OCR
Oxford Cambridge and RSA

Tuesday 16 January 2024 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873 Unit 3: Principles of mechanical engineering

Time allowed: 1 hour 30 minutes
C303/2401

C303/2401

You must have:
- the Formula Booklet for Level 3 Cambridge Technical in Engineering (inside this document)
- a ruler (cm/mm)
- a scientific calculator

05822-03

Please write clearly in black ink. **Do not write in the barcodes.**

Centre number | | | | | | Candidate number | | | | |

First name(s) _____

Last name _____

Date of birth | D | D | M | M | Y | Y | Y | Y |

INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.
- Give your final answers to a degree of accuracy that is appropriate to the context.
- The acceleration due to gravity is denoted by g m s^{-2}. When a numerical value is needed use g = 9.8 unless a different value is specified in the question.

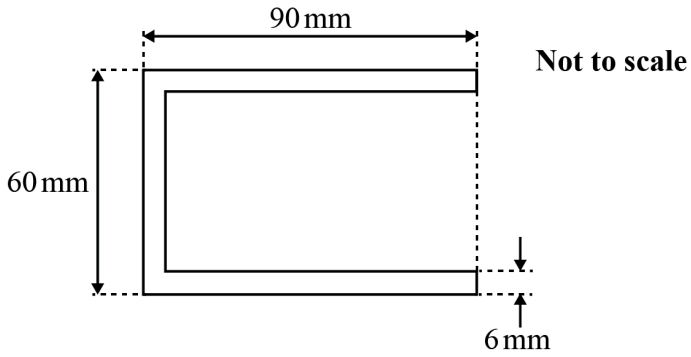
INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- This document has **16** pages.

ADVICE
- Read each question carefully before you start your answer.

1

(a) **Fig. 1** shows the cross-section of a piece of aluminium framework. The aluminium has a uniform thickness of 6 mm, a uniform width of 90 mm and a uniform height of 60 mm. The length is 2500 mm.

Fig. 1



(i) Calculate the volume of the aluminium framework in $kg\,m^{-3}$.

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(ii) The mass of the framework is 9.268 kg.

Calculate the density of the aluminium.

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(iii) An engineer changes the material of the framework to mild steel, which has a density of $7860\,kg\,m^{-3}$.

Assuming that the cross-section and length of the framework remain the same calculate its **additional** mass.

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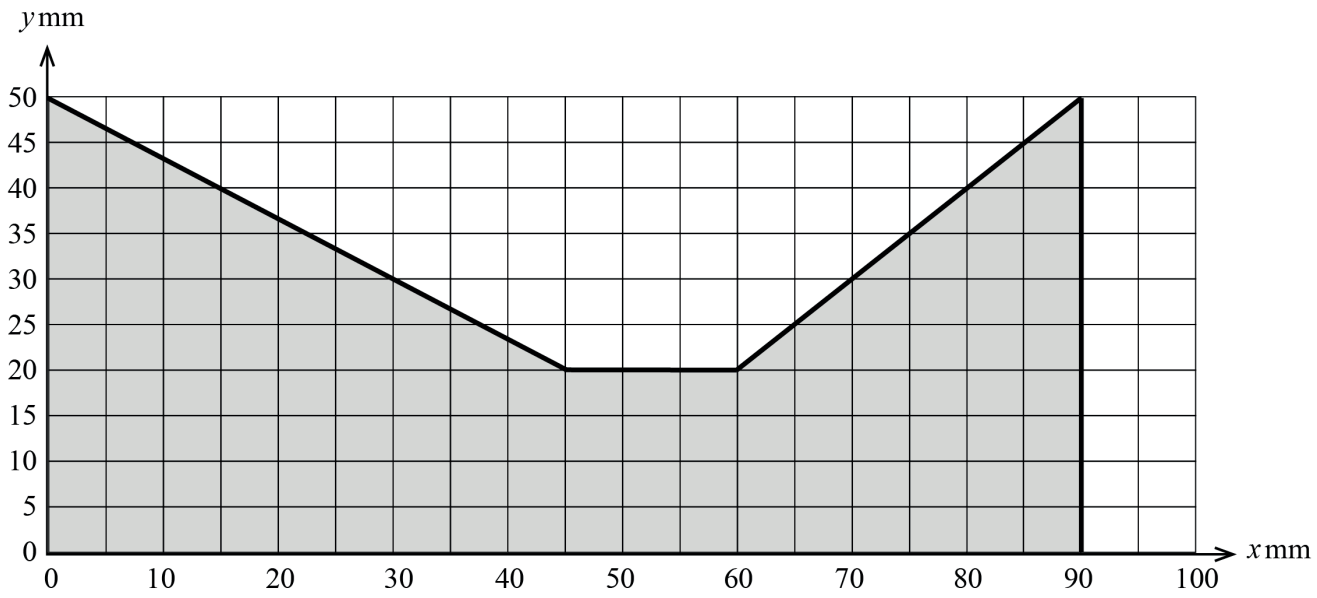
(b) **Fig. 2** shows a steel plate aligned within a Cartesian coordinate system (x, y). The units for both x and y are in millimetres.

Fig. 2



Calculate the coordinates of the centroid of the plate.

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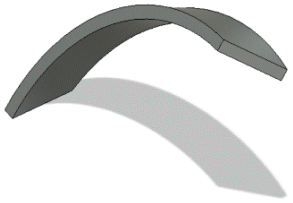
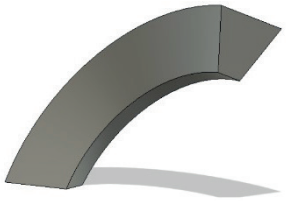
2

(a)

(i) State the name of each pulley belt shown below.



A



B

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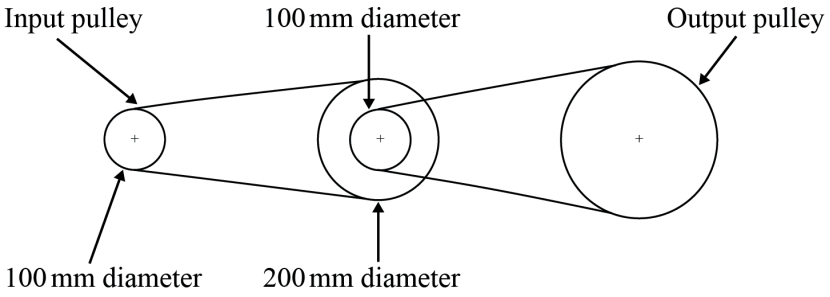
[3]

(ii) This compound pulley system requires an overall velocity ratio of 0.2.



Not to scale

Calculate the diameter of the output pulley.

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(b) An engineer has designed a class one lever that will lift a 50 kN load off the floor. This load is positioned 0.5 m from one side of the fulcrum. A vertical input force, *F* kN, is to be applied 3.5 m from the other side of the fulcrum and to be of sufficient magnitude to lift the 50 kN load.

(i) Draw a diagram of this lever showing:

- the position and direction of the load force
- the position and direction of the input force
- the distance of the load and input force from the fulcrum.

[2]

(ii) Calculate the minimum magnitude of the input force, *F*, required to lift the 50 kN load.

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3

(a) **Fig. 3** shows a simply supported beam with one uniformly distributed load (UDL) of $3\,\text{kN}\,\text{m}^{-1}$ at the position indicated.

Fig. 3

Not to scale

Calculate the magnitude of the equivalent point load for the UDL and its distance from the left-hand support.

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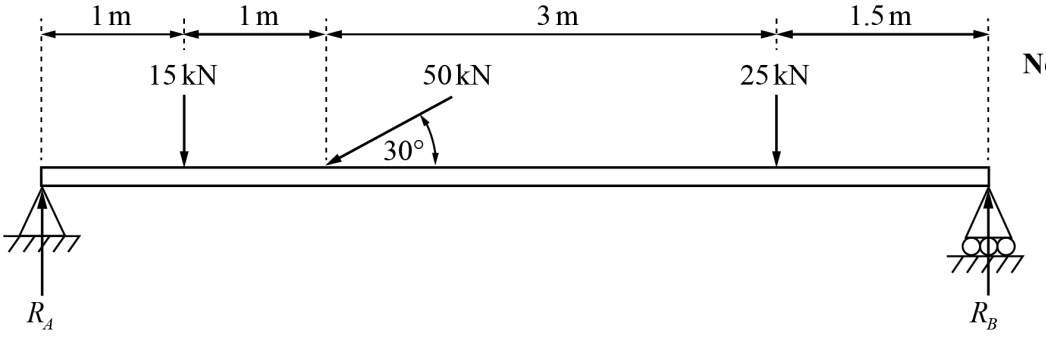
(b) **Fig. 4** shows a simply supported beam with three point loads.

Fig. 4



Not to scale

(i) Calculate the vertical component of the 50 kN point load.

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(ii) Calculate the magnitude of the two vertical reaction forces R_A and R_B.

The self-weight of the beam can be ignored.

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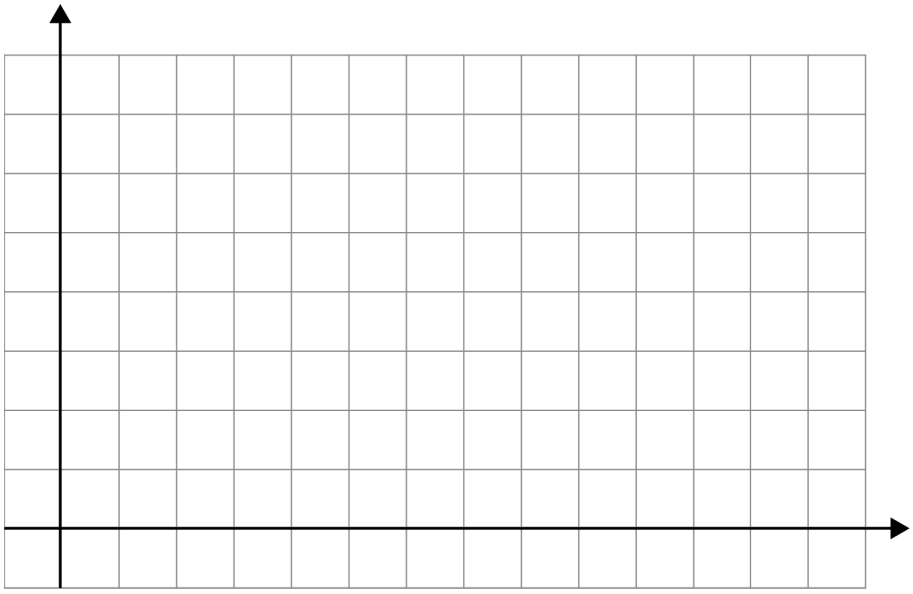
(iii) Draw a labelled bending moment diagram for the beam in **Fig. 4** on the grid below.



[5]

4 An engineer is designing a steel structure with a safety factor of 2.5. Each steel column has an ultimate tensile stress of 400 MPa.

(i) Calculate the allowable working stress of the steel columns.

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(ii) The column is subjected to an axial compressive force of 12 000 kN.

Calculate the cross-sectional area of the column using the ultimate tensile stress of 400 MPa.

Give the units of your answer.

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(a) A cannon is positioned 15 m above horizontal ground and fires a ball horizontally at a speed of 200 m s^{-1}. The motion of the ball is modelled as a projectile under the influence of gravity.

(i) By first finding the time taken for the ball to reach the ground, calculate the horizontal distance it travels during this time. Air resistance can be ignored.

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(ii) The mass of the ball is 5.4 kg and the mass of the cannon is 100 kg.

Using the conservation of momentum principle calculate the recoil speed of the cannon.

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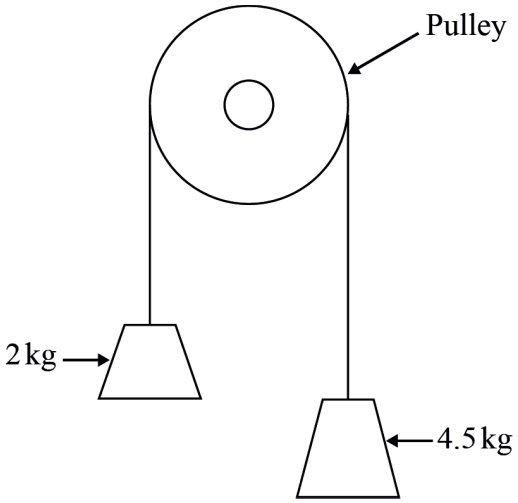
(b) **Fig. 5** shows two masses of 4.5 kg and 2 kg held in suspension by a light inextensible cable on opposite sides of a frictionless pulley. When the masses are released the 4.5 kg mass accelerates downwards and the 2 kg mass accelerates upwards.

Fig. 5



Using the principle of conservation of energy calculate the speed of the masses when they have travelled 0.5 m. The inertial energy of the rotating pulley can be ignored.

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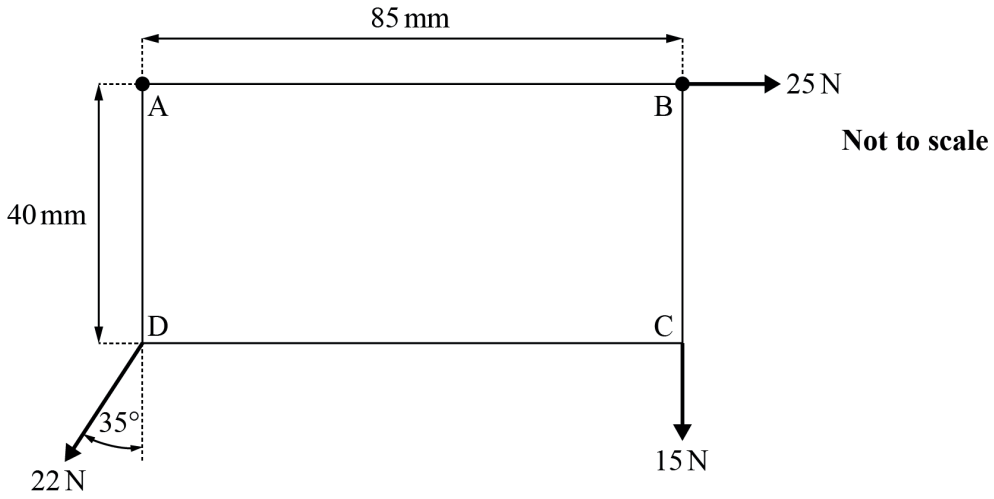
Turn over for the next question

6 This diagram shows three coplanar forces acting on a rectangular steel plate, A B C D, in a vertical plane.



(i) Calculate the magnitude and direction, relative to the horizontal, of the resultant of the three forces acting on the plate.

You should first resolve the force at D into its perpendicular components.

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(ii) Calculate the moment acting about point A.

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END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.