OCR
Oxford Cambridge and RSA

Level 3 Cambridge Technical in Engineering
05822/05823/05824/05825/05873

Unit 3: Principles of mechanical engineering

Monday 16 January 2017 – Afternoon
Time allowed: 1 hour 30 minutes

You must have:
- the formula booklet for Level 3 Cambridge Technical in Engineering (inserted)
- a ruler (cm/mm)
- a scientific calculator

First Name		Last Name	
Centre Number		Candidate Number	
Date of Birth			

INSTRUCTIONS
- Use black ink. You may use an HB pencil for graphs and diagrams.
- Complete the boxes above with your name, centre number, candidate number and date of birth.
- Answer **all** the questions.
- Write your answer to each question in the space provided. Additional paper may be used if required but you must clearly show your candidate number centre number and question number(s).
- The acceleration due to gravity is denoted by g m s^{-2}. Unless otherwise instructed, when a numerical value is needed, use g = 9.8.

INFORMATION
- The total mark for this paper is **60**.
- The marks for each question are shown in brackets **[ ]**.
- Where appropriate, your answers should be supported with working.
- Marks may be given for a correct method even if the answer is incorrect.
- An answer may receive no marks unless you show sufficient detail of the working to indicate that a correct method is being used.
- Final answers should be given to a degree of accuracy appropriate to the context.
- This document consists of **12** pages.

FOR EXAMINER USE ONLY	
Question No	**Mark**
1	/10
2	/10
3	/10
4	/10
5	/10
6	/10
Total	**/60**

Answer **all** questions.

1 Fig. 1 shows a steel tube with length 50 mm. The outside diameter is 20 mm and the inside diameter is 14 mm.

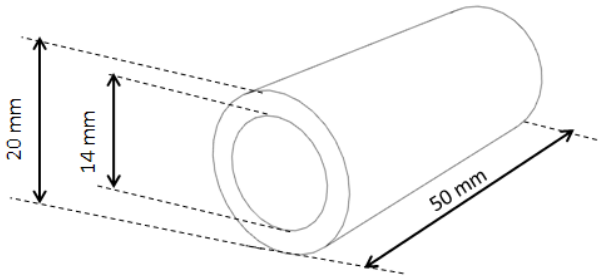

Fig. 1

(i) Calculate the cross-sectional area of this tube. Give your answer in mm^2.

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

(ii) Convert your answer from part **(i)** into m^2.

.....

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

(iii) The tube is subjected to an axial compressive force of 14 000 N. Calculate the axial stress in the steel under this force. You must provide the units of your answer.

.....

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

(iv) Under this loading the tube reduces to a length of 49.978 mm. Calculate the axial strain in the tube.

.....

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

(v) Using the value of stress calculated in part **(iii)** and the value of strain calculated in part **(iv)**, calculate Young's modulus for the steel used in the tube.

.....

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

(vi) The tube is replaced with a solid bar with the same outside diameter and the same length. The solid bar is made of the same steel as the tube and is subject to the same compressive force of 14 000 N. State, without performing any further calculations, whether the magnitude of each of your values calculated in parts **(iii)**, **(iv)** and **(v)** would become larger, smaller or stay the same.

Part (iii) .....

Part (iv).....

Part (v).....

[1]

2 **(i)** A toy rocket of mass 3 kg is fired into the air, by means of a catapult, with an initial vertical speed of 13 m s^{-1}. Assume that the rocket remains in flight under the influence of gravity with no other forces resisting its motion. Calculate the maximum height reached by the rocket.

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

In reality, other forces exist which affect the motion of the rocket while it travels upwards. At a particular moment in time an air-resistance force of magnitude 8 N resists the vertical motion of the rocket. The combined effect of the wind and air-resistance also creates a horizontal force of magnitude 12 N acting on the rocket.

(ii) Draw a diagram showing **all** the forces acting on the rocket at this moment in time. You may represent the rocket as a particle.

[2]

(iii) Calculate the **vertical** deceleration of the rocket at this moment in time.

.....

.....

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

(iv) Calculate the magnitude of the resultant force acting on the rocket.

.....

.....

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

(v) Calculate the direction of this resultant force relative to the vertical.

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

3 **(a)** A beam with uniform density has a cross-sectional area of 0.51 m^2 and a length of 8 m.

(i) Calculate the volume of the beam.

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

(ii) The beam is made from concrete with a density of 2400 kg m^{-3}. Calculate the mass of the beam.

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

(iii) Calculate the weight of the beam in Newtons.

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

(b) Fig. 2 shows the beam supported at points A and B. Point A is at the left end of the beam while point B is 2 m from the right end of the beam. A force of 34 000 N acts at an upward angle of 30° at the right end of the beam as shown.

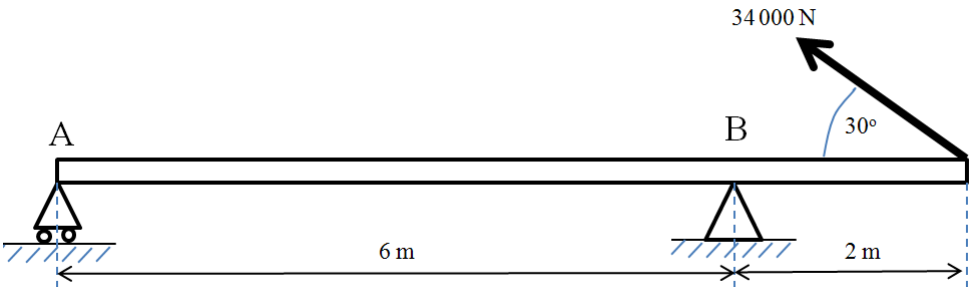

Fig. 2

(i) The 34 000 N force can be resolved into two components which act perpendicular to and parallel to the beam. Calculate the magnitude of the **perpendicular** component.

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

(ii) Name the type of support indicated at point A.

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

(iii) Calculate the support reactions at points A and B due to the combined 34 000 N force **and** the self-weight of the beam as calculated in part **(a) (ii)**. You may neglect the component of the 34 000 N force parallel to the beam and consider only the perpendicular component.

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

4 **(a)** Fig. 3 shows a semi-circular plate of radius 45 mm. The plate has uniform density and is aligned within a Cartesian coordinate system with the origin O, as shown.

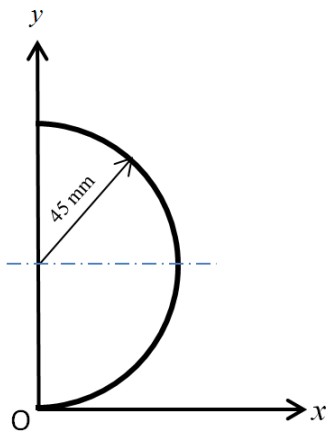

Fig. 3

Calculate the coordinates, $\bar{x}$ and $\bar{y}$, of the centroid of this semi-circular plate.

.....

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

(b) Fig. 4 shows a rectangular plate, ABCD, which has uniform density. The plate is 400 mm long and 150 mm wide.

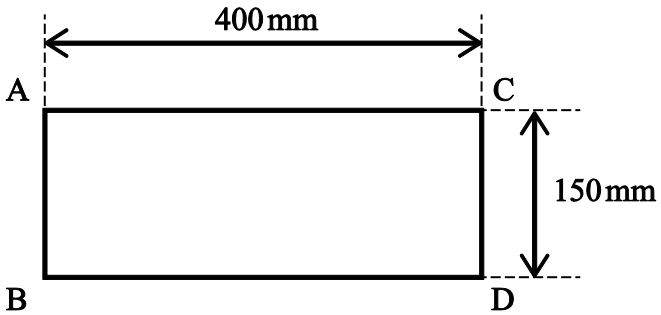

Fig. 4

The plate is freely suspended in a state of equilibrium from corner A. Calculate the angle that side AB makes with the vertical.

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

(c) Fig. 5 shows a cantilever beam with length 15 m attached to a wall. The total weight of the beam is modelled by a vertical downward force of 20 N acting at a point 6 m from the wall. A vertical upward force of 100 N acts at the other end of the beam.

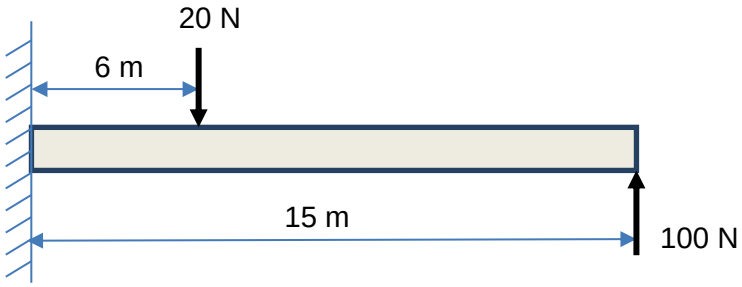

Fig. 5

(i) Calculate the vertical reaction at the wall.

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

(ii) Calculate the bending moment at the wall.

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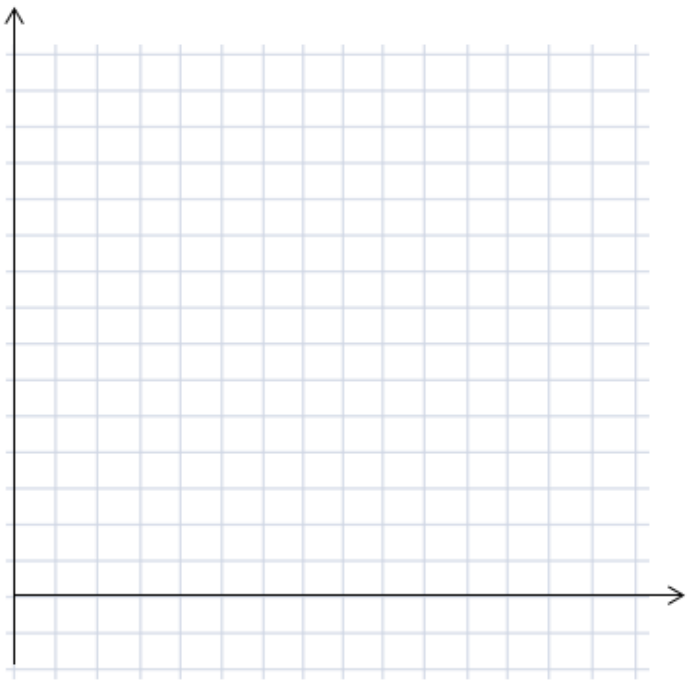
..... **[2]**

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



[3]

5 **(a)** A simple gear train consisting of two spur gears has a velocity ratio of 2.4. The output gear rotates at a speed of 36 rpm.

(i) Calculate the rotation speed of the input gear.

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

(ii) Calculate the mechanical advantage (MA) of this gear train.

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

(b) Give one advantage and one disadvantage of a flat belt for use in a belt and pulley system.

Advantage .....

.....

Disadvantage.....

.....

[2]

(c) A belt and pulley system has an input pulley and an output pulley. The diameter of the output pulley is 40 cm. When the input pulley turns through an angle of $\frac{\pi}{6}$ radians a point on its circumference moves through an arc of length 7.85 cm. Calculate the velocity ratio of this belt and pulley system.

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

(d) Fig. 6, below, shows an image of a wheelbarrow. The labels A, B and C indicate key features of the wheelbarrow in the context of a **lever**.

(i) State the class of lever associated with this wheelbarrow.

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

(ii) Complete the labels for A, B and C on the diagram which should name the key features of a lever to which they relate.

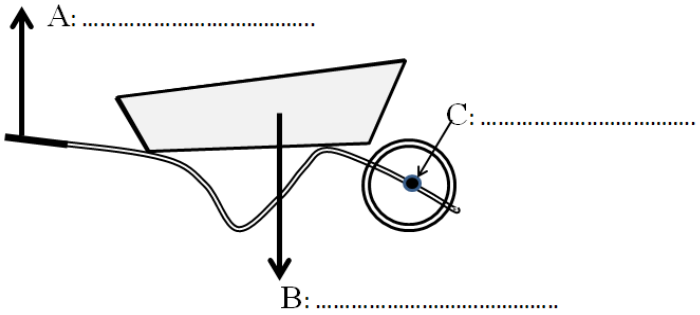

Fig. 6

[2]

6 Fig. 7 shows a cyclist travelling down a slope on a smooth road inclined at 6° to the horizontal. The combined mass of the cyclist and bike is 80 kg.

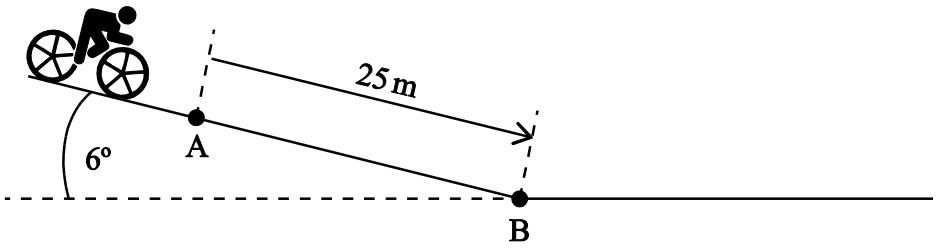

Fig. 7

(i) At point A along the slope the cyclist has a speed of 2.7 m s^{-1}. Calculate the combined kinetic energy of the cyclist and bike at this point.

.....

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

(ii) The cyclist then travels a distance of 25 m along the slope to point B. Calculate the change in gravitational potential energy between points A and B.

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

(iii) Between points A and B the cyclist is rolling along the slope under the influence of gravity only with no other forces affecting motion. Calculate the speed of the bike when it reaches the bottom of the slope at point B.

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.....

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

(iv) At the bottom of the slope at point B the road changes to a rough horizontal surface where the coefficient of friction, μ, between the bike and the road is 0.15. Calculate the maximum frictional force acting on the bike.

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

(v) At the bottom of the slope the cyclist uses the pedals for the next 50 m to maintain a constant speed as calculated in part **(iii)**. Calculate the work done by the cyclist over this distance.

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

END OF QUESTION PAPER