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 $\frac{4\pi r^3}{3}$

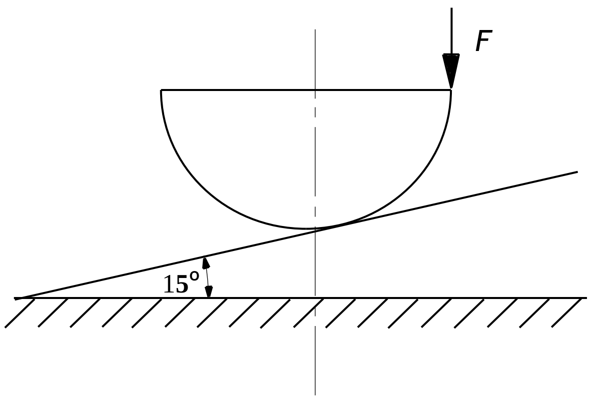

Fig Q1

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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)

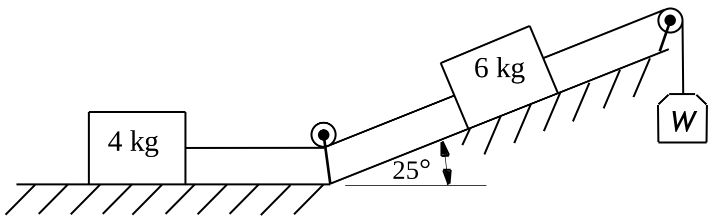

Fig Q2

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* $T = \frac{2}{3}\mu n W \frac{\left(r_1^3 - r_2^3\right)}{r_1^2 - r_2^2}$

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

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)

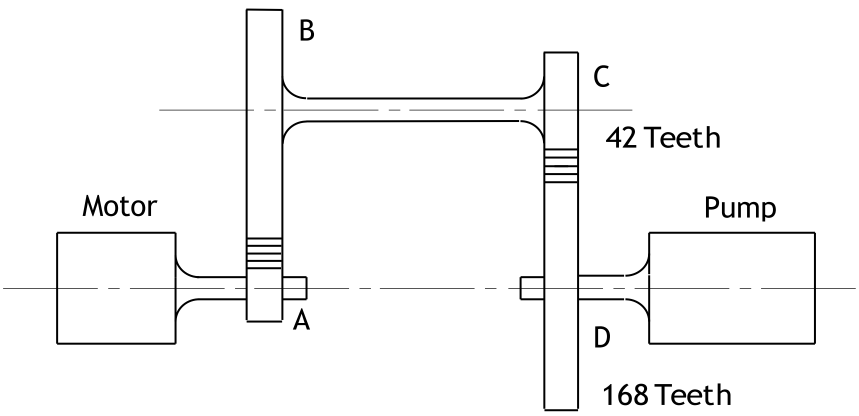

Fig Q6

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 mm² and the outer hollow column is steel of cross section area 50 mm². 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/m²

The Modulus of Elasticity for brass = 97 GN/m²

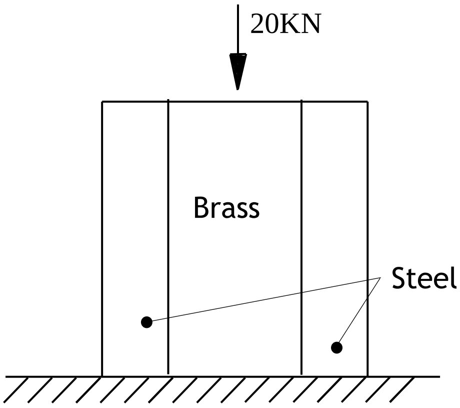

Fig Q7

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 30*x*.

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

Note: The Modulus of Rigidity for the shaft material = 80 GN/m²
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 120ºC and at this temperature, it is free of stress. The spindle cools to 20ºC 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/m^2*
Coefficient of linear expansion for spindle material = 12×10^{-6} per ºC

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM

SUBJECT: 040-31 Applied Mechanics

DATE: December 2017

General Comments on Examination Paper

Candidates would improve their marks considerably by taking the time to read the question and by making a sketch before starting calculations. No marks can be awarded for doing a question that is different to the one set.

General Comments of Specific Examination Questions

Q1. A surprising number of candidates could not provide a description of the 3 states of equilibrium. The formula for the volume of a sphere had been given, but many candidates forgot that the question dealt with a hemisphere.

Q2 Generally well attempted.

Q3. Some candidates calculated the time to maximum height for both projectiles, but this was not what was asked for or required, and no marks can be given for something unrelated to the question, which was about the projectiles meeting.

Q4. Because both rotational and translational kinetic energy are involved an 'energy' method is the best way to do this question, rather than an 'inertia' (F = mxa) approach.

Q5. Flat plate clutch. This should have been a straightforward question, but wasn't particularly well attempted. It is always possible to make a calculation error under exam conditions, but if the calculation gives a coefficient of friction greater than one, then it's a sign that something is wrong.

Q6. The key to starting this question is to realise that the two axis are parallel, i.e. "ra +rb = rc +rd". Parts (b) and (c) were relatively straightforward and did not have to rely on an answer from part (a).

Q7. The load is shared, and the extension and strain are the same. Some students ignored this simple principle, and others treated this as an 'offset load' question, which it was not.

Q8. The S.I. unit of angular displacement is the radian, not the degree, and radians should be used in the standard formula applied to this question.

Q9. The first step to answering this question was to work out how much the arrangement would have expanded if free, which then yields by how much the bar has been constrained.

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EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
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MARITIME AND COASTGUARD AGENCY

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

041-31 – APPLIED MECHANICS

TUESDAY, 13 DECEMBER 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 person is working on a ladder inclined at 30° to a smooth vertical wall. The ladder is of uniform cross section and has a mass of 20 kg. The person has a mass of 80 kg and is working two thirds of the way up the ladder, which stands on rough horizontal ground.

   (a) Sketch the arrangement showing all the forces present. (4)

   (b) Calculate the minimum coefficient of friction between the ground and the ladder if the ladder is not to slip. (8)

   (c) If the minimum coefficient of friction calculated in Q1(b) is reduced by 20%, calculate the magnitude of an additional mass which could be placed on the ground at the foot of the ladder to just prevent slipping. Assume the coefficient of friction for the mass is the same as for the ladder. (4)

2. Ship X is travelling at 7 knots in a direction 30° North of West when it sights ship Y dead ahead at a distance of 4 nautical miles, travelling on a true course due East at 12 knots.

   Determine EACH of the following:

   (a) the velocity of ship Y relative to ship X, in both magnitude and direction; (6)

   (b) the nearest distance of approach of the two ships to each other; (6)

   (c) the time taken for the ships to lose sight of each other, after the time of nearest approach, if the limit of visibility remains at 4 nautical miles. (4)

3. A turbine rotor has 60 equally spaced blades and rotates at 12000 rev/min. Due to damage, material is lost from 3 consecutive blades as follows:

   4 grams is lost from the first blade at an effective radius of 102 mm
   3 grams is lost from the next blade at an effective radius of 103 mm
   2 grams is lost from the third blade at an effective radius of 104 mm

   Calculate the magnitude and position of the resultant out of balance force on the rotor. (16)

4. A Porter governor has arms of equal length, 3 flyweights each of mass 4 kg and a central mass of 21 kg. Friction at the sleeve is constant at 24 N.

Calculate the maximum and minimum speeds for a governor height of 110 mm. (16)

5. A symmetrical I-shaped beam has a flange width of 100 mm and flange thickness of 20 mm. The overall height is 300 mm and the web thickness is 18 mm. The beam is simply supported at both ends and carries a uniformly distributed load of 20 kN/m along its whole length. There is also a single concentrated load of 8 kN at mid-span.

Calculate EACH of the following:

(a) the support reactions in terms of the length L of the beam; (2)

(b) the maximum bending moment in the beam in terms of the length L of the beam; (6)

(c) the maximum permissible length L of the beam if the bending stress in the beam is not to exceed 120 MN/m^2. (8)

6. A hollow steel propeller shaft is 7 m long with an outside diameter of 450 mm and is to transmit a maximum torque of 1700 kNm. The torsional shear stress in the shaft is not to exceed 100 MN/m^2. At full power the propeller efficiency is 80%, the shaft speed is 90 rev/min and the speed of the ship is 16 knots.

Calculate EACH of the following:

(a) the maximum permissible inside diameter of the shaft; (6)

(b) the angle of twist, in degrees, in the shaft when transmitting maximum torque; (4)

(c) the force resisting the motion of the ship at full power. (6)

Note: *Modulus of Rigidity for steel* = *80* GN/m^2
One nautical mile = *1852 m*

7. A welded pressure vessel of circular cross section has an oblique welded seam at an angle of 30° to the circumferential joint. The internal diameter of the pressure vessel is 1.8 m, the shell plate thickness is 30 mm and the working pressure is 28 bar.

Calculate EACH of the following:

(a) the tensile stress normal to the circumferential seam; (3)

(b) the tensile stress normal to the oblique seam; (7)

(c) the percentage increase in the stress normal to the oblique seam if corrosion on the outside of the vessel leads to a 10% reduction in shell thickness at the seam. (6)

8. A pump delivers oil of density 980 kg/m^3 at the rate of 40 tonne/hour through a discharge pipe of 150 mm bore. The outlet of this pipe is 10 m higher than the inlet. The pipe is 1000 m long with a friction factor coefficient of 0.006.

Calculate EACH of the following:

(a) the friction head loss in the pipe; (6)

(b) the minimum gauge pressure required at the inlet to the pipe to ensure that the gauge pressure at the outlet is not less than 60 kN/m^2. (10)

9. A circular life-buoy has a cross sectional area of 120 cm^2 and floats in sea water. It is being tested and with a 12 kg steel mass attached to the lower side of the buoy, one quarter of the volume of the buoy remains above the surface.

Calculate EACH of the following:

(a) the mean diameter of the buoy; (12)

(b) the time taken for the mass to reach the sea bed if the steel mass becomes detached and falls to the sea bed 8 m below. (4)

Note: *Density of sea water* = *1025 kg/m^3*
Density of buoy = *240 kg/m^3*
Density of steel = *7840 kg/m^3*

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM
PART I

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 13th December 2016

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Question 1 covered equilibrium of a non-concurrent force system. Free body diagrams were required for part (a), but most of these were very poor. Taking moments and summing forces was also poor and solution of the equations was not well attempted. Question 2 involved relative motion where a space diagram and a velocity diagram were required. These could be drawn to scale or sketched and solved using trig. Attempted by only a few students and produced the lowest overall average mark on the exam. Question 3 concerned rotating unbalance where again a scale force diagram could be drawn or a diagram could be sketched and solved using trig. Attempted by the fewest number of students, but producing a reasonable average mark. Question 4 was a Porter governor. In this case there were 3 rotating flyweights. A large number of students simply wrote down an equation which had been memorised and solved this. Unfortunately, this assumed there were only 2 flyweights and so no marks could be given. Attempted by nearly all candidates, but producing a poor average mark.

Questions 5, 6 and 7 covered the strength of materials section of the syllabus. Question 5 had a symmetrically loaded beam where the length of the beam is unknown. Nevertheless, each support reaction must carry half the total load, which can be found in terms of the length L. Since it is symmetrically loaded, the maximum bending moment must occur in the centre of the beam and the bending moment can be found at this position in terms of the length L. Question 6 on torsion produced the best average mark on the paper. Part (a) and (b) used the standard torsion equation. Part (c) used power equals force times velocity. Question 7 involved stresses on an oblique seam. Again, most students used equations which had been memorised, but these only apply in certain situations and therefore produced an incorrect answer.

Question 8 and 9 covered the fluids section of the syllabus. Question 8 had a pipe with friction loss. Part (a) used D'Arcy's equation to find this friction loss. Part (b) used Bernoulli or manometric head to find the inlet gauge pressure. Question 9 involved using Archimedes' Principle for part (a) and linear kinetics and kinematics for part (b).

General Comments of Specific Examination Questions

Q1. A question on static equilibrium for a non-concurrent force system. Part (a) required a sketch of a free body diagram. This was not done very well. The question states the wall is smooth, which implies no friction force. Part (b) uses the three equations of static equilibrium with moments being taken about the base of the ladder on the ground providing the easiest solution. Part (c) is a concurrent force system to find the mass.

Q2 Relative motion between two ships which requires a space diagram and a velocity diagram. These can be drawn to scale or sketched and solved by trig. Attempted by very few students and giving the lowest average mark on the examination.

Q3. A question on rotating unbalance. The unbalanced force can be found from a scale diagram of 'mr' values or by vector analysis. Attempted by the fewest number of students, but those who did attempt it achieved good marks.

Q4. A Porter governor with three flyweight masses. A large number of students attempted to use a memorised equation rather than solving using summation of moments about a convenient point. Where the memorised equation may work for particular situations, care must be taken since it does not always apply. In this case the three masses caused problems. Attempted by the largest number of students and overall producing a good average.

Q5. A symmetrically loaded, simply supported beam which caused a large number of problems. Symmetrically loaded implies that the support reactions at each end must have the same value, which is half the total load. This is obtained in terms of the beam length 'L'. The maximum bending moment must occur at the centre of the beam and again can be found in terms of beam length 'L'. Using the standard bending equation the bending moment at the centre can be found using bending stress, 'I' value and 'y'. This can then be used to find the length of the beam (a quadratic equation has to be solved).

Q6. Torsion questions are always popular and this was the case for this question. Attempted by a large number of students and giving the highest average on the paper. Most errors were caused by incorrect calculation of 'J'. Also, the angle of twist in part (b) is in radians from the torsion equation. The question asks for degrees, therefore a conversion is needed. Some students assumed the answer from the torsion equation was in degrees. This was heavily penalised. Part (c) uses power equals force times linear speed.

Q7. A question concerning stresses on an oblique plane in a thin cylinder. Part (a) caused a great deal of confusion. The stress normal to the circumferential seam will be the longitudinal (or axial) stress. The angle of 30^0 was incorrectly drawn by some students. Again, a large number of students attempted to solve part (b) by using a memorised equation. This caused errors with sine and cosine being incorrect. Part (c) states that corrosion occurs on the outside of the vessel. Therefore the inside diameter remains the same value of 1.8 m, but the wall thickness is reduced to 27 mm.

Q8. Part (a) is solved using the standard D'Arcy equation. Velocity can be found using mass flow rate in kg/s, density and pipe cross sectional area. Part (b) is solved by either using Bernoulli (where inlet and exit velocities are the same since pipe diameter is constant) or by converting all values to equivalent metres of head and changing this back to a pressure reading.

Q9. A question on the use of Archimedes' Principle. Part (a) has two downward forces (the buoy and the steel mass) and two upward forces (buoyancy on the buoy and buoyancy on the steel). The only unknown should be the mean diameter of the buoy. Part (b) requires calculation of the acceleration of the steel mass in the sea water when it becomes detached. This must be less than the value of 'g' (9.81 m/s^2) since the steel is being buoyed up by the sea water. Using the calculated value of acceleration in a kinematic equation, the time taken can be found. Errors were caused by students taking the acceleration of the steel as 9.81 m/s^2. This was heavily penalised.

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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)

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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/m²
Modulus of Elasticity for copper = 90 GN/m²

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)

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM
PART I

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 18th October 2016

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Question 1 covered angular kinetics involving a simple gear train with an efficiency. This was attempted by fewest students and produced a low average. Question 2 was a vehicle on a banked track. Free body diagrams were either very poorly sketched or omitted altogether and they are essential for solution. Question 3 concerned a flat plate clutch where the standard equations were given. Question 4 was a statics question involving equations of equilibrium for concurrent forces. Free body diagrams were poorly drawn in most cases and resolution of forces was also poor.

Questions 5, 6 and 7 covered the strength of materials section of the syllabus. Question 5 had two components in parallel undergoing a tensile load. Well done by most students producing a good average mark. Question 6 was a combined direct and bending stress question together with torsional stress. Question 7 involved two springs in parallel where the standard spring equations had to be used.

Question 8 and 9 covered the fluids section of the syllabus. Question 8 involved linear kinematics and kinetics together with Archimede's Principle. Question 9 had a centrifugal pump which involved sketching the velocity diagrams. This question produced the highest average mark.

General Comments of Specific Examination Questions

Q1. A question on angular kinematics and angular kinetics. It also involved a simple gear system with an efficiency. Most errors were caused by not knowing how to apply the gear ratio to angular speed and acceleration. Values of Mass Moment of Inertia were calculated correctly by all students, but referring these values to different shafts using the gear ratio and efficiency were poorly attempted when finding the torque. Power calculations in part (c) were also very poor. This question was attempted by the fewest number of students and produced a low average mark.

Q2 A vehicle travelling around a banked track in an attempt to prevent overturning and side slipping. Attempted by a few students but producing a good average mark. Most errors caused by poor free body diagrams, incorrect use of sign conventions and not understanding the dimensions given in the question.

Q3. A single flat plate clutch with both sides effective. This means the value of 'n' is 2 (two pairs of contact surfaces) and the total wear is therefore 1.6 mm (0.8 mm for each pair of contact surfaces). Attempted by a large number of students producing a good average mark. Errors caused by incorrect value of 'n', incorrect total wear and not knowing how to find spring compression after wear has occurred.

Q4. A question on static equilibrium for concurrent force system. Again, a free body diagram is essential and most of these were very poor or non-existent. Very few students indicated any kind of sign convention or used the sign convention incorrectly, expecting the exam marker to understand what they were doing. Solution of several simultaneous equations was a challenge to a large number of students but done well by others. Also, a large number of students attempted to use a trigonometrical equation without derivation. This type of equation may solve particular problems but students are discouraged from this since it will not solve every problem.

Q5. Attempted by the largest number of students and producing a good average mark. Two components are in parallel to form a compound bar. Some students failed to realise that the steel tube has both inside and outside diameters when calculating the cross-sectional area. Some students assumed that the 100 kN load was applied to the copper and also 100 kN was applied to the steel. This makes for an easier solution which is totally incorrect. The load is shared by both materials and one possible solution is to calculate how much of the 100 kN is taken by the copper and how much by the steel.

Q6. A question involving different types of stresses: direct compressive, bending (which gives both tensile and compressive) and shear. Part (a) was answered correctly by nearly all students attempting the question. This gives a direct compressive stress. Part (b) uses power and speed to give torque which can then be used in the torsion equation to give torsional shear stress. Values of 'J' were nearly all correctly calculated. Part (c) uses the bending moment of the propeller and the bending equation to find tensile and compressive bending stresses. Part (d) uses the stress values from (a) and (c) to give the overall maximum and minimum stresses.

Q7. Attempted by a large number of students but producing a poor average mark. Part (a) involved two separate problems. Since the outer spring has a longer free length than the inner, some of the 400 N is needed to compress this spring a distance of 25 mm. The remainder of the 400 N is then used to compress both springs together. There are several ways to solve the problem, but perhaps the easiest is to first find the spring stiffness k N/m for each spring and use this to find the load for the outer spring and then the deflection of the compound system. Part (b) was well attempted by most students using the standard shear stress equation for a spring.

Q8. Part (a) of the question uses linear kinematic equations with constant acceleration ('g' = 9.81 m/s^2). Most errors were caused by failing to realise that the instrument module has an upward velocity of 6 m/s at the instant it breaks free. Therefore it travels upwards to reach a maximum height before falling back to ground level. This upward motion also takes some time to occur and together with the time to fall from maximum height gives the total time. Part (b) also involves linear kinematics with constant acceleration, but again the instrument module has an initial upward velocity of 6 m/s. Part (c) requires the use of linear kinetics realising that the upward buoyancy force is 18g Newton and the weight of the balloon is 16g Newton. The difference between these (2g) divided by the mass of the balloon (16 kg) will give the acceleration.

Q9. A centrifugal pump question producing the best average mark. A large number of students achieved full marks for this question, most errors being caused by not knowing what each vector was on the velocity vector diagrams for inlet and exit. A number of students thought the diffuser angle on the exit diagram was the blade exit angle. Also the calculation of the whirl velocity caused some problems.

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, 12 JULY 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 cam follower of mass 4 kg moves with simple harmonic motion. It is lifted upwards 60 mm and has a periodic time of 0.2 seconds.

   Calculate EACH of the following:

   (a) the velocity of the follower when 8 mm from the end of its upward travel; (5)

   (b) the maximum force between the follower and the cam; (3)

   (c) the time taken for the follower to move from a point 15 mm before mid-travel to the end of its travel. (8)

2. A centrifugal shoe clutch is shown in Fig Q2 and has four shoes retained by springs. The shoes first contact the output drum at 480 rev/min, at which point the centre of gravity of EACH shoe is at a radius of 125 mm from the shaft axis. The internal radius of the output drum 160 mm. When the drive shaft speed is increased to 840 rev/min, the power transmitted to the output shaft is 26 kW.

   Calculate the mass of EACH shoe if the coefficient of friction between the shoes and the output drum is 0.4. (16)

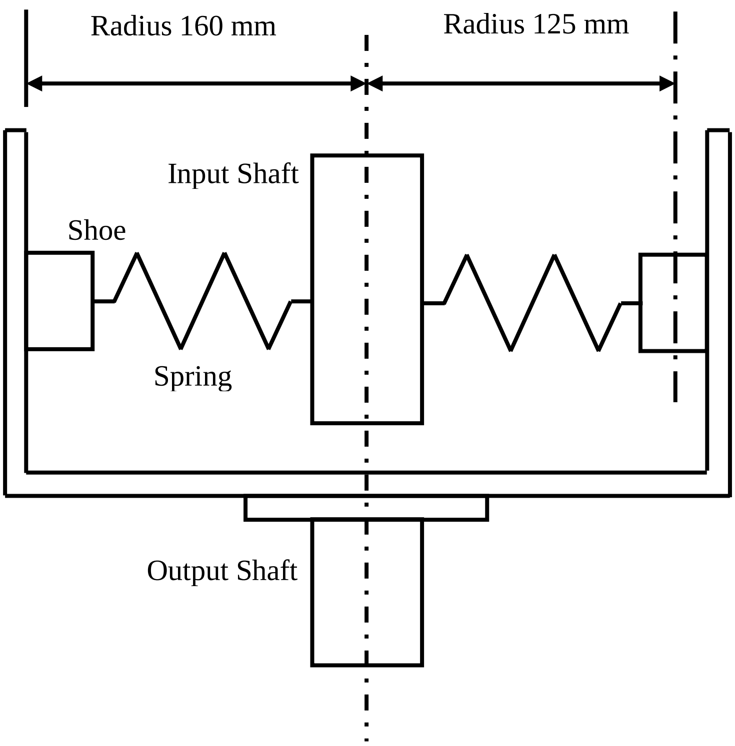

Fig Q2

[OVER

3. A ball is suspended by a fine, light wire 1 m long and when hanging vertically the point of suspension is 1.8 m above ground level. The ball is then rotated at a constant speed about a vertical axis forming a conical pendulum and the wire assumes an angle of 30^0 to the vertical.

Calculate EACH of the following:

(a) the angular velocity of the ball; (6)

(b) the horizontal distance from the vertical axis that the ball will travel before hitting the ground if the wire suddenly breaks. (10)

4. A uniform 5 m long ramp has a mass of 1.2 tonne and is suspended at 15^0 to the horizontal by two 15 mm diameter cables as shown in Fig Q4. The cables are attached 1.5 m away from the free end of the ramp and are at angle of 50^0 above the ramp. The other end of the ramp is hinged using two pins EACH of 30 mm diameter and EACH is in double shear.

Calculate EACH of the following:

(a) the tensile stress in EACH cable when supporting the ramp; (8)

(b) the shear stress in EACH of the hinge pins. (8)

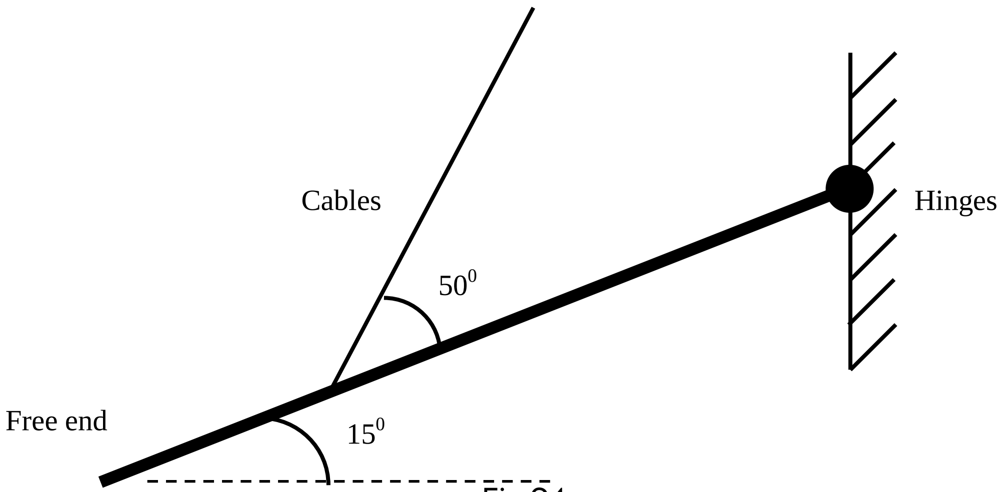

Fig Q4

5. A cast iron cylinder cover is secured by 12 steel bolts EACH of diameter 20 mm. The effective cross sectional area of the cover is 0.16 m^2. On assembly the bolts are tightened up so that the tensile stress in each bolt is 18 MN/m^2. The resulting stress in the cylinder cover is evenly distributed across its effective area.

Calculate EACH of the following:

(a) the initial stress in the cylinder cover; (6)

(b) the temperature rise at which the stress in the bolts and cover will become zero. (10)

Note: *For Cast Iron, Modulus of Elasticity = 100 GN/m^2*
For Steel, Modulus of Elasticity = 200 GN/m^2
For Cast Iron, Coefficient of Linear Expansion = 11 x 10^{-6} per ^0C
For Steel, Coefficient of Linear Expansion = 12 x 10^{-6} per ^0C

6. The cross section of a symmetrical I-shaped beam is shown in Fig Q6. The beam is simply supported at both ends and carries a uniformly distributed load of 30 kN/m and a single concentrated load of 6 kN at mid-span.

Calculate the maximum permissible length of the beam if the bending stress in the beam is not to exceed 140 MN/m^2. (16)

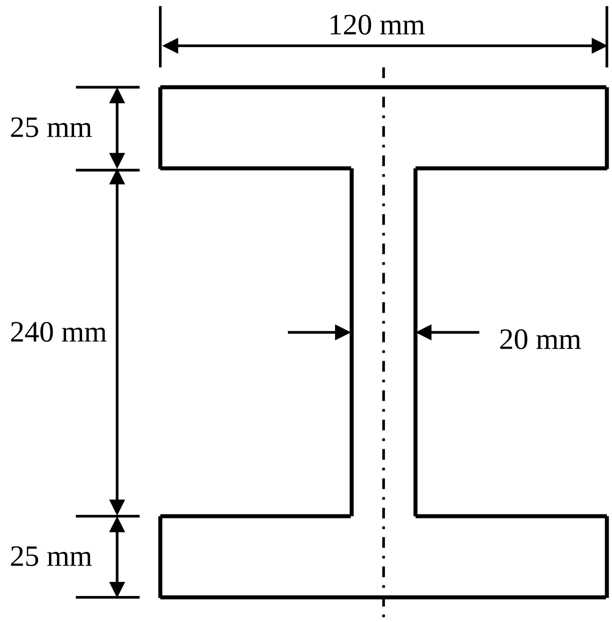

Fig Q6

[OVER

7. A container of mass 2 tonnes is being lowered onto the deck of a ship. It is supported by 4 steel wires each of 12 mm diameter. The container is being lowered at a constant speed of 0.2 m/s. When the length of the wires is 30 m the brake is suddenly applied.

Calculate EACH of the following:

(a) the static stress in EACH wire when supporting the weight of the container; (2)

(b) the additional stress imposed on the wires due to the sudden stop; (10)

(c) the maximum extension of the wires due to the sudden stop. (4)

Note: Modulus of Elasticity for steel = 200 GN/m^2

8. A conical buoy with a base diameter of 2.8 m and a vertical height of 3 m is placed in sea water with its apex downwards. The buoy floats at a draught of 1.6 m. When an anchor is suspended from the buoy, the draught increases to 2.4 m.

Calculate the tension in the chain which suspends the anchor from the buoy. (16)

Note: Density of sea water = 1025 kg/m^3
Volume of a cone = $\frac{1}{3}\pi r^2 h$

9. A centrifugal pump has an impeller with an inlet diameter of 240 mm and an outlet diameter of 600 mm. The impeller rotates at 600 rev/min and has a flow rate of 550 tonnes of fresh water per hour. Water flow at entry is radial and the radial velocity through the impeller is constant. The impeller width at entry is 55 mm and the vane exit angle is 40^0.

Calculate EACH of the following:

(a) the width of the impeller at the outlet; (3)

(b) the whirl velocity at outlet; (5)

(c) the angle of the outlet diffuser vanes for shockless entry to the diffuser; (2)

(d) the theoretical pump head; (3)

(e) the theoretical pump power. (3)

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, 5 APRIL 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 vessel travelling due West at 18 knots sights another vessel 8 nautical miles away in a direction 20^0 South of West. Thirty minutes later the second vessel is 3 nautical miles away in a direction 50^0 South of West.

   Determine EACH of the following:

   (a) the distance of nearest approach between the TWO vessels if they both maintain their present speed and course; (8)

   (b) the absolute course and speed of the second vessel. (8)

2. A lift of mass 700 kg is attached to a balance mass of 500 kg by a cable passing over a power driven drum of diameter 2.2 m and mass 200 kg. The drum has a radius of gyration of 0.8 m. At a certain instant the lift is ascending at 3 m/s but is decelerating at a rate of 0.2 m/s^2.

   (a) Sketch the arrangement showing all forces and torques present. (4)

   (b) Calculate the driving power required at the drum at this instant. (12)

3. A basic flapper/nozzle device is shown in Fig Q3 (not drawn to scale). The pneumatic signal for the input bellows unit is proportional to the measured temperature within the range 0-120^{0}C. The output signal range is to be 20–100 kN/m^2.

The characteristic of the input bellows is 5 μm/^{0}C, and the characteristic of the nozzle is 0.2 kN/m^2 per μm of flapper movement.

$$\text{The gain of the device} = \frac{\text{\% change in output}}{\text{\% change in input}}$$

Calculate EACH of the following:

(a) the flapper movement at the nozzle for 100% input change; (2)

(b) the resulting change in output; (2)

(c) the gain of the device; (2)

(d) the new setting of 'y', the distance from the pivot to the nozzle, to achieve a gain of 0.5; (5)

(e) the output pressure at 75 ^{0}C with a gain of 0.5 if the output pressure was 40 kN/m^2 at a temperature of 30 ^{0}C. (5)

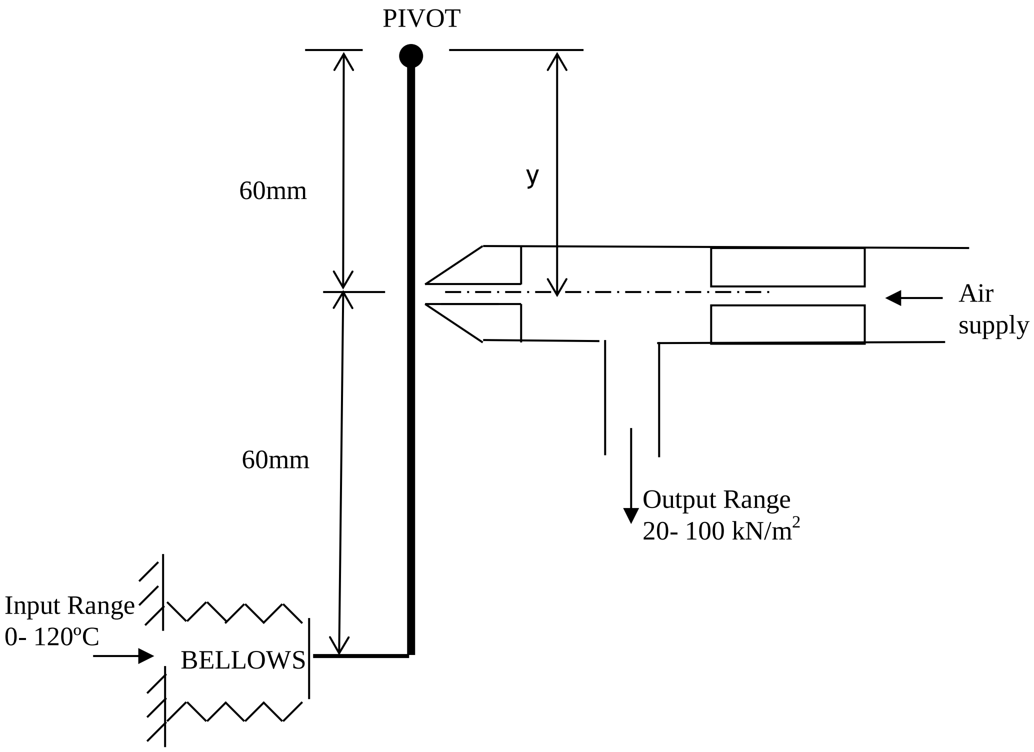

Fig Q3

4. A horizontal turbine rotor of mass 200 kg becomes unbalanced such that its centre of gravity is 0.2 mm from the centre of rotation. The rotor shaft is 750 mm long and is supported in bearings at each end. The weight of the rotor acts 300 mm from one end of the shaft.

Calculate EACH of the following:

(a) the maximum force at EACH bearing when the shaft speed is 2000 rev/min; (8)

(b) the speed at which the shaft would first lift from the bearings. (8)

5. A steel rod is 280 mm long with a diameter of 28 mm. It is firmly attached at one end to a copper rod of length 580 mm. When the combined assembly is subjected to a tensile pull of 40 kN, the extensions of the steel and copper are found to be equal.

Calculate EACH of the following:

(a) the diameter of the copper rod; (4)

(b) the stress in EACH rod; (4)

(c) the total extension; (4)

(d) the stored strain energy in the assembly when extended. (4)

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

[OVER

6. A short vertical hollow cylindrical column, 180 mm high and fixed at the base, is 80 mm outside diameter and 10 mm thick. It carries concentrated loads of 9 kN and 5 kN as shown in Fig Q6.

Calculate EACH of the following:

(a) the maximum compressive stress in the column; (8)

(b) the maximum tensile stress in the column. (8)

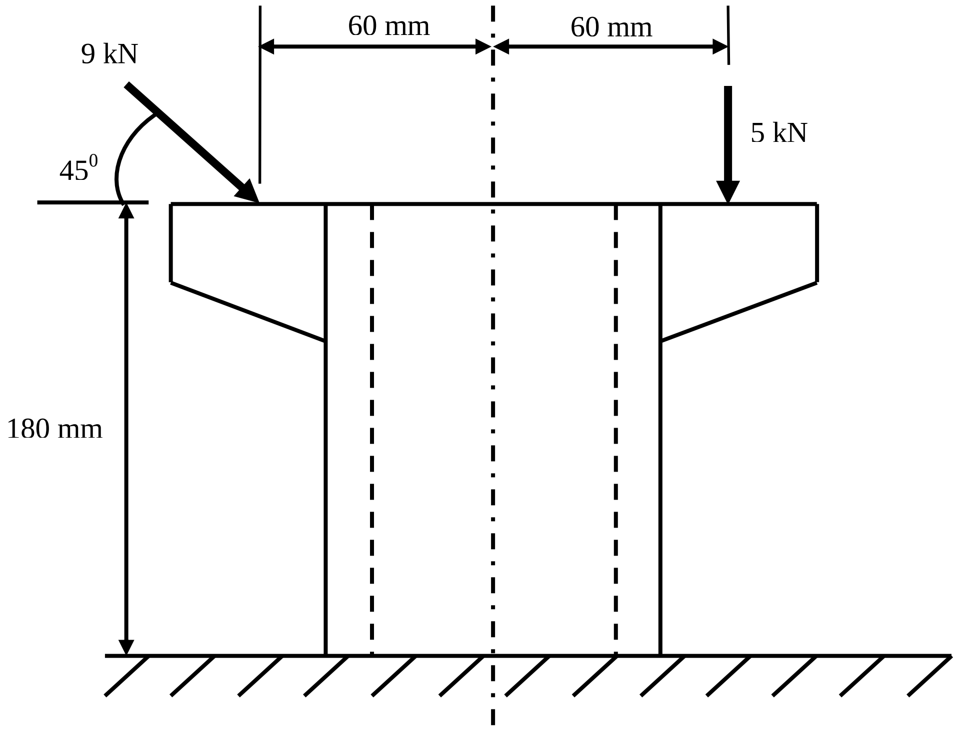

Fig Q6

7. A compound shaft consists of a 28 mm thick bronze sleeve fitted over a 380 mm diameter steel shaft. The compound shaft transmits 2.8 MW at 90 rev/min.

Calculate EACH of the following:

(a) the torque transmitted by the bronze sleeve; (6)

(b) the torque transmitted by the steel shaft; (6)

(c) the maximum shear stress in the bronze sleeve; (2)

(d) the maximum shear stress in the steel shaft. (2)

Note: Modulus of Rigidity of the steel = 80 GN/m²
Modulus of Rigidity of the bronze = 45 GN/m²

8. A regular cube of sides 100 mm floats vertically in a tank containing two non-mixing liquids of densities 700 and 1050 kg/m^3.
Calculate EACH of the following:

(a) the depth of the lighter liquid if 20 mm of the cube remains above the liquid surface; (8)

(b) the mass of steel which should be attached to the base of the cube to ensure that the cube is just submerged. (8)

Note: Density of cube material = 750 kg/m^3
Density of steel = 7800 kg/m^3

9. Sea water flows through a horizontal pipe at a rate of 80 m^3/hour. A bend in the pipe turns the sea water through 30° and the pipe is tapered from 90 mm diameter at the inlet to 40 mm diameter at the outlet. The outlet discharges to atmosphere and friction losses within the pipe can be neglected.

Determine EACH of the following:

(a) the velocity of the sea water at outlet from the bend; (4)

(b) the gauge pressure at inlet to the bend; (5)

(c) the force acting on the bend due to the change in velocity alone. (7)

Note: Density of sea water = 1025 kg/m^3

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM
PART I

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 5th April 2016

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Question 1 relative motion. This was attempted by very few students and produced the lowest average. Question 2 was a combination of linear and angular motion. Free body diagrams were either very poorly sketched or omitted altogether and they are essential for solution. Question 3 is a control type question that has appeared several times in the past. Attempted by about two thirds of students and producing a good average mark. Question 4 involves centripetal motion, but a number of students failed to realise this. Attempted by the lowest number of students.

Questions 5, 6 and 7 covered the strength of materials section of the syllabus. Question 5 had two components in series and also involved strain energy. Most errors were caused by students using the incorrect assumptions for components in series. However, this question was attempted by almost every student and produced the highest average mark with a large number of students obtaining full marks. Question 6 concerned combined direct and bending stresses. Attempted by a large number of students and producing a good average mark. Question 7 had a compound shaft in torsion. Attempted by almost every student, but the average mark was low. Most errors were caused by incorrect transposition of the torsion equation and not realising that the bronze sleeve is a tube and the J value has to take account of this.

Question 8 and 9 covered the fluids section of the syllabus. Question 8 had two non-mixing liquids acting on a floating body. Most errors were caused by incorrect calculations in Archimedes' Equation. Question 9 involved Bernoulli and Continuity to find velocity and pressure. The force can be calculated in several different ways, but most students failed to use any method correctly.

Some general notes are the same as the previous examinations :

- Neatness. A large number of workings in some scripts were difficult to follow.
- Accuracy of calculations. A large number of students only used one or two figures of accuracy. This leads to larger errors when values are raised to a power. A minimum of three and preferred four significant figures should be used.
- SI units. All calculations are based on SI units which use exponents to the power of multiples of 3. Students should be encouraged to use this and not other powers (eg. 10^4, 10^5 etc) Also, a large number of students give answers without units or in a large number of cases give the incorrect unit. Simply stating a number or incorrect unit is not good enough and again this will be punished.
- Questions attempted for marking must be indicated on the front of the examination script. Some students did not declare any questions for consideration on the front and the marker is entitled to not mark any of the work and award zero for the paper.
- Value of "g" is accepted to be 9.81 m/s^2 in engineering examinations. Some students used 9, 9.8 or 10. This will be punished.

I have written these comments on a number of examiners reports, but it appears that either students or lecturers or even both are not bothering to read them or are ignoring them.

General Comments of Specific Examination Questions

Q1. Attempted by 17 students producing an average mark of 1.2 out of 16.
The poorest attempted question with a very poor average. The concept of constructing both a space diagram and a velocity diagram seemed alien to most students.

Q2 Attempted by 28 students producing an average mark of 6.6 out of 16.
Linear and angular dynamics combined. Free body diagrams are essential and part (a) asks for these. Most diagrams were incorrectly drawn and therefore the calculations in part (b) become difficult.

Q3. Attempted by 56 students producing an average mark of 10.7 out of 16.
This control type question has appeared several times on past papers. As a result it was either attempted very well with some students obtaining full marks or students had not revised previous papers and obtained low marks.

Q4. Attempted by 14 students producing an average mark of 8.1 out of 16.
Attempted by the lowest number of students. This question involves calculation of the centripetal force produced by the unbalanced turbine and then using this together with the turbine weight to calculate the bearing forces.

Q5. Attempted by 75 students producing an average mark of 12.1 out of 16.
Attempted by the largest number of students (almost 100%) and producing the best average mark. It consists of two components in series and most errors were caused by using the incorrect assumptions. Part (d) asked for strain energy which can be found in several ways. Generally, students either obtained full marks for this part or did not attempt to solve it.

Q6. Attempted by 62 students producing an average mark of 10.8 out of 16.
A question on combined direct and bending stress. Most errors were caused by using the incorrect values for diameters for the column. The outside diameter is given in the question as 80 mm and with the stated wall thickness the inside diameter must be 60 mm. These can be used to find “I” and “y” in the bending equation. Some students used 120 mm as outside diameter which is the offset of the loads.

Q7. Attempted by 73 students producing an average mark of 8.7 out of 16.
A compound shaft using the torsion equation with the necessary assumptions for such a component. Attempted well by most students. Errors caused by poor transposition of the torsion equation and incorrect calculations for “J”.

Q8. Attempted by 49 students producing an average mark of 8.7 out of 16.
A body floating in two non-mixing liquids. Most errors were in part (b). There are two weights on one side of Archimedes’ equation and three buoyancy forces on the other side. The buoyancy force acting on the steel is provided by the ratio of densities of the steel and lower liquid.

Q9. Attempted by 48 students producing an average mark of 6.6 out of 16.
Bernoulli and Continuity are used for part (a) and (b). Both of these parts were attempted well by most students. Part (c) can be solved in a number of ways (change in momentum, mass flow rate times vector change in velocity) but most students failed to use either of these succesfully.

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, 15 December 2015

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 truck of mass 18 tonnes is pulled up an incline of sine 1 in 40 by a wire wound around the drum of a winch. The effective length of the incline is 420 m and frictional resistance to motion is constant at 100 N/tonne. The winch drum has a mass of 2 tonnes, a diameter of 1.8 m and a radius of gyration of 0.8 m. The tension in the wire is not to exceed 12 kN.

   Calculate EACH of the following:

   (a) the shortest time in which the truck, starting from rest, can ascend the incline; (8)

   (b) the driving torque required at the drum. (8)

2. Two masses are connected by a wire passing over a light, smooth pulley as shown in Fig Q2. The coefficient of friction between the masses and the inclines is 0.2.

   When the masses are released from rest, calculate EACH of the following:

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

   (b) the tension in the cable; (3)

   (c) the time taken for the masses to move 10 m. (3)

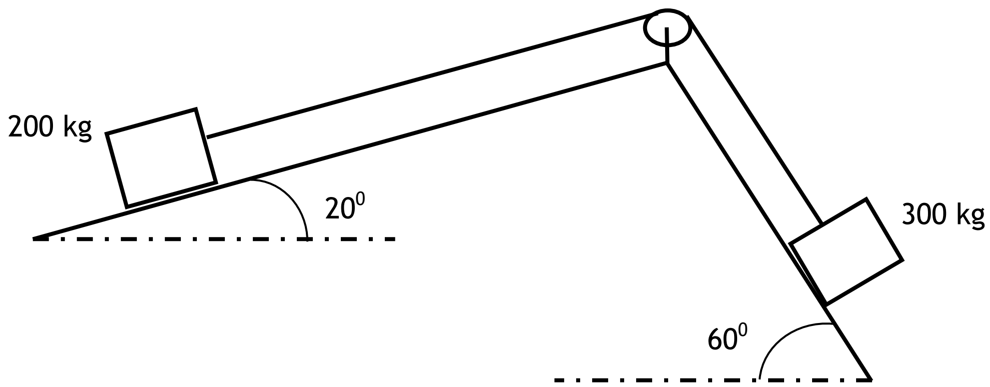

Fig Q2

[OVER

3. An engine of total moment of inertia 180 kgm^2 drives a propulsion shaft by means of a clutch. The propulsion shaft has a diameter of 180 mm and a mass of 4 tonne. Before the clutch engages, the engine is rotating at 300 rev/min and the shaft is stationary. The engine is capable of delivering 550 Nm of torque.

Calculate EACH of the following:

(a) the common speed of the engine and shaft after the clutch engages; (6)

(b) the time taken for the engine and shaft to reach this common speed (the time of slip); (3)

(c) the angular impulse received by the shaft due to the clutch engagement; (4)

(d) the time taken for the engine and shaft to regain the original speed of 300 rev/min after the time of slip if the torque remains constant at 550 Nm. (3)

Note: For a solid shaft the radius of gyration (k) is $\frac{r}{\sqrt{2}}$

4. A speedboat has an initial velocity when it is then subjected to a constant acceleration. During the acceleration period it travels a distance of 60 m in 5 seconds and then a further 110 m in the next 5 seconds.

(a) Sketch the velocity – time graph that represents this accelerated motion. (3)

(b) Calculate EACH of the following:

(i) the acceleration of the speedboat; (8)

(ii) the initial and final velocities of the speedboat. (5)

5. A valve is fitted with two close coiled helical springs, each of the same material and with the same free length.

The outer spring has 14 coils, mean diameter 120 mm and wire diameter 8 mm. The inner spring has 20 coils of wire diameter 5 mm.

Each spring is to have the same shear stress when the springs are compressed.

Calculate EACH of the following:

(a) the mean coil diameter of the inner spring; (10)

(b) the stiffness of the combined springs. (6)

Note: Modulus of Rigidity for spring material = 70 GN/m^2

6. A solid steel shaft of 80 mm diameter is connected to a hollow steel shaft by a shear pin of 10 mm diameter fitted diametrically through the solid and hollow shafts. The inside diameter of the hollow shaft is 80 mm. The shear stress in the pin must not exceed 60 MN/m^2.

Calculate EACH of the following:

(a) the maximum power that can be transmitted at a speed of 300 rev/min; (8)

(b) the minimum outside diameter of the hollow shaft so that its angle of twist does not exceed 0.1^0 per metre length when transmitting the maximum power. (8)

Note: Modulus of Rigidity for shaft material = 80 GN/m^2

[OVER

7. An “I” section beam is loaded as shown in Fig Q7.

Calculate EACH of the following:

(a) the maximum stress due to shear in the beam; (6)

(b) the maximum bending moment on the beam; (6)

(c) the maximum bending stress in the beam. (4)

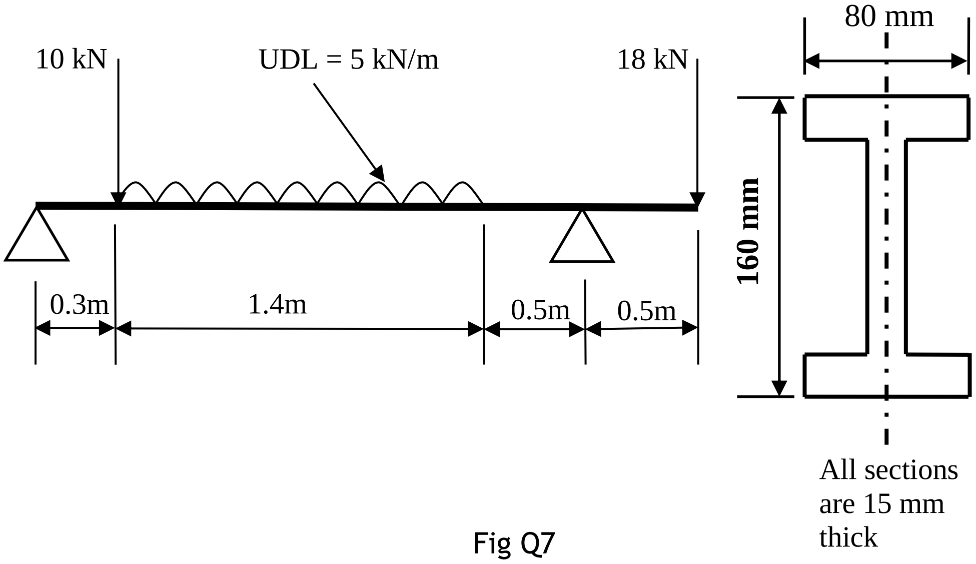

Fig Q7

8. A tank 3 m wide contains fresh water to a depth of 2 m. Oil of depth 1.2 m floats above the fresh water.

Calculate EACH of the following:

(a) the total hydrostatic force acting on the vertical tank wall; (6)

(b) the position of the resultant centre of pressure above the tank base; (6)

(c) the equivalent depth of fresh water alone that would exert the same force on the vertical wall as the TWO liquids combined. (4)

Note: *Density of the oil = 780 kg/m^3*

9. A Venturi meter having an inlet diameter of 60 mm and a throat diameter of 30 mm is used to measure the upward vertical flow of fresh water in a pipeline. The throat of the Venturi is 160 mm above the inlet and a differential pressure device connected to these points gives a reading equivalent to 250 mm head of fresh water. The Venturi coefficient is 0.95.

Calculate the mass flow rate of fresh water in tonnes per hour. (16)

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM
PART I

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 15th December 2015

Total No. of Candidates	*Pass*	*Fail*	*% Pass*
62	26	36	42

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Question 1 concerned linear and angular dynamics where the equations had to be developed and solved simultaneously. This was attempted by very few students and produced a low average mark which seems to indicate that students are not willing to use fundamental equations which need to be developed by themselves and this needs to be addressed. Question 2 was linear motion with friction. Again, this was attempted by very few students and a low average mark was obtained. Free body diagrams were either very poorly sketched or omitted altogether for both question 1 and 2 and they are essential for solution. Question 3 concerned conservation of angular momentum and angular impulse. Attempted by about one third of students and produced the lowest average mark on this paper. Question 4 was about linear kinematics with constant acceleration. It can be solved in a number of different ways. Attempted well by a number of students who obtained full marks.

Questions 5, 6 and 7 covered the strength of materials section of the syllabus. Question 5 had two parallel springs and the equations for shear stress and deflection had to be solved simultaneously for part (a). Question 6 concerned power transmission through a shear pin. A number of students attempted to use the torsion equation for the shear pin which is incorrect. Question 7 had a beam in bending. The shear force diagram needs to be sketched to determine maximum values and also positions of maximum or minimum bending moment.

Question 8 and 9 covered the fluids section of the syllabus. These were attempted by a large majority of the students. Question 8 had two non-mixing liquids acting on a vertical wall. Most errors resulted from not calculating the three hydrostatic forces acting. Some students only calculated two. Question 9 concerned a vertical venturi meter. Continuity equation and Bernoulli's equation had to be solved simultaneously to find flow velocities and this is then used to find mass flow rate.

Some general notes are the same as the previous examinations :

- Neatness. A large number of workings in some scripts were difficult to follow.
- Accuracy of calculations. A large number of students only used one or two figures of accuracy. This leads to larger errors when values are raised to a power. A minimum of three and preferred four significant figures should be used.
- SI units. All calculations are based on SI units which use exponents to the power of multiples of 3. Students should be encouraged to use this and not other powers (eg. 10^4, 10^5 etc) Also, a large number of students give answers without units or in a large number of cases give the incorrect unit. Simply stating a number or incorrect unit is not good enough and again this will be punished.
- Questions attempted for marking must be indicated on the front of the examination script. Some students did not declare any questions for consideration on the front and the marker is entitled to not mark any of the work and award zero for the paper.

General Comments of Specific Examination Questions

Q1. Attempted by 11 students producing an average mark of 5.5 out of 16.
A problem on linear and angular dynamics. The student has to develop and solve several equations and this again has been unpopular and shows that the manipulation of several maths equations causes errors. Also, the free body diagram was incorrectly drawn or not drawn at all by a number of students.

Q2 Attempted by 18 students producing an average mark of 6.8 out of 16.
Linear dynamics involving friction which again requires a free body diagram and solution of several simultaneous equations. Same problems as Question 1 in solving these equations

Q3. Attempted by 21 students producing an average mark of 2.2 out of 16.
A problem on conservation of angular momentum andcalculation of angular impulse. Produced the lowest average for this paper. Mass moment of inertia was misunderstood and incorrectly calculated. Part (d) attempted by almost no students.

Q4. Attempted by 27 students producing an average mark of 6.0 out of 16.
Involves linear kinematic equations to find acceleration in part (a). Could use standard kinematic equations or calculate average velocity values. Part (b) well done by most students.

Q5. Attempted by 52 students producing an average mark of 9.1 out of 16.
Two parallel springs where the standard equations for shear stress and deflection have to be solved simultaneously for part (a) Well attempted by most students, most errors occuring where a student assumed that the load taken by each spring was the same and cancelled from the equations. The springs will take different loads most often in parallel.

Q6. Attempted by 56 students producing an average mark of 9.4 out of 16.
Attempted by most students and producing a good average. The shear pin is not in torsion and this caused most errors when some students attempted in part (a) to use the torsion equation on the pin. Part (b) does require the use of the torsion equation to determine 'J' for the hollow shaft and therefore the outside diameter. Errors caused by not changing degrees to radians for use in the torsion equation.

Q7. Attempted by 47 students producing an average mark of 8.3 out of 16.
The support reaction forces need to be found and errors occured when taking moments to do this. Not all students sketched the shear force diagram. This is required to determine the maximum shear force for part (a) and also to determine the position of maximum bending moment for part (b). A bending moment diagram is not required for solution, though a large number of students did sketch one, very often incorrectly. 'I' value for the beam is required for part (c).

Q8. Attempted by 55 students producing an average mark of 7.5 out of 16.
Non-mixing oil and water acting on a vertival wall. There are three hydrostatic forces to find in part (a), but a number of students only found two. Moments about the base of the tank are required for part (b). Therefore, the centre of pressure for each hydrostatic force is required. These can be calculated, but could be found much more easily from the pressure diagram. Part (c) completed well by most students.

Q9. Attempted by 45 students producing an average mark of 9.7 out of 16.
A vertical venturi meter. Continuity and Bernoulli have to be solved simultaneously to find flow velocities. The velocity can then be used to find flow rate. Produced the best average mark for this paper.

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, 13 OCTOBER 2015

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 light cord passing over a light, smooth pulley has masses of 2 kg and 4 kg respectively attached to its ends. The pulley has a diameter of 300 mm. The 4 kg mass is held 3 m above ground level, with tension in the cord, and then released.

   Calculate EACH of the following:

   (a) the time taken for the 4 kg mass to reach ground level; (10)

   (b) the time the cord remains slack after the 4 kg mass reaches ground level if the 4 kg mass does not bounce. (6)

2. A winch motor drives a pinion with 320 teeth. Friction at the motor bearings is constant at 20 Nm. The pinion then meshes with a gear wheel having 640 teeth which drives a shaft of 120 mm diameter. This shaft is supported in bearings having a coefficient of friction of 0.12 and drives a winch drum of diameter 340 mm.

   Calculate EACH of the following:

   (a) the driving torque required by the motor when raising a mass of 2 tonnes at a steady speed; (10)

   (b) the input power required by the motor when raising the mass of 2 tonnes at a steady speed of 0.3 m/s if the motor efficiency is 90%. (6)

3. An extending ladder has two sections, each of length 4 m and mass 20 kg. It stands on rough, horizontal ground and leans against a smooth wall at an angle of 30° to the wall. The coefficient of friction between the ladder and the ground is 0.2. A person of mass 80 kg is working half way (2 m) up the lower section.

(a) Sketch the arrangement showing all forces present. (4)

(b) Calculate the minimum overlap of the two sections if the ladder is not to slide away from the wall. (12)

4. A freefall lifeboat is released from rest on an incline of 30° to the horizontal. The lifeboat takes 2.4 seconds to travel 10 m along the incline, at which point it starts to freefall under the effect of gravity alone.

Calculate EACH of the following:

(a) the acceleration of the lifeboat as it travels down the incline; (2)

(b) the velocity at which the lifeboat leaves the incline; (2)

(c) the horizontal distance the lifeboat will travel after leaving the incline when the vertical distance to the water at this point is 40 m; (7)

(d) the velocity and angle at which the lifeboat enters the water. (5)

5. A hammer of mass 1.5 kg moves vertically downwards with a velocity of 10 m/s to drive a steel pin of mass 40 gramme into a horizontal floor to a depth of 28 mm.

Calculate EACH of the following:

(a) the common velocity of the hammer and pin immediately after impact; (3)

(b) the percentage reduction of energy at impact; (6)

(c) the average resisting force offered by the floor. (7)

6. A cable consists of one steel wire 4 mm diameter and eight brass wires each 2 mm diameter. The stress in the brass wires is not to exceed 60 MN/m^2.

Calculate EACH of the following:

(a) the maximum load the cable can carry; (10)

(b) the equivalent Modulus of Elasticity for the cable. (6)

Note: *Modulus of Elasticity for Steel = 210* GN/m^2
Modulus of Elasticity for Brass = 80 GN/m^2

7. The stepped steel shaft shown in Fig Q7 is to transmit a torque. The larger diameter section of the shaft is to have a hole drilled in it to a depth of 100 mm.

Calculate EACH of the following:

(a) the diameter of the drilled hole '*d*' that would make the maximum stress in the hollow part of the shaft equal to the maximum stress in the 34 mm diameter section; (6)

(b) the length of the 34 mm section if the total angle of twist for the shaft is to be 0.02 rad when a torque of 400 Nm is applied. (10)

Note: *Modulus of Rigidity for shaft material = 80* GN/m^2

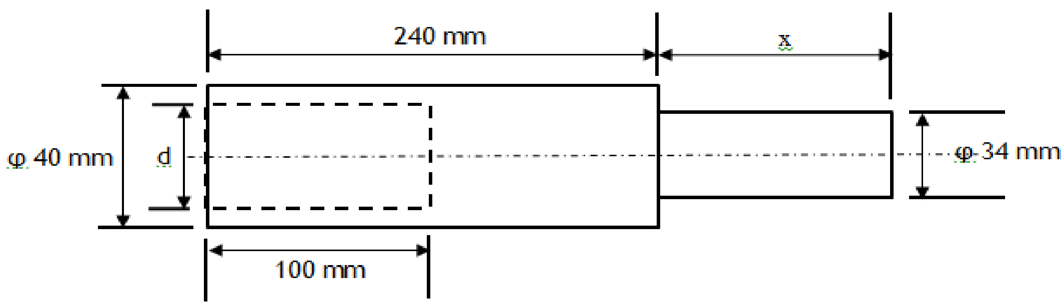

Fig Q7

8. A canal of width 7 m is sealed by a hinged lock gate as shown in Fig Q8. The fresh water is 4.2 m deep on one side of the gate and 1.5 m deep on the other side.

Calculate EACH of the following:

(a) the resultant hydrostatic force on the gate; (6)

(b) the reaction force R between the lock gate and the canal wall when closed; (4)

(c) the minimum force which could be applied to the lock gate to just open it. (6)

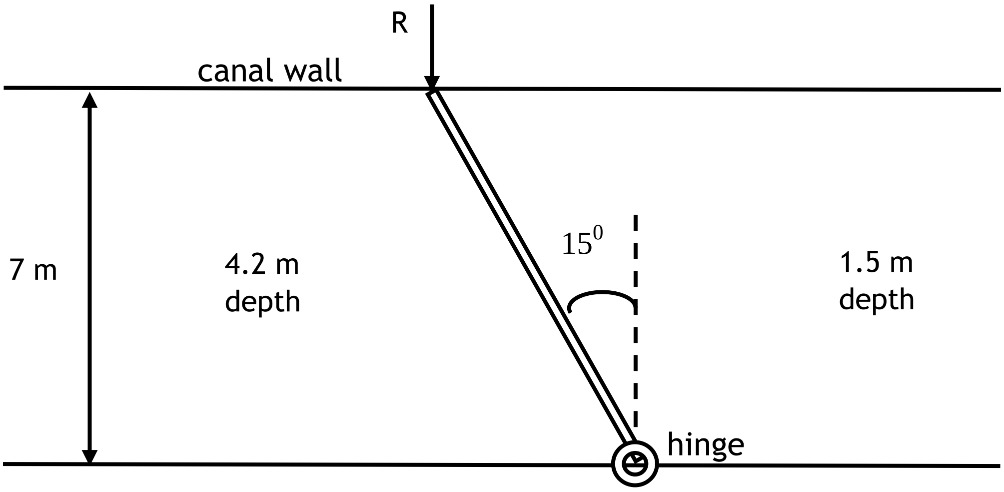

Fig Q8

9. A tank containing lubrication oil of density 850 kg/m^3 has two sharp edged outlet orifices on one side of the tank. The upper orifice is 15 mm diameter and has its centre 1.3 m below the oil surface. The lower orifice is 20 mm diameter and has its centre 2.8 m below the oil surface. Oil is supplied to the tank at 1.8 kg/s to maintain a constant oil level in the tank.

Calculate EACH of the following:

(a) the mass flow rate of oil from the 15 mm diameter orifice; (8)

(b) the coefficient of velocity for the 20 mm diameter orifice. (8)

Note: For 15 mm diameter orifice, Coefficient of Velocity = 0.97
Coefficient of Contraction = 0.68
For 20 mm diameter orifice, Coefficient of Contraction = 0.72

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 13th October 2015

General Comments on Examination Paper

The first 5 questions covered the statics/dynamics sections of the syllabus. Question 1 concerned linear dynamics where the equations had to be developed and solved simultaneously. This was attempted by nearly half the students but it produced the lowest average mark on the paper which seems to indicate that students are not willing to use fundamental equations which need to be developed by themselves and this needs to be addressed. Question 2 was about combined linear and angular motion. This was attempted by very few students, but acceptable marks were obtained by most who did attempt it. Question 3 concerned static equilibrium with a non-concurrent force system. This requires drawing a correct free body diagram and solving three simultaneous equations. Attempted by about half the students, but very poor marks obtained by most. Question 4 was about linear kinematics and motion due to gravity with projectile motion. Part (a) and (b) were reasonably attempted, most marks being lost on part (c). Question 5 concerned conservation of linear momentum and kinetic energy loss during impact. A number of students assumed kinetic energy was constant during impact which is incorrect. Part (c) involved linear kinematics and kinetics.

Questions 6 and 7 covered the strength of materials section of the syllabus. Question 6 concerned two components in parallel where the total force is given by adding the forces on each material. The extension of each material is the same. Some students had these the other way round. Question 7 concerned torsion in series components and was the best attempted question on the paper producing the highest average mark.

Question 8 and 9 covered the fluids section of the syllabus. These were attempted by a large majority of the students. Question 8 was either not understood or misread by some students who did not appreciate that centre of pressure was not required for the solution. Question 9 concerned the three coefficients for orifice plates. A large number used Bernoulli's equation which was not required.

Some general notes are the same as the previous examinations :

- Neatness. A large number of workings in some scripts were difficult to follow.
- Accuracy of calculations. A large number of students only used one or two figures of accuracy. This leads to larger errors when values are raised to a power. A minimum of three and preferred four significant figures should be used.
- SI units. All calculations are based on SI units which use exponents to the power of multiples of 3. Students should be encouraged to use this and not other powers (eg. 10^4, 10^5 etc) Also, a large number of students give answers without units or in a large number of cases give the incorrect unit. Simply stating a number or incorrect unit is not good enough and again this will be punished.
- Questions attempted for marking must be indicated on the front of the examination script. Some students did not declare any questions for consideration on the front and the marker is entitled to not mark any of the work and award zero for the paper.

General Comments of Specific Examination Questions

Q1. Attempted by 25 students producing an average mark of 4.4 out of 16.
A problem on linear dynamics. The student has to develop and solve several equations and this again has been unpopular and shows that the manipulation of several maths equations causes errors. Also, the free body diagram was incorrectly drawn by a number of students.

Q2 Attempted by 9 students producing an average mark of 8.2 out of 16.
Involves converting linear quantities to angular. The gear ratio then has to be used to produce values at the motor shaft. Attempted by very few students but completed quite well by most.

Q3. Attempted by 30 students producing an average mark of 4.3 out of 16.
A problem on static equilibrium involving friction. A correct free body diagram is needed to show a non-concurrent force system. Three equations of equilibrium are then needed for solution. Most errors caused by poor diagram and poor development of equations.

Q4. Attempted by 28 students producing an average mark of 5.6 out of 16.
Part (a) involves linear kinematic equations to find velocity and part (b) to find acceleration. Some students assumed a value of 'g', 9.81 m/s^2, for the acceleration down the incline which is incorrect. Part (c) and (d) are based on free fall due to gravity and projectile motion.

Q5. Attempted by 38 students producing an average mark of 6.9 out of 16.
Part (a) uses conservation of linear momentum to determine the velocity. Part (b) used kinetic energy equation to find energy before and after impact. Some students assumed energy is conserved during impact which is incorrect. Part (c) requires a free body diagram and linear dynamics.

Q6. Attempted by 59 students producing an average mark of 9.7 out of 16.
Attempted by most students, though not very well in some cases. The question concerns two materials in parallel and therefore the assumptions are that the change in length is the same and the total force is the addition of the forces in each material. Some students assumed the force in each material was the same.

Q7. Attempted by 58 students producing an average mark of 10.8 out of 16.
A question on torsion in three series components. Some students only considered two components for part (b). Completed very well by most students giving the best average for this examination paper.

Q8. Attempted by 40 students producing an average mark of 5.0 out of 16.
Attempted by a large number of students, but not very well in most cases. A large number of students wasted time and effort calculating positions for centres of pressure. This was not required for this question and no marks could be awarded. Part (a) is solved using the standard equation for hydrostatic force. Part (b) and (c) are solved by taking moments of forces about the hinge position.

Q9. Attempted by 41 students producing an average mark of 10.6 out of 16.
A question on using the three coefficients for an orifice plate. Attempted well by most students with part (b) causing most errors. Some students obtained a coefficient value greater than 1, which is not possible.

**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, 24 MARCH 2015

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 2 m long uniform ladder of mass 15 kg rests against a smooth vertical wall. The ladder stands on an inclined plane, which rises at 10° away from the wall.

   (a) Sketch the ladder arrangement showing all forces acting. (4)

   (b) Calculate the largest angle possible between the ladder and the wall for the ladder to be stable and not slide away from the wall. (12)

   Note: Coefficient of friction between the ladder and the inclined plane is 0.24

2. An engine room lift cage has a mass of 1 tonne. The hoist wire is wound around a motor driven drum, with the lift cage on one end and a balance mass of 0.8 tonne suspended from the other end. The drum is 1.4 m diameter with a mass of 250 kg and radius of gyration of 450 mm.

   The maximum tension in the hoist wire is not to exceed 12 kN.

   Calculate EACH of the following:

   (a) the maximum allowable acceleration of the lift cage when being raised; (3)

   (b) the driving torque required at the drum to achieve the acceleration found in part Q2(a); (8)

   (c) the motor output power when the lift is moving upwards with a constant velocity of 3 m/s. (5)

[OVER

3. A Hartnell governor has two rotating flyweights each of mass 0.8 kg. The pivot arms are vertical and the flyweights are at an orbital radius of 100 mm at a mean speed of 720 rev/min.

The length of the flyweight arms is 120 mm and the length of the sleeve arms is 80 mm. The spring stiffness is 30 kN/m and friction in the governor is equivalent to a force of 12 N at the sleeve if the governor speed increases or decreases.

Calculate EACH of the following:

(a) the spring force when the governor is running at its mean speed, assuming friction is not present; (6)

(b) the vertical movement of the sleeve for a speed decrease of 20 rev/min, including the effect of friction. (10)

4. A single acting vertical bilge pump operates at 40 rev/min against a constant discharge pressure of 2.8 bar. The pump delivers 10 m^3/hour of fresh water for the single 120 mm diameter piston. The combined mass of the piston and entrapped water is 18 kg and the piston can be assumed to move with simple harmonic motion.

The piston is moving upwards and is 80 mm away from the top of the stroke.

Calculate EACH of the following:

(a) the force required to move the piston; (12)

(b) the input power to the pump motor at the given instant if the motor efficiency is 80%. (4)

5. A piece of steel is tested in compression and when the compressive yield stress is applied to a test specimen of 100 mm length, the compression is measured to be 0.16 mm.

A strut is to be made from the same type of steel and it is to be a solid, square section column of 450 mm^2 cross-section and 2 m long. It will be fixed at both ends.

Calculate EACH of the following:

(a) the Modulus of Elasticity for the steel being used; (4)

(b) the critical load for the strut using Euler's equation; (8)

(c) the ratio of compressive yield stress to critical stress for the strut. (4)

Note: Compressive Yield Stress for the steel = 320 MN/m^2

For a fixed end strut, $F_C = \dfrac{4\pi^2 EI}{L^2}$

6. An intermediate propeller shaft is fitted to an engine of power output 16 MW running at 110 rev/min. The shaft is solid with a coupling flange at each end. Each flange has 12 bolts on a pitch circle diameter of 1.5 times the shaft diameter. The limiting shear stress is 180 MN/m^2 for the shaft material and 160 MN/m^2 for the bolt material.

Calculate EACH of the following:

(a) the diameter of the shaft for a safety coefficient (factor of safety) of 2; (8)

(b) the diameter of the bolts for a safety coefficient (factor of safety) of 2. (8)

7. A steel bar is 1.1 m long and 60 mm diameter. An axial hole 38 mm diameter is to be drilled from one end to such a depth that the extension of the drilled part is twice the extension of the solid part when an axial tensile force is applied.

Calculate EACH of the following:

(a) the required depth of the drilled hole; (8)

(b) the strain energy in the bar when an axial tensile load of 20 kN is applied. (8)

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

8. Two oil tanks are separated by a vertical bulkhead fitted with a circular inspection door, 800 mm diameter. The door is hinged at its top edge, which is 2.8 m above the bottom of the tank. Both tanks contain oil of density 900 kg/m^3, in one tank to a depth of 2.8 m and in the other to a depth of 3.1 m.

Calculate EACH of the following:

(a) the hydrostatic forces produced by the oil on each side of the door; (6)

(b) the horizontal force required at the bottom edge of the door to open it against the resultant hydrostatic force. (10)

9. A pump delivers fresh water at the rate of 32 tonne/hour. The delivery pipe is 90 mm bore. Suction is from a tank which is 0.9 m below the pump and delivery is to a tank which is 19.5 m above the pump. The discharge pipe has a total length of 25 m and a friction factor coefficient of 0.01 for use in D'Arcy's equation. Friction losses and velocity in the suction pipe can be neglected.

Calculate EACH of the following:

(a) the total manometric head in the system; (12)

(b) the input power of the pump required if its efficiency is 75%. (4)

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 24th March 2015

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Question 1 concerned friction in a static situation were the equations had to be developed and solved simultaneously. This was attempted by a minority of students which seems to indicate that students are not willing to use fundamental equations which need to be developed by themselves and this needs to be addressed. Question 2 concerned a combination of linear and angular dynamics and again fundamental equations had to be developed and solved simultaneously. This question was attempted by the fewest number of students. Question 3 was a Hartnell governor question and was attempted by most students, though not very well. Question 4 was SHM and attempted by only a few students.
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Questions 5 to 7 covered the strength of materials section of the syllabus. Question 5 was an Euler strut problem and historically these questions are well liked and well solved by students due to the fact that the equations are given. Question 6 covered torsion in a shaft and the coupling bolts connecting shafts together. A large number of students thought the bolts were also under torsion. Question 7 concerned components in series together with strain energy. Attempted by the majority of students, but not very well.

Question 8 and 9 covered the fluids section of the syllabus. These were attempted by a large majority of the students. Question 8 was either not understood or misread by some students who did not appreciate that moments about the hinge of the door needed to be taken.. Question 9 was the best attempted question on the paper.

Some general notes are :

- Neatness. A large number of workings in some scripts were difficult to follow.
- Accuracy of calculations. A large number of students only used one or two figures of accuracy. This leads to larger errors when values are raised to a power. A minimum of three and preferred four significant figures should be used.
- Following on from point 2, the accepted value of 'g' is 9.81 m/s^2. A large number of students used 9.8 and a few used 10. This is not acceptable and will be punished.
- SI units. All calculations are based on SI units which use exponents to the power of multiples of 3. Students should be encouraged to use this and not other powers (eg. 10^4, 10^5 etc) Also, a large number of students give answers without units or in a large number of cases give the incorrect unit. Simply stating a number or incorrect unit is not good enough and again this will be punished.
- Questions attempted for marking must be indicated on the front of the examination script. Some students did not declare any questions for consideration on the front and the marker is entitled to not mark any of the work and award zero for the paper.
- As prospective Chief Engineers, some concept of values is required. Some answers given in this paper showed that some students had no concept of their answer. For example a power of 65 watts was calculated to raise a 1 tonne mass at constant speed. A water velocity in a pipeline was calculated as 1300 m/s, faster than the speed of a supersonic airplane. These answers were given with no comment from the students, indicating that they assumed they were perfectly acceptable.

General Comments of Specific Examination Questions

Q1. Attempted by 15 students producing an average mark of 0.8 out of 16.
A problem on friction in a static situation. The student has to develop and solve several equations and this again has been unpopular and shows that the manipulation of several maths equations causes errors. Also, the free body diagram was incorrectly drawn by a number of students.

Q2 Attempted by 9 students producing an average mark of 6.8 out of 16.
Both linear and angular dynamics combined in the same question. Once more incorrect free body diagrams were drawn which made the solution more difficult. The value of 'g' should be 9.81 m/s^2 , but some students used 9.8 or even 10. This is not acceptable.

Q3. Attempted by 47 students producing an average mark of 8.9 out of 16.
A very popular question, but poorly attempted in a large number of cases. Part (a) says that friction is not present, but some students still included it in the equations. In part (b) the speed is reduced by 20 rev/min, but some students had great difficulty in subtracting 20 from 720 to give 700 rev/min.

Q4. Attempted by 9 students producing an average mark of 6.6 out of 16.
A simple harmonic motion question which was not popular. The main problem was to determine the stroke and therefore amplitude of the motion using the delivery rate and speed. Most students did not manage this.

Q5. Attempted by 41 students producing an average mark of 11.1 out of 16.
Historically, Euler strut questions are popular and well done. This is probably due to the equations being given. This applies at this sitting with a good average mark and a number of students achieving full marks. Most errors were in calculating the value of E in part (a) and the critical stress in part (c).

Q6. Attempted by 49 students producing an average mark of 10.3 out of 16.
A question involving torsion and coupling bolts. Well attempted by most students, with some achieving full marks. Most errors were caused by doubling the stress values using the safety coefficient instead of dividing by 2. Also, some students applied the safety coefficient to torque rather than stress, The coupling bolts are in direct shear, but a number of students tried to apply the torque equation to the bolts as well as the shaft.

Q7. Attempted by 48 students producing an average mark of 7.9 out of 16.
Attempted by a large number of students, but as seen by the average mark not very well. Most errors were caused by not reading the question correctly or not understanding the question. It says the extension of the hollow section is twice that of the solid, but some students had this the other way around. Some students labelled the sections 1 and 2 but did not use the correct section in the calculations. Perhaps H for hollow and S for solid may have been better.

Q8. Attempted by 46 students producing an average mark of 7.5 out of 16.
As for Q7, attempted by a large number of students but not very well in most cases. Some students used the equation for pressure rather than force, did not understand or could not calculate the value of 'h' for vertical depth to centroid of wet area, could not add and subtract simple numbers to find values for taking moments, could not calculate position of centre of pressure.

Q9. Attempted by 51 students producing an average mark of 12.7 out of 16.
The most popular and best attempted question on the paper. Full marks were obtained by a large number of students with very good solutions. Main sources of error were not knowing D'Arcy's equation, miscalculating velocity in discharge pipe (one student had a value of about 1300 m/s and another 0.005 m/s). As mentioned in general comments above, accuracy of calculated values caused errors since velocity is squared in D'Arcy.

CERTIFICATES OF COMPETENCY IN THE MERCHANT NAVY –
MARINE ENGINEER OFFICER

EXAMINATIONS ADMINISTERED BY THE
SCOTTISH QUALIFICATIONS AUTHORITY
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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)

[OVER

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)

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM
PART I

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 16th December 2014

General Comments on Examination Paper

The first 3 questions covered the statics/dynamics sections of the syllabus. Question 1 concered a Porter governor and was attempted by most students. Question 2 concerned friction in a static situation were the equations had to be developed and solved simultaneously. This was attempted by the fewest number of students which seems to indicate that students are not willing to use fundamental equations which need to be developed by themselves and this needs to be addressed. Question 3 concerned rotating unbalance and could be solved graphically or by vector algebra. Most students chose a vector algebra solution.

Question 4 concerned mathematical solution of control type questions. A large number of students who attempted this question did not appear to understand that the variables in the equation had specific units attached to them (for example kg/hour) and decided to change this to a different unit (kg/s). This leads to an incorrect solution.

Questions 5,6 and 7 covered the strength of materials sections of the syllabus and these were attempted by a larger number of students. This could be due to more standard specific equations being used to solve this type of problem.

Question 8 and 9 covered the fluids section of the syllabus. These were attempted by a large majority of the students. Question 8 was either not understood or misread by some students who did not appreciate that the pressure of the gas is constant over the full depth of the tank. Question 9 was the best attempted question on the paper.

General Comments of Specific Examination Questions

Q1. Attempted by 39 students producing an average mark of 11.3 out of 16.
A Porter governor question which proved very popular and well attempted by most students. A standard equation is used, but most errors were due to there being three flyweights rather than two.

Q2 Attempted by 15 students producing an average mark of 6.5 out of 16.
A problem on friction in a static situation. The student has to develop and solve several equations and this again has been unpopular and shows that the manipulation of several maths equations causes errors. A vector diagram solution could have been used, but no students attempted this.

Q3. Attempted by 18 students producing an average mark of 9.5 out of 16.
This concerns rotating unbalance in a single plane and could be solved graphically or by vector algebra. There was a mixture of both types of solution with errors occuring in both. Sin and cos caused problems in vector algebra and incorrect vector diagrams were drawn graphically.

Q4. Attempted by 22 students producing an average mark of 10.0 out of 16.
The equation is given in the question and requires transposition to solve for the unknown variable. The main source of error was students not using the units stipulated in the question for each variable. Part (b) of the question requires the solution of a quadratic equation and some students struggled with this.

Q5. Attempted by 43 students producing an average mark of 10.2 out of 16.
The most popular question on the paper involving the standard torsion equation applied to a shaft. A large number of students obtained full marks for the question. The main source of error was not converting degrees into radians for use in the torsion equation. This is fundamental and was punished severly. Also the factor of safety applies to the torsional stress but some students applied it to the torque.

Q6. Attempted by 39 students producing an average mark of 11.7 out of 16.
Close coiled spring equations for deflection and shear stress had to be solved together to calculate the coil diameter. Most students did this very well. Most errors were due to incorrect equations being used, confusing radius with diameter, confusing wire diameter with coil diameter.

Q7. Attempted by 28 students producing an average mark of 9.3 out of 16.
A question involving the standard bending equation for a beam. Normally in engineering the bent beam radius is very large, but in this question it is relatively very small at 2.8 m. This should have indicated the size of the beam will also therefore be small, but some students calculated a beam depth larger than the radius given which is not possible. Confusion appeared in all areas of the question between bending moment and bending stress, I values for beams in bending and J values for shafts in torsion.

Q8. Attempted by 36 students producing an average mark of 6.8 out of 16.
Attempted by a large number of students but not very well in most cases. Most obtained full marks for part (a) with errors being caused by not obtaining the total pressure due to gas and oil. Part (b) caused most marks to be lost by not understanding that gas pressure is considered as constant over the full 4 m height of the tank. This gives a pressure rectangle for the gas and a pressure triangle superimposed onthis for the oil. The force for each diagram can then be found and added together for the total force.

Q9. Attempted by 38 students producing an average mark of 13.6 out of 16.
The best attempted question on the paper probably due to the use of inlet and exit velocity diagrams making the calculations easier to visualise. Most errors were caused by not knowing what each of the velocity vectors were on each diagram.

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, 14 OCTOBER 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 packing case rests on an inclined plane of 14°. A force of 1400 N acting parallel to and up the plane is applied and just moves the packing case up the incline.

   When a force of 1510 N is applied to the same packing case but now horizontal and acting into the plane, the packing case also just moves up the incline.

   Determine EACH of the following:

   (a) the coefficient of friction between the packing case and the plane; (11)

   (b) the mass of the packing case. (5)

2. A helicopter is 300 nautical miles due South of a ship. The absolute speed of the ship is 18 knots in a direction 30° South of East. The speed of the helicopter is 120 knots.

   Determine EACH of the following:

   (a) the course to be taken by the helicopter to meet the ship as quickly as possible; (12)

   (b) the time taken by the helicopter to meet the ship. (4)

3. A winch motor drives a pinion which has 320 teeth. Friction in the motor bearings is constant at 20 Nm. The pinion meshes with a gear wheel having 640 teeth and this gear wheel drives a winch drum of diameter 340 mm. The winch drum raises an anchor of mass 2 tonne at a steady speed of 0.3 m/s. Assume the efficiency of the gearing is 100%.

   Calculate EACH of the following:

   (a) the total torque to be supplied at the output from the winch motor; (8)

   (b) the input power required by the winch motor if the motor efficiency is 85%. (8)

4. 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 12 kW at 600 rev/min. The axial thrust on the clutch faces is provided by six identical springs, each with a stiffness of 8 kN/m. The coefficient of friction at the clutch surfaces is 0.6.

Calculate EACH of the following:

(a) the required compression of each spring to deliver the designed power when the clutch is new; (8)

(b) the power transmitted when a total of 2 mm of plate wear occurs and the clutch is worn. (8)

Note:

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

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

n = number of pairs of contact surfaces.

5. A short vertical column consists of a hollow steel tube of 48 mm outside diameter and 40 mm inside diameter with a solid brass rod of 34 mm diameter within it. The steel tube is 380 mm long and the brass rod is 1 mm shorter. The brass rod is supported on a raised boss so that the top of the tube and the top of the rod are level.

Calculate the maximum load that can be applied to the column so that the compressive stress in the brass rod does not exceed 50 MN/m^2. (16)

Note: For steel, Modulus of Elasticity = 210 GN/m^2
For brass, Modulus of Elasticity = 80 GN/m^2

6. When a four ram hydraulic steering gear has the rudder at an angle of 30°, the hydraulic oil pressure is 60 bar and the rudder is moving at 0.033 rad/s. The rams are 250 mm diameter and the distance between the centreline of the rams and the centre of the rudder stock is 1.2 m.

Calculate EACH of the following:

(a) the power delivered to the rudder stock; (10)

(b) the bending moment on the tiller arm at a point 800 mm from the centre of the rudder stock. (6)

7. A hollow square section beam of external dimension 100 mm and thickness 5 mm is loaded as shown in Fig Q7.

Calculate EACH of the following:

(a) the maximum stress due to shear in the beam; (8)

(b) the position of the point of contraflexure from the left hand side of the beam. (8)

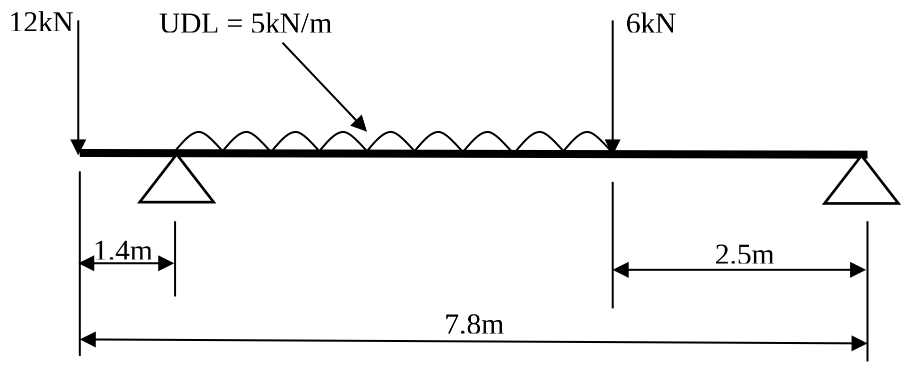

Fig Q7

8. A tank is 4 m deep and filled with fresh water. A 400 mm diameter circular access door is fitted into one side of the tank and its centre is 600 mm from the tank floor. The access door is vertical and is hinged at its top edge and is secured by a single bolt at its lowest edge.

A pressure test is applied to the tank by filling the air vent pipe to give an additional head of 800 mm of fresh water.

Calculate EACH of the following:

(a) the hydrostatic force on the access door; (3)

(b) the position of the centre of pressure of the hydrostatic force below the centroid of the door; (6)

(c) the tensile force in the bolt. (7)

9. A vertical pipe is 8 m long. It is 100 mm diameter at the bottom and 140 mm diameter at the top. Sea water flows upwards through the pipe and the pressure at the top is 0.7 bar less than the pressure at the bottom. Friction head loss in the pipe is found to be 0.5 m.

Calculate the sea water flow rate in tonne/hour. (16)

Note: Density of sea water is 1025 kg/m^3.

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM

SUBJECT: 041-31 Applied Mechanics

DATE OF EXAMINATION: 14th October 2014

General Comments on Examination Paper

The first 4 questions covered the statics/dynamics sections of the syllabus. Of these very few students attempted any of the first 3 questions. Question number 4 concerned a flat plate clutch where the equations were given, leading to a larger number of students attempting this question. This seems to indicate that students are not willing to use fundamental equations which need to be developed by themselves and this needs to be addressed.

Questions 5,6 and 7 covered the strength of materials sections of the syllabus and these were attempted by a larger number of students. This could be due to more specific equations being used to solve this type of problem. Question 5 was misinterpreted by a number os students even though it states that the top of the tube and rod are level. Diagrams were not drawn in a number of cases which may have helped.

Question 8 and 9 covered the fluids section of the syllabus. These were attempted by a large majority of the students, but basic mistakes were made in calculating distances in Q8 and transposition of Bernoulli's equation in Q9 caused problems.

General Comments of Specific Examination Questions

Q1. Attempted by 14 students producing an average mark of 6.4 out of 16.
This requires a free body diagram indicating forces acting on the object. Few students were willing to attempt this and the subsequent development of the necessary equations was lacking.

Q2 Attempted by 10 students producing an average mark of 3.7 out of 16.
A question on relative motion which was very unpopular and poorly attempted by those who did opt for it. Not one student correctly drew a velocity vector diagram or used a space diagram to determine the relative velocity direction.

Q3. Attempted by 7 students producing an average mark of 7.1 out of 16.
Angular dynamics is never popular and only 7 students attempted this question. Incorrect equations were used and the concept of frictional torque was missed by a number of students.

Q4. Attempted by 40 students producing an average mark of 10.7 out of 16.
A standard question on power transmission through a flat plate clutch. Well attempted by most students with a few not being able to transpose the torque equations. The question states that the total wear is 2 mm but some students doubled this because of the value of 'n'.

Q5. Attempted by 45 students producing an average mark of 9.4 out of 16.
Misunderstood by a large number of students. The question clearly states that the top of the tube and rod are level, but a number had the rod 1 mm shorter than the tube and the top of the rod below the top of the tube. A case of read the question carefully.

Q6. Attempted by 44 students producing an average mark of 12.0 out of 16.
The best attempted question. This involves standard equations and appears to be the type of question most favoured by students. Most mistakes were in part (b) where the bending stress was calculated, but this was not required.

Q7. Attempted by 44 students producing an average mark of 6.9 out of 16.
Misreading or misunderstanding the question gave most errors. Part (a) asks for shear stress, but a large number of students calculated the bending stress. Part (b) asks for the point of contraflexure, but a large number of students used only the shear force diagram and not the bending moment diagram.

Q8. Attempted by 41 students producing an average mark of 7.9 out of 16.
Basic calculation of the position of the centroid of the door below the liquid surface proved difficult for a large number of students. Misreading of part (b) caused errors. Very few students attempted part (c).

Q9. Attempted by 45 students producing an average mark of 8.4 out of 16.
The continuity equation and Bernoulli had to be used as simultaneous equations. A large number of students had difficulty with this. Also, giving a pressure difference caused confusion. Students seemed unaware that Bernoulli is about differences in energy levels at inlet and outlet and actual values at inlet and outlet need not be used.

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 22 JULY 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 Hartnell governor has two flyweights each of mass 0.5 kg. The flyweight arm length is 60 mm and the sleeve arm length is 25 mm. At a governor speed of 1600 rev/min and rising, the radius of the flyweights is 30 mm. A speed increase of 2% causes the central sleeve to move by 1.2 mm. Friction in the governor is equivalent to a force of 40 N at the sleeve.

   Calculate the spring stiffness. (16)

2. A crane lifting wire of 22 mm diameter is found to extend by 1.2 mm per metre length when subjected to a tensile load of 70 kN.

   The crane wire is attached to a spare piston ready for lifting. Whilst the crane wire is still slack the piston becomes dislodged from its storage mounting and falls a distance of 30 mm before taking up the slack in the crane wire. The crane wire is 3.8 m long and the instantaneous extension due to the falling piston is 2.8 mm.

   Calculate EACH of the following:

   (a) the modulus of elasticity for the crane wire material; (3)

   (b) the mass of the piston. (13)

3. A winch motor drives a pinion with 320 teeth, and friction at the motor bearings is constant at 18 Nm. The pinion then meshes with a gear wheel having 960 teeth which drives a shaft of 140 mm diameter. This shaft is supported in bearings having a coefficient of friction of 0.1 and drives a winch drum of diameter 380 mm.

   Calculate EACH of the following:

   (a) the driving torque required by the motor when raising a mass of 2 tonnes at steady speed; (10)

   (b) the input power required by the motor when raising the load in Q3(a) at a steady speed of 0.2 m/s if the motor efficiency is 88%. (6)

[OVER

4. A basic flapper/nozzle device is shown in Fig Q4. The pneumatic signal for the input bellows unit is proportional to the measured temperature within the range 0 - 500°. The output signal range is to be 20 - 100 kN/m^2.

The characteristic of the input bellows is 3 μm/°C, and the characteristic of the nozzle is 0.1 kN/m^2 per μm of flapper movement.

$$\text{The gain of the device} = \frac{\text{\% change in output}}{\text{\% change in input}}$$

Calculate EACH of the following:

(a) the flapper movement at the nozzle for 100% input change; (2)

(b) the resulting change in output; (2)

(c) the gain of the device; (2)

(d) the new setting of *x*, the distance from the pivot to the nozzle, to achieve a gain of magnitude 0.7; (5)

(e) the output pressure at 450°C with a gain of magnitude 0.7 if the output pressure was 50 kN/m^2 at a temperature of 430°C. (5)

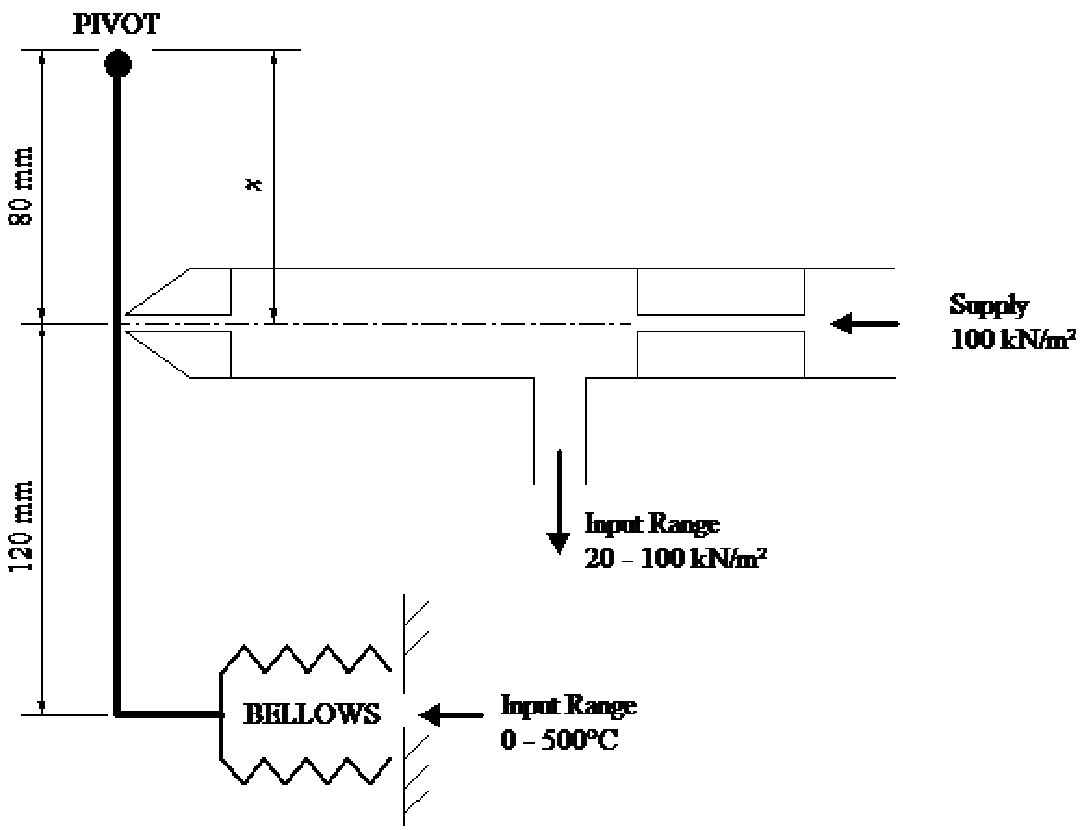

Fig Q4

5. A compound shaft consists of a 25 mm thick bronze sleeve fitted over a 375 mm diameter steel shaft. The compound shaft transmits 2.9 MW at 92 rev/min.

Calculate EACH of the following:

(a) the torque transmitted by the bronze sleeve; (6)

(b) the torque transmitted by the steel shaft; (6)

(c) the maximum shear stress in the bronze sleeve; (2)

(d) the maximum shear stress in the steel shaft. (2)

Note: Modulus of Rigidity of the steel = 80 GN/m^2
Modulus of Rigidity of the bronze = 45 GN/m^2

6. A cable consists of one steel wire 6 mm diameter and eight brass wires each 3 mm diameter. The stress in the brass wires is not to exceed 50 MN/m^2.

Calculate EACH of the following:

(a) the maximum load the cable can carry; (10)

(b) the equivalent modulus of elasticity for the cable. (6)

Note: Modulus of Elasticity for Steel = 210 GN/m^2
Modulus of Elasticity for Brass = 80 GN/m^2

7. A pump delivers fresh water at the rate of 30 tonne/hour. The discharge pipe is 75 mm bore and delivers water to the bottom of a tank located 11 m above the pump. The suction lift of the pump is 1.6 m. The discharge pipe is 28 m long with a friction coefficient for Darcy's equation of 0.01. Friction losses in the suction pipe may be neglected.

Calculate the output power of the pump when the water level in the tank has risen to 3 m. (16)

8. A vertical pipe 6 m long is 80 mm diameter at the bottom and 120 mm diameter at the top. Sea water flows upwards through the pipe and the pressure at the top is 0.6 bar less than the pressure at the bottom. Friction head loss in the pipe is 0.4 m.

Calculate the sea water flow rate in tonne/hour. (16)

Note: Density of sea water = 1025 kg/m^3

9. A steel beam of symmetrical I section is shown in Fig Q9. The beam has a mass of 30 kg per metre run and is 9 m long. The beam is simply supported at each end and the maximum bending stress is not to exceed 140 MN/m^2 at any point.

Calculate EACH of the following:

(a) the maximum uniformly distributed load that can be carried; (12)

(b) the minimum radius of curvature when this maximum uniformly distributed load is carried. (4)

Note: Modulus of elasticity for steel = 210 GN/m^2

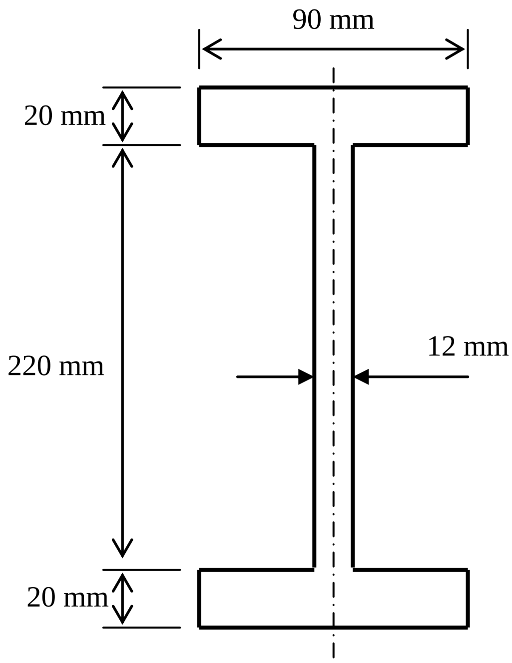

Fig Q9

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, 8 APRIL 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 shell is fired with a velocity of 420 m/sec at 40° above the horizontal from a point at the foot of a slope inclined at 12° above the horizontal.

   Calculate the range of the shell, as measured along the slope. (16)

2. A four stroke single cylinder engine produces 120 kW at 720 rev/min. The fluctuation of energy is 18% of the work done per cycle.

   In order to stabilise the speed for electrical generation purposes a 0.2 m thick flywheel is to be fitted. The frequency must not fluctuate more than +/- 0.2 Hz from the standard 60 Hz.

   Calculate the diameter of the solid flywheel. (16)

   Note: Density of flywheel material = 7800 kg/m^3

3. The piston of a reciprocating engine has a mass of 800 kg. The engine has a stroke of 2.4 m and a bore of 950 mm. At an engine speed of 90 rev/min the cylinder pressure just after TDC is 110 bar. The piston rod has a diameter of 340 mm. The piston may be assumed to move with simple harmonic motion.

   Calculate EACH of the following:

   (a) the velocity of the piston when 0.8 m from TDC; (3)

   (b) the maximum acceleration of the piston; (3)

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

4. A load of 3 tonne resting on tapered block A is to be raised using two identical wedges B and C as shown in Fig Q4.

The coefficient of friction between the wedges and block A is 0.3 and between the wedges and the ground is 0.4. The load on each wedge can be assumed to remain equal.

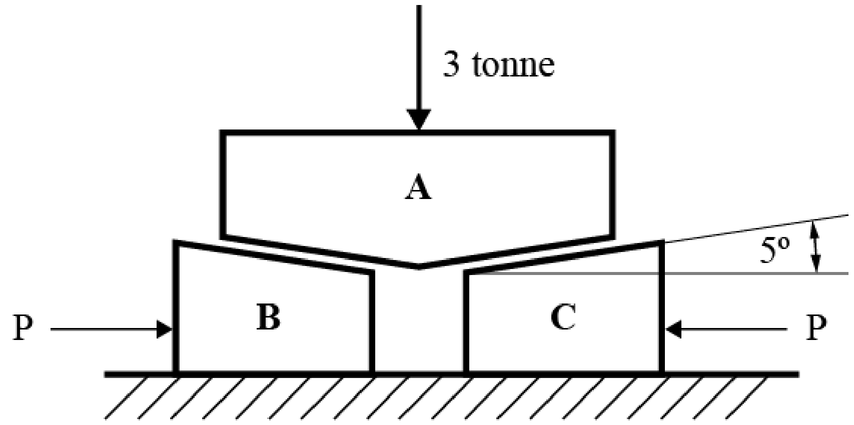

Fig Q4

Calculate the horizontal force 'P' required at each wedge (16)

5. A propeller shaft is designed to be solid with a diameter of 280 mm. It is then decided to replace this shaft with a hollow shaft of 350 mm outside diameter of the same material and length. Neither the maximum shear stress nor the angular twist per unit length of the original shaft is to be exceeded.

Calculate EACH of the following:

(a) the maximum permissible inside diameter of the hollow shaft; (12)

(b) the percentage reduction in weight. (4)

6. A horizontal cantilever beam is 2.8 m long. It carries a concentrated load of 2400 N at its free end and a uniformly distributed load of 360 N/m over its entire length. The beam has a hollow rectangular cross-section with outside dimensions of 100 mm wide by 150 mm deep and a constant thickness of 14 mm.

Calculate EACH of the following:

(a) the maximum bending stress in the beam; (10)

(b) the total deflection at the free end of the beam. (6)

Note: $\delta = \dfrac{WL^3}{3EI}$ *for a concentrated load where W = concentrated load (N)*

$\delta = \dfrac{wL^4}{8EI}$ *for a distributed load where w = distributed load (N/m)*

Modulus of Elasticity for beam material = 210 GN/m^2

7. A steel bar is 0.9 m long and 50 mm diameter. An axial hole 30 mm diameter is to be drilled from one end to such a depth that the extension of the drilled part is twice the extension of the solid part when an axial tensile load is applied.

Calculate EACH of the following:

(a) the required depth of the drilled hole; (8)

(b) the strain energy in the bar when an axial tensile load of 24 kN is applied. (8)

Note: Modulus of Elasticity for steel is 210 GN/m^2.

8. A tank, 4 m wide and 3 m deep is filled with fresh water. A pressure test is applied by filling the air vent pipe to give an additional head of 750 mm of water. A 380 mm diameter circular access door is fitted with its centre 600 mm from the tank floor. The access door is hinged at its top edge and secured by a single bolt at its lowest edge.

Calculate EACH of the following:

(a) the hydrostatic force on the access door; (3)

(b) the tension on the bolt; (6)

(c) the maximum permissible depth of water in the tank if the bolt tension is limited to 1.2 kN. (7)

9. A pump is required to draw fresh water from a depth of 4 m at the rate of 2.8 m^3/minute. The pressure in the pump suction line is not to fall below 24 kN/m^2. Barometric pressure may be taken as 750 mm mercury.

Calculate the required minimum diameter of the suction pipe. (16)

Note: The relative density of mercury is 13.6

SCOTTISH QUALIFICATIONS AUTHORITY
MARKERS REPORT FORM

SUBJECT: 041-31 Applied Mechanics

DATE: 8 April 2014

General Comments on Examination Paper

Too many candidates failed to make a decent attempt at six questions, indicating lack of preparation across the whole syllabus. Candidates should spend enough time reading the question and understanding the basic arrangements and a simple sketch is useful for this.

Comments of Specific Examination Questions

Q1. A projectile question. Perhaps because this type of question appears infrequently, it was not attempted by many students.

Q2. A question about angular kinetic energy. Despite the fact that similar questions have appeared before, not many students attempted the question, indicating that students are ignoring this part of the syllabus.

Q3. A simple harmonic motion question. This was straightforward for all who had studied and revised the topic, but it appeared that many had not.

Q4. A straightforward friction question, with the load shared equally between two wedges, it was as straightforward as a single wedge question and could be solved by resolution of forces or the friction angle method.

Q5. A torsion question, with two limiting conditions (equal torsional stress and equal twist). A surprisingly high number of students could not work out the percentage reduction in weight.

Q6. A beam question with the deflection formulae given. Reasonably well attempted in most cases.

Q7. A relatively straightforward stress/strain question. Some careless work led to several students trying to work out the stress in the wrong 'part' of the hollow shaft, i.e. thin air.

Q8. A hydrostatic question. Although a popular question, part b) was not well attempted (finding the resultant Centre of Pressure). For part c) the maximum depth also affects the position of the centre of pressure

Q9. A simple application of Bernoulli and the continuity equation, but some students seemed to be attempting a different question.