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 of the following **6x2= 12**

i) Define - **(Each term 01 mark)**

1**. Mechanism :**

When one of the links of a kinematic chain is fixed, the chain is known as mechanism.

2. Inversion of mechanism

The method of obtaining different mechanisms by fixing different links in a kinematic chain, is known as **inversion of the** mechanism. So we can obtain as many mechanisms as the number of links in a kinematic chain by fixing, in turn, different links in a kinematic chain.

ii) State any two types of motion of the follower.

(Any two, 01 mark each.)

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.

iii) Define slip and creep in the belt. **each term 01 mark**

Slip : When the frictional grip becomes insufficient. This may cause some forward motion of the driver without carrying the belt with it. This may also cause some forward motion of the belt without carrying the driven pulley with it. This is called slip of the belt and is generally expressed as a percentage.
Creep : 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.

iv) State any two advantages of V belt drive over flat belt drive.

(Any two, one mark each)

Advantages
1. The V-belt drive gives compactness due to the small distance between the centres of pulleys.
2. The drive is positive, because the slip between the belt and the pulley groove is negligible.
3. Since the V-belts are made endless and there is no joint trouble, therefore the drive is smooth.
4. It provides longer life, 3 to 5 years.

5. It can be easily installed and removed.
6. The operation of the belt and pulley is quiet.
7. The belts have the ability to cushion the shock when machines are started.
8. The high velocity ratio (maximum 10) may be obtained.
9. The wedging action of the belt in the groove gives high value of limiting ratio of tensions.
Therefore the power transmitted by V-belts is more than flat belts for the same coefficient of friction, arc of contact and allowable tension in the belts.
10. The V-belt may be operated in either direction with tight side of the belt at the top or bottom. The centre line may be horizontal, vertical or inclined.

v) State the function of flywheel in IC engine.

A flywheel controls the speed variations caused by the fluctuation of the engine turning moment during each cycle of operation.

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.

vi) Define stability and hunting of governor. **(Each term 01 mark)**

Stability of governor.

A governor is said to be ***stable*** when for every speed within the working range there is a definite configuration *i.e.* there is only one radius of rotation of the governor balls at which the governor is in equilibrium. For a stable governor, if the equilibrium speed increases, the radius of governor balls must also increase.

Hunting of governor:

A governor is said to be ***hunt*** if the speed of the engine fluctuates continuously above and below the mean speed. This is caused by a too sensitive governor which changes the fuel supply by a large amount when a small change in the speed of rotation takes place.

vii) Compare brakes and dynamometers (two points)

(two points, 01 mark each.)

Brakes :

- A ***brake*** is a device by means of which artificial frictional resistance is applied to a moving machine member, in order to retard or stop the motion of a machine.
- . Types :
  Hydraulic brakes
  Electric brakes
  Mechanical brakes.
- The brake absorbs either kinetic energy of the moving member or potential energy given up by objects being lowered by hoists, elevators etc.
- The energy absorbed by brakes is dissipated in the form of heat.
- This heat is dissipated in the surrounding air (or water which is circulated through the passages in the brake drum) so that excessive heating of the brake lining does not take place.

Dynamometers :

- A dynamometer is a brake but in addition it has a device to measure the frictional resistance.
- Knowing the frictional resistance, we may obtain the torque transmitted and hence the power of the engine.
- Types :

  1. Absorption dynamometers, and
  2. Transmission dynamometers

viii) State any two adverse effects of imbalance.

(Any two, one mark each)

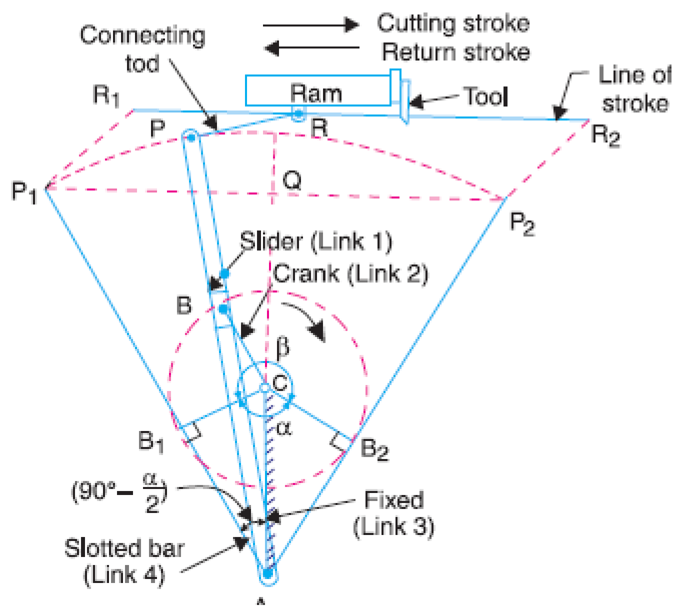
All the rotating and reciprocating parts should be completely balanced as far as possible. If these parts are not properly balanced,

- The dynamic forces are set up.
- These forces increase the loads on bearings and stresses in the various members.
- Also produce unpleasant and even dangerous vibrations.

b) Any two of the following **2x4 =8**

i) Draw neat labeled sketch of crank and slotted lever mechanism. Label all parts.

(Sketch 02 m, label 02 marks)



Crank and slotted lever mechanism

ii) What is the necessity of clutch? State its types.

(Necessity 02 m, types 02 m.)

Necessity: A clutch is necessary for the transmission of power of shafts and machines which must be started and stopped frequently. Its application is also found in cases in which power is to be delivered to machines partially or fully loaded.
The force of friction is used to start the driven shaft from rest and gradually brings it up to the proper speed without excessive slipping of the friction surfaces.

In automobiles, friction clutch is used to connect the engine to the driven shaft.
It may be noted that

1. The contact surfaces should develop a frictional force that may pick up and hold the load with reasonably low pressure between the contact surfaces.
2. The heat of friction should be rapidly dissipated and tendency to grab should be at a minimum.
3. The surfaces should be backed by a material stiff enough to ensure a reasonably uniform distribution of pressure.

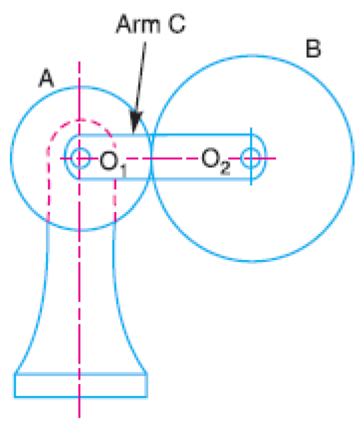
Types :

1. Disc or plate clutches (single disc or multiple disc clutch),
2. Cone clutches, and
3. Centrifugal clutches.

iii) Draw the neat sketch of epicyclic gear train and explain how it works.

(Sketch 01 m, working 03 m.)

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 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 moves 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 ***compound.***

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.

Q.2 Any four of the following. 4x4 =16

a) State and explain various types of constrained motions with suitable examples. (Any two, 02 mark each.)

Types of Constrained Motions

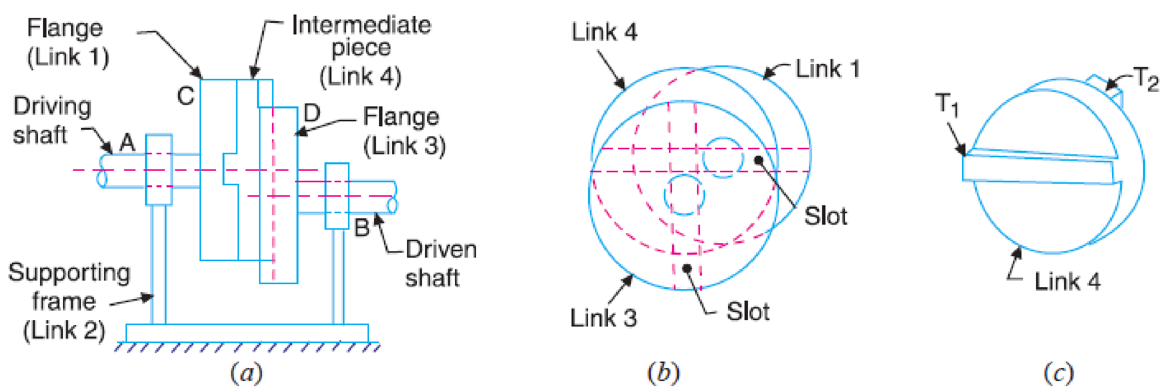
Following are the three types of constrained motions:

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.

2. ***Incompletely constrained motion***. When the motion between a pair can take place in more than one direction, then the motion is called an incompletely constrained motion. The change in the direction of impressed force may alter the direction of relative motion between the pair. A circular bar or shaft in a circular hole is an example of an incompletely constrained motion as it may either rotate or slide in a hole. These both motions have no relationship with the other.

3. ***Successfully constrained motion.*** When the motion between the elements, forming a pair, is such that the constrained motion is not completed by itself, but by some other means, then the motion is said to be successfully constrained motion. Consider a shaft in a foot-step bearing. The shaft may rotate in a bearing or it may move upwards. This is a case of incompletely constrained motion. But if the load is placed on the shaft to prevent axial upward movement of the shaft, then the motion of the pair is said to be successfully constrained motion.

b) Draw the neat labeled sketch of Oldham's coupling. State its applications. (Sketch 03m, applications 01 mark.)



Oldham's coupling.

Applications:

- An Oldham's coupling is used for connecting two parallel shafts whose axes are at a small distance apart.
- Used to transmit motion and power.

c) Define the terms velocity, relative velocity, angular velocity, and angular acceleration. (Each term 01 mark)

Velocity: It may be defined as the rate of change of linear displacement of a body with respect to the time. Since velocity is always expressed in a particular direction, therefore it is a vector quantity. Mathematically, linear velocity,

$$v = ds/dt$$

Relative velocity: relative velocity is the velocity of an object or an observer B in the rest frame of another object or an observer A.

Consider two bodies *A* and *B* moving along parallel lines in the same direction with absolute velocities v_A and v_B such that $v_A > v_B$, as shown in Fig. 7.1 (*a*). The relative velocity of *A* with respect to *B*,

$$v_{AB} = \text{Vector difference of } v_A \text{ and } v_B = \overline{v_A} - \overline{v_B}$$

Angular velocity: It may be defined as the rate of change of angular displacement with respect to time. It is usually expressed by a Greek letter ⎤(omega). Mathematically, angular velocity,

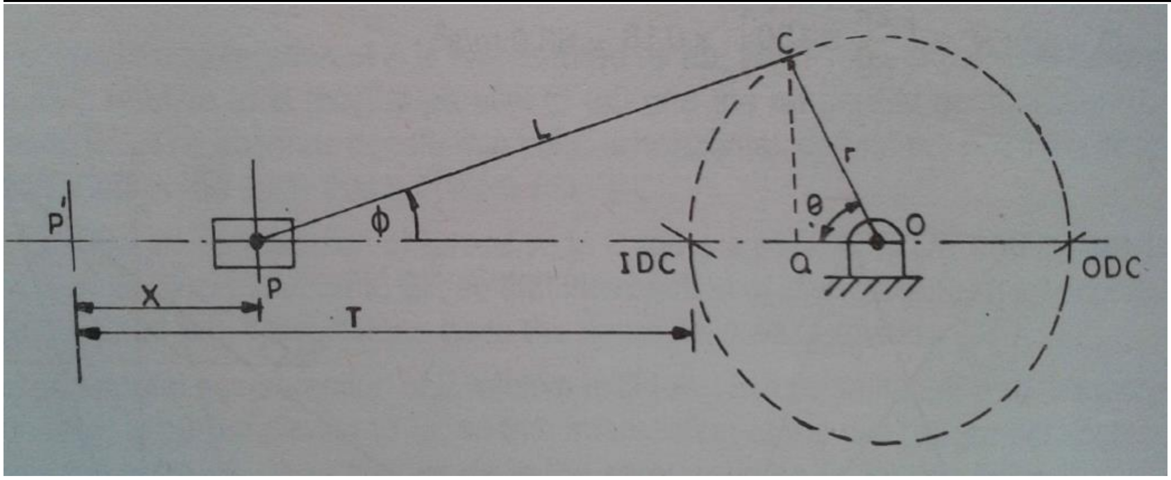
$$\omega = d\theta / dt$$

Angular acceleration: It may be defined as the rate of change of angular velocity with respect to time. It is usually expressed by a Greek letter 〈 (alpha). Mathematically, angular acceleration,

$$\alpha = \frac{d\omega}{dt} = \frac{d}{dt}\left(\frac{d\theta}{dt}\right) = \frac{d^2\theta}{dt^2} \qquad \ldots \left(\because \omega = \frac{d\theta}{dt}\right)$$

d) For a single slider crank mechanism , state the formulae to calculate by analytical method – Also state the meaning of each term.

(Each term 01 mark.)



single slider crank mechanism

i) Velocity of slider:

$$V_p = w.r\left[\sin\theta + \frac{\sin 2\theta}{2n}\right]$$

where,

V_p - velocity of slider

w- angular velocity

θ – angle of crank to line of stroke ‘PO’

n- l/r = ratio of length of connecting rod to crank radius.

ii) Acceleration of slider:

$$f_p = w^2 r\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

where,

f_p – acceleration of slider

iii) Angular velocity of connecting rod.:

$$W_{pc} = \frac{w\cos\theta}{(n^2 - \sin 2\theta)^{1/2}}$$

Where, W_{pc} is angular velocity of connecting rod

iv) Angular acceleration of connecting rod.:

$$\alpha_{pc} = \frac{-w^2 \sin\theta\,(n^2-1)}{(n^2-\sin^2\theta)^{3/2}}$$

Where, α_{pc} is angular acceleration of connecting rod

e) Define the following terms related to cams.

(01 mark each)

i) Trace point

It is a reference point on the follower and is used to generate the *pitch curve*.
In case of knife edge follower, the knife edge represents the trace point and the pitch curve corresponds to the cam profile. In a roller follower, the centre of the roller represents the trace point.

ii) Pitch curve

It is the curve generated by the trace point as the follower moves relative to the cam. For a knife edge follower, the pitch curve and the cam profile are same whereas for a roller follower, they are separated by the radius of the roller.

iii) Prime circle

It is the smallest circle that can be drawn from the centre of the cam and tangent to the pitch curve. For a knife edge and a flat face follower, the prime circle and the base circle are identical. For a roller follower, the prime circle is larger than the base circle by the radius of the roller.

iv) Lift of stroke.

It is the maximum travel of the follower from its lowest position to the topmost position.

f) Given: W= T1= 9 kN =9000N, d= 0.3 m, N = 20 rpm , μ= 0.25,

(i) Force reqd. by a man 02 marks

T2- force reqd. by man

As rope makes 2.5 turns,

Therefore angle of contact , $\theta = 2.5 \times 2\pi = 5\pi$ rad.

We know that,

2.3 log {T1/T2} = μ θ = 0.25 x 5 π = 3.9275 log {T1/T2} = 3.9275/2.3 = 1.71 or T1/T2 = 51

T2 = 9000/51 = **176.47 N**

(ii) Power to raise casting 02 marks

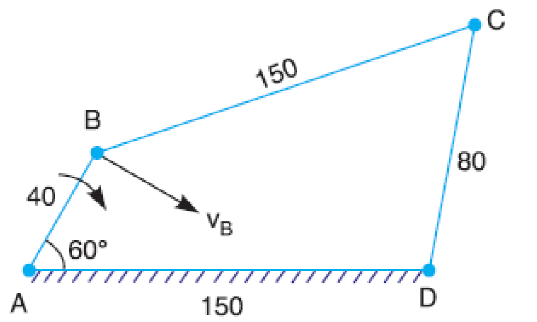
As velocity of rope, v = πdN/60 = 3.14x0.3x20/60 = 0.3142 m/s

Power to raise casting = **(T1-T2) x v** = (9000-176.47) x 0.3142

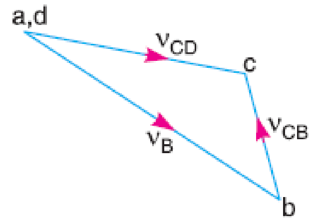
= **2.772 kW.**

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,

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

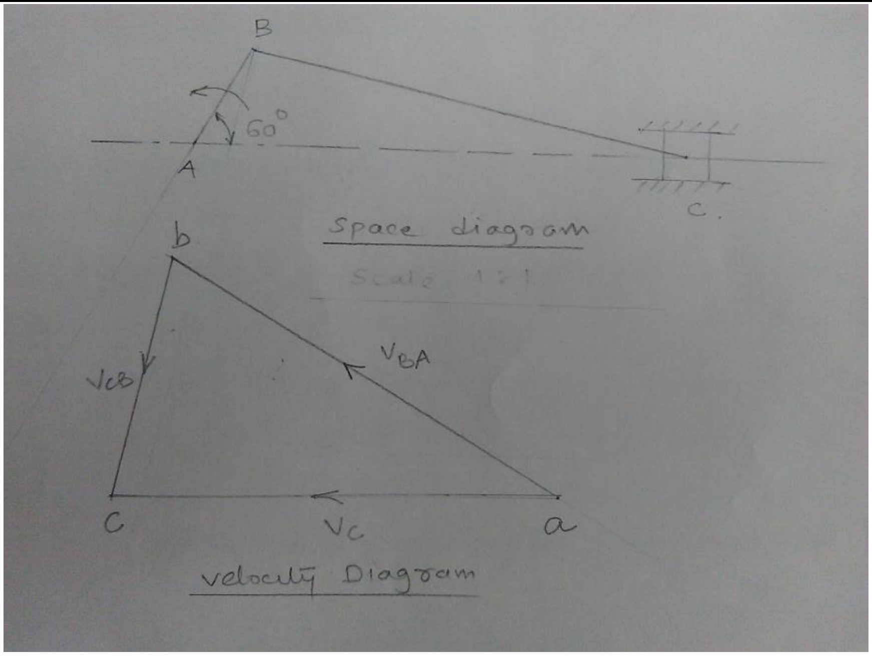
b) A Single slider crank mechanism:

(Space diagram 1M, velocity diagram 1M, Velo. of CR 1M, velo. of piston 1M)

Given: Crank AB = 20 mm = 0.02 m, C. R. BC = 80 mm = 0.08 m

N = 1000 rpm, $\omega_{BA} = 2\pi N/60 = 2\pi \times 1000/60 = 104.7$ rad/sec

$V_{BA} = \omega_{BA} \times AB = 104.7 \times 0.02 = 2.09$ m/s



From velocty diagram:

Velocity of C w.r.t. B -

V_{CB} = vector cb = 1.15 m/s

Angular velocity of Connecting rod 'BC'

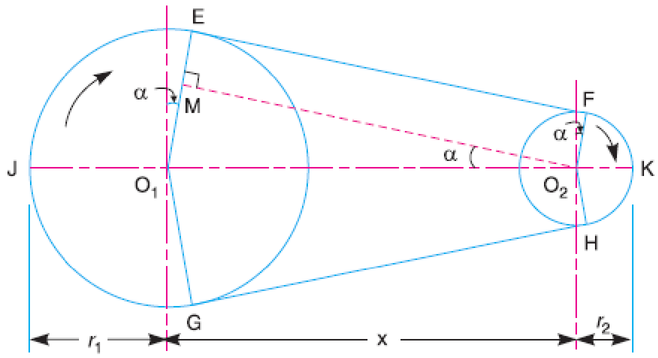
$\omega_{CB} = V_{CB} / CB = 1.15/0.08 = 14.375$ rad /sec

Velocity of slider 'C'

V_C= vector ac = 2 m/sec

c) Formulae to calculate the length of open belt drive

(Diagram 01 M each Formula and meaning 01 M each)



$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 - r_2)^2}{x}$$

Where,

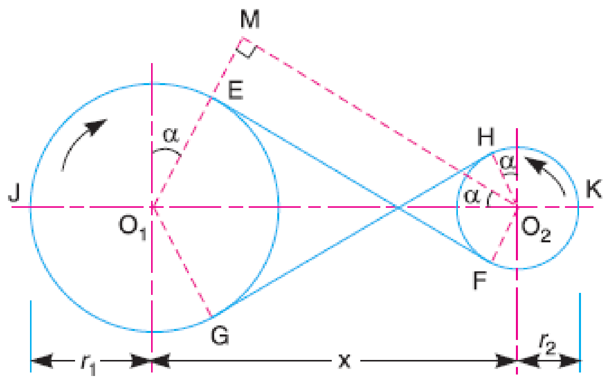
r_1 and r_2 = Radii of the larger and smaller pulleys,

x = Distance between the centres of two pulleys (*i.e.* $O_1 O_2$),

L = Total length of the belt.

α = angle of lap

Formulae to calculate the length of Cross belt drive



$$L = \pi(r_1 + r_2) + 2x + \frac{(r_1 + r_2)^2}{x}$$

Where,

r_1 and r_2 = Radii of the larger and smaller pulleys,

x = Distance between the centres of two pulleys (*i.e.* $O_1 O_2$),

L = Total length of the belt.

α = angle of lap

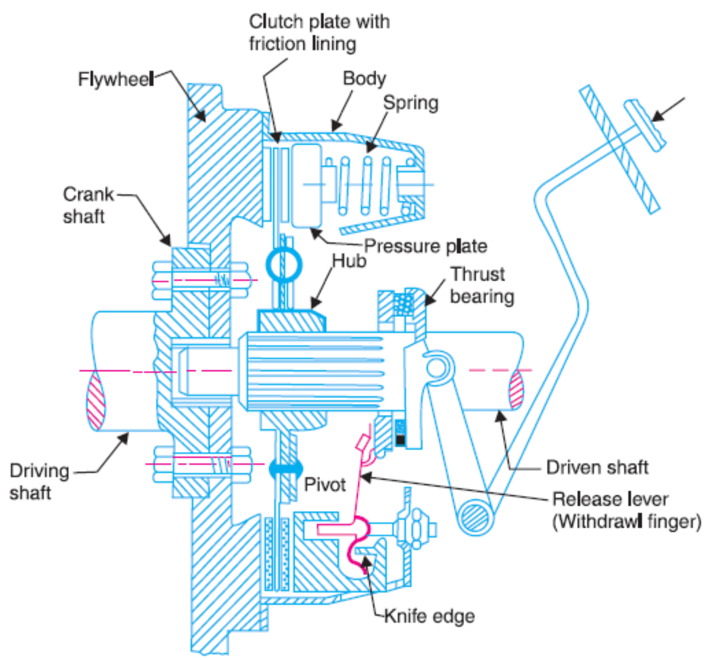
d) Single plate clutch: (Working – 2M, sketch – 2M)

Working:

A single disc or plate clutch, as shown in Fig. 10.21, consists of a clutch plate whose both sides are faced with a friction material (usually of Ferrodo). It is mounted on the hub which is free to move axially along the splines of the driven shaft. The pressure plate is mounted inside the clutch body which is bolted to the flywheel. Both the pressure plate and the flywheel rotate with the engine crankshaft or the driving shaft. The pressure plate pushes the clutch plate towards the flywheel by a set of strong springs which are arranged radially inside the body. The three levers (also known as release levers or fingers) are carried on pivots suspended from the case of the body. These are arranged in such a manner so that the pressure plate moves away from the flywheel by the inward movement of a thrust bearing. The bearing is mounted upon a forked shaft and moves forward when the clutch pedal is pressed.

When the clutch pedal is pressed down, its linkage forces the thrust release bearing to move in towards the flywheel and pressing the longer ends of the levers inward. The levers are forced to turn on their suspended pivot and the pressure plate moves away from the flywheel by the knife edges, thereby compressing the clutch springs. This action removes the pressure from the clutch plate and thus moves back from the flywheel and the driven shaft becomes stationary. On the other hand, when the foot is taken off from the clutch pedal, the thrust bearing moves back by the levers. This allows the springs to extend and thus the pressure plate pushes the clutch plate back towards the flywheel.

The axial pressure exerted by the spring provides a frictional force in the circumferential direction when the relative motion between the driving and driven members tends to take place. If the torque due to this frictional force exceeds the torque to be transmitted, then no slipping takes place and the power is transmitted from the driving shaft to the driven shaft.



Sketch: Single plate clutch

e) Procedure for balancing single rotating mass when its balancing mass is rotating in same plane: (Sketch 2M, explanation 2M)

Consider a disturbing mass m_1 attached to a shaft rotating at ω rad/s as shown in Fig. 21.1. 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,

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

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.

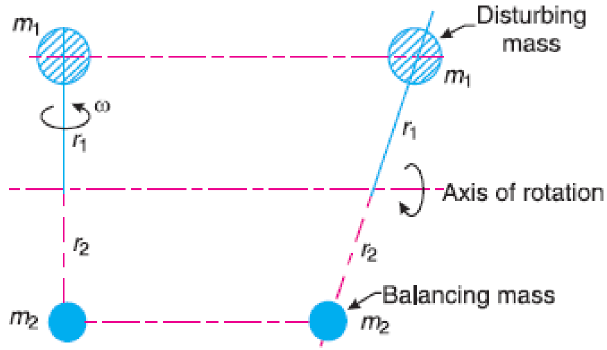


Fig. 21.1. Balancing of a single rotating mass by a single mass rotating in the same plane.

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,

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

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) Detailed Classification of Followers: (1/2 marks each = 04M)

The followers may be classified as 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

(*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.*** The followers, according to its motion, are of the following two types:

(*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.*** The followers, according to its path of motion, are of the following two types:

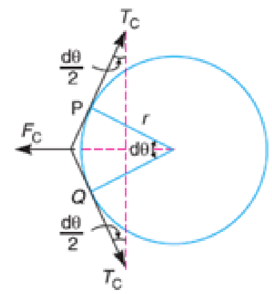
(*a*) ***Radial follower.*** When the motion of the follower is along an axis passing through the centre of the cam, it is known as radial follower.

(*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.

Q.4 a) Centrifugal tension: (Definition -2M, formula-1M, Effect-1M)

Since the belt continuously runs over the pulleys, therefore, some centrifugal force is caused, whose effect is to increase the tension on both, tight as well as the slack sides. The tension caused by centrifugal force is called *centrifugal tension*.

Centrifugal Tension Tc = m.v²



Power, P = $(T_1 - T_2) \times v$ Hence there is no any effect on power transmitted by a belt drive.

b) Meaning of different types of kinematic pairs:

(Meaning-1/2M, one example-1/2M each)

Sliding pair. When the two elements of a pair are connected in such a way that one can only slide relative to the other, the pair is known as a sliding pair. The piston and cylinder, cross-head and guides of a reciprocating steam engine, ram and its guides in shaper, tail stock on the lathe bed etc. are the examples of a sliding pair. A little consideration will show, that a sliding pair has a completely constrained motion.

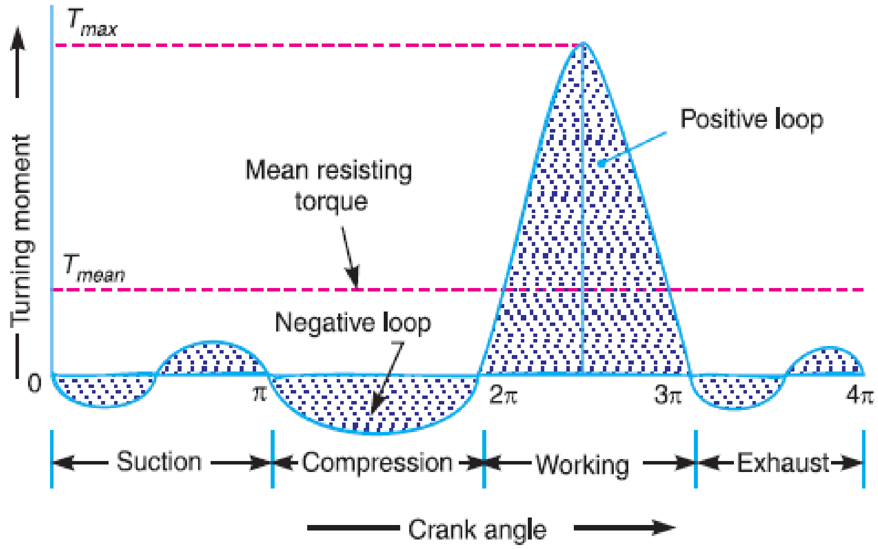
Turning pair. When the two elements of a pair are connected in such a way that one can only turn or revolve about a fixed axis of another link, the pair is known as turning pair. A shaft with collars at both ends fitted into a circular hole, the crankshaft in a journal bearing in an engine, lathe spindle supported in head stock, cycle wheels turning over their axles etc. are the examples of a turning pair. A turning pair also has a completely constrained motion.

Rolling pair. When the two elements of a pair are connected in such a way that one rolls over another fixed link, the pair is known as rolling pair. Ball and roller bearings are examples of rolling pair.

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.

c) Turning moment diagram for single cylinder four stroke I.C. engine:

(Diagram – 2 M, Labeling – 2 M)



d) Rope Brake Dynamometer: (02 marks for sketch, 02 marks for explanation)

It is another form of absorption type dynamometer which is most commonly used for measuring the brake power of the engine. It consists of one, two or more ropes wound around the flywheel or rim of a pulley fixed rigidly to the shaft of an engine. The upper end of the ropes is attached to a spring balance while the lower end of the ropes is kept in position by applying a dead weight as shown in Fig.

In order to prevent the slipping of the rope over the flywheel, wooden blocks are placed at intervals around the circumference of the flywheel.

In the operation of the brake, the engine is made to run at a constant speed. The frictional torque, due to the rope, must be equal to the torque being transmitted by the engine.

Let W = Dead load in newtons,

S = Spring balance reading in newtons,

D = Diameter of the wheel in metres,

d = diameter of rope in metres, and

N = Speed of the engine shaft in r.p.m.

∴ Net load on the brake

$= (W - S)$ N

We know that distance moved in one revolution

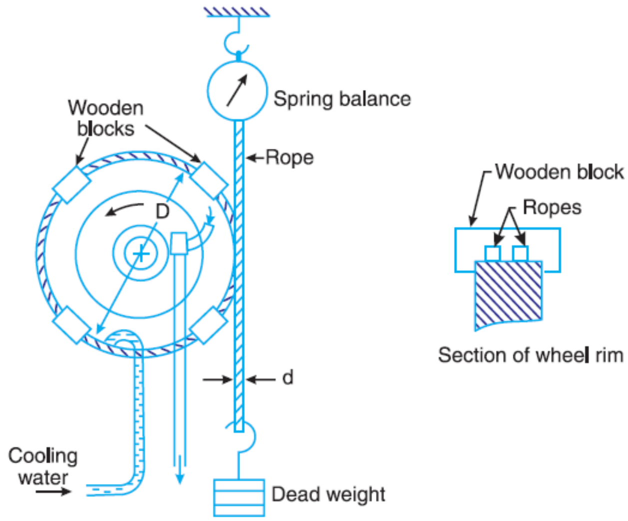
$= \pi(D + d)$ m

∴ Work done per revolution

$$= (W - S)\pi(D + d) \text{ N-m}$$

and work done per minute

$$= (W - S)\pi(D + d)\, N \text{ N-m}$$



Rope brake dynamometer.

∴ Brake power of the engine,

$$\text{B.P} = \frac{\text{Work done per min}}{60} = \frac{(W - S)\,\pi\,(D + d)N}{60} \text{ watts}$$

If the diameter of the rope (d) is neglected, then brake power of the engine,

$$\text{B.P.} = \frac{(W - S)\pi D\, N}{60} \text{ watts}$$

e) Foot step bearing: Uniform pressure distribution-

(Given 2M, torque 1M, Power 1M)

Given : $D = 150$ mm or $R = 75$ mm $= 0.075$ m ; $\mu = 0.05$

$N = 100$ r.p.m

$\omega = 2\,\pi \times 100/60$

$= 10.47$ rad/s ;

$W = 20$ kN $= 20 \times 10^3$ N ;

We know that for uniform pressure distribution, the total frictional torque,

$$T = \frac{2}{3} \times \mu.W.R = \frac{2}{3} \times 0.05 \times 20 \times 10^3 \times 0.075 = 50 \text{ N-m}$$

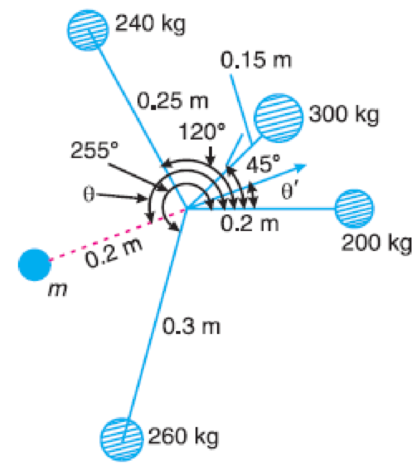
∴ Power lost in friction,

$$P = T.\omega = 50 \times 10.47 = 523.5 \text{ W} \quad \textbf{Ans.}$$

f) Position and magnitude of balance mass required:

(Mass – 2 M, Position – 1 M, Sketch – 1 M)

Given : $m_1 = 200$ kg ; $m_2 = 300$ kg ; $m_3 = 240$ kg ; $m_4 = 260$ kg ; $r_1 = 0.2$ m ; $r_2 = 0.15$ m ; $r_3 = 0.25$ m ; $r_4 = 0.3$ m ; $\theta_1 = 0°$; $\theta_2 = 45°$; $\theta_3 = 45° + 75° = 120°$; $\theta_4 = 45° + 75° + 135° = 255°$; $r = 0.2$ 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

$$m_1 \cdot r_1 = 200 \times 0.2 = 40 \text{ kg-m}$$

$$m_2 \cdot r_2 = 300 \times 0.15 = 45 \text{ kg-m}$$

$$m_3 \cdot r_3 = 240 \times 0.25 = 60 \text{ kg-m}$$

$$m_4 \cdot r_4 = 260 \times 0.3 = 78 \text{ kg-m}$$

The problem may, now, be solved either analytically or graphically. But we shall solve the problem by both the methods one by one.

Analytical method

The space diagram is shown in Fig.

Resolving $m_1.r_1$, $m_2.r_2$, $m_3.r_3$ and $m_4.r_4$ horizontally,

$$\Sigma H = m_1 \cdot r_1 \cos\theta_1 + m_2 \cdot r_2 \cos\theta_2 + m_3 \cdot r_3 \cos\theta_3 + m_4 \cdot r_4 \cos\theta_4$$

$$= 40\cos 0° + 45\cos 45° + 60\cos 120° + 78\cos 255°$$

$$= 40 + 31.8 - 30 - 20.2 = 21.6 \text{ kg-m}$$

Now resolving vertically,

$$\Sigma V = m_1 \cdot r_1 \sin\theta_1 + m_2 \cdot r_2 \sin\theta_2 + m_3 \cdot r_3 \sin\theta_3 + m_4 \cdot r_4 \sin\theta_4$$
$$= 40\sin 0° + 45\sin 45° + 60\sin 120° + 78\sin 255°$$
$$= 0 + 31.8 + 52 - 75.3 = 8.5 \text{ kg-m}$$

$\therefore$ Resultant, $R = \sqrt{(\Sigma H)^2 + (\Sigma V)^2} = \sqrt{(21.6)^2 + (8.5)^2} = 23.2$ kg-m

We know that $m \cdot r = R = 23.2$ or

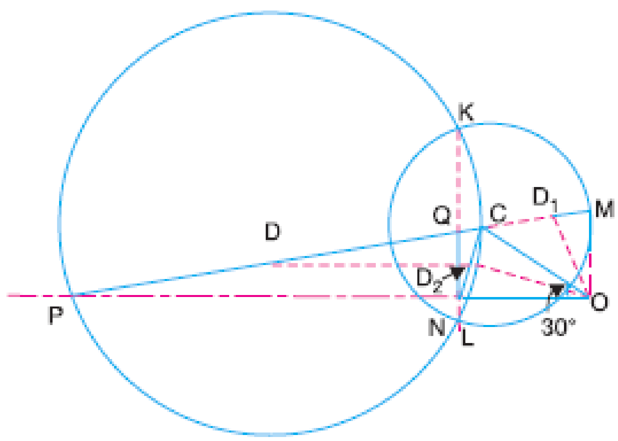
Balancing mass $m = 23.2 / r = 23.2 / 0.2 = 116$ kg **Ans.**

and $\tan\theta' = \Sigma V / \Sigma H = 8.5/21.6 = 0.3935$ or $\theta' = 21.48°$

Since θ' is the angle of the resultant R from the horizontal mass of 200 kg, therefore the angle of the balancing mass from the horizontal mass of 200 kg,

$$\theta = 180° + 21.48° = 201.48° \text{ **Ans.**}$$

Q5 (a) Construction – **(04 marks, calculation 1 & 2 – 02 marks each)**



1. Velocity and acceleration of the piston

We know that the velocity of the piston P,

$$v_P = \omega \times OM = 120 \times 0.127 = 15.24 \text{ m/s} \quad \textbf{Ans.}$$

and acceleration of the piston P,

$$a_P = \omega^2 \times NO = (120)^2 \times 0.2 = 2880 \text{ m/s}^2 \quad \textbf{Ans.}$$

3. Angular velocity and angular acceleration of the connecting rod

We know that the velocity of the connecting rod PC (*i.e.* velocity of P with respect to C),

$$v_{PC} = \omega \times CM = 120 \times 0.173 = 20.76 \text{ m/s}$$

∴ Angular acceleration of the connecting rod PC,

$$\omega_{PC} = \frac{v_{PC}}{PC} = \frac{20.76}{0.7} = 29.66 \text{ rad/s} \quad \textbf{Ans.}$$

We know that the tangential component of the acceleration of P with respect to C,

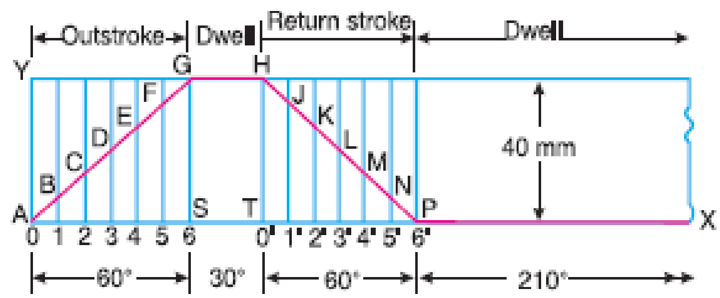
$$a^t_{PC} = \omega^2 \times QN = (120)^2 \times 0.093 = 1339.2 \text{ m/s}^2$$

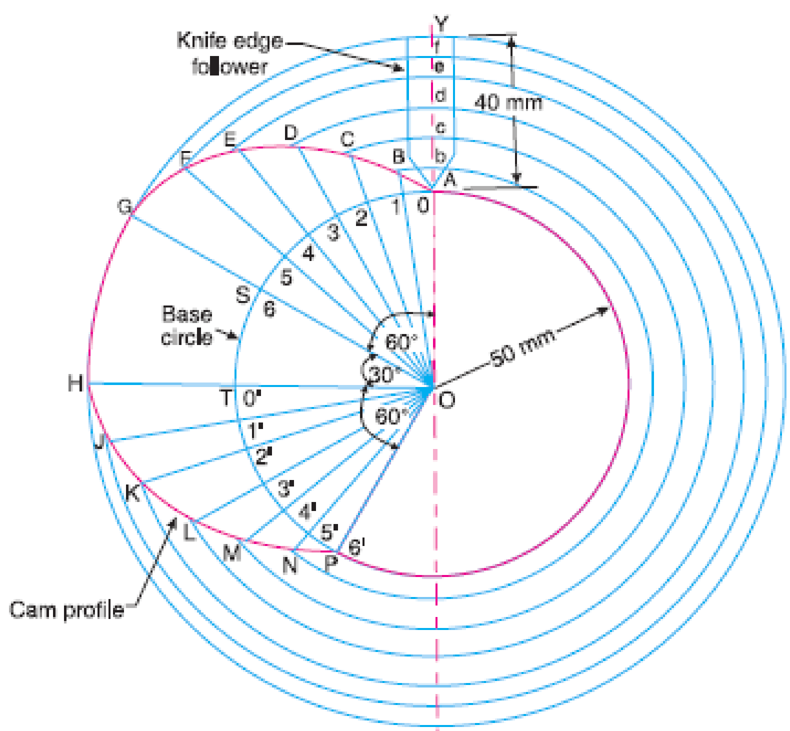
∴ Angular acceleration of the connecting rod PC,

$$\alpha_{PC} = \frac{a^t_{PC}}{PC} = \frac{1339.2}{0.7} = 1913.14 \text{ rad/s}^2 \quad \textbf{Ans.}$$

Q5 (b) Displacement diagram – 03 marks , cam profile – 05 marks

Displacement Diagram





Q5 © 01 mark for calculation of each correct parameter……….(Total 08 marks)

We know that velocity of the belt,

$$v = \frac{\pi d_2 . N_2}{60} = \frac{\pi \times 1 \times 400}{60} = 21 \text{ m/s}$$

and centrifugal tension, $T_C = m.v^2 = 1.5\,(21)^2 = 661.5$ N

Let T_1 = Tension in the tight side, and

T_2 = Tension in the slack side.

We know that initial tension (T_0),

$$3000 = \frac{T_1 + T_2 + 2T_C}{2} = \frac{T_1 + T_2 + 2 \times 661.5}{2}$$

$$\therefore \quad T_1 + T_2 = 3000 \times 2 - 2 \times 661.5 = 4677 \text{ N} \quad \text{...}(i)$$

For an open belt drive,

$$\sin\alpha = \frac{r_1 - r_2}{x} = \frac{d_1 - d_2}{2x} = \frac{1.5 - 1}{2 \times 4.8} = 0.0521 \quad \text{or} \quad \alpha = 3°$$

$\therefore$ Angle of lap on the smaller pulley,

$$\theta = 180° - 2\,\alpha = 180° - 2 \times 3° = 174°$$

$$= 174° \times \pi / 180 = 3.04 \text{ rad}$$

We know that

$$2.3 \log\left(\frac{T_1}{T_2}\right) = \mu . \theta = 0.3 \times 3.04 = 0.912$$

$$\log\left(\frac{T_1}{T_2}\right) = \frac{0.912}{2.3} = 0.3965 \quad \text{or} \quad \frac{T_1}{T_2} = 2.5 \quad \text{...}(ii)$$

...(Taking antilog of 0.3965)

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

$$T_1 = 3341 \text{ N}; \text{ and } T_2 = 1336 \text{ N}$$

$\therefore$ Power transmitted,

$$P = (T_1 - T_2)\,v = (3341 - 1336)\,21 = 42\,100 \text{ W} = 42.1 \text{ kW} \quad \textbf{Ans.}$$

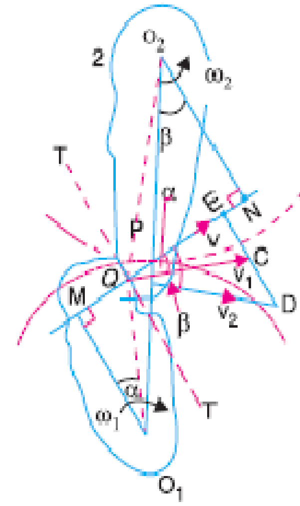
Q 6 (a) (i) **(Law 02 marks & 02 marks for sketch)**

Law of gearing:

Consider the portions of the two teeth, one on the wheel 1 (or pinion) and the other on the wheel 2, as shown by thick line curves in Fig. Let the two teeth come in contact at point Q, and the wheels rotate in the directions as shown in the figure.

Let $T\,T$ be the common tangent and MN be the common normal to the curves at the point of contact Q. From the centres O_1 and O_2, draw O_1M and O_2N perpendicular to MN. A little consideration will show that the point Q moves in the direction QC, when considered as a point on wheel 1, and in the direction QD when considered as a point on wheel 2.

Let v_1 and v_2 be the velocities of the point Q on the wheels 1 and 2 respectively. If the teeth are to remain in contact, then the components of these velocities along the common normal MN must be equal.



Law of gearing.

$$\therefore \qquad v_1 \cos\alpha = v_2 \cos\beta$$

or
$$(\omega_1 \times O_1Q)\cos\alpha = (\omega_2 \times O_2Q)\cos\beta$$

$$(\omega_1 \times O_1Q)\frac{O_1M}{O_1Q} = (\omega_2 \times O_2Q)\frac{O_2N}{O_2Q} \quad \text{or} \quad \omega_1 \times O_1M = \omega_2 \times O_2N$$

$$\therefore \qquad \frac{\omega_1}{\omega_2} = \frac{O_2N}{O_1M} \qquad \ldots(i)$$

Also from similar triangles O_1MP and O_2NP,

$$\frac{O_2N}{O_1M} = \frac{O_2P}{O_1P} \qquad \ldots(ii)$$

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

$$\frac{\omega_1}{\omega_2} = \frac{O_2N}{O_1M} = \frac{O_2P}{O_1P} \qquad \ldots(iii)$$

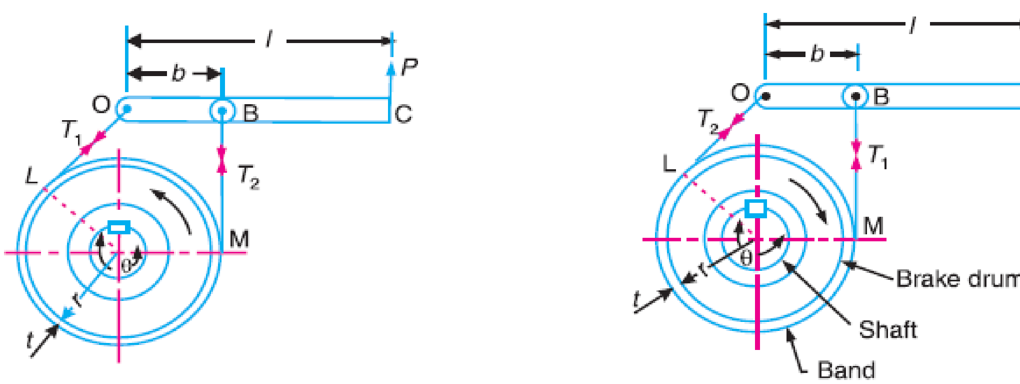
From above, we see that the angular velocity ratio is inversely proportional to the ratio of the distances of the point P from the centres O_1 and O_2, or the common normal to the two surfaces at the point of contact Q intersects the line of centres at point P which divides the centre distance inversely as the ratio of angular velocities.

Therefore in order to have a constant angular velocity ratio for all positions of the wheels, the point P must be the fixed point (called pitch point) for the two wheels. In other words, *the common normal at the point of contact between a pair of teeth must always pass through the pitch point.* This is the fundamental condition which must be satisfied while designing the profiles for the teeth of gear wheels. It is also known as *law of gearing.*

Q 6 (a) (ii) (Any 4 points – 4 Marks)

Sr.NO.	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.

Q 6 (b) Case (a)– 06 marks case (b) – 02 marks



(*a*) Anticlockwise rotation of drum. (*b*) Clockwise rotation of drum.

(a) Operating force when drum rotates in anticlockwise direction

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),

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

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

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

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

$\therefore \quad P = 44.4 / 0.5 = 88.8\text{ N}$ **Ans.**

(b) Operating force when drum rotates in clockwise direction

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

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

$\therefore \quad P = 144.4 / 0.5 = 288.8\text{ N}$ **Ans.**

Q 6 © Single plate clutch **(1M for each calculation)**

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,

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

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

$\therefore$ Power transmitted by a clutch,

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