1.4 Polymers and composites

AQA 8552 · Calculator allowed · about 55 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions.

1 A designer is choosing a polymer for a reusable lunch-box lid. It needs to be shaped in production and may be warmed during washing. Explain the difference between thermoplastic and thermosetting polymer behaviour when heated. [4 marks]

(Total for Question 1 is 4 marks)

2 A maker has clean sprues from a thermoplastic injection-moulding run. Explain one possible way to use this production waste and one reason the material may not be suitable for unlimited closed-loop recycling. [3 marks]

(Total for Question 2 is 3 marks)

3 Choose a suitable forming process for each product: (i) a low-volume, shallow thermoplastic packaging insert; (ii) a high-volume, detailed thermoplastic appliance casing; (iii) a small batch of a thermoset electrical component. Use vacuum forming, injection moulding or compression moulding once each. [3 marks]

(Total for Question 3 is 3 marks)

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4 A company is selecting a material and process for an outdoor cycle mudguard. The part needs a curved shape, low mass, resistance to water and impact, and a realistic end-of-life plan. Recommend a material family and forming process, then justify your choice and identify one trade-off. [6 marks]

(Total for Question 4 is 6 marks)

5 A small batch of 24 bespoke protective cases needs one shallow, open shell shape with no undercuts. A second order would be 20,000 identical cases. Choose an appropriate forming process for each order from vacuum forming, injection moulding and compression moulding. Give a reason for each choice. [4 marks]

(Total for Question 5 is 4 marks)

6 A plug housing must electrically insulate live components, resist heat from normal operation and keep its shape. Select either a thermoplastic or thermosetting polymer and explain your choice. [3 marks]

(Total for Question 6 is 3 marks)

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7 A glass-fibre composite panel is made from glass fibres held in a cured resin. State the role of each constituent. [3 marks]

(Total for Question 7 is 3 marks)

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8 A design team compares a glass-fibre composite with unreinforced resin for a lightweight support. Explain how the fibres can change performance and identify one design consideration. [4 marks]

(Total for Question 8 is 4 marks)

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9 A moulded part has mass 0.36 kg. Its density is 1.2 g/cm3. Calculate its volume in cm3. Show your unit conversion and working. [3 marks]

(Total for Question 9 is 3 marks)

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10 A manufacturer makes 1,500 identical thermoplastic clips using injection moulding. Each clip takes 18 seconds of machine time. Calculate the total machine time in hours. [3 marks]

(Total for Question 10 is 3 marks)

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11 A designer proposes a thermoplastic tray and says, 'Thermoplastics are recyclable, so this tray will be recycled.' Explain why this claim is too broad. [4 marks]

(Total for Question 11 is 4 marks)

12 Two designs provide the same function. Design A uses 0.8 kg of material and lasts 4 years. Design B uses 1.2 kg and lasts 8 years. Compare material use per year of service. State the assumptions needed before treating this as an environmental comparison. [5 marks]

(Total for Question 12 is 5 marks)

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Mark scheme · 1.4 Polymers and composites

Question 1

Thermoplastic softens when heated	**B1**
Thermoplastic can be reshaped and sets on cooling	**B1**
Thermosetting polymer is cured into a rigid structure	**B1**
It does not remelt for reshaping on reheating (allow: may char/decompose)	**B1**

Answer: Thermoplastics soften when heated and can be reshaped; on cooling they set again. Thermosetting polymers form a rigid, cross-linked structure during curing and do not soften into a mouldable melt on reheating; excessive heat eventually causes damage or decomposition.

Question 2

Describes collecting/granulating/reusing clean production scrap	**B1**
Links reuse to suitable reprocessing/blending in another run	**B1**
Gives a valid limit such as degradation, contamination, mixed grades or specification constraints	**B1**

Answer: The clean sprues can be separated, granulated and blended into feedstock for another moulding run if the process and product specification allow it. Repeated heating and processing can degrade polymer properties, and contamination or mixed grades can make the material unsuitable for the intended component.

Question 3

(i) Vacuum forming	**B1**
(ii) Injection moulding	**B1**
(iii) Compression moulding	**B1**

Answer: (i) Vacuum forming; (ii) injection moulding; (iii) compression moulding.

Question 4

Selects a plausible material family or named suitable grade	**B1**
Selects a suitable process for the stated volume/geometry	**B1**
Links material choice to low mass and/or water resistance	**B1**
Addresses impact, stiffness, outdoor use or testing with a relevant condition	**B1**
Identifies a realistic trade-off	**B1**
Gives a conditional end-of-life plan based on identification, separation and available collection/processing	**B1**

Answer: One defensible choice is a tough thermoplastic such as polypropylene, formed by injection moulding for a high-volume run. It can produce a consistent curved part, has low density and resists water; the grade and thickness must be selected and tested for impact and outdoor exposure. A trade-off is that impact performance and stiffness vary with grade, temperature and geometry. End-of-life planning should identify the exact polymer, minimise incompatible attachments and confirm that a suitable local collection and processing route exists; thermoplastic behaviour alone does not prove the part will be recycled.

Question 5

Vacuum forming selected for the small batch	**B1**
Valid small-batch/tooling or sheet-over-mould reason	**B1**
Injection moulding selected for the large repeat order	**B1**
Valid mass-production/repeatability or tooling-cost-per-part reason	**B1**

Answer: For 24 cases, vacuum forming a thermoplastic sheet over a mould is suitable because tooling can be relatively simple and the batch is small. For 20,000 identical cases, injection moulding is suitable because the high tooling cost can be spread over many parts and the process is repeatable for complex shapes.

Question 6

Thermosetting polymer selected (accept a heat-resistant thermoplastic grade where the choice is justified by the operating temperature)	**B1**
Links the cross-linked/rigid behaviour to retaining shape under heat	**B1**
Identifies electrical insulation and/or checking the grade against the operating conditions	**B1**

Answer: A thermosetting polymer is a suitable choice because its rigid cross-linked structure resists softening in service, and many thermosets provide electrical insulation. The chosen grade must still be specified for the actual operating temperature and safety requirements.

Question 7

Fibres provide strength and/or stiffness	**B1**
Matrix binds/holds fibres in position	**B1**
Matrix transfers load between fibres or protects them	**B1**

Answer: The glass fibres provide much of the tensile strength and stiffness. The resin matrix binds and supports the fibres, transfers load between them and protects them from damage.

Question 8

Fibres increase strength or stiffness	**B1**
Relates useful strength/stiffness to low mass	**B1**
Identifies direction, lay-up, bonding or load path as affecting performance	**B1**
Gives a valid design consideration, such as anisotropy, damage inspection, joining or end-of-life separation	**B1**

Answer: Fibres can increase stiffness and strength while keeping the support relatively light. Performance depends on fibre direction, distribution and bonding: a unidirectional laminate is stronger along the fibres than across them, so loads and lay-up must be considered. Composite separation at end of life may also be difficult.

Question 9

Converts 0.36 kg to 360 g	**M1**
Uses volume = mass / density	**M1**
360 / 1.2 = 300 cm^3	**A1**

Answer: 300 cm^3

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Question 10

Multiplies 1,500 by 18 seconds	**M1**
Obtains 27,000 seconds and divides by 3,600	**M1**
7.5 hours	**A1**

Answer: 7.5 hours

Question 11

Distinguishes ability to soften/reprocess from guaranteed collection or recycling	**B1**
Identifies material composition, additives or contamination as a factor	**B1**
Identifies local collection/sorting/processing access as a factor	**B1**
Identifies a further limitation such as design, economics, quality loss or downcycling	**B1**

Answer: Thermoplastics can soften and be reprocessed in principle, but that behaviour does not guarantee that a particular tray will be collected or recycled. Resin identification, colour and additives, contamination, local sorting and processing facilities, product design and the economics of recovery all matter. Reprocessing may also reduce material quality, and some thermoplastics are not accepted in a local scheme.

Question 12

Calculates A as 0.8 / 4	**M1**
A = 0.20 kg per service-year	**A1**
Calculates B as 1.2 / 8	**M1**
B = 0.15 kg per service-year and identifies B as lower on this measure	**A1**
States an explicit valid comparison assumption, such as achieving the stated service lives under comparable use conditions, using the same life-cycle boundary and impact measures, or equal impact per kilogram and negligible/equal other impacts if using mass alone as a proxy. A limitation alone, or merely listing life-cycle stages, does not earn this mark.	**B1**

Answer: A: 0.8 / 4 = 0.20 kg per service-year. B: 1.2 / 8 = 0.15 kg per service-year. On this narrow measure, B uses less material per service-year. For an environmental comparison, assume both designs deliver the same function under comparable use conditions and achieve their stated service lives. Use the same life-cycle boundary and environmental measures for both, including relevant production, transport, maintenance, use and end-of-life impacts. Treating material mass alone as a proxy would additionally assume equal environmental impact per kilogram and negligible or equal other impacts; the data do not establish those assumptions.

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