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, 18 JULY 2023

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. A simply supported beam carries a load which uniformly varies from 0 kN/m at the left hand edge to 15 kN/m at the right hand edge as shown in Fig Q1.

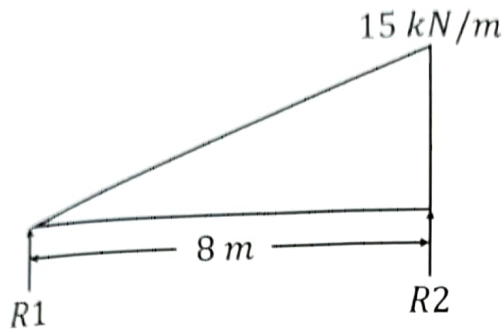

Fig Q1

Calculate the magnitude and position of the maximum bending moment. (16)

2. A 20 kg stepped pulley system supports TWO masses on separate cables as shown in Fig Q2. The outer pulley has a 0.8 m diameter, the inner pulley a 0.6 m diameter, the radius of gyration is 0.65 m and frictional torque at the pulley bearings is a constant 0.8 Nm. Mass A is 30 kg and is at rest on horizontal ground when the system is released. Mass B is 45 kg and drops vertically from a height of 1 m.

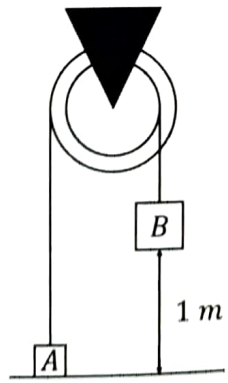

Fig Q2

Calculate the velocity of mass B at the instant it makes contact with the horizontal. (16)

3. The drive shaft of an engine rotates at a constant speed of 300 rpm. The stroke of the engine is 1040 mm and the length of the connecting rod is 1700 mm.

When the crank is 45° past top dead centre the instantaneous torque transmitted is 68 kNm.

Determine EACH of the following:

(a) the reaction force at the guide face; (10)

(b) the relative velocity between crank and connecting rod. (6)

4. In a set of sheer legs both front legs are 10 m long and are fixed 12 m apart on a horizontal base. The back stay of the system is 15 m long and is fixed on the same base at 10 m measured linearly from the centre of the front legs shown in Fig Q4. The mass suspended by the system is 15.29 tonnes.

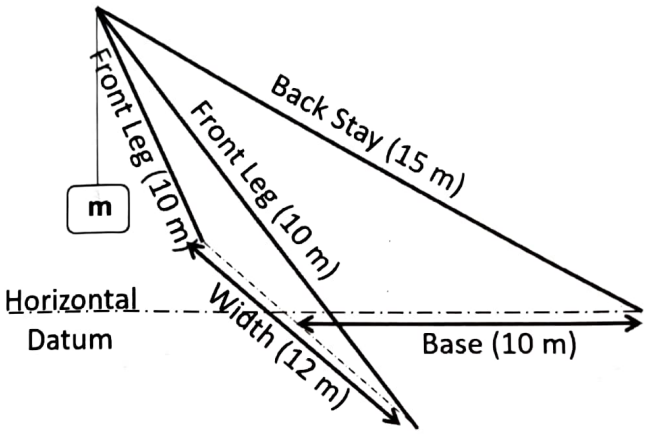

Fig Q4

Determine EACH of the following:

(a) the magnitude and nature of the force in the back stay; (10)

(b) the magnitude and nature of the force in each of the front legs. (6)

5. A 2.8 m long rectangular box section cantilever beam is fabricated using 14 mm thick steel plate so that the cross-section has a maximum width of 100 mm and a maximum depth of 150 mm. The beam supports a concentrated load of 2400 N at its free end and a uniformly distributed load of 360 N/m over its entire length. Using the deflection relationships:

$$\delta = \frac{WL^3}{3EI} \quad and \quad \delta = \frac{\omega L^4}{8EI}$$

where: δ = beam deflection
W = concentrated load
ω = concentrated load

Calculate EACH of the following:

(a) the minimum total deflection of the beam at its free end; (8)

(b) the maximum bending stress induced at the wall support. (8)

Note: Modulus of Elasticity for steel = 206 GN/m²

6. An engine room lift-cage has a mass of 1 tonne. The hoist wire is wound around a motor driven drum, with the cage on one end and a balance mass of 0.8 tonne suspended from the other end. The 700 mm diameter drum has a mass of 250 kg and a radius of gyration of 450 mm. The maximum tension in the hoist wire during operation cannot exceed 12 kN.

Calculate EACH of the following:

(a) the driving torque required at the drum for this acceleration; TD (12)

(b) the minimum output power of the motor when raising the lift-cage at a constant velocity of 3 m/s. (4)

7. A 125 mm diameter solid steel bar 100 mm in length supports a 275 kN compressive axial load. The line of action for the axial load is offset by 12 mm from the centre of the bar.

Calculate EACH of the following:

(a) the maximum stress within the bar; (10)

(b) the percentage change in length of the bar induced by tensile stress. (6)

Note: Modulus of Elasticity for steel = 207 GN/m²

8. In a tensile test experiment a single core cable with a 5 mm diameter central steel wire encased by 6 alloy wires that are each 2.5 mm in diameter is found to extend 0.85 mm per metre when subjected to a load of 10 kN.

During a lifting operation the mounting supporting a mass this cable is attached to collapses and the mass freely falls a vertical distance of 30 mm causing an instantaneous extension of 2.8 mm in a 4 m length of cable.

Calculate EACH of the following:

(a) the equivalent Modulus of Elasticity for the single core cable; (6)

(b) the magnitude of the falling mass. (10)

9. A flat plate clutch with 100 mm internal diameter and 225 mm external diameter is fully engaged with an axial pressure of 125 kN/m^2. The coefficient of friction between the contact surfaces is 0.41 and the transmission efficiency is 85%. The cylindrical alloy motor shaft has an internal diameter of 70 mm and a wall thickness of 5 mm.

Calculate the shearing stress within the motor shaft during operation. (16)