Task 0: Pre-assignment

Instructions: Check the following questions and exercises. Access the course textbook and read chapters 1 (4th edition available in the Aalto Library as an e-book).

1.1 INTRODUCTION AND SYNOPSIS

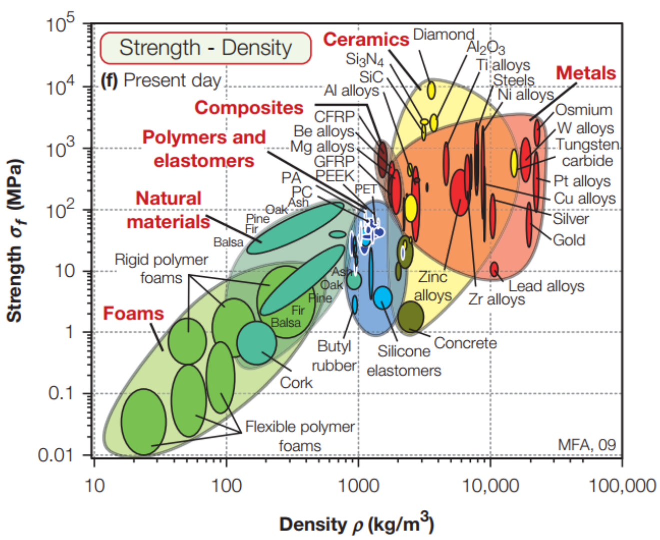
- Mechanical components have mass; they carry loads; they conduct heat and electricity; they are exposed to wear and to corrosive environments; they are made of one or more materials; they have shape; and they must be manufactured. Therefore, material selection is important.

1.2 MATERIALS IN DESIGN

- The number of materials available to engineers is vast: 160,000 or more
- A strategy that relies on experience is not in tune with today's computer-based environment. We need a more systematic procedure
- Design problems are almost always open-ended. There is no clear answer
- Real life always involves conflicting objectives—minimizing mass while at the same time minimizing cost is an example—requiring the use of trade-off methods.
- The role of aesthetics in engineering design is discussed. The forces driving change in the materials world are surveyed

1.3 THE EVOLUTION OF ENGINEERING MATERIALS

- Throughout history, materials have had limited design. The ages of man are named for the materials he used: stone, bronze, iron
- Current age is the age of an immense range of materials. There has never been an era in which their evolution was faster and the range of their properties more varied.
- the age of advanced materials currently
- The rate of development of new metallic alloys is now slow
- The polymer and composite industries, on the other hand, are growing rapidly

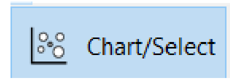


1.5 SUMMARY AND CONCLUSIONS

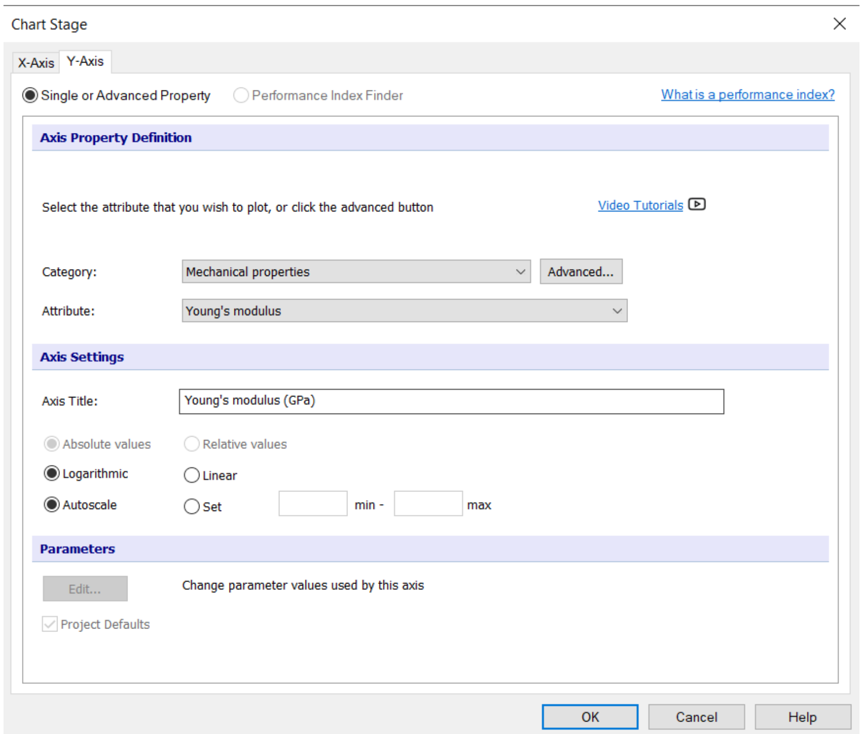
Engineering materials are evolving faster, and the choice is wider than ever before.

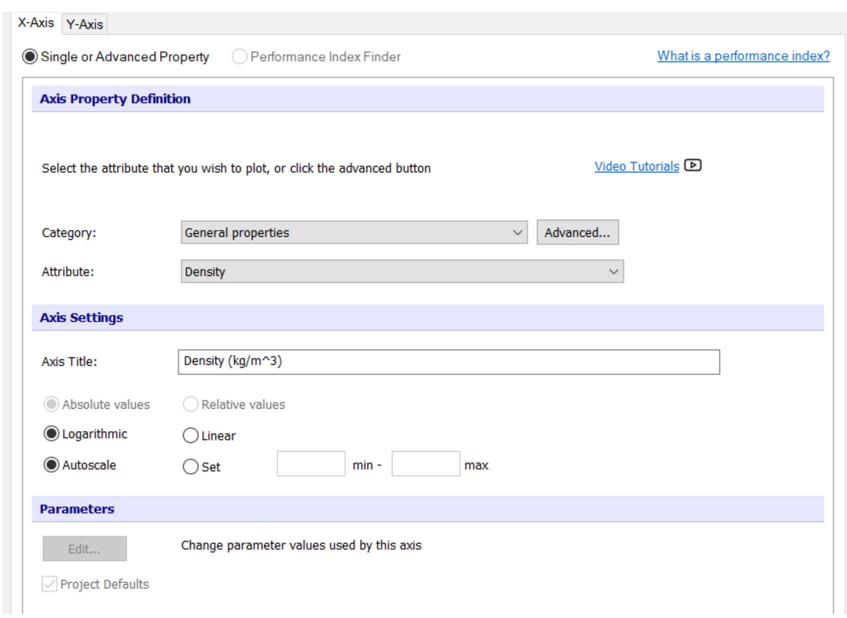
Task 0_0: Check GRANTA EduPack software and learn the user interface, watch tutorial videos and follow the exercises by yourself (In GRANTA EduPack 2023 R2 go to → Help/Video Tutorials → "GRANTA EduPack overview", and "Select" videos).

Learn Granta Edupack from this link
https://www.youtube.com/playlist?list=PLtt6-ZgUFmMK4aApOU0A85CvaJ_udGDCe

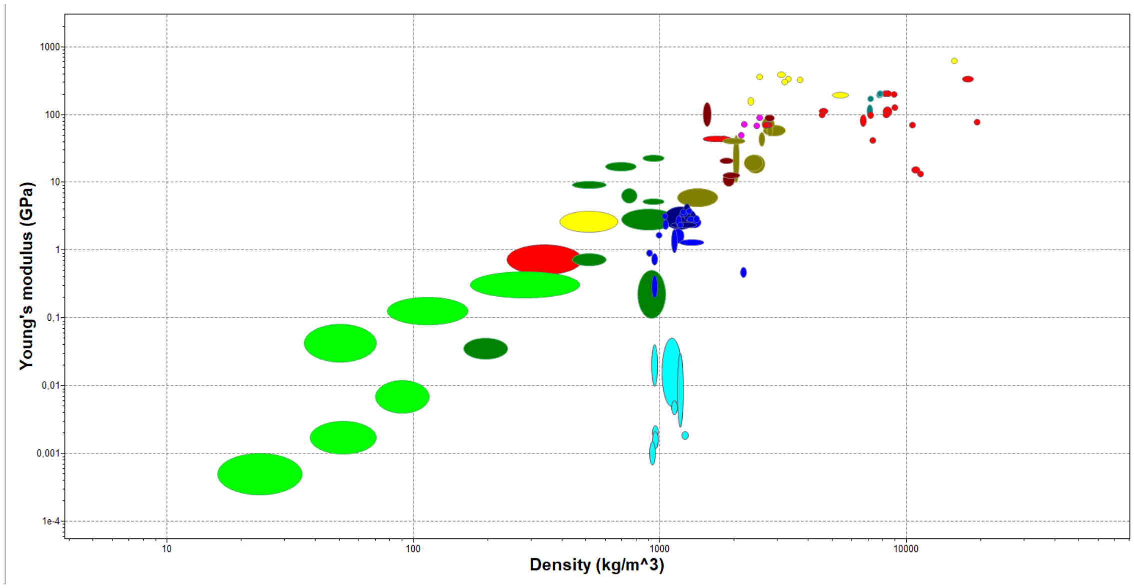
First, we can create Figures with different properties with the button 

Lesson 1: Creating charts

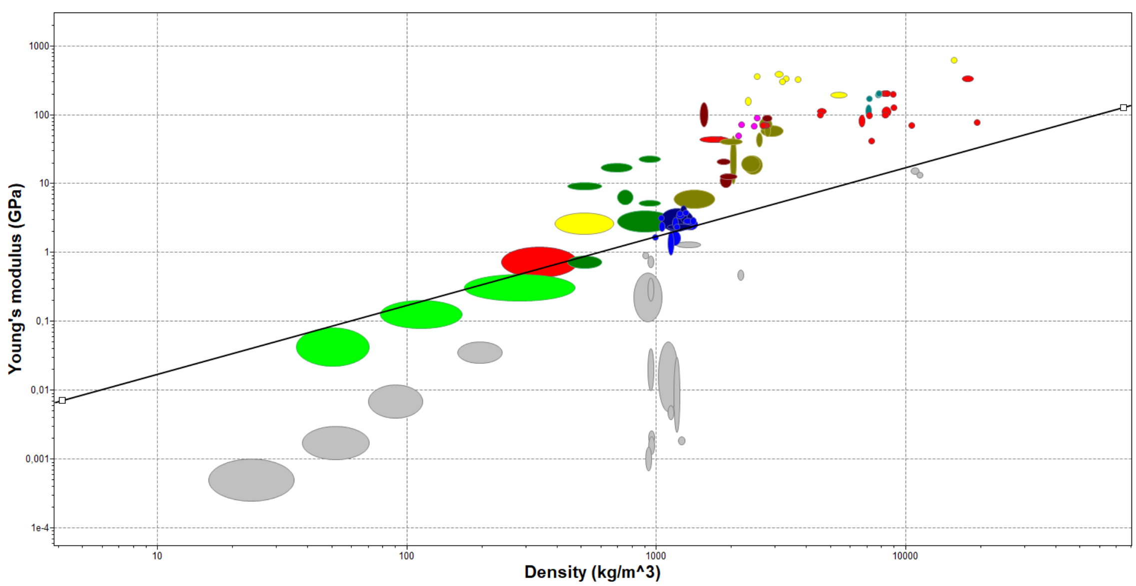




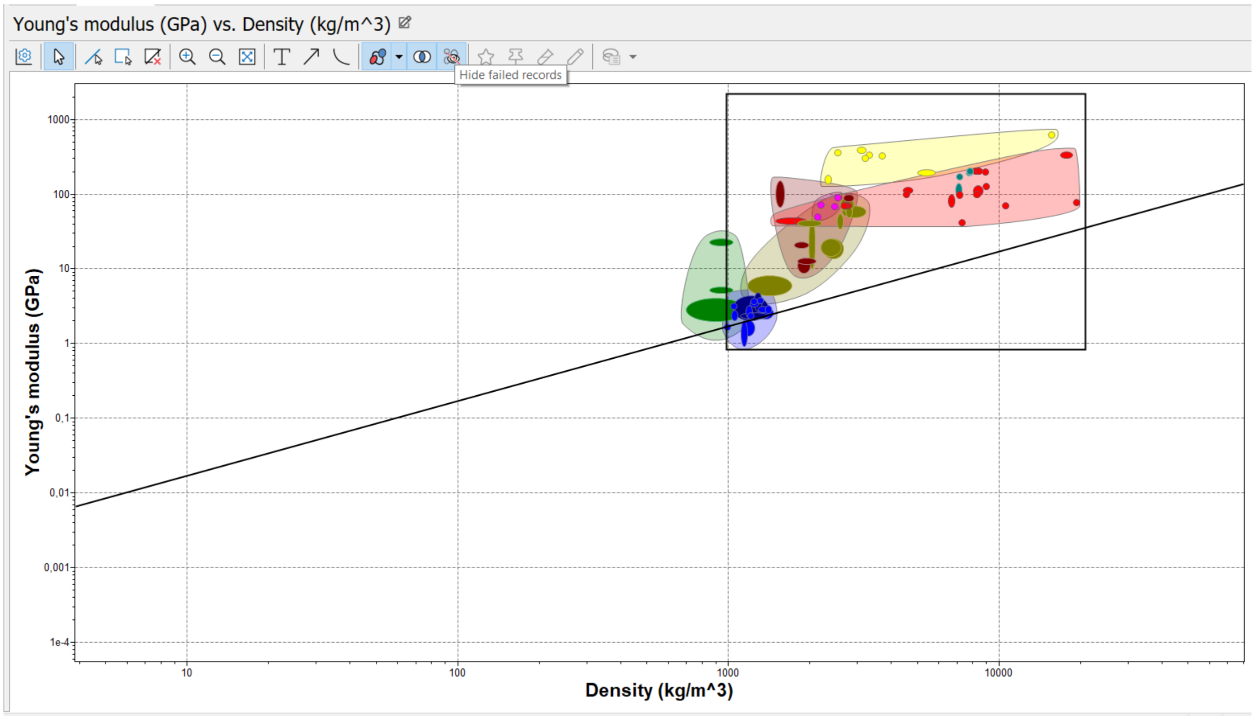
Lesson 2: Formatting charts



Above are the tools for the graph. What's an index line?
https://support.grantadesign.com/resources/grantaedupack/2023R1/en/help/index.htm?rhcsh=1#t=html%2Fchart%2Findexlines_about.htm

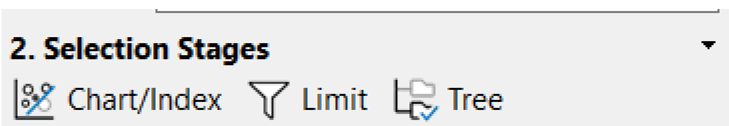


We can use Hide Failed Records to hide away materials that do not lie within the boundaries of the index line or the box lines.

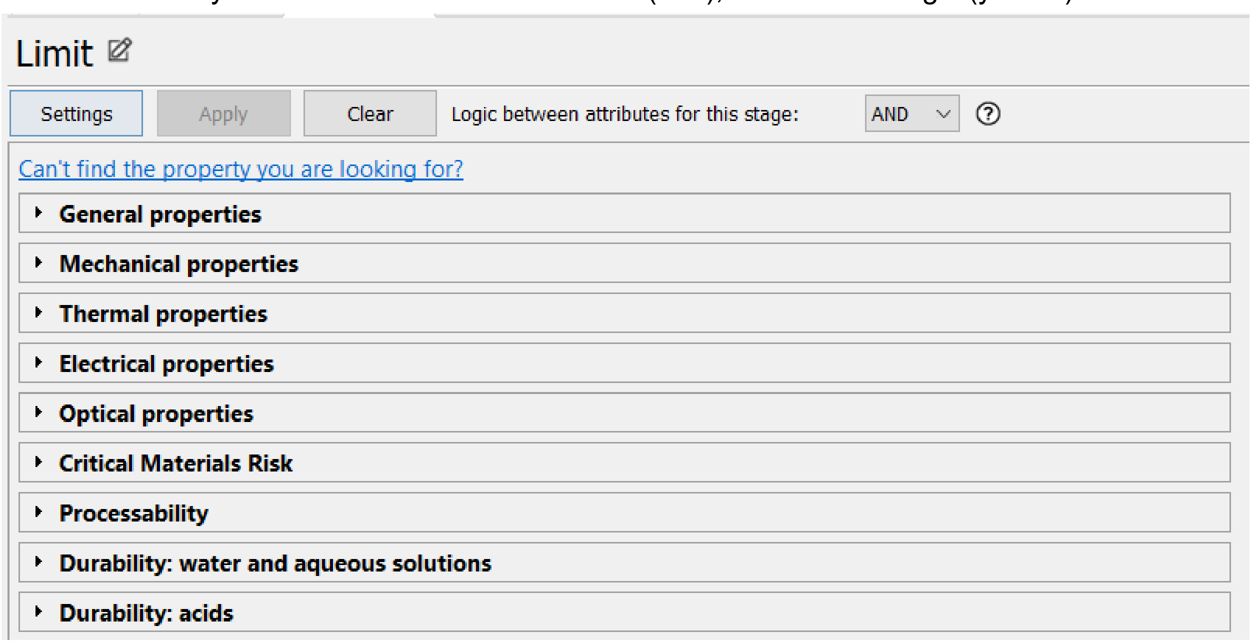


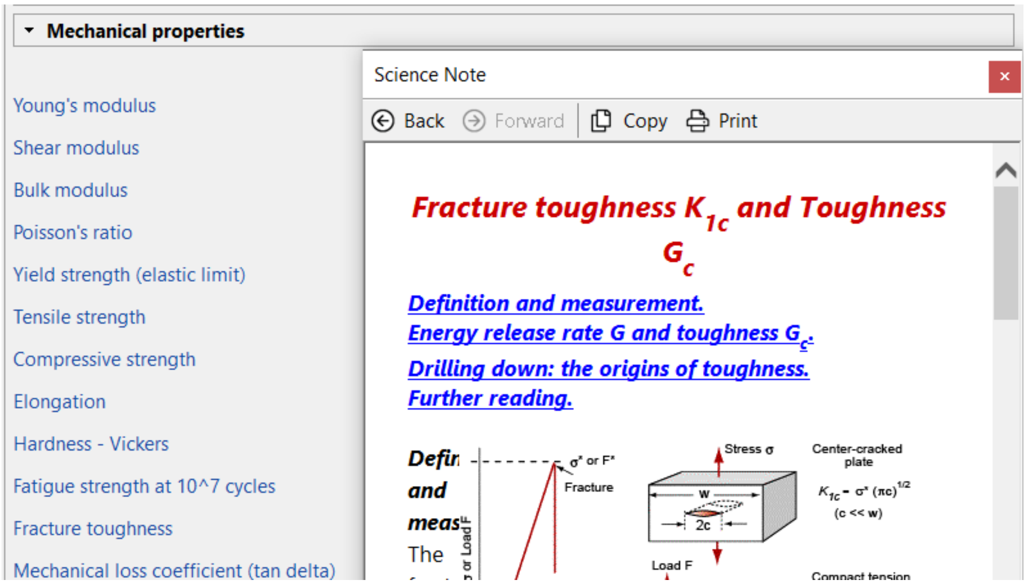
Lesson 3: How to use the Limit Stage

Choose the Limit Stage

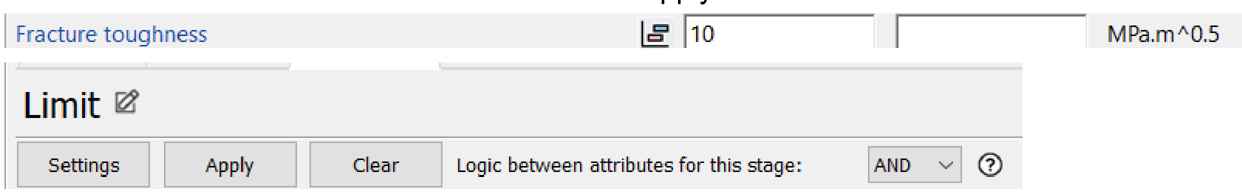


We will find many details. There are both numeric (real), discrete and logic (yes/no) attributes





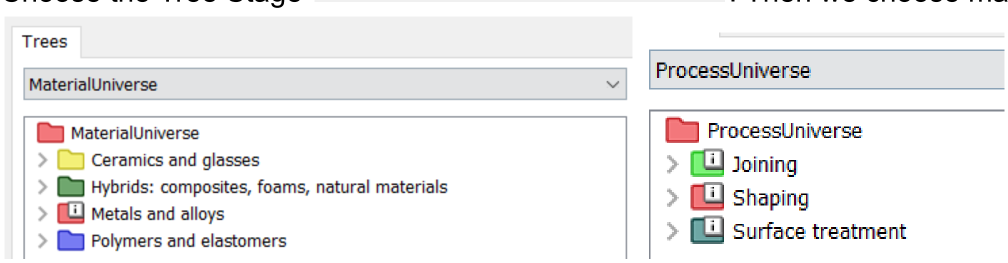
We can choose lower limit for KIc as 10 and click apply



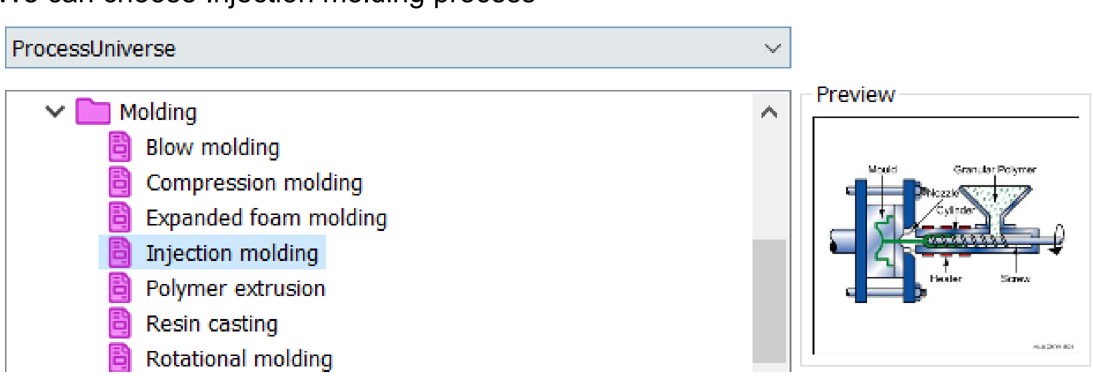
Lesson 4: How to use the Tree stage

Choose the Tree Stage 

. Then we choose material or process



We can choose Injection molding process



Therefore, stages in Granta EduPack are used to filter materials that pass the previous stages.

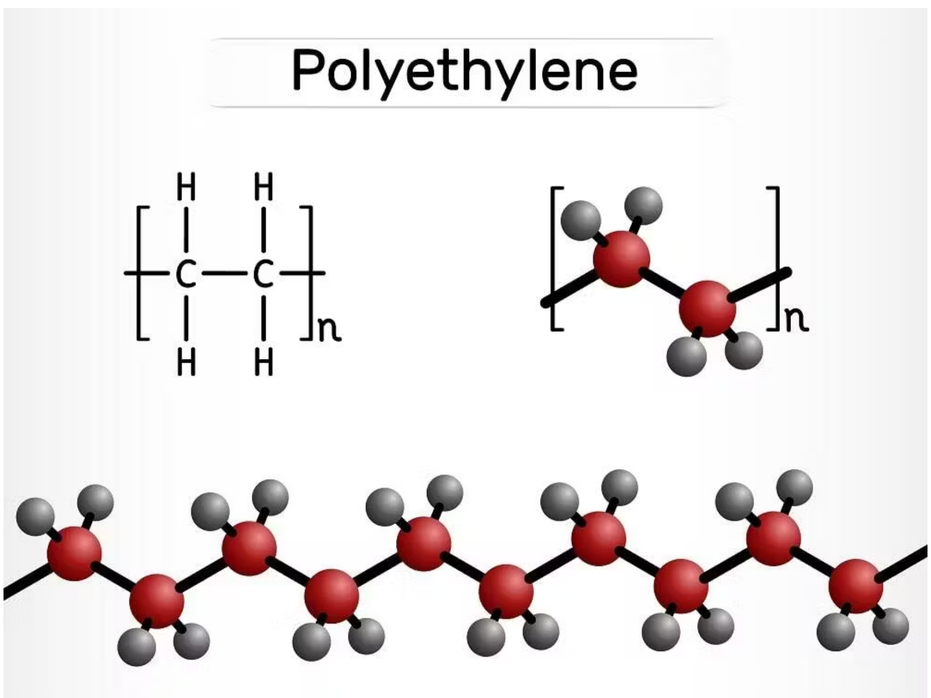
Task 0_1: You will be given the following material groups to study and choose one as you wish:

Composites	Plastics
Foams	Non-technical ceramics
Metals	Technical ceramics
Elastomers	Natural materials

- Explain the description of given material group (what it is, what are the typical material in the group, etc.)

My material group: Polymers in Elastomers

A polymer is a large molecule consisting of chains or rings of linked repeating subunits, which are called monomers. Polymers usually have high melting and boiling points (source: https://www.thoughtco.com/definition-of-polymer-605912). The monomer are usually made up of nonmetal elements such as Carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N), Sulfur (S), Chlorine (Cl), Fluorine (F), Silicon (Si), Phosphorus (P), and Bromine (Br).



For example, Polyethylene is a polymer consisting of monomers C2H4 (ethylene)

- Give three examples of specific materials representative of this group and corresponding examples of what they are used for.

Examples of Specific Materials Representative of Polymers:

These information are from Level 2 Database, Typical Use Section

Polyethylene (PE):

- PE is widely used in household products and food containers. Common products made from PE are oil containers, street bollards, milk bottles, toys, beer crate, food packaging, shrink wrap, squeeze tubes, disposable clothing, plastic bags, paper coatings, cable insulation, artificial joints, and as fibers - low cost ropes and packing tape reinforcement.

Polylactide (PLA):

- Injection molded: pencil sharpeners, rulers, cartridges, toys, plant pots, plastic bones and other toys for pets, plastic cutlery, hair combs.
- Thermo-formed: trays for fresh food packaging, especially fruit and vegetables.
- Film extrusion: shopping bags, bubble film for wrapping, plastic laminates for paper cups and plates, bags for rubbish disposal, lining for baby nappies, mulching films for horticulture, wrapping for fruit, vegetables and sanitary products .

Polypropylene (PP):

- PP is used in a variety of applications: Ropes, automobile air ducting, parcel shelving and air-cleaners, garden furniture, washing machine tank, wet-cell battery cases, pipes and pipe fittings, beer bottle crates, chair shells, capacitor dielectrics, cable insulation, kitchen kettles, car bumpers, shatterproof glasses, crates, suitcases, artificial turf, thermal underwear.

Task 0_2: From the GRANTA EduPack-database, find the following material properties:

Fracture toughness	Flammability
Transparency	Maximum operating Temperature
Specific heat capacity	CO_2 footprint
Thermal conductivity	Coefficient of thermal expansion
Electrical conductivity	Toxicity

- What do they mean and how they can be measured/evaluated? (Use short discussion with terms, charts, etc.)

All of these terms can be found by Chart/Select => Choose Limit in Selection Stages. Note: the subsections are in Database Level 3:

Impact & fracture properties > Fracture toughness
Optical, aesthetic and acoustic properties > Transparency

Fracture toughness

Measure of resistance of a material to crack propagation.

Test notes

The fracture toughness K1c, is a measure of the resistance of a material to the propagation of a crack. It can be measured by loading a sample containing a deliberately-introduced crack of length 2c and then recording the tensile stress σ at which the crack propagates.

Fracture toughness values can be used to calculate Toughness (G), which is a measure of a material's ability to absorb energy before fracture.

Toughness (G) includes the letter G to differentiate it from fracture toughness and can be calculated from Fracture toughness as well as Young's modulus using the following equation:

Toughness = (Fracture toughness ^2) / Young's Modulus

Transparency

Transparency of a material is represented by four ratings:

Opaque	Completely non-transparent, no light passes through
Translucent	Diffuse light is transmitted through the material with the result that images cannot be clearly distinguished
Transparent	Very good transparency though may be inherently tinted
Optical quality	Outstanding transparency, suitable for use in such applications as lenses for spectacles

For interpreting these ratings, bear in mind that a thin film of a translucent material may be considered transparent.

Thermal properties > Specific heat capacity
Thermal properties > Thermal conductivity

Specific heat capacity

The energy required to raise the temperature of a unit mass of material by one degree of temperature – J/kg.°C (same as J/kg.K) in metric or cal/lb.°F in US customary units.

Test notes

Specific heat capacity, Cp, or just 'specific heat', is measured by calorimetry. Cp increases steadily as material temperature increases and rapidly when the material goes through a phase transition, e.g. glass transition (Tg) or melting (Tm). Values given here are for the region of room temperature (23°C).

Thermal conductivity

Thermal conductivity (λ) is a measure of how well a material transfers heat.

Test notes

Measured by recording the steady state heat flux J (W/m^2) flowing through a material of thickness X, under the influence of a fixed temperature gradient.

Thermal conductivity varies with temperature. Values quoted in the database represent room temperature performance (around 23°C) and may not represent the performance at other temperatures.

Electrical properties > Electrical conductivity
Durability > Flammability

Electrical conductivity

A measure of the ease that an electric charge moves through a material.

Notes

Electrical conductivity is defined as:

Electrical conductivity = 1 / Electrical resistivity

Calculating the electrical conductivity using the equation above reports values in the SI units of Siemens per meter. However, electrical conductivity is often reported in units of %IACS, which stands for the International Annealed Copper Standard. This standard relates all conductivity values back to the conductivity of the annealed copper, which is defined to be 100 %IACS at 20°C.

Flammability

Flammability rating on a four-point scale. These are the approximate correspondences to LOI and UL-94 at 1.6 mm thickness.

Flammability rating	LOI % (limiting oxygen index)	UL-94 rating (1.6 mm nominal thickness)
Highly flammable	< 20	Unclassified or HB
Slow-burning	20–25	HB
Self-extinguishing	26–49	V-2, V-1, V-0, 5VA and 5VB
Non-flammable	> 50	Exceeds all UL94 ratings

UL94 ratings are for plastics only. There are very few UL V-1 rated materials. LOI of 50 is an arbitrary cut-off point above which materials are rated 'non-flammable'.

Thermal properties > Maximum Service Temperature
Primary production energy, CO2 and water > CO2 footprint, primary production

Maximum service temperature (Tmax)

Highest temperature at which material can be used for an extended period without significant problems, such as oxidation, chemical change, excessive creep, loss of strength, or other primary property for which the material is normally used.

Test notes

There is no universal test for Tmax. It is frequently reported on the basis of manufacturer recommendation.

For plastics, Tmax is defined in the following order of priority, depending on data availability:

1. Relative Thermal Index (RTI, UL 746b). RTI is the temperature at which 50% of electrical insulation or strength or impact properties are retained after 60,000 hours. Only electrical and strength RTI's are used to assess Tmax, not impact RTI. Generic RTI's (65°C for many materials) are ignored for this purpose.
2. Maximum continuous use temperature (ASTM D794). This test is very broadly defined.
3. Manufacturer recommendations.

CO2 footprint, primary production (typical grade)

The CO2-equivalent mass of greenhouse gases (kg CO2e), in kg, produced and released into the atmosphere as a consequence of the production of 1 kg of the material from a combination of its ores and some recycled content.

Notes

Typical % accounts for the level of recycled material incorporated back into the supply chain as standard practice. This applies to materials, such as metals and glasses, where end of life recycling has become integrated into the supply chain. This practice leads to standard grades containing significant levels of recycled material.

The calculation used to determine the environmental burden of grades containing recycled material is as follows:

Typical Grade Footprint*=*[((100-Recycle Fraction)/100) ×Virgin Grade Footprint]*+*[((Recycle Fraction)/100) ×Recycling Footprint]

For the typical grade, the calculation takes Rf as the Recycle Fraction in Current Supply.

Thermal properties > Thermal expansion coefficient
(Database level 2) Discrete attributes > Toxicity rating

Thermal expansion coefficient

The fraction a material expands per degree of temperature.

Thermal expansion with temperature curves are given as Mean (secant) CTE. The reference temperature is an arbitrary value defined for the specific curve where the thermal strain is zero.

Test notes

Most materials expand when they are heated. The linear thermal expansion coefficient α is the thermal strain per degree C or F.

Toxicity rating

Definition.

Definition. Some materials are toxic, creating potential problems during production, during use, and during disposal. The database ranks toxicity on a 4-point scale: *non-toxic, slightly toxic, toxic* and *very toxic*. More pertinent, often, is information about whether a material can be used in contact with skin or food, for childrens' toys, or for storing medical supplies.

- Find typical values for the material group given in Task 0_1. Choose 4 material properties and compare these properties in Level 2 and Level 3 (see the tutorials to understand the meaning of "levels"). Shortly discuss what are the differences in the results.

Difference 1: There is toxicity description in Level 2 but no toxicity in Level 3
Difference 2: For a given material, Database Level 2 has only 1 material, but Level 3 has much more different specialties of that material, such as Polyethylene and Polypropylene
Difference 3: Because of difference 2, Level 3 has a general information of the material that is shared across all varieties

- PE-MD (molding and extrusion)
- PE-LLD (molding and extrusion)
- PE-LD (molding and extrusion)
- Low density PE
- Cross-linked PE
- High density PE
- PE-UHMW (molding and extrusion)
- PE (cross-linked, molding)
- PE (cross-linked, wire and cable grade)

Comparison between 4 material properties of three polymers are given below
We can see that most of the time, the numeric data properties share close ranges between Level 2 and Level 3 Database. However, there are sometimes conflicts, such as opaque transparency for PLA at level 3, but Transparent at level 2 database

Comparing Polyethylene (PE):

Level 2:

Transparency	Translucent			
Flammability	Highly flammable			
Thermal conductivity	0,403	-	0,435	W/m.°C
Maximum service temperature	* 90	-	110	°C

Level 3:

Transparency	Translucent			
Flammability	Highly flammable			
Thermal conductivity	0,48			W/m.°C
Maximum service temperature	* 85	-	105	°C

Comparing Polylactide (PLA):

Level 2:

Transparency	Transparent			
Flammability	Slow-burning			
Thermal conductivity	* 0,12	-	0,15	W/m.°C
Maximum service temperature	* 39,9	-	60	°C

Level 3:

Transparency	Opaque			
Flammability	Highly flammable			
Thermal conductivity	* 0,12	-	0,15	W/m.°C
Maximum service temperature	* 40	-	60	°C

Comparing Polypropylene (PP):

Level 2:

Transparency	Translucent			
Flammability	Highly flammable			
Thermal conductivity	* 0,192	-	0,199	W/m.°C
Maximum service temperature	* 66,9	-	83,9	°C

Level 3:

Transparency	Translucent			
Flammability	Highly flammable			
Thermal conductivity	* 0,183	-	0,19	W/m.°C
Maximum service temperature	* 59,6	-	76,4	°C

Task 0_3. Find translations of the material properties in the list in Task 0_2 in at least two languages that are not English. Use your native language if that is not English, and at least one additional language you consider important in technology/engineering.

My native language is Vietnamese. Here are the translations of the terms:

Tiếng Việt (Vietnamese)

độ dẻo khi bị gãy	tính dễ cháy
độ trong suốt	nhiệt độ hoạt động tối đa
nhiệt dung riêng	dấu chân lượng khí cacbon dioxit
hệ số dẫn nhiệt	hệ số nở nhiệt
độ dẫn điện	độ độc

Two important languages for technology in my opinion are German and Chinese

Deustch (German):

die Bruchzähigkeit	die Brennbarkeit
die Transparenz	die maximale Betriebstemperatur
die spezifische Wärmekapazität	Kohlendioxid-Fußabdruck
die Wärmeleitfähigkeit	der thermische Ausdehnungskoeffizient
die elektrische Leitfähigkeit	die Toxizität

中文 (Chinese):

斷裂韌性	可燃性
透明度	最高操作溫度
比热容	二氧化碳足跡
熱導率	熱膨脹係數
電導率	毒性