OCR
Oxford Cambridge and RSA

Monday 5 June 2023 – Afternoon

Level 3 Cambridge Technical in Engineering

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

Time allowed: 1 hour 30 minutes
C303/2306

C303/I/2306

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

0 5 8 2 2 – 0 3

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

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

First name(s) _____

Last name _____

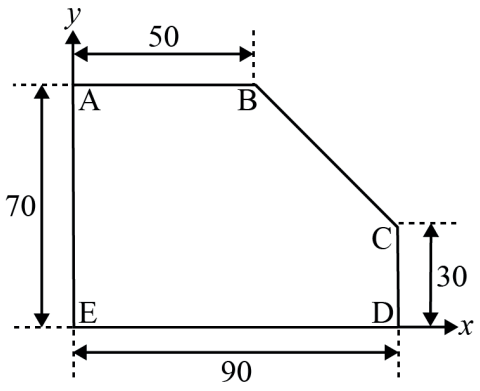
Date of birth | D | D | M | M | Y | Y | Y | Y |

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 The shape of a steel plate of uniform thickness is shown below. All dimensions are in millimetres.



(i) Calculate the cross-sectional area of this steel plate.

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..... **[2]**

(ii) The steel plate is aligned within a Cartesian coordinate system, (x, y), with the origin at corner E and with side ED along the x-axis.

Calculate the coordinates of the centroid of the steel plate.

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..... **[5]**

(iii) Explain what the centroid of the plate represents.

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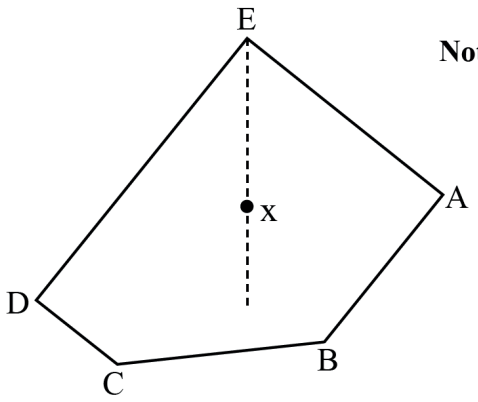
..... **[1]**

(iv) The plate is suspended from corner E.



Not to scale

In the diagram **X** represents the centroid.

Calculate the angle between side EA and the vertical.

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..... **[2]**

2 **(a)** Explain what **concurrent forces** means.

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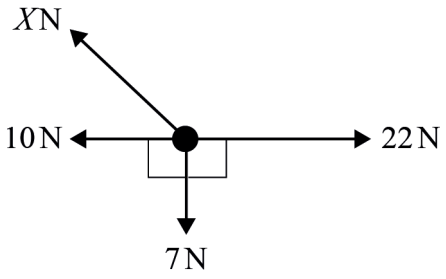
..... **[1]**

(b) Four co-planar forces are acting upon a body with magnitudes as shown.



Given the body is in equilibrium calculate the magnitude of force ***X***.

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(c) A structural column with a cross-sectional area of 5500 mm^2 is subjected to an axial compressive load of 2.5 kN.

(i) Calculate the stress in the column. Give the units for your answer.

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(ii) The column is 3 m in length. Assuming Young's Modulus is 200 GPa calculate the change in length.

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..... **[4]**

3 **(a)** Identify **two** types of gear mechanisms that will allow the transfer of rotational motion between two adjacent shafts that are not in parallel alignment.

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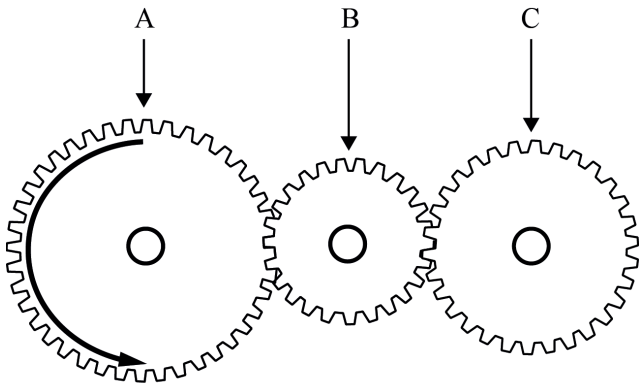
2 .....

[2]

(b) A gear train consisting of three gears, A, B, and C is shown below.

Gear A is the input gear.



(i) Within a gear train it is often useful to associate each gear with a term that indicates its function or use.

Choose an appropriate term from the list below for gears B and C.

Compound gear **Driver gear** **Idler gear**

Output gear **Transition gear**

Gear B .....

Gear C .....

[2]

(ii) If gear A has 25 teeth, gear B 12 teeth and gear C 20 teeth, calculate the total velocity ratio of the gear train.

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(iii) Give **two** reasons why an idler gear may be used within a gear train.

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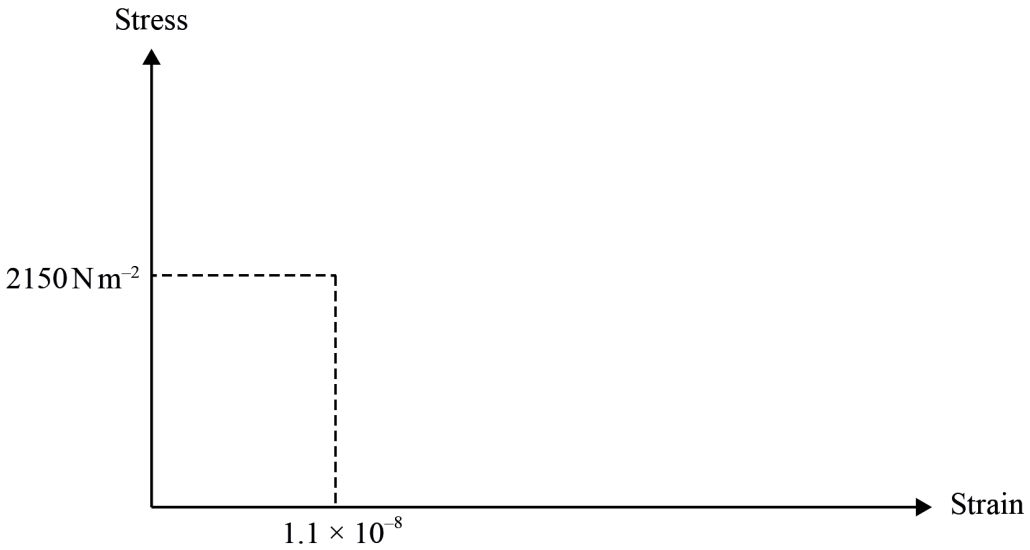
[2]

Turn over for the next question

4 (a) (i) Sketch a typical stress–strain graph for a metallic material on the axes shown in **Fig. 1.** The values on the axes indicate the limits of the region where the Young's modulus remains constant (so Hooke's law applies).

Fig. 1



[2]

(ii) The table below lists the values for Young's modulus of four common metals.

Metal	**Young's Modulus**
Aluminium	70×10^9 N m^{-2}
Steel	200×10^9 N m^{-2}
Copper	110×10^9 N m^{-2}
Cast Iron	120×10^9 N m^{-2}

Using this table determine the most likely type of metal associated with the values indicated on the axes shown in **Fig. 1.**

Justify your answer.

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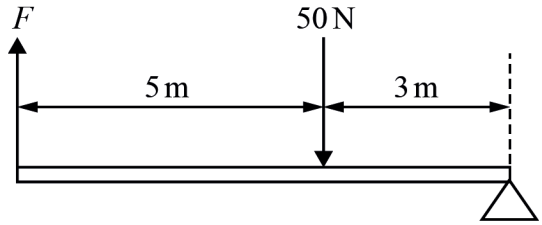
..... **[2]**

(b) Calculate the minimum force F, required to lift the load of 50 N shown on this lever.

Assume that the weight of the lever is negligible.



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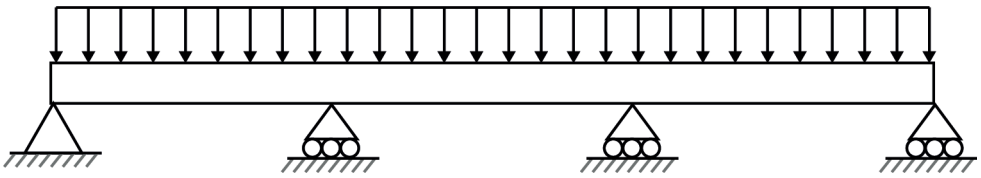
Turn over for the next question

5 **(a)** A Uniform Distributed Load (UDL) is shown on a supported beam.



(i) State the name of this type of supported beam.

..... **[1]**

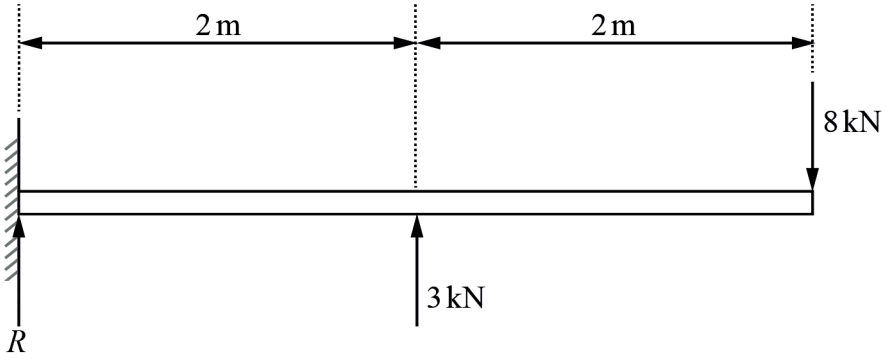
(ii) Give an example of what the UDL could represent.

..... **[1]**

(b) **Fig. 2** shows a cantilever beam attached to a wall.

The beam is subjected to two vertical forces of 3 kN and 8 kN.

Fig. 2



(i) Calculate the magnitude of the vertical reaction force, *R*, at the wall.

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(ii) Draw a labelled bending moment diagram on the grid below for the cantilever beam shown in **Fig. 2**.

[5]

6 (a) Two vehicles, A and B, are travelling in the same direction. Vehicle A is directly behind vehicle B. Vehicle A has a mass of 2600 kg and a speed of $15.6\,m\,s^{-1}$. Vehicle B has a mass of 1600 kg and a speed of $13\,m\,s^{-1}$.

Vehicle A then collides into the back of vehicle B. Immediately after the collision both vehicles continue to travel in the same direction but the speed of vehicle A has reduced to $9.4\,m\,s^{-1}$.

(i) Assuming that total momentum is conserved calculate the speed of vehicle B immediately after the collision.

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Immediately after the collision both vehicles slow down with a constant deceleration of $4\,m\,s^{-2}$ until they come to rest.

(ii) Calculate the distance travelled by vehicle A after the collision to when it comes to rest.

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(iii) Calculate the magnitude of the braking force experienced by vehicle A while it is decelerating.

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(iv) Calculate the total work done by vehicle A while it is decelerating.

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(b) A crane lifts a load with a mass of 150 kN to a height of 8.4 m above the ground. The cable holding the load then breaks and the load falls to the ground.

Air resistance can be neglected.

(i) Calculate the kinetic energy in the load when it reaches the ground.

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(ii) Calculate the time it takes for the load to reach the ground.

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END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown – for example, 2(a) or 4(b).

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