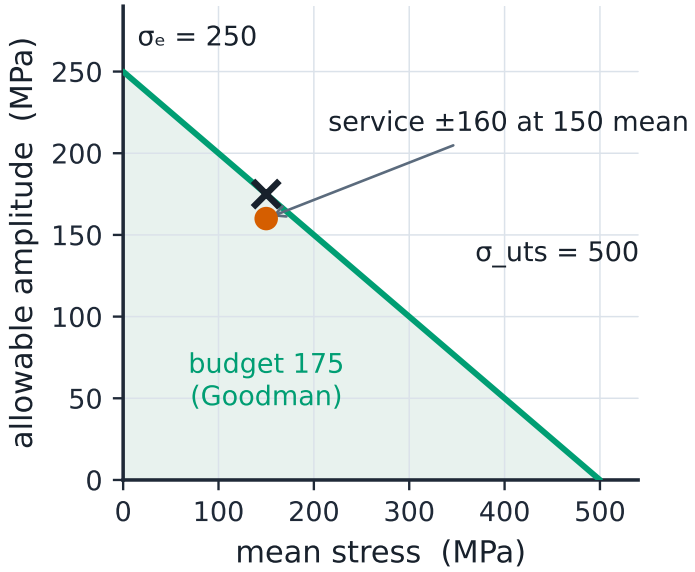
Exercise walk-through

# 4.1
# Structure and bonding

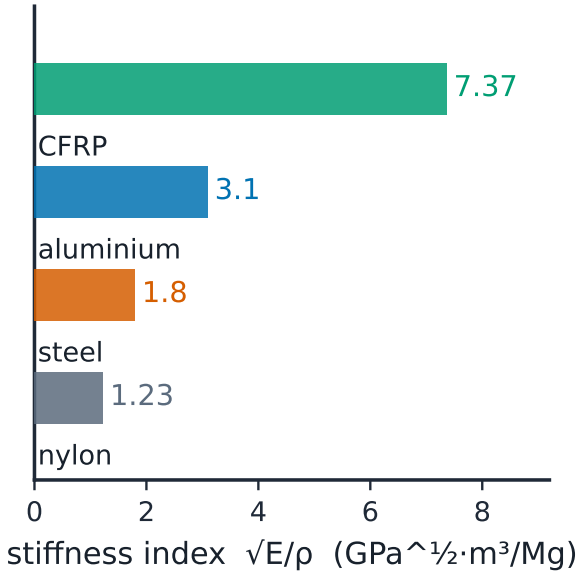
University Mechanical Engineering

# Failure and selection: show the arithmetic

Goodman: the mean eats the budget




The index ranks; constraints eliminate




Goodman cuts 250 to **175** MPa at 150 mean; CFRP leads the stiffness index.

# Selection in action: one method, two answers

1. **Rank** $\sqrt{E}/\rho$: CFRP 7.37 wins stiffness-per-mass at 2.4× aluminium.
2. **Eliminate** Plain nylon fails the $T_g$ constraint; ceramics fail the survival probability at these loads.
3. **Split** The mount ships quenched-and-tempered steel (620 MPa, 16%); the carry-handle ships CFRP.

# The project sheet, reproducible

1. **Structure** BCC 0.6802, FCC 0.7405; Hall-Petch 183.6 $\rightarrow$ 262.3 MPa for 50 $\rightarrow$ 10 µm.
2. **Certificate** Rod 191.0 MPa: 0.477 vs 1.364 mm; true ln 1.2 $=$ 0.1823; **toughness** 176 MJ/m$^3$.
3. **Choice** Routes 280/24, 260/26, 620/16, 950/8; Chvorinov 22.2 vs 50.0 s; Basquin 226.1 $\rightarrow$ 142.6; Goodman 175.0; index 7.37 / 3.10 / 1.80 / 1.23 - steel mount, CFRP handle.

# Exercises 2.1·2.2

**2.1** The yield strength at grain sizes 25 µm and 16 µm (one decimal each). [4]

**2.2** The largest grain size that meets a 300 MPa specification (micrometres, one decimal). [3]

# Exercises 2.1·2.2

**2.1** The yield strength at grain sizes 25 µm and 16 µm (one decimal each). [4]

**2.1**

- $\sigma_y(25) = 100 + 0.60/\sqrt{25 \times 10^{-6}} = 100 + 120.0 = 220.0$ MPa.
- $\sigma_y(16) = 100 + 0.60/0.004 = 250.0$ MPa.

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**2.2** The largest grain size that meets a 300 MPa specification (micrometres, one decimal). [3]

**2.2**

- $100 + 0.60/\sqrt{d} \geq 300$ gives $\sqrt{d} \leq 0.003$ m$^{1/2}$.
- $d \leq 9.0$ µm.

# Exercises 2.3·2.4

**2.3** The atomic packing factors of BCC and FCC (four decimals each), computed from the hard-sphere geometry. [4]

**2.4** One sentence each: why does FCC deform more easily than BCC at room temperature, and why do grain boundaries strengthen a metal? [3]

# Exercises 2.3·2.4

**2.3** The atomic packing factors of BCC and FCC (four decimals each), computed from the hard-sphere geometry. [4]

**2.3**

- BCC: $2 \times \frac{4}{3}\pi(\sqrt{3}a/4)^3/a^3 = \pi\sqrt{3}/8 = 0.6802$.
- FCC: $4 \times \frac{4}{3}\pi(\sqrt{2}a/4)^3/a^3 = \pi/(3\sqrt{2}) = 0.7405$.

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**2.4** One sentence each: why does FCC deform more easily than BCC at room temperature, and why do grain boundaries strengthen a metal? [3]

**2.4**

- FCC's closer packing (0.7405 vs 0.6802) carries more close-packed slip systems, so dislocations glide more easily.
- Grain boundaries block dislocation motion; more boundaries (smaller grains) mean more blocking and higher yield.