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, 10 DECEMBER 2019

1315 - 1615 hrs

Materials to be supplied by examination centres

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

All formulae used must be stated and the method of working and all intermediate steps must be made clear in the answer.

1. The effective pressure on a 400 mm diameter piston is 1.1 MN/m^2 when the crank is 32° beyond top dead centre. The stroke of the engine is 900 mm, the connecting rod is 1500 mm in length and the coefficient of friction for the lubricated crosshead guide is 0.025.

   Calculate EACH of the following:

   (a) the magnitude of the instantaneous torque; (12)

   (b) the magnitude of the instantaneous force to overcome guide friction. (4)

2. A 2.5 tonne mass is hauled up a 15° incline by a cable running parallel to the incline at a constant velocity of 0.3 m/s. The cable passes over a 500 mm diameter winding drum driven by an electric motor with a 25:1 reduction gearing that is 76% efficient. The friction angle between contact surfaces is constant at 13°.

   Calculate EACH of the following:

   (a) the torque on the winding drum; (10)

   (b) the motor power; (3)

   (c) the motor speed in rpm. (3)

3. A body is fired vertically upwards from ground level with an initial velocity of 36 m/s. At the same instant that a second body is allowed to fall from rest from a height of 170 m above ground level.

Calculate EACH of the following:

(a) the elapsed time to the point at which the bodies pass each other; (3)

(b) the height above the ground at which they meet; (2)

(c) the difference between the velocities at which the bodies hit the ground; (5)

(d) the difference in time between each body hitting the ground. (6)

4. An electric motor drives a pump through a reverted gear train as shown in Fig Q4. All of the gears have the same pitch and the train has a velocity ratio of 24. Transmission efficiency is 80% developing a pump output of 80 kW at 125 rpm.

Calculate EACH of the following:

(a) the number of teeth in gears A and B; (8)

(b) the output torque of the motor; (6)

(c) the rotational speed of gear B. (2)

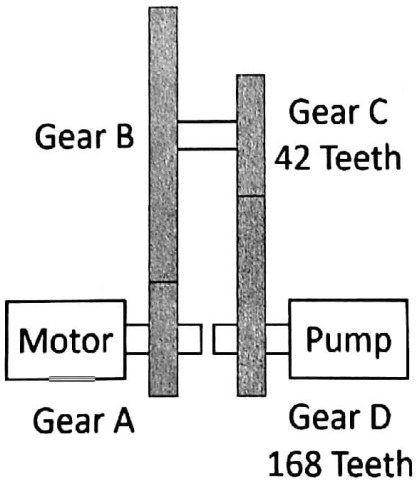

Fig Q4

5. A 125 kg stepped flywheel supports two masses on separate cables as shown in Fig Q5. The radius of gyration for the flywheel is 0.9 m and the bearing torque is a constant 20 Nm.

Calculate EACH of the following:

(a) the angular acceleration of the drum when released; (8)

(b) the kinetic energy of the system after two revolutions. (8)

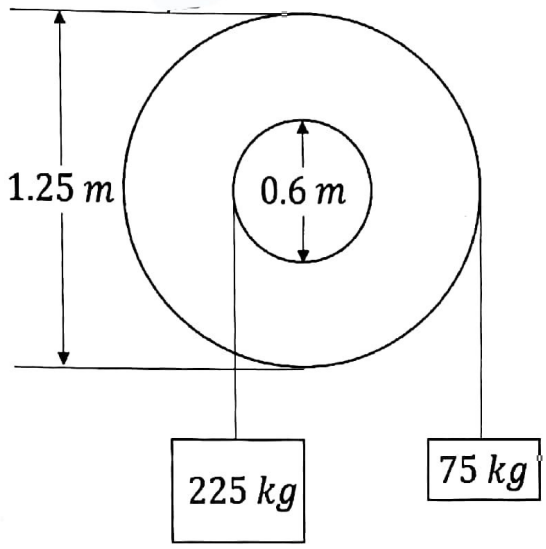

Fig Q5

6. A cage of mass 1000 kg is lowered 1500 m down a mine shaft. During the descent it accelerates uniformly from rest for 10 s, moves at constant velocity for a further 50 s before uniformly decelerating to rest in 15 s.

Calculate EACH of the following:

(a) the cable tension during the initial 10 s; (10)

(b) the cable tension during the final 15 s; (4)

(c) the vertical displacement of the lift whilst decelerating. (2)

7. A single cylinder 4 stroke engine develops 15 kW at an average speed of 200 rpm. The energy fluctuation per cycle is 75% of the total when the speed variation is restricted to $\pm$ 2.5% by a flywheel with a radius of gyration of 0.9 m.

Calculate the mass of the flywheel. (16)

8. A steel bar is 1.5 m long and 75 mm diameter. An axial hole of 50 mm diameter is to be drilled at one end so that the extension of the hollow section is twice that of the solid section under load.

Calculate EACH of the following:

(a) the length of the hollow section; (10)

(b) the extension of the hollow section when a tensile load of 27.5 kN is applied. (6)

Note: Modulus of Elasticity for steel = 200 GN/m²

9. A 1.6 m diameter cast iron cylinder cover is secured by 16 steel bolts which are each under a tensile stress of 18 MN/m². Each bolt is 25 mm in diameter and the stress in the cylinder cover is evenly distributed due to bolt tension.

Calculate EACH of the following:

(a) the stress in the cylinder cover; (8)

(b) the temperature rise which will reduce the stress in the cylinder cover and bolts to zero. (8)

Note: *Modulus of Elasticity for steel* = *200 GN/m²*
Modulus of Elasticity for cast iron = *100 GN/m²*
Coefficient of linear expansion for steel = *12 x 10^{-6} / °C*
Coefficient of linear expansion for cast iron = *11 x 10^{-6} / °C*