Please write clearly in block capitals.

Centre number	
Candidate number	
Surname	
Forename(s)	
Candidate signature	

A-level
PHYSICS

Paper 3
Section B Engineering physics

Thursday 29 June 2017 Morning

Time allowed: The total time for both sections of this paper is 2 hours. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:
- a pencil and a ruler
- a scientific calculator
- a Data and Formulae booklet.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- Do all rough work in this book. Cross through any work you do not want to be marked.
- Show all your working.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 35.
- You are expected to use a scientific calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For Examiner's Use	
Question	Mark
1	
2	
3	
4	
5	
TOTAL	

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Section B

Answer **all** questions in this section.

0 1 . 1 There is an analogy between quantities in rotational and translational dynamics.

Complete **Table 1**, stating in words the quantities in rotational dynamics that are analogous to force and mass in translational dynamics.

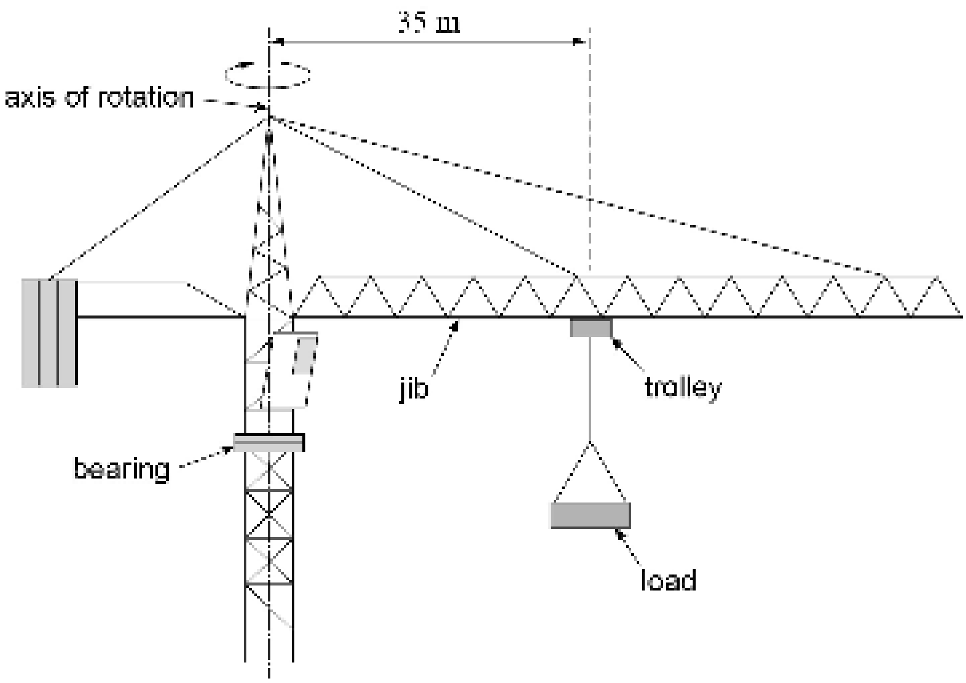
[2 marks]

Table 1

Translational dynamics	Rotational dynamics
force	
mass	

Figure 1 shows a side view of the jib of a tower crane. The load is supported by a trolley which can move along the jib. The jib consists of all the parts of the crane above the bearing, but excluding the trolley and load.

Figure 1



The moment of inertia of the jib about the axis of rotation = 2.6×10^7 kg m^2

Mass of trolley and load = 2.2×10^3 kg

0 1 . 2 The load is at a distance of $35\ \mathrm{m}$ from the axis of rotation.

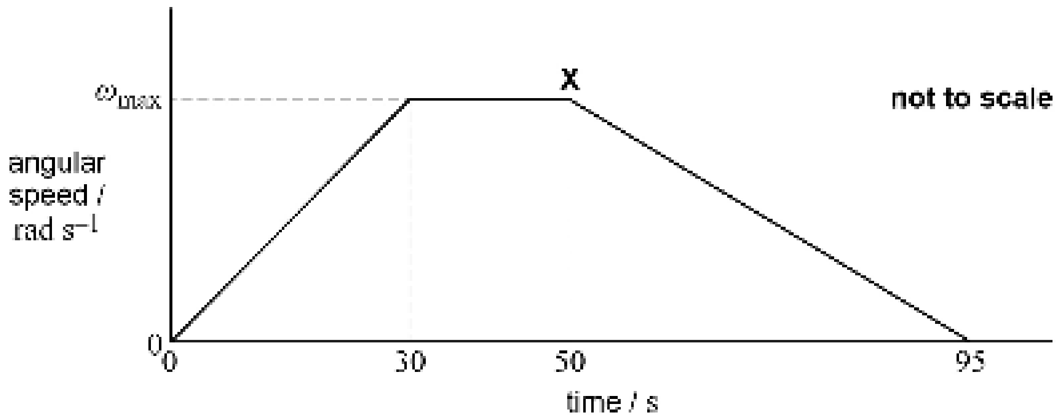
Show that the total moment of inertia of the jib, and the trolley and load, about the axis of rotation is about $3 \times 10^7\ \mathrm{kg\ m^2}$.

[1 mark]

Question 1 continues on the next page

0 1 . 3 **Figure 2** shows the variation of angular speed of the jib as it turns through an angle of 4.7 rad (270°) in a total time of 95 s. The trolley and load remain at a distance of 35 m from the axis.

Figure 2



Calculate the maximum angular speed ω_{max} of the jib.

[2 marks]

maximum angular speed = ______________________ rad s^{-1}

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0 1 . 4 At time **X** in **Figure 2** the motor that is driving the jib is disengaged. A constant braking torque is then applied to bring the jib to a standstill from its maximum angular speed.

The crane driver repeats the movement of the jib with the same load at $35\ \text{m}$ from the axis of rotation. Up to time **X** the motion is the same as before. From time **X** the trolley is driven at a steady speed away from the axis as the jib continues to rotate until the jib comes to a standstill.

Assume the braking torque remains the same as before.

Discuss how the motion of the trolley affects the time taken for the jib to come to a standstill.

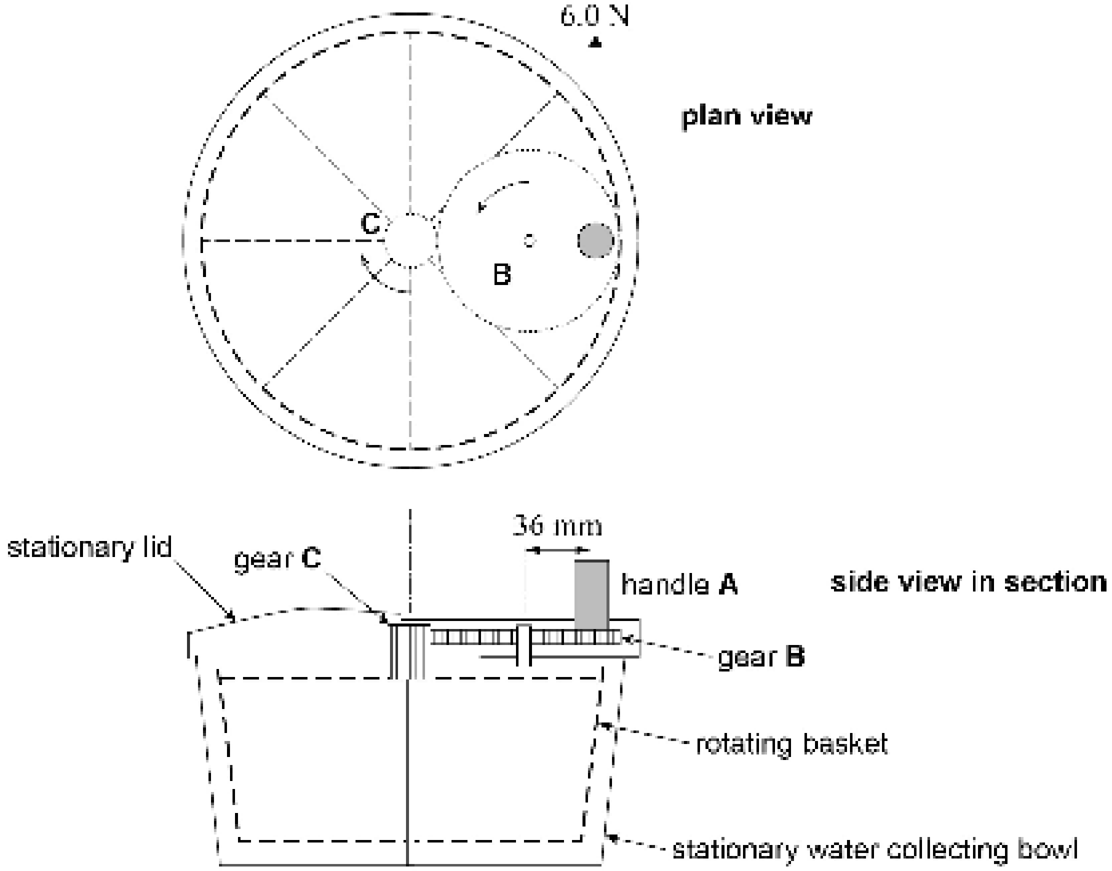
[3 marks]

8

Turn over for the next question

0 2 **Figure 3** shows the basic principle of operation of a hand-operated salad spinner used to dry washed salads.

Figure 3



The salad is placed in the basket and the lid is attached.

When handle **A** is turned the basket and its contents spin rapidly. Water on the salad is driven through holes in the basket into the stationary water collecting bowl. The pivot for gear **B** is fixed to the lid. This pivot and the lid do not move. When gear **B** rotates, gear **C** also rotates but at a greater angular speed. Gear **C** is fixed to the basket and rotates it.

A force of 6.0 N is applied to handle **A** as shown. Handle **A** is at a radius of 36 mm from its centre of rotation.

0 2 . 1 Calculate the input torque.

[1 mark]

torque = ____________________ N m

0 2 . 2 Gear **C** rotates four times for every one revolution of gear **B**.

Deduce whether it is possible for the torque on gear **C** to be greater than one quarter of the input torque.

[2 marks]

____

____

____

____

____

____

0 2 . 3 It takes 2.1 s for the empty basket to reach an angular speed of 76 rad s^{-1}. The torque on gear **C** is a constant 0.054 N m during this time. Frictional losses are negligible.

Calculate the moment of inertia of the basket about its axis of rotation.

[2 marks]

moment of inertia = ____________________ kg m^2

Question 2 continues on the next page

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0 2 . 4 The gears are made from polymer (plastic). An early version of this salad spinner suffered from damaged gear teeth.

Explain with reference to angular impulse why a great force is put on the gear teeth if the user tries to stop the loaded basket too quickly using the handle.

[3 marks]

8

Turn over for the next question

Turn over ►

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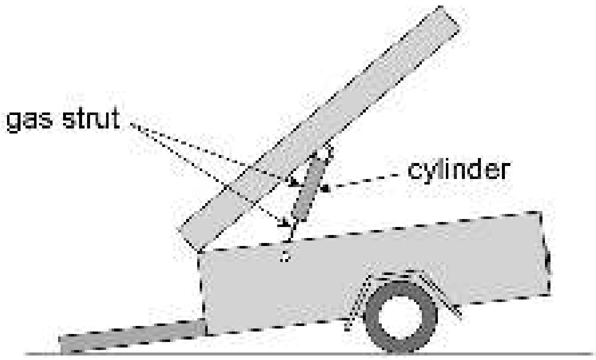
0 3 **Figure 4** shows a gas strut supporting the lid of a trailer.

Figure 4



A fixed mass of nitrogen gas is sealed into the cylinder of the strut.

0 3 . 1 The gas is initially at a pressure of 1.2×10^{6} Pa, a volume of 9.0×10^{-5} m^{3} and a temperature of 290 K.

When the lid is closed quickly the gas is compressed rapidly to a final volume of 6.8×10^{-5} m^{3}.

Calculate the pressure and temperature of the gas at the end of the compression assuming the compression to be an adiabatic process.

adiabatic index γ for nitrogen = 1.4

[4 marks]

pressure = ____________________________ Pa

temperature = ____________________________ K

0 3 . 2 Explain why the rapid compression of the gas can be assumed to be an adiabatic process.

[2 marks]

0 3 . 3 When the lid is closed slowly, the compression can be assumed to be isothermal.

The gas can be compressed either isothermally or adiabatically from the same initial conditions to the same final volume.

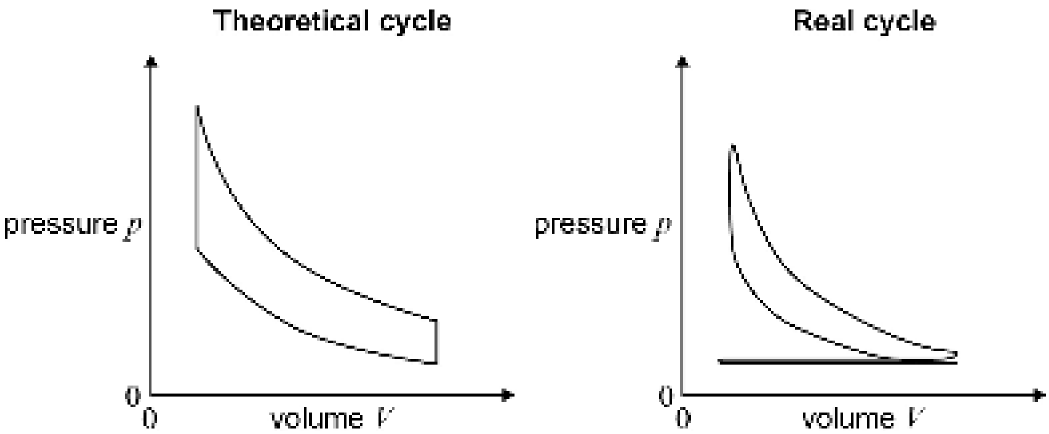
Compare without calculation the work done in each process.

[3 marks]

9

0 4 **Figure 5** shows the $p-V$ diagram for a theoretical petrol engine cycle compared to the indicator diagram for a real four-stroke petrol engine with the same maximum and minimum volumes.

Figure 5



Compare the theoretical and real engine cycles. In your answer you should:

- state and explain the differences between the cycles
- explain why the work output per cycle of the real engine is less than that predicted by an analysis of the theoretical cycle.

[6 marks]

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0 5 . 1 An ideal heat pump and an ideal refrigerator operate between the same hot and cold spaces.

Which statement relating to the coefficient of performance (COP) is correct?
Tick (✓) the correct answer.

[1 mark]

The COP of the refrigerator must be < 1.	☐
The COP of the heat pump must be greater than the COP of the refrigerator.	☐
The COP of the heat pump will increase if the temperature of the hot space is increased.	☐
The COP of the refrigerator will decrease if the cold space temperature increases.	☐

0 5 . 2 An ideal refrigerator operates between a cold space at a temperature of $-1\ ^\circ\mathrm{C}$ and a hot space at a temperature of $70\ ^\circ\mathrm{C}$.

Calculate the input power to the refrigerator if the rate of transfer of energy to the hot space is $100\ \mathrm{W}$.

[3 marks]

input power = ____________________ W

4

END OF QUESTIONS

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