CAMBRIDGE TECHNICALS

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Examiners' report

ENGINEERING

05822–05825, 05873

Unit 3 January 2022 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

Unit 3 series overview

This Level 3 paper examined the principles of mechanical engineering. It followed a similar format to previous papers.

To do well on this paper, candidates needed to:

- be familiar with all the parts of the specification examined
- show clear and legible workings especially for 2, 3 and 4 mark questions
- attempt all questions
- be familiar with and make appropriate use of the formula booklet
- be familiar with and make use of engineering language and terms.

The paper appeared to be accessible with most questions being attempted by most candidates from most centres. However, candidates from some centres demonstrated limited understanding of bending moment diagrams (Question 5 (b)(iv)), conservation of momentum (Question 6(i)) and elastic/inelastic collisions (Question 6(ii)).

Candidates who did well on this paper generally did the following:	***Candidates who did less well on this paper generally did the following:***
• Used appropriate engineering language. • Showed clear working in calculations. • Attempted all questions. • Converted units correctly. • Showed familiarity with all parts of the specification including bending moment diagrams, conservation of momentum and elastic/inelastic collisions.	• Made mistakes in calculations. • Used incorrect engineering language. • Seemed to be less familiar with some parts of the specification including bending moment diagrams, conservation of momentum and elastic/inelastic collisions. • Seemed unfamiliar with the contents of the formula booklet.

Question 1 (a) (i)

1 **(a)** A ridged rectangular plate with corners A, B, C and D is subjected to three coplanar forces at corners B, C and D as shown in **Fig. 1**.

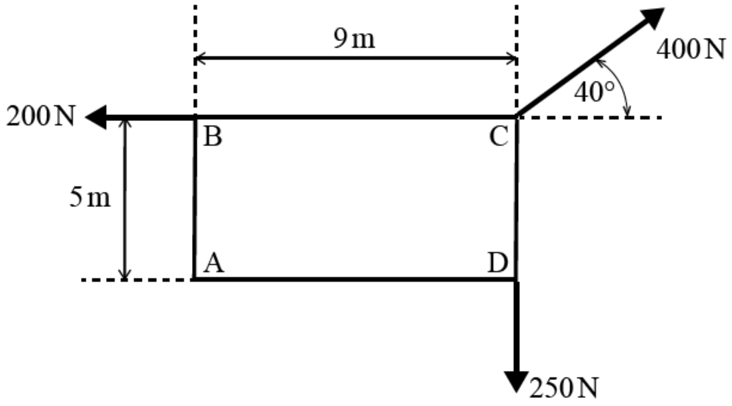


Fig. 1

(i) Resolve the 400 N force into horizontal and vertical components.

Horizontal ....

Vertical ....
[2]

Candidates were expected to calculate the vertical and horizontal components of the force. Most candidates from most centres scored both marks.

Question 1 (a) (ii)

(ii) Calculate the moment about corner A caused by all of the forces acting on the plate.

....

....

....

.... **[3]**

Successful candidates showed a correct expression for the moment about A, taking into account each of the four forces and their directions. These candidates then calculated the correct magnitude and direction to score 3 marks. Many candidates scored 1 mark by writing down three of the terms correctly with or without the correct direction.

	AfL	Centres should make sure that candidates understand the importance of showing their working.

Question 1 (a) (iii)

(iii) Explain why the forces cause a zero moment about corner C.

....

.... **[1]**

A small minority of candidates scored this mark. Successful candidates demonstrated an understanding that the line of action of each of the forces passed through point C. Some of these candidates also stated that the "perpendicular distance" of each force from point C was zero.

Question 1 (b)

(b) A particle suspended in space is subjected to four coplanar forces with magnitudes 180 N, 300 N, Q N and P N as shown in **Fig. 2**.

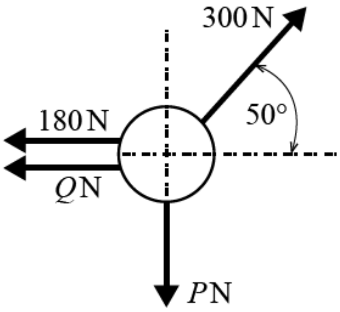


Fig. 2

Calculate the magnitudes of P and Q so that the particle remains in static equilibrium.

....

....

....

....

....

.... **[3]**

Successful candidates applied the condition for equilibrium in both the horizontal and vertical directions to calculate the correct answers. Some candidates who did not score full marks received 1 mark credit for writing correct workings for P or Q.

Question 2 (a)

2 **(a)** Name **three** types of gear system used to transmit rotary motion.

1 ....

2 ....

3 ....

[3]

Most candidates named at least one type of gear system. More successful candidates named two or three types.

Question 2 (b)

(b) Calculate the Mechanical Advantage (MA) of a gear system that has a Velocity Ratio (VR) of 0.4.

....

.... **[1]**

Most candidates calculated the correct value of MA.

Question 2 (c) (i)

(c) **Fig. 3** shows a lever which has an upward input force of 2000 N at one end and a fulcrum at the other end.

A load is positioned at a distance of 0.6 m from the fulcrum and x m from the input force.

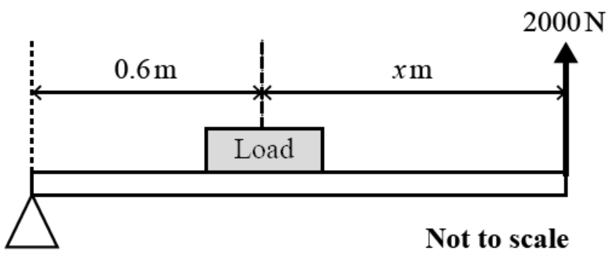


Fig. 3

(i) State the class of this lever.

.... **[1]**

Most candidates stated correctly that this was a class 2 lever. A substantial minority thought that this was a class 3 lever.

Question 2 (c) (ii)

(ii) The value of x is set so that the Mechanical Advantage (MA) of the lever is 2.5.

Calculate the maximum mass of the load that can be lifted.

Give your answer in kilograms.

....

....

.... **[2]**

Successful candidates multiplied the MA by the input force to calculate the output force. These candidates then divided the output force by 9.8. Some candidates who did not score 2 marks calculated the output force correctly and scored 1 mark.

	AfL	Centres should make sure that candidates understand the importance of showing their working.

Question 2 (c) (iii)

(iii) Calculate the value of x.

....

....

....

.... **[2]**

Successful candidates began by calculating the distance from the output force to the fulcrum correctly. They subtracted 0.6 from this value to score both marks. Some candidates did not carry out this final subtraction and scored 1 mark.

Question 2 (d)

(d) In a belt and pulley system, the diameter of the input pulley is 120 mm.

When the output pulley moves through an angle of $\frac{\pi}{3}$ radians, a point on its circumference moves through an arc of length 80 mm.

Calculate the Velocity Ratio (VR) of this belt and pulley system.

[3]

Successful candidates recalled the arc length formula (or referred to the formula booklet) and used it to find the radius. They multiplied their answer by 2 to find the diameter of the output pulley. Finally they divided the input pulley diameter by the output pulley diameter to calculate the velocity ratio. Candidates who used the radius instead of the diameter in an otherwise correct calculation could score 2 marks. Other candidates who calculated an incorrect value of diameter (other than the radius) could score 1 mark by dividing 120 by their diameter.

	AfL	Centres should make sure that candidates are familiar with section 1.1.1 of the formula booklet.

Question 3 (a)

3 (a) Fig. 4 shows a semicircle with a radius of 70 mm aligned within a Cartesian coordinate system, (x, y), with the origin at point O.

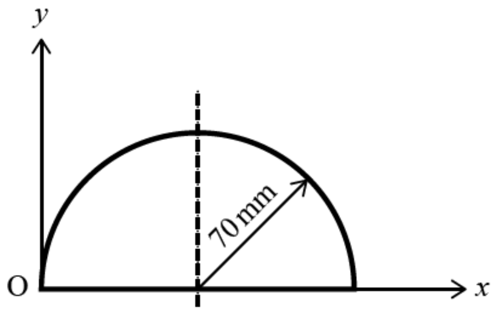


Fig. 4

Calculate the coordinates of the centroid of this semicircle.

....

....

....

.... **[2]**

Successful candidates recalled how to calculate the locations of centroids (or referred to the formula booklet) and scored both marks. Less successful candidates who did not recall this or did not refer to the formula booklet scored 0 or 1 marks.

	AfL	Centres should make sure that candidates are familiar with section 1.3 of the formula booklet.

Question 3 (b)

(b) **Fig. 5** shows a triangle aligned within a Cartesian coordinate system (x, y), with the origin at point O.

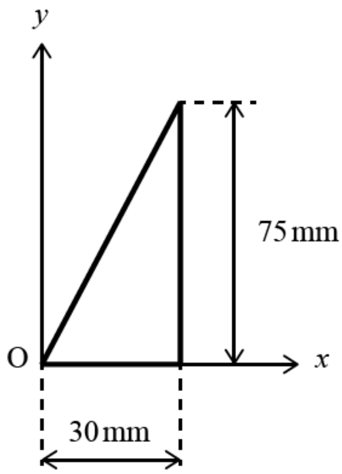


Fig. 5

Calculate the coordinates of the centroid of this triangle.

....

....

....

.... **[2]**

Successful candidates recalled how to calculate the locations of centroids (or referred to the formula booklet) and scored both marks. Less successful candidates who did not recall this or did not refer to the formula booklet scored 0 or 1 mark.

	AfL	Centres should make sure that candidates are familiar with section 1.3 of the formula booklet.

Question 3 (c) (i)

(c) **Fig. 6** shows the cross-section of a beam. All dimensions shown are in millimetres (mm).

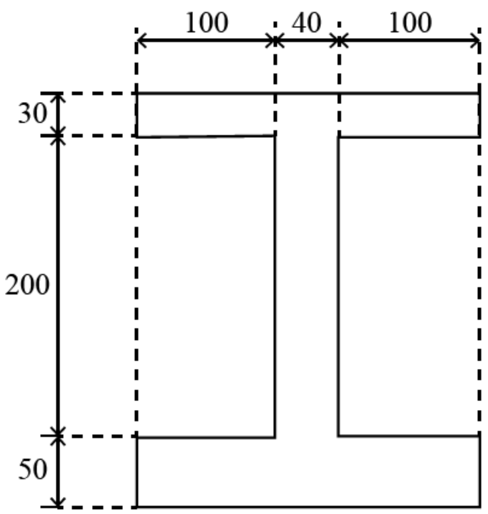


Fig. 6

(i) Calculate the area of the beam's cross-section.

Give your answer in square metres (m^2).

....

....

....

.... **[3]**

Successful candidates divided the area into simple rectangles which they showed by annotating the diagram. They calculated the individual areas before adding them together to find the area of the cross section in mm^2. They then converted their answer to m^2 to score 3 marks. Candidates who made a single error in their calculation or candidates who had a POT error could score 2 marks. Candidates who did not attempt conversion and had a single error could score 1 mark.

	AfL	Centres should make sure that candidates understand the importance of showing their working.

Question 3 (c) (ii)

(ii) The beam is 9 m long and made from steel with a density of $8000\,\mathrm{kg\,m^{-3}}$.

Calculate the mass of the beam.

....

....

.... **[2]**

Successful candidates multiplied the area they had calculated by the length of the beam. They then multiplied their volume by the density to calculate the mass to score 2 marks. Some candidates calculated the volume but did not calculate the mass (or calculated it incorrectly). These candidates scored 1 mark.

Question 3 (c) (iii)

(iii) A stress of 150 MPa in the beam is caused by a compressive force of F N.

Calculate the magnitude of F.

....

....

.... **[2]**

Successful candidates multiplied the stress by the area they had calculated to find the force. Candidates who did not score both marks could score 1 mark by showing the correct method in their working.

Question 4 (i)

4 An aircraft with a mass of 80 000 kg flying in a straight path at a constant altitude is subjected to four principal forces as follows:

a forward thrust force, F N, generated by the engine,

a backward aerodynamic drag force, D N,

an upward lift force, L N, provided by the wings,

a downward force, W N, due to the mass of the aircraft.

(i) Draw a diagram showing all forces acting on the aircraft. You can represent the aircraft as a box.

[2]

Most candidates scored 2 marks for this question by showing four arrows with arrowheads, correctly labelled and drawn with a ruler. A small number scored 1 or zero by labelling incorrectly or by omitting one or more arrowhead.

Question 4 (ii)

(ii) Calculate the magnitude of the lift force, L, so that the aircraft remains at a constant altitude.

....

.... **[2]**

Successful candidates multiplied the mass by 9.8 to calculate the weight of the aircraft and then used vertical equilibrium to find the lift force. Some candidates attempted to use the value of mass rather than force and could score 1 mark.

Question 4 (iii)

(iii) At a particular moment in time the aircraft is flying with a speed of $144\,\text{km}\,\text{h}^{-1}$ and has a constant horizontal acceleration of $0.3\,\text{m}\,\text{s}^{-2}$.

Calculate the time it would take the aircraft to travel a further 2 kilometres.

....

....

....

....

....

.... **[4]**

Successful candidates identified the correct suvat equation and substituted into it the correct values having converted speed and displacement appropriately. These candidates then found both solutions and discounted the negative solution to score 4 marks. Many less successful candidates selected the correct suvat equation and substituted the unconverted values of s and u. These candidates scored just 1 mark. Candidates who substituted the correct values into the correct equation scored 3 marks. There was a stand alone mark for converting from km/h to m/s.

Question 4 (iv)

(iv) When the aircraft is experiencing a constant drag force of 70 000 N, calculate the thrust force required to maintain a forward acceleration of $0.3\,\text{m}\,\text{s}^{-2}$.

....

....

....

.... **[3]**

Successful candidates applied F=ma correctly, substituting for resultant force, mass, and acceleration. These candidates showed clearly in their workings that the resultant force = thrust – 70 000. Some less successful candidates substituted the correct values of mass acceleration into the equation without showing thrust – 70 000 as the resultant force and these candidates scored 1 mark.

Question 4 (v)

(v) When the aircraft is flying with a speed of 144 $km h^{-1}$ and the engine is producing the thrust force as calculated in part **(iv)**, calculate the instantaneous power of the engine.

....

.... **[1]**

Most candidates scored this mark for multiplying their calculated value of force by a converted or unconverted value of velocity.

Question 5 (a)

5 (a) State whether each of the following situations should be modelled as a point load or a Uniform Distributed Load (UDL).

Snow accumulated on a flat roof. ....

Heavy tiles covering a floor. ....

A pedestrian standing on a footbridge. ....

[1]

Most candidates made all three correct statements and scored 1 mark.

Question 5 (b) (i)

(b) **Fig. 7** shows a beam with a length of 10 m securely attached to a wall at one end.

The weight of the beam is modelled by a force of 600 N acting vertically downward at a distance of 5 m from the wall.

A force of 200 N acts vertically downward at the free end of the beam while an additional force of 1000 N acts vertically downward at a point which is 8 m from the wall.

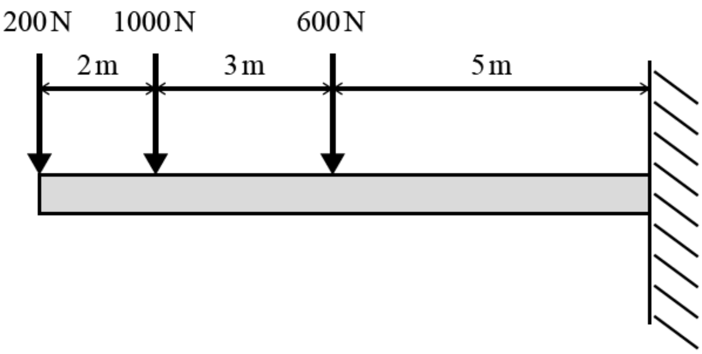


Fig. 7

(i) Name the type of beam.

.... **[1]**

Most candidates identified this correctly as a cantilever.

Question 5 (b) (ii)

(ii) Calculate the vertical reaction at the wall.

.... **[1]**

Most candidates stated the correct value of 1800 (N).

Question 5 (b) (iii)

(iii) Calculate the bending moment at the wall.

....

....

....

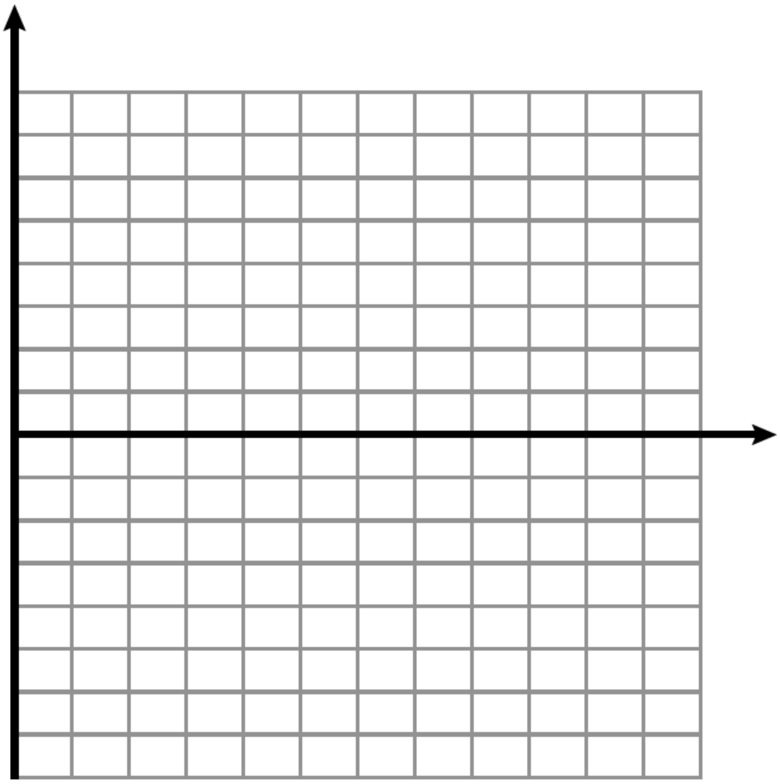
.... **[2]**

Most candidates from most centres calculated the correct value of the bending moment as 13 000 (Nm). Some candidates who did not calculate this correctly scored 1 mark for showing two out of the three terms correctly in their working.

	AfL	Centres should make sure that candidates understand the importance of showing their working.

Question 5 (b) (iv)

(iv) Draw a labelled bending moment diagram for the beam in **Fig. 7** on the grid below.



[4]

Successful candidates drew the correct linear diagram with zero bending moment at 0m, 400(Nm) at 2m, 4 000 at 5m and 13 000 at 10m. Candidates from a small number of centres typically scored 4 or 3 marks. Candidates from some centres seemed relatively unfamiliar with bending moment diagrams and scored lower marks – typically 0 or 1.

	AfL	Centres should make sure that candidates are familiar with the bending moment diagrams for different types of beam.

Question 6 (i)

6 Two particles, A and B, are travelling directly towards each other and experience a collision.

Particle A has a mass of 1.5 kg and a speed of $4\,\mathrm{m\,s^{-1}}$.

Particle B has a mass of 0.5 kg and a speed of $2\,\mathrm{m\,s^{-1}}$.

After the collision, particle A continues in the same direction as before with a speed of $1\,\mathrm{m\,s^{-1}}$.

(i) Assuming that momentum is conserved, calculate the speed and direction of particle B after the collision.

[4]

Successful candidates frequently drew "before and after" diagrams showing velocities before and after the collision. These candidates then applied the principal of conservation of momentum correctly to calculate the correct speed and direction and typically scored 3 or 4 marks. Many candidates from some centres seemed relatively unfamiliar with the principle of conservation of momentum and scored typically zero marks. Some candidates scored 1 mark for stating the correct direction after the collision.

	AfL	Centres should make sure that candidates are familiar with the principle of conservation of momentum and are familiar with the use of diagrams showing velocities (and masses) "before and after" collisions.

Question 6 (ii)

(ii) An elastic collision is one in which both momentum and kinetic energy are conserved. Using your result from part **(i)** determine whether this is an elastic collision.

....

....

....

....

....

.... **[3]**

Successful candidates calculated the kinetic energy before and after collision, stating that there was no change in kinetic energy and therefore that the collision was elastic. These candidates scored 3 marks.

Other candidates showed two calculations with one correct value and one incorrect and stated that the collision was inelastic. These candidates scored 2 marks.

Candidates who showed one or two correct calculations but no or an incorrect conclusion scored 1 or 2 marks respectively. Candidates who made a statement without any supporting calculation scored zero marks.

Candidates from a small number of centres typically scored 2 or 3 marks. Candidates from some centres seemed relatively unfamiliar with elastic/inelastic collisions and typically scored zero marks.

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