OCR
Oxford Cambridge and RSA

Friday 13 January 2023 – Morning

Level 3 Cambridge Technical in Engineering

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

Time allowed: 1 hour 30 minutes
C303/2301

C303_I_2301

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. You can use extra paper if you need to, but you must clearly show your candidate number, the centre number and the question numbers.
- 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 **12** pages.

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

Answer **all** the questions.

1 **Fig. 1** shows a bolt being subjected to particular loading conditions.

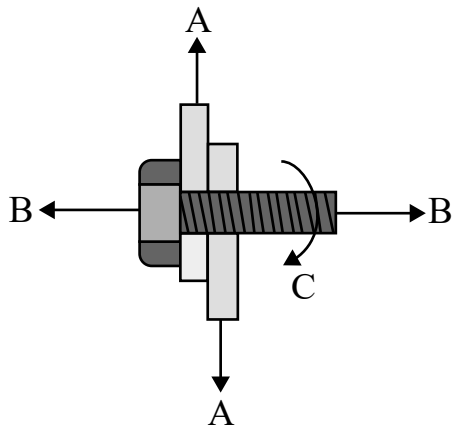

Fig. 1

(a) **(i)** State which of the arrows (A, B or C) represent the following type of loading on the bolt:

Torque .....

Shear force .....

Tension force .....

[2]

(ii) The bolt is considered to be in single shear subjected to a shear force of 250 N.

The diameter of the bolt is 16 mm.

Calculate the shear stress in the bolt. Give the units for your answer.

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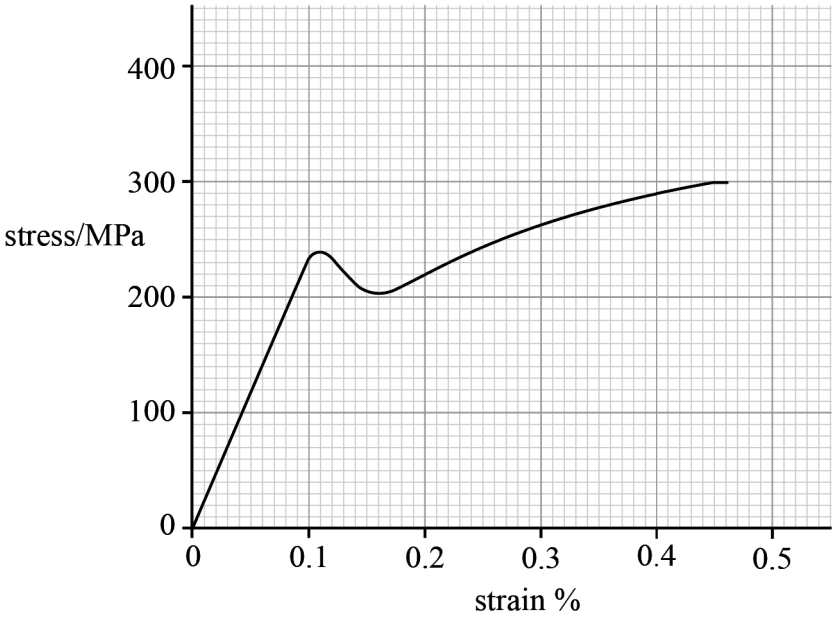
..... **[3]**

(b) This is a stress–strain graph for steel used to make wires.



(i) On the graph, mark an X to show the position of the elastic limit.

[1]

(ii) An engineer studying the graph attempts to calculate Young's modulus for this steel.

The engineer uses the following calculation:

$$\text{Young's modulus} = \frac{\text{stress}}{\text{strain}} = \frac{260 \times 10^6}{0.3} = 8.67 \times 10^8 \text{ Pa}.$$

Identify **two** errors made in the engineer's calculation.

1 .....

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2 .....

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[2]

(iii) A wire made from this steel with an initial length of 1.2 m is subjected to a tensile force which causes a stress of 140 MPa.

Calculate the increase in length of the wire.

Give your answer in millimetres.

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..... **[3]**

2 **(a)** Describe **one** advantage of using a gear system instead of a flat belt and pulley system.

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

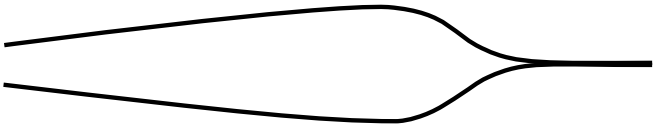
(b) State **two** different types of gear or gear system.

1 .....

2 .....

[2]

(c) This is a diagram of a pair of tweezers which can be modelled as a lever.



(i) On the diagram label with arrows:

- the fulcrum
- the input force (F_I)
- the output force (F_O).

[2]

(ii) State the class of lever for these tweezers.

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

(d) **Fig. 2** shows two gears, A and B, combined with two pulleys, C and D.

Gear A is the input gear and is meshed with gear B.

Pulley D is an output pulley and is driven by a flat belt connected to pulley C.

Pulley C rotates on the same shaft as gear B.

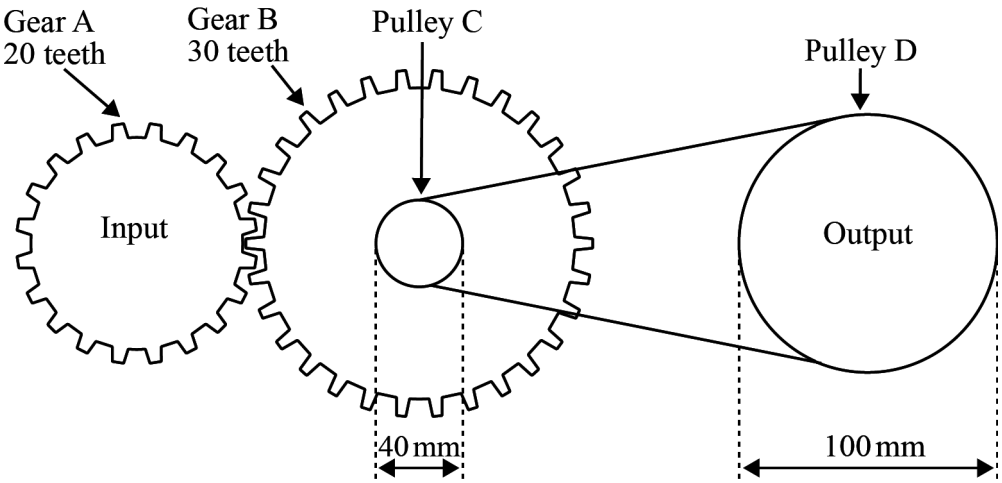


Fig. 2

The rotational speed of the input gear, A, is 75 rpm.

Calculate the rotational speed of the output pulley, D in rpm.

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

3 **Fig. 3** shows a plate, OABC, aligned within a Cartesian coordinate system, (x, y), with the origin at point O.

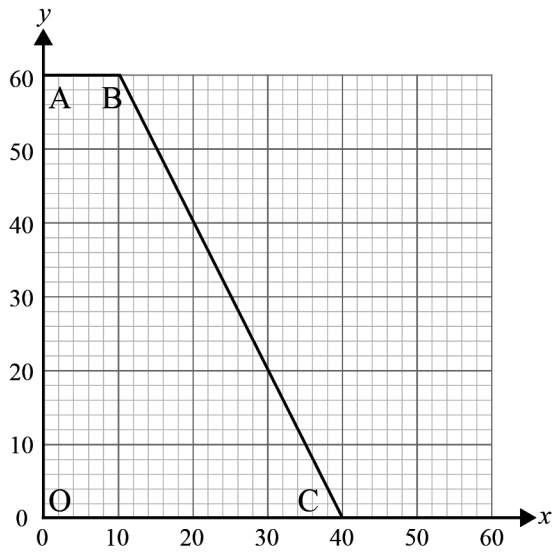

Fig. 3

(i) Calculate the x-coordinate and y-coordinate of the centroid of the plate.

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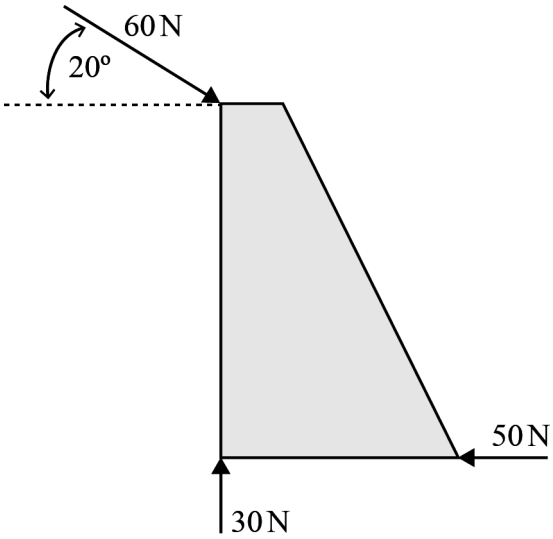
..... **[5]**

(ii) The plate is now subjected to the three co-planar forces of 60 N, 30 N and 50 N as shown below.



Explain, with a reason, whether these three forces are concurrent or non-concurrent.

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

(iii) Calculate the magnitude of the resultant of these three forces.

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

4 A car of mass 1800 kg travels along a horizontal road. At a particular time the car experiences a driving force of 3000 N and a total resistance force of 600 N.

(i) Calculate the acceleration of the car at this time.

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..... **[3]**

(ii) Calculate the instantaneous power of the car when it is travelling with a speed of $10\,m\,s^{-1}$.

Give the units in your answer.

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

In a period when the car increases its speed from $10\,m\,s^{-1}$ to $26\,m\,s^{-1}$ assume that acceleration is constant and equal to $0.8\,m\,s^{-2}$.

(iii) Calculate the distance travelled by the car in this period.

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..... **[3]**

(iv) Calculate the increase in kinetic energy of the car in this period.

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

5 **(a)** A box of mass 30 kg rests on a rough horizontal floor. A person attempts to push the box along the floor by applying a horizontal force of 75 N.

(i) Draw a diagram showing **all** forces acting on the box.

[2]

(ii) The coefficient of friction between the surface of the box and the floor is 0.27.

Determine whether the person attempting to push the box is successful in making it move.

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

(b) A red snooker ball is a sphere with diameter 57.2 mm and mass 160 g.

(i) Calculate the density of the material the red ball is made from.

Give your answer in units of kilograms per cubic metre.

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

(ii) A white ball with diameter 57.2 mm and mass 170 g moving at a speed of $0.9\,m\,s^{-1}$ directly hits a stationary red ball. Immediately after the collision the white ball continues to move in the same direction as before with a speed of $0.027\,m\,s^{-1}$.

Assuming that total momentum is conserved, calculate the speed of the red ball immediately after the collision.

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6 (a) **Fig. 4** shows a cantilever beam subjected to three point loads of 8 kN, 10 kN, and 15 kN. The beam has a self-weight of 300 N m^{-1}.

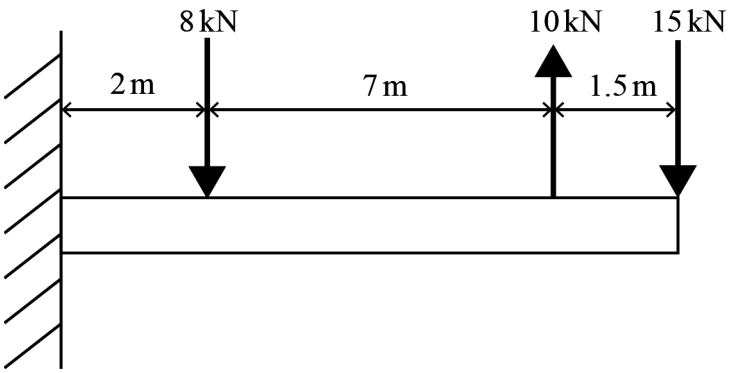

Fig. 4

Calculate the magnitude of the reaction force at the wall.

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(b) **Fig. 5** shows a beam with two point loads, and two reaction forces R_A and R_B. The point loads have magnitude 2000 N and P N. The magnitude of reaction force R_B is 3800 N.

The bending moment diagram for the beam has been drawn for you, with some key values provided. The self-weight of the beam can be ignored.

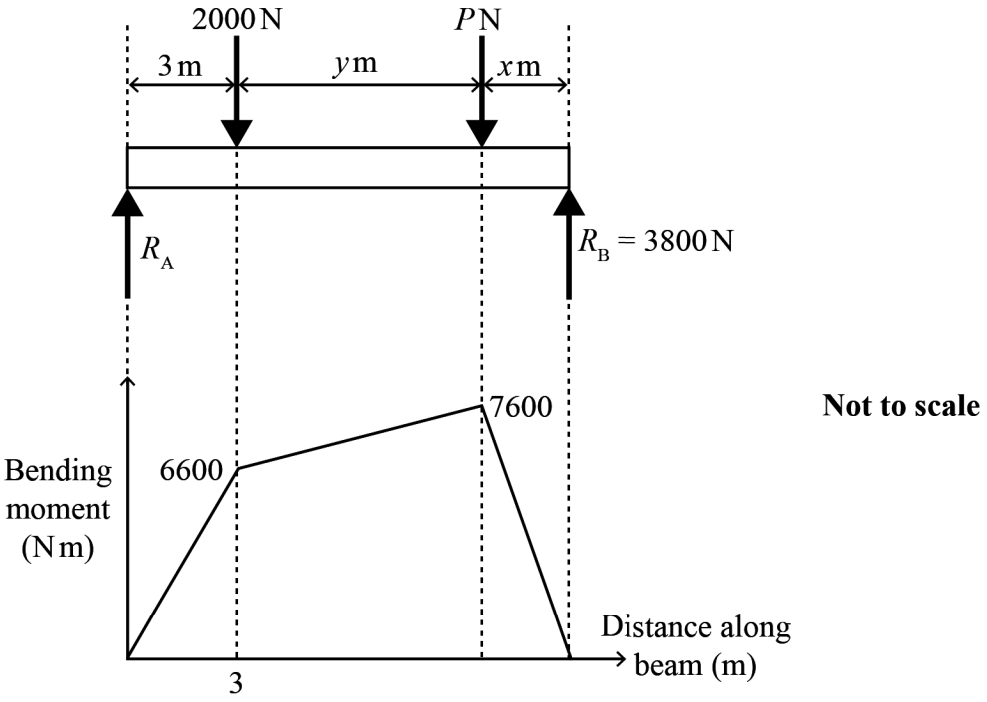

Fig. 5

(i) Calculate the magnitude of reaction force R_A and the distance x.

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

(ii) Calculate the magnitude of point load P and the distance y.

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END OF QUESTION PAPER