OCR
Oxford Cambridge and RSA

Wednesday 11 January 2023 – Morning

Level 3 Cambridge Technical in Engineering

05822/05823/05824/05825/05873 Unit 2: Science for engineering

Time allowed: 1 hour 30 minutes
C302/2301

C302/2301

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

05822-02

Please write clearly in black ink. **Do not write in the barcodes.**

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

First name(s) _____

Last name _____

Date of birth | D | D | M | M | Y | Y | Y | Y |

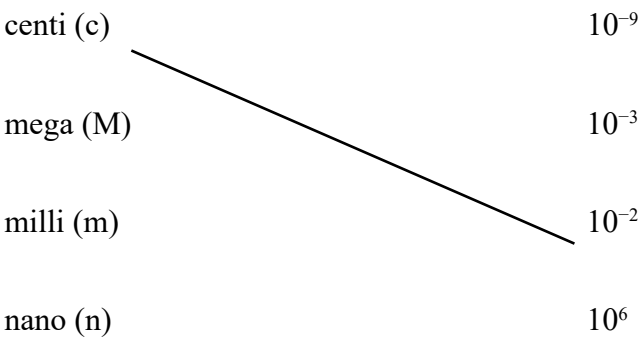
INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where 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.

Answer **all** the questions.

1 **(a)** Draw lines to match the SI prefix to the corresponding power of ten.
One has been completed for you.



[2]

(b) A measurement of the diameter of a bolt is 1.565 cm.
The desired true value is 1.500 cm.

(i) Calculate the absolute error.

absolute error = ... cm **[1]**

(ii) Calculate the relative error.

relative error = ... **[2]**

(iii) Four more measurements are taken. The mean (average) value is 1.564 cm.

	1	**2**	**3**	**4**	**5**	**Mean ($\bar{x}$)**
Diameter / cm	1.565	1.563	1.566	1.565	1.561	1.564
$x - \bar{x}$						
$\left(x - \bar{x}\right)^2$						

Calculate the standard deviation.

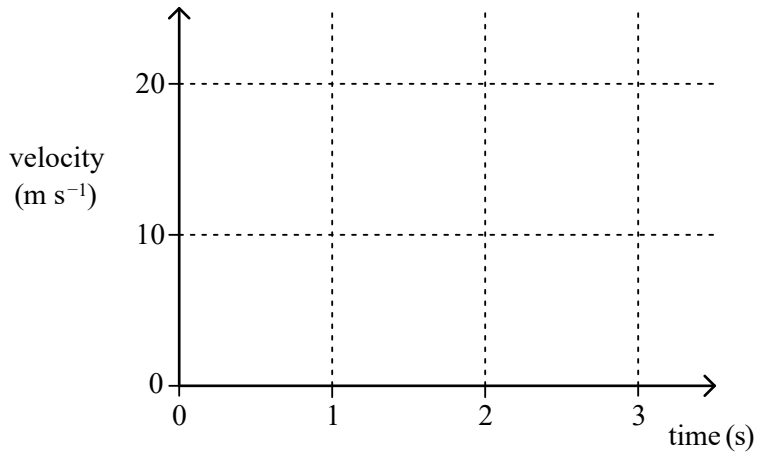
You may use the rows in the table for your working.

standard deviation = ... **[4]**

Turn over for the next question

2 **(a)** A car sets off from rest with a constant acceleration of 5.0 m s^{-2} for 3.0 s.

Sketch this motion on the velocity–time axes below.



[2]

(b) A second car sets off from rest with a constant acceleration of 4.0 m s^{-2}.

Calculate the speed of this car after it has travelled 18 m.

speed = ... m s^{-1} **[3]**

(c) Later, this second car is on a motorway travelling at a constant speed of 35 m s^{-1}.

(i) Calculate the time it takes for this car to travel 70 m.

time = ... s **[1]**

(ii) When travelling at this constant speed, the (forward) driving force is 4 kN.
Calculate the work done by this force when the car travels 70 m.

work done = ... J **[2]**

(iii) Calculate the minimum engine power required.
Use your answers from parts **(c)(i)** and **(c)(ii)**.

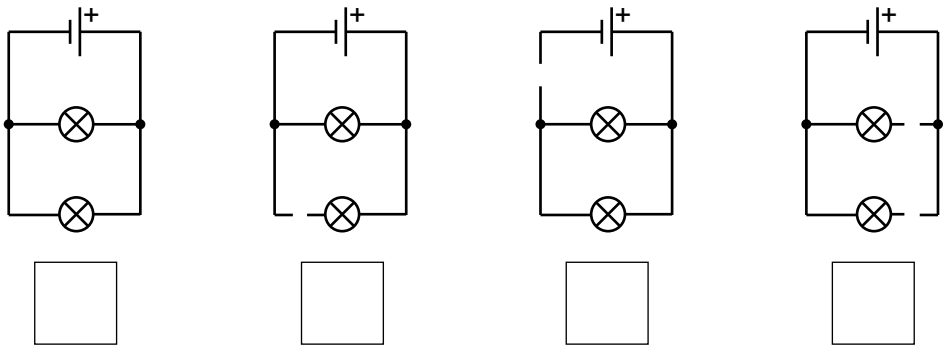
power = ... W **[2]**

3 An electric car has two headlamps.

(a) Only one of the headlamps is lit. The other headlamp has a failed bulb.

(i) Which circuit best represents this scenario?

Tick **one** box.



[1]

(ii) The resistance of the working bulb is 48 Ω.

The potential difference across the bulb is 12 V.

Calculate the current in the bulb.

current = ... A **[2]**

(iii) The failed bulb is replaced with one of a different type.

The new bulb has resistance 24 Ω.

Calculate the total resistance of the two bulbs in parallel.

resistance = ... Ω **[3]**

(b) When there is a current in the bulb, there is a difference between the drift velocity and root mean square (r.m.s.) speed of the electrons.

Which column of the table correctly represents their size relative to one another?

Tick **one** box.

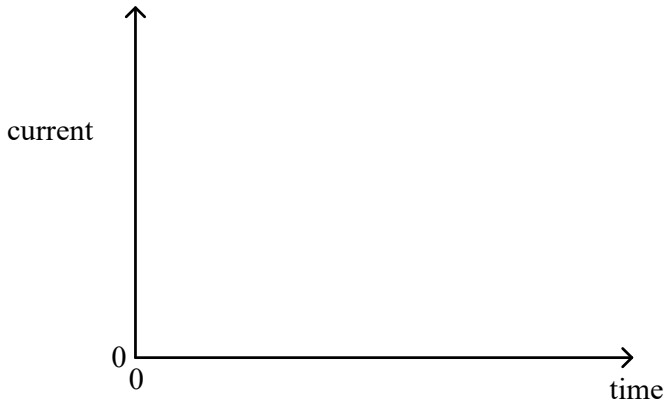
drift velocity	low	low	high	high
r.m.s. speed	low	high	low	high
	☐	☐	☐	☐

[1]

(c) One limitation of electric cars is the amount of energy that can be stored in the battery.

A proposed alternative power source is a capacitor with a very large capacitance (sometimes called a supercapacitor). A fully charged supercapacitor is tested by discharging through a resistance.

(i) Sketch a graph on the axes below showing how the current in the circuit changes over time.



[2]

(ii) The supercapacitor is fully charged at a potential of 24 V. Its capacitance is 85 F.

The resistance in the discharging circuit is 20 Ω.

Calculate the potential difference across the capacitor after 6 minutes (360 s).

potential difference = ... V **[3]**

4 **(a)** Complete the sentence below by writing the correct words in the spaces.
Each word can be used once, more than once or not at all.

attractive **gravitational** **magnetic** **repulsive** **resultant**

The ..... force between two atoms in a crystal is the

vector sum of ..... and ..... forces.

[3]

(b) State Hooke's law.

.....

.....

.....

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

(c) **Fig. 1** shows the net force–separation graph for two adjacent atoms in a crystal.

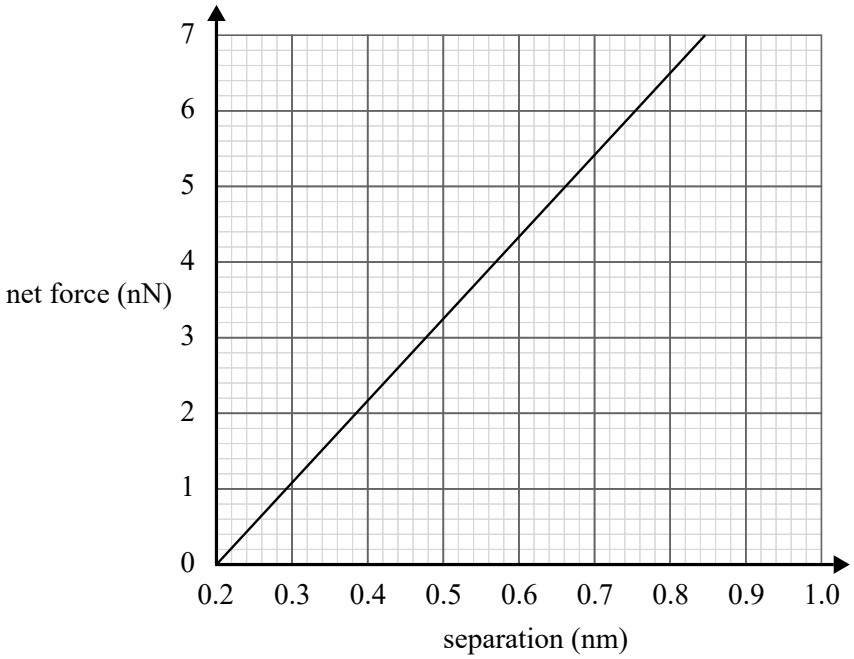


Fig. 1

Calculate the energy stored when the separation of the atoms is increased from 0.2 nm to 0.8 nm.

energy stored = ... J **[4]**

5 Gases and liquids are both fluids, but they can behave differently.

(a) State what happens to the volume and density of fluids when increased pressure is applied.

Write the words 'increases', 'decreases' or 'stays the same' in each box.

	Volume	**Density**
Gas		
Liquid		

[4]

(b) **Fig. 2** shows the airflow across an aerofoil section (aeroplane's wing).

Draw lines to join the labels (streamline, laminar flow and turbulent flow) to the correct parts of the diagram.

The wing has been labelled for you.

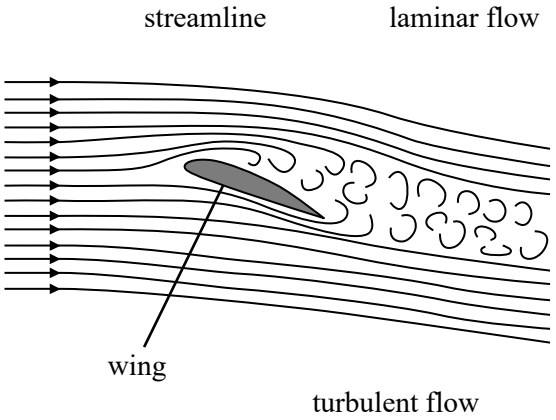


Fig. 2

[3]

(c) List these three fluids in order of increasing viscosity.

detergent **treacle** **water**

least viscous .....

.....

most viscous .....

[1]

(d) Water has dynamic viscosity 1.05×10^{-3} Pa s and density 1030 kg m^{-3}.

Calculate the kinematic viscosity.

kinematic viscosity = ... $m^2\ s^{-1}$ **[2]**

Turn over for the next question

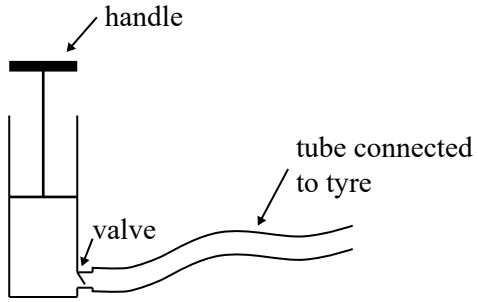
6 **(a)** State Boyle's law.

.....

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

(b) A cyclist pumps up a tyre.

A diagram of the pump is shown below.



When the cyclist pushes down on the handle, the pressure inside the pump increases until it is the same as the pressure in the tyre. The valve opens to let air into the tyre.

Initially the volume of air in the pump is 50 cm^3 and the pressure is 100 kPa. The pressure in the tyre is 150 kPa.

The cyclist pushes down on the handle.

(i) Calculate the volume of air in the pump just as the valve opens.

volume = ... cm^3 **[3]**

(ii) The cyclist keeps pumping more air into the tyre.

Explain why the cyclist requires more and more effort as they continue to inflate the tyre.

.....

.....

.....

.....

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

(iii) The cyclist uses the pump at a faster rate and the air in the pump gets hotter.

Calculate the final temperature of the air in the pump given the following data.

Initial conditions: volume 50 cm^3, pressure 100 kPa, temperature 293 K

Final conditions: volume 25 cm^3, pressure 250 kPa

temperature = ... K **[3]**

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, 1(d) or 6(b).

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....