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FINAL EXAMINATION QUESTION BOOKLET	
COURSE CODE	: BME 3013
COURSE	: MECHANICS OF MACHINE
SEMESTER/SESSION	: 1-2024/2025
DURATION	: 3 HOURS

Instructions:

1. This booklet contains 4 questions. Answer **ALL** questions.
2. All answers should be written in answer booklet.
3. Write legibly and draw sketches wherever required.
4. If in doubt, raise your hands and ask the invigilator.

DO NOT OPEN THIS BOOKLET UNTIL YOU ARE TOLD TO DO SO

THIS BOOKLET CONTAINS 11 PRINTED PAGES INCLUDING COVER PAGE

QUESTION 1

a) A gear box has an input speed of 2000 rev/min clockwise and an output speed of 500 rev/min anticlockwise. The input power is 50 kW and the efficiency is 60%. **Find** the following:

   i. the input torque (1 mark)

   ii. the output power (2 marks)

   iii. the output torque (2 marks)

b) Power is transmitted using a V-belt drive. The included angle of V-groove is 30°. The belt is 20 mm deep and maximum width is 20 mm. If the mass of the belt is 0.35 kg per metre length and maximum allowable stress is 1.4 MPa, the angle of lap is 140° and coefficient of friction, μ is 0.15. **Compute**

   i. the maximum power transmitted (4 marks)

   ii. the power can be transmitted by the belt (6 marks)

c) A shaft rotating at 200 r.p.m. drives another shaft at 300 r.p.m. and transmits 6 kW through a belt. The belt is 100 mm wide and 10 mm thick. The distance between the shafts is 4m. The smaller pulley is 0.5 m in diameter. **Determine** the stress in the belt, if it is an open belt drive. (10 marks)

QUESTION 2

a) Figure 1 shows a shaft carries four masses A, B, C and D of magnitude 200 kg, 300 kg, 400 kg and 200 kg respectively and revolving at radius 80 mm, 70 mm, 60 mm and 80 mm in planes measured from A at 300 mm, 400 mm and 700 mm. The angles between the cranks measured anticlockwise are A to B 45°, B to C 70° and C to D 120°. The balancing masses are to be placed in planes X and Y. The distance between the planes A and X is 100 mm, between X and Y is 400 mm and between Y and D is 200 mm. If the balancing masses revolve at a radius of 100 mm, **solve** their magnitudes and angular positions. (7 marks)

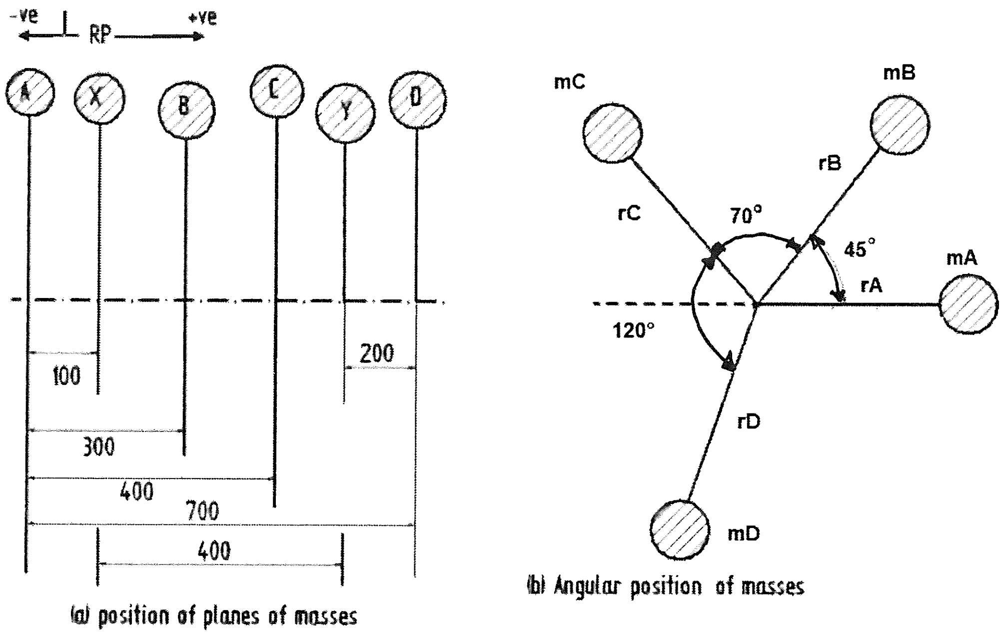

Figure 1

b) A multi plate clutch must have five contact surfaces and transmits power at 2000 rev/min. The coefficient of friction is 0.25. The inner and outer diameters are 80 mm and 150 mm respectively. The axial force applied to the plate is 600 N. **Calculate** the power that can be transmitted without slipping using

i. the uniform pressure theory (4 marks)

ii. the uniform wear theory (4 marks)

c) A rotating shaft at constant angular velocity carries four masses, A, B, C and D, rigidly attached to it as shown in Figure 2 and the centers of mass are at 30 mm, 36 mm, 39 mm and 33 mm respectively from the axis of rotation. The mass of A, C and D are 7.5 kg, 5 kg and 4 kg. The axial distance between A and B is 400 mm and that between B and C is 500 mm. The eccentricities of A and C are 90^o to one another and B is starting point. If the system is fully balance, **determine**

i. the axial distance, *x* between the planes of C and D. (5 marks)

ii. the angles of mass B and mass D relative to mass C. (3 marks)

iii. the mass B. (2 marks)

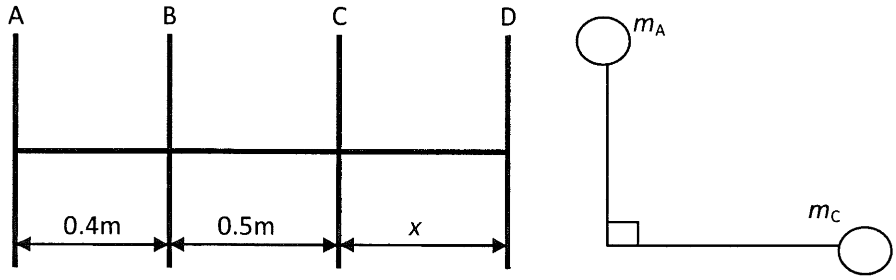

Figure 2

QUESTION 3

a) The graph of torque against the crank angle for a petrol engine is drawn to the following scales: torque, 1 mm = 5 Nm; crank angle, 1 mm = 1° as shown in Figure 3 below. The areas above and below the mean torque, τ_P line, taken in order, are 295 mm^2, 685 mm^2, 40 mm^2, 340 mm^2, 960 mm^2 and 270 mm^2. The rotating parts are equivalent to mass of 36 kg at a radius of gyration of 150 mm. **Compute** the coefficient of fluctuation of speed, when the engine runs at 1800 rev/min. (6 marks)

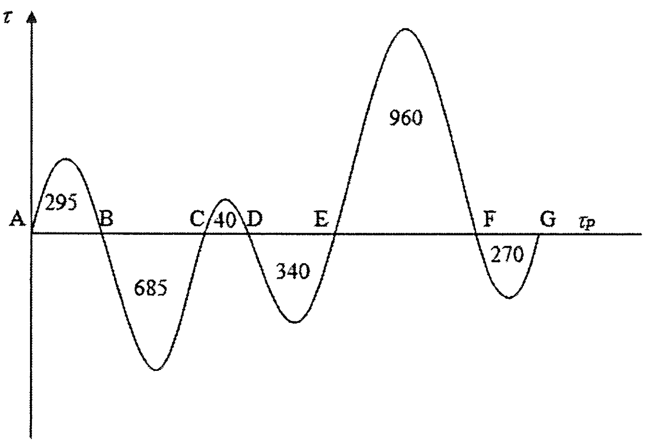

Figure 3

b) A governor of the Proell type has each arm 300 mm long shown in Figure 4. The pivots of the upper and lower arms are pivot on the axis of the governor. The central load acting on the sleeve has a mass of 100 kg and the each rotating ball has a mass of 10 kg. When the governor sleeve is in mid-position, the extension link of the lower arm is vertical and the radius of the path of rotation of the masses is 180 mm. the vertical height of the governor is 200 mm. If the governor speed is 160 rev/min. when in mid-position, **solve**

i. the length of extension link (6 marks)

ii. the tension in the upper link (3 marks)

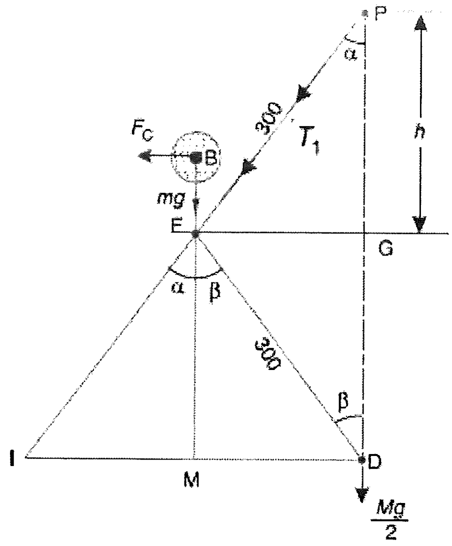

Figure 4

c) The turning moment diagram for a petrol engine is drawn to the following scales: Turning moment, 1 mm = 5 Nm; crank angle, 1 mm = 3° horizontally shown in Figure 5. The turning moment diagram repeats itself at every half revolution of the engine and the areas above and below the mean turning moment line taken in order are 295 mm^2, 685 mm^2, 40 mm^2, 340 mm^2, 960 mm^2, 270 mm^2 when the engine is running at a speed of 600 rev/min. If the total fluctuation of speed is not to exceed ± 1.5% of the mean, **determine** the necessary mass of the flywheel of radius 0.5 m.

(10 marks)

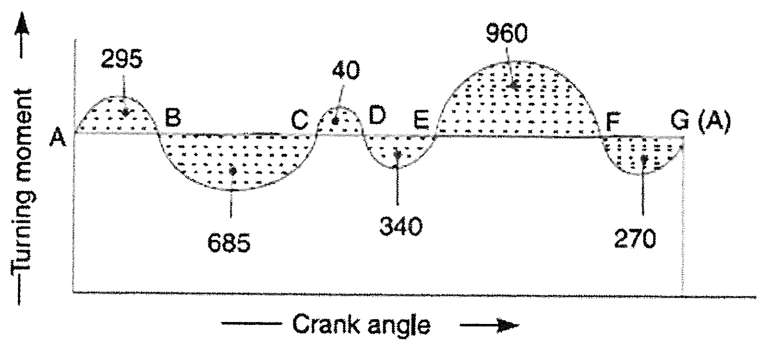

Figure 5

QUESTION 4

a) The diagram in Figure 6 shows a mass-spring-dashpot system. The mass has a harmonic disturbing force applied to it given by the equation F= 400 sin (30 t) Newton. **Compute**

i. the amplitude of the mass (5 marks)

ii. The phase angle (2 marks)

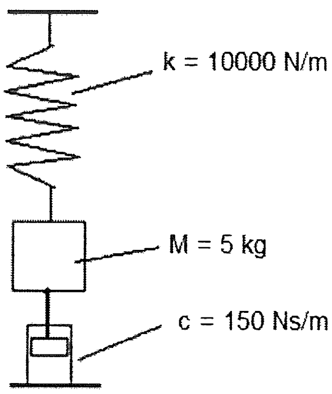

Figure 6

b) Figure 7 shows a Porter governor has equal arms each 250 mm long and pivoted on the axis of rotation. Each ball has a mass of 5 kg and the mass of the central load on the sleeve is 25 kg. The radius of rotation of the ball is 150 mm when the governor begins to lift and 200 mm when the governor is at maximum speed. **Determine**

i. the minimum and maximum speed of the governor (6 marks)

ii. the range of speed (2 marks)

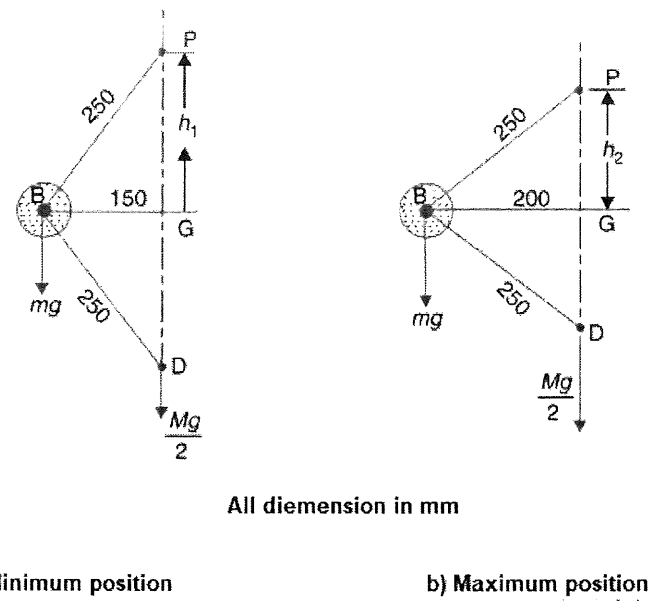

Figure 7

c) A mass of 5 kg is suspended on a spring and set oscillating. It is observed that the amplitude reduces to 5 % of its initial value after 2 oscillations. It takes 0.5 seconds to do them. **Calculate**

i.	the damping ratio	(2 marks)
ii.	the natural frequency	(2 marks)
iii.	the actual frequency	(2 marks)
iv.	the critical damping coefficient	(2 marks)
v.	the actual damping coefficient	(2 marks)

---**End of question**--------------------------------------

FORMULAE

Belting and power transmitted:

$$Open\ belt:\ \sin\alpha = \frac{r_1 - r_2}{x}$$

$$\text{Angle of contact, } \theta_A = 180° - 2\alpha \text{ X } \frac{\pi}{180}\ rad$$

$$Cross\ belt: \sin\alpha = \frac{r_1 + r_2}{x}$$

$$\text{Angle of contact, } \theta_A = 180° + 2\alpha \text{ X } \frac{\pi}{180}\ rad$$

$$V\ belt: \frac{\mathrm{T1}}{\mathrm{T2}} = e^{\frac{\mu\theta}{\sin\beta}} \quad Flat\ belt: \frac{\mathrm{T1}}{\mathrm{T2}} = e^{\mu\theta}$$

$$\mathrm{P} = (\mathrm{T1} - \mathrm{T2})\mathrm{v}, \quad \mathrm{P} = \mathrm{T}\omega, \text{where } \omega = \frac{2\pi\mathrm{N}}{60}$$

$$\eta = \frac{\mathrm{Po}}{\mathrm{Pi}}$$

$$\mathrm{v} = \omega\mathrm{r}\ ;\ \mathrm{v} = \frac{\pi\mathrm{dN}}{60}$$

$$\mathrm{v} = \sqrt{\frac{\mathrm{T}}{3\mathrm{m}}}\ , m = A\ x\ length\ x\ density\ , A = b\ x\ t$$

$$\mathrm{T_0} = \frac{\mathrm{T_1} + \mathrm{T_2}}{2}$$

$$\mathrm{P} = \frac{2\pi\mathrm{NT}}{60}$$

$$\mathrm{Tc} = \frac{\mathrm{T}}{3}\ ;\mathrm{T1} + \mathrm{Tc} = \mathrm{Tmax}$$

$$Tc = mv^2$$

$$Tmax = \sigma.b.t$$

For Plate/ multiplate:

$$T = \frac{\mu R}{3}\left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right) X\ n\text{, uniform pressure}$$

$$T = \frac{\mu R}{4}(D_o + D_i)\ X\ n\text{, uniform wear}$$

$$P = T\omega$$

For Conical:

$$T = \frac{\mu R}{3\sin\beta}\left(\frac{D_o^3 - D_i^3}{D_o^2 - D_i^2}\right)\text{, uniform pressure}$$

$$T = \frac{\mu R}{4\sin\beta}(D_o + D_i)\text{, uniform wear}$$

Gear:

$$\frac{\text{speed of first driver}}{\text{speed of last driven}} = \frac{\text{product of no. of teeth on drivens}}{\text{product of no. of teeth on drivers}}$$

$$\frac{\omega_A}{\omega_B} = \frac{t_B}{t_A}$$

$$\frac{N_1}{N_2} = \frac{T_2}{T_1} = G.R.$$

Flywheel, Balancing, Governor and Vibration:

$$Cs = \frac{\omega_{max} - \omega_{min}}{\omega}, = \frac{N_{max} - Nmin}{N},$$

$$I = \frac{\beta W}{\omega^2 Cs} \qquad I = mk^2\ K.E = \frac{I\omega^2}{2}$$

$$Porter\ \ (N)^2 = \left(\frac{m+M}{m}\right)\left(\frac{895}{h}\right) \qquad Proell\ \ (N)^2 = \frac{FM}{BM}\left(\frac{m+M}{m}\right)\left(\frac{895}{h}\right)$$

$$\text{momentum} = I\omega$$

$$F = m\omega^2 r$$

$$I = \frac{\pi D^4}{64} \text{ circular}$$

$$f = \frac{1}{2}\sqrt{\frac{3EI}{ML^3}}$$

$$Cc = \sqrt{4Mk}$$

$$C = Cc \times \delta$$

$$f = f_n(\sqrt{1-\delta^2})$$

$$\omega_n = \sqrt{\frac{k}{I}}$$

$$\omega = \omega_n\sqrt{1-\delta^2}$$

$$fn = \frac{no\ of\ oscillation}{time\ taken}$$

$$f_n = \frac{1}{2\pi}\sqrt{\frac{k}{M}}$$

$$\ln\left(\frac{x_1}{x_2}\right) = \frac{2\pi\delta m}{\sqrt{1-\delta^2}}$$

$$\text{Sensitivity}, \alpha = \frac{\omega}{\omega_1 - \omega_2}$$