WINTER– 14 EXAMINATION

Subject Code: **17412 (TOM)** **Model Answer**

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 1 A) Any SIX (02 Marks each)

a) **i) Spherical pair:** When the two elements of a pair are connected in such a way that one element (with spherical shape) turns or swivels about the other fixed element, the pair formed is called a spherical pair. The ball and socket joint, attachment of a car mirror, pen stand etc., are the examples of a spherical pair.

ii) Higher Pair : When two kinematic links are joined together so that they have point or line contact between them, they are said to form Higher pair. e.g. Ball bearing

b) **i) Radial follower**: If the axis of follower and center of rotation of cam lie on a same straight line, it is known as Radial follower.

ii) Offset follower: If the axis of follower and center of rotation of cam have some distance (offset) between them, it is known as offset follower.

c) Crowning of Pulley: To avoid the slipping of the belt from the flat pulleys, two sides of pulleys are tapered. This kind of tapering is known as crowning of pulleys.

d) Initial tension : When a belt is wound round the two pulleys (i.e. driver and follower), its two ends are joined together ; so that the belt may continuously move over the pulleys, since the motion of the belt from the driver and the follower is governed by a firm grip, due to friction between the belt and the pulleys.

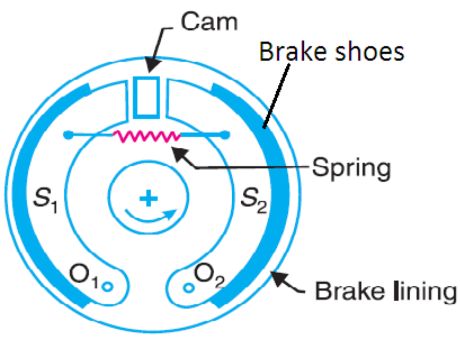
Effects: In order to increase this grip, the belt is tightened up. At this stage, even when the pulleys are stationary, the belt is subjected to some tension, called initial tension. When the driver starts rotating, it pulls the belt from one side (increasing tension in the belt on this side) and delivers it to the other side (decreasing the tension in the belt on that side). The increased tension in one side of the belt is called tension in tight side and the decreased tension in the other side of the belt is called tension in the slack side.

e) Fluctuation of speed : The variations of energy above and below the mean speed value are called fluctuations of speed. It is abbreviated as C_S

Fluctuation of energy : The variations of energy above and below the mean resisting torque line are called fluctuations of energy. It is abbreviated as $C_{E.}$

f) Sensitivity: The sensitiveness is defined as the ratio of the difference between the maximum and minimum equilibrium speeds to the mean equilibrium speed. It is an indicator of variation in speeds at different loads conditions. It is considered that for a small change in load there should be minimum change in the configuration of governor.

g) Internal expanding brakes:



h) Adverse effect of imbalance in rotating elements: i) Vibrations are caused ii) Machine accuracy gets disturbed iii) Life of machine decreases iv) Friction increases v) Noise level increases

Q 1 B) Any two

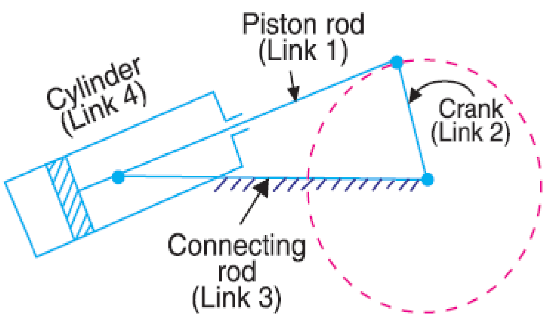
a) Inversions of single slider crank chain: **(01 mark)**

i) Oscillating cylinder mechanism

ii) Pendulum pump

iii) Rotary engine

iv) Whitworth's quick return mechanism



Oscillating cylinder engine

(01 mark for figure, 02 marks explanation)

The arrangement of oscillating cylinder engine mechanism, as shown in Fig. is used to convert reciprocating motion into rotary motion. In this mechanism, the link 3 forming the turning pair is fixed. The link 3 corresponds to the connecting rod of a reciprocating steam engine mechanism. When the crank (link 2) rotates, the piston attached to piston rod (link 1) reciprocates and the cylinder (link 4) oscillates about a pin pivoted to the fixed link at *A*.

Q 1 B) b) Four types of friction clutches: **(01 mark each)**

Single Disc or plate clutch: Heavy motor vehicles like trucks and buses
Multi plate clutch: Motor bikes / motorcycles
Cone clutches : Earlier it was used in automobiles but now used in special machines only
Centrifugal clutches: Mopeds

Q 1 B) c) Slip: **(02 marks)**

Due to increasing load that can 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.

Creep: **(02 marks)**

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.

Q 2 : Any FOUR

a) Machine: **(01 mark for definition , 03 marks for difference)**

It is defined as combination of number of links having relative motion between them so as to do some useful work by consuming some energy as input.

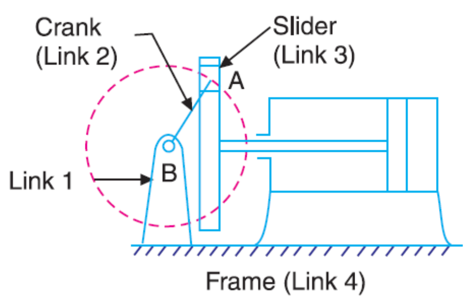
Difference Between a Machine and a Structure

The following differences between a machine and a structure :

- The parts of a machine move relative to one another, whereas the members of a structure do not move relative to one another.
- A machine transforms the available energy into some useful work, whereas in a structure no energy is transformed into useful work.
- The links of a machine may transmit both power and motion, while the members of a structure transmit forces only.

Q 2 b) Scotch Yoke mechanism: **(figure 02 marks, explanation 02 marks)**

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.



Q 2 c) Relation between Linear and Angular velocity **(02 marks)**

Consider link OA of any mechanism.
Let V as linear velocity of a point A w.r.t. O , say, in cm/sec
ω as angular velocity of a link OA, in Rad/sec
r as length of a link OA in cm
Then,

$$V_{AO} = r \times \omega$$

Relation between Linear and Angular acceleration **(02 marks)**

Let f as linear acceleration of a point A w.r.t. O , say, in cm/sec^2
α as angular acceleration of a link OA, in Rad/sec^2

Then,

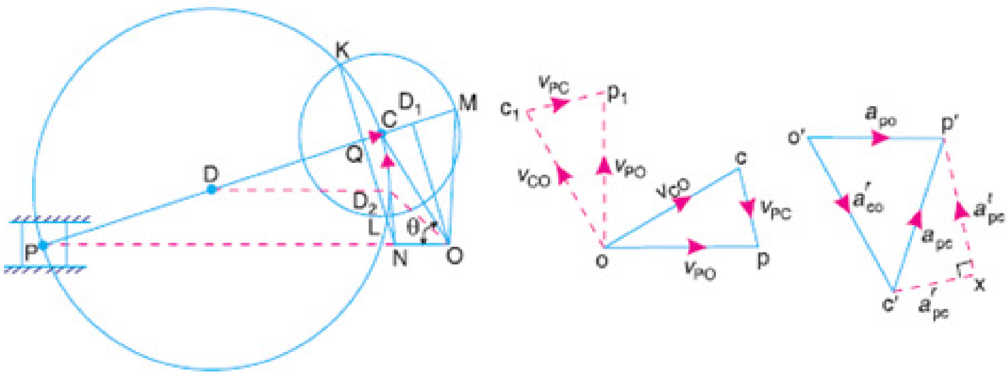
$$f_{AO} = r \times \omega^2 \text{ or } V^2_{AO} / r$$

$$\alpha_{OA} = f^t_{AO} / r \quad \text{rad /sec}^2$$

where f^t_{AO} is the tangential component of acceleration of point A w.r.t. O

Q 2 d) Klein's Construction

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:



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

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*.

We have already discussed that 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*1 *p*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*1*p*1 represents *v*PC (*i.e.* velocity of *P* with respect to *C*) and is parallel to *CP*.
A little consideration will show, that the triangles *oc*1*p*1 and *OCM* are similar. Therefore,

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

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

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

Thus, we see that by drawing the Klein'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 diagram 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.***

We have already discussed that the acceleration diagram for the given configuration is as shown in Fig. We know that
(*i*) *o'c'* represents CO
ar (*i.e.* radial component of the acceleration of crank pin *C* with respect to *O*) and is parallel to *CO*;
(*ii*) *c'x* represents PC *ar* (*i.e.* radial component of the acceleration of crosshead or piston *P* with respect to crank pin *C*) and is parallel to *CP* or *CQ*;
(*iii*) *xp'* represents PC *at* (*i.e.* tangential component of the acceleration of *P* with respect to *C*)
and is parallel to *QN* (because *QN* is perpendicular to *CQ*); and
(*iv*) *o'p'* represents *a*PO (*i.e.* acceleration of *P* with respect to *O* or the acceleration of piston
P) and is parallel to *PO* or *NO*.
A little consideration will show that the quadrilateral *o'c'x p'* is similar to
quadrilateral *CQNO* . Therefore,

$$\frac{o'c'}{OC} = \frac{c'x}{CQ} = \frac{xp'}{QN} = \frac{o'p'}{NO} = \omega^2 \text{ (a constant)}$$

or $$\frac{a^r_{CO}}{OC} = \frac{a^r_{PC}}{CQ} = \frac{a^t_{PC}}{QN} = \frac{a_{PO}}{NO} = \omega^2$$

$\therefore$ $$a^r_{CO} = \omega^2 \times OC;\ a^r_{PC} = \omega^2 \times CQ$$

$$a^t_{PC} = \omega^2 \times QN;\ \text{and } a_{PO} = \omega^2 \times NO$$

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

Notes: 1. The acceleration of piston P with respect to crank pin C (*i.e.* a_{PC}) may be obtained from:

$$\frac{c'p'}{CN} = \omega^2 \quad \text{or} \quad \frac{a_{PC}}{CN} = \omega^2$$

$\therefore$ $$a_{PC} = \omega^2 \times CN$$

2. To find the velocity of any point D on the connecting rod PC, divide CM at D_1 in the same ratio as D divides CP. In other words,

$$\frac{CD_1}{CM} = \frac{CD}{CP}$$

$\therefore$ Velocity of D, $v_D = \omega \times OD_1$

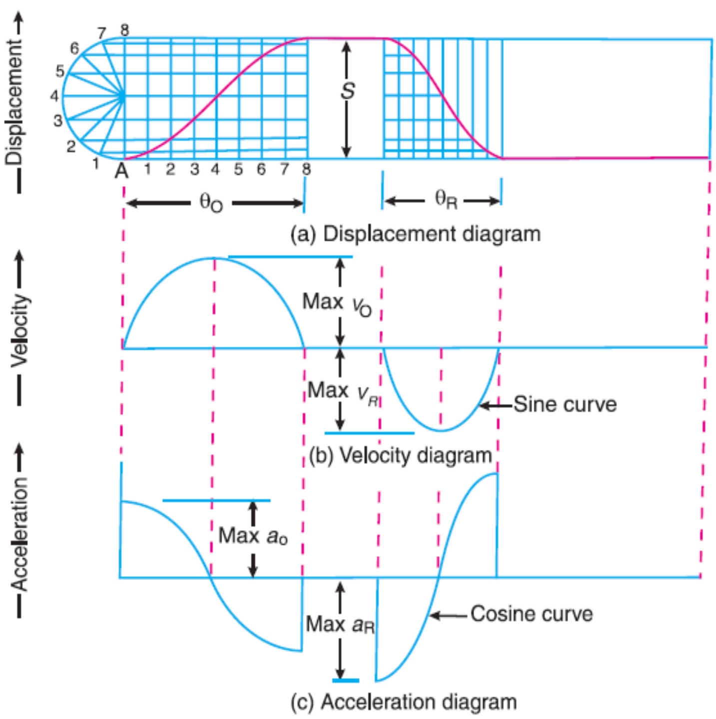
3. To find the acceleration of any point D on the connecting rod PC, draw a line from a point D parallel to PO which intersects CN at D_2.

$\therefore$ Acceleration of D, $a_D = \omega^2 \times OD_2$

4. If the crank position is such that the point N lies on the right of O instead of to the left as shown in Fig. then the acceleration of the piston is negative. In other words, the piston is under going retardation.

5. The acceleration of the piston P is zero and its velocity is maximum, when N coincides with O. There is no simple graphical method of finding the corresponding crank position, but it can be shown that for N and O to coincide, the angle between the crank and the connecting rod must be slightly less than 90°. For most practical purposes, it is assumed that the acceleration of piston P is zero, when the crank OC and connecting rod PC are at right angles to each other.

Q 2 e) Velocity & Acceleration diagrams for a follower moving with SHM (02 + 02 + 02 marks)



Q2 f) **(For T_1 & T_2 values 02 marks, for width 02 marks)**

Given : P = 40 kW = 40,000 W ; θ = 170° = 170° × π / 180 = 2.04 rad ; μ = 0.24 ;
V = 50 m/s

Let b = Width of belt in metres,
T_1 = Tension in the tight side of the belt in N, and
T_2 = Tension in the slack side of the belt in N.

We know that
power transmitted (P),

$$40000 = (T_1 - T_2)\, v = (T_1 - T_2)\, 50$$

$$\therefore \quad T_1 - T_2 = 800 \qquad \ldots(i)$$

We know that

$$\frac{T_1}{T_2} = e^{\mu.\theta} = e^{2.967}$$

$$= 2.04 \qquad \ldots(ii)$$

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

$$T_1 = 1569.23 \text{ N and } T_2 = 769.23 \text{ N}$$

We know that
Safe tension pull = 400 N /cm of belt width b

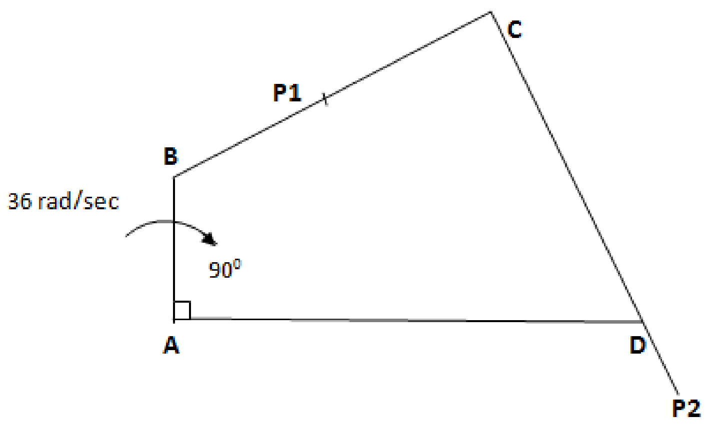
= 1569.23 /400 = 3.92 cm

Q3 a) Four bar link mechanism **(Diagrams-02 marks, calculations -02 marks)**

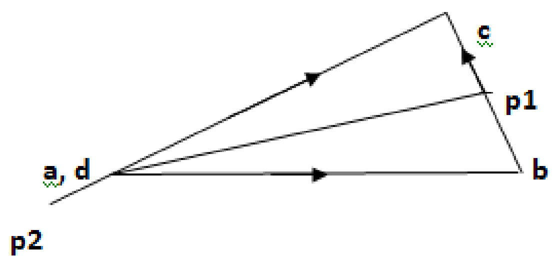
Data: Crank AB = 200 mm, BC = 400 mm, CD = 450 mm, fixed link AD = 600 mm,

W = 36 rad/sec, Crank angle = 45^0

P1 = mid point of link BC, P2 = on the link CD 100 mm from pin connecting link AD and CD



Space diagram



velocity diagram

Velocity of crank AB, Vab = w x AB = 36 x 0.2 = 7.2 m/sec

With a certain scale draw ab perpendicular to link AB for Vab = 7.2 m/s.

Draw bc perpendicular to link BC and also draw cd perpendicular to link CD through point a or d as AD is a fixed link.

From Velocity diagram, Velocity of midpoint p1 of link BC = 2.2 m/s,

Velocity of point p2 on the link CD = 1.4 m/s

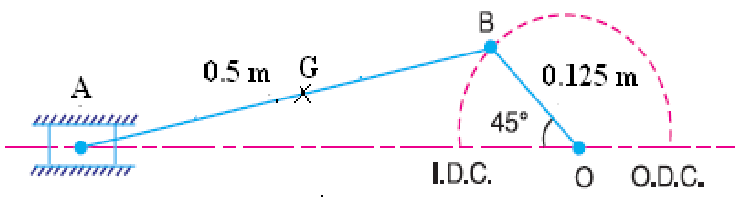
Q3 b) Data: **(Diagrams-02 marks, calculations -02 marks)**

Crank OB = 125 mm, Conn. Rod AB = 500 mm, Angle of crank from IDC = 45^0

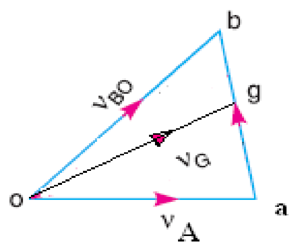
C.G. of Conn rod G = 275 mm from slider,

N_{BO} = 600 rpm, W_{BO} =2 π X 600/60 = 62.84 rad/s

Vector ob = V_{BO} = V_B = W_{BO} x OB = 62.84 x .125 = 7.855 m/s



Configuration Diagram



Velocity diagram

Velocity of slider Vector oa = V_{oa} = 6.79 m/s

Velocity of conn. Rod Vector ab = V_{AB} = 5.66 m/s

Velocity of point 'G' Vector og = Vg = 7.2 m/s

Q3 c) Advantages and disadvantages of chain drive over belt drive (02 + 02 Marks)

Advantages

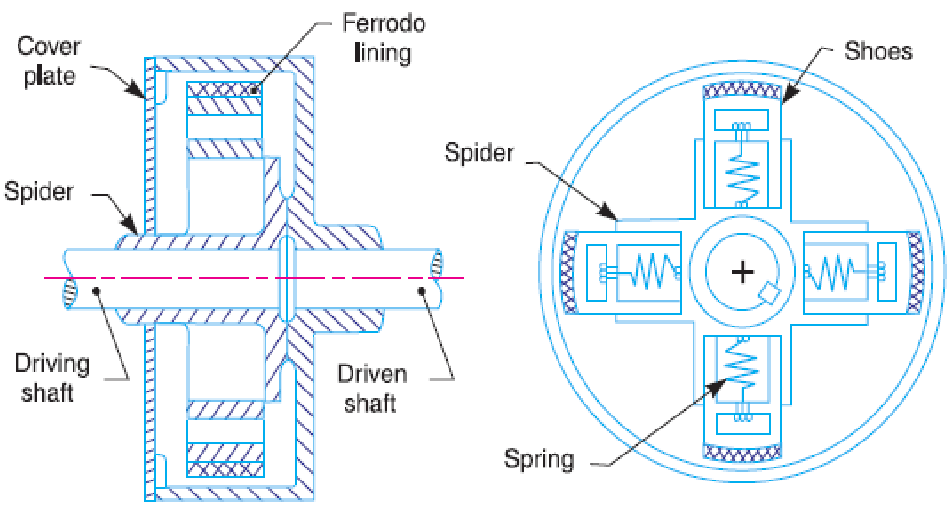
1. As no slip takes place during chain drive, hence perfect velocity ratio is obtained.
2. Since the chains are made of metal, therefore they occupy less space in width than a belt or rope drive.
3. The chain drives may be used when the distance between the shafts is less.
4. The chain drive gives a 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.

Disadvantages

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.

Q3 d) Working of centrifugal clutch (fig 02 marks, explanation 02 marks)

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.



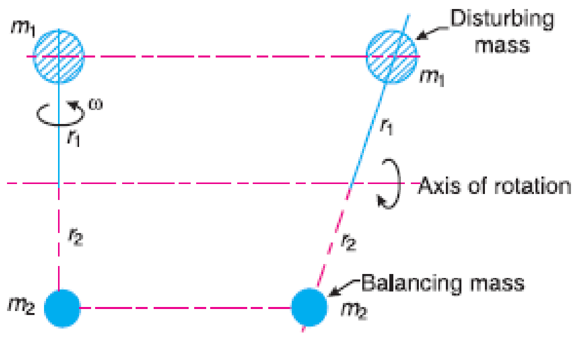
Q3 e) Process of balancing of single rotating masse by a single rotating mass in the same plane (04 marks)

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,

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

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.



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

Let $\quad r_2$ = 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,

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

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

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

Q3 f) Terms as applied to cams- **(01 mark each)**

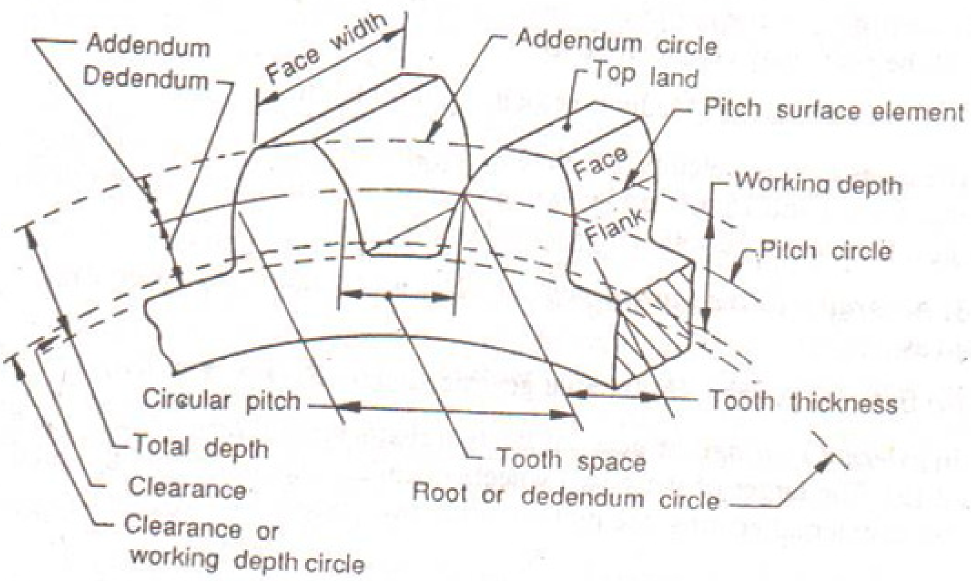
i) **Base circle:** it is smallest circle that can be drawn to the cam profile.

ii) **Pitch circle**: it is the circle that can be drawn from the center of the cam through the pitch points.

iii) **Pressure angle**: it the angle between the direction of follower motion and a normal to the pitch curve.

iv) **Stroke of the follower**: it is maximum travel of the follower from its lowest position to the topmost position

Q4 a) Spur gear terminology- (neat figure 04 marks)

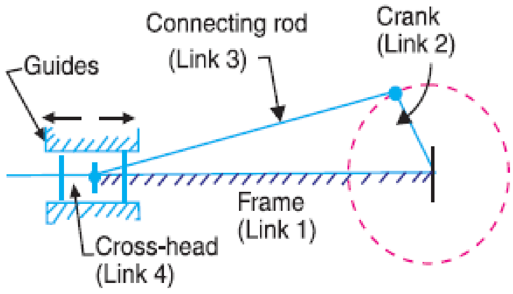


Q 4 b) Justification- Slider crank mechanism is modification of a basic four bar chain mechanism.

A single slider crank chain is a modification of the basic four bar chain, because it consist of one sliding pair and three turning pairs. It is,usually, found in reciprocating steam engine mechanism. This type of mechanism converts rotary motion into reciprocating motion and vice versa.

A four bar chain mechanisn is made up of four links and four turning pairs whereas single slider crank chain mechanism has one sliding pair and three turning pairs.

_ Fig shows a single slider crank chain, the links 1 and 2, links 2 and 3, and links 3 and 4 form three turning pairs while the links 4 and 1 form a sliding pair.



Single slider crank chain.

The link 1 corresponds to the frame of the engine, which is fixed. The link 2 corresponds to the crank ; link 3 corresponds to the connecting rod and link 4 corresponds to cross-head. As the crank rotates, the cross-head reciprocates in the guides and thus the piston reciprocates in the cylinder.

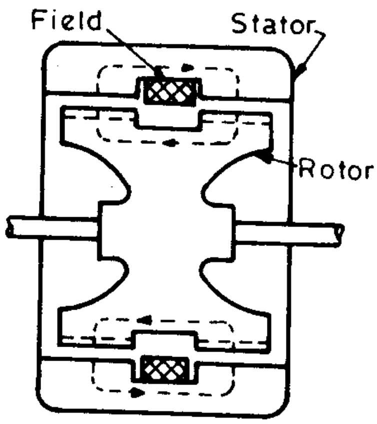
(04 marks)

Q 4 c) Comparison between flywheel and Governor (04 Marks)

Sr.N0.	Flywheel	Governor
1	Flywheel is a device which stores when produced in excess & release when required by m/c.	Governor is a device controls the supply of energy of fuel to engine & controls mean speed.
2	It regulates fluctuation of speed when there is a variation in cyclic torque of m/c	It regulates speed of engine when there is a external load variation.
3	It acts by virtue of its inertia	It acts as a mechanism to control fuel supply
4	If torque variation is high, flywheel required is larger size.	If external load variation is higher, more control on fuel supply necessary.
5	Used in Engines, forging m/c, Sheet metal press, shearing m/c.	Used in Engines.

Q4 d) Eddy current dynamometer- (Fig 02 marks, Explanation 02 marks)

Working principle: 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.



Eddy current dynamometer.

Q4 e) Problem on clutch **(01 + 02 + 01 Marks)**

Given : d_1 = 25 cm : or r_1 = 125 mm d_2 = 20 cm or r_2 = 100 mm ;
$\mu = 0.3$; N = 700 rpm or $\omega = 2\pi \times 700/60 = 73.31$ rad/s **W = 1500 N**

mean radius of the friction surfaces for uniform wear,

$$R = \frac{r_1 + r_2}{2} = \frac{125 + 100}{2} = 0.1125 \text{ meter}$$

We know that torque transmitted,

$$T = n.\mu.W.R = 2 \times 0.3 \times 1500 \times 0.1125 = 101.25 \text{ N-m}$$

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

$\therefore$ Power transmitted by a clutch,

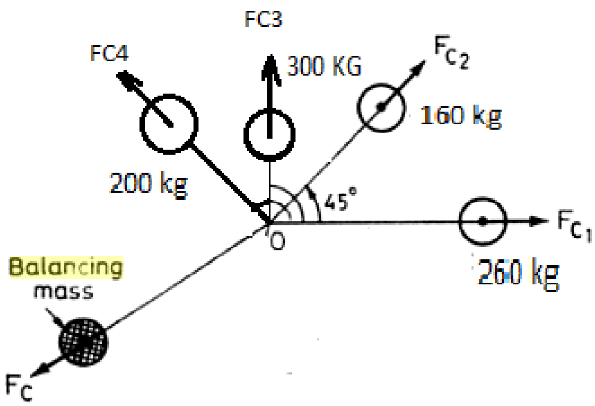
$$P = T.\omega = 101.25 \text{ x } 73.30 = 7421.625 \text{ N-m/sec i.e. Watt}$$

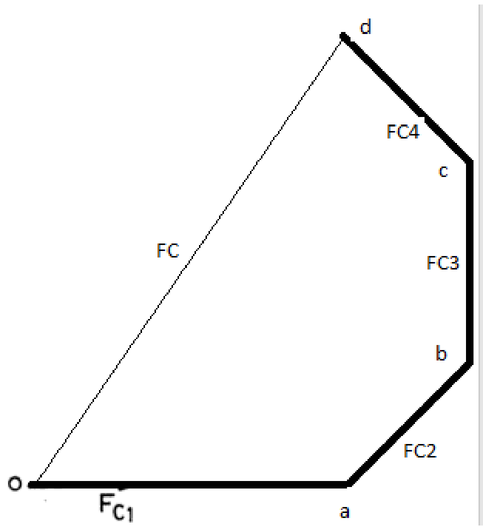
Q4 f) Balancing of masses **(Diagrams-02 marks, calculations -02 marks)**

Data : m1 = 260 kg, m2 = 160 kg, m3 = 300 kg, m4 = 200 kg,

r1 = 300 mm = 0.3 m, r2 = 250 mm = 0.25 m, r3 = 150 mm = 0.15 m, r4 = 200 mm = 0.2 m

θ1 = 0^0 θ1 = 45^0 θ1 = 90^0 θ1 = 135^0





Now the vector diagram is drawn as shown in Fig. to some suitable scale. Take any point o. From o, draw oa parallel to F_{C_1} and take $oa = m_1r_1 = 78$ kg-m. From a, draw ab parallel to F_{C_2} and equal to $m_2r_2 = 40$ kg-m. From b, draw bc parallel to F_{C_3} and equal to $m_3r_3 = 45$ kg-m. From c, draw cd parallel to F_{C_4} and equal to $m_4r_4 = 40$ kg-m.

The closing side of the polygon od represents the resultant force. Measure od. This is equal to 34.8 kg-m on the chosen scale. Hence $od = 128$ kg-m.

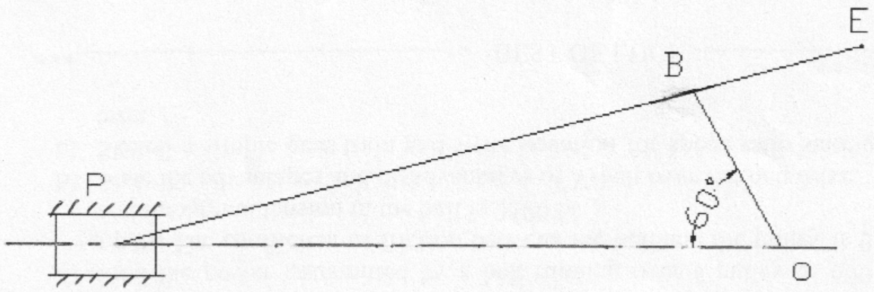
The centrifugal force due to balancing mass is equal to the resultant force but *opposite in direction*. But balancing force is proportional to $m \times r$, therefore

$$m \times r = 128$$

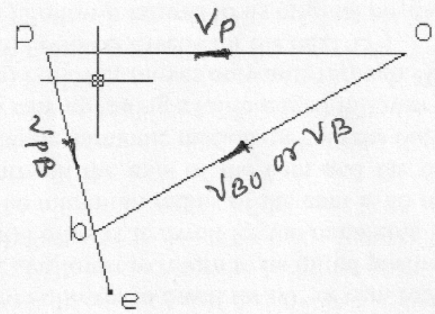
or
$$m \times 0.2 = 128$$

or
$$m = \frac{34.8}{0.2} = 640 \text{ kg.} \quad \textbf{Ans.}$$

Q 5 (a) **(Space diagram 02 marks, Velocity diagram 03 marks, each answer 01 marks)**



Space Diagram



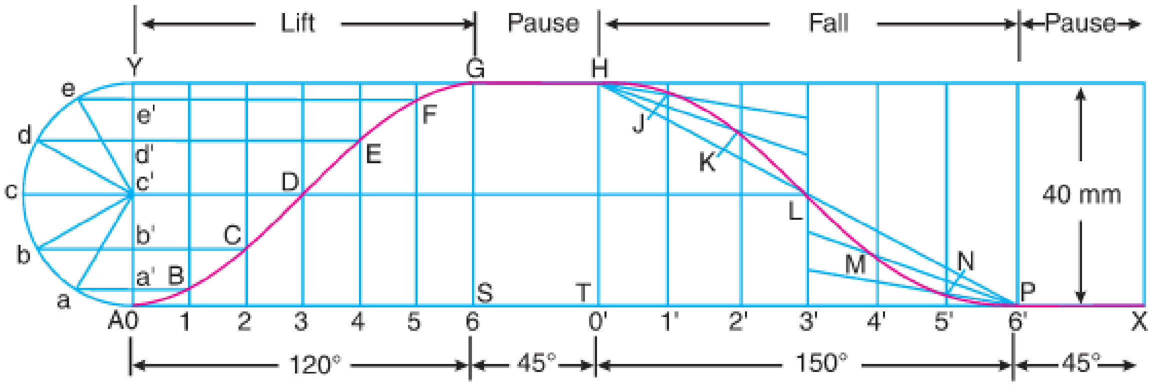
Velocity Diagram

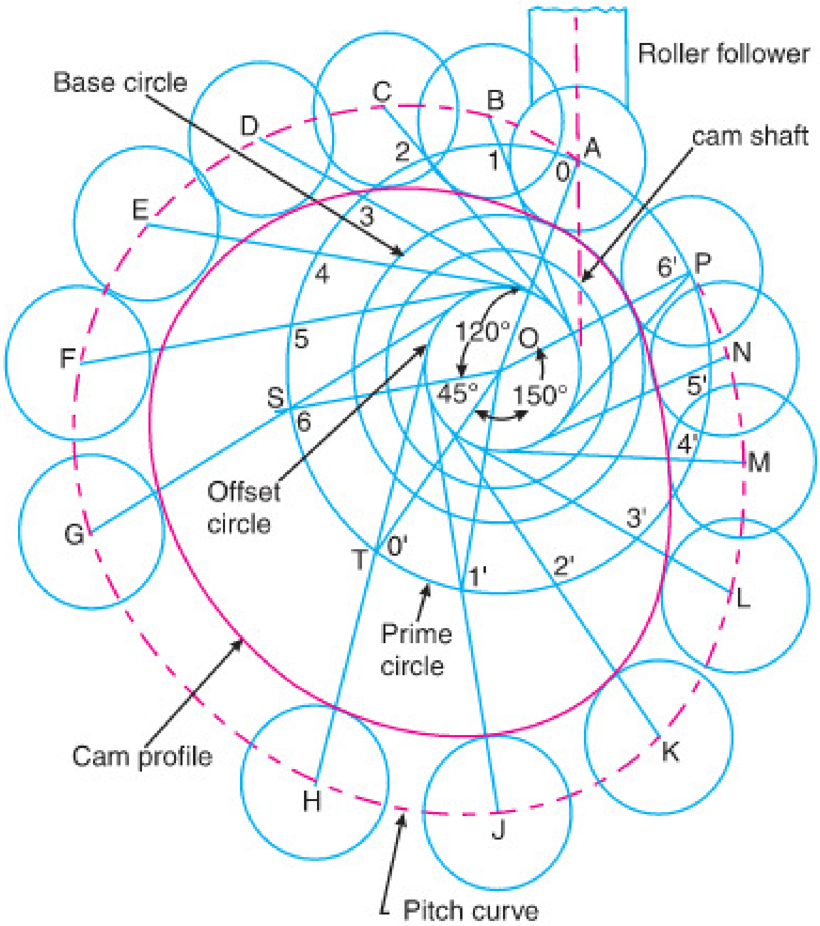
(i) Velocity of slider (Vp)
= Vector op × scale
= 9.6 m/sec.

(ii) Velocity of point E (VE)
= vector pe × scale
= 6.40 m/sec.

(iii) Angular velocity of connecting rod (ω_{PB}) = $\frac{V_{PB}}{PB}$
= $\frac{\text{Vector } pb \times \text{scale}}{PB}$
= 3.125 ~~rad~~ rad/s

Q 5 (b) **(Displacement diagram 03 marks, Cam Profile 05 marks)**





Q 5 (c) **(Case 1 = 04 marks, Case 2 = 04 marks)**

Given: $T_A = 80$; $T_D = 200$

Let us find the number of teeth on gears C & D ie (T_C & T_D)

Let d_A, d_B, d_C & d_D be the PCD of gears A, B, C & D.

∴ from the Geometry of the fig.

$d_A + d_C + d_D = d_B$ or $d_A + 2d_C$ (∵ $d_C = d_D$)

Since the no. of teeth are proportional to their PCD's

∴ $T_A + 2T_C = T_B$ or $80 + 2T_C = 200$

∴ $T_C = 200 - 80/2 = 60$

∴ $T_D = 60$ (∵ $T_C = T_D$)

Table of Motions.

Step No.	Conditions of Motion	Revolutions of elements.			
		Arm	Gear A	Compound gear C-D	Gear B
1.	Arm fixed, gear A rotates through −100 rev (ie 100 revol. clockwise)	0	−100	$+\frac{T_A}{T_C}$	$+\frac{T_A}{T_C} \times \frac{T_C}{T_B} = +\frac{T_A}{T_B}$
2.	Arm fixed, gear A rotates through −x ~~rpm~~ rev.	0	−x	$+x \times \frac{T_A}{T_B}$	$+x \times \frac{T_A}{T_B}$
3.	Add −y rev. to all elements.	−y	−y	−y	−y
4	Total motion	−y	−x−y	$x \times \frac{T_A}{T_C} - y$	$x \times \frac{T_A}{T_B} - y$

1. Speed of arm when A makes 100 rev. clockwise & B makes 50 rev. anticlockwise.

From the fourth row of table

$-x - y = -100$ or $x + y = 100$ ...(i) [since Gear A makes 100 rev. clo

$x \times \frac{T_A}{T_B} - y = 50$ or $x \times \frac{80}{200} - y = 50$

∴ $80x - 200y = 10,000$

∴ $x - 2.5y = 125$ ....(ii)

[Also, the Gear D makes 50 rev anticlockwise.]

from eqn I & II

$x = 107.14$ and $y = -7.14$

∴ Speed of arm $= -y = -(-7.14) = +7.14$ rev. anticlockwise

2. Speed of Arm when A makes 100 rev. clockwise and B is stationary,

from the fourth row of table

$-x-y=-100$ or $x+y=100$ ....(iii) - Since the Gear A makes 100 rev. clockwise

$x \times \frac{T_A}{T_B} - y = 0$ or $x \times \frac{80}{200} - y = 0$

$\therefore 80x - 200y = 0$ ....(iv) - The Gear B is stati

$\therefore x - 2.5y = 0$

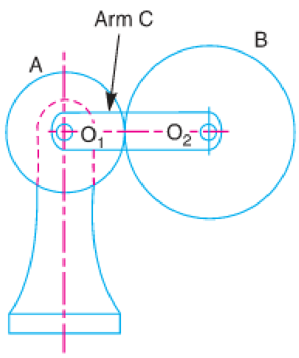
From eqn (iii) & (iv)

$x = 71.43$ and $y = 28.57$

$\therefore$ Speed of Arm $= -y = -28.57 = 28.57$ rev. clockwise.

Q 6 (a) (i) **(Sketch 02 marks, Working principle 02 marks)**

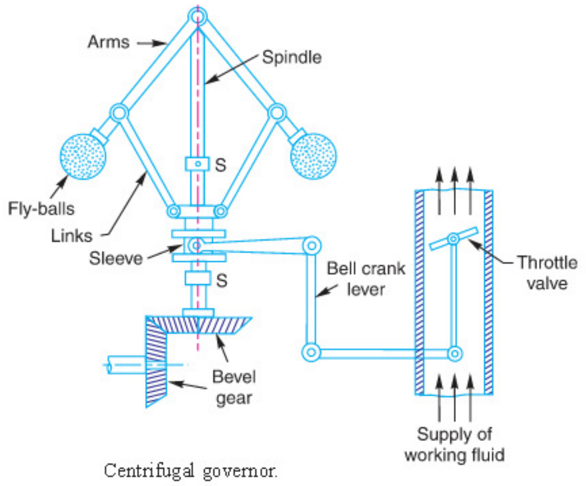
Epicyclic Gear Train



Epicyclic gear train.

We have already discussed that in an epicyclic gear train, the axes of the shafts, over which the gears are mounted, may move relative to a fixed axis. A simple epicyclic gear train is shown in Fig., where a gear A and the arm C have a common axis at O1 about which they can rotate. The gear B meshes with gear A and has its axis on the arm at O2, 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 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 (epi.means upon and cyclic means around). The epicyclic gear trains may be simple or com-pound. The epicyclic gear trains are useful for transmitting high velocity ratios with gears of moderate size in a compara-tively lesser space. The epicyclic gear trains are used in the back gear of lathe, differential gears of the automobiles, hoists, pulley blocks, wrist watches etc

Q 6 (a) (ii) (Neat labeled sketch 04 marks)



Centrifugal governor.

Q 6 (b) (Case a = 06 marks, Case b = 02 marks)

(a) Operating force when drum rotates in anticlockwise direction

We know that angle of wrap,

$$\theta = \frac{3}{4}\text{th of circumference} = \frac{3}{4} \cdot 360° = 270°$$

$$= 270 \cdot \square/180 = 4.713 \text{ rad}$$

and $$2.3 \log \frac{T_1}{T_1} = \mu\,\theta = 0.25 \cdot 4.713 = 1.178$$

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

... (Taking antilog of 0.5123)

We know that braking torque (T_B),

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

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

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

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

Now taking moments about the fulcrum O, we have

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

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

(b) Operating force when drum rotates in clockwise direction

When the drum rotates in clockwise direction, then taking mo- ments about the fulcrum O, we have

$$P \times l = T_1 .\, b \quad \text{or} \quad P \times 0.5 = 1444 \times 0.1 = 144.4$$

$$P = 144.4 / 0.5 = 288.8 \text{ N}$$

Q 6 c

(i) Considering Uniform Pressure Condition

Frictional Torque, T = 2/3 μWR = 2/3 x 0.05 x (15 x 1000) x 7.5
= 3750 N-cm or 37.5 N-m ……………**02 marks**

Power lost in friction, P = 2πNT/60 x 1000 kW
= 2π x 100 x 37.5/60 x 1000
= 0.393 kW …………………………**02 marks**

(ii) Considering Uniform Wear Condition

Frictional Torque, T = 1/2 μWR = 1/2 x 0.05 x (15 x 1000) x 7.5
= 2812 N-cm or 28.12 N-m **…………02 marks**

Power lost in friction, P = 2πNT/60 x 1000 kW
= 2π x 100 x 28.12/60 x 1000
= 0.294 kW **…………………………02 marks**
