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, 16 JULY 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. The mass centre of a solid 25 cm diameter cylinder weighing 500 N is initially rolling without slipping at 10 m/s up a slope inclined at an angle of 20° above the horizontal.

   Calculate the time it will take to reach its highest point of travel. (16)

2. A 220 mm long steel bolt has a 30 mm diameter for 150 mm of its length and a 25 mm diameter for the remainder of its length. The bolt is tightened so that there is a total extension of 0.4 mm.

   Calculate EACH of the following:

   (a) the tensile force within the bolt; (6)

   (b) the strain energy stored within the bolt. (10)

   Note: Modulus of Elasticity for the spring bolt material = 190 GN/m²

3. A cam operated valve moves vertically with simple harmonic motion. The camshaft speed is 740 rpm and the valve is opened and closed during 140° of cam rotation. The valve travel is 90 mm, its mass is 1.7 kg and the valve opens vertically downwards against a spring.

   Calculate EACH of the following:

   (a) the minimum spring constant required at full opening to ensure that the valve remains in contact with the cam profile; (10)

   (b) the percentage difference in valve velocity between maximum and a 20 mm displacement from the mid-travel position. (6)

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4. A four-stroke single cylinder engine produces 260 kW at 600 RPM with a 15% energy fluctuation of the work done per cycle. A flywheel is to be fitted to stabilise the speed for power generation so that the frequency is 60 ± 0.15 Hz.

Calculate the diameter of a solid flywheel that is 300 mm thick. (16)

Note: Density of the flywheel material = 7800 kg/m³

5. A 2.5 tonne pile driver falls vertically onto a 500 kg pile driving it 325 mm into horizontal ground against an average resistance force of 285 kN.

Calculate EACH of the following:

(a) the vertical height the pile driver falls; (10)

(b) the percentage of energy lost during impact. (6)

6. A 450 mm internal diameter pipe is made of mild steel plate 25mm thick. When running full with diesel fuel oil the maximum stress due to bending is restricted to 80 MN/m². The pipe is to be simply supported at its TWO end points.

Calculate the maximum permissible length of pipe. (16)

Note: Density of diesel fuel oil = 860 kg/m³
Density of mild steel = 7860 kg/m³

7. A winch motor drives a pinion with 120 teeth. The friction at the motor bearings is a constant 20 Nm. The pinion meshes with a gear wheel that has 360 teeth which drives a 120 mm diameter shaft. The horizontal shaft supports a winch drum with an effective diameter of 420 mm and the assembly is balanced in bearings with a coefficient of friction of 0.12 as shown in Fig Q7.

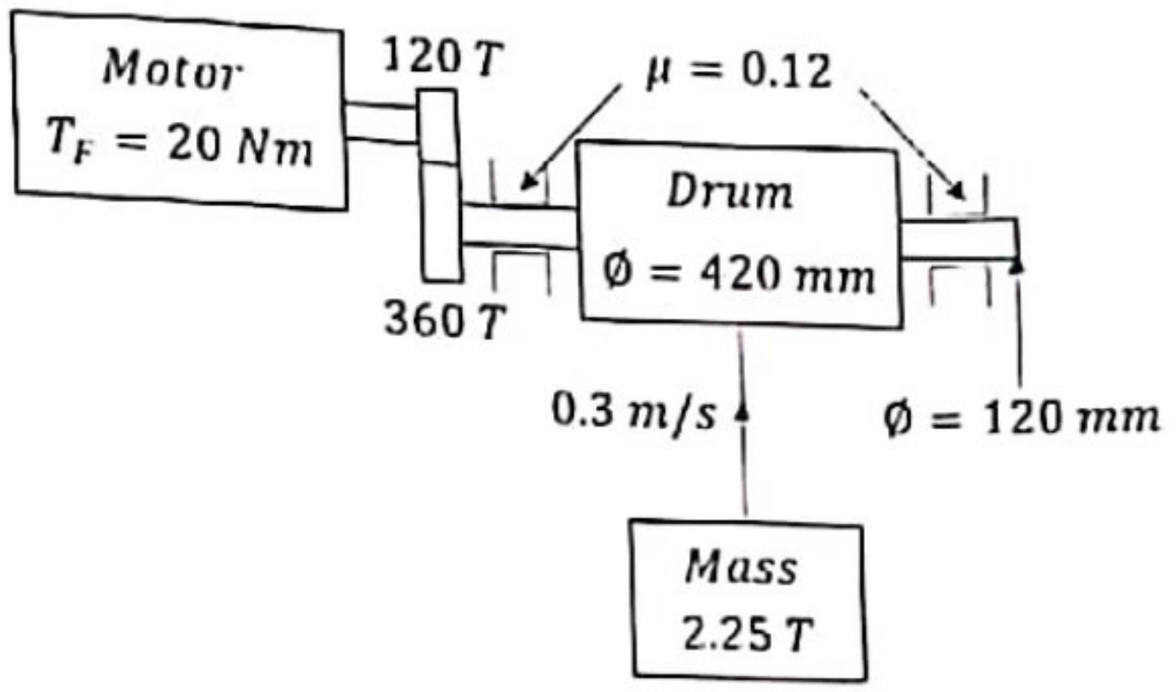

Fig Q7

The winch drum raises a mass of 2.25 tonnes at a constant vertical velocity of 0.3 m/s.

Calculate the minimum input power for an 86% efficient motor. (16)

8. A sphere rolls without slipping up a smooth plane inclined 25° above the horizontal with an initial velocity of 8 m/s.

Calculate EACH of the following:

(a) the maximum linear displacement of the sphere up the plane; (10)

(b) the time taken for the sphere to roll 5 m back down the plane from this point. (6)

Note: Moment of Inertia for a sphere $= \frac{2}{5}mr^2$

9. A 25 kg wheel and shaft runs in horizontal bearings. The shaft is 60 mm in diameter and has a cord wound around it with a hook at its free end. A mass of 0.7 kg hanging from the hook is just sufficient to overcome friction whilst a 4.5 kg mass falls 1.8 m in 10 seconds from rest.

Calculate the minimum torque transmitted to the wheel and shaft by the falling 4.5 kg mass. (16)