OCR
Oxford Cambridge and RSA

Friday 12 January 2024 – Morning

Level 3 Cambridge Technical in Engineering

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

Time allowed: 1 hour 30 minutes
C302/2401

C302/2401

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 |

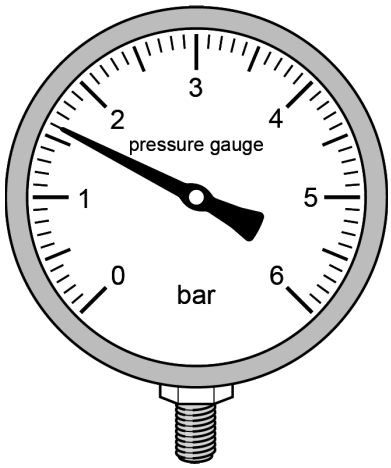
INSTRUCTIONS
- Use black ink. You can use an HB pencil, but only for graphs and diagrams.
- Write your answer to each question in the space provided. If you need extra space use the lined pages at the end of this booklet. The question numbers must be clearly shown.
- Answer **all** the questions.
- Where 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 **20** pages.

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

1

(a) State the reading on this pressure gauge.



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

(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]

(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]**

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]**

(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]

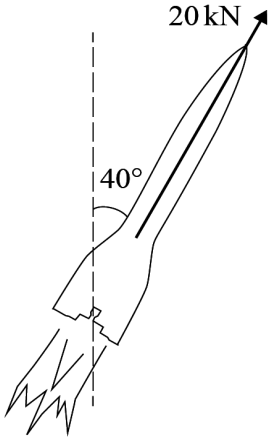
(iii) Power is a scalar quantity.

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

.....

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

(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]**

(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]**

(iii) The rocket climbs to higher altitude.

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

.....

.....

.....

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

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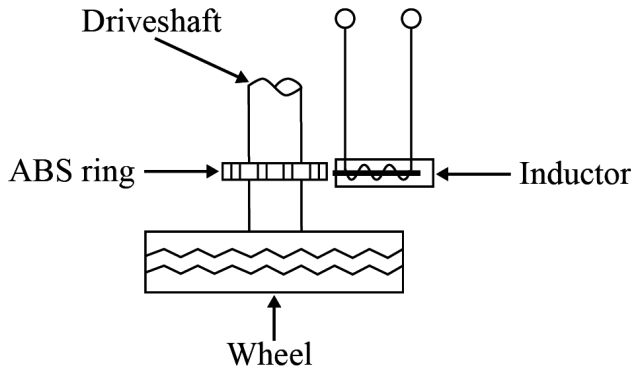
3 This diagram shows an anti-lock braking system on a car wheel viewed from above.

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.

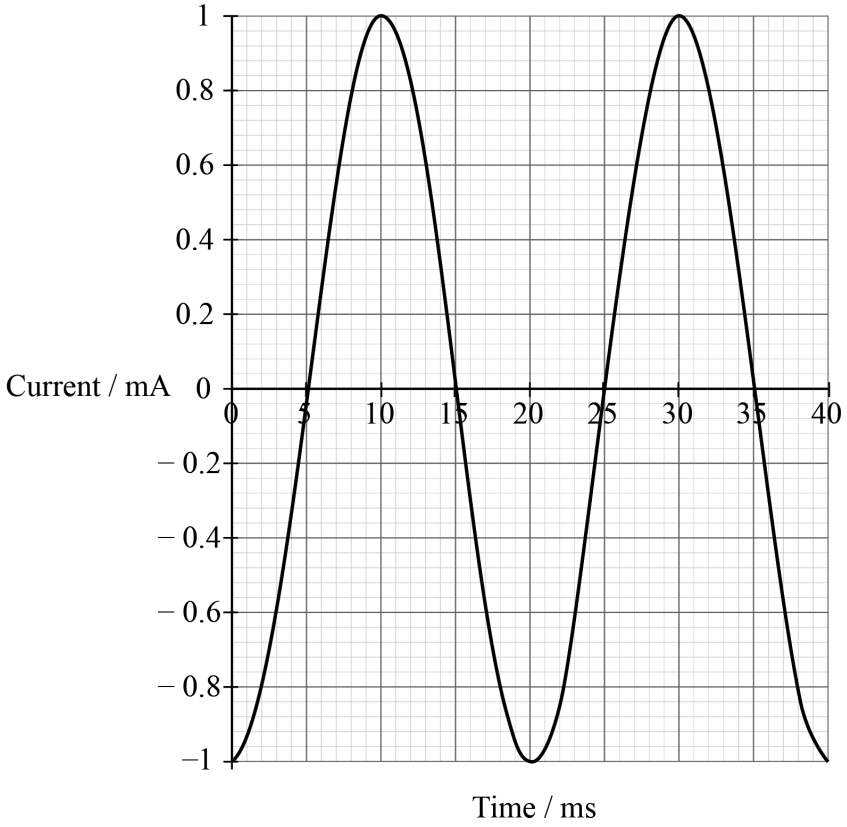
ampere **coulomb** **joule** **second** **volt**

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]

(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]**

(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]**

(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]**

Turn over for the next question

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

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

.....

.....

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

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

.....

..... **[1]**

(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]

(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. ☐

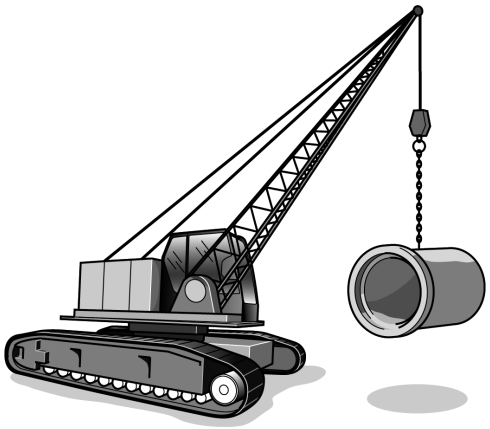
Measuring the ultimate tensile strength. ☐

Tests only a sample of the cables. ☐

[2]

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]**

(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]**

(ii) Determine the new tension in the cable.

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

(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

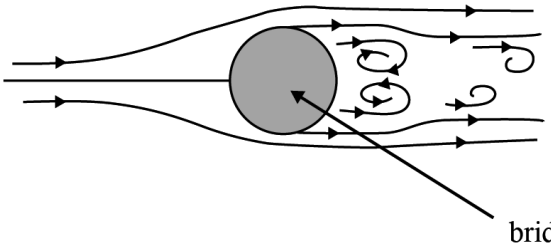
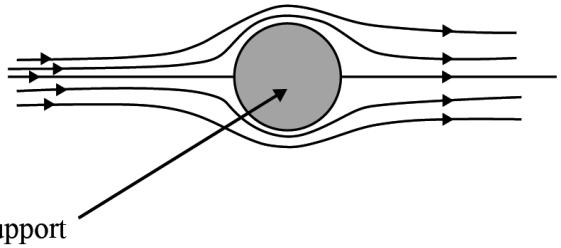


Fig. 1b



bridge support

(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]**

(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]

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**

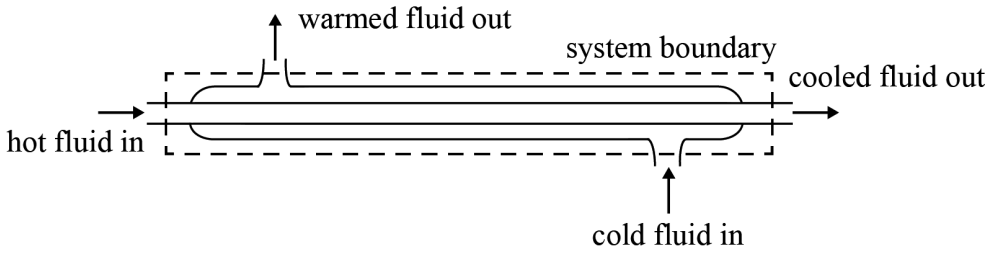
The ……..….. energy of a system is the sum of the

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

[2]

(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]

(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]**

(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]**

(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 2.3×10^6 J kg^{-1}.

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

END OF QUESTION PAPER

EXTRA ANSWER SPACE

If you need extra space use these lined pages. You must write the question numbers clearly in the margin.

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