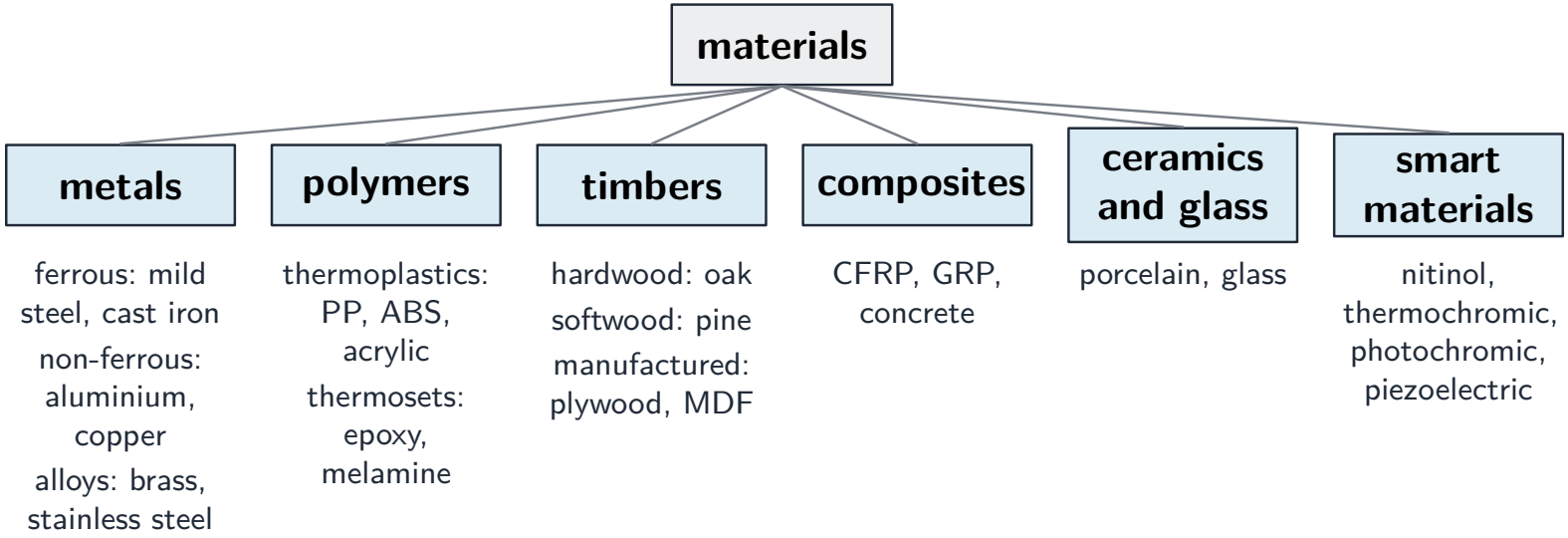
Exercise walk-through

# 2.3
# Materials and their properties

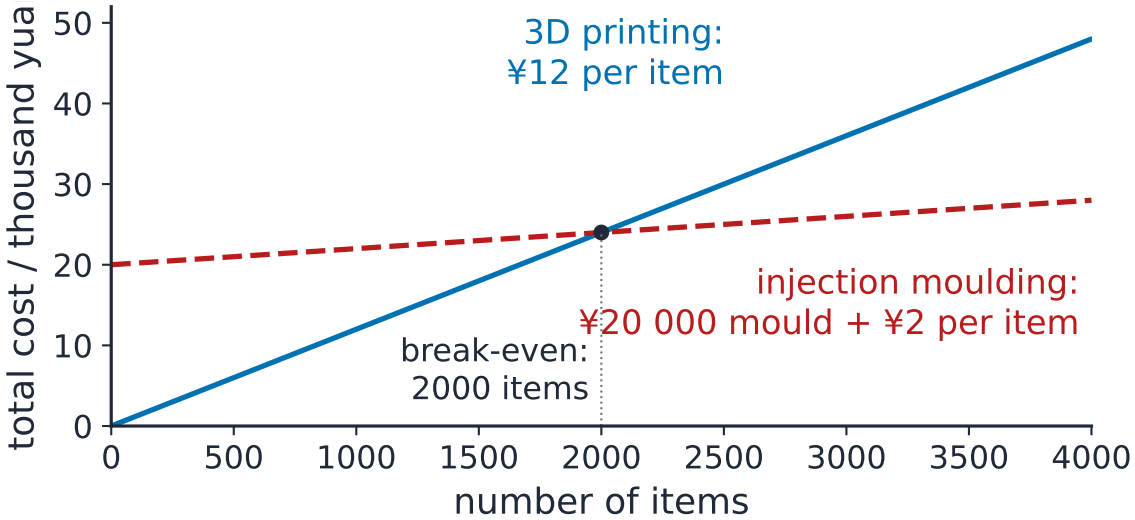
International Baccalaureate · IB Diploma · Design Technology · SL

# Six material groups



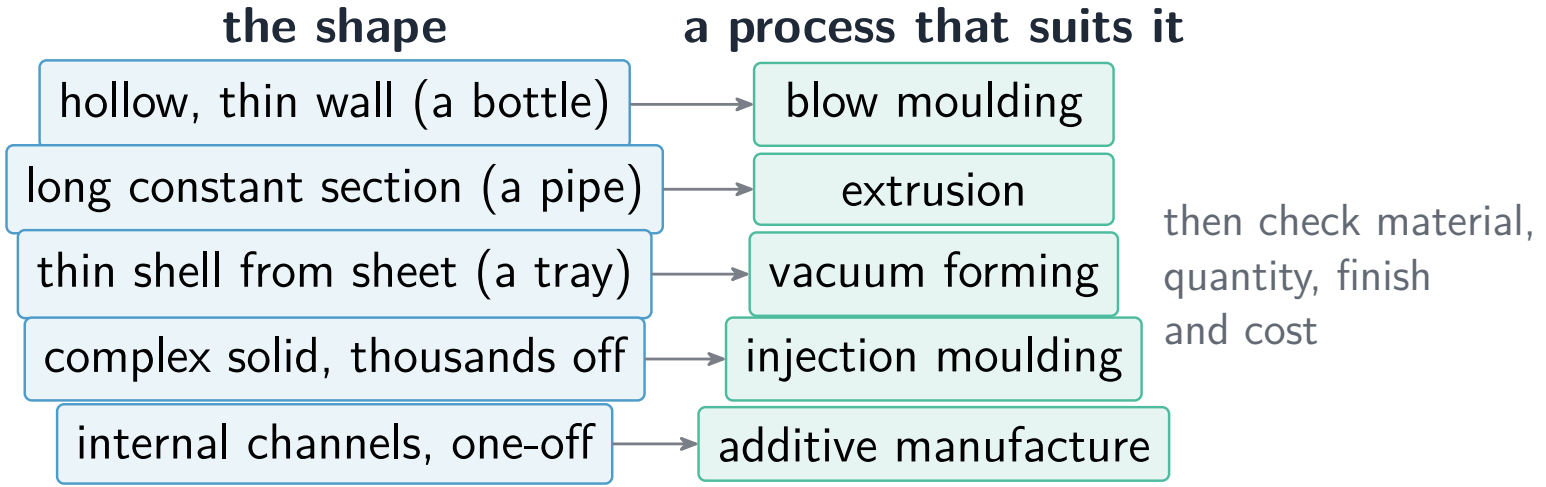

> Name the group, then the family, then the material

# Break-even




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

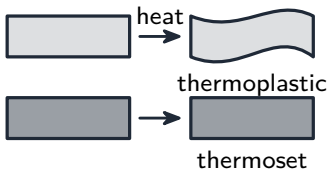
# Choose the process from the shape




> The shape and the quantity choose the process

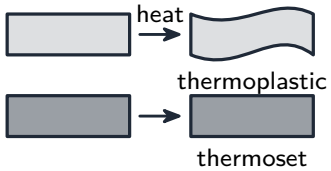
# Exercise 2.1

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



# Exercise 2.1

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




**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)

**2.2** Identify a suitable smart material for:

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



(b) photochromic material

# Exercise 2.3

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





# Exercise 2.3

**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

# Exercise 2.4 (a)

**2.4** A steel rod with a cross-sectional area of 20 $\text{mm}^2$ carries a load of 3000 N. The steel yields at 250 MPa.

(a) Calculate the stress in the rod. [2]

# Exercise 2.4 (a)

**2.4** A steel rod with a cross-sectional area of 20 $\text{mm}^2$ carries a load of 3000 N. The steel yields at 250 MPa.

(a) Calculate the stress in the rod. [2]

(a) $3000 \div 20 = \mathbf{150}$ MPa

# Exercise 2.4 (b)

**2.4** A steel rod with a cross-sectional area of 20 $mm^2$ carries a load of 3000 N. The steel yields at 250 MPa.

(b) Calculate the factor of safety against yielding. [1]



# Exercise 2.4 (b)

**2.4** A steel rod with a cross-sectional area of 20 $\text{mm}^2$ carries a load of 3000 N. The steel yields at 250 MPa.

(b) Calculate the factor of safety against yielding. [1]




(b) $250 \div 150 \approx \mathbf{1.7}$

# 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 |

# 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 |

**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 |

# 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 |

(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]

# 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]

(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]

# 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]

(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