CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY –
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
ON BEHALF OF THE
MARITIME AND COASTGUARD AGENCY

STCW 78 as amended CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-31 – APPLIED MECHANICS

TUESDAY, 18 OCTOBER 2016

1315 - 1615 hrs

Examination paper inserts:

Notes for the guidance of candidates:

1. Non-programmable calculators may be used.
2. All formulae used must be stated and the method of working and ALL intermediate steps must be made clear in the answer.

Materials to be supplied by colleges:

Candidate's examination workbook
Graph paper

APPLIED MECHANICS

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. A starter motor with 10 teeth engages on a flywheel rim having 120 teeth. The efficiency of this gearing is 96%.

   The starter motor rotor and pinion mass is 2 kg with a radius of gyration of 0.1 m, whilst the engine has a rotational mass of 800 kg with a radius of gyration of 0.6 m. To start the engine, an engine speed of 240 rev/min is required within 6 seconds.

   Calculate EACH of the following:

   (a) the angular acceleration required by the starter motor; (4)

   (b) the torque required by the starter motor; (10)

   (c) the average power required by the starter motor during the start period. (2)

2. A vehicle travels around a bend on a banked track at a constant speed of 24 m/s and at an effective radius of 96 m. The vehicle has a wheel base width of 1.2 m and a centre of gravity 1.4 m above the track surface.

   Calculate EACH of the following:

   (a) the minimum angle of banking required to prevent the vehicle from overturning; (8)

   (b) the minimum coefficient of friction between the track and the vehicle to prevent the vehicle sliding at a speed of 24 m/s, when the track is banked at the angle calculated in Q2(a). (8)

3. A single plate clutch with both sides effective has an outside diameter of 380 mm and an inside diameter of 140 mm. The clutch is designed to transmit 20 kW at 800 rev/min when new. In this condition the coefficient of friction for the contact surfaces is 0.4.

The axial thrust on the clutch faces is provided by 8 identical springs each with a stiffness of 20 kN/m. Maximum wear of the clutch plates is limited to 0.8 mm for each pair of contact surfaces.

Calculate EACH of the following:

(a) the total spring load required when the clutch is new; (4)

(b) the minimum coefficient of friction of the worn clutch plates if 80% of the original maximum power can be transmitted by the worn clutch. (12)

Note:

For constant pressure $T = \dfrac{2\mu n W(r_o^3 - r_i^3)}{3(r_o^2 - r_i^2)}$

For constant wear $T = \dfrac{\mu n W(r_o + r_i)}{2}$

n = number of pairs of contact surfaces.

4. A mass rests on a plane inclined at 15°. A force of 1500 N acting parallel to and up the incline just causes the mass to move up the incline. A horizontal force of 1620 N will also cause the same mass to just move up the incline.

Calculate EACH of the following:

(a) the coefficient of friction between the mass and the incline; (10)

(b) the magnitude of the mass. (6)

5. A compound bar consists of a round copper bar of 28 mm diameter tightly encased in a steel tube of 40 mm outside diameter and of the same length. A tensile load of 100 kN is applied to this compound system.

Calculate EACH of the following:

(a) the stress in the copper bar; (14)

(b) the stress in the steel bar. (2)

Note: Modulus of Elasticity for steel = 210 GN/m^2
Modulus of Elasticity for copper = 90 GN/m^2

6. A propeller shaft for a controllable pitch propeller that rotates at 160 rev/min is driven by an engine that develops 4 MW at this speed. The shaft has an external diameter of 250 mm and an internal diameter of 70 mm. The propeller has a submerged net mass of 2.5 tonne and its centre of gravity overhangs the aft stern tube bearing by 1.2 m. The propeller thrust at 160 rev/min is 1720 kN.

Calculate EACH of the following:

(a) the direct compressive stress due to the propeller thrust; (3)

(b) the maximum shear stress due to torsion; (4)

(c) the maximum stress due to bending from the propeller weight; (5)

(d) the maximum and minimum combined stresses resulting from the direct compressive and bending stresses, stating if compressive or tensile. (4)

7. Two close coiled helical springs are fitted concentrically in parallel to support a total weight of 400 N. The data for the two springs is given below:

	Outer Spring	Inner Spring
Mean coil diameter	55 mm	35 mm
Wire diameter	6 mm	4 mm
Number of coils	12	8
Free length	110 mm	85 mm

Calculate EACH of the following:

(a) the compression of EACH spring when supporting the weight; (10)

(b) the shear stress due to torsion in EACH spring. (6)

Note: Modulus of Rigidity of the spring material = 80 GN/m^2

8. A weather balloon and its instrument module have a total mass of 18 kg. The balloon is at a height of 120 m and moving vertically upwards at a constant velocity of 6 m/s when the instrument module of mass 2 kg breaks free. Assume there is negligible buoyancy force acting on the instrument module.

Calculate EACH of the following:

(a) the time taken for the instrument module to reach the ground; (4)

(b) the velocity at which the instrument module strikes the ground; (4)

(c) the subsequent upward acceleration of the weather balloon. (8)

9. A centrifugal pump has an impeller with inner and outer diameters of 260 mm and 600 mm respectively. The pump runs at 480 rev/min and fresh water enters the pump with a radial velocity of 3.2 m/s which is constant across the impeller vane. The absolute velocity of the water at exit from the pump is 9 m/s.

Calculate EACH of the following:

(a) the impeller vane angles at both entry and exit so that the water enters and leaves the impeller without shock; (12)

(b) the theoretical head which the pump could deliver. (4)