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 MANAGEMENT ENGINEER REG. III/2 (UNLIMITED)

040-31 - APPLIED MECHANICS

TUESDAY, 12 DECEMBER 2017

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 examination centres:

APPLIED MECHANICS

Attempt SIX questions only

All questions carry equal marks

Marks for each part question are shown in brackets

1. (a) Define EACH of the following terms:

(i) stable equilibrium; (2)

(ii) unstable equilibrium; (2)

(iii) neutral equilibrium. (2)

(b) A solid aluminium hemisphere 250 mm diameter rests its curved surface on a rough plane inclined at an angle of 15° to the horizontal. Calculate the force F needed on the edge of the hemisphere, as shown in Fig Q1, to maintain the axis of the hemisphere in the vertical position. (10)

Note: *The density of aluminium = 2800 kg/m³*

The volume of a sphere can be calculated from $\frac{4\pi r^3}{3}$

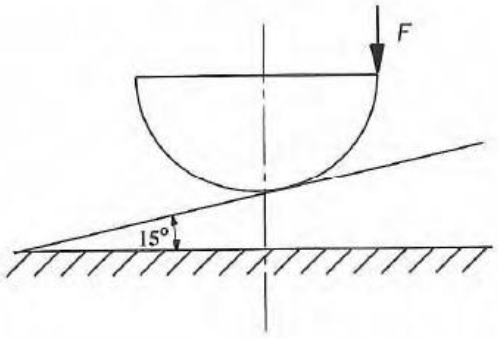

Fig Q1

2. A block of mass 4 kg rests on a horizontal plane and a second block of mass 6 kg rests on a plane inclined at 25° to the horizontal. The blocks are connected together by a light inextensible wire passing under a pulley as shown in Fig Q2.

The blocks are further connected by a light inextensible wire and pulley to a deadweight *W* which is sufficient to move the system with a constant velocity. The coefficient of friction between both blocks and the planes is 0.2 and the friction in the pulleys is negligible.

(a) Sketch the system showing all the forces acting for steady motion. (6)

(b) Calculate the magnitude of the mass required at the deadweight *W*. (10)

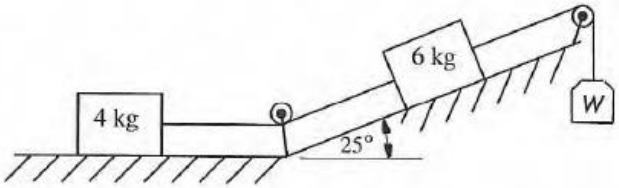

Fig Q2

3. A projectile is fired vertically upwards from ground level with an initial velocity of 22 m/s. Two seconds later a second projectile is fired vertically upwards, from the same point, with an initial velocity of 15 m/s.

Calculate EACH of the following:

(a) the height above ground level at which they will meet; (12)

(b) the magnitude and direction of the velocity of the first projectile at the instant of meeting. (4)

4. A loaded truck with a total mass of 6 tonne has four wheels each of mass 250 kg, diameter 400 mm and radius of gyration 300 mm. The truck is travelling at 2 m/s when it starts to descend an incline of 3°. The incline is 150 m long and resistance to motion is constant at 450 N.

Calculate EACH of the following:

(a) the energy lost in descending the incline; (2)

(b) the speed of the truck at the bottom of the incline. (14)

5. A single plate friction clutch with both sides effective having an outside diameter of 400 mm and an inside diameter of 160 mm, is designed to transmit 10 kW at 500 rev/min when new. In this condition the coefficient of friction between the contact surfaces can be taken to be 0.62. There are eight clutch springs each having a stiffness of 8 kN/m. The maximum wear of the clutch friction plate is limited to 1.5 mm of each contact surface.

During service, clutch plate wear takes place, the surfaces become contaminated and the power reduces.

Calculate EACH of the following:

(a) the total spring load required when the clutch is in the new condition; (8)

(b) the minimum coefficient of friction of the worn clutch if 75% of the original power can still be transmitted at the same speed. (8)

Note : *For constant pressure* $T = \frac{2}{3}\mu n W \frac{(r_1^3 - r_2^3)}{r_1^2 - r_2^2}$

For constant wear $T = \frac{\mu n W}{2}(r_1 + r_2)$

n = Number of pairs of surfaces in contact

6. An electric motor drives a pump through the compound gear train as shown in Fig Q6. The power required by the pump is 70 kW at a speed of 125 rev/min. The velocity ratio of the entire gear system is 24. The transmission efficiency is 90 per cent and the pitch of the teeth is the same for all gear wheels.

Calculate EACH of the following:

(a) the number of teeth on gears A and B; (7)

(b) the output torque from the motor; (7)

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

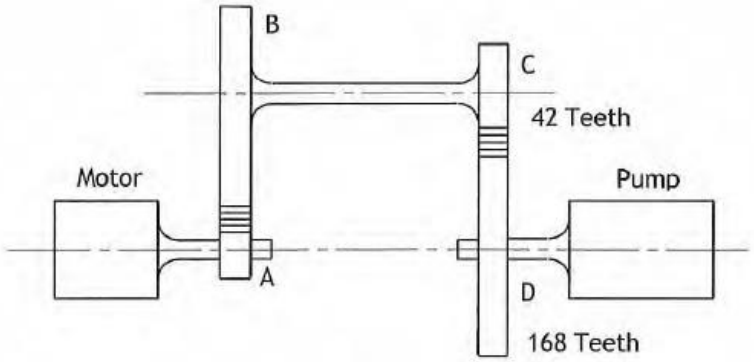

Fig Q6

7. A concentric vertical column consists of two columns each 100 mm high as shown in Fig Q7. The inner column is brass of cross section area 122 mm^2 and the outer hollow column is steel of cross section area 50 mm^2. The column supports an axial load of 20 kN.

Calculate EACH of the following:

(a) the stress in each material; (12)

(b) the change in length of the column. (4)

Note: *The Modulus of Elasticity for steel = 208 GN/m^2*

The Modulus of Elasticity for brass = 97 GN/m^2

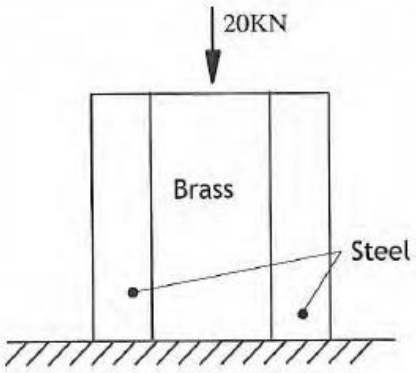

Fig Q7

8. A winding drum is driven through 1:1 gearing by a shaft of square section with a length of side x. The shaft rotates at 150 rev/min and the efficiency of the gearing is 85%.

When a mass of 20 tonne is being lifted at a constant velocity of 0.25 m/s, the angle of twist in the square shaft is not to exceed 1° over a length of 30x.

Calculate the minimum suitable dimension for the length of side x. (16)

Note: *The Modulus of Rigidity for the shaft material = 80 GN/m^2*
The polar second moment of area for a square section can be calculated from $\frac{x^4}{6}$

9. A valve spindle of total length 250 mm is 20 mm diameter for 100 mm of its length and 30 mm diameter for the remainder.

The valve spindle is at a temperature of 120°C and at this temperature, it is free of stress. The spindle cools to 20°C but is only able to contract by 0.25 mm lengthwise.

Calculate the maximum stress in the spindle.

(16)

Note: *The Modulus of Elasticity for the spindle material = 200 GN/m²*
Coefficient of linear expansion for spindle material = 12×10^{-6} per °C