AQA

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

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	

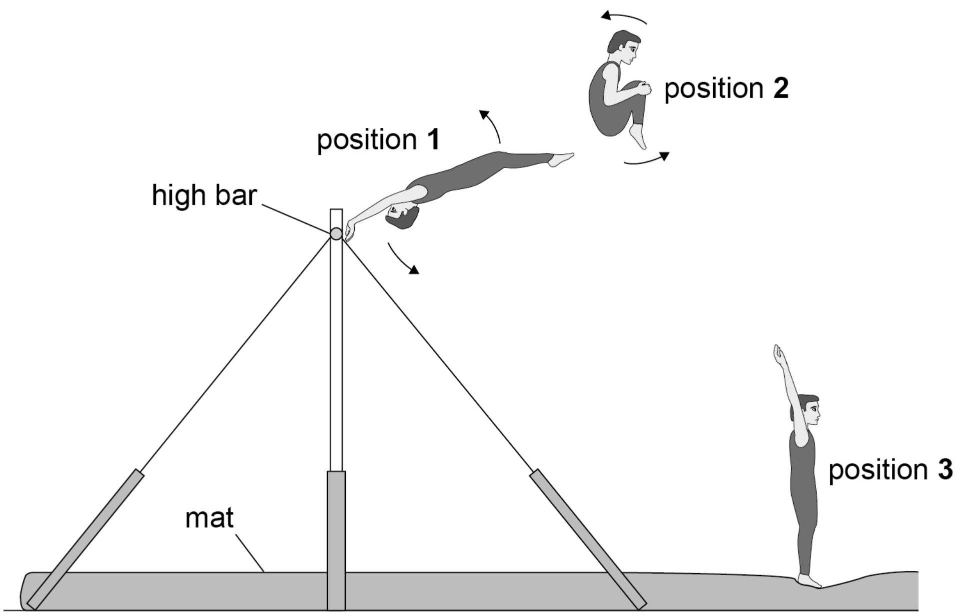
Section B

Answer **all** questions in this section.

0 1 A gymnast dismounts from an exercise in which he swings on a high bar. The gymnast rotates in the air before landing.

Figure 1 shows the gymnast in three positions during the dismount.

Figure 1



The arrows show the direction of rotation of the gymnast.

In position **1** the gymnast has just let go of the bar. His body is fully extended.

Position **2** shows the rotating gymnast a short time later. His knees have been brought close to his chest into a 'tuck'.

Position **3** is at the end of the dismount as the gymnast lands on the mat. His body is once again fully extended.

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0 1 . 1 Explain why the moment of inertia about the axis of rotation decreases when his knees are moved towards his chest.
Go on to explain the effect this has on his angular speed.

[3 marks]

Table 1 gives some data about the gymnast in position **1** and in position **2**.

Table 1

Position	Moment of inertia / $kg\ m^2$	Angular speed / $rad\ s^{-1}$
1	13.5	ω
2	4.1	14.2

0 1 . 2 Calculate the angular speed ω of the gymnast in position **1**.

[1 mark]

ω = ______________________ $rad\ s^{-1}$

Question 1 continues on the next page

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0 1 . 3 The gymnast stays in the tuck for $1.2\ \text{s}$.

Determine the number of **complete** rotations performed by the gymnast when in the tuck during the dismount.

[2 marks]

number of complete rotations = ________________________

0 1 . 4 The gymnast repeats the exercise. The height of the bar remains unchanged.

State and explain **two** actions the gymnast can take to complete more rotations during the dismount.

[4 marks]

1 ____

2 ____

10

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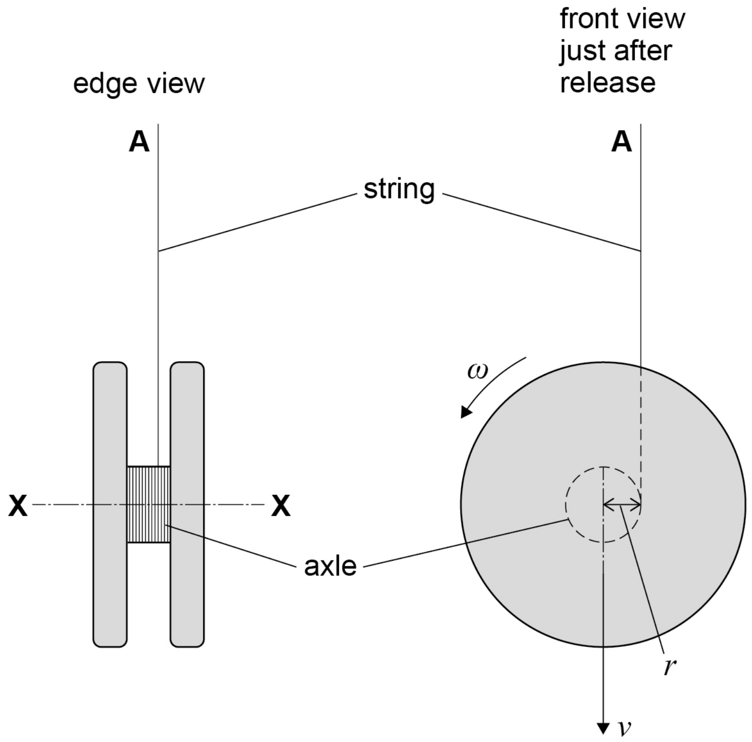
0 2 **Figure 2** shows a yo-yo made of two discs separated by a cylindrical axle. Thin string is wrapped tightly around the axle.

Figure 2



Initially both the free end **A** of the string and the yo-yo are held stationary.

With **A** remaining stationary, the yo-yo is now released so that it falls vertically. As the yo-yo falls, the string unwinds from the axle so that the yo-yo spins about its centre of mass.

The linear velocity v of the centre of mass of the falling yo-yo is related to the angular velocity ω by $v = r\omega$ where r is the radius of the axle.

Question 2 continues on the next page

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0 2 . 1 The yo-yo accelerates uniformly as it falls from rest. The string remains taut and has negligible thickness.

mass of yo-yo = 9.2×10^{-2} kg
radius of axle = 5.0×10^{-3} m
moment of inertia of yo-yo about axis **X-X** = 8.6×10^{-5} kg m^2

When the yo-yo has fallen a distance of 0.50 m, its linear velocity is V.

Calculate V by considering the energy transfers that occur during the fall.

[3 marks]

V = ____________________ m s^{-1}

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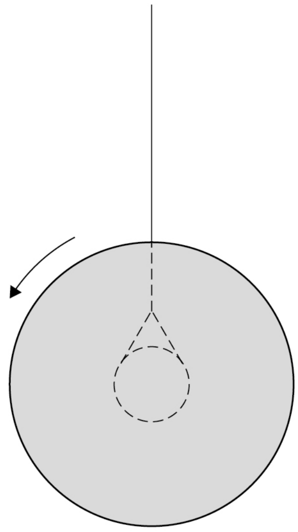
0 2 . 2 The yo-yo falls further until all the string is unwound. The yo-yo then 'sleeps'. This means the yo-yo continues to rotate in a loose loop of string as shown in **Figure 3**.

Figure 3



The string applies a constant frictional torque of 8.3×10^{-4} N m to the axle.
The angular velocity of the yo-yo at the start of the sleep is 145 rad s^{-1}.

Determine, in rad, the total angle turned through by the yo-yo during the first 10 s of sleeping.

[3 marks]

angle = ____________________ rad

6

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0 3 **Figure 4** shows the results of a test on an internal combustion engine which uses purified biogas.

Figure 4

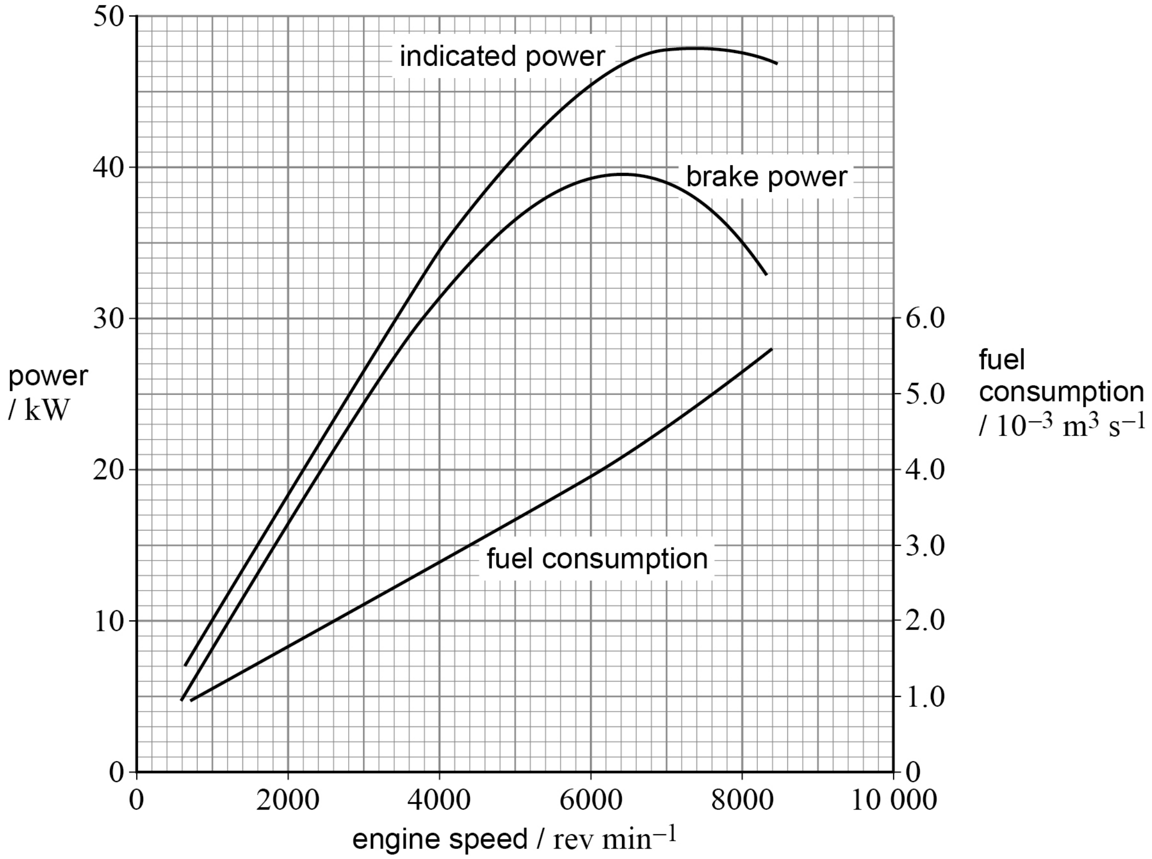

Figure 4 shows how the indicated power, brake (or output) power and fuel consumption of the engine vary with the engine speed. The scale on the left-hand axis is power and the scale on the right-hand axis is fuel consumption.

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0 3 . 1 **Figure 4** can be used to analyse the performance of the engine.

Determine, for the speed at which the engine develops its maximum brake power:

- the overall efficiency
- the thermal efficiency
- the mechanical efficiency.

Go on to explain how knowledge of these efficiencies can be useful to an engineer.

calorific value of biogas used in the test $= 32.3 \times 10^6$ J m^{-3}

[6 marks]

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0 3 . 2 Explain why it is **not** advisable to run this engine at speeds above $7000 \text{ rev min}^{-1}$.
Refer to **Figure 4** in your answer.

[2 marks]

8

Turn over for the next question

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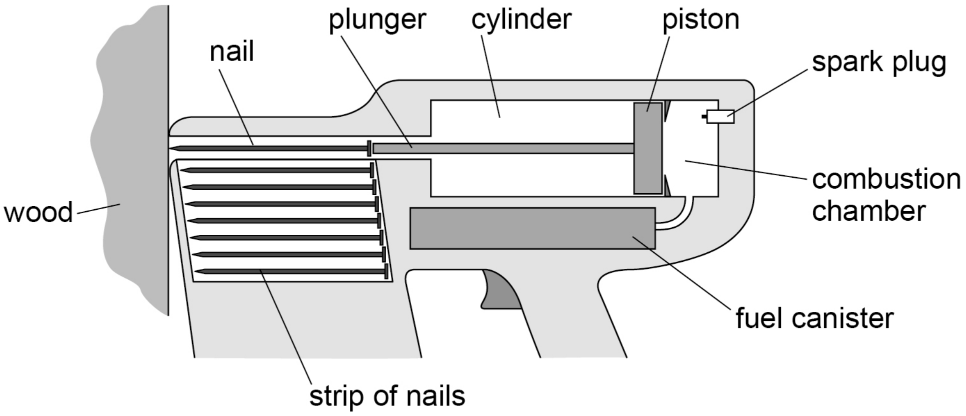
0 4 **Figure 5** shows a tool for driving nails into wood. Only part of the tool is shown.

Figure 5



Fuel is mixed with air in the combustion chamber and is ignited by a spark. The gas expands rapidly and drives the piston along the cylinder. The plunger attached to the piston drives the nail into the wood.

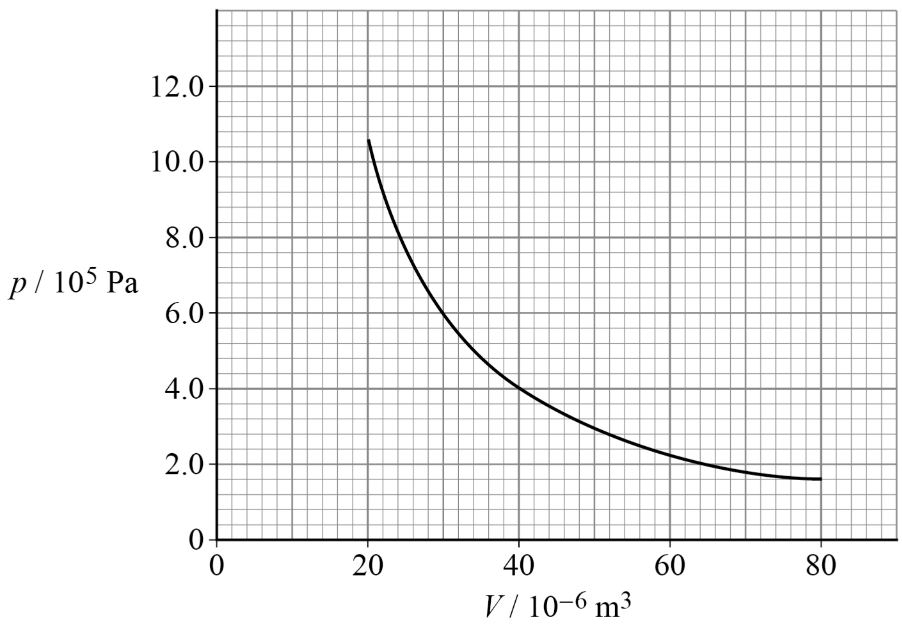
Table 2 shows the average force needed to drive nails of various lengths completely into a particular type of wood.

Table 2

Nail	Length / mm	Average force / N
A	32	250
B	38	320
C	45	370
D	50	420
E	63	560

0 4 . 1 **Figure 6** shows the variation of pressure p with volume V as the gas expands on the right-hand side of the piston when the correct nail is used.

Figure 6



The combustion chamber has a volume of 20×10^{-6} m^3 and the piston moves through a volume of 60×10^{-6} m^3.

The work done by the expanding gas is just enough to drive the correct nail completely into the wood.

Deduce which nail in **Table 2** is the correct one to use in the tool.

[5 marks]

Question 4 continues on the next page

Turn over ►

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0 4 . 2 After a nail has been used, another nail takes its place automatically. The tool can drive up to 180 nails per minute.

Discuss why the expansion **cannot** be isothermal.

[3 marks]

8

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0 5 . 1 Which is a correct statement about an ideal heat engine?
Tick (✓) **one** box.

[1 mark]

The efficiency is increased when the kelvin temperatures of the hot source and the cold sink are increased by equal amounts. ☐

The maximum efficiency depends on the p–V cycle. ☐

The efficiency is 50% when the kelvin temperature of the hot source is twice the kelvin temperature of the cold sink. ☐

0 5 . 2 An ideal heat engine has an efficiency of 0.33
The same engine works in reverse as an ideal refrigerator between the same hot and cold spaces.

Determine the coefficient of performance COP_{ref} of the refrigerator.

[2 marks]

$COP_{\text{ref}} =$ ____________________

3

END OF QUESTIONS

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