Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

a thermoplastic softens when heated, so it can be reshaped and recycled; a thermosetting polymer sets permanently when cured and does not soften again

2.2

(a) thermochromic pigment / polymer

(b) photochromic material

2.3

toughness: absorbs energy / impact without breaking; e.g. polycarbonate safety glasses; hardness: resists scratching and wear; e.g. ceramic floor tiles / tool steel

2.4

stress $= 5600 \div 40 = 140$ MPa and strain $= 0.8 \div 400 = 0.002$; $E = 140 \div 0.002 = 70\,000$ MPa $=$ **70** GPa

2.5

titanium $900 \div 4.5 = 200$; steel $400 \div 7.85 \approx 51$; titanium, as it carries about four times the load for the same mass

3.1

(a) steel $670 \div 7.85 \approx$ **85**; aluminium $310 \div 2.7 \approx$ **115**; CFRP $600 \div 1.6 =$ **375**

(b) it combines two materials: strong, stiff carbon fibres in a polymer matrix; together they give properties neither has alone, e.g. high strength with low density

(c) any two, explained: cost: material and process cost per frame must fit the selling price; manufacture: steel and aluminium tubes can be cut and welded; CFRP needs moulds and hand lay-up; environment: steel and aluminium are easy to recycle; CFRP is hard to recycle; aesthetics or availability

(d) award up to [8]: CFRP has the best strength-to-weight (375) but costs about $40 per kg and is hard to recycle; it suits racing bikes, not low-cost city bikes; steel is the cheapest and easy to weld and repair; but it is heavy (low ratio, 85) and can rust unless protected; aluminium is lighter than steel (ratio 115) at moderate cost; it resists corrosion, useful for bikes left outside; both metals are recyclable, unlike CFRP; judgement: aluminium or steel, e.g. steel if cost matters most, aluminium if lower mass is needed

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