Tutorial Sheet 1: Materials

1. For an axially loaded rod, prove that $\beta = 1$ for the S^β/ρ guidelines.
2. For an axially loaded rod, prove that $\beta = 1$ for the E^β/ρ guidelines.
3. Consider a rod transmitting a tensile force. The following materials are being considered: tungsten carbide, zinc alloy, polycarbonate polymer, and aluminium alloy. Using the Ashby charts, recommend the best material for a design situation in which failure is by exceeding the strength of the material, and it is desired to minimize the weight. [Maximize S/ρ. Aluminium alloys]
4. Repeat the previous problem, except that the design situation is failure by excessive deflection (deflection under axial load; remember BEM), and it is desired to minimize the weight. [Maximize E/ρ. Tungsten carbide is best; aluminium alloys are also good. Think about cost.]
5. For a cantilever beam loaded in bending, prove that $\beta = 2/3$ for the S^β/ρ guidelines.
6. For a cantilever beam loaded in bending, prove that $\beta = 1/2$ for the E^β/ρ guidelines.
7. Consider a cantilever beam that is loaded with a transverse force at its tip. The following materials are being considered: tungsten carbide, high-carbon steel, polycarbonate polymer, and aluminium alloy. Using the Ashby charts, recommend the best material for a design situation in which failure is by exceeding the strength of the material and it is desried to minimize the weight. [Maximize $S^{2/3}/\rho$. High strength aluminium alloy.]
8. Repeat the previous problem, except that the design situation is failure by excessive deflection, and it is desired to minimize the weight. [Maximize $E^{1/2}/\rho$. Aluminium alloys.]
9. Consider a tie rod transmitting a tensile force F. Using the Ashby charts, explore what ductile materials are best suited for a light, stiff, *and* strong tie rod. *Hint:* Consider stiffness and strength separately. [Considering both stiffness and strength: Common materials are steel, titanium, aluminium alloys, and composites.]
10. Search the internet for the top Indian companies involved in the production of steel, aluminium, copper, zinc, titanium, composites, and plastics. What kinds of metal products are exported by India? (Make generous use of LLMs. Use different LLMs. Ensure that you verify the answers with your own research.)
11. Rare earth minerals (RMEs) have recently been in the news a lot. Why is there so much demand for RMEs – what is their role in modern technology? Is there really an ongoing scarcity? What is India's position in all this – both in terms of reserves and industry usage? (Again use different LLMs, but also do your own research.)

12. *Thought exercise:* Think how would you go about leveraging the power of machine learning (ML) for material selection for the development of a real-world engineering product that is much more complicated than the straightforward rod and beam exercises of Q1 to Q9. Could you perhaps combine the power of ML with those of Finite Element (FE) models? Since trial and error through physical experimentation can be prohibitively costly and time-consuming, perhaps FE models can be utilized to create sufficiently dense *synthetic* datasets. These datasets could then be utilized for the training of the ML models. How would you go about setting up the problem? What would be the inputs (features) and what would be the outputs? Would it involve predictor type or classifier type models or both?