MODEL ANSWER

SUMMER– 18 EXAMINATION

Subject Title: THEORY OF MACHINES 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
1	A a)	**Inversion of single slider crank mechanism: (Any Two)** 1. Pendulum pump or Bull engine 2. Oscillating cylinder engine 3. Rotary internal combustion engine or Gnome engine. 4. Crank and slotted lever quick return motion mechanism. 5. Whitworth quick return motion mechanism.	1 M for each
	b)	**Law of gearing**:-The common normal at the point of contact between a pair of teeth must always pass through the pitch point. This is the fundamental condition which must be satisfied while designing the profiles for the teeth of gear wheels. It is also known as law of gearing.	2 M
	c)	i) **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, coefficient of fluctuation of energy, $C_E = \frac{\text{Maximum fluctuation of energy}}{\text{Work done per cycle}}$ (ii) **Coefficient of Fluctuation of Speed**: The difference between the maximum and minimum speeds during a cycle is called the maximum fluctuation of speed. The ratio of the maximum fluctuation of speed to the mean speed is called the coefficient of fluctuation of speed.	1 M Each

Let N_1 and N_2 = Maximum and minimum speeds in r.p.m. during the cycle, and

$$N = \text{Mean speed in r.p.m.} = \frac{N_1 + N_2}{2}$$

∴ Coefficient of fluctuation of speed,

$$C_S = \frac{N_1 - N_2}{N} = \frac{2(N_1 - N_2)}{N_1 + N_2}$$

$$= \frac{\omega_1 - \omega_2}{\omega} = \frac{2(\omega_1 - \omega_2)}{\omega_1 + \omega_2} \quad \text{...(In terms of angular speeds)}$$

$$= \frac{v_1 - v_2}{v} = \frac{2(v_1 - v_2)}{v_1 + v_2} \quad \text{...(In terms of linear speeds)}$$

d)

Functions of Brakes: 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. — 1 M Each (Any 2)

The brake absorbs either kinetic energy of the moving member or potential energy given up by objects being lowered by hoists, elevators etc

Brakes are used to stop a moving member or to control its speed.

e)

Why balancing is necessary for high speed?

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. 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 — 2 M

f)

(i) Each part of a machine, which moves relative to some other part, is known as a **kinematic link** (or simply link) or element — 1 M Each

(ii) When the kinematic pairs are coupled in such a way that the last link is joined to the first link to transmit definite motion (i.e. completely or successfully constrained motion), it is called a **kinematic chain.**

g)

The **relative velocity** is the velocity of an object or observer **B** in the rest frame of another object or observer **A**. — 1 M Each

The **relative acceleration** is defined as the time derivative of relative velocity. For example, consider an observer looking at a ball falling from a building. The relative acceleration of the ball with respect to the observer is 9.8 m/s/s downwards.

h)

Motion of the Follower:

1. Uniform velocity, 2. Simple harmonic motion, — ½ M Each

3. Uniform acceleration and retardation, and 4. Cycloidal motion.

B

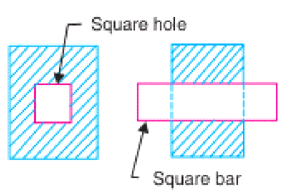
(a)

1. 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. For example, 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, as shown in Fig.

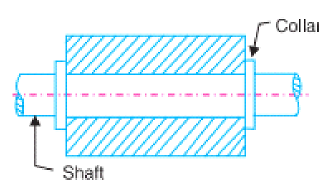
2. Incompletely constrained motion. When the motion between a pair can take place in more than one direction, then the motion is called an incompletely constrained motion. The change in the direction of impressed force may alter the direction of relative motion between the pair. A circular bar or shaft in a circular hole, as shown in Fig. 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.

3. 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. 5.5. 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. The motion of an I.C. engine Mechanisms valve (these are kept on their seat by a spring) and the piston reciprocating inside an engine cylinder are also the examples of successfully constrained motion.

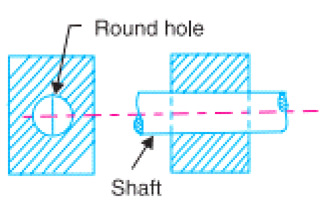
2 M Explain + 2M Sketch



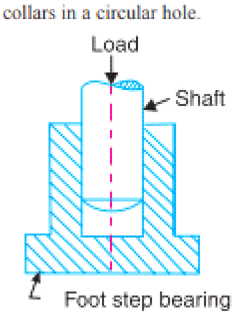
Square bar in a square hole.



Shaft with collars in a circular hole.



Shaft in a circular hole.



Shaft in a foot step bearing.

b)

Function of the Clutch:

- Function of transmitting the torque from the engine to the drive train.
- Smoothly deliver the power from the engine to enable smooth vehicle movement.
- Perform quietly and to reduce drive-related vibration.

2 M

WORKING PRINCIPLE OF CLUTCH:
It operates on the principle of friction. When two surfaces are brought in contact and are held against each other due to friction between them, they can be used to transmit power. If one is rotated, then other also rotates. One surface is connected to engine and other to the transmission system of automobile. Thus, clutch is nothing but a combination of two friction surfaces.

2 M

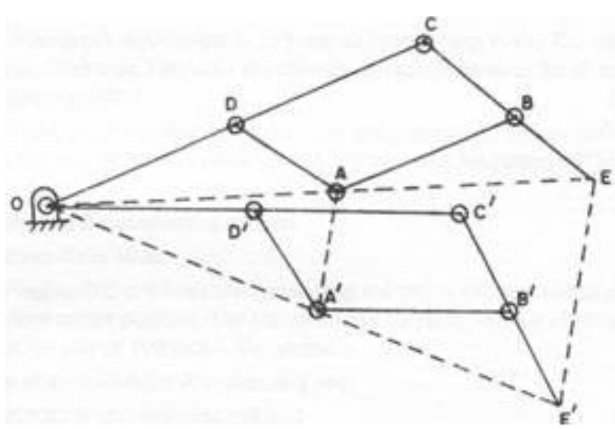
c)

Sr. no.	Parameters	Cross belt drive	Open belt drive
1	Velocity ratio	High velocity ratio	Low velocity ratio
2	Application	Sawmills, buck saws	Conveyors, electrical generator
3	Direction of driven pulley	Rotated in opposite direction as the driving as the driving pulley	Rotated in the same direction to the driving pulley
4	Length of belt drive	$L = \pi (r_1 + r_2) + 2x + (r_1 + r_2)^2 / x$	$L = \pi (r_1 + r_2) + 2x + (r_1 - r_2)^2 / x$

1 M For Each Parameter

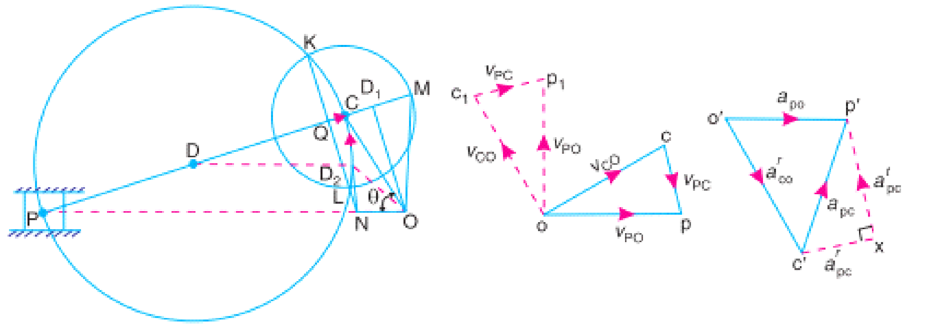
2 a)

Pantograph : It is a mechanism which is used trace a path to an enlarged or reduced scale. It is an example of four bar kinematic chain. It consists of a four links joined in such a way to form a parallelogram ABCD in which AB=CD and AD=BC. In figure, OAE always remains in straight line. Pantograph consists of four turning pair It is used to guide the cutting tools, for the reproduction of maps and plans on enlarged or reduced scale, and a modified pantograph is used to collect the electric power at the top of an electric locomotive.



2 M Explain + 2M Sketch

b)



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

Klien's construction.

2 M Sketch & 2 M For Explanation

Klien'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 Klien'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

CO may be regarded as a line parallel to CO.

Klien's acceleration diagram :

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 & 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.

c)

Compare Flywheel & Governor

Sr. No.	Flywheel	Governor
1	The flywheel stores the energy and gives up the energy whenever required during cycle.	It regulates the speed by regulating the quantity of charge of prime mover.
2	It has no control over the quantity of working fluid.	Governor takes care of quantity of working fluid.
3	It regulates the speed during one cycle only.	It regulates the speed over period of time.
4	It is not essential element for every prime mover.	It is an essential element of a prime mover.
5	It is used in toys, IC engine, hand watches.	It is used in automobile vehicles.

1 M For Each Parameter

d)

Difference between Brakes & Dynamometer

Sr. No.	Brakes	Dynamometer
1	It Is a device use the principle of frictional resistance to stop or retard the moving body by absorbing kinetic energy and dissipating it as heat	It is a braking device used to measure the frictional resistance applied on body and measure the power developed by machines
2	It is used in retard or stop	It is able to measure absorb K.E. transmitted to prime mover.
3	No torque or power is measured	It measures torque, and hence power
4	Examples: Hydraulic brakes, Mechanical brakes, and Electric brakes	Examples: Absorption & Transmission dynamometers

1 M For Each parameter

e)

Slip of Belt: There is always some amount of frictional grip between the belts and the shafts. But sometimes, this frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt with it. This may also cause some forward motion of the belt without carrying the driven pulley with it. This is called slip of the belt and is generally expressed as a percentage. The result of the belt slipping is to reduce the velocity ratio of the system. As the slipping of the belt is a common phenomenon, thus the belt should never be used where a definite velocity ratio is of importance (as in the case of hour, minute and second arms in a watch).

2M

Let $s_1\,\%$ = Slip between the driver and the belt, and

$s_2\,\%$ = Slip between the belt and the follower.

∴ Velocity of the belt passing over the driver per second

$$v = \frac{\pi d_1 . N_1}{60} - \frac{\pi d_1 . N_1}{60} \times \frac{s_1}{100} = \frac{\pi d_1 . N_1}{60}\left(1 - \frac{s_1}{100}\right) \quad \ldots(i)$$

and velocity of the belt passing over the follower per second,

$$\frac{\pi d_2 . N_2}{60} = v - v \times \frac{s_2}{100} = v\left(1 - \frac{s_2}{100}\right)$$

Substituting the value of v from equation (i),

$$\frac{\pi d_2\, N_2}{60} = \frac{\pi d_1\, N_1}{60}\left(1 - \frac{s_1}{100}\right)\left(1 - \frac{s_2}{100}\right)$$

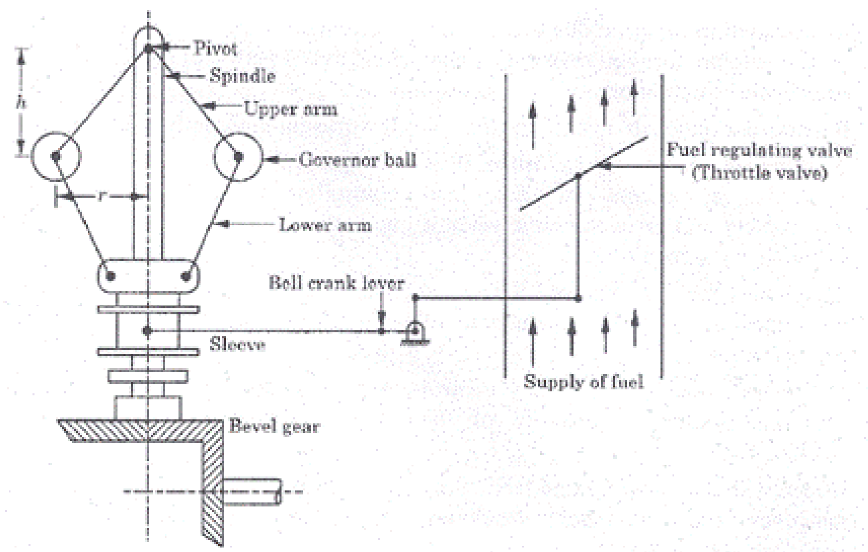
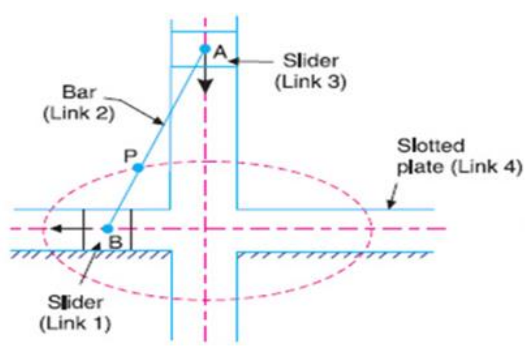
$$\frac{N_2}{N_1} = \frac{d_1}{d_2}\left(1 - \frac{s_1}{100} - \frac{s_2}{100}\right) \quad \ldots\left(\text{Neglecting } \frac{s_1 \times s_2}{100 \times 100}\right)$$

$$= \frac{d_1}{d_2}\left(1 - \frac{s_1 + s_2}{100}\right) = \frac{d_1}{d_2}\left(1 - \frac{s}{100}\right)$$

... (where $s = s_1 + s_2$, *i.e.* total percentage of slip)

If thickness of the belt (t) is considered, then

$$\frac{N_2}{N_1} = \frac{d_1 + t}{d_2 + t}\left(1 - \frac{s}{100}\right)$$

	f)	**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. The total effect of creep is to reduce slightly the speed of the driven pulley or follower. Considering creep, the velocity ratio is given by $$\frac{N_2}{N_1} = \frac{d_1}{d_2} \times \frac{E + \sqrt{\sigma_2}}{E + \sqrt{\sigma_1}}$$ where 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. **Gear train:** Two or more gears are made to mesh with each other to transmit power from one shaft to another. Such a combination is called gear train **Types of gear trains**: 1. Simple gear train, 2. Compound gear train, 3. Reverted gear train, and 4. Epicyclic gear train	2M 2 M 2 M
3		**Attempt any Four of the following.**	**12**
	a)	**Centrifugal Governor**  	02mark sketch 02mark Label
	b)	**Elliptical Trammel**  	02mark sketch 02mark label

c) **Angular acceleration**, also called rotational **acceleration**, is a quantitative expression of the change in **angular** velocity that a spinning object undergoes per unit time. It is simply rate of change of angular velocity. 2M

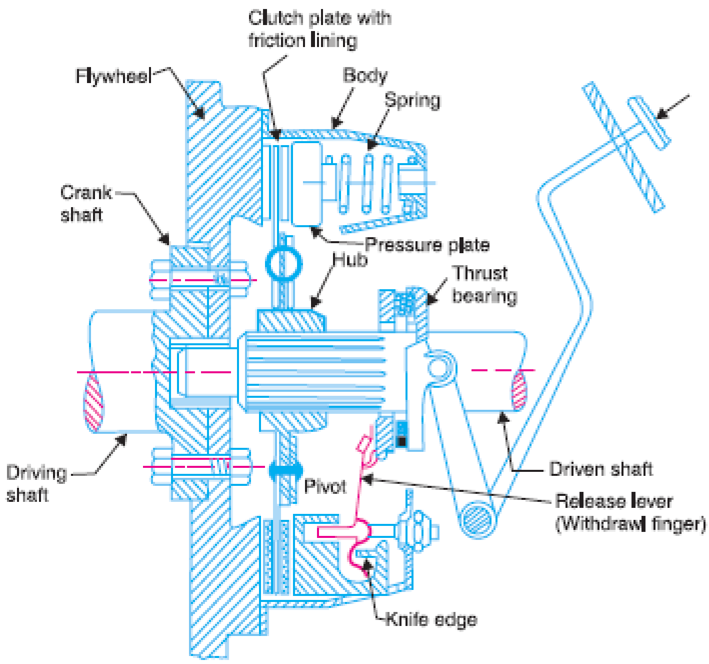
Inter-relation between linear velocity, angular velocity and acceleration:

Linear velocity V = angular Velocity x radius of rotation = ω x r 1M

Acceleration f = V^2 /r or ω^2 x r 1M

d) **Single plate clutch:**

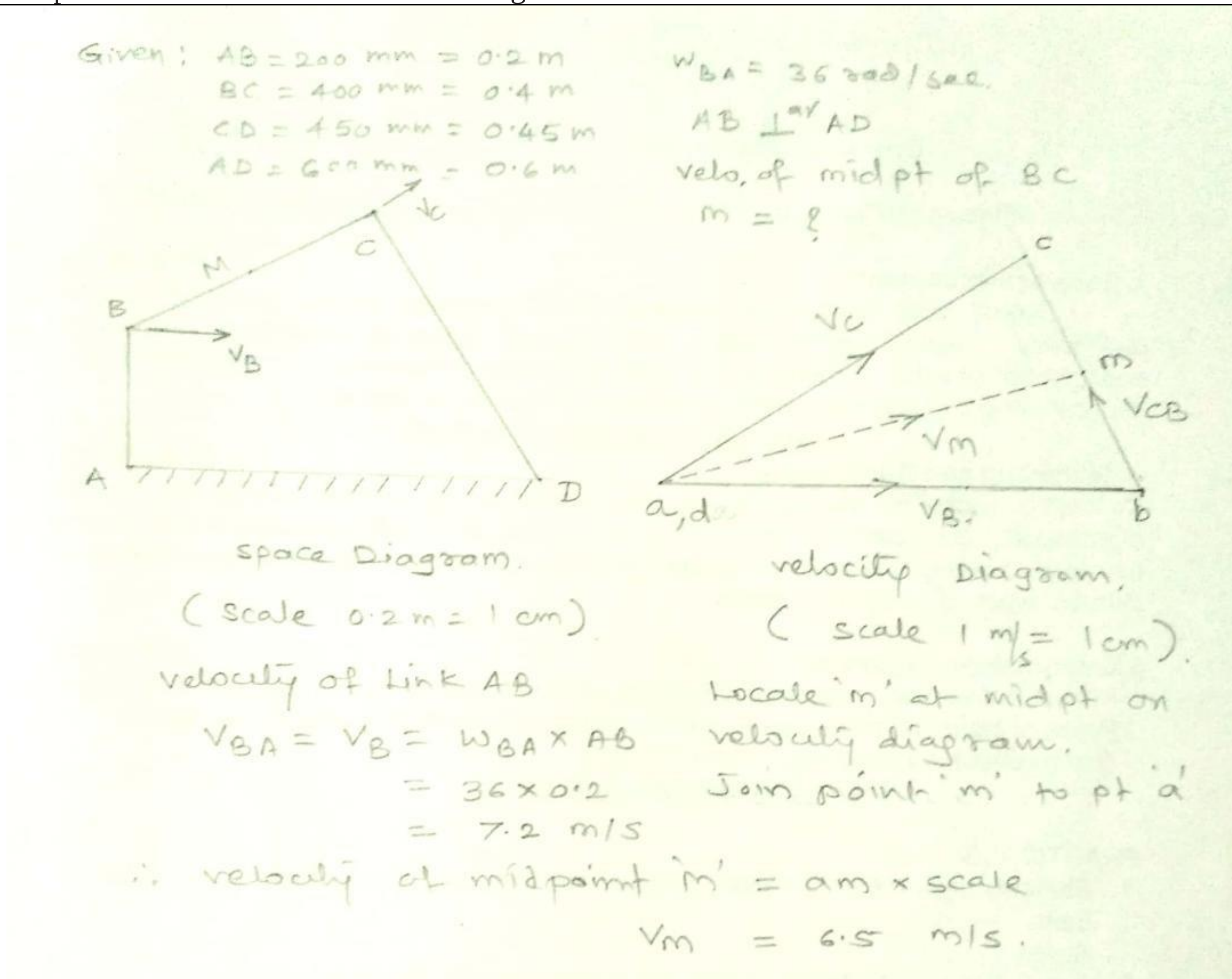
02 marks Sketch



Single disc or plate clutch.

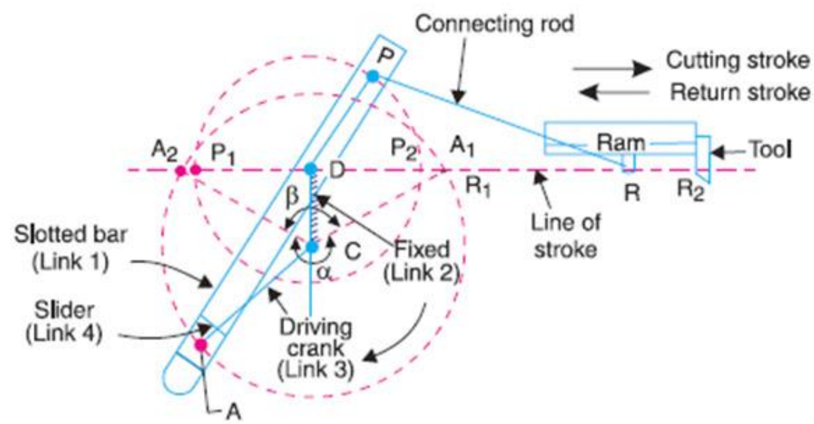
02 marks Explanation

A single disc or plate clutch, as shown in Fig. consists of a clutch plate whose both sides are faced with a friction material (usually of Ferrodo). It is mounted on the hub which is free to move axially along the splines of the driven shaft. The pressure plate is mounted inside the clutch body which is bolted to the flywheel. Both the pressure plate and the flywheel rotate with the engine crankshaft or the driving shaft. The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body. The three levers (also known as release levers or fingers) are carried on pivots suspended from the case of the body. These are arranged in such a manner so that the pressure plate moves away from the flywheel by the inward movement of a thrust bearing. The bearing is mounted upon a forked shaft and moves forward when the clutch pedal is pressed. When the clutch pedal is pressed down, its linkage forces the thrust release bearing to move in towards the flywheel and pressing the longer ends of the levers inward. The levers are forced to turn on their suspended pivot and the pressure plate moves away from the flywheel by the knife edges, thereby compressing the clutch springs. This action removes the pressure from the clutch plate and thus moves back from the flywheel and the driven shaft becomes stationary. On the other hand, when the foot is taken off from the clutch pedal, the thrust bearing moves back by the levers. This allows the springs to extend and thus the pressure plate pushes the clutch plate back towards the flywheel. The axial

		pressure exerted by the spring provides a frictional force in the circumferential direction when the relative motion between the driving and driven members tends to take place. If the torque due to this frictional force exceeds the torque to be transmitted, then no slipping takes place and the power is transmitted from the driving shaft to the driven shaft.	
	e		1M Space Dia 1M velocity Dia 2M Calcul.
	f	**i) Angle of lap:** The angle of lap is defined as the angle subtended by the portion of the belt which is in contact at the pulley surface of the pulley. **ii) Applications of cam and followers: (Any Two)** 1. For operating the inlet and exhaust valves of internal combustion engines, 2. automatic attachment of machineries, 3. paper cutting machines, 4. spinning and weaving textile machineries, 5. feed mechanism of automatic lathes etc.	02marks 01 mark each

Q 4.		**Attempt any Four of the following.**	08

a **Whitworth quick return motion mechanism:**



02 mark Sketch

Whitworth quick return mechanism is an application of third inversion which is obtained by fixing the crank i.e. link 2. This mechanism is shown in the figure. The crank OC is fixed and OQ rotates about O. The slider slides in the slotted link and generates a circle of radius CP. Link 5 connects the extension OQ provided on the opposite side of the link 1 to the ram (link 6). The rotary motion of P is taken to the ram R which reciprocates. The quick return motion mechanism is used in shapers and slotting machines. The angle covered during cutting stroke from P1 to P2 in counter clockwise direction is α or 360 -2θ. During the return stroke, the angle covered is 2θ or β.

02 marks Explain

$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\alpha}{\beta} = \frac{\alpha}{360° - \alpha} \quad \text{or} \quad \frac{360° - \beta}{\beta}$$

b

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

We know that velocity of the belt,

$$v = \frac{\pi d . N}{60} = \frac{\pi \times 0.6 \times 200}{60} = 6.284 \text{ m/s}$$

01 mark

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

We know that $2.3 \log\left(\frac{T_1}{T_2}\right) = \mu.\theta = 0.25 \times 2.793 = 0.6982$

$$\log\left(\frac{T_1}{T_2}\right) = \frac{0.6982}{2.3} = 0.3036$$

01 mark

$\therefore \quad \frac{T_1}{T_2} = 2.01$ ...(Taking antilog of 0.3036)

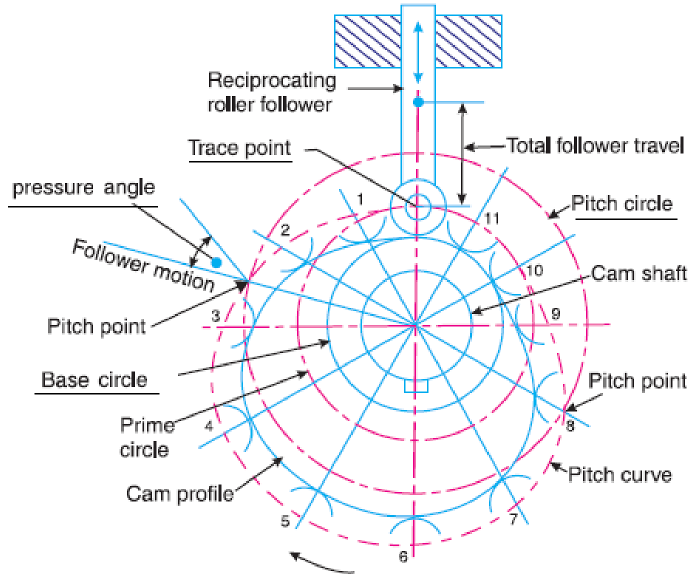
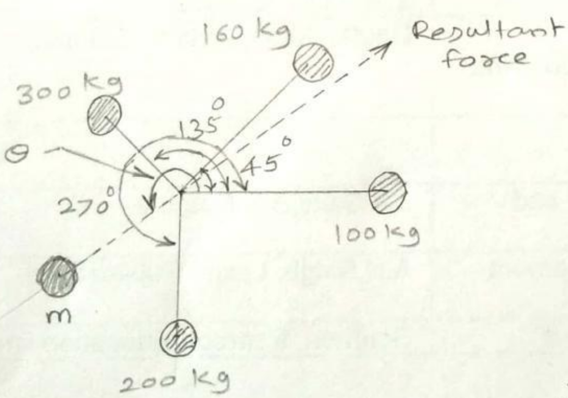
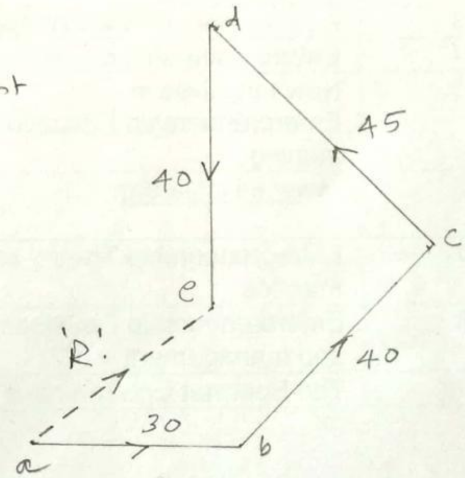
and $T_2 = \frac{T_1}{2.01} = \frac{2500}{2.01} = 1244$ N

01 mark

We know that power transmitted by the belt,

$$P = (T_1 - T_2)\, v = (2500 - 1244)\, 6.284 = 7890 \text{ W}$$
$$= 7.89 \text{ kW} \quad \textbf{Ans.}$$

01 mark

	c	**Radial cam with roller follower:**  	02 mark Sketch 02 mark Label
	d.	Given: $m_1 = 100$ kg $m_2 = 160$ kg $m_3 = 300$ kg $m_4 = 200$ kg $r_1 = 300$ mm $= 0.3$ m $r_2 = 250$ mm $= 0.25$ m $r_3 = 150$ mm $= 0.15$ m $r_4 = 200$ mm $= 0.2$ m $m_1 r_1 = 100 \times 0.3 = 30$ kgm $m_3 r_3 = 300 \times 0.15 = 45$ kgm $m_2 r_2 = 160 \times 0.25 = 40$ kgm $m_4 r_4 = 200 \times 0.2 = 40$ kgm $\theta_1 = 0$, $\theta_2 = 45^0$ $\theta_3 = 135^0$ (45+90) $\theta_4 = 45 + 90 + 135 = 270^0$  (space diagram)  (vector diagram) from vector diagram: Balancing mass 'm' $m \times 0.2 =$ vector ea $\therefore$ $m = 32/0.2 = 160$ kg Ans. Position of balancing mass $= \theta = 215^0$ **(Here Radius of rotation r=0.2 as given in problem)** **Therefore Balancing mass = 160 kg, Position $\Theta = 215^0$ Ans.**	01 mark **01M Calculations** **01M Space Diag.** **01M Vector Diag.** **01M Ans**

e) Comparison between flat belt and V belt (Any four points)

Sr.No	Factor	Flat Belt	Vee Belt
1.	Cross sectional area	Rectangular	Trapezoidal
2.	Area of application	They are used when the two pulleys are not more than 8 m apart.	They are used when the two pulleys are 2 - 3 m apart.
3.	Efficiency	Low (due to slippage) as compared to Vee Belt	More as compared to Flat Belt
4.	Joint	They have a joint	They are endless
5.	Construction of pulley	Simple	Complicated
6.	Cost	Cheaper	Costlier
7.	Precise alignment	Not required	Required
8.	Constant velocity ratio	Can not be obtained	Can be obtained
9.	Power transmitting capacity	Less as compared to Vee Belt	More as compared to Flat Belt
10.	Speed reduction ratio	Less	More
11.	Operation	Noisy as compared to Vee Belt	Quiet as compared to Flat Belt

04marks

f. Advantages of Roller Follower over Knife Edge Follower (any 4 points)

04 Marks

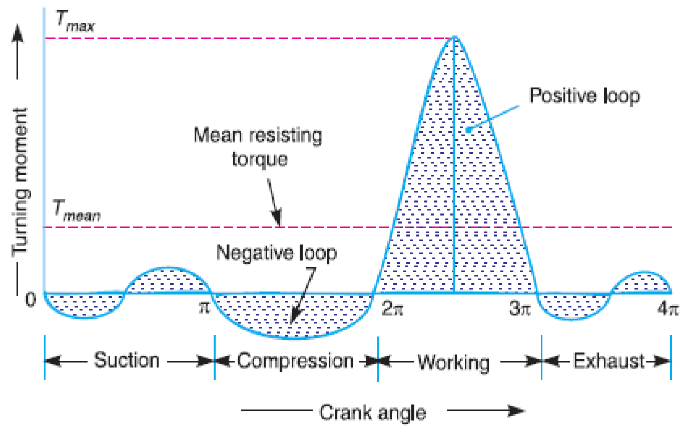
a) Roller follower has less wear and tear than knife edge follower.
b) Side thrust is less as compared to knife edge follower.
c) Power required for driving the cam is less due to less frictional force between cam and follower
d) Function is smooth
e) Life of Cam-follower arrangement is more
f) Surface of cam not damaged in roller follower due to rolling
g) No possibility of noise

5 a)

Function of Flywheel

A flywheel used in machines serves as a reservoir, which stores energy during the period when the supply of energy is more than the requirement, and releases it during the period when the requirement of energy is more than the supply.

2M Functio

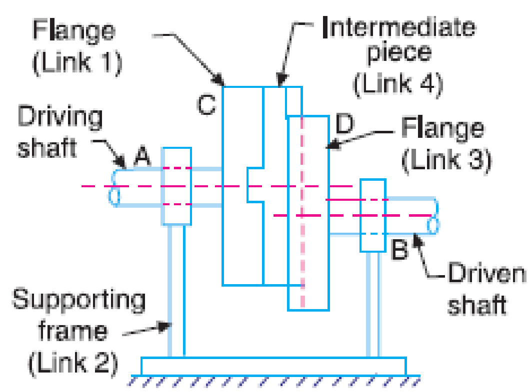


2M Fig

A turning moment diagram for single slider four stroke internal combustion engine is shown in Fig. during the power stroke energy is stored in the flywheel which is then supplied during other strokes like suction, compression and exhaust.

b)

Working of Oldham's Coupling



2M Fig

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, as shown in Fig.The shafts to be connected have two flanges (link 1 and link 3) rigidly fastened at their ends by forging. The link 1 and link 3 form turning pairs with link 2. These flanges have diametrical slots cut in their inner faces, as shown in Fig. The intermediate piece (link 4) which is a circular disc have two tongues (*i.e.* diametrical projections) *T*1 and *T*2 on each face at right angles to each other, as shown in Fig. The tongues on the link 4 closely fit into the slots in the two flanges (link 1 and link 3). The link 4 can slide or reciprocate in the slots in the flanges.

2M Expln

When the driving shaft *A* is rotated, the flange *C* (link 1) causes the intermediate piece (link 4) to rotate at the same angle through which the flange has rotated, and it further rotates the flange *D* (link 3) at the same angle and thus the shaft *B* rotates. Hence links 1, 3 and 4 have the same angular velocity at every instant. A little consideration will show, that there is a sliding motion between the link 4 and each of the other links 1 and 3.

c)

Advantages of chain drive over belt drive (Any two points)

1. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
2. Since the chains are made of metal, therefore they occupy less space in width than a belt or rope drive.
3. The chain drives may be used when the distance between the shafts is less.
4. The chain drive gives a high transmission efficiency (upto 98 per cent).
5. The chain drive gives less load on the shafts.
6. The chain drive has the ability of transmitting motion to several shafts by one chain only.

2 M

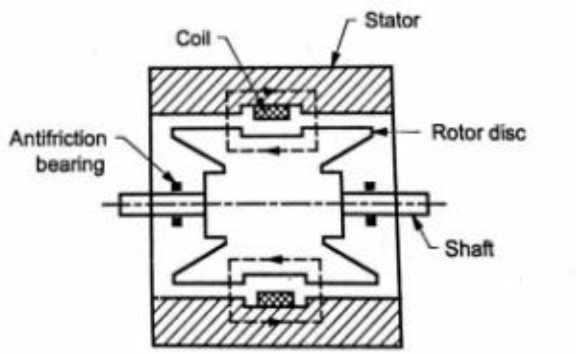
+

Disadvantages (Any two points)

1. The production cost of chains is relatively high.
2. The chain drive needs accurate mounting and careful maintenance.
3. The chain drive has velocity fluctuations especially when unduly stretched.

2M

d)



2M Fig

Sketch represents working principle of this transmission type dynamometer, to measure torque and hence power output of an engine.

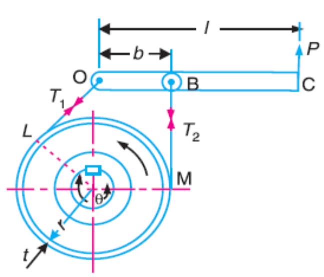
- It consists of rotor disc made of steel or copper. The rotor shaft is supported in bearings and it is coupled to engine shaft.
- Stator is fitted with number of electromagnets and the stator cradles in the trunion bearings. When rotor rotates, it produces eddy currents in the stator due to magnetic flux by passage of field current in the electromagnets.
- These currents oppose the rotor motion, thus loading the engine.
- The torque is measured with the help of torque arm.
- This dynamometer requires some cooling arrangement since the eddy current generate heat.
- This dynamometer is compact and versatile; as it can measure high power output at all speeds. These are used to test automobile and aircraft engines.

2M

Expln

e)

Problem on Simple Band Brake :



Given: Drum diameter d = 40 cm = 0.4 m, Radius r = 0.2 m,
$\mu = 0.3$, $\Theta = 225^0 = 3.926$ rad, b = 8 cm = 0.08 m, length L = 0.4 m, Effort P = 400 N
Assume T_1 and T_2 as tensions in belt,

We have, $T_1 / T_2 = e^{\mu\Theta} = e^{0..3x3.926}$

$= 3.24$ .... (1) Ans

Also taking moments about fulcrum 'O'

$P \times L = T_2 \times b$

$400 \times 0.4 = T_2 \times 0.08$ ....(2)

From (1) and (2)

$T_2 = 2000$ N Ans

So, $T_1 = 6489.25$ N Ans

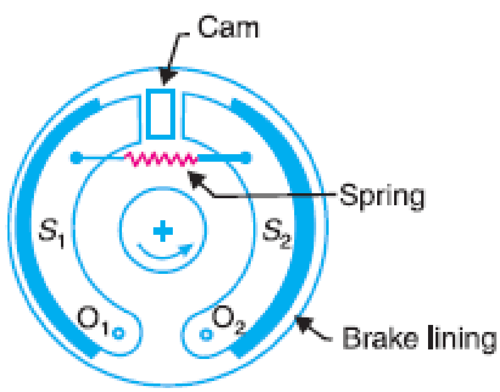
Braking Torque $= T_B = (T_1 - T_2) \times r$

$= 897.85$ N-m Ans

1 Mark for each answer

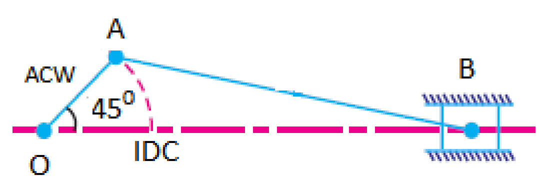
6 f)

Internal Expanding Shoe Brake:



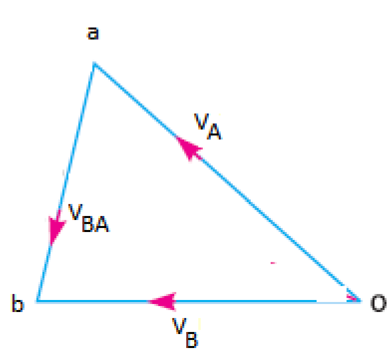
4M Fig with names

a.

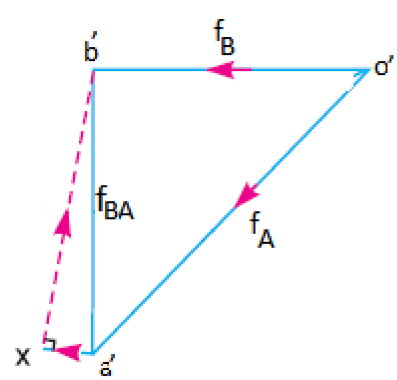


Space diagram.

2M Space Diagram



Velocity diagram.



Acceleration diagram.

2M Vel. Diagram

2M Accln. Diagram

Ang. vel. of Link OA

$$\omega_{OA} = 200 \text{ rad/sec}$$

$OA = 200$ mm, $AB = 80$ mm $= 0.08$ m
$= 0.02$ m

$\therefore$ Vel. of A w.r.t. O is

$$V_{AO} = V_A = 0.02 \times 200 = 4 \text{ m/sec}$$

Also $V_{BA} = \text{Vector } ba = 3.4 \text{ m/sec}$

$V_B = \text{Vector } ob = 4.0 \text{ m/sec}$ ------Ans

Accln $f_A = f^R_{AO} = \dfrac{V_{AO}^2}{AO} = 800 \text{ m/s}^2$

$$f^R_{BA} = \frac{V_{BA}^2}{BA} = \frac{3.4^2}{0.08} = 144.5 \text{ m/s}^2$$

Ang. vel. of Con. rod $\omega = \dfrac{V_{BA}}{0.08} = 42.5 \text{ rad/sec}$ ----Ans

Accl^n of Piston $f_B = \text{vector } o'b'$

$= 162 \text{ m/s}^2$ ---- Ans.

Ang. Accln of Con. Rod,

$$\alpha_{BA} = \frac{f^T_{BA}}{0.08} = \frac{140}{0.08}$$

$= 1750 \text{ rad/sec}^2$ ---- Ans.

2M for Answers (1/2 each)

b

Given : $d_1 = 400$ mm or $r_1 = 200$ mm ; $d_2 = 250$ mm or $r_2 = 125$ mm ; $p = 0.35$ N/mm^2 ; $\mu = 0.05$; $N = 105$ r.p.m or $\omega = 2\pi \times 105/60 = 11$ rad/s ; $W = 150$ kN $= 150 \times 10^3$ N

1. *Power absorbed*

We know that for uniform pressure, total frictional torque transmitted,

$$T = \frac{2}{3} \times \mu W \left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right] = \frac{2}{3} \times 0.05 \times 150 \times 10^3 \left[\frac{(200)^3 - (125)^3}{(200)^2 - (125)^2}\right] \text{N-mm}$$

$$= 5000 \times 248 = 1240 \times 10^3 \text{ N-mm} = 1240 \text{ N-m}$$

2M

∴ Power absorbed,

$$P = T.\omega = 1240 \times 11 = 13\,640 \text{ W} = 13.64 \text{ kW} \quad \textbf{Ans.}$$

2M

2. *Number of collars required*

Let n = Number of collars required.

We know that the intensity of uniform pressure (p),

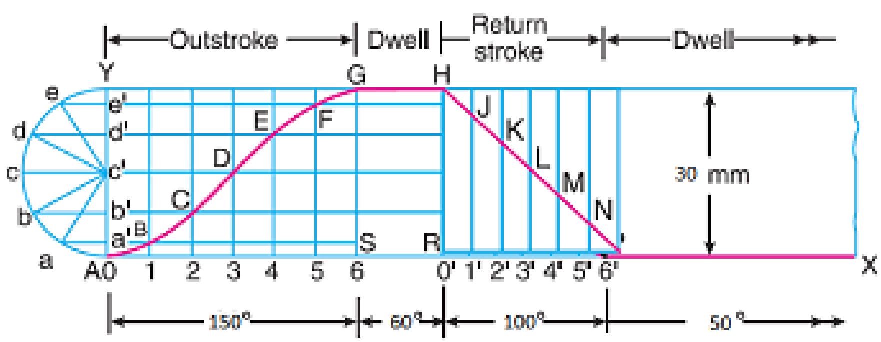
$$0.35 = \frac{W}{n.\pi[(r_1)^2 - (r_2)^2]} = \frac{150 \times 10^3}{n.\pi[(200)^2 - (125)^2]} = \frac{1.96}{n}$$

4M

∴ $n = 1.96 / 0.35 = 5.6$ say 6 **Ans.**

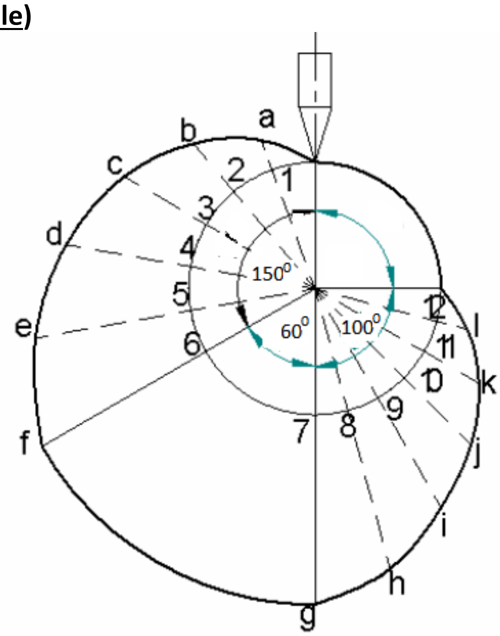
c

Displacement Diagram



4M DD

Cam Profile (<u>Angles not to scale</u>)



4M Profile