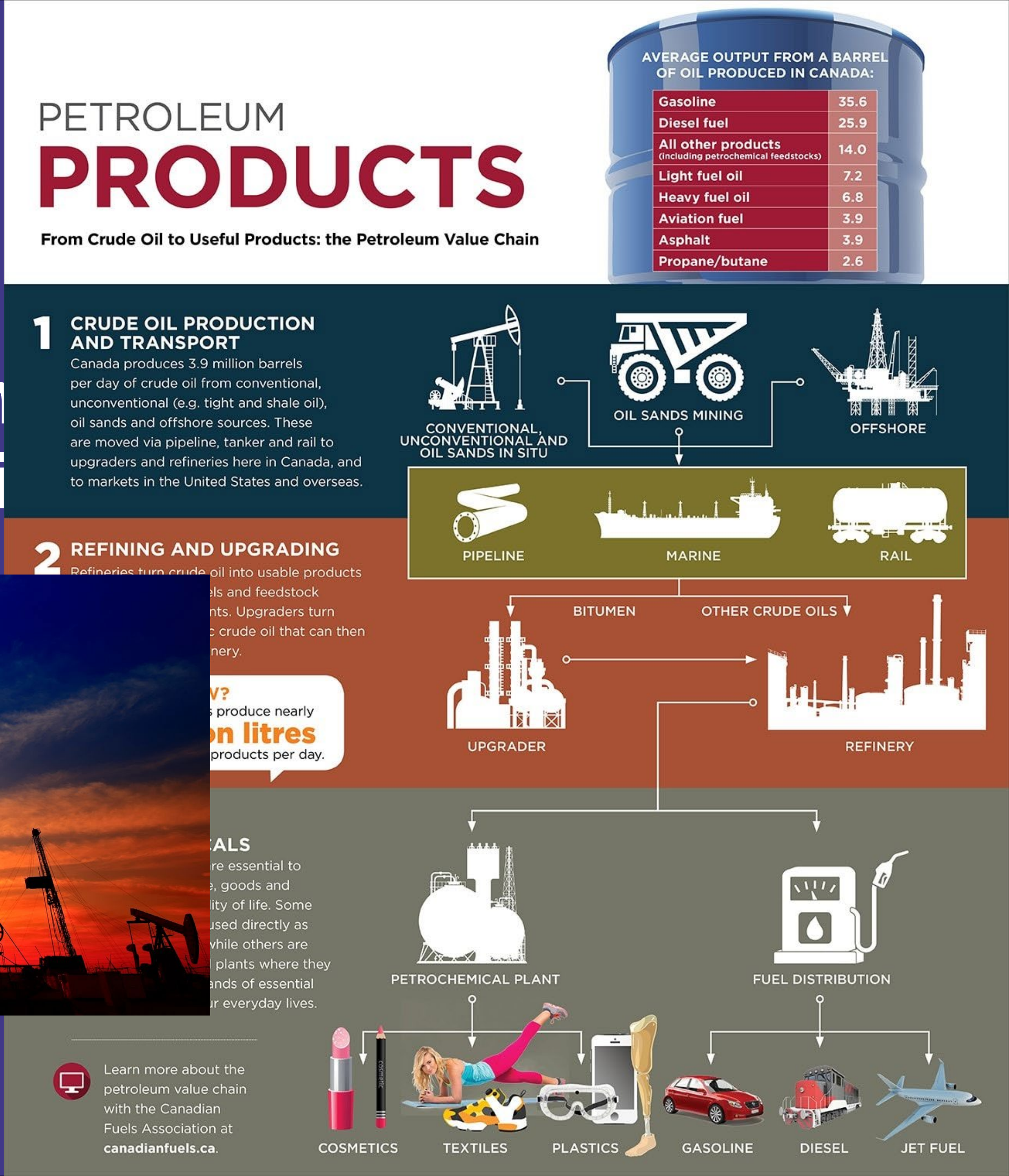
Imperial College London

Materials an Manufacturi

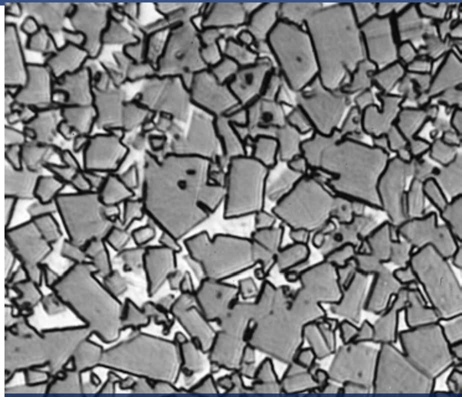


https://www.youtube.com/watch?v=winJj-1Q3uk

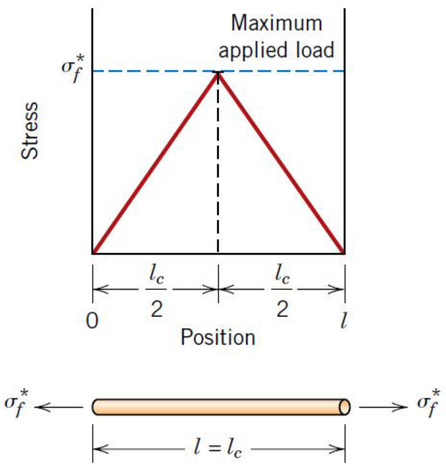
Last time on M&M…

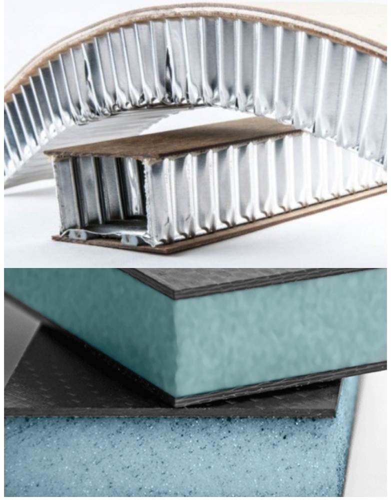
Composites

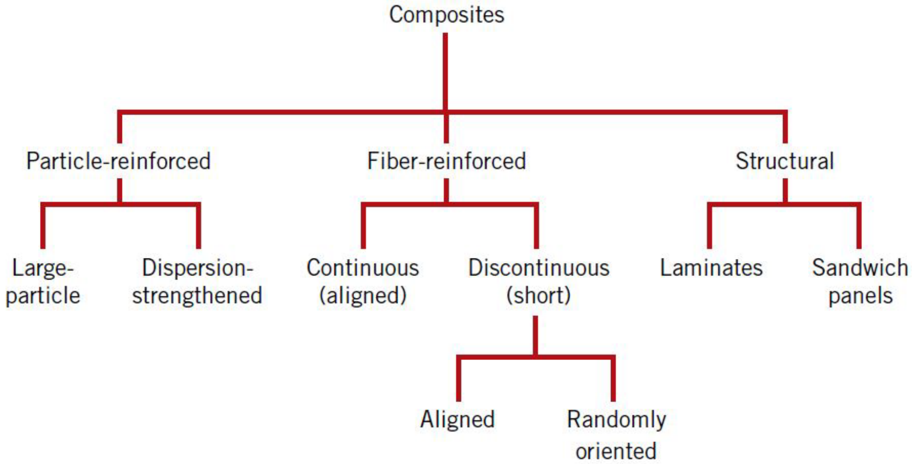
- Particle-reinforced composites
  - Large particle and dispersion strengthened
- Fiber-reinforced composites
  - Continuous and discontinuous
  - Critical fiber length
  - Longitudinal and transverse loading
- Structural composites
  - Laminates and sandwich panels
- Metal-matrix, polymer-matrix, Ceramic-matric composites



Micrograph of tungsten carbide particles in a cobalt matrix







Learning objectives

- Evaluate the recyclability/disposability issues relative to different materials
- Analyse how the strength performance index is determined
- Apply materials selection charters for the determination of optimal materials in an application

Why is it important?

Artificial total hip replacement

Perhaps one of the most important tasks that an engineer may be called upon to perform is that of materials selection with regard to component design.

Inappropriate or improper decisions can be disastrous from both economic and safety perspectives. Therefore, it is essential that the engineering student become familiar with and versed in the procedures and protocols that are normally employed in this process.

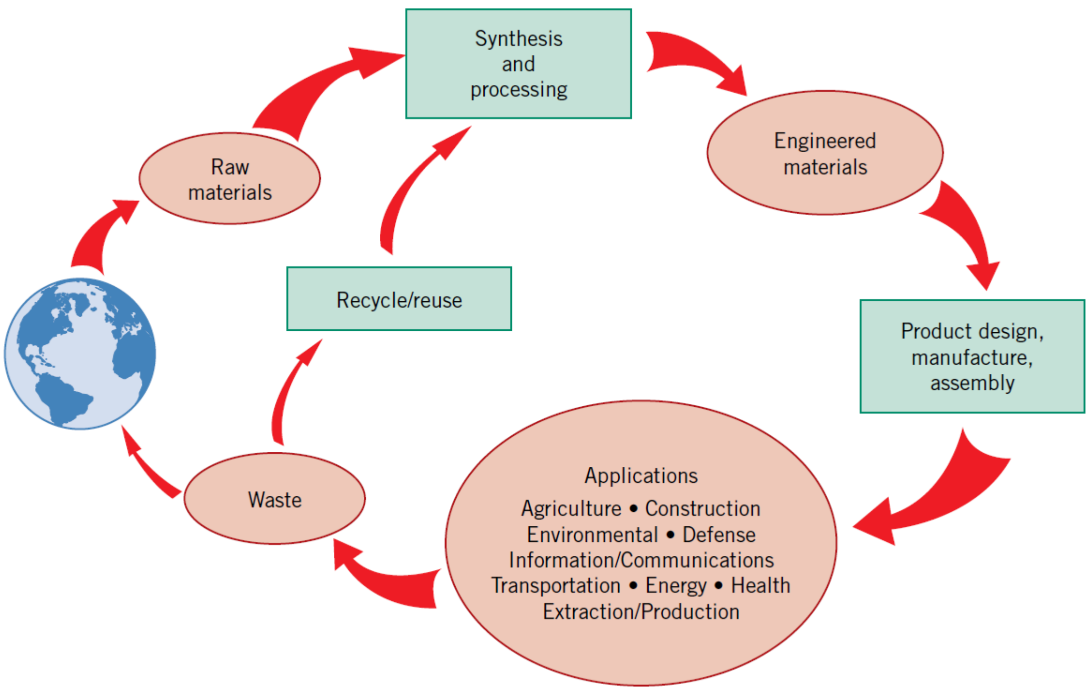
As a design engineer you might…

- Design a new materials having unique property combinations
- Selecting a new material having a better combination of characteristics for a specific application
- Developing a process for producing a material having better properties

Recycling

Important stages in the materials cycle where materials science and engineering plays a significant role are recycling and disposal.

- **Recyclable** - a material, after having completed its life cycle in one component, could be reprocessed, could reenter the materials cycle, and could be reused in another component
  - A process that could be repeated an indefinite number of times
- **Biodegradable** - by interactions with the environment (natural chemicals, microorganisms, oxygen, heat, sunlight, etc.), the material deteriorates and returns to virtually the same state in which it existed prior to the initial processing
- Engineering materials exhibit varying degrees of recyclability and biodegradability



Recycling - Metals

- Most metals (Fe, Cu) undergo corrosion and are also biodegradable
- Some metals are toxic (Hg, Pb) and are health risks
- Quality of alloys drops with each cycle
- Product designs should allow for the dismantling of components composed of different alloys
- Should think about how to separate different metals after shredding (magnetic and gravity)
- Coating and paints may act as contaminates preventing recyclability
- Aluminium is very corrosion resistant and therefore non-biodegradable
    - But aluminium is very recyclable and the relative energy cost is low

Recycling - Glass

- Glass is the largest quantity ceramic material which is consumed
- Very inert and does not decompose – not biodegradable
- A significant proportion of land-fills consists of waste glass
- Not much of an economic drive for glass recycling as the raw materials are very cheap
- Also salvaged glass (cullet) must be sorted by colour, type and composition
  - Adds to the cost of the recycling
  - Scrap glass has a low market value
- Advantages are more rapid production rate and a reduction in pollutant emissions

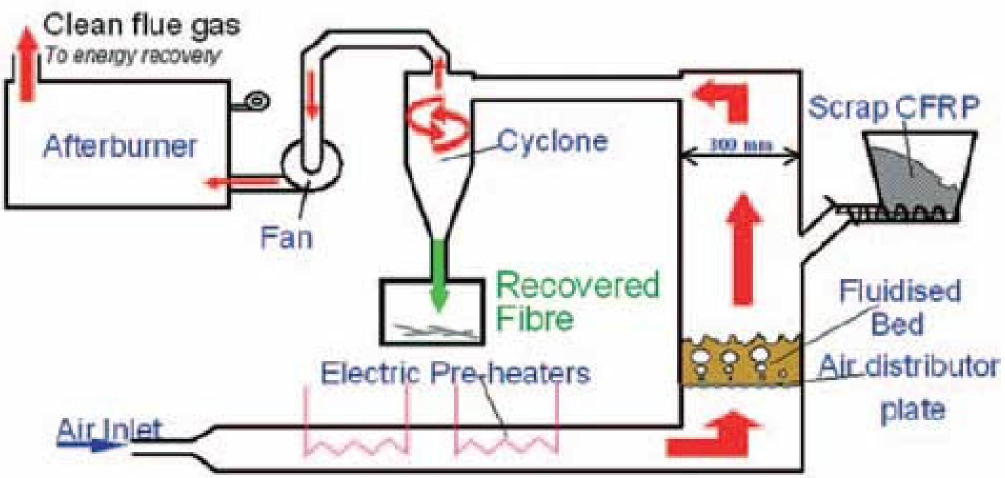
Plastics and rubbers

- Typically biologically inert
- Significant land-fill proportion
- Do have biodegradable polymers but are expensive
- Some polymers are combustible and can incinerate
- Plastics need to be sorted
- Application changes depending if it's the virgin material or recycled
- Recycled plastic is cheaper but properties have degraded
- Thermoplastics are easiest to recycle
- Thermosets are hard

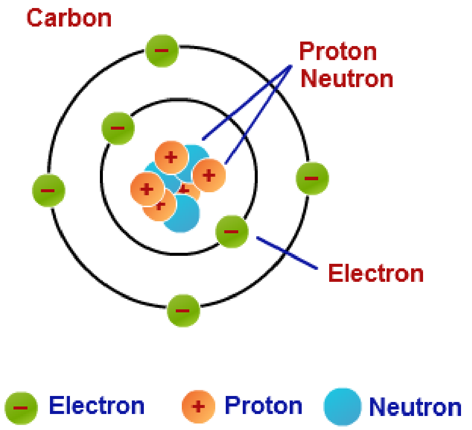
Recycle code	Polymer name	Uses of virgin material	Recycled products
1	Poly(ethylene terephthalate)(PET or PETE)	Plastic beverage containers, mouthwash jars, peanut butter and salad dressing bottles	Liquid-soap bottles, strapping, fiberfill for winter coats, surfboards, paint brushes, fuzz on tennis balls, soft-drink bottles, film, egg cartons, skis, carpets, boats
2	High-density polyethylene (HDPE)	Milk, water and juice containers, grocery bags, toys, liquid detergent bottles	Soft-drink bottle base caps, flower pots, drain pipes, signs, stadium seats, trash cans, recycling bins, traffic-barrier cones, golf bag liners, detergent bottles, toys
3	Poly(vinyl chloride) or vinyl (V)	Clear food packaging, shampoo bottles	Floor mats, pipes, hose, mud flaps
4	Low-density polyethlyene (LDPE)	Bread bags, frozen-food bags, grocery bags	Garbage can liners, grocery bags, multipurpose bags
5	Polypropylene (PP)	Ketchup bottles, yogurt containers and margarine tubs, medicine bottles	Manhole steps, paint buckets, videocassette storage cases, ice scrapers, fast food trays, lawn mower wheels, automobile battery parts
6	Polystyrene (PS)	Videocassette cases, compact disc jackets, coffee cups; knives, spoons, and forks; cafeteria trays, grocery store meat trays, and fast-food sandwich containers	License plate holders, golf course and septic tank drainage systems, desktop accessories, hanging files, food service trays, flower pots, trash cans, videocassettes

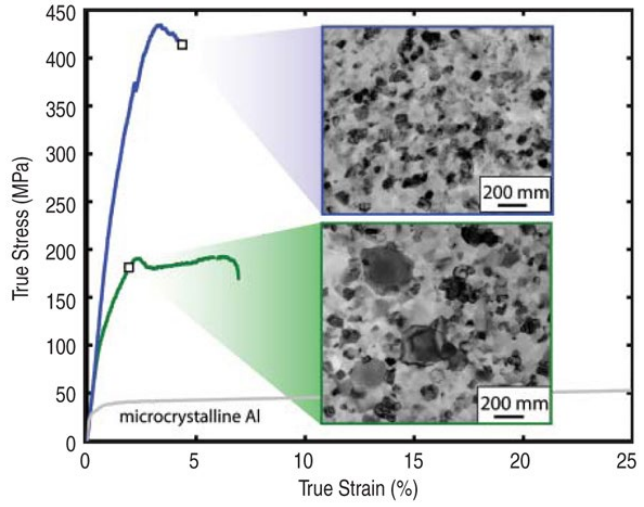
Recycling - Composites

- Composites are difficult to recycle as they are multi-phase materials
- Very difficult to separate the phases
- Some success has been made with polymer-matrix composites
- First step is shredding to fine particles
- Sometimes the particles are used as fillers and blended into other polymer matrices
- Some techniques allow for the separation of fibres and matrix materials
- After the shredding process the fibers becomes shorter and strength will be degraded



Combining all your knowledge



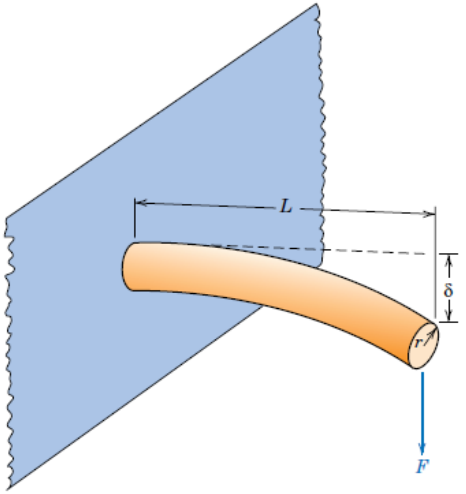


Example – Telephone line ladder

Select a material for the poles on a telephone line ladder

Requirements

- Stiffness



Cantilevered beam

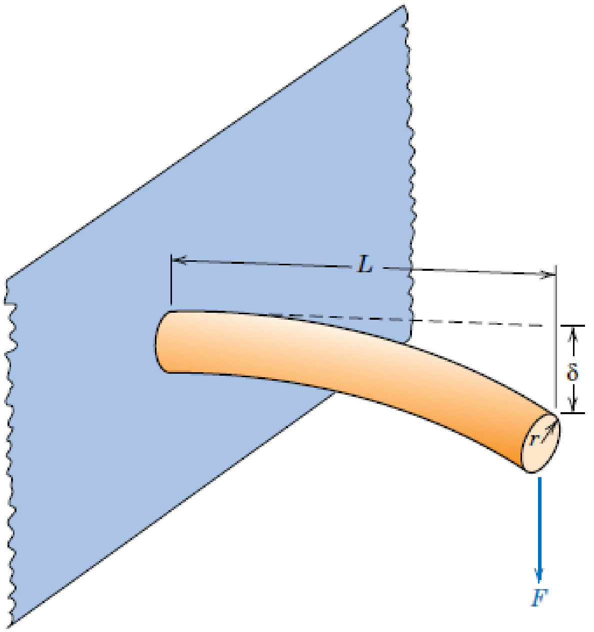
Establish criterion for selection of stiff and strong materials

$$\delta = \frac{FL^3}{3EI}$$

$$I = \frac{\pi r^4}{4}$$

$$\delta = \frac{4FL^3}{3E\pi r^4}$$

δ = End deflection
L = Length
W = Load
E = Young's Modulus
I = Polar moment of inertia



Performance index - Strength

Taking mass into consideration

$$m = \pi r^2 L\rho$$

$$r = \sqrt{\frac{m}{\pi L\rho}}$$

Substituting into the shear strength equation

$$\delta = \frac{4FL^3}{3E\pi r^4}$$

$$\delta = \frac{4FL^3}{3\pi E\left(\sqrt{\frac{m}{\pi L\rho}}\right)^4} = \frac{4FL^5\pi\rho^2}{3Em^2}$$

Solving this equation results in

$$m = \left(\frac{4FL^5\pi}{3\delta}\right)^{1/2}\frac{\rho}{\sqrt{E}}$$

Safe functioning of the shaft

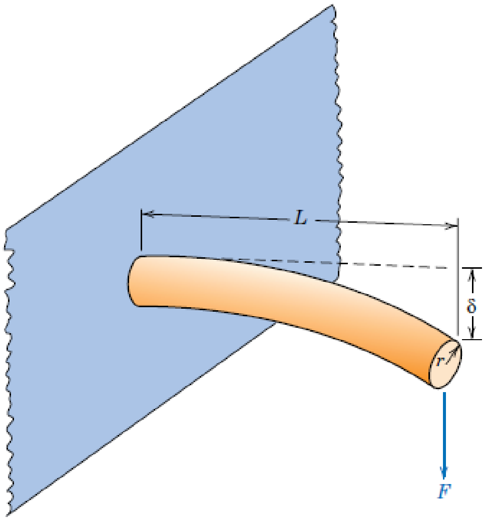
Geometric parameters

Material properties

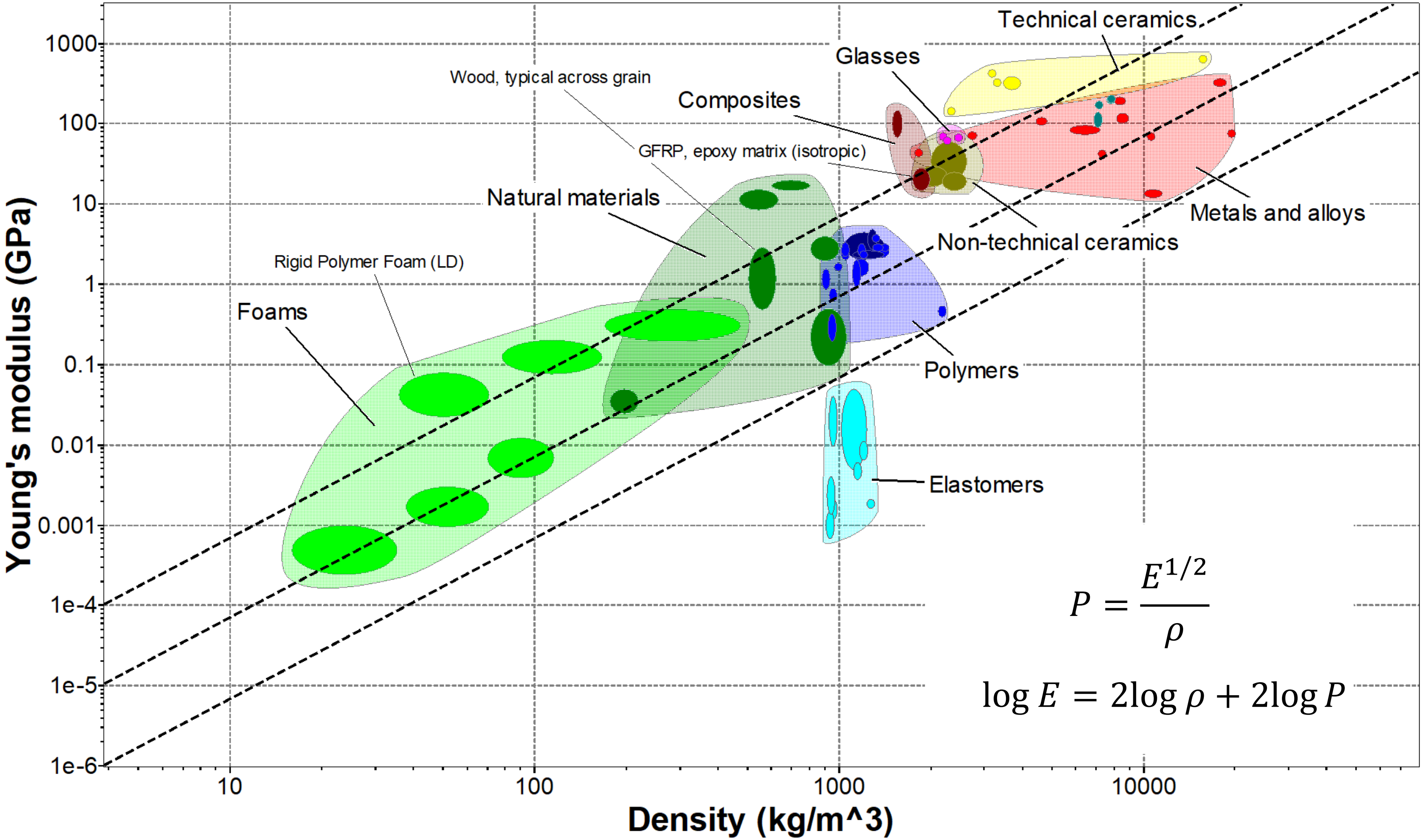
Performance index

$$P = \frac{E^{1/2}}{\rho}$$

We want materials with a high performance index



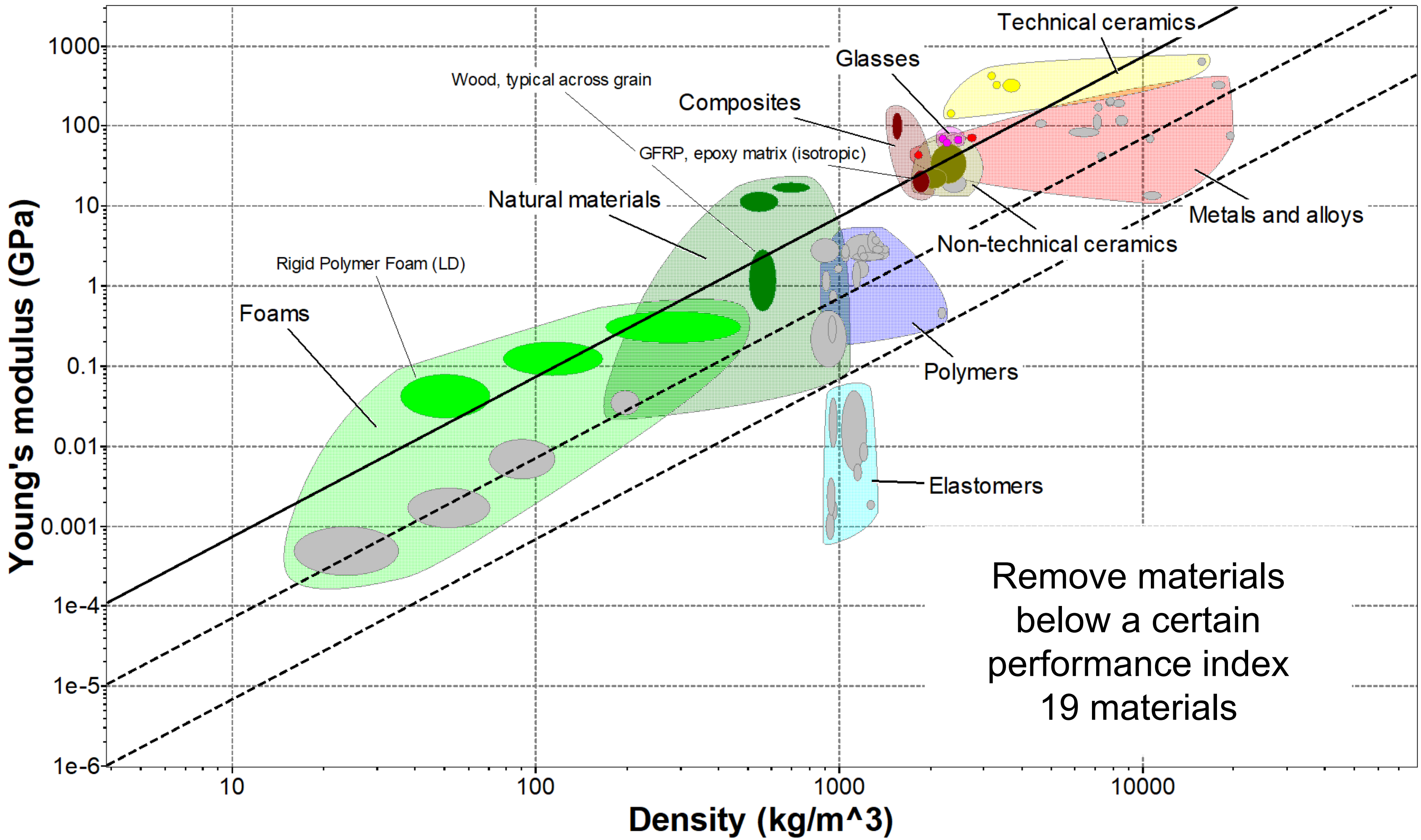
Ashby plot



$$P = \frac{E^{1/2}}{\rho}$$

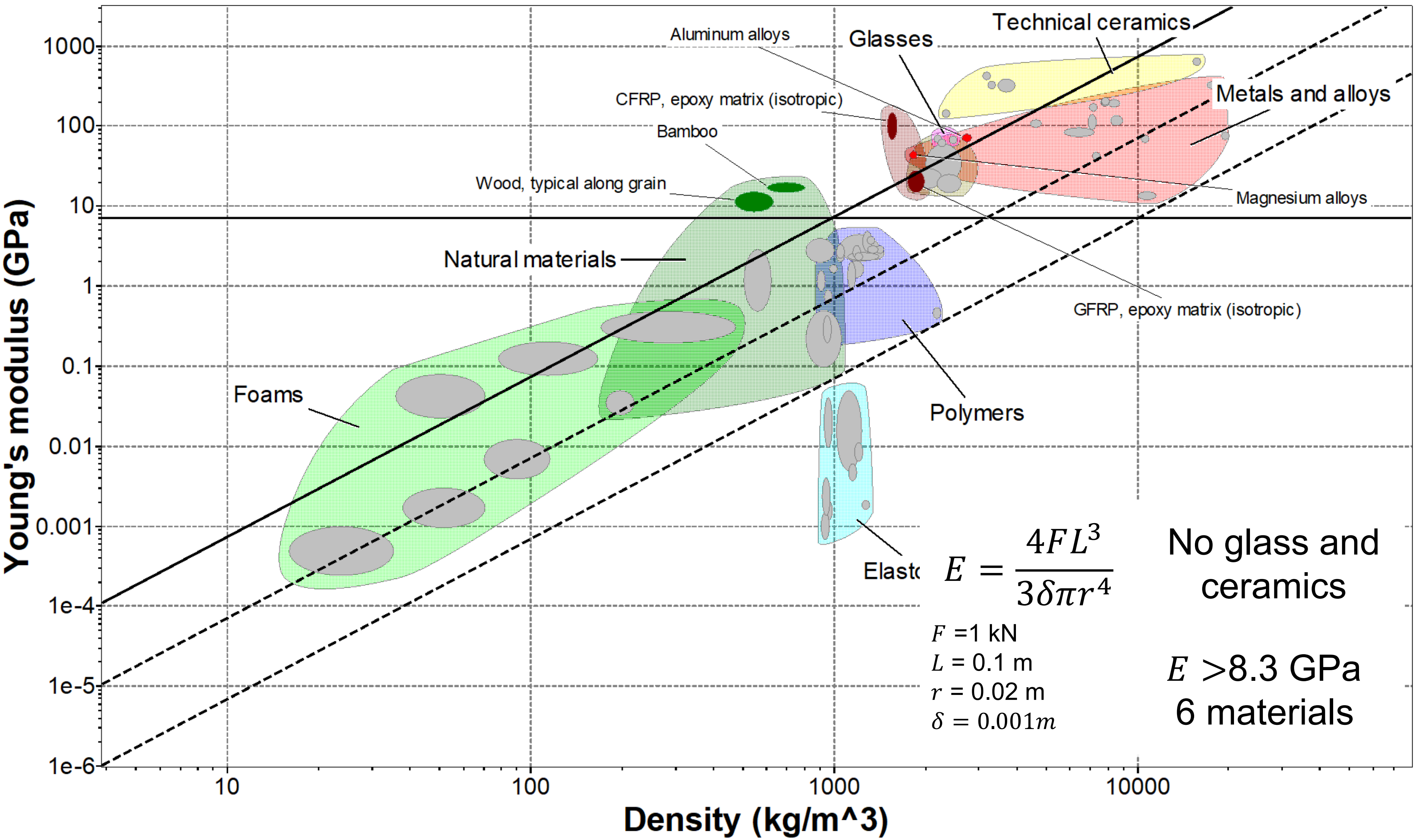
$$\log E = 2\log\rho + 2\log P$$

Ashby plot



Remove materials below a certain performance index
19 materials

Ashby plot



$$E = \frac{4FL^3}{3\delta\pi r^4}$$

F =1 kN
L = 0.1 m
r = 0.02 m
$\delta = 0.001m$

No glass and ceramics

E >8.3 GPa
6 materials

Performance index of materials

Material	Young's Modulus (GPa)	Density (kg/m^3)	Performance index $E^{1/2}/\rho$
Carbon fibre reinforced polymer	110	1550	7.81
Aluminium alloy	72	2725	1.90
Magnesium alloy	44	1810	1.07
Bamboo	18	700	0.46
Wood	12	485	0.30
Glass fibre reinforced polymer	22	1860	0.26

Summary

- Evaluate the recyclability/disposability issues relative to different materials
- Analyse how the strength performance index is determined
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Next time on M&M…