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 MARCH 2024

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 ships leave the same port at the same time. Ship A travels at 27° North of West at a constant velocity of 18 knots whilst ship B travels 15° South of West at a constant velocity of 14 knots.

Calculate EACH of the following:

(a) the magnitude and direction of the relative velocity of ship A in relation to ship B; (10)

(b) the absolute distance covered by both ships when they are 75 nautical miles apart if both hold their original course and velocity. (6)

2. A 10 kg block is at rest upon a smooth inclined plane that is free to rotate around the y-axis. It is connected to axis of rotation by a cable that is 2 m in length as shown in Fig Q2.

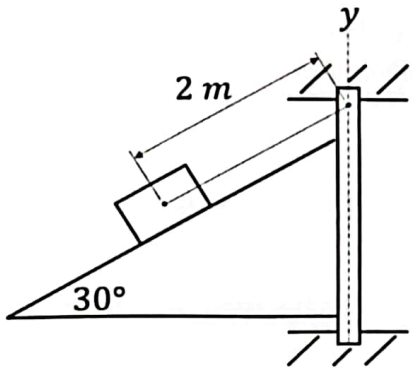

Fig Q2

Calculate EACH of the following:

(a) the tension in the cord at an angular velocity of 2 rad/s; (6)

(b) the minimum angular velocity that will cause the block to lift from the plane. (10)

[OVER

3. A 1000 kg pile driver freely falls vertically and drives a 180 kg post into horizontal ground to a vertical depth of 700 mm with no rebound. The average resisting force of the ground is 48 kN.

Calculate EACH of the following:

(a) the initial vertical height of the pile driver above the post; (14)

(b) the percentage kinetic energy loss on impact. (2)

4. A 5 m long tube has an external diameter of 13 mm and a 1.5 mm wall thickness.

It is coiled into a helical spring with a mean diameter of 150 mm. The spring is positioned within a cylinder to oppose the motion of a 200 mm diameter piston. During operation the effective pressure on the piston is 0.105 bar.

Calculate EACH of the following:

(a) the angle of twist in the spring material at this effective pressure; (14)

(b) the corresponding strain energy stored within the spring. (2)

Note: Modulus of Rigidity for the spring material = 103 GN/m²

5. A projectile is launched at an angle of 60° above the horizontal from a position 300 m above level ground. The initial velocity of the projectile is 100 m/s.

Calculate EACH of the following:

(a) the magnitude and direction of the projectile's velocity 12 seconds after it is launched; (8)

(b) the horizontal range of the projectile from launch site to impact site. (8)

6. A 75 mm internal diameter hollow shaft drives a 75 mm external diameter solid shaft at a constant rotational speed of 260 rpm via a diametrically fitted shear pin. Both shafts have a modulus of rigidity of 100 GN/m^2 and the output power is 12 kW. The maximum allowable shear stress within the pin is 70 MN/m^2.

Calculate EACH of the following:

(a) the minimum diameter of the shear pin; 10.3 mm (8)

(b) the minimum wall thickness of the hollow drive shaft if the maximum angle of twist per metre must not exceed 0.1°. (8)

6.01 mm

7. A gearing consists of a 28 tooth pinion on the solid input shaft driving an 84 tooth wheel on the solid output shaft. The 75 mm diameter input shaft rotates at 300 rpm and its shear stress is restricted to 13.9 MN/m^2. The output shaft is 100 mm in diameter and the efficiency of the gearing is 90%.

Calculate EACH of the following:

(a) the input power; (8)

(b) the output shear stress. (8)

8. A screwed steel rod has 5 threads per centimetre and an effective cross-sectional area of 1000 mm^2. It is placed inside a bronze tube 280 mm long, 52 mm external diameter that is 4 mm thick. Nuts at each end of the screwed rod are made finger tight against the tube. ONE nut is then tightened up an additional quarter of a turn.

Calculate EACH of the following:

(a) the stress in the bronze tube; (12)

(b) the strain energy stored in the screwed steel rod. (4)

Note: Modulus of Elasticity for steel = 200 GN/m^2
Modulus of Elasticity for bronze = 120 GN/m^2

9. An I-beam is fabricated from 10 mm thick steel plate so that the external breadth is 110 mm and the external depth is 120 mm. It is then simply supported and loaded with a linearly varying load spanning its entire length as shown in Fig Q9.

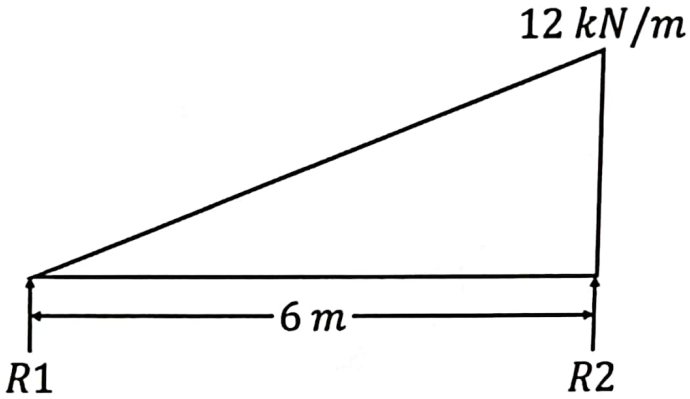

Fig Q9

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

3.464 m
From Left end

221.518 x 10^6 N/m^2