Please write clearly in block capitals.

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

Surname _____

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.

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 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

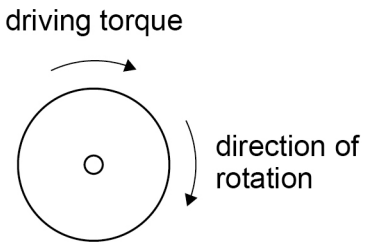
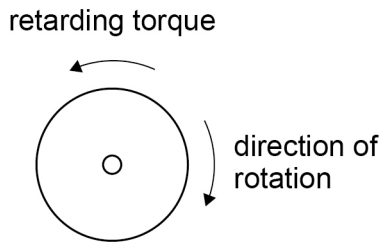


Figure 2



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 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 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 = _____ N m s

Question 1 continues on the next page

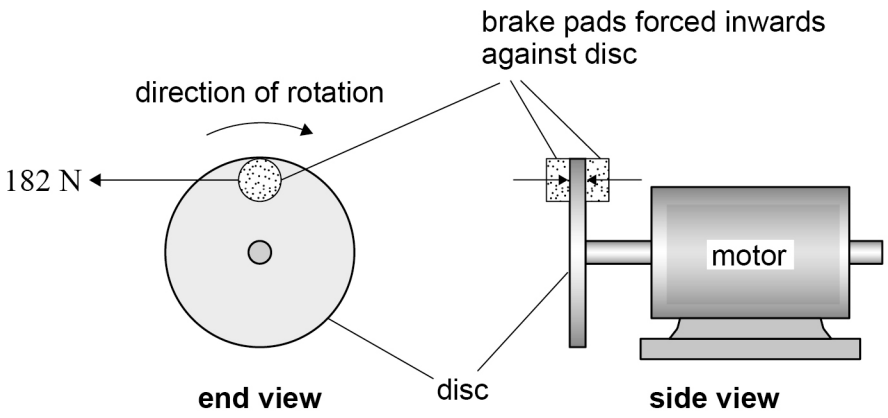
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0 1 . 4 Another way of quickly stopping the motor is to use a disc brake. The motor is brought to rest by switching off the power supply and then forcing two brake pads against the disc.

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

Figure 3

not to scale



moment of inertia of rotor and disc about the axis of rotation = 0.101 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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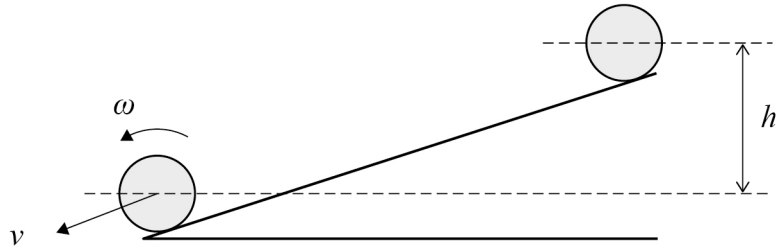
0 2 . 1 The moment of inertia I of any rolling object about its axis of rotation is given by

$$I = Amr^2$$

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 ω.
For a rolling object the linear velocity v of the centre of mass is related to the angular velocity ω by $v = r\omega$.

Show, by considering the energy transfers that occur, that

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

[3 marks]

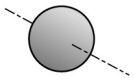
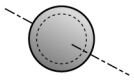
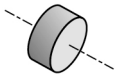
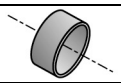
Question 2 continues on the next page

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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

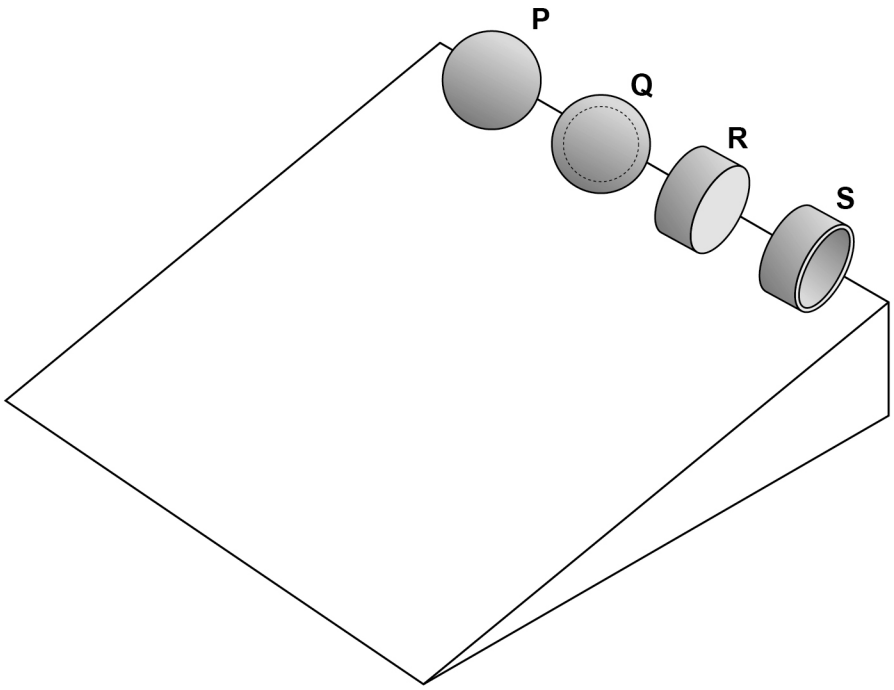
0 2 . 2 Explain why the hollow sphere **Q** has a greater moment of inertia about its axis of rotation than the solid sphere **P**.

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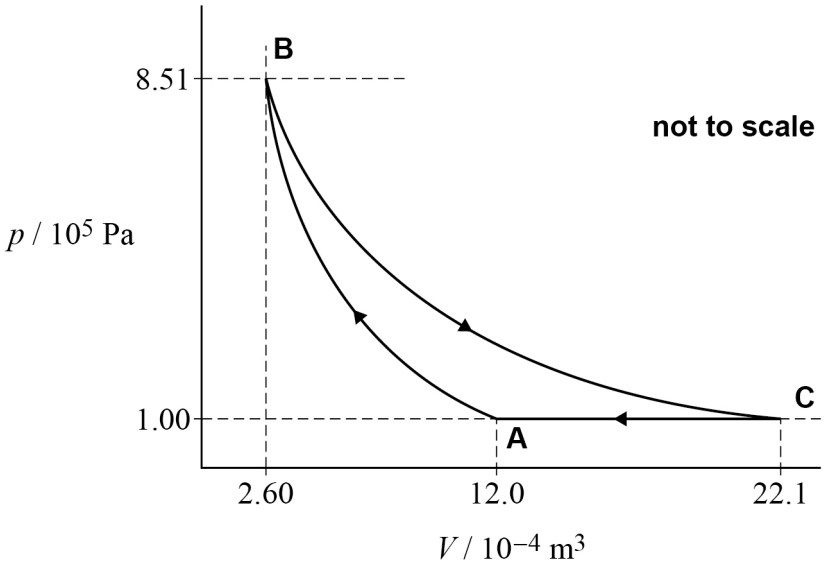
0 3 . 1 State what is meant by an isothermal change.

[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 K and the minimum temperature is 291 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	ΔU / 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

Turn over ►

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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_{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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