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MEC-E1070
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Task 4.1

The main objective of the door is to keep heat in, so what we want to do is minimise the heat exchange between the in- and outside. Other thing we want are lightweight, low cost, and some sort of strength in the door.

Table 1: Isolating door for greenhouse	
Function	Greenhouse door
Constraints	Withstand a force from natural forces. Modest cost Operating temperature down to 10 °C
Objective	Minimise heat exchange
Free variables	Choice of material, door thickness t

From the Design requirements table 1 we can draw a conclusion that we want to compare thermal conductivity against strength. To derive a material index we start from the describing the heat flux through the door as:

$$q = h_1 \Delta T_1$$

Where h is the heat transfer coefficient and ΔT is the temperature drop between the air on one side of the door to the door. Conduction can be described as

$$q = \lambda \frac{\Delta T}{t}$$

Where λ is the thermal conductivity of the door and ΔT is the temperature difference across it. We can think of thermal resistance at a surface 1 as $1/h_1$ and for surface 2 as 1 as $1/h_2$ and for the door itself $1/\lambda$ the continuity of heat flux requires total resistance 1/U

$$\frac{1}{U} = \frac{1}{h_1} + \frac{1}{\lambda} + \frac{1}{h_2}$$

Uis the total heat transfer coefficient, the heat flux from inside to the outside air is then given as

$$q = U(T1 - T2)$$

So in conclusion with a door with the length L, height, h and thickness of t, we want to minimize the total heat flow

$$Q = qA = \frac{A\lambda}{t} \Delta \mathrm{T}$$

This is the objective function our constraint is that it also withstands a certain load. This requires the stress in the door to remain bellow a elastic limit of what the material is made of

$$\sigma = \frac{F}{t} < \sigma_y$$

This constraints the minimum value of t eliminating t between the equations gives us

$$Q = \frac{A\Delta \mathrm{T}}{F}(\lambda/\sigma_y)$$

The heat flow per unit area of the door, Q/A is minimized by minimising

$$\boldsymbol{M1} = \lambda/\sigma_y$$

We start by plotting thermal conductivity against yield strength in level 2 to se what types of elements could be used in this situation.

We also add e density and maximum thermal conductivity constraint, since we don't want it to let through a certain amount of heat, and not wanting it to be crazy heavy. Thermal conductivity to be <10 W/m°C and density < 2000kg/m^3

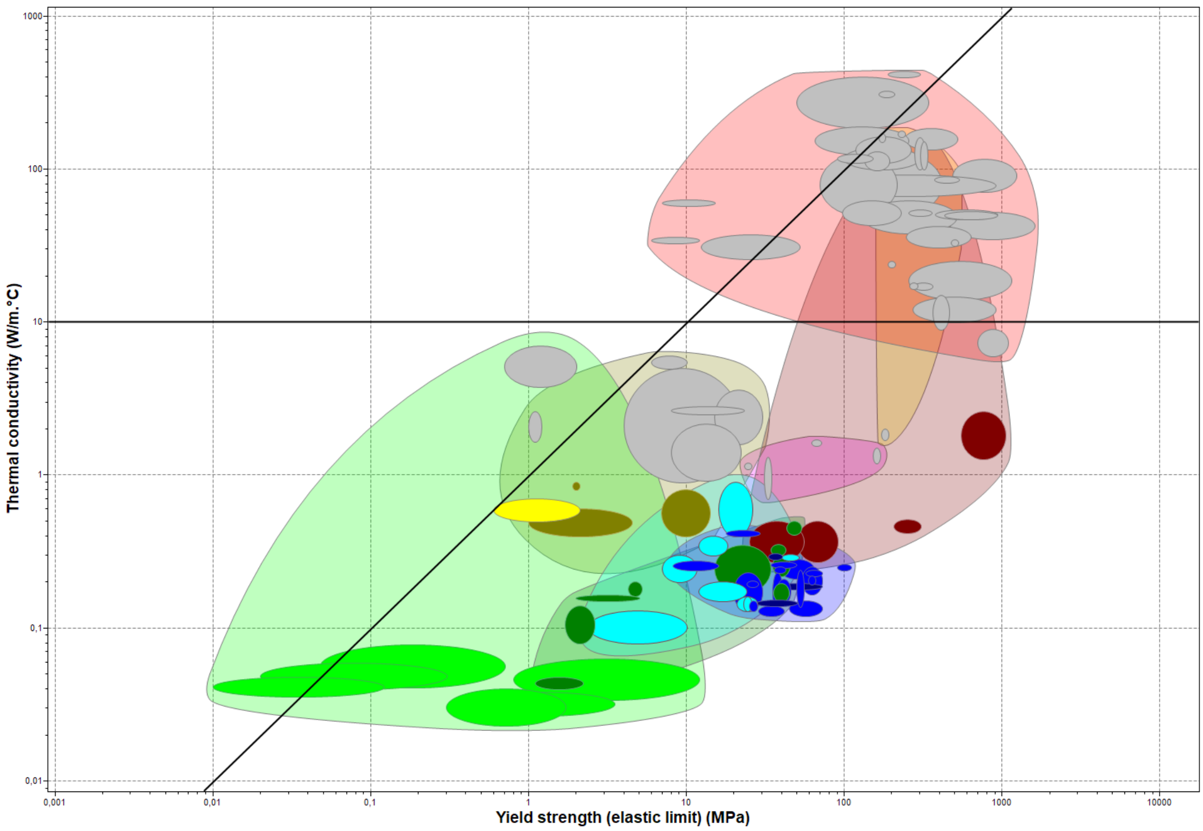

Figure 1: thermal conductivity against yield strength

We can se in Figure 1 that if we were to choose a single material we would most likely choose an elastomer since the material in the right hand corner are the best alternatives. However by making a combination between materials we can achieve an even greater material index value.
I decided to try and do several different combinations for the hybrid materials. Since we as well as having a great strength and low thermal conductivity, also want relatively cheap door, I opted to use more of the cheaper materials, often resulting in having the isolator as a core and a material that gives more strength as the walls.

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This lead to that most combinations I tried lead to foam cores. With some sort of elastomer. plastic or composites as walls. The different combinations are plotted in Figure 2

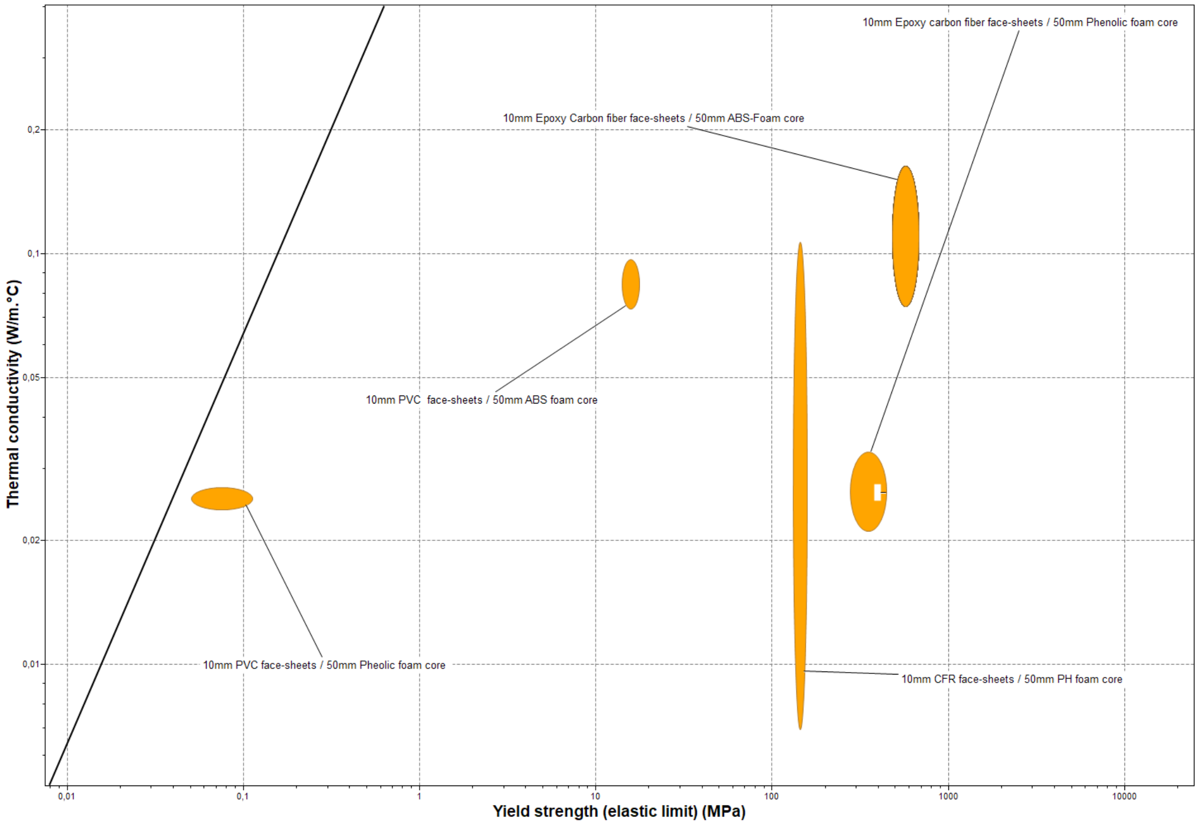


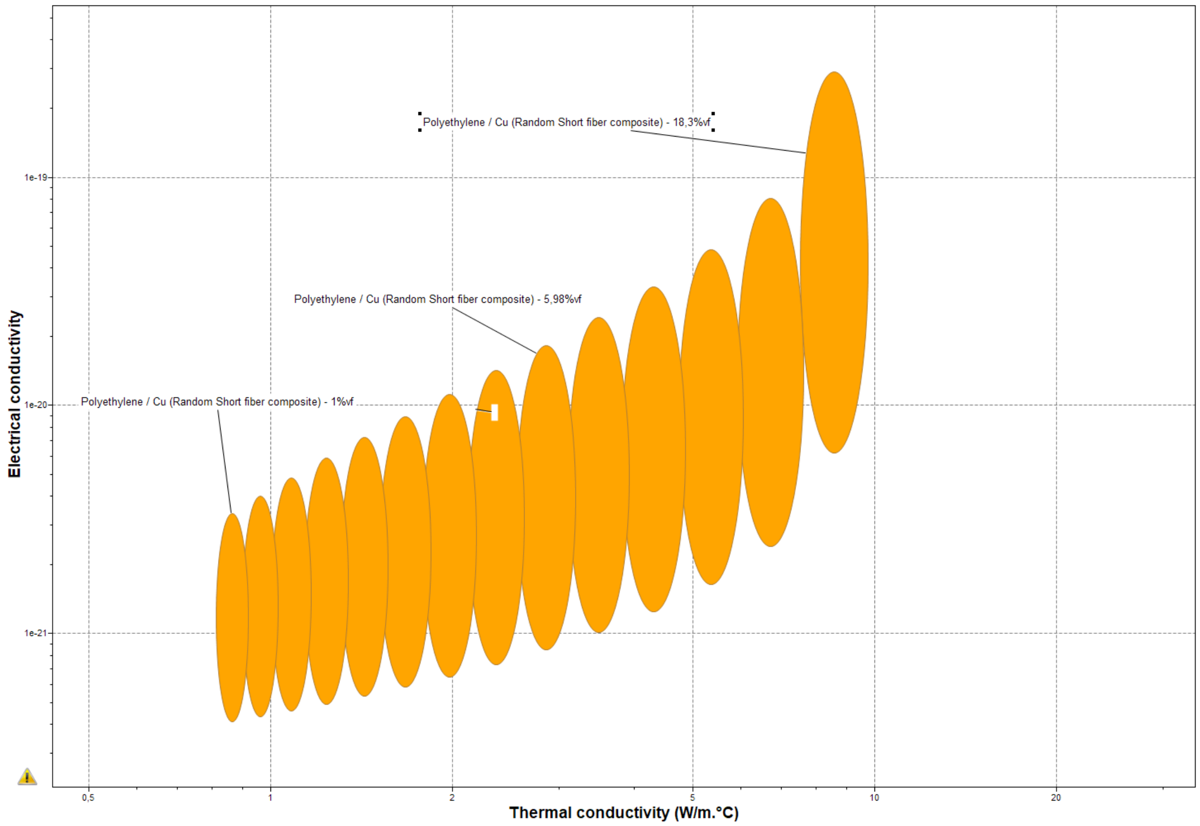
Figure 2: Thermal conductivity against yield strength for synthetic material combinations

In the end many of the combinations tried was not at all suitable. These where some of the best. The one with 10m epoxy carbon fibre sheet wall and Phenolic foam core gives the best Material index however this material would be expensive to use compared to other. Out of the combinations in Figure 2 the 10mm PVC face-sheets / 50mm ABS foam core would be the most viable having a low thermal conductivity and quite a high yield strength while being cheap. If the price is not wanted to keep at an absolute minimum 10mm Epoxy Carbon fiber face-sheets / 50mm ABS-Foam core would be a great alternative since it gives a lot of extra strength, while still being affordable.

In conclusion the material that I would choose from these would be 10mm PVC face-sheets / 50mm ABS foam core.

Task 4.2

For gloves that work on a phone screen you need a material that both is electrically conductive but also thermally isolating. To achieve this, you can combine certain materials in a certain way. For example, copper is a both electrical and thermal conductive material, but combined in a certain way with Polyethylene which is a isolator for both you can achieve the wanted properties. Figure 3 shows the electrical resistivity and thermal conductivity of a synthesized material of Polyethylene, which is a common elastomer used in outdoor clothing and copper. Combined where short copper fibres are inserted with in a random orientation, with a high aspect ratio.



Since we are wanting a quite high conductivity and relatively low thermal conductivity, the choice of synthetic would fall in the middle, so choosing Polyethylene with about 6% of copper would be the most reasonable.