendicular to *BD*

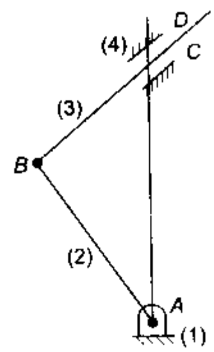


Fig.19

190. The instantaneous centre of motion of a rigid thin disc wheel rolling on a plane rigid surface shown in Fig.20, is located at the point

(a) A (b) B (c) C (d) D

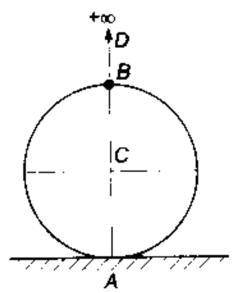


Fig.20

191. In a cam drive with uniform velocity follower, the slope of the displacement curve must be as shown in Fig.21(a). But in actual practice it is as shown in Fig.21(b), that is, rounded at the corners.

This is because of

(a) the difficulty in manufacturing cam profile
(b) loose contact of follower with cam surface
(c) the acceleration in the beginning and retardation at the end of stroke would require to be infinitely high
(d) uniform velocity motion is a partial parabolic motion

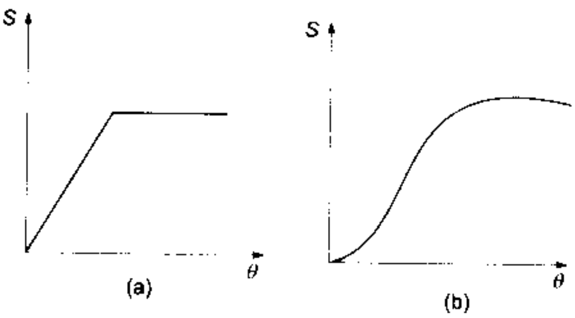


Fig.21

192. In a four stroke internal combustion engine, the turning moment during the compression stroke is
   (a) positive throughout
   (b) negative throughout
   (c) positive during major portion of the stroke
   (d) negative during major portion of the stroke

193. For a spring controlled governor to be stable, the controlling force F is related to the radius r by the equation
   (a) $F = ar - b$ (b) $F = ar + b$ (c) $F = ar$ (d) $F = a/r + b$

194. A rotor supported at *A* and *B*, carries two masses as shown in Fig.22.

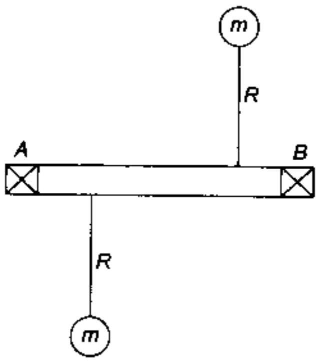


Fig.22

The rotor is
   (a) dynamically balanced (b) statically balanced
   (c) statically and dynamically balanced (d) not balanced

195. A round bar A passes through the cylindrical hole *B* as shown in Fig.23. Which one of the following statements is correct in this regard?
   (a) the two links shown form a kinematic pair
   (b) the pair is completely constrained
   (c) the pair has incomplete constraint
   (d) the pair is successfully constrained

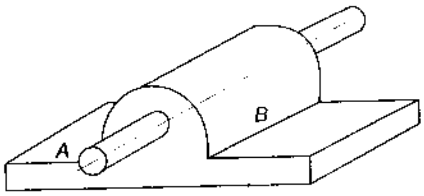


Fig.23

196. The instantaneous centre of rotation of a rigid thin disc rolling on a plane rigid surface is located at

(a) the centre of the disc

(b) an infinite distance on the plane surface

(c) the point of contact

(d) the point on the circumference situated vertically opposite to the contact point

197. The direction of Coriolis component of acceleration, $2\omega v$, of the slider A with respect to the coincident point *B* is shown in Fig.24 (i to iv).

Directions shown by figures

(a) 2 and 4 are correct

(b) 1 and 2 are correct

(c) 1 and 3 are correct

(d) 2 and 3 are correct

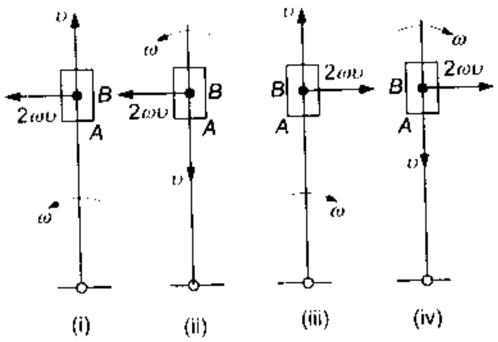


Fig.24

198. Klein's construction for determining the acceleration of piston P is shown in Fig.25.

When *N* coincides with *O*

(a) acceleration of piston is zero and its velocity is zero

(b) acceleration is maximum and velocity is maximum

(c) acceleration is maximum and velocity is zero

(d) acceleration is zero and velocity is maximum

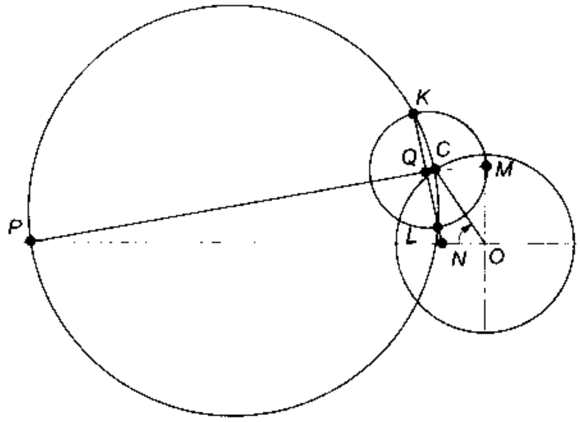


Fig.25

199. The cylinder shown in Fig.26 rolls without slipping. Towards which of the following points is the acceleration of the point of contact A on the cylinder directed?

(a) The mass centre (b) The geometric centre

(c) The point P as marked (d) None of the above

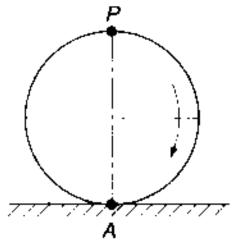


Fig.26

200. Total slip will occur in a belt drive when

(a) angle of rest is zero

(b) angle of creep is zero

(c) angle of rest is greater than angle of creep

(d) angle of creep is greater than angle of rest

201. To make a worm drive reversible, it is necessary to increase

(a) the centre distance (b) the worm diameter factor

(c) the number of starts (d) the reduction ratio

202. The cross-head velocity in the slider–crank mechanism, for the position shown in Fig.27 is,

(a) $v_c \cos[90° - (\alpha + \beta)] \cos\beta$ (b) $v_c \cos[90° - (\alpha + \beta)] \sec\beta$

(c) $v_c \cos[90° - (\alpha - \beta)] \cos\beta$ (d) $v_c \cos[90° - (\alpha - \beta)] \sec\beta$

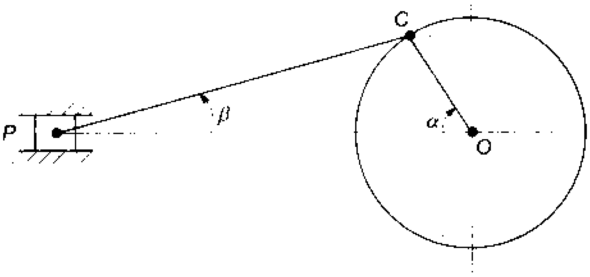


Fig.27

203. The percentage improvement in power capacity of a flat belt drive, when the wrap angle at the driving pulley is increased from 150° to 210° by an idler arrangement, for a friction coefficient of 0.3, is

(a) 25.21 (b) 392 (c) 40.17 (d) 67.85

204. The difference between tensions on the tight and slack sides of a belt drive is 3000 N. If the belt speed is 15 m/s, the transmitted power in kW is

(a) 45 (b) 22.5 (c) 90 (d) 100

205. The profile of a cam in a particular zone is given by $x = \sqrt{3}\cos\theta$ and $y = \sin\theta$.

The normal to the cam profile at $\theta = \pi/4$ is at an angle (with respect to x-axis)

(a) $\pi/4$ (b) $\pi/2$ (c) $\pi/3$ (d) 0

206. A flywheel of moment of inertia 9.8 kgm^2 fluctuates by 30 rpm for a fluctuation in energy of 1936 Joules. The mean speed of the flywheel is (in rpm)

(a) 600 (b) 900 (c) 968 (d) 2940

207. Consider the triangle formed by the connecting rod and the crank of an internal combustion engine as the two sides of the triangle. If the maximum area of this triangle occurs when the crank angle is 75°, the ratio of the connecting rod length to the crank radius is

(a) 5 (b) 4 (c) 73 (d) 3

208. Match List I and List II and select the correct answer using the codes given below the lists:

List I	List II
A. Quadric cycle chain	1. Elliptic trammel
B. Single slider crank chain	2. Rapson's slide
C. Double slider crank chain	3. Ackerman steering
D. Crossed slider crank chain	4. Eccentric mechanism
5. Pendulum pump	

Codes:

	A	B	C	D
(a)	5	4	2	1
(b)	3	1	5	4
(c)	5	3	4	2
(d)	3	5	1	2

209. For a twin cylinder V-engine, the crank positions for primary reverse cranks and secondary direct cranks are given in Fig.28.

The engine is a

(a) 60° V-engine (b) 120° V-engine
(c) 30° V-engine (d) 150° V-engine.

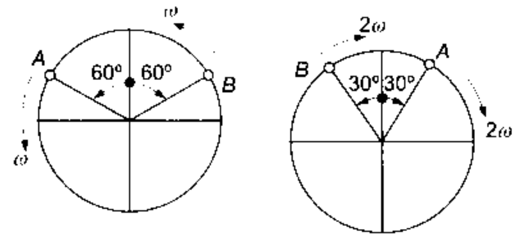


Fig.28

210. Consider the following statements:

1. A round bar in a round hole forms a turning pair.
2. A square bar in a square hole forms a sliding pair.
3. A vertical shaft in a footstep bearing forms a successful constraint.

Of these statements,

(a) 1 and 2 are correct (b) 2 and 3 are correct
(c) 1 and 3 are correct (d) 1, 2 and 3 are correct

211. The given Fig.29 shows the output torque plotted against crank positions for a single cylinder four stroke cycle engine. The areas lying above the zero-torque line represent positive work and the areas below represent negative work. The engine drives a machine which offers a resisting torque equal to the average torque. The relative magnitude of the hatched areas are given by the numbers (in the areas) as shown:

During the cycle, the minimum speed occurs in the engine at

(a) B (b) D
(c) H (d) F

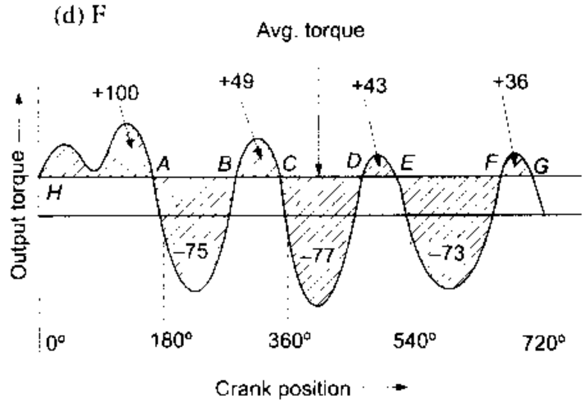


Fig.29

212. With reference to the engine mechanism shown in the Fig.30, match List I and List II and select the correct answer.

List I	List II
A. F_Q	1. Inertia force of reciprocating mass
B. F_R	2. Inertia force of connecting rod
C. F_W	3. Crank effort
D. F_C	4. Piston side thrust

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	2	3	4
(c)	4	1	2	3
(d)	4	1	3	2

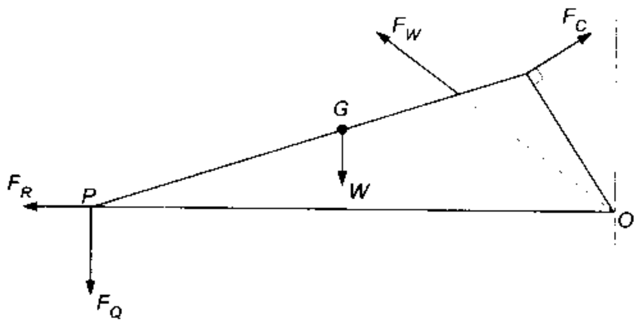


Fig.30

213. Match List I with List II and select the correct answer.

List I	List II
A. Hunting	1. One radium rotation for each speed.
B. Isochronism	2. Too sensitive.
C. Stability	3. Mean force exerted at the sleeve during change of speed.
D. Effort	4. Constant equilibrium speed for all radii of rotation.

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	4	2
(c)	2	1	4	3
(d)	1	2	3	4

214. Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
A. Quadric cycle chain	1. Rapson's slide.
B. Single slider crank chain	2. Oscillating cyclinder engine mechanism
C. Double slider crank chain	3. Ackermann steering mechanism
D. Crossed slider crank chain	4. Oldham's coupling

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	4	3	2	1
(c)	3	4	1	2
(d)	3	2	4	1

215. Which of the following pair(s) is/are correctly matched?

I. Four bar chain	Oscillating-oscillating converter
II. Inertia governor	Rate of change of engine speed
III. Hammer bellow	Reciprocating unbalance

Select the correct answer using the codes given below:

Codes:

(a) I alone (b) I, II and III (c) II and III (d) I and II

216. Which of the following (Fig.31) are examples of a kinematic chain?

Select the correct answer using the codes given below:

Codes:

(a) 1, 3 and 4 (b) 2 and 4 (c) 1, 2 and 3 (d) 1, 2, 3 and 4

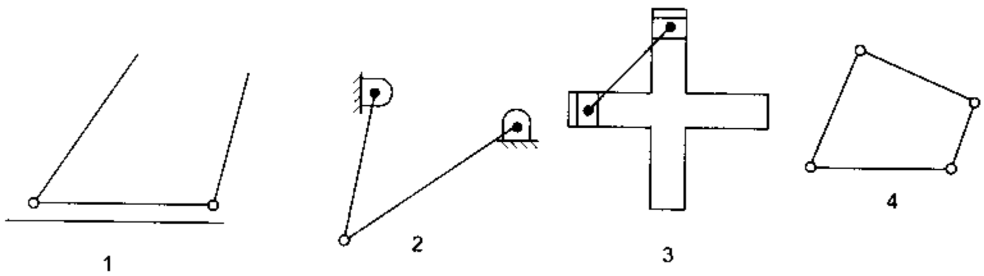


Fig.31

217. Which of the following pairs are correctly matched? Select the correct answer using the codes given below the pairs.

Mechanism	Chain from which derived
1. Whitworth quick-return motion	Single slider crank chain
2. Oldham's coupling	Four bar chain

3. Scotch-Yoke | Double slider crank chain

Codes:

(a) 1 and 2 (b) 1, 2 and 3 (c) 1 and 3 (d) 2 and 3

218. The link *OA* and *OB* are connected by a pin joint at *O*. The link *OA* turns with angular velocity ω_1 radians per second in the clockwise direction and the link *OB* turns with angular velocity ω_2 radians per second in the counter-clockwise direction. If the radius of the pin at *O* is r, then the rubbing velocity at the pin joint *O* will be

(a) $\omega_1 \cdot \omega_2 \cdot r$ (b) $(\omega_1 - \omega_2)\,r$ (c) $(\omega_1 + \omega_2)\,r$ (d) $(\omega_1 - \omega_2)\,2r$

219. Which one of the following shown in Fig.32(a–d) representing Hooke's jointed inclined shaft system will result in a velocity ratio of unity?

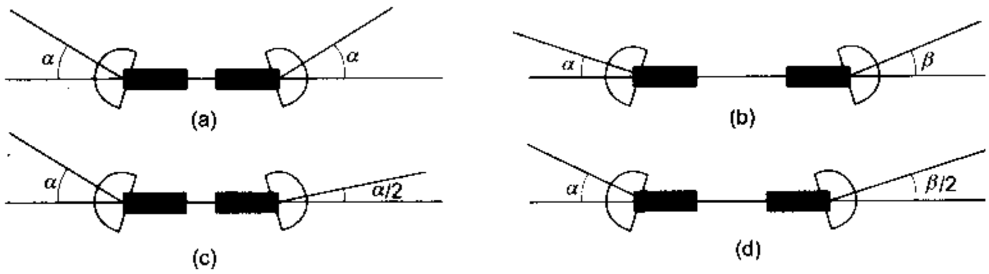


Fig.32

220. A four-cylinder symmetrical in-line engine is shown in Fig.33. Reciprocating weights per cylinder are R_1 and R_2 and the corresponding angular disposition of the crank are α and β.

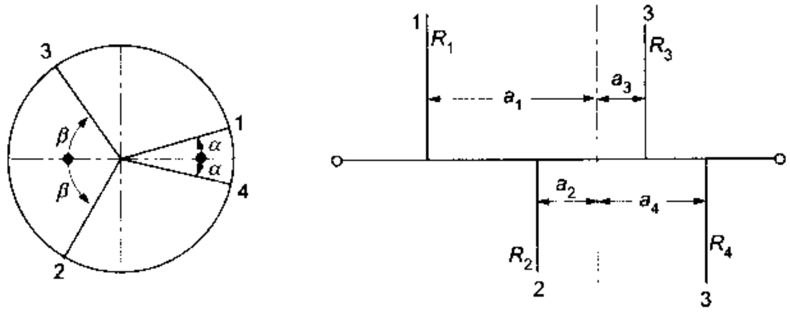


Fig.33

Which one of the following equations should be satisfied for its primary force balance?

(a) $a_1 \tan\alpha = a_2 \tan\beta$ (b) $\cos\alpha = 0.5\sec\beta$

(c) $R_1 a_1 \sin 2\alpha = R_2 a_2 \sin 2\beta$ (d) $a_1 \cos\alpha = R_2 \cos\beta$

221. Match List I with List II and select the correct answer using the codes given below the lists:

List I	**List II**
A. 4 links, 4 turning pairs	1. Complete constraint
B. 3 links, 3 turning pairs	2. Successful constraint
C. 5 links, 5 turning pairs	3. Rigid frame
D. Footstep bearing	4. Incomplete constraint

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	1	3	2	4
(c)	3	1	2	4
(d)	1	3	4	2

222. Consider the four-bar mechanism shown in Fig.34. The driving link *DA* is rotating uniformly at a speed of 1000 r.p.m. clockwise. The velocity of *A* will be:

(a) 300 cm/s (b) 314 cm/s (c) 325 cm/s (d) 400 cm/s

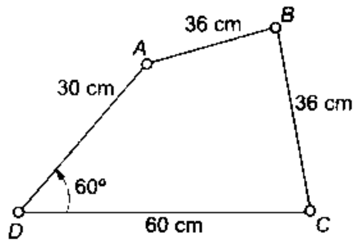


Fig.34

223. Which one of the following pairs in correctly matched?

(a) Governors	Interference
(b) Gears	Hunting
(c) Klein's construction	Accelration of piston
(d) Cam	Pinion

224. For a given lift of the follower in a given angular motion of the cam, the acceleration/retardation of the follower will be the least when the profile of the cam during the rise portion is:

(a) such that the follower motion is simple harmonic

(b) such that the follower motion has a constant velocity from start to end

(c) a straight line, it being a tangent cam

(d) such that the follower velocity increases linearly for half the rise portion and the decreases linearly for the remaining half of the rise portion

225. Consider the following statements regarding the choice of conjugate teeth for the profile of mating gears:

1. They will transmit the desired motion
2. They are difficult to manufacture
3. Standardisation is not possible
4. The cost of production is low

Which of these statements are correct?

(a) 1,2 and 3 (b) 1, 2 and 4 (c) 2, 3 and 4 (d) 1, 3 and 4

226. Consider the following parameters:

1. Limit of peripheral speed
2. Limit of centrifugal stress
3. Coefficient of fluctuation of speed
4. Weight of the rim

Which of these parameters are used in the calculation of the diameter of flywheel rim?

(a) 1,3 and 4 (b) 2, 3 and 4 (c) 1, 2 and 3 (d) 1, 2 and 4

227. Consider the following speed governors:

1. Porter governor 2. Hartnell governor 3. Watt governor 4. Proell governor

The correct sequence of development of these governors is:

(a) 1, 3, 2, 4 (b) 3, 1, 4, 2 (c) 3, 1, 2, 4 (d) 1, 3, 4, 2

228. Consider the gear train shown in Fig.35 and table of gears and their number of teeth.

Gear	:	A	B	C	D	E	F
No. of teeth	:	20	50	25	75	26	65

Gears *BC* and *DE* are moulded on parallel shaft rotating together.

If the speed of *A* is 975 rpm, the speed of *F* will be

(a) 39 rpm (b) 52 rpm (c) 75 rpm (d) 80 rpm

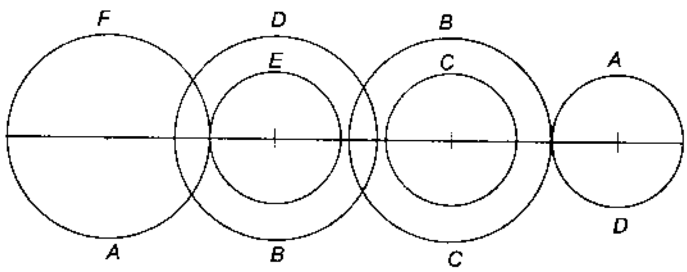


Fig.35

229. The kinematic chain shown in Fig.36 is a

(a) structure

(b) mechanism with one degree of freedom

(c) mechanism with two degrees of freedom

(d) mechanism with more than two degrees of freedom

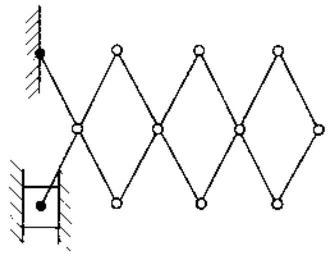


Fig.36

230. A point on a link connecting a double slider crank chain will trace a

(a) straight line (b) circle
(c) parabola (d) ellipse

231. A wheel is rolling on a straight level track with a uniform velocity v. The instantaneous velocity of a point on the wheel lying at the midpoint of a radius

(a) varies between $3v/2$ and $v/2$
(b) varies between $v/2$ and $-v/2$
(c) varies between $3v/2$ and $-v/2$
(d) does not vary and is equal to v

232. A four-bar chain has

(a) all turning pairs
(b) one turning pair and others are sliding pairs
(c) one sliding pair and the others are turning pairs
(d) all sliding pairs

233. Masses B_1 and B_2 and 9 kg are attached to a shaft in parallel planes as shown in Fig.37. If the shaft is rotating at 100 rpm, the mass B_2 is

(a) 3 kg (b) 6 kg (c) 9 kg (d) 27 kg

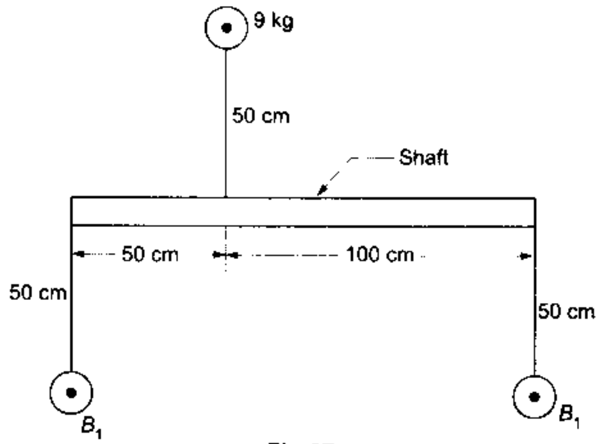


Fig.37

234. The velocity ratio in the case of the compound train of wheels is equal to

(a) number of teeth on first driver/number of teeth on last driver

(b) number of teeth on last driver/number of teeh on first driver

(c) product of teeth on the drivers/product of teeth on the followers

(d) product of teeth on the followers/product of teeth on the drivers

235. Consider the following pairs of parts

1. Pair of gear in mesh
2. Belt and pulley
3. Cylinder and piston
4. Cam and follower

Among these, the higher pairs are

(a) 1 and 4 (b) 2 and 4 (c) 1, 2 and 3 (d) 1, 2 and 4

236. Which one of the following sets of accelerations is involved in the motion inside the cylinder of a uniformly rotating cylinder mechanism?

(a) Coriolis and radial acceleration

(b) Radial and tangential acceleration

(c) Coriolis and gyroscopic acceleration

(d) Gyroscopic and tangential acceleration

237. Consider the following statements:

1. Round bar in a round hole forms a turning pair.
2. A square bar in a square hole forms a sliding pair.
3. A vertical shaft in a foot-step bearing forms a successful constraint.

Which of these statements are correct?

(a) 1 and 3 (b) 1 and 2 (c) 2 and 3 (d) 1, 2 and 3

238. Consider the following statements regarding the turning moment diagram of a reciprocating engine shown in Fig.38. (Scale 1 cm^2 = 100 Nm)

1. It is four stroke internal combustion engine.
2. The compression stroke is 0° to 180°.
3. The mean turning moment, $T_m = 580/\pi$ Nm.
4. It is a multi-cylinder engine.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1, 2 and 4 (c) 2, 3 and 4 (d) 1, 3 and 4

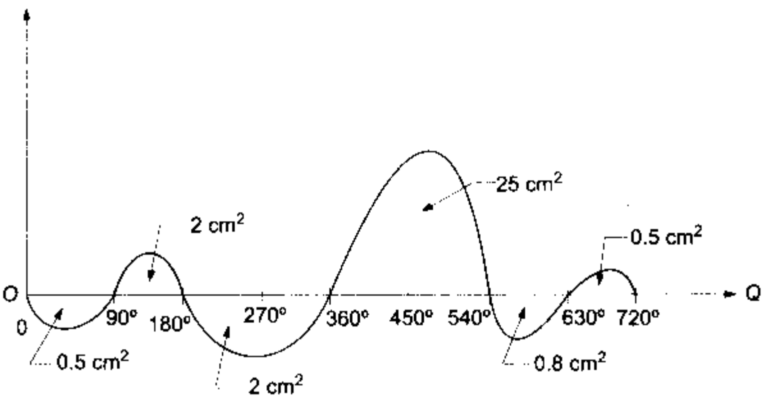


Fig.38

239. The pitching of a ship in the ocean is an oscillatory periodic motion. A ship is pitching 6° above and 6° below with a period of 20 s from its horizontal plane. Consider the following statements in this regard:

1. The motion has a frequency of oscillation (that is pitching) of 3 cycles / minute.
2. The motion has an angular frequency of 3.14 rad/s.
3. The angular velocity of precession of ship's rotor is $\pi^2/300$ rad/s.
4. The amplitude of pitching is $\pi/30$ rad.

Which of these statements are correct?

(a) 1 and 2 (b) 1, 2 and 4 (c) 2, 3 and 4 (d) 1, 3 and 4

240. Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
A. Compound train	1. Hart mechanism
B. Quick return mechanism	2. Coriolis force
C. Exact straight line motion	3. Transmission of motion around bends and corners
D. Approximate straight line motion	4. Watt mechanism

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	2	1	4
(c)	3	4	1	2
(d)	1	4	3	2

241. Match List I (Kinematic inversions) with List II (Applications) and select the correct answer using the codes given below the lists:

A. 1. Hand pump

B. 2. Compressor

C. 3. Whitworth quick-return mechanism

D. 4. Oscillating Cylinder Engine

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	2	4	3	1
(c)	2	3	4	1
(d)	1	4	3	2

242. Match List I (Applications) with List II (Drive elements) and select the correct answer using the codes given below the lists:

List I	**List II**
A. Automobile differential	1. Flat belt
B. Bi-cycle	2. V-belt
C. Planing machine	3. Chain drive
D. Radiator fan of automobile	4. Gear drive

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	3	4	2
(c)	4	2	1	3
(d)	1	2	4	3

243. Consider the following statements regarding motions in machines:

1. The tangential acceleration is a function of angular velocity and the radial acceleration is a function of angular acceleration.
2. The resultant acceleration of a point A with respect to a point B on a rotating link is perpendicular to AB.
3. The direction of the relative velocity of a point A with respect to a point B on a rotating link is perpendicular to AB

Which of these statements is/are correct?

(a) 1 alone (b) 2 and 3 (c) 1 and 2 (d) 3 alone

244. Consider the following statements:

In petrol engine mechanism, the piston is at its dead centre position when piston:

1. the acceleration is zero
2. the acceleration is maximum
3. the velocity is zero
4. the velocity is infinity

Which of these statements are correct?

(a) 1 and 4 (b) 1 and 3 (c) 2 and 3 (d) 2 and 4

245. The speed of driving shaft of a Hooke's joint of angle 19.5° (given sin 19.5° = 0.33, cos 19.5° = 0.94) is 500 rpm. The maximum speed of the driven shaft is nearly

(a) 168 rpm (b) 444 rpm (c) 471 rpm (d) 531 rpm

246. The given Fig.39 shows the Klein's construction for acceleration of the slider–crank mechanism.

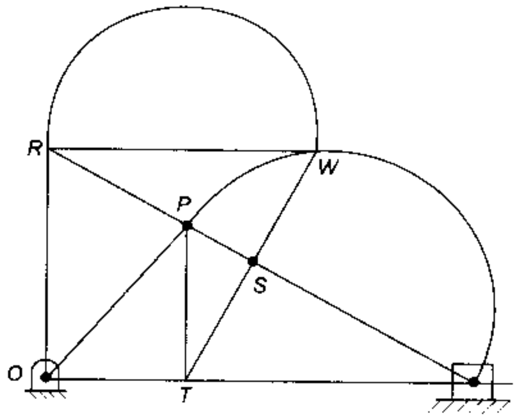


Fig.39

Which one of the following quadrilaterals represents the required acceleration diagram?

(a) ORST (b) OPST (c) ORWT (d) ORPT

247. The creep in a belt drive is due to the

(a) material of the pulleys

(b) material of the belt

(c) unequal size of the pulleys

(d) unequal tension on tight and slack sides of the belt

248. Match List I with List II and select the correct answer using the codes given below the lists:

List I	List II
A. Cam and follower	1. Grubler's rule
B. Screw pair	2. Grashof's linkage
C. 4-bar mechanism	3. Pressure angle
D. Degree of freedom of planar mechanism	4. Single degree of freedom.

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	1	2	4	3
(c)	1	4	2	3
(d)	3	2	4	1

249. Consider the following statements:

When two gears are mating, the clearance is given by the

1. difference between dedendum of one gear and addendum of the mating gear.
2. difference between total and the working depth of a gear tooth.
3. distance between the bottom land of one gear and the top land of the mating gear.
4. difference between the radii of the base circle and the dedendum circle.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2, 3 and 4 (c) 1, 3 and 4 (d) 1, 2 and 4

250. A body of mass m and radius of gyration k is to be replaced by two masses m_1 and m_2 located at distances h_1 and h_2 from the centre of gravity of the original body. An equivalent dynamic system will result, if

(a) $h_1 + h_2 = k$ (b) $h_1^2 + h_2^2 = k^2$ (c) $h_1 h_2 = k^2$ (d) $\sqrt{h_1 h_2} = k^2$

251. In a simple gear train, if the number of idler gears is odd, then the direction of motion of driven gear will

(a) be same as that of the driving gear
(b) be opposite to that of the driving gear
(c) depend upon the number of teeth on the driving gear
(d) depend upon the total number of teeth on all gears of the train

252. A motor car has wheel base of 280 cm and the pivot distance of front stub axles is 140 cm. When the outer wheel has turned through 30°, the angle of turn of the inner front wheel for correct steering will be

(a) 60° (b) $\cot^{-1} 2.23$ (c) $\cot^{-1} 1.23$ (d) 30°

253. In a multi-plate clutch with n_0 number of outer discs and n_i number of inner discs, the number of pairs of active services is

(a) $n_i + n_o$ (b) $n_i + n_o + 1$ (c) $n_i + n_o - 1$ (d) $n_i + n_o - 2$

254. In a slider–crank mechanism, the maximum acceleration of slider is obtained when the crank is

(a) at the inner dead centre position
(b) at the outer dead centre position
(c) exactly midway position between the two dead centres
(d) slightly in advance of the midway position between the two dead centres

255. For the planar mechanism shown in Fig.40, select the most appropriate choice for the motion of link 2 when link 4 is moved upwards.

(a) Link 2 rotates clockwise.
(b) Link 2 rotates counter-clockwise.
(c) Link 2 does not move.
(d) Link 2 motion can not be determined.

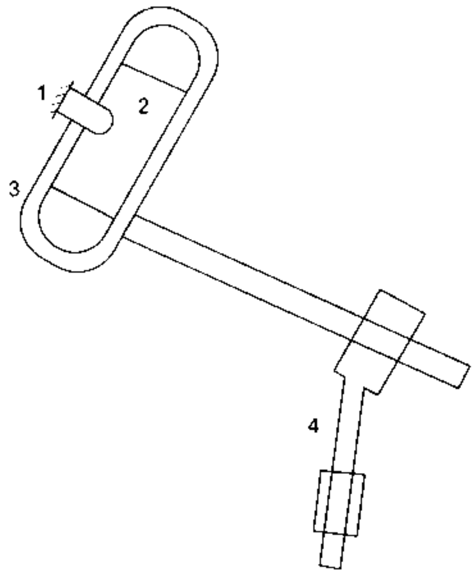


Fig.40

256. For the audio cassette mechanism shown in Fig.41, where is the instantaneous centre of rotation (point) of the two spools?

(a) Point P lies to the left of both the spools but at infinity along the line joining *A* and *H*.
(b) Point P lies between the two spools on the line joining *A* and *H*, such that $PH = 2AP$.
(c) Point P lies to the right of both the spools on the line joining *A* and *H*, such that $AH = HP$.
(d) Point P lies at the intersection of the line joining *B* and *C* and the line joining *G* and *F*.

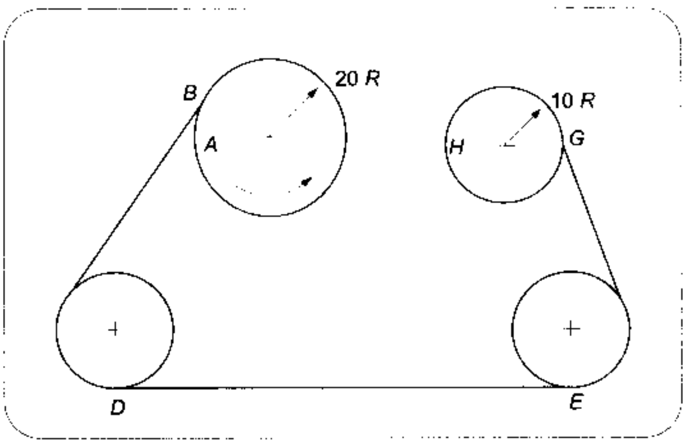


Fig.41

257. With regard to belt drives with given pulley diameters, centre distance and coefficient of friction between the pulley and the belt materials, which of the statements below are FALSE?

(a) A crossed flat belt configuration can transmit more power than an open flat belt configuration.
(b) A V-belt has greater power transmission capacity than an open flat belt.

(c) Power transmission is greater when the belt tension is higher due to centrifugal effects than the same belt drive when centrifugal effects are absent.

(d) Power transmission is the greatest just before the point of slipping is reached.

258. The ratio of tension on the tight side to that on the slack side in a flat belt drive is

(a) proportional to the product of coefficient of friction and lap angle

(b) an exponential function of the product of coefficient of friction and lap angle

(c) proportional to the lap angle

(d) proportional to the coefficient of friction

259. A 1.5 kW motor is running at1440 rev/min. It is to be connected to a stirrer running at 36 rev/min. The gearing arrangement suitable for this application is:

(a) a differential gear (b) a helical gear (c) a spur gear (d) a worm gear

260. A steel wheel of 600 mm diameter rolls on a horizontal steel rail. It carries a load of 500 N. The coefficient of rolling resistance is 0.3. The force in Newtons, necessary to roll the wheel along the rail is

(a) 0.5 (b) 5 (c) 15 (d) 150

261. An automobile of weight W is shown in Fig.42. A pull P is applied as shown. The reaction of the front wheel (location A) is

(a) $W/2 - Pb/2a$ (b) $W/2 + Pb/2a$ (c) $W/2 - Pa/2b$ (d) $W/2$

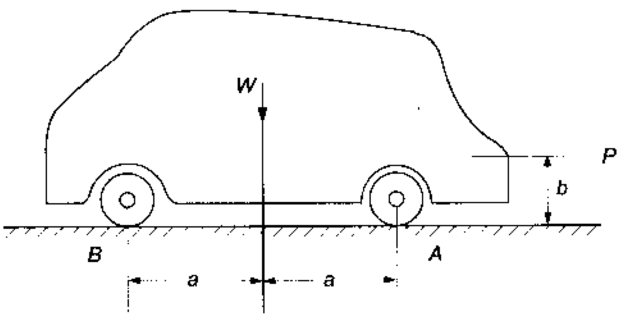


Fig.42

262. In an experiment to find the velocity and acceleration of a particular cam rotating at 10 rad/s, the values of displacement and velocities are recorded. The slope of displacement curve at an angle of q is 1.5 m/s and the slope of velocity curve at the same angle is -0.5 m/s^2. The velocity and acceleration of the cam at the instant are respectively:

(a) 15 m/s and -5 m/s^2 (b) 15 m/s and 5 m/s^2

(c) 1.2 m/s and -0.5 m/s^2 (d) 1.2 m/s and 0.5 m/s^2

263. For a spring loaded roller-follower driven with a disc cam,

(a) the pressure angle should be larger during rise than that during return for ease of transmitting motion

(b) the pressure angle should be smaller during rise than that during return for ease of transmitting motion

(c) the pressure angle should be large during rise as well as during return for ease of transmitting motion

(d) the pressure angle does not affect the ease of transmitting motion

264. Which of the following statement is correct?

(a) Flywheel reduces speed fluctuations during a cycle for a constant load, but flywheel does not control the mean speed of the engine if the load changes.

(b) Flywheel reduces reduce speed fluctuations during a cycle for a constant load, but flywheel does control the mean speed of the engine if the load changes.

(c) Governor controls speed fluctuations during a cycle for a constant load, but governor does not control the mean speed of the engine if the load changes.

(d) Governor controls speed fluctuations during a cycle for a constant load and governor also controls the mean speed of the engine if the load changes.

265. The sun gear in Fig.43 is driven clockwise at 100 rpm. The ring gear is held stationary. For the number of teeth shown on the gears, the arm rotates at

(a) 0 rpm (b) 20 rpm (c) 33.33 rpm (d) 66.67 rpm

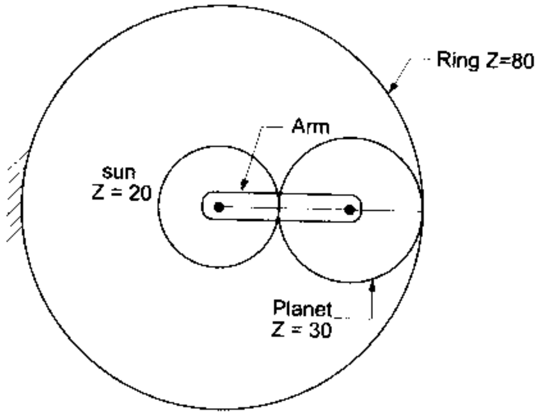


Fig.44

Answers

1.(d)	2.(c)	3.(a)	4.(d)	5.(d)	6.(d)	7.(b)	8.(c)	9.(d)	10.(b)
11.(c)	12.(d)	13.(c)	14.(c)	15.(b)	16.(b)	17.(a)	18.(a)	19.(a)	20.(a)
21.(b)	22.(a)	23.(b)	24.(b)	25.(c)	26.(c)	27.(b)	28.(b)	29.(a)	30.(b)
31.(c)	32.(d)	33.(b)	34.(b)	35.(b)	36.(b)	37.(a)	38.(a)	39.(a)	40.(a)
41.(a)	42.(a)	43.(a)	44.(c)	45.(b)	46.(b)	47.(c)	48.(b)	49.(b)	50.(b)
51.(a)	52.(c)	53.(a)	54.(b)	55.(a)	56.(a)	57.(b)	58.(b)	59.(a)	60.(a)
61.(d)	62.(b)	63.(a)	64.(a)	65.(b & d)	66.(a)	67.(c)	68.(c)	69.(c)	70.(a)
71.(d)	72.(d)	73.(d)	74.(b)	75.(c)	76.(c)	77.(d)	78.(d)	79.(b)	80.(b)
81.(d)	82.(d)	83.(b)	84.(d)	85.(d)	86.(d)	87.(a)	88.(c)	89.(c)	90.(a)
91.(d)	92.(a)	93.(c)	94.(a)	95.(d)	96.(c)	97.(a)	98.(b)	99.(c)	100.(a)
101.(c)	102.(b)	103.(a)	104.(a)	105.(b)	106.(c)	107.(c)	108.(a)	109.(a)	110.(b)
111.(b)	112.(c)	113.(c)	114.(d)	115.(b)	116.(d)	117.(b)	118.(a)	119.(c)	120.(b)
121.(b)	122.(d)	123.(b)	124.(b)	125.(d)	126.(b)	127.(b)	128.(a)	129.(c)	130.(c)
131.(c)	132.(b)	133.(b)	134.(a)	135.(d)	136.(d)	137.(b)	138.(a)	139.(c)	140.(b)
141.(a)	142.(b)	143.(d)	144.(a)	145.(d)	146.(a)	147.(c)	148.(d)	149.(c)	150.(b)
151.(d)	152.(b)	153.(a)	154.(a)	155.(b)	156.(b)	157.(d)	158.(c)	159.(d)	160.(c)
161.(d)	162.(a)	163.(d)	164.(b)	165.(d)	166.(a)	167.(a)	168.(b)	169.(a)	170.(a)
171.(d)	172.(b)	173.(a)	174.(a)	175.(a)	176.(b)	177.(d)	178.(b)	179.(a)	180.(a)
181.(d)	182.(a)	183.(a)	184.(a)	185.(b)	186.(b)	187.(c)	188.(d)	189.(d)	190.(a)
191.(c)	192.(d)	193.(a)	194.(c)	195.(c)	196.(c)	197.(c)	198.(d)	199.(c)	200.(a)
201.(c)	202.(b)	203.(d)	204.(a)	205.(c)	206.(a)	207.(c)	208.(d)	209.(a)	210.(d)
211.(d)	212.(c)	213.(a)	214.(d)	215.(c)	216.(d)	217.(c)	218.(d)	219.(a)	220.(d)
221.(d)	222.(b)	223.(c)	224.(b)	225.(a)	226.(a)	227.(b)	228.(b)	229.(b)	230.(d)
231.(b)	232.(a)	233.(b)	234.(c)	235.(d)	236.(a)	237.(d)	238.(a)	239.(d)	240.(b)
241.(c)	242.(a)	243.(d)	244.(c)	245.(d)	246.(c)	247.(d)	248.(a)	249.(a)	250.(c)
251.(a)	252.(c)	253.(c)	254.(a)	255.(b)	256.(d)	257.(c)	258.(b)	259.(d)	260.(d)
261.(b)	262.(c)	263.(c)	264.(b)	265.(b)					

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