CAMBRIDGE TECHNICALS

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CAMBRIDGE TECHNICALS LEVEL 3 (2016)

Examiners' report

ENGINEERING

05822–05825, 05873

Unit 2 January 2024 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 Teach Cambridge.

Unit 2 series overview

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

In order to perform well with calculations in this paper, candidates needed to be familiar with the formula booklet and remember to convert units correctly from one form to another. The written short answer questions needed candidates to be able to use scientific vocabulary to explain concepts and properties.

On the whole candidates tended to perform better on the calculation questions than on the written questions.

Many candidates struggled with the differences between absolute correction and absolute error as well as using the incorrect values to find relative error in Question 1.

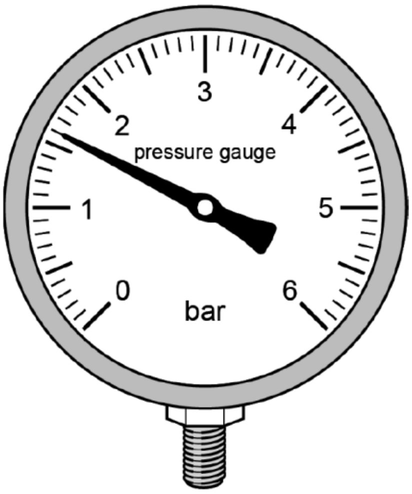
Candidates also found Question 4 challenging. Many were unable to explain toughness and struggled to describe dislocation in metallic structures and how they affected plastic deformation.

Candidates who did well on this paper generally:	**Candidates who did less well on this paper generally:**
• clearly set out working in calculations • recalled definitions • were able to use appropriate scientific vocabulary correctly.	• were unfamiliar with the equations in the formula booklet • used incorrect or no conversion factors for units.

Question 1 (a)

1

(a) State the reading on this pressure gauge.



reading = ... bar **[1]**

Most candidates correctly read the pressure gauge.

Question 1 (b) (i), (ii) and (iii)

(b) The gauge is calibrated in bar.

(i) State the name of the SI derived unit for pressure.

.... **[1]**

(ii) Which derived quantity has the same unit as pressure?

Tick (✓) **one** box.

strain ☐

stress ☐

viscosity ☐

[1]

(iii) Which statement describes gauge pressure?

Tick (✓) **one** box.

absolute pressure + atmospheric pressure ☐

absolute pressure – atmospheric pressure ☐

atmospheric pressure – absolute pressure ☐

[1]

Many candidates correctly recalled the SI derived unit for pressure in part (i). Some misinterpreted the question and attempted to work out the equivalent combination of SI base units. A few candidates gave the answer 'bar', which may have been taken from the meter in part (a).

In part (ii) many candidates correctly recalled that stress has the same unit as pressure.

In part (iii) most candidates chose the correct relationship between absolute, gauge and atmospheric pressure.

Question 1 (c) (i) and (ii)

(c) The mass of a plastic cup is found using a balance to be 1.20 g.

The balance reads −0.20 g when the cup is removed.

(i) What is the absolute correction?

absolute correction = ... g **[1]**

(ii) Calculate the relative error.

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

Many candidates mistakenly took the true value of the mass to be 0.20 g less than the reading of 1.20 g, rather than the true mass being 1.20 + 0.20 = 1.40 g. Some candidates gave the true value as the absolute correction. Some candidates used the correct equation from the formula booklet to find relative error but then used the indicated value (1.20 g) as the denominator instead of the true value.

Misconception

?

Candidates need to understand the difference between absolute correction and absolute error. The indicated value is the reading taken.

Absolute correction = true value – indicated value

Absolute error = indicated value – true value

Whenever candidates need to find relative error or relative correction they should always divide by the true value.

Question 2 (a) (i)

2 A rocket is travelling through the upper part of the atmosphere.

(a) The rocket engine has converted 360 MJ of energy during its flight time of 2 minutes.

(i) Calculate the average power developed in the engine during the flight so far.

average power = ... MW **[2]**

Most candidates used the correct equation to calculate average power, but a common error was to leave the time in minutes, rather than convert to seconds.

Question 2 (a) (ii)

(ii) Which combination of base units is equivalent to the watt?

Circle one answer.

$kg\,m\,s^{-1}$ $kg\,m^2\,s^{-2}$ $kg\,m\,s^{-2}$ $kg\,m^2\,s^{-3}$

[1]

Some candidates selected the correct combination, and many of them showed some working on the page. A common error was to select $kg\,m^2\,s^{-2}$, which is equivalent to a joule of energy, rather than a watt of power.

Question 2 (a) (iii)

(iii) Power is a scalar quantity.

Describe what is meant by the term **scalar**.

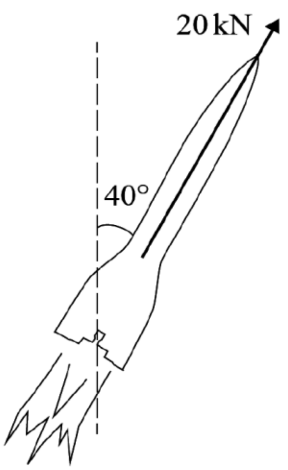
....

.... **[2]**

This was well answered by many candidates. Only a few candidates got vector and scalar quantities the wrong way round, but some candidates gave vague statements for example, a scalar quantity can be measured.

Question 2 (b) (i)

(b) The rocket is travelling at an angle of 40° to the vertical and has a thrust of 20 kN.



(i) Calculate the component of thrust in the vertical direction.

component of thrust = ... kN **[2]**

Many candidates used trigonometry correctly to resolve the thrust force. Common errors were to use the tan or sin function instead of cos function.

Question 2 (b) (ii)

(ii) The weight of the rocket is 7.0 kN.

Calculate the resultant force in the vertical direction.

Give your answer in Newtons.

resultant force = ... N **[2]**

Many candidates answered this straightforward question correctly. A common error was to leave the answer in kN, and there were some candidates who added the two forces algebraically rather than subtracted them.

Question 2 (b) (iii)

(iii) The rocket climbs to higher altitude.

Explain why at higher altitudes, the effects of air resistance are reduced.

....

....

....

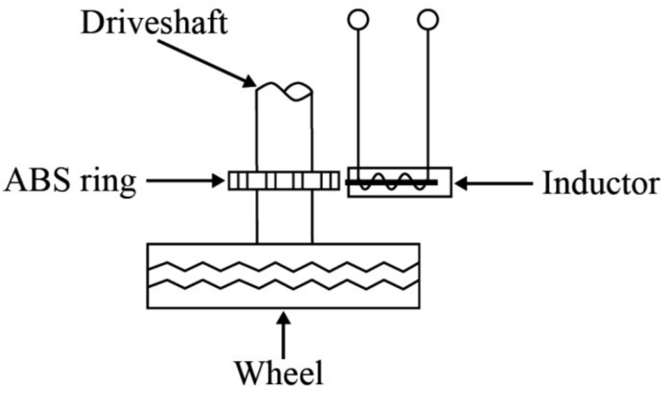
.... **[2]**

Candidates found it difficult to explain this situation using clear scientific terminology or they rewrote the words in the question stem. Many candidates referred to 'thinner' air without explaining what this actually meant. Some also suggested that the gravitational force was lower further from the Earth, which was not relevant to this situation.

Question 3 (a) (i) and (ii)

3 This diagram shows an anti-lock braking system on a car wheel viewed from above.

The sensor in the system uses an inductor. The inductor is placed close to the car wheel.



(a) The inductance of the inductor in this system is between 0.2 and 0.8 henry.

(i) Which statement is correct?

Tick (✓) **one** box.

The henry is an SI base unit. ☐

The henry is an SI derived unit. ☐

The henry is not an SI unit. ☐

[1]

(ii) Complete the definition of the henry using the words below.

Use each word once, more than once or not at all.

ampere **coulomb** **joule** **second** **volt**

A coil has a self-inductance of 1 henry if an emf of 1 …………………………..….. is

induced in the coil when the current through the coil changes at a rate of

1 …………………………..….. per …………………………..….. .

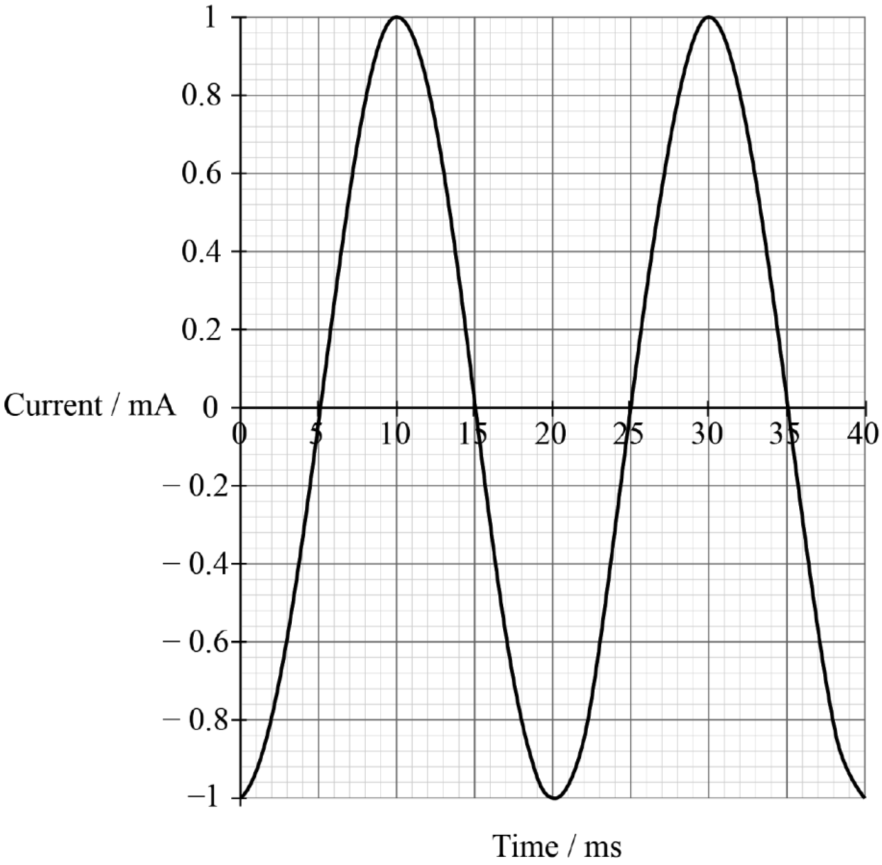
[3]

Many candidates did not appear to be familiar with the unit 'henry'. Some did identify it as an SI derived unit but very few managed to gain full marks in part (ii). Many did get at least 1 mark for the final word 'second'. Part (ii) was really testing if candidates could recall the units for emf, and current.

Question 3 (b) (i)

(b) An engineer is testing the inductor. They pass an alternating current through the inductor.

This graph shows how the current changes over time.



(i) Calculate the magnetic flux in the inductor at time 10 ms.

The inductor has 200 turns of wire and inductance 0.6 H.

Give your answer in micro-weber.

magnetic flux = ... μWb **[4]**

Many candidates managed to complete this calculation correctly. Common errors were to read the current at 10 ms as 1 mA, but then they forgot to convert this to SI units (1×10^{-3} A) before using it in the correct equation. Some candidates did not rearrange the equation correctly to find magnetic flux. Then the final step was to convert the answer to μWb and this was not done well.

Question 3 (b) (ii) and (iii)

(ii) State the magnetic flux in the inductor at time 5 ms.

magnetic flux = ... μWb **[1]**

(iii) State the change in magnetic flux in the inductor between 0 ms and 10 ms.

change in magnetic flux = ... μWb **[1]**

There were a variety of responses to both Question 3(b)(ii) and 3(b)(iii). Some candidates showed that they understood the concept of electromagnetic induction well, but others may have guessed.

Question 3 (c)

(c) A different inductor has an inductance of 2.5 H.

Calculate the energy stored in the inductor when the current through it is 40 mA.

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

Most candidates selected and used the correct equation to calculate the energy stored in an inductor. Common errors were to forget to square the value of current and/or to omit the conversion of current into A.

Question 4 (a)

4 Most metals are tough and are elastic for small strains.

(a) Explain what is meant by the term **tough**.

....

....

.... **[2]**

Few candidates were able to explain the meaning of 'tough'. Many gave vague descriptions relating to strength or hardness of a material. Many candidates made poor use of scientific terminology and there was a confusion between plastic deformation and failure.

Assessment for learning

Candidates need to be taught the difference between material properties such as strength, hardness and toughness.

The strength of a material is usually given as either the yield strength or the ultimate tensile strength. Yield strength is the maximum stress before the material starts to plastically deform, whereas ultimate tensile strength is the maximum stress before failure.

Hardness of a material is a measure of the material's resistance to abrasion, indentation or scratches.

Toughness is a measure of the material's ability to absorb energy and plastically deform without fracturing.

Question 4 (b)

(b) State what happens to the distance between adjacent atoms in a metal when a small tensile force is applied.

....

.... **[1]**

Most candidates answered this question correctly.

Question 4 (c) (i) and (ii)

(c) Many properties of metals are due to the presence of **dislocations** in their crystal structures.

(i) What are dislocations?

You may draw in the space below to illustrate your answer.

....

....

[2]

(ii) Explain why plastic deformation happens more easily when dislocations are present.

You may draw in the space below to help your explanation.

....

....

[2]

Question 4(c) was split into two parts to try to help candidates think about dislocations, first to explain what they were before attempting to explain why they make plastic deformation easier. However most candidates were unable to describe or draw correctly what a dislocation in a metallic crystal actually was. Many candidates suggested that dislocations only appeared once the metal started to deform, rather than just be irregularities or extra partial planes of atoms being present in the metal already. The most common error in part (ii) was to suggest that the bonds were weaker. Some candidates did manage to get a mark for an attempt to describe the process of slip.

Question 4 (d)

(d) After manufacture, metal cables undergo quality assurance tests.

These tests can be destructive or non-destructive.

Tick the statements that refer to **destructive** testing.

Tick (✓) **two** boxes.

Cable can be used after testing.	☐
Finding flaws in the cable material using ultrasonic waves.	☐
Measuring the ultimate tensile strength.	☐
Tests only a sample of the cables.	☐

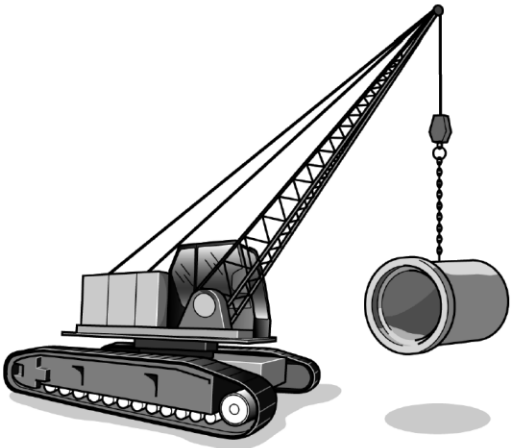
[2]

Most candidates gained at least 1 mark here.

Question 5 (a)

5 A bridge is being constructed over a river. Concrete cylinders are used as bridge supports.

This diagram shows a crane lifting a concrete cylinder.



The weight of the concrete cylinder is 72 kN.

(a) State the tension in the cable when the concrete cylinder is stationary.

tension = ... N **[1]**

Most candidates correctly stated the tension in the cable as the weight of the concrete cylinder. Some candidates misinterpreted the information and multiplied or divided the 72kN by the acceleration of gravity.

Question 5 (b) (i)

(b) The concrete cylinder is lowered into the water and fully submerged.

(i) Calculate the upthrust force on the concrete cylinder.

The volume of concrete is $3.2\,m^3$.

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

upthrust force = ... N **[2]**

Many candidates selected the correct equation to calculate upthrust from the formula booklet, but some calculated mass.

Question 5 (b) (ii)

(ii) Determine the new tension in the cable.

tension = ... N **[1]**

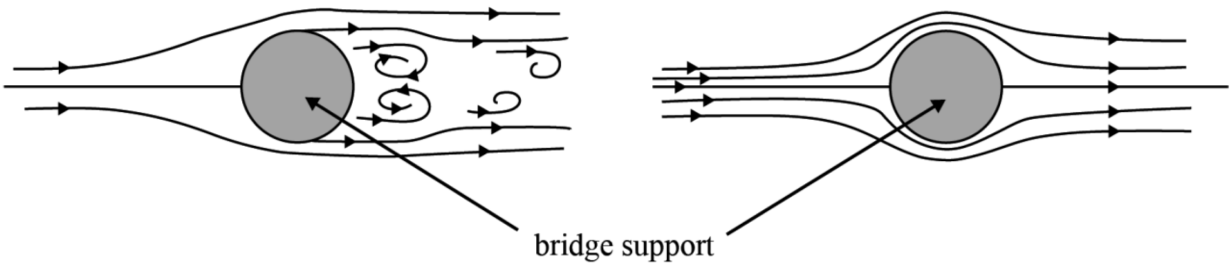
Most candidates correctly calculated the new tension as the original tension minus the upthrust force. Many of the candidates who did not correctly state the original tension did not get this part correct either.

Question 5 (c) (i) and (ii)

(c) When the bridge support is complete, water flows around it.

Looking from above, **Fig. 1a** shows the flow for high speeds and **Fig. 1b** shows low-speed flow.

Fig. 1a **Fig. 1b**



(i) State the name of the type of flow around the bridge support shown in **Fig. 1a**.

.... **[1]**

(ii) Describe the location and type of the boundary layer in **Fig. 1b**.

....

.... **[2]**

Question 5(c)(i) was answered well, but many candidates struggled to identify what was meant by a boundary layer in part (ii).

Question 5 (d)

(d) The size of the boundary layer depends on the viscosity of the water.

Which statements about viscosity are correct?

Tick (✓) **two** boxes.

Dynamic viscosity is the ratio of kinematic viscosity to density.	☐
Kinematic viscosity is velocity per unit shear stress.	☐
Viscosity is a fluid's ability to resist shear forces.	☐
Viscosity is zero for an ideal fluid.	☐

[2]

Most candidates gained at least 1 mark here.

Question 6 (a)

6 This question is about energy.

(a) Complete the sentence using the words chosen from the list below.

Use each word once, more than once, or not at all.

elastic **external** **internal** **kinetic** **thermal**

The ……………………………..….. energy of a system is the sum of the

……………………………..….. and potential energies of its particles.

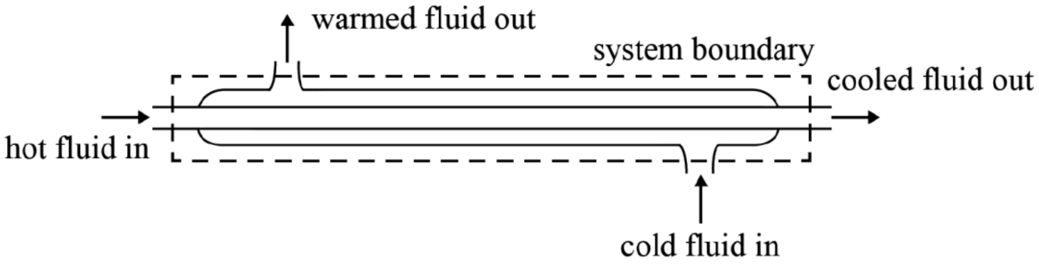
[2]

Many candidates gained at least 1 mark here. It was more common to get the second mark for kinetic energy than to get the first mark for internal energy. Many candidates incorrectly put thermal in one or other of the spaces.

Question 6 (b) (i) and (ii)

(b) This diagram shows a heat exchanger made from a tube enclosed inside a larger tube.

The work done by the system is zero.



(i) Which statement explains why the work done by the system is zero?

Tick (✓) **one** box.

The system applies a force and transfers energy to the surroundings equally. ☐

The system does not apply a force to its surroundings. ☐

The system does not lose energy to its surroundings. ☐

[1]

(ii) Use the steady-flow energy equation to show that the energy entering the system is the same as the energy leaving the system.

[2]

These questions were not well answered. Some candidates showed good understanding of the steady flow equation. As this was a 'show-that' question, candidates need to show their working clearly. Some candidates gained 1 mark for identifying that the work done by the system (W) was equal to zero. Some candidates then attempted to substitute numbers in for other variables in the equation without explaining why these numbers were used.

Question 6 (c) (i)

(c) A heat exchanger is used in a central heating 'combi' boiler where hot water inside the boiler is used to heat cold water before it flows to the hot taps.

0.20 kg of cold water flows through the outer tube in one second.

(i) Calculate the energy needed per second to warm the cold water from 10 °C to 50 °C.

Specific heat capacity of water is 4200 J kg^{-1} K^{-1}.

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

Most candidates used the correct equation to calculate the energy needed, but there were still some candidates who decided to convert the temperature change (40°C) into Kelvin by adding this value to 273.

Misconception

In a specific heat capacity calculation temperature change is used, not actual temperature.

A temperature change will be the same regardless of whether the temperature is measured in °C or K.

Question 6 (c) (ii)

(ii) Calculate the final temperature of the hot water if 0.40 kg of water at 80 °C flows through the inner tube in one second.

final temperature = ... °C **[3]**

Very few candidates realised that doubling the mass of water would mean that the temperature difference would halve, so many attempted to calculate a new temperature difference. Some candidates used a different amount of energy input, and a common error was to think that the temperature was increasing rather than decreasing.

Question 6 (d)

(d) The boiler burns gas to heat the water. The exhaust gases pass through another heat exchanger to warm the water entering the boiler. Some of the water vapour in the exhaust gases condenses in this heat exchanger.

Calculate the energy released when 17 g of water vapour condenses at its boiling point.

Specific latent heat of vaporisation of water is $2.3 \times 10^6 \text{ J kg}^{-1}$.

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

Most candidates used the correct equation to calculate the energy released when the vapour condenses but some did not convert the mass into kg.

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