AQA

Please write clearly in block capitals.

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

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I declare this is my own work.

A-level PHYSICS

Paper 3
Section B Engineering physics

Friday 5 June 2020 Afternoon

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.

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

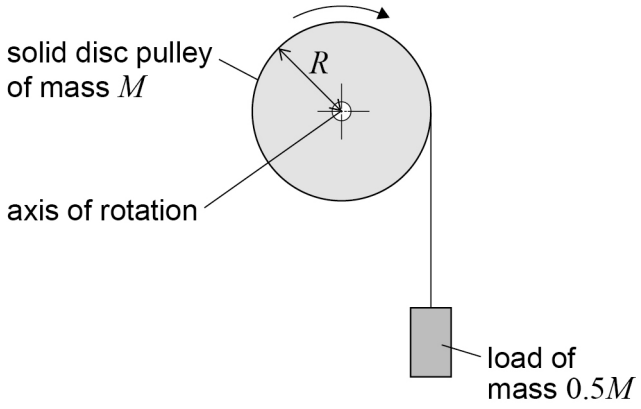
Answer **all** questions in this section.

0 1 . 1 State what is meant by the moment of inertia of an object about an axis.

[1 mark]

0 1 . 2 A student does an experiment using the apparatus shown in **Figure 1**.

Figure 1



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A solid disc pulley of mass M and radius R is supported in bearings which have negligible friction.

A string of negligible mass is wrapped around the circumference of the pulley.
A load of mass $0.5M$ is fixed to the free end of the string. The string does not slip on the pulley.
The moment of inertia of the pulley about the axis of rotation is $0.5MR^2$.
The student holds the pulley stationary.

When the student releases the pulley, the load accelerates downwards uniformly and is at a velocity v after moving a distance h.

Show that the acceleration of the load is $0.5g$.

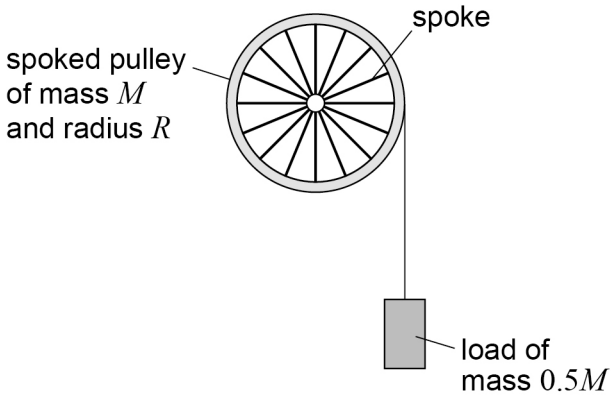
[4 marks]

Question 1 continues on the next page

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0 1 . 3 The student repeats the experiment using a spoked pulley of the same mass and radius, as shown in **Figure 2**.

Figure 2



Compare the acceleration of the load in this experiment with its acceleration in the previous experiment.
A calculation is **not** required.

[3 marks]

8

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0 2 . 1 State the condition necessary so that the law of conservation of angular momentum applies to a rotating system.

[1 mark]

A clutch is used to connect two rotating shafts together so that they rotate at the same speed.

0 2 . 2 **Figure 3** shows two shafts, **A** and **B**, rotating freely about the same axis.
Table 1 gives information about the two shafts.

Figure 3

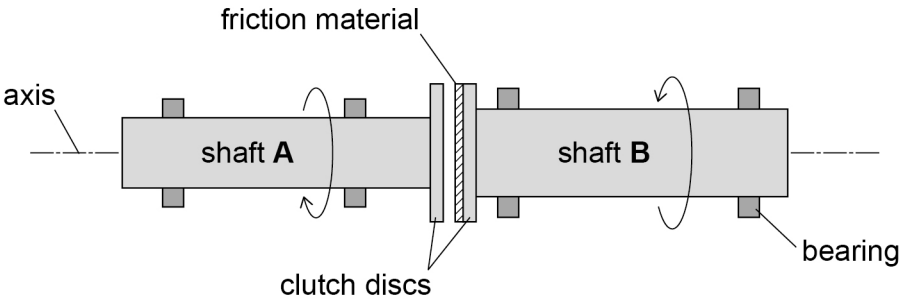


Table 1

	Shaft **A**	Shaft **B**
Angular speed / rad s^{-1}	95	45
Moment of inertia / kg m^2	7.2	11.5
Direction of rotation	Clockwise looking from left	Anticlockwise looking from left

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The two shafts are connected by forcing the clutch discs together.
Friction acts between the discs and slipping occurs for a short time until both shafts rotate at a common angular speed.
The clutch is now said to be engaged.

Show that the common angular speed of the two shafts immediately after the clutch is engaged is about $9\ \text{rad}\ \text{s}^{-1}$.

State whether the direction of the common angular speed is clockwise or anticlockwise when viewed from the left.

[3 marks]

direction when viewed from the left = _____

Question 2 continues on the next page

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0 2 . 3 **Table 2** gives information about two clutches, **C** and **D**.
C and **D** provide different constant frictional torques during slipping at the clutch discs.

Table 2

Clutch	Frictional torque during slipping / N m
C	600
D	320

The slipping time is to be kept between 1.0 s and 2.0 s with the same initial conditions shown in **Table 1**, and the same final common angular speed.

Deduce whether either or both clutches allow this.

[3 marks]

7

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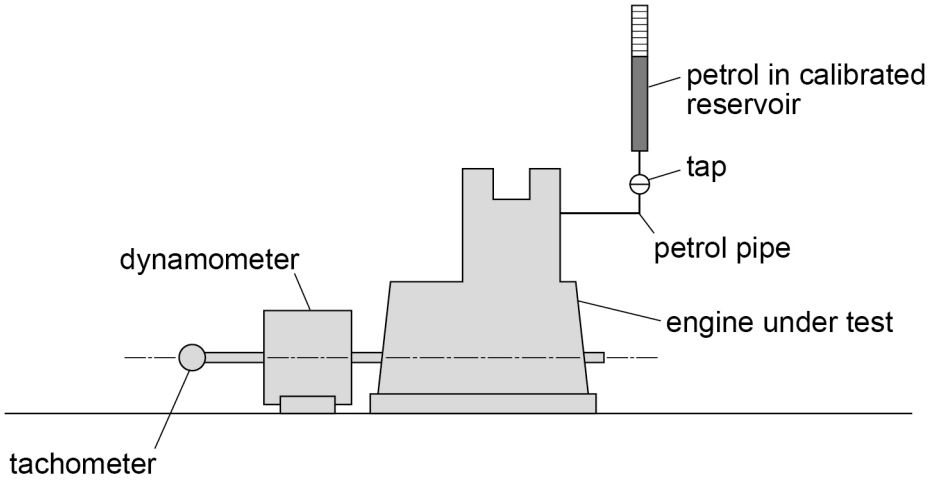
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0 3 **Figure 4** shows some of the equipment used to investigate the thermal and mechanical efficiencies of a single-cylinder four-stroke petrol engine.

Figure 4



- Petrol is supplied to the engine from a calibrated reservoir.
- Sensors are used to measure the volume V and pressure p above the piston inside the cylinder.
- The dynamometer applies a load to the output shaft and measures the output torque of the engine.
- The tachometer measures the rotational speed of the engine in revolutions per second.

In one test the air intake valve (throttle) setting remains fixed and the load provided by the dynamometer is kept constant.

Describe how you would determine the input power, the indicated power, the brake power, the thermal efficiency and the mechanical efficiency.

In your answer you should
- describe the measurements that you would take
- show how you would use the measurements and any other necessary data.

[6 marks]

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0 4 . 1 Which row in **Table 3** shows

- **Process 1** in which work done is zero, and
- **Process 2** in which the change in internal energy is zero?

Tick (✓) **one** box.

[1 mark]

Table 3

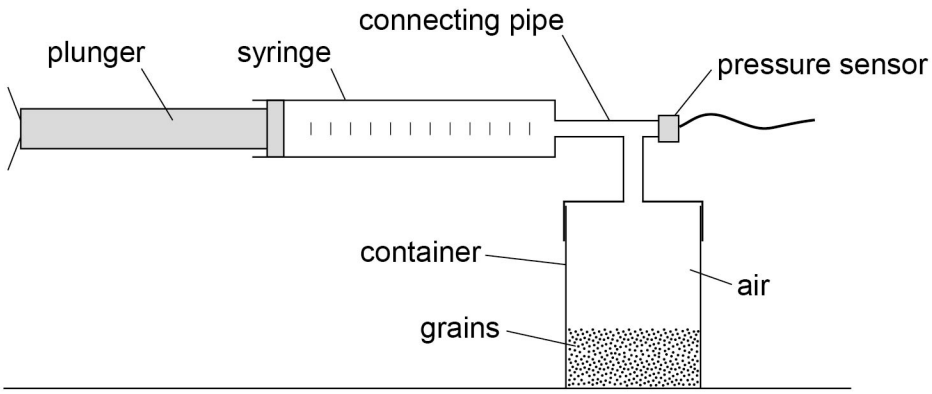
Process 1	Process 2	
constant pressure	isothermal	☐
constant volume	adiabatic	☐
constant pressure	adiabatic	☐
constant volume	isothermal	☐

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0 4 . 2 When irregular particles are packed, air gaps are left between the particles.
The true volume of a quantity of irregular particles must be determined using a method that does not include the volume of the air spaces between them.

The apparatus shown in **Figure 5** is used by an agricultural engineer to measure the true volume of some grains.

Figure 5



The volume of air in the syringe is 1.00×10^{-4} m^3.
The volume of the **empty** container and connecting pipe is 2.80×10^{-4} m^3.
Grains of total true volume V are now placed in the container and the lid is screwed on.
The pressure inside both the syringe and the container is 1.01×10^5 Pa.
The plunger is slowly pushed fully into the cylinder of the syringe, compressing the air isothermally.
The pressure increases to 1.83×10^5 Pa.

Determine V.

[3 marks]

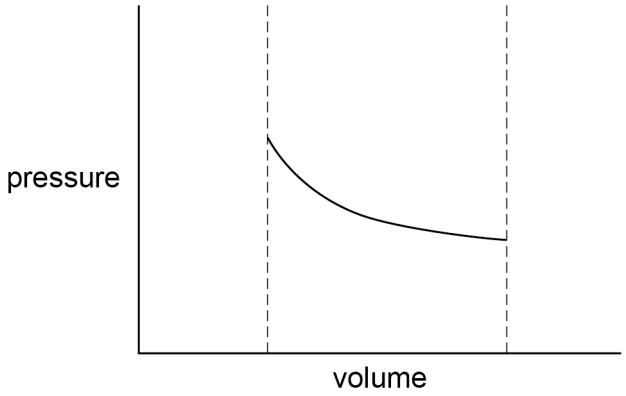
$V =$ _____ m^3

Question 4 continues on the next page

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Figure 6 shows how the pressure in the container and syringe varies with volume as the plunger is pushed in fully very slowly.

Figure 6



0 4 . 3 Sketch on **Figure 6** the variation of pressure with volume when the plunger is pushed in fully very quickly and then left for several seconds.
Assume no leakage past the plunger.

[2 marks]

0 4 . 4 Explain why the compression of a gas can be considered to be an isothermal change when the gas is compressed very slowly.

[2 marks]

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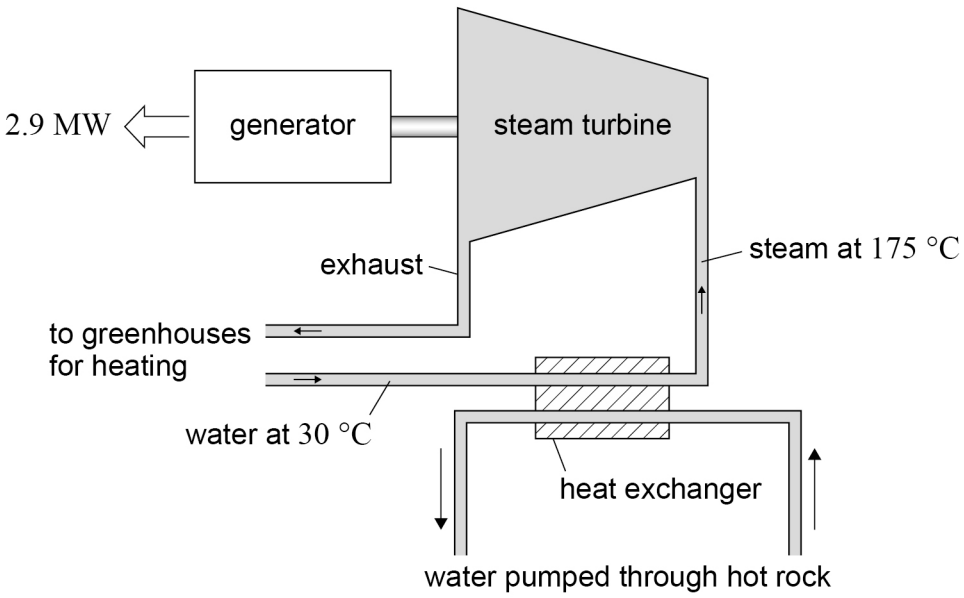
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0 5 . 1 Explain how the second law of thermodynamics predicts that a heat engine can never be 100% efficient.

[2 marks]

0 5 . 2 A company plans to build a geothermal power station in a region where there is hot rock deep below the surface. The scheme is shown in **Figure 7**.

Figure 7



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In the heat exchanger, energy from the hot rock is used to produce steam at $175\ °C$.
The steam passes through a turbine that drives an electric generator.
The exhaust steam is used to heat nearby greenhouses where it condenses before returning to the heat exchanger.

The lowest temperature in the turbine cycle is $30\ °C$.

The company claims that when the electrical power output is $2.9\ MW$, the power station will provide $6.4\ MW$ for heating the greenhouses.

Deduce whether this claim is likely to be true.
Treat the power station as an ideal heat engine which obeys the second law of thermodynamics.

[4 marks]

6

END OF QUESTIONS

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