SE104 Structural Materials
Sample Midterm Exam

1. Mechanical properties of a material are usually characterized by
(A) Stiffness and strength
(B) Young's modulus, yield strength, and fracture toughness
(C) True stress and true strain
(D) Performance index

2. A scaffold must be as tall as the building. This statement specifies ______ for the scaffold design.
(A) A constraint
(B) An objective
(C) a free variable
(D) None of the above

3. Free variables are system parameters that can change freely in large ranges. Thus, they don't need to be taken into consideration in a design process. This statement is
(A) True
(B) False

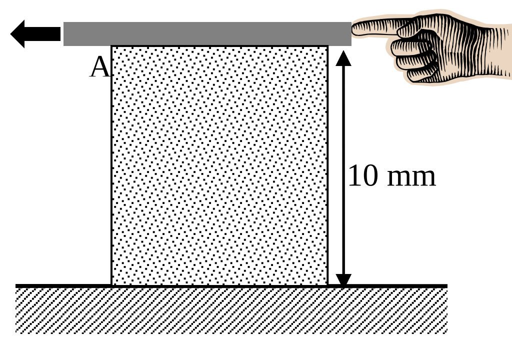
4. Usually, in a materials selection process, we first eliminate irrelevant candidates that do not meet the requirements of the objective.
(A) True
(B) False

5. We need to design a beam that deflects less than $\delta = 0.1$ mm when the load is $F = 1000$ N. Which of the following materials meets this requirement?
(A) A material with the Young's modulus of 20 GPa.
(B) A material with the Young's modulus of 2 MPa
(C) A material with the yield strength of 20 MPa
(D) No enough information

6. The weight density of a polymer cube is measured in air as 1.2 g/cm^3. When it is weighted in vacuum, its weight increases by 0.1%. What is the density of air?
(A) 1.2×10^{-3} g/cm^3
(B) 1.2 g/cm^3
(C) 0.1 g/cm^3
(D) 0.001 g/cm^3

7. Which of the following is NOT a basic loading mode:
(A) Pulling a rod along its axial direction
(B) Bending a beam at its both ends
(C) Applying a hydrostatic pressure on a block, by immersing it in deep water
(D) Stepping on the top of a column

8. As shown by the diagram on the right, a gray glass cover is pushed by the finger to slide on the upper surface of a block. The sliding of the cover causes a _____ in the block.
   (A) shear stress
   (B) tensile stress
   (C) compression stress
   (D) bending stress



9. In the above problem, if the size of the block is 10 mm, and the friction force between the glass cover and the block is 10 N. The stress in the block is
   (A) 0.1 GPa
   (B) 0.1 MPa
   (C) 10 N
   (D) 10 Pa

10. In the above problem, it is measured that the upper left corner of the block, point "A", displaces by 0.1 mm. We may conclude that
    (A) The shear modulus of the glass cover is 10 MPa
    (B) The Young's modulus of the block is 10 MPa
    (C) the shear modulus of the block is 10 MPa
    (D) the shear modulus of the block is 10 GPa

11. A truss member has a circular cross section, with the initial diameter of 1". As an axial tensile load of 10 kN is applied, the diameter decreases by 10%. The true stress is
    (A) 20 MPa
    (B) 24 MPa
    (C) 13 GPa
    (D) 16 GPa

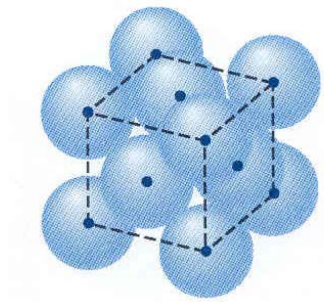
12. In the above problem, assume the volume of the truss member does not vary before and after the deformation. The true strain is
    (A) 0.235
    (B) 0.111
    (C) 0.207
    (D) 0.105

13. The Young's modulus and shear modulus of a material are 400 and 190 MPa, respectively. The Poisson's ratio of this material is
    (A) 0.05
    (B) 1.05
    (C) 0.5
    (D) 0.4

14. In the above problem, it is likely that the material is a
    (A) metal
    (B) ceramic
    (C) elastomer
    (D) foam

15. In terms of the crystalline structure, a FCC crystal is most similar to a
    (A) BCC crystal
    (B) amorphous material
    (C) glass
    (D) HCP crystal

16. The diagram on the right shows a
    (A) FCC unit cell
    (B) HCP unit cell
    (C) BCC unit cell
    (D) None of the above



17. A FCC material has the atomic radius of 0.143 nm. The size of its unit cell is
    (A) 0.286 nm
    (B) 0.330 nm
    (C) 0.071 nm
    (D) 0.404 nm

18. In the above problem, if the density of the material is 2.7 g/cm^3, what is the atomic mass?
    (A) 15 g/mol
    (B) 30 g/mol
    (C) 27 g/mol
    (D) 54 g/mol

19. In a composite material, 40 vol.% of reinforcement fibers are used. The density of the fiber is 7.8 g/cm^3, and the density of the matrix is 1.5 g/cm^3. What is the mass percentage of the matrix?
    (A) 77.6%
    (B) 22.4%
    (C) 11.2%
    (D) 88.8%

20. In the above problem, the stiffness of fiber is 200 GPa, and the stiffness of matrix is 10 GPa. Which of the following is NOT a possible value of the stiffness of the composite?
    (A) 30 GPa
    (B) 25 GPa
    (C) 20 GPa
    (D) None of the above (i.e. all the above are possible values)

21. In a foam, if 75% of the volume is occupied by cells, compared with the solid material, the stiffness of the foam would decrease by
(A) 4 times
(B) 2 time
(C) 75%
(D) 25%

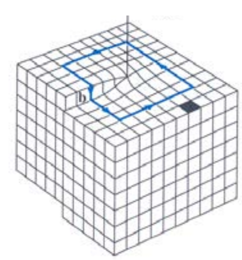
22. In a portable musical instrument, a string is clamped at its both ends. Its natural frequency must be equal to f_0; its diameter must be less than d_0 and the cross section must be circular. Its weight should be as small as possible. Which one is NOT a constraint?
(A) Cross-sectional size
(B) Length
(C) Natural frequency
(D) None of the above (i.e. all the above are constraints)

23. In the above problem, in order to minimize the weight, we should
(A) maximize E/ρ
(B) minimize E/ρ
(C) minimize $E^{1/2}/\rho$
(D) None of the above

24. In the above problem, among the following materials, __________ is the best candidate:
(A) Glass fiber reinforced polymer (GFRP)
(B) Tungsten carbide (WC)
(C) Polypropylene (PP)
(D) Copper (Cu) alloy

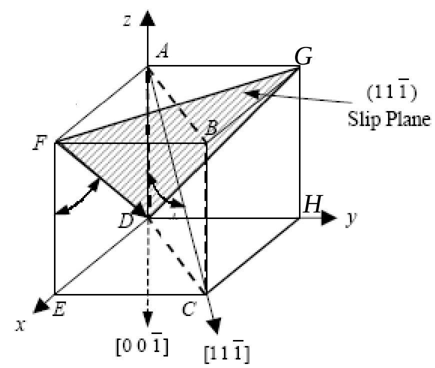
25. Usually, plastic yielding of a material happens when the atomic bonds are broken uniformly in a material. This statement is
(A) True
(B) False

26. The diagram on the right depicts
(A) an edge dislocation
(B) a screw dislocation
(C) a dislocation of unknown type
(D) a grain boundary



27. When slip bands show up on the surface of a material,
(A) dislocations move
(B) precipitation hardening takes place
(C) surface treatment is needed
(D) fracture will happen soon

28. A tensile stress of 9.5 MPa is applied along the z axis in a unit cell of a cubic crystal, shown in the diagram on the right. The slip plane is “FGD” and the slip direction is “GD”. What is the angle between the loading axis and the normal of the slip plane?
(A) 54.7°
(B) 45°
(C) 30°
(D) 60°

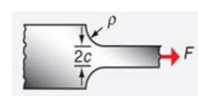


29. In the above problem, the angle between the loading axis and the slip direction is
(A) 54.7°
(B) 45°
(C) 30°
(D) 60°

30. In the above problem, the resolved shear stress is
(A) 0
(B) 1.94 MPa
(C) 3.88 MPa
(D) 7.76 MPa

31. In the above problem, if the slip direction is “FG”, the resolved shear stress is
(A) 0
(B) 1.94 MPa
(C) 3.88 MPa
(D) 7.76 MPa

32. A tensile testing sample is shown in the diagram on the right. The curvature, ρ, is 1”; the width of the gauge area, $2c$ = 0.32”, is much smaller than the width of the holding area. The sample thickness is 0.1”. The loading factor (α) can be taken as 1. If the yield strength of the material is 70 MPa, what is the maximum axial load, F, that can be applied without causing any permanent damage?
(A) 5,020 N
(B) 1,032 N
(C) 1,445 N
(D) 2,240 N



33. A helical spring must be able to support an axial load of F_0, without any plastic damage. Under the given load (F_0), the elastic energy that the spring stores should be as much as possible. Denote the wire diameter as d, the radius of coil as R, the number of coils as n, the shear modulus of the material as G, and the yield strength of the material as σ_y. To

design such a spring,
(A) The spring stiffness, *S*, must be minimized.
(B) The spring stiffness, *S*, must be maximized.
(C) The strength of the material must be higher than $F_0/\pi R^2$.
(D) The strength of the material must be higher than $4F_0/\pi d^2$.

34. If the wire diameter, *d*, is specified, the free variable that we can use for the materials selection should be
(A) The Young's modulus of the material, *E*
(B) The material strength, σ_y
(C) The radius of coil, *R*
(D) All the above

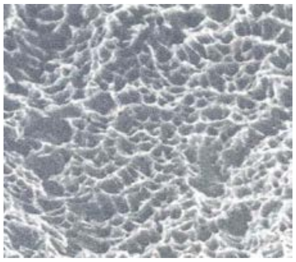
35. In the above problem, which of the following helps reach the design objective?
(A) Make more coils so that the spring is longer
(B) Use a material of a lower yield strength
(C) Use a material of a higher shear modulus
(D) All of the above

36. In the above problem, if the wire diameter, *d*, does not matter while the coil radius must be equal to a specified value, R_0, the design index becomes
(A) σ_y^3/G
(B) σ_y^2/G
(C) σ_y/G
(D) $\sigma_y^{4/3}/G$

37. In the above problem, when the coil radius is specified, among the following candidates ________ is the best one. Hint: assume the shear modulus is proportional to the Young's modulus.
(A) Brick
(B) Tungsten (W) alloys
(C) Ethylene vinyl acetate (EVA)
(D) Wood

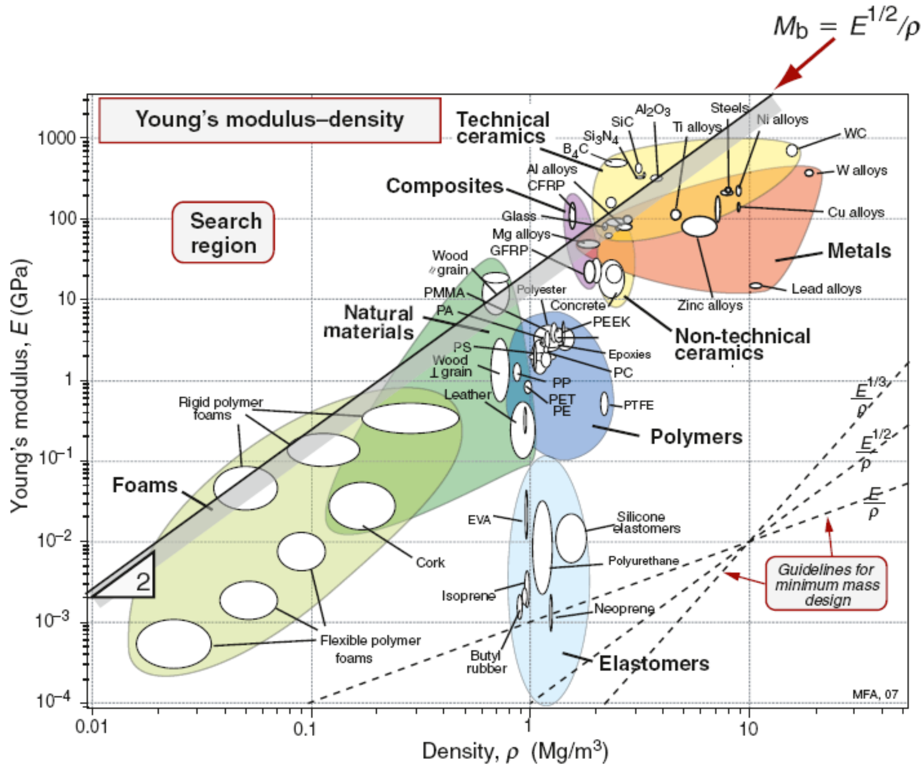
38. Stress intensity factor (K_I) is a parameter describing the fracture toughness of a material. This statement is
(A) True
(B) False

39. The picture on the right shows the surface of a
(A) cleavage crack
(B) crack in a brittle material
(C) crack in a ductile material
(D) crack in a composite material

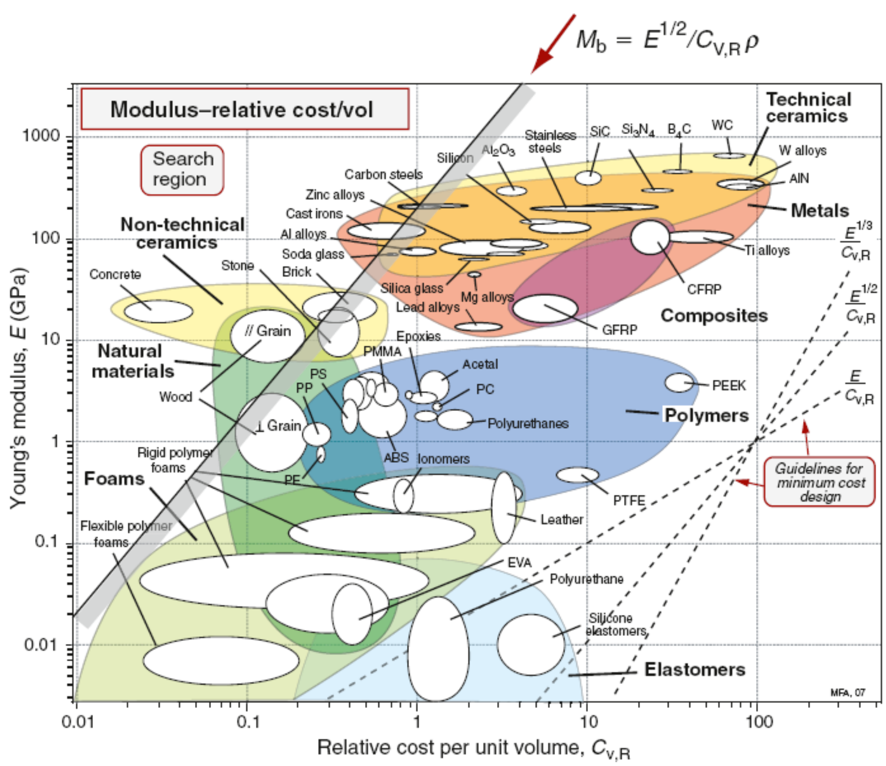


40. Usually, when the strength of a material is increased by a hardening treatment,
    (A) its fracture toughness tends to decrease
    (B) its fracture toughness tends to increase
    (C) its fracture toughness is not affected
    (D) it undergoes a brittle-to-ductile transition.

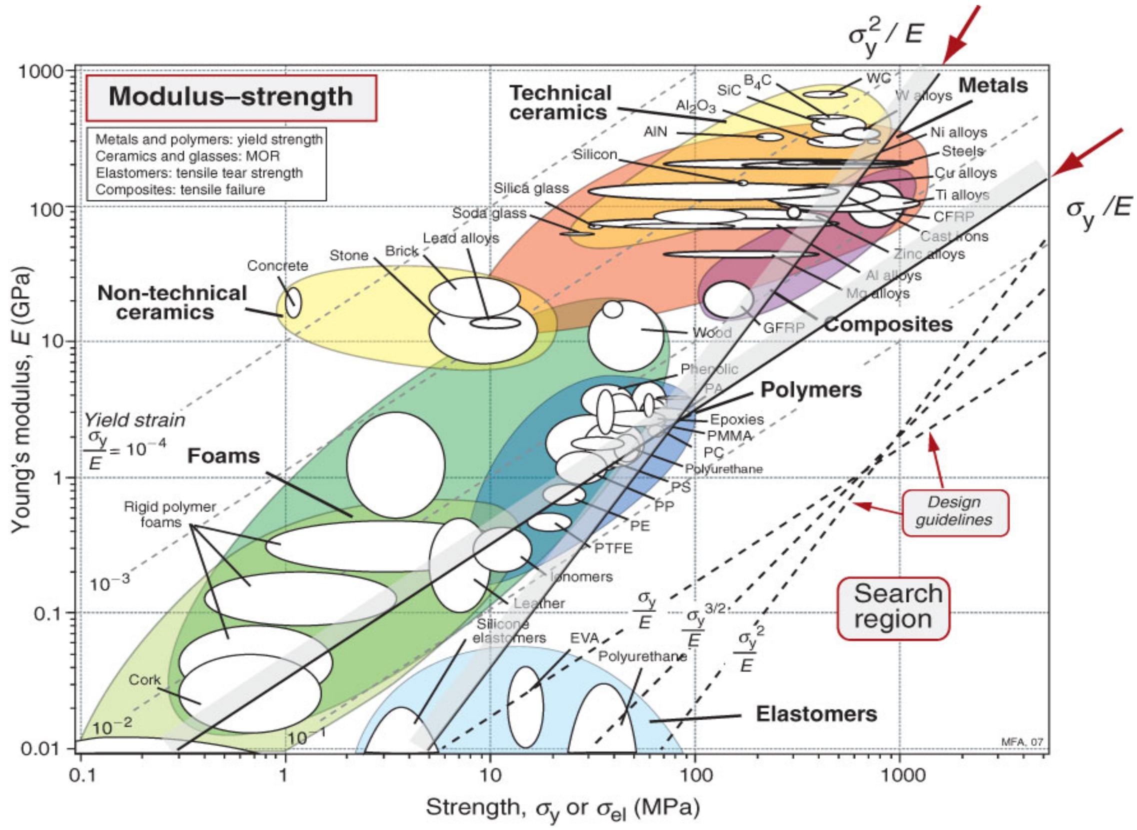
41. Which of the following is a widely employed technique to enhance the strength of a polymer:
    (A) Solute hardening
    (B) Adding reinforcements
    (C) Precipitation hardening
    (D) None of the above



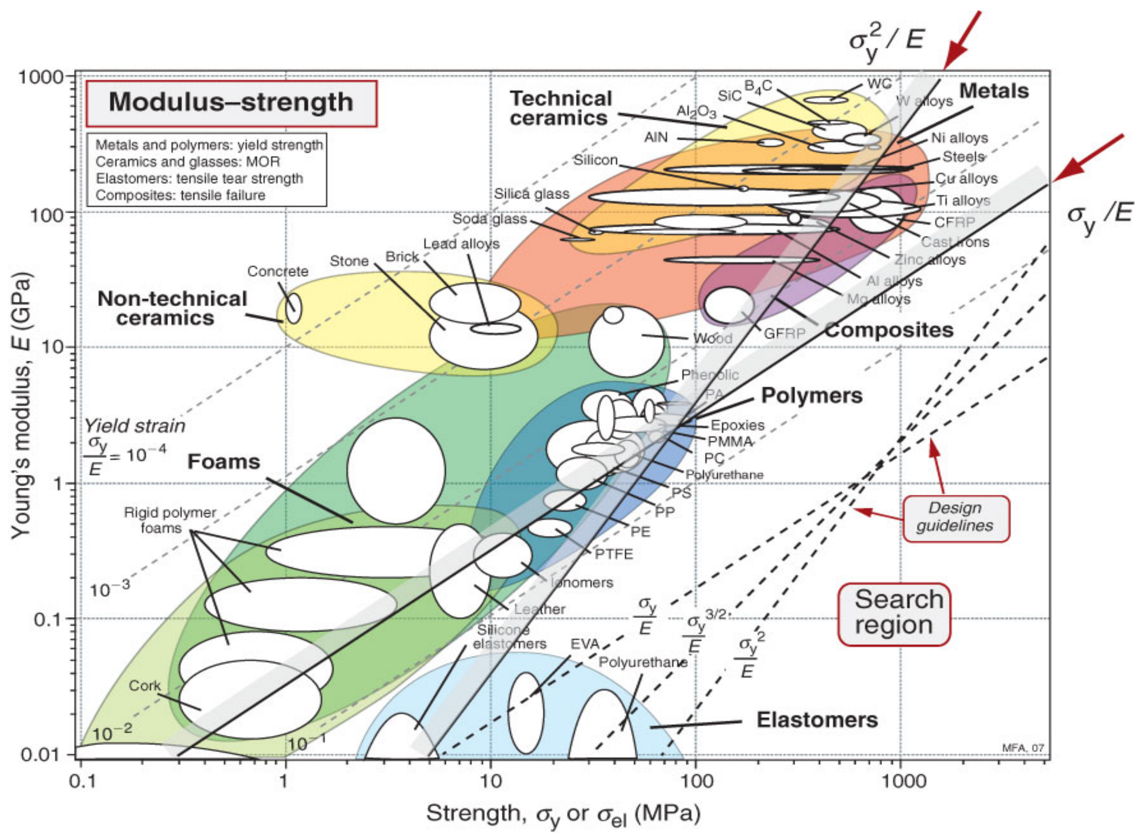
$M_b = E^{1/2}/\rho$
Young's modulus–density
Technical ceramics
Composites
Search region
Natural materials
Foams
Metals
Non-technical ceramics
Polymers
Elastomers
WC
W alloys
Cu alloys
Lead alloys
Zinc alloys
Steels
Ni alloys
Ti alloys
Al_2O_3
SiC
Si_3N_4
B_4C
Al alloys
CFRP
Glass
Mg alloys
GFRP
Wood // grain
PMMA
PA
Polyester
Concrete
PEEK
Epoxies
PC
PS
Wood ⊥ grain
PP
PET
PE
PTFE
Leather
Rigid polymer foams
Cork
EVA
Silicone elastomers
Polyurethane
Isoprene
Neoprene
Butyl rubber
Flexible polymer foams
2
$E^{1/3}/\rho$
$E^{1/2}/\rho$
E/ρ
Guidelines for minimum mass design
MFA, 07
Young's modulus, E (GPa)
Density, ρ (Mg/m³)



$M_b = E^{1/2}/C_{v,R}\,\rho$
Modulus–relative cost/vol
Search region
Technical ceramics
Metals
Composites
Non-technical ceramics
Natural materials
Polymers
Foams
Elastomers
Stainless steels
SiC
Si_3N_4
B_4C
WC
W alloys
AlN
Silicon
Al_2O_3
Carbon steels
Zinc alloys
Cast irons
Al alloys
Soda glass
Brick
Stone
Concrete
Silica glass
Lead alloys
Mg alloys
Ti alloys
CFRP
GFRP
// Grain
Wood
⊥ Grain
PMMA
Epoxies
Acetal
PC
PS
PP
Polyurethanes
PEEK
ABS
Ionomers
PE
PTFE
Rigid polymer foams
Flexible polymer foams
Leather
EVA
Polyurethane
Silicone elastomers
$E^{1/3}/C_{v,R}$
$E^{1/2}/C_{v,R}$
$E/C_{v,R}$
Guidelines for minimum cost design
MFA, 07
Young's modulus, E (GPa)
Relative cost per unit volume, $C_{v,R}$



Modulus–strength
Metals and polymers: yield strength
Ceramics and glasses: MOR
Elastomers: tensile tear strength
Composites: tensile failure
Technical ceramics
Non-technical ceramics
Metals
Composites
Polymers
Foams
Elastomers
WC
B_4C
SiC
Al_2O_3
AlN
Silicon
Silica glass
Soda glass
W alloys
Ni alloys
Steels
Cu alloys
Ti alloys
CFRP
Cast irons
Zinc alloys
Al alloys
Mg alloys
GFRP
Concrete
Stone
Brick
Lead alloys
Wood
Phenolic
PA
Epoxies
PMMA
PC
Polyurethane
PS
PP
PE
PTFE
Ionomers
Leather
Rigid polymer foams
Cork
Silicone elastomers
EVA
Polyurethane
Yield strain
$\frac{\sigma_y}{E} = 10^{-4}$
10^{-3}
10^{-2}
10^{-1}
σ_y^2 / E
σ_y / E
$\frac{\sigma_y}{E}$
$\frac{\sigma_y^{3/2}}{E}$
$\frac{\sigma_y^2}{E}$
Design guidelines
Search region
Young's modulus, E (GPa)
Strength, σ_y or σ_{el} (MPa)
0.01
0.1
1
10
100
1000
0.1
1
10
100
1000
MFA, 07



Modulus–strength
Metals and polymers: yield strength
Ceramics and glasses: MOR
Elastomers: tensile tear strength
Composites: tensile failure
Technical ceramics
Non-technical ceramics
Metals
Composites
Polymers
Foams
Elastomers
Yield strain
$\frac{\sigma_y}{E} = 10^{-4}$
σ_y^2 / E
σ_y / E
Design guidelines
Search region
Young's modulus, E (GPa)
Strength, σ_y or σ_{el} (MPa)
MFA, 07