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Examiners' report

ENGINEERING

05822–05825, 05873

Unit 2 Summer 2023 series

Version 1

Contents

Introduction

Our examiners' reports are produced to offer constructive feedback on candidates' performance in the examinations. They provide useful guidance for future candidates.

The reports will include a general commentary on candidates' performance, identify technical aspects examined in the questions and highlight good performance and where performance could be improved. The reports will also explain aspects which caused difficulty and why the difficulties arose, whether through a lack of knowledge, poor examination technique, or any other identifiable and explainable reason.

Where overall performance on a question/question part was considered good, with no particular areas to highlight, these questions have not been included in the report.

A full copy of the question paper and the mark scheme can be downloaded from OCR.

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Unit 2 series overview

Most candidates attempted all the questions and there was a very wide spread of marks across the ability range.

Many candidates were not always able to recall definitions of both physical quantities and units and found it difficult to explain concepts clearly. Calculations were generally done well, and candidates seemed familiar with most of the equations needed. There were some multi-stage calculations in this paper (Question 3(c)(ii), Question 3(f) and Question 4(c)(i)) where candidates needed to show working clearly.

One of the more challenging topics in this paper seemed to be properties of materials, where a number of candidates showed a need to improve their understanding of the difference between properties such as strength, stiffness, toughness, ductility, and malleability.

Candidates who did well on this paper generally:	Candidates who did less well on this paper generally:
• were able to recall definitions well • were able to use appropriate scientific terminology in explanations • laid out calculations clearly.	• struggled to explain scientific concepts and definitions clearly • were unable to carry out multi-stage calculations.

Question 1 (a) (i)

1 **(a)** **(i)** State the SI base unit for the following:

Amount of substance ....

Luminous intensity ....

[2]

Many candidates did not know the SI base units for these two quantities. Common incorrect suggestions for the amount of substance included litre and kilogram. Many candidates gave the unit 'lumen' for luminous intensity, even though this unit is not mentioned in the specification.

Question 1 (a) (ii)

(ii) Draw lines to match the SI prefixes with their values.

micro (μ) •	• 10^{-9}
milli (m) •	• 10^{-6}
nano (n) •	• 10^{-3}

[2]

This question was answered well, with nearly all responses identifying the correct power of ten to each prefix.

Question 1 (b) (i)

(b) The image below shows a digital timer.

The digital timer can be started and stopped either by hand (using the buttons) or electronically (using the connections on the front).

The timer reads to the nearest 1/100th of a second (0.01).

(i) An engineer measures and records the time for a prototype robot to climb a short ramp.

	time = (2.64 ± 0.01) s

Calculate the percentage uncertainty (error) for this measurement.

percentage uncertainty = ... % **[2]**

Most candidates correctly calculated the percentage uncertainty here. Some responses just gave the percentage uncertainty as 1%, from the absolute uncertainty of ±0.01, and some did other calculations.

Question 1 (b) (ii)

(ii) The engineer used the buttons to start and stop the timer.

Explain why the engineer was wrong to use ±0.01 as the uncertainty of the measurement.

....

.... **[2]**

Most candidates showed some appreciation about why ±0.01 was inappropriate to use as the uncertainty but did not explain their ideas well, and there were many vague responses. A few responses did state that the precision of the timer was to the nearest 0.01s, and many tried to explain something about the reaction time of the engineer being a relevant factor.

Question 1 (b) (iii)

(iii) The engineer then sets up some light gates to control the timer electronically.

The engineer measures the time for the robot to climb the ramp four more times.

Trial	**Time (s)**
1	2.64
2	2.72
3	2.28
4	2.86
5	2.55

Calculate the average (mean) time.

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

Nearly all the responses correctly calculated the mean of the readings. A small minority treated the smallest value (2.28) as an outlier. Although this had the greatest difference from its nearest neighbour but is far enough from the mean to warrant it being excluded.

Question 1 (b) (iv)

(iv) Explain how the results show that the precision of the average time is still not ±0.01.

....

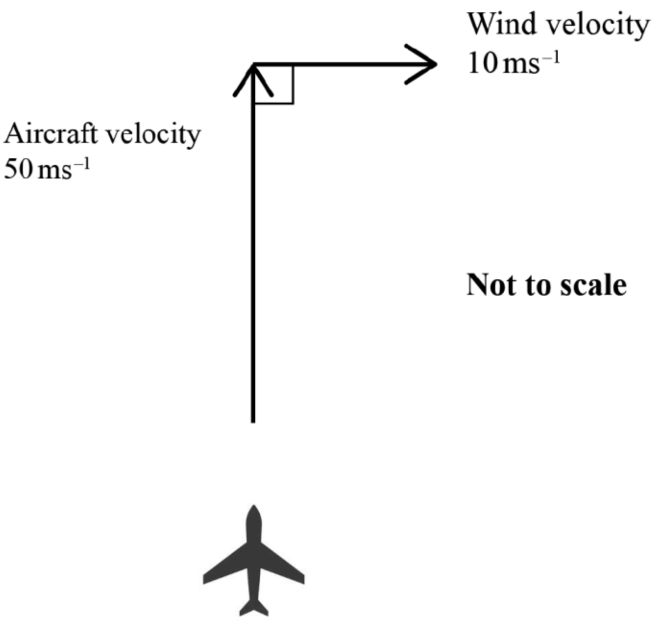
.... **[2]**

This was another question where many candidates had difficulty expressing their ideas using appropriate scientific language. Many candidates only compared the mean value with the initial reading of 2.64, rather than comparing all the values in the table.

Question 2 (a) (i) and (ii)

2 **(a)** **Fig. 1** shows an aircraft flying in a crosswind.

Fig. 1



(i) Draw an arrow on **Fig. 1** showing the resultant velocity of the aircraft over the ground.

[1]

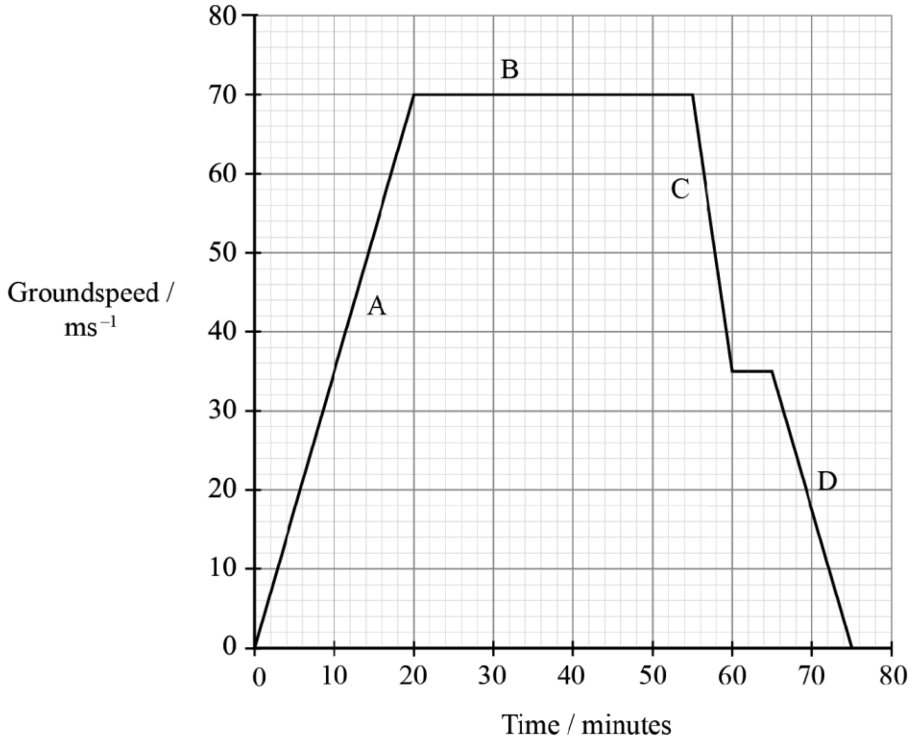
(ii) Calculate the magnitude of the resultant velocity (the 'groundspeed').

groundspeed = ... ms^{-1} **[2]**

Most responses included an appropriate arrow to show the ground speed of the aircraft and most successfully used Pythagoras to calculate the value of ground speed. Some responses did not round the calculated value correctly and then put an incorrect answer on the answer line. For example, the calculated value was 50.99, but some candidates then rounded this to 50.1 ms^{-1} instead of 51 ms^{-1}.

Question 2 (b) (i)

(b) The graph shows how the groundspeed of another aircraft varies as it flies from Manchester to Cambridge.



(i) Which part of the graph shows the largest magnitude of acceleration?

Tick (✓) **one** box.

A ☐

B ☐

C ☐

D ☐

[1]

Many candidates here gave the incorrect answer of A, which has a positive acceleration, although its magnitude is actually the same as the deceleration at D. Some responses actually showed some rough calculations of the acceleration of each section, although the gradient of the line on a speed-time graph visually shows the relative acceleration of each section.

Question 2 (b) (ii)

(ii) Calculate the distance travelled while the aircraft's groundspeed is $70\,\text{ms}^{-1}$.

distance travelled = ... m **[3]**

Many candidates knew that the area under the graph represented the distance travelled, but some candidates found the area of the initial acceleration period (up to 20 s) or the total area under the graph. Some candidates misread the scale of the graph, but the most common error was to omit the conversion of the time from minutes into seconds.

Question 2 (c)

(c) The aircraft's engine develops the most power during take-off.

Define the term 'power'.

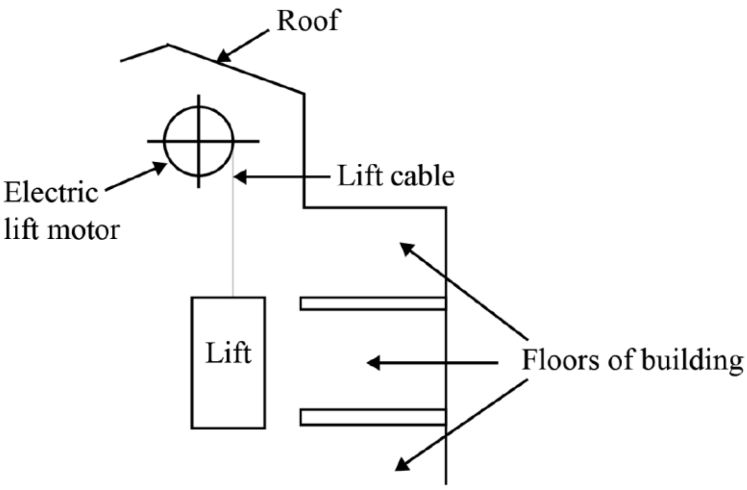
....

.... **[1]**

Many candidates were unable to define power using correct scientific vocabulary, and many descriptions showed some confusion between force, energy, and power.

Question 3 (a)

3 A schematic diagram of the lift mechanism in a tall building is shown below.



(a) State **two** properties of materials that are important for the lift cable.

1 ....

2 ....
[2]

Many candidates were able to give two suitable properties of materials. Several responses suggested elasticity as a suitable property. Clearly any material which are used as lift cable do need to be elastic, but it is more important for them to be stiff so that they do not have significant elastic deformation when loaded.

Question 3 (b)

(b) The top floor is 30 m above the ground floor.

Calculate the energy required to lift a 75 kg person from the ground to the top floor.

energy = ... J **[2]**

Most candidates were able to calculate the energy correctly. Some candidates incorrectly used the mass of the person rather than the weight, hence not multiplying by the acceleration of gravity.

Question 3 (c) (i)

(c) The electric lift motor is supplied from the 230 V mains supply.

(i) Define a volt.

....

....

.... **[1]**

Most candidates were unable to correctly define a volt. Some responses did correctly define potential difference which is measured in volts, but this is not what the question was asking.

Assessment for learning

A definition of a unit should be in terms of other units. So, the definition of a volt is a joule per coulomb.

The definition of a physical quantity should not include any units. So, the definition of a potential difference is the energy converted out of electrical form per unit of charge.

Question 3 (c) (ii)

(ii) The lift motor supplies 146 kJ carrying passengers for 42 s.

Calculate the average current input to the motor during this time.

current input = ... A **[3]**

Some candidates were able to do this two stage calculation correctly. Some candidates who showed their working clearly gained some credit for getting part way in the calculation. Some candidates did not clearly show their working, and this meant that they may not have gained any credit for doing part of the calculation correctly.

Assessment for learning

Candidates who show their working in calculation questions are likely to gain marks even if the final value is incorrect.

In a two-step calculation it is important for candidates to write out each equation in symbol form first. Then they will either need to use some algebra to combine the two equations or they can just substitute in the values into one equation on the next line down directly underneath the symbols. Then repeat for the next equation. Then it is clear to both the examiner and the candidate themselves, and mistakes are less likely to happen.

Question 3 (d)

(d) The electric lift motor is a large contribution to the building's electricity bill.

The bill is calculated from the number of kWh used.

What quantity can be measured in kWh?

Tick (✓) **one** box.

Charge ☐

Energy ☐

Potential ☐

Power ☐

[1]

Many candidates incorrectly thought that as the unit kWh included the symbol for Watts it must be a unit of power. However, it is actually a combination of kW (a unit of power) and hour (a unit of time). Power multiplied by time gives energy.

Question 3 (e) (i)

(e) The electric lift motor has an efficiency of 40%.

(i) Define the term 'efficiency'.

....

.... **[1]**

This is another definition question which only a few candidates answered well. Many candidates tried to explain that the efficiency was the useful energy output, rather than a ratio or percentage of the energy input.

Question 3 (e) (ii)

(ii) Calculate the required energy input to the motor to provide 32 kJ of output.

energy input = ... **kJ [2]**

Most candidates were able to correctly calculate the energy input using the equation for calculating efficiency. Common errors in the calculation included incorrect rearrangement to find the energy input.

Question 3 (f)

(f) An energy company proposes the lift could be partly powered from a supercapacitor, charged from solar cells during the day.

The supercapacitor has capacitance 45 F.

Calculate the voltage across the capacitor when it stores 32 kJ of energy.

voltage = ... V **[3]**

This was a challenging two stage calculation where many candidates did not select the correct equations from the formula booklet. For this calculation they needed to combine the two equations first before rearranging to find voltage. Candidates who did not do this ended up incorrectly substituting the given value for capacitance as a charge which gave an incorrect answer.

Question 4 (a)

4 Pylons are used to carry electricity distribution cables high above the ground.

The cables are made from aluminium. Aluminium is a ductile metal with a relatively high electrical conductivity.

(a) Explain what 'ductile' means.

....

....

.... **[2]**

Many responses partially explained the term ductile by saying that it was the ability to be drawn into wires. Some responses just said that it plastically deformed, but in order for a material to be ductile it has a very large plastic deformation region. A number of responses incorrectly indicated that a ductile material would resist deformation or would deform elastically and there was also some confusion between ductility and malleability.

Question 4 (b)

(b) One such cable has cross-sectional area $1.3 \times 10^{-3}\,\text{m}^2$ and carries a current of 700 A.

Calculate the drift velocity of electrons in the cable.

The number of conduction electrons per unit volume in aluminium is $6.0 \times 10^{28}\,\text{m}^{-3}$.

drift velocity = ... ms^{-1} **[2]**

Candidates needed to be able to rearrange the equation and recall the charge on an electron to calculate the drift velocity correctly, and this proved challenging to many.

Question 4 (c) (i)

(c) This cable crosses a river supported on pylons.

The length of cable between the pylons is 1200 m.

The cable has a mass per unit length of $4.5\,\text{kg}\,\text{m}^{-1}$.

(i) Calculate the stress in the cable.

Assume the tension in the cable is due only to the weight.

stress = ... Pa **[3]**

Some responses correctly interpreted the data given in this question, but many were unable to calculate the weight of the cable correctly. Some just used the mass per unit length, and some did calculate the total mass but forgot to multiply by the acceleration of gravity to find the weight or the load. The cross sectional area of the cable was given in part (b) and those candidates who did not notice this then used the length of the wire instead of the area in their calculation of stress. As this was another multi-step calculation, those candidates who showed their working clearly were able to gain some credit even if they did not get the correct final answer.

Question 4 (c) (ii)

(ii) Explain why it is important that the ultimate tensile stress of aluminium is greater than your answer to part **(c)(i)**.

....

....

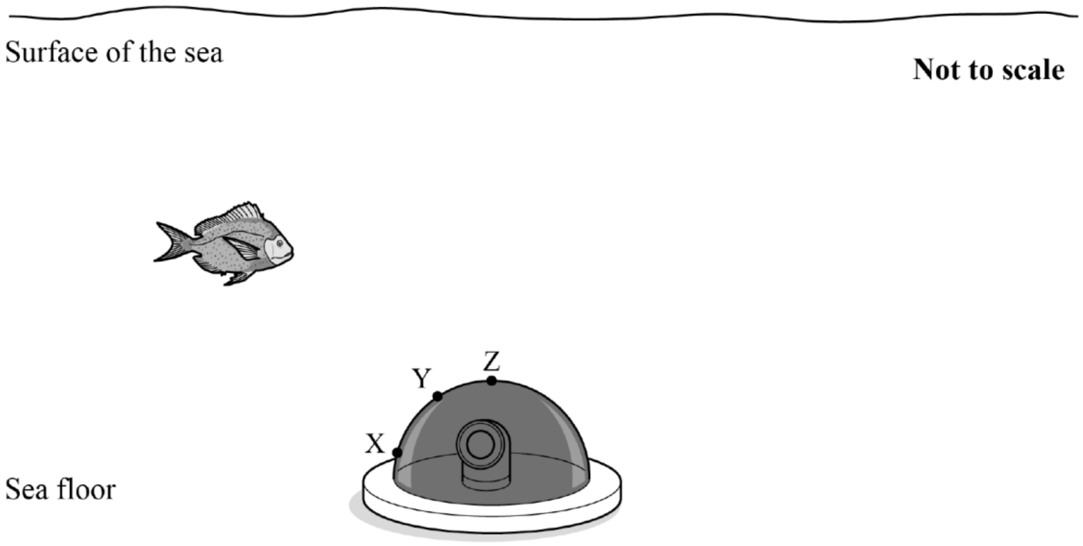
.... **[2]**

Most candidates were able to gain some credit for realising that if the ultimate tensile stress of aluminium was not greater than the value calculated in part (i), then the wire would break or fail. Only a few responses developed the idea that there needed to be a safety factor incorporated to allow for any extra stresses put onto the cable during normal use, caused by environmental factors.

Question 5 (a) (i)

5 **Fig. 2** shows a camera placed on the sea floor to take photographs of marine animals.

Fig. 2



The camera is enclosed in a waterproof dome of plastic material.

(a) **(i)** Draw arrows on **Fig. 2** to show the direction of the pressure on the dome at the points X, Y and Z.

[2]

There was quite a generous tolerance on the drawing arrows acting perpendicular to represent pressure on the dome, so many responses gained both marks. A few lost marks because of careless drawing, but a number put all three arrows acting vertically downwards from the surface of the sea.

Question 5 (a) (ii)

(ii) Calculate the pressure at Z due to the column of water above the dome.

Point Z is 64 m below the surface of the sea.

Density of sea water = 1200 $kg\,m^{-3}$.

Use an appropriate number of significant figures and give the correct unit.

pressure = ... unit .... **[4]**

Many responses used the required equation to calculate the correct numerical answer but then did not round to an appropriate number of significant figures (2 or 30) and/or did not give a correct unit.

Question 5 (a) (iii)

(iii) Explain why your answer to **(a)(ii)** is a **gauge pressure**.

....

....

.... **[2]**

There were many unsuccessful responses to this question which missed the point that gauge pressure does not include atmospheric pressure. Full marks could have been gained by recall of the relevant equation, absolute pressure = gauge pressure + atmospheric pressure.

Question 5 (b)

(b) The dome is made of a material that retains its shape when submerged so that the camera images are not distorted.

State the name of this property of materials.

.... **[1]**

There were many incorrect responses giving a wide range of material properties (or their descriptions) which indicated that candidates, on the whole, need to improve their understanding of 'stiffness' within the context of applications of materials.

Assessment for learning

Stiffness is defined as the ratio between force and extension, and is sometimes referred to as the spring constant, and is related to the Young modulus of a material.

What this means in practice is that a stiff material will have a very small deformation when loaded, so in other words is able to keep its original shape when force is applied.

Question 6 (a)

6 A gas is stored in an expansion tank at constant pressure.

Gases are fluids.

(a) Name another kind of fluid.

.... **[1]**

Nearly all responses to this question were correct.

Question 6 (b) (i)

(b) The volume of gas in the tank is $0.020\,m^3$ at 27 °C.

(i) Convert 27 °C to Kelvin.

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

This question was generally well answered, but some candidates were unable to recall '273' and used other numbers to convert Celsius into Kelvin. Some divided or multiplied by a factor rather than added.

Question 6 (b) (ii)

(ii) Calculate the volume of gas if the temperature falls to −3 °C.

volume = ... m^3 **[2]**

It was good to see that most candidates attempted to use V/T = constant in some way, but a number of responses did not take the prompt from the previous part of the question to convert both temperatures to Kelvin before using the equation.

Question 6 (c)

(c) The gas cools further.

Energy is released as the gas condenses at its boiling point.

State in full the name given to the amount of energy released when 1 kg of the gas condenses at its boiling point.

....

.... **[3]**

This question was straight recall of the term 'Specific Latent Heat of condensation' and only a small number of responses answered all three parts correctly. Most responses got the term 'latent heat' although there was some confusion with 'sensible heat' or 'heat capacity'. Some candidates did pick up on the fact that the question referred to 1 kilogram, hence the 'specific'. Very few included the condensation or vaporisation.

Question 6 (d)

(d) What name is given to the temperature at which substances have minimum internal energy?

.... **[1]**

A number of responses correctly stated that this was 'absolute zero' but many gave the response 'frozen' or gave a variation on the answer to the previous part of the question.

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Question 2(a) Fig. 1 Image - aircraft diagram: Shutterstock aircraft silhouette 1120242566.

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