Machine Elements

Instructor: Dr. Sotiria Chouliara
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Course Outline

OBJECTIVES:

Machines consist of interrelated elements. This course will focus on design of important **conventional machine design elements**. The basic principles from the fields of Statics, Dynamics and Mechanics of Materials are employed in the design of standard mechanical components subjected to operating force and moment fields. This course will highlight the adaptation of theoretical relationships/formulas to practical design problems.

EVALUATION SCHEME:

The course grade will be based only on the **final exam** (**100%**) (''closed-book'' exam type)

EVALUATION SCHEME:

-**Στοιχεία Μηχανών, Παπαδόπουλος Χρήστος, Εκδόσεις Τζιόλα**

-Shigley's Mechanical Engineering Design (McGraw-Hill Series in Mechanical Engineering)

-Fundamentals of Machine Component Design, R.C. Juvinall and K.M. Marshek

course plan		
3/2/2020	week 01	**Fundamental Topics from Mechanics of Materials**
10/2/2020	week 02	**Static Failure Theories**
17/2/2020	week 03	**Fatigue Failure Theories**
24/2/2020	week 04	
2/3/2020	week 05	**Screws and Fasteners**
9/3/2020	week 06	
16/3/2020	week 07	
23/3/2020	week 08	**Shafts**
30/3/2020	week 09	
6/4/2020	week 10	
27/4/2020	week 11	**Belts (flexible mechanical elements)**
4/5/2020	week 12	
11/5/2020	week 13	**Spur Gears**
18/5/2020	week 14	**Review**

The design process

- Design involves constrained creation
- Constraints:
  - Technology limits
  - Human and environment concerns
  - Durability and reliability
  - Cost
  - Market requirements
  - Etc.

TABLE 1.3 Major Categories of Design Considerations

Traditional Considerations

1. Materials
2. Geometry
3. Operating conditions
4. Cost
5. Availability
6. Producibility
7. Component life

Modern Considerations

1. Safety
2. Ecology
3. Quality of life

Miscellaneous Considerations

1. Reliability and maintainability
2. Ergonomics and aesthetics
3. Assembly and disassembly
4. Analysis

Table 1.3

Προτεινόμενο Μάθημα 8ου εξ.

ΕΠΙΛΟΓΗ ΥΛΙΚΩΝ ΣΤΟΝ ΜΗΧΑΝΟΛΟΓΙΚΟ ΣΧΕΔΙΑΣΜΟ

Young's modulus E versus density ρ for various materials. *(Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)*

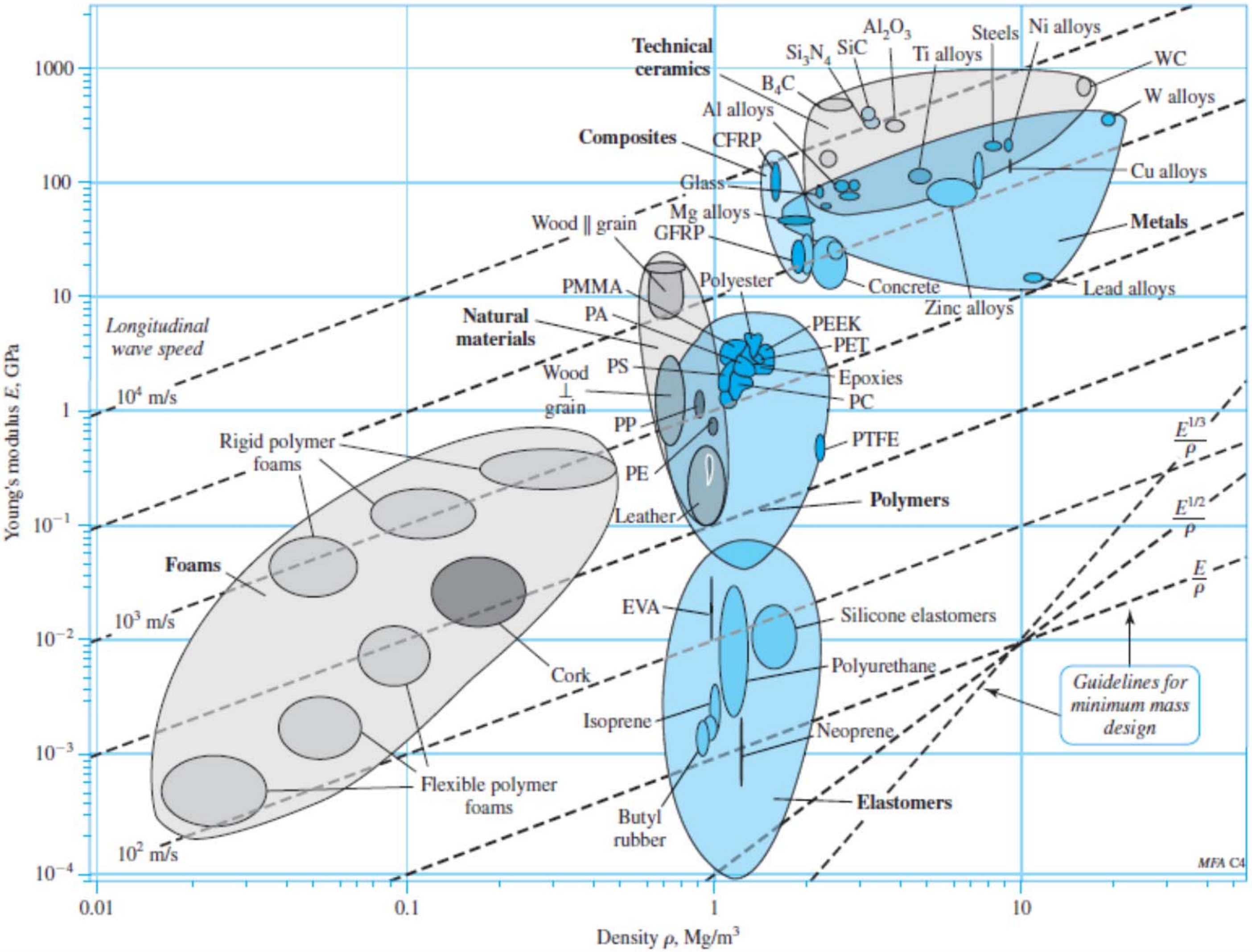


Figure 2–17

A schematic E versus ρ chart showing a grid of lines for various values the material index $M = E^{1/2}/\rho$. *(From M. F. Ashby, Materials Selection in Mechanical Design, 3rd ed., Elsevier Butterworth-Heinemann, Oxford, 2005.)*

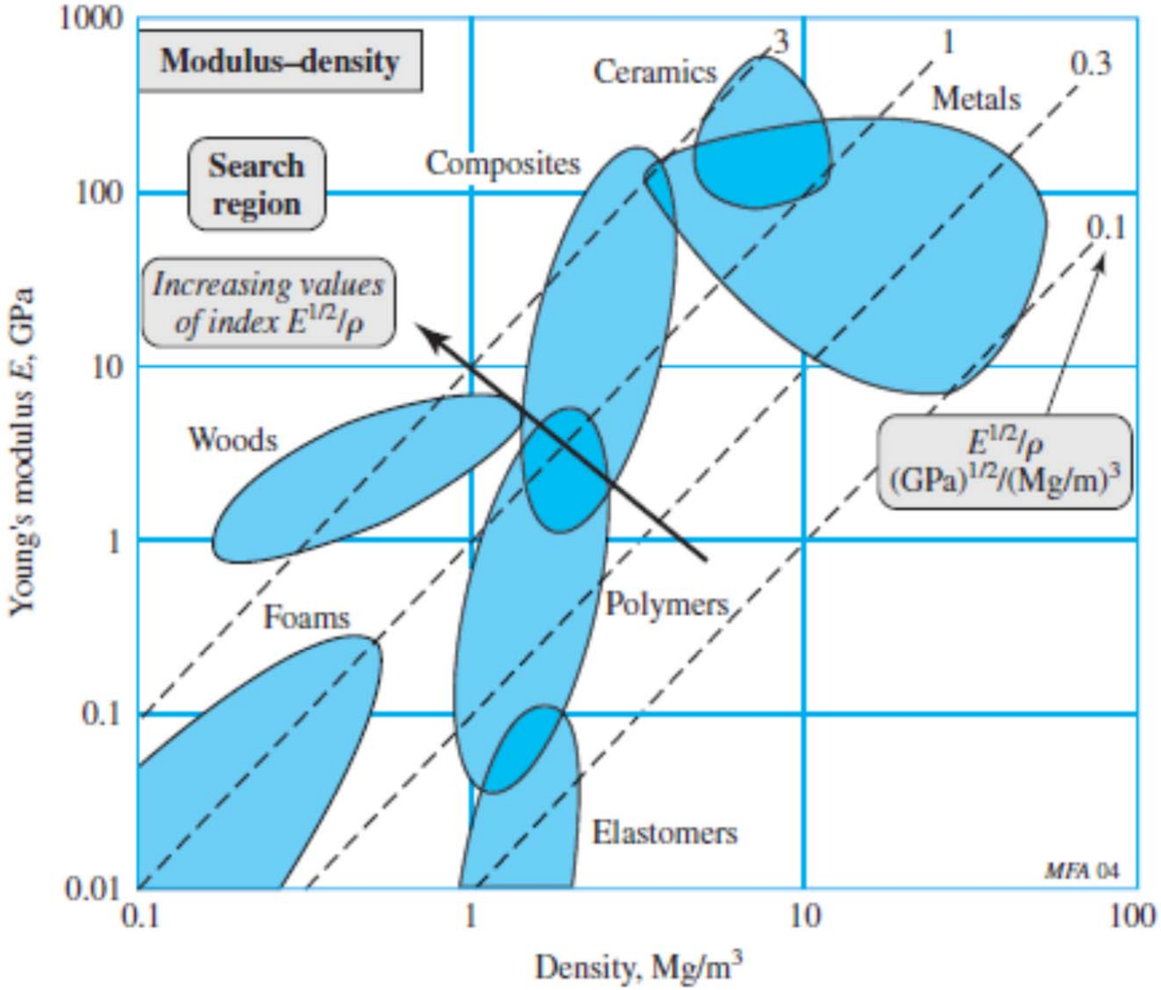


Figure 2–18

The search region of Fig. 2–16 further reduced by restricting $E \geq 50$ GPa, *(From M. F. Ashby, Materials Selection in Mechanical Design, 3rd ed., Elsevier Butterworth-Heinemann, Oxford, 2005.)*

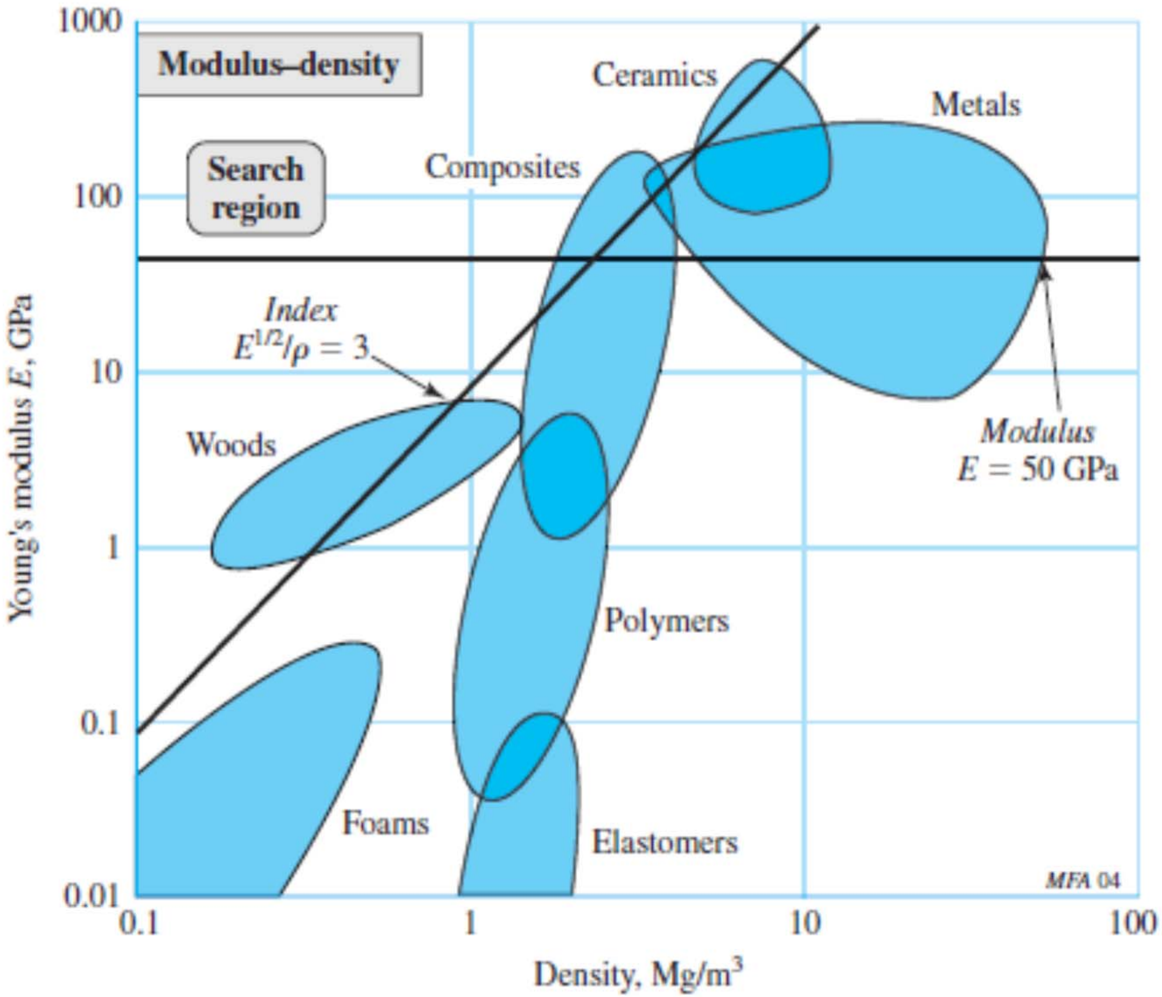
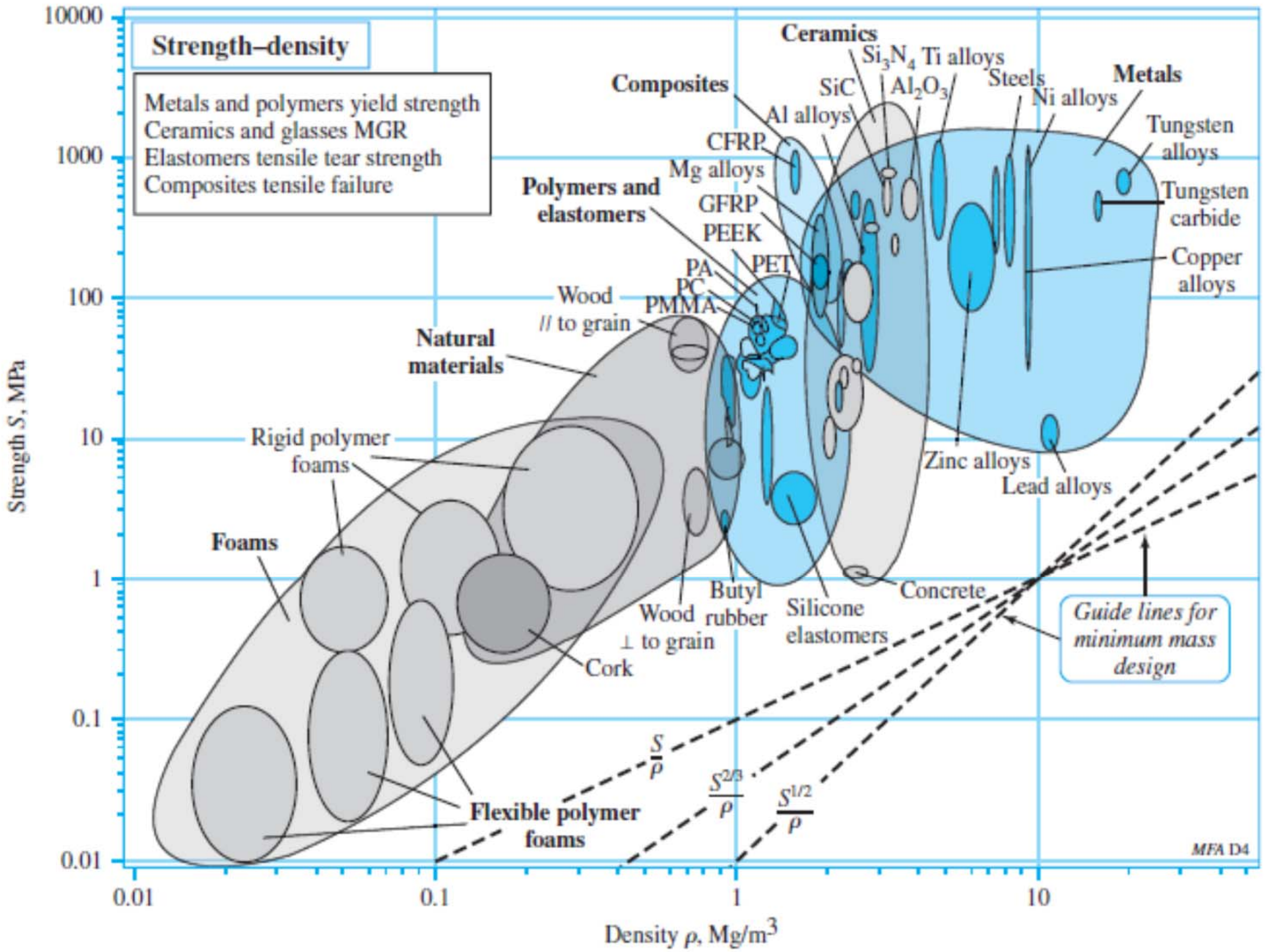


Figure 2–19

Strength S versus density ρ for various materials. For *metals,* S is the 0.2 percent offset yield strength. For *polymers,* S is the 1 percent yield strength. For *ceramics and glasses,* S is the compressive crushing strength. For *composites,* S is the tensile strength. For *elastomers,* S is the tear strength. *(Figure courtesy of Prof. Mike Ashby, Granta Design, Cambridge, U.K.)*



Engineering Design

n συντελεστής ασφαλείας (safety factor)

Factor of Safety N =

$$\frac{\text{Material Strength}}{\text{Design Load}}$$

Potential Critical Points/Cross-Sections:

-maximum load (force or moment)

-geometric discontinuities

-**stress concentration factors**

$$\sigma \leq \sigma_{\varepsilon\pi} = \frac{\sigma_y}{n}$$

$$\delta \leq \delta_{\varepsilon\pi}$$

After certain initial applied loads have been determined or estimated, the basic equations of equilibrium enable loads at other points to be determined. For a nonaccelerating body, these equations can be simply expressed as

$$\Sigma F = 0 \quad \text{and} \quad \Sigma M = 0$$

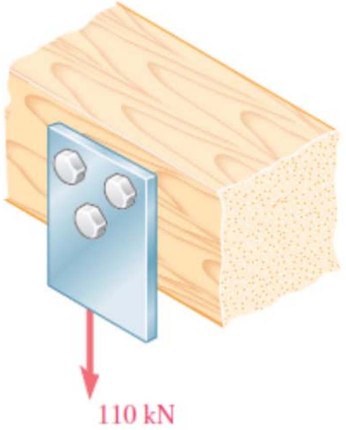
For an accelerating body they are

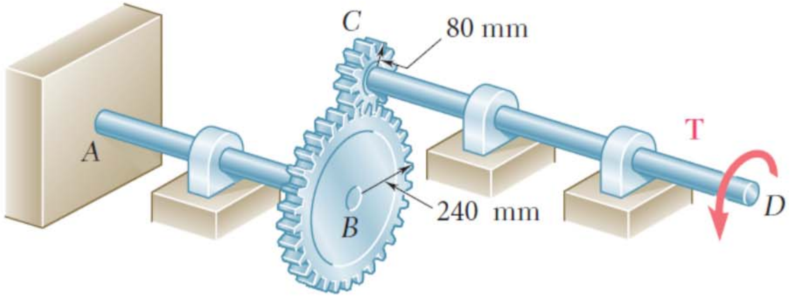
$$\Sigma F = ma \quad \text{and} \quad \Sigma M = I\alpha$$

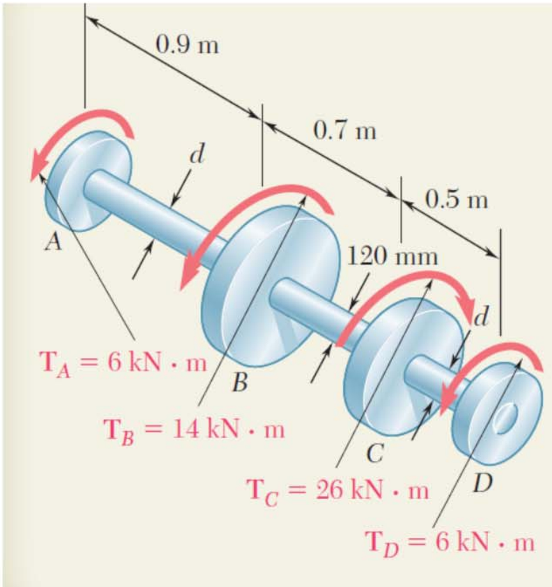
These equations apply with respect to each of any three mutually perpendicular axes (commonly designated X, Y, and Z), although in many problems forces and moments are present with respect to only one or two of these axes.

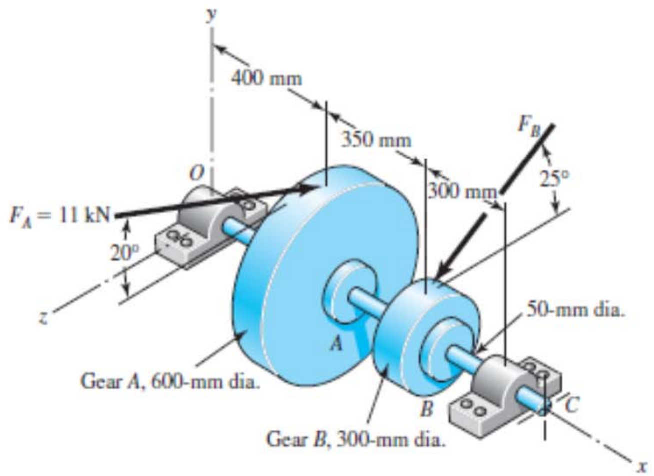
The importance of equilibrium analysis as a means of load determination can hardly be overemphasized.

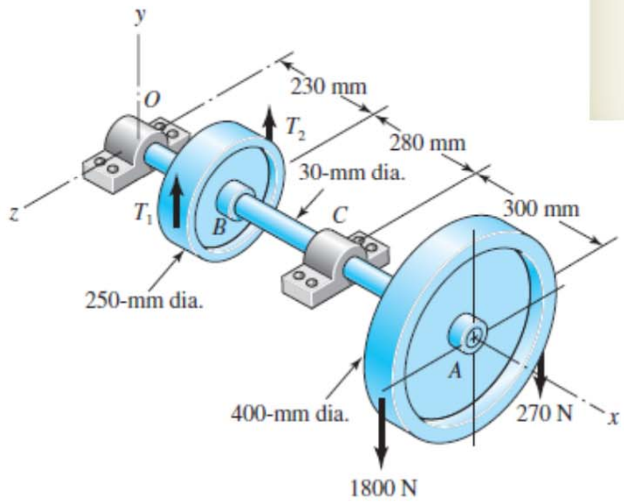
Mechanics of materials ~ Machine elements components

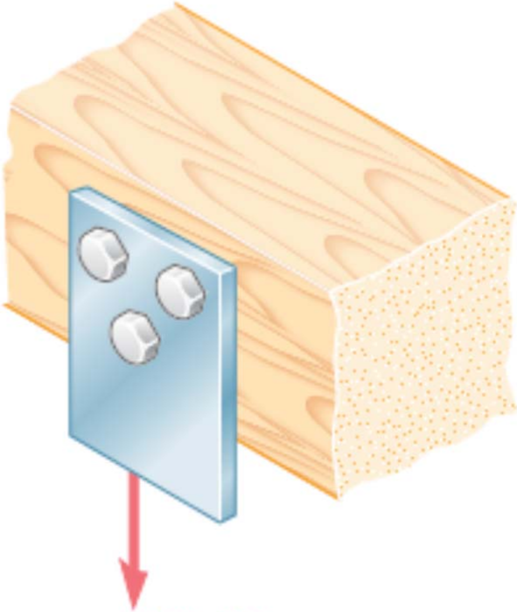




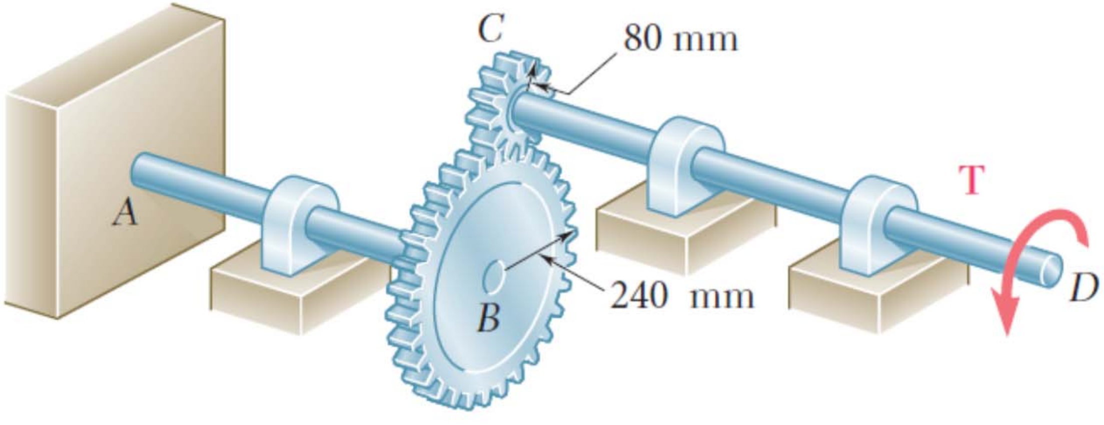




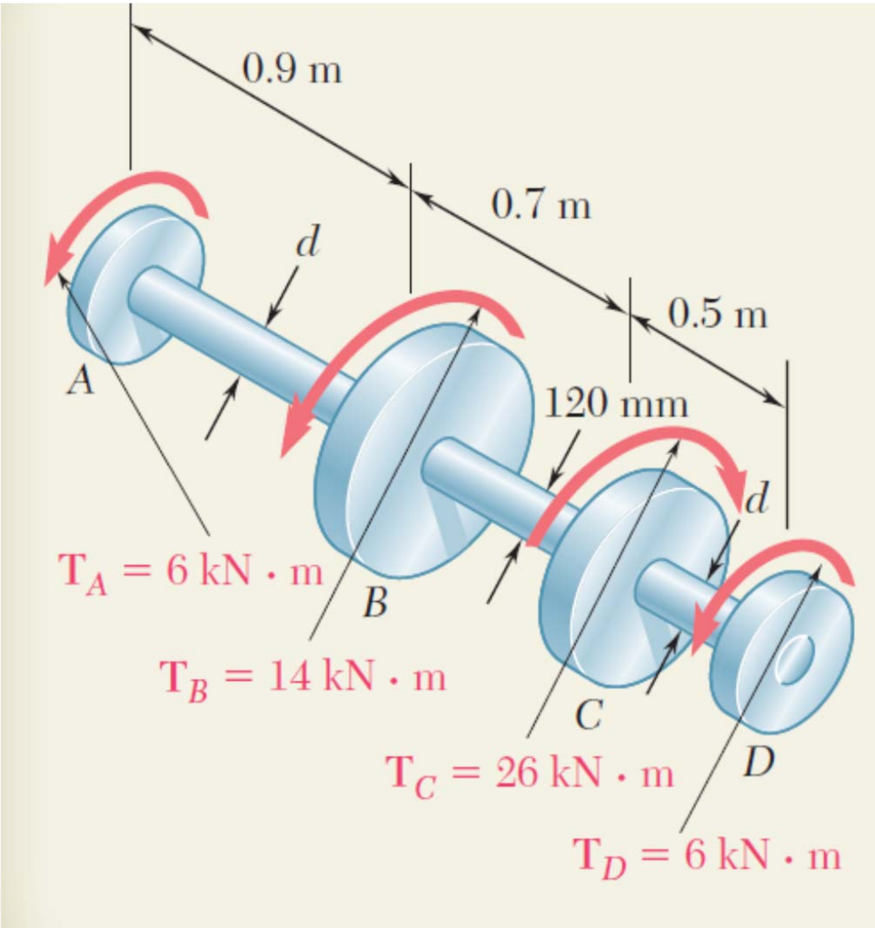




Three steel bolts are to be used to attach the steel plate shown to a wooden beam. Knowing that the plate will support a 110-kN load, that the ultimate shearing stress for the steel used is 360 MPa, and that a factor of safety of 3.35 is desired, determine the required diameter of the bolts.

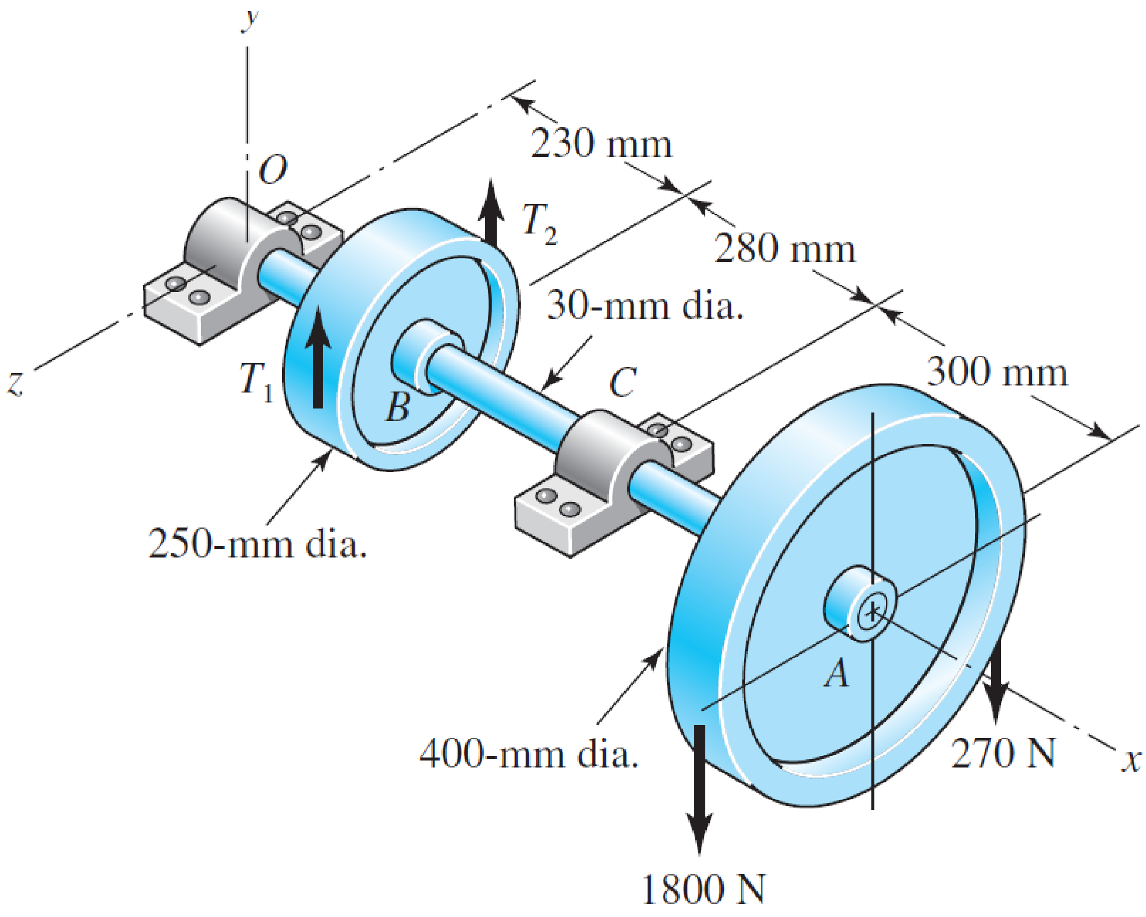


A torque of magnitude T=900 N.m is applied at D as shown. Knowing that the allowable shearing stress is 50MPa, determine the required diameter of shaft AB and shaft CD.



Shaft BC is hollow with inner and outer diameters of 90 mm and 120 mm, respectively. Shafts AB and CD are solid and of diameter d. For the loading shown, determine (a) the maximum and minimum shearing stress in shaft BC, (b) the required diameter d of shafts AB and CD if the allowable shearing stress in these shafts is 65 MPa.

maximum shearing stress in shaft BC = 86.2MPa
minimum shearing stress in shaft BC = 64.7MPa
required diameter d of shafts AB and CD =77.8mm



belts system

1. The shaft has constant speed, find tensions in the belt in pulley B ($T_2=0.15T_1$)

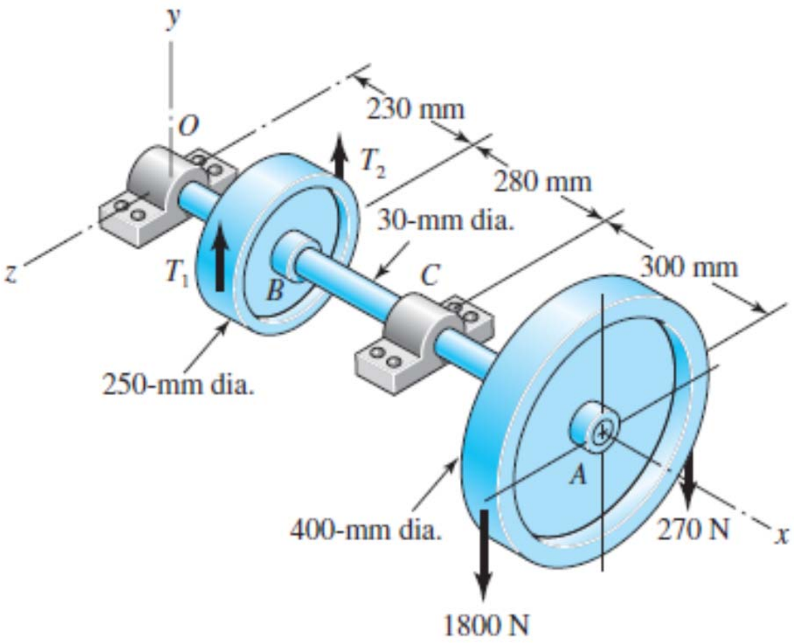
2. Reactions forces at O, C

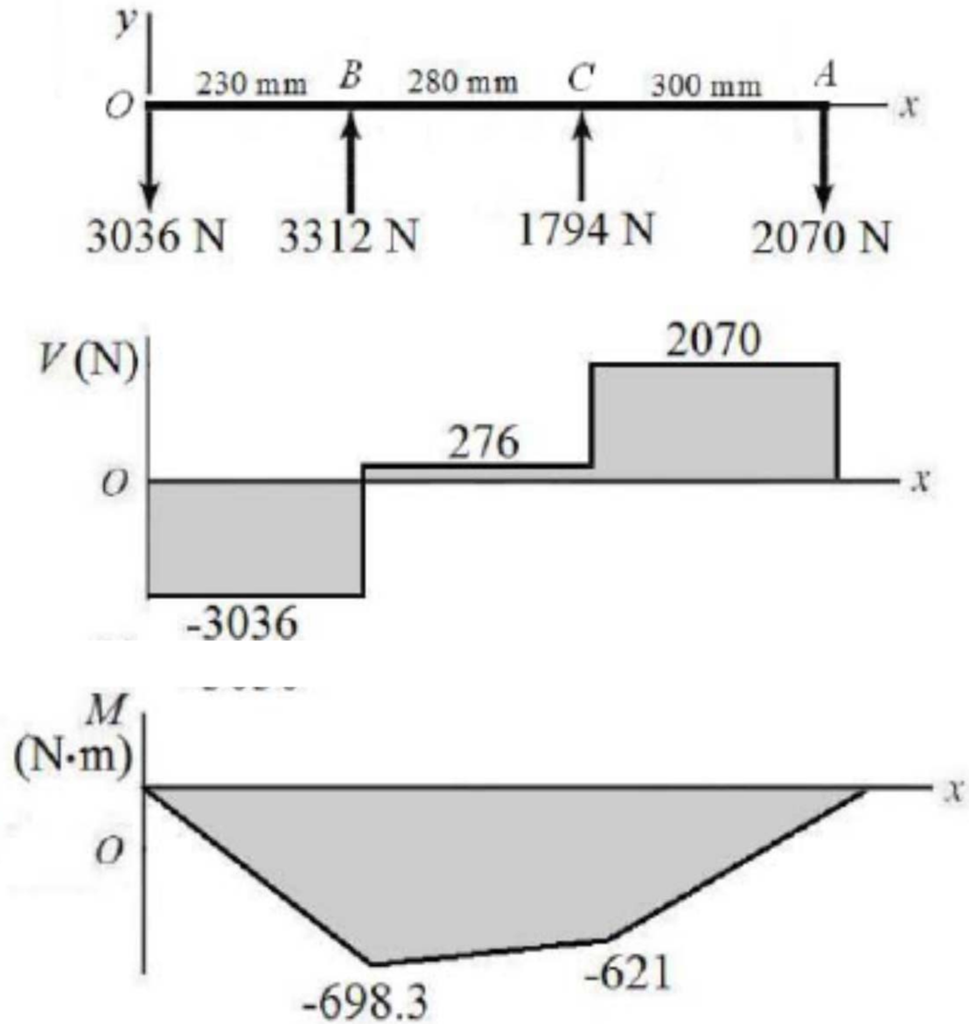
3. Shear force and Bending moments diagrams

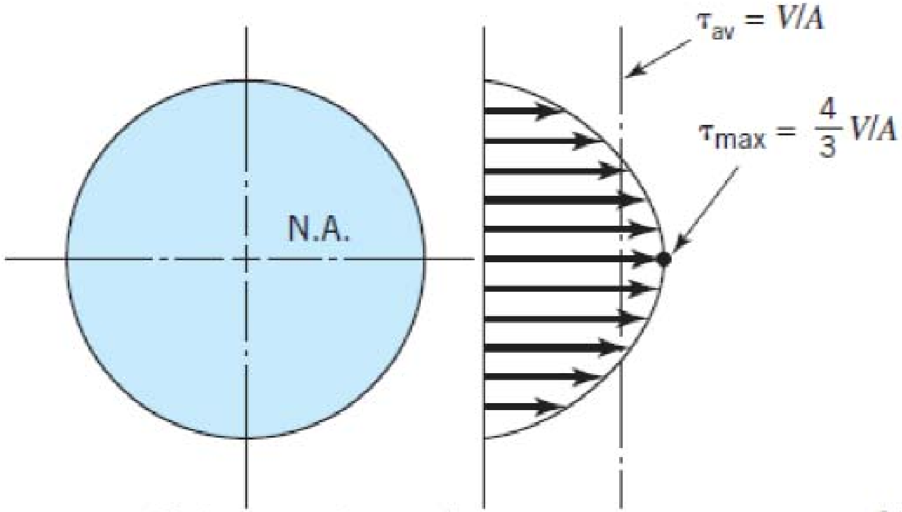
4. At the maximum bending moment point determine maximum bending stress and maximum torsional stress

5. Find σ_e, n

** Μηχανική Υλικών, Ν. Αράβας, Παρ. 6.3 Διαστασιολόγηση Ατράκτων

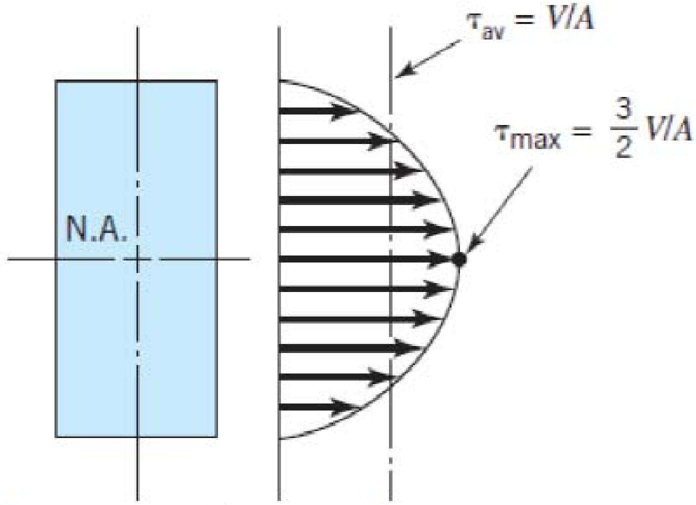

y
O
230 mm
T_2
280 mm
30-mm dia.
z
T_1
B
C
300 mm
250-mm dia.
A
400-mm dia.
270 N
x
1800 N


y
O
230 mm
B
280 mm
C
300 mm
A
x
3036 N
3312 N
1794 N
2070 N
V (N)
2070
276
O
x
-3036
M
(N·m)
x
O
-698.3
-621



solid round sections

$$\tau_{max} = \tfrac{4}{3} V/A$$

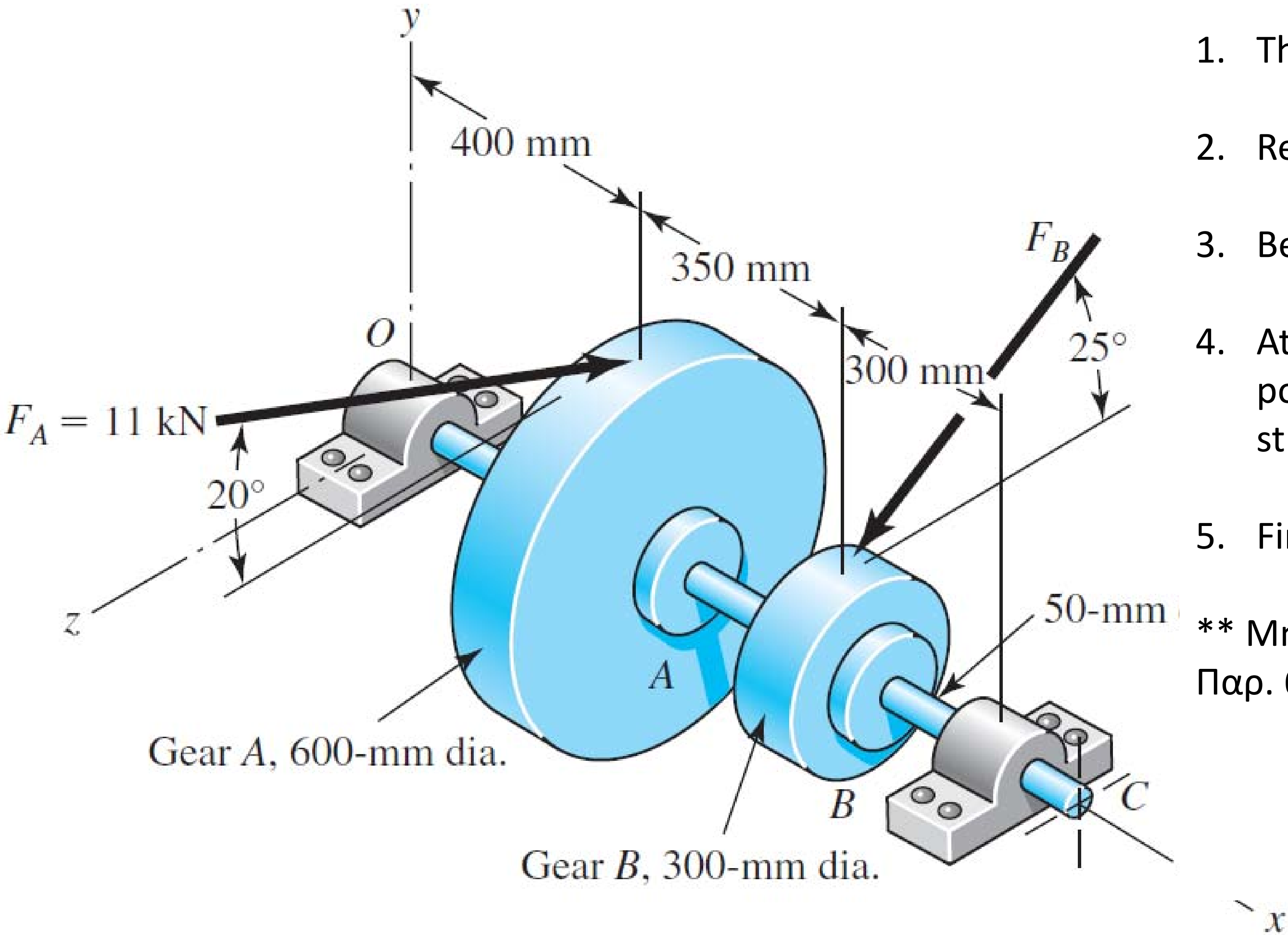


solid rectangular sections

$$\tau_{max} = \tfrac{3}{2} V/A$$

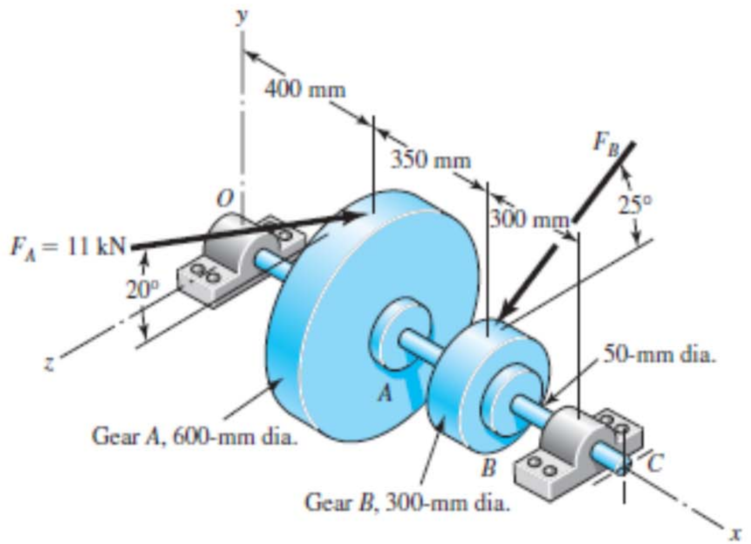
For a hollow round section, the stress distribution depends on the ratio of inside to outside diameter, but for *thin-wall tubing*, a good approximation of the maximum shear stress is

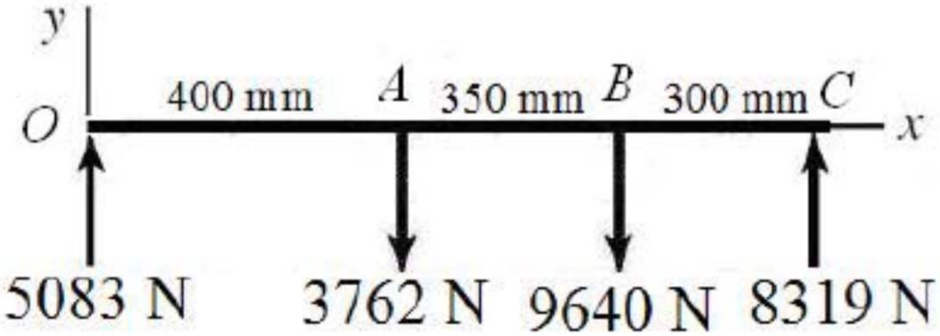
$$\tau_{max} = 2V/A \qquad \textbf{(4.15)}$$

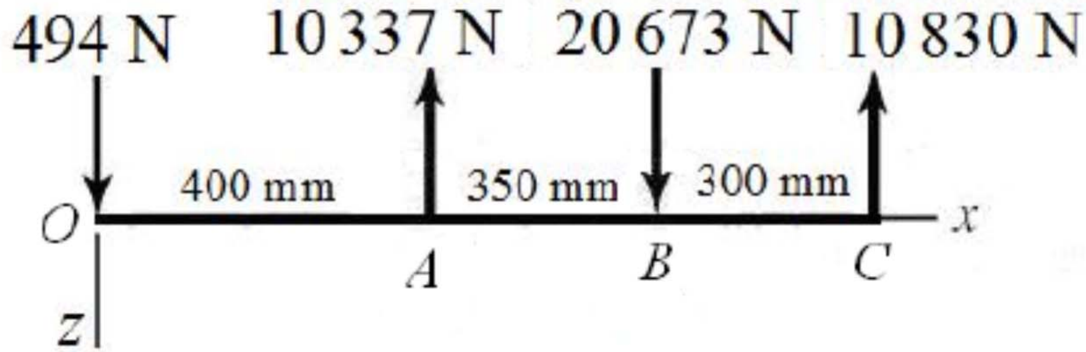


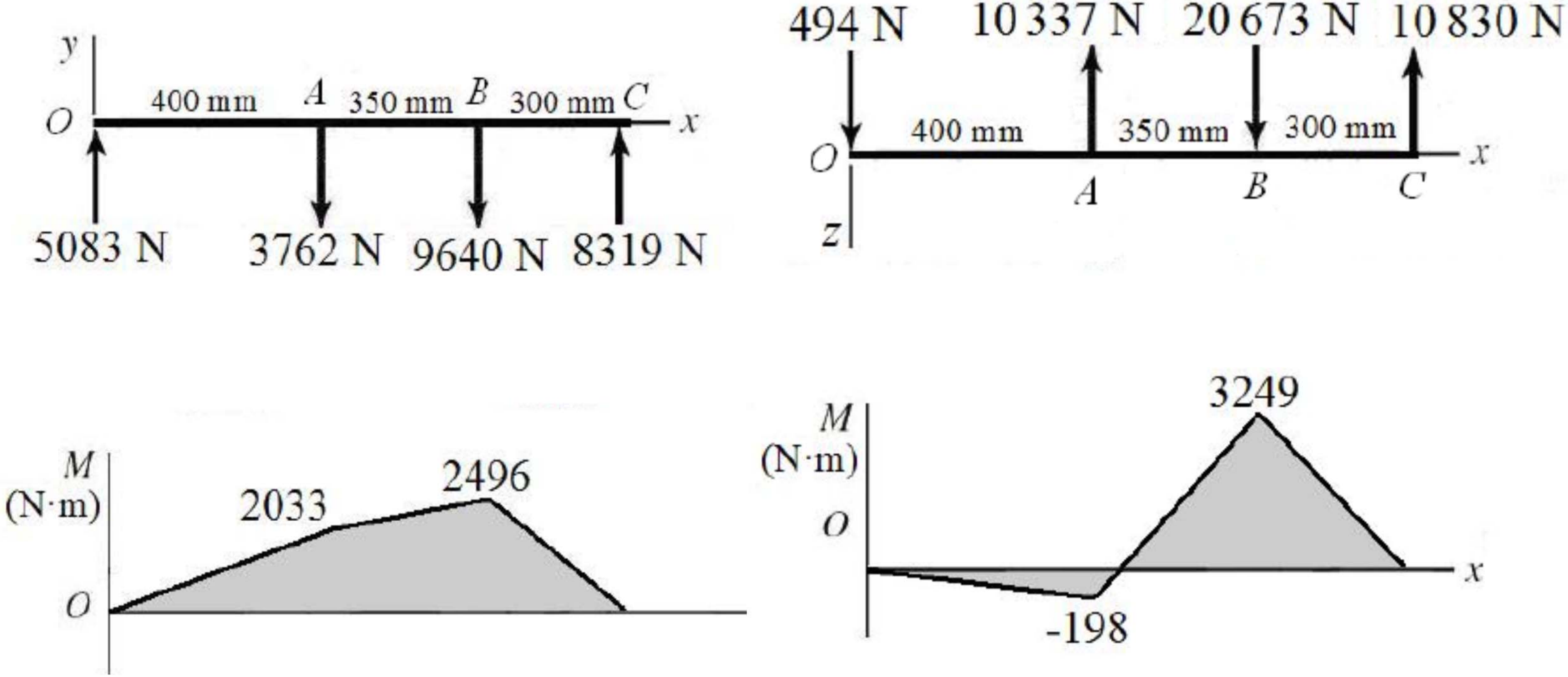
1. The shaft has constant speed, F_B=?
2. Reactions forces at O, C
3. Bending moments diagrams
4. At the maximum bending moment point determine maximum bending stress and maximum torsional stress
5. Find σ_e, n

** Μηχανική Υλικών, Ν. Αράβας, Παρ. 6.3 Διαστασιολόγηση Ατράκτων


y
400 mm
350 mm
300 mm
F_B
25°
O
F_A = 11 kN
20°
z
50-mm dia.
A
Gear A, 600-mm dia.
B
C
Gear B, 300-mm dia.
x


y
O
400 mm
A
350 mm
B
300 mm
C
x
5083 N
3762 N
9640 N
8319 N


494 N
10 337 N
20 673 N
10 830 N
O
400 mm
350 mm
300 mm
x
A
B
C
z



y
O
400 mm
A
350 mm
B
300 mm
C
x
5083 N
3762 N
9640 N
8319 N
494 N
10 337 N
20 673 N
10 830 N
z
M
(N·m)
2033
2496
3249
-198