



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

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.

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	
5	
TOTAL	



J U N 2 3 7 4 0 8 3 B C 0 1

1B/M/Jun23/E7

7408/3BC

Section B

Do not write
outside the
box

Answer **all** questions in this section.

0 1 . 1 One equation used in translational dynamics is:

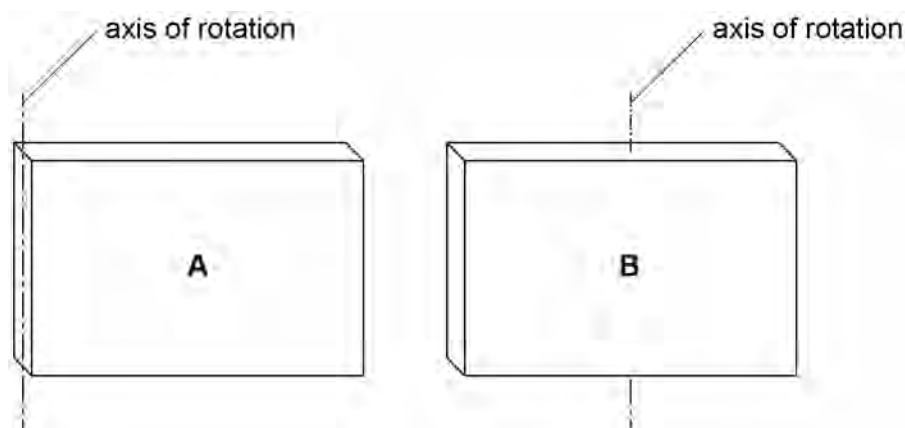
$$\text{force} = \text{mass} \times \text{acceleration}$$

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]



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

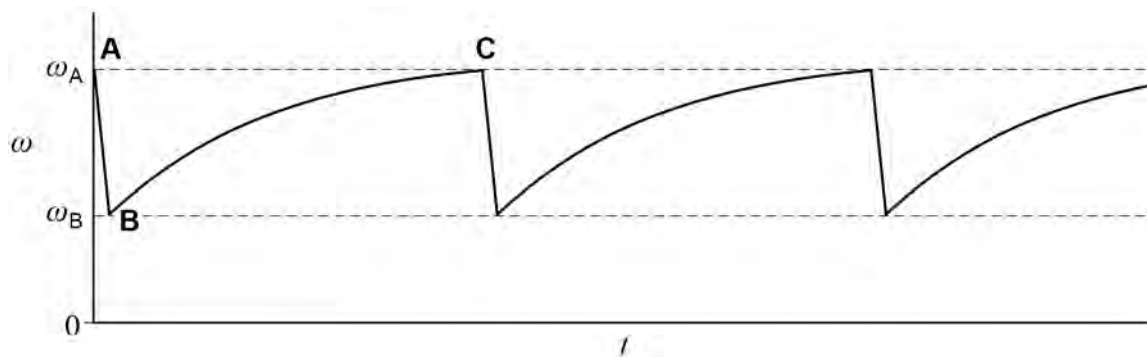


Table 1 describes the sequence for the machine after it has been brought up to speed ω_A .

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

Turn over ►



Do not write
outside the
box

0 1 . 4

Explain **one** difference between your graph and the original graph.

[1 mark]

7

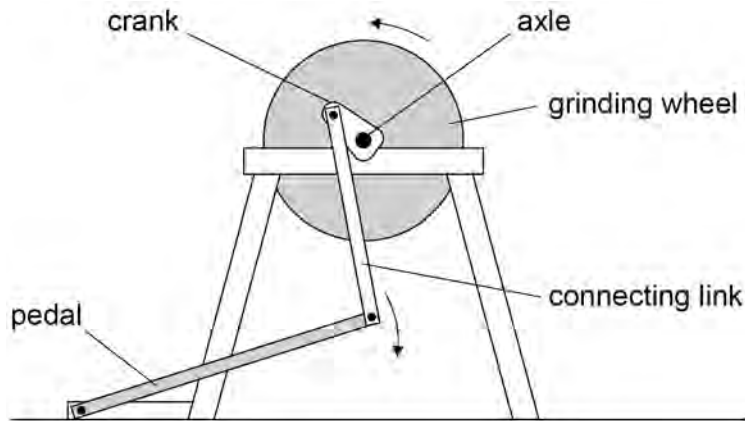


Do not write outside the box

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

Turn over ►



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 rad s^{-1} .

It takes 15.0 s for the wheel to come to rest.

The frictional torque acting at the axle bearings is 0.77 N m and is constant for all speeds.

Calculate the moment of inertia of the wheel.

[2 marks]

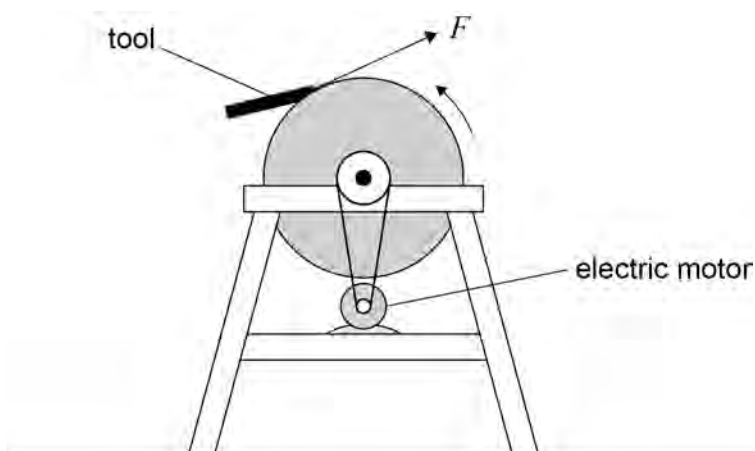
moment of inertia = _____ kg m^2



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.

Do not write
outside the
box

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 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 N m
radius of wheel = 0.24 m

Calculate F .

[2 marks]

$F =$ _____ N

Question 2 continues on the next page

Turn over ►

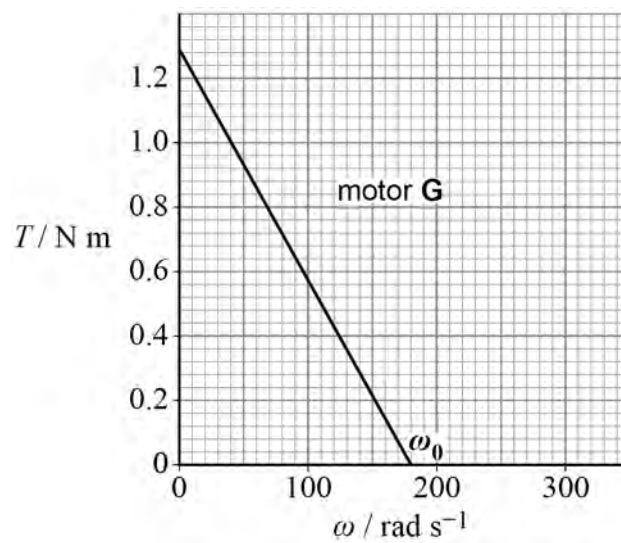
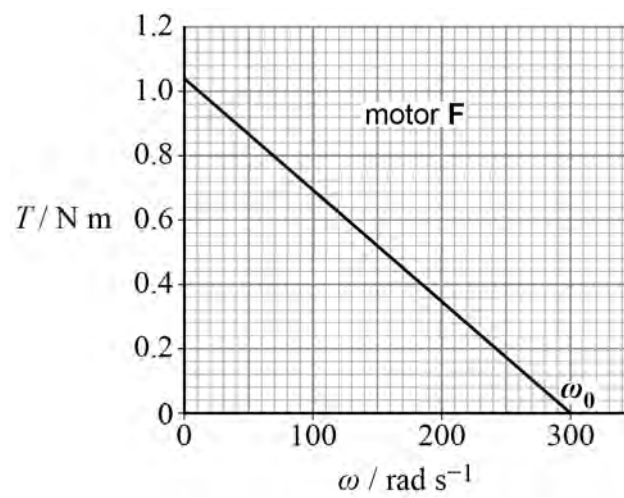
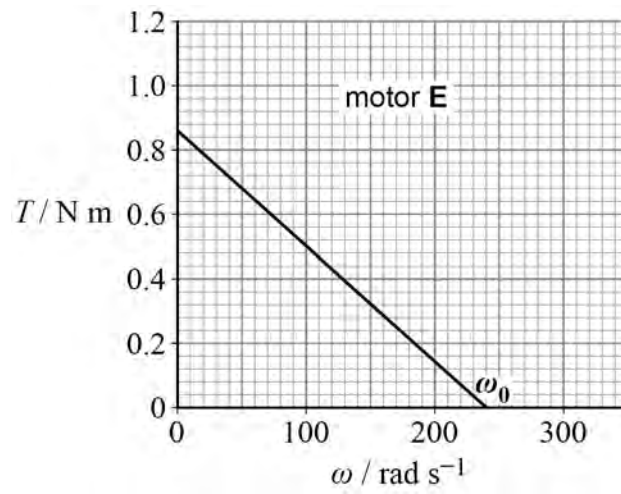


0 2 . 5

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.

Do not write outside the box

Figure 5



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 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

Turn over for the next question

Turn over ►



0 3 . 1

The first law of thermodynamics can be written as:

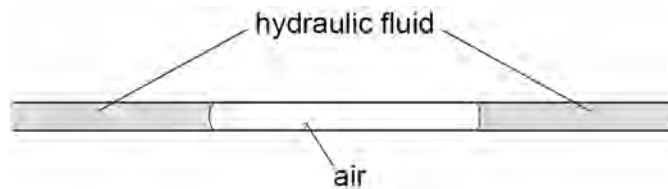
$$Q = \Delta U + W$$

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 mJ.

Which row is correct for this adiabatic compression?

Tick (✓) **one** box.

[1 mark]

W / mJ	Q / mJ	$\Delta U / \text{mJ}$	
-10.8	0	10.8	<input type="checkbox"/>
10.8	10.8	0	<input type="checkbox"/>
-10.8	-10.8	0	<input type="checkbox"/>
10.8	0	-10.8	<input type="checkbox"/>



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

$$\text{volume of air} = 2.91 \times 10^{-8} \text{ m}^3$$

$$\text{pressure of air} = 1.05 \times 10^5 \text{ Pa}$$

$$\text{temperature of air} = 293 \text{ K.}$$

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

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

$$\gamma \text{ for air} = 1.4$$

[3 marks]

pressure = _____ Pa

temperature = _____ K

Question 3 continues on the next page

Turn over ►



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 mJ.

Deduce without calculation whether the cyclist is correct.

[2 marks]

<hr/>
7



Turn over for the next question

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**

Turn over ►



Do not write outside the box

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

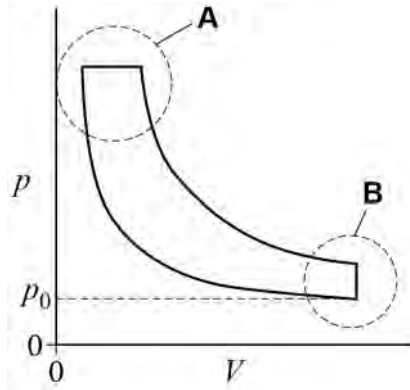
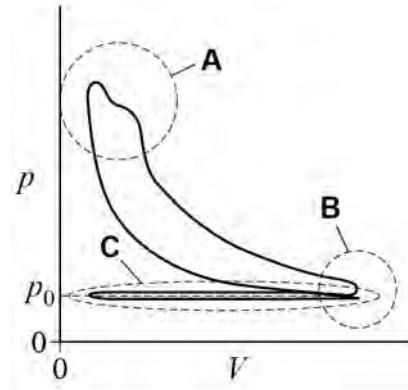


Figure 8



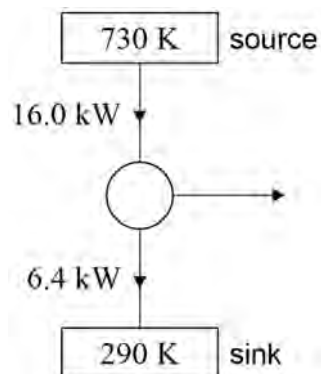
p_0 is atmospheric pressure.

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]



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 = _____

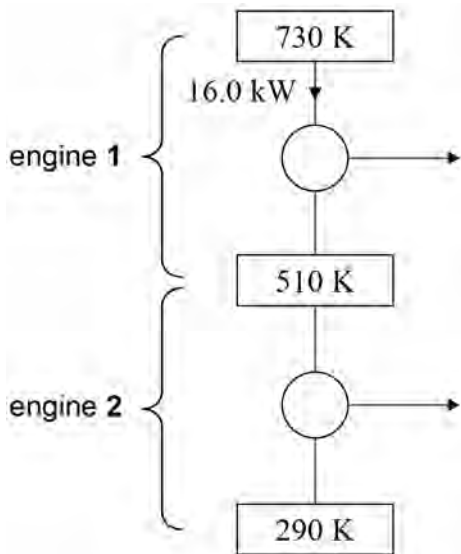


Do not write outside the box

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]

END OF QUESTIONS

4



There are no questions printed on this page

*Do not write
outside the
box*

**DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED**



