WINTER – 19 EXAMINATION

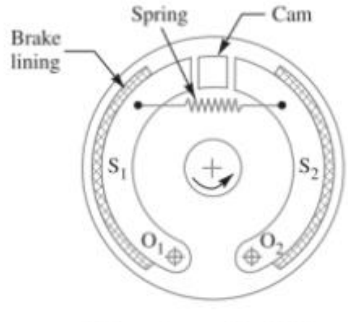
Subject Name: Theory of Machines **Model Answer** Subject Code: 22438

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
Q.1	a)	1) Link 1 and 2 -- Sliding Pair 2) Link 2 and 3 -- Turning Pair 3) Link 3 and 4 -- Turning Pair 4) Link 4 and 1 -- Sliding pair	1/2 Marks Each Pair
	b)	**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. **2)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.	1 Mark Each
	c)	1) Acceleration diagram is important in mechanism , because acceleration is directly related to force. $F = m*a$ 2) By calculating acceleration, we calculate inertia force acting on different links. 3) Design of machine parts rotating at higher speed becomes safe.	2 Marks
	d)	1) Roller follower has less wear and tear than knife edge follower. 2) Power required for driving the cam is less due to less frictional force between cam and follower.	2 Marks
	e)	1) Base circle. It is the smallest circle that can be drawn to the cam profile. 2) Pressure angle. It is the angle between the direction of the follower motion and a normal to the pitch curve.	1 Mark Each

f)



(a) Internal expanding brake.

1 Mark diagram

1 Mark labeling

g)

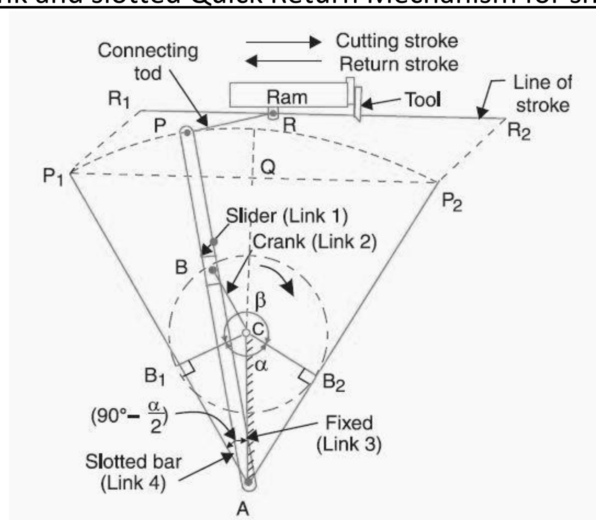
1) The dynamic forces are set up and these forces increase the loads on bearings and stresses in the various members.

2) Produce unpleasant noise and dangerous vibrations.

1 Mark Each

Q.2 a)

<u>Crank and slotted Quick Return Mechanism for shaper</u>



3 Marks Diagram

<u>Formula of cutting ratio</u>

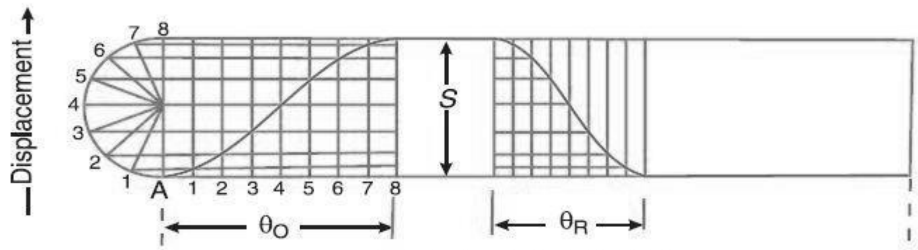
$$\frac{\text{Time of cutting stroke}}{\text{Time of return stroke}} = \frac{\beta}{\alpha} = \frac{\beta}{360^\circ - \beta} \quad \text{or} \quad \frac{360^\circ - \alpha}{\alpha}$$

1 Mark Formula

b)

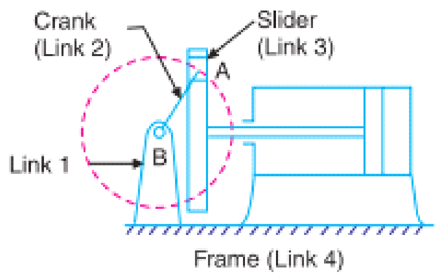
Particulars	Belt drive	Chain drive
Slip	Slip may occur	No slip (Positive drive)
Use	For low Velocity Ratio	For moderate Velocity Ratio
Suitability	For large centre distance	For moderate centre distance
Space requires	Large	Moderate
Lubrication	Not required	Require
Installation cost	Less	Moderate
Example	Floor Mill, Compressor, Conveyors	Bicycle, Automobile

Any Four Points 1 Mark Each

	c)	 (a) Displacement diagram The displacement diagram is drawn as follows for SHM of follower : 1. Draw a semi-circle on the follower stroke as diameter. 2. Divide the semi-circle into any number of even equal parts (say eight). 3. Divide the angular displacements of the cam during out stroke and return stroke into the same number of equal parts. 4. The displacement diagram is obtained by projecting the points as shown in Figure	2 Marks Diagram 2 Marks Method
	d)	Given Data :- power (P) = 10 kW = 10×10^3 watts. Diameter of pulley (D) = 0.8 m = 800 mm speed of pulley (N) = 300 rpm Angle of lap (θ) = 170° = $175\times\frac{\pi}{180}$ = 3.05 rad co-efficient of friction (μ) = 0.25 Find T_1 = Tight side tension = ? T_2 = slack side tension = ? Solution :- velocity of Belt (v) = $\frac{\pi D N}{60}$ $\therefore v = \frac{\pi\times0.8\times300}{60}$ $v = 12.56$ m/sec —— 1 Mark power transmitted by belt (P) $\therefore P = (T_1 - T_2)\times v$ $10\times10^3 = (T_1 - T_2)\times 12.56$ $\therefore T_1 - T_2 = 796.17$ .... (1) — 1 Mark Belt tension Ratio $\frac{T_1}{T_2} = e^{\mu\theta} = e^{(0.25\times3.05)}$ $\therefore \frac{T_1}{T_2} = 2.14$ $\therefore T_1 = 2.14\,T_2$ — 1 Mark put value of T_1 in equ^n (1) $2.14\,T_2 - T_2 = 796.17$ $\therefore T_2 = 698.3$ N. $\therefore T_1 = 2.14\times698.3$ —— 1 Mark. $T_1 = 1494.3$ N ∴ Tight side Tension (T_1) = 1494.3 N, slack side Tension (T_2) = 698.3 N	

Q.3 a) **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 Fig. link 1 is fixed. In this mechanism, 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

2 M



2M
Sketch

b) **Difference between Mechanism & machine**

Sr.No	Mechanism	Machine
1	Primary function is used to transmit or modify the motion.	Primary function is to obtain the mechanical advantage
2	It is not used to transmit the force.	It is used transmit the force
3	A mechanism is a single system to transfer the motion	A machine has one or more mechanism to perform the desired function.
4	eg.i) In watch, energy stored on winding the spring is used to move hands. ii) An indicator is used to draw P-V diagram of engine	eg. i) Shaper receives mechanical power which is used to suitably convert to do work of cutting the metal. ii) A hoist is machine to lift the loads.

1M each

c) **Functions of clutch:**

i) A clutch is a device used to transmit rotary motion of one shaft to the other shaft when desired.

ii) A clutch is a device used for engaging and disengaging the engine crank shaft instantaneously when desired by the driver.

iii) A clutch is a device used to deliver power to machines partially or fully loaded.

2M
(ANY 2 functions)

Applications:

i) Single plate clutch: Heavy vehicles, four-wheeler such as car, truck, bus

ii) Multi plate clutch: Two wheelers, mopeds, scooters, bikes

iii) Cone clutch: Machine tools, automobiles, press work

iv) Centrifugal clutch: mopeds, Luna

2M
(ANY 2 applications)

d) Classification of follower: **03 M for classification**

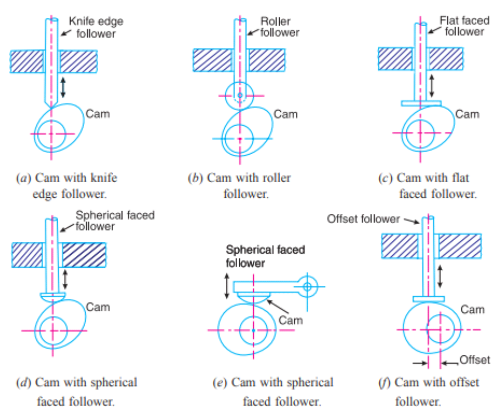
i) As per shape:

- Knife-edge follower: When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower.
- Roller follower: When the contacting end of the follower is a roller, it is called a roller follower.
- Flat faced or mushroom follower: When the contacting end of the follower is a perfectly flat face, it is called a flat faced follower and when the flat faced follower is circular, it is then called a mushroom follower.
- Spherical follower: When the contacting end of the follower is of spherical shape, it is called a spherical faced follower.

ii) As per motion:

- Reciprocating or translating follower: When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower.
- Oscillating or rotating follower: When the uniform rotary motion of the cam is converted into predetermined oscillatory motion of the follower, it is called oscillating or rotating follower.

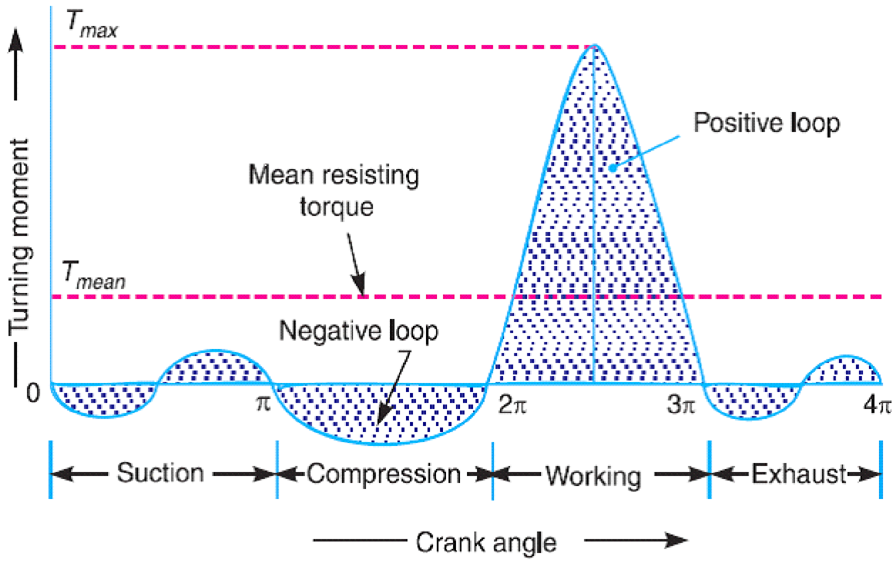
(Sketch any one 01 marks) **01 M Sketch**



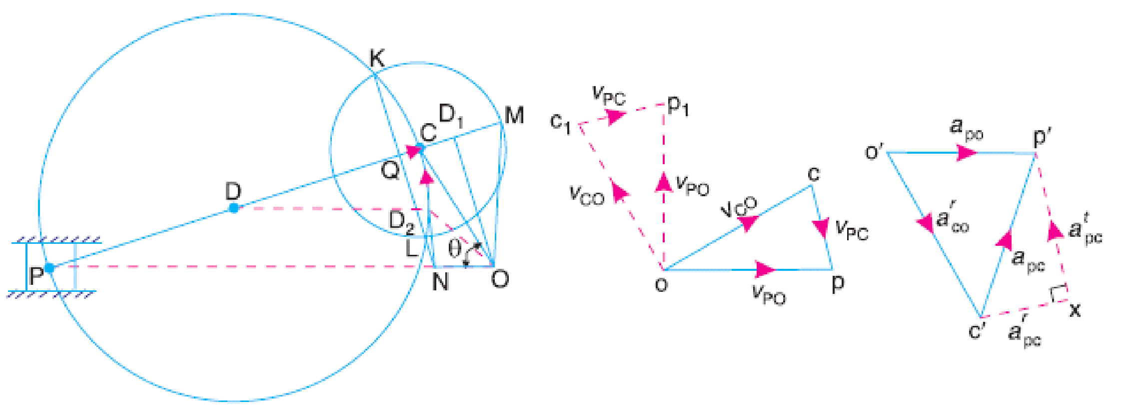
(*a*) Cam with knife edge follower. (*b*) Cam with roller follower. (*c*) Cam with flat faced follower.
(*d*) Cam with spherical faced follower. (*e*) Cam with spherical faced follower. (*f*) Cam with offset follower.

e) A turning moment diagram for a four stroke cycle internal combustion engine is shown. 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 ð radians). Turning moment diagram for a four stroke cycle internal combustion engine. **2M**

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. During the compression stroke, the work is done on the gases, therefore a higher negative loop is obtained. 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. During exhaust stroke, the work is done on the gases, therefore a negative loop is formed. It may be noted that the effect of the inertia forces on the piston is taken into account in Fig

			2M
Q.4	a)	(i) **Kinematic link**: Each part of a machine, which moves relative to some other part, is known as a kinematic link. (ii) **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. (iii) **Kinematic chain**: 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. (iv) **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 e.g. engine indicators, typewriter etc. (v) **Machine**: A machine is a device which receives energy and transforms it into some useful work. (vi) **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.	1M Each
	b)	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 Klien's velocity and acceleration diagrams are drawn as discussed below:	

3M



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

Klien's construction

3M

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 ...(_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*,

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

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

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

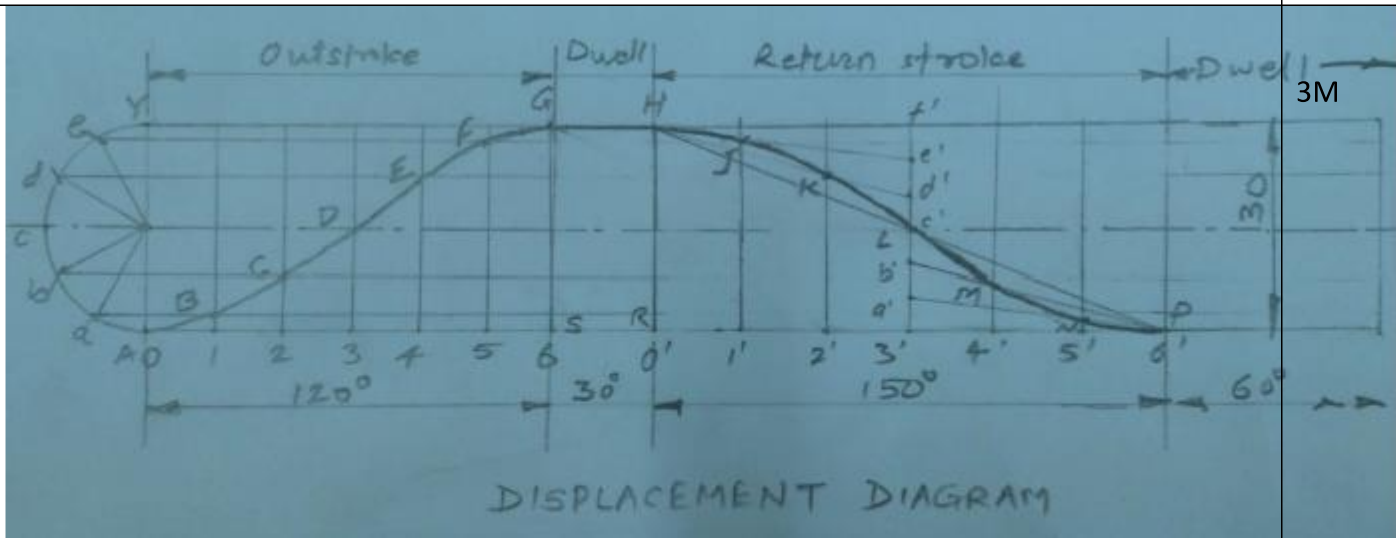
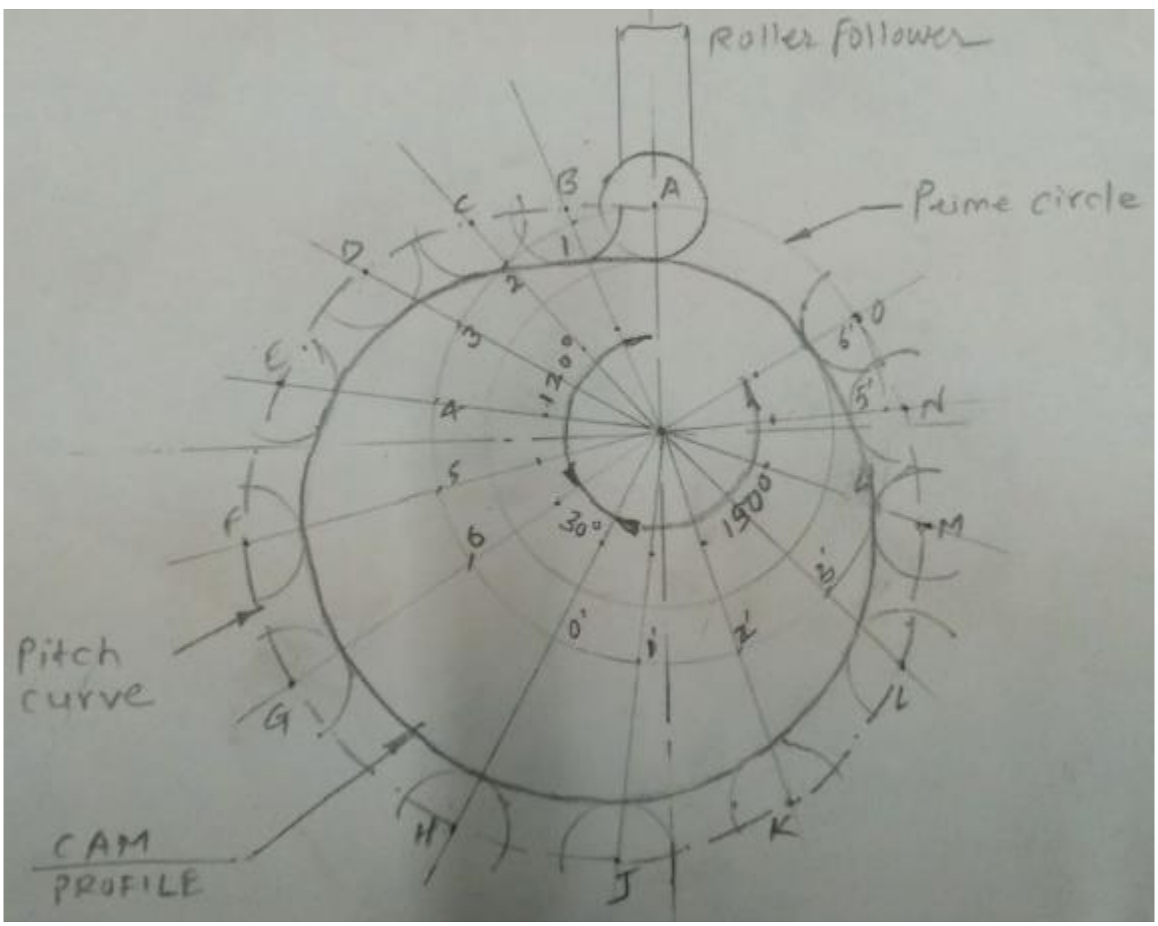
Thus, we see that by drawing the Klien's velocity diagram, the velocities of various points may be obtained without drawing a separate velocity diagram.

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

	c)	Outstroke
Dwell
Return stroke
Dwell
120°
30°
150°
60°
30
DISPLACEMENT DIAGRAM Roller follower
Prime circle
Pitch curve
CAM PROFILE
120°
30°
150°	3M 3M

Q.5 a)

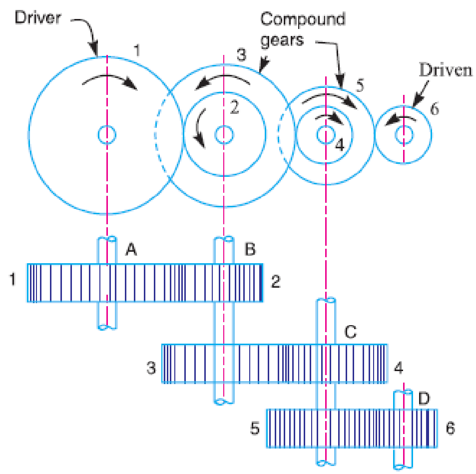
Compound Gear Train:

When there are more than one gear on a shaft, as shown in Fig. , it is called a ***compound train of gear*. I**n a simple train of gears do not affect the speed ratio of the system. But these gears are useful in bridging over the space between the driver and the driven. **2M**

Gear trains inside a mechanical watch

But whenever the distance between the driver and the driven or follower has to be bridged over by intermediate gears and at the same time a great (or much less) speed ratio is required, then the advantage of intermediate gears is intensified by providing compound gears on intermediate shafts. In this case, each intermediate shaft has two gears rigidly fixed to it so that they may have the same speed. One of these two gears meshes with the driver and the other with the driven or follower attached to the next shaft as shown in Fig.

1M



In a compound train of gears, as shown in Fig., the gear 1 is the driving gear mounted on shaft *A*, gears 2 and 3 are compound gears which are mounted on shaft *B*. The gears 4 and 5 are also compound gears which are mounted on shaft *C* and the gear 6 is the driven gear mounted on shaft *D*. **2M**

Let *N*1 = Speed of driving gear 1,

*T*1 = Number of teeth on driving gear 1,

*N*2 ,*N*3 ..., *N*6 = Speed of respective gears in r.p.m., and

*T*2 ,*T*3..., *T*6 = Number of teeth on respective gears.

Since gear 1 is in mesh with gear 2, therefore its speed ratio is

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} \quad \text{...}(i)$$

Similarly, for gears 3 and 4, speed ratio is

$$\frac{N_3}{N_4} = \frac{T_4}{T_3} \quad \text{...}(ii)$$

and for gears 5 and 6, speed ratio is

$$\frac{N_5}{N_6} = \frac{T_6}{T_5} \quad \text{...}(iii)$$

The speed ratio of compound gear train is obtained by multiplying the equations (*i*), (*ii*) and (*iii*),

$$\therefore \quad \frac{N_1}{N_2} \times \frac{N_3}{N_4} \times \frac{N_5}{N_6} = \frac{T_2}{T_1} \times \frac{T_4}{T_3} \times \frac{T_6}{T_5} \quad \text{or} \quad {}^{*}\frac{N_1}{N_6} = \frac{T_2 \times T_4 \times T_6}{T_1 \times T_3 \times T_5}$$

1M

Applications – 1. Automobile gear box 2. Lathe machines

3. Clocks/ watches 4. Electro mechanical meter

b)

Given : $r = 0.25$ $l = 1$ m ; $N = 150$ r.p.m. or $\omega = \pi \times 150/60 = 7.85$ rad/s; $\theta = 30°$

Velocity of the piston — 1M

We know that ratio of lengths of the connecting rod and crank,

$$n = l/r = 4$$

∴ Velocity of the piston,

$$v_P = \omega r\left(\sin\theta + \frac{\sin 2\theta}{2n}\right)$$

$$= 7.85 \times 0.25\left(\sin 30° + \frac{\sin 60°}{2 \times 4}\right) \text{m/s}$$

$$= 1.19 \text{ m/s}$$

2M

Acceleration of the piston

We know that acceleration of piston, — 1M

$$a_P = \omega^2 . r\left(\cos\theta + \frac{\cos 2\theta}{n}\right)$$

$$= (7.85)^2 \times 0.25\left(\cos 30° + \frac{\cos 60°}{5}\right) \text{m/s}^2$$

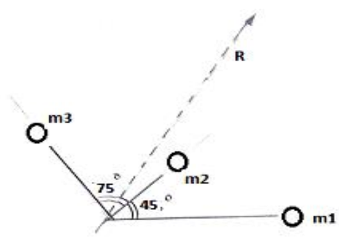
$$= 14.88 \text{ m/s}^2$$

2M

c)

Given data $m_1 = 100$N, $m_2 = 200$ N , $m_3 = 150$ N , $r_1 = 0.3$m , $r_2 = 0.15$ m, $r_3 = 0.25$m

Radius of rotation = r= 0.2m



SPACE DIAGRAM — 1M

VECTOR DIAGRAM — 3M

Balancing force is equal to resultant force — 2M

So, m x r = 63

m x 0.2 = 63

m = 315 N

Measurement $\theta = 60^0$

Q.6	a)	Given : d_1 = 450 mm = 0.45 m or r_1 = 0.225 m ; d_2 = 200 mm = 0.2 m or r_2 = 0.1 m ; x = 1.95 m ; N_1 = 200 r.p.m. ; T_1 = 1 kN = 1000 N ; μ = 0.25 We know that speed of the belt, $v = \frac{\pi d_1 . N_1}{60} = \frac{\pi \times 0.45 \times 200}{60} = 4.714$ m/s	1M
		Length of the belt We know that length of the crossed belt, $L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$ $= \pi(0.225 + 0.1) + 2 \times 1.95 + \frac{(0.225 + 0.1)^2}{1.95} = 4.975$ m **Ans.**	1M
		Angle of contact between the belt and each pulley Let θ = Angle of contact between the belt and each pulley. We know that for a crossed belt drive, $\sin \alpha = \frac{r_1 + r_2}{x} = \frac{0.225 + 0.1}{1.95} = 0.1667$ or $\alpha = 9.6°$ $\therefore \theta = 180° + 2\alpha = 180° + 2 \times 9.6° = 199.2°$ $= 199.2 \times \frac{\pi}{180} = 3.477$ rad **Ans.**	1M
		We know that $2.3 \log\left(\frac{T_1}{T_2}\right) = \mu . \theta = 0.25 \times 3.477 = 0.8692$ $\log\left(\frac{T_1}{T_2}\right) = \frac{0.8692}{2.3} = 0.378$ or $\frac{T_1}{T_2} = 2.387$ ...(Taking antilog of 0.378)	1M
		$\therefore T_2 = \frac{T_1}{2.387} = \frac{1000}{2.387} = 419$ N	1M
		We know that power transmitted, $P = (T_1 - T_2)\, v = (1000 - 419)\, 4.714 = 2740$ W = 2.74 kW	1M
	b)	Multi – Plate clutch consists of a number of clutch plates instead of only one clutch plate like in the Single plate clutch. Friction surface also increased because of a number of clutch plates. Because of number of friction surfaces, the capacity of the clutch to transmit torque is also increased. The plates are alternately fitted to the engine crankshaft and gearbox shaft. They are firmly pressed by strong coil springs and assembled in a drum type casing. Each of the alternate clutch plate slides on the grooves on the flywheel and the other slides on splines on the pressure plate. Thus, each alternate clutch plate has inner and outer splines.	2M
		A multiple disc clutch, as shown in Fig., may be used when a large torque is to be transmitted. The inside discs (usually of steel) are fastened to the driven shaft to permit axial motion (except for the last disc). The outside discs (usually of bronze) are held by bolts and are fastened to the	2M

housing which is keyed to the driving shaft. The multiple disc clutches are extensively used in motor cars, machine tools etc.

Let n_1 = Number of discs on the driving shaft, and n_2 = Number of discs on the driven shaft.

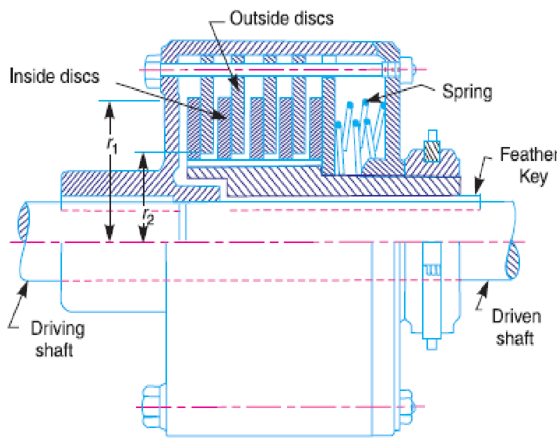
Number of pairs of contact surfaces,

$n = n_1 + n_2 - 1$

and total frictional torque acting on the friction surfaces or on the clutch,

$T = n.\mu.W.R$

where R = Mean radius of the friction surfaces



2M

c) **Difference between Flywheel and Governor**

FLYWHEEL	GOVERNOR
1.Function- To control the speed variations caused by fluctuations of engine turning moment during a cycle.	1.Function- To regulate the mean speed of engine within prescribed limit when there are variations of load.
2. Flywheel acts as a reservoir; it stores energy due to its mass moment of inertia and releases energy when required during a cycle.	2. A governor regulates the speed by regulating the quantity of charge/working fluid of prime mover.
3.It regulates speed in one cycle only	3. It regulates speed over a period of time.
4.Flywheel has no control over supply of fluid/charge	4. Governor takes care of quantity of fluid
5. It is not an essential element of every prime mover. It is used when there are undesirable cyclic fluctuations.	5. It is an essential element of prime mover since varying demand of power is met by it.
6. Mathematically it controls $\delta N/\delta t$	6. Mathematically it controls δN

1 M each