Theory of Machines-II

Q.No.1. a. Derive the expression to determine Gyroscopic couple. *5*

Ans: Let, I = Mass moment of inertia of the disc about OX and

ω = Angular velocity of the disc

Therefore, angular momentum of the disc = I. ω

Change in angular momentum = $\overrightarrow{ox'} - \overrightarrow{ox} = \overrightarrow{xx'} = \overrightarrow{ox'}.\delta\theta$

$= I \ \omega \ . \ \delta\theta$

And rate of Change of angular momentum = $I \ \omega \times \frac{\delta\omega}{\delta t}$

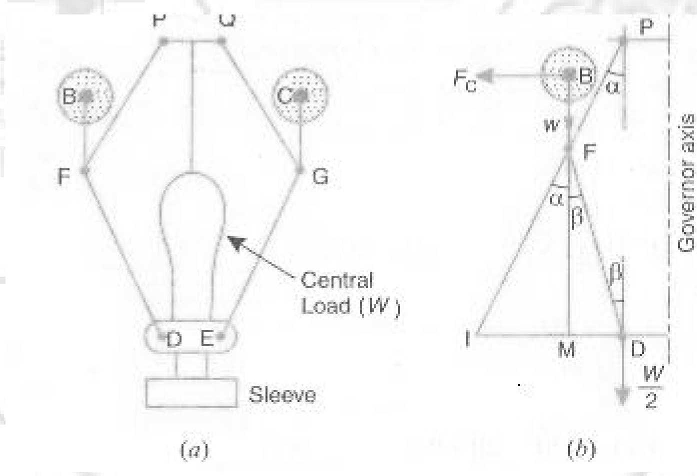
Since the rate of change of angular momentum will result by the application of the couple to the disc therefore the couple applied to the disc

$$C = \lim_{\delta t \to 0} I \ \omega \times \frac{\delta\omega}{\delta t} = I \ \omega \times \frac{d\theta}{dt} = I \ \omega \ . \ \omega_p$$

b Explain distinguishing features of Watt, porter, proell governors. *5*

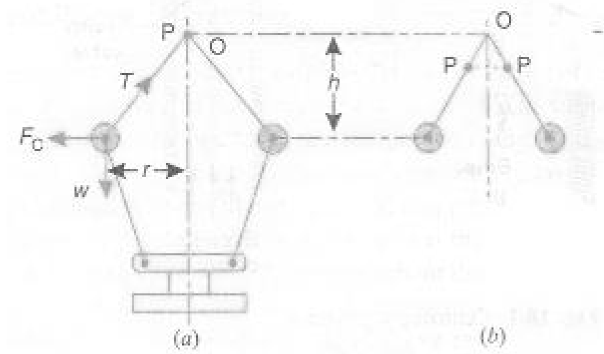
Ans:

Watt governor:



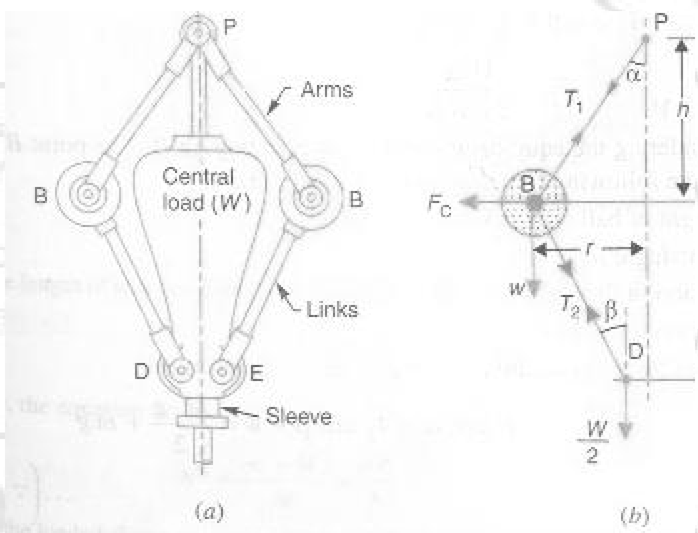
It is a simplest form of centrifugal governor. It basically a conical pendulum which links attached to a sleeve of negligible mass.

Porter governor:



It is a modification of a Watt governor with central load attached to a sleeve.

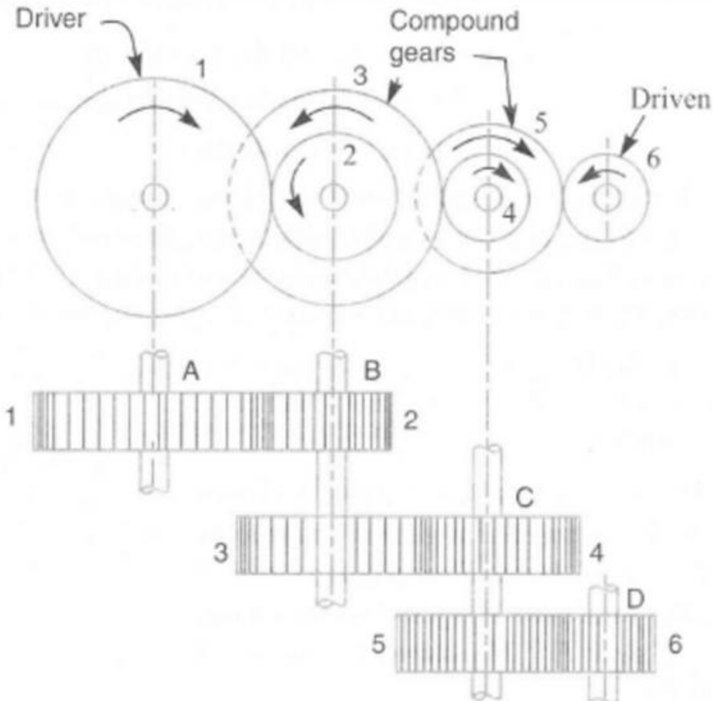
Proell governor:



It has balls fixed at B and C to the extension of links DF & EG.

c. Draw a sketch of a compound gear train involving 6 gears and calculate the reduction ratio assuming suitable no. of teeth ***5***

Ans:



Let,

N1 = Speed of driving gear 1,

T1 = Number of teeth on driving gear 1,

N2,*N3* , *N6* = Speed of respective gears in r.p.m., and

T2 ,*T3* , *T6* = Number of teeth on respective gears.

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

$$\frac{N1}{N2} = \frac{T2}{T1}$$

Similarly, for gears 3 and 4, speed ratio is

$$\frac{N3}{N4} = \frac{T4}{T3}$$

And for gears5 and 6, speed ratio is

$$\frac{N5}{N6} = \frac{T6}{T5}$$

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

$$\frac{N1\times N3\times N5}{N2\times N4\times N6} = \frac{T2\times T4\times T6}{T1\times T3\times T5}$$

Or

$$\frac{N1}{N6}=\frac{T2\times T4\times T6}{T1\times T3\times T5}$$

$$(Speed\cdot Ratio)=\frac{\text{Speed of the first driver}}{\text{Speed of the last driven or follower}}$$

$$=\frac{\text{Product of the no. of teeth on the drivens}}{\text{Product of the no. of teeth on the drivers}}$$

$$(TrainValue)=\frac{\text{Speed of the last driven or follower}}{\text{Speed of the first driver}}$$

$$=\frac{\text{Product of the no. of teeth on the drivers}}{\text{Product of the no. of teeth on the drivens}}$$

The advantage of a compound train over a simple gear train is that a much larger speed reduction from the first shaft to the last shaft can be obtained with small gears. If a simple gear train is used to give a large speed reduction, the last gear has to be very large. Usually for a speed reduction in excess of 7 to I, a simple train is not used and a compound train or worm gearing is employed.

d. *Explain how governor and flywheel are different as far as their working principle and applications are concerned?* **5**

Ans:

Sr. No.	Flywheel	Governor
1.	Function is to limit the fluctuation of speed during each cycle which arises from the fluctuation of turning moment on the crank shaft.	Function is to control the mean speed of rotation over a long period due to variation of load.
2.	Regulation of speed is done by absorbing energy during power stroke and subsequently release it in other strokes.	Regulation of speed is done by actuating mechanism to control working fluid to enter into engine.
3.	The working of flywheel requires heavy mass.	The working of Governors is required to have dead weight or spring force at centre.
4.	It is mounted on driving shaft of engines and fabricating machine.	It is mounted on driven shaft, prime movers and turbine.
5.	It works continuously from cycle to cycle.	It works intermittantly.
6.	In fabrication machine it reduces capital investment on prime movers and their running expenses.	It economises consumption of fuel.

e. Explain the following for cam and follower (I)Lift (II) Base circle (III) Angle of Ascent (IV) pressure angle. *5*

(I) Lift: It is the maximum travel of the follower from its lowest position to the topmost position.

(II) Base circle: It is the smallest circle that can be drawn to the cam profile.

(III) Angle of Ascent: It is the angle designed in a cam profile to achieve the desired lift during the forward stroke

(IV) Pressure angle: It is the angle between the direction of the follower motion and a normal to the pitch curve.

Q.No 2 The following data refers to a car in which brakes are applied to front wheel:-

W heel base	*3 meters*
Height of center of gravity above ground level	*1 meter.*
Distance of CG from the rear axle	*1·35 meters*
Coefficient of friction between road and tyre	*0·5*

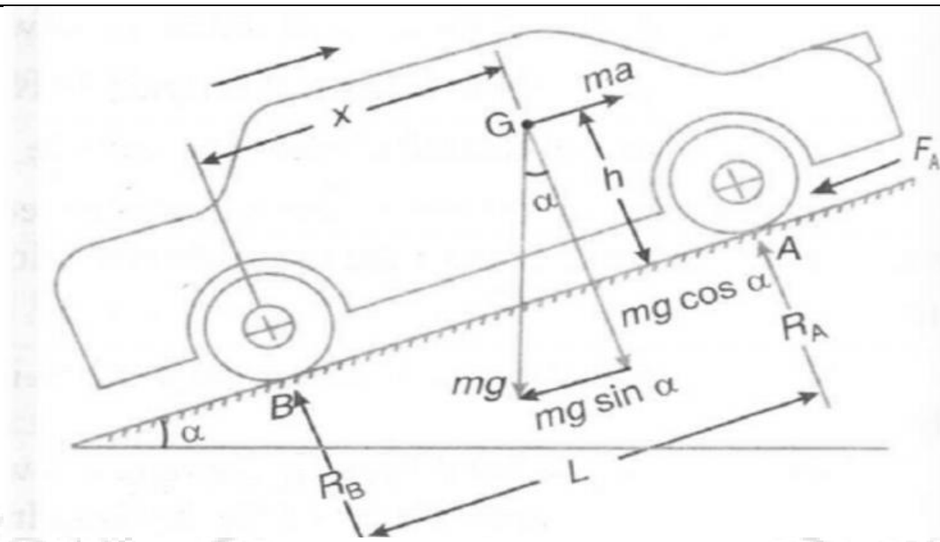
(a) Find the distance travelled by the car before coming to rest when travelling at 50 km per hour while moving on a level track.
(b) Will be there be any change in your answer if brakes are applied to the rear wheels. If yes,determine the same.
(c) Derive the formula if you use any. *20*

Ans:

L= 3 m, h = 1 m, x = 1.35 m, μ = 0.5,

u = 50 km/hr= 13.89 m/s, S = ?

1. When brakes are applied to front wheel only:



Resolving the forces parallel to the plane,

F_A + m.g. Sin α = m.a.

Resolving the forces perpendicular to the plane,

$R_A + R_B$ = m.g.cosα

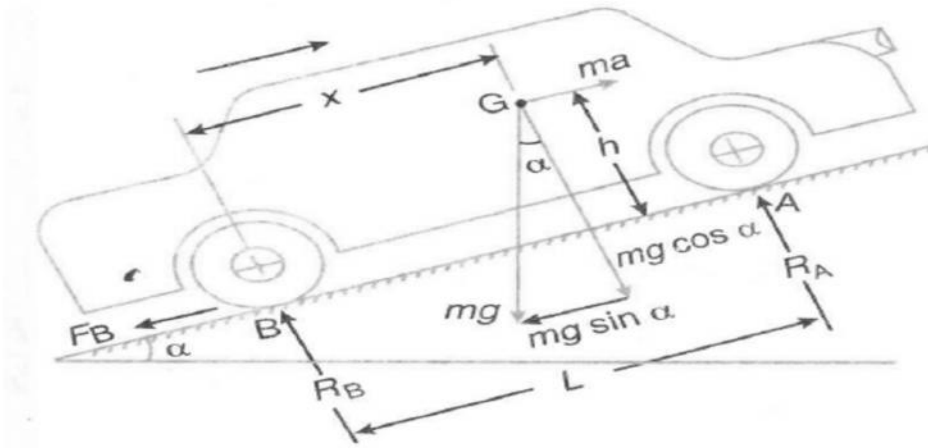
R_B = = m.g.cosα ($\frac{L-\mu H - x)}{L-\mu h}$)

$R_A = \frac{mg.\cos\alpha \times x}{L-\mu h}$

$a = \frac{\mu g x}{L-\mu h}$ = 2.6487 m/s^2

s = u^2/ 2a = 36.42 m

2. When brakes are applied to rear wheel only:



Resolving the forces parallel to the plane,

F_B + m.g. Sin α = m.a.

Resolving the forces perpendicular to the plane,

$R_A + R_B$ = m.g.cosα

$R_B = \dfrac{mg(L-x)}{L+\mu h}$

$R_A = \dfrac{mg(x+\mu h)}{L+\mu h}$

And, $a = \dfrac{\mu g(L-x)}{L+\mu h}$ = 2.31 m/s^2

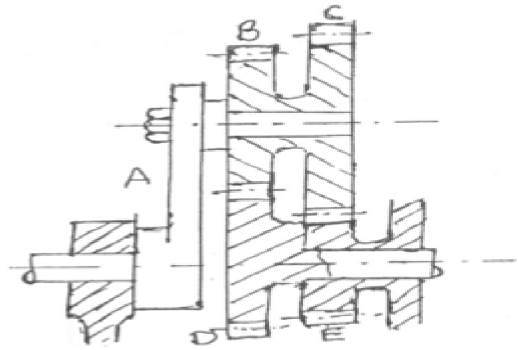
= $u^2/ 2a$ = 5.96 m

Q.No. 3.

An epicyclic speed reduction gear is shown in the figure below, the driving shaft carries on the arm A of a pin, on which the compound wheel B-C is free to revolve. Wheel C meshes with the fixed wheel E and wheel B meshes with wheel D keyed to the driven shaft. The number of teeth on the wheels are:

TB =27,Tc =30,To =24and TE =21.

Find the ratio of speed of the driving shaft to the speed of the driven shaft. If the input torque to the driving shaft is 35 Nm, what are the load torques on D and the holding torque on E? *20*



Ans:

DATA:

TB =27, Tc =30, To =24, TE =21.

Input torque to the driving shaft is 35 Nm

Table of Motion:

Step No.	Condition of Motion	Revolutions of Elements			
		Arm	Compound Gear B-C	Gear D	Gear E
01	Arm fixed – Comp Gear B-C rotated through +1 Revolution	0	+1	- T_B/T_D	- T_C/T_E
02	Arm fixed – Comp Gear B-C rotated through +x Revolution	0	+x	- x T_B/T_D	- x T_C/T_E
03	Add +y revolutions to all the elements	+y	+y	+y	+y
04	Total motion	+y	x+y	y- x T_B/T_D	y- x T_C/T_E

Q.No. 4.a.

A car engine rated at 10 kW gives a maximum torque of 100 Nm. The clutch is of single plate type, both sides being effective. If the coefficient of friction is 0·3, mean

axia pressure is limited to 0·1 N/mm2 and the ratio of the radii of the friction surfaces is 1·25, find the dimensions of he clutch plate and the total axial pressure which must be exertedby the springs. Derive theformula you use. ? *20*

Ans:

DATA:

T= 100 Nm = 100 x 10^3 Nmm, P = 10 kW,

μ = 0.3, p = 0.1 N/mm^2, r1/r2 = 1.25

We have,

P x r2 = C

C = 0.1 r2 = 9.808 N/mm

W = 2πC (r1 – r2) = 2 π x 0.1 x r2 x(1.25 r2 – r2)

= 0.157 $r2^2$

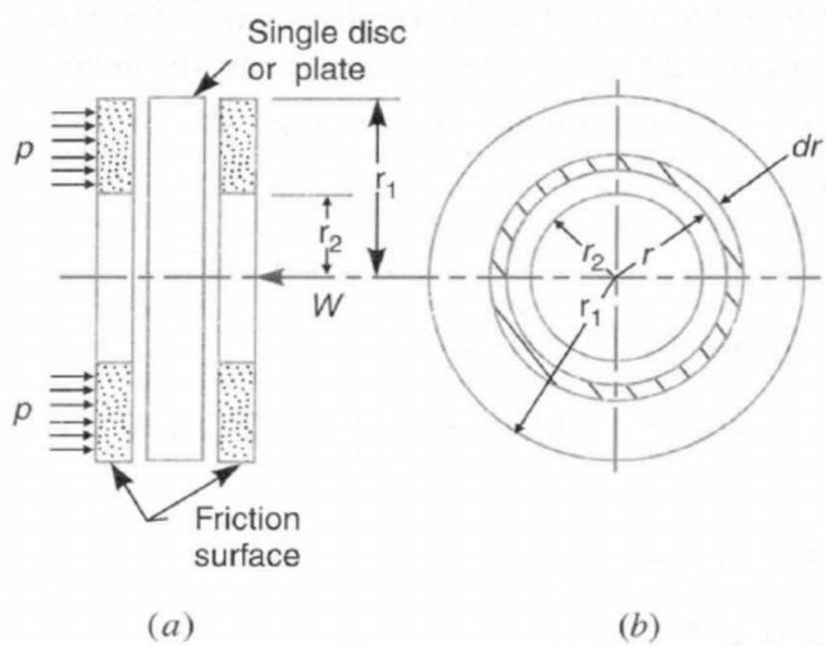
R = (r1 + r2)/ 2 = 1.125 x r2

Now,

T = n μ W R

∴ 100 x 10^3 = 2 x0.3 x 0.157x $r2^2$x 1.125 r2

∴ r2 = 98.08 mm r1 = 110.34 mm W = 2πC (r1 – r2) = 755.52 N



Let T = Torque transmitted by the clutch,
p = Intensity of axial pressure with which the contact surfaces are held together,
rl and $r2$ = External and internal radii of friction faces, and
μ = Coefficient of friction.

/. Considering uniform pressure

When the pressure is uniformly distributed over the entire area of the friction face, then the
Intensity of pressure,

T = n. μ.W.R

Where R $= \frac{2}{3}[\frac{r1^3 - r2^3}{r1^2 - r2^2}]$

$$T = 2\,\mu\pi p\,[\frac{r1^3 - r2^3}{3}]$$

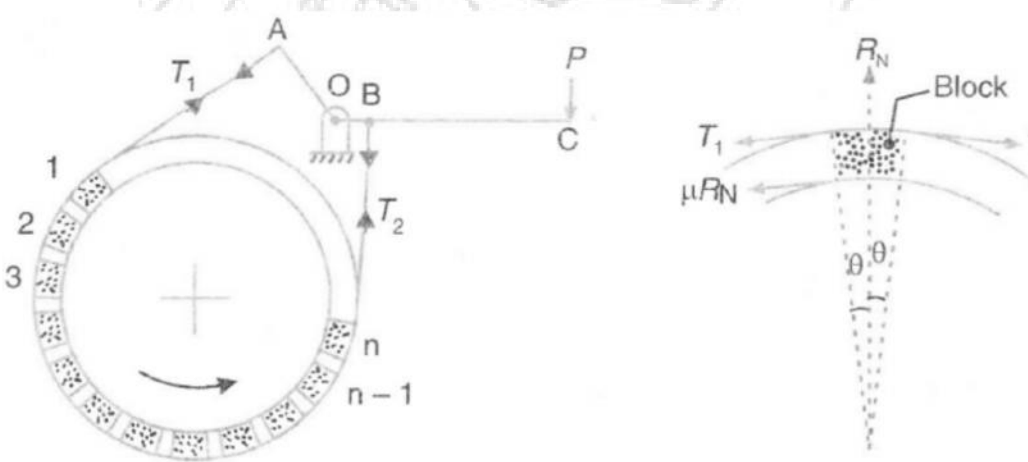
2. Considering uniform wear

T = n. μ.W.R
Where R = (r1 + r2) / 2

Q.No. 4. b.

Develop an expression for ratio of tensions on the tight and slack sides of the six band in case of a band and block type of brake having n number of blocks. ***6***

Ans:



(a) (b)

Let $T1$ = Tension in the tight side,
T2 = Tension in the slack side,
μ = Coefficient of friction between the blocks and drum,
T1' = Tension in the band between the first and second block.
T2', *T3'* etc.= Tensions in the band between the second and third block, between the third and fourth block etc.
Consider one of the blocks (say first block) as shown in Fig. This is in equilibrium under the action of the following forces:

1. Tension in the tight side *(T1)*,
2. Tension in the slack side *(T1')* or tension in the band between the first and second block,
3. Normal reaction of the drum on the block (R_N), and
4. The force of friction (μR_N).

2. Resolving the forces radially, we have
$(T1 + T1')\sin\theta = R_N$
Resolving the forces tangentially, we have
$(T1 - T1')\cos\theta = \mu R_N$
Dividing equation (ii) by (i), we have

$$\frac{T1}{T1'} = \frac{1+\mu\tan\theta}{1-\mu\tan\theta}$$

Similarly, it can be proved for each of the blocks
3.

$$\therefore \frac{T1}{T2} = \frac{T1}{T1'} \times \frac{T1'}{T2'} \times \frac{T2'}{T3'} \times ---------- \times \frac{T_{n-1}}{T2} = \left(\frac{1+\mu\tan\theta}{1-\mu\tan\theta}\right)^n$$

Braking torque on the drum of effective radius *re*,
$T_B = (T1 - T2)\, re$
$= (T1 - T2)\, r$ ... [Neglecting thickness of band]

Q.No. 5.a.

A Hartnell governor with a central sleeve, spring and two right angled bell cranked levers rotates between 288 and 320 rpm, for a sleeve lift of 3 cm. The sleeve arm and the ball arm are 10 and 14 cm respectively. The levers are pivoted at 12 cm from the governor axis and the mass of each ball is 3 kg. The space restriction imposes the condition that maximum radius of rotation of the fly ball not to exceed 15 cm. Calculate -
(i) Load on the spring at the lowest and the highest equilibrium speed and
(ii) Stiffness of the spring. *14*

Ans:

DATA:

N_1 = 288 rpm, $\omega_1 = 2\pi \times 288 / 60 = 30.16$ rad/sec

N_2 = 320 rpm, $\omega_2 = 2\pi \times 320 / 60 = 33.51$ rad/sec

h = 0.03 m, x = 140 mm = 0.14 m,

y = 100mm = 0.1 m, r = 0.12 mm

m_3 = 3 kg, r_2 = 150 mm= 0.15 m

s_1 =? s_2 =? s =?

We have,

$r_2 = r_1 + h(x/y)$

$r_1 = r_2 - h(x/y) = 0.108$ m

Also,

$Fc1 = mr1\ \omega1^2$

$= 294.71$ N

$Fc2 = mr2\ \omega2^2$

$= 505.31$ N

Mg+S1 = 2 Fc1 (x/y)

S1 = 82.51 N

Mg+S2 = 2 Fc2 (x/y)

S2 = 141.48 N

S = (s2 – s1)/ h = 1965. 89 N/m = 1.965 N/mm

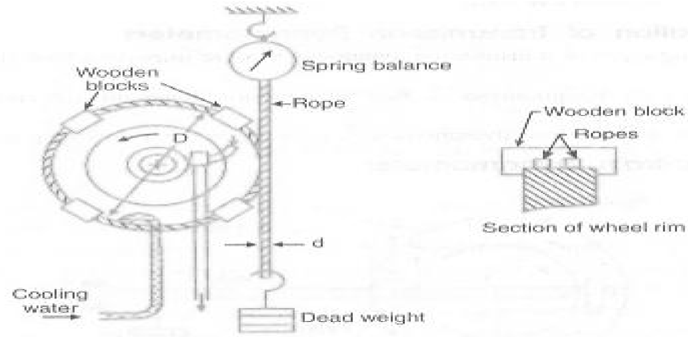
Q.No. 5.b. Explain the working of any one of the Dynamometers. *6*

Ans:

Rope Brake Dynamometer:

It is 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 the pulley fixed rigidly to the shaft of engine. The upper end of the rope is attached to the spring balance while the lower end of the rope is kept in the position by applying the dead weight. 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.



Then, Brake power of the engine,

B.P. = $[(W - S)\ \pi\ (D+d)\ N]/60$

Where,

W = Dead load in Newtons

S=spring balance reading in newtons

D=Diameter of wheel in meters

d=Diameter of rope in meters

N =Speed of engine shaft in rpm

Q.No. 6.

The radius of gyration of a turbine rotor in a ship with a mass of 20,000 kg is 50 cm the rotor rotates at 2000 rpm in a clockwise direction when viewed from the stern of the ship. The ship pitches with total pitch angle of 15°. The motion can be considered to be a simple harmonic motion with equal deviation on both sides of the axis of spin with a time period of 15 seconds. Calculate the maximum gyroscopic couple on the bolt of the turbine and the direction of steering as the bow rises. *20*

Ans:

DATA:

m = 20,000 kg, k = 0.5 m, N = 2000 rpm

For pitching, $2\Phi = 15^0$, tp = 15 sec, Cmax =?

We have,

$C = I\,\omega\,\omega_p$

$I = mk^2 = 5000\ kgm^2$

$\omega = 2\,\pi \times (2000/60) = 209.4395$ rad /sec

$\omega_p = \Phi \times \omega 1 = 0.0548$ rad /sec

$\therefore\ C = I\,\omega\,\omega_p = 57.42$ kNm.

Q.No. 7.a. *The following data refers to a cam operating a vertical spindle :-*
(i) Lift of the follower: 35 mm
(ii) Angle of ascent: 90
(iii) Angle of descent: 150°
(iv) Angle of dwell between ascent and descent: 60°
(v) Motion of the follower during ascent: SHM
(vi) Motion of the follower during descent: parabolic
Draw the displacement, velocity, acceleration and jerk curves. Show clearly the values of maximum velocity and maximum acceleration. *16*

Ans:

During ascent for SHM,

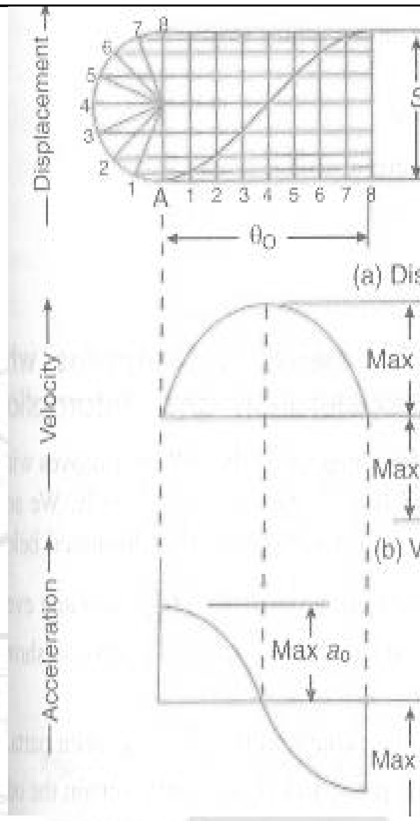
Max $V_0 = \dfrac{\Pi \omega s}{2\theta_0} = 0.035\ \omega$ m/s

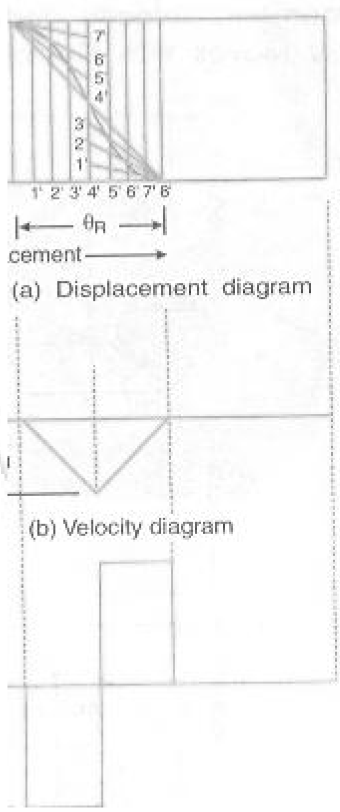
Max $a_0 = \dfrac{\Pi^2 \omega^2 s}{2\theta_0^{\,2}} = 0.07\ \omega^2\ m/s^2$

During decent for UARM (Parabolic),

Max $V_r = \dfrac{2\omega s}{\theta_r} = 0.267\ \omega$ m/s

Max $a_r = \dfrac{4\omega^2 s}{\theta_R^{\,2}} = 0.02\ \omega^2\ m/s^2$

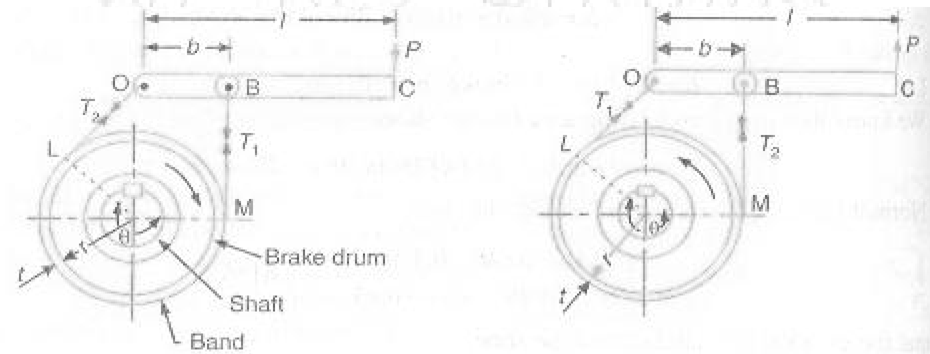

Displacement
Velocity
Acceleration
A 1 2 3 4 5 6 7 8
S
θ_O
(a) Dis
Max
Max
(b) V
Max a_o
Max


1' 2' 3' 4' 5' 6' 7' 8'
θ_R
cement
(a) Displacement diagram
(b) Velocity diagram

Q.No. 7.b.

Explain with the help of a neat sketch the difference between a simple band brake and differential band brake. *4*

Ans:



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

Simple Band Brake:
A simple band brake consists of a flexible band of leather, one or more ropes, or steel lined with friction material, which embraces a part of circumference of the drum. A band brake, as shown in fig. is a simple band brake in which one end of the band is attached to a fixed pin or fulcrum of the lever while t he other end is attached to the lever at a distance b from the fulcrum.

Differential Band Brake:
In a differential band brake, as shown in fig., the ends of the band are joined at A and B t a lever AOC pivoted on a fixed pin or fulcrum O. It may be noted that for the band to tighten, the length OA must be grater than the length OB.