SUMMER– 14 EXAMINATION

Subject Code: **17412** **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.

Que. No. 1 a) Attempt any SIX 12

i) List of various types of clutches used to transmit Power

(FOUR TYPES two marks, each type - half mark)

a) Single plate clutch b) Multi plate clutch c) Cone clutch d) Centrifugal clutch

ii) Classification of follower:

(Two marks, 1 + ½ + ½)

1. According to the surface in contact:

- Knife-edge follower
- Roller follower
- Flat faced or mushroom follower
- Spherical follower

2. According to the motion of the follower:

- Reciprocating or translating follower
- Oscillating or rotating follower

3. According to the path of motion of follower:

- Radial follower
- Off-set follower

iii) **(Two marks, 1 + 1)**

Advantages of chain drive: (any two)

1. As no slip takes place, hence, perfect velocity ratio is obtained (Positive drive).
2. Chain drive gives high transmission efficiency (up to 98 %).
3. Chain drive may be used when the distance between the shafts is less.
4. Chain is made up of metal which would occupy less space as compared with belt or rope drive.
5. Ability to transmit power to several shafts by one chain.
6. Load on the shaft is less and long life.

Disadvantages of chain drive: (any two)

1. Manufacturing cost of chains is relatively high
2. The chain drive needs accurate mounting and careful maintenance
3. High velocity fluctuations especially when unduly stretched
4. Chain operations are noisy as compared to belts

iv) **(Any FOUR TYPES to be written. Two marks, each type - half mark)**

List of various types bearings used

1. Flat pivot
2. Conical pivot
3. Truncated pivot
4. Single flat collar
5. Multiple flat collar

v) (**Function to be written. Two marks)**

The function of governor is to regulate the mean speed of the engine, when there are variations in the load. Governor automatically adjusts and controls the supply of fuel / working fluid to the engine with the varying load conditions and keeps the mean speed within the certain desired limits.

e.g. When the load on an engine increases, its speed decreases, therefore it becomes necessary to increase the supply of fuel or working fluid. The configuration of the governor changes and valve is moved to increase the supply of working fluid. Conversely, when the load on the engine decreases, its speed increases, and thus, less working fluid is required. Hence, the governor decreases the supply of working fluid.

vi) **(Definition of fluctuation of speed one mark, fluctuation of energy one mark)**

Fluctuation of speed: It is the difference between the maximum and minimum speed of Flywheel.

Fluctuation of speed = $(N_1 - N_2)$ rpm N_1 – maximum speed, N_2 – minimum speed

Fluctuation of energy: It is the difference between the maximum and minimum energy of Flywheel.

Maximum energy of Flywheel $= \frac{1}{2} I \omega_1^2$

Minimum energy of Flywheel = $\frac{1}{2} I \omega_2^2$

Fluctuation of energy = $\frac{1}{2} I (\omega_1^2 - \omega_2^2)$ in **N-m** or **J**

I – moment of inertia of flywheel = mk^2

where, m – mass of the flywheel, kg and k - radius of gyration of flywheel, m^2

ω_1 – Maximum Angular velocity, rad/sec

ω_2 – Minimum Angular velocity, rad/sec

vii) **(Any FOUR TYPES to be written. Two marks, each type - half mark)**

Types of brakes:

Based on actuation or means of transforming energy:

1. Hydraulic brakes
2. Electric brakes
3. Mechanical brakes
4. Pneumatic brakes

Based on the direction of acting force:

- Radial brakes
    - External a) shoe brake b) band brake c) band and block brake

- Internal a) Internal expanding brake

- Axial or disc brakes

viii) **Balancing meaning one mark, methods one mark (any two methods)**

The process of providing the second mass in order **to counter act** the effect of the centrifugal force of the ***disturbing*** mass is called balancing. In order to prevent the bad effect of centrifugal force of disturbing mass, another mass (balancing) is attached to the opposite side of the shaft at such a position, so as to balance the effect of centrifugal force of disturbing mass. This is done in such a way that the centrifugal forces of both the masses are made equal and opposite.

Methods of balancing:

- Balancing of rotating masses
  1) Balancing of a single rotating mass by a single rotating mass in the same plane
  2) Balancing of a single rotating mass by two masses rotating in the different planes
     * Disturbing mass lies in a plane between the planes of balancing masses
     * Disturbing mass lies in a plane on one end of the planes of balancing masses
  3) Balancing of different masses rotating in the same plane
  4) Balancing of different masses rotating in the different planes

- Balancing of reciprocating masses

Que. No. 1 b) Attempt any **TWO**

i) **(Definition of Kinematic pair One mark, Types Three marks)**

Kinematic pair:

When two kinematic links or elements are in contact with each other such that relative motion between them is either completely constrained or successfully constrained.

Types:

- **Based on nature of relative motion**
  Sliding pair / Prismatic pair
  Turning pair / Revolute pair
  Screw pair / Helical pair
  Spherical pair / Globular pair
  Rolling pair
- **Based on nature of contact**

Lower pair
Higher pair

- **Based on nature of closure**
  Self closed pair
  Force- closed pair

ii) **(Types of clutches: Two marks, applications Two marks)**

Types of clutches:

a) Single plate clutch b) Multi plate clutch c) Cone clutch d) Centrifugal clutch

Applications:

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

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

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

d) Centrifugal clutch: mopeds, Luna

iii) **One application ONE mark**

- V- Belt drive – air compressor, machine tools (drilling machine)
- Flat belt drive - lathe headstock, floor mill, stone crusher unit
- Gear drive – gear box of vehicles, cement mixing unit, machine tools, I.C. Engine, differential of automobile, dial indicator
- Chain drive – Bicycle, cranes, Hoists, bikes

Que. No. 2 Attempt any **FOUR** 16

a) **(Any Four points - four marks)**

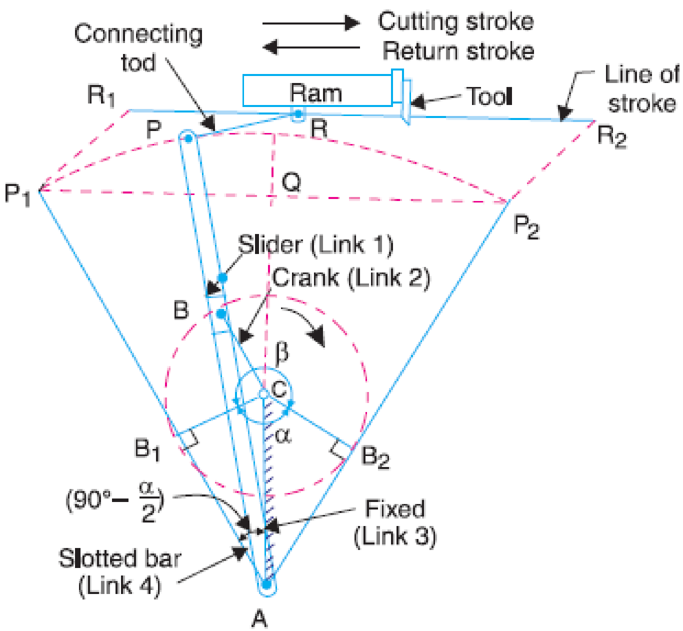
Sl. No.	Machine	Structure
1	All parts / links have relative motion	No relative motion between the links
2	It transforms the available energy into some useful work	No energy transformations

3	The kinematic link of a machine may transmit both power and motion	The member of the structure transmit forces only
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) **(Sketch 2 marks, explanation 2 marks)**

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



In the extreme positions, *AP*1 and *AP*2 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 *CB*1 to *CB*2 (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,
therefore,

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

Since the tool travels a distance of $R_1 R_2$ during cutting and return stroke, therefore travel of the tool or length of stroke

$$= R_1R_2 = P_1P_2 = 2P_1Q = 2AP_1 \sin \angle P_1AQ$$

$$= 2AP_1 \sin\left(90^\circ - \frac{\alpha}{2}\right) = 2AP \cos\frac{\alpha}{2} \quad \text{..... } (\because AP_1 = AP)$$

$$= 2AP \times \frac{CB_1}{AC} \quad \cdots \left(\because \cos\frac{\alpha}{2} = \frac{CB_1}{AC}\right)$$

$$= 2AP \times \frac{CB}{AC} \quad \ldots (\because CB_1 = CB)$$

c) **(one mark each for stating formulae for velocity and acceleration of piston & connecting rod)**

Velocity of piston, $\mathbf{V_p = \omega\, r \left(\sin\theta + \frac{\sin 2\theta}{2n}\right)}$

State all the terms:

ω = angular velocity of the crank, rad/sec

n = Ratio of length of connecting rod to the radius of crank

= **l / r** (Obliquity of connecting rod)

θ = Angle made by the crank with Inner Dead Centre (IDC)

r = radius of crank, l = length of connecting rod

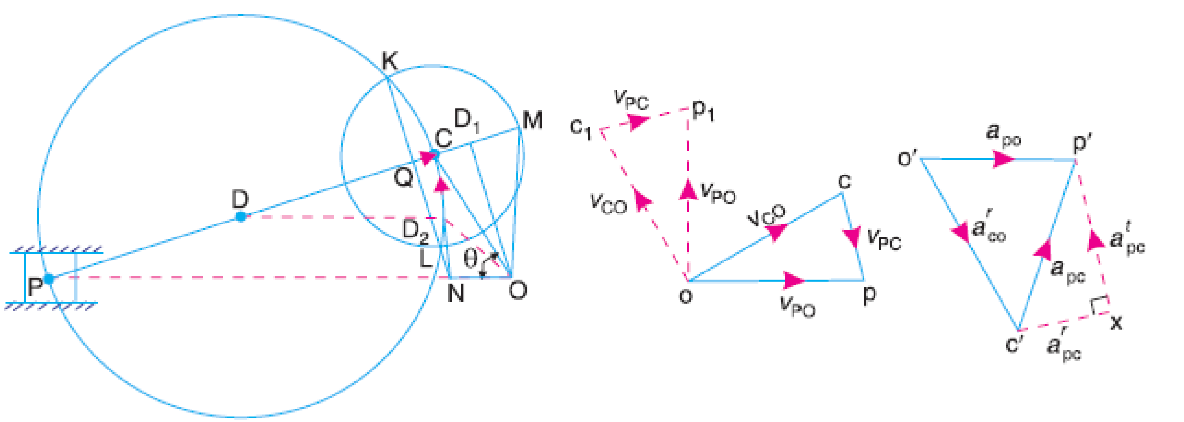
Acceleration of piston, $\mathbf{A_p = \omega^2 r \left\{\cos\theta + \frac{\cos 2\theta}{n}\right\}}$

Angular velocity of connecting rod $= \dfrac{\omega \cos\theta}{(n^2 - \sin^2\theta)^{1/2}}$

Angular acceleration of connecting rod, $\alpha_{cr} = -\omega^2 \dfrac{\sin\theta\,(n^2-1)}{[n^2-\sin^2\theta]^{3/2}}$

d) **(Sketch 3 marks, explanation 1 mark)**

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 construction

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 $oc_1 p_1$, 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_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*.

$$\text{Acceleration of piston, } \alpha_p = \omega^2\ ON$$

e) **Any Four reasons – four marks**

Roller follower is preferred over knife edge follower

- Knife-edge of the follower will cause the wear of the cam.
- Higher load on the small contact area the follower likely to cause wear at the tip of Knife-edge due to more stresses.
- Knife-edge follower practically not feasible for higher torque / load applications.
- More friction due to sliding motion of the knife-edge follower and hence, more maintenance.
- Roller follower on the other hand produces smooth operation with less wear and tear of both cam and follower.
- Pure rotational motion of roller follower causes less friction and less loss of power.
- Considerable side thrust exists between knife-edge follower and the guide.

f) Data: Initial tension, $T_o = 2000$ N, coefficient of friction, $\mu = 0.3$,

Angle of lap, $\theta = 150^0 = 150^0 \times \Pi / 180 = 2.618$ rad, Smaller pulley radius, R = 200 mm, hence, D = 400 mm, Speed of smaller pulley, N = 500 r.p.m.

We know that the velocity of the belt, $v = \frac{\Pi D N}{60} = \frac{\Pi \times 0.4 \times 500}{60} = 10.47$ m/sec **(01 mark)**

Let T_1 = Tension in the belt on the tight side, N

Let T_2 = Tension in the belt on the slack side, N

We know that, $T_0 = \frac{(T1 + T2)}{2}$ Hence, $2000 = (T_1 + T_2) / 2$

Thus, $(T_1 + T_2) = 4000$ N .... (1)

We also know that, $\frac{T1}{T2} = e^{\mu\theta}$ therefore, $\frac{T1}{T2} = e^{0.3 \times 2.618}$ or $\frac{T1}{T2} = 2.2$ .... (2)

From equations 1 and 2, $T_1 = 2750$ N and $T2 = 1250$ N **(02 marks)**

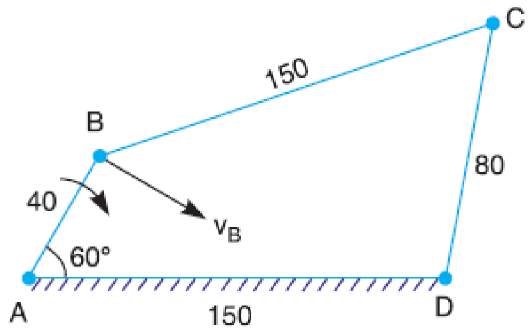
Power transmitted by belt, $P = [T_1 - T_2]\, v$

$= [2750 - 1250]\, 10.47$

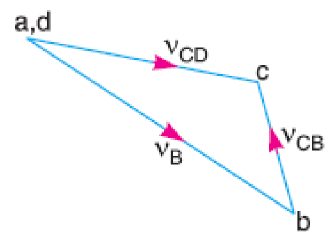
$= 15700$ watts = 15.7 kW **(01 mark)**

Q3 a) For Space diagram 01 Mark, Velocity Diagram 02 marks , Calculations 01 Mark

(Note In QP length BC & AB are equal. Read length AD = length BC = 150 mm)



Space diagram (All dimensions in mm).



Velocity diagram.

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),

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

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

∴ Angular velocity of link CD,

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

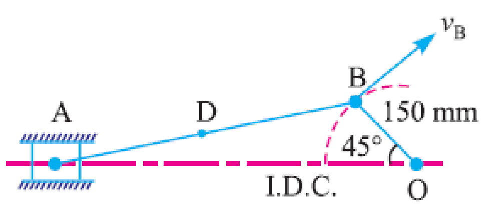
Q3 b) For Space diagram 01 Mark, Velocity Diagram 01 marks ,Accln Diagram 01 Mark & Calculations 01 Mark

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

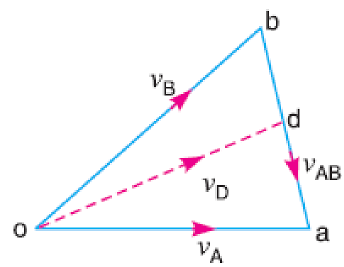
We know that linear velocity of B with respect to O or velocity of B,

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

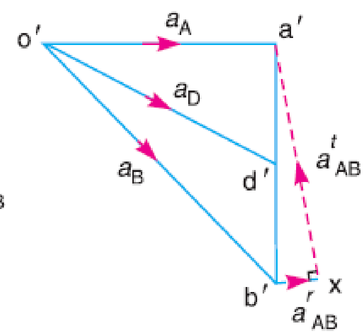
...(Perpendicular to BO)



Space diagram.



Velocity diagram.



Acceleration diagram.

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

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

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

$$\mathbf{a_D = \text{vector } o'd' = 117 \text{ m/s}^2}$$

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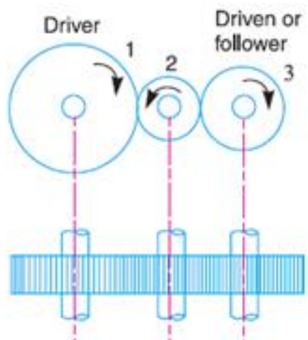
Q3 c) For Types 01 Mark, Explain any one type with figure 03 marks

Following are the different types of gear trains, depending upon the arrangement of wheels :
1. Simple gear train, **2.** Compound gear train,
3. Reverted gear train, and **4.** Epicyclic gear train.

When there is only one gear on each shaft, as shown in Fig. 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 1 and 2 are made to mesh with each other to

transmit motion from one shaft to the other, as shown in Fig. Since the gear 1 drives the gear 2, therefore gear 1 is called the *driver* and the gear 2 is called the *driven* or *follower*. It may be noted that the motion of the driven gear is opposite to the motion of driving gear.



Simple gear train.

Let
N_1 = Speed of gear 1(or driver) in r.p.m.,
N_2 = Speed of gear 2 (or driven or follower) in r.p.m.,
T_1 = Number of teeth on gear 1, and
T_2 = Number of teeth on gear 2.

$$\text{Speed ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

Similarly, as the intermediate gear 2 is in mesh with the driven gear 3, therefore speed ratio for these two gears is

$$\frac{N_2}{N_3} = \frac{T_3}{T_2}$$

The speed ratio of the gear train as shown in Fig. is obtained by multiplying the equations

$$\therefore \quad \frac{N_1}{N_2} \times \frac{N_2}{N_3} = \frac{T_2}{T_1} \times \frac{T_3}{T_2} \quad \text{or} \quad \frac{N_1}{N_3} = \frac{T_3}{T_1}$$

i.e.
$$\text{Speed ratio} = \frac{\text{Speed of driver}}{\text{Speed of driven}} = \frac{\text{No. of teeth on driven}}{\text{No. of teeth on driver}}$$

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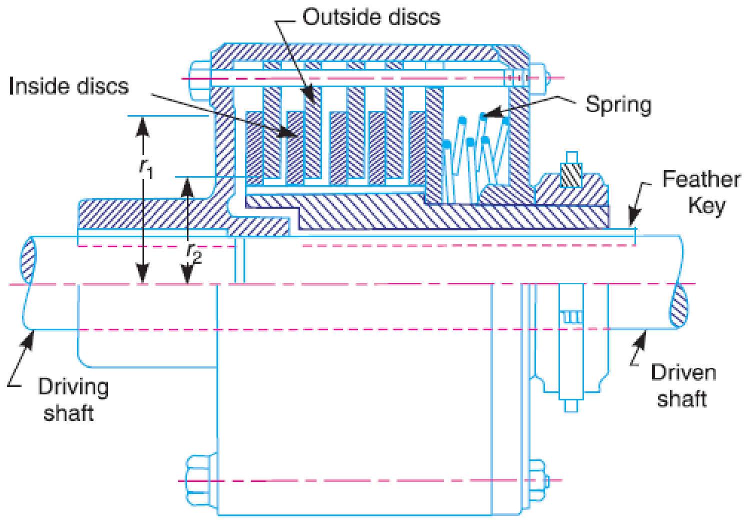
Subject Code: **17412** **Model Answer**

Q3 d) For Labeled sketch 02 Mark, Brief working 02 marks



Multiple disc clutch.

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 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

$$= \frac{2}{3}\left[\frac{(r_1)^3 - (r_2)^3}{(r_1)^2 - (r_2)^2}\right] \quad \text{...(For uniform pressure)}$$

$$= \frac{r_1 + r_2}{2} \quad \text{...(For uniform wear)}$$

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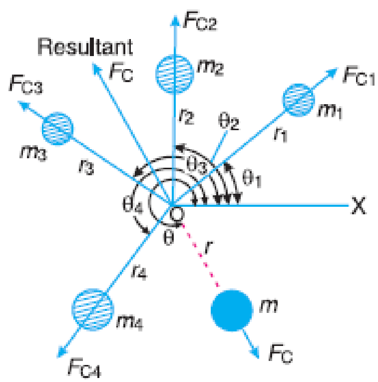
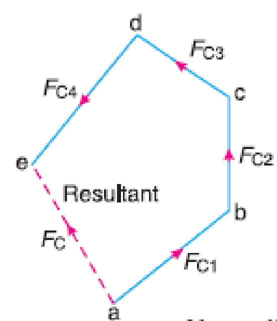
Q3 e) For Diagrams 02 Mark, Method 02 marks

Consider any number of masses (say four) of magnitude m_1, m_2, m_3 and m_4 at distances of r_1, r_2, r_3 and r_4 from the axis of the rotating shaft. Let $\theta_1, \theta_2, \theta_3$ and θ_4 be the angles of these masses with the horizontal line OX, as shown in Fig. Let these masses rotate about an axis through O and perpendicular to the plane of paper, with a constant angular velocity of ω rad/s.

The magnitude and position of the balancing mass may be found out analytically or graphically as discussed below :



Space diagram.



Vector diagram.

Balancing of several masses rotating in the same plane.

The magnitude and position of the balancing mass may also be obtained graphically as discussed below :

1. First of all, draw the space diagram with the positions of the several masses, as shown in Fig.
2. Find out the centrifugal force (or product of the mass and radius of rotation) exerted by each mass on the rotating shaft.
3. Now draw the vector diagram with the obtained centrifugal forces (or the product of the masses and their radii of rotation), such that *ab* represents the centrifugal force exerted by the mass m_1 (or $m_1.r_1$) in magnitude and direction to some suitable scale. Similarly, draw *bc*, *cd* and *de* to represent centrifugal forces of other masses m_2, m_3 and m_4 (or $m_2.r_2$, $m_3.r_3$ and $m_4.r_4$).
4. Now, as per polygon law of forces, the closing side *ae* represents the resultant force in magnitude and direction, as shown in Fig.
5. The balancing force is, then, equal to the resultant force, but in ***opposite direction.***
6. Now find out the magnitude of the balancing mass (m) at a given radius of rotation (r), such that

$$m \cdot \omega^2 \cdot r = \text{Resultant centrifugal force}$$

or

$$m.r = \text{Resultant of } m_1.r_1,\ m_2.r_2,\ m_3.r_3 \text{ and } m_4.r_4$$

f) For follower motions 02 Mark, for cam motions 02 marks

The follower, during its travel, may have one of the following motions.

1. Uniform velocity,

2. Simple harmonic motion,

3. Uniform acceleration and retardation,

4. Cycloidal motion.

In addition follower may have

1. Translatory motion
2. Oscillating motion

Also the cam may have one of the following motions

1. Rotary motion (as in radial / cylindrical cam)
2. Linear motion (as in wedge cam)

Q4 a) For equation 02 Mark, for terms 02 marks

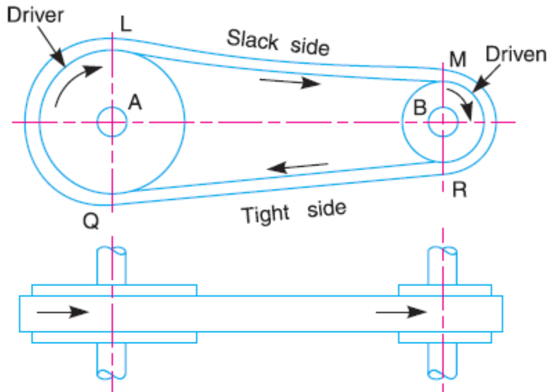
$$\frac{T_1}{T_2} = e^{\mu.\theta}$$

Where T_1 = Tension in the belt on the tight side,

T_2 = Tension in the belt on the slack side, and

Θ = Angle of contact or lap in radians i.e angle subtended by the belt arc lapping over small pulley.

The open belt drive, as shown in Fig. is used with shafts arranged parallel and rotating in the same direction. In this case, the driver *A* pulls the belt from one side (*i.e.* lower side *RQ*) and delivers it to the other side (*i.e.* upper side *LM*). Thus the tension in the lower side belt will be more than that in the upper side belt. The lower side belt (because of more tension) is known as ***tight side*** whereas the upper side belt (because of less tension) is known as ***slack side***, as shown in Fig.

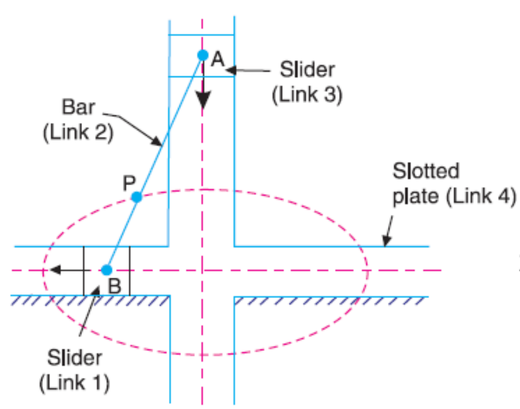


Open belt drive.

Q4 b) For sketch 02 Mark, for explanation 02 marks

It is an instrument used for drawing ellipses. This inversion is obtained by fixing the slotted plate (link 4), as shown in Fig. The fixed plate or link 4 has two straight grooves cut in it, at right angles to each other. The link 1 and link 3, are known as sliders and form sliding pairs with link 4. The link *A B* (link 2) is a bar which forms turning pair with links 1 and 3.

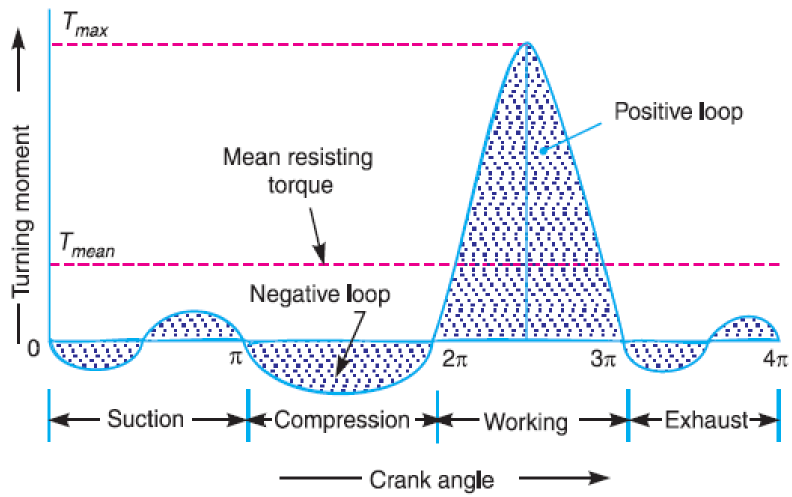
Since slider A forms first sliding pair with its groove(guide) and slider B forms second sliding pair with its groove (guide), this mechanism falls under double slider mechanism.



Elliptical trammel

Q4 c) For sketch 02 Mark, for explanation 02 marks

A turning moment diagram for a four stroke cycle internal combustion engine is shown in Fig. 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 π radians).

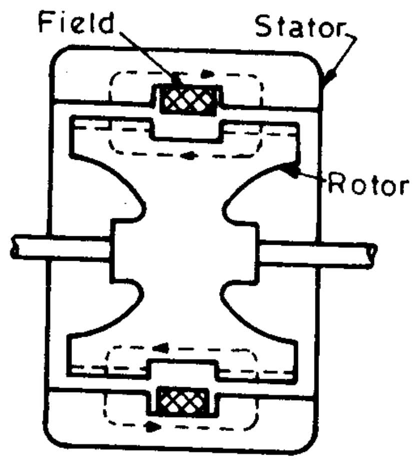


Turning moment diagram for a four stroke cycle internal combustion engine.

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.

Q4 d) For sketch 02 Mark, for explanation 02 marks

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.



Eddy current dynamometer.

Q4 e) For W , R, T & P each 01 Mark

Given : $d_1 = 300$ mm or $r_1 = 150$ mm ; $d_2 = 200$ mm or $r_2 = 100$ mm ; $p = 0.1$ N/mm² ; $\mu = 0.3$; $N = 2500$ r.p.m. or $\omega = 2\pi \times 2500/60 = 261.8$ rad/s

Since the intensity of pressure (p) is maximum at the inner radius (r_2), therefore for uniform wear,

$$p.r_2 = C \quad \text{or} \quad C = 0.1 \times 100 = 10 \text{ N/mm}$$

We know that the axial thrust,

$$W = 2\pi C (r_1 - r_2) = 2\pi \times 10 (150 - 100) = 3142 \text{ N}$$

and mean radius of the friction surfaces for uniform wear,

$$R = \frac{r_1 + r_2}{2} = \frac{150 + 100}{2} = 125 \text{ mm} = 0.125 \text{m}$$

We know that torque transmitted,

$$T = n.\mu.W.R = 2 \times 0.3 \times 3142 \times 0.125 = 235.65 \text{ N-m}$$

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

$\therefore$ Power transmitted by a clutch,

$$P = T.\omega = 235.65 \times 261.8 = 61\ 693 \text{ W} = 61.693 \text{ kW}$$

Q4 f) For space diagram 01 Mark, Vector diagram 02 mark, Show resultant 01 Mark

Masses are A= 12 kg, B= 10 kg, C= 18 kg D=15 kg
Radii are r1 = 40 mm, r2 = 50 mm, r3 = 60 mm & r4 = 30 mm
Angular positions are

$$\theta_1 = 0° ; \theta_2 = 60° ; \theta_3 = 135° \quad \theta_4 = 270°$$

$$r = 0.1 \text{ m}$$

Let m = Balancing mass, and

θ = The angle which the balancing mass makes with m_1.

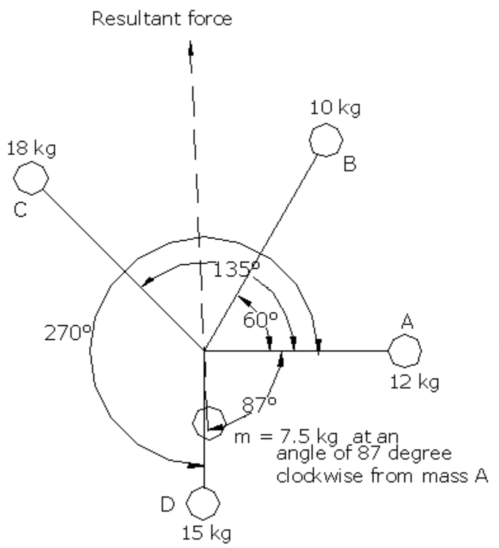
Since the magnitude of centrifugal forces are proportional to the product of each mass and its radius, therefore

$$A \cdot r_1 = 12 \times 0.04 = 0.48 \text{ kg-m}$$

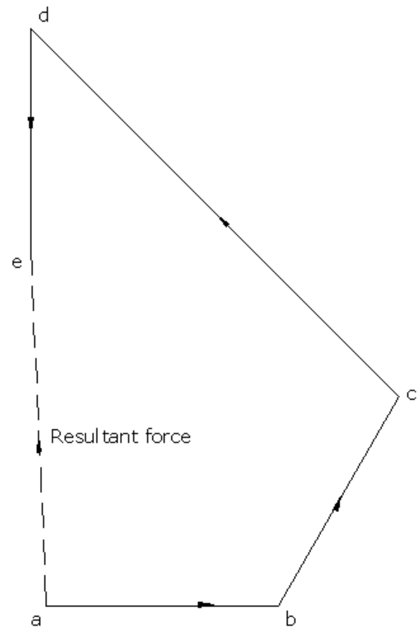
$$B \cdot r_2 = 10 \times 0.05 = 0.50 \text{ kg-m}$$

$$C \cdot r_3 = 18 \times 0.06 = 1.08 \text{ kg-m}$$

$$D \cdot r_4 = 15 \times 0.03 = 0.45 \text{ kg-m}$$



Space diagram



Vector diagram

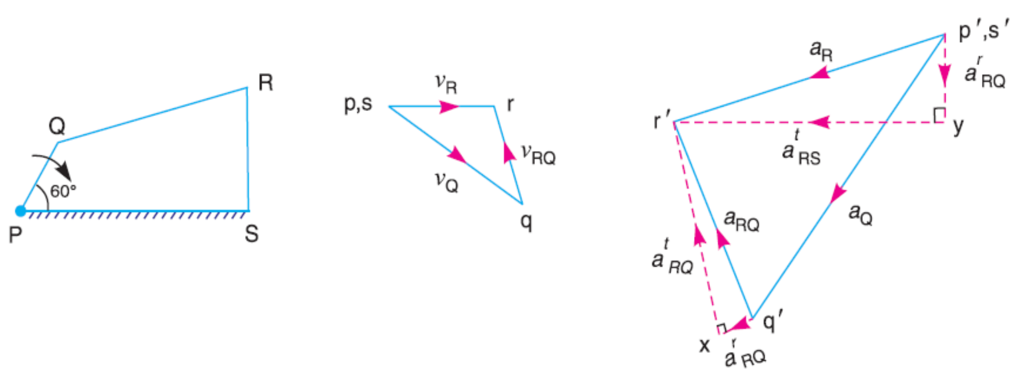
Q 5 (a) For Space diagram 01 Mark, Velocity diagram02 Marks, Accln diagram 03 Marks , Calculations 02 Marks

We know that velocity of Q with respect to P or velocity of Q,

$$v_{QP} = v_Q = \omega_{QP} \times PQ = 10 \times 0.0625 = 0.625 \text{ m/s}$$

...(Perpendicular to PQ)

Angular velocity of links QR and RS



(*a*) Space diagram. (*b*) Velocity diagram. (*c*) Acceleration diagram.

vector $pq = v_{QP} = v_Q = 0.625$ m/s

v_{RQ} = vector $qr = 0.333$ m/s, and $v_{RS} = v_R$ = vector $sr = 0.426$ m/s

We know that angular velocity of link QR,

$$\omega_{QR} = \frac{v_{RQ}}{RQ} = \frac{0.333}{0.175} = 1.9 \text{ rad/s (Anticlockwise)}$$

and angular velocity of link RS,

$$\omega_{RS} = \frac{v_{RS}}{SR} = \frac{0.426}{0.1125} = 3.78 \text{ rad/s (Clockwise)}$$

Angular acceleration of links QR and RS

Since the angular acceleration of the crank PQ is not given, therefore there will be no tangential component of the acceleration of Q with respect to P.

We know that radial component of the acceleration of Q with respect to P (or the acceleration of Q),

$$a^r_{QP} = a_{QP} = a_Q = \frac{v^2_{QP}}{PQ} = \frac{(0.625)^2}{0.0625} = 6.25 \text{ m/s}^2$$

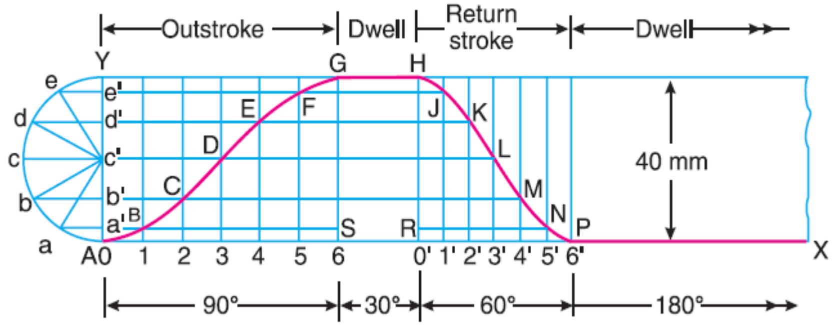
Radial component of the acceleration of R with respect to Q,

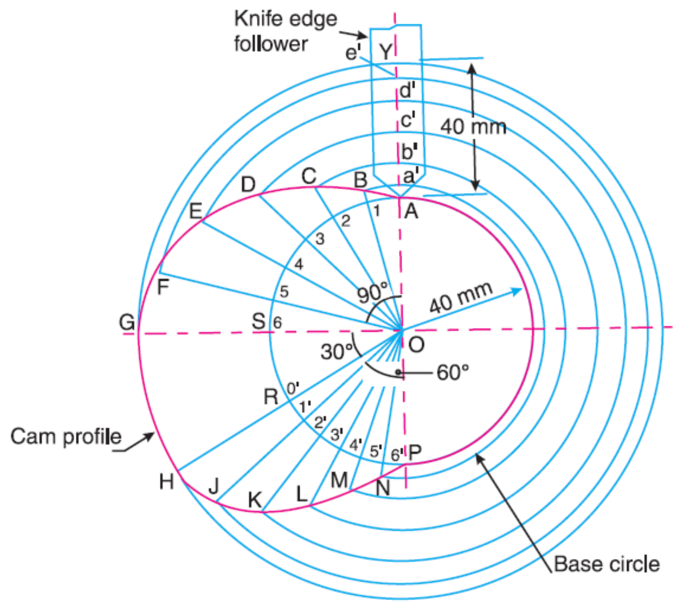
$$a^r_{RQ} = \frac{v^2_{RQ}}{QR} = \frac{(0.333)^2}{0.175} = 0.634 \text{ m/s}^2$$

and radial component of the acceleration of R with respect to S (or the acceleration of R),

$$a^r_{RS} = a_{RS} = a_R = \frac{v^2_{RS}}{SR} = \frac{(0.426)^2}{0.1125} = 1.613 \text{ m/s}^2$$

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





Q 5 c) For T1 & T2 : 02 Marks , For Min belt width: 02 Marks, Initial Belt tension: 02 Marks , Belt length : 02 Marks

1. *Minimum width of belt*

We know that velocity of the belt,

$$v = \frac{\pi d_2 . N_2}{60} = \frac{\pi \times 0.24 \times 300}{60} = 3.77 \text{ m/s}$$

Let T_1 = Tension in the tight side of the belt, and

T_2 = Tension in the slack side of the belt.

$\therefore$ Power transmitted (P),

$$4000 = (T_1 - T_2)\, v = (T_1 - T_2)\, 3.77$$

or $$T_1 - T_2 = 4000 / 3.77 = 1061 \text{ N} \quad ...(i)$$

We know that for an open belt drive,

$$\sin \alpha = \frac{r_1 - r_2}{x} = \frac{d_1 - d_2}{2x} = \frac{0.6 - 0.24}{2 \times 3} = 0.06 \quad \text{or} \quad \alpha = 3.44°$$

and angle of lap on the smaller pulley,

$$\theta = 180° - 2\alpha = 180° - 2 \times 3.44° = 173.12°$$

$$= 173.12 \times \pi / 180 = 3.022 \text{ rad}$$

We know that

$$2.3 \log \left(\frac{T_1}{T_2} \right) = \mu . \theta = 0.3 \times 3.022 = 0.9066$$

$$\log \left(\frac{T_1}{T_2} \right) = \frac{0.9066}{2.3} = 0.3942 \quad \text{or} \quad \frac{T_1}{T_2} = 2.478 \quad ...(ii)$$

...(Taking antilog of 0.3942)

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

$$T_1 = 1779 \text{ N}, \text{ and } T_2 = 718 \text{ N}$$

Since the safe working tension is 10 N per mm width, therefore minimum width of the belt,

$$b = \frac{T_1}{10} = \frac{1779}{10} = 177.9 \text{ mm} \quad \textbf{Ans.}$$

2. *Initial belt tension*

We know that initial belt tension,

$$T_0 = \frac{T_1 + T_2}{2} = \frac{1779 + 718}{2} = 1248.5 \text{ N} \quad \textbf{Ans.}$$

3. *Length of the belt required*

We know that length of the belt required,

$$L = \frac{\pi}{2}(d_1 - d_2) + 2x + \frac{(d_1 - d_2)^2}{4x}$$

$$= \frac{\pi}{2}(0.6 + 0.24) + 2 \times 3 + \frac{(0.6 - 0.24)^2}{4 \times 3}$$

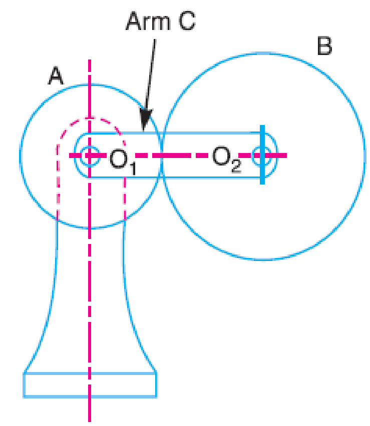
$$= 1.32 + 6 + 0.01 = 7.33 \text{ m} \quad \textbf{Ans.}$$

Q 6 (a) (i) Sketch 02 Marks , Explanation 02 Marks

Epicyclic Gear Train

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 O_1 about 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 axis of gear A (*i.e.* O_1), 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 comparatively 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.



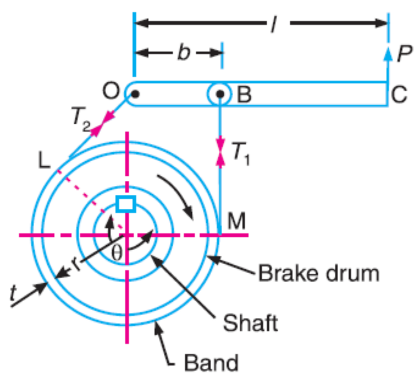
Epicyclic gear train.

Q 6 (a) (ii) Any four points 04 Marks

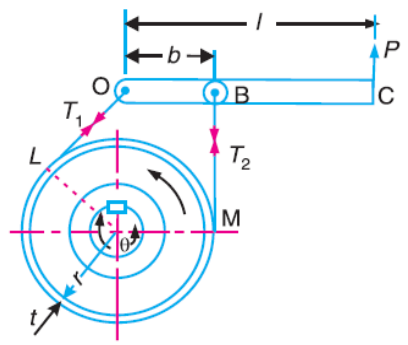
Flywheel	Governor
i) Flywheel is a device which stores of energy when produced in excess & release when required by m/c	i) Governor is a device controls the supply of fuel to engine & controls mean speed
ii) It regulates fluctuation of speed when there is a variation in cyclic torque of m/c	ii) It regulates speed of engine when there is a external load variation.
iii) It acts by virtue of its inertia	iii) It acts as a mechanism to control fuel supply
iv) If torque variation is high, flywheel size required is larger	iv) If external load variation is higher, more control on fuel supply necessary

v) Used in Engines, forging m/c, Sheet metal press, shearing m/c	v) Used in Engines

Q 6 (b) Sketch 02 Marks , Clockwise & Anticlockwise rotations each 03 Marks



(*a*) Clockwise rotation of drum.



(*b*) Anticlockwise rotation of drum.

(a) Operating force when drum rotates in anticlockwise direction

The band brake is shown in Fig. **(a)** . Since one end of the band is attached to the fulcrum at *O*, therefore the operating force *P* will act upward and when the drum rotates anticlockwise, as shown in Fig. (*b*) , the end of the band attached to *O* will be tight with tension T_1 and the end of the band attached to *B* will be slack with tension T_2. First of all, let us find the tensions T_1 and T_2.

We know that angle of wrap,

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

$$= 270\times\pi/180 = 4.713 \text{ rad}$$

and $$2.3\log\left(\frac{T_1}{T_1}\right) = \mu.\theta = 0.25\times 4.713 = 1.178$$

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

. . . (Taking antilog of 0.5123)

We know that braking torque (T_B),

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

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

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

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

Now taking moments about the fulcrum *O*, we have

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

$\therefore$ $P = 44.4 / 0.5 = 88.8$ N **Ans.**

(b) Operating force when drum rotates in clockwise direction

When the drum rotates in clockwise direction, as shown in Fig.19.11 (*a*), then taking moments about the fulcrum *O*, we have

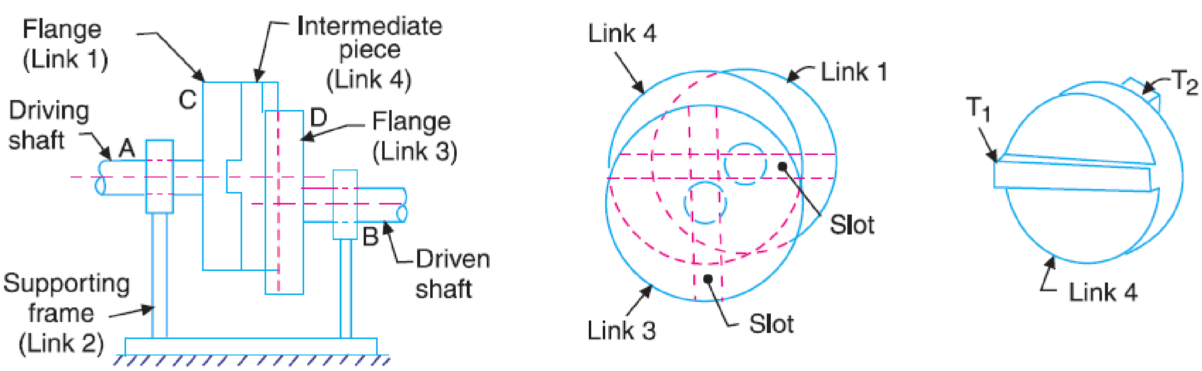
$$P \times l = T_1.\, b \quad \text{or} \quad P \times 0.5 = 1444 \times 0.1 = 144.4$$

$\therefore$ $P = 144.4 / 0.5 = 288.8$ N **Ans.**

Q 6 (c) List 01 Marks, Sketch 04 Marks, explanation 03 Marks

Inversions of double slider crank mechanism:

(i) Elliptical Trammels (ii) Scotch Yoke Mechanism (iii) Oldham's Coupling.



(*a*) (*b*) (*c*)

Oldham's coupling. 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. (*a*). 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. (*b*) . 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. (*c*) . 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.

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.

If the distance between the axes of the shafts is constant, the centre of intermediate piece will describe a circle of radius equal to the distance between the axes of the two shafts. Therefore, the maximum sliding speed of each tongue along its slot is equal to the peripheral velocity of the centre of the disc along its circular path.

Let ω = Angular velocity of each shaft in rad/s, and

r = Distance between the axes of the shafts in metres.

∴ Maximum sliding speed of each tongue (in m/s),

$$v = \omega . r$$