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 95 CHIEF ENGINEER REG. III/2 (UNLIMITED)

041-31 - APPLIED MECHANICS

TUESDAY 16 DECEMBER 2014

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 Porter governor has arms of equal length and three flyweights each of mass 5 kg. The central mass is 24 kg and friction at the sleeve is constant at 18 N if the central mass moves.

   When running at a steady state speed the governor height is 116 mm.

   Calculate EACH of the following:

   (a) the steady state speed of the governor in rev/min, assuming no friction is acting; (6)

   (b) the speed in rev/min at which the governor will start to move from the steady state speed if the speed is increasing, including the effect of friction; (6)

   (c) the speed in rev/min at which the governor will start to move from the steady state speed if the speed is decreasing, including the effect of friction. (4)

2. A tool box of mass 300 kg is dragged at steady speed up a ramp inclined at 20° above the horizontal. The force used to drag the box is 1600 N and it is acting horizontally.

   (a) Sketch the ramp and box showing all forces acting. (3)

   (b) Calculate EACH of the following:

      (i) the coefficient of friction between the box and the ramp; (5)

      (ii) the minimum force that could be used to move the box and its line of action measured from the horizontal. (8)

3. Three masses are attached to a disc and rotate in the same plane. Mass A is 4.5 kg at 0.9 m radius, mass B is 5.2 kg at radius 1 m, mass C is 3.2 kg at radius 1.4 m. Masses B and C are 130° and 200° respectively clockwise from mass A.

Determine EACH of the following:

(a) the magnitude and direction of the resultant out of balance force when the disc rotates at 60 rev/min; (12)

(b) the radius and angular position at which a 6 kg balance mass should be placed. (4)

4. The flow of oil through a cooler is regulated by varying the area of an orifice plate in the oil line. The mass flow of oil through the cooler varies according to the relationship:

$$m = \frac{Kd^2(\rho h)^{0.5}}{(70 - d)}$$

Where
- m = mass flow rate of oil (kg/hour)
- K = a constant
- d = diameter of the orifice plate (mm)
- ρ = density of oil flowing through the orifice (kg/m^3)
- h = differential pressure across the orifice (mm of fresh water)

The maximum oil flow rate through the cooler is 20 tonnes/hour when an orifice of 50 mm diameter is used. Under these conditions the differential pressure across the orifice plate is measured as 5 mm of mercury.

Calculate EACH of the following:

(a) the numerical value of the constant K; (6)

(b) the diameter of the orifice plate required to give an oil flow rate of 10 tonnes/hour if the differential pressure across the plate under these conditions is 4 mm of mercury. (10)

Note: *Density of oil = 800 kg/m^3*
Density of mercury = 13600 kg/m^3

5. In a torsional test on a steel specimen of 18 mm diameter, the elastic limit is reached when the applied torque is 190 Nm and the angle of twist is 1.8 degrees over a length of 140 mm.

A hollow shaft of 60 mm inside diameter and 120 mm outside diameter is made from the same steel. It is required to transmit power at a speed of 500 rev/min. The safety coefficient (factor of safety) for the hollow shaft, based on the elastic limit torsional stress, is to be 3.

Calculate EACH of the following:

(a) the Modulus of Rigidity of the steel; (6)

(b) the maximum power that can be transmitted by the shaft. (10)

6. A close coiled helical spring has a free length of 120 mm and 20 coils of 6 mm diameter wire. Under load the spring length increases to 160 mm whilst the maximum shear stress in this condition is 45 MN/m^2.

Calculate the mean diameter of the coils. (16)

Note: Modulus of Rigidity for the spring material = 83 GN/m^2.

7. A beam is bent to form an arc of diameter 2.8 m. It has to remain elastic and must be capable of recovering its original straight form.

Calculate EACH of the following:

(a) the maximum allowable depth of the beam; (5)

(b) the maximum bending moment applied to the beam if a square cross-section is used; (6)

(c) the maximum bending moment applied to the beam if a circular cross-section is used. (5)

Note: Maximum bending stress allowed at the elastic limit = 230 MN/m^2
Modulus of Elasticity for the beam material = 200 GN/m^2

8. An oil tank is 4 m high and of square cross section with vertical sides 3 m wide. The tank contains oil to a depth of 2.5 m and the space above the oil is pressurised with inert gas to 60 kN/m^2. The density of the oil is 900 kg/m^3.

Calculate EACH of the following:

(a) the theoretical velocity at which the oil would escape from the base of the tank; (4)

(b) the total force on one side of the tank; (6)

(c) the position of the resultant centre of pressure on one side of the tank. (6)

9. A centrifugal pump has an impeller with inner and outer diameters of 280 mm and 620 mm respectively. The pump runs at 480 rev/min and fresh water enters the pump with a radial velocity of 3 m/s. The absolute velocity of the water at exit from the pump is 8 m/s and exit radial velocity is the same as inlet.

Calculate EACH of the following:

(a) the angles of the impeller vanes at entry and exit so that the fluid enters and leaves the impeller without shock; (12)

(b) the theoretical head delivered by the pump. (4)