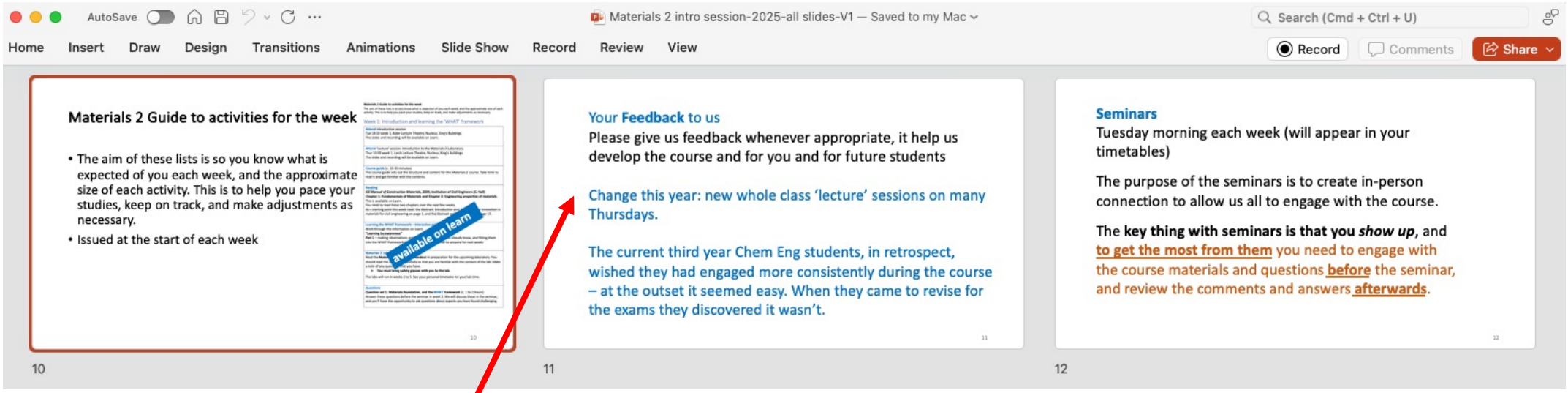
Materials 2

Thursday week 2

‘Bringing material properties to life’

Clarifying the course activities and how they link

Slides from Intro session Tuesday Week 1

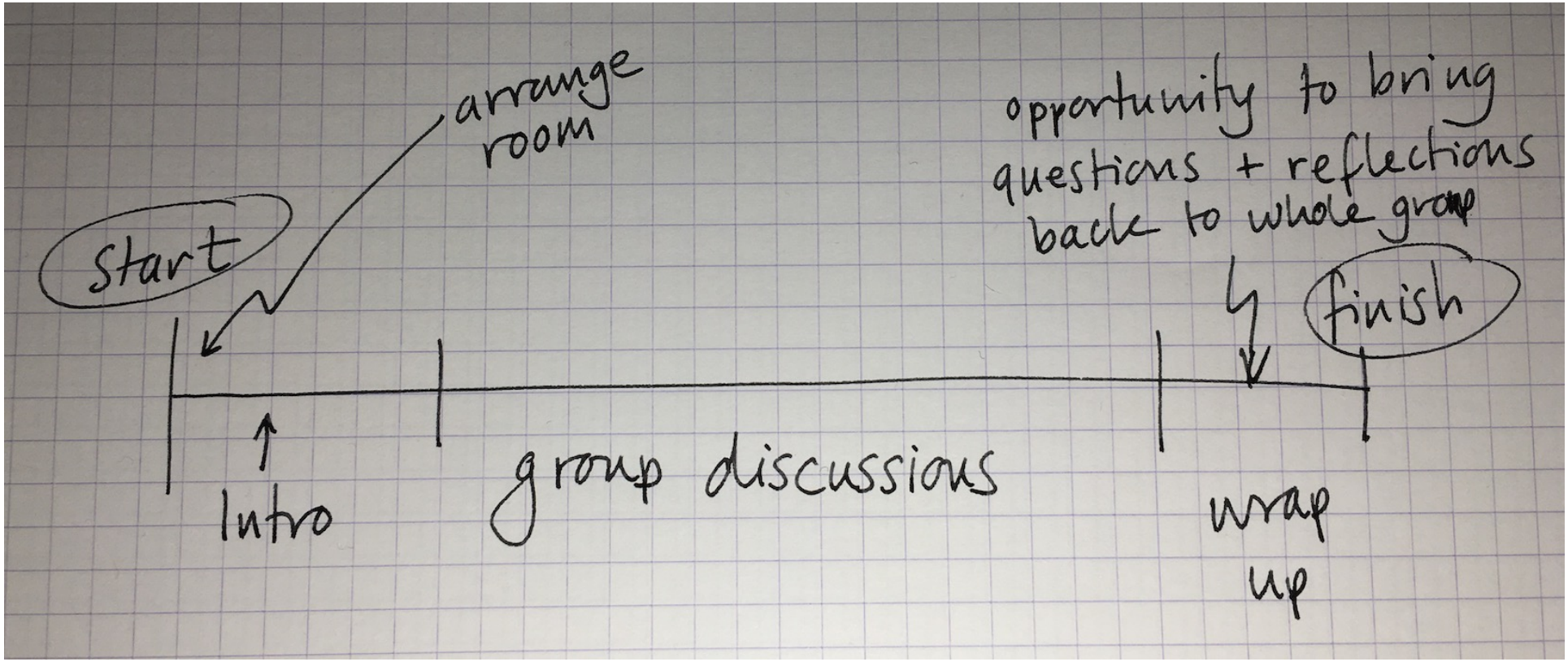


Change this year: new whole class 'lecture' sessions on many Thursdays.

Purpose of these sessions

- is to bring the course content to life, and to pick up on interesting and important matters that arise in Tuesday's seminars
- Most of the course is delivered with online videos, reading, question sets, seminars and answers & comments to question sets
- In weeks 7 & 9 we we deliver course content as lectures

Tuesday's seminar 'choreography' timeline and activities for seminar



Monday Week 1

Materials 2 Questions set 1
Materials foundation, and the WHAT framework

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

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*):
a) Identify the materials in the objects.
b) What are the objects used for (i.e. what are their applications)?
c) What properties of materials are needed in these applications?
d) What can you say, or speculate, about how the materials and objects have been processed / manufactured?

*This question links to the **WHAT** framework, and learning the foundations of engineering materials.*

WHAT Framework
Materials
- **Classifications**
- **Properties**
- **Small scale structure** (microstructure)
- Processing / manufacturing
- **Applications**

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

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.

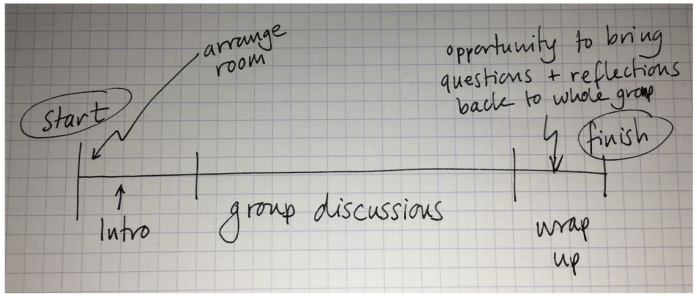
In the video
a) Where can you see examples of materials which are linked to chemical, civil, and mechanical engineering in practice?

b) What would happen if the following materials were used?
concrete : saddle • rubber : frame • aluminium alloy : tyres • polymer foam : block

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

Tuesday Week 2

Tuesday's seminar 'choreography' timeline and activities for seminar



Tuesday Week 2, 1pm

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.

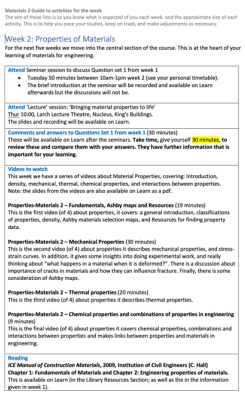
This is important when learning a new subject e.g. materials science and engineering in Materials 2, and when collaborating across disciplines where the same terminology can mean different things – in engineering and research. And in collaboration when the other person does not understand the specific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

Thursday Week 2

Whole class sessions *now*

Monday Week 2


Materials 2 Guide to activities for the week
The aim of these lists is so you know what is expected of you each week, and the approximate size of each activity. This is to help you pace your studies, keep on track, and make adjustments as necessary.

Week 2: Properties of Materials
For the next five weeks we move into the central section of the course. This is at the heart of your learning of materials for engineering.

Attend Seminar session to discuss Question set 1 from week 1
- Tuesday 50 minutes between 10am-1pm week 2 (see your personal timetable).
- The brief introduction at the seminar will be recorded and available on Learn afterwards but the discussions will not be.

Attend 'Lecture' session: 'Bringing material properties to life'
Thur 10:00, Larch Lecture Theatre, Nucleus, King's Buildings.
The slides and recording will be available on Learn.

Comments and answers to Questions Set 1 from week 1 (30 minutes)
These will be available on Learn after the seminars. **Take time,** give yourself **30 minutes, to review these and compare them with your answers. They have further information that is important for your learning.**

Videos to watch
This week we have a series of videos about Material Properties, covering: introduction, density, mechanical, thermal, chemical properties, and interactions between properties.
Note: the slides from the videos are also available on Learn as a pdf.

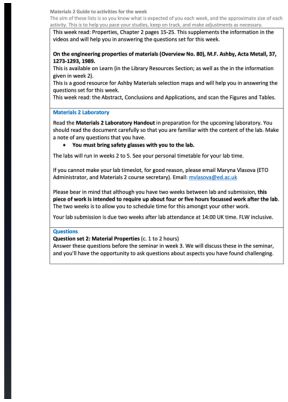
Properties-Materials 2 – Fundamentals, Ashby maps and Resources (19 minutes)
This is the first video (of 4) about properties, it covers: a general introduction, classifications of properties, density, Ashby materials selection maps, and Resources for finding property data.

Properties-Materials 2 – Mechanical Properties (30 minutes)
This is the second video (of 4) about properties it describes mechanical properties, and stress-strain curves. In addition, it gives some insights into doing experimental work, and really thinking about "what happens in a material when it is deformed?". There is a discussion about importance of cracks in materials and how they can influence fracture. Finally, there is some consideration of Ashby maps.

Properties-Materials 2 – Thermal properties (20 minutes)
This is the third video (of 4) about properties it describes thermal properties.

Properties-Materials 2 – Chemical properties and combinations of properties in engineering (9 minutes)
This is the final video (of 4) about properties it covers chemical properties, combinations and interactions between properties and makes links between properties and materials in engineering.

Reading
***ICE Manual of Construction Materials*, 2009, Institution of Civil Engineers (C. Hall)**
Chapter 1: Fundamentals of Materials and Chapter 2: Engineering properties of materials.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 1).


Materials 2 Guide to activities for the week
The aim of these lists is so you know what is expected of you each week, and the approximate size of each activity. This is to help you pace your studies, keep on track, and make adjustments as necessary.

This week read: Properties, Chapter 2 pages 15-25. This supplements the information in the videos and will help you in answering the questions set for this week.

On the engineering properties of materials (Overview No. 80), M.F. Ashby, Acta Metall, 37, 1273-1293, 1989.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 2).
This is a good resource for Ashby Materials selection maps and will help you in answering the questions set for this week.
This week read: the Abstract, Conclusions and Applications, and scan the Figures and Tables.

Materials 2 Laboratory
Read the **Materials 2 Laboratory Handout** in preparation for the upcoming laboratory. You should read the document carefully so that you are familiar with the content of the lab. Make a note of any questions that you have.
- **You must bring safety glasses with you to the lab.**

The labs will run in weeks 2 to 5. See your personal timetable for your lab time.

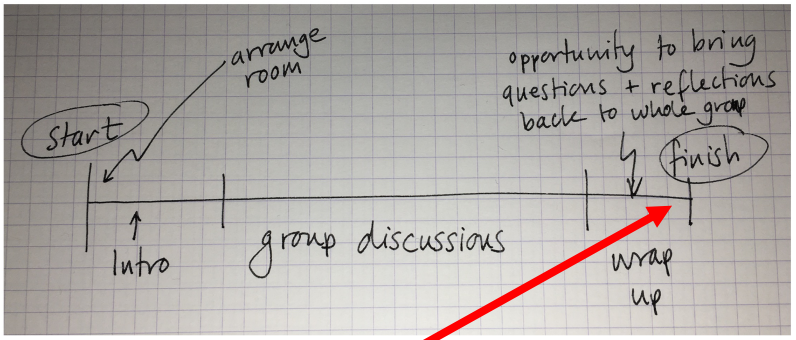
If you cannot make your lab timeslot, for good reason, please email Maryna Vlasova (ETO Administrator, and Materials 2 course secretary). Email: mvlasova@ed.ac.uk

Please bear in mind that although you have two weeks between lab and submission, **this piece of work is intended to require up about four or five hours focussed work after the lab.** The two weeks is to allow you to schedule time for this amongst your other work.

Your lab submission is due two weeks after lab attendance at 14:00 UK time. FLW inclusive.

Questions
Question set 2: Material Properties (c. 1 to 2 hours)
Answer these questions before the seminar in week 3. We will discuss these in the seminar, and you'll have the opportunity to ask questions about aspects you have found challenging.

Tuesday's seminar 'choreography'
timeline and activities for seminar



Great question …

mug
breaks
glue it together

is it now a composite?

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.

Selected slides from these videos copied in this slide set: from Properties W2 slide set

from Properties W2 slide set

Week 2: Properties of Materials

For the next five weeks we move into the central section of the course. This is at the heart of your learning of materials for engineering.

Attend Seminar session to discuss Question set 1 from week 1

- Tuesday 50 minutes between 10am-1pm week 2 (see your personal timetable).
- The brief introduction at the seminar will be recorded and available on Learn afterwards but the discussions will not be.

Attend 'Lecture' session: 'Bringing material properties to life'
Thur 10:00, Larch Lecture Theatre, Nucleus, King's Buildings.
The slides and recording will be available on Learn.

Comments and answers to Questions Set 1 from week 1 (30 minutes)
These will be available on Learn after the seminars. **Take time,** give yourself 30 minutes, **to review these and compare them with your answers. They have further information that is important for your learning.**

Videos to watch
This week we have a series of videos about Material Properties, covering: Introduction, density, mechanical, thermal, chemical properties, and interactions between properties.
Note: the slides from the videos are also available on Learn as a pdf.

Properties-Materials 2 – Fundamentals, Ashby maps and Resources (19 minutes)
This is the first video (of 4) about properties, it covers: a general introduction, classifications of properties, density, Ashby materials selection maps, and Resources for finding property data.

Properties-Materials 2 – Mechanical Properties (30 minutes)
This is the second video (of 4) about properties it describes mechanical properties, and stress-strain curves. In addition, it gives some insights into doing experimental work, and really thinking about "what happens in a material when it is deformed?". There is a discussion about importance of cracks in materials and how they can influence fracture. Finally, there is some consideration of Ashby maps.

Properties-Materials 2 – Thermal properties (20 minutes)
This is the third video (of 4) about properties it describes thermal properties.

Properties-Materials 2 – Chemical properties and combinations of properties in engineering (9 minutes)
This is the final video (of 4) about properties it covers chemical properties, combinations and interactions between properties and makes links between properties and materials in engineering.

Reading
***ICE Manual of Construction Materials*, 2009, Institution of Civil Engineers (C. Hall)**
Chapter 1: Fundamentals of Materials and Chapter 2: Engineering properties of materials.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 1).

Materials 2 Guide to activities for the week
The aim of these lists is so you know what is expected of you each week, and the approximate size of each activity. This is to help you pace your studies, keep on track, and make adjustments as necessary.

This week read: Properties, Chapter 2 pages 15-25. This supplements the information in the videos and will help you in answering the questions set for this week.

On the engineering properties of materials (Overview No. 80), M.F. Ashby, Acta Metall, 37, 1273-1293, 1989.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 2).
This is a good resource for Ashby Materials selection maps and will help you in answering the questions set for this week.
This week read: the Abstract, Conclusions and Applications, and scan the Figures and Tables.

Materials 2 Laboratory

Read the **Materials 2 Laboratory Handout** in preparation for the upcoming laboratory. You should read the document carefully so that you are familiar with the content of the lab. Make a note of any questions that you have.

- **You must bring safety glasses with you to the lab.**

The labs will run in weeks 2 to 5. See your personal timetable for your lab time.

If you cannot make your lab timeslot, for good reason, please email Maryna Vlasova (ETO Administrator, and Materials 2 course secretary). Email: mvlasova@ed.ac.uk

Please bear in mind that although you have two weeks between lab and submission, **this piece of work is intended to require up about four or five hours focussed work after the lab**. The two weeks is to allow you to schedule time for this amongst your other work.

Your lab submission is due two weeks after lab attendance at 14:00 UK time. FLW inclusive.

Questions
Question set 2: Material Properties (c. 1 to 2 hours)
Answer these questions before the seminar in week 3. We will discuss these in the seminar, and you'll have the opportunity to ask questions about aspects you have found challenging.

Materials 2 Guide to activities for the week
The aim of these lists is so you know what is expected of you each week, and the approximate size of each activity. This is to help you pace your studies, keep on track, and make adjustments as necessary.

Week 2: Properties of Materials

For the next five weeks we move into the central section of the course. This is at the heart of your learning of materials for engineering.

Attend Seminar session to discuss Question set 1 from week 1

- Tuesday 50 minutes between 10am-1pm week 2 (see your personal timetable).
- The brief introduction at the seminar will be recorded and available on Learn afterwards but the discussions will not be.

Attend 'Lecture' session: 'Bringing material properties to life'
Thur 10:00, Larch Lecture Theatre, Nucleus, King's Buildings.
The slides and recording will be available on Learn.

Comments and answers to Questions Set 1 from week 1 (30 minutes)
These will be available on Learn after the seminars. **Take time,** give yourself 30 minutes, **to review these and compare them with your answers. They have further information that is important for your learning.**

Video
This v
densi
Note:

Prope
This i
of pr
data.

Prope
This i
strain
think
impo
consi

Prope
This i

Prope
(9 mi
This i
intera
engin

Reading
***ICE Manual of Construction Materials*, 2009, Institution of Civil Engineers (C. Hall)**
Chapter 1: Fundamentals of Materials and Chapter 2: Engineering properties of materials.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 1).

Materials 2 Guide to activities for the week
The aim of these lists is so you know what is expected of you each week, and the approximate size of each activity. This is to help you pace your studies, keep on track, and make adjustments as necessary.

This week read: Properties, Chapter 2 pages 15-25. This supplements the information in the videos and will help you in answering the questions set for this week.

On the engineering properties of materials (Overview No. 80), M.F. Ashby, Acta Metall, 37, 1273-1293, 1989.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 2).
This is a good resource for Ashby Materials selection maps and will help you in answering the questions set for this week.
This week read: the Abstract, Conclusions and Applications, and scan the Figures and Tables.

Materials 2 Laboratory

Read the **Materials 2 Laboratory Handout** in preparation for the upcoming laboratory. You should read the document carefully so that you are familiar with the content of the lab. Make a note of any questions that you have.

- **You must bring safety glasses with you to the lab.**

The labs will run in weeks 2 to 5. See your personal timetable for your lab time.

On the engineering properties of materials (Overview No. 80), M.F. Ashby, Acta Metall, 37, 1273-1293, 1989.
This is available on Learn (in the Library Resources Section; as well as the in the information given in week 2).
This is a good resource for Ashby Materials selection maps and will help you in answering the questions set for this week.
This week read: the Abstract, Conclusions and Applications, and scan the Figures and Tables.

‘Bringing material properties to life’

Property classes

Table 3.1 Basic Design-Limiting Material Properties and Their Usual SI Units*

Class	Property	Symbol and Units
General	Density	ρ (kg/m^3 or Mg/m^3)
	Price	C_m ($/kg)
Mechanical	Elastic moduli (Young's, shear, bulk)	E, G, K (GPa)
	Yield strength	σ_y (MPa)
	Tensile (ultimate) strength	σ_{ts} (MPa)
	Compressive strength	σ_c (MPa)
	Failure strength	σ_f (MPa)
	Hardness	H *(Vickers)*
	Elongation	ε (–)
	Fatigue endurance limit	σ_e (MPa)
	Fracture toughness	K_{1c} (MPa.m$^{1/2}$)
	Toughness	G_{1c} (kJ/m^2)
	Loss coefficient (damping capacity)	η (–)
	Wear rate (Archard) constant	K_AMPa^{-1}
Thermal	Melting point	T_m (°C or K)
	Glass temperature	T_g (°C or K)
	Maximum service temperature	T_{max} (°C or K)
	Minimum service temperature	T_{min} (°C or K)
	Thermal conductivity	λ (W/m.K)
	Specific heat	C_p (J/kg.K)
	Thermal expansion coefficient	α (K^{-1})
	Thermal shock resistance	ΔT_s (°C or K)
Electrical	Electrical resistivity	ρ_e (Ω.m or $\mu\Omega$.cm)
	Dielectric constant	ε_r (–)
	Breakdown potential	V_b (10^6 V/m)
	Power factor	P (–)
Optical	Refractive index	n (–)
Eco-properties	Embodied energy	H_m (MJ/kg)
	Carbon footprint	CO_2 (kg/kg)

from Properties W2 slide set

[Ref: Materials selection in mechanical design (textbook), Ashby]

core

Density

quantitative behaviour

qualitative understanding – what you already know and can discover by observing

materials selection charts

from Properties W2 slide set

experiment

core

‘Everyday’ understanding

you already know much about **materials** and **properties**

- *your challenge: to think about and link this ‘everyday’ understanding to the science, to enable you to apply it – qualitatively and quantitatively – in engineering*

from Properties W2 slide set

core

Qualitative understanding

- Begin to develop a sense for the density of materials by handling them (kinaesthetic learning and #real-stuff)
- You can tell what a material is, *to some extent*, by picking it up and feeling how heavy it is; while seeing its shape (which gives you an idea of its volume)
  - *e.g. aluminium cf. steel*

- *THOUGHT EXPERIMENT: imagine picking up an apple if it was made of lead*

from Properties W2 slide set

core

Quantitative understanding

- Density is a fundamental property of all engineering materials
  - used in: many engineering formulae & materials selection for minimum weight design

- **Definition of density**: ratio of mass/volume *(usually denoted by the symbol ρ)*

$$\rho = m/v$$

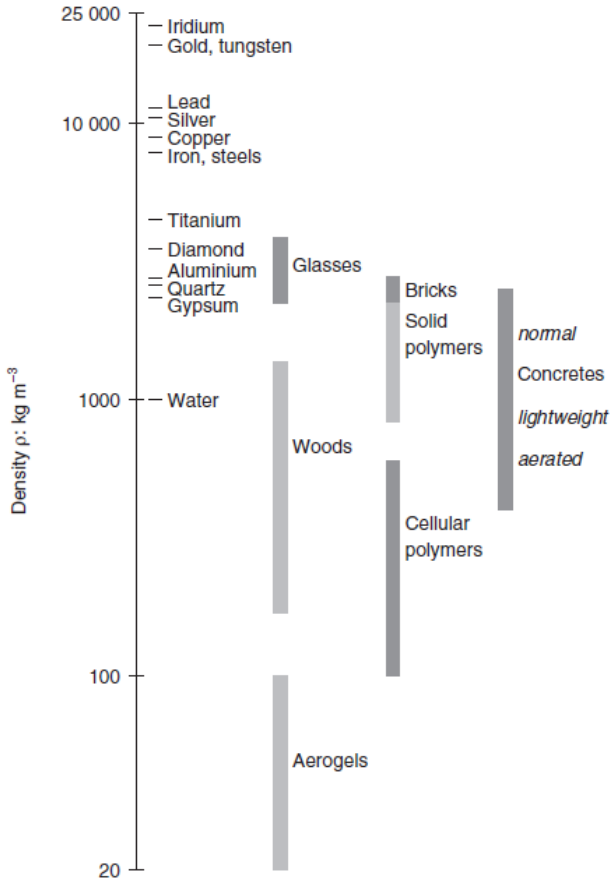
- In solids it is determined mainly by the masses of the constituent atoms
  - see *Periodic Table of elements (e.g. in microstructure section of course)*
  - the effective atomic density rises rapidly as we move across and down the periodic table

from Properties W2 slide set

core

Quantitative understanding

- Definition
- Units kg/m^3
- Values (range)
  - *cultivate a semi-quantitative idea of these for different material classes*
  - *How can you find a way to know them approximately without memorising them all?*



from Properties W2 slide set

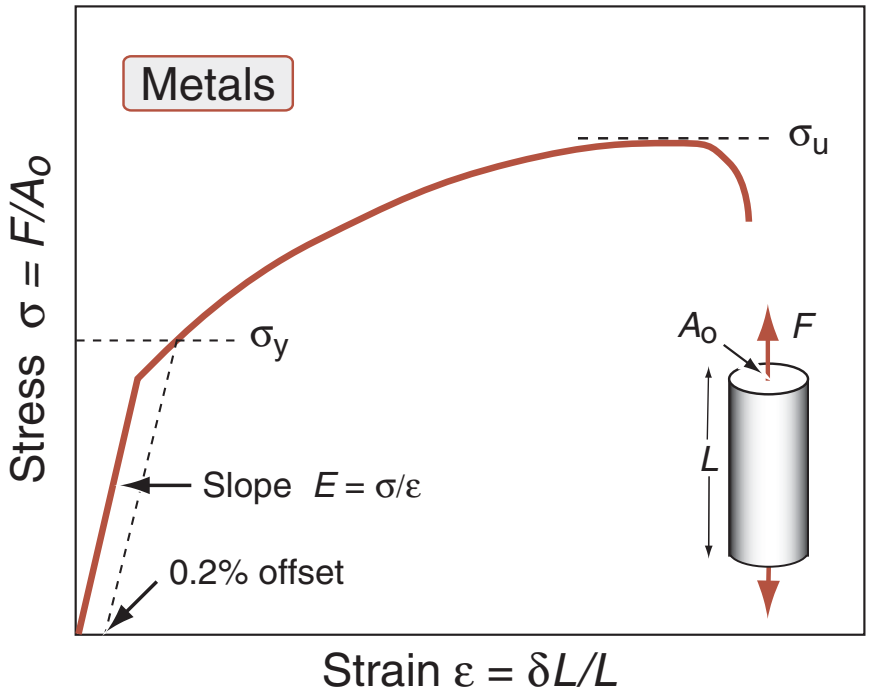
core

Mechanical properties, symbol & units

- Elastic modulii (Young's, shear, bulk) E, G, K [GPa]
- Poisson's ratio [no units]
- Yield stress σ_y [MPa]
- Ultimate stress σ_{uts} [MPa] (state whether in tension, compression or shear)
- Strain ε [no units]
- Fracture toughness K_{ic} [MPa $m^{½}$]
  - You should know the definitions for these properties, and be able to find them in **Resources**
- *Ductility* (which gives a measure of toughness) is proportional to the area of irreversible deformation under the stress-strain curve*
- *Hardness* (units vary)*
  - ** not fundamental material properties; useful in engineering*
- To note: Mechanical props vary with time and temperature

core

Mechanical properties: stress-strain curve – for a ductile metal



Ashby 2005, Materials selection... Fig 3.2

experiment

Making links with the Materials 2 Foundation – the WHAT framework

Materials classification: metals, polymers & ceramics

Saddle: polymer foam

Tyres: rubber

Frame: aluminium alloy

Block: concrete

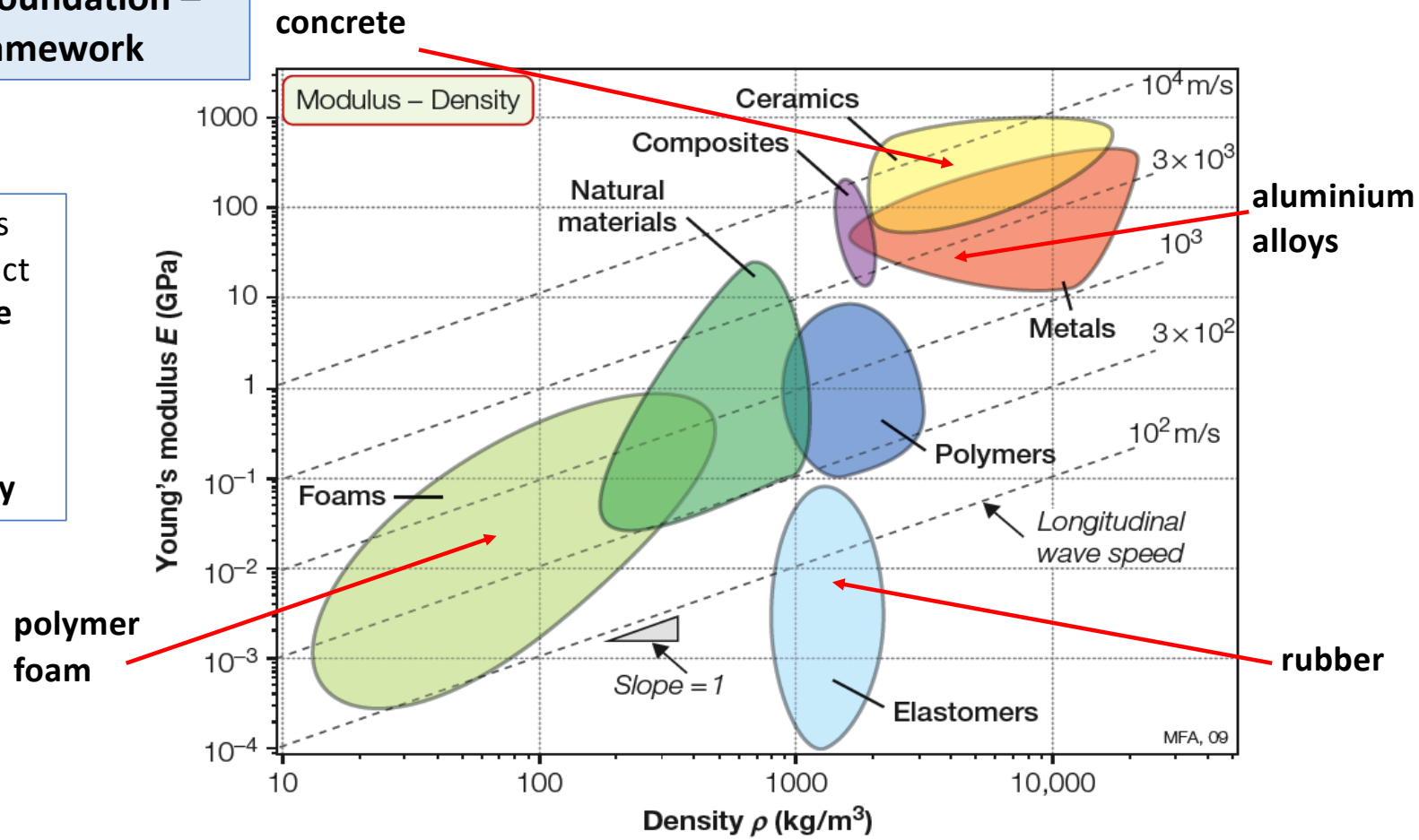
from Properties W2 slide set

core

Making links with the Materials 2 Foundation – the WHAT framework

Ashby Materials selection charts: modulus-density

these charts enable depict **quantitative** data, which can also be seen **qualitatively**



from Properties W2 slide set

Q. Where does stiffness (E as mat property) matter in real life? Buckle, rucksack fabrics, boot soles (soft/stiff rock boots...)

Nice

Summing up

Property classes • Density • Young's modulus •
Ashby Materials Selection Maps • Learning outcomes

Learning outcomes: Properties

from Properties W2 slide set

At the end of this section of the course, you should be able to

- Recognise classifications of properties, and have a basic knowledge of them **#WHAT**
- Recognise your own 'everyday knowledge' of properties. And to cultivate a qualitative/semi- quantitative sense for material properties #real-stuff
- Know properties have **precise definitions** and **units**, and be able to state these **#Resources** **#rigour**
- To know, and be able to find out, values of properties for engineering materials **#Resources**
- To begin to learn how to locate **material property data**, and evaluate its quality (what quality do I need it to be? how accurate is it? how reliable is it?) **#Resources**
- Be familiar with Ashby **material selection charts** and how they can be used **#Resources**
- Describe how mechanical properties are measured by mechanical testing **#rigour** #real-stuff
  - *appreciate there are subtleties in measuring material mechanical behaviour*
- Question (and begin to answer) what goes on in a material when it is deformed mechanically? #Qs
- Sketch stress-strain curves for materials
- Begin, and continue to make links between properties, material classes and engineering applications. And to move between **'parts'** and **'big-picture'** **#thinking&linking**
- Recognise that in engineering we often deal with **combinations of properties, and interactions between materials** **#thinking&linking**