UNIVERSITY OF GHANA

BSC. MATERIALS SCIENCE AND ENGINEERING SECOND SEMESTER EXAMINATIONS: 2014/2015

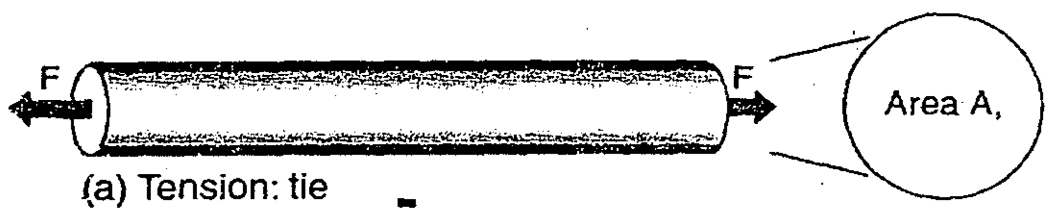
COURSE CODE: COURSE TITLE (Credits)
MTEN412: MATERIALS SELECTION & DESIGN (2 Credits)

INSTRUCTION:
ANSWER ALL QUESTIONS

TIME ALLOWED:
TWO HOURS

1. a) The four main steps involved in selecting a material for a particular application are; Translation, Screening, Ranking and Supporting Information. Briefly describe each of these steps.
   b) An engineering component has one or more functions. List three (3) of these functions.
   c) In designing a component the designer has an objective. List three (3) possible objectives. **(20 points)**

2. A design calls for a cylindrical tie-rod of specified length L to carry a tensile force F without failure; it is to be of minimum mass as in the figure below:



(a) Tension: tie

The design requirements are as shown below:

Design requirements for the light tie

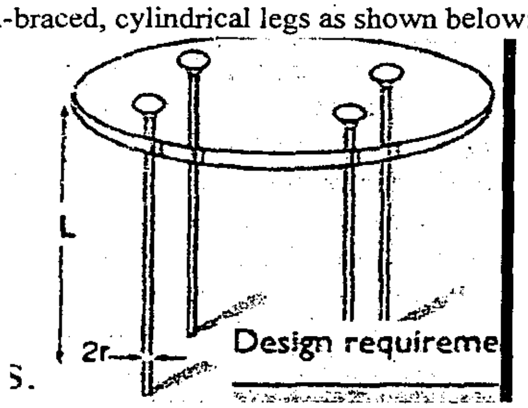
Function	Tie rod
Constraints	• Length L is specified • Tie must support axial tensile load F without failing
Objective	Minimize the mass m of the tie
Free variables	• Cross-section area, A • Choice of material

Develop a ***Performance Metric, P,*** as shown in the equation below for this bar:

$$P = \left[\begin{pmatrix} Functional \\ requirenments, F \end{pmatrix}\right], \begin{pmatrix} Geometric \\ parameters, G \end{pmatrix}, \begin{pmatrix} Material \\ properties, M \end{pmatrix}$$ **(15 points)**

3. **Materials for table legs**

A furniture designer, conceives of a light-weight table: a flat sheet of toughened glass supported on slender, un-braced, cylindrical legs as shown below:



The legs must be solid (to make them thin) and as light as possible (to make the table easier to move). They must support the table top and whatever is placed upon it without buckling.
This is a problem with two objectives: weight is to be minimized, and slenderness maximized.

The ***Performance Metric*** for the mass of the legs is:

$$m \geq \left(\frac{4F}{\pi}\right)^{1/2} (L)^2 \left[\frac{\rho}{E^{1/2}}\right]$$

which gives a material index of: $M_1 = \frac{E^{1/2}}{\rho}$

The ***Performance metric*** for the thinnest leg that will not buckle is:

$$r \geq \left(\frac{4F}{\pi^3}\right)^{1/4} (L)^{1/2} \left[\frac{1}{E}\right]^{1/4}$$

which gives material index of: $M_2 = E$

The design requirements for the oar are as follows:

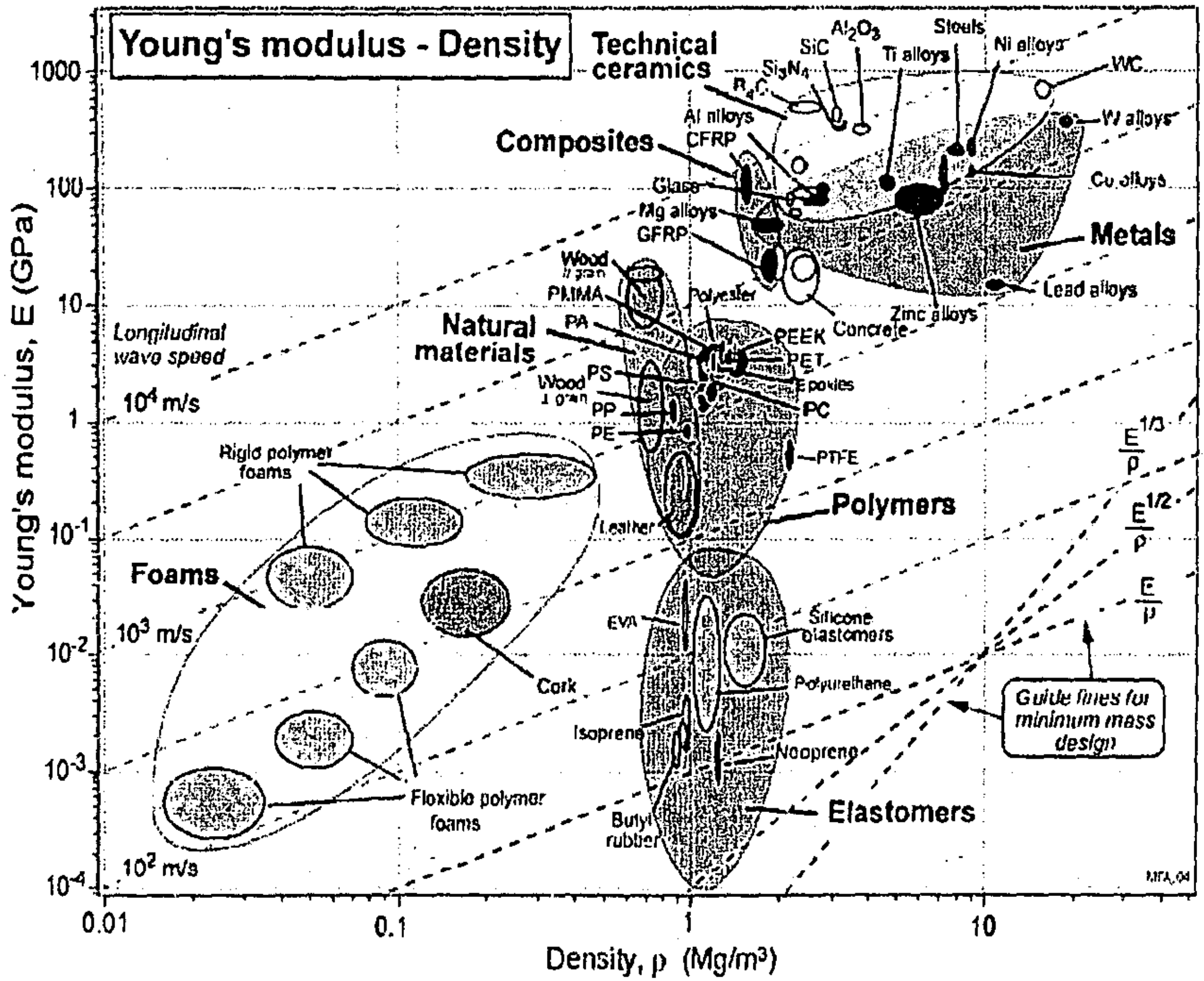
Function	**Column (supporting compressive loads)**
Constraints	• **Length L is specified** • **Must not buckle under design loads** • **Must not fracture if accidentally struck**
Objective	• **Minimize the mass, m** • **Maximize slenderness**
Free variables	• **Diameter of legs, 2r** • **Choice of material**

Given these requirements and setting $M_1 = 5.5\ GPa^{1/2}/\left({}^{Mg}/_{m^3}\right)$ and $M_2 > 100$ GPa on the Young's modulus axis, what materials would you choose? Eliminate polymers (not stiff enough), metals (too heavy) and ceramics (too brittle).
(Use Young's modulus – Density chart). **(25 points)**

4. Use the Young's modulus – density (E - ρ) chart to identify materials with both E > 100 GPa and $E^{1/3}/\rho > 3\ (GPa)^{1/3}/\left(Mg/m^3\right)$.

   Hint: Change the last material index to logarithms and find two points through which the guide line will pass. **(25 points)**

5. Use the Young's modulus – density (E - ρ) chart to find (a) metals that are stiffer and less dense than steels and (b) materials (not just metals) that are both stiffer and less dense than steel. **(15 points)**


Young's modulus - Density
Technical ceramics
Composites
Metals
Natural materials
Polymers
Foams
Elastomers
Longitudinal wave speed
10^4 m/s
10^3 m/s
10^2 m/s
Rigid polymer foams
Flexible polymer foams
Cork
Leather
Wood
PMMA
PA
PS
PP
PE
Polyester
PEEK
PET
Epoxies
PC
PTFE
EVA
Silicone elastomers
Polyurethane
Isoprene
Neoprene
Butyl rubber
Al alloys
CFRP
Glass
Mg alloys
GFRP
Concrete
Zinc alloys
Lead alloys
Cu alloys
W alloys
WC
Ni alloys
Steels
Ti alloys
Al_2O_3
SiC
Si_3N_4
B_4C
$\frac{E^{1/3}}{\rho}$
$\frac{E^{1/2}}{\rho}$
$\frac{E}{\rho}$
Guide lines for minimum mass design
Young's modulus, E (GPa)
Density, ρ (Mg/m³)
0.01
0.1
1
10
1000
100
10
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}