B.Tech.

Fifth Semester Examination

Dynamics of Machines (ME-301-F)

Note : Attempt any *five* questions.

Q. 1. The length of the connecting rod of a gas engine is 500 mm and its centre of gravity lies at 165 mm from the crank pin centre. The rod has a mass of 80 kg and a radius of gyration of 182 mm about an axis through the centre of mass. The stroke of the piston is 225 mm and the crank speed is 300 rpm. Determine the inertia force on the crank shaft when the crank has turned (a) 30° and (b) 135° from the inner-dead centre.

Ans. Length of stroke $= L = 225 - r = \frac{225}{2}$

Centre of gravity $= 165 \text{ mm}$

Length of the connecting rod $l = 500 \text{ mm}$

Crank radius $r = 0.1125 \text{m}$

Radius of gyration $K_g = 182 \text{ mm}$

Mass of rod $M_c = 80 \text{kg}$

Engine speed $N = 300 \text{ R.P.M.}$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 300}{60} = 10\pi = 31.4 \text{rad/s}$$

We know that the distance of C.G. from P.

$$l_1 = l - CG$$

$$= 500 - 165 = 0.335 M$$

Inertia Force at 30° :

$$F_I = \left[m_R + \frac{L - L_1}{L} \times M_C\right]\omega^2 . r\left[\cos\theta + \frac{\cos 2\theta}{n}\right]$$

$$= \left[\frac{0.335}{.500} \times 80\right] 31.4^2 \times 0.1125\left[\cos 30° + \frac{\cos 2 \times 30}{2}\right]$$

$$n = \frac{l}{r} = \frac{225}{112.5} = 2$$

$$= 6635.149 \text{ N}$$

Inertia force at 135° :

$$= \left[\frac{0.335}{0.5} \times 80\right] \times 31.4^2 \times 0.1125\left[\cos 135 + \frac{\cos 2 \times 135}{2}\right]$$

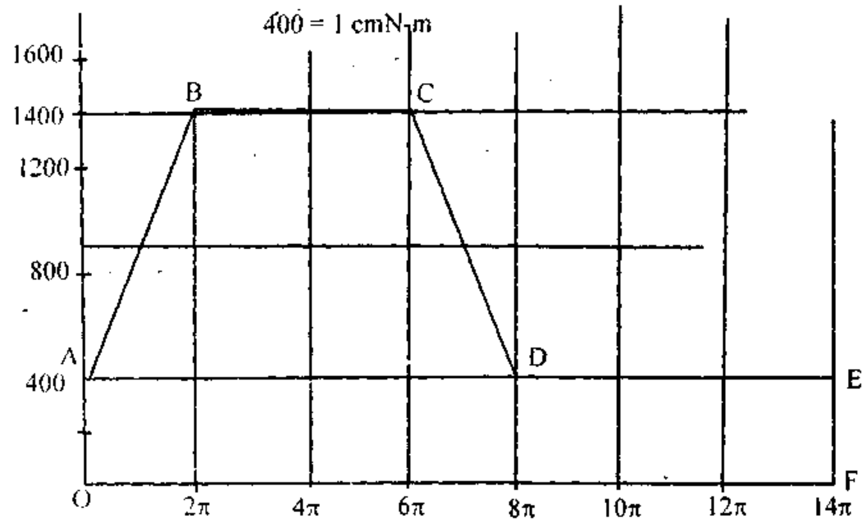
$= -4203.98\,N$ (reverse direction).

Q. 2. A machine shaft running at an average speed of 340 rpm. requires a constant torque of 1400 N-m during two revolutions and constant torque of 400 N-m during the next three revolutions, this cycle being repeated. It is to be driven directly by a constant torque motor. Find the H.P. of the motor required and the moment of inertia of a fly wheel in order that the total fluctuation of speed will not exceed 5 % of mean speed which is 300 rpm.

Ans. Given : $N = 340$ r.p.m.

$$\omega_1 = \frac{2\pi N}{60} = \frac{2\pi \times 340}{60} = 35.6 \text{rad/s}$$

400 = 1 cmN-m



Torque required to complete on cycle.

$$= 3\pi \times 400$$

Mean torque $= \dfrac{400 + 1400}{2} = 900\,N - m$

Power required $= T_{mean} \times \omega = 900 \times 35.6$

$= 32040\,W$

$= 32.04\,kW$

Coefficient of Fluctuation : $\pm 5\%$

$$C_S = \frac{\omega_1 - \omega_2}{W} = 10 = 0.1$$

Power of Electric Motor $= T_m \times \dfrac{2\pi N}{60}$

$$= \frac{900 \times 2\pi \times 300}{60} = 28274.33$$

$= 28.274\ KW.$

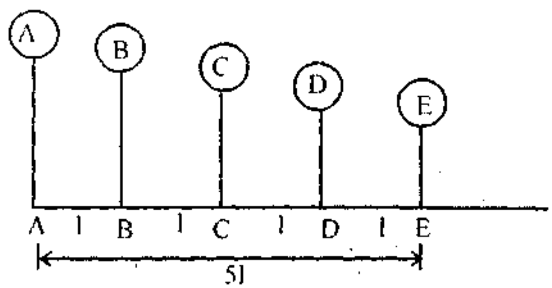
Q. 3. A shaft carries five masses A, B, C, D and E which revolve at the same radius on planes which are equidistant from one another. The magnitude of the masses in planes A, C and D are 50 kg. 40 kg and 80kg respectively. The angle between A and C is 90° and that between C and D is 135°. Determine the magnitude of the masses in planes B and E and their positions to put the shaft in complete rotating balance.

Ans. Given : $m_A = 50,\ m_B = ?\ m_C = 40,\ m_D = 80\,kg$

$$r_A = r_B = r_C = r_D = r$$

$$\angle AOC = 90°,\ \angle COD = 135°$$

Plane (1)	Mass (m) kg (2)	Eccentricity (r)m (3)	Centre force $\div W^2$ (mr) kg-m (4)	Distance from plane A (l) m (5)	Couple $\div W^2$ $\div W^2$ (mrl) kg – m^2 (6)
(R.P)	50	r	50r	0	0
	m_B	r	$m_B r$	r	$m_B rl$
	40	r	40r	2l	80 rl
	80	r	80r	3l	240 rl
	m_E	r	$m_E r$	4l	4 $m_E r$



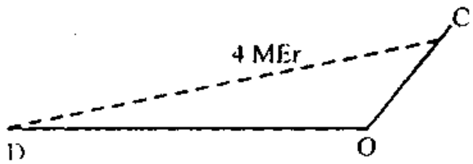
Draw as discuss below.

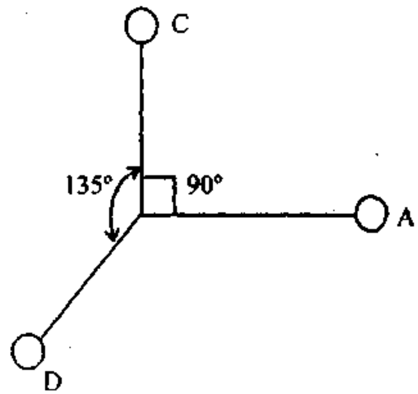
1. Draw vector o' b' in horizontal direction.

$$1\,cm = 40$$

$$CD = 7.7\,cm \times 40 = 308$$

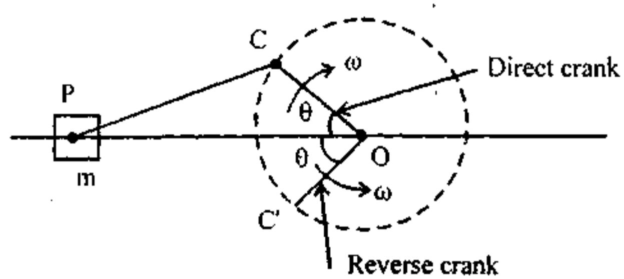
$$m_E = 77\,kg$$





Q. 4. (a) Explain the direct and reverse crank method of determining unbalanced forces in radial engines.

Ans. Balancing of Radial Engines (Direct and Reverse Cranks Method) :



The method of direct and reverse cranks is used in balancing of radial or V engines, in which the connecting rods are connected to a common crank. Since the plane of rotation of the various cranks is some, therefore there is no unbalanced primary or secondary couple.

Consider a reciprocating engine mechanism as shown in fig. Let the crank OC (known as the direct crank) rotates uniformly at W radians per second in a clockwise direction. Let at any instant the crank makes an angle θ with the line of stroke OP. The indirect or reverse crank OC' is the image of the direct crank OC. When seen through the mirror placed at the line stroke.

Q. 4. (b) The pistons of a 60° twin v-engine has strokes of 120 mm. The connecting rods driving a common crank has a length of 200 mm. The mass of the reciprocating parts per cylinder is 1 kg and the speed of the crank shaft is 2500 rpm. Determine the magnitude of primary and secondary forces.

Ans. Given : $2\alpha = 60°$,

$$m = kg,\ r = \frac{L}{2} = \frac{200}{2} = 100\,mm = 0.1m$$

$$N = 2500\,rpm$$

$$\omega = \frac{2\pi N}{60} = \frac{2\pi \times 2500}{60} = 261.79\,rad/s$$

Resultant Primary Force :

$$F_P = 2m\omega^2 r\sqrt{(\cos^2\alpha\cos\theta)^2 + (\sin^2\alpha.\sin\theta)^2}$$

$$= 2.m.\omega^2.r\sqrt{(\cos^2 30\cos\theta)^2 + (\sin^2 30\cos\theta)^2}$$

$$= 2m\omega^2 r.\sqrt{\left(\frac{3\cos\theta}{4}\right)^2 + \left[\frac{\sin\theta}{4}\right]^2}$$

Maximum Resultant For :

$$F_S = \sqrt{2}\frac{m}{n}\omega^2 r\sin 2\theta$$

This is maximum when $\sin 2\theta$ is maximum

$$\sin 2\theta = \pm 1 \quad \theta = 45^\circ \text{ or } 135^\circ$$

$$F_{S\,max} = \sqrt{2}.\frac{1}{\frac{0.2}{0.1}}(261.79)^2 \times (0.1).1$$

$$= 4846.08\,N.$$

Q. 5. (a) Define and explain the following terms relating to governors :

(i) Hunting **(ii) Isochronism**

(iii) Stability **(iv) Sensitiveness**

(v) Height.

Ans. (i) Hunting : A governor is said to be hunt of the speed of the engine fluctuates continuously above and below the mean speed.

(ii) Isochronism : A governor is said to be Isochronous when the equilibrium speed is constant for all radii of rotation of the balls within working range, neglecting friction.

(iii) Stability : A governor is said to be stable when for every speed within the working range there is definite configuration.

(iv) Sensitiveness : Speed increases or decreases by a certain amount, the lift of the sleeve of governor A is greater than the lift of the sleeve of governor B. It is then said that the governor A is more sensitive.

(v) Height : It is vertical distance from the centre of ball to a point where the axes of the arms. Interact on the spindle axis. It is usually denoted by h.

Q. 5. (b) A governor of the Hartnell type has equal balls of mass 3 kg, set initially at a radius of 200 mm. The arms of the bell crank lever are 110 mm vertically and 150 mm horizontally. Find : (i) The initial compressive force on the spring, if the speed for an initial ball radius of 200 mm is 240 rpm. and (ii) The stiffness of the spring required to sleeve movement of 4 mm on a fluctuation 7.5% in the engine speed.

Ans. Given :

$$m = 3kg,\ x = 110 = .11m,\ y = 150mm = .15m$$

$$N_1 = 240\,rpm$$

$$\omega_1 = \frac{2\pi N}{60} = \frac{2\pi \times 240}{60} = 25.13 \text{ rad/s}$$

$$\omega_2 = 1.075 \times 25.13 = 27.01 \text{ rad/s}$$

We know that centrifugal force at minimum speed.

$$F_{C_1} = m(\omega_1)^2 \times r_1$$

$$= 3\left[(25.13)^2 \times .20\right] = 378.9 \text{ N}$$

$$F_{C_2} = 2\left[(27.01)^2 \times .204\right] = 446.47 \text{ N}$$

(i) Initial Compression :

$$\frac{S_1}{S} = \frac{555.72}{18.16} = 30.556 \text{ MM}.$$

(ii) Stiffness of Spring :

$$mg = S_1 = 2F_{C_1} \times \frac{x}{y}$$

$$S_1 = 2 \times 378.9 \times \frac{0.11}{0.15} \qquad M = 0$$

$$= 555.72 \text{ N}$$

And maximum,

$$M_g + S_2 = 2F_{C_2} \times \frac{x}{y}$$

$$S_2 = 2 \times 446.47 \times \frac{0.11}{.15}$$

$$= 654.82$$

$$h = (r_2 - r_1)\frac{y}{x} = (0.204 - .2)\frac{0.15}{.11} = 5.45 \times 10^{-3}$$

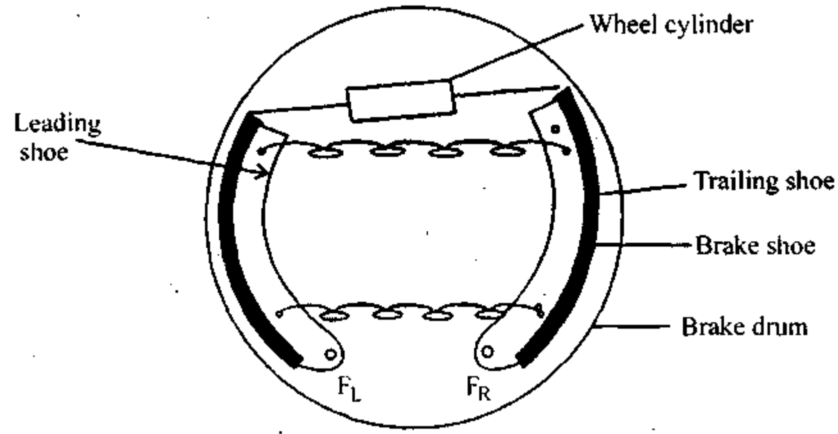
$$S = \frac{S_2 - S_1}{h} = \frac{654.82 - 555.72}{5.4 \times 10^{-3}} = 18168.33 \text{ N/m}$$

$$= 18.16 \text{ N/mm}.$$

Q. 6. (a) Explain with necessary sketches the working of a well known type of hydraulic dynamometer. What are the reasons for its popularity?

Ans. Hydraulic Dynamometer : Tesla fluid friction dynamometer : The viscous resistance of fluid is made use of for reducing the speed or prime mover. The corresponding viscous resistance having determined, the output is found.

In the fluid dynamometer; a polished, brake dis, mounted on the revolving shaft of the prime mover is enclosed in a casing. The space between the disc and the casing is partially filled with viscous liquid.



Suppose the viscous surface, shear stress on this ring,

$$\sigma_s = \mu \frac{du}{dy}$$

Area of ring $= (2\pi r \times dr) \times (2 \text{ for both sides})$

Shear resistance $= dF = \mu \frac{du}{dy} \times 4\pi r\, dr$

Brake torque $dT_B = \mu \frac{du}{dy} \times 4\pi r dr \times r$

$$= u \frac{du}{dy} 4\pi r^2 dr$$

For entire disc,

$$T_B = \int dT_B$$

Brake power or output power $= T_B w$.

Q. 6. (b) In a vertical belt transmission dynamometer, the diameter of the driving pulley rotating at 1500 rpm is 80 mm. The centre distance of the intermediate pulleys from the fulcrum is also 80 mm each. The weighting pan on the lever is at a distance of 250 mm. Find the power transmitted when a mass of 20 kg is required in the pan, including its own mass.

Ans. $N = 1500$ rpm

Suppose d = diameter of each of the driven and intermediate pulleys

$$a = \frac{d}{2} + \frac{d}{2} = d = 80 \text{ mm}$$

$L = 250$ mm

D = diameter of driven

$= d + d + d = 3 \times 80 = 240$ mm

$$T_1 - T_2 = \frac{WL}{2a}$$

$$\Rightarrow \quad T_1 - T_2 = \frac{20 \times 250}{2 \times 80} = 31.25\,N$$

Brake output power,

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

$$v = \frac{2DN}{60} = \frac{20 \times 1500 \times 0.24}{60}$$

$$= \frac{31.25 \times 2 \times 1500 \times .24}{60} = 375\,Nm/s.$$

Q. 7. (a) What do you understand by gyroscopic couple? Derive a formula for its magnitude.

Ans. Gyroscopic Couple : Since the plane in which the disc is rotating to the plane YOZ, therefore it is called plane of spinning.

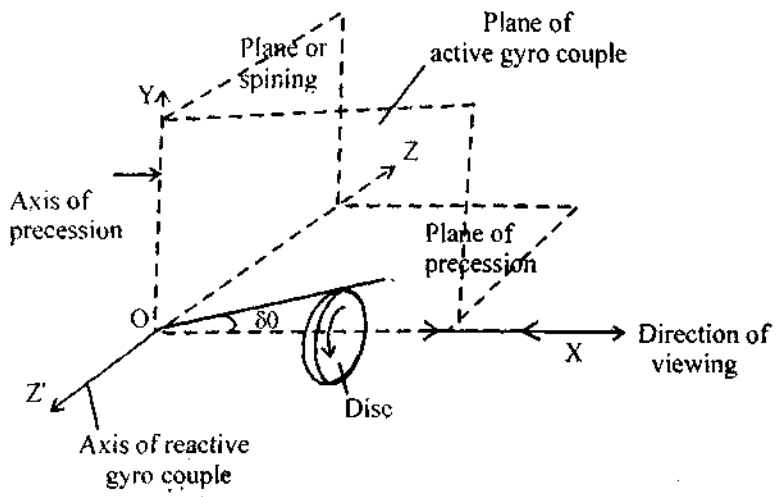
The horizontal plane XOZ is called plane of precession and OY is the axis of precession.

Let $\quad I$ = Mass moment of inertia

ω = Angular velocity

Angular momentum of the disc

$$= I\omega$$



Change in angular momentum

$$= OX' - Ox = xx' = Ox\delta\theta$$

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

And rate of change of angular momentum

$$= I\omega \frac{\delta\theta}{dt}$$

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

Q. 7. (b) Each paddle wheel of a steamer have a mass of 1600 kg and a radius of gyration of 1.2 m. The steamer turns to port in a circle of 160 m radius at 24 km/hr, the speed of the paddles being 90 rpm. Find the magnitude and effect of the gyroscopic couple acting on the steamer.

Ans. Given : $m = 1600$ kg

$k = 1.2$m

$N = 90,$

$$\omega = \frac{2\pi N}{60} = \frac{2 \times \pi \times 90}{60} = 9.42 \text{ rad/s}$$

$R = 160$m

$v = 24$ km / hr

We know that moment of inertia,

$$I = mK^2 = 1600 \times (1.2)^2$$

$$= 2304 \text{ kg} - \text{m}^2$$

And angular velocity of precession,

$$\omega_P = \frac{v}{R} = \frac{24}{160} = 0.15 \text{ rad/sec}$$

We know that gyroscopic couple,

$$C = I.\omega.\omega_P$$

$$= 2304 \times 9.42 \times 0.15$$

$$= 3255.55 \text{ N-m}$$

$$= 3.255 \text{ KN-m.}$$