AQA

Please write clearly in block capitals.

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I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Engineering physics

Thursday 15 June 2023 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	
5	
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 One equation used in translational dynamics is:

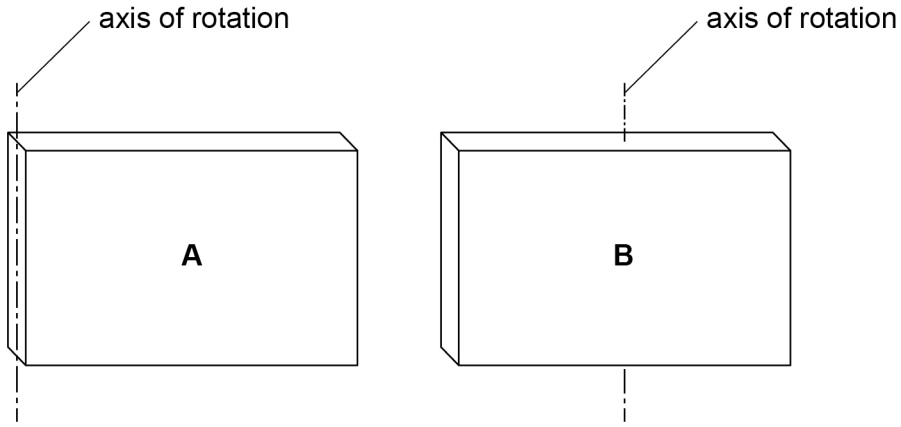
$$\text{force} = \text{mass} \times \text{acceleration}$$

State **in words** the equivalent equation used in rotational dynamics.

[2 marks]

Figure 1 shows two identical uniform plates **A** and **B**. The axis of rotation of each plate is shown.

Figure 1



0 1 . 2 State and explain which plate has the greater moment of inertia about its axis of rotation.

[2 marks]

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An electric motor drives a machine that punches out plates from a long strip of sheet metal. The motor runs continuously and is fitted with a flywheel.
Figure 2 shows how the angular velocity ω of the flywheel varies with time t.

Figure 2

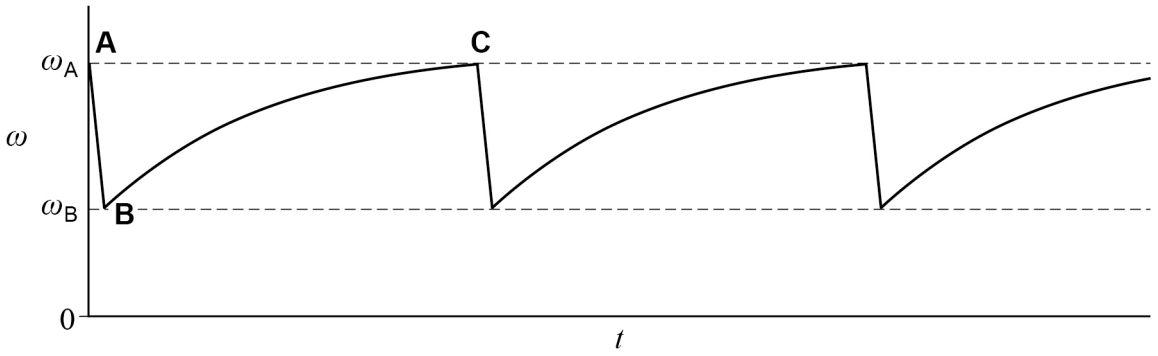


Table 1 describes the sequence for the machine after it has been brought up to speed ω_A.

Table 1

A	The punching operation starts.
A to **B**	The flywheel transfers some of its energy during the punching operation.
B to **C**	The flywheel is again brought up to speed ω_A by the motor.
C	The next punching operation starts.

0 1 . 3 A new flywheel with a greater moment of inertia is fitted in place of the original flywheel. The motor torque is constant and the same as before.

Sketch on **Figure 2** a graph showing how the angular velocity varies with time for the machine fitted with the new flywheel.

Assume that:

- the punching operation starts at the same angular speed ω_A
- the same quantity of energy is transferred when punching the metal sheet.

[2 marks]

Question 1 continues on the next page

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0 1 . 4 Explain **one** difference between your graph and the original graph.

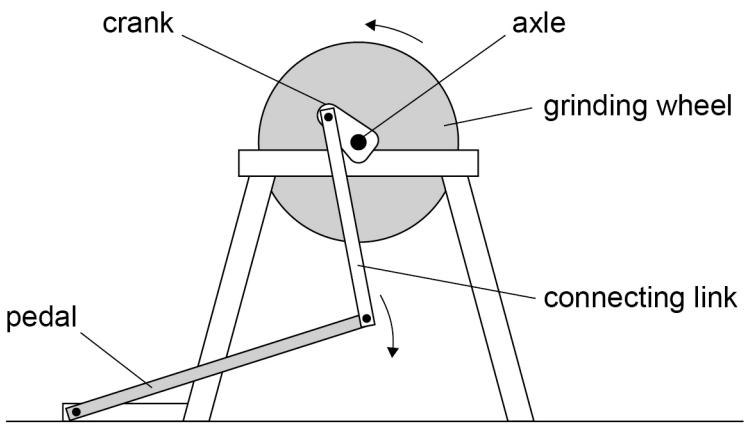
[1 mark]

7

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0 2 **Figure 3** shows a heavy stone grinding wheel used for sharpening tools.

Figure 3



The pedal is connected to the axle of the wheel by a connecting link and crank.
The operator pushes the pedal downwards to accelerate the wheel from rest.
The wheel begins to rotate in the direction shown.

0 2 . 1 Explain why the torque applied to the axle varies as the operator pushes downwards on the pedal.

[2 marks]

Question 2 continues on the next page

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0 2 . 2 The wheel is rotating at a high angular speed. The operator is told not to use the pedal to stop the rotation of the wheel suddenly.

Explain, with reference to angular impulse, why a sudden stop is likely to damage the mechanism.

[2 marks]

0 2 . 3 The connecting link breaks. At this instant the angular speed of the wheel is $13.8\ \text{rad s}^{-1}$.
It takes $15.0\ \text{s}$ for the wheel to come to rest.
The frictional torque acting at the axle bearings is $0.77\ \text{N m}$ and is constant for all speeds.

Calculate the moment of inertia of the wheel.

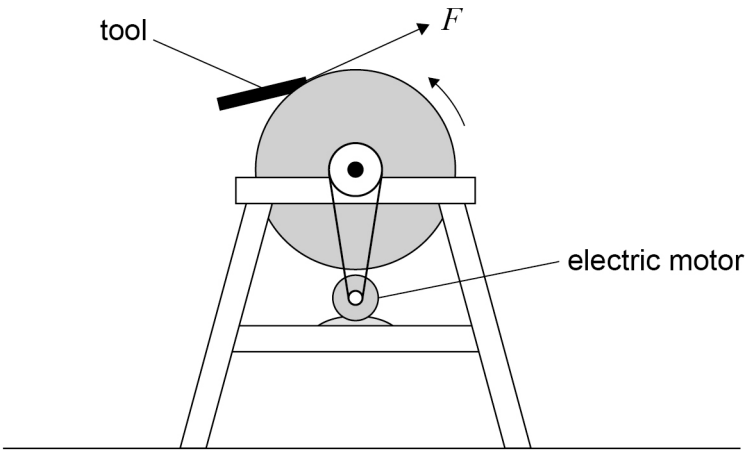
[2 marks]

moment of inertia = _____ kg m^2

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The arrangement is modified as shown in **Figure 4**. The pedal, connecting link and crank are removed and the grinding wheel is driven by an electric motor.

Figure 4



0 2 . 4 **Figure 4** also shows a tool being sharpened by pressing it on the edge of the rotating wheel.
The tool applies a tangential force F on the wheel.
A torque of $3.10\ \text{N m}$ is needed at the axle to drive the wheel at constant angular speed while the tool is being sharpened.

frictional torque at the axle bearings $= 0.77\ \text{N m}$
radius of wheel $= 0.24\ \text{m}$

Calculate F.

[2 marks]

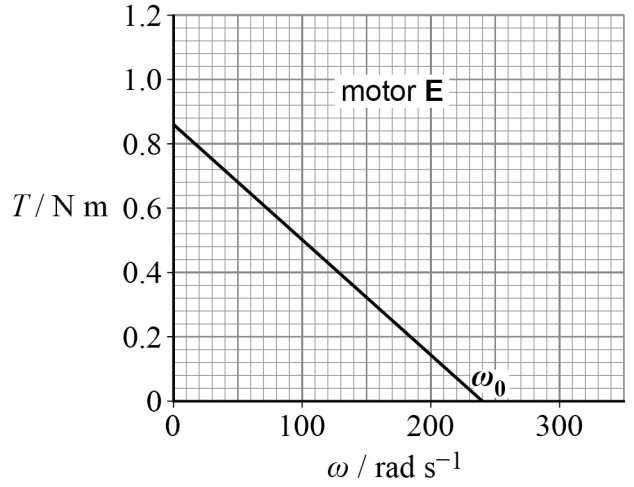
$F =$ _____ N

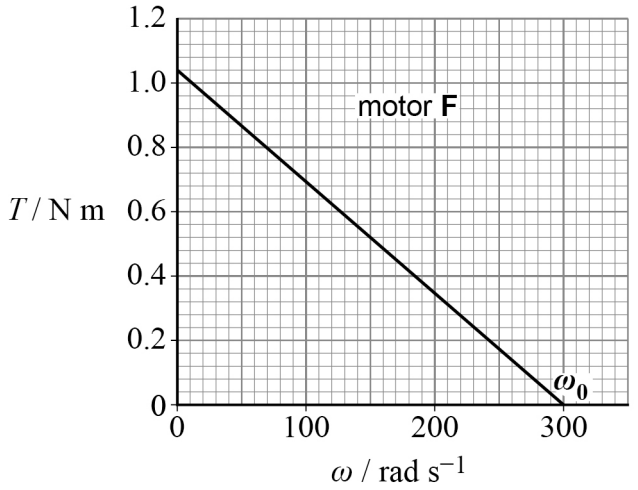
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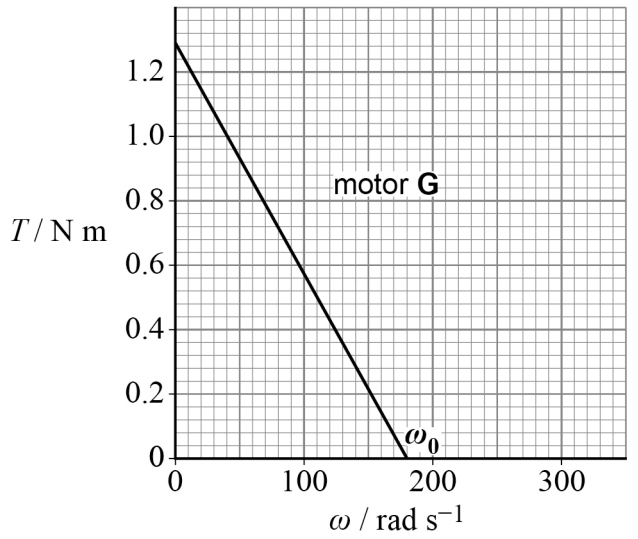
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0 2 . 5 Three motors **E**, **F** and **G** were available to drive the wheel in **Figure 4**.
Figure 5 shows how the torque T varies with angular speed ω for each motor.

Figure 5







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The no-load speed ω_0 is the angular speed of a motor when the torque applied is zero.

The maximum power of each motor is developed at about $0.5\omega_0$.

The required output power of the motor when a tool is being sharpened is $52\ \text{W}$.

The required output power of the chosen motor should be about $\frac{2}{3}$ of its maximum power.

Deduce which motor **E**, **F** or **G** was chosen for this application.

[3 marks]

11

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0 3 . 1 The first law of thermodynamics can be written as:

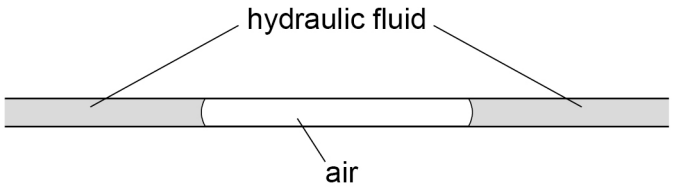
$$Q = \Delta U + W$$

State what Q represents in this equation.

[1 mark]

Air in the brake pipe of a bicycle hydraulic brake system can be dangerous.
Figure 6 shows a bubble of air in a brake pipe.

Figure 6



Assume that the hydraulic fluid is incompressible.
During a sudden application of the brake, the air is compressed adiabatically to a high pressure.

0 3 . 2 The work done on the air when it is compressed is $10.8\ \text{mJ}$.

Which row is correct for this adiabatic compression?

Tick (✓) **one** box.

[1 mark]

W / mJ	Q / mJ	ΔU / mJ	
−10.8	0	10.8	
10.8	10.8	0	
−10.8	−10.8	0	
10.8	0	−10.8	

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0 3 . 3 The initial conditions for the air are:

volume of air = 2.91×10^{-8} m^3
pressure of air = 1.05×10^5 Pa
temperature of air = 293 K.

During sudden braking, the air in the bubble is compressed adiabatically to a volume of 3.19×10^{-9} m^3.

Calculate the pressure and the temperature of the air immediately after the compression.

γ for air = 1.4

[3 marks]

pressure = _____ Pa

temperature = _____ K

Question 3 continues on the next page

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0 3 . 4 To produce the adiabatic change, the brake lever is pulled very quickly.
The cyclist thinks that by applying the brake slowly, the work done to compress the bubble to a volume of $3.19 \times 10^{-9}\ \text{m}^3$ will be greater than $10.8\ \text{mJ}$.

Deduce without calculation whether the cyclist is correct.

[2 marks]

7

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0 4 **Figure 7** shows the p–V diagram for a theoretical diesel engine cycle.
Figure 8 shows the indicator diagram for a real four-stroke diesel engine working between the same maximum and minimum volumes.

Figure 7

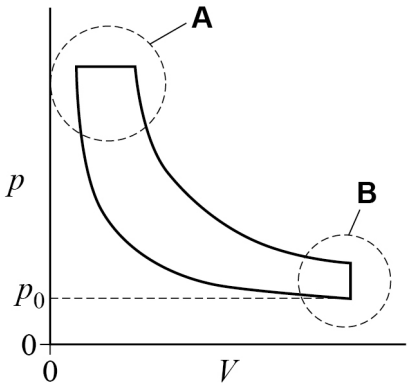
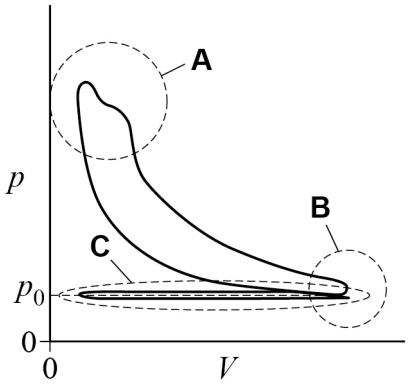


Figure 8



p_0 is atmospheric pressure.

Compare the indicator diagram with the theoretical diesel cycle.
In your answer, explain:

- the differences between region **A** on **Figure 7** and region **A** on **Figure 8**
- the differences between region **B** on **Figure 7** and region **B** on **Figure 8**
- why the features shown in region **C** appear only on the indicator diagram
- why the efficiency of the real engine will always be less than the efficiency predicted by an analysis of the theoretical cycle.

[6 marks]

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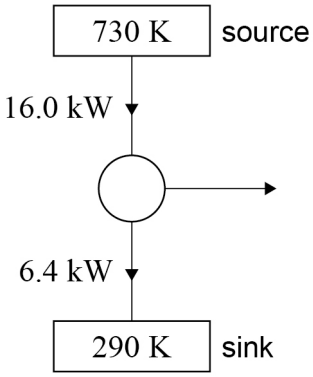
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0 5 **Figure 9** shows an ideal heat engine.

Figure 9



The engine operates between a source at a temperature of 730 K and a sink at a temperature of 290 K.
The input power is 16.0 kW and the power rejected to the sink is 6.4 kW.

0 5 . 1 Calculate the efficiency of this engine.

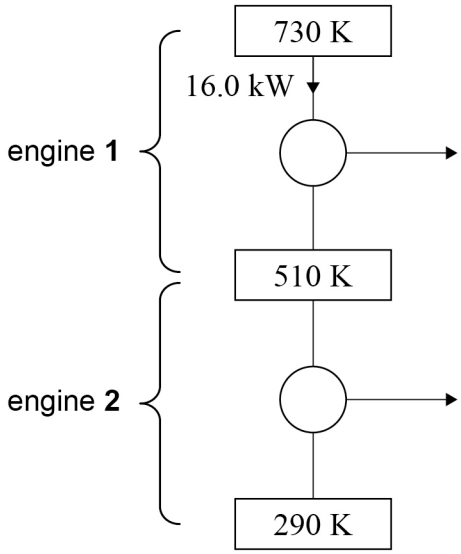
[1 mark]

efficiency = _____

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0 5 . 2 **Figure 10** shows another system operating between the same overall temperatures and with the same input power as the engine in **Figure 9**. This system consists of two ideal engines.

Figure 10



The sink for engine **1** forms the source for engine **2**. The temperature of the intermediate reservoir is 510 K.
All the energy rejected by heat transfer in engine **1** provides the input energy to engine **2**.
A student suggests that the system in **Figure 10** can provide more output power and be more efficient than the engine in **Figure 9**.

Deduce whether the student's suggestions are correct.
You may annotate **Figures 9** and **10**.

[3 marks]

4

END OF QUESTIONS

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