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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Friday 15 January 2021 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873

Unit 3: Principles of mechanical engineering

Time allowed: 1 hour 30 minutes plus your additional time allowance

You must have:
the Formula Booklet for Level 3 Cambridge Technical in Engineering (with this document)
Loose Sheet for Fig. 5
a ruler (cm/mm)
a scientific calculator

Please write clearly in black ink.

Centre number								
Candidate number								
First name(s)								
Last name								
Date of birth	D	D	M	M	Y	Y	Y	Y

READ INSTRUCTIONS BELOW

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 [ ].

ADVICE

Read each question carefully before you start your answer.

Answer ALL the questions.

1 Fig. 1 opposite shows a sphere of mass 2 kg falling under the influence of gravity subjected to three co-planar forces, 40 N, 15 N and W N, where W is the weight of the sphere.

(i) Calculate the value of W.

_____

_____ **[1]**

(ii) Calculate the magnitude of the resultant force acting on the sphere, including its weight.

_____

_____

_____

_____ **[3]**

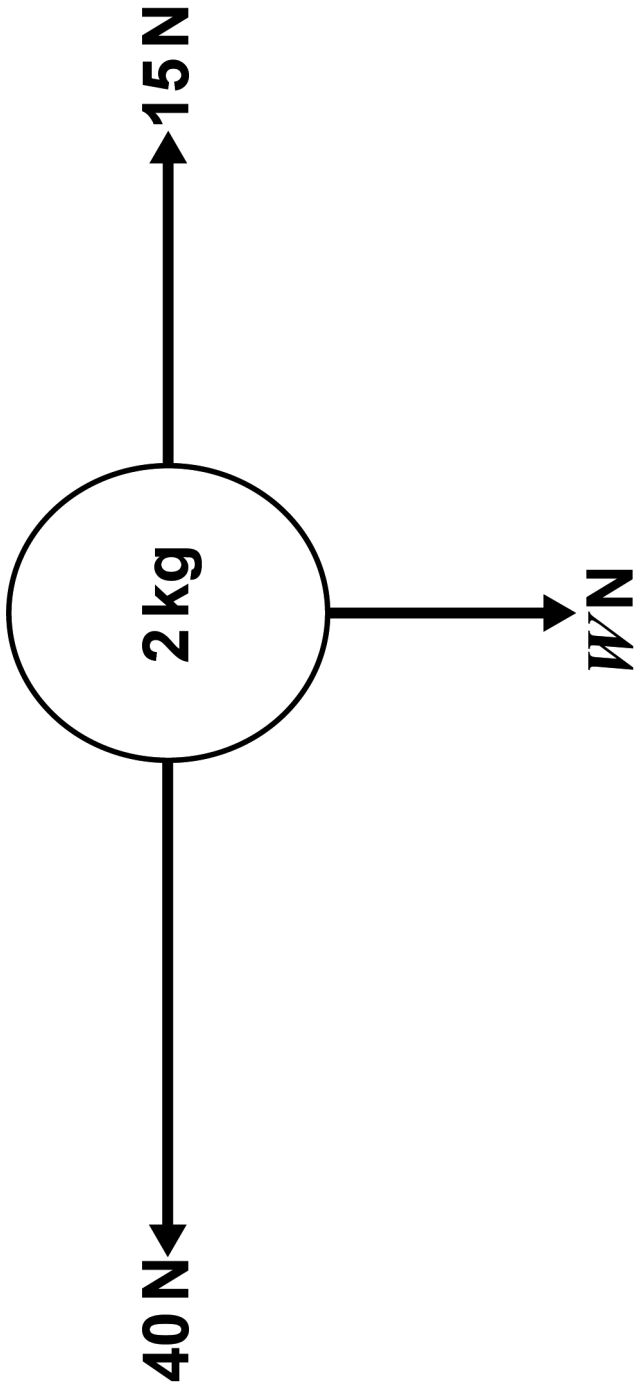


Fig. 1

(iii) Calculate the magnitude of acceleration of the sphere in the direction of the resultant force.

Give the units for your answer.

_____

_____

_____ [2]

(iv) Calculate the speed of the sphere when it has a momentum of $15\,\text{kg m s}^{-1}$.

_____

_____ [1]

(v) Calculate the kinetic energy of the sphere at this time.

_____

_____ [1]

(vi) State what property the system of forces must have in order for the sphere to be modelled as a particle.

_____

_____ [1]

2 (a) Name the type of gear systems shown in the following figures.

Fig. 2a

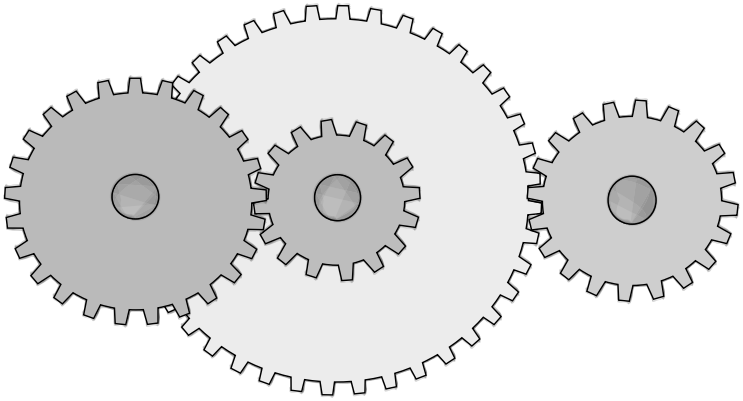


Fig. 2b

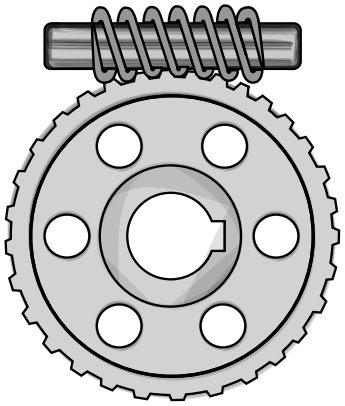
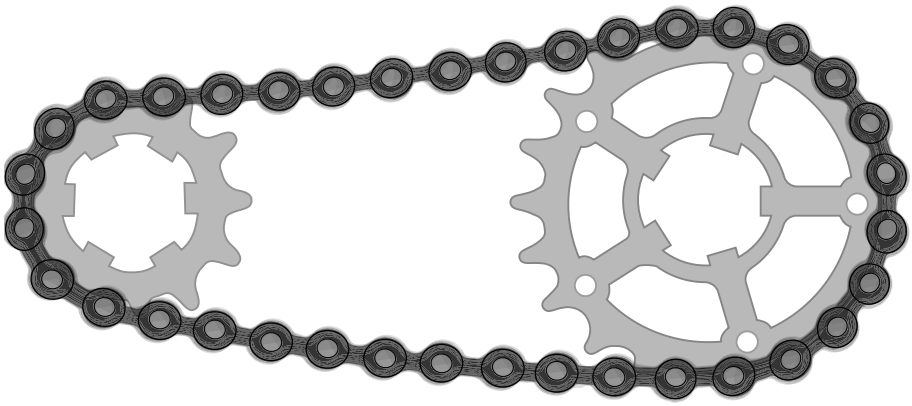


Fig. 2c



(i) Fig. 2a _____ [1]

(ii) Fig. 2b _____ [1]

(iii) Fig. 2c _____ [1]

(b) A lever has an input force of 150 N and an output force of 105 N.

(i) Calculate the mechanical advantage (MA) of this lever.

_____

_____ [1]

(ii) The distance between the output force and the fulcrum is 1.2 m.

Calculate the distance between the input force and the fulcrum.

_____

_____ [1]

(c) (i) A spur gear system containing two gears only is required to have a velocity ratio (VR) of 2.5. The input gear has 48 teeth.

Explain why it is not possible to achieve this required velocity ratio.

[2]

(ii) Instead of a spur gear system an engineer suggests using a belt and pulley system with a velocity ratio of 2.5. The output pulley has a diameter of 220 mm.

Calculate the diameter of the input pulley required.

[1]

(iii) State one disadvantage of using a belt and pulley system rather than a spur gear system.

_____

_____ [1]

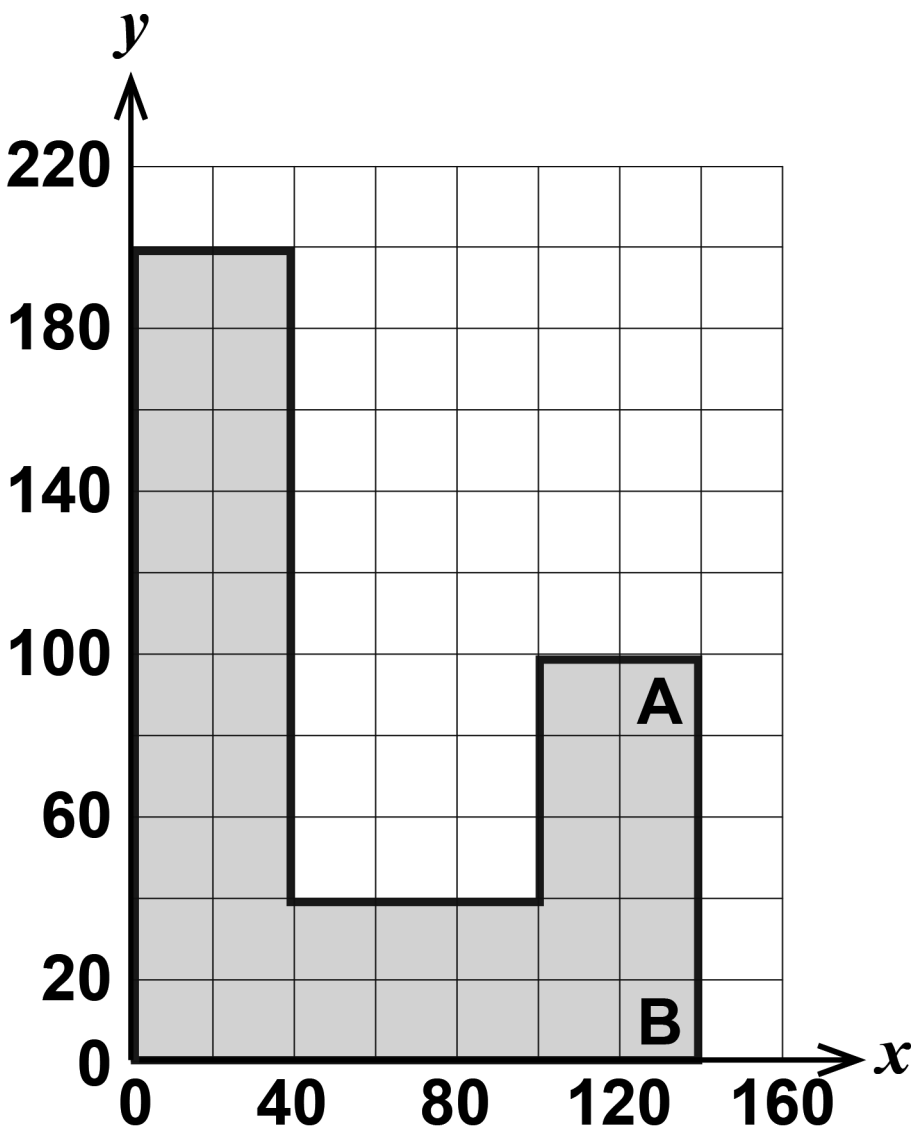
(d) Where in a car could you find a rack and pinion gear system?

_____

_____ [1]

3 (a) Fig. 3 shows a plate with a uniform density aligned within a Cartesian coordinate system, (x, y).

Fig. 3



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

[5]

(ii) The plate is suspended from corner A.

Calculate the angle that side AB makes with the vertical.

[2]

(b) A titanium alloy rod has a length of 1.2 m and a solid circular cross-section of diameter 12 mm. In a test to determine its material properties it is subjected to an axial tensile force of 60 kN.

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

[3]

(ii) The length of the rod increases by 6 mm as a result of the tensile force.

Calculate the strain in the rod.

[2]

(iii) The manufacturer of the rod claims that the titanium used has a Young's modulus of between 105 GPa and 120 GPa.

Explain whether the results of the test support this claim.

_____

_____

_____ [2]

(iv) The elastic limit of the titanium used in the rod is 800 MPa.

Explain whether the results of the test are consistent with this.

_____

_____

_____ [1]

4 A car of mass 1800 kg accelerates uniformly from rest to a speed of 18 m s^{-1} in a distance of 120 m.

(i) Calculate the acceleration of the car.

_____

_____

_____ [2]

(ii) While the car is accelerating it is subjected to a constant, resistive frictional force of R N. The driving force of the engine is D N and the work done by this force in the 120 m of travel is 360 kJ.

Calculate the value of D and hence the value of R.

[5]

5 Workers on a construction site need to cross a gap between two parts of a building.

The gap is bridged by a 4.5 m long wooden beam which is 1 m wide and 80 mm deep. The wood has a density of 740 kg m^{-3} and the beam is safe to support one worker with a mass of 100 kg standing at its centre. The beam is simply supported at either end of the gap.

(i) Calculate the mass of the beam.

_____

_____

_____

_____

_____ **[4]**

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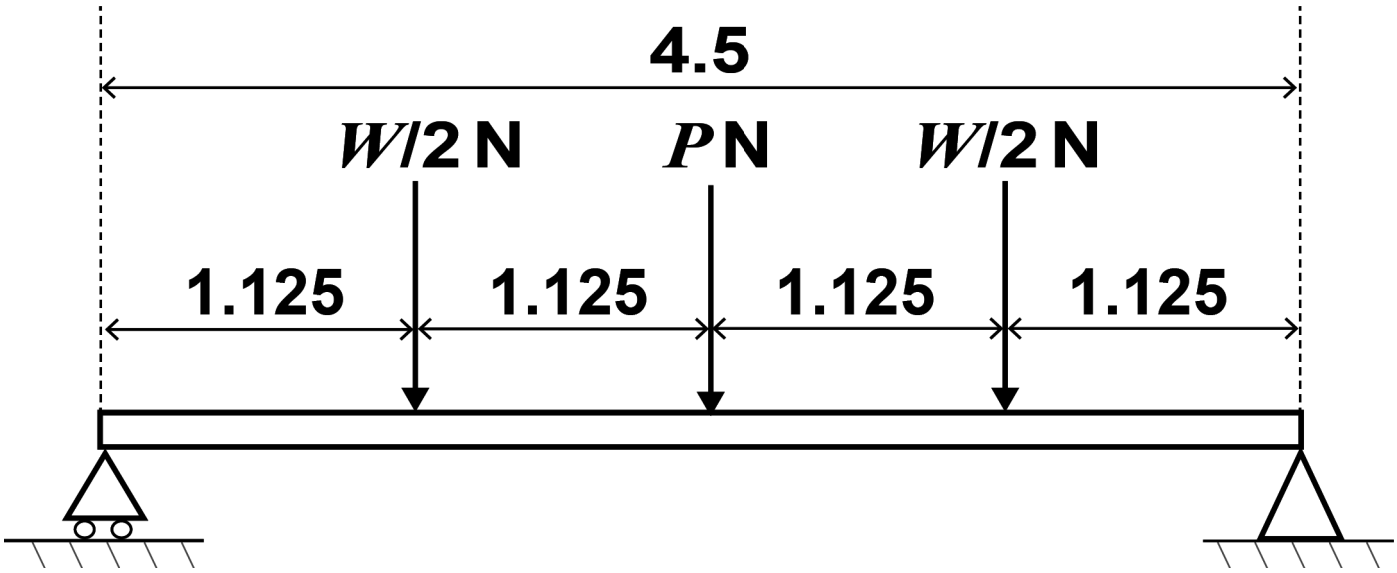
(ii) Fig. 4 shows the self-weight of the beam, W N, modelled by two equal loads of $W/2$ N positioned at 1.125 m from each support. A worker of mass 100 kg standing at the centre of the beam is represented by a downward force of P N.

Fig. 4



(*A*) **Calculate the magnitude of the reaction force at each support.**

_____

_____

_____

_____ **[3]**

(*B*) **Calculate the bending moment at the centre of the beam.**

_____

_____

_____

_____ **[3]**

6 (a) Fig. 5 on the Loose Sheet shows part of a tower crane which has a load-supporting jib of length 8 m and a counter-jib of length 3 m. The counter-jib supports a fixed counterweight of 20 000 N located at its end. A second counterweight of 40 000 N can be moved along the counter-jib to a distance of x m from the top of the tower at point A. The total weight of the two jibs is modelled by a force of 28 000 N acting at a distance of 2.5 m to the right of point A. The load being lifted is located at the end of the load-supporting jib.

(i) In an UNLOADED situation the position of the 40 000 N counterweight is adjusted so that there is a zero moment about point A.

Calculate the value of x in this case.

[3]

(ii) The 40 000 N counterweight is now moved so that x = 2.6.

Calculate the weight of a load that will maintain a zero moment about point A.

[3]

(b) In lifting a load of 200 kg the work done by a crane is 20 000 J. Assuming that the load starts and finishes at rest calculate the vertical distance through which it is lifted.

_____

_____

_____

_____

_____ [3]

END OF QUESTION PAPER

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