1.1 Material properties and selection

AQA 8552 · Calculator allowed · about 50 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions.

1 A school designs a reusable lunch box. A steel sample resists a sharp point scratching its surface, but a similar steel sample with greater toughness absorbs more energy before fracturing. State the property that describes resistance to scratching and explain what toughness describes.

(a) Name the property measured by resistance to scratching. **(1)**

(b) Explain what the toughness result tells the designer. **(2)**

(Total for Question 1 is 3 marks)

2 A child-safe toy wheel must resist surface wear and should not crack when it hits the floor. Data from tests: polymer A has hardness score 7 and impact energy 4 J; polymer B has hardness score 5 and impact energy 10 J. Higher hardness score means greater resistance to indentation.

(a) Which polymer is harder? **(1)**

(b) Which polymer is tougher? **(1)**

(c) Recommend a polymer if avoiding cracks on impact is the priority. Explain. **(1)**

(Total for Question 2 is 3 marks)

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3 A lightweight camera support has a maximum permitted mass of 1.5 kg. A solid component has volume 800 cm^3. Material R has density 1.8 g/cm^3; material S has density 2.1 g/cm^3.

(a) Calculate the mass of the component made from R in grams. **(2)**

(b) Convert this mass to kilograms and decide whether R meets the limit. **(2)**

(c) State whether S would meet the limit, showing a calculation. **(2)**

(Total for Question 3 is 6 marks)

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4 A manufacturer chooses a material for a protective knee pad shell. Requirements: low density, high toughness and sufficient stiffness to keep its shape. Data: U density 0.9 g/cm^3, impact energy 18 J, deflection 8 mm; V density 1.1 g/cm^3, impact energy 24 J, deflection 3 mm; W density 0.8 g/cm^3, impact energy 10 J, deflection 2 mm. All deflections were measured under the same load.

(a) Identify the material with the lowest density. **(1)**

(b) Identify the material with the greatest toughness. **(1)**

(c) Recommend a material for the knee pad, considering all three requirements. Justify your choice and one trade-off. **(3)**

(Total for Question 4 is 5 marks)

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5 A bicycle light bracket is tested by pulling it until it breaks. Material P withstands a greater maximum force than material Q. A separate bending test shows material P bends less under the same load. Identify the property shown by the breaking test and the property shown by the bending test.

(a) Name the property indicated by the maximum force before breaking. **(1)**

(b) Name the property indicated by how much a material bends under load. **(1)**

(Total for Question 5 is 2 marks)

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6 A design team compares three panels for a lightweight tool case. The data are from identical-sized samples.
Material A: mass 180 g; indentation depth 0.4 mm; energy absorbed before fracture 8 J.
Material B: mass 140 g; indentation depth 0.8 mm; energy absorbed before fracture 14 J.
Material C: mass 220 g; indentation depth 0.3 mm; energy absorbed before fracture 5 J.

(a) Which material has the greatest hardness? Use the data. **(1)**

(b) Which material has the greatest toughness? Use the data. **(1)**

(Total for Question 6 is 2 marks)

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7 A portable speaker casing must be light and should not fracture if dropped. Equal-volume samples have these results: X mass 90 g and impact energy absorbed 3 J; Y mass 120 g and impact energy absorbed 9 J; Z mass 75 g and impact energy absorbed 2 J.

(a) Calculate the density of sample Y if each sample has a volume of 60 cm^3. **(2)**

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(b) Select the best sample if drop resistance is the priority. Give the data-based reason. **(1)**

(Total for Question 7 is 3 marks)

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8 A folding stool leg must support a load without breaking and should not flex noticeably. Test results: alloy A breaks at 900 N and deflects 4 mm under 300 N; alloy B breaks at 700 N and deflects 2 mm under 300 N.

(a) Which alloy is stronger? State the evidence. **(1)**

(b) Which alloy is stiffer? State the evidence. **(1)**

(Total for Question 8 is 2 marks)

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9 A reusable drinks bottle is made from polymer R. It has low density, but its surface scratches easily. The designer considers a second polymer with higher hardness and the same density. Explain whether the second polymer would reduce the bottle mass and identify the likely surface benefit.

(a) Explain the effect on mass if bottle volume and density remain the same. **(1)**

(b) State the likely benefit of higher hardness. **(1)**

(Total for Question 9 is 2 marks)

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10 A phone stand must be stiff enough to hold a tablet at a fixed angle. A test applies 20 N to identical beams and measures deflection: material L deflects 5 mm; material M deflects 2 mm. In a separate tensile test, L breaks at 500 N and M at 350 N.

(a) Select the stiffer material and support your choice with the data. **(1)**

(b) Select the stronger material and support your choice with the data. **(1)**

(Total for Question 10 is 2 marks)

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11 A garden tool handle should withstand knocks. Two materials are tested with identical notched samples. Material P absorbs 6 J before the notch fractures; material Q absorbs 11 J. Explain which material is tougher and what that implies for the handle.

(a) Identify the tougher material and explain using the test result. **(2)**

(b) State one likely product advantage of this result. **(1)**

(Total for Question 11 is 3 marks)

12 A storage tray is to be made from one of two materials. It must have a mass below 300 g for a 200 cm^3 tray. Material P has density 1.2 g/cm^3; material Q has density 1.6 g/cm^3.

(a) Calculate the mass of a tray made from P. **(2)**

(b) Calculate the mass of a tray made from Q. **(2)**

(c) Select the material that meets the mass requirement. **(1)**

(Total for Question 12 is 5 marks)

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Mark scheme · 1.1 Material properties and selection

Question 1

(a) hardness **B1**

(a) Answer: Hardness

(b) toughness is the ability to absorb energy (or resist fracture) before breaking **B1**

(b) greater toughness means the lunch box is less likely to crack or shatter on impact **B1**

(b) Answer: Toughness is the ability to absorb energy before fracturing; a tougher box is less likely to crack if dropped

Question 2

(a) A, with hardness score 7 **B1**

(a) Answer: Polymer A

(b) B, because it absorbs more impact energy before fracture (10 J) **B1**

(b) Answer: Polymer B

(c) B, as it absorbs more impact energy / is tougher **B1**

(c) Answer: Polymer B, because it absorbs more impact energy

Question 3

(a) mass = density x volume = 1.8 x 800 **M1**

(a) 1440 g **A1**

(a) Answer: 1440 g

(b) 1440 g / 1000 = 1.44 kg **M1**

(b) yes, since 1.44 kg is below 1.5 kg **A1**

(b) Answer: 1.44 kg; yes

(c) 2.1 x 800 = 1680 g **M1**

(c) 1.68 kg, which exceeds 1.5 kg **A1**

(c) Answer: No; 1.68 kg

Question 4

(a) W, at 0.8 g/cm^3 **B1**

(a) Answer: W

(b) V, because it absorbs the greatest impact energy (24 J) **B1**

(b) Answer: V

(c) V has the greatest toughness (24 J), useful for resisting fracture on impact **B1**

(c) V deflects only 3 mm, so it is reasonably stiff compared with U (8 mm); lower deflection indicates greater stiffness **B1**

(c) V has greater density than W or U (1.1 g/cm^3), a trade-off; a justified choice of V prioritises toughness and shape retention, or another choice with coherent trade-off may earn credit **B1**

(c) Answer: V is a balanced choice: it absorbs the most impact energy and deflects only 3 mm, but is denser than U and W

Question 5

(a) strength **B1**

(a) Answer: Strength

(b) stiffness **B1**

(b) Answer: Stiffness

Question 6

(a) Material C; it has the smallest indentation depth (0.3 mm) **B1**

(a) Answer: Material C, because it has the smallest indentation depth

(b) Material B; it absorbs the most energy before fracture (14 J) **B1**

(b) Answer: Material B, because it absorbs the most energy before fracture

Question 7

(a) density = mass / volume = 120 / 60 **M1**

(a) 2 g/cm^3 **A1**

(a) Answer: 2 g/cm^3

(b) Y, because it absorbs the most impact energy (9 J) **B1**

(b) Answer: Y, because it absorbs the most impact energy

Question 8

(a) A, since it withstands the greater force before breaking: 900 N **B1**

(a) Answer: Alloy A; it breaks at a greater force

(b) B, since it deflects less under the same load: 2 mm **B1**

(b) Answer: Alloy B; it deflects less under the same load

Question 9

(a) mass would remain the same because mass = density x volume and both are unchanged **B1**

(a) Answer: Its mass would remain the same because density and volume are unchanged

(b) greater resistance to scratching / indentation **B1**

(b) Answer: It should resist scratching or indentation better

Question 10

(a) M; it has the smaller deflection under the same 20 N load **B1**

(a) Answer: M, because it deflects only 2 mm under 20 N

(b) L; it withstands a greater force before breaking (500 N) **B1**

(b) Answer: L, because it breaks at a greater force

Question 11

(a) Q is tougher **B1**

(a) it absorbs more energy before fracture (11 J compared with 6 J) **B1**

(a) Answer: Q is tougher because it absorbs 11 J before fracture, compared with 6 J

(b) the handle is less likely to fracture when it receives an impact / knock **B1**

(b) Answer: The handle is less likely to fracture when knocked

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Question 12

(a) mass = density x volume = 1.2 x 200 **M1**

(a) 240 g **A1**

(a) Answer: 240 g

(b) mass = density x volume = 1.6 x 200 **M1**

(b) 320 g **A1**

(b) Answer: 320 g

(c) P; 240 g is below 300 g, whereas Q is 320 g **B1**

(c) Answer: P; its mass is below 300 g

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