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, 25 AUGUST 2020

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. A ship, with centre of gravity G, is being manoeuvred by three tugs as shown in Fig Q1.

   Calculate EACH of the following:

   (a) the magnitude and direction of the resultant force acting on the ship; (10)

   (b) the magnitude and direction of the resultant moment. (6)

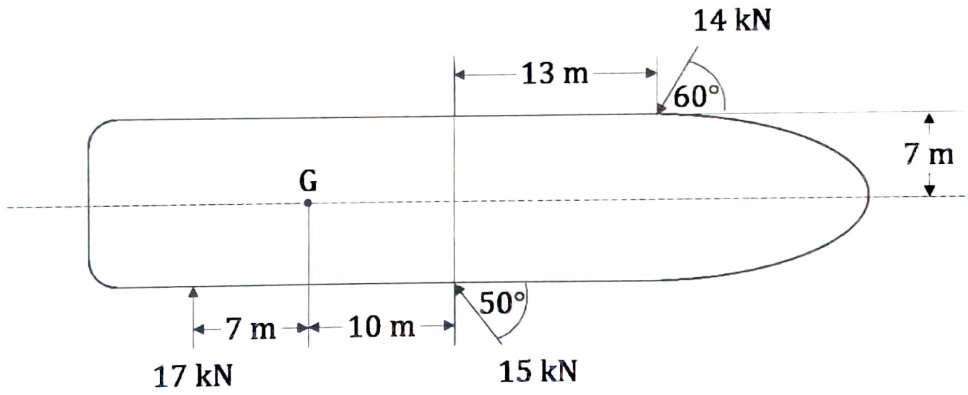

Fig Q1

2. Two masses initially at rest are connected by a cable which passes over a light frictionless pulley as shown in Fig Q2. Mass A is 45 kg and mass B is 65 kg. The coefficient of friction for mass A is 0.27 and the coefficient of friction for mass B is 0.23. The system is then released.

Calculate EACH of the following:

(a) the common acceleration of the masses; (10)

(b) the time taken for mass A to reach a velocity of 1.5 m/s; (3)

(c) the displacement of mass B after 2.5 seconds. (3)

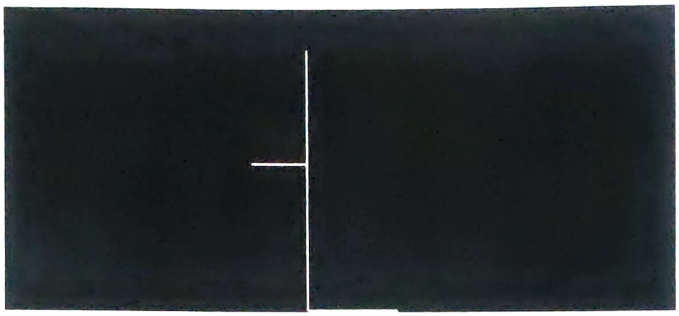

Fig Q2

3. A projectile is fired from level ground with an initial velocity of 80 m/s. The linear horizontal displacement of the projectile is 590 m at the point of impact with the ground.

Calculate the angle of elevation which minimises the projectile's time of flight. (16)

4. A vee belt pulley has an included angle of 60°. The tension when stationary is 110 N. The drive wheel is 240 mm diameter and rotates at 1500 rpm. The coefficient of friction between contact surfaces is 0.32 and the angle of lap is 165°.

Using the relationship;

$$\frac{F_1}{F_2} = e^{\mu\theta}$$

where: F_1 = the maximum force in the tight side of the belt
F_2 = the minimum force in the slack side of the belt
μ = the coefficient of friction
θ = the angle of lap in radians.

calculate EACH of the following;

(a) the tension on each side of the belt during operation; (12)

(b) the maximum power transmitted. (4)

5. A flywheel of mass 100 kg with radius of gyration 500 mm rotates at a speed of 200 rpm. A second flywheel of mass 75 kg with radius of gyration 400 mm rotates at 275 rpm in the same direction as shown in Fig Q5. The flywheels are coupled by an engaging clutch.

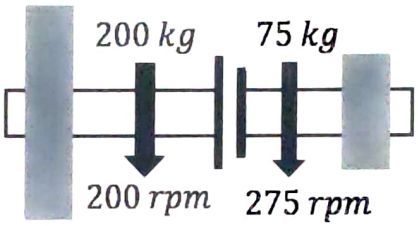

Fig Q5

Calculate EACH of the following:

(a) the speed of the coupled flywheels in rpm; (8)

(b) the energy lost during coupling; (6)

(c) the angular impulse generated in the 75 kg flywheel due to coupling. (2)

6. A vertical reciprocating engine runs at 90 rpm with a stroke of 2.4 m and a cylinder bore of 950 mm. The mass of the piston is 800 kg piston. The diameter of the piston rod is 340 mm. The pressure in the cylinder is 110 bar just after TDC and the piston reciprocates with simple harmonic motion.

Calculate EACH of the following:

(a) the piston velocity 0.8 m from TDC; (4)

(b) the maximum piston acceleration; (2)

(c) the magnitude and nature of the stress in the piston rod just after TDC. (10)

7. The thin rim of an 800 mm diameter wheel rotates at a constant speed of 3000 rpm.

Calculate EACH of the following:

(a) the factor of safety (safety coefficient) for the rim; (8)

(b) the strain induced within the thin rim; (4)

(c) the change in diameter of the rim. (4)

Note: *Modulus of Elasticity for the thin rim = 80 GN/m^2*
Density of the thin rim material = 7700 kg/m^3
Ultimate tensile strength of the thin rim material = 525 MN/m^2

8. Two close coiled helical springs are fitted concentrically to support a load of 400 N. The free length of the outer spring is 110 mm with 12 coils that have a mean diameter of 55 mm and a wire diameter of 6 mm. The free length of the inner spring is 85 mm with 8 coils that have a mean diameter of 35 mm and a wire diameter of 4 mm.

Calculate EACH of the following:

(a) the compression of each spring; (12)

(b) the maximum shear stress on the inner spring. (4)

Note: Modulus of Rigidity for both springs = 80 GN/m^2

9. A 24 tonne container is being lowered onto the deck of a cargo ship at a velocity of 0.1 m/s. It is evenly supported by three steel wires 75 mm in diameter and 25 m in length. The brake is suddenly applied.

Calculate EACH of the following:

(a) the stress induced in each wire due to the sudden stop; (14)

(b) the resultant instantaneous wire extension. (2)

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

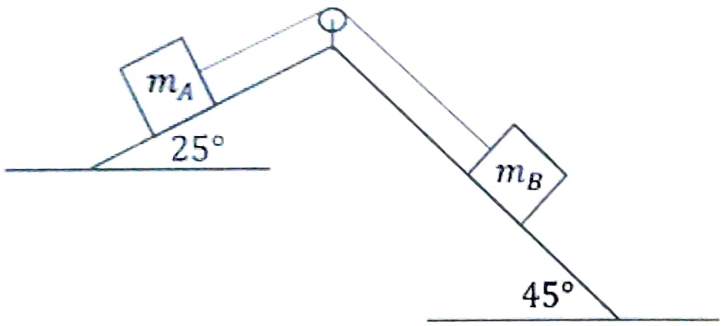

Fig Q2