Please write clearly in block capitals.

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

Surname ______________________________

Forename(s) ______________________________

Candidate signature ______________________________

A-level
PHYSICS

Paper 3BC – Engineering Physics

Specimen materials (set 2)

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
- 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 calculator where appropriate.
- A Data and Formulae Booklet is provided as a loose insert.

For examiner's use	
Question	Mark
1	
2	
3	
4	
TOTAL	

Section B

Answer **all** questions in this section.

0 1 . 1 A metal flywheel is rotating on frictionless bearings. The temperature is increased so that the flywheel expands.

Consider **each** of the following statements and indicate with a tick (✓) if it is correct.

[1 mark]

	✓ if correct
The moment of inertia will decrease.	
The angular velocity will decrease.	
The angular momentum will be unaltered.	

An electric motor drives a machine which stamps out shapes from sheet steel. The machine is fitted with a flywheel of moment of inertia 25 kg m^2 which is accelerated uniformly until it is rotating at 640 rev min^{-1}. The machine then starts a stamping operation which reduces the flywheel's angular speed to 360 rev min^{-1}.

0 1 . 2 Explain why a flywheel is fitted between the motor and the stamping machine.

[2 marks]

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0 1 . 3 Calculate the energy needed for the stamping operation.

[2 marks]

energy = ________________ J

0 1 . 4 Immediately after the stamping operation the flywheel is accelerated to its initial speed of $640\ \text{rev min}^{-1}$ in a time of $5.0\ \text{s}$. The next stamping operation then begins.

Calculate the constant torque provided by the motor during this $5.0\ \text{s}$. Assume that the bearing frictional torque is negligible.

[2 marks]

torque = ____________________ N m

0 1 . 5 Calculate the minimum power output of the electric motor required.

[2 marks]

power = __________________ W

Question 1 continues on the next page

0 1 . 6 The flywheel is a solid disc. It is to be replaced with a flywheel which gives a smaller angular speed change for each stamping operation.

Two replacement flywheels, **A** and **B**, are available and information about them and the original flywheel is given in **Table 1**.

Table 1

flywheel	density of material / kg m^{-3}	thickness of disc / m	outer radius / m
original	7800	0.10	0.38
A	8800	0.20	0.30
B	2900	0.10	0.50

Deduce which flywheel, **A** or **B**, would be more suitable. Explain your choice.

The moment of inertia I of a solid disc of mass m and outer radius r about an axis through the centre is given by

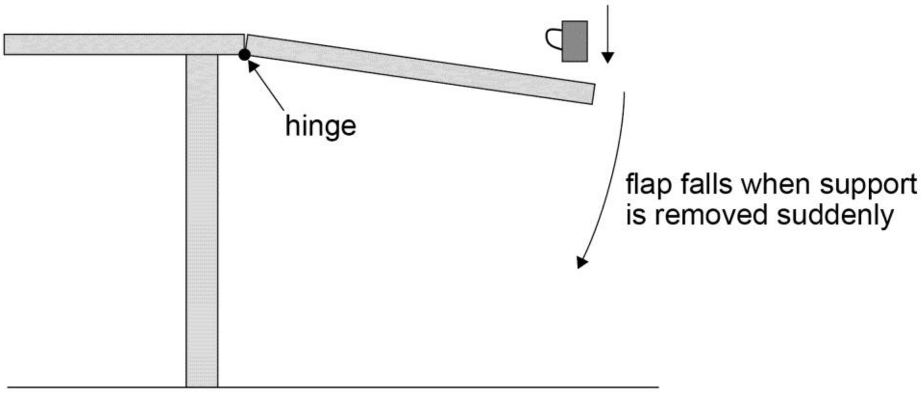
$$I = \frac{1}{2} m r^2$$

[3 marks]

12

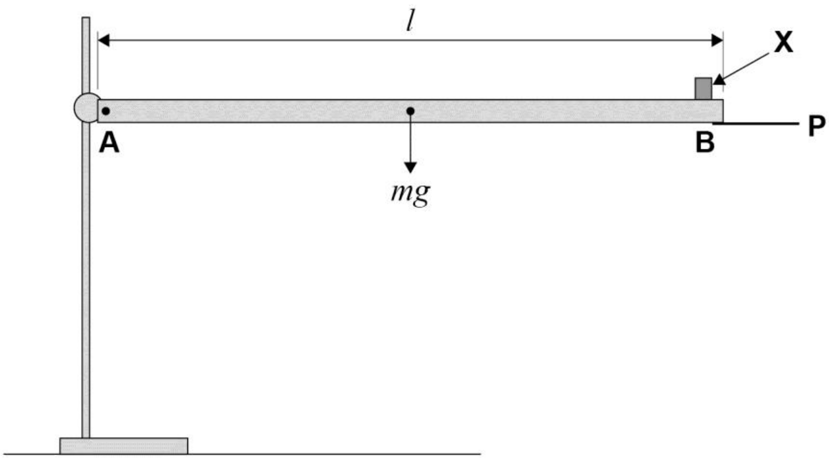
0 2 A student is told that if a small cup of coffee is placed near the edge of a table flap, the cup and the flap will lose contact if the flap support is suddenly removed. This is shown in **Figure 1**.

Figure 1



The student does not believe this to be true so decides to model the arrangement using a metre ruler free to pivot about one end **A**, with a small mass **X** resting on the ruler at the other end **B**. The arrangement is shown in **Figure 2**. The mass of **X** is negligible compared to the mass of the ruler. The metre ruler is held in the horizontal position by a support **P** which is quickly removed. A video is taken of the subsequent motion of the ruler and mass.

Figure 2



Assume the ruler is a thin uniform beam of mass m and length l.

0 2 . 1 Derive an expression for the torque T acting on the ruler at the moment of release.

[1 mark]

0 2 . 2 The moment of inertia I of the metre ruler about the axis through **A** is given by

$$I = \frac{m}{3}\ l^2$$

Show that the angular acceleration α of the ruler at the moment of release is given by

$$\alpha = \frac{3g}{2l}$$

[2 marks]

0 2 . 3 The linear acceleration a of a point on a rotating rigid body at a distance r from the axis of rotation is related to the angular acceleration α by

$$a = r \times \alpha$$

Explain why this causes the small mass to lose contact with the metre ruler as soon as the ruler is released.

[2 marks]

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0 2 . 4 Estimate how far from **A** the small mass must be placed to ensure it just maintains contact with the ruler when the ruler is released.

[1 mark]

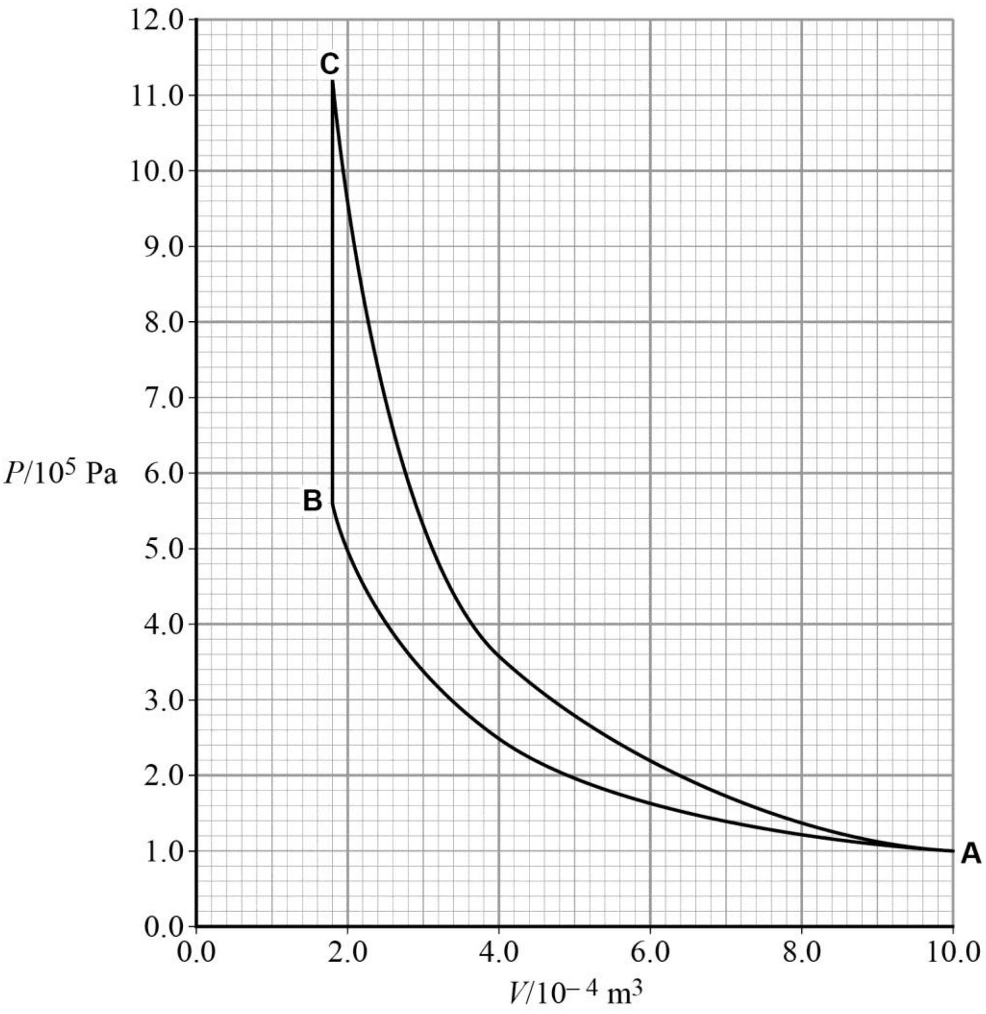
0 3 **Figure 3** shows a $p-V$ diagram of a theoretical engine cycle in which a fixed mass of gas at an initial pressure of 1.00×10^5 Pa and temperature 295 K is taken through the following stages in turn:

A → **B** isothermal compression

B → **C** heat addition of 251 J at constant volume to a temperature 2.0 times the initial temperature

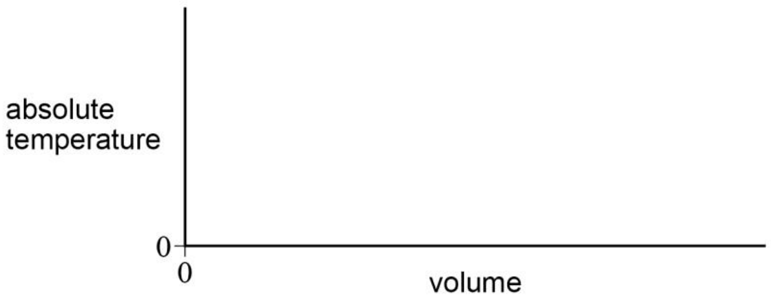
C → **A** adiabatic expansion to the initial temperature and pressure.

Figure 3



0 3 . 1 Sketch, on the axes below, a graph to show how the temperature will vary with volume during the cycle. Label the points **A**, **B** and **C**.

[2 marks]



0 3 . 2 Determine the work output of the cycle.

[3 marks]

work = ________________ J

0 3 . 3 Determine the power output of this theoretical engine if the engine were to run at 80 cycles per second.

[1 mark]

power = ________________ W

0 3 . 4 An engineer is thinking about designing a real engine which works as closely as possible to this cycle.

Discuss some of the problems that will have to be overcome.
Go on to discuss, with reference to the power output and efficiency of the cycle, whether the engineer should go ahead with the design.

[6 marks]

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0 4 . 1 Explain what is meant by a reversed heat engine.

[2 marks]

0 4 . 2 The coefficient of performance of a heat pump is given by

$$COP_{\mathrm{hp}} = \frac{Q_{\mathrm{H}}}{Q_{\mathrm{H}} - Q_{\mathrm{C}}}$$

Explain the term Q_{H} with reference to a heat pump used to provide heating in a building.

[1 mark]

0 4 . 3 An ideal heat engine of efficiency 0.50 is reversed to operate as a heat pump working between the same temperature limits.
Determine the coefficient of performance of the heat pump.

[2 marks]

COP_{hp} ______________

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END OF QUESTIONS