AQA

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A-level PHYSICS

Paper 3
Section B Engineering physics

Thursday 14 June 2018 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.

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

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.

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Section B

Answer **all** questions in this section.

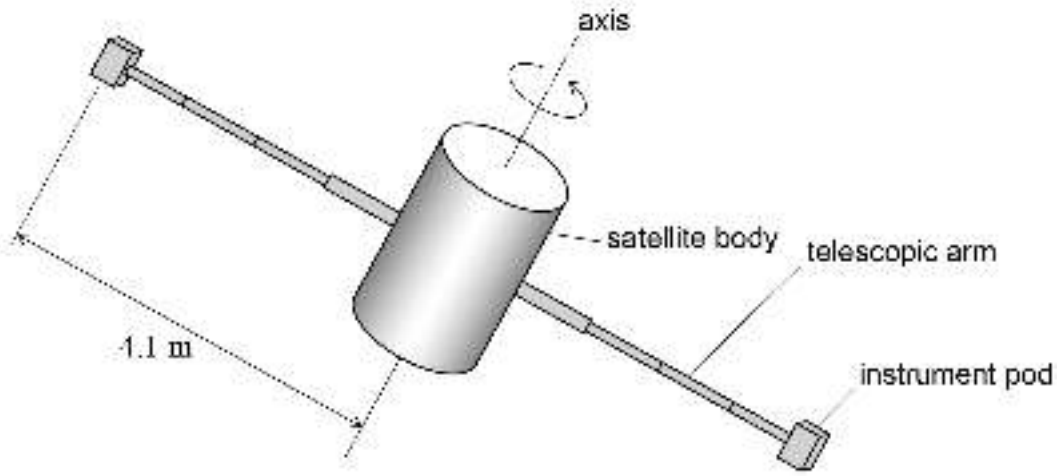
0 1 . 1 State the law of conservation of angular momentum.

[1 mark]

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0 1 . 2 **Figure 1** shows an orbiting satellite fitted with two small instrument pods attached to the ends of telescopic arms. The arms can be extended or retracted by a motor in the body of the satellite.

Figure 1



With the telescopic arms fully extended, the centre of mass of each instrument pod is at a radius of $4.1\ \text{m}$ from the axis of rotation.

moment of inertia of satellite body about axis = $71\ \text{kg m}^2$
mass of each instrument pod = $5.0\ \text{kg}$

The mass of the telescopic arms is negligible.

Show that the total moment of inertia of the satellite with the arms fully extended is $240\ \text{kg m}^2$

[2 marks]

Question 1 continues on the next page

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0 1 . 3 The satellite is initially rotating slowly about its axis with the arms fully extended. The arms are slowly retracted so that the instrument pods move closer to the body of the satellite.

State and explain the change in the angular speed of the satellite as the arms are retracted.

[3 marks]

0 1 . 4 The satellite is initially rotating at $1.3\ \text{rad s}^{-1}$ with the telescopic arms fully extended. When fully retracted the instrument pods are at a radius of $0.74\ \text{m}$ from the axis. The satellite contains sensitive equipment that may be damaged if the rotational speed exceeds $4.2\ \text{rad s}^{-1}$

Deduce whether the arms can be retracted fully without the satellite exceeding its maximum permitted angular speed.

[3 marks]

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0 2 . 1 State **one** function of a flywheel.

[1 mark]

Question 2 continues on the next page

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0 2 . 2 A student does an experiment to determine the frictional torque acting at the bearings of a steel flywheel. The flywheel has a radius of $0.075\ \text{m}$ and is perfectly balanced.

The student places a small magnet of mass $0.020\ \text{kg}$ at point **A** on the circumference of the flywheel on a horizontal line through the axis of rotation as shown in **Figure 2a**. The student releases the flywheel. The flywheel first comes to rest when it has moved through an angle of $3.00\ \text{rad}\ (172°)$, with the magnet now in position **B** as shown in **Figure 2b**.

Figure 2a

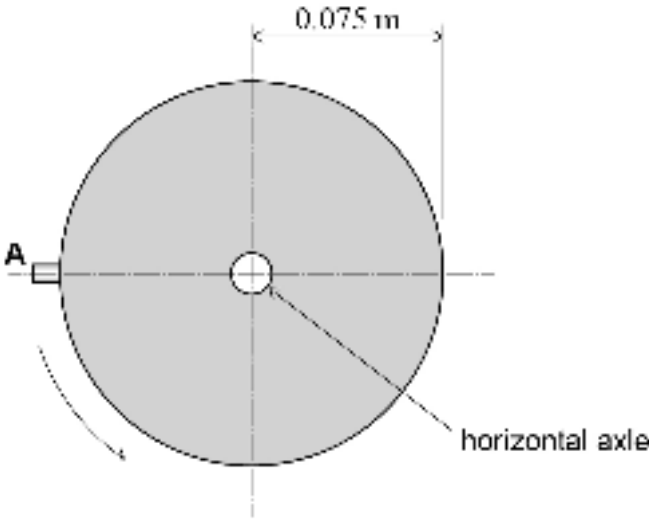
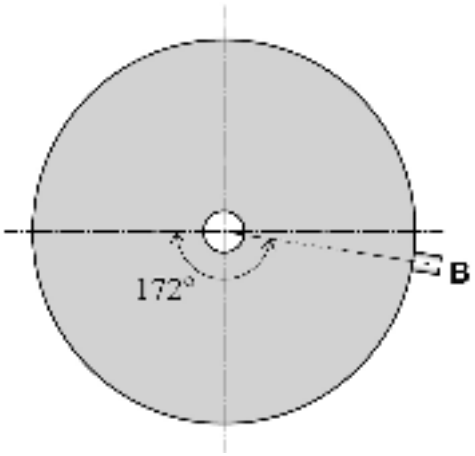


Figure 2b



The loss in gravitational potential energy of the magnet equals the work done against the frictional torque acting at the bearings.

Show that the frictional torque is about $7 \times 10^{-4}\ \text{N m}$

[3 marks]

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0 2 . 3 The student goes on to determine the moment of inertia of the flywheel.

The magnet is removed and the flywheel is made to spin. Measurements show that the flywheel makes 573 rotations as its angular speed reduces uniformly from 25.0 rad s^{-1} to zero. Assume the frictional torque at the bearings is constant and the same as in question **02.2**.

Determine the moment of inertia of the flywheel about its axis of rotation.

[3 marks]

moment of inertia = _____ kg m^2

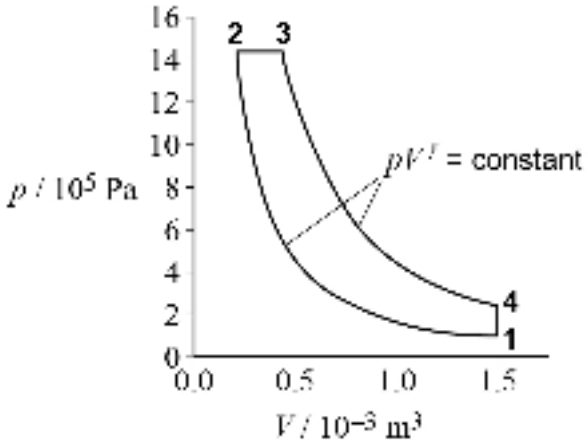
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Turn over for the next question

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0 3 **Figure 3** shows the p–V diagram for an idealised diesel engine cycle. In this cycle a fixed mass of air is taken through four processes **1** → **2** → **3** → **4** → **1**.

Figure 3



0 3 . 1 Which statement about this cycle is true?
Tick (✓) the correct answer.

[1 mark]

Work is done by the air in process **4** → **1**. ☐

Energy is supplied to the air by heating only in process **2** → **3**. ☐

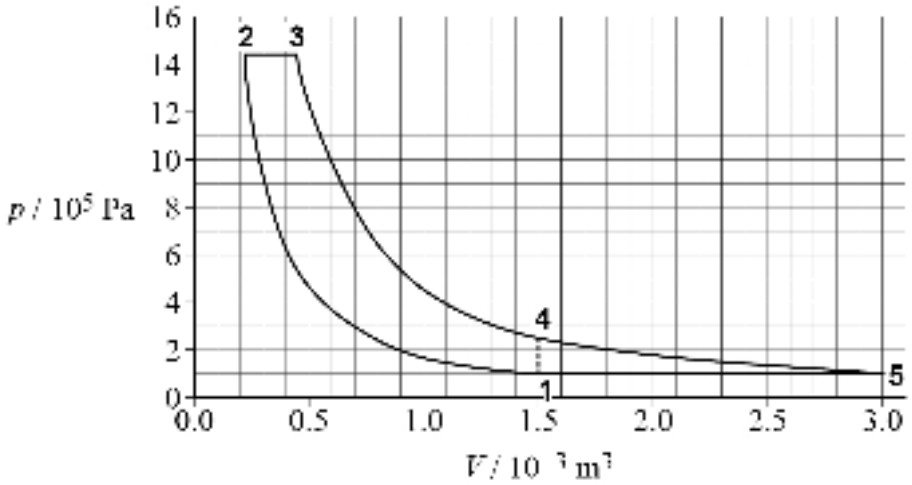
The temperature of the air rises in process **3** → **4**. ☐

The area enclosed by the loop **1** → **2** → **3** → **4** → **1** is the power output of the cycle. ☐

0 3 . 2 The cycle in **Figure 3** may be modified by allowing the air to continue to expand adiabatically from state **4** until it is at atmospheric pressure at state **5**.
Figure 4 shows the modified cycle.

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Figure 4



The expansion stroke **3** → **5** is now longer than the compression stroke **1** → **2**. Process **5** → **1** takes place at constant pressure.

It has been claimed that, compared to the cycle in **Figure 3**, the modified cycle of **Figure 4** gives

A an increase in work done per cycle of $130\ \text{J}$
B an increase in efficiency of more than 15%

Deduce whether these claims are true.

[5 marks]

Claim **A**

Claim **B**

Question 3 continues on the next page

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0 3 . 3 The first law of thermodynamics can be written as

$$Q = \Delta U + W$$

State the meaning of the terms Q and ΔU in this equation.

[2 marks]

Q _____

_____

ΔU _____

_____

0 3 . 4 For the air in process **5** $\rightarrow$ **1** in **Figure 4**, ΔU **=** -374 J

Calculate the energy that must be removed by cooling for process **5** $\rightarrow$ **1**.

[2 marks]

energy removed by cooling = _____ J

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0 3 . 5 $0.060\ \text{mol}$ of air is taken through the cycle.

Determine the maximum temperature in the cycle.

[3 marks]

maximum temperature = _____ K

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Turn over for the next question

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0 4 The National Grid is supplied mainly from power stations which have overall efficiencies of up to about 40%

Table 1 shows the average power requirements of a large paper-manufacturing business (a paper mill).

Table 1

Requirement	**Average power / MW**
for driving electric motors for wood grinders, pumps, fans, etc.	49
for heating, ie boiling and drying in the paper-making process and for heating the paper mill	141
for running electrical office equipment, lighting, etc.	8

The paper mill can either

- take all of its energy from the National Grid, or
- install an electrical generator of output 60 MW driven by a gas turbine of efficiency 36% as part of a combined heat and power (CHP) scheme. The hot exhaust gases from the turbine are used to produce steam at high temperature and pressure for heating.

The owners of the paper mill are considering the CHP option.

Explain, with reference to the data above and any other factors, the advice you would give them.

In your answer you should

- explain why the maximum theoretical efficiency of a heat engine is much less than 100%
- use the information above, including the numerical data, to compare the two options.

[6 marks]

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Question 4 continues on the next page

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