MODEL ANSWER

WINTER– 17 EXAMINATION

Subject Title: THEORY OF MACHINE 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) **Kinematic link**: Each part of a machine, which moves relative to some other part, is known as a kinematic link (or simply link) or element. **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. b) **Types of cam**: 1. Radial or disc cam 2. Cylindrical cam c) **Law of Gearing**: The law of gearing states that the angular velocity ratio of all Gears of a meshed gear system must remain constant also the common normal at the point of contact must pass through the pitch point. **d) Types of Chains & Sprockets:** **The chains**, on the basis of their use, are classified into the following three groups : **1.** Hoisting and hauling (or crane) chains, **2.** Conveyor (or tractive) chains, and **3.** Power transmitting (or driving) chains.	2M each

Sprockets:

1. Taper lock sprockets

2.Pilot bore sprocket

3.Platewheel sprocket

e) **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.

In other words, a flywheel controls the speed variations caused by the fluctuation of the engine turning moment during each cycle of operation.

f) **The function of a governor** is to regulate the mean speed of an engine, when there are variations in the load e.g. when the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of working fluid. On the other hand, when the load on the engine decreases, its speed increases and thus less working fluid is required. The governor automatically controls the supply of working fluid to the engine with the varying load conditions and keeps the mean speed within certain limits

g**) Compare Brakes & Dynamometers:**

A dynamometer is a mechanical device used to indirectly measure the power output of a prime mover like an engine or a motor.

Examples: hydraulic brake dynamometer, eddy current dynamometer, prony brake dynamometer.

A brake is a mechanical device usually found in automobiles that helps in decelerating a vehicle and brings it to a complete stop.

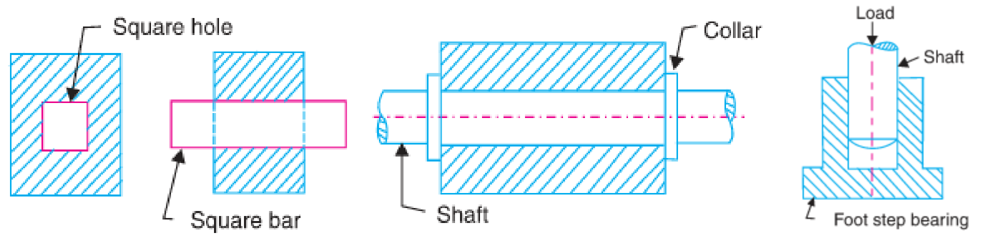
Examples: internal expanding shoe brake, single and double shoe brake, simple and differential band brake. 08 Marks

h) **Reasons for balancing of rotating elements of machine:** 2M each
The balancing of the moving parts both rotating and reciprocating of such machine is having greater importance. Because, if these parts are not balanced properly then the unbalanced dynamic forces can cause serious consequences, which are harmful to the life of the machinery itself, the human beings and all the property around them. These unbalanced forces not only increase the load on the bearings and stresses in various members, but also produces unpleasant and dangerous vibrations in them.

1 (B) a)

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.
Examples:

1. The motion of a square bar in a square hole
2. the motion of a shaft with collars at each end in a circular hole, 2M



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

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. 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 con-strained 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. — 2M

Examples:1. The motion of an I.C. engine valve (these are kept on their seat by a spring)

2. The piston reciprocating inside an engine cylinder
3. Shaft in a foot step bearing

b) b) **Function of the Clutch**

1. Function of transmitting the torque from the engine to the drive train.
2. Smoothly deliver the power from the engine to enable smooth vehicle movement. — 2M
3. Perform quietly and to reduce drive-related vibration.

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. — 2M

c) C) **Application of Belts:**

1. V- Belt drive – In I.C. Engine power transmission from crankshaft pulley to water pump pulley. — 1M each
2. Flat Belt drive – Floor mill
3. Chain drive – motor cycle
4. Gear drive – In automotive gear boxes

2 (a)

Sl. No.	Machine	Structure
1	All parts / links have relative motion	No relative motion between the links
2	It transforms the available energy into some useful work	No energy transformations
3	The kinematic link of a machine may transmit both power and	The member of the structure transmit forces only

4 Pts

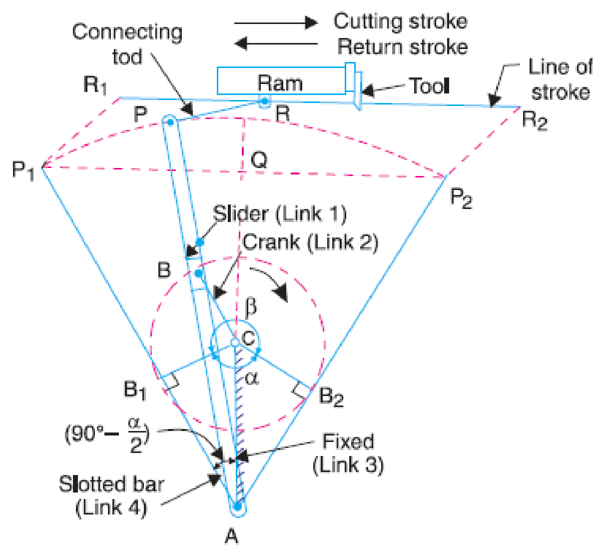
1M each

	motion	
4	Examples: I.C. Engine, Machine tools, steam engine, type writer, etc.	Example: Truss of roof, frame of machine, truss of bridge
5	Studied under 'Dynamics'	Studied under 'Statics'

(b) **Crank and slotted lever quick return motion mechanism:**

This mechanism is mostly used in shaping machines, slotting machines and in rotary internal combustion engines. In this mechanism, the link AC (i.e. link 3) forming the turning pair is fixed, as shown in fig. The link 3 corresponds to the connecting rod of a reciprocating steam engine. The driving crank CB revolves with uniform angular speed about the fixed centre C. A sliding block attached to the crank pin at B slides along the slotted bar AP and thus causes AP to oscillate about the pivoted point A. A short link PR transmits the motion from AP to the ram which carries the tool and reciprocates along the line of stroke R1R2. The line of stroke of the ram (i.e. R1R2) is perpendicular to AC produced

2M EXPL.



2M FIG

In the extreme positions, AP1 and AP2 are tangential to the circle and the cutting tool is at the end of the stroke. The forward or cutting stroke occurs when the crank rotates from the position CB1 to CB2 (or through an angle β) in the clockwise direction. The return stroke occurs when the crank rotates from the position CB2 to CB1 (or through angle α) in the clockwise direction. Since the crank has uniform angular speed,

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

c)

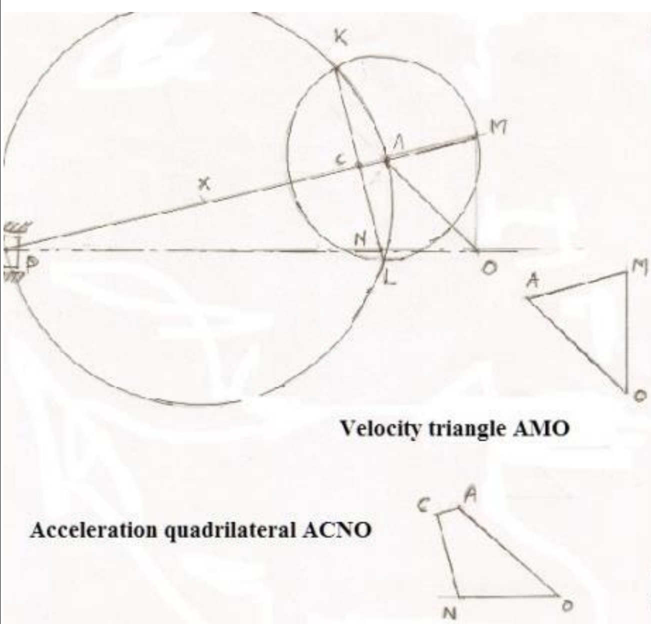
Term	Definition	Mathematical/representation (optional)
Linear velocity	Rate of change of ***linear displacement*** per unit time	$V = \frac{d_x}{d_t}$ m/sec
Angular velocity	Rate of change of ***angular displacement*** per unit time	$\omega = \frac{d_\theta}{d_t}$ rad/sec
Absolute velocity	Velocity of any point with respect any point ***fixed point***	V_{ao} ; velocity of point a w.r.t. o

1M each

Relation between linear and angular velocity: **V = ω.r**

(d)

Klein's construction:



klein's construction

1) Draw the basic diagram with the angle made by crank , crank (AO) and connecting rod (AP) with dimensions and scale.
2) Extend the connecting rod upto the vertical line of the crank circle and mark intersection point M, the triangle created ΔOAM is the velocity triangle.
3) Bisect the connecting rod at X.
4) Draw the circle with radius equal to XA or XB.
5) Draw the circle with Centre as "A" and radius equal to AM.
6) Both circles will intersect each other at two points (K, L), join these two points.
7) This line will intersect the connecting rod at point "C" and line of stroke at point "N".

Quadrilateral OACN is the acceleration diagram. This is required acceleration diagram of the links

2M fig

2M explain

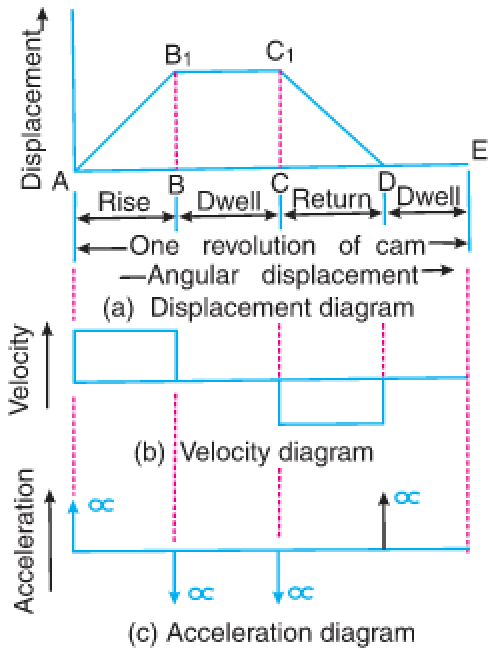
If ω_{AO} is the angular velocity of the crank, then

Linear velocity's of the links is given by-

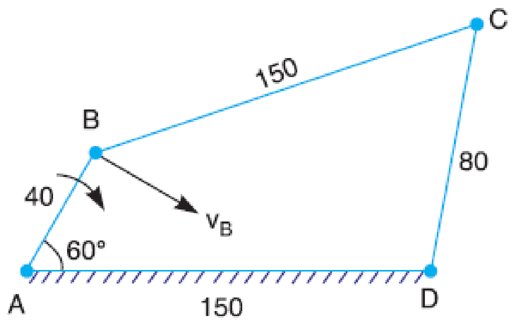
$V_{AO} = \omega_{AO} \times AO$, $V_{AP} = \omega_{AO} \times AM$, $V_{PO} = \omega_{AO} \times MO$

Acceleration of the links is given by-

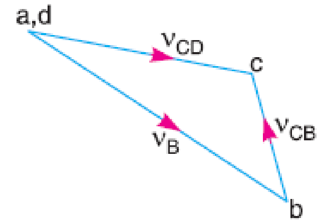
$a^r_{AO} = \omega^2_{AO} \times AO$, $a^r_{AP} = \omega^2_{AO} \times AC$, $a^t_{AP} = \omega^2_{AO} \times CN$, $a_{PO} = \omega^2_{AO} \times NO$

	(e)		4M
	(f)	Given: $d = 1.5\ m$, $N = 300\ rpm$, $\mu = 0.3$, $P = 35\ KW$ $\theta = \frac{11}{24} \times 360^\circ = 165^\circ$ $\therefore \theta = 165^\circ \times \pi/180 = 2.88\ rad.$	1M
		We know that velocity of belt, $V = \frac{\pi . d . N}{60} = \frac{\pi \times 1.5 \times 300}{60} = 23.55\ m/s.$	1M
		$\frac{T_1}{T_2} = e^{\mu . \theta} = e^{0.3 \times 2.88} = e^{0.864}$ $\therefore \frac{T_1}{T_2} = e^{0.864}$ .... eqn. No. 1 We know that Power transmitted by the belt $P = (T_1 - T_2) V$ $\therefore 35 \times 10^3 = (T_1 - T_2)\ 23.55$ $\therefore T_1 - T_2 = 1486.20$ ...... eqn No. 2 By solving eqn 1 & 2, Max. tension in the belt is 2571 N	2M

3 a)



Space diagram (All dimensions in mm).



Velocity diagram.

g.

Given : $N_{BA} = 120$ r.p.m. or $\omega_{BA} = 2\,\pi \times 120/60 = 12.568$ rad/s

Since the length of crank $AB = 40$ mm $= 0.04$ m, therefore velocity of B with respect to A or velocity of B, (because A is a fixed point),

$$v_{BA} = v_B = \omega_{BA} \times AB = 12.568 \times 0.04 = 0.503 \text{ m/s}$$

cu.

vector $ab = v_{BA} = v_B = 0.503$ m/s

By measurement, we find that

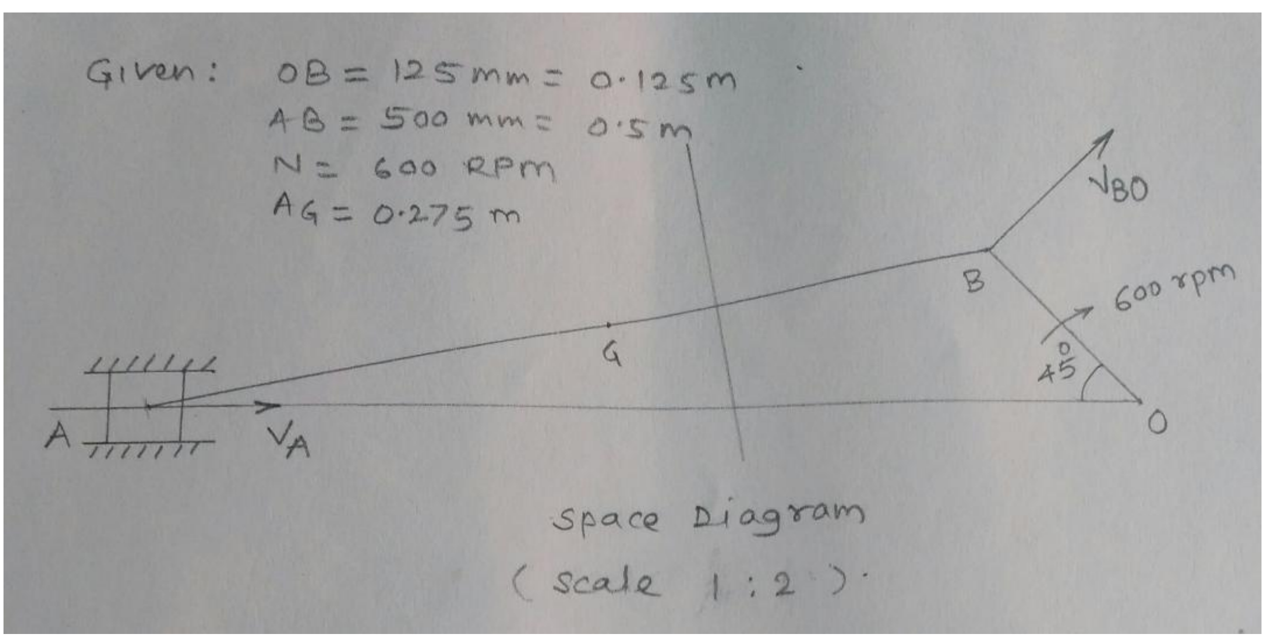
$$v_{CD} = v_C = \text{vector } dc = 0.385 \text{ m/s}$$

We know that $CD = 80$ mm $= 0.08$ m

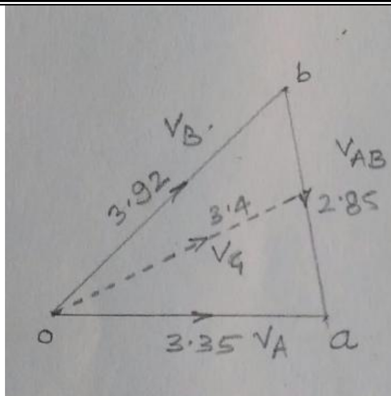
$\therefore$ Angular velocity of link CD,

$$\omega_{CD} = \frac{v_{CD}}{CD} = \frac{0.385}{0.08} = 4.8 \text{ rad/s (clockwise about } D\text{)}$$

b)



2M Diag



Velocity Diagram
(Scale 2 : 1)

Angular velo. of crank 'OB'.

$$\omega_{BO} = \frac{2\pi N}{60} = \frac{2\pi \times 600}{60} = 62.83 \text{ rad/s}$$

Velo. of crank

$$V_B = \omega_{BO} \times BO = 62.83 \times 0.125$$
$$= 7.85 \text{ m/s}$$

∴ Velocity of slider 'A'

$$V_A = ao \times \text{scale}$$
$$= 3.35 \times 2 = 6.70 \text{ m/s} \; \ldots\text{Ans}$$

Location of point 'G' on velo. Dia

$$ag = \frac{AG}{AB} \times ab = 1.57 \text{ cm}$$

∴ velocity of point 'G'.

$$V_G = og \times \text{scale} = 3.4 \times 2$$
$$= 6.8 \text{ m/s} \; \ldots\ldots\text{Ans}$$

2M Calcu.

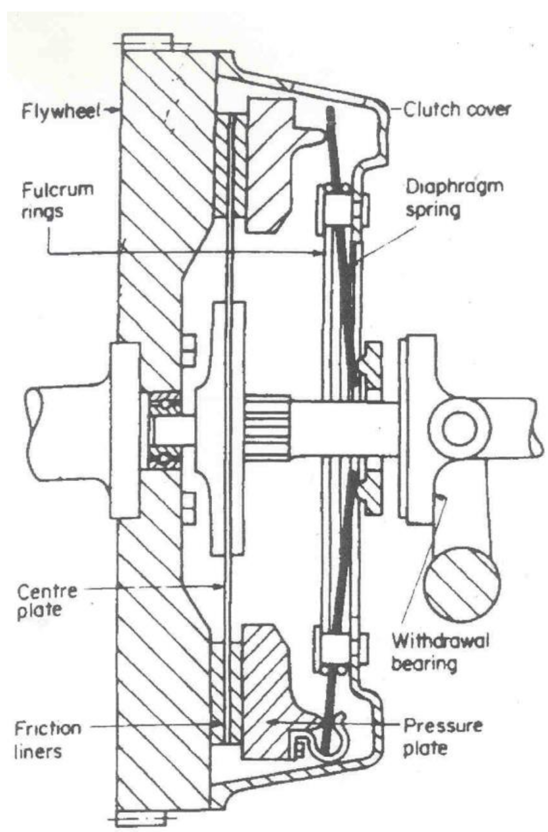
c) **Define slip and creep in the belt drive**

Slip --- Slip is defined as *insufficient frictional grip* between pulley (driver/driven) and belt.
Slip is the difference between the linear velocities of pulley (driver/driven) and belt.

Creep ----- Uneven extensions and contractions of the belt when it passes from tight side to slack side. There is relative motion between belt and pulley surface, this phenomenon is called creep of belt.

2M Expl.

d)



2M Fig.

Diaphragm Spring Type Single Plate Clutch

A diaphragm spring type clutch is shown in fig. where shows the clutch in the engaged position and in the disengaged position.

It is seen from the above figures that the diaphragm spring is supported on a fulcrum retaining ring so that any section through the spring can be regarded as a simple lever. The pressure plate E is movable axially, but it is fixed radically with respect to the cover. This is done by providing a series of equally spaced lugs cast upon the back surface of the pressure plate. The drive from the engine flywheel is transmitted through the cover, pressure plate and the friction plate to the gear box input shaft.

The clutch is disengaged by pressing the clutch pedal which actuates the release fingers by means of a release ring. This pivots the spring about its fulcrum, relieving the spring load on the outside diameter, thereby disconnecting the drive.

2M

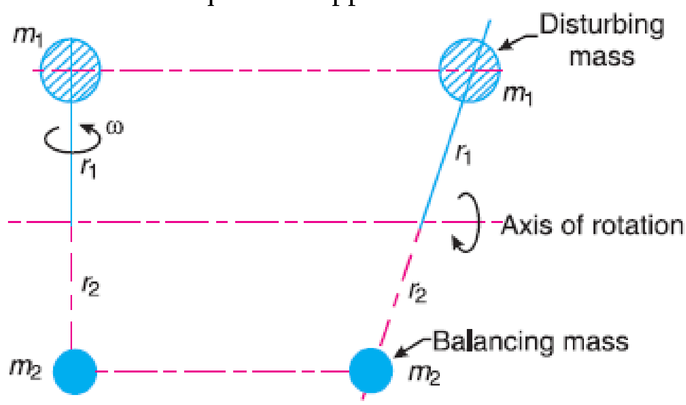
e) **Procedure :Balancing of a Single Rotating Mass By a Single Mass Rotating in the Same Plane** Pro.

Consider a disturbing mass m_1 attached to a shaft rotating at ω rad/s as shown in Fig.
Let r_1 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,

$$F_{C1} = m_1 . \omega^2 . r_1 \quad \ldots (i)$$

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. 2M

Fig.



Balancing of a single rotating mass by a single mass rotating in the same plane.

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).

$\therefore$ Centrifugal force due to mass m_2,

$$F_{C2} = m_2 \cdot \omega^2 \cdot r_2 \quad \ldots (ii)$$

Equating equations (*i*) and (*ii*),

$$m_1 . \omega^2 \cdot r_1 = m_2 \cdot \omega^2 \cdot r_2 \quad \text{or} \quad m_1 \cdot r_1 = m_2 \cdot r_2$$

	f)	**Types of followers** The followers may be classified as discussed below: 1. According to the surface in contact. (a)Knife edge follower. When the contacting end of the follower has a sharp knife edge, it is called a knife edge follower. (b) Roller follower. When the contacting end of the follower is a roller, it is called a roller follower. (c) 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. (d) Spherical faced follower. When the contacting end of the follower is of spherical shape, it is called a spherical faced follower. 2.According to the motion of the follower. ***(a)*** Reciprocating or translating follower. When the follower reciprocates in guides as the cam rotates uniformly, it is known as reciprocating or translating follower. ***(b)*** 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. 3. According to the path of motion of the follower. (a) Radial follower. When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower (b) Off-set follower. When the motion of the follower is along an axis away from the axis of the cam centre, it is called off-set follower.	4M
4	a)	**Advantages of chain drive over belt drive (Any four)** a) ***No slip*** takes place in chain drive as in belt drive there is slip. b) Occupy ***less space*** as compare to belt drive. c) ***High*** transmission **efficiency**. d) More power transmission than belts drive. *e)* Operated at ***adverse temperature*** and ***atmospheric conditions.*** f) Higher velocity ratio. g) Used for both ***long as well as short distances***. **Disadvantages of chain drive:** 1. Manufacturing cost of chains is relatively high 2. The chain drive needs accurate mounting and careful maintenance	2M Any 4 Adv. 2M Any 4 Disad.

3. High velocity fluctuations especially when unduly stretched
4. Chain operations are noisy as compared to belts

b) **Justification for a single slider crank mechanism is a modification of four bar chain mechanism is as given below.** 4M

Any 4 pts.

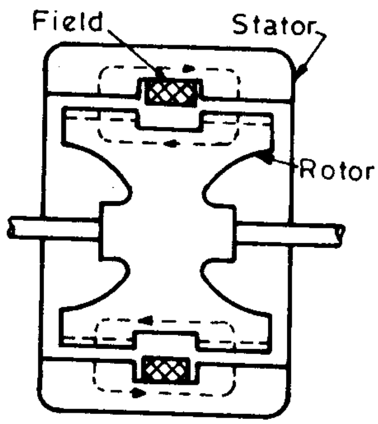
1) Single slider mechanism has four kinematic links – crank, connecting rod, frame and slider and four bar mechanism has crank, coupler, frame and a follower.
2) A follower in four bar mechanism is replaced by a slider.
3) A four bar mechanism has 4 turning pairs and single slider crank mechanism has also four pairs, but one of the turning pairs is replaced by a sliding pairs.
4) A four bar mechanism rotary motion of the crank into oscillating motion of the follower whereas in single slider motion is converted in sliding motion of the piston

c) **Difference between flywheel and governor:**

4M

Any 4 Pts.

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.
6	It is used in toys, IC engine, hand watches.	It is used in automobile vehicles.

	d)	**Eddy Current Dynamometer** : It consists of a stator on which are fitted a number of electromagnets and a rotor disc made of copper or steel and coupled to the output shaft of the engine. When the rotor rotates, eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents oppose the motion of the rotor thus loading the engine. The eddy currents are dissipated in producing heat so that this type of dynamometer also requires some cooling arrangements. The torque is measured similar to absorption dynamometers i.e. with the help of moment arm. The load is controlled by regulating the current in the electromagnets.	2M Exp 2M Fig.
		 Eddy current dynamometer.	
	e)	**Problem on Foot step bearing** D = 225 mm = 0.225 m W = 7500 N μ = 0.09 N = 600 rpm $\omega = 2 \pi N / 60$ =62.83 rad/sec Uniform pressure condition Frictional torque T = 2/3 μ W R = 50.625 Nm Power lost in friction = T x ω = 50.625 x 62.83 = 3180.8 W --------Ans Uniform wear condition Frictional torque T = 1/2 μ W R = 37.98 Nm Power lost in friction = T x ω = 37.98 x 62.83 = 2385.57 W -------- Ans	2M 2M

f) Given :

m1 = 180 kg, m2 = 300 kg, m3 = 230 kg, m4 = 260 kg

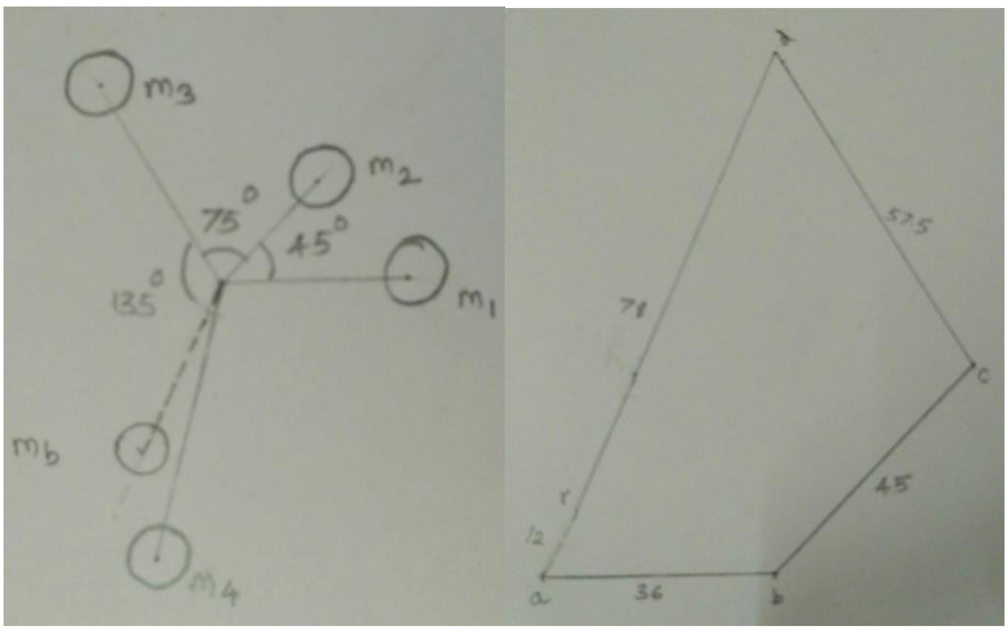
r1 = 0.2 m, r2 = 0.15 m, r3 = 0.25 m, r4 = 0.3 m — 2M

ϴ1 = 45, ϴ2 = 75, ϴ = 135 — Diag

The centrifugal forces are given by - m1r1 = 36, m2r2 = 45, m3r3 = 57.5, m4r4 = 78

2M

Calcu.



a) Space diagram b) Vector diagram

From vector diagram the resultant force is at 60 to the mass m1 and is represented by ar

ar = 12 kg m

Therefore mb * rb = 12 kgm

Balancing mass mb = 12/0.2 = 60 kg at an angle of 240^0 with the direction of m1 mass

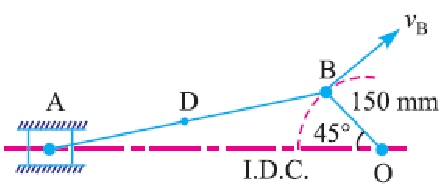
5 a) — 2M Vel. Diagm

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

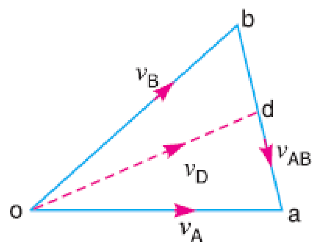
We know that linear velocity of B with respect to O or velocity of B,

$$v_{BO} = v_B = \omega_{BO} \times OB = 31.42 \times 0.15 = 4.713 \text{ m/s}$$

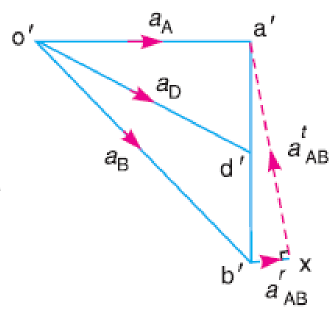
...(Perpendicular to BO)



Space diagram.



Velocity diagram.



Acceleration diagram.

2M Accel. Diagm

In order to find the velocity of the midpoint *D* of the connecting rod *AB*, divide the vector *ba* at *d* in the same ratio as *D* divides *AB*, in the space diagram. In other words,

bd / ba = BD/BA

Note: Since *D* is the midpoint of *AB*, therefore *d* is also midpoint of vector *ba*.

Join *od*. Now the vector *od* represents the velocity of the midpoint *D* of the connecting rod *i.e.* V_D.

By measurement, we find that

$$\mathbf{V_D = \text{vector } od = 4.1 \text{ m/s}}$$

Acceleration of the midpoint of the connecting rod

2M Calcu. Of each

We know that the radial component of the acceleration of B with respect to O or the acceleration of B,

$$a^r_{BO} = a_B = \frac{v^2_{BO}}{OB} = \frac{(4.713)^2}{0.15} = 148.1 \text{ m/s}^2$$

and the radial component of the acceleraiton of A with respect to B,

$$a^r_{AB} = \frac{v^2_{AB}}{BA} = \frac{(3.4)^2}{0.6} = 19.3 \text{ m/s}^2$$

In order to find the acceleration of the midpoint *D* of the connecting rod *AB*, divide the vector *a′ b′* at *d′* in the same ratio as *D* divides *AB*. In other words

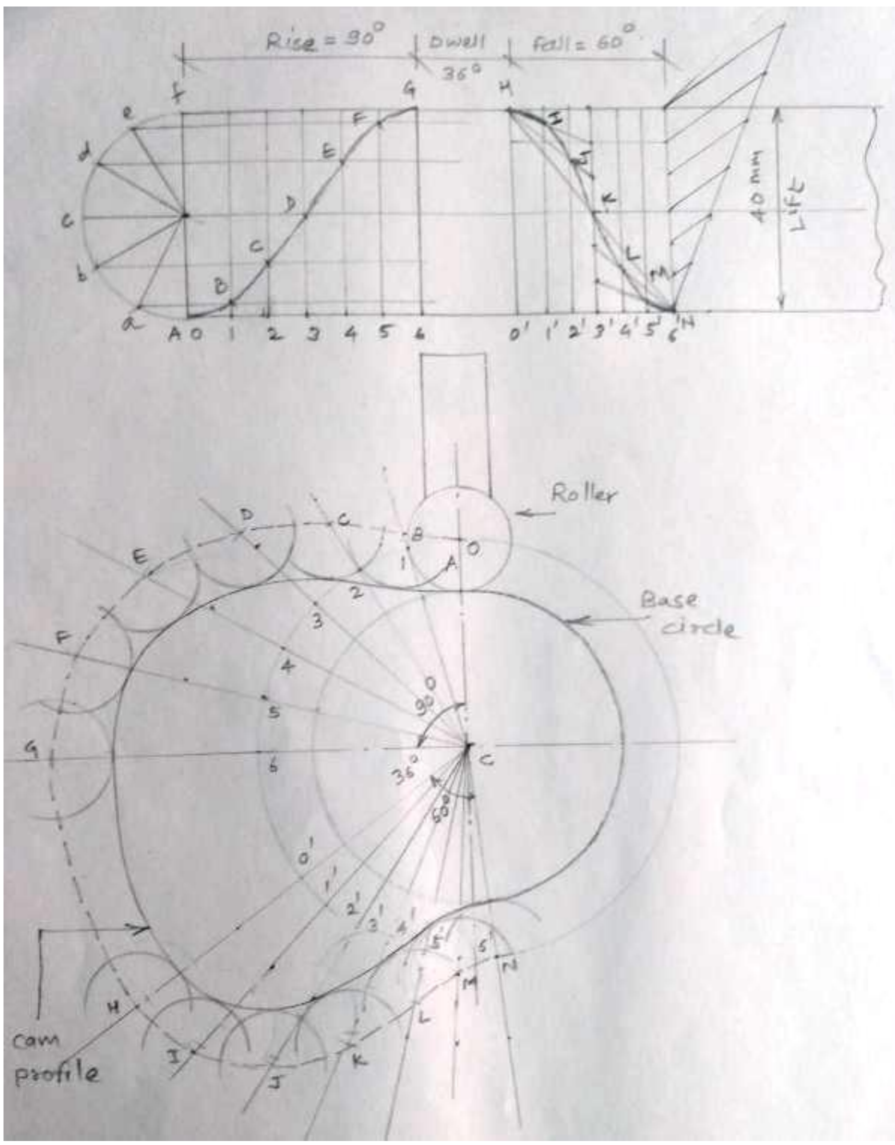
$$b'd'/b'a' = BD/BA$$

Note: Since *D* is the midpoint of *AB*, therefore *d′* is also midpoint of vector *b′ a′*.

Join *o′ d′*. The vector *o′ d′* represents the acceleration of midpoint *D* of the connecting rod *i.e.* a_D.

By measurement, we find that

$\mathbf{a_D}$ **= vector *o′ d′* = 117 m/s²**

		Angular velocity of the connecting rod We know that angular velocity of the connecting rod AB, $\omega_{AB} = \frac{v_{AB}}{BA} = \frac{3.4}{0.6} = 5.67 \text{ rad/s}^2$ (Anticlockwise about B) Ans. *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.	
	b)	Given: Lift = 40 mm Rise = ¼ x 360 = 90^0 Fall =1/6 x 360 = 60^0 Dwell = 1/10 x 360 =36^0 Fig shows a displacement diagram and a cam profile for the roller follower. 	4M Each Diagm

	c)	**Solution.** 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, $$v = \frac{\pi d_1 . N_1}{60} = \frac{\pi \times 0.45 \times 200}{60} = 4.714 \text{ m/s}$$ *Length of the belt* We know that length of the crossed belt, $$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$$ $$= \pi(0.225 + 0.1) + 2 \times 1.95 + \frac{(0.225 + 0.1)^2}{1.95} = 4.975\text{m}$$ **Ans.** *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, $$\sin\alpha = \frac{r_1 + r_2}{x} = \frac{0.225 + 0.1}{1.95} = 0.1667 \text{ or } \alpha = 9.6°$$ $$\therefore \theta = 180° + 2\alpha = 180° + 2 \times 9.6° = 199.2°$$ $$= 199.2 \times \frac{\pi}{180} = 3.477 \text{ rad}$$ **Ans.** *Power transmitted* Let T_2 = Tension in the slack side of the belt. We know that $$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu.\theta = 0.25 \times 3.477 = 0.8692$$ $$\log\left(\frac{T_1}{T_2}\right) = \frac{0.8692}{2.3} = 0.378 \text{ or } \frac{T_1}{T_2} = 2.387$$ ...(Taking antilog of 0.378) $$\therefore T_2 = \frac{T_1}{2.387} = \frac{1000}{2.387} = 419 \text{ N}$$ We know that power transmitted, $$P = (T_1 - T_2)\,v = (1000 - 419)\,4.714 = 2740 \text{ W} = 2.74 \text{ kW}$$ **Ans.**	1M 2M 2M 2M 1M
6	a)	**i) Types of gear trains** 1) Simple gear train 2) Compound gear train 2) Epicyclic gear train 4) Inverted gear train ***Simple gear train.*** When there is only one gear on each shaft, it is known as ***simple gear train.*** The gears are represented by their pitch circles. When the distance between the two shafts is small, the two gears are made to mesh with each other to transmit motion from one shaft to the other **Epicyclic gear train:** A simple epicyclic gear train is shown in Fig. where a gear *A* and the arm *C* have a common axis at O_1about which they can rotate. The gear *B* meshes with gear *A* and has its axis on the arm at O_2, about which the gear *B* can rotate. If the arm is fixed, the gear train is simple and gear *A* can drive gear *B* or ***vice- versa***, but if gear A is fixed and the arm is rotated about the	1M 2M Expl

axis of gear A (i.e. O1), then the gear B is forced to rotate upon and around gear A. Such a motion is called **epicyclic** and the gear trains arranged in such a manner that one or more of their members move upon and around another member are known as ***epicyclic gear trains.***

Compound Gear Train

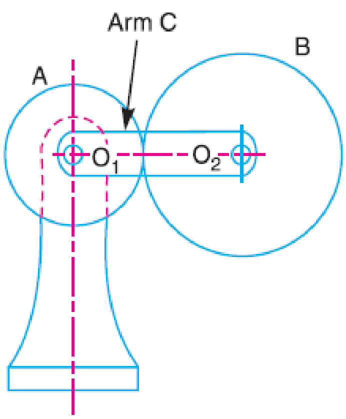
When there are more than one gear on a shaft, it is called a ***compound train of gear***.

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.

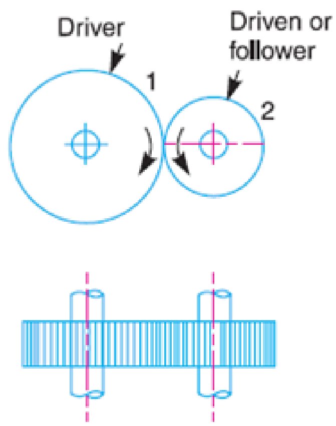
Reverted Gear Train

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. 1M

Fig



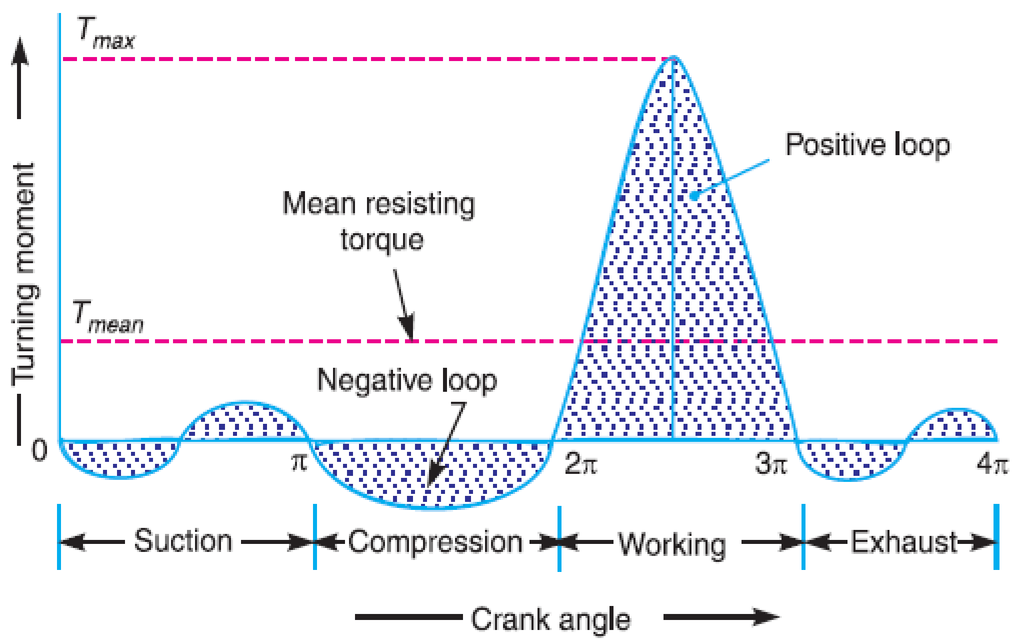
Epicyclic gear train.



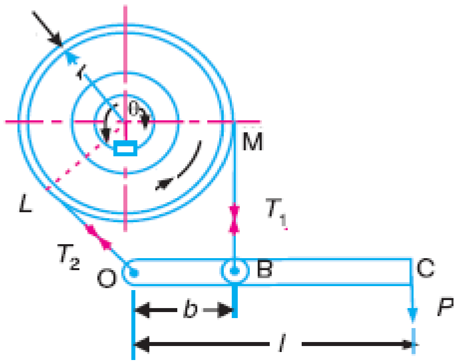
Simple gear train.

ii) Turning Moment Diagram: 4M

Fig



Turning moment diagram for a four stroke cycle internal combustion engine.

	b)	Simple band brake:	1M Fig
		 Simple band brake. (Anticlockwise rotation of drum.)	1M
		Given: Length of lever l = 40 cm = 0.4m, diameter d = 40 cm = 0.4, μ = 0.25, b =0 .08 m Θ = Angle of wrap = 5/8 x 360 = 225 x π /180 = 3.93 rad Braking torque = (T1 –T2) x r T1/T2 = $e^{\mu\Theta}$ = $e^{0.25 \times 3.93}$ = 2.67 Taking moments about fulcrum P x l = b x T1 500 x 0.40 = 0.08 x T1 T1 = 2500 N T2 = 2500 / 2.67 = 936.3 N Braking Torque = (2500 – 936.3) x 0.2 = 312.74 N-m	2M 2M 2M
	c)	**Solution.** Given: $n = 2$; $P = 25$ kW $= 25 \times 10^3$ W ; $N = 3000$ r.p.m. or $\omega = 2\pi \times 3000/60 = 314.2$ rad/s ; $\mu = 0.255$; $r_1/r_2 = 1.25$; $p = 0.1$ N/mm^2 *Outer and inner radii of frictional surface* Let r_1 and r_2 = Outer and inner radii of frictional surfaces, and T = Torque transmitted. Since the ratio of radii (r_1/r_2) is 1.25, therefore $r_1 = 1.25\, r_2$ We know that the power transmitted (P), $25 \times 10^3 = T.\omega = T \times 314.2$ $\therefore\ T = 25 \times 10^3/314.2 = 79.6$ N-m $= 79.6 \times 10^3$ N-mm	2M 2M

		Since the intensity of pressure is maximum at the inner radius (r_2), therefore $p.r_2 = C$ or $C = 0.1\ r_2$ N/mm and the axial thrust transmitted to the frictional surface, $W = 2\pi C (r_1 - r_2) = 2\pi \times 0.1\ r_2 (1.25\ r_2 - r_2) = 0.157\ (r_2)^2$ ...(*i*) We know that mean radius of the frictional surface for uniform wear, $R = \frac{r_1 + r_2}{2} = \frac{1.25\ r_2 + r_2}{2} = 1.125\ r_2$ We know that torque transmitted (T), $79.6 \times 10^3 = n.\mu.W.R = 2 \times 0.255 \times 0.157\ (r_2)^2 \times 1.125\ r_2 = 0.09\ (r_2)^3$ $\therefore$ $(r_2)^3 = 79.6 \times 10^3 / 0.09 = 884 \times 10^3$ or $r_2 = 96$ mm **Ans.** and $r_1 = 1.25\ r_2 = 1.25 \times 96 = 120$ mm **Ans.** *Axial thrust to be provided by springs* We know that axial thrust to be provided by springs, $W = 2\pi C (r_1 - r_2) = 0.157\ (r_2)^2$ ...[From equation (*i*)] $= 0.157\ (96)^2 = 1447$ N **Ans.**	2M 2M