OCR
Oxford Cambridge and RSA

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873

Unit 3: Principles of mechanical engineering

Monday 15 January 2018 – 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	D	D	M	M	Y	Y	Y	Y

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. If additional space is required, you should use the lined page(s) at the end of this booklet. The question number(s) must be clearly shown.
- 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 **16** pages.

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Question No	**Mark**
1	/9
2	/11
3	/8
4	/9
5	/12
6	/11
Total	**/60**

Answer **all** the questions.

1 A small box of mass 20 kg is being pulled along a rough horizontal surface by a rope inclined at an angle of 20° above the horizontal, as shown in Fig. 1. The tension in the rope is 150 N. The magnitude of the frictional force between the box and the surface is 30 N. The box is also subjected to a resistive force of 40 N opposing its motion.

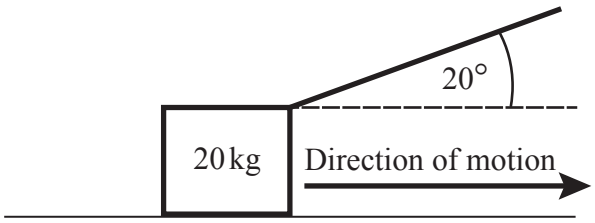

Fig. 1

(i) Show **all** forces acting on the box in the diagram below.

[2]

(ii) The tension force in the rope can be resolved into a horizontal component and a vertical component. Calculate the value of each of these components.

Horizontal: .....

Vertical: .....

[2]

(iii) Calculate the magnitude of the normal reaction of the surface on the box.

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

(iv) Calculate the acceleration of the box.

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

2 **(a)** Fig. 2 shows a diagram of a compound gear train consisting of four gears; A, B, C and D. Gears B and C rotate together on the same shaft.

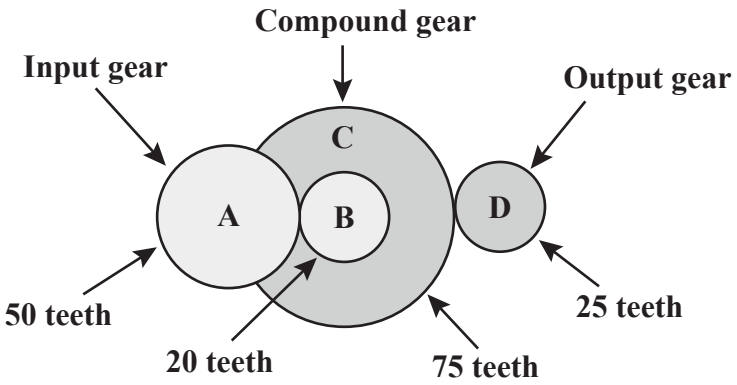

Fig. 2

(i) The input gear rotates at a speed of 120 rpm. Calculate the rotational speed of the output gear.

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(ii) Gear A is now replaced with a new gear, E. Calculate the number of teeth required on gear E in order to achieve an overall Velocity Ratio (VR) of 9.

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(b) Give one example of an application that uses a rack and pinion.

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

(c) Fig. 3 shows a diagram of a lever. The mass of the lever can be ignored.

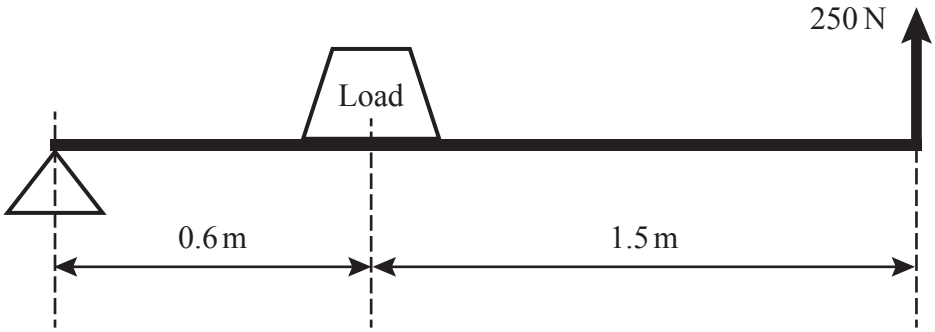

Fig. 3

(i) Name the class of lever shown in Fig. 3.

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

(ii) An input force, F_I, of 250 N is applied to the lever. Calculate the maximum load that can be lifted using this force.

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

(iii) Calculate the Mechanical Advantage (MA).

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

(d) A belt and pulley system has a Velocity Ratio (VR) of 2.5. The diameter of the input pulley is 800 mm. Calculate the diameter of the output pulley.

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

(e) The input to another belt and pulley system is adjusted so that the Velocity Ratio doubles. State what effect this has on the Mechanical Advantage.

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

3 Fig. 4 shows a uniform rectangular plate with length 10 m and width 5 m. The plate is subjected to three forces of 20 N, 90 N and 40 N.

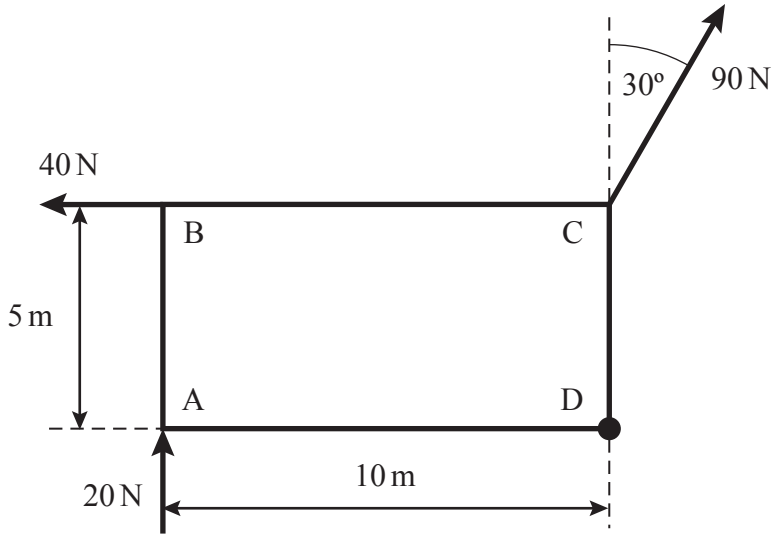

Fig. 4

(i) Calculate the moment exerted by the forces about corner D.

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

(ii) Calculate the magnitude of the resultant force acting on the plate.

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

(iii) An additional horizontal force is now applied to corner C. Calculate the magnitude and direction of this force that will cause the total moment about corner D to become zero.

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

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Turn over for the next question

4 **(a)** Fig. 5 shows a plate of uniform density aligned within a Cartesian coordinate system, (x, y), with the origin at corner O. The plate has the shape of a rectangle, 120 mm wide and 180 mm long and contains a circular hole. The hole has a diameter of 40 mm with its centre at coordinates (90, 150).

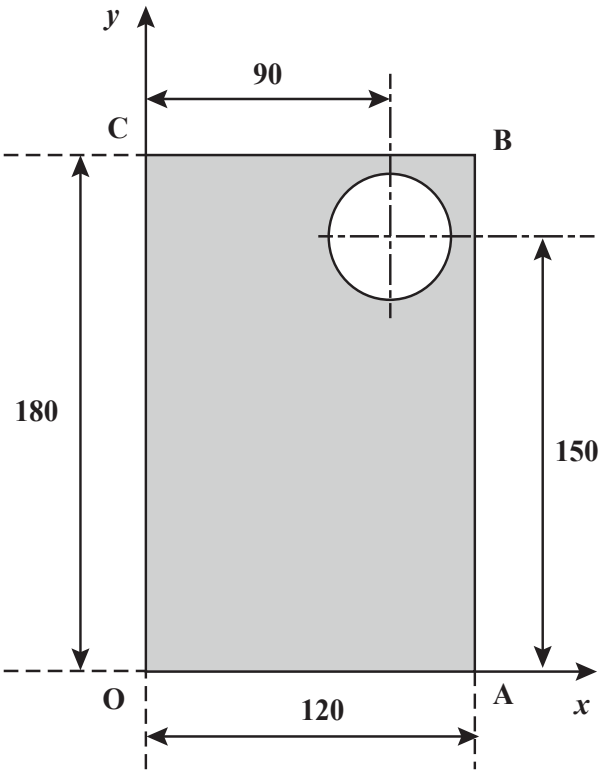

Fig. 5

(i) Calculate the coordinates of the centroid of the plate.

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

(ii) The plate has a weight of 80 N and is suspended from corner C. By considering moments about corner C calculate the vertical force required at corner A so that side OA remains horizontal.

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(b) A steel beam of length 1.8 m undergoes an axial strain of 0.2 %. Calculate the change in length of the beam.

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

5 **(a)** A steel pile is in the shape of a cylinder with a diameter of 0.14 m and a height of 0.8 m. The mass of the pile is 105 kg. Calculate the density of the steel.

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

(b) A different pile of mass 100 kg is dropped from rest and has a speed of 7.5 m s^{-1} when it makes contact with the ground.

(i) Calculate the distance fallen by the pile before it reaches the ground. (You may assume that the pile falls under the influence of gravity, with no other forces affecting its motion.)

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

(ii) Calculate the kinetic energy of the pile when it reaches the ground.

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

(iii) After initially reaching the ground the pile sinks to a depth of 0.3 m before coming to a complete rest. Calculate the loss in gravitational potential energy between the time it initially reaches the ground to the time it comes to a complete rest.

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

(iv) Using an energy method, calculate the work done by the resistive force in bringing the pile to rest. Hence calculate the value of this resistive force.

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

(c) Fig. 6 shows an aluminium plate in the shape of a rectangle aligned within a Cartesian coordinate system, (x, y), with the origin at the corner marked O. The plate is 30 mm long and 25 mm wide and near each corner is a hole with diameter 4 mm.

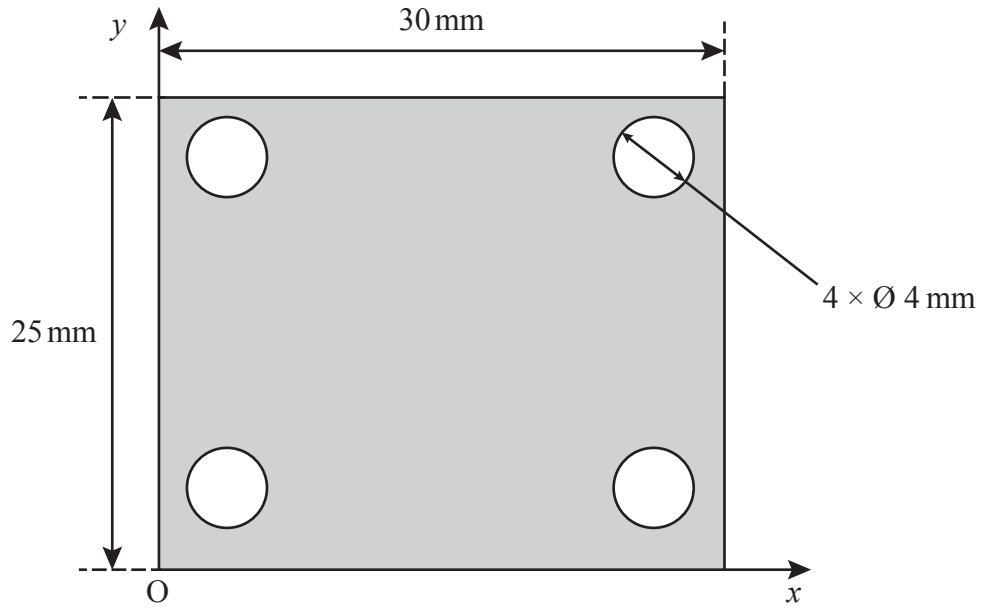

Fig. 6

(i) Calculate the area of the aluminium in the plate. You should give your final answer in units of mm^2.

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

(ii) A fifth hole, also of diameter 4 mm, is to be made in the plate. State the coordinates of the centre of this new hole so that the centroid of the plate remains unchanged.

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

6 **(a)** Name the type of beam which has a fixed support at each end.

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

(b) Fig. 7 shows a cantilever beam of length 10 m fixed to a wall. The beam is subjected to point loads of 500 N, 600 N and 200 N. The mass of the beam can be ignored.

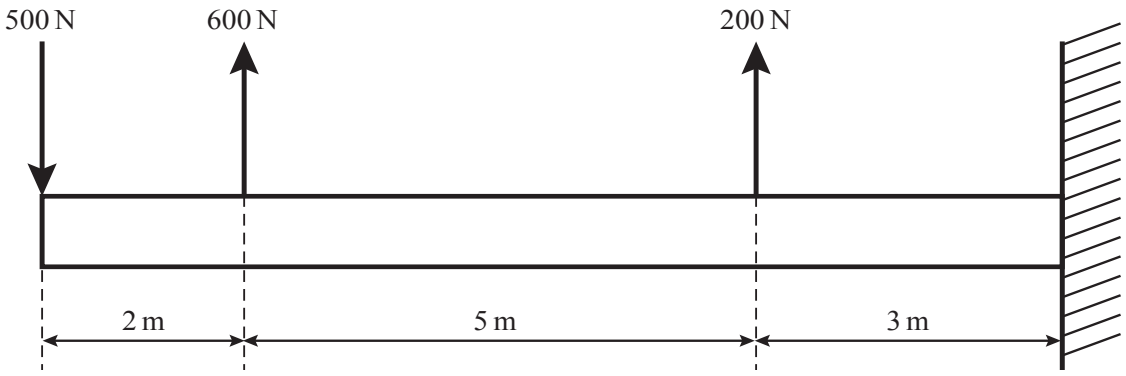

Fig. 7

(i) Calculate the vertical reaction force at the wall.

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

(ii) Calculate the value of the bending moment at the wall.

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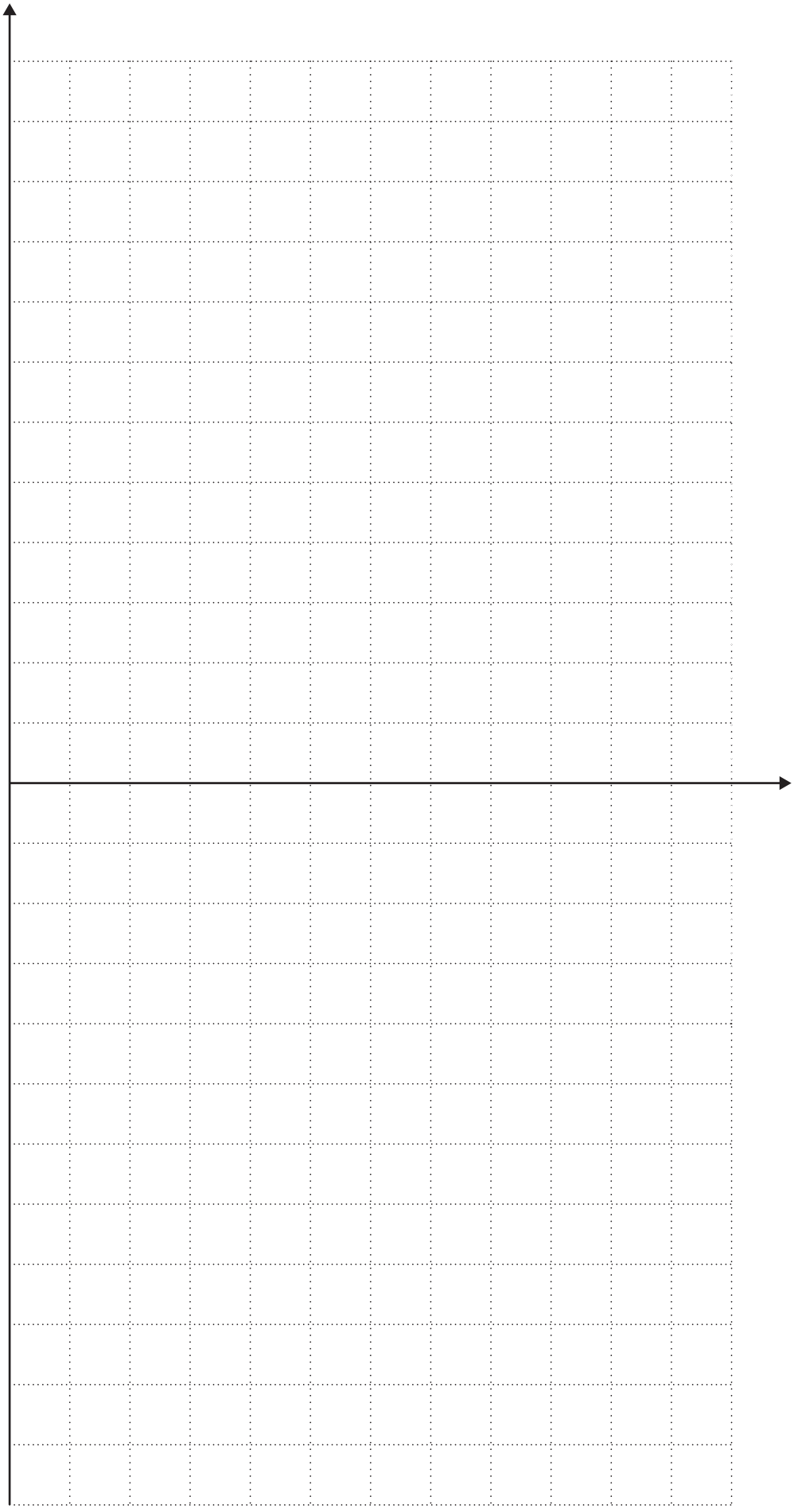
..... **[2]**

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



[4]

(c) Two particles of mass 3 kg and 5 kg are travelling towards each other and collide. Before the collision the speed of the 3 kg particle is 2.4 m s^{-1} and the speed of the 5 kg particle is 1.8 m s^{-1}. After the collision the 3 kg particle has a speed of 0.5 m s^{-1} in the **opposite** direction to its initial motion. Calculate the speed and direction of the 5 kg particle after the collision. (You may assume momentum is conserved during the collision.)

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

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

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

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