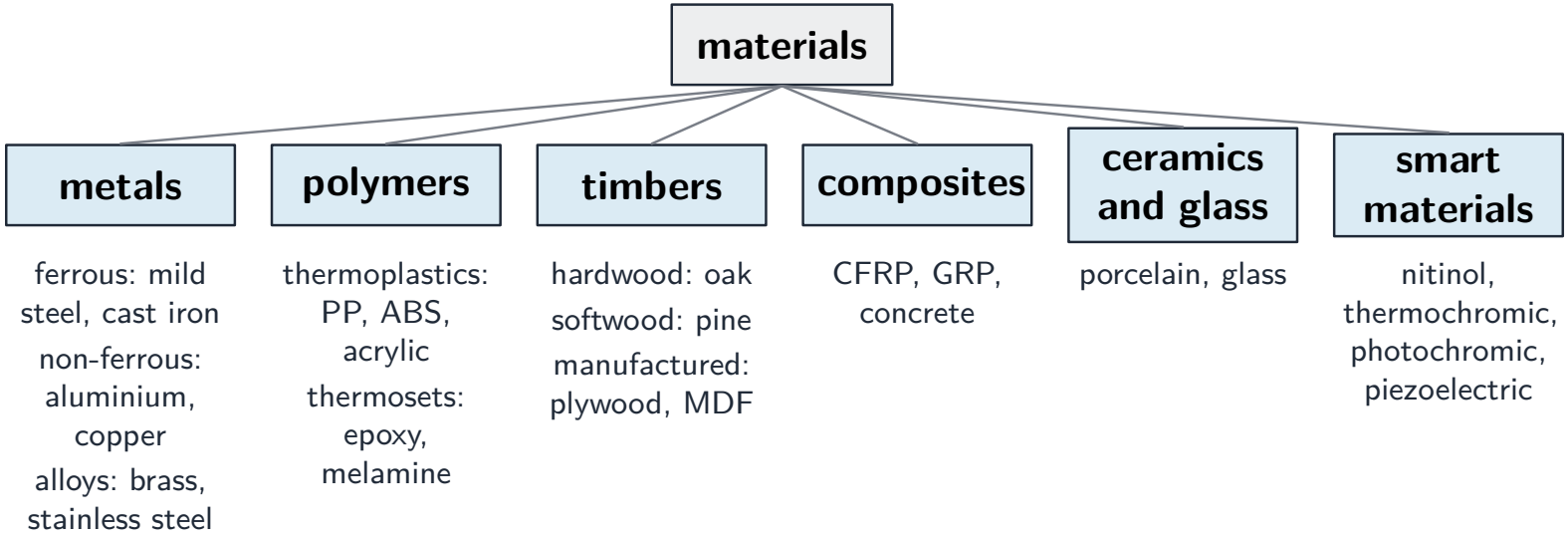
Exercise walk-through

2.3
Materials and their properties

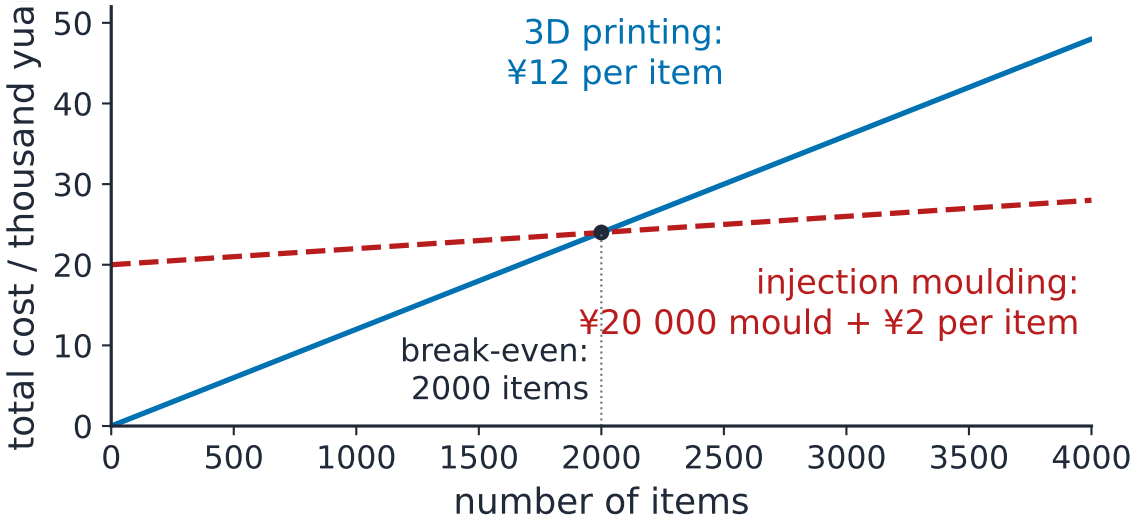
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Six material groups



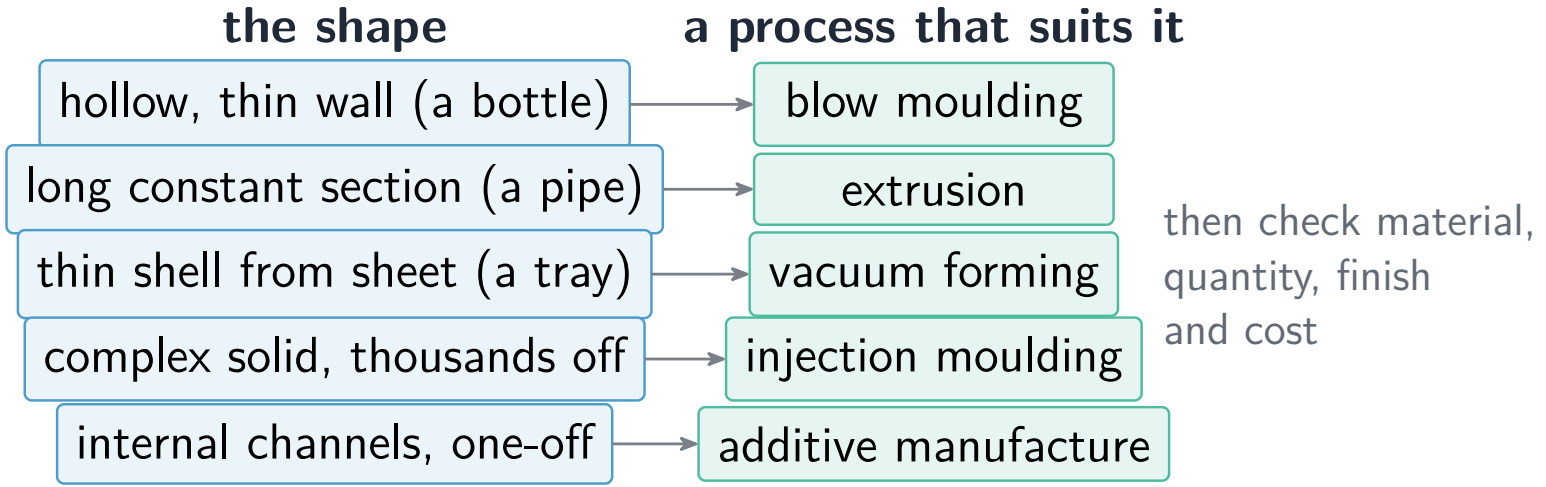
> Name the group, then the family, then the material

Break-even



- Printing ¥12 per item, no tooling.
- Moulding ¥20 000 mould, then ¥2 per item.

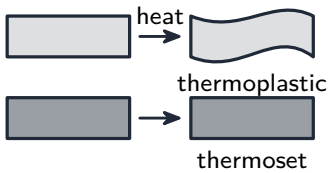
Choose the process from the shape



> The shape and the quantity choose the process

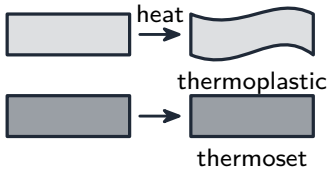
Exercise 2.1

2.1 Distinguish between a **thermoplastic** and a **thermosetting polymer**. [2]



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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

Exercise 2.2 (a)

2.2 Identify a suitable smart material for:

(a) a baby spoon that warns when food is too hot; [1]

Exercise 2.2 (a)

2.2 Identify a suitable smart material for:

(a) a baby spoon that warns when food is too hot; [1]

(a) thermochromic pigment / polymer

Exercise 2.2 (b)

2.2 Identify a suitable smart material for:

(b) glasses lenses that darken outdoors. [1]



Exercise 2.2 (b)

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(b) glasses lenses that darken outdoors. [1]



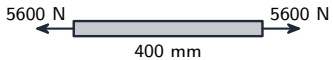
(b) photochromic material

Exercises 2.3·2.4

2.3 Explain the difference between **toughness** and **hardness**, with a product example of each. [4]



2.4 An aluminium rod has a cross-sectional area of 40 mm^2 and a length of 400 mm. A load of 5600 N stretches it by 0.8 mm. Calculate Young's modulus of the aluminium in GPa. [3]



Exercises 2.3·2.4

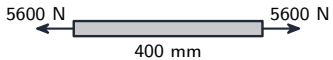
2.3 Explain the difference between **toughness** and **hardness**, with a product example of each. [4]



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 An aluminium rod has a cross-sectional area of 40 mm^2 and a length of 400 mm. A load of 5600 N stretches it by 0.8 mm. Calculate Young's modulus of the aluminium in GPa. [3]



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

Exercise 2.5

2.5 A titanium alloy has a tensile strength of 900 MPa and a density of 4.5 g/cm^3. A steel has a tensile strength of 400 MPa and a density of 7.85 g/cm^3. Calculate the strength-to-weight ratio of each and state which is better for a racing bicycle part. [2]

	strength (MPa)	density (g/cm^3)
titanium alloy	900	4.5
steel	400	7.85

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	strength (MPa)	density (g/cm^3)
titanium alloy	900	4.5
steel	400	7.85

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

Exercise 3.1 (a)

3.1 A bicycle maker is choosing the frame material for a new model. Typical data are shown.

(a) Calculate the strength-to-weight ratio of each material. [3]

	steel	aluminium alloy	CFRP
tensile strength (MPa)	670	310	600
density (g/cm^3)	7.85	2.7	1.6
cost per kg ($)	2	4	40
easy to recycle?	yes	yes	no

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

Exercise 3.1 (b)

3.1 A bicycle maker is choosing the frame material for a new model. Typical data are shown.

(b) Explain why CFRP is described as a **composite**. [2]

Exercise 3.1 (b)

3.1 A bicycle maker is choosing the frame material for a new model. Typical data are shown.

(b) Explain why CFRP is described as a **composite**. [2]

(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

Exercise 3.1 (c)

3.1 A bicycle maker is choosing the frame material for a new model. Typical data are shown.

(c) Explain **two** factors, other than mechanical properties, that affect the choice of frame material. [4]

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(c) Explain **two** factors, other than mechanical properties, that affect the choice of frame material. [4]

(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

Exercise 3.1 (d)

3.1 A bicycle maker is choosing the frame material for a new model. Typical data are shown.

(d) Discuss which material the firm should use for a low-cost city bicycle made in large numbers. [8]

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(d) Discuss which material the firm should use for a low-cost city bicycle made in large numbers. [8]

(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