SUMMER – 2019 EXAMINATIONS

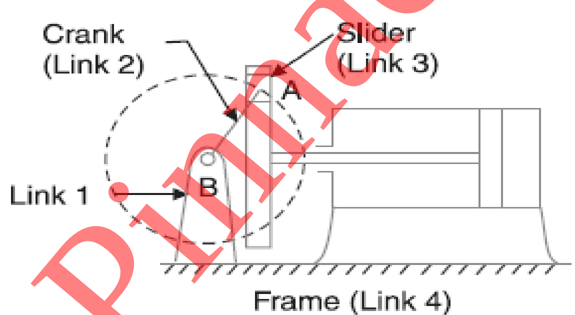
Subject Name: Theory of Machines **Model Answer** **Subject Code: 22438**

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.

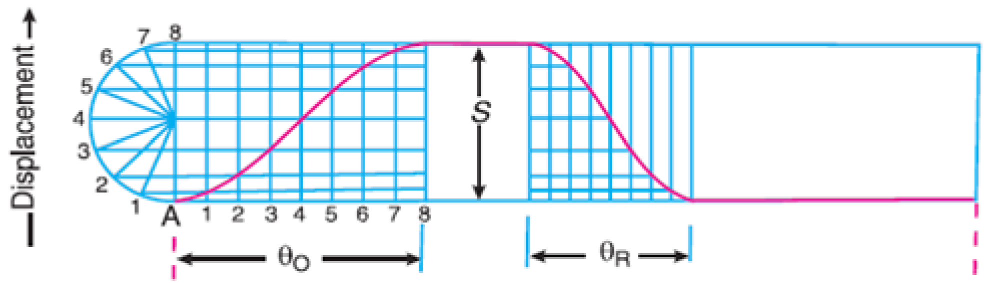
Q. No.	Sub Q. N.	Answer	Marking Scheme
1		**Attempt any FIVE of the following: (2 x 5)**	10
1	(a)	**Define term 'Kinetics'.**	02
	Ans.	**(02 Mark for the appropriate significance of Kinetics)** **Definition of Kinetics:** It is that branch of Theory of Machines which deals with the inertia forces which arise from the combined effect of the mass and motion of the machine parts.	02
1	(b)	**List different types of 'Kinematic Pair'.**	02
		(Classification on any 2 basis with sub types, 01 Mark each) **Types of Kinematic pairs:** **[1] According to the type of relative motion between the elements:** (a) Sliding pair. (b) Turning pair. (c) Rolling pair. (d) Screw pair. (e) Spherical pair. **[2] According to the type of contact between the elements:** (a) Lower pair. (b) Higher pair. **[3] According to the type of closure:** (a) Self closed pair. (b) Force - closed pair. **[4] According to Constrained Motion:** (a) Incompletely Constrained (b) Completely Constrained (c) Successfully Constrained	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
1	(c)	**State the relation between relative velocity and motion of link in mechanism.**	02
	Ans.	**Relation between Relative Velocity and motion of link in mechanism:** The relative velocity is the velocity of any point with respect to any other some point on the same link. Let, V be the relative velocity of one end w.r.t. other end of link in m/sec ω be the angular motion in rad/sec & r as the length of same link in meter Then, the relation is expressed as; $V = r \times \omega$ m/sec	02
1	(d)	**List any four applications of 'cam' and 'follower'.**	02
	Ans.	**(Any four applications, ½ Marks for each)** **Applications of Cam and Follower:** [1] Operating the inlet and exhaust valves of internal combustion engines [2] Used in Automatic attachment of machineries, paper cutting machines [3] Used in Spinning and weaving textile machineries. [4] Used in Feed mechanism of automatic lathes etc. [5] Used in Diesel Fuel Pumps. [6] Used in printing control mechanism [7] Used in wall clock [8] Used in feed mechanism of automatic lathe.	02
1	(e)	**Define the term 'Dwell' w.r.t. cam profile.**	02
	Ans.	**Definition of Dwell:** It is duration of cam rotation during which there is no motion to the follower. That means during dwell period though cam rotates but follower remains stationary. **OR** When the follower is not moving upward and downward even when the cam rotates is called as dwell.	02
1	(f)	**State the functions of clutches.**	02
	Ans.	**Functions of Clutches:** [1] To engage and disengage output shaft with the engine shaft as and when required. [2] To engage shafts very smoothly without much slipping of friction surfaces. [3] To transmit power from engine shaft to output shaft without loss. [4] To engage the shafts smoothly without noise and jerk	02

Q. No.	Sub Q. N.	Answer	Marking Scheme
1	(g)	**Define coefficient of fluctuation of energy.**	**02**
	Ans.	**Definition of Coefficient of Fluctuation of Energy:** It may be defined as the ratio of the maximum fluctuation of energy to the work done per cycle. Mathematically it is expressed as; $$C_E = \frac{\text{Maximum fluctuation of energy}}{\text{Work done per cycle}}$$ The work done per cycle (in N-m or joules)	**02**
2		**Attempt any THREE of the following: (3 x 4)**	**12**
2	(a)	**Draw a neat diagram of 'Scotch Yoke Mechanism'. Explain its constructional features in brief.**	**04**
		 Scotch yoke mechanism. **Constructional Features of Scotch Yoke Mechanism:** [1] In this mechanism, two sliding pairs and two turning pairs are used. So it is an inversion of Double Slider Crank Chain Mechanism. [2] It consists of following types of links with relative motion as mentioned below; Link 1 (B) – Fixed Link – Guide the Frame Link 2 – Crank – Turning Motion – Rotates about Point B in Link 1 Link 3 - Slider -Sliding Motion Link 4 – Fixed Link – Frame – Reciprocating Motion [3] The inversion is obtained by fixing either the Link 1 or Link 3.	**02 Marks for Labeled Sketch** **02 Marks for Constructional Features**

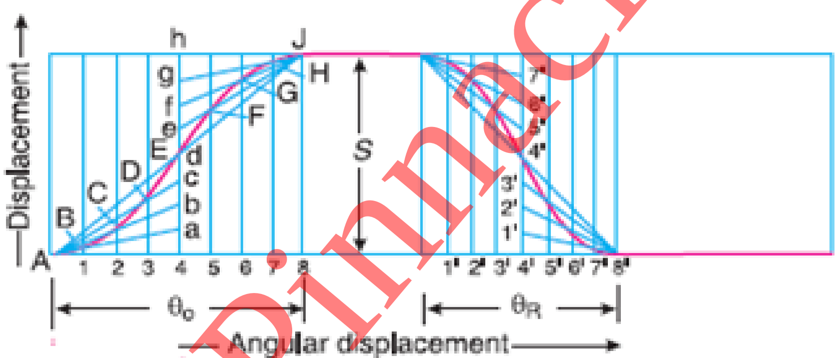
Q. No.	Sub Q. N.	Answer	Marking Scheme
2	(a)	**Draw a neat diagram of 'Scotch Yoke Mechanism'. Explain its constructional features in brief.**	04
	Ans.	[4] When the link 2 (which corresponds to crank) rotates about *B* as centre, the link 4 (which corresponds to a frame) reciprocates. It is used for converting rotary motion into a reciprocating motion.	
2	(b)	**Explain the term: (i) Slip (ii) Creep**	04
	Ans.	**Slip:** The forward motion of the driver without carrying the belt with it or forward motion of the belt without carrying the driven pulley with it, is called slip of the belt. Slip reduces velocity ratio and also power transmission capacity of the belt drive. Less slip in the belt drive is desirable. **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 ***<u>Slip of the belt</u>*** & generally expressed in % **Slip of Belt by neglecting thickness** of belt is expressed as below; $\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{s}{100}\right)$ **Creep:** 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. Creep reduces velocity ratio and also power transmission capacity of the belt drive. Less creep in the belt drive is desirable. **Creep of Belt is expressed as below;** $\frac{N_2}{N_1} = \frac{d_1}{d_2} \times \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$ σ_1 and σ_2 = Stress in the belt on the tight and slack side respectively, and E = Young's modulus for the material of the belt.	01 01 01 01

Q. No.	Sub Q. N.	Answer	Marking Scheme
2	(c)	**Draw the following displacement diagram for follower:** **(i) SHM (ii) Uniform acceleration and deceleration**	**04**
	Ans.	**Displacement Diagram for Simple Harmonic Motion (SHM):**	**02**



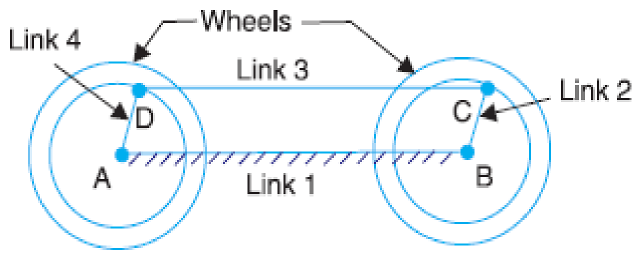
Angular Displacement

Displacement Diagram for Uniform Acceleration and Deceleration: — **02**

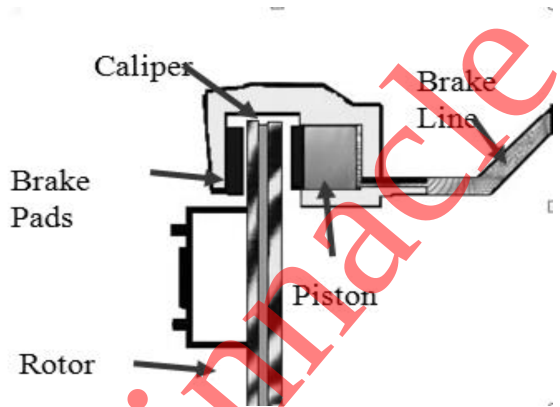
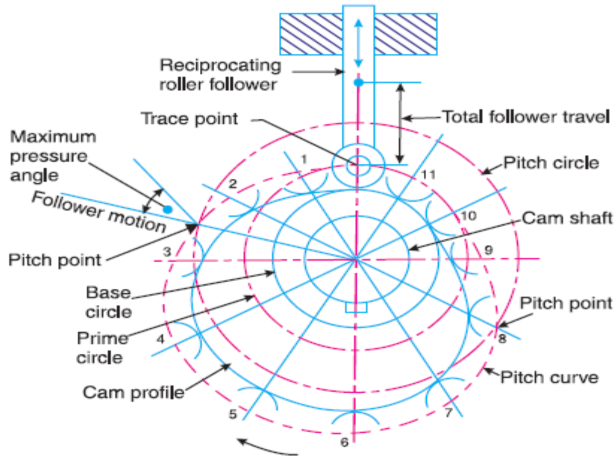


Q. No.	Sub Q. N.	Answer	Marking Scheme
2	(d)	**Differentiate between belt drive and gear drive.**	**04**
	Ans.	**Difference between Belt and Gear Drive: (Any 04 Points, 01 Mark for each)**	**04**

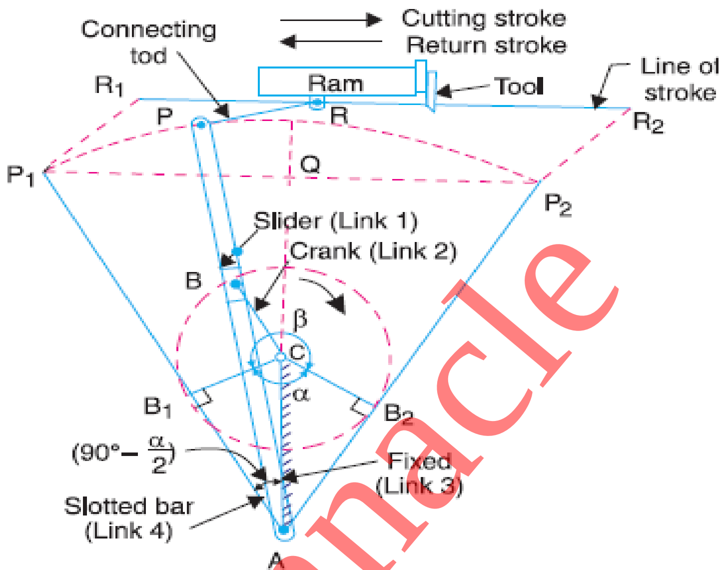
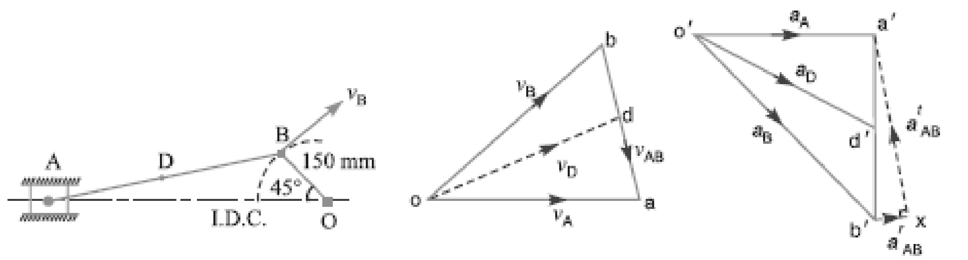
Basis	Belt Drive	Gear Drive
Power transmitting capacity	Less	High
Slip & Creep	Occurs	No
Material used	Flexible in nature	Rigid material used
Type of drive	Slip drive	Positive drive
Centre distance between the shafts	Medium or large	Very less
Overload taking capacity	Slips when overloaded	Damages when overloaded
Velocity Ratio	Does not remain constant	Remain constant
Use	Low to moderate power transmission	High power transmission

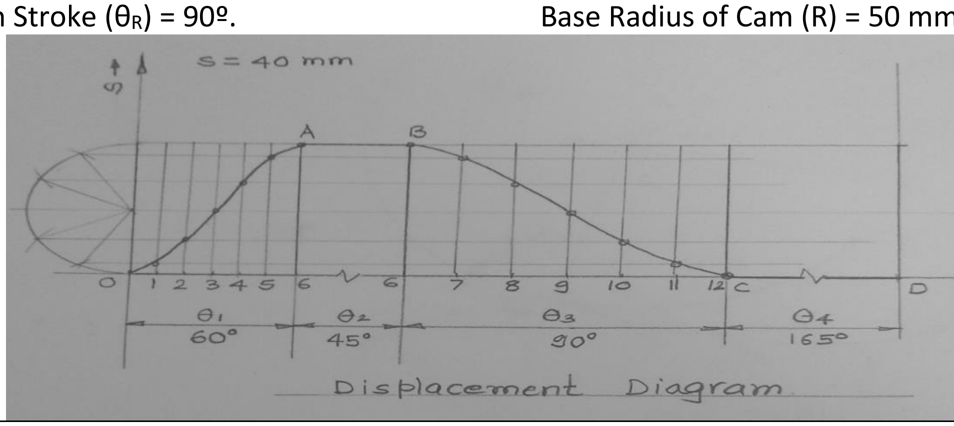
Q. No.	Sub Q. N.	Answer	Marking Scheme
3	(a)	**Draw a neat sketch of 'Locomotive coupler' mechanism. Explain its working in brief.**	04
		 **Figure: Coupler Rod of Locomotive** (**Link AD** = **Link BC** = Crank **Link CD** = Coupling Rod **Link AB** = Fixed Link = Frame)	02
		Working of Coupler Rod of Locomotive: It is an example of Double Crank Mechanism in which, Links AD and BC (having equal length) act as cranks and are connected to the respective wheels. Link CD acts as a coupling rod and link AB is fixed in order to maintain a Constant center to center distance between them. This mechanism is meant for ***transmitting rotary motion from one wheel to the other wheel.***	02
3	(b)	**Name the suitable mechanism to be used for following applications:**	04
		(Correct Name of Suitable Mechanism for Given Application, 01 Mark for each)	04

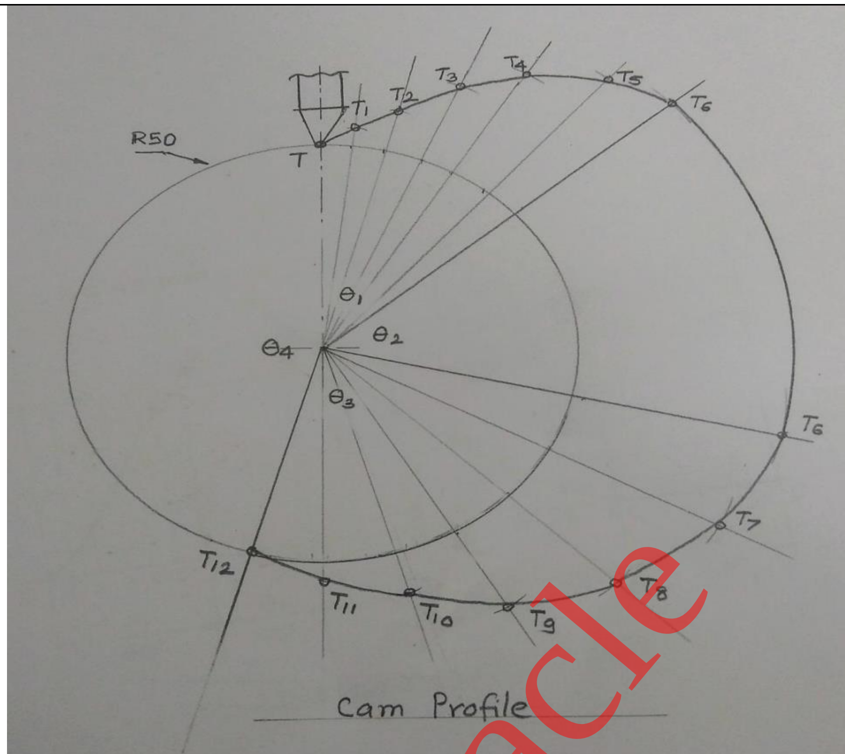
S.N.	Application	Suitable Mechanism
(i)	**Lifting water from well**	Pendulum pump (Bull Engine)
(ii)	**Connecting misaligned shaft**	Oldham's coupling
(iii)	**Converting rotary motion into reciprocating motion**	Beam Engine (Crank & Lever Msm)
(iv)	**Maintain constant relative motion between two rotary elements**	Coupling rod of locomotive

Q. No.	Sub Q. N.	Answer	Marking Scheme
3	(c)	**Explain the construction of 'Disc Brake' with neat sketch.**	**04**
	Ans.	**Construction of Disc Brake:** Modern vehicles always equipped with disc brakes on at least the front two wheels. It consists of mainly 3 parts, [1] Rotor [2] Caliper [3] Brake pads In between each piston and disc, friction pad held in position by springs. Higher applied forces can be used in disc brakes than in drum brakes, because the design of the rotor is stronger than the design of the drum. Due to this, large resistance is carried by flat disc. In this, Flat plate disc with flat friction pad are used against heavy drum. Friction surface directly exposed to air cooling which results better (faster) heat dissipation.  **Figure: Disc Brake**	**02** **02**
3	(d)	**Draw basic 'cam-follower' diagram showing its terminology (Minimum four terms)**	**04**
	Ans.	**Basic Cam Follower Profile:** 	**02 Marks for Cam Profile** **02 Marks for 04 Terms indicating on it**

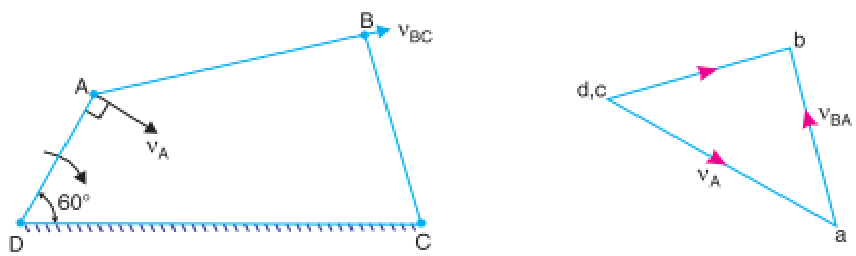
Q. No.	Sub Q. N.	Answer	Marking Scheme
3	(e)	**State the necessity of Balancing. List different types of Balancing Methods.**	**04**
		(02 Marks for Necessity, 02 Marks for Types) **Necessity of Balancing:** [1] The high speed of engines and other machines is a common phenomenon now-a-days. It is, therefore, very essential that all the rotating and reciprocating parts should be completely balanced as far as possible. [2] If these parts are not properly balanced, the dynamic forces are set up. These forces not only increase the loads on bearings and stresses in the various members, but also produce unpleasant and even dangerous vibrations. [3] The balancing of unbalanced forces is caused by rotating masses, in order to minimize pressure on the main bearings when an engine is running. **Types of Balancing Methods:** **[1] Balancing of rotating masses:** (a) Balancing of a single rotating mass by a single rotating mass in the same plane (b) Balancing of a single rotating mass by two masses rotating in the different planes (c) Balancing of different masses rotating in the same plane (d) Balancing of different masses rotating in the different planes **[2] Balancing of Several masses revolving in same plane:**	**02** **02**

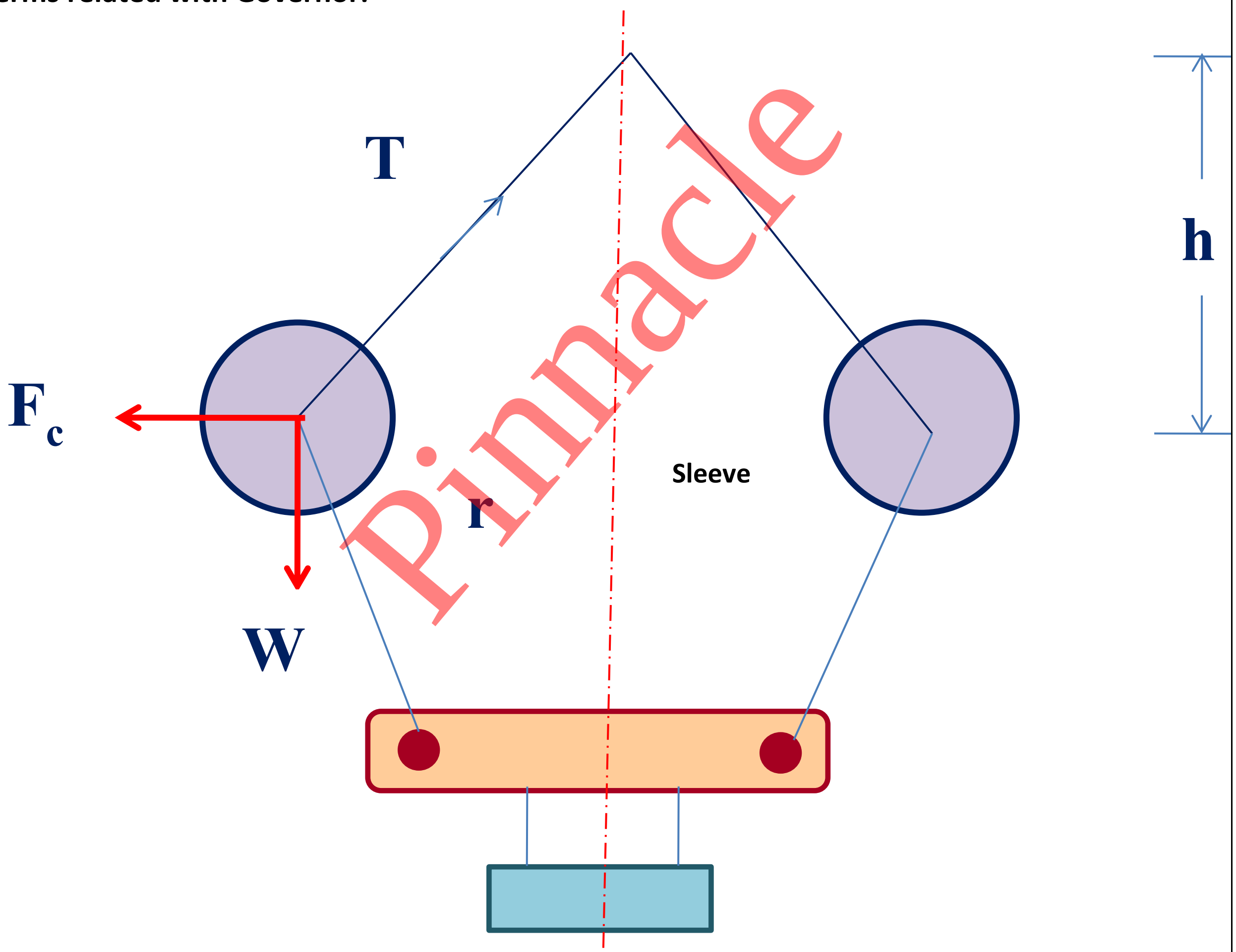
Q. No.	Sub Q. N.	Answer	Marking Scheme
4		**Attempt any TWO of the following (2 x 6)**	**12**
4	(a)	**Draw the labeled diagram of Crank and slotted lever Quick Return Mechanism.**	**06**
		Neat labeled Sketch of Crank and Slotted Lever Quick Return Mechanism: 	**04 Marks for suitable sketch** **02 Marks for Labeling**
4	(b)	**A crank of slider crank mechanism rotates clock wise at constant speed of 300 rpm. The crank is 150 mm and connecting rod is 600 mm long. Determine:** **(i) Linear velocity of the mid-point of connecting rod.** **(ii) Angular acceleration of connecting rod at a crank angle of 45º from inner dead centre position.**	**06**
	Ans.	**Given Data:** Given : N_{BO} = 300 r.p.m. or $\omega_{BO} = 2\pi \times 300/60 = 31.42$ rad/s; OB = 150 mm = 0.15 m ; BA = 600 mm = 0.6 m We know that linear velocity of B with respect to O or velocity of B, $v_{BO} = v_B = \omega_{BO} \times OB = 31.42 \times 0.15 = 4.713$ m/s ...(Perpendicular to BO)  (*a*) Space diagram. (*b*) Velocity diagram. (*c*) Acceleration diagram.	**01 Mark for Given Data** **01 Mark for each of Space, Velocity & Acc. Diagram**

Q. No.	Sub Q. N.	Answer	Marking Scheme
4	(b)	**(i) Linear velocity of the midpoint of connecting rod :** By measurement, we find that v_D = vector od = 4.1 m/s Ans. (ii) **Angular acceleration of connecting rod at a crank angle of 45º from inner dead centre position:** *Angular acceleration of the connecting rod* From the acceleration diagram, we find that $a^t_{AB} = 103 \text{ m/s}^2$ ...(By measurement) We know that angular acceleration of the connecting rod AB, $\alpha_{AB} = \frac{a^t_{AB}}{BA} = \frac{103}{0.6} = 171.67 \text{ rad/s}^2$ (Clockwise about B) Ans.	01 01
4	(c)	**Draw the profile of cam operating a knife edge follower from following data:** **(i) Follower to move outwards through 40 mm during 60º of cam rotation.** **(ii) Follower dwells for next 45º.** **(iii) Follower to return to its original position during next 90º.** **(iv) Follower to dwell for rest of the rotation. The displacement of follower is to take place with simple harmonic motion during both outward and return strokes. The least radius of cam is 50 mm. if the cam rotates at 300 rpm.**	06
		(02 Marks for Displacement Diagram, 04 Marks for Cam Profile) **Given Data:** Lift (S) = 40 mm Outward Stroke (θ_o) = 60º Dwell (θ_D) = 45º Return Stroke (θ_R) = 90º. Base Radius of Cam (R) = 50 mm 	02

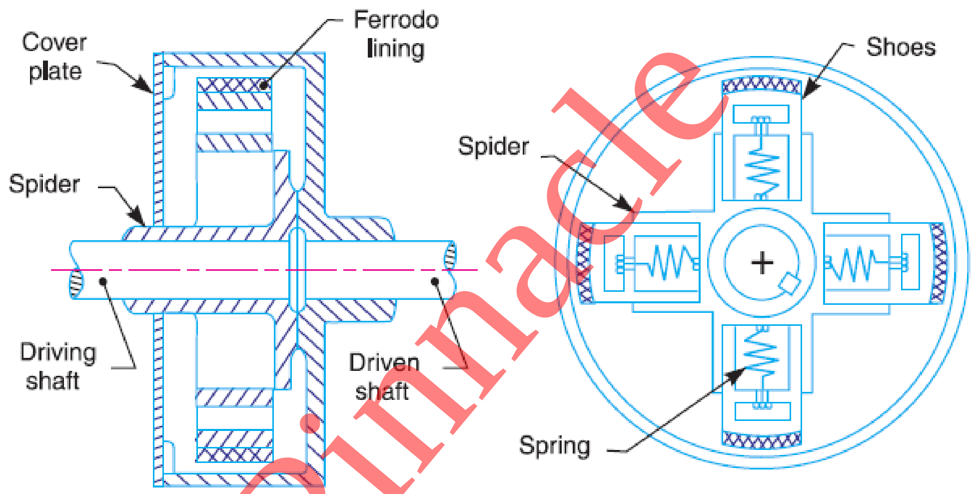
Q. No.	Sub Q. N.	Answer	Marking Scheme
4	(c)		04
5		**Attempt any TWO of the following: (2 x 6)**	**12**
5	(a)	**Two parallel shafts whose centre lines are 4.8 m apart are connected by open belt drive. The diameter of larger pulley is 1.5 m and that of smaller pulley 1 m. the initial tension in the belt when stationary is 3 KN. The mass of the belt is 1.5 Kg/m length. The coefficient of friction between belt and pulley is 0.3. Taking centrifugal tension in to account, calculate power transmitted when smaller pulley rotates at 400 rpm.**	**06**
	Ans.	**Given Data:** **Open Belt Drive:** Where, C = 4.8 m $D_1 = 1.5$ m $D_2 = 1$ m $N_2 = 400$ rpm Ti = 3 KN = 3 x 10^3 N m = 1.5 Kg/m length μ = 0.3 Considering Centrifugal Tension (Tc) =mV^2 [1] We know that, Velocity (V) of the Open Belt Drive; $$v = \frac{\pi d_2 . N_2}{60} = \frac{\pi \times 1 \times 400}{60} = 21 \text{m/s}$$	**01 Mark for Given Data**

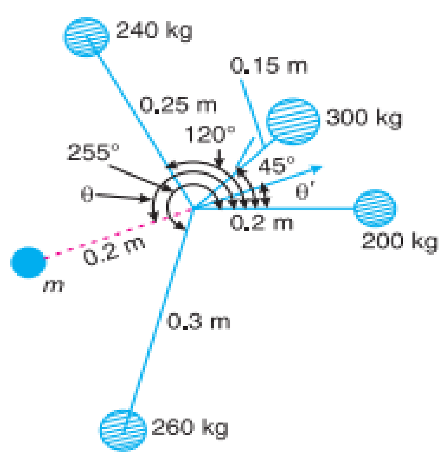
Q. No.	Sub Q. N.	Answer	Marking Scheme
5	(a)	**[2] Centrifugal Tension in Belt (Tc),** $(T_c) = mV^2 = 1.5 \times (21)^2 = 661.5$ N **[3] We know that initial tension in Belt (T_i) as,** Let, T_1 = Tension in Tight Side (N) T_2 = Tension in Slack Side (N) **T_i =** $= \frac{T_1 + T_2 + 2T_C}{2}$ $3000 \times 2 = T_1 + T_2 + 2 \times (661.5)$ **$T_1 + T_2 = 4677$ N ……………………………Eq. [1]**	01 Mark for T_C & T_i Calculation
		[4] For an Open Belt Drive, $\sin\alpha = \frac{r_1 - r_2}{x} = \frac{d_1 - d_2}{2x} = \frac{1.5 - 1}{2 \times 4.8} = 0.0521$ or $\alpha = 3°$ **So, angle of lap on the smaller pulley is;** $\theta = 180° - 2\alpha = 180° - 2 \times 3° = 174°$ $= 174° \times \pi / 180 = 3.04$ rad	01 Mark for ά & θ Calculation
		[5] We know that relation between T_1 & T_2 is; $2.3\log\left(\frac{T_1}{T_2}\right) = \mu.\theta = 0.3 \times 3.04 = 0.912$ $\log\left(\frac{T_1}{T_2}\right) = \frac{0.912}{2.3} = 0.3965$ or $\frac{T_1}{T_2} = 2.5$ **…………………E1. [2]** **From Eq.1 and Eq. 2 , we get,** $T_1 = 3341$ N ; and $T_2 = 1336$ N	02 Marks for T_1 & T_2 Calculation
		[6] Power transmitted by Belt (P), $P = (T_1 - T_2)\,v = (3341 - 1336)\,21 = 42\,100$ W $= 42.1$ kW. **Answer: Power Transmitted by Belt = 42.1 KW**	01 Mark for Calculation of Power (P)

Q. No.	Sub Q. N.	Answer	Marking Scheme
5	(b)	**A 4-bar mechanism has following dimensions: *l*(DA) = 300 mm, *l*(CB) = *l*(AB) = 360mm, *l*(DC) = 600 mm. the link 'DC' is fixed. The angle ADC is 60º. The driving link 'DA' rotates at a speed of 100 rpm clockwise and constant driving torque is 50 N-m. Calculate the velocity of point 'B' and angular velocity of driven link 'CB'.**	**06**
	Ans.	**Given Data:** N_{AD} = 100 rpm DA = 300 mm = 0.3 m T_A = 50 N-m ω_{AD} = 2 π x 100 /60 = 10.47 rad/sec. **Velocity of A w.r.t. D (V_{AD});** $v_{AD} = v_A = \omega_{AD} \times DA = 10.47 \times 0.3 = 3.14$ m/s ……….Perpendicular to DA **Velocity of Point B:** **[1]** Since the link *DC* is fixed, therefore points d and c are taken as one point in the velocity diagram. Draw vector da perpendicular to *DA*, to some suitable scale, to represent the velocity of *A* with respect to *D* or simply velocity of A (i.e. V_{AD} or V_A) such that, Vector *da* = $V_{AD} = V_A$ = 3.14 m/s **[2]** Now from point a, draw vector ab perpendicular to *AB* represents the velocity of *B* with respect to A (i.e. V_{BA}), and from point c draw vector *cb* perpendicular to *CB* to represent the velocity of *B* with respect to *C* or simply velocity of B (i.e. V_{BC} or V_B). The Vectors ab and cb intersect at b. **[3]** By measurement, we find that velocity of point B, $V_B = V_{BC}$ = vector *cb* = 2.25 m/s  (*a*) Space diagram. (*b*) Velocity diagram.	**01 Mark for Given Data** **01 Mark for Calculation of V_{AD} and V_B** **02 Marks for Space & Vector Diagram**

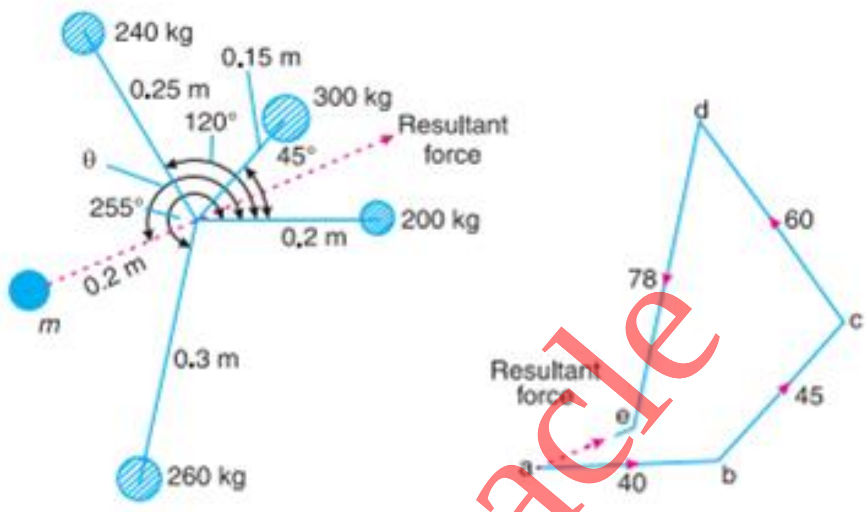
Q. No.	Sub Q. N.	Answer	Marking Scheme
5	(b)	**[4] Angular Velocity of driven link CB** Since *CB* = 360 mm =0.36 m, therefore angular velocity of the driven link *CB*, $\omega_{BC} = \frac{v_{BC}}{BC} = \frac{2.25}{0.36} = 6.25$ rad/s (Clockwise about *C*)	**02 Marks for ω_{BC}**
5	(c)	**Explain the following terms of centrifugal governor with neat sketch:** **(i) Height of Governor** **(ii) Equilibrium Speed** **(iii) Sleeve Lift**	**06**
	Ans.	**(1.5 Marks for Sketch, 1.5 Marks for significance of each term)** **Terms related with Governor:**  **(i) Height of Governor:** It is the vertical distance from the centre of the ball to a point where the axes of the arms (or arms produced) intersect on the spindle axis. It is usually denoted by h as shown in figure. (ii) **Equilibrium Speed:** It is the speed at which the governor balls, arms etc. are in complete equilibrium & the sleeve does not tend to move upwards or downwards.	**1.5 Mark** **1.5 Mark** **1.5 Mark** **1.5 Mark**

		(iii) Sleeve Lift: It is the vertical distance which the sleeve travels due to change in equilibrium speed.	
6		**Attempt any TWO of the following: (2 x 6)**	**12**
6	**(a)**	**Two pulleys one 450 mm diameter and the other 200 mm diameter are on parallel shafts 1.95 m apart and are connected by a crossed belt. Find the length of belt required and angle of contact between belt and each pulley. Estimate the power transmitted by belt when the larger pulley rotates at 200 rpm. If the maximum tension in the belt is 1 KN and coefficient of friction between belt and pulley is 0.25.**	**06**
6	**(a)**	**Given Data:** **Crossed Belt Drive** D_1 = 450 mm = 0.45 m D_2 = 200 mm = 0.20 m C = 1.95 m N_1 = 200 rpm μ = 0.25 $T_1 = T_{max}$ = 1 KN = 1000 N L_{Cross} = ? Θs = ? P = ? **[1] We know that speed of the Belt is;** $v = \frac{\pi d_1 . N_1}{60} = \frac{\pi \times 0.45 \times 200}{60} = 4.714 \text{ m/s}$ **[2] Length of the Crossed Belt Drive (L_{Cross});** $L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$ $= \pi(0.225 + 0.1) + 2 \times 1.95 + \frac{(0.225 + 0.1)^2}{1.95} = 4.975 \text{m}$ **[3] Angle of Contact between belt and each pulley;** $\sin\alpha = \frac{r_1 + r_2}{x} = \frac{0.225 + 0.1}{1.95} = 0.1667 \text{ or } \alpha = 9.6°$ $\theta = 180° + 2\alpha = 180° + 2 \times 9.6° = 199.2°$ $= 199.2 \times \frac{\pi}{180} = 3.477 \text{ rad}$ **Ans.** **[4] Power transmitted by Belt;** Let, T2 = Tension in Slack side of the belt We know that, $2.3 \log\left(\frac{T_1}{T_2}\right) = \mu.\theta = 0.25 \times 3.477 = 0.8692$ $\log\left(\frac{T_1}{T_2}\right) = \frac{0.8692}{2.3} = 0.378 \text{ or } \frac{T_1}{T_2} = 2.387$ ...(Taking antilog of 0.378)	**01 Mark for Given Data** **01 Mark for Speed** **01 Mark for L_{Cross}** **01 Mark for Θ** **01**

		$T_2 = \frac{T_1}{2.387} = \frac{1000}{2.387} = 419\ \text{N}$	Mark for T_2
6	(a)	**Power transmitted by belt (P) is;** **P = (T_1 – T_2) x V** = $(1000 - 419)\ 4.714 = 2740\ \text{W} = 2.74\ \text{kW}$ Answers: **L_{Cross} = 4.975 m** Θs = **3.477 rad.** P = **2.74 KW**	**01 Mark for P**
6	(b)	**Draw the constructional details diagram of Centrifugal clutch. Explain its working principle.**	**06**
	Ans.	**(03 Marks for neat labeled sketch, 03 Marks for Working principle in brief)**  Centrifugal clutch. **Working Principle of Centrifugal Clutch:** The centrifugal clutch uses ***centrifugal force***, instead of spring force for keeping it in engaged position. Also, it does not require clutch pedal for operating the clutch. The clutch is operated automatically depending upon the engine speed. The vehicle can be stopped in gear without stalling the engine. Similarly the vehicle can be started in any gear by pressing the accelerator pedal. This makes the driving operation very easy. **OR**	**03 Marks for neat labeled sketch** **03 Marks for Appropriate principle of working**

Q. No.	Sub Q. N.	Answer	Marking Scheme
6	(b)	The centrifugal clutches are usually incorporated into the motor pulleys. It consists of a number of shoes on the inside of a rim of the pulley, as shown in Fig. The outer surface of the shoes is covered with a friction material. These shoes, which can move radially in guides, are held against the boss (or spider) on the driving shaft by means of springs. The springs exert a radially inward force which is assumed constant. The mass of the shoe, when revolving, causes it to exert a radially outward force (i.e. centrifugal force). The magnitude of this centrifugal force depends upon the speed at which the shoe is revolving. A little consideration will show that when the centrifugal force is less than the spring force, the shoe remains in the same position as when the driving shaft was stationary, but when the centrifugal force is equal to the spring force, the shoe is just floating. When the centrifugal force exceeds the spring force, the shoe moves outward and comes into contact with the driven member and presses against it. The force with which the shoe presses against the driven member is the difference of the centrifugal force and the spring force. The increase of speed causes the shoe to press harder and enables more torque to be transmitted.	
6	(c)	**The weights of four masse A, B, C, D are 200 Kg, 300 Kg, 240 Kg and 260 Kg respectively. The corresponding radii of rotation are 200 mm, 150 mm, 250 mm and 300 mm respectively and the angle between successive masses are 45º, 75º and 135º. Find the position and magnitude of the balance weight required if its radius of rotation is 200 mm.**	06
	Ans.	**Given Data: (Either solve by Analytical Or Graphical Method)** Given : m_1 = 200 kg ; m_2 = 300 kg ; m_3 = 240 kg ; m_4 = 260 kg ; r_1 = 0.2 m ; r_2 = 0.15 m ; r_3 = 0.25 m ; r_4 = 0.3 m ; $\theta_1 = 0°$; $\theta_2 = 45°$; $\theta_3 = 45° + 75° = 120°$; $\theta_4 = 45° + 75° + 135° = 255°$; r = 0.2 m  **Figure: Space Diagram**	01 Mark for Given Data 02 Mark for Space Diagram

Q. No.	Sub Q. N.	Answer	Marking Scheme
6	(c)	Let m = Balancing mass, and θ = The angle which the balancing mass makes with m_1. Since the magnitude of centrifugal forces are proportional to the product of each mass and its radius, therefore $m_1 \cdot r_1 = 200 \times 0.2 = 40$ kg-m $m_2 \cdot r_2 = 300 \times 0.15 = 45$ kg-m $m_3 \cdot r_3 = 240 \times 0.25 = 60$ kg-m $m_4 \cdot r_4 = 260 \times 0.3 = 78$ kg-m **[a] Analytical Method:** Resolving $m_1.r_1$, $m_2.r_2$, $m_3.r_3$ and $m_4.r_4$ horizontally, $\Sigma H = m_1 \cdot r_1 \cos\theta_1 + m_2 \cdot r_2 \cos\theta_2 + m_3 \cdot r_3 \cos\theta_3 + m_4 \cdot r_4 \cos\theta_4$ $= 40\cos 0° + 45\cos 45° + 60\cos 120° + 78\cos 255°$ $= 40 + 31.8 - 30 - 20.2 = 21.6$ kg-m Now resolving vertically, $\Sigma V = m_1 \cdot r_1 \sin\theta_1 + m_2 \cdot r_2 \sin\theta_2 + m_3 \cdot r_3 \sin\theta_3 + m_4 \cdot r_4 \sin\theta_4$ $= 40\sin 0° + 45\sin 45° + 60\sin 120° + 78\sin 255°$ $= 0 + 31.8 + 52 - 75.3 = 8.5$ kg-m $\therefore$ Resultant, $R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2} = \sqrt{(21.6)^2 + (8.5)^2} = 23.2$ kg-m We know that $m \cdot r = R = 23.2$ or $m = 23.2 / r = 23.2/0.2 = 116$ kg **Ans.** and $\tan\theta' = \Sigma V / \Sigma H = 8.5/21.6 = 0.3935$ or $\theta' = 21.48°$ Since θ' is the angle of the resultant R from the horizontal mass of 200 kg, therefore the angle of the balancing mass from the horizontal mass of 200 kg, $\theta = 180° + 21.48° = 201.48°$ **Ans.** **OR**	03 Marks for Calculation of Magnitude and Direction by Analytically.

Q. No.	Sub Q. N.	Answer	Marking Scheme
6	(c)	**[b] Graphical Method:** Now draw the vector diagram with the above values, to some suitable scale, as shown in Fig (*b*). The closing side of the polygon *ae* represents the resultant force. By measurement, we find that *ae* = 23 kg-m.  (*a*) Space diagram. (*b*) Vector diagram The balancing force is equal to the resultant force, but ***opposite*** in direction as shown in Fig. 21.6 (*a*). Since the balancing force is proportional to *m.r*, therefore $m \times 0.2$ = vector *ea* = 23 kg-m or $m = 23/0.2 =$ **115 kg Ans.** By measurement we also find that the angle of inclination of the balancing mass (*m*) from the horizontal mass of 200 kg, $\theta = 201°$ **Ans.**	02 Marks for Space Diagram 02 Marks for Vector Diagram 01 Marks for Calculation of Magnitude & Direction by Graphically.