CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY MARINE ENGINEER OFFICER

STCW 78 as amended MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-31 - APPLIED MECHANICS

TUESDAY, 19 JULY 2022

1315 - 1615 hrs

Materials to be supplied by centre

Candidate's examination workbook Graph paper

Examination paper inserts

Notes for the guidance of candidates:

1. Examinations administered by the SQA on behalf of the Maritime & Coastguard Agency.
2. Candidates should note that 96 marks are allocated to this paper. To pass, candidates must achieve 48 marks.
3. Non-programmable calculators may be used.
4. All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

Maritime & Coastguard Agency

SQA

APPLIED MECHANICS

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. TWO blocks with the same weight are released simultaneously from rest on a plane inclined 25° above the horizontal. There is a linear displacement of 30 m in the direction of the slope between the upper block and the lower block when they are released from rest.

   The coefficient of friction between the upper block and the plane is 0.15, whilst the coefficient of friction between the lower block and the plane is 0.25.

   Calculate the time taken for the upper block to close the 30 m displacement between the blocks. (16)

2. A simply supported pin-jointed framework is loaded as shown in Fig Q2.

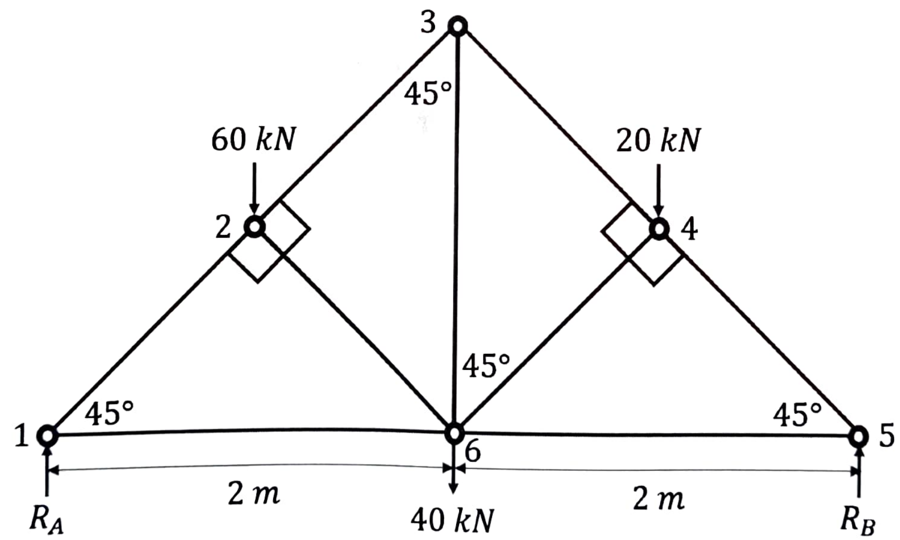

Fig Q2

   Determine EACH of the following:

   (a) the magnitude and nature of the force in the member connected by nodes 2 and 6; (14)

   (b) the magnitude and nature of the force in the member connected by nodes 4 and 6. (2)

3. Crank OA rotates anti-clockwise at a constant angular velocity of 80 rpm driving the chain bar mechanism shown in Fig Q3. Crank OA is 130 mm, crank BC is 230 mm, bar AC is 340 mm and connecting rod CD is 620 mm in length respectively.

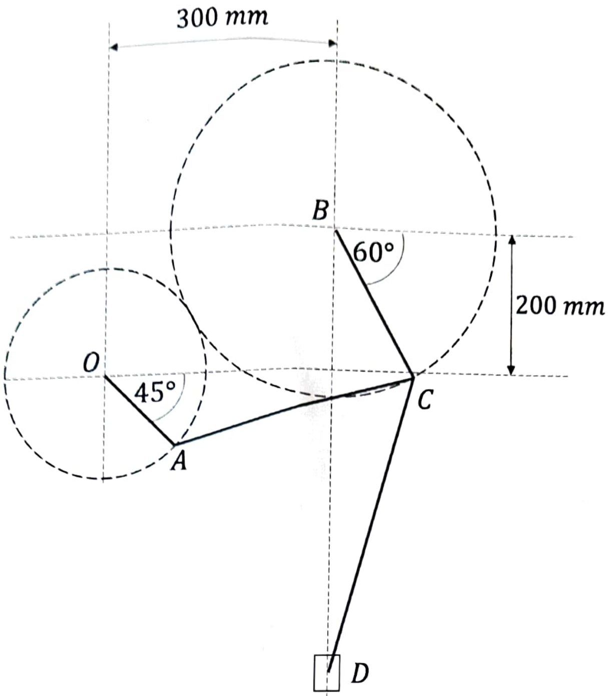

Fig Q3

Determine the angular velocities of connecting rod CD and bar AC. (16)

4. A 500 mm diameter pulley is driven at 400 rev/min by a belt 100 mm wide by 20 mm thick with a safe working stress of 400 kN/m^2. The tension in the tight side of the belt is 2.5 times the tension in the slack side and the coefficient of friction between contact surfaces is 0.35.

Calculate EACH of the following:

(a) the power input at 85% efficiency; (10)

(b) the angle of lap in degrees using the relationship:

$$\frac{F_1}{F_2} = e^{\mu\theta}$$

where: F_1 = force in the tight side of the belt.
F_2 = force in the slack side of the belt.
μ = the coefficient of friction.
θ = the angle of lap in radians. (6)

5. An 18 tonne truck is pulled up a 1 in 40 incline (sine) by a wire wound around a winch drum. The effective length of the incline is 420 m and the tractive resistance to motion is a constant 100 N/tonne. The 2 tonne winch drum is 1.8 m in diameter, has an 800 mm radius of gyration and a constant bearing friction of 100 Nm. The tension in the wire must not exceed 12 kN.

Calculate EACH of the following:

(a) the shortest time in which the truck can ascend the incline starting from rest; (6)

(b) the average power of the winch drum during the ascent. (10)

6. A conical friction clutch has a semi-apex angle of 45° and transmits torque at an effective diameter of 75 mm. The axial thrust applied to the clutch is 400 N and the coefficient of friction between contact surfaces is 0.4. The clutch connects an electric motor running at 1512 rpm to a flywheel of mass 20 kg with an 85 mm radius of gyration.

Calculate EACH of the following:

(a) the time taken for the flywheel to reach maximum speed from rest with a transmission efficiency of 75%; (14)

(b) the angular impulse transmitted to the flywheel during acceleration. (2)

7. A close coiled helical spring is required to have an overall stiffness of 90 kN/m with SIX coils such that ratio of the mean diameter to the wire diameter is 5:1.

Calculate EACH of the following:

(a) the mean diameter of the coils; (8)

(b) the maximum shearing stress for a deflection of 3 mm. (8)

Note: Modulus of Rigidity for the spring wire = 80 GN/m^2

8. The overall length of a stepped rod is 250 mm with 100 mm of the rod having a diameter of 20 mm and the remainder a diameter of 30 mm. At a temperature of 120°C the rod is free of stress. It is then cooled to 20°C and contraction is restricted to 0.25 mm axially.

Calculate the maximum stress in the rod caused by cooling. (16)

Note: Modulus of Elasticity for the rod material = 200 GN/m^2
Coefficient of linear expansion for the rod material = 12 x 10^{-6} per °C

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9. A 2 m long solid, square section steel column has a 2500 mm^2 cross-sectional area and is fixed at both ends to support a compressive axial load. A 100 mm long test specimen of the column material extends 0.16 mm when axially loaded to its yield stress.

Using Euler's relationship for a column with both ends fixed:

$$P_C = \frac{4\pi^2 EI}{L^2}$$

where: P_C = Euler's critical load
E = Young' modulus
I = the 2nd moment of area
L = the effective length

Calculate EACH of the following:

(a) the maximum load the column can support for a safety coefficient of 4; (12)

(b) the slenderness ratio of the column. (4)

Note: Yield stress for the column material = 320 MN/m^2