Please write clearly in block capitals.

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| Forename(s) | |
| Candidate signature | I declare this is my own work. |

# A-level
# PHYSICS

## Paper 3
## Section B Engineering physics

Tuesday 17 June 2025 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
- a protractor.

### 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.
- If you need extra space for your answer(s), use the lined pages at the end of this book. Write the question number against your answer(s).
- 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 | |
| **TOTAL** | |

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## Section B

Answer **all** questions in this section.

**0 1** The rotating part of an electric motor is called the rotor.

**Figure 1** shows an end view of a rotor turning clockwise due to a driving torque from the motor. In this question, the clockwise direction is treated as positive.

**Figure 1**

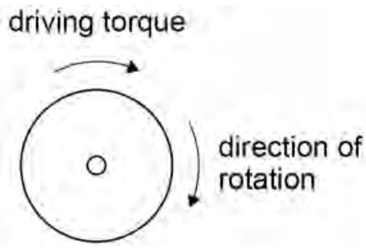
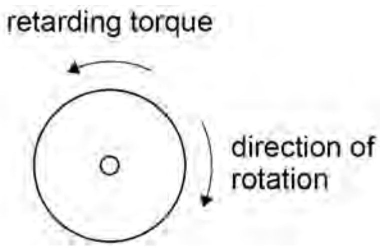



**Figure 2**




The rotor can be brought to rest rapidly by reversing the electrical supply connections to the motor. **Figure 2** shows the rotor at time $t = 0$ when the supply connections are reversed.
The rotor then slows down due to a constant anticlockwise retarding torque so that it stops at time $t = t_1$.

The angular velocity of the rotor at $t = 0$ is $98.0\ \text{rad s}^{-1}$ clockwise.
The applied torque on the rotor at $t = 0$ is anticlockwise.
The applied torque produces a constant angular acceleration of $-303\ \text{rad s}^{-2}$.
Friction torque is negligible.

**0 1 . 1** Determine $t_1$.

**[2 marks]**

$t_1$ = ____________________ s

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The electrical supply remains connected and the rotor now accelerates uniformly anticlockwise with an acceleration of magnitude $303 \text{ rad s}^{-2}$.
At a later time $t = t_2$, the angular velocity of the rotor is $-120 \text{ rad s}^{-1}$.

**0 1 . 2** Determine the number of anticlockwise revolutions made by the rotor between $t_1$ and $t_2$.

**[2 marks]**

number of revolutions = ______________________

**0 1 . 3** The moment of inertia of the rotor about the axis of rotation is $9.60 \times 10^{-2} \text{ kg m}^2$.

Calculate the angular impulse on the rotor between $t = 0$ and $t_2$.

**[1 mark]**

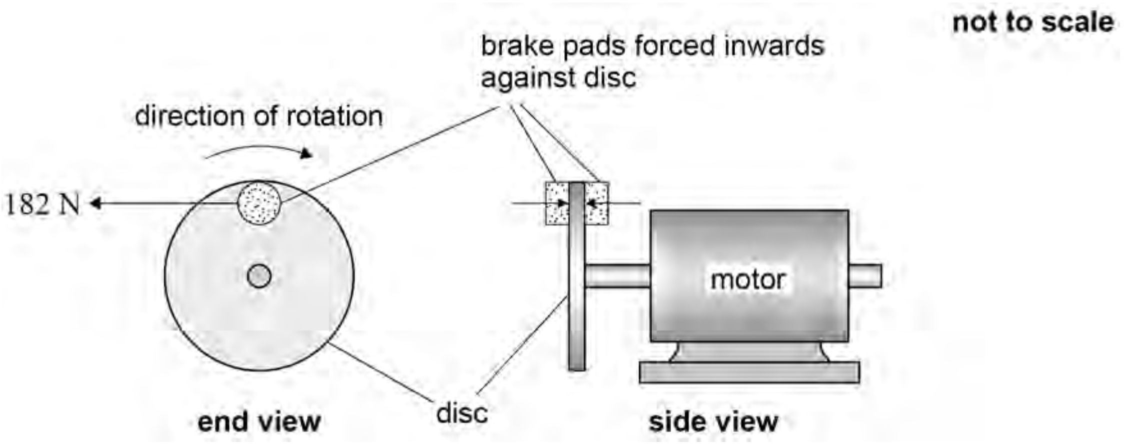
angular impulse = ______________________ $\text{N m s}$

**Question 1 continues on the next page**

**0 1 . 4** Another way of quickly stopping the motor is to use a disc brake. The motor is brought to rest by switching off the power supply and then forcing two brake pads against the disc.

**Figure 3** shows the two brake pads each applying a constant retarding force of 182 N to the disc.

**Figure 3**




moment of inertia of rotor and disc about the axis of rotation = $0.101\ \text{kg m}^2$
diameter of disc = $0.160$ m
diameter of pad = 22 mm

Compare the angular deceleration produced by the disc brake system with the angular deceleration produced by reversing the electrical connections.

**[3 marks]**

8

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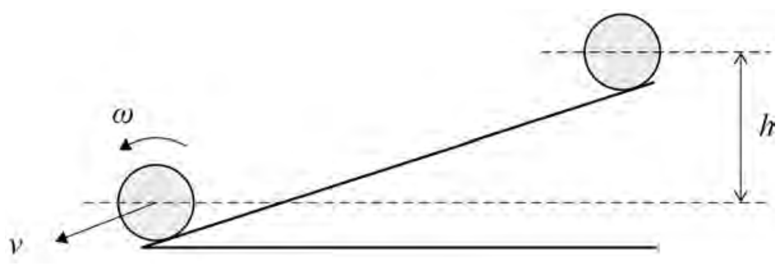
**0 2 . 1** The moment of inertia $I$ of any rolling object about its axis of rotation is given by

$$I = Amr^2$$

where $A$ is a constant that depends on the shape of the object
$m$ is the mass of the object
$r$ is the radius of the object.

**Figure 4** shows an object that starts from rest and rolls down a slope without slipping.

**Figure 4**




The object falls a vertical distance $h$. It then has a linear velocity $v$ and angular velocity $\omega$.
For a rolling object the linear velocity $v$ of the centre of mass is related to the angular velocity $\omega$ by $v = r\omega$.

Show, by considering the energy transfers that occur, that

$$v = \sqrt{\frac{2gh}{1 + A}}$$

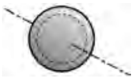
**[3 marks]**

**Question 2 continues on the next page**

**Table 1** gives the moments of inertia of a solid sphere **P**, a hollow sphere **Q**, a solid cylinder **R** and a hollow cylinder **S** about their axes of rotation.

**P**, **Q**, **R** and **S** have the same mass $m$ and outer radius $r$.

**Table 1**

| Object | | Moment of inertia |
|---|---|---|
| solid sphere **P** |  | $\frac{2}{5}mr^2$ |
| hollow sphere **Q** |  | $\frac{2}{3}mr^2$ |
| solid cylinder **R** |  | $\frac{1}{2}mr^2$ |
| hollow cylinder **S** |  | $mr^2$ |

**0 2 . 2** Explain why the hollow sphere **Q** has a greater moment of inertia about its axis of rotation than the solid sphere **P**.

**[1 mark]**

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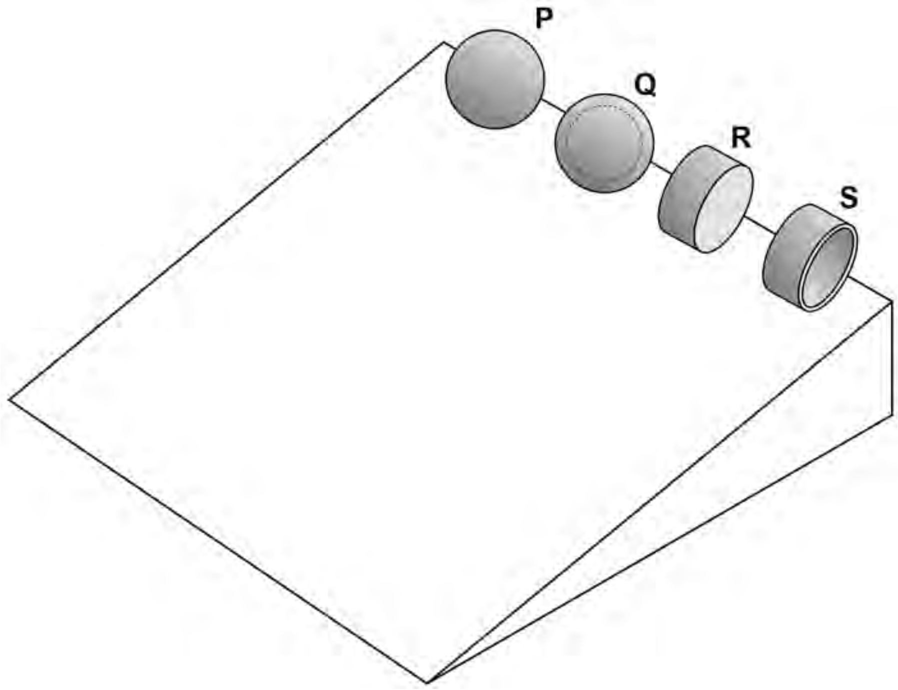
**0 2 . 3** **Figure 5** shows all four objects at rest at the top of a slope. They are released at the same time and roll down the slope without slipping.

**Figure 5**




Deduce the order in which the objects reach the bottom of the slope.

**[3 marks]**

7

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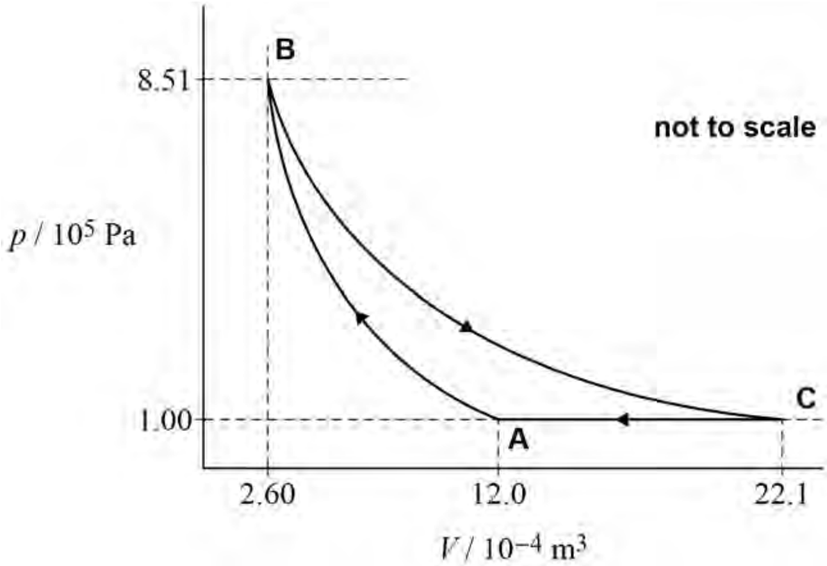
**0 3 . 1** State what is meant by an isothermal change.

**[1 mark]**

**Figure 6** shows a $p$–$V$ diagram in which a fixed mass of an ideal gas is taken through a cycle of three processes.

**A** → **B**: adiabatic change
**B** → **C**: isothermal change
**C** → **A**: reduction in volume at constant pressure

**Figure 6**




The maximum temperature of the gas in the cycle is $536\ \mathrm{K}$ and the minimum temperature is $291\ \mathrm{K}$.

**0 3 . 2** Calculate, in mol, the amount of gas.

**[2 marks]**

amount of gas = ____________________ mol

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**0 3 . 3** Show that the work done in process **C** → **A** is about 100 J.

**[1 mark]**

**0 3 . 4** Complete **Table 2** for each process and for the whole cycle.

**[3 marks]**

**Table 2**

| | $Q$ / J | $W$ / J | $\Delta U$ / J |
|---|---|---|---|
| Process **A** → **B** | | −253 | |
| Process **B** → **C** | 473 | | |
| Process **C** → **A** | | | −253 |
| Whole cycle | | 119 | |

**0 3 . 5** Two criteria for a heat engine to achieve the maximum theoretical efficiency are:

1. the gas must always be at the same temperature as the hot source when energy is being transferred **to** the gas by heat transfer
2. the gas must always be at the same temperature as the cold sink when energy is being transferred **from** the gas by heat transfer.

The temperatures of the source and sink do not change.

Deduce whether the cycle in **Figure 6** satisfies either or both of these criteria.

**[2 marks]**

**Question 3 continues on the next page**

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**0 3 . 6** The overall efficiency of a heat engine is defined as

$$\text{overall efficiency} = \frac{\text{net work output in one cycle}}{\text{energy supplied by heat transfer in one cycle}}$$

An engineer suggests designing a real engine based on the cycle shown in **Figure 6**.

Discuss the engineer's suggestion.

In your answer you should:

- use **Table 2** to determine the overall efficiency of a theoretical engine that uses the cycle
- compare this overall efficiency with the efficiency of an ideal engine working between the same temperatures as the cycle
- discuss with reasons the problems that would need to be overcome in making a real engine work on this cycle
- explain whether the engineer's suggestion would lead to a useful engine.

**[6 marks]**

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15

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**0 4 . 1** State what is meant by the coefficient of performance of a heat pump.

**[1 mark]**

A jeweller hopes to reduce workshop heating costs by replacing a gas-fired boiler with an electric heat pump. The heat pump will provide underfloor heating using water at a temperature of $40\ °C$.

The air outside the building provides the low-temperature reservoir for the heat pump. Over the winter period the outside temperature will vary between $12\ °C$ and $-8\ °C$.

The salesperson for a heat pump company claims that:

- the coefficient of performance will vary greatly, depending on the outside temperature
- the colder the outside temperature, the lower the energy costs will be for running the heat pump.

**0 4 . 2** Comment on the salesperson's claims.

**[3 marks]**

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0 4 . 3 A heat pump is installed. The average $COP_{\mathrm{hp}}$ over the winter period is 7.5
In this period the heat pump delivers 2880 kW h of underfloor heating.

What is the electrical energy used by the heat pump in this period?

Tick (✓) **one** box.

**[1 mark]**

333 kW h ☐

384 kW h ☐

2500 kW h ☐

21 600 kW h ☐

5

**END OF QUESTIONS**

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**ANSWER IN THE SPACES PROVIDED**

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