WINTER – 19 EXAMINATION

Subject Name: Theory of Machines **Model Answer** Subject Code: **17412**

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q. 1	**(A)**	**Attempt any SIX of the following: (2 x 6)**	**12**
	(a)	**Define Mechanism. State any one example of Mechanism.**	**02**
	Ans.	**Mechanism**: When one of the links of a kinematic chain is fixed, the chain is known as mechanism. It may be used for transmitting or transforming motion. **Example of Mechanism:** Engine Indicators, Typewriter, Screw Jack etc, Gear Pump, Slider Crank. **(01 Mark for Definition, 01 Mark for any one appropriate example)**	01 01
	(b)	**Define machine and structure.**	**02**
	Ans.	**Machine**: Machine is a device which receives energy and transforms it into some useful work. A machine consists of a number of parts or bodies. **Structure:** A 'structure' may be regarded as an assemblage of a number of resistant bodies called members, having no relative motion between them and meant for carrying loads having straining action. **(01 Mark for each appropriate definition)**	01 01

	(c)	**Define fluctuation of energy and coefficient of fluctuation of energy.**	**02**
	Ans.	**Fluctuation of Energy:** The variations of energy above and below the mean resisting torque line are called fluctuations of energy. **Coefficient of Fluctuation of Energy:** It may be defined as the ratio of the maximum fluctuation of energy to the work done per cycle. **(01 Mark for each appropriate definition)**	01 01
	(d)	**Define Slip and Creep in case of belt drive.**	**02**
	Ans.	**Slip of belt:** The forward motion of the belt without carrying the driven pulley with it is called **slip of the belt.** **Or** When belt is transmitted power from driver to driven pulley, there is a loss of motion due to insufficient frictional grip and therefore the speed of driven pulley is less than driver pulley. This is known as ***Slip of the belt*** and generally expressed in percentage (%) **Creep of Belt:** When the belt passes from the slack side to the tight side, a certain portion of the belt extends and it contracts again when the belt passes from the tight side to slack side. Due to these changes of length, there is a relative motion between the belt and the pulley surfaces. This relative motion is termed as ***creep.*** **(01 Mark for each appropriate definition)**	01 01
	(e)	**State the function of flywheel in an I.C. Engine**	**02**
	Ans.	**Function of flywheel:** A flywheel stores energy when the supply is in excess and releases energy when energy is in deficit. **Or** Flywheel is a mechanical device which stores the excess energy and releases it whenever required by the crankshaft during non power strokes with following function. [1] To absorb energy. [2] To reduce fluctuation of speed. **(02 Marks for appropriate functional statement)**	02

	(f)	**Explain the concept of balancing.**	**02**
	Ans.	**Concept of balancing:** Whenever a certain mass is attached to a rotating shaft, it exerts some *centrifugal force*, whose effect is to bend the shaft and to produce vibrations in it. In order to prevent the effect of centrifugal force, another mass is attached to the opposite side of the shaft, at such a position so as to balance the effect of the centrifugal force of the first mass. This is done in such a way that the centrifugal force of both the masses is made to be equal and opposite. *The process of providing the second mass in order to counteract the effect of the centrifugal force of the first mass, is called balancing of rotating masses.* **(02 Marks for a brief explanation of Concept of Balancing with key terms)**	02
	(g)	**Define Pitch curve and Prime Circle w.r.t. cams.**	**02**
	Ans.	**Pitch curve:** It is the curve generated by the trace point as the follower moves relative to the cam. **Or** The path generated by the trace point as the follower is rotated about a stationery cam is known as Pitch Curve. **Prime circle:** It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve. **(01 Mark for each appropriate Definition)**	01 01
	(h)	**State the function of brake and dynamometer.**	**02**
	Ans.	**Brake:** A brake is a device by means of which artificial frictional resistance is applied to a moving machine member, in order to retard or stop the motion of a machine. **Dynamometer:** A dynamometer is a brake but in addition it has a device to measure the frictional resistance and by Knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine. **(01 Mark for each appropriate functional Statement)**	01 01
Q.1	**(B)**	**Attempt any TWO of the following: (2x 4)**	**08**
	(a)	**Distinguish between mechanism and machine.**	**04**
	Ans.	(table below)	

Sr. No.	Mechanism	Machine
1	One of links in a kinematic chain is fixed known as a **Mechanism.**	**Machine** receives energy in some available form & uses it to do some work.
2	Having relative motion with respect	Link or part of Machine has relative

	to other parts.	motion with respect to another.
3	Primary function is used to transmit or modify the motion.	Primary function is to obtain the mechanical advantage.
4	It is not used to transmit the force.	It is used transmit the force.
5	A mechanism is a single system to transfer the motion	A machine has one or more mechanism to perform the desired function
6	eg. In watch, energy stored on winding the spring is used to move hands An indicator is used to draw P-V diagram of engine, Engine Indicators, Type Writer, Gear Pump, Slider Crank etc.	eg. Shaper receives mechanical power which is used to suitably convert to do work of cutting the metal. A hoist is machine to lift the loads, Steam Engine, I C Engine, Turbine, Lathe Machine.

01 mark for each points

(Any 04 Points, 01 Mark for each)

(b) **A conical pivot bearing supports a vertical shaft of 200 mm diameter. It is subjected to a load of 30 KN. The angle of the cone is 120° and the coefficient of friction is 0.025. Find the power lost in friction when the speed is 140 rpm. Assuming (i) Uniform Pressure (ii) Uniform Wear.** **04**

Ans.

Given : $D = 200$ mm or $R = 100$ mm $= 0.1$ m ; $W = 30$ kN $= 30 \times 10^3$ N ; $2\alpha = 120°$ or $\alpha = 60°$; $\mu = 0.025$; $N = 140$ r.p.m. or $\omega = 2\pi \times 140/160 = 14.66$ rad/s — 01 Mark

1. Power lost in friction assuming uniform pressure

We know that total frictional torque,

$$T = \frac{2}{3} \times \mu W.R.\ \text{cosec}\ \alpha$$

1.5 Mark

$$= \frac{2}{3} \times 0.025 \times 30 \times 10^3 \times 0.1 \times \text{cosec}\ 60° = 57.7\ \text{N-m}$$

∴ Power lost in friction,

$$P = T.\omega = 57.7 \times 14.66 = 846\ \text{W}$$

1.5 Mark

2. Power lost in friction assuming uniform wear

We know that total frictional torque,

$$T = \frac{1}{2} \times \mu W.R.\ \text{cosec}\ \alpha$$

$$= \frac{1}{2} \times 0.025 \times 30 \times 10^3 \times 0.1 \times \text{cosec}\ 60° = 43.3\ \text{N-m}$$

∴ Power lost in friction, $P = T.\omega = 43.3 \times 14.66 = 634.8$ W

(01 Mark for Given Data, 1.5 Mark for each Condition)

	(c)	**State the advantages of V Belt drive over flat belt drive.**	**04**
	Ans.	**Advantages of V-belt drive over flat belt drive:** 1. It gives compactness due to the small distance between the centres of pulleys. 2. The drive is positive, because the slip between the belt and the pulley groove is negligible. 3. Since the V-belts are made endless and there is no joint trouble, therefore the drive is smooth. 4. It provides longer life, 3 to 5 years. 5. It can be easily installed and removed. 6. The operation of the belt and pulley is quiet. 7. The belts have the ability to cushion the shock when machines are started. 8. The high velocity ratio (maximum 10) may be obtained. 9. The wedging action of the belt in the groove gives high value of limiting ratio of tensions. Therefore the power transmitted by V-belts is more than flat belts for the same coefficient of friction, arc of contact and allowable tension in the belts. 10. The V-belt may be operated in either direction with tight side of the belt at the top or bottom. The centre line may be horizontal, vertical or inclined. **(Any four appropriate points, 01 Mark each)**	04
Q.2		**Attempt any FOUR of the following: (4 x 4)**	**16**
	(a)	**Define Inversion. Explain the various inversions of double slider crank chain mechanism.**	**04**
	Ans.	**Inversion:** When one of links is fixed in a kinematic chain, it is called a mechanism. So we can obtain as many mechanisms as the number of links in a kinematic chain by fixing, in turn, different links in a kinematic chain. This method of obtaining different mechanisms by fixing different links in a kinematic chain is known as inversion of the mechanism. **Or** A Mechanism is a Kinematic Chain with one Fixed Link. The **Fixed Link** is called as **Frame.** Different Mechanism is obtained by fixing different link in a kinematic chain. The process of choosing different link in a kinematic chain for the frame is known as **Inversion.** *Thus by fixing one by one links of the mechanism, we can obtain the* **inversion.** **Various Inversions of Double Slider Crank Chain mechanisms:** 1. Elliptical Trammel 2. Scotch Yoke Mechanism 3. Oldham's Coupling **Brief Explanation of Various Double Slider Crank chain Mechanisms**: **Elliptical trammels:**	01 01

It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4). The fixed plate or link 4 has two straight grooves cut in it, at right angles to each other. The link 1 and link 3, are known as sliders and form sliding pairs with link 4. The link A B (link 2) is a bar which forms turning pair with links 1 and 3.

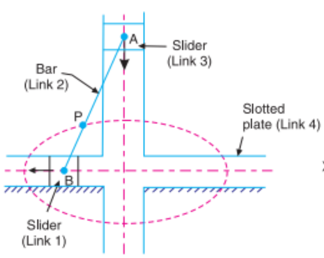
Scotch yoke mechanism:

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

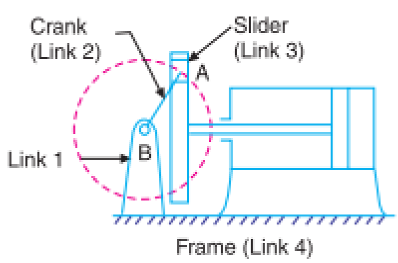
Oldham's coupling:

An Oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart. The shafts are coupled in such a way that if one shaft rotates, the other shaft also rotates at the same speed. This inversion is obtained by fixing the link 2, the shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging. — **02**

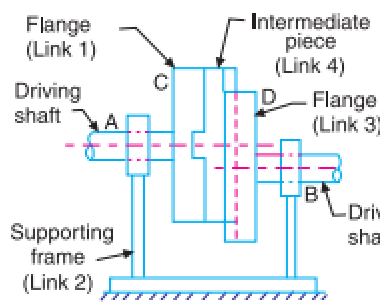
(01 Mark for Definition, 01 Mark for various types of inversions, 02 Marks for Brief explanation of each)



Elliptical trammels.



Scotch yoke mechanism.



Oldham's coupling.

(b) Define kinematic pair. Explain the various types of constrained motions with the help of neat sketches. — **04**

Ans.

Kinematic Pair:

The two links or elements of a machine, when in contact with each other, are said to form a pair. If the relative motion between them is completely or successfully constrained (i.e. in a definite direction), the pair is known as kinematic pair. — 01

The two kinematic links are grouped together, they form a ***Kinematic Pair.***

Different Types of Constrained Motions: — 01

1. Completely Constrained Motion
2. Incompletely Constrained Motion
3. Successfully Constrained Motion

Brief Explanation of Different Constrained Motion with Sketches:

Completely constrained motion:

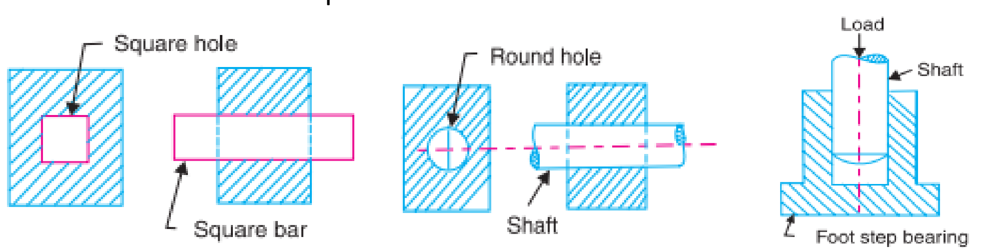
When the motion between a pair is limited to a definite direction irrespective of the direction of force applied, then the motion is said to be a completely constrained motion. E.g. The piston and cylinder (in a steam engine) form a pair and the motion of the piston is limited to a definite direction (i.e. it will only reciprocate) relative to the cylinder irrespective of the direction of motion of the crank. The motion of a square bar in a square hole is an example of Completely constrained motion.

Incompletely constrained motion:

When the motion between a pair can take place in more than one direction, then the motion is called an incompletely constrained motion. The change in the direction of impressed force may alter the direction of relative motion between the pair. A circular bar or shaft in a circular hole, is an example of an incompletely constrained motion as it may either rotate or slide in a hole. These both motions have no relationship with the other. 01

Successfully constrained motion:

When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself, but by some other means, then the motion is said to be successfully constrained motion. Consider a shaft in a foot-step bearing as shown in Fig. The shaft may rotate in a bearing or it may move upwards. This is a case of incompletely constrained motion. But if the load is placed on the shaft to prevent axial upward movement of the shaft, then the motion of the pair is said to be successfully constrained motion ions have no relationship with the other



Square bar in a square hole. Shaft in a circular hole. Shaft in a foot step bearing. 01

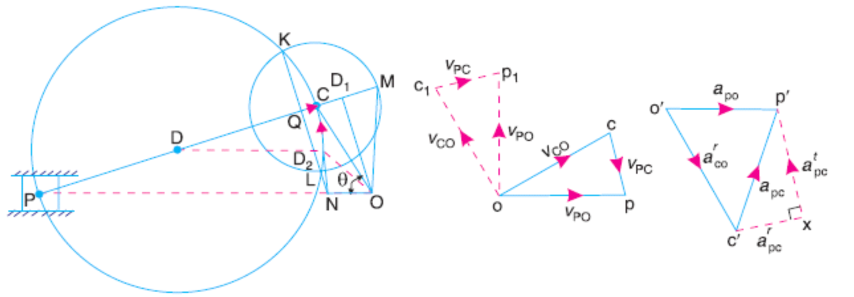
Fig. Sketches of Completely, Incompletely and Successfully Constrained Motion Pairs

(01 Mark for Definition, 01 Mark for Types of Constrained Motion, 01 Mark for Brief Explanation with example, 01 Mark for simple sketches)

(c) **Explain the procedure for construction of Klein's velocity and acceleration diagrams for a single slider crank mechanism. Use suitable data.** **04**

Ans. **Procedure for construction of Klein's velocity and acceleration diagrams for a single slider crank mechanism:**

Let *OC* be the crank and *PC* the connecting rod of a reciprocating steam engine, as shown in Fig. Let the crank makes an angle θ with the line of stroke *PO* and rotates with uniform angular velocity ω rad./s in a clockwise direction. The Klein's velocity and acceleration diagrams are drawn as discussed below:



(a) Klien's acceleration diagram. (b) Velocity diagram. (c) Acceleration diagram.

Klien's construction

02

Klein's velocity diagram:

First of all, draw *OM* perpendicular to *OP*; such that it intersects the line *PC* produced at *M*. The triangle *OCM* is known as Klein's velocity diagram. In this triangle *OCM*, *OM* may be regarded as a line perpendicular to *PO*, *CM* may be regarded as a line parallel to *PC*, and …(_It is the same line.) *CO* may be regarded as a line parallel to *CO*. The velocity diagram for given configuration is a triangle *ocp*

as shown in Fig. If this triangle is revolved through 90°, it will be a triangle oc_1p_1, in which oc_1 represents v_{CO} (*i.e.* velocity of *C* with respect to *O* or velocity of crank pin *C*) and is paralel to *OC*,

02

op_1 represents v_{PO} (*i.e.* velocity of *P* with respect to *O* or velocity of cross-head or piston *P*) and is perpendicular to *OP*, and

c_1p_1 represents v_{PC} (*i.e.* velocity of *P* with respect to *C*) and is parallel to *CP*.

the triangles oc_1p_1 and *OCM* are similar. Therefore,

$$\frac{oc_1}{OC} = \frac{op_1}{OM} = \frac{c_1p_1}{CM} = \omega \text{ (a constant)}$$

or
$$\frac{v_{CO}}{OC} = \frac{v_{PO}}{OM} = \frac{v_{PC}}{CM} = \omega$$

$$\therefore \quad v_{CO} = \omega \times OC\,;\ v_{PO} = \omega \times OM, \text{ and } v_{PC} = \omega \times CM$$

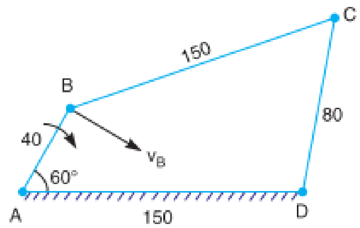
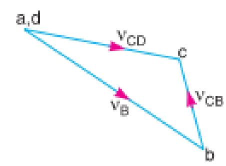
Thus, we see that by drawing the Klien's velocity diagram, the velocities of various points may be obtained without drawing a separate velocity diagram.

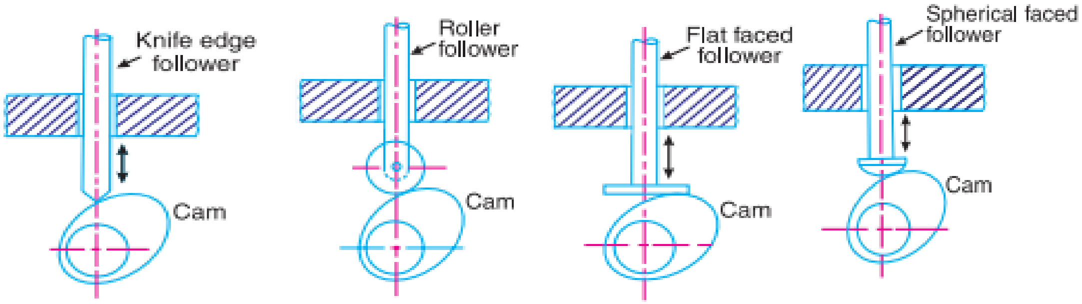
Klien's acceleration diagram

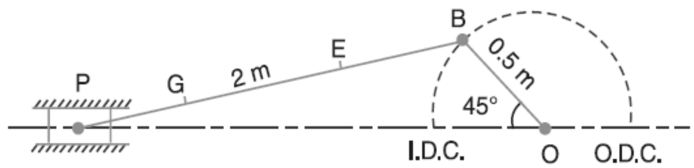
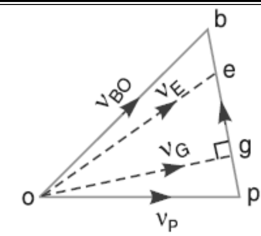
The Klien's acceleration dia- gram is drawn as discussed below:

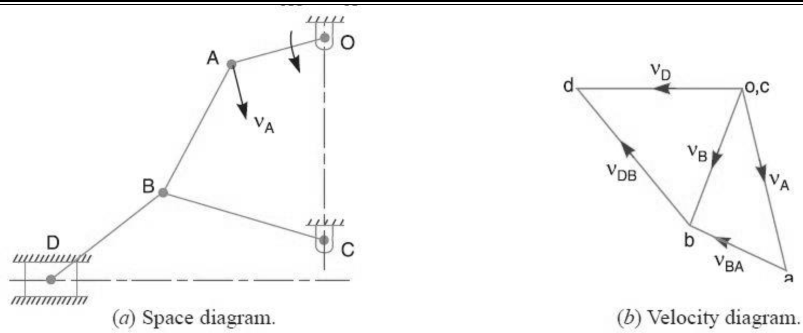
1. First of all, draw a circle with *C* as centre and *CM* as radius.
2. Draw another circle with *PC* as diameter. Let this circle intersect the previous circle at *K* and *L*.
3. Join *KL* and produce it to intersect *PO* at *N*. Let *KL* intersect *PC* at *Q*. This forms the quadrilateral *CQNO*, which is known as *Klien's acceleration diagram.*

Acceleration of piston, $\alpha_p = \omega^2$ ON

	(d)	**In a four bar chain ABCD, AD is fixed and is 150 mm long. The cranks AB is 40 mm long & rotates at 120 rpm clockwise, while the link CD, 80 mm long, oscillates about D. BC and AD are of equal length. Find the angular velocity of link CD when angle BAD = 60°.**	**04**
	Ans.	**Given Data:** N_{BA} = 120 r.p.m. or $\omega_{BA} = 2\pi \times 120/60 = 12.568$ rad/s Since the length of crank A B = 40 mm = 0.04 m, therefore velocity of B with respect to A or velocity of B, (because A is a fixed point), $v_{BA} = v_B = \omega_{BA} \times AB = 12.568 \times 0.04 = 0.503$ m/s  (a) Space diagram (All dimensions in mm).  (b) Velocity diagram. Since the link AD is fixed, therefore points a and d are taken as one point in the velocity diagram. Draw vector ab perpendicular to B A, to some suitable scale, to represent the velocity of B with respect to A or simply velocity of B (i.e. vBA or vB) such that vector ab = $v_{BA} = v_B = 0.503$ m/s Now from point b, draw vector bc perpendicular to CB to represent the velocity of C with respect to B (i.e. v_{CB}) and from point d, draw vector dc perpendicular to CD to represent the velocity of C with respect to D or simply velocity of C (i.e. v_{CD} or v_C). The vectors bc and dc intersect at c. By measurement, we find that $v_{CD} = v_C$ = vector dc = 0.385 m/s We know that CD = 80 mm = 0.08 m ∴ Angular velocity of link CD, **ω CD = V CD / CD = 0.385/0.08 = 4.8 rad/s (clockwise about D)**	01 01 01 01
	(e)	**State the four types of followers according to the surface in contact with the cam. Draw respective sketches.**	**04**
	Ans.	**(02 Marks for Types, ½ Mark for sketch of each type)** Types of Followers according to Surface in Contact with the Cam: 1. Knife edge follower 2. Roller follower 3. Flat faced or mushroom follower 4. Spherical faced follower	02

		 (*a*) Cam with knife edge follower. (*b*) Cam with roller follower. (*c*) Cam with flat faced follower. (*d*) Cam with spherical faced follower. **Fig.: Types of follower according to the surface in contact with the cam**	½ Mark for sketch of each type
	(f)	**An engine running at 150 rpm, drives a line shaft by means of a belt. The engine pulley is 750 mm diameter & the pulley on the line shaft being 450 mm. A 900 mm diameter pulley on the line shaft drives a 150 mm diameter pulley keyed to a dynamo shaft. Find the speed of the dynamo shaft, when: (i) There is no slip (ii) There is a slip of 2% at each drive.**	**04**
	Ans.	**Given Data:** N1 = 150 rpm, d1 = 750 mm, d3 = 900 mm, d2 = 450 mm, d4 = 150 mm 1. When there is no slip We know that $\frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4}$ or $\frac{N_4}{150} = \frac{750 \times 900}{450 \times 150} = 10$ $\therefore \quad N_4 = 150 \times 10 = 1500$ r.p.m. 2. When there is a slip of 2 % at each drive We know that $\frac{N_4}{N_1} = \frac{d_1 \times d_3}{d_2 \times d_4}\left(1 - \frac{s_1}{100}\right)\left(1 - \frac{s_2}{100}\right)$ $\frac{N_4}{150} = \frac{750 \times 900}{450 \times 150}\left(1 - \frac{2}{100}\right)\left(1 - \frac{2}{100}\right) = 9.6$ $\therefore \quad N_4 = 150 \times 9.6 = 1440$ r.p.m.	01 01 02
Q.3		**Attempt any FOUR of the following: (4 x 4)**	**16**
	(a)	**The crank and connecting rod of a theoretical steam engine are 0.5 m and 2m long respectively. The crank makes 180rpm in clockwise direction. When it has turned 45° from the inner dead centre position. Determine: (i) Velocity of piston (ii) Angular velocity of connecting rod (iii) Velocity of point E on the connecting rod 1.5 m from the gudgeon pin.**	**04**
	Ans.	$N_{BO} = 180$ r.p.m. or $\omega_{BO} = 2\pi \times 180/60 = 18.852$ rad/s Velocity of Crank $v_{BO} = v_B = \omega_{BO} \times OB = 18.852 \times 0.5 = 9.426$ m/s	

		 (*a*) Space diagram.  (*b*) Velocity diagram. **1. Velocity of piston *P*** v_P = vector op = 8.15 m/s **Ans.** **2.** ***Angular velocity of connecting rod*** From the velocity diagram, we find that the velocity of *P* with respect to *B*, v_{PB} = vector bp = 6.8 m/s Since the length of connecting rod *PB* is 2 m, therefore angular velocity of the connecting rod, $\omega_{PB} = \frac{v_{PB}}{PB} = \frac{6.8}{2} = 3.4$ rad/s (Anticlockwise) **Ans.** **3.** ***Velocity of point E on the connecting rod*** The point *e* on the vector *bp* may also be obtained as follows : $\frac{BE}{BP} = \frac{be}{bp}$ or $be = \frac{BE \times bp}{BP}$ v_E = vector oe = 8.5 m/s **Ans.**	01 mark for Space diagram 02 Mark for Velocity Diagram 01 Mark for Calculation
	(b)	**In Fig. (a) the angular velocity of the crank OA is 600 rpm. Determine the linear velocity of the slider D and the angular velocity of the link BD, when the crank is inclined at an angle 75° to the vertical. The dimensions of various links are: OA = 28 mm, AB = 44 mm, BC = 49 mm and BD = 46 mm. The center distance between the centres rotation O & C is 65 mm. The path of travel of the slider is 11 mm below the fixed point C. The slider moves along a horizontal path and OC is vertical.**	**04**
	Ans.	Angular Velocity Of Crank OA $\omega_{AO} = 2\pi \times 600/60 = 62.84$ rad/s $v_{AO} = v_A = \omega_{AO} \times OA = 62.84 \times 0.028 = 1.76$ m/s	01 mark for Space diagram 01 Mark for Velocity Diagram



(a) Space diagram. (b) Velocity diagram.

01 Mark for Velocity of slider

Velocity of slider D

v_D = vector od = 1.6 m/s **Ans.**

Angular velocity of the link BD

01 Mark for Angular Velocity of BD

v_{DB} = vector bd = 1.7 m/s

$$\omega_{BD} = \frac{v_{DB}}{BD} = \frac{1.7}{0.046} = 36.96 \text{ rad/s (Clockwise about } B) \text{ Ans.}$$

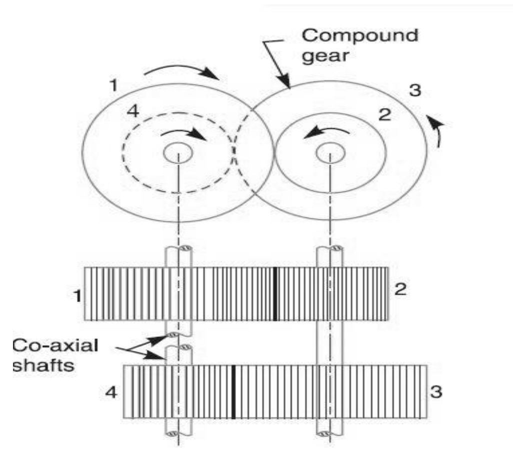
	(c)	**Discuss with sketch the working principle of reverted gear train.**	**04**

Ans.

Working Principle of Reverted Gear Train:

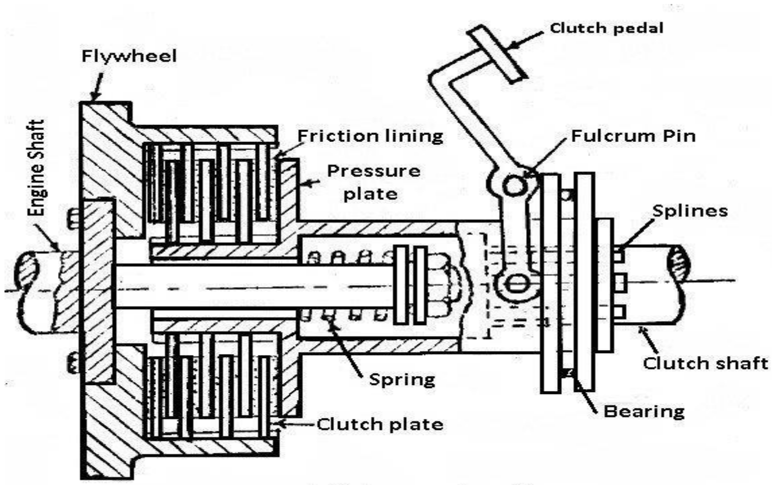
When the axes of the first gear (i.e. first driver) and the last gear (i.e. last driven or follower) are co-axial, then the gear train is known as reverted gear train. We see that gear 1 (*i.e.* first driver) drives the gear 2 (*i.e.* first driven or follower) in the opposite direction. Since the gears 2 and 3 are mounted on the same shaft, therefore they form a compound gear and the gear 3 will rotate in the same direction as that of gear 2. The gear 3 (which is now the second driver) drives the gear 4 (*i.e.* the last driven or follower) in the same direction as that of gear 1. Thus we see that in a reverted gear train, the motion of the first gear and the last gear is *same*. *The reverted gear trains are used in automotive transmissions, lathe back gears, industrial speed reducers, and in clocks (where the minute and hour hand shafts are co-axial).*

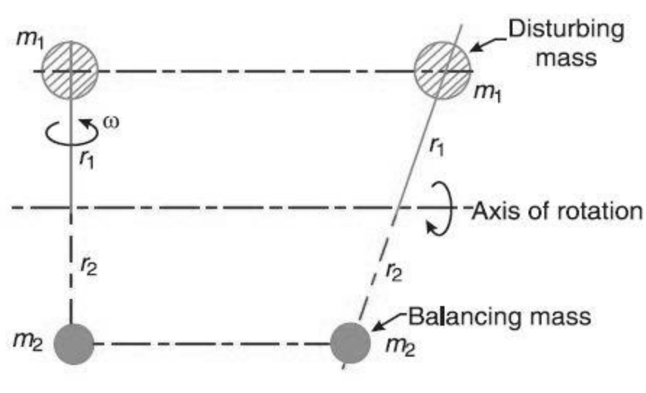
02 Mark for Working Principle



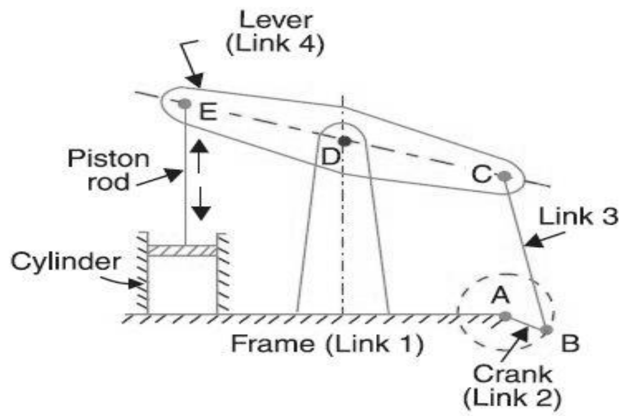
02 Mark for Sketch

(02 Marks for Working Principle, 02 Marks for neat sketch)

	(d)	Explain with neat sketch the construction and working of Multiplate clutch.	04
	Ans.	**Construction of Multiplate Clutch:** [1] Multi plate clutch consists of a number of clutch plates, instead of only one clutch plate as in the case of single plate clutch. [2] As the number of clutch plates is increased, the friction surface also increases. The increased number of friction surfaces obviously increases the capacity of the clutch to transmit torque. [3] The plates are alternately fitted to the engine shaft and the gear box shaft. They are firmly pressed by strong coil spring and assembled in a drum. [4] Each of the alternate plate slides in grooves on the flywheel and the other slides on splines on the pressure plate. Thus, each alternate plate has inner and outer splines. **Working of Multiplate Clutch:** **Clutch Engagement:** During clutch engagement, spring pressure forces the pressure plate towards engine flywheel. This causes the friction plates and the steel driven plates to be held together. Friction locks them together tightly. Then the clutch basket, drive plates, driven plates, clutch hub and the gearbox input shaft all spin together as one unit. Now power flows from the clutch basket through the plates to the inner clutch hub and into the main shaft of the transmission. **Clutch Disengagement:** The clutch gets released or disengaged when the clutch pedal is pressed. This causes the clutch pressure plate to be moved away from the drive and driven plates, overcoming the clutch spring force. This movement of the pressure plate, relieves the spring pressure holding the drive and driven plates together. Then the plates float away from each other and slip axially. Thus, the clutch shaft speed reduces slowly. Finally, the clutch shaft stops rotating. Power is no longer transferred into the transmission gearbox.  **Multiplate Clutch** **(01 Mark for Construction, 01 Mark for Working in brief, 02 Mark for simple labeled sketch)**	01 Mark for Construction 01 Mark for Working 02 Mark for labeled sketch

	(e)	Explain the process of balancing a single rotating mass when balancing masses are on the opposite side of disturbing mass.	04
	Ans.	**Process of Balancing a Single Rotating mass when balancing masses are on the opposite side of disturbing mass:** Consider a disturbing mass m_1 attached to a shaft rotating at ω rad/s. Let $r1$ be the radius of rotation of the mass m_1 (*i.e.* distance between the axis of rotation of the shaft and the centre of gravity of the mass m_1). We know that the centrifugal force exerted by the mass m_1 on the shaft, $$FC_l = m_1 . \omega^2 . r_1 \ldots \quad (i)$$ This centrifugal force acts radially outwards and thus produces bending moment on the shaft. In order to counteract the effect of this force, a balancing mass (m_2) may be attached in the same plane of rotation as that of disturbing mass (m_1) such that the centrifugal forces due to the two masses are equal and opposite. Let r_2 = Radius of rotation of the balancing mass m_2 (*i.e.* distance between the axis of rotation of the shaft and the centre of gravity of mass m_2). **Centrifugal force due to mass m_2,** $$FC_2 = m_2 . \omega^2 r_2 \ldots (ii)$$ Equating equations **(*i*)** and **(*ii*)**, $m_1 . \omega^2 . r_1 = m_2 . \omega^2 . r_2$ or $m_1 . r_1 = m_2 . r_2$ **Magnitude and position of balancing mass can be found.**  **(02 Marks for appropriate process, 02 Marks for appropriate sketch)**	02 marks for Appropriate Process 02 Marks for appropriate sketch

	(f)	**State the four applications of Cam.**	**04**
	Ans.	**Applications of CAM:** 1. It is used in internal combustion engine for opening and closing intake valve and outlet valve. 2. It is used in machine tools. 3. It is used in automated machines. 4. It is used in control mechanisms of printing, hydraulic system. 5. It is used in Shoe making machines. 6. It is used in Sawing machine 7. It is used in Paper cutting machine **(Any 04 suitable applications, 01 Mark for each)**	04
Q. 4		**Attempt any FOUR of the following: (4 x 4)**	**16**
	(a)	**Find the power transmitted by a belt running over a pulley of 600 mm diameter at 200 rpm. The coefficient of friction between the belt and the pulley is 0.25, angle of lap 160° and maximum tension in the belt is 2500 N.**	**04**
	Ans.	**Solution.** Given : $d = 600$ mm $= 0.6$ m ; $N = 200$ r.p.m. ; $\mu = 0.25$; $\theta = 160° = 160 \times \pi / 180 = 2.793$ rad ; $T_1 = 2500$ N	01 Mark
		We know that velocity of the belt, $v = \frac{\pi d . N}{60} = \frac{\pi \times 0.6 \times 200}{60} = 6.284$ m/s Let T_2 = Tension in the slack side of the belt.	01 Mark
		We know that $2.3 \log\left(\frac{T_1}{T_2}\right) = \mu . \theta = 0.25 \times 2.793 = 0.6982$ $\log\left(\frac{T_1}{T_2}\right) = \frac{0.6982}{2.3} = 0.3036$ $\therefore \frac{T_1}{T_2} = 2.01$ ...(Taking antilog of 0.3036) and $T_2 = \frac{T_1}{2.01} = \frac{2500}{2.01} = 1244$ N	01 Mark
		We know that power transmitted by the belt, $P = (T_1 - T_2)\, v = (2500 - 1244)\, 6.284 = 7890$ W $= 7.89$ kW **Ans.**	01 Mark

	(b)	**Explain with neat sketch the construction and working of beam engine.**	**04**
	Ans.	**<u>Construction of Beam Engine:</u>** *<u>A part of the mechanism of a beam engine (also known as crank and lever mechanism) which consists of four links.</u>* Crank AB Connected to link 3. Link 3 is connected to Link 4 which is lever and centrally pivoted at point D. At the other end of lever Piston rod is connected. **<u>Working of Beam Engine:</u>** In this mechanism, when the crank rotates about the fixed centre *A*, the lever oscillates about a fixed centre *D*. The end *E* of the lever *CDE* is connected to a piston rod which reciprocates due to the rotation of the crank. In other words, the purpose of this mechanism is to convert rotary motion into reciprocating motion.  **Fig.: Beam Engine** **(01 Mark for Construction, 01 Mark for Working, 02 Mark for Simple labeled Sketch)**	01 Mark for Construction 01 Mark for Working 02 Mark for Sketch
	(c)	**Explain the construction and working of centrifugal governor with the help of neat sketch.**	**04**
	Ans.	**<u>Construction of Centrifugal Governor:</u>** The centrifugal governors are based on the balancing of centrifugal force on the rotating balls by an equal and opposite radial force, known as the controlling force. [1] It consists of **two balls** of equal mass, which are attached to **the arms**. [2] These balls are known as governor balls or fly balls. [3] The balls revolve with a **spindle**, which is driven by the engine through **bevel gears**. [4] The upper ends of the arms are pivoted to the spindle, so that the balls may rise up or fall down as they revolve about the vertical axis. [5] The arms are connected by the links to a **sleev**e, which is keyed to the spindle. This sleeve revolves with the spindle; but can slide up and down. [6] The balls and the sleeve rise when the spindle speed increases, and falls when the speed decreases. [7] In order to limit the travel of the sleeve in upward and downward directions, **two stops** ***S***, *S* are provided on the spindle. [8] The sleeve is connected by a **bell crank lever** to a throttle valve. The supply of the working fluid decreases when the sleeve rises and increases when it falls.	01 Mark for Brief Construction

Working of Centrifugal Governor:

When the load on the engine increases, the engine and the governor speed decreases. This results in the decrease of centrifugal force on the balls. Hence the balls move inwards and the sleeve moves downwards. The downward movement of the sleeve operates a throttle valve at the other end of the bell crank lever to increase the supply of working fluid and thus the engine speed is increased. In this case, the extra power output is provided to balance the increased load. When the load on the engine decreases, the engine and the governor speed increases, which results in the increase of centrifugal force on the balls. Thus the balls move outwards and the sleeve rises upwards. This upward movement of the sleeve reduces the supply of the working fluid and hence the speed is decreased. In this case, the power output is reduced.

01 Mark for brief Working

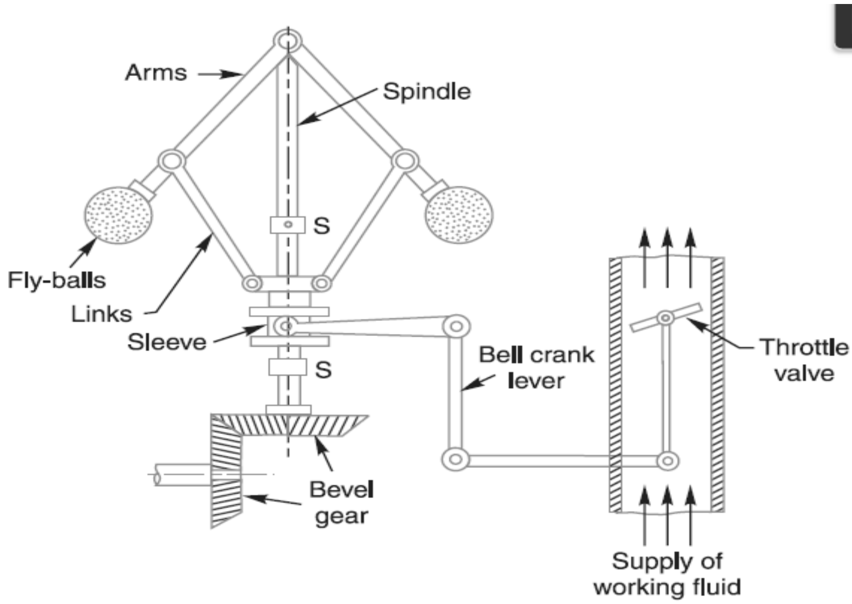


Fig.: Centrifugal Governor

02 Marks for simple labeled sketch

(01 Mark for Construction, 01 Mark for Working, 02 Mark for Simple Labeled Sketch)

(d)	**Differentiate between brakes and dynamometers.**	**04**

Ans. **Difference between Brakes & Dynamometers:**

S. No.	Brakes	Dynamometers
1	Device which retards or stops the motion of rotating member of machine	Device which measures power of an engine or machine
2	To stop the motion	To measure brake power
3	Safety device & essential for various materials	Measuring device installed if required

Any 04 Point

01 Mark for each

4	Frictional resistance to stop the motion	Measurement of power by absorbing energy
5	It offers frictional resistance to body, so as to bring the body to rest.	It is able to measure frictional resistance, which is measure of power.
6	Shoe brakes, drum & disc brakes, Band brakes	Absorption & Transmission
7	Automobiles, Locomotives, Lifts	Testing Machines

(Any 04 appropriate points, 01 Mark for each)

(e) **A single plate clutch, with both sides effective, has outer and inner diameters 300 mm and 200 mm respectively. The maximum intensity of pressure at any point in the contact surface is not to exceed 0.1 N/mm². If the coefficient of friction is 0.3, Determine the power transmitted by clutch at a speed of 2500 rpm.** **04**

Ans. **Given Data:** 1/2 Mark

Solution. Given : $d_1 = 300$ mm or $r_1 = 150$ mm ; $d_2 = 200$ mm or $r_2 = 100$ mm ; $p = 0.1$ N/mm^2 ; $\mu = 0.3$; $N = 2500$ r.p.m. or $\omega = 2\pi \times 2500/60 = 261.8$ rad/s

Since the intensity of pressure (p) is maximum at the inner radius (r_2), therefore for uniform wear, 1/2 Mark

$$p.r_2 = C \quad \text{or} \quad C = 0.1 \times 100 = 10 \text{ N/mm}$$

We know that the axial thrust,

$$W = 2\pi C(r_1 - r_2) = 2\pi \times 10\,(150 - 100) = 3142 \text{ N}$$

01 Mark

and mean radius of the friction surfaces for uniform wear,

$$R = \frac{r_1 + r_2}{2} = \frac{150 + 100}{2} = 125 \text{ mm} = 0.125 \text{ m}$$

01 Mark

We know that torque transmitted,

$$T = n.\mu.W.R = 2 \times 0.3 \times 3142 \times 0.125 = 235.65 \text{ N-m}$$

...($\because n = 2$, for both sides of plate effective)

$\therefore$ Power transmitted by a clutch,

$$P = T.\omega = 235.65 \times 261.8 = 61\,693 \text{ W} = 61.693 \text{ kW } \textbf{Ans.}$$

01 Mark

(f) **Four masses are 200 kg, 300 kg, 240 kg and 260 kg. The corresponding radii of rotation are 0.2 m, 0.15 m, 0.25 m and 0.3 m respectively. The angles between successive masses are 45°, 75° and 135°. Find the position and magnitude of balance mass required, if its radius of rotation is 0.2 m. Use graphical method.** **04**

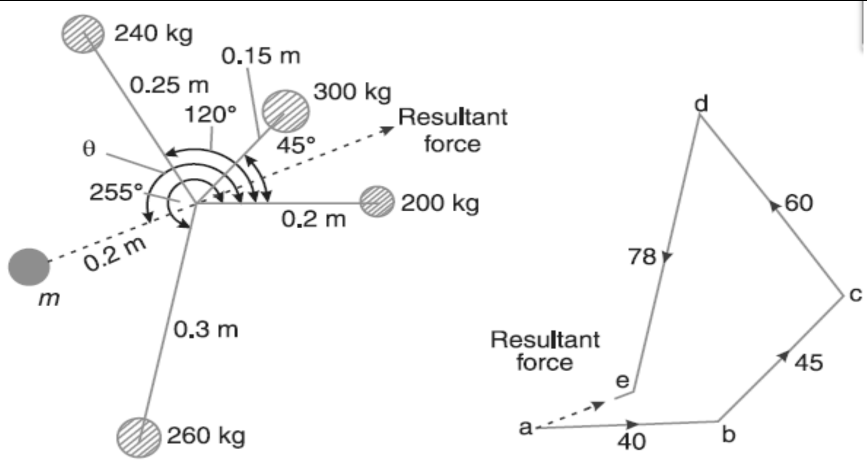
Ans. **Given Data:** 01 Mark

$m_1.r_1 = 200 \times 0.2 = 40$ kg-m

$m_2.r_2 = 300 \times 0.15 = 45$ kg-m

$m_3.r_3 = 240 \times 0.25 = 60$ kg-m

$m_4.r_4 = 260 \times 0.3 = 78$ kg-m



(*a*) Space diagram. (*b*) Vector diagram

Fig. Graphical Representation

01 Mark for Space Diagram

01 Mark for Vector Diagram

m × 0.2 = vector ea = 23 kg-m or m = 23/0.2 = **115 kg Ans.**

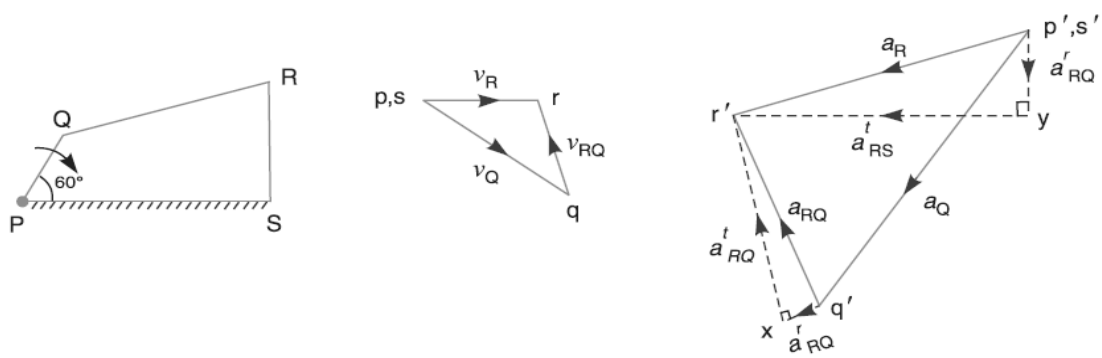
Θ = 201° Ans. — 01 Mark

Q.5		**Attempt any TWO of the following: (2 x 8)**	**16**
	(a)	**PQRS is a four bar chain with link PS fixed. The lengths of the links PQ, QR, RS & PS are 62.5 mm, 175 mm, 112.5 mm and 200 mm respectively. The crank PQ rotates at 10 rad/s clockwise. Draw the velocity and acceleration diagram when angle QPS = 60° and Q & R lie on the same side of PS. Find the angular velocity and angular acceleration of links QR & RS.**	**08**

Ans.

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

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



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

02 Mark for Space Diagram

02 Mark for Velocity Diagram

02 Mark for Acceleration Diagram

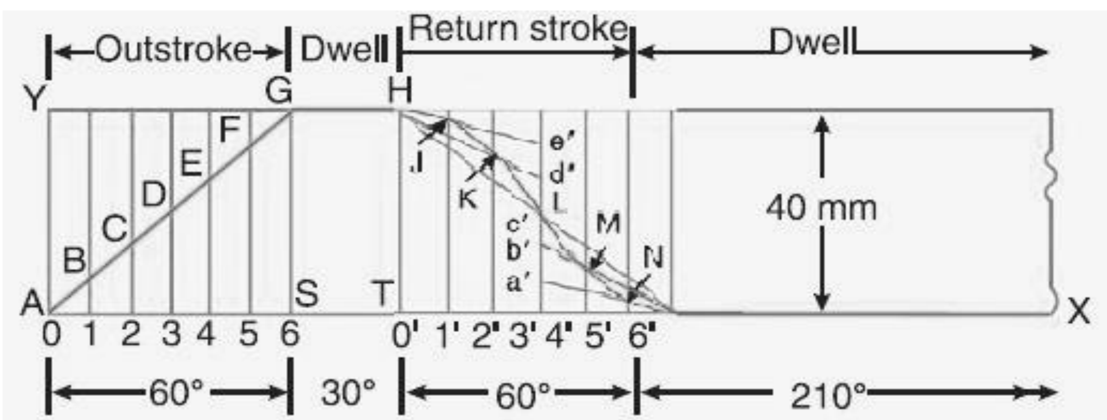
vector $pq = v_{QP} = v_Q = 0.625$ m/s

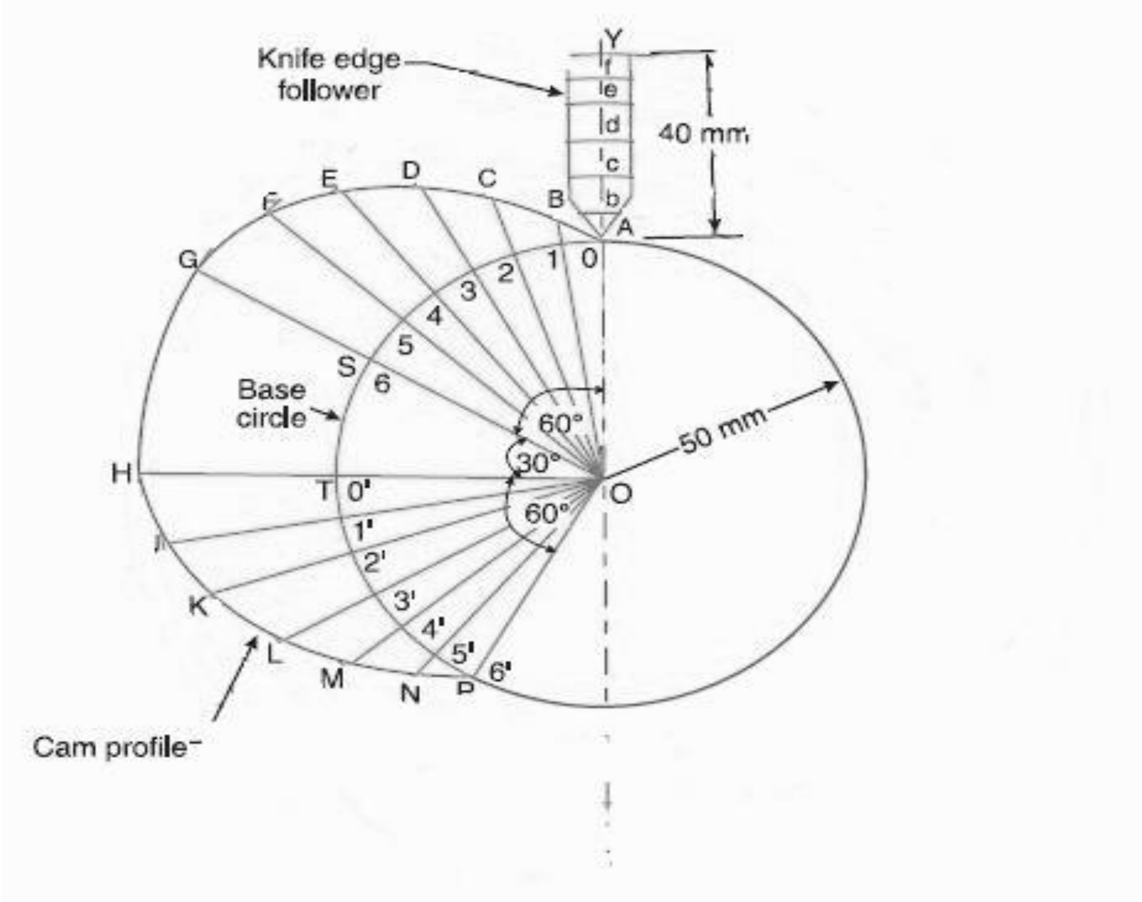
v_{RQ} = vector $qr = 0.333$ m/s, and $v_{RS} = v_R$ = vector $sr = 0.426$ m/s

1.. Angular Velocity OF Link QR :-

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

½ Mark

		2. Angular Velocity OF Link RS :- $$\omega_{RS} = \frac{v_{RS}}{SR} = \frac{0.426}{0.1125} = 3.78 \text{ rad/s (Clockwise)}$$ **3. Angular Acceleration OF Link QR :-** $$\alpha_{QR} = \frac{a^t_{RQ}}{QR} = \frac{4.1}{0.175} = 23.43 \text{ rad/s}^2 \text{ (Anticlockwise)}$$ **4. Angular Acceleration OF Link RS :-** $$\alpha_{RS} = \frac{a^t_{RS}}{SR} = \frac{5.3}{0.1125} = 47.1 \text{ rad/s}^2 \text{ (Anticlockwise)}$$	½ Mark ½ Mark ½ Mark
Q.5	**(b)**	**A cam is to give the following motion to a knife-edge follower: (1) Outstroke during 60° of cam rotation; (2) Dwell for next 30° of cam rotation; (3) Return stroke during next 60° o cam rotation, and (4) Dwell for remaining 210° of cam rotation. The lift of follower is 40 mm and the minimum radius of cam is 50 mm. The follower moves with uniform velocity during outstroke and with uniform acceleration and retardation during return stroke. Draw the profile of cam when the axis of follower passes through the axis of cam shaft.**	**08**
	Ans.	**Displacement Diagram** 	03 Mark for Displacement Diagram 05 Marks for Cam

			Profile
Q.5	(c)	**Two pulleys of 450 mm and 200 mm diameter are mounted on parallel shafts 1.95 m apart and are connected by a crossed belt. Find the length of belt required and the angle of contact between belt and each pulley. What power can be transmitted by the belt when larger pulley rotates at 200 rpm, if maximum permissible tension in the belt is 1 KN and coefficient of friction between the belt & pulley is 0.25?**	**08**
	Ans.	**Given Data:** d1 = 450 mm = 0.45 m, d2 = 200 mm = 0.20 m, N1 = 200 rpm, x = 1.95 m, Tmax = 1 KN = 1000 N, μ = 0.25	01 Mark
		Velocity of Belt :- $v = \frac{\pi d_1 . N_1}{60} = \frac{\pi \times 0.45 \times 200}{60} = 4.714 \text{ m/s}$	01 Mark
		Length of Crossed Belt Drive: length of the crossed belt, $L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$ $= \pi(0.225 + 0.1) + 2 \times 1.95 + \frac{(0.225 + 0.1)^2}{1.95} = 4.975 \text{m}$	02 Mark
		Angle of Contact between Belt & Pulley:	

θ = Angle of contact between the belt and each pulley.

for a crossed belt drive,

$$\sin \alpha = \frac{r_1 + r_2}{x} = \frac{0.225 + 0.1}{1.95} = 0.1667 \quad \text{or} \quad \alpha = 9.6°$$

$$\theta = 180° + 2\alpha = 180° + 2 \times 9.6° = 199.2°$$

$$= 199.2 \times \frac{\pi}{180} = 3.477 \text{ rad} \quad \textbf{Ans.}$$

02 Mark

Power Transmitted by Belt:

Power transmitted

Let T_2 = Tension in the slack side of the belt.

We know that

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu.\theta = 0.25 \times 3.477 = 0.8692$$

$$\log\left(\frac{T_1}{T_2}\right) = \frac{0.8692}{2.3} = 0.378 \quad \text{or} \quad \frac{T_1}{T_2} = 2.387 \qquad \text{...(Taking antilog of 0.378)}$$

$$\therefore \quad T_2 = \frac{T_1}{2.387} = \frac{1000}{2.387} = 419 \text{ N}$$

We know that power transmitted,

$$P = (T_1 - T_2)\,v = (1000 - 419)\,4.714 = 2740 \text{ W} = 2.74 \text{ kW} \quad \textbf{Ans.}$$

02 Mark

Q.6 **Attempt any TWO of the following: (2 x 8)** **16**

(a) **(i) Differentiate between Flywheel & Governor.**
(ii) Explain the turning moment diagram for single cylinder 4 Stroke IC Engine. **08**

Ans. **Difference between Flywheel & Governor:**

S. No	Flywheel	Governor
1	It is used to store available mechanical energy, when it is in excess of load requirement & to give it away when the available energy is less than the load requirement.	It is used to regulate the supply of working fluid according to load requirement and to maintain a constant speed.
2	It takes care of fluctuation of speed during each revolution due to **variation in output torque** of engine. **(Cyclic Revolution)**	It takes care of fluctuation of speed during no. of revolutions due to **variation of load upon engine. (No. of Revolution)**
3	Operation is **continuous**	Operation is **intermittent**
4	Flywheel may not be used if there is no undesirable cyclic fluctuation of energy output. **(Desirable)**	Governor is essential for all types of engine as it adjust the supply of fuel according to demand. **(Essential)**

04 Marks

		5	Flywheel has no control over quantity of working fluid	Governor takes care about changing the quantity of working fluid	
		6	Mathematically it controls δN/δT	Mathematically it controls δN	
		7	**Use:** Rolling Mills, Punching & Shearing Machines, I C Engine etc.	**Use:** Prime Movers such as Engines & Turbines	

(Any 04 Points, 01 Mark for each)

Q. 6 (a) (ii)

Turning Moment Diagram for Single Cylinder 4 Stroke I.C. Engine:

We know that in a four stroke cycle internal combustion engine, there is one working stroke after the crank has turned through two revolutions, *i.e.* 720° (or 4 π radians).

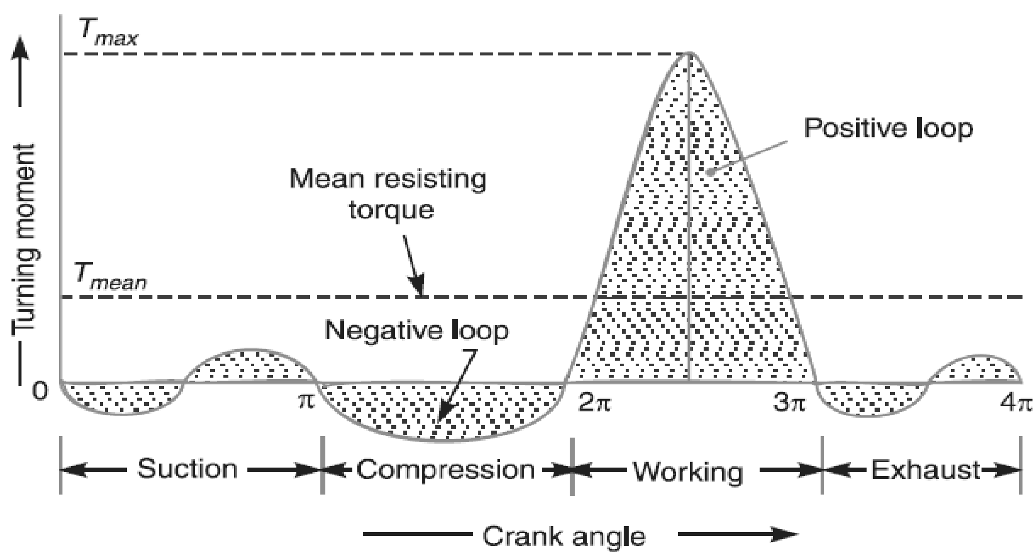
[1] Since the pressure inside the engine cylinder is less than the atmospheric pressure during the **suction stroke**, therefore a negative loop is formed as shown in Fig.

[2] During the **compression stroke**, the work is done on the gases; therefore a higher negative loop is obtained.

[3] During the **expansion or working stroke**, the fuel burns and the gases expand; therefore a large positive loop is obtained. In this stroke, the work is done by the gases.

[4] During **exhaust stroke**, the work is done on the gases; therefore a negative loop is formed.

02 Marks for Brief Explanation



02 Marks for neat labeled sketch

Figure: Turning Moment Diagram for SIngle Cylinder 4 Stroke IC ENgine

	(b)	**A band brake acts on the 3/4th of circumference of a drum of 450 mm diameter which is keyed to the shaft. The band brake provides a braking torque of 225 Nm. One end of the band is attached to a fulcrum pin of the lever and the other end to a pin 100 mm from the fulcrum. If the operating force is applied at 500 mm from the fulcrum and the coefficient of friction is 0.25, find the operating force when the drum rotates in the (a) anti clockwise direction (b) clockwise direction**	**08**

Ans.

1. Operating force when drum rotates in anticlockwise direction:-

Angle of wrap :-

$$\theta = \frac{3}{4}\text{th of circumference} = \frac{3}{4}\times 360^\circ = 270^\circ$$

$$= 270\times\pi/180 = 4.713 \text{ rad}$$

$$2.3\log\left(\frac{T_1}{T_1}\right) = \mu.\theta = 0.25\times 4.713 = 1.178$$

$$\log\left(\frac{T_1}{T_2}\right) = \frac{1.178}{2.3} = 0.5123 \text{ or } \frac{T_1}{T_2} = 3.253 \quad \text{. . . (i)}$$

We know that braking torque (T_B),

$$225 = (T_1 - T_2)\,r = (T_1 - T_2)\,0.225$$

$$\therefore \quad T_1 - T_2 = 225/0.225 = 1000 \text{ N} \quad \text{. . . (ii)}$$

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

$$T_1 = 1444 \text{ N; and } \quad T_2 = 444 \text{ N}$$

Now taking moments about the fulcrum *O*, we have

$$P\times l = T_2.b \quad \text{or} \quad P\times 0.5 = 444\times 0.1 = 44.4$$

$$\therefore \quad P = 44.4/0.5 = 88.8 \text{ N } \textbf{Ans.}$$

04 Mark

2. Operating force when drum rotates in clockwise direction:-

taking moments about the fulcrum *O*, we have

$P\times l = T1.\ b$ or $P\times 0.5 = 1444\times 0.1 = 144.4$

∴$P = 144.4/0.5 = 288.8$ N **Ans.**

04 Mark

	(c)	**A conical pivot supports a load of 20 KN. The cone angle is 120° and the intensity of normal pressure is not to exceed 0.3 N/mm². The external diameter is twice the internal diameter. Find the outer and inner radii of the bearing surface. If the shaft rotates at 200 rpm and the coefficient of friction is 0.1, Find the power absorbed in friction. Assume uniform pressure.**	**08**
	Ans.	**Given Data:** $W = 20$ KN $= 20 \times 10^3$ N, $2\alpha = 120°$, $\alpha = 60°$, $p = 0.3$ N/mm², $N = 200$ rpm, $\mu = 0.1$ r1 = 2r2 **[1] Outer and Inner Radii of the Bearing Surface:** *Outer and inner radii of the bearing surface* Let r_1 and r_2 = Outer and inner radii of the bearing surface, in mm. Since the external diameter is twice the internal diameter, therefore $r_1 = 2\,r_2$ We know that intensity of normal pressure (p_n), $$0.3 = \frac{W}{\pi[(r_1)^2 - (r_2)^2]} = \frac{20 \times 10^3}{\pi[(2r_2)^2 - (r_2)^2]} = \frac{2.12 \times 10^3}{(r_2)^2}$$ $\therefore \quad (r_2)^2 = 2.12 \times 10^3 / 0.3 = 7.07 \times 10^3$ or $r_2 = 84$ mm **Ans.** and $\quad r_1 = 2\,r_2 = 2 \times 84 = 168$ mm **Ans.** **[2] Power absorbed in Friction:** *Power absorbed in friction* We know that total frictional torque (assuming uniform pressure), $$T = \frac{2}{3} \times \mu.W.\text{cosec}\,\alpha \left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right]$$ $$= \frac{2}{3} \times 0.1 \times 20 \times 10^3 \times \text{cosec}\,60° = \left[\frac{(168)^3 - (84)^3}{(168)^2 - (84)^2}\right] \text{N-mm}$$ $= 301760$ N-mm $= 301.76$ N-m $\therefore$ Power absorbed in friction, $P = T.\omega = 301.76 \times 20.95 = 6322$ W $= 6.322$ kW **Ans.**	01 Mark 03 Mark 02 Mark 02 Mark