OCR
Oxford Cambridge and RSA

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
C302/2201

C302201

You must have:
- the Formula Booklet for Level 3 Cambridge Technical in Engineering (inside this document)
- a ruler (cm/mm)
- a protractor
- a scientific calculator

0 5 8 2 2 – 0 2

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 |

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 **[ ]**.
- This document has **16** pages.

ADVICE
- Read each question carefully before you start your answer.

FOR EXAMINER USE ONLY	
Question No	**Mark**
1	/8
2	/12
3	/13
4	/10
5	/11
6	/6
Total	**/60**

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 $9.95\,\text{m}\,\text{s}^{-2}$.

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

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 below.

Complete the **three** missing values in the table.

Engineer	**Value for g (ms^{-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		

[2]

(iii) The standard deviation is 0.158.

Calculate the standard error of the mean.

Use the equation: standard error of the mean = $\dfrac{\text{standard deviation}}{\sqrt{\text{number of measurements}}}$

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.

Density	Mass	Speed	Weight
☐	☐	☐	☐

[1]

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

Explain how weight is different to mass.

.....

.....

..... **[2]**

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

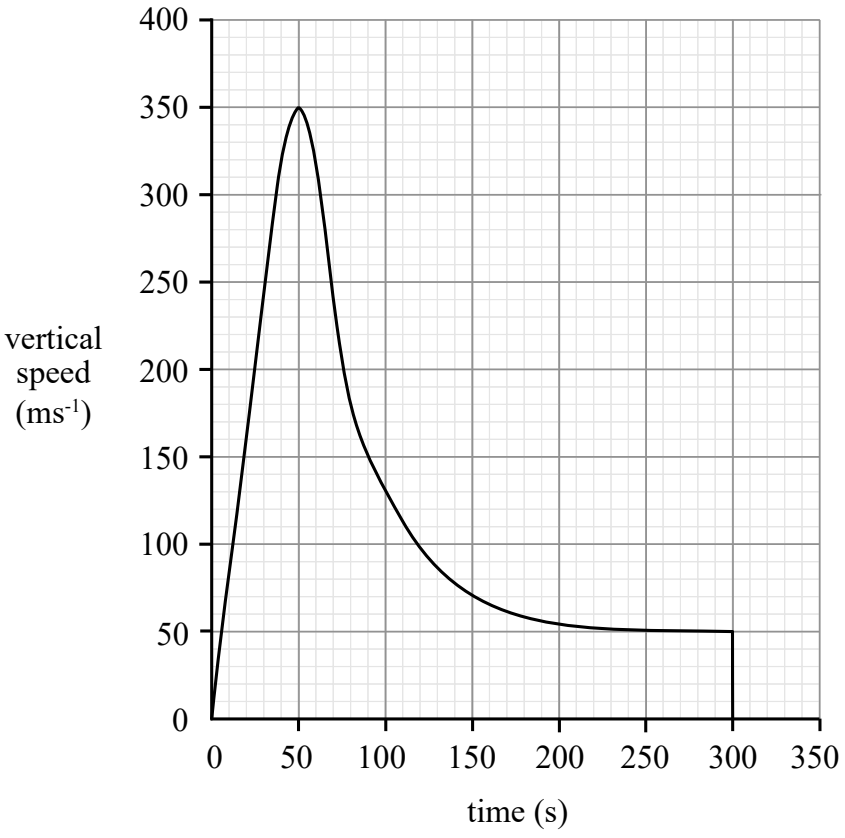

Fig. 1

(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** to estimate the height of the jump.

You may draw on the graph to show your method.

estimated height = ... m **[5]**

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

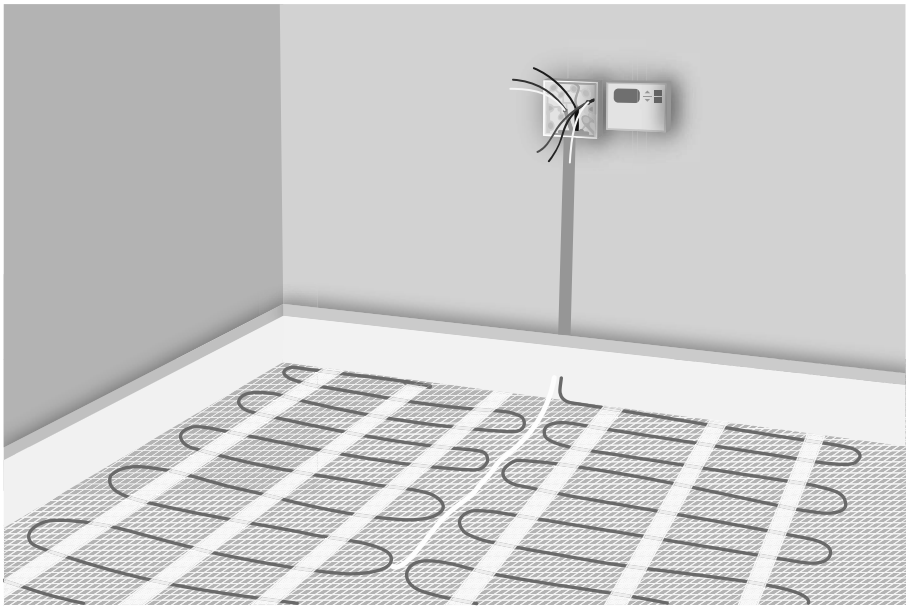

Fig. 2

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]**

(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.

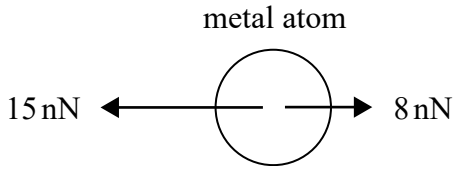

Fig. 3

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

force = ... nN **[1]**

direction = ... **[1]**

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

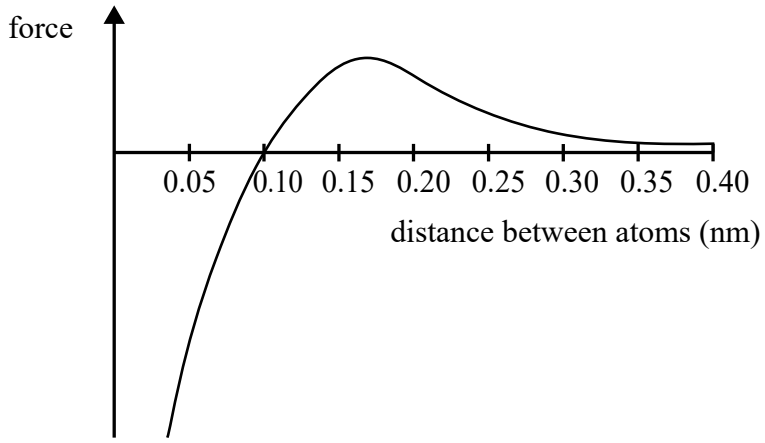

Fig. 4

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

distance = ... nm **[1]**

(ii) Explain what is meant by equilibrium separation.

.....

.....

.....

.....

..... **[2]**

(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.

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. ☐

[1]

(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**.

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.

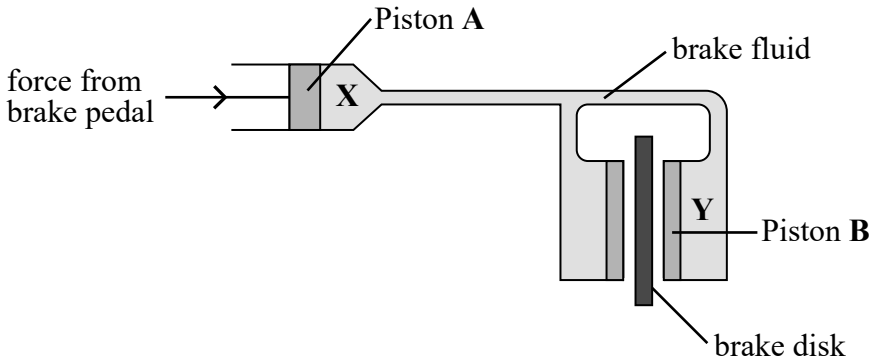

Fig. 5

(a) Circle the correct phrase from column **A and** the correct phrase from column **B** to complete the sentence.

	A		B
	less than		cannot be compressed.
The pressure at **X** is	more than	at **Y** because liquids	can be compressed.
	the same as		cannot be expanded.

[2]

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

Piston **A** has a cross-sectional area of $2.0 \times 10^{-4}\,m^2$.

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: $\text{kinematic viscosity} = \dfrac{\text{dynamic viscosity}}{\text{density}}$

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**.

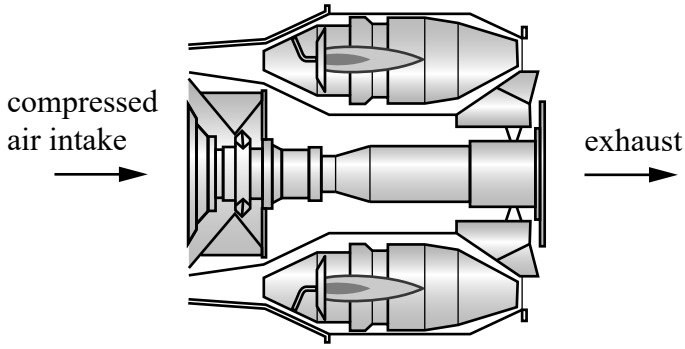

Fig. 6

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

(a) Convert 350 °C to kelvin.

temperature = ... K **[1]**

(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).

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