City&
Guilds

9210-130
Level 6 Graduate Diploma in Engineering
Mechanics of machines and strength of materials

Sample Paper

You should have the following for this examination
- one answer book
- non-programmable calculator
- pen, pencil, ruler, drawing instruments

The following data is attached
- Worksheet booklet WSQ2
- Worksheet booklet WSQ5

General instructions
- This examination paper is of **three hours** duration.
- This examination paper contains nine questions in sections A and B.
- Answer **five** questions selecting at least **two** questions from each section.
- All the question carry equal marks. The maximum marks for each section within a question are given against that section.
- An electronic, non-programmable calculator may be used, but the candidates **must** show clearly the steps prior to obtaining final numerical values.
- Drawing should be clear, in good proportion and in pencil. Do **not** use red ink.

Section A

1 a) A rod of length L, cross sectional area A_1 and modulus of elasticity E_1 has been placed inside a tube of the same length L but of cross sectional area A_2 and modulus of elasticity E_2 as shown in Figure Q1(a).

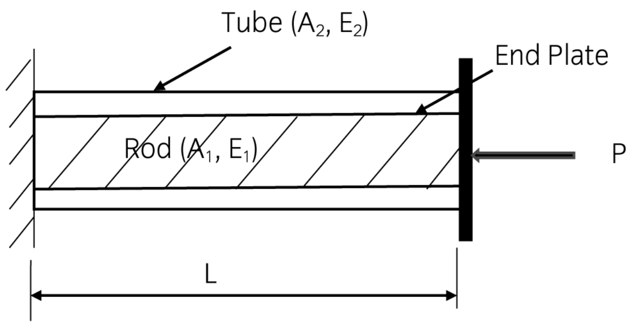

Figure Q1(a)

i) What is the deformation of the rod and tube when a force P is exerted on a rigid end plate as shown? (6 marks)

ii) If the axial forces in the rod and the tube are P_1 and P_2 respectively, show that

$$P_1 = \frac{A_1E_1P}{A_1E_1 + A_2E_2} \quad \text{and} \quad P_2 = \frac{A_2E_2P}{A_1E_1 + A_2E_2}$$ (6 marks)

b) As shown in Figure Q1(b), a 1.35 m long and 0.50 m diameter concrete post is reinforced with six steel bars, each with of 30 mm diameter. If the modulus of rigidity of steel E_s = 200 GPa and modulus of rigidity of concrete E_c = 30 GPa. Determine the normal stresses in the steel and in the concrete when a 1500 kN axial centric force P is applied to the post. (8 marks)

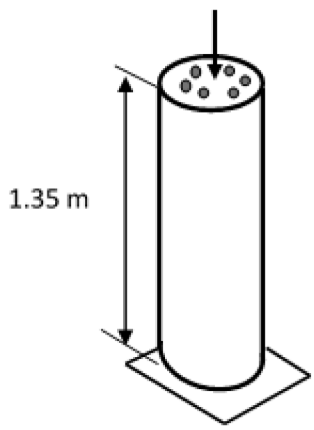

Figure Q1(b)

2 a) Derive an expression for the stresses on an oblique plane of a rectangular body, when the body is subjected to a simple shear stress. (6 marks)

b) At a point in a strained material, on plane ***BC*** there are normal and shear stresses of 640 N/mm^2 and 160 N/mm^2 respectively. On plane ***AC***, which is perpendicular to ***BC***, there are normal and shear stresses of 320 N/mm^2 and 160 N/mm^2 respectively. These stresses are shown in Figure Q2. Determine the followings.

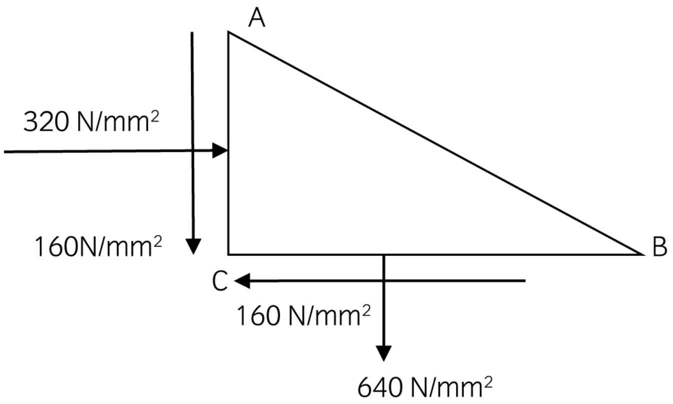

Figure Q2

i) Principal stresses and location of the planes on which they act. (10 marks)

ii) Maximum shear stress and the plane on which it acts. (4 marks)

3 a) Show that $\mathbf{I_o = I_G + Ah^2}$,
where $\mathbf{I_G}$ is the second moment of area of a cross section with area '**A**' about an axis through the centroid and '**h**' is the distance from the centroid to a parallel axis in the same plane about which its second moment of area is $\mathbf{I_o}$. (6 marks)

b) Considering section Y-Y of the beam and loading shown in Figure Q3, determine

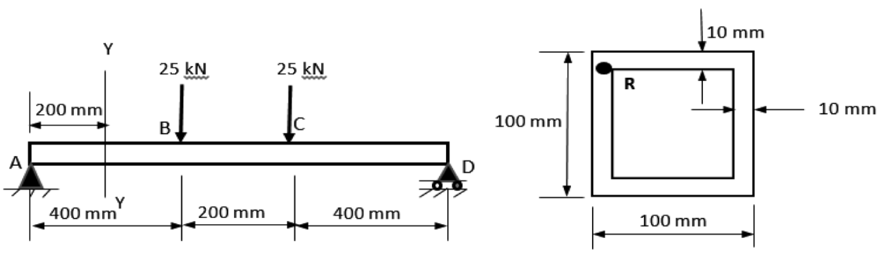

Figure Q3

i) The largest shearing stress in that section. (7 marks)

ii) The shearing stress at point 'R'. (7 marks)

4 a) Explain the meaning of each symbol in the simple torsion formula given by
$\frac{T}{J} = \frac{\tau}{r} = G\frac{\theta}{l}$ (4 marks)

b) Write down **four** assumptions made to derive the torsion formula. (4 marks)

c) A solid circular shaft transmits 60 kW power at 120 rev/min. Calculate the shaft diameter, if the twist in the shaft is not to exceed 1° in 3 m length of shaft, and shear stress is limited to 50 MPa. Take Modulus of Rigidity of the material G = 80 GPa. (12 marks)

Section B

5 a) Figure Q5(a) shows a slider A moving outwards on the rod OB at a velocity v and an acceleration $\boldsymbol{a}$. The rod has an angular velocity ω counterclockwise about O and an acceleration α clockwise as shown in the figure. OA = r. Determine the absolute acceleration of the slider A. (6 marks)

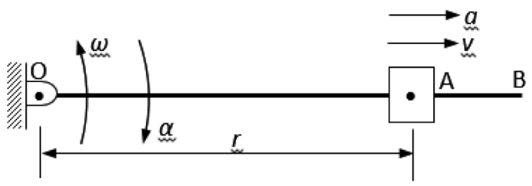

Figure Q5(a)

b) Figure Q5(b) shows a scotch yoke mechanism in which the slider P moves along the guide path of yoke R. At the instant shown in the figure, the crank OP makes an angle of 30° with the horizontal and its angular velocity and angular acceleration are 10 rad/s and 20 rad/s^2 respectively. OP = 300 mm. Determine

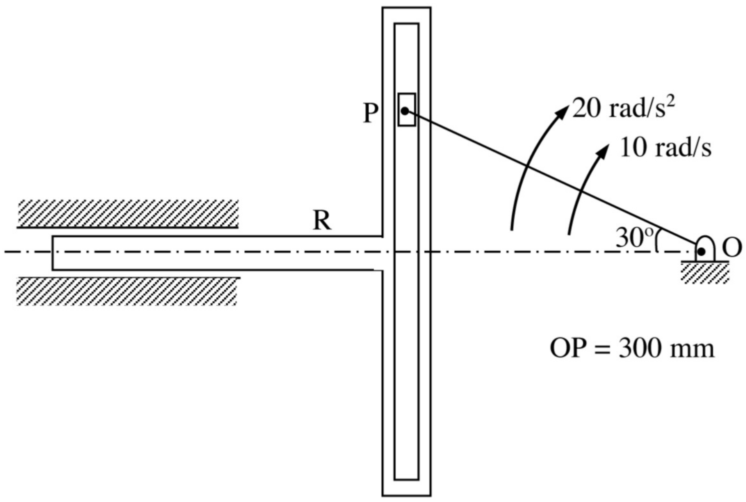

Figure Q5(b)

i) The horizontal velocity of the yoke. (6 marks)

ii) The acceleration of the slider P in the yoke. (4 marks)

iii) The horizontal acceleration of the yoke. (4 marks)

6 a) In a belt drive system, a belt of mass *m* per unit length runs over a driving pulley at a linear speed *v*.

i) Show that the centrifugal tension in the belt (T_c) is given by $T_c = mv^2$ (3 marks)

ii) Show that, $\frac{T_1 - T_c}{T_2 - T_c} = e^{\mu\theta}$, where T_1 and T_2 are the tensions in the tight side and slack side respectively in an open belt drive where μ is the coefficient of friction between the belt and the pulley and θ is the angle of lap. (5 marks)

b) Power is transmitted between two parallel shafts, the axes of which are 2 m apart, by means of an open belt of thickness 3 mm and width 60 mm. The diameter of the pulley on the driving shaft is 800 mm and it rotates at 360 rev/min. The speed ratio between the driving and driven shafts is 1.8. The belt material has a density of 3 kg/m and a permissible stress of 5 N/mm^2. The coefficient of friction between the belt and the pulley is 0.25.

Determine

i) The angle of lap on the smaller pulley. (4 marks)

ii) The maximum power transmitted. (8 marks)

7 a) Explain the terms, sensitiveness, hunting, and stability relating to governors. (6 marks)

b) In a spring controlled Hartnell governor, the length of the sleeve arm is 150 mm and that of the ball arm is 125 mm. The mass of each ball is 3 kg and the fulcrum of each bell crank lever is at a distance of 160 mm from the axis of rotation of the governor. The extreme radii of the balls are 130 mm and 170 mm. The maximum equilibrium speed is 10% higher than the minimum equilibrium speed and the stiffness of the control spring is 5 N/mm.

Neglecting obliquity of arms and friction determine

i) The maximum and minimum equilibrium speeds of the governor. (8 marks)

ii) The equilibrium speed when the ball arms are vertical. (6 marks)

8 a) Explain why it is necessary to attach a flywheel to a machine, which requires a non-uniform operating torque when it is driven by a constant torque motor. (4 marks)

b) A constant torque motor of capacity 2.5 kW drives a riveting machine. The moving parts including the flywheel are equivalent to a mass of 120 kg at a radius of gyration of 750 mm. Each riveting operation absorbs 10 kJ of energy and the operation takes 1.2 seconds. The speed of the flywheel just before the riveting operation is 300 rev/min. Determine

i) The speed of the flywheel immediately after riveting operation. (12 marks)

ii) The number of rivets completed per minute. (4 marks)

See next page

9 a) Figure Q9 shows a uniform rod AB of length 3*a* and mass *m* hinged at A and supported by a spring of stiffness *k* at B. A mass *m* is attached to the rod at a distance *a* from A and a dashpot having a damping constant *b* is attached at a distance 2*a* from A.

Assuming the system to be under damped,

i) Derive the equation of motion. (4 marks)

ii) Obtain expressions for the damped natural frequency and the logarithmic decrement. (10 marks)

b) If m = 20 kg, k = 1000 N/m and b =100 Ns/m, determine

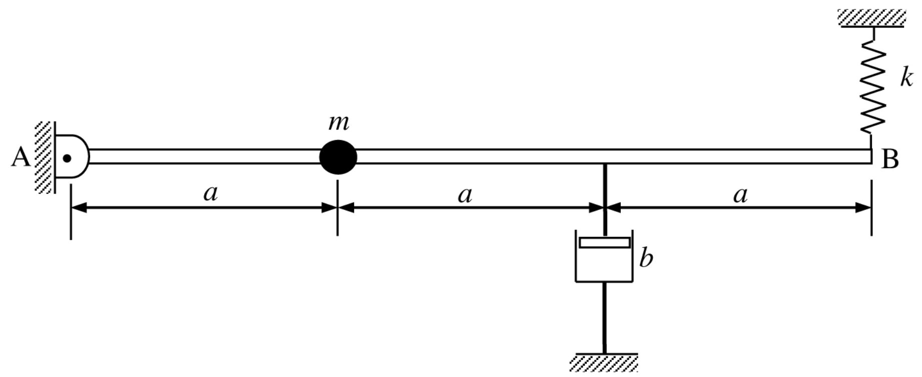

Figure Q9

i) Frequency of damped vibrations. (3 marks)

ii) The ratio of successive amplitudes on the same side of the equilibrium position. (3 marks)