City& Guilds

9210-130 JUNE 2014
Level 6 Graduate Diploma in Mechanical Engineering
Mechanics of machines and strength of materials

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Tuesday 24 June 2014 **09:30 – 12:30**	**You should have the following for this examination** • one answer book • non-programmable calculator • pen, pencil, drawing instruments	**The following is included within the attached booklet** • Worksheets for Q1, Q2, Q5, Q8

General instructions
• This paper consists of **nine** questions over two sections A and B.
• Answer **five** questions, at least **two** questions from each section.
• A non-programmable electronic calculator may be used but candidates **must** show sufficient steps to justify their answers.
• Drawings should be clear, in good proportion and in pencil. Do not use red ink.
• All questions carry equal marks. The maximum marks for each section within a question are shown.

Section A

1   a)   Define briefly the terms principal stress and principal plane in a two dimensional
         stress system.   (5 marks)
    b)   i)   Draw the Mohr's stress circle for direct stresses of 65 MN/m² (tensile) and
               35 MN/m² (compressive) and estimate the magnitude and direction of the
               resultant stresses on planes making angles of 20° and 65° with the plane of
               the first principal stress.   (7 marks)
         ii)   Find the normal stresses on these planes.   (4 marks)
         iii) Find the tangential stresses on these planes.   (4 marks)
    Detach worksheet WSQ1 from the question paper, write your name, centre number
    and candidate number in the spaces provided and enclose it with your answer book.

2   Figure Q2 shows a loaded beam.
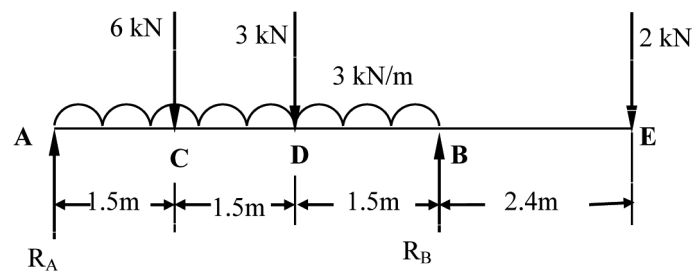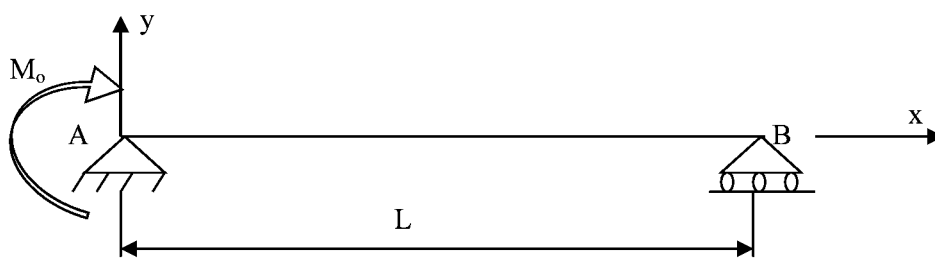

Figure Q2

    a)   Draw the shear force and bending moment diagrams for the beam giving
         important numerical values.   (16 marks)
    b)   Hence determine the position and the magnitude of the maximum bending
         moment in the beam.   (4 marks)
    Detach worksheet WSQ2 from the question paper, write your name, centre
    number and candidate number in the spaces provided and enclose it with
    your answer book.

3   a)   Derive the equation of the deflection curve for a simple beam AB loaded by a
         couple M_0 at the support A as shown in Figure Q3.   (12 marks)
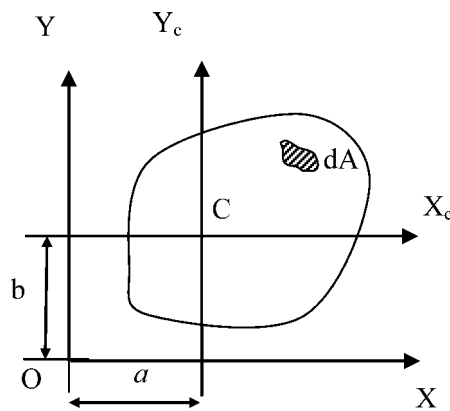

Figure Q3

    b)   Hence show that the maximum deflection (δ_{max}) of the beam is   (8 marks)

$$\delta_{max} = \frac{M_O L^2}{9\sqrt{3}EI}$$

4 a) Show that the second moment of area (I_{OX}) of any area (A) with respect to any axis (OX) shown in Figure Q4a, is the sum of second moment of area about a parallel centroidal axis (I_{CX_C}) and product of the same area with the square of the distance (b) between the two axes: (8 marks)
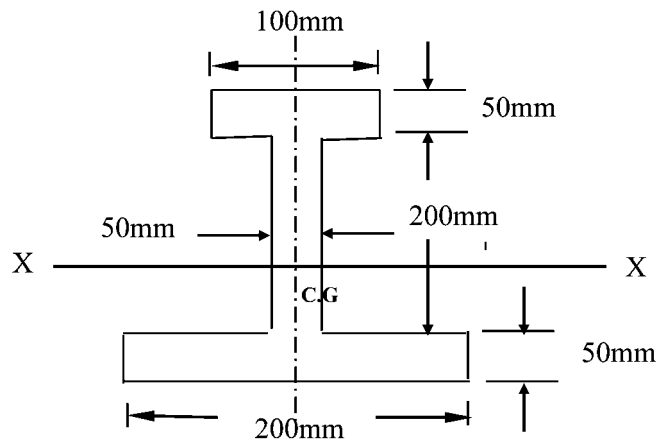
$$I_{OX} = I_{CX_C} + b^2 A$$

Figure Q4a

b) Figure Q4b shows an asymmetrical I-section. Determine the second moment of area about the axes X-X passing through its center of gravity (C.G). (12 marks)

Figure Q4b

See next page

Section B

5 a) Figure Q5a shows a link OA rotating about O with an angular velocity ω and an angular acceleration α. B is a point on link OA such that OB = r. Determine the magnitude and direction of the absolute acceleration of B. (4 marks)
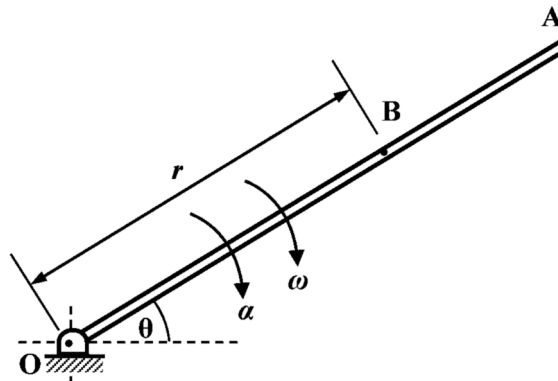

Figure Q5a

b) In the mechanism shown in Figure Q5b, the crank OA rotates about the fixed point O with an angular velocity ω and an angular acceleration α. The link AB connects the pin joint A and the piston B which is constrained to move along XX. The lengths of the links are OA = 80 mm, AB = 160 mm. ω = 10 rad/s (clockwise) and α = 25 rad/s^2 (clockwise).
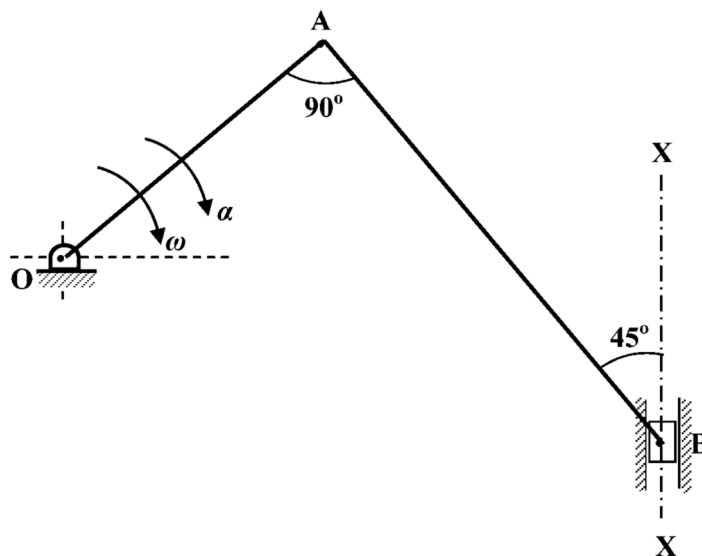
Figure Q5b

For the configuration shown, determine;
i)   velocity of piston B, (6 marks)
ii) angular velocity of link AB, (2 marks)
iii) acceleration of piston. (8 marks)

Detach worksheet WSQ5 from the question paper, write your name, centre number and candidate number in the spaces provided and enclose it with your answer book.

4

6   a)   State and prove the belt friction formula for a flat belt with negligible mass.   (6 marks)
    b)   Figure Q6 shows the application of a band brake to a circular drum of diameter
         120 mm. The two ends of the flat belt are connected to the cranked lever ABCD
         which pivots about B. The angle of lap is 210° and the coefficient of friction
         between the belt and the pulley is 0.20. The braking force P is applied at point D
         as shown.
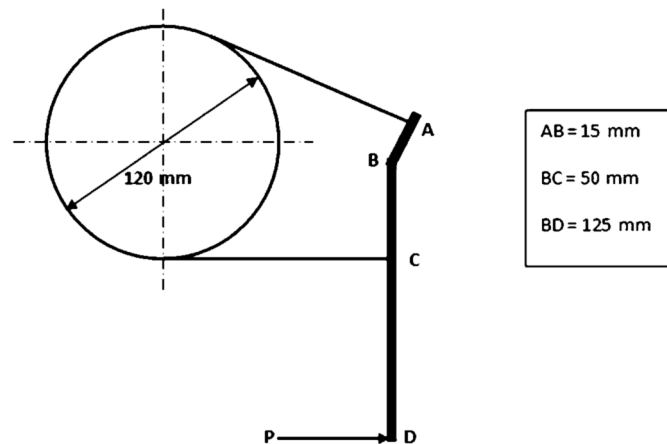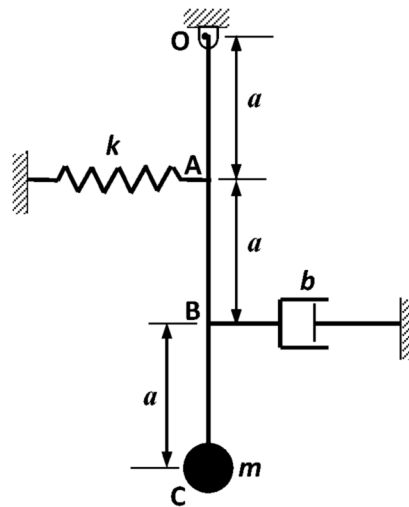

Figure Q6

         Determine the magnitude of P necessary to provide a braking torque of 36 Nm
         on the drum when the drum is rotating,
         i)   Clockwise,   (8 marks)
         ii)   Anticlockwise.   (4 marks)
         iii) Comment on the difference between the forces found in part i) and
               part ii) above.   (2 marks)

7   a)   Distinguish between the functions of the governor and the flywheel of an engine.   (4 marks)
    b)   An engine develops an output torque of $(1600 + 360 \sin 3\theta)$ Nm, where θ is the
         crank angle measured from some datum. If the engine runs at a mean speed of
         240 rev/min against a constant resisting torque, determine;
         i)   the power developed by the engine,   (4 marks)
         ii)   the moment of inertia of a flywheel which will limit the fluctuation of speed
               to ± 1.2% of the mean speed,   (8 marks)
         iii) the angular acceleration of the flywheel when $\theta = 45°$.   (4 marks)

8   a)   Explain the terms 'static balance' and 'dynamic balance'.   (4 marks)
    b)   Three masses P, Q and R are attached to a rotating shaft and their mass centres
         are 250 mm, 400 mm and 150 mm respectively from the axis of rotation. The
         masses P, Q and R are 16 kg, 12.5 kg and 20 kg respectively. The angular positions
         of Q and R are 60° and 135° respectively from P measured in the same direction.
         The axial distance between the planes of rotation of P and Q is 1.5 m while that
         between Q and R is 2.0 m. Two balance masses, each with a mass centre of 200 mm
         from the axis of rotation, are to be fitted in planes midway between P and Q, and
         Q and R.
         Determine the following:
         i)   Magnitude of each balance mass.   (8 marks)
         ii)   Angular position of each balance mass with respect to P.   (8 marks)
    Detach worksheet WSQ8 from the question paper, write your name, centre number
    and candidate number in the spaces provided and enclose it with your answer book.

9   Figure Q9 shows a rod OC of negligible mass, pivoted at O and carrying a mass m at end C. A spring of stiffness k and a dashpot having a damping constant b are attached to the rod at A and B respectively. The system executes vibration in the vertical plane.

Figure Q9

   a) Derive the equation of motion for small oscillations of the system.   (4 marks)
   b) Obtain expressions for the natural frequency and damped natural frequency of the system.   (10 marks)
   c) If the dashpot is replaced by a spring of stiffness $2k$, show that the natural frequency (Ω) of the system is given by $\Omega = \sqrt{\dfrac{k}{m} + \dfrac{g}{3a}}$.   (6 marks)