Please write clearly in block capitals.

Centre number | | | | | | Candidate number | | | | |

Surname ______________________

Forename(s) ______________________

Candidate signature ______________________

A-level
PHYSICS A

Unit 5C Applied Physics
Section B

Wednesday 21 June 2017 Morning

Time allowed: The total time for both sections of this paper is 1 hour 45 minutes. You are advised to spend approximately 50 minutes on this section.

Materials

For this paper you must have:
- a calculator
- a pencil and a ruler
- a Data and Formulae Booklet (enclosed).

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 section is 35.
- You are expected to use a calculator where appropriate.
- A *Data and Formulae Booklet* is provided as a loose insert.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use specialist vocabulary where appropriate.

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

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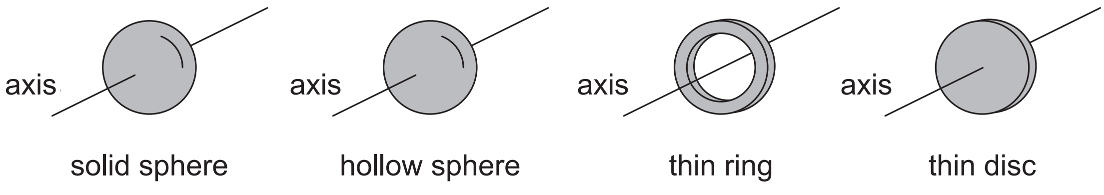
Section B

The maximum mark for this section is 35. You are advised to spend approximately 50 minutes on this section.

1 (a) **Figure 1** shows four objects each with the same mass and the same external radius.

Figure 1



The axis of rotation is through the centre of each object as shown in **Figure 1**.

Which object has the greatest moment of inertia about the axis of rotation?
Tick (✓) the correct box.

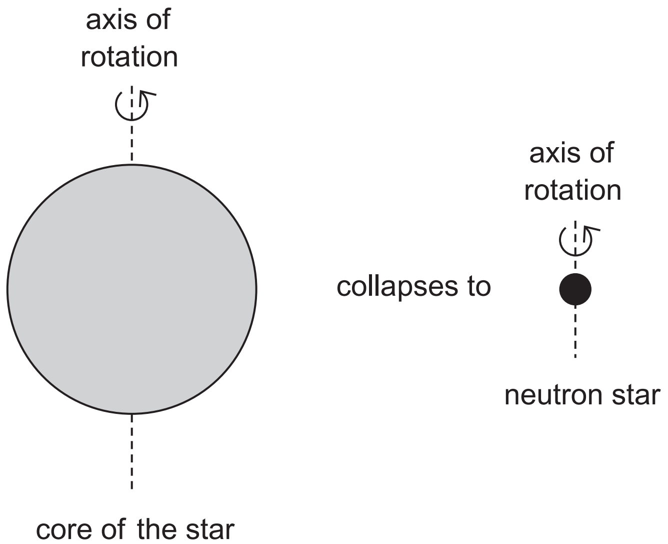
[1 mark]

solid sphere	☐
hollow sphere	☐
thin ring	☐
thin disc	☐

Question 1 continues on the next page

1 (b) When a star undergoes a supernova explosion, the star's spherical core collapses to become a much smaller, spherical neutron star of the same mass. **Figure 2** illustrates this change.

Figure 2



not to scale

Before collapsing, the star's core has a radius of 5.3×10^7 m and a period of rotation of 5.9×10^6 s about an axis through its centre. The neutron star formed has a smaller period of rotation and a radius of 1.4×10^4 m.

Assume that the core of the star always behaves as a uniform solid sphere.

Moment of inertia of a spherical object of uniform mass m and radius R about an axis through its centre = $0.40\,mR^2$.

1 (b) (i) Explain why the period of rotation of the star decreases as it becomes a neutron star.

[2 marks]

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1 (b) (ii) Determine the period of rotation of the neutron star.
Give your answer to an appropriate number of significant figures.

[4 marks]

period = ______________________________ s

7

Turn over for the next question

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2 Some motor racing cars are fitted with a kinetic energy recovery system (KERS). In this system, as the car brakes approaching a bend, instead of all the lost kinetic energy being dissipated as heat, some of the energy is used to accelerate a flywheel. When the car needs to accelerate out of the bend, the energy in the flywheel assists the engine in providing extra power.

2 (a) A KERS flywheel has a moment of inertia of $0.041\ \mathrm{kg\ m^2}$ and rotates at its maximum angular speed of $6700\ \mathrm{rad\ s^{-1}}$. When the flywheel is used to help accelerate the car, the flywheel's speed reduces uniformly to $3300\ \mathrm{rad\ s^{-1}}$ in a time of $7.2\ \mathrm{s}$. Assume that frictional losses in the drive mechanism are negligible.

2 (a) (i) Calculate the energy transferred from the flywheel to the car.

[1 mark]

energy = ____________________________ J

2 (a) (ii) Calculate the average power produced by the decelerating flywheel.

[1 mark]

average power = ____________________________ W

2 (a) (iii) Calculate the decelerating torque on the flywheel.
State an appropriate unit for your answer.

[2 marks]

torque = ____________ unit = ____________

Question 2 continues on the next page

Turn over ▶

2 (b) Describe and explain some of the design features of a flywheel in order for it to store maximum energy.

Your answer should include consideration of:

- the shape of the flywheel
- the material from which the flywheel is made
- the design of the flywheel for high angular speeds.

The quality of your written communication will be assessed in your answer.

[6 marks]

10

Turn over for the next question

Turn over ▶

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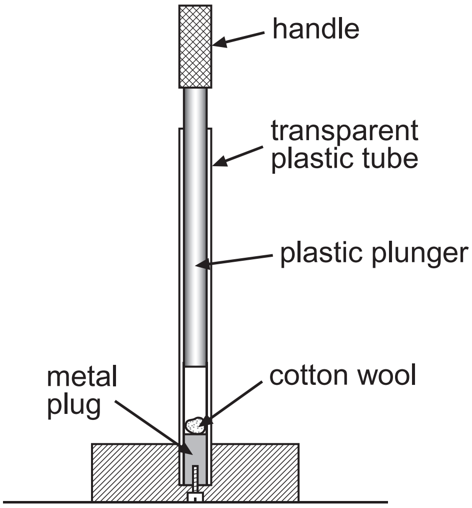
3 **Figure 3** shows a device for demonstrating an effect of adiabatic compression. A small pad of dry cotton wool is placed on the metal plug at the lower end of a long transparent plastic tube. The plunger is pushed quickly down the tube, compressing the air in the tube. When the plunger nears the bottom the cotton wool is seen to ignite.

Figure 3



3 (a) With the plunger at the top of the tube the air inside the tube has a volume of 5.8×10^{-6} m^3 and is at atmospheric pressure of 1.0×10^5 Pa.
The temperature of the air before the compression is 293 K.
When the plunger has been pushed down the tube to its lowest point, the volume of air in the tube is 2.3×10^{-7} m^3.
Assume that the compression of the air is adiabatic.

3 (a) (i) Show that the final pressure of air in the tube is about 9×10^6 Pa at the end of the compression.

γ for air = 1.4

[2 marks]

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3 (a) (ii) Calculate, in mol, the quantity of air in the tube.

[2 marks]

quantity of air = ______________________ mol

3 (a) (iii) Calculate the temperature of the air at the end of the compression just before the cotton wool ignites.

[2 marks]

temperature = ______________________ K

3 (b) Use the first law of thermodynamics to explain why the cotton wool will not ignite when the plunger is pushed down the tube very slowly.

[3 marks]

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Turn over ▶

4 'Atmospheric' engines were once used to pump water out of mines. These single-cylinder engines operated on the following cycle:

- the weight of the pump rod raised the piston and at the same time steam was admitted to the cylinder (see **Figure 4**)
- the steam valve was closed and the water valve opened, allowing a jet of cold water into the cylinder to condense the steam. This created a partial vacuum. Atmospheric pressure forced the piston down, lifting the pump rod and raising water from the mine (see **Figure 5**)
- when the piston was at the bottom of its stroke, the drain valve was opened to let the condensed steam and cooling water out of the cylinder.

Figure 4

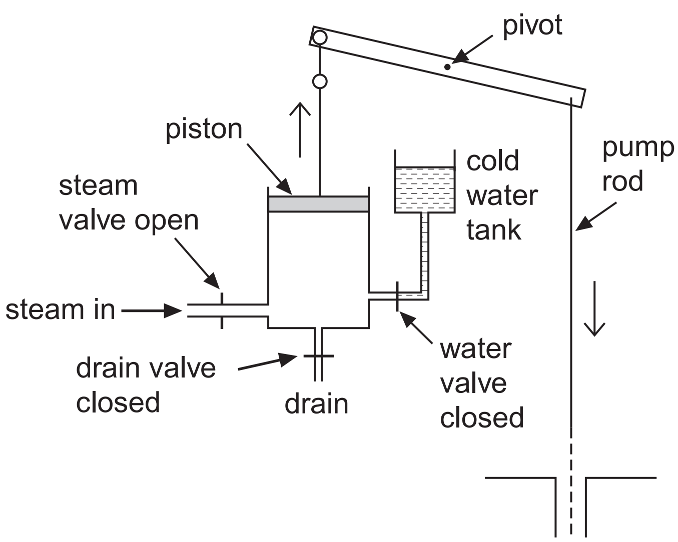
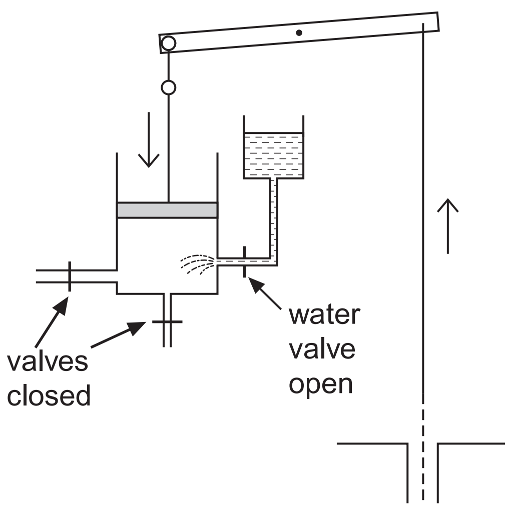
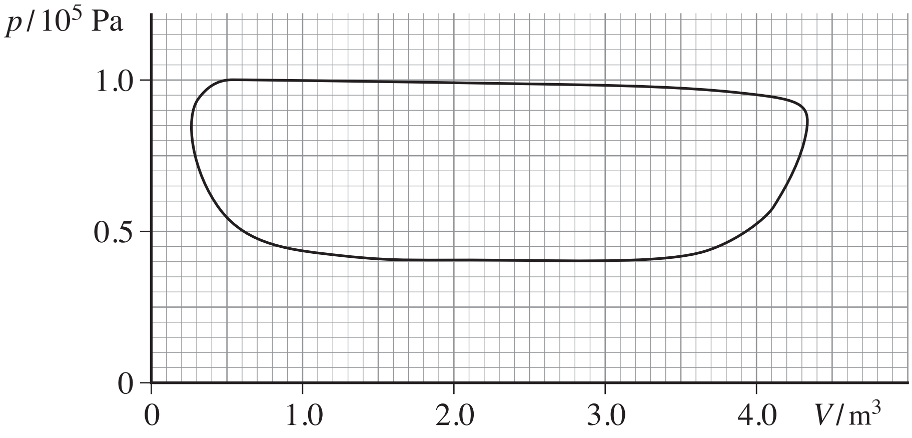


Figure 5



The $p - V$ diagram for one particular atmospheric engine is shown in **Figure 6**.

Figure 6



4 (a) (i) Use **Figure 6** to determine the indicated work done by the engine in one cycle.

[3 marks]

work = ____________________________ J

4 (a) (ii) One cycle of the engine was completed in 5.9 s.

Calculate the indicated power of the engine.

[1 mark]

power = ____________________________ W

Question 4 continues on the next page

4 (b) In each cycle, a mass of $5700\ \text{kg}$ of water was raised a height of $2.1\ \text{m}$.

4 (b) (i) Determine the output power of this engine.

[1 mark]

power = ____________________________ W

4 (b) (ii) Determine the mechanical efficiency of this engine.

[1 mark]

efficiency = ______________________________

4 (c) The temperature of the steam was $375\ \text{K}$ and the temperature of the cooling water was $285\ \text{K}$.

4 (c) (i) Calculate the maximum theoretical efficiency of a heat engine operating between these temperatures.

[1 mark]

maximum theoretical efficiency = ______________________________

Do not write outside the box

4 (c) (ii) The actual overall efficiency of this engine was less than 1%.

Suggest **two** reasons why the efficiency of the engine was so very low.

[2 marks]

1 ____

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2 ____

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9

END OF QUESTIONS

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