Materials 2 Questions set 1, Comments and answers
Materials foundation, and the **WHAT** framework

All the questions in this set are **open questions** – that means they can have a range of answers. In consideration and discussions different opinions can be shared and shaped. Some answers will be wrong, but there is not a single correct answer.

In future Questions sets there will be questions that have a single "correct" answer (these may feel more familiar and comfortable for many of you, as many engineering courses use these types of questions).

However, engaging with open questions, and getting somewhat comfortable with them, is valuable for your learning:
"Developing a broad knowledge of the underpinning science of materials, and how this links with properties, enables you to apply these concepts in engineering. This involves **thinking carefully**, **discerning key concepts** in a particular situation, and beginning to appreciate the **complexities**, **subtleties** and **ambiguities** that arise when dealing with materials. This skillset is part of your development as a problem-solving engineer." Course Guide, p1.

PRINCIPLE: Being clear on terminology **core**

When we deal with and communicate about materials & engineering **being clear** on what we mean is important.

In terms of learning and using specific **terminology**, and more generally ensuring we have a shared understanding of what we mean when we use particular words in particular situations.

This is important when learning a new subject e.g. materials science and engineering in Materials 2, and when collaborating across disciplines where the same terminology can mean different things – in engineering and research. And in collaboration when the other person does not understand the specific words because they have limited knowledge of the subject.

extra Examples I have come across in my research, where one word is used in two ways: the term **'avalanche'** is used for (a) snow avalanches and (b) for the collective movement of dislocations in metals, and **'basal sliding'** is used for (a) the motion of a glacier down a mountain – the bulk glacial ice sliding over the earth surface that is under the ice), and (b) to describe deformation phenomena at the level of atoms in a crystal structure, (plastic deformation of ice in a glacier). *I recall feeling confused about this when I first got into the topic, but now I generally understand what's meant, and if I'm not clear I ask.*

1. What are the important and interesting materials in your engineering discipline, and why?

This question links to **applications** and the **classification** of materials (**WHAT** framework).

In considering this question it is worth reflecting on **what you find interesting**, as well as what's important. When something interests us in it's easier and more fun to engage with – this is a great principle to hold in mind for learning well.

What follows is a **compilation of links and comments on important and interesting materials in engineering**. *You do not need to look at all these but it's worth looking at the range of applications that involve materials – and not only in your engineering discipline.*

Chemical Engineering, and materials with links with some links with mechanical engineering (From Simone Dimartino)

4D printing of shape memory polymers
https://selfassemblylab.mit.edu/ or https://www.nature.com/articles/srep13616

Self-healing materials
https://www.nature.com/articles/s41578-020-0202-4, https://softroboticstoolkit.com/book/current-applications-self-healing-materials,https://link.springer.com/article/10.1134/S207511331805026X

Nature (mussel) inspired adhesives for use in wound repair (biomed/surgery)
https://www.sciencedirect.com/science/article/pii/S0014305719300588, https://www.pharmaceutical-journal.com/news-and-analysis/opinion/blogs/mussel-adhesive-for-wounds/11117439.blog?firstPass=false, https://www.sciencedaily.com/releases/2015/07/150721111211.htm, https://berkshire.com/mussel-glue-fetal-surgery/,https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6044989/, https://link.springer.com/article/10.1134/S207511331805026X

Something else quite cool (to me at least!) is superhydrophobic and self-cleaning coatings.

Cellular structures
https://www.sciencedirect.com/science/article/pii/S0264127519300176#f0005

Civil Engineering Applications (from Tom Reynolds):

Mjostarnet 18-storey timber building:
https://www.moelven.com/mjostarnet/

The MX3D 3D-printed steel footbridge
https://mx3d.com/industries/mx3d-bridge/

Aberfeldy footbridge GFRP, Aramid cables
https://www.research.ed.ac.uk/portal/files/3582804/CGB_STRAT.pdf

London Aquatics Centre: concrete for (almost) everything https://www.concretecentre.com/Case-Studies/Aquatics-Centre,-London.aspx

Glass fibre reinforced concrete facade panels :
https://grca.org.uk/pdf/congress-2011/10%20The%20Masdar%20Institutes%20GRC%20Residential%20Facade.pdf

Queensferry crossing towers:
Queensferry Crossing: Role of concrete in the design and execution of the project

Mechanical Engineering Applications (from JB):

Composite materials, e.g. for tidal turbines, bikes, skis
https://www.fastblade.eng.ed.ac.uk
https://www.cannondale.com/en-gb/bikes/road/gravel/topstone-carbon
https://www.hexcel.com/Markets/WinterSports

Jet turbines, aerospace industry
https://www.rolls-royce.com/products-and-services/civil-aerospace.aspx

Biomedical engineering
https://www.imeche.org/industry-sectors/biomedical-engineering

Automotive industry
https://www.smmt.co.uk/industry-topics/uk-automotive/

Energy industries
Here's one example Sunamp is a local & global company, they employ mechanical, chemical and electrical engineers, and chemists
https://sunamp.com/en-gb/

Processing and manufacturing industries, e.g. steel industry, and additive manufacturing
https://www.uksteel.org
https://www.twi-global.com/technical-knowledge/faqs/what-is-additive-manufacturing

Bike components (metallic alloys and composites) – a UK company
https://www.hopetech.com
it's history – how it began as a subcontracting machining company for the aerospace industry before becoming a bike component manufacturer
https://www.hopetech.com/about-us/#:~:text=Hope%20Technology%20began%20life%20in,the%20newly%20developed%20mountain%20bikes.

Foiling – wing and surf
https://deltahydrofoil.com
https://armstrongfoils.com/en-gb/products/surf-board

Drones, e.g. Flowcopter – a local company that has its origins in research from Mechanical Engineering in Edinburgh University – in Stephen Salter's research group
https://www.flowcopter.com/team
The Guardian newspaper has captured Stephen Salter's maverick brilliance:
https://www.theguardian.com/technology/2024/mar/08/stephen-salter-obituary

W.L. Gore – materials – used across disciplines:
https://www.gore.com
https://www.bbc.co.uk/news/world-us-canada-54224405

Multidisciplinary of engineering
Although you are taking degrees in specific subjects often interesting engineering challenges cross the boundaries between traditional disciplines. Quite a few PhD students and academic staff move between these boundaries. This is why research in our School of Engineering in Edinburgh is organised into Research institutes https://www.eng.ed.ac.uk/research/institutes rather than in line with traditional engineering disciplines that we teach.

All of us who were involved in curating the course found that our technical direction and interests have shifted during our careers, often expertise in *mechanics* has been supplemented by more expertise in *chemistry* and vice versa. And areas that interested us as undergraduates generally still interest us, for some of us this is decades later. It is worth being aware the direction you take is likely to change over time, and being open to what opportunities arise.

2. Consider the objects in the photograph below, from left to right they are: a spoon, a teacup and a water bottle for outdoor sport use.
Briefly answer the following (*answer based on what you know already, or you can find out easily. We will cover properties and small scale structure of materials in in the course*):

This question is about identifying materials and beginning to apply the **WHAT** framework to several everyday objects.

a) Identify the materials in the objects.

This question links to the **classification** of materials (**WHAT** framework).

The question can be answered on a number of levels from simple: spoon, metal; teacup, ceramic; water bottle, polymer, to more detailed (considered below).

Consider how you [already] know what these materials are? (My answer is that I 'just do', I learned this years ago). This fits with "**learning by awareness** [of what I already know and understand]"

Resource:
Techniques for identifying different material classes (it is useful to know about this information and how much detail you can go into)
https://www.doitpoms.ac.uk/tlplib/artefact/metals.php
https://www.doitpoms.ac.uk/tlplib/artefact/polymers.php
https://www.doitpoms.ac.uk/tlplib/artefact/ceramics.php

Objects: spoon, mug, water bottle **What materials are they made from?**
(a) spoon
metal
probably stainless steel
And more you could see if you can hold it and look more closely:
18:10, it says on the back
what does 18:10mean?
Fe + 18Cr + 10Ni
Fe = iron
what is 18Cr what's 10Ni? 18 weight % Cr 10 weight % Ni and the rest is Fe

(b) Mug
ceramic / pottery
ceramic (traditional clay based ceramic)
glazed (the blue outer coating)

(c) Water bottle
Polymer
And more you could see if you can hold it and look more closely:
it's an amorphous polyester
how we found this out is detailed below:
7 [it says on the base] What does that mean …?

Other ?? what does this mean?
More information … nalgene [it says on the side – the company that made it]
https://nalgene.com/product/32oz-wide-mouth-bottle/
Material = "Tritan" … manufactured by Eastman, Tritan is an amorphous polyester. See its datasheet:
https://productcatalog.eastman.com/tds/ProdDatasheet.aspx?product=71070314

b) What are the objects used for (i.e. what are their applications)?

This question links to **applications** (**WHAT** framework).

spoon – for eating food, like soup or yogurt
teacup – for drinking beverages (hot and cold)
water bottle – for transporting water (or hydrating liquid)

c) What properties of materials are needed in these applications?

This question links to **properties** of materials (**WHAT** framework).

In later weeks we will ask you to choose a material for a particular **application**, so thinking about the required **properties** for an application like this is a valuable exercise.

Mechanical:
All materials need to be strong enough and stiff enough for their use.
As the polymer water bottle will be transported it is beneficial if it is resistant to fracture (in terms of properties this means it needs to have a reasonable *fracture toughness*).
The lid of this water bottle is screwed on, it needs to have a good seal – so liquid doesn't leak out – this is achieved by a combination of design of the screw closure and the materials: the stiffness and hardness of the polymers (especially the relatively low stiffness, and relatively low hardness of the lid).
Thermal:
reasonably low thermal conductivity for the spoon and especially the teacup (so a user isn't burned by holding the spoon, if it's used for soup), or burned by the cup when it has tea in it. The materials need to withstand c. 100 ˚C.
Chemical:
minimal degradation, and non toxic when in contact with foodstuffs – as all objects are used for food/drink
Environmental impact:

the metal and polymer can be recycled, and all the objects potentially last for many years
Cost:
reasonably low, but as the objects are intended to be used for many years the cost can be higher than it would be for 'disposable'/single use similar objects.
There are some interesting interactions between cost / environmental impact / single use objects – there may be an environmental benefit of making a higher cost object if it means that the object is more valued by the owner and used for longer.

d) What can you say, or speculate, about how the materials and objects have been processed / manufactured?
You are not expected to know about this yet.
But if you examine almost any water bottle (or milk bottle) you will be able to see evidence of moulding processes.
For the other objects to answer this you would need to know more about processing, the spoon is made by a cutting and thermomechanical forming method, and the cup by a moulding process.

Note: The **processing** technique used links with the **properties** of the materials being processed, and the **application**, hence shape, of the object.

3. Imagine if glass suddenly didn't exist. What wouldn't you be able to do anymore?
core+ **extra**

This question links to **applications**, **properties** of materials, at first sight it's about one **classification** of materials: glass, but can lead to being curious about what other materials could be used instead of glass (**WHAT** framework).

this is an open question
Drink water or beer from a glass. Have glass in windows.

No fibre optic cables. Not having these would likely affect all of us. (Imagine intercontinental zoom calls).

No glass lenses – microscopes and telescopes.

A question that stems from this question is for a given object what other materials could be used instead?

4. Questions about the interactive activity: **Learning the WHAT framework**
"Learning by awareness" Part 1 – making observations and linking them to what you already know, and fitting them into the WHAT framework.

In the video
a) Where can you see examples of materials which are linked to chemical, civil, and mechanical engineering in practice?

This question links to **applications**, and the **classification** of materials (**WHAT** framework).

There are many examples including:
Chemical: a petrochemical plant, many polymer products that were manufactured by chemical engineers.
Civil: the Forth Bridges, many buildings.
Mechanical: cars, bike, helmet.

b) What would happen if the following materials were used?

This question links to **applications**, **properties** of materials, the **classification** of materials (**WHAT** framework).

• concrete : saddle
It would be difficult to manufacture and uncomfortable.

• rubber : frame
The bike would collapse/buckle

• aluminium alloy : tyres
Poor grip and very uncomfortable to ride

• polymer foam : block
it would collapse

Some of the proposals for using certain materials for these applications seem crazy – and mostly they are. You probably knew that… be curious how did you 'just' know it…?

When you think more deeply about an object, what it needs to do in the **application** (design specification), you can define material **properties** then you can go about selecting specific materials (i.e. **classifications** of materials). *We will cover **materials selection** in the later parts of the course because it depends on understanding many aspects of materials (which are in the **WHAT** framework).*

Going deeper still the separate parts of the bike need to connect with other parts, these parts interact which means that the materials they are made from interact. Many failures in engineering have resulted from poor understanding of these interactions *(we cover failures in engineering later in the course)*.

c) What material properties are needed for: bike frame, saddle, tyres, and structural block?

This question links mainly to **properties** of materials (**WHAT** framework).

For the bike frame see **"Learning by awareness" Part 1**.
Saddle – some compliance, and possible to join to other materials.
Tyres – good grip, impermeable to air, wear resistance.
Structural block – strength, stiffness, low cost (as the dimensions are large).