Name:

Date:

MATERIALS
TEST 2

AS-Level

Mark

Grade

PHYSICS

For this paper you must have:

- Ruler
- Pencil and Rubber
- Scientific calculator, which you are expected to use when appropriate

Instructions

- Answer all questions
- Answer questions in the space provided
- All working must be shown

Information

- The marks for the questions are shown in brackets

1 A wire of length L and cross-sectional area A is stretched a distance e by a tensile force. The Young modulus of the material of the wire is E.

Which expression gives the elastic energy stored in the stretched wire?

A $\frac{1}{2}\frac{EAe^2}{L}$ ☐

B $\frac{1}{2}\frac{L}{Ae}$ ☐

C $\frac{1}{2}\frac{Ae^2}{EL}$ ☐

D $\frac{1}{2}\frac{EAL}{e}$ ☐

(Total 1 mark)

2 A steel wire has a cross-sectional area 0.5 mm^2. The Young modulus of steel is 2.0×10^{11} Pa. Assume the wire obeys Hooke's law.

What load must be suspended from the wire to produce an extension which is 0.1% of the original length?

A 40 N ☐

B 50 N ☐

C 100 N ☐

D 200 N ☐

(Total 1 mark)

3 If lengths of rail track are laid down in cold weather, they may deform as they expand when the weather becomes warmer. Therefore, when rails are laid in cold weather they are stretched and fixed into place while still stretched. This is called pre-straining.

The following data is typical for a length of steel rail:

Young modulus of steel =	2.0×10^{11} Pa
cross sectional area of a length of rail =	7.5×10^{-3} m^2
amount of pre-strain =	2.5×10^{-5} for each kelvin rise in temperature the rail is expected to experience.

A steel rail is laid when the temperature is 8 °C and the engineer decides to use a pre-strain of 3.0×10^{-4}.

(a) Calculate the tensile force required to produce the pre-strain in the rail required by the engineer.

tensile force = ____________________ N

(3)

(b) Calculate the elastic strain energy stored in a rail of unstressed length 45 m when pre-strained as in part (a)

elastic strain energy = ____________________ J

(2)

(c) Calculate the temperature at which the steel rail becomes unstressed.

temperature = ____________________ °C

(2)

(d) Explain why the engineer does not use the highest observed temperature at the location of the railway track to determine the amount of pre-strain to use.

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(2)

(Total 9 marks)

4 The term **ultrasound** refers to vibrations in a material that occur at frequencies too high to be detected by a human ear. When ultrasound waves move through a solid, both longitudinal and transverse vibrations may be involved. For the longitudinal vibrations in a solid, the speed c of the ultrasound wave is given by

$$c = \sqrt{\frac{E}{\rho}}$$

where E is the Young modulus of the material and ρ is the density. Values for c and ρ are given in the table below.

Substance	c **/ m s^{-1}**	ρ **/ kg m^{-3}**
glass	5100	2500
sea water	1400	1000

Ultrasound waves, like electromagnetic radiation, can travel through the surface between two materials. When all the energy is transmitted from one material to the other, the materials are said to be **acoustically matched**. This happens when ρc is the same for both materials.

(a) Calculate the magnitude of the Young modulus for glass.

Young modulus = ____________________

(1)

(b) State your answer to (a) in terms of SI fundamental units.

(1)

(c) The passage states that 'when ultrasound waves move through a solid both longitudinal and transverse vibrations may be involved'.

State the difference between longitudinal and transverse waves.

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(2)

(d) Show that when two materials are acoustically matched, the ratio of their Young moduli is equal to the ratio of their speeds of the ultrasound waves.

(2)

(e) The wave speed in a material X is twice that in material Y. X and Y are acoustically matched.

Determine the ratio of the densities of X and Y.

X = ____________________ Y = ____________________

(1)

(f) Ultrasound waves obey the same laws of reflection and refraction as electromagnetic waves.

Using data from **Table 1**, discuss the conditions for which total internal reflection can occur when ultrasound waves travel between glass and sea water.

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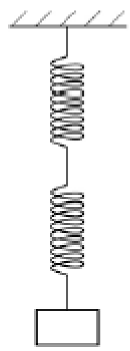
(3)
(Total 10 marks)

5 A load of 3.0 N is attached to a spring of negligible mass and spring constant 15 N m^{-1}.

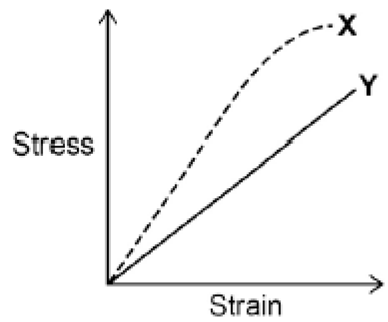


What is the energy stored in the spring?

A	0.3 J	☐
B	0.6 J	☐
C	0.9 J	☐
D	1.2 J	☐

(Total 1 mark)

6 The diagram shows how the stress varies with strain for metal specimens X and Y which are different. Both specimens were stretched until they broke.

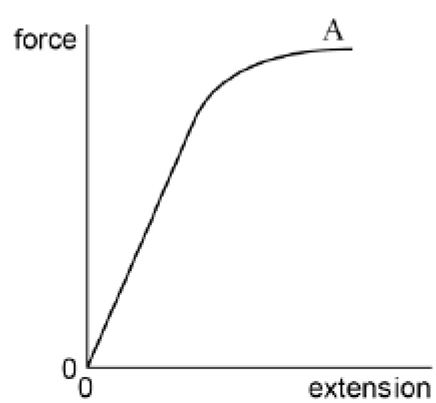


Which of the following is incorrect?

A	X is stiffer than Y	⬭
B	X has a higher value of the Young modulus	⬭
C	X is more brittle than Y	⬭
D	Y has a lower maximum tensile stress than X	⬭

(Total 1 mark)

7 A student adds a series of masses to a vertical metal wire of circular cross–section and measures the extension of the wire produced. The figure below is a force-extension graph of the data.



(a) Mark on the figure the point P, the limit beyond which Hooke's law is no longer obeyed.

(1)

(b) Outline how the student can use these results and other measurements to determine the Young modulus of the wire.

(3)

(c) When the wire has been extended to A, the masses are removed one by one and the extension re-measured.

Draw, on the figure above, the shape of the graph that the student will obtain.

(1)

(d) Explain why the graph has the shape you have drawn.

(2)

(e) The metal wire is used to make a cable of diameter 6.0 mm. The Young modulus of metal of the cable is 2.0×10^{11} Pa.

Calculate the force necessary to produce a strain of 0.20% in the cable.

force = ____________________ kN

(3)

(f) The cable is used in a crane to lift a mass of 600 kg.

Determine the maximum acceleration with which the mass can be lifted if the strain in the cable is not to exceed 0.20%.

acceleration = ____________________ m s^{-2}

(3)

(g) An engineer redesigns the crane to lift a 1200 kg load at the same maximum acceleration.

Discuss the changes that could be made to the cable of the crane to achieve this, without exceeding 0.20% strain.

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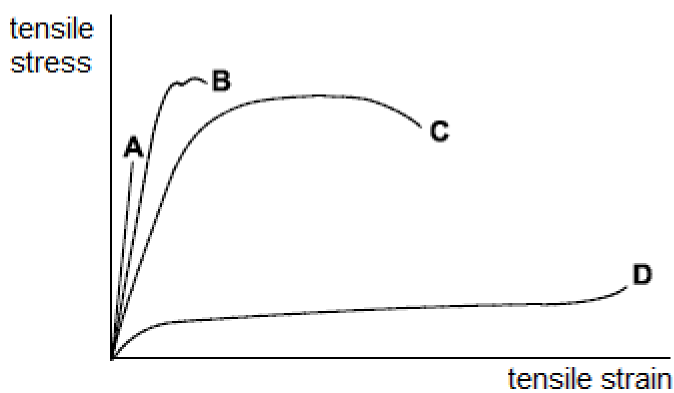
(3)

(Total 16 marks)

8 The diagram below shows the tensile stress–tensile strain graphs for four materials, **A**, **B**, **C** and **D**, up to their breaking stress.



(a) State what is meant by tensile stress and tensile strain.

tensile stress ____

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tensile strain ____

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(2)

(b) Identify a property of material **A** using evidence from the graph to support your choice.

property ____

evidence ____

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(2)

(c) A cylindrical specimen of material **A** under test has a diameter of 1.5×10^{-4} m and a breaking stress of 1.3 GPa.

Calculate the tensile force acting on the specimen at its breaking point.

tensile force = ____________________ N

(3)

(d) Discuss which of the four materials shown on the graph is most suitable for each of the following applications:

- the cable supporting a lift in a tall building
- a rope or cable attached to a person doing a bungee jump.

For each application, you should discuss the reason for your choice and why you rejected the other materials.

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(6)

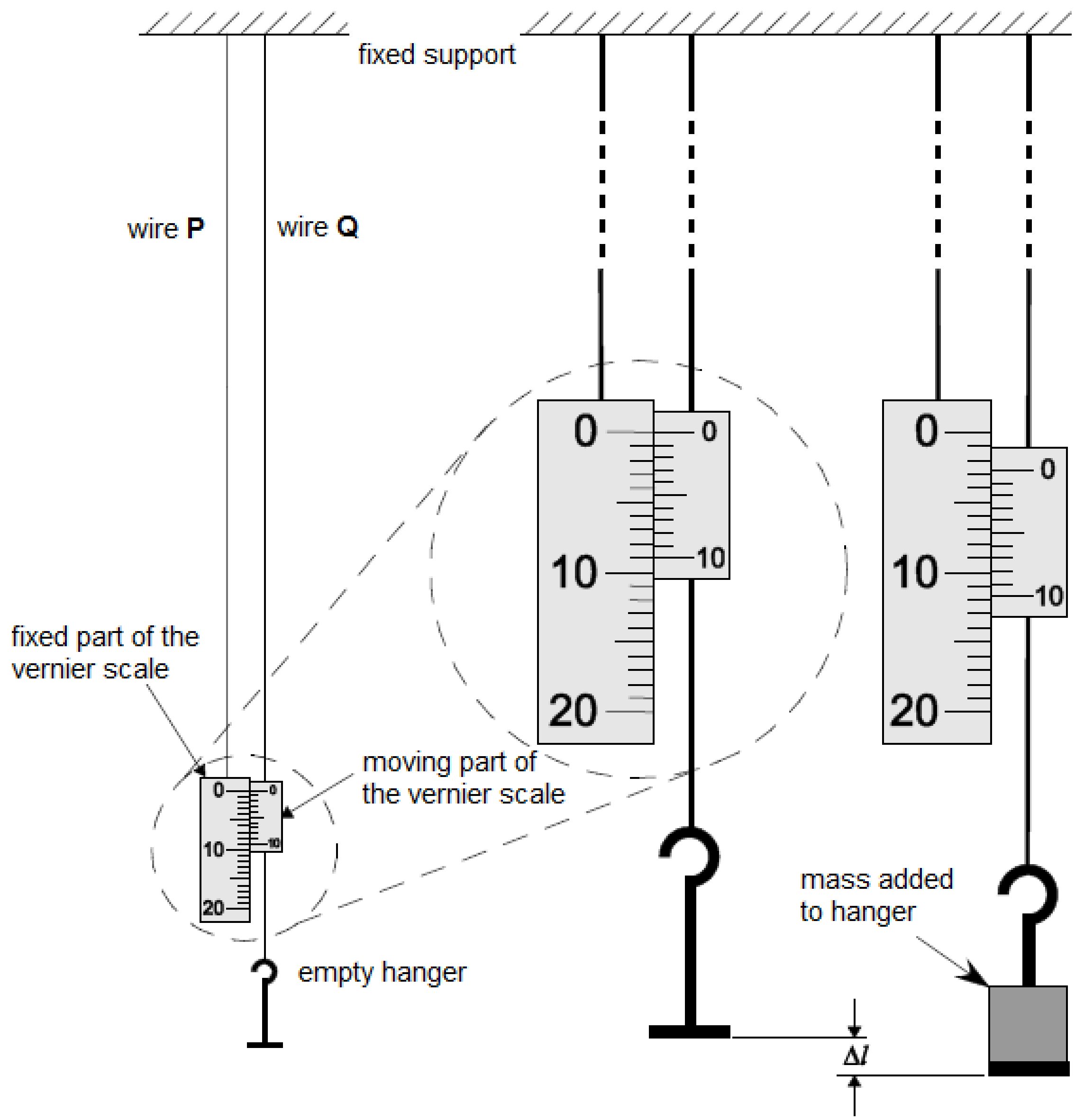
(Total 13 marks)

9 This question is about the determination of the Young modulus of the metal of a wire.

In an experiment, two vertical wires **P** and **Q** are suspended from a fixed support. The fixed part of a vernier scale is attached to **P** and the moving part of the scale is attached to **Q**. The divisions on the fixed part of the scale are in mm.

An empty mass hanger is attached to **Q** and the scale is set to zero. A load is added to the mass hanger so that the extension of **Q** can be measured as shown in **Figure 1**.

Figure 1



(a) The reading on the vernier scale can be used to determine Δl, the extension of **Q**.

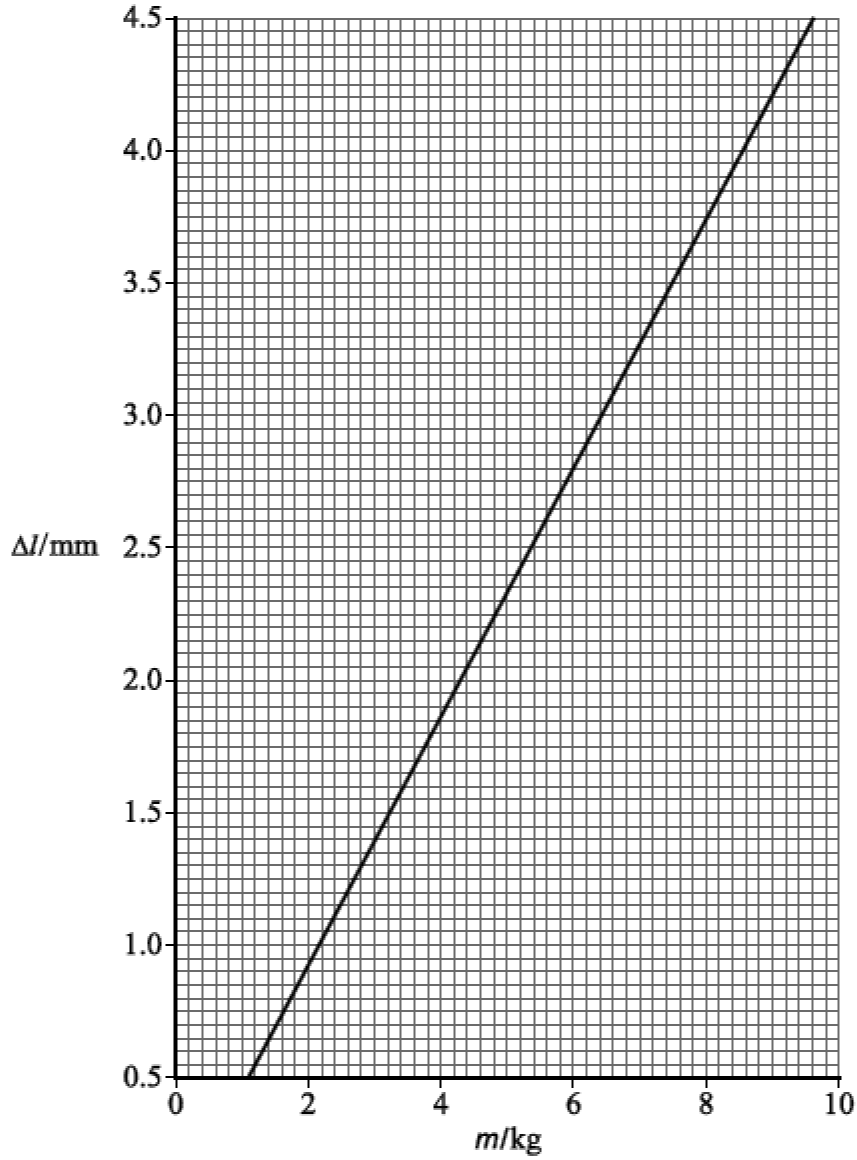
Determine Δl using **Figure 1**.

Δl = ____________________ mm

(1)

(b) **Figure 2** shows how Δl varies with m, the mass added to the hanger.
Determine the mass added to the hanger shown in **Figure 1**.

Figure 2



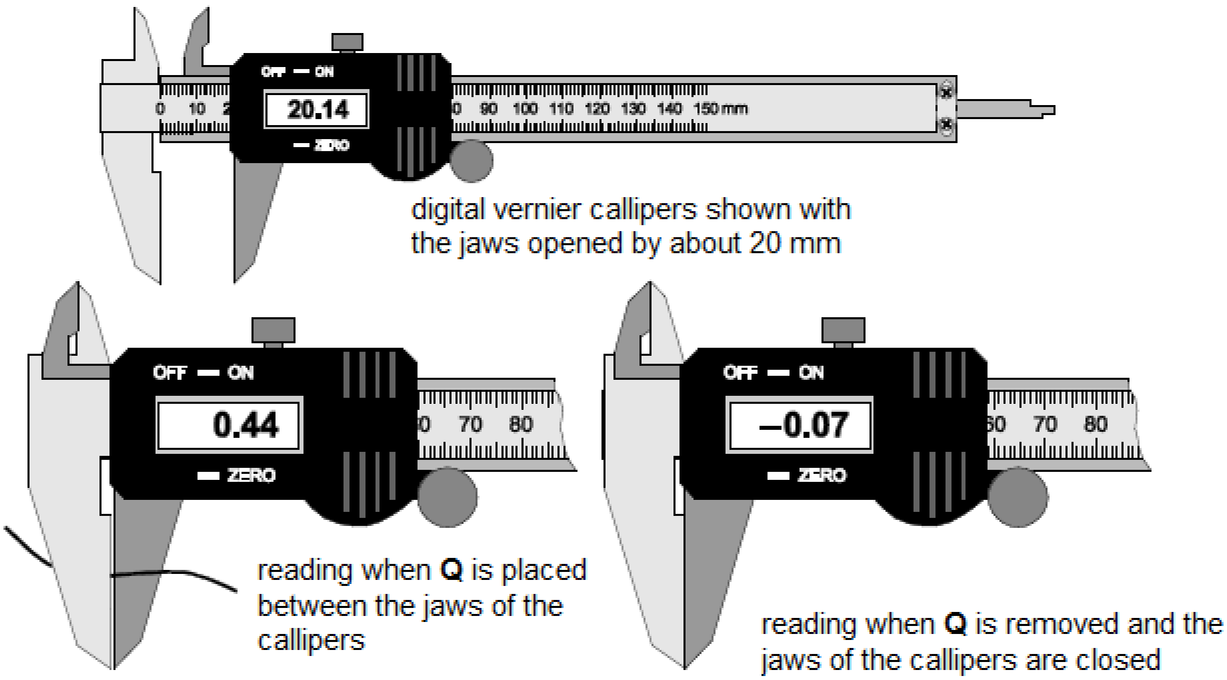
mass = ____________________ kg

(1)

(c) A student uses digital vernier callipers to measure the diameter of **Q**. She places **Q** between the jaws of the callipers and records the reading indicated. Without pressing the zero button she removes **Q** and closes the jaws.

Views of the callipers before and after she closes the jaws are shown in **Figure 3**.

Figure 3



Calculate the true diameter of **Q**.

diameter = ____________________ mm

(1)

(d) The original length of **Q** was 1.82 m.

Determine the Young modulus of the metal in **Q**.

Young modulus = ____________________ Pa

(4)

(e) The student repeats her experiment using a wire of the same original length and metal but with a smaller diameter.

Discuss **two** ways this change might affect the percentage uncertainty in her result for the Young modulus.

1. ____

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2. ____

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(4)

(Total 11 marks)

10 An aerospace engineer has built two differently designed wings. One wing is made from an aluminium alloy and the other is made from a carbon fibre composite.

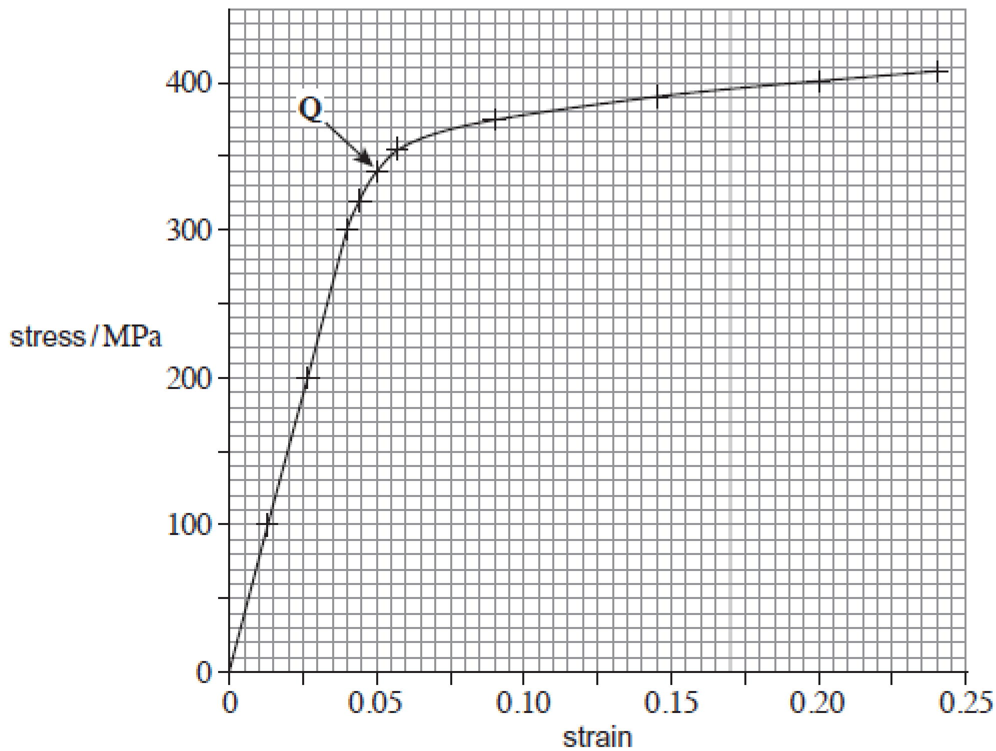
The engineer tests a sample of each material by applying a varying stress.

(a) Tick (✓) **two** of the boxes in the table below to indicate which are properties of the material from which the wing is made.

breaking stress	
stiffness constant, k	
tensile strain	
tensile stress	
Young modulus	

(1)

(b) Below is the stress−strain graph that the engineer obtains for the aluminium alloy.



(i) The engineer has labelled a point **Q** on the graph. This is a point beyond which the behaviour of the material changes irreversibly. State the name for this point.

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(1)

(ii) Use the graph to determine the Young modulus of the aluminium alloy. Show your working.

Young modulus = ____________________ Pa

(2)

(c) The engineer who carried out the experiment to obtain the stress−strain graph decided to stretch another sample to a strain of 0.10. She then gradually reduced the stress to zero.

Show by drawing on the graph how you would expect the stress to vary with strain as the stress is reduced.

(2)

(d) Calculate the volume of 25.0 kg of the aluminium alloy.

density of aluminium alloy = 2.78×10^3 kg m^{-3}.

volume = ____________________ m^3

(1)

(e) 1.28% of the aluminium alloy's volume is copper.
Calculate the mass of pure aluminium needed to make 25.0 kg of the aluminium alloy.

density of pure aluminium = 2.70×10^3 kg m^{-3}.

mass of pure aluminium = ____________________ kg

(2)

(Total 9 marks)