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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

Wednesday 12 January 2022 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873

Unit 2: Science for engineering

Time allowed: 1 hour 30 minutes plus your additional time allowance

You must have:
the Formula Booklet for Level 3 Cambridge Technical in Engineering (with this document)
the Insert for Fig. 1 and Question 5(a)
a ruler (cm/mm)
a protractor
a scientific calculator

Please write clearly in black ink.

Centre number								
Candidate number								

First name(s) ______________________________

Last name ______________________________

Date of birth	D	D	M	M	Y	Y	Y	Y

READ INSTRUCTIONS BELOW

INSTRUCTIONS

Use black ink. You can use an HB pencil, but only for graphs and diagrams.

Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.

Answer ALL the questions.

Where appropriate, your answer should be supported with working. Marks might be given for using a correct method, even if your answer is wrong.

Give your final answers to a degree of accuracy that is appropriate to the context.

The acceleration due to gravity is denoted by g m s^{-2}. When a numerical value is needed use $g = 9.8$ unless a different value is specified in the question.

INFORMATION

The total mark for this paper is **60**.

The marks for each question are shown in brackets [ ].

ADVICE

Read each question carefully before you start your answer.

Answer ALL the questions.

1 (a) Name the SI base unit for:

(i) electric current

______________________________ **[1]**

(ii) luminous intensity

______________________________ **[1]**

(b) (i) Engineer A measures the value of g, the acceleration due to gravity.

The engineer's result is $9.95\,m\,s^{-2}$.

The accepted true value for g is $9.81\,m\,s^{-2}$.

Calculate the relative error in the engineer's measurement.

relative error = ______________________ [2]

(ii) Four other engineers also measure g.

All results are shown in the table opposite.

Complete the THREE missing values in the table opposite. [2]

Engineer	Value for g ($m\,s^{-2}$)	Deviation	Deviation^2
A	9.95	+0.15	+0.0225
B	9.80	0	0
C	9.65	–0.15	
D	10.00	+0.20	
E	9.60		+0.0400
	Mean = 9.80		

(iii) The standard deviation is 0.158.

Calculate the standard error of the mean.

Use the equation:
standard error of the mean =

$$\frac{\text{standard deviation}}{\sqrt{\text{number of measurements}}}$$

standard error of the mean =

______________________________ [2]

2 In 2012, a skydiver jumped from the edge of space.

(a) (i) During the fall, the skydiver experienced forces that changed their motion.

What property of an object resists any change in its motion?

Tick (✓) ONE box. [1]

Density	Mass	Speed	Weight
☐	☐	☐	☐

(ii) The combined mass of the skydiver and their spacesuit was 110 kg.

Explain how weight is different to mass.

____

____

____ [2]

(b) **Fig. 1 on the Insert shows how the skydiver's speed changed over time.**

(i) **State the unit of acceleration.**

______________________________ **[1]**

(ii) **Explain how to use the graph to find the acceleration at any point during the fall.**

No calculation is required.

____

____

____

____

______________________________ **[3]**

(c) **Use the graph in Fig. 1 on the Insert to estimate the height of the jump.**

You may draw on the graph in the Insert to show your method.

estimated height =

______________________________ m [5]

3 Fig. 2 opposite shows an underfloor heating mat. The heating mat is used underneath floor tiles to heat rooms such as bathrooms.

The heating mat uses insulated, thick alloy wires. When there is an electric current in the wire there is a heating effect.

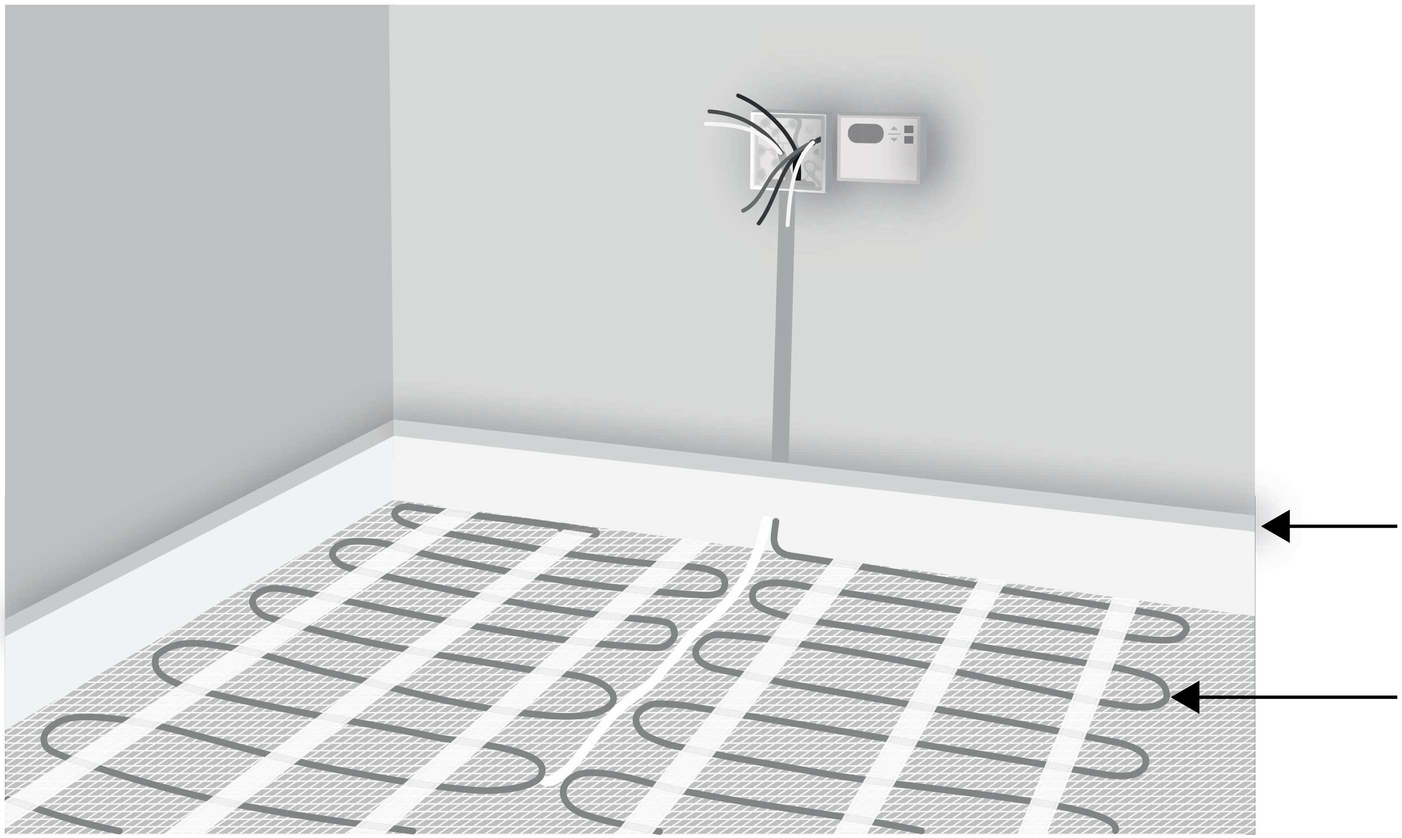
(a) Define electric current.

____

____

______________________________________ [2]

Fig. 2



(b) **An underfloor heating mat with an operating resistance of 128 Ω is connected to the 240 V a.c. mains.**

(i) **Calculate the power input to the mat.**

power = ______________________________ W [2]

(ii) The mat is manufactured using wire with a cross-sectional area of $1.5\,mm^2$.

The resistivity of the wire when operating is $4.8 \times 10^{-6}\,\Omega\,m$.

Calculate the length of wire needed to manufacture the mat.

length = ______________________________ m [3]

(iii) The resistance of the underfloor heating mat is measured when it is turned off. The resistance is much less than expected.

Explain why the resistance of the wire is much less when turned off than when it is turned on.

____

____

____

____

____ [2]

(c) A different heating mat has a power output of 200 W.

The floor tiles have mass 15 kg.

The specific heat capacity of the tile material is 1150 J kg^{-1} K^{-1}.

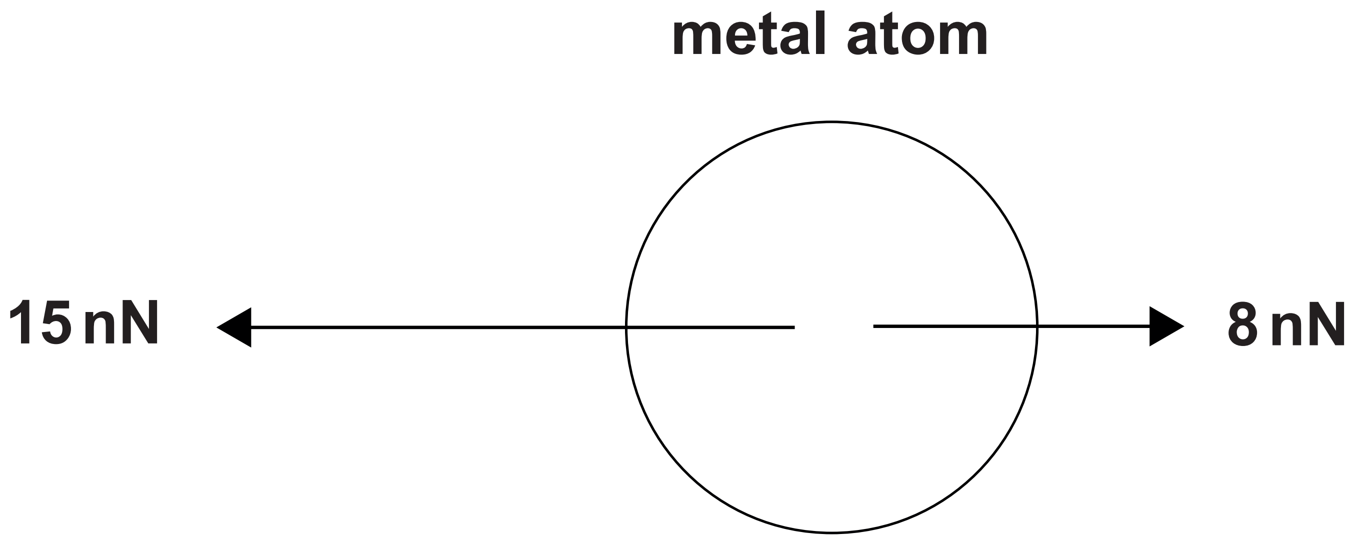
Calculate the time taken for the tiles to warm up from 15 °C to 20 °C. Assume all the energy from the wires is absorbed by the tiles.

time taken = ______________________ s [4]

4 The atoms that make up a sample of metal are held together by forces.

Fig. 3 shows two forces, acting in opposite directions, on an atom due to the surrounding atoms.

Fig. 3



(a) Determine the resultant force on the atom shown and state its direction.

force = ______________________________ nN [1]

direction = ______________________________ [1]

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(b) **Fig. 4 opposite shows the resultant force on one atom due to a neighbouring atom when they are different distances apart.**

(i) **Use Fig. 4 opposite to determine the distance between the atoms when the force is zero.**

distance = ______________________ nm [1]

(ii) **Explain what is meant by equilibrium separation.**

____

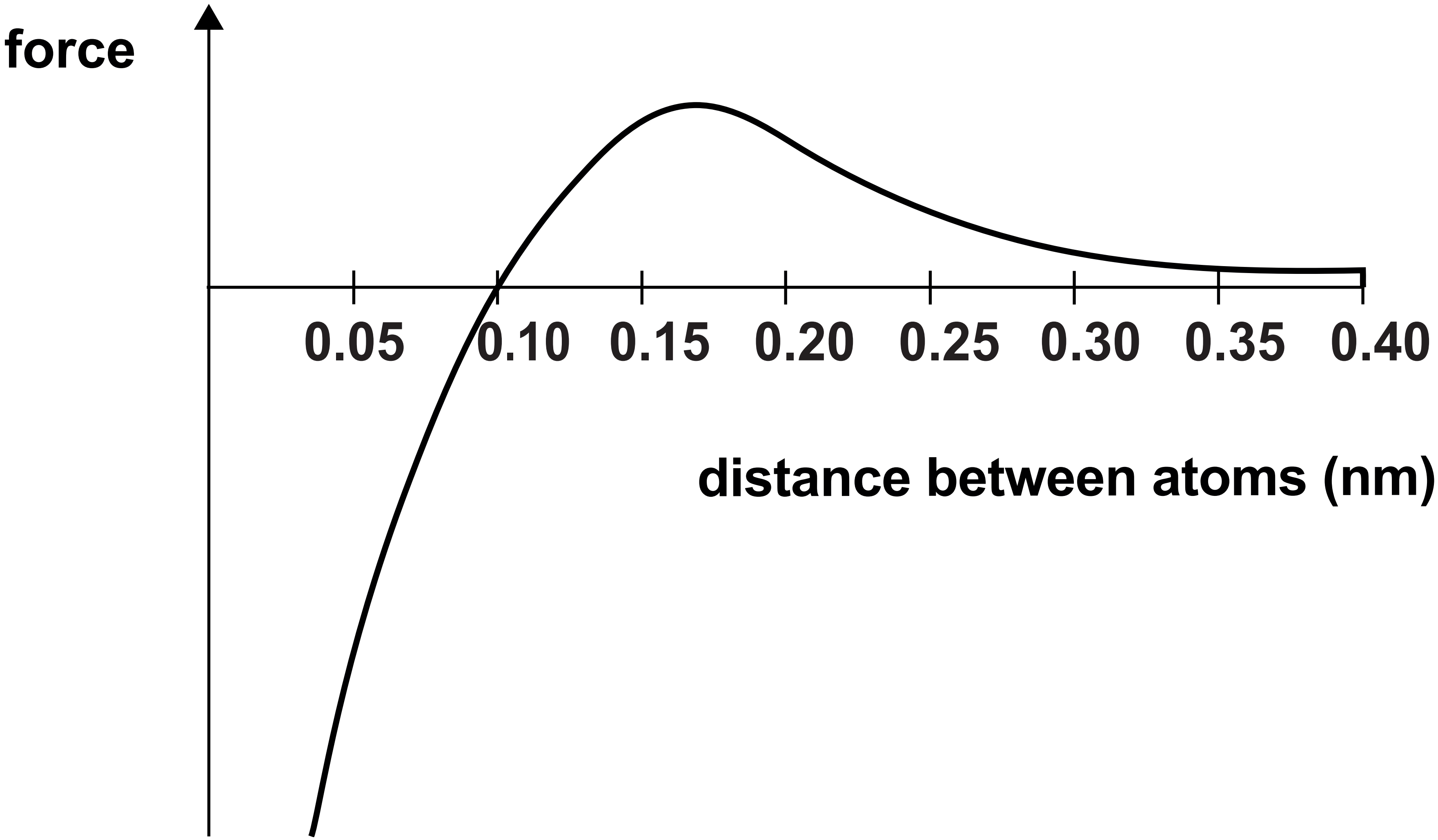
____

____

____

______________________________________ **[2]**

Fig. 4


force
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
distance between atoms (nm)

(c) When a metal sample is loaded lightly it will extend a small amount.

Which pair of statements describes what happens when the load is removed?

Tick (✓) ONE box. [1]

The atoms attract and move apart.
The metal shows plastic deformation. ☐

The atoms attract and move together.
The metal shows elastic deformation. ☐

The atoms repel and move apart.
The metal shows elastic deformation. ☐

The atoms repel and move together.
The metal shows plastic deformation. ☐

(d) A wire is made from a metal.

The cross-sectional area is $2.4 \times 10^{-6}\,m^2$.

The wire is stretched with a force 5.5 kN.

The resulting strain in the wire is 0.015.

Calculate the Young's modulus for this metal.

Young's modulus =

______________________________ Pa [4]

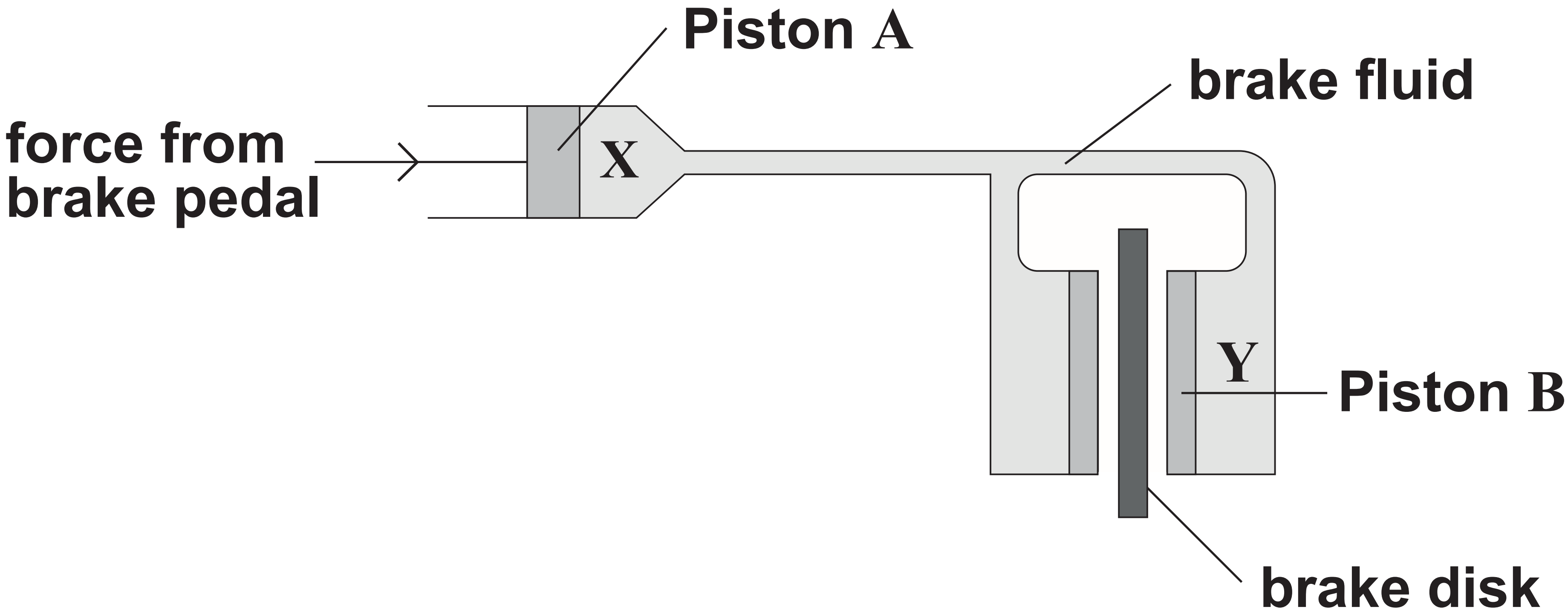
5 A car braking system works using pressure in a fluid as shown in Fig. 5 opposite.

When the driver presses the brake pedal, a force is applied to Piston A.

Piston B moves to press against the brake disk on the car's wheels and slows them down.

(a) On the Insert circle the correct phrase from column A AND the correct phrase from column B to complete the sentence. [2]

Fig. 5



Piston A
brake fluid
force from brake pedal
X
Y
Piston B
brake disk

(b) The driver brakes gently and applies a force on Piston A of 450 N.

Piston A has a cross-sectional area of 2.0×10^{-4} m².

Calculate the pressure at X.

pressure at X = ____________________ Pa [2]

(c) The driver brakes sharply so that the pressure at Y is 5 MPa.

(i) Convert 5 MPa to Pa.

______________________________ Pa [1]

(ii) The area of Piston B is 0.0018 m^2.

Calculate the force on Piston B.

force = ______________________________ N [2]

(d) The brake fluid must have low viscosity.

(i) Describe what is meant by low viscosity.

____

______________________________________ [1]

(ii) **Calculate the kinematic viscosity of brake fluid with density 1050 kg m^{-3} and dynamic viscosity of 0.25 N s m^{-2}.**

Give the unit in SI base units.

Use the equation:

$$\text{kinematic viscosity} = \frac{\text{dynamic viscosity}}{\text{density}}$$

kinematic viscosity =

______________________________________ **[3]**

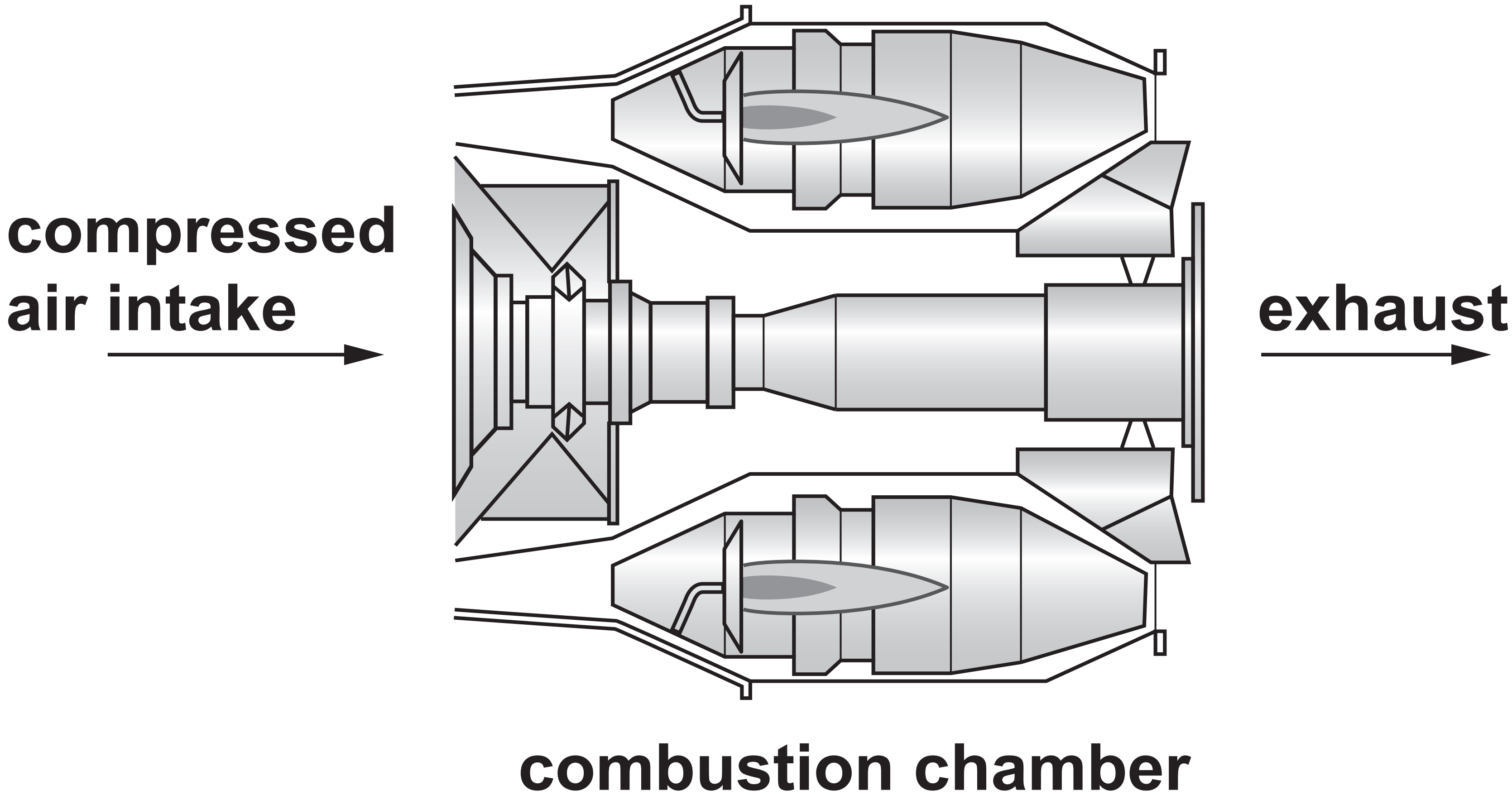
6 An aeroplane engine uses a combustion chamber to power a gas turbine. A schematic diagram of a combustion chamber is shown in Fig. 6 opposite.

Compressed air enters the combustion chamber at a temperature of 350 °C.

(a) Convert 350 °C to kelvin.

temperature = ______________________ K [1]

Fig. 6



(b) The gas in the combustion chamber is heated from 350 °C to 1800 °C.

The volume of gas before heating is 1.2 m^3.

The pressure in the combustion chamber remains constant.

Calculate the volume of gas after heating.

volume = ______________________________ m^3 [3]

(c) **The aircraft accelerates along the runway during take-off.**

Energy is released from fuel at a rate of 160 MW.

The aircraft gains kinetic energy at a rate of 32 MW.

Calculate the overall efficiency of the engine.

efficiency = ______________________________ [2]

END OF QUESTION PAPER

ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined pages. The question numbers must be clearly shown – for example, 2(b)(ii) or 3(a).