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, 28 MARCH 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 6 m long ramp onto a vehicle deck has a mass of 1.5 tonnes and is suspended at 20° below the horizontal by TWO 16 mm diameter cables as shown in Fig Q1. The cables are attached 2 m away from the free and of the ramp and are angled at 45° to the ramp. The ramp is attached to the vessel by TWO hinges fitted with 20 mm diameter pins.

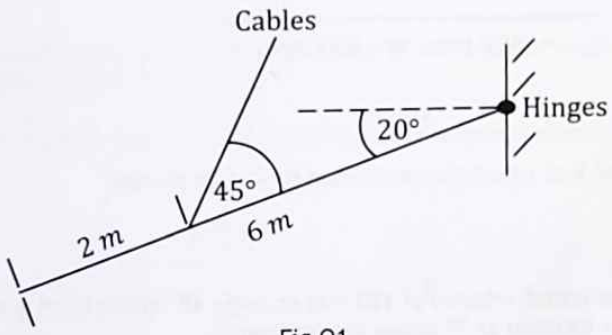

Fig Q1

Calculate EACH of the following:

(a) the tensile stress in each of the cables as the lifting process is initiated; (8)

(b) the shearing stress within each of the hinge pins at the same moment. (8)

2. A ball is suspended from a 0.8 m wire attached to a pivot point 2 m above level ground. The ball rotates at constant speed as a conical pendulum where the wire forms an angle of 30° with the vertical axis of rotation.

Calculate the horizontal displacement of the ball at the instant it hits the ground if the wire suddenly breaks. (16)

3. A rigid bar weighing 5 kN is supported by THREE springs with spring constants S1 = 30 kN/m, S2 = 18 kN/m and S3 = 12 kN/m that are equal in length when unloaded. A 20 kN point load is to be placed to the left of spring S2 so that the bar is held horizontal as shown in Fig Q3.

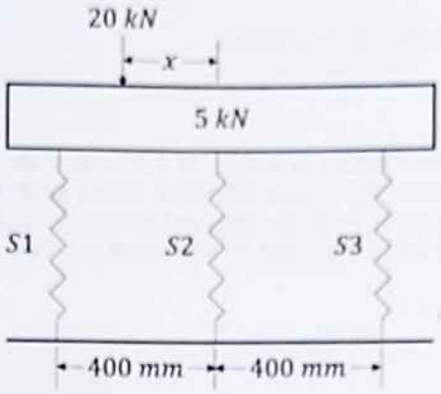

Fig Q3

Calculate the distance x at which the point load should be placed. (16)

4. A flare is fired with an initial velocity of 180 m/s at angle 40° above level ground at the base of a slope inclined at 5° above the horizontal.

Calculate EACH of the following:

(a) the maximum height of the flare above the slope when the flare reaches its maximum height; (10)

(b) the time of flight from this point until impact. (6)

5. A 3.2 m long alloy tube has an external diameter of 18 mm and a wall thickness of 2.5 mm. A compression of 1.1 mm is recorded when an axial load of 4.5 kN is applied to the tube. 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 length

Calculate Euler's critical load for the tubular alloy column using a safety coefficient of 1.8. (16)

6. In the shaper mechanism shown in Fig Q6, which is not to scale, crank *BC* rotates at 5 rad/s counter clockwise.

Slider C is free to move along link AD which imparts horizontal motion to slider E.

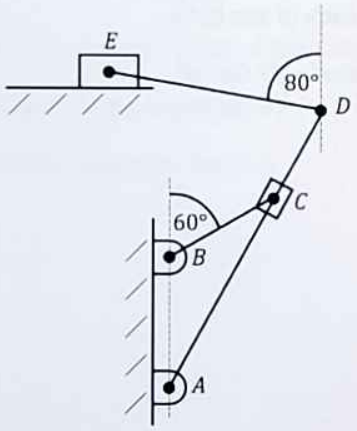

Fig Q6

Links AD, BC and DE are 7 cm, 2.5 cm and 5 cm in length respectively and the distance between axes of rotation A and B is 3 cm.

Determine the velocity of slider E. (16)

7. A vessel with a displacement of 50 tonne is being hauled up an inclined dry dock by a steel cable running parallel to the dry dock. The steel cable is wound onto a power driven capstan drum that has a mass of 4 tonnes, effective diameter of 3 m and a radius of gyration of 1.1 m. It is driven by an electric motor via an 87% efficient reduction gearbox of ratio 1:48.

   The dry dock has an incline of 1:40 (sine), and the coefficient of friction between contact surfaces is 0.6 and the velocity of the vessel increases uniformly from 0.1 m/s to 0.2 m/s in 20 seconds during the operation.

   Calculate the minimum torque transmitted to the capstan by the motor. (16)

8. TWO identical hollow steel shafts of are connected by a flanged coupling with eight 67 mm diameter steel bolts evenly spaced on a pitch circle diameter of 560 mm.

   The external diameter of the shafts is 350 mm and the maximum shear stress in the shafts and bolts is of equal magnitude. The length of the drive shaft is 1.5 m and the angle of twist is 0.25°.

   Calculate the shearing stress in each of the bolts. (16)

   Note: Modulus of Rigidity for steel = 77 GN/m²

9. Blocks A and B are supported by a pair of identical massless, frictionless pulleys as shown in Fig Q9. The upper pulley is fixed to the same horizontal surface as Block B which is secured by a fixed length of cable running over both pulleys. Block A is suspended by a fixed length cable from the lower pulley which can move freely. Block A has a mass of 90 kg, block B has a mass of 80 kg and the system is initially at rest.

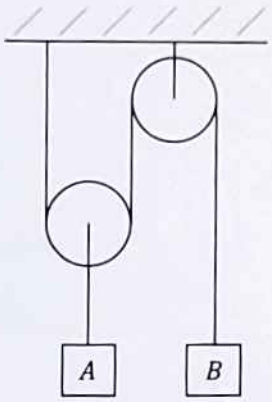

Fig Q9

Once the system is released calculate EACH of the following:

(a) the tension in the cable supporting block B; (14)

(b) the tension in the cable supporting block A. (2)