

# MATERIAL SELECTION

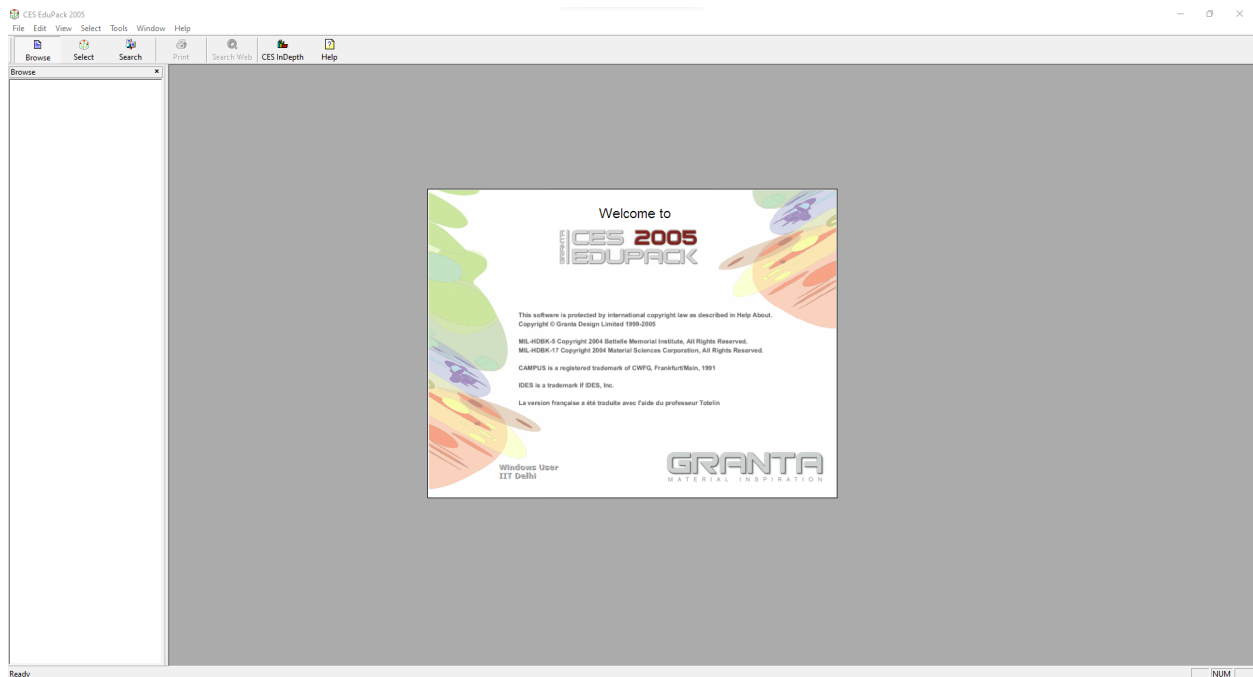
Use Material selection software to select material for the following three cases:

- Body of electric switch/plug
- Coffee mug
- Cover of mobile phone

*Suggest manufacturing process(es) if 500000 units of the above component have to be produced.*

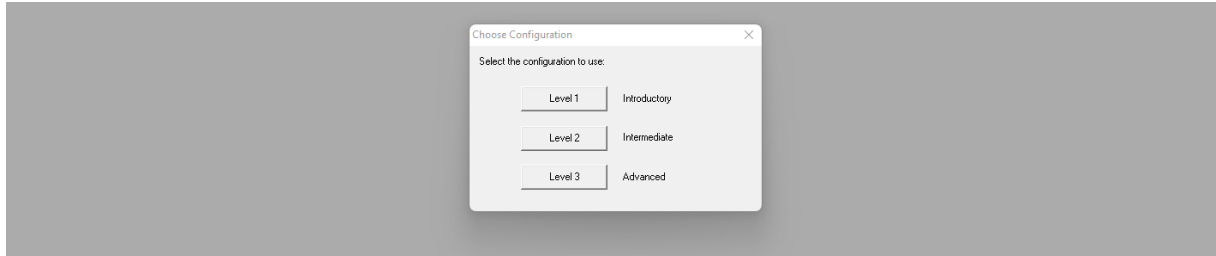
## CHALLENGE

Knowledge of materials and the selection process is less. Using the software is very new. Used software ie: CES (Cambridge Engineering Selector) Edupack has been used for the process of selecting materials for this assignment.



*Homescreen CES (Cambridge Engineering Selector) Edupack has been used for the process of selecting materials for this assignment*

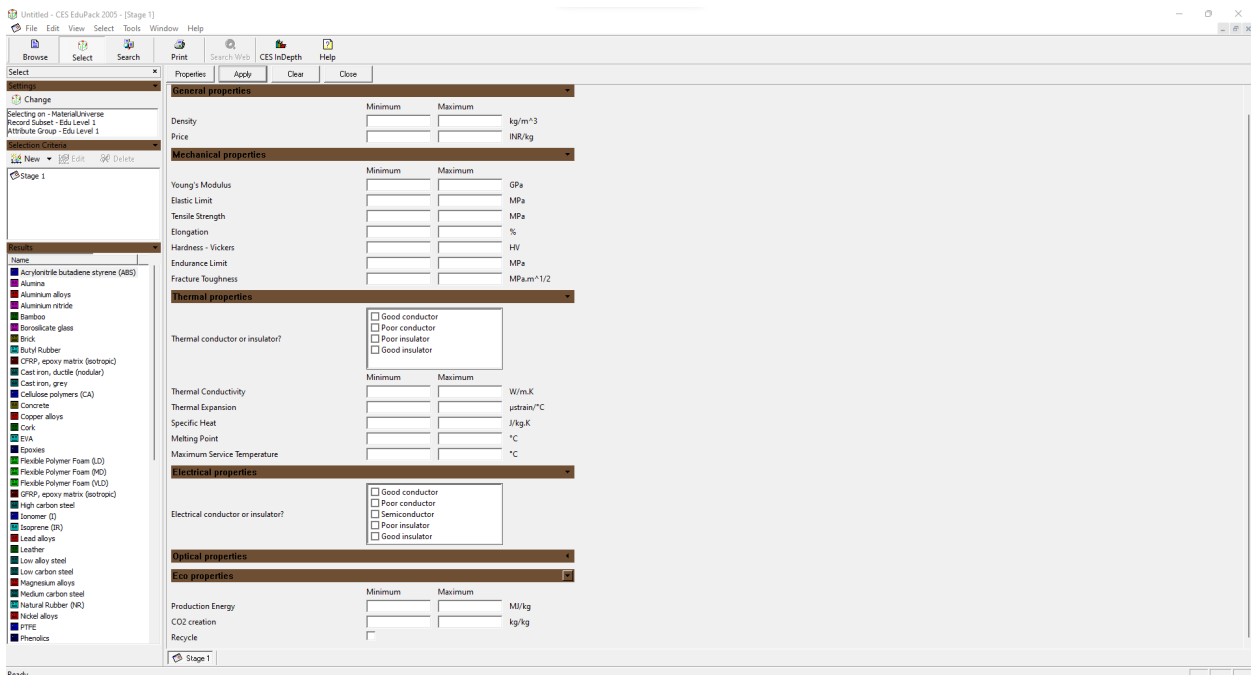
The selection depends on items are based on the user's needs and the material availability and scope.



For this assignment, Level 1 Introductory and Level 3 Advanced levels have been used to select the materials

## PROCESS OF SELECTION

- Selected the configuration Level 1 – Introductory.
- Created a new project under material-based selection.
- Limit Stage as the selection criteria.
- Graph stage check perfect material
- In this stage, define the properties that are considered such as density, tensile strength, specific heat and insulation properties



Using different parameter we can modify the items and selection on the stage.

# 1 Material selection **ELECTRIC PLUG/ SWITCH**

When designing devices that carry voltage the spacing of the contacts is fixed so the material separating them has to have a low minimum insulating property. This is called dielectric strength. Which is the voltage required to cause tracking along the material surface. So we chose a material with such properties in place.

## **CRITERIA**

### **FUNCTION**

To insulate the devices from electric current and provide protection against electric shocks.  
To protect the pins, fuse and wires from exposure.

### **CONSTRAINTS**

Highly durable enough to withstand damage due to wear and tear over time.

### **VARIABLES**

Properties considered: Density – 1320 kg/m<sup>3</sup>, Tensile Strength – 40-60 MPa, Specific Heat – 1530 J/kg.K, Good insulator. Material used may be of different colours, easy to manufacture and affordable.

## **PROCESS OF SELECTION**

- Selected the configuration Level 1 – Introductory.
- Created a new project under material-based selection.
- Limit Stage as the selection criteria.
- In this stage, define the properties that are considered such as density, tensile strength, specific heat and insulation properties

The screenshot shows the CES EduPack 2005 software interface. The left sidebar lists various material classes, with 'Cellulose polymers (CA)' selected. The main window displays the 'General properties' and 'Mechanical properties' sections for this material class. The 'General properties' section includes fields for Density (1200 kg/m³), Price, and Young's Modulus. The 'Mechanical properties' section includes fields for Elastic Limit, Tensile Strength, Elongation, Hardness - Vickers, Endurance Limit, and Fracture Toughness. Below these are sections for Thermal properties, Electrical properties, Optical properties, and Eco properties.

All the properties that have been used are by research on the internet.

The screenshot shows the CES EduPack 2005 software interface for 'Cellulose polymers (CA)'. The 'Description' section explains that cellulose is a natural polymer found in plants, and cellulose acetate (CA) is a common cellulose material. The 'Image' section shows a red-handled screwdriver. The 'Caption' states that cellulose acetate is used for handles and knobs. The 'General properties' section includes fields for Density (980 kg/m³), Price (197.8 INR/kg), and Young's Modulus (1.6 GPa). The 'Mechanical properties' section includes fields for Shear Modulus, Bulk modulus, Poisson's Ratio, Hardness - Vickers, Elastic Limit, Tensile Strength, Compressive Strength, Elongation, Endurance Limit, Fracture Toughness, and Loss Coefficient. The 'Thermal properties' section includes fields for Thermal conductivity, Thermal expansion, Specific heat, Glass temperature, Maximum service temperature, and Minimum service temperature.

The screenshot shows the CES EduPack 2005 software interface for 'Phenolics'. The 'Description' section explains that Bakelite, commercialized in 1909, triggered a revolution in product design. The 'Image' section shows a red Bakelite distributor cap. The 'Caption' states that phenolics are good insulators and resist heat and chemical attack. The 'General properties' section includes fields for Density (1240 kg/m³), Price (70.49 INR/kg), and Young's Modulus (2.76 GPa). The 'Mechanical properties' section includes fields for Shear Modulus, Bulk modulus, Poisson's Ratio, Hardness - Vickers, Elastic Limit, Tensile Strength, and Fracture Toughness. The 'Thermal properties' section includes fields for Thermal conductivity, Thermal expansion, Specific heat, Glass temperature, Maximum service temperature, and Minimum service temperature.

## RESULT

Considering the constraints both the materials **Bakelite** and **CA** are good for such properties and requirements. But since Bakelite has better flammability properties it's advisable to choose Bakelite as the material of choice.

Untitled - CES EduPack 2005 - [MaterialUniverse/Polymers and elastomers/Thermosets]

File Edit View Select Tools Window Help

Browse Select Search Print Search Web CES InDepth Help

Select Previous Next Layout: Edu Level 2 Graphs

Settings

Change

Selecting on - MaterialUniverse  
Record Subset - Edu Level 1  
Attribute Group - Edu Level 1

Selection Criteria

New Edit Delete

Stage 1

Results

Name

- Acrylonitrile butadiene styrene (ABS)
- Cellulose polymers (CA)
- Epoxies
- Phenolics
- Polyester
- Polyethylene terephthalate (PET)
- Poly(methyl methacrylate) (Acrylic, ...)
- Polyvinylchloride (PVC)


**Phenolics**

**Description**

**The Material**

Bakelite, commercialized in 1909, triggered a revolution in product design. It was stiff, fairly strong, could (to a muted degree) be colored, and - above all - was easy to mould. Products that, earlier, were handcrafted from woods, metals or exotics such as ivory, could now be molded quickly and cheaply. At one time the production of phenolics exceeded that of Fe, PS and PVC combined. Now, although the reason has changed, phenolics still have a unique value. They are stiff, chemically stable, have good electrical properties, are fire-resistant and easy to mould - and they are cheap.

**Image**



**Caption**

Phenolics are good insulators, and resist heat and chemical attack exceptionally well, making them a good choice for electrical switchgear like this distributor cap.

## RESULT of the analysis

### General properties

Density	1240	-	1320	kg/m <sup>3</sup>
Price	70.49	-	1111.1	INR/kg

### Mechanical properties

Young's Modulus	2.76	-	4.83	GPa
Elastic Limit	*27.6	-	49.68	MPa
Tensile Strength	34.5	-	62.1	MPa
Elongation	1.5	-	2	%
Hardness - Vickers	8.3	-	14.9	HV
Endurance Limit	*13.8	-	24.84	MPa
Fracture Toughness	*0.7869	-	1.212	MPa.m <sup>1/2</sup>

### Thermal properties

Thermal conductor or insulator?	Good insulator			
Thermal Conductivity	0.141	-	0.152	W/m.K
Thermal Expansion	120.1	-	124.9	µstrain/°C
Specific Heat	*1467	-	1526	J/kg.K
Maximum Service Temperature	*141.9	-	156.9	°C

### Electrical properties

Electrical conductor or insulator?	Good insulator
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### Optical properties

Transparency	Opaque
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### Eco properties

Production Energy	*85.9	-	95	MJ/kg
CO2 creation	*2.83	-	3.12	kg/kg
Recycle	X			

### Supporting information

#### Typical uses

Electrical parts - sockets, switches, connectors, general industrial, water-lubricated bearings, relays, pump impellers, brake pistons, microwave cookware, handles, bottles tops, coatings, adhesives, bearings, foams and sandwich structures.

#### Links

Reference	...
ProcessUniverse	...
Producers	...

# PRODUCTION

For the production of 500000 switches, the best method to do is injection moulding.

# 2 Material selection **COFFEE MUG**

When designing a coffee mug the separating material must withstand hot beverages and should highly insulate the heat from the beverage to the hands hence it should be a good thermal insulator. It should reduce the transmission of heat to the outer environment. It should be able to add colours due to personalisation and customisation.

## **CRITERIA**

### **FUNCTION**

To insulate the beverage from the hands. It should reduce the transmission of heat.

### **CONSTRAINTS**

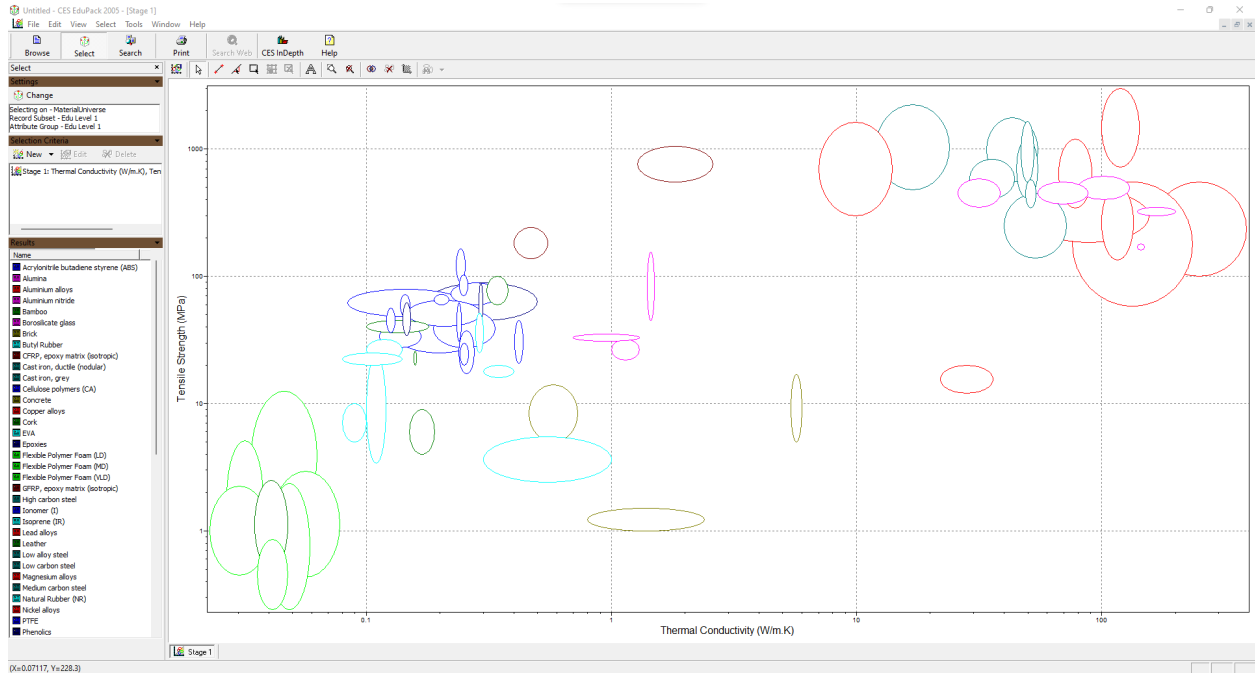
Highly customisable with the addition of colours

### **VARIABLES**

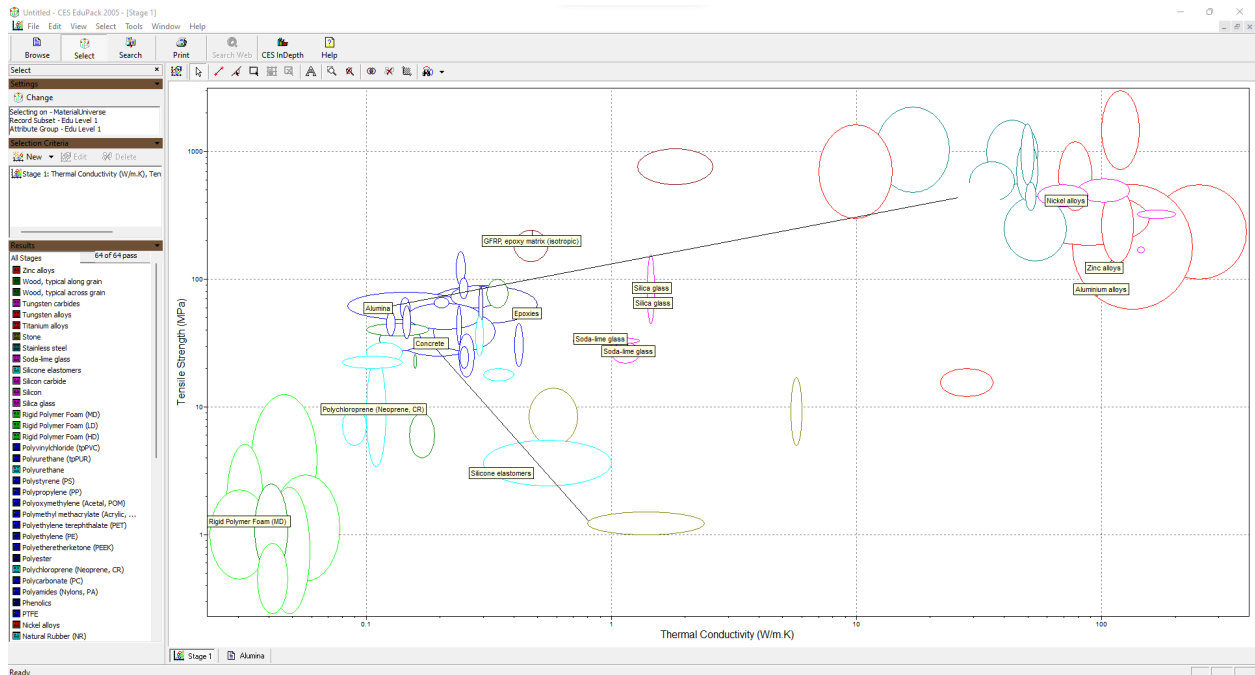
The thermal conductivity of 3.8 W/mK. densities of 2607–2739kg/m<sup>3</sup> makes it lighter to hold.

## **PROCESS OF SELECTION**

- Selected the configuration Level 1 – Introductory.
- Created a new project under material-based selection.
- Limit Stage as the selection criteria.
- Graph stage check perfect material
- In this stage, define the properties that are considered such as density, tensile strength, specific heat and insulation properties.



Finding best material that fits both thermal and strength needs.



Silicate glass and alumina was the perfect material for glasses/ mug

When designing a coffee mug the separating material must withstand hot beverages and should highly insulate the heat from the beverage to the hands hence it should be a good thermal insulator. It should reduce the transmission of heat to the outer environment. It should be able to add colours due to personalisation and customisation.

**Alumina**

**Description**

**The Material**

Alumina (Al<sub>2</sub>O<sub>3</sub>) is to technical ceramics what mild steel is to metals - cheap, easy to process, the workhorse of the industry. It is the material of spark plugs, electrical insulators and ceramic substrates for microcircuits. In single crystal form it is sapphire, used for watch faces and cockpit windows of high-speed aircraft. More usually it is made by pressing and sintering powder, giving grades ranging from 80 to 99.9% alumina - the rest is porous, glassy impurities or deliberately added components. Pure aluminas are white; impurities make them pink or green. The maximum operating temperature increases with increasing alumina content. Alumina has a low cost and a useful and broad set of properties: electrical insulation, high mechanical strength, good abrasion and temperature resistance up to 1650 C, excellent chemical stability and moderately high thermal conductivity, but it has limited thermal shock and impact resistance. Chromium oxide is added to improve abrasion resistance; sodium silicate, to improve processability but with some loss of electrical resistance. Competing materials are magnesia, silica and borosilicate glass.

**Composition**

Al<sub>2</sub>O<sub>3</sub>, often with some porosity and some glassy phase.

**Image**

**Caption**

On the left: alumina components for wear resistance and for high temperature use (Kyocera Industrial Ceramics Corp.). On the right: an alumina spark plug insulator.

**General properties**

Density	3800	-	3980	kg/m <sup>3</sup>
Price	164.9	-	247.3	INR/kg

**Mechanical properties**

Young's Modulus	343	-	390	GPa
Elastic Limit	350	-	588	MPa
Tensile Strength	350	-	588	MPa
Elongation	0	-	2060	%
Hardness - Vickers	1200	-	2060	HV
Endurance Limit	* 200	-	488	MPa
Fracture Toughness	3.3	-	4.8	MPa.m <sup>1/2</sup>

Alumina is chosen

**General properties**

Density	3800	-	3980	kg/m <sup>3</sup>
Price	164.9	-	247.3	INR/kg

**Mechanical properties**

Young's Modulus	343	-	390	GPa
Elastic Limit	350	-	588	MPa
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Elongation	0	-	2060	%
Hardness - Vickers	1200	-	2060	HV
Endurance Limit	* 200	-	488	MPa
Fracture Toughness	3.3	-	4.8	MPa.m <sup>1/2</sup>

**Thermal properties**

Thermal conductor or insulator?	Poor conductor			
Thermal Conductivity	26	-	38.5	W/m.K
Thermal Expansion	7	-	7.9	µstrain/°C
Specific Heat	790	-	820	J/kg.K
Melting Point	2004	-	2096	°C
Maximum Service Temperature	1077	-	1841	°C

**Electrical properties**

Electrical conductor or insulator?	Good insulator
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**Optical properties**

Transparency	Opaque
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**Eco properties**

Production Energy	* 49.5	-	54.7	MJ/kg
CO2 creation	* 2.67	-	2.95	kg/kg
Recycle	X			

**Supporting information**

**Typical uses**

Electrical insulators and connector bodies; substrates; high temperature components; water faucet valves; mechanical seals; vacuum chambers and vessels; centrifuge linings; spur gears; fuse bodies; heating elements; plain bearings and other wear resistant components; cutting tools; substrates for microcircuits; spark plug insulators; tubes for sodium vapor lamps.

- Links**
- Reference [...](#)
  - ProcessUniverse [...](#)
  - Producers [...](#)



## RESULT

Considering the constraints materials **Alumina** are good for such properties and requirements. Since alumina has the features required such as

- Cheap, easy to process, the workhorse of the industry. (for 50000 units)
- Poor conductor of heat
- Good insulator
- As per human tendency, the Coffe is drank always in an opaque glass.

## PRODUCTION

This is used for multiple casting and batch-wise baking. For using for 50000 units at a time.

# 3 Material selection **MOBILE COVER**

When designing a mobile cover the requirements usually are the material should be durable and elastic material that can easily protect your phone from small scratches and moisture. Moreover, impact proofing can be done using the elastic property

## **CRITERIA**

### **FUNCTION**

To protect the mobile from sudden impact and to protect from accidental moisture contact.

### **CONSTRAINTS**

Highly customisable with the addition of colours

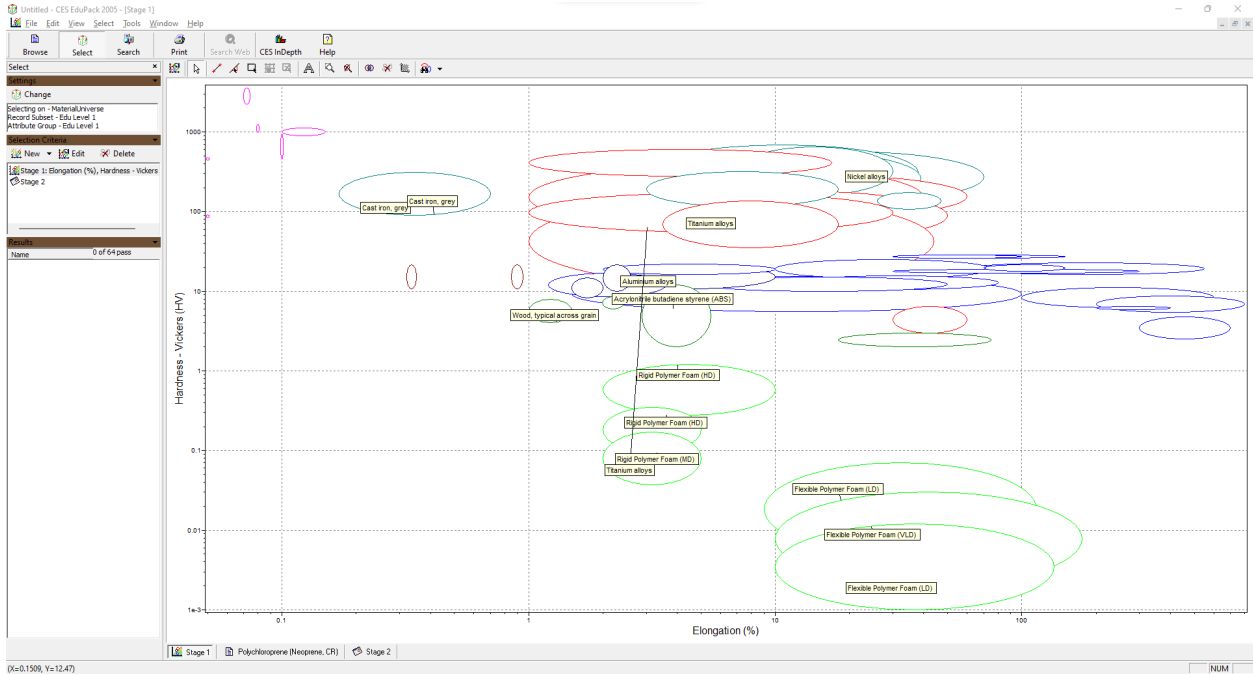
### **VARIABLES**

The thermal conductivity of 3.8 W/mK. densities of 2607–2739kg/m<sup>3</sup> makes it lighter to hold. elasticity and rigidity

Density – 1250 kg/m<sup>3</sup> • Specific Heat – 1700 J/kg.K • Good insulator highly elastic

## **PROCESS OF SELECTION**

- Selected the configuration Level 1 – Introductory.
- Created a new project under material-based selection.
- Limit Stage as the selection criteria.
- Graph stage check perfect material



The selection of an idea for which type is possible

The screenshot shows a software interface for material selection. On the left, there is a list of materials: EVA, Flexible Polymer Foam (HD), Polyurethane, and Rigid Polymer Foam (LD). On the right, there is a detailed properties table for the selected material.

General properties	
Density	Minimum: 1250, Maximum: kg/m <sup>3</sup>
Price	Maximum: INR/kg

Mechanical properties	
Young's Modulus	Minimum: 0.01, Maximum: 0.03 GPa
Elastic Limit	MPa
Tensile Strength	MPa
Elongation	%
Hardness - Vickers	HV
Endurance Limit	MPa
Fracture Toughness	MPa.m <sup>1/2</sup>

Thermal properties	
Thermal conductor or insulator?	<input type="checkbox"/> Good conductor <input type="checkbox"/> Poor conductor <input type="checkbox"/> Poor insulator <input checked="" type="checkbox"/> Good insulator
Thermal Conductivity	Minimum: , Maximum: W/m.K
Thermal Expansion	µstrain/°C
Specific Heat	J/kg.K
Melting Point	°C
Maximum Service Temperature	°C

Electrical properties	
Electrical conductor or insulator?	<input type="checkbox"/> Good conductor <input type="checkbox"/> Poor conductor <input type="checkbox"/> Semiconductor <input type="checkbox"/> Poor insulator <input checked="" type="checkbox"/> Good insulator

Optical properties	
Transparency	<input type="checkbox"/> Optical Quality <input type="checkbox"/> Transparent <input type="checkbox"/> Translucent <input type="checkbox"/> Opaque

Choosing the material with required properties

Untitled - CES EduPack 2005 - [MaterialUniverse/Polymers and elastomers/Elastomers]

Selecting on: MaterialUniverse  
Record Subset - Edu Level 1  
Attribute Group - Edu Level 1

Selection Criteria

Stage 1

Results

All Stages

- EVA
- Flexible Polymer Foam (4D)
- Polurethane
- Rigid Polymer Foam (LD)

**Polyurethane**

**Description**


**The Material**

Think of polyurethanes and you think of the soft, the stretchy, materials and fabrics (Lyca or Spandex). Like PVC, polyurethanes have thermoplastic, elastomeric and thermosetting grades. They are easily foamed; some 40% of all PU is made into foam by mixing it with a blowing agent. The foams can be open- or closed-cell, microcellular or filler grades. They are the strongest of elastomers.

**Composition**

(CO-NH-R-NH-CO-O-R-O)<sub>n</sub>

**Image**



**General properties**

Density	1020	-	1250	kg/m <sup>3</sup>
Price	164.9	-	374.7	INR/kg

**Mechanical properties**

Young's Modulus	2e-3	-	0.03	GPa
Elastic Limit	25	-	51	MPa
Tensile Strength	25	-	51	MPa
Elongation	380	-	720	%
Endurance Limit	* 18.8	-	38.3	MPa
Fracture Toughness	0.2	-	0.4	MPa.m <sup>1/2</sup>

**Thermal properties**

Thermal conductor or insulator?	Good insulator			
Thermal Conductivity	0.28	-	0.3	W/m.K
Thermal Expansion	150	-	165	µstrain/°C
Specific Heat	1650	-	1700	J/kg.K
Maximum Service Temperature	66.85	-	86.85	°C

**Electrical properties**

Electrical conductor or insulator?	Good insulator			
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Ready

Untitled - CES EduPack 2005 - [MaterialUniverse/Polymers and elastomers/Elastomers]

Selecting on: MaterialUniverse  
Record Subset - Edu Level 1  
Attribute Group - Edu Level 1

Selection Criteria

Stage 1

Results

All Stages

- EVA
- Flexible Polymer Foam (4D)
- Polurethane
- Rigid Polymer Foam (LD)

**EVA**

**Description**


**The Material**

Ethylene-Vinyl-Acetate elastomers (EVA) are built around polyethylene. They are soft, flexible and tough, and retain these properties down to -60 C. Fillers improve both hardness and stiffness, but with some degradation of other properties. EVA's blend well with PE because of their chemical similarity. EVA is available in pastel or deep hues; it has good clarity and gloss. It has good barrier properties, little or no odor, is UV resistant and FDA-approved for direct food contact. The toughness and flexibility is retained even at low temperatures and it has good stress-crack resistance and good chemical resistance. EVA can be processed by most normal thermoplastic processes: co-extrusion for films, blow molding, rotational molding, injection molding and transfer molding.

**Composition**

(CH<sub>2</sub>)<sub>n</sub>(CH<sub>2</sub>-CHR)<sub>m</sub>

**Image**



**General properties**

Density	945	-	955	kg/m <sup>3</sup>
Price	69.85	-	120.7	INR/kg

**Mechanical properties**

Young's Modulus	0.01	-	0.04	GPa
Elastic Limit	12	-	18	MPa
Tensile Strength	16	-	20	MPa
Elongation	730	-	770	%
Endurance Limit	* 12	-	12.8	MPa
Fracture Toughness	* 0.5	-	0.7	MPa.m <sup>1/2</sup>

**Thermal properties**

Thermal conductor or insulator?	Good insulator			
Thermal Conductivity	0.3	-	0.4	W/m.K
Thermal Expansion	160	-	190	µstrain/°C
Specific Heat	* 2090	-	2200	J/kg.K
Maximum Service Temperature	46.85	-	51.85	°C

**Electrical properties**

Electrical conductor or insulator?	Good insulator			
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Ready

Hence we choose the material EVA or Polurethanes

**General properties**

Density	1020	-	1250	kg/m <sup>3</sup>
Price	164.9	-	374.7	INR/kg

**Mechanical properties**

Young's Modulus	2e-3	-	0.03	GPa
Elastic Limit	25	-	51	MPa
Tensile Strength	25	-	51	MPa
Elongation	380	-	720	%
Endurance Limit	* 18.8	-	38.3	MPa
Fracture Toughness	0.2	-	0.4	MPa.m <sup>1/2</sup>

**Thermal properties**

Thermal conductor or insulator?	Good insulator			
Thermal Conductivity	0.28	-	0.3	W/m.K
Thermal Expansion	150	-	165	µstrain/°C
Specific Heat	1650	-	1700	J/kg.K
Maximum Service Temperature	66.85	-	86.85	°C

**Electrical properties**

Electrical conductor or insulator?	Good insulator			
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**Optical properties**

Transparency	Translucent			
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**Eco properties**

Production Energy	* 109	-	120	MJ/kg
CO2 creation	* 4.47	-	4.94	kg/kg
Recycle	✓			

**Supporting information**

**Typical uses**

Cushioning; packaging; shoe soles; tires; fuel hoses; gears; bearings; car bumpers; adhesives; fabric-coating.

**Links**

Reference [\[1\]](#)

ProcessUniverse [\[2\]](#)

Producers [\[3\]](#)

## RESULT

Considering the above conditions of elasticity and even the rigidity it is advisable to use polyurethane for the material for mobile covers.

## PRODUCTION

For having a production basis of 50000 units moulding can be used for doing the same.