СОПРОТИВЛЕНИЕ МАТЕРИАЛОВ

(STRENGTH OF MATERIALS)

Учебное пособие

по профессиональному английскому языку (English for Specific Purposes)

ФЕДЕРАЛЬНОЕ АГЕНТСТВО ПО ОБРАЗОВАНИЮ
Государственное образовательное учреждение высшего профессионального образования
«Томский политехнический университет»

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Учебное пособие подготовлено совместно с кафедрой ТПМ МСФ ТПУ. В пособии рассмотрены основные вопросы для сопротивления материалов. Учебное пособие предназначено для студентов машиностроительных специальностей, а также может быть полезно для студентов и других специальностей, интересующихся вопросами сопротивления материалов.

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ПРЕДИСЛОВИЕ

Предлагаемое учебное пособие по профессиональному английскому языку «Сопротивление материалов» предназначено для студентов третьего курса МСФ. Оно может быть также использовано для обучения профессиональному английскому языку студентов других факультетов, изучающих данную дисциплину. Пособие рассчитано на 72 часа.

Целью учебного пособия является ознакомление студентов с терминологией и лексикой по сопротивлению материалов и их использование в профессионально-ориентированной речи.

Учебное пособие включает шесть разделов, основу которых составляют аутентичные тексты. Каждый раздел включает список терминологии по теме раздела, Warm up, упражнения на произношение и словообразование, упражнения, направленные на усвоение лексики и грамматических явлений, упражнения на развитие навыков письменной речи. Предлагаются задания, которые имеют коммуникативную направленность. Включены задания на подготовку презентации. Также в пособии использованы материалы для аудирования. Каждый раздел содержит необходимые формулы, уравнения, чертежи и диаграммы.

В пособие включены шесть приложений, в которых представлены: математические символы и греческий алфавит; задачи по теме каждого раздела, предназначенные для самостоятельной работы студентов; глоссарий терминов по сопротивлению материалов; теорию по написанию summary; а также иллюстрированный словарь терминов.

Пособие разработано на каф. АЯ № 3 ИЯК совместно с кафедрой ТПП МСФ.

Contents

Unit I
Pin-Jointed Frames or Trusses

WORDLIST

1 bar – стержень
2 equilibrium – равновесие
3 external force – внешняя сила
4 equation – уравнение
5 force – сила
6 framework – каркас, стержневая система
7 free-body diagram – силовая схема свободного тела
8 internal force – внутренняя сила
9 method of joints – метод вырезания узлов
10 method of sections – метод сечений
11 pin-joint – узловое соединение
12 redundant member – лишняя связь
13 rigid – жёсткий
14 statically determinate structure – статически определимая конструкция
15 statically indeterminate structure – статически неопределимая конструкция
16 simply- stiff frame – рама с жесткими узлами
17 stress – напряжение
18 section – сечение
19 tension – растяжение
20 to calculate – рассчитывать
21 to assume – принимать, получать
22 to determine – определять
23 to consider – рассматривать
24 truss – балка
25 wire – проволока, трос, проволочное соединение

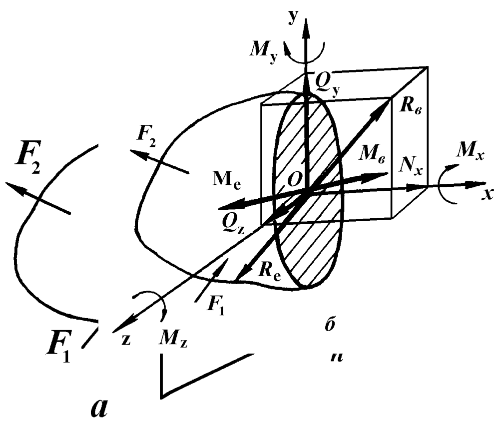
WORD FORMATION

strength (n) – strong (adj)	прочность – прочный
rigidity(n) – rigid (adj)	жёсткость – жёсткий
destruct (v) – destruction (n)	разрушать – разрушение
homogeneous (adj) – homogeneity (n)	однородный - однородность

deform (v) – deformation (n) – deformable (adj)	деформировать – деформация - деформированный
resist (v) – resistance (n)	сопротивляться- сопротивление

WARM UP

1. Explain the essence of the method of sections by means of the following figures



These phrases may help you:

- *method of sections*
- *internal forces*
- *equilibrium*
- *plane*
- *body*
- *cross-section*
- *vector of forces*
- *projections*
- *axis of coordinates*

PRONUNCIATION

2. Pay attention to the pronunciation of the following words

plus, minus, plus or minus, sign of multiplication, multiplication sign, sign of division, division sign round brackets; parentheses, curly brackets; braces square brackets; brackets, approaches, equivalent, similar, is approximately equal

3. Read and remember the pronunciation of the following equations. Write down these equations

a equals b; a is equal to b
a is not equal to b; a is not b
a approximately equals b
a plus or minus b
a is greater than b
a is substantially greater than b
a is less than b
a second is greater than a d-th
x tends to infinity
a is greater than or equals b
p is identically equal to q
a prime
a double prime, a second prime
a triple prime
a vector; the mean value of a
a first
a sub one
a suffix one
a second
a sub two
a suffix two
a n^{th}
a sub n
a suffix n
ninety degrees
ten seconds, also ten inches

a plus b is c
a plus b equals c
a plus b is equal to c
a plus b makes c
a plus b all squared
four plus seven is eleven
four plus seven equals eleven
four plus seven is equal to eleven
twelve is greater than five plus five
five plus five is less than twelve
c minus b is a
c minus b equals a
c minus b is equal to a
c minus b leaves a
bracket two x minus y close the bracket
eighteen minus six is equal to twelve
eighteen minus six equals twelve
eighteen minus six is twelve
eighteen minus six leaves twelve

WORD FORMATION

4. Form the words with the opposite meaning by means of the prefixes

ex: include
non: parallel, uniform
de: composition, composite
im: possible
un: satisfactory, like, equal, balanced

anti: clockwise
in: definite, direct, complete, appropriate, different

5. Form the words by means of the following suffixes and translate them into Russian:

- **ation:** consider, deform, approximate, fabricate, orient, alter
- **ition:** define, compose, impose
- **ion:** select, distribute, direct, destruct, interact
- **sion:** express, expand, conclude
- **ence:** differ
- **ant:** distance, resist
- **th:** long, strong, wide
- **ment:** measure
-

READING

6. Skim through the text and underline the sentences or the words that best sum up the main idea of the text (key words). With a partner discuss the main idea of the text using the key words or sentences

Introduction

In problems of stress analysis we discriminate between two types of structure; in the first, the forces in the structure can be determined by considering only its statical equilibrium. Such a structure is said to be statically determinate. The second type of structure is said to be statically indeterminate. In the case of the latter type of structure, the forces in the structure cannot be obtained by considerations of statical equilibrium alone. This is because there are more unknown forces than there are simultaneous equations obtained from considerations of statical equilibrium alone. For statically indeterminate structures, other methods have to be used to obtain the additional number of the required simultaneous equations; one such method is to consider compatibility.

Figure 1.1 shows a rigid beam BD supported by two vertical wires BF and DG; the beam carries a force of 4W at C. We suppose the wires extend by negligibly small amounts, so that the geometrical configuration of the structure is practically unaffected; then for equilibrium the forces in the wires must be 3 W in BF and W in DG. As the forces in the wires are known, it is a simple matter to calculate their extensions and hence to determine the displacement of any point of the beam. The calculation of the forces in the wires and structure of Figure 1.1 is said to be statically determinate. If, however, the rigid beam be supported by three wires, with an additional wire, say, between H and J in Figure 1.1, then the forces in the three wires cannot be solved by considering statical equilibrium alone; this gives a second type of stress analysis problem, such a structure is statically indeterminate.

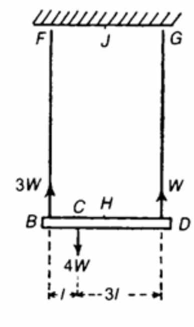


Figure 1.1. Statically determinate system of a beam supported by two wires.

7. You are going to read about statically determinate pin-jointed frames. For questions 1-5 find the answers in the text

1 What is a frame?
2 What is truss?
3 What is a redundant framework?
4 What are the symbols for a total number of members and total number of joints?
5 What is the condition for the frame to be simply-stiff for a pin-jointed space frame attached to three joints in a rigid wall?

Statically Determinate Pin-Jointed Frames

By a frame we mean a structure which is composed of straight bars joined together at their ends.
A pin-jointed frame or truss is one in which no bending actions can be transmitted from one bar to another as described in the introductory chapter; ideally this could be achieved if the bars were joined together through pin-joints. If the frame has just sufficient bars or rods to prevent collapse without the application of external forces, it is said to be simply-stiff, when there are more bars or rods than this, the frame is said to be redundant. A redundant framework is said to contain one or more redundant members, where the latter are not required for the framework to be classified as a framework, as distinct from being a mechanism. It should be emphasised, however, that if a redundant member is removed from the framework, the stresses in the remaining members of the framework may become so large that the framework

collapses. A redundant member of a framework does not necessarily have a zero internal force in it. Definite relations exist which must be satisfied by the numbers of bars and joints if a frame is said to be simply-stiff, or statically determinate.
In the plane frame of Figure 1.2**,** BC is one member. To locate the joint D relative to BC requires two members, namely, BD and CD; to locate another joint F requires two further members, namely, CF and DF. Obviously, for each new joint of the frame, two new members are required. If m be the total number of members, including BC, and **j** is the total number of joints, we must have

$$m = 2j - 3 \tag{1.1}$$

if the frame is to be simply-stiff or statically determinate.

When the frame is rigidly attached to a wall, say at B and C, BC is not part of the frame as such, and equation (1.1) becomes, omitting member BC, and joints B and C,

$$m = 2j \tag{1.2}$$

These conditions must be satisfied, but they may not necessarily ensure that the frame is simply-stiff.
For example, the frames of Figures 1.2 and 1.3 have the same numbers of members and joints; the frame of Figure1.2 is simply-stiff. The frame of Figure 1.3 is not simply-stiff, since a mechanism can be formed with pivots at D, G, J, F. Thus, although a frame having j joints must have at least (2j - 3) members, the mode of arrangement of these members is important.

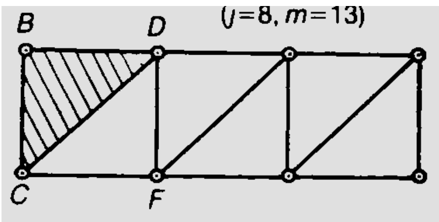


Figure 1.2.

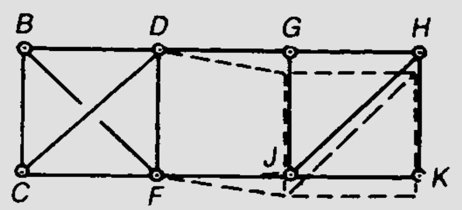


Figure 1.3.

For a pin-jointed space frame attached to three joints in a rigid wall, the condition for the frame to be simply-stiff is

$$m = 3j \tag{1.3}$$

where m is the total number of members, and j is the total number of joints, exclusive of the three joints in the rigid wall. When a space frame is not rigidly attached to a wall, the condition becomes

$$m = 3j - 6 \qquad (1.4)$$

where m is the total number of members in the frame, and j the total number of joints.

8. Read the passage and decide if the sentences below are TRUE or FALSE? If one of them is TRUE put T next to it, if it's FALSE put F.

The Method of Joints and Method of Sections

The method of joints can only be used to determine the internal forces in the members of statically determinate pin-jointed trusses. It consists of isolating each joint of the framework in the form of a free-body diagram and then by considering equilibrium at each of these joints, the forces in the members of the framework can be determined. Initially, all unknown forces in the members of the framework are assumed to be in tension, and before analysing each joint it should be ensured that each joint does not have more than two unknown forces (figure 1.4)

The method of sections is useful if it is required to determine the internal forces in only a few members. The process is to make an imaginary cut across the framework, and then by considering equilibrium, to determine the internal forces in the members that lie across this path. In this method, it is only possible to examine a section that has a maximum of three unknown internal forces, and here again; it is convenient to assume that all unknown forces are in tension (figure 1.5)

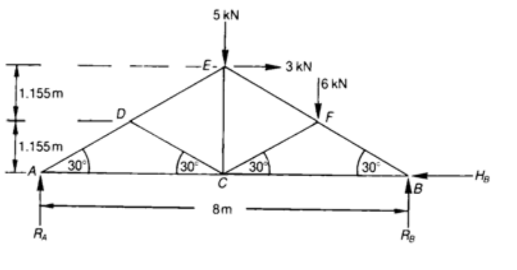


Figure 1.4. Method of joints

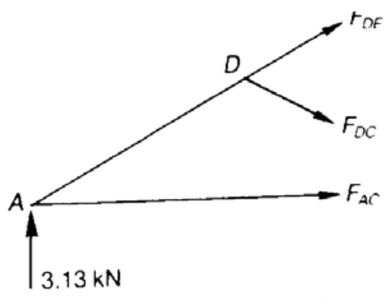


Figure 1.5. Free-body diagram. Method of sections

1 One can use the method of joints to determine the internal forces in the members of statically indeterminate pin-jointed trusses.
2 The method of sections consists of isolating each joint of the framework in the form of a free-body diagram.
3 When one determines the internal forces in only a few members the method of joints is used.
4 The method of sections is making an imaginary cut across the framework.

VOCABULARY

9. Match the notions and their definitions. Then listen and check.

1 isotropy	a) changing in the time of deformations and stresses by the action of permanent external load on a body
2 elasticity	b) force of interaction between single elements of the structure or between single parts of the elements
3 plasticity	c) body, where three sizes are commensurable in three directions
4 fragility	d) body with lateral dimensions which are incommensurably less than length
5 creeping	e) ability of a body to regain its initial shape and dimensions after unloading
6 bar	f) load, acting on a body by its interaction with other bodies
7 plate	g) an action that changes, or tends to change, the state of motion of a body on which it acts.
8 massif	h) ability of a body to be destroyed without considerable residual

	deformation
9 force	i) body, where two sizes are considerably greater than other sizes
10 external force	j) independence of material properties on direction
11 internal force	k) ability of a body to keep considerable residual deformation after unloading

10. Write the meanings of these words. You may use a dictionary

- strength
- rigidity
- stability
- bar
- massif
- plate

11. Fill in the spaces with the correct form of the word given

Noun	Adjective
strength	**strong**
rigidity	______________
______________	stable
fragility	______________
______________	elastic
homogeneity	______________
______________	able
plasticity	______________
______________	elastic
plane	______________
______________	statical

12. Write the verbs which have the following meaning

- make something softer
- to make something stronger
- to make something weaker
- to make something thicker

- to make something harder

13. Translate the following verbs (+ prepositions). Compose sentences using the nouns in the brackets

- to take up (a problem)
- to be based on (concept)
- to be under the action (loading)
- to be subjected to (force)
- to derive (formula)
- to obey (law)

14. Find the Russian equivalent to the following English one

framework	сечение
force	приложение\применение
application	каркас
strength	соединение
equation	сила
equilibrium	уравнение
section	равновесие
joint	прочность

GRAMMAR

15. State the key words in the word combinations and translate them into Russian

- stress analysis
- zero internal force
- plane frame
- space frame
- metal bar
- free-body diagram

16. Translate the sentences into Russian paying attention to the passive Voice.

1 Such a structure is said to be statically determinate.
2 The method of joints can only be used to determine the internal forces in the members of statically determinate pin-jointed trusses.
3 The method of sections is useful if it is required to determine the internal forces in only a few members.
4Two types of structures are discriminated in stress analysis.
5 Other methods have to be used for statically indeterminate structures.
6 If the frame has just sufficient bars or rods to prevent collapse without the application of external forces, it is said to be simply-stiff.
7 The frame is said to be redundant, when there are more bars or rods than sufficient.
8 Initially, all unknown forces in the members of the framework are assumed to be in tension.

COMMUNICATION

17. Work in pairs. Discuss the difference between statically determined and statically indetermined structures. Use the following phrases:

- stress analysis
- two types of structures
- statical equilibrium
- frame
- rigid beam
- to determine the displacement

18. Work in pairs or groups and discuss the following problems:

1 Two types of structures are discriminated in the problems of stress analysis
2 Method of joints and method of sections

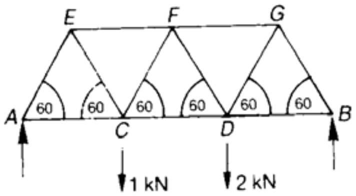
Use the following as phrase-openings:

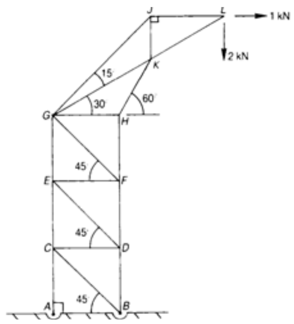
1. I would like to tell/say/speak …
2. Let me say some/a few words/ideas about …

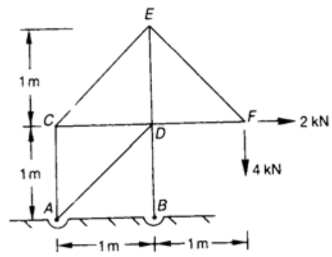
3 I need/have to point out that …
4 The problem(s) I want to tell about concern(s) …
5 As far as I know …
6 Finally/In the end I must/shall mention

LISTENING

19. You are going to listen to three problem situations. Match them to the following figures







a) **b)** **c)**

Problem situation 1
Problem situation 2
Problem situation 3

WRITING

20. Write the summary of the text following the instructions:

1 Read the whole of the text to gain an impression of its content and its relevance to your work

2 Highlight the main points as you read

3 Make notes of your own on these points

4 Put away the original and rewrite your notes in your own words in complete sentences

5 Begin your summary with a statement of the main idea at the start

6 Using your notes, write out your subsidiary or supporting points in well-connected sentences

7 Re-read your work to check that you have included all the information that you need

8 Write a summary of the text

(see APPENDIX 4, p. 104)

Classification of Forces

When in operation, the elements of structures and machines are subjected to external loads, which they transmit to one another, a dam bears its own weight and the pressure of water that it holds and transmits these forces to foundation. The steel trusses of bridges take the weight of the train through the wheels and rails and transmit it to the stone supports, and the latter, in turn, communicate this load to the foundation. Hence, the elements of structures are subject to either volume forces acting on each element of the structure (dead weight) or forces of interaction between the elements under consideration and adjoining elements or between the element and the surrounding medium (water, steam or air). In future, when we say that an external force is being applied to an element of the structure, this will imply the transmission of force of pressure (motion) to the element under consideration from adjoining elements of the structure or the surrounding medium.

The forces may be classified according to a number of criteria. We distinguish between the concentrated and distributed forces. A concentrated force is defined as the force of pressure transmitted to the element of structure through an area which is very small as compared to the size of the element, for example, the pressure of the wheels of a moving train on the rails. In practice the concentrated force is considered to be acting at a point owing to the small area through which the pressure is transmitted. We must keep in mind that this is an approximation which has been introduced to simplify the calculation; actually, no pressure can be transmitted through a point. However, the error due to this approximation is so small that it may be generally ignored.

A distributed force is defined as the force applied continually over a certain length or area of the structure. A layer of sand of uniform thickness spread over the sidewalk of a bridge represents a force which is uniformly distributed over a certain area; if the thickness of the sand layer is not uniform we shall obtain a non-uniformly distributed load. The dead weight of a beam in the ceiling represents a load distributed over its length.

The concentrated loads are measured in units of force (newtons); the loads distributed over an area are measured in terms of force per unit area (N/m); the loads distributed along the length of an element are expressed as force per unit length (N/m).

The loads may further be classified as permanent and temporary. The permanent loads act throughout the whole life of the structure, e.g. dead weight. The temporary loads act on the structure only for certain period of time – the weight of the train moving along the bridge may be cited as an example.

According to the nature of action, the loads may be classified as static and dynamic.

Static loads act on the structure gradually, after being applied to the structure they either do not change at all or change insignificantly; the majority of loads acting in civil and hydraulic structures are of this nature.

Under the influence of static loading all elements of the construction remain in equilibrium; accelerations in the elements of the structure are either totally absent or so small that they may be neglected.

If, however, the acceleration is considerable and the change in velocity of the machine or structure takes place in a short time, the load is known as dynamic.

The example of dynamic loads are suddenly applied load, impact load and repeated variable load.

Suddenly applied loads are transmitted instantaneously in their total magnitude. Impact loads appear when there is a sharp change in the velocity of adjoining elements of a structure.

The repeated variable loads act on the elements of structures for a considerable number of times. In a number of cases the load represents a combination of dynamic loads of different nature.

We shall first of all study the resistance of materials to static loads; the selection of material and cross-sectional area for each element of the structure does not present many difficulties in this case.

Concluding the classification of forces acting on the elements of structures, let us consider the action of parts which support these elements; the forces acting on these supports are known as the reaction forces – they are unknown quantities and are determined from the condition that each element of the structure must remain in equilibrium under the action of all the external forces applied to it and the reaction forces.

MAKING A PRESENTATION

21. Make up a presentation "Pin-Jointed Frames or Trusses" following the instructions:

Include these four parts into your presentation:

1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:

- Good afternoon.
- First, let me introduce myself: I'm …….. from
- The problem(s) I want to tell about concern(s) …
- I'll begin by describing ………, and go on to ………., and I'll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I'd like to talk about ………
- First of all ………… Next …………
- I'd like now to turn to ………..
- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I'd like to run through the main points again …
- In conclusion ………
- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I'll be glad to answer them

Use visual aids such as chart, drawings and equations.
Be ready to answer the questions of the audience after your presentation.

Unit 2
Shearing Stress

WORDLIST

1 behaviour – поведение
2 bearing – подшипник, опора; несущая поверхность
3 bending action – изгиб
4 circular shaft – круговой цилиндр
5 collar – кольцо; втулка, узкая втулка; хомут; манжета
6 direct stress – нормальное напряжение
7 intact – интактный, неповрежденный, нетронутый
8 imaginary plane – мнимая плоскость
9 linearly – линейно
10 nondimensional – безразмерный
11 rivet – заклёпка
12 rotational equilibrium – равновесие вращающегося тела
13 surface – поверхность
14 shearing action – сдвигающее действие
15 shearing stress – касательное напряжение
16 steel bolt – стальной болт
17 shearing force – поперечная сила
18 shearing strain – простой сдвиг
19 shearing modulus – модуль сдвига
20 tangential – касательный, тангенциальный
21 tensile force – растягивающая сила, сила растяжения
22 tension and compression – растяжение и сжатие
23 to glue – наклеивать; склеивать(ся)
24 to slide – перемещать, перемещаться; скользить
25 to resist – сопротивляться, противостоять
26 to induce – индуцировать, наводить
27 to distort – деформировать(ся)
28 within the limits – в пределах
29 Young's modulus – модуль эластичности, модуль Юнга

VERBS WITH PREPOSITIONS

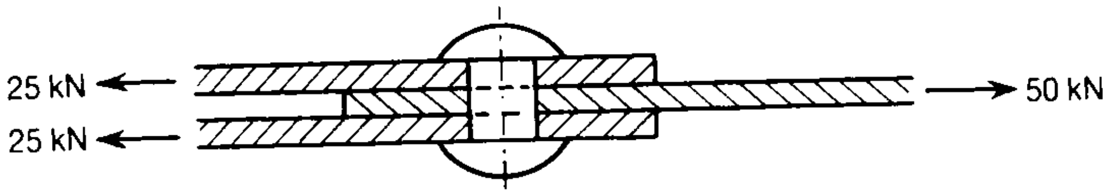
1 to be subjected to – подвергать(ся)
2 to set up – налаживать, настраивать
3 to pull by – тянуть; тащить; открывать; растягивать, вытягивать, выдёргивать (напр. сваю)
4 to push out – выталкивать, вытеснять; сбрасывать

WARM UP

1. Discuss in groups the following problem situation

Three steel plates are held together by a 1.5 cm diameter rivet, the load transmitted is 50 *kN*. Estimate the shearing stress in the rivet

Use the following figure and phrases:



- tendency
- to shear across the planes
- broken lines
- cross-sectional area
- average shearing stress

PRONUNCIATION

2. Read and remember the pronunciation of the following equations
Write down these equations

once one is one
twice two is four
twice two makes four
five times five is twenty five
five multiplied by five equals twenty
five by five is equal to twenty five

a is equal to the ratio of e to 1
ab square (divided) by b equals ab
sixteen divided by four is four
sixteen by four equals four
sixteen by four is equal to four
the ratio of sixteen to four is four
the ratio of one to two

the ratio of fifty one to one
two to three is as four to six
a (one) half
a (one) third
a (one) quarter, a (one) fourth
two thirds
three quarters; three fourth
five sixths
twenty five fifty sevenths
two and a half
three and three quarters
one two hundred and seventy
o [ou] point five
zero point five
nought point five

point five
one half
o [ou] point o [ou] o [ou] two
zero point zero zero two
point two oes [ouz]two
point two noughts two
o[ou]point six noughts one
one point one
two point one two
Fifteen point five nought five
Two point one two
x square; x squared
the square of x
the second power of x

WORD FORMATION

3. Read and translate the words having the same root

- place – to place – to replace
- to reduce – reductor – reduction
- to consider – consideration – considerable – inconsiderable – considerably
- center – central
- origin – original – originate
- algebra – algebraic
- axis – axial
- geometry – geometrical
- direct – direction
- to change – change –changing – changeable – unchangeable
- necessary – unnecessary – necessity
- to define – definite – indefinite – definition
- clock – clockwise – anticlockwise – counterclockwise
- to alter – alteration

READING

4. You are going to read the text shearing stresses. For questions 1-3 find the answers in the text

1 What is a shearing stress?
2 What is the difference between direct stresses and tangential stresses?
3 Can you give an example to illustrate shearing stress?

Introduction

There is a type of stress which plays a vital role in the behaviour of materials, especially metals. Consider a thin block of material, Figure 2.1, which is glued to a table; suppose a thin plate is now glued to the upper surface of the block. If a horizontal force F is applied to the plate, the plate will tend to slide along the top of the block of material, and the block itself will tend to slide along the table. Provided the glued surfaces remain intact, the table resists the sliding of the block, and the block resists the sliding of the plate on its upper surface. If we consider the block to be divided by any imaginary horizontal plane, such as ab**,** the part of the block above this plane will be trying to slide over the part below the plane. The material on each side of this plane will be trying to slide over the part below the plane. The material on each side of this plane is said to be subjected to a shearing action; the stresses arising from these actions are called shearing stresses. Shearing stresses act tangential to the surface, unlike direct stresses which act perpendicular to the surface.

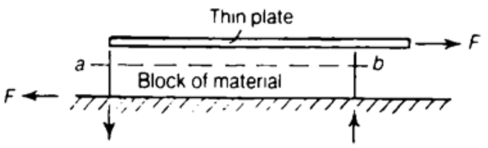


Figure 2.1. Shearing stresses caused by shearing forces.

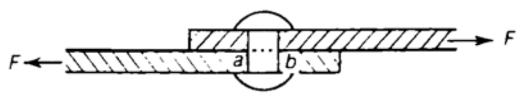


Figure 2.2. Shearing stresses in a rivet; shearing forces *F* is transmitted over the face *ab* of the rivet

In general, a pair of garden shears cuts the sterns of shrubs through shearing action and not bending action. Shearing stresses arise in many other practical problems. Figure 2.2 shows two flat plates held together by a single rivet, and carrying a tensile force F. We imagine the rivet divided into two portions by the plane ab; then the upper half of the rivet is tending to slide over the lower half, and a shearing stress is set up in the plane ab. Figure 2.3 shows a circular shaft a, with a collar c, held in bearing b, one end of the shaft being pushed with a force F; in this case there is, firstly, a tendency for the shaft to

be pushed bodily through the collar, thereby inducing shearing stresses over
the cylindrical surfaces d of the shaft and the collar; secondly, there is a tendency for the collar to push through the bearing, so that shearing stresses are set up on cylindrical surfaces such as e in the bearing. As a third example, consider the case of a steel bolt in the end of a bar of wood, Figure 2.4, the bolt being pulled by forces F; suppose the grain of the wood runs parallel to the length of the bar; then if the forces F are large enough the block abcd will be pushed out, shearing taking place along the planes ab and cd

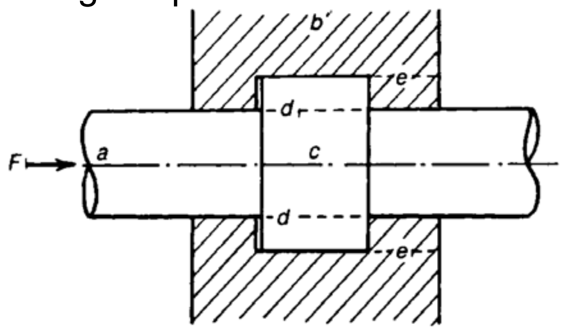


Figure 2.3. Thrust on the collar of a shaft, generating shearing stress over the planes d.

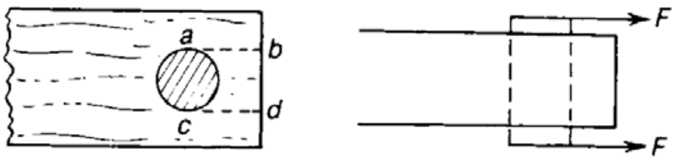


Figure 2.4 Tearing of the end of a timber member by a steel bolt, generating a shearing action on the planes ab and cd.

5. Skim through the text and underline the sentences or the words that best sum up the main idea of the text (key words). In pairs discuss the main idea of the text using the key words or sentences.

Complementary Shearing Stress

Let us return now to the consideration of the block shown in Figure 2.1. We have seen that horizontal planes, such as ab, are subjected to shearing stresses. In fact the state of stress is rather more complex than we have supposed, because for rotational equilibrium of the

whole block an external couple is required to balance the couple due to the shearing forces *F*. Suppose the material of the block is divided into a number of rectangular elements, as shown by the full lines of Figure *2.5.* Under the actions of the
shearing forces *F*, which together constitute a couple, the elements will tend to take up the positions shown by the broken lines in Figure *2.5.* It will be seen that there is a tendency for the vertical faces of the elements to slide over each other. Actually the ends of the elements do not slide over each other in this way, but the tendency to so do shows that the shearing stress in horizontal planes is accompanied by shearing stresses in vertical planes perpendicular to the applied shearing forces. This is true of all cases of shearing action: a given shearing stress acting on one plane is always accompanied by a complementary shearing stress on planes at right angles to the plane on which the given stress acts.

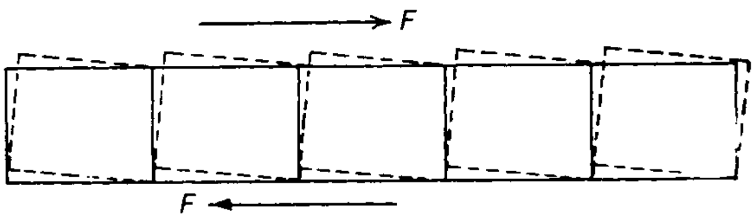


Figure 2.5. Tendency for a set of disconnected blocks to rotate when shearing forces are applied.

Consider now the equilibrium of one of the elementary blocks of Figure *2.5.* Let τ_{xy} be the shearing stress on the horizontal faces of the element, and τ_{xy} the complementary shearing stress on vertical faces of the element, Figure 2.6. Suppose a is the length of the element, ***b*** its height, and that it has unit thickness. The total shearing force on the upper and lower faces is then

$$\tau_{xy} \times a \times 1 = a\tau_{xy}$$

while the total shearing force on the end faces is

$$\tau_{yx} \times b \times 1 = b\tau_{yx}$$

For rotational equilibrium of the element we then have

$$(a\tau_{xy}) \times b = (b\tau_{yx}) \times a$$

and thus

$$\tau_{xy} = \tau_{yx}$$

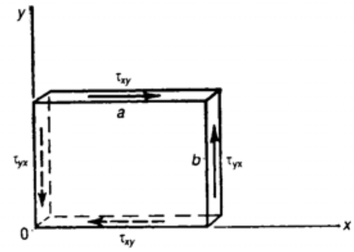


Figure 2.6. Complementary shearing stresses over the faces of a block when they are connected.

We see then that, whenever there is a shearing stress over a plane passing through a given line, there must be an equal complementary shearing stress on a plane perpendicular to the given plane, and passing through the given line. The directions of the two shearing stresses must be either both towards, or both away from, the line of intersection of the two planes in which they act. It is extremely important to appreciate the existence of the complementary shearing stress, for its necessary presence has a direct effect on the maximum stress in the material.

6. Read the passage and decide if the sentences below are TRUE or FALSE? If one of them is TRUE put T next to it, if it's FALSE put F.

Shearing Strain

Shearing stresses in a material give rise to shearing strains. Consider a rectangular block of material, Figure 2.7, subjected to shearing stresses τ in one plane. The shearing stresses distort the rectangular face of the block into a parallelogram. If the right-angles at the comers of the face change by amounts γ, then y is the shearing strain. The angle γ is measured in radians, and is nondimensional therefore.

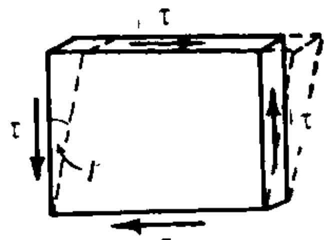


Figure 2.7. Shearing strain in a rectangular block; small values of y lead to a negligible change of volume in shear straining.

For many materials shearing strain is linearly proportional to shearing stress within certain limits. This linear dependence is similar to the case of direct tension and compression. Within the limits of proportionality

$$\tau = G_{\gamma} ,$$

where G is the shearing modulus or modulus of rigidity, and is similar to Young's modulus E, for direct tension and compression. For most materials E is about 2.5 times greater than G. It should be noted that no volume changes occur as a result of shearing stresses acting alone. In Figure 2.7 the volume of the strained block is approximately equal to the volume of the original rectangular prism if the angular strain γ is small.

1 Shearing strains are given rise by shearing stresses in a material.
2 The angle γ is measured in radians.
3 For many materials shearing strain is inversely proportional to shearing stress within certain limits.
4 Modulus of rigidity is similar to Young's modulus.

VOCABULARY

7. Match numbers 1-10 with letters a-j to make collocations.

1 shearing	**a)** area
2 tangential	**b)** modulus
3 rotational	**c)** stress
4 horizontal	**d)** action
5 cross-sectional	**e)** compression
6 direct	**f)** plane
7 Young's	**g)** stress
8 tension and	**h)** blocks
9 average	**i)** equilibrium
10 elementary	**j)** stress

8. Read the definitions and decide what they mean. Share your ideas with other students.

Example

“an event in which something is displaced without rotation is **deformation**”

- alteration in the shape or dimensions of an object as a result of the application of stress to it
- an event in which something is distorted
- an event in which something is distorted
- an unbounded two-dimensional shape
- the area created by a plane cutting through a solid
- force that produces strain on a physical body
- the act of imposing something

9. Find the Russian equivalent to the following English one.

Nouns:		Verbs:	
- behaviour	- сила	- distort	- скользить
- surface	- плоскость	- induce	- приклеивать
- plane	- поведение	- slide	- наводить
- stress	- цилиндр	- resist	- деформировать
- force	- поверхность	- glue	- вращаться
- shaft	- напряжение		

10. Match the notions and their definitions. Then listen and check.

1 stress	a) a geometric distortion in the neighbourhood of a material point
2 displacement	b) a quantitative measurement of intensity of distribution of internal forces over section, determining the interaction between material elements of a body.
3 deformation	c) changing of the position of section or the whole element of structure in domain of point

GRAMMAR

11. Use the verbs in brackets in the Passive Voice.

1 If a horizontal force F (to apply) to the plate, the plate will tend to slide along the top of the block of material.
2 Suppose the material of the block (to divide) into a number of rectangular elements.
3 The angle γ (to measure) in radians, and is nondimensional therefore.
4 The material on each side of this plane (to say) (to subject) to a shearing action.
5 The rectangular block of material (to subject) to shearing forces.
6 A thin block of material (to glue) to a table.
7 The state of stress (to suppose)to be more complex.
8 The rivet (to divide) into two portions by a plane.

12. Translate the sentences into Russian paying attention to the Participle.

1 We imagine the rivet divided into two portions by the plane ab.
2 There is a tendency for the shaft to be pushed bodily through the collar, thereby inducing shearing stresses over the cylindrical surfaces.
3 There is a shearing stress over a plane passing through a given line
4 Consider the case of a steel bolt in the end of a bar of wood, the bolt being pulled by forces F.
5 If the forces F are large enough, the block abcd will be pushed out, shearing taking place along the planes ab and cd.
6 The angle γ measured in radians, is nondimensional value.
7 Consider a thin block of material glued to a table.
8 Provided the glued surfaces remain intact, the table resists the sliding of the block, and the block resists the sliding of the plate on its upper surface.

COMMUNICATION

15. Discuss in pairs the following problem situation

Rivet holes 2.5 cm diameter are punched in a steel plate 1 cm thick. The shearing strength of the plate is 300 MN/m_2. Find the average compressive stress in the punch at the time of punching.

16. Work in pairs or groups. Discuss the following problems

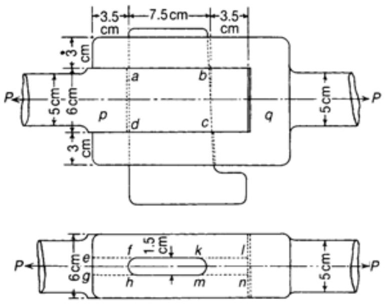
1 Shearing stress plays a vital role in the behaviour of materials
2 Complementary shearing stress
3 Shearing strain

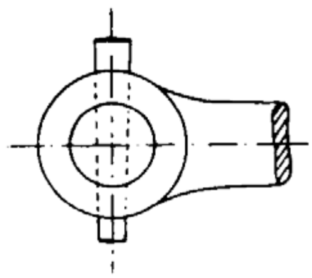
Use the following as phrase-openings*:*

1. I would like to tell/say/speak …
2. Let me say some/a few words/ideas about …
3. I need/have to point out that …
4. The problem(s) I want to tell about concern(s) …
5. As far as I know …
6. Finally/In the end I must/shall mention

LISTENING

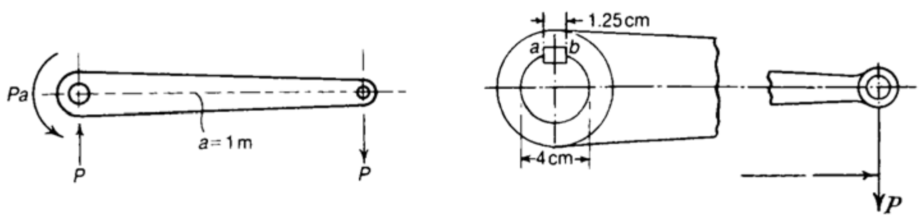
17.You are going to listen to three problem situations. Match them to the following figures*.*





a) b)

c)



Problem situation 1
Problem situation 2
Problem situation 3

WRITING

18. Write the summary of the text following the instructions:

1 Read the whole of the text to gain an impression of its content and its relevance to your work

2 Highlight the main points as you read

3 Make notes of your own on these points

4 Put away the original and rewrite your notes in your own words in complete sentences

5 Begin your summary with a statement of the main idea at the start

6 Using your notes, write out your subsidiary or supporting points in well-connected sentences

7 Re-read your work to check that you have included all the information that you need

8 Write a summary of the text

(see APPENDIX 4, p. 104)

Deformations and stresses

In theoretical mechanics (static) we study the equilibrium of a perfectly rigid body; this concept of material in static is sufficient to determine the conditions in which the body will remain in equilibrium under the action of external forces applied to it. However, this rough and approximate concept of the properties of materials does not hold good in strength of materials; here we must take into account the fact that there does not exist a perfectly rigid body.The elements of a structure,

as well as the structure as a whole, change their dimensions and shape to some extent under the action of external forces and
are liable to complete failure in the end. This change in shape and size is called deformation.

The magnitude and nature of the deformation depend upon the structure of the material used. All materials may be divided into two groups: crystalline and amorphous.

Crystalline materials consist of a very large number of extremely small crystals. Each of these is a system of atoms arranged very close to each other in regular rows. These rows form the so-called crystalline lattice. In amorphous materials the atoms are not arranged in a particular order. They are held in due to change in the location of atoms, i.e. due to their getting closer or farther equilibrium by the forces of interaction. The deformation of bodies takes place.

Deformations are divided into elastic and plastic. Elastic deformation disappears when the force causing the deformation is removed; in this case, the body completely regains its initial shape and dimensions. This deformation occurs due to elastic distortion in the crystalline lattice. It has been experimentally observed that the elastic deformation continues till the forces being applied do not exceed a certain limit.

If, however, the external force exceeds this particular limit, the body fails to regain completely its initial shape and size after the force is removed; the difference in size which thus remains is called the plastic (residual) deformation. In crystalline materials, this deformation is caused by the irreversible displacement of one layer of crystalline lattice with respect to the other. After the removal of external forces the displaced layers of atoms retain their position.

In deformation, the displacement of atoms under the action of external forces is accompanied by a change in the forces of interaction between the atoms, i.e. the forces of attraction and repulsion.

Additional internal forces accompanying the deformation appear in the elements of structures under the action of external forces. These internal forces resist the external forces and try to prevent them from breaking the element, changing its shape or separating one part from the other. They try to regain the initial shape and size of a deformed part of the structure. In order to assess the effect of the external forces on the deformed element, we must know how to measure and calculate the interatomic forces that appear as a result of the deformation caused by the action of external forces.

 **MAKING A PRESENTATION**

19. Make up a presentation “Shearing Stresses” following the instructions:

Include these four parts into your presentation:

1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:

- Good afternoon.
- First, let me introduce myself: I’m …….. from
- The problem(s) I want to tell about concern(s) …
- I’ll begin by describing ………, and go on to ……….., and I’ll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I’d like to talk about ………
- First of all ………… Next …………
- I’d like now to turn to ………..
- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I’d like to run through the main points again …
- In conclusion ………
- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I’ll be glad to answer them

Use visual aids such as chart, drawings and equations.
Be ready to answer the questions of the audience after your presentation.

Unit 3
Joints and Connections

WORDLIST

1 bearing pressure – опорное давление, реакция опоры

2 bond metal – связующий метал

3 butt weld – стыковое сварное соединение; стыковой сварной шов

4 bolted joint – болтовое соединение

5 centroid – центроид, центр тяжести

6 cold-driven rivet – заклёпка, посаженная в холодном состоянии

7 friction-grip bolt – фрикционный зажим

8 frictional force – сила трения

9 fillet weld – угловой сварной шов

10 high-tensile – высокопрочный

11 joint – соединение

12 mode of failure – вид разрушения; характер разрушения

13 overlap – наплыв (дефект шва)

14 polar second moment – полярный момент инерции

15 repeated load – многократно повторяющаяся нагрузка

16 rivet joint – заклёпочное соединение; заклёпочный шов

17 tensile load – растягивающая нагрузка

18 throat of the weld – расчётное сечение сварного шва

19 to connect – соединять; присоединять

20 to taper – сужать(ся)

21 to withstand – выдерживать

22 ultimate tensile stress – предельное напряжение при растяжении

23 welded joint – сварное соединение

WARM UP

1. Discuss with other students:

- What do you know about the joints?
- Why are the joints so important?

Now read the passage and check your guesses

Importance of Connections

In metallic materials, the joints may take a number of different forms, as for example welded joints, bolted joints and riveted joints. In general, such joints are stressed in complex ways, and it is not usually possible to calculate stresses accurately because of the geometrical discontinuities in the region of a joint. For this reason, good design of connections is a mixture of stress analysis and experience of the behaviour of actual joints; this is particularly true of connections subjected to repeated loads.

Bolted joints are widely used in structural steel work and recently the performance of such joints has been greatly improved by the introduction of high-tensile, friction-grip bolts. Welded joints are widely used in steel structures, as for example, in ship construction. Riveted joints are still widely used in aircraft-skin construction in light-alloy materials. Epoxy resin glues are often used in the aeronautical field to bond metals.

PRONOUNCIATION

2. Read and remember the pronunciation of the following equations. Write down these equations

x raised to the second power	y cube, y cubed
x to the second power	the cube of y
the second power of four is sixteen	the third power of y
	y raised to the third power
four squared is sixteen	y to the third power

the cube of three is twenty seven
a to the n-th power
a raised to the fifth power
a to the n-th power
a to the n-th power
y to the minus tenth power
the square root of sixteen is four
the square root of a
the cube root of twenty seven is three

the cube root of a
the fourth root of sixteen is two
the fifth root of a square
d two y over d x square
the integral from n to m
integral between limits n and m
Tangent r
The logarithm of two
Logarithm of d to the base c

WORD FORMATION

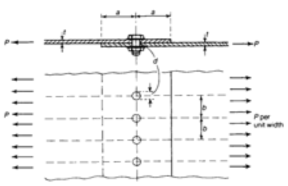
3. Read and translate the words having the same root

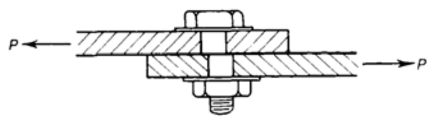
Verb	**Noun**
to fail	failure
to press	pressure
to connect	connection
to assume	assumption
to deform	deformation
to equilibrate	equilibrium
to construct	construction

READING

4. You are going to read the text

- Look at the title of the text and the figures and say what you think this text is about.
- Answer the following questions, then read quickly through the text and see if your guesses are correct.





1 What is the simplest type of joint between two plates of materials?
2 What modes of failure of simple bolted and riveted joints are there?

Modes of Failure of Simple Bolted and Riveted Joints

One of the simplest types of joint between two plates of material is a bolted or riveted lap joint, Figure 3.1.

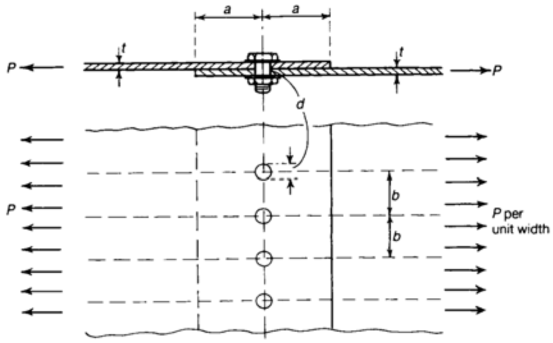


Figure 3.1. Single-bolted lap joint under tensile load.

We shall discuss the forms of failure of the joint assuming it is bolted, but the analysis can be extended in principle to the case of a riveted connection. Consider a joint between two wide plates, Figure 3.1; suppose the plates are
each of thickness t, and that they are connected together with a single line of bolts, giving a total overlap of breadth $2a$. Suppose also that the bolts are each of diameter d**,** and that their centres are a distance b apart along the line of bolts; the line
of bolts is a distance a from the edge of each plate. It is assumed that a bolt fills a hole, so that the holes in the plates are also of diameter d. We consider all possible simple modes of failure when each plate carries a tensile load of P per unit width of plate:

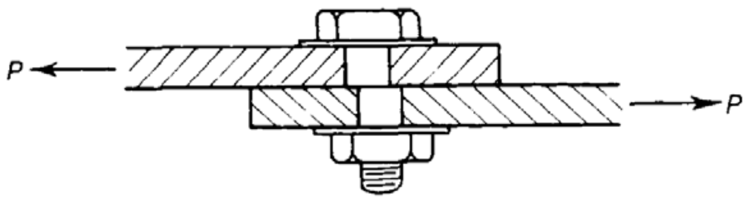


Figure 3.2. Failure by shearing of the bolts.

(1) The bolts may fail by shearing, as shown in Figure 3.2; if τ_1 is the maximum shearing stress the bolts will withstand, the total shearing force required to shear a bolt is

$$\tau_1 \times \left(\frac{\pi d^2}{4}\right)$$

Now, the load carried by a single bolt is Pb, so that a failure of this type occurs when

$$Pb = \tau_1 \left(\frac{\pi d^2}{4}\right)$$

This gives

$$P = \frac{\pi d^2 \tau_1}{4b}$$

(2) The bearing pressure between the bolts and the plates may become excessive; the total bearing load taken by a bolt is Pb, Figure 3.3, so that the average bearing pressure between a bolt and its surrounding hole is

$$\frac{Pb}{td}$$

If Pb is the pressure at which either the bolt or the hole fails in bearing, a failure of this type occurs when:

$$P = \frac{P_b td}{b}$$

a) b)

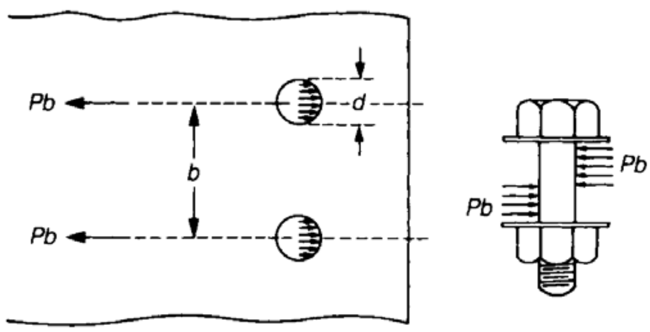


Figure 3.3. (a) Bearing pressure on the holes of the upper plate. (b) Bearing pressures on a bolt.

(3) Tensile failures may occur in the plates; clearly the most heavily stressed regions of the plates are on sections such as *ee*, Figure 3.4, through the line of bolts. The average tensile stress on the reduced area of plate through this section is

$$\frac{Pb}{(b-d)t}$$

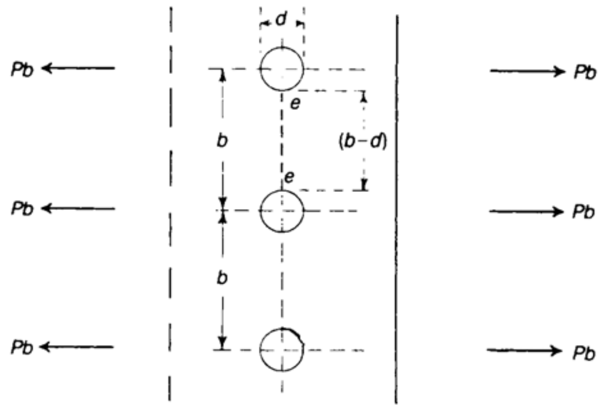


Figure 3.4. Tensile failures in the plates.

If the material of the plate has an ultimate tensile stress of σ_{ult}, then a tensile failure occurs when

$$P = \frac{\sigma_{ult}\, t(b-d)}{b}$$

(4) Shearing of the plates may occur on planes such as *cc*, Figure 3.5, with the result that the whole block of material *cccc* is sheared out of the plate. If τ_2
is the maximum shearing stress of the material of the plates, this mode of failure occurs when

$$Pb = \tau_2 \times 2at$$

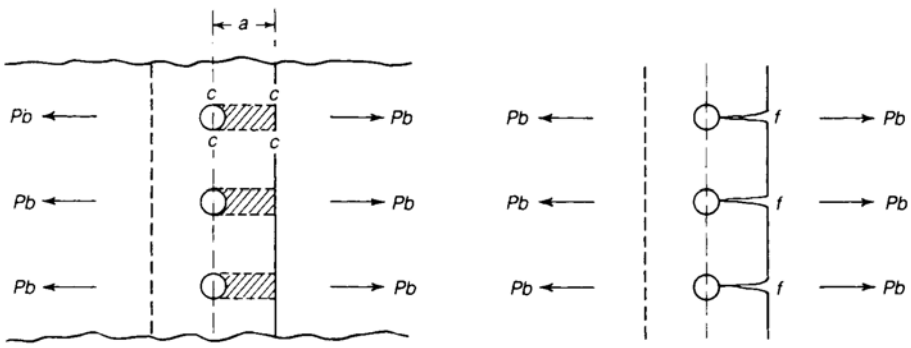


Figure 3.5. Shearing failure in the plates.

Figure 3.6. Tensile failures at the free edges of the plates.

This gives

$$P = \frac{2at\tau_2}{b}$$

(5) The plates may fail due to the development of large tensile stresses in the regions of points such as *f*; Figure 3.6. The failing load in this condition is difficult to estimate, and we do not attempt the calculation at this stage.

In riveted joints it is found from tests on mild-steel plates and rivets that if the centre of a rivet hole is not less than *1½* times the rivet hole diameter from the edge of the plate, then failure of the plate by shearing, does not occur. Thus, if for mild-steel plates and rivets,

$$a \geq 1.5d$$

we can disregard the modes of failure discussed above. In the case of wrought aluminium alloys, the corresponding value of *a* is

$$a \geq 2d$$

We have assumed, in discussing the modes of failure that all load applied to the two plates of Figure 3.1 is transmitted in shear through the bolts or rivets. This is so only if there is a negligible frictional force between the two plates. If hot-driven rivets are used, appreciable frictional forces are set up on cooling;
these forces play a vital part in the behaviour of the connection. With cold-driven rivets the frictional force is usually small, and may be neglected.

5. Read the text below, for questions 1-5 decide which answer, A or B best fits each space

Efficiency of a Connection

After (1)_______ the connection of Figure 3.1, suppose we find that in the (2)_______ mode of failure the carrying capacity of the joint is P_0. If the two plates were continuous through the connection, that is, if there were no overlap or bolts, the strength of the plates in tension would be

$$P_{ult} = \sigma_{ult} t$$

where σ_{ult} is the (3)_______ tensile stress of the material of the plates. The ratio

$$\eta = \frac{P_0}{P_{ult}} = \frac{P_0}{\sigma_{ult} t}$$

is known as the *efficiency* of the connection; clearly, η defines the extent to which the (4)_______ of the connection attains the full strength of the continuous5_______.

1	**A** determining	**B** analysing
2	**A** weakest	**B** strongest
3	**A** ultimate	**B** average
4	**A** resistance	**B** strength
5	**A** planes	**B** plates

6. Skim through the texts and underline the sentences or the words that best sum up the main idea of the texts (key words). In pairs discuss the main idea of the text using the key words or sentences.

Group-Bolted and - Riveted Joints

When two members are connected by cover plates bolted or riveted in the manner shown in Figure 3.7, the joint is said to be *group-bolted* or *-riveted.* The greatest efficiency of the joint shown in Figure 3.7 is obtained when the bolts or rivets are re-arranged in the form shown in Figure 3.8, where it is supposed six bolts or rivets are required each side of the joint. The loss of cross-section in the main members, on the line a, is that due to one bolt or rivet hole. If the load is assumed to be equally distributed among the bolts or rivets, the bolt or rivet on the line a will take one-sixth of the total load, so that the tension in the main plates, across b, will be *5/6ths* of the total.

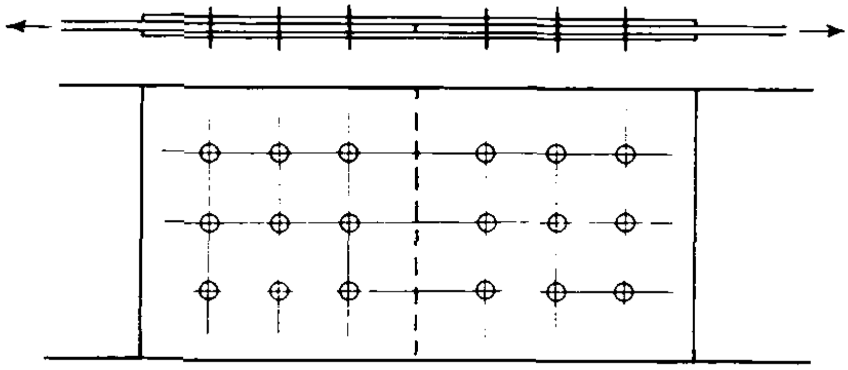


Figure 3.7. A group-bolted or -riveted joint.

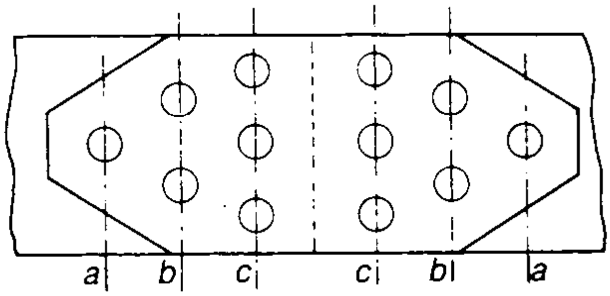


Figure 3.8. Joint with tapered cover plates.

But this section is reduced by two bolt or rivet holes, so that, relatively, it is as strong as the section *a*, and so on: the reduction of the nett cross-section of the main plates increases as the load carried by these plates decreases. Thus a more efficient joint is obtained than when the bolts or rivets are arranged as in Figure 3.7.

7. Read the statements 1-5 and decide whether they are true or false. Then read the text and check your guesses.

1 Steel and aluminium can be deposited in a molten state between the components to form a joint, which is then called a welded connection.
2 There are three types of weld, which are in common use.
3 The weld material carries largely tensile stresses, when the plates carry a tensile load.
4 Butt welds transmit force between the two plates by shearing actions within the welds.

5 To estimate approximately the strength of the welds it is assumed that failure of the welds takes place by shearing across the throats of the welds.

Welded Connections

Some metals used in engineering – such as steel and aluminium – can be deposited in a molten state between the components to form a joint, which is then called a welded connection. The metal deposited to form the joint is called the weld. Two types of weld are in common use, the *butt weld* and the *fillet weld*; Figure 3.9 shows two plates connected by a butt weld; the plates are tapered at the joint to give sufficient space for the weld material. If the plates carry a tensile load the weld material carries largely tensile stresses. Figure 3.10 shows two plates connected by fillet welds; if the joint carries a tensile load the welds carry largely shearing stresses, although the state of stress in the welds is complex, and tensile stresses may also be present. Fillet welds of the type indicated in Figure 3.10 transmit force between the two plates by shearing actions within the welds; if the weld has the triangular cross-section shown in Figure 3.11(a), the shearing stress is greatest across the narrowest section of the weld, having a thickness $t/\sqrt{2}$. This section is called the throat of the weld. In Figure 3.11(b), the weld has the same thickness t at all sections. To estimate approximately the strength of the welds in Figure 3.11 it is assumed that failure of the welds takes place by shearing across the throats of the welds.

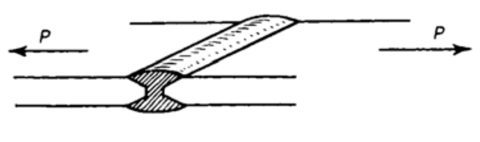


Figure 3.9. Butt weld between two plates.

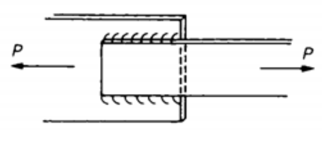
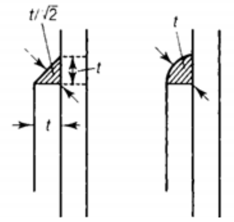


Figure 3.10 Fillet welds in a plate connection.

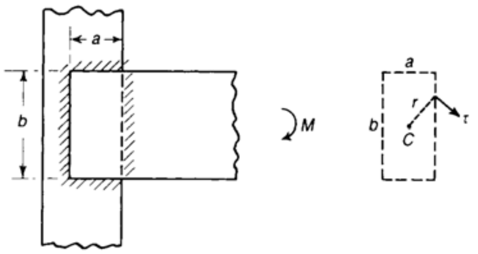


a) **b)**

Figure 3.11 Throat of a fillet weld.

8. Read the text and answer the questions below

1 What should we do when a welded connection is required to transmit a bending moment?
2 What does this figure illustrate?



Welded Connections under Bending Actions

Where a welded connection is required to transmit a bending moment we adopt a simple empirical method of analysis similar to that for bolted and riveted connections. We assume that the shearing stress in the weld is proportional to the distance of any part of the weld from the centroid of the weld. Consider, for example, a plate which is welded to a stanchion and which carries a bending moment M in the plane of the welds, Figure 3.12. We suppose the fillet welds are of uniform thickness t around the parameter of a rectangle of sides u and b. At any point of the weld we take the shearing stress, τ, as acting normal to the line joining that point to the centroid *C* of the weld. If δA is an elemental area of weld at any point, then

$$M = \int \tau r \, dA$$

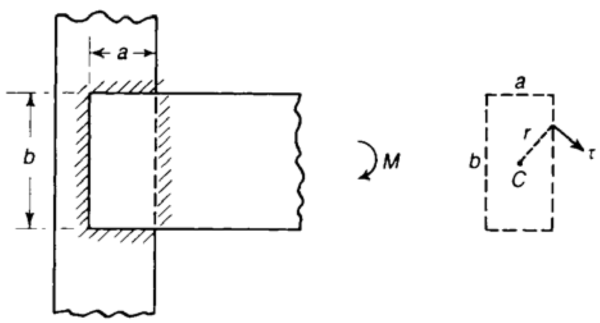


Figure 3.12. A plate fillet welded to a column, and transmitting a bending moment *M.*

If

$$\tau = kr$$

then

$$M = \int kr^2 \, dA = kJ$$

where J is the polar second moment of area of the weld about the axis through C and normal to the plane of the weld. Thus

$$k = \frac{M}{J}$$

and

$$\tau = \frac{Mr}{J}$$

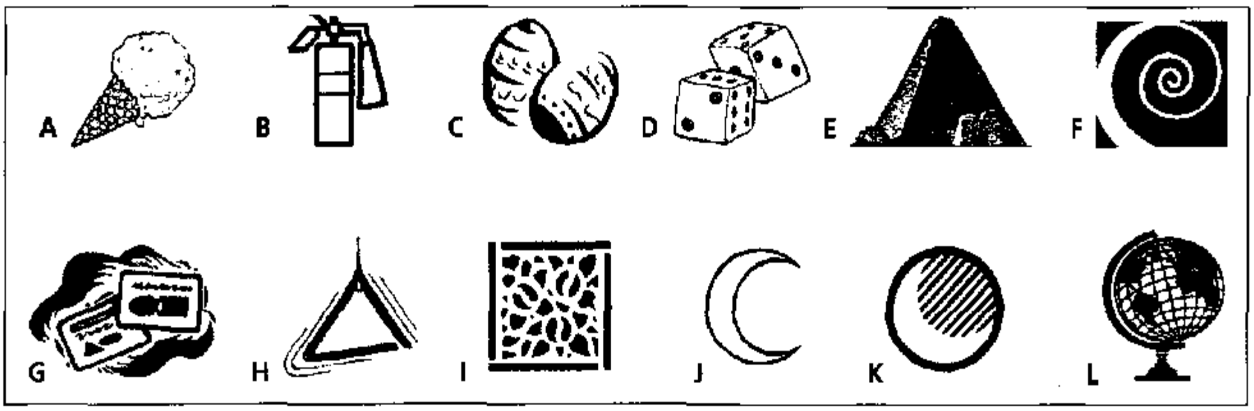
According to this simple empirical theory, the greatest stresses occur at points of the weld most remote from the centroid C.

VOCABULARY

9. Match each word (1-12) with the appropriate picture (A-L)

1 pyramid **2** cube **3** crescent **4** spiral **5** cone **6** sphere

7 rectangle **8** triangle **9** square **10** circle **11** cylinder **12** oval



10. Look at the following list of words and decide what adjective form A, B or C is correct. Then listen and check.

1 sphere	A spherous	B spherical	C spherocous
2 cube	A cubed	B cubous	C cubal
3 cone	A conacular	B conous	C conical
4 rectangle	A rectanalous	B rectanglis	C rectangular
5 triangle	A triangular	B trianalous	C triangled
6 circle	A circled	B circulous	C circular
7 square	A square	B squaret	C squarous
8 cylinder	A cilindrous	B cylindal	C cylindrical

11. Match the notions (1-3) and their definitions (a-c)

1 stress	a) changing of the position of section or the whole element of structure in domain of point
2 displacement	b) action, that changes the state of motion of a body on which it acts
3 deformation	c) geometric distortion in the neighbourhood of a material point

12. Write the meanings of these words. Use a dictionary.

- joint
- welded joint
- bolted joint
- riveted joint
- friction force
- cold-rivet joint

13. Write the synonyms of the following words. Use a dictionary.

- domain
- execution
- alteration
- mutual
- to asses
- to assign
- to tick

GRAMMAR

14. Translate the following phrases into English using the Passive Voice.

1. Говорят, что …

2. Предполагается, что …
3. Можно надеяться, что …
4. Следует признать, что …
5. Было найдено, что …
6. Обще признано, что …
7. Считают, что …
8. Широко распространено мнение, что …

15. Make up sentences with the phrases from activity 14

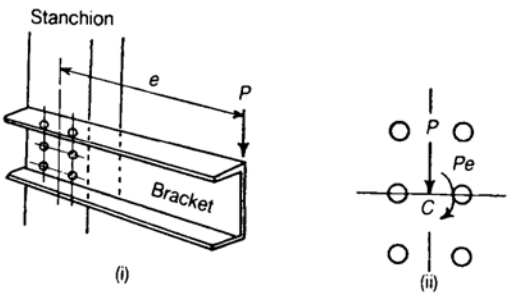
16. Translate the sentences into Russian paying attention to the modal verbs.

1 In metallic materials, the joints may take a number of different forms.
2 We shall discuss the forms of failure of the joint assuming it is bolted, but the analysis can be extended in principle to the case of a riveted connection.
3 The bolts may fail by shearing.
4 With cold-driven rivets the frictional force is usually small, and may be neglected.
5 Steel and aluminium can be deposited in a molten state between the components to form a joint, which is then called a welded connection.

COMMUNICATION

17. In pairs discuss the figure below. Share your ideas with other students.

Use the following phrases:



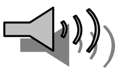
- structural connections
- to transmit moments
- axial forces
- vertical load
- diameter
- parallel load
- centroid

 **18. Work in pairs or groups. Discuss the following problems:**

1. Different forms of joint in metallic materials
2. A bolted or riveted lap joint is the simplest type of joint between two plates of a material
3. The forms of failure of the joint
4. Efficiency of a connection
5. Group-bolted and –riveted joints
6. Welded joints

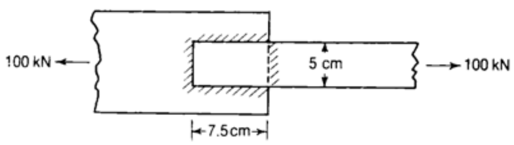
Use the following as phrase-openings:

1. I would like to tell/say/speak …
2. Let me say some/a few words/ideas about …
3. I need/have to point out that …
4. The problem(s) I want to tell about concern(s) …
5. As far as I know …
6. Finally/In the end I must/shall mention

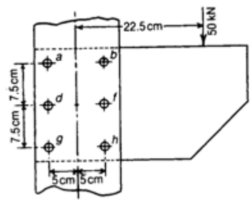


LISTENING

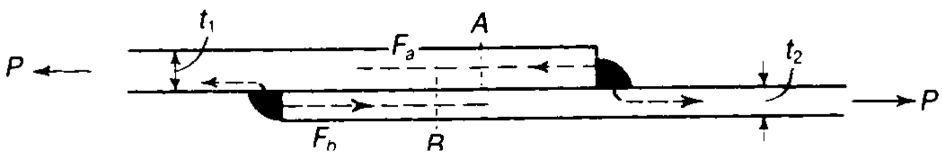
19. You are going to listen to three problem situation. Match them to the following figures.



a)



b



c)

Problem situation 1
Problem situation 2

Problem situation 3

WRITING

20. Write the summary of the text following the instructions:

9 Read the whole of the text to gain an impression of its content and its relevance to your work

1 Highlight the main points as you read

2 Make notes of your own on these points

3 Put away the original and rewrite your notes in your own words in complete sentences

4 Begin your summary with a statement of the main idea at the start

5 Using your notes, write out your subsidiary or supporting points in well-connected sentences

6 Re-read your work to check that you have included all the information that you need

7 Write a summary of the text

(see APPENDIX 4, p. 104)

Scheme of a Solution of the Fundamental Problem of Strength of Materials

While selecting the size and material for an element of the structure we must provide for a certain factor against its failure and plastic deformation. The element should be designed so that the maximum stresses that occur during its operation should always be less than the stresses at which the material fails or undergoes plastic deformation.

The stress at which the material fails is called the *ultimate (tensile) strength;* we shall denote it with the same letter as stress but with subscript $\boldsymbol{p}_u$. The stress beyond which the material deforms insignificantly and only up to a predetermined value is known as the *elastic limit*. These quantities are known as the mechanical characteristics of resistance of materials to failure and plastic deformations. To ensure the smooth functioning of the structure without a risk of failure, we must see to it that the element is only subjected to stresses which are less than its ultimate strength. The *permissible stress* is denoted by the same letter but is put in square brackets; it is related to the ultimate strength $\boldsymbol{p_u}$ by the following expression:

$$[p]=p_u/k$$

where $\boldsymbol{k}$ is the *safety factor* which shows how many times the permissible stress is less than the ultimate (tensile) strength. The value of this factor varies from 1.7-1.8 to 8-10 and depends upon the operating conditions of the structure. Denoting by $\boldsymbol{p_{max}}$ the maximum stress that appears in the designed element under the action of external forces, we may write the basic condition, which the size and material of the element must satisfy, as follows

$$p_{max} \leq [p]$$

This is *the strength condition*, which states that the actual stress must be not greater than the permissible. Now we may compile the plan for solving the problems of strength of materials as follows.

Ascertain the magnitude and nature of all the external forces, including the reactions, acting on the element under consideration.

(1) Select an appropriate material that is most suitable in the working conditions of the element (structure) and the nature of loading; determine the permissible stress.

(2) Set the cross-sectional area of the element in numerical or algebraic form, and calculate the maximum actual stress $\boldsymbol{p_{max}}$, which develops in it.

(3) Write down the strength condition $p_{max} \leq [\ p\ ]$ and with the help of it calculate the cross-sectional area of the element or check whether the set value is sufficient.

In the majority of cases the strength condition must be supplemented by stability and rigidity tests. The first test ensures that the elements of structure must not change their predetermined type of equilibrium, and the second test sets limits to the deformations of elements. While solving problems on strength of materials, we have to take the help of theoretical mechanics and experimental techniques. The determination of external forces is based on equations of statics; in statically indeterminate structures, it is essential to determine the deformation of the material. This is possible only if we have reliable experimental data on the relation between deformations and forces or stresses.

MAKING A PRESENTATION

21. Make up a presentation “Joints and Connections” following the instructions:

Include these four parts into your presentation:

1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:

- Good afternoon.
- First, let me introduce myself: I’m …….. from
- The problem(s) I want to tell about concern(s) …
- I’ll begin by describing ………, and go on to ……….., and I’ll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I’d like to talk about ………
- First of all ………… Next …………
- I’d like now to turn to ………..
- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I’d like to run through the main points again …
- In conclusion ………
- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I’ll be glad to answer them

Use visual aids such as chart, drawings and equations.

Be ready to answer the questions of the audience after your presentation.

Unit 4
Thin Shells under Internal Pressure

WORDLIST

1 average value – среднее значение
2 beam – балка, брус
3 bending stress – напряжение при изгибе
4 circumferential stress – окружное напряжение
5 direct strain – относительная линейная деформация
6 thin shell – тонкая оболочка, тонкостенная оболочка
7 internal pressure – внутреннее давление
8 circular cross-section – круговое (поперечное) сечение
9 diametral plane – диаметральная плоскость
10 elastic foundation – упругое основание
11 fluid – текучая среда
12 hemisphere – полусфера
13 longitudinal force – осевая сила, продольная сила
14 longitudinal stress – осевое [продольное] напряжение
15 mean radius – средний радиус
16 membrane theory – мембранная теория (для расчёта оболочек)
17 maximum shearing stress – макс. касательное напряжение
18 principal stress – главное напряжение
19 radial stress – радиальное напряжение
20 remote – удалённый; действующий на расстоянии
21 radial expansion – радиальное расширение
22 spherical shell – сферическая оболочка
23 tangent plane – касательная плоскость
24 tensile stress – растягивающее напряжение
25 transverse cross-section – поперечное сечение
26 total force – равнодействующая (результирующая) сила
27 to be subjected to – подвергаться
28 to transmit – передавать
29 to eliminate – устранять, исключать
30 to oppose – противодействовать; препятствовать
31 to approximate – аппроксимировать, приближать(ся)
32 volumetric strain – объёмная деформация
33 vessel – сосуд; резервуар

WARM UP

1. Work in pairs. Comment the following statement:

"A problem in which combined stresses are present is that of a cylindrical shell under internal pressure"

Use the following phrases:

- long circular shell
- circumferential stress
- to be subjected to
- to give rise to
- to transmit to the walls
- to produce a longitudinal stress

Read the text and check your guesses.

READING

2. Read the text for the gist (overall idea) and decide whether the sentences below are true or false.

Thin Cylindrical Shell of Circular Cross-Section

A problem in which combined stresses are present is that of a cylindrical shell under internal pressure. Suppose a long circular shell is subjected to an internal pressure p, which may be due to a fluid or gas enclosed within the cylinder, Figure 4.1. The internal pressure acting on the long sides of the cylinder gives rise to a circumferential stress in the wall of the cylinder; if the ends of the cylinder are closed, the pressure acting on these ends is transmitted to the walls of the cylinder, thus producing a longitudinal stress in the walls.

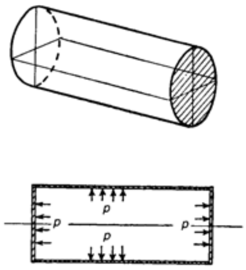


Figure 4.1. Long thin cylindrical shell with closed ends under internal pressure.

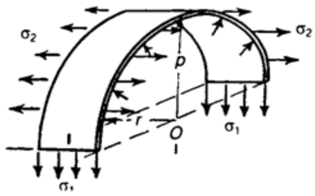


Figure 4.2. Circumferential and longitudinal stresses in a thin cylinder with closed ends under internal pressure.

Suppose r is the mean radius of the cylinder, and that its thickness t is small compared with r. Consider a unit length of the cylinder remote from the closed ends, Figure 4.2; suppose we cut this unit length with a diametral plane, as in Figure 4.2. The tensile stresses acting on the cut sections are σ_1, acting circumferentially, and σ_2, acting longitudinally. There is an internal pressure p on the inside of the half-shell. Consider equilibrium of the half-shell in a plane perpendicular to the axis of the cylinder, as in Figure 4.3; the total force due to the internal pressure p in the direction OA is

$$p \times (2r \times 1)$$

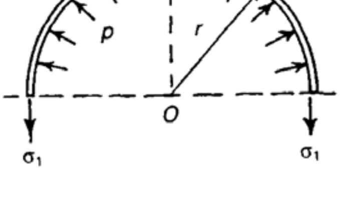
because we are dealing with a unit length of the cylinder. This force is opposed by the stresses σ_1; for equilibrium we must have

$$p \times (2r \times 1) = \sigma_1 \times 2(t \times 1),$$

Then

$$\sigma_1 = \frac{pr}{t}$$

We shall call this the *circumferential* (or *hoop) stress.*



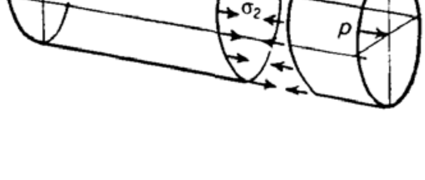


Figure 4.3. Derivation of circumferential stress.

Figure 4.4. Derivation of longitudinal stress.

Now consider any transverse cross-section of the cylinder remote from the ends, Figure 4.4; the total longitudinal force on each closed end due to internal pressure is

$$p \times \pi r^2$$

At any section this is resisted by the internal stresses σ_2, Figure 4.4. For equilibrium we must have

$$p \times \pi r^2 = \sigma_2 \times 2\pi r t$$

,

which gives

$$\sigma_2 = \frac{pr}{2t}$$

We shall call this the *longitudinal stress.* Thus the longitudinal stress σ_2, only half the circumferential stress, σ_1. The stresses acting on an element of the wall of the cylinder consist of a circumferential stress σ_1, a longitudinal stress σ_2, and a radial stress p on the internal face of the element, Figure 4.5. As (r/t) is very much greater than unity, p is small compared with σ_1 and σ_2. The state of stress in the wall of the cylinder approximates then to a simple two-dimensional system with principal stresses σ_1 and σ_2.

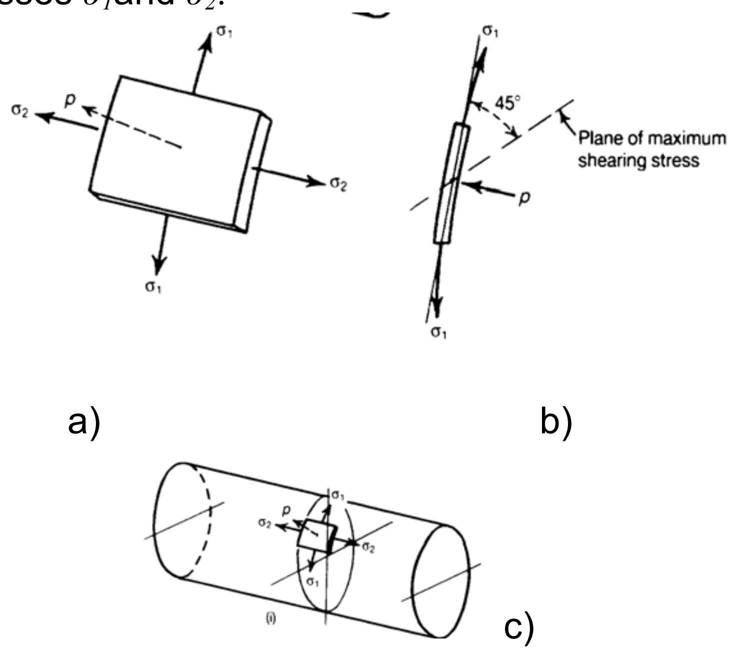


Figure 4.5. Stresses acting on an element of the wall of a circular cylindrical shell with closed ends under internal pressure.

The maximum shearing stress in the plane of σ_1 and σ_2 is therefore

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2) = \frac{pr}{4t}$$

This is not, however, the maximum shearing stress in the wall of the cylinder, for, in the plane of $\sigma_1$and p, the maximum shearing stress is

$$\tau_{max} = \frac{1}{2}(\sigma_1) = \frac{pr}{2t}$$

since p is negligible compared with σ_1 ;again, in the plane of $\sigma_1$and p, the maximum shearing stress is

$$\tau_{max} = \frac{1}{2}(\sigma_2) = \frac{pr}{4t}$$

The greatest of these maximum shearing stresses is given by equation; it occurs on a plane at 45° to the tangent and parallel to the longitudinal axis of the cylinder, Figure 4.5(c).The circumferential and longitudinal stresses are accompanied by direct strains. If the material of the cylinder is elastic, the corresponding strains are given by

$$\varepsilon_1 = \frac{1}{E}(\sigma_1 - v\sigma_2) = \frac{pr}{Et}\left(1 - \frac{1}{2}v\right)$$

$$\varepsilon_1 = \frac{1}{E}(\sigma_2 - v\sigma_1) = \frac{pr}{Et}\left(\frac{1}{2} - v\right)$$

The circumference of the cylinder increases therefore by a small amount $2\pi r\varepsilon$; the increase in mean radius is therefore $r\varepsilon_1$. The increase in length of a unit length of the cylinder is ε_2, *so* the change in internal volume of a unit length of the cylinder is

$$\delta V = \pi (r + r\varepsilon_1)^2 (1 + \varepsilon_2) - \pi r^2$$

The volumetric strain is therefore

$$\frac{\delta V}{\pi r^2} = (1 + \varepsilon_1)^2 (1 + \varepsilon_2) - 1$$

But $\varepsilon_1$and ε_2 are small quantities, so the volumetric strain is

$$(1 + \varepsilon_1)^2 (1 + \varepsilon_2) - 1 \doteq (1 + 2\varepsilon_1)(1 + \varepsilon_2) - 1$$

$$\doteq 2\varepsilon_1 + \varepsilon_2$$

In terms of σ_1 and σ_2 this becomes

$$2\varepsilon_1 + \varepsilon_2 = \frac{pr}{Et}\left[2\left(1 - \frac{1}{2}v\right) + \left(\frac{1}{2} - v\right)\right] = \frac{pr}{Et}\left(\frac{5}{2} - 2v\right)$$

1 The problem considered in the text deals with a cylindrical shell under internal pressure. A long circular shell is taken as an example.
2 The internal pressure acting on the long sides of the cylinder gives rise to a longitudinal stress in the wall of the cylinder.
3 The radius of the cylinder is small compared to its thickness.
4 In the text there is a figure illustrating a transverse cross-section of the cylinder remote from the ends.
5 The stresses acting on an element of the wall of the cylinder consist of a circumferential stress σ_1 and a longitudinal stress σ_2 on the internal face of the element.
6 Radial stress is negligible compared with circumferential stress.
7 The greatest of maximum shearing stresses occurs on a plane at 90° to the tangent and parallel to the longitudinal axis of the cylinder.

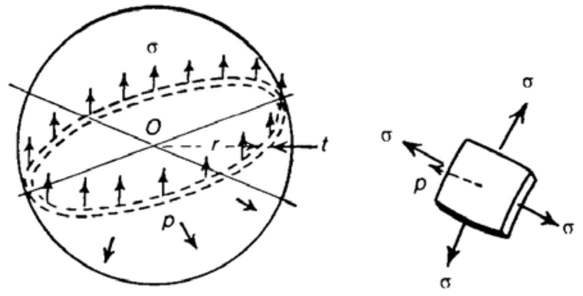
3. Before reading the following text, work with a partner and ask and answer the questions below. Base your answers on your possible knowledge of the topic.

1 What is a spherical shell?
2 What is internal pressure?
3 What is a hemisphere?
4 What is a tensile stress?
5 Can you illustrate a thin spherical shell by an example?

Thin Spherical Shell

We consider next a thin spherical shell of mean radius r, and thickness t, which is subjected to an internal pressure p. Consider any diameter plane through the shell, Figure 4.6; the total force normal to this plane due top acting on a hemisphere is

$p \times \pi r^2$



a) b)

Figure 4.6. Membrane stresses in a thin spherical shell under internal pressure

This is opposed by a tensile stress σ in the walls of the shell. By symmetry σ is the same at all points of the shell; for equilibrium of the hemisphere we must have

$$p \times \pi r^2 = \sigma \times 2\pi r t$$

This gives

$$\sigma = \frac{pr}{2t}$$

At any point of the shell the direct stress σ has the same magnitude in all directions in the plane of the surface of the shell; the state of stress is shown in Figure 4.6(b). *As* p is small compared with σ the maximum shearing stress occurs on planes at 45' to the tangent plane at any point. If the shell remains elastic, the circumference of the sphere in any diametral plane is strained an amount

$$\varepsilon = \frac{1}{E}(\sigma - \nu\sigma) = (1 - \nu)\frac{\sigma}{E}$$

The volumetric strain of the enclosed volume of the sphere is therefore

$$3\varepsilon = 3(1 - \nu)\frac{\sigma}{E} = 3(1 - \nu)\frac{pr}{2Et}$$

If the spherical shell is fabricated, so that its joint is weaker than the remainder of the shell, then equation takes on the following modified form:

$$\sigma = \text{stress} = \frac{pr}{2\eta t}$$

where

η = joint efficiency ≤ 1

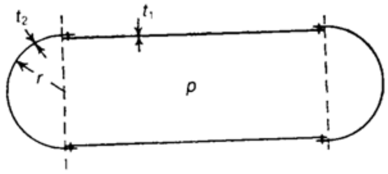
4. Look at the illustration below and the words and phrases taken from the passage. With a partner try to predict what is being discussed:

hemispherical ends

bending stresses

circumferential strain

pressure



vessels

cylindrical

section

average value

equation

Cylindrical Shell with Hemispherical Ends

Some pressure vessels are fabricated with hemispherical ends; this has the advantage of reducing the bending stresses in the cylinder when the ends are flat. Suppose the thicknesses t_1 and t_2 of the cylindrical section and the hemispherical end, respectively (Figure 4.7), are proportioned so that the radial expansion is the same for both cylinder and hemisphere; in this way we eliminate bending stresses at the junction of the two parts.

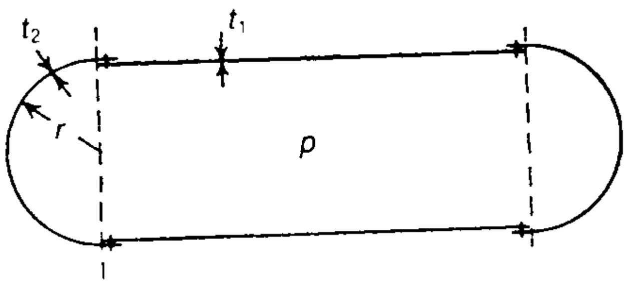


Figure 6.7. Cylindrical shell with hemispherical ends, so designed as to minimize the effects of bending stresses.

From previous equations, the circumferential strain in the cylinder is

$$\frac{pr}{Et_1}\left(1 - \frac{1}{2}v\right)$$

and from previous equation the circumferential strain in the hemisphere is

$$\left(1 - v\right)\frac{pr}{2Et_2}$$

If these strains are equal, then

$$\frac{pr}{Et_1}\left(1 - \frac{1}{2}v\right) = \frac{pr}{2Et_2}\left(1 - v\right)$$

This gives

$$\frac{t_1}{t_2} = \frac{2 - v}{1 - v}$$

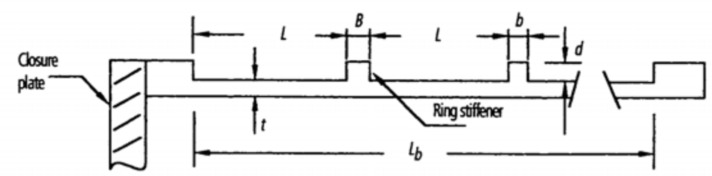
For most metals v is approximately *0.3*, so an average value of (t_1/t_2) is *1.7/0.7 ± 2.4.* The hemispherical end is therefore thinner than the cylindrical section.

5. Read the text to answer the question:

- How can one demonstrate end effects and ring stiffness?

Bending Stresses in Thin-Walled Circular Cylinders

The theory presented in Unit 4 is based on membrane theory and neglects bending stresses due to end effects and ring stiffness. To demonstrate these effects, Figures 4.9 to 4.13 show plots of the theoretical predictions for a ring stiffened circular cylinder together with experimental values, shown by crosses. This ring stiffened cylinder, which was known as Model №2, was firmly fixed at its ends, and subjected to an external pressure of 0.6895 *MPa (100 psi),* as shown by Figure 4.8.



L	L_b	B	b	d	N
95.25	616.6	10.16	8.26	15.75	5

t = 0.08 N = number of ring stiffeners

E = Young's modulus = 71 GPa υ = Poisson's ratio = 0.3

Figure 4.8. Details of model № 2 (mm).

The theoretical analysis was based on beam on elastic foundations, and is described by Ross.

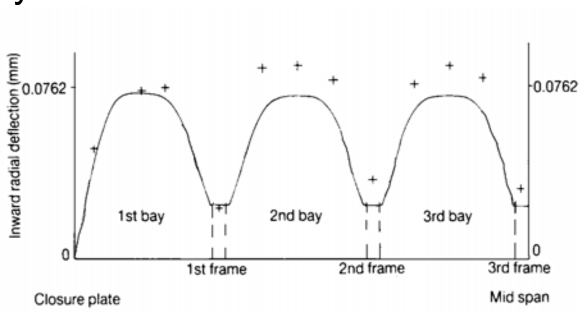


Figure 4.9. Deflection of longitudinal generator at 0.6895 MPa (100 psi), Model No. 2.

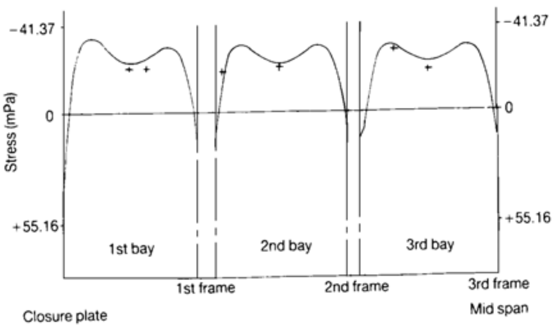


Figure 4.10. Longitudinal stress of the outermost fibre at 0.6895 MPa (1 00 psi), Model No. 2.

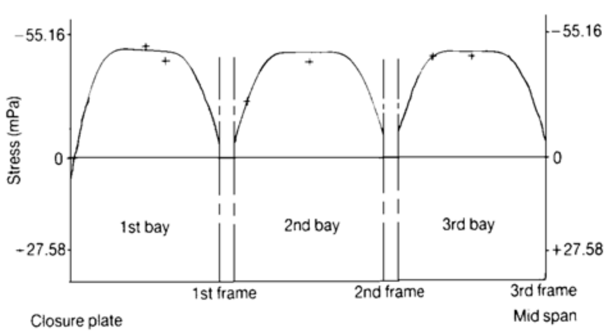


Figure 4.11. Circumferential stress of the outermost fibre at 0.6895 MPa (1 00 psi), Model N2

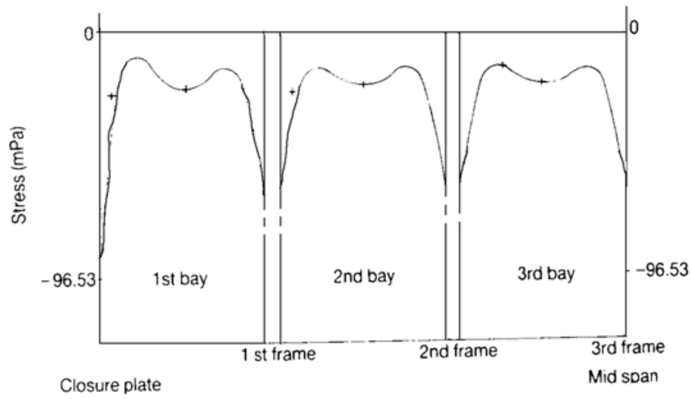


Figure 4.12. Longitudinal stress of the innermost fibre at 0.6895 MPa (100 psi), Model No. 2.

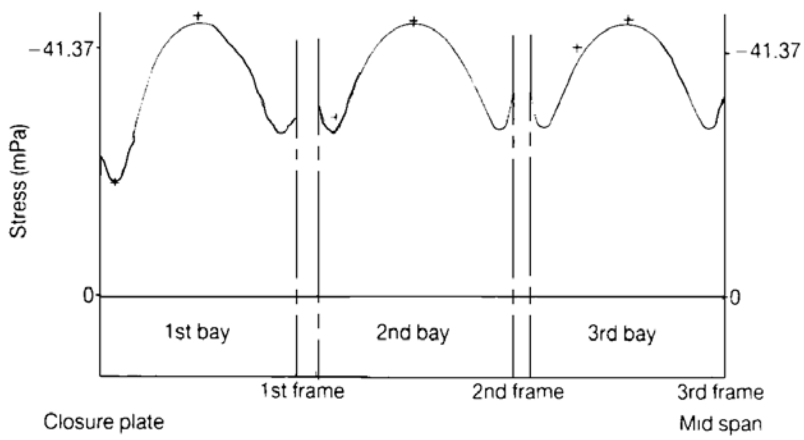


Figure 6.13 Circumferential stress of the innermost fibre at 0.6895 MPa (100 psi), Model No.2.

From Figures 4.9 to 4.13, it can be seen that bending stresses in thin-walled circular cylinders are much localised.

WORD FORMATION

6. Note the meanings of the suffixes given in the box below and translate the examples into Russian.

- ful = with – meaning**ful**, master**ful**
- less = without – dimension**less**, end**less**
- able = can be, able to be, must be – deform**able**, consider**able**

- en = make – hard**en**, soft**en**

7. Think of three more words ending with each of the suffixes listed in the activity 6.

VOCABULARY

8. Work in pairs. Read the definitions and decide what they mean. Share your ideas with other students.

Example
'half of a sphere is a hemisphere'

- the length of a line segment between the center and circumference of a circle or sphere
- the length of a straight line passing through the center of a circle and connecting two points on the circumference
- a three-dimensional closed surface such that every point on the surface is equidistant from the center
- deformation of a physical body under the action of applied forces
- outer covering of something

9. Match the words (1-5) with their opposites (a-e). Use a dictionary.

1 external	a) longitudinal
2 close	b) inexact
3 transverse	c) direct
4 exact	d) internal
5 inverse	e) remote

10. Write the synonyms of the following words. Use a dictionary.

- average
- to annihilate
- to transfer
- to contradict
- peripheral

11. Put the words in the right order in the following sentences. Then listen and check.

1 advantage bending some when pressure reducing vessels ends are with ends; this the of the stresses has in the cylinder the hemispherical are flat fabricated.
2 membrane bending the effects presented based theory stresses theory and due to end on and ring neglects stiffness is.
3 on was on beam analysis theoretical based elastic the.

12. Make a list of expressions with the following words and use them in sentences of your own.

Example
cylinder – circular cylinder
Consider the circular cylinder subjected to an internal pressure.

shell	pressure	stress	force	plane
section	radius	strain	value	theory

GRAMMAR

13. Define the form of the Participle and translate the sentences into Russian.

1 Suppose a long circular shell is subjected to an internal pressure p, which may be due to a fluid or gas enclosed within the cylinder.
2 The internal pressure acting on the long sides of the cylinder gives rise to a circumferential stress in the wall of the cylinder.
3 The theory presented in Unit 4 is based on membrane theory and neglects bending stresses due to end effects and ring stiffness.
4 These figures show plots of the theoretical predictions for a ring stiffened circular cylinder together with experimental values, shown by crosses.
5 The substance formed was made up of two elements.
6 If placed in a strong magnetic field iron becomes magnetized.
7 The experiment described in the article attracted my attention.
8 When speaking about a direct current we mean a continuous current.

 COMMUNICATION

14. Read the text and do the tasks (1-2) below.

Flying Chickens

Scientists at NASA have developed a gun built specifically to launch dead chickens at the windshields of airliners, military jets, and the space shuttle, all traveling at maximum velocity. The idea is to simulate the frequent incidents of collisions with airborne fowl to test the strength of the windshields. British engineers heard about the gun and were eager to test it on the windshields of their new high-speed trains. Arrangements were made to borrow the gun. When the gun was fired, the engineers stood shocked as the chicken hurtled out of the barrel, crashed into the shatterproof shield, smashed it to smithereens, crashed through the control console, snapped the engineer's backrest in two, and embedded itself in the back wall of the cabin. Horrified Britons sent NASA the disastrous results of the experiment, along with the designs of the windshield, and begged the U.S. scientists for suggestions.

Answer the question: What is the response of NASA?

Role play.

Divide into two groups, A and B. Students in A group are the British engineers. Students in B group are the scientists from NASA. Dramatize the dialogue between British engineers and scientists form NASA.

LISTENING

15. Listen to the recording and fill in the gaps in the following problem situations.

1 A pipe has an … diameter of … centimeter and is … centimeter thick. What is the maximum allowable internal pressure if the maximum … stress does not … 55 mega Newton per square meter? Assume a … distribution of stress over the cross-section.

2 A long … tube has to withstand an internal test pressure of 4 mega Newton per square meter, when the mean … stress must not exceed … mega Newton per square meter. The internal diameter of the tube is … centimeter and the … is 7 thousand eight hundred forty. Find the … of the tube per metre run.

3 A long, steel tube, … centimeter internal diameter and 0 point 15 centimeter thick, is …. at the ends and subjected to internal … pressure such that the maximum direct stress in the tube is … mega Newton per square meter. Assuming v equals to … and E equals to … giga Newton per square meter, find the percentage increase in the … of the tube.

WRITITNG

16. Write the summary of the following text (see Appendix 4)

Physical Compression

Physical compression is the result of the subjection of a material to compressive stress, resulting in reduction of volume. Compression has many implications in material science, physics and structural engineering, for compression yields noticeable amounts of stress and tension. By inducing compression, mechanical properties such as compressive strength or modulus of elasticity, can be measured. Scientists may utilize press machines to induce compression.

In mechanical engineering the term is applied to the arrangement by which the exhaust valve of a steam engine is made to close, shutting a portion of the exhaust steam in the cylinder, before the stroke of the piston is quite complete. This steam being compressed as the stroke is completed, a cushion is formed against which the piston does work while its velocity is being rapidly reduced, and thus the stresses in the mechanism due to the inertia of the reciprocating parts are lessened. This compression, moreover, obviates the shock which would otherwise be caused by the admission of the fresh steam for the return stroke. In internal combustion engines it is a necessary condition of economy to compress the explosive mixture before it is ignited: in the Otto cycle, for instance, the second stroke of the piston effects the compression of the charge which has been drawn into the cylinder by the first forward stroke.

PRESENTATION

17. Make up a presentation "Thin Shells under Internal Pressure" following the instructions:

Include these four parts into your presentation:
1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:
- Good afternoon.
- First, let me introduce myself: I'm …….. from
- The problem(s) I want to tell about concern(s) …
- I'll begin by describing ………, and go on to ……….., and I'll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I'd like to talk about ………
- First of all ………… Next …………
- I'd like now to turn to ………..
- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I'd like to run through the main points again …
- In conclusion ………

- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I'll be glad to answer them

Use visual aids such as chart, drawings and equations.

Be ready to answer the questions of the audience after your presentation.

Unit 5
Bending moments and shearing forces
Geometrical properties of cross-sections

WORDLIST:

1 angle bar – уголок (металлический профиль)
2 axial thrust – осевое давление; осевое усилие
3 built-in end – заделанный конец (балки)
4 bearing pressure – опорное давление, реакция опоры
5 cantilever – консоль; консольная балка
6 concave – вогнутая поверхность
7 centroid – центроид, центр тяжести
8 concentrated load – сосредоточенная нагрузка
9 curve – кривая
10 distributed load – распределённая нагрузка
11 extensively – в значительной степени, сильно
12 efficient – действенный, результативный, эффективный
13 fluid pressure – давление текучей среды; давление жидкости
14 girder – ригель; балка; (балочная) ферма; (балочное) пролётное строение моста
15 grain – зерно; кристалл; гранула
16 hogging – искривление; прогиб
17 "I" beam – балка двутаврового сечения
18 infinitely – бесконечно, безгранично, беспредельно
19 infinitesimally small – бесконечно малый
20 inflection – изгиб; сгиб; перегиб
21 limb - лимб; шкала с делениями; круговая шкала
22 plane curved beam – пологая криволинейная балка
23 plane lamina – пластина; лист; плоскость отслоения

24 rotational equilibrium – равновесие вращающегося тела
25 rolled steel joist – стандартный двутавровый профиль
26 straight beam – прямолинейный пучок
27 stationary value – стационарное значение, установившееся значение
28 sign convention – правило знаков
29 sagging bending moment – изгибающий момент при оседании, изгибающий момент при провесе, изгибающий момент при прогибе
30 simply supported beam – свободно опёртая балка
31 “T” beam – балка таврового сечения
32 to embed – заделывать; закладывать; вмонтировать; вставлять
33 to confine – ограничивать
34 wholly – полностью, целиком

WARM UP

1. Complete and comment the following statement:

“When a bar carries lateral forces, two important types of loading action are set up at any section: these are … “

WORD FORMATION

2. Certain suffixes indicate that the word is a noun, an adjective, a verb or an adverb. Sort the suffixes below into the correct boxes according to the parts of speech they indicate:

-al
-ly
-ment
-er
-ous
-ise (-ize)
-ish
-tion
-ive
-ism
-ist
-ship
-ness
-ate

Noun indicators	Adjective indicators	Verb indicators	Adverb indicators
- er	-al	-ise (-ize)	-ly

3. Think of three of words ending in each of the suffixes listed in activity 2.

Nouns	Adjectives	Verbs	Adverbs
action	compressive	dramatize	slowly

READING

4. Read the text for the gist. In pairs discuss the main idea of the text. Share your ideas with other students.

Introduction

When a bar carries lateral forces, two important types of loading action are set up at any section: these are a bending moment and a shearing force. Consider first the simple case of a beam which is fixed rigidly at one end *B* and is quite free at its remote end *D*, Figure 5.1 ; such a beam is called a *cantilever,* a familiar example of which is a fishing rod held at one end.

Imagine that the cantilever is horizontal, with one end *B* embedded in a wall, and that a lateral force *W* is applied at the remote end *D*. Suppose the cantilever is divided into two lengths by an imaginary section *C;* the lengths *BC* and *CD* must individually be in a state of statical equilibrium. If we neglect the mass of the cantilever itself, the loading actions over the section *C* of *CD* balance the actions of the force *W* at *C*. The length *CD* of the cantilever is in equilibrium if we apply an upwards vertical force *F* and an anti-clockwise couple *A4* at *C; F* is equal in magnitude to *W*, and M is equal to *W(L - z),* where *z* is measured from *B*. The force *F* at *C* is called a *shearing force,* and the couple *M* is a *bending moment.*

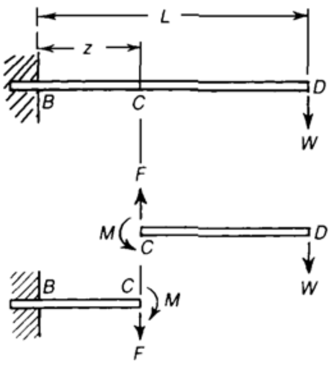


Figure 5.1. Bending moment and shearing force in a simple cantilever beam.

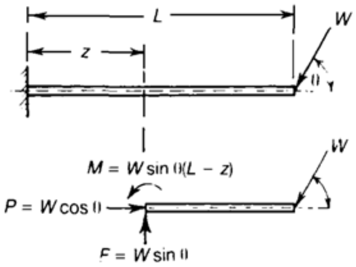


Figure 5.2. Cantilever with and inclined end load.

But at the imaginary section *C* of the cantilever, the actions *F* and *M* on *CD* are provided by the length *BC* of the cantilever. In fact, equal

and opposite actions *F* and *M* are applied by *CD* to *BC*. For the length *BC*, the actions at *C* are a downwards shearing force *F*, and a clockwise couple *M.*
When the cantilever carries external loads which are not applied normally to the axis of the beam, Figure 5.2, axial forces are set up in the beam. If *W* is inclined at an angle θ to the axis of the beam, Figure 5.2, the axial thrust in the beam at any section is

$$P = W \cos \theta$$

The bending moment and shearing force at a section a distance *z* from the built-in end are

$$M = W(L - z) \sin \theta \qquad F = W \sin \theta$$

5. Match the halves of the sentences, then read the text below and check.

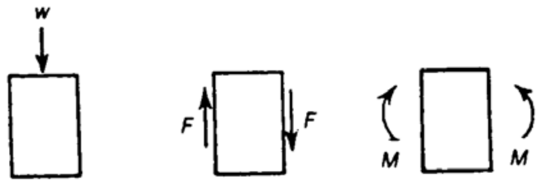
1 A concentrated load on a beam is …
2 Concentrated loads arise …
3 In practice there are many examples of distributed loads: …
a) on a beam where the beam is connected to other transverse beams.
b) they arise when a wall is built on a girder; they occur also in many problems of fluid pressure.
c) one which can be regarded as acting wholly at one point of the beam.

Concentrated and Distributed Loads

A concentrated load on a beam is one which can be regarded as acting wholly at one point of the beam. For the purposes of calculation such a load is localised at a point of the beam; in reality this would imply an infinitely large bearing pressure on the beam at the point of application of a concentrated load. All loads must be distributed in practice over perhaps only a small length of beam, thereby giving a finite bearing pressure. Concentrated loads arise frequently on a beam where the beam is connected to other transverse beams.
In practice there are many examples of distributed loads: they arise when a wall is built on a girder; they occur also in many problems of fluid pressure, such as wind pressure on a tall building, and aerodynamic forces on an aircraft wing.

6. Look at the illustration below and the words and phrases taken from the passage. With a partner try to predict what is being discussed:

downwards vertical loads   clockwise shearing forces



sagging bending moments   diagrams   loads

Sign Conventions for Bending Moments and Shearing Forces

The bending moments on the elemental length δz of Figure 5.3 tend to make the beam concave on its upper surface and convex on its lower surface; such bending moments are sometimes called *sagging bending moments*. The shearing forces on the elemental length tend to rotate the element in a clockwise sense. In deriving the equations in this section it is assumed implicitly, therefore, that

(a) downwards vertical loads are positive;

(b) sagging bending moments are positive; and

(c) clockwise shearing forces are positive.

These sign conventions are shown in Figure 5.3. Any other system of sign conventions can be used, provided the signs of the loads, bending moments and shearing forces are considered when equations above are applied to any particular problem.

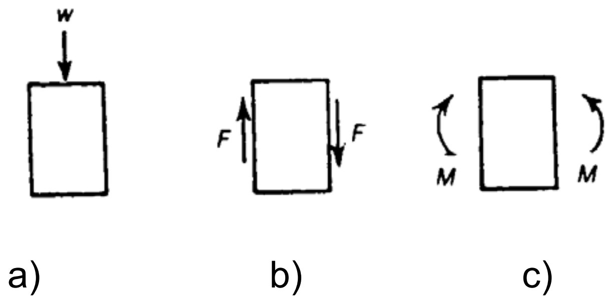


Figure 5.3. Positive values of *w*, F and *M*, (a) downward vertical loading, (b) clockwise shearing forces, (c) sagging bending-moment.

Figures that show graphically the variations of bending moment and shearing force along the length of a beam are called *bending moment diagrams* and *shearing force diagrams.* Sagging bending moments are considered positive and clockwise shearing forces taken as positive. The two quantities are plotted above the centre line of the beam when positive, and below when negative. Before we can calculate the stresses and deformations of beams, we must be able to find the bending moment and shearing force at any section.

7. Skim through the text and underline the sentences or the words that best sum up the main idea of the text (key words). In pairs discuss the main idea of the text. Share your ideas with other students.

Cantilevers

A cantilever is a beam supported at one end only; for example, the beam shown in Figure 5.1 is held rigidly at *B*. Consider first the cantilever shown in Figure 5.4(a), which carries a concentrated lateral load *W* at the free end. The bending moment at a section a distance *z* from *B* is

$$M = -W(L-z)$$

the negative sign occurring since the moment is hogging, as shown in Figure 5.4 (b). The variation of bending moment is linear, as shown in Figure 5.4 (c). The shearing force at any section is

$$F = +W$$

the shearing force being positive as it is clockwise, as shown in Figure 5.4 (d). The shearing force is constant throughout the length of the cantilever. We note that

$$\frac{dM}{dz} = W = F$$

Further *dF/dz* = 0, as there are no lateral loads between *B* and *D.* shown in Figure 5.4 (e). The bending moment diagram is shown in Figure 5.4 (c) and the shearing force diagram is

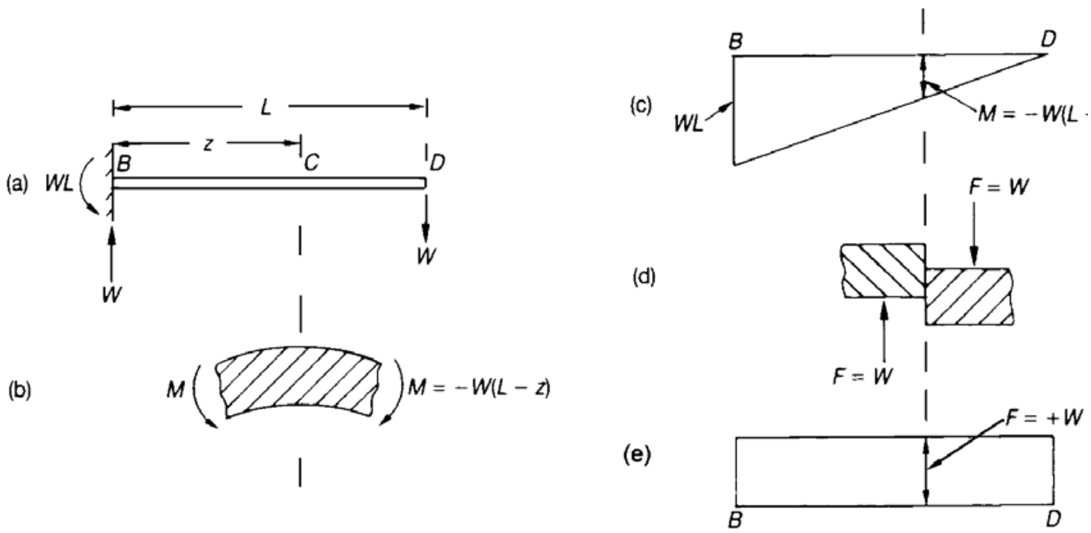


Figure 5.4 Bending-moment and shearing-force diagrams for a cantilever with a concentrated load at the free end.

Now consider a cantilever carrying a uniformly distributed downwards vertical load of intensity *w,* Figure 5.5 (a). The shearing force at a distance *z* from *B* is

$$F = +w(L - z)$$

as shown in Figure 7.6 (d). The bending moment at a distance ***z*** from *B* is

$$M = -\frac{1}{2} w(L - z)^2$$

as shown in Figure 5.5 (b). The shearing force varies linearly and the bending moment parabolically along the length of the beam, as shown in Figure 5.5 (e) and 5.5 (c), respectively. We see that

$$\frac{dM}{dz} = w(L - z) = +F$$

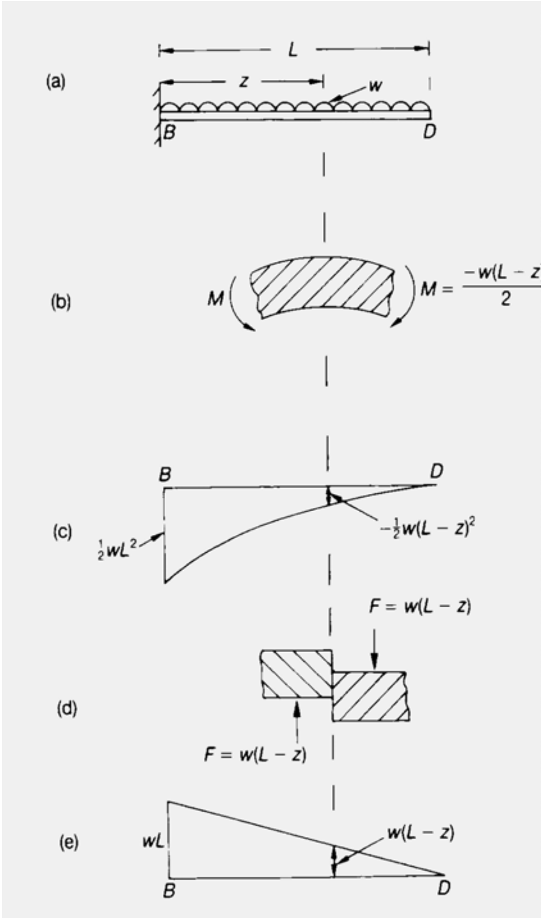


Figure 5.5. Bending-moment and shearing-force diagrams for a cantilever under uniformly distributed load.

8. Before reading the following text, work with a partner and ask and answer the questions below. Base your answers on your possible knowledge of the topic.

1 What is a simply-supported beam?

2 Can you give an example of a simply-supported beam?

Simply-Supported Beams

By simply-supported we mean that the supports are of such a nature that they do not apply any resistance to bending of a beam; for instance, knife-edges or functionless pins perpendicular to the plane of bending cannot transmit couples to a beam. The remarks concerning bending moments and shearing forces, which were made earlier in relation to cantilevers, apply equally to beams simply-supported at each end, or with any conditions of end support.

As an example, consider the beam shown in Figure 5.6 (a), which is simply-supported at *B* and *C,* and carries a vertical load *W* a distance *a* from *B*. If the ends are simply-supported no bending moments are applied to the
beam at *B* and *C*. By taking moments about *B* and *C* we find that the reactions at these supports are

$$\frac{W}{L}(L-a) \text{ and } \frac{Wa}{L}$$

respectively. Now consider a section of the beam a distance *z* from *B;* if $z < a$, the bending moment and shearing force are

$$M = +\frac{Wz}{L}(L-a), \quad F = +\frac{W}{L}(L-a),$$

as shown by Figures 5.6 (b) and 5.6 (d)

If $z > a$,

$$M = +\frac{Wz}{L}(L-a) - W(z-a) = +\frac{Wa}{L}(L-z)$$

$$F = -\frac{Wa}{L}$$

The bending moment and shearing force diagrams show discontinuities at $z = a$; the maximum bending moment occurs under the load *W,* and has the value

$$M_{max} = \frac{Wa}{L}(L-a)$$

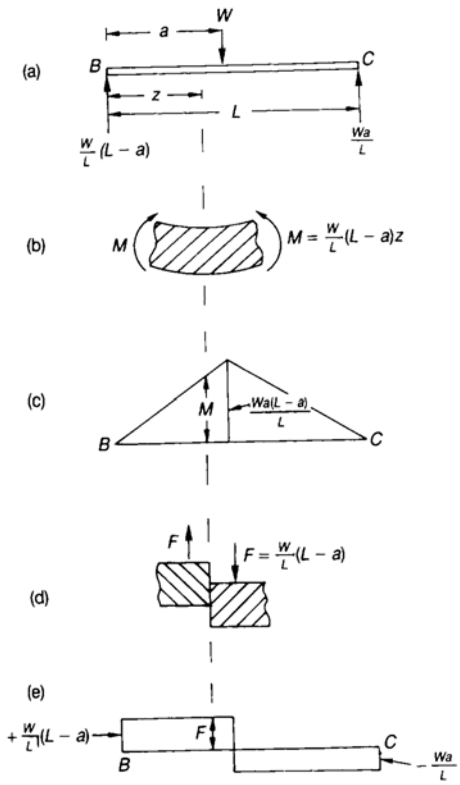


Figure 5.6. Bending-moment and shearing-force diagrams for a simply-supported beam with a single concentrated lateral load.

9. Read the text below, for questions 1-5 decide which answer, A or B best fits each space.

Plane curved beams

Consider a **1**_____ *BCD,* Figure 5.7, which is curved in the plane of the figure. The beam is loaded so that no **2**_____ occurs, and **3**_____ is confined to the plane of Figure 5.7. Suppose an imaginary cross-section of the beam is taken at *C;* statical equilibrium of the length *CD* of the beam is ensured if, in general, a force and a couple act at *C;* it is convenient to consider the resultant force at *C* as consisting of two components - an **4**_____ force *P,* acting along the centre line of the beam, and a **5**_____ force *F,* acting along the normal to the centre line of the beam. The couple *M* at *C* acts about an axis perpendicular to the plane of bending and passing through the centre line of the beam. The actions at *C* on the length *BC* of the beam are equal and opposite to those at *C* on the length *CD.*
As before the couple *M* is the ***6***_____ *moment* in the beam at *C,* and the lateral force *F* is the *shearing force.*

As an example, consider the beam of Figure 5.8, which has a centre line of constant radius *R.* The beam carries a radial load W at its free end. Consider a section of the beam at some angular position θ: for statical equilibrium of the length of the bar shown in Figure 5.8 (b),

$$M = WR\sin\theta$$

$$F = W\cos\theta$$

$$P = W\sin\theta$$

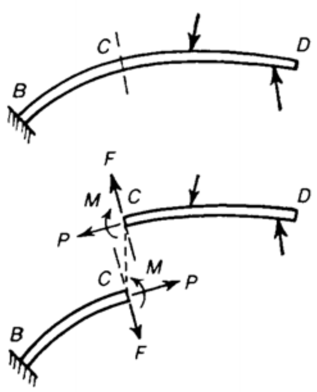


Figure 5.7. Bending and shearing actions in a plane curved beam.

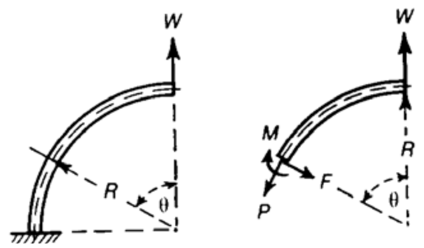


Figure 5.8 Plane curved beam of circular form carrying an end load.

Consider again, the beam shown in Figure 5.9, consisting of two straight limbs, *BC* and *CD,* connected at *C.* In *CD* the bending moment varies linearly, from zero at *D* to 70 000 *Nm* at *C.*

In *BC* the bending moment is constant and equal to 70 000 Nm. In Figure 5.10 the bending moments are plotted on the concave sides of the bent limbs; this is equivalent to following the sign convention, that sagging bending moments are positive.

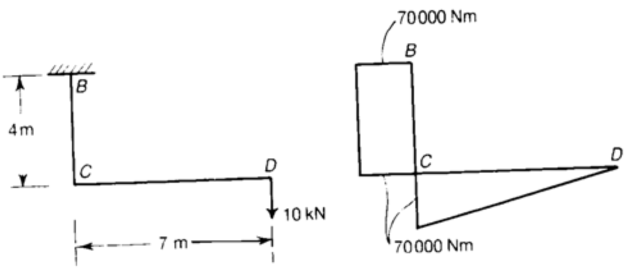


Figure 5.9 Bending moments in a bracket.

In Figure 5.10, *OBC* represents the centre line of a beam of any **7_____** ; the line *OBC* is curved in space in general. Suppose the beam carries any system of external loads; consider the actions over a section of the beam at *B.* For statical equilibrium of *BC* we require at *B* a force and a couple.

The force is resolved into two components-an axial force *P* along the centre line of the beam, and a shearing force *F* normal to the centre line; the couple is resolved into two components - a torque *T* about the centre line of the beam, and **a** bending moment *M* about an axis perpendicular to the centre line. The axis of *M* is not necessarily coincident with the axis of *F.*

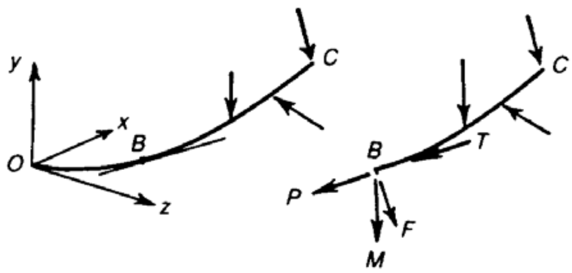


Figure 5.10. Lateral loading of a curved beam.

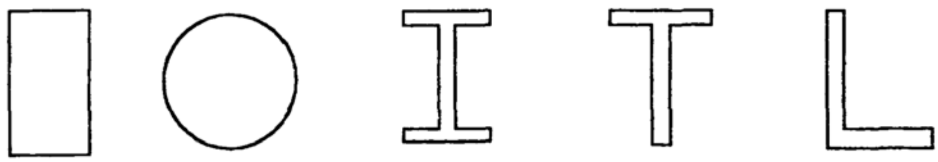
1	a) beam	b) bar
2	a) tension	b) twisting
3	a) bending	b) twisting
4	a) axial	b) lateral
5	a) axial	b) lateral
6	a) twisting	b) bending
7	a) dimensions	b) shape

10. Before reading the following text, work with a partner and ask and answer the questions below. Base your answers on your possible knowledge of the topic.

1 What typical cross-sections of structural components do you know?
2 Where is a rolled steel joist used?
3 What cross-section do wooden beams have?
4 What is the position of the centroid of a cross-section?

Geometrical Properties of Cross-Sections

For example, a beam with a large cross-section will, in general, be able to resist a bending moment more readily than a beam with a smaller cross-section. Typical cross-sections of structural members are shown in Figure 5.11.



(a) Rectangle (b) Circle (c) 'I' beam (d) 'Tee' beam (e) Angie bar

Figure 5.11. Some typical cross-sections of structural components

The cross-section of Figure 5.11 (c) is also called a *rolled steel joist* (RSJ); it is used extensively in structural engineering. It is quite common to make cross-sections of metal structural members in the form of the cross-sections of Figure 5.11 (c) to (e), as such cross-sections are structurally more efficient in bending than cross-sections such as Figures 5.11 (a) and (b). Wooden beams are usually of rectangular cross-section and not of the forms shown in Figures 5.11 (c) to (e). This is because wooden beams have grain and will have lines of weakness along their grain if constructed as in Figures 5.11 (c) to (e).

The position of the centroid of a cross-section is the centre of the moment of area of the cross-section. If the cross-section is constructed from a homogeneous material, its centroid will lie at the same position as its centre of gravity.

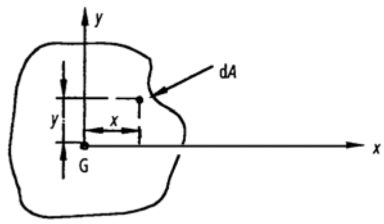


Figure 5.12. Cross-section.

Let G denote the position of the centroid of the plane lamina of Figure 5.12.At the centroid the moment of area is zero, so that the following equations apply

$$\Sigma\, x \;\; dA \;=\; \Sigma\, y \;\; dA \;=\; 0$$

where dA = elemental area of the lamina

x = horizontal distance of dA from G

y = vertical distance of dA from G

VOCABULARY

11. Read the following definitions and decide what they mean. Use a dictionary.

Example 'a half of a sphere is a hemisphere'

- long thick piece of wood or metal or concrete, etc., used in construction
- beam used to support floors or roofs
- a thin plate or layer
- projecting horizontal beam fixed at one end only
- the force applied to a unit area of surface; measured in Pascal's (SI unit)
- a beam made usually of steel; a main support in a structure
- a stable situation in which forces cancel one another

12. Make a list of expressions with the following words and use them in sentences of your own.

Example

cylinder – circular cylinder
Consider the circular cylinder subjected to an internal pressure.

beam	load	pressure	section	plane
curve	bar	equilibrium	joist	girder

13. Match the numbers (1-10) with the letters (a-j). Make up the sentences of your own using these phrases.

1 imaginary	**a)** thrust
2 plane	**b)** load
3 angle	**c)** end
4 concentrated	**d)** lamina
5 rotational	**e)** convention
6 axial	**f)** pressure
7 sign	**g)** section
8 built-in	**h)** equilibrium
9 bearing	**i)** load
10distributed	**j)** bar

14. Write the synonyms of the following words. Use a dictionary.

- center of mass
- uniform
- attribute
- balance
- fanciful
- to bound

15. Unscramble the following sentences. Then listen and check.

1 are carries when lateral two shearing important section: types loading action set any a bending of moment up at a bar forces, and a force.
2 be a beam is one concentrated which can as acting wholly at one point of the beam load on a regarded.
3 to other concentrated transverse frequently loads on a beam arise where the is beam connected beams.

4 of cross-section the centre the position of the centroid of a cross-section is the of area moment of the.

GRAMMAR

16. Translate the sentences into Russian paying attention to the Passive Voice.

1 When a bar carries lateral forces, two important types of loading action are set up at any section: these are a bending moment and a shearing force.
2 Suppose the cantilever is divided into two lengths by an imaginary section C.
3 The two quantities are plotted above the centre line of the beam when positive, and below when negative.
4 The force is resolved into two components.
5 If the cross-section is constructed from a homogeneous material, its centroid will lie at the same position as its centre of gravity.
6 The damaged parts were immediately examined and repaired by a specialist.
7 The examined articles were given to all according to their speciality.
8 Different elements are produces artificially.

17. Translate the sentences into Russian paying attention to the Participle.

1 All loads must be distributed in practice over perhaps only a small length of beam, thereby giving a finite bearing pressure.
2 Now consider a cantilever carrying a uniformly distributed downwards vertical load.
3 The remarks concerning bending moments and shearing forces, which were made earlier in relation to cantilevers, apply equally to beams simply-supported at each end, or with any conditions of end support.
4 Consider the beam shown in Figure, consisting of two straight limbs, BC and CD, connected at C.
5 A substance resisting all ordinary or chemical efforts to decompose it into simpler substances is an element.
6 Being a good conductor, copper is often used in industry.
7 Adding heat we can change the state of a substance.

8 If taken from the library books must be returned in time.

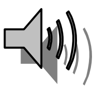

COMMUNICATION

18. Work in pairs or groups. Discuss the following problems:

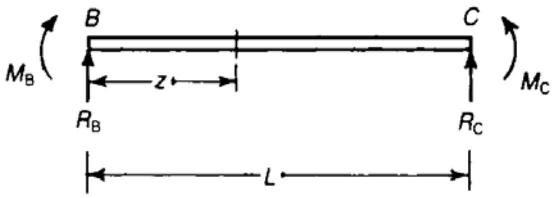
1 Two important types of loading are bending moment and shearing force
2 Concentrated and distributed loads
3 Sign conventions for bending moments and shearing forces
4 Cantilever
5 Geometrical properties of cross-sections

Use the following as phrase-openings:

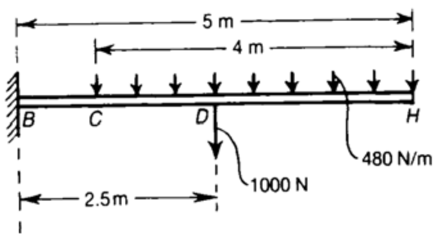
1 I would like to tell/say/speak …
2 Let me say some/a few words/ideas about …
3 I need/have to point out that …
4 The problem(s) I want to tell about concern(s) …
5 As far as I know …
6 Finally/In the end I must/shall mention


LISTENING

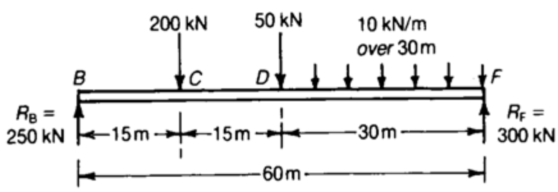
19. You are going to listen to three problem situations. Match them to the following figures.



a)



b)



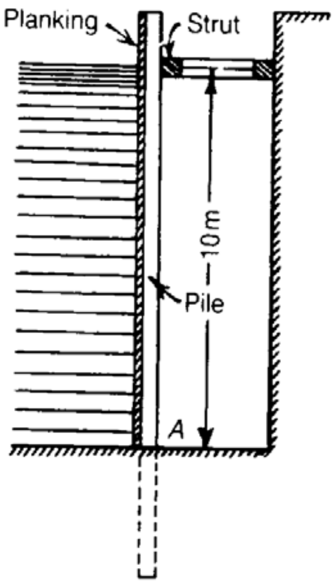
c)

Problem situation 1
Problem situation 2
Problem situation 3

WRITING

20. Write the solution of the following problem situation.

A timber dam is made of planking backed by vertical piles. The piles are built-in at the section *A* where they enter the ground and they are supported by horizontal struts whose centre lines are 10 m above *A.* The piles are spaced 1 m apart between centres and the depth of water against the dam is 10 m.
Assuming that the thrust in the strut is two-sevenths the total water pressure resisted by each pile, sketch the form of the bending moment and shearing force diagrams for a pile. Determine the magnitude of the bending moment at *A* and the position of the section which is free from bending moment.



PRESENTATION

21. Make up a presentation "Bending Moments and Shearing Forces" or "Geometric Properties of Cross-Sections" following the instructions:

Include these four parts into your presentation:
1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:
- Good afternoon.
- First, let me introduce myself: I'm …….. from
- The problem(s) I want to tell about concern(s) …

- I'll begin by describing ………, and go on to ………., and I'll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I'd like to talk about ………
- First of all ………… Next …………
- I'd like now to turn to ………..
- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I'd like to run through the main points again …
- In conclusion ………
- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I'll be glad to answer them

Use visual aids such as chart, drawings and equations.
Be ready to answer the questions of the audience after your presentation.

Unit 6
Longitudinal stresses in beams
Wordlist

1 allowable – допустимый (о нагрузке, напряжении)

2 bending moment – изгибающий момент

3 beam – балка; брус

4 breadth – ширина

5 bent – кривой; изогнутый; рамный элемент конструкции

6 cantilever – консоль; консольная балка; кронштейн

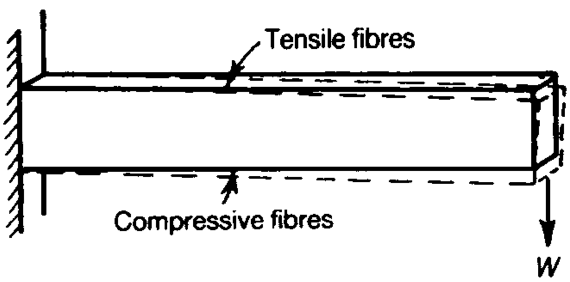
7 curvature – кривизна; искривление

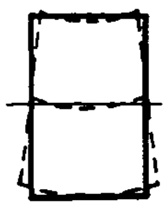
8 depth – глубина

9 direct stress – нормальное напряжение
10 deflection – отклонение; (упругая) деформация; прогиб; стрела прогиба; провес, провисание
11 elastic section modulus – упругий момент сопротивления сечения
12 flexural stiffness – жёсткость при изгибе, изгибная жёсткость
13 to induce – индуцировать, наводить
14 lateral load – боковая (поперечная) нагрузка
15 longitudinal fibre – продольное волокно
16 longitudinal stress – осевое [продольное] напряжение
17 longitudinal strain – продольная деформация
18 modulus of resistance – модуль сопротивления, коэффициент прочности
19 neutral axis – нейтральная линия (при изгибе)
20 pure bending – чистый изгиб
21 tensile stress – растягивающее напряжение
22 to deduce – выводить
23 to sustain – выдерживать; выносить; поддерживать;
24 unstrained surface – недеформированная поверхность

READING

1. Describe the figures using the phrases below.





- cantilever
- to carry a concentrated load
- section of the beam
- to stretch longitudinally
- the Poisson ratio

2. Read the following text to check up.

Introduction

We have seen that when a straight beam carries lateral loads the actions over any cross-section of the beam comprise a bending moment and shearing force; we have also seen how to estimate the magnitudes of these actions. The next step in discussing the strength of beams is to consider the stresses caused by these actions.

As a simple instance consider a cantilever carrying a concentrated load *W* at its free end, Figure 6.1. At sections of the beam remote from the free end the upper longitudinal fibres of the beam are stretched, i.e. tensile stresses are induced; the lower fibres are compressed. There is thus a variation of the stress throughout the depth of any section of the beam. In any cross-section of the beam, as in Figure 6.2, the upper fibres which are stretched longitudinally contract laterally owing to the Poisson ratio effect, while the lower fibres extend laterally; thus the whole cross-section of the beam is distorted.

In addition to longitudinal direct stresses in the beam, there are also shearing stresses over any cross-section of the beam. In most engineering problems shearing *distortions* in beams are relatively unimportant; this is not true, however, of shearing *stresses.*

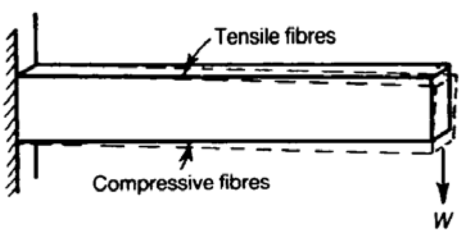


Figure 6.1 Bending strains in a loaded cantilever.

Figure 6.2 Cross-sectional distortion of loaded cantilever.

3. Read the text for the gist (overall idea). In pairs discuss the main idea of the text. Shear your ideas with other students.

Pure Bending of a Rectangular Beam

An elementary bending problem is that of a rectangular beam under end couples. Consider a straight uniform beam having a rectangular cross-section of breadth *b* and depth *h*, Figure 6.3; the axes of symmetry of the cross-section are *Cx, Cy.*

A long length of the beam is bent in they *z-plane*, Figure 6.4**,** in such a way that the longitudinal centroidal axis, *Cz,* remains unstretched and takes up a curve of uniform radius of curvature, R.

We consider an elemental length *Sz* of the beam, remote from the ends; in the unloaded condition, *AB* and *FD* are transverse sections at the ends of the elemental length, and these sections are initially parallel. In the bent form we assume that planes such as *AB* and *FD* remain flat planes; *A´ B´* and *F´ D´* in Figure 6.4 are therefore cross-sections of the bent beam, but are no longer parallel to each other.

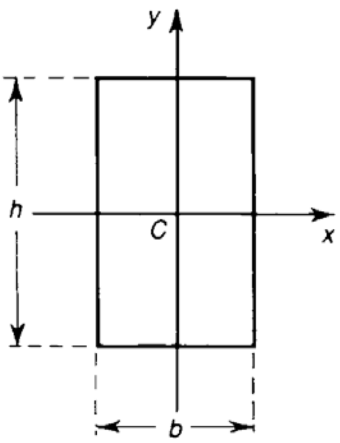


Figure 6.3. Cross-section of a rectangular beam.

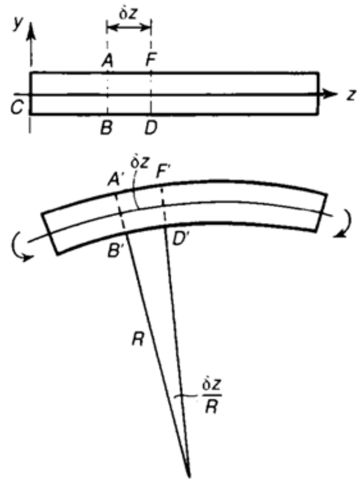


Figure 6.4. Beam bent to a uniform radius of curvature *R* in the yz-plane.

whereas others, such as *B′ D′* are compressed. The unstrained middle surface of the beam is known as the *neutral* axis. Now consider an elemental fibre *HJ* of the beam, parallel to the longitudinal axis *Cz,* Figure 6.5; this fibre is at a distance *y* from the neutral surface and on the tension side of the beam. The original length of the fibre *HJ* in the unstrained beam is *Sz*; the strained length is

$$H'J' = (R + y)\frac{\delta z}{R}$$

because the angle between *A′ B′* and *F′ D′* in Figure 6.4 and 6.5 is *(δz/R).* Then during bending *HJ* stretches an amount

$$H'J' - HJ = (R + y)\frac{\delta z}{R} - \delta z = \frac{y}{R}\delta z$$

The longitudinal strain of the fibre *HJ* is therefore

$$\varepsilon = \left(\frac{y}{R}\delta z\right) / \delta z = \frac{y}{R}$$

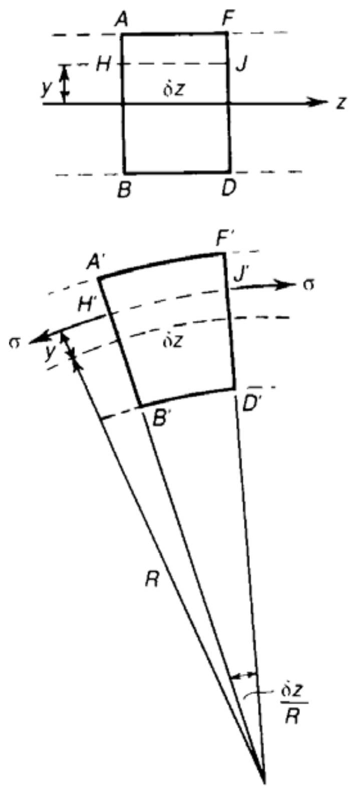


Figure 6.5. Stresses on a bent element of the beam.

Then the longitudinal strain at any fibre is proportional to the distance of that fibre from the neutral surface; over the compressed fibres, on the lower side of the beam, the strains are of course negative. If the material of the beam remains elastic during bending then the longitudinal stress on the fibre *HJ* is

$$\sigma = E\varepsilon = \frac{Ey}{R}$$

The distribution of longitudinal stresses over the cross-section takes the form shown in Figure 6.6; because of the symmetrical distribution of these stresses about *Cx*, there is no resultant longitudinal thrust on the cross-section of the beam. The resultant hogging moment is

$$M = \int_{-\frac{1}{2}h}^{+\frac{1}{2}h} \sigma b y \, dy$$

On substituting for *σ* from equation we have

$$M = \frac{E}{R}\int_{-\frac{1}{2}h}^{+\frac{1}{2}h} b y^2 \, dy = \frac{EI_x}{R}$$

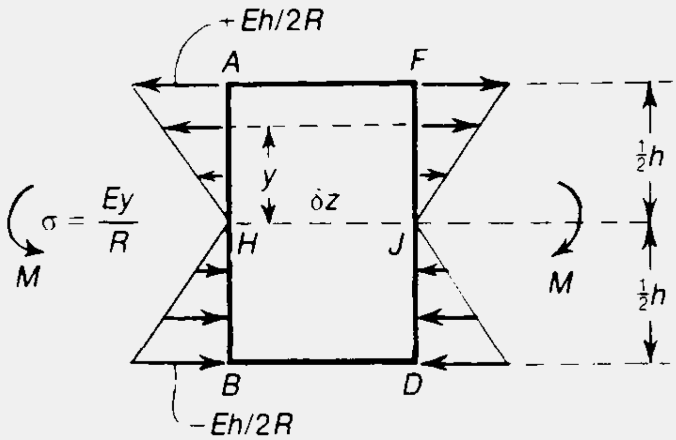


Figure 6.6. Distribution of bending stresses giving zero resultant longitudinal force and a resultant couple M.

where I_x is the second moment of area of the cross-section about *Cx.* From equations we have

$$\frac{\sigma}{y} = \frac{E}{R} = \frac{M}{I_x}$$

We deduce that a uniform radius of curvature, R, of the centroidal axis *Cz* can be sustained by end couples *M,* applied about the axes *Cx* at the ends of the beam. Equation implies a linear relationship between *M*, the applied moment, and (*I*/R), the curvature of the beam. The constant *EI*, in this linear relationship is called the *bending* stiffness or sometimes the *flexural stiffness* of the beam; this stiffness is the product of Young's modulus, *E*, and the second moment of area, *Ix*, of the cross-section about the axis of bending.

4. Read the text. Choose the most suitable heading from the list A-D for each part 1-3 of the text. There is an extra heading which you do not need to use.

A Beam having two axes of symmetry in the cross-section

B Bending of a beam about a principal axis

C Stresses on a bent element of the beam

D Beams having only one axis of symmetry

1____________________

Above we considered the bending of a straight beam of rectangular cross-section; this form of cross-section has two axes of symmetry. More generally we are concerned with sections having only one, or no, axis of symmetry.

Consider a long straight uniform beam having any cross-sectional form, Figure 6.7; the axes *Cx* and *Cy* are principal axes of the cross-section. The principal axes of a cross-section are those centroid axes for which the product second moments of area are zero. In Figure 6.7, *C* is the centroidal of the cross-section; *Cz* is the longitudinal centroidal axis.

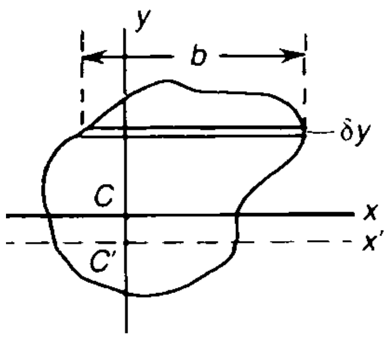


Figure 6.7. General cross-sectional form of a beam.

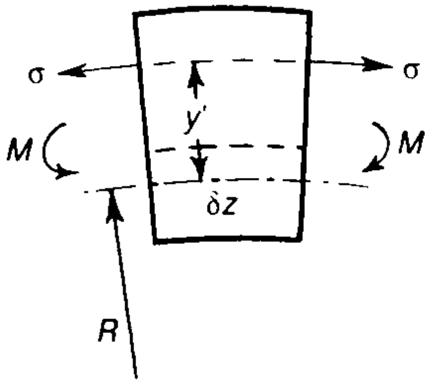


Figure 6.8. Elemental length of a beam.

When end couples M are applied to the beam, we assume as before that transverse sections of the beam remain plane during bending. Suppose further that, if the beam is bent in the *yz-plane* only, there is a neutral axis $C'x'$; Figure 6.7, which is parallel to *Cx* and is unstrained; radius of curvature of this neutral surface is R, Figure 6.8. As before, the strain in a longitudinal fibre at a distance y 'from $C'x'$ is

$$\varepsilon = \frac{y'}{R}$$

If the material of the beam remains elastic during bending the longitudinal stress on this fibre is

$$\sigma = \frac{Ey'}{R}$$

If there is to be no resultant longitudinal thrust on the beam at any transverse section we must have

$$\int_A \sigma b\,dy' = 0$$

Where *b* is the breadth of an elemental strip of the cross-section parallel to *Cx*, and the integration is performed over the whole cross-sectional area, *A*. But

$$\int_A \sigma b\,dy' = \frac{E}{R}\int_A y' b\,dy'$$

This can be zero only if *C′ **x** ′* is a centroidal axis; now, *Cx* is a principal axis, and is therefore a centroidal axis, so that *C′ x ′* and *Cx* are coincident, and the
neutral axis is *Cx* in any cross-section of the beam. The total moment about *Cx* of the internal stresses is

$$M = \int_A \sigma b y\, dy = \frac{E}{R}\int_A b y^2\, dy$$

But $\int_A by^2 dy$ is the second moment of area of the cross-section about *Cx*; if h s is denoted by I_x then

$$M = \frac{EI_x}{R}$$

The stress in any fibre a distance *y* from *Cx* is

$$\sigma = \frac{Ey}{R} = \frac{My}{I_x}$$

No moment about *Cy* is implied by this stress system, for

$$\int_A \sigma x\, dA = \frac{E}{R}\int_A xy\, dA = 0$$

because *Cx* and *Cy* are principal axes for which $\int_A xy\, dA$, or the product second moment of area, is zero; δA is an element of area of the cross-section.

2

Many cross-sectional forms used in practice have two axes of symmetry; examples are the *I*-section and circular sections, Figure 6.9, besides the rectangular beam already discussed.

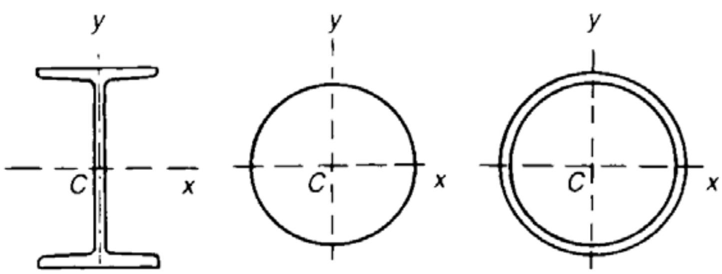


Figure 6.9. (a) I-section beam. (b) Solid circular cross-section. (c) Hollow circular cross-section.

An axis of symmetry of a cross-section is also a principal axis; then for bending about the axis *Cx* we have,

$$\sigma = \frac{Ey}{R_x} = \frac{M_x y}{I_x}$$

where *R,* is the radius of curvature in the *yz-plane*, *M,* is the moment about *Cx,* and *I*, is the second moment of area about *Cx*. Similarly for bending by a couple *My* about Cy,

$$\sigma = \frac{Ex}{R_y} = \frac{M_y x}{I_y}$$

where R_y is the radius of curvature in the *xz-plane*, and *I,* is the second moment of area about *Cy.* The longitudinal centroid axis is *Cz.* From equations we see that the greatest bending stresses occur in the extreme longitudinal fibres of the beams.

3

Other common sections in use, as shown in Figure 6.10, have only one axis of symmetry *Cx.* In each of these, *Cx* is the axis of symmetry, and *Cx* and *Cy* are both principal axes. When bending moments *M,* and *My* are applied about *Cx* and *Cy,* respectively, the bending stresses are again given by equations. However, an important feature of beams of this type is that their behaviour in bending when shearing forces are also present is not as simple as that of beams having two axes of symmetry.

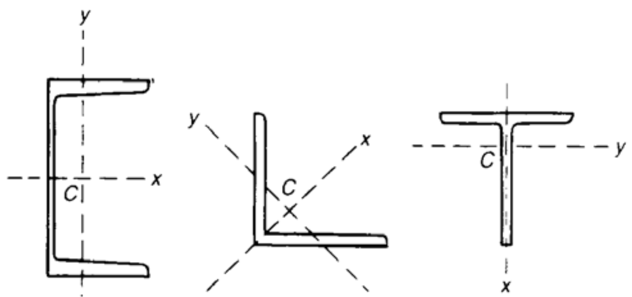


Figure 6.10. (a) Channel section. (b) Equal angle section. (c) T-section.

5. Before reading the following text, work with a partner and explain what the elastic section modulus is. Base your answers on your possible knowledge of the topic.

Elastic Section Modulus

For bending of a section about a principal axis *Cx*, the longitudinal bending stress at a fibre a distance *y* from *Cx*, due to a moment *M*, is

$$\sigma = \frac{M_{xy}}{I_x}$$

where *I*, is the second moment of area about *Cx.* The greatest bending stress occurs at the fibre most remote from *Cx.* If the distance to the extreme fibre is y_{max} the maximum bending stress is

$$\sigma_{max} = \frac{M_{xy_{max}}}{I_x}$$

The allowable moment for a given value of σ_{max} is therefore

$$M_x = \frac{I_x \sigma_{max}}{y_{max}}$$

The geometrical quantity (I_x / σ_{max}) is the *elastic section modulus,* and is denoted by $Z_{e.}$ Then

$$M_x = Z_e \ \sigma_{max}$$

The allowable bending moment is therefore the product of a geometrical quantity, Z_e and the maximum allowable stress, $\sigma_{max.}$ The quantity Z_e σ_{max}, is frequently called the *elastic moment of resistance.*

6. Look at the words and phrases taken from the text. With a partner try to predict what is being discussed. Then read the text.

- longitudinal stresses
- shearing forces

- uniform bending moment
- along the length of the beam
- a slight shearing distortion

Longitudinal Stresses While Shearing Forces are Present

The analysis of the proceeding paragraphs deals with longitudinal stresses in beams under uniform bending moment. No shearing forces are present at cross-sections of the beam in this case.
When a beam carries lateral forces, bending moments may vary along the length of the beam. Under these conditions we may assume with sufficient accuracy in most engineering problems that the longitudinal stresses at any section are dependant only on the bending moment at that section, and are unaffected by the shearing force at that section.
Where a shearing force is present at the section of a beam, an elemental length of the beam undergoes a slight shearing distortion; these shearing distortions make a negligible contribution to the total deflection of the beam in most engineering problems.

7. You are going to read the text. Four phrases have been removed from the passage. Choose from the phrases A – E the one which fits each gap (1 – 4). There is one extra phrase, which you don't need to use.

Change of Cross-Section in Pure Bending

Above we pointed out the change which takes place in the shape of the **1______** when a beam is bent. This change involves Infmitesimal lateral strains in the beam. The upper and lower edges of a cross-section which was originally rectangular are strained into concentric **2______** with their centre on the opposite side of the beam to the **3______**. The upper and lower surfaces of the beam then have *antielastic curvature,* the general nature of the strain being as shown in Figure 6.11. The anticlastic curvature effect can be readily observed by bending a flat piece of India-rubber. If the beam is bent to **4______**, we find that cross-sections are bent to a mean radius *(R/v).*

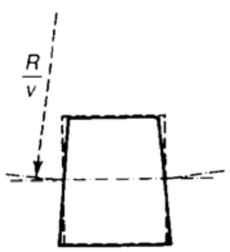


Figure 6.11. Anticlastic curvature in the cross-section of a bent rectangular beam

A axis of bending
B shearing force
C cross-section
D a mean radius R
E circular arcs

WORD FORMATION

8. Complete the chart to provide the correct form of the words shown for the given parts of speech. (Not all forms are possible)

NOUN	VERB	ADJECTIVE	ADVERB
relation	relate	relative	relatively
equation			
	conclude		
		necessary	
			satisfactorily

VOCABULARY

9. Work in pairs. Read the definitions and decide what they mean. Share your ideas with other students.

Example
'half of a sphere is a hemisphere'

- the property possessed by the curving of a line or surface
- deformation of a physical body under the action of applied forces
- the physical property of being inflexible and hard to bend
- a slender and greatly elongated solid substance
- relating to tension

10. Write the synonyms of the following words. Use a dictionary.

- far distant in space
- value
- coefficient
- dispersion
- curve
- bendable
- shape
- cross

11. Match numbers 1-10 with letters a-j to make collocations. Then listen and check. Make up the sentences of your own using these phrases.

1 lateral	**a)** stiffness
2 tensile	**b)** distortion
3 shearing	**c)** axis
4 pure	**d)** curvature
5 neutral	**e)** load
6 flexural	**f)** modulus
7 longitudinal	**g)** surface
8 elastic	**h)** stress
9 antielastic	**i)** fibre
10 unstrained	**j)** bending

12. Make a list of expressions with the following words and use them in sentences of your own.

Example
cylinder – circular cylinder
Consider the circular cylinder subjected to an internal pressure.

stress	load	beam	surface

GRAMMAR

13. Translate the sentences into Russian paying attention to the translation of "that" as a demonstrative pronoun, conjunction, word substitute or connective word:

1. An elementary bending problem is *that* of a rectangular beam under end couples.
2. Then the longitudinal strain at any fibre is proportional to the distance of *that* fibre from the neutral surface; over the compressed

fibres, on the lower side of the beam, the strains are of course negative.

3. Under these conditions we may assume with sufficient accuracy in most engineering problems *that* the longitudinal stresses at any section are dependant only on the bending moment at *that* section, and are unaffected by the shearing force at *that* section.

4. However, an important feature of beams of this type is *that* their behaviour in bending when shearing forces are also present is not as simple as *that* of beams having two axes of symmetry.

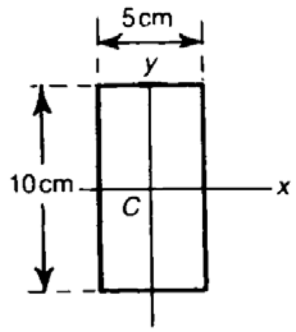
14. Fill in the gaps with the appropriate prepositions.

1 When end couples M are applied … the beam, we assume as before that transverse sections … the beam remain plane … bending.
2 Many cross-sectional forms used … practice have two axes … symmetry; examples are the *I*-section and circular sections.
3 The analysis of the proceeding paragraphs deals … longitudinal stresses in beams … uniform bending moment.
4 When a beam carries lateral forces, bending moments may vary … the length … the beam.

COMMUNICATION

15. In pairs discuss the following problem situation.

A steel bar of rectangular cross-section, 10 cm deep and 5 cm wide, is bent in the planes of the longer sides. Estimate the greatest allowable bending moment if the bending stresses are not to exceed 150 MN/m^2 in tension and compression.



The following figure and phrases may help you

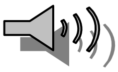
- bending moment
- second moment of inertia
- bending stress
- the greatest stress
- the greatest allowable bending moment

16. Work in pairs or groups. Discuss the following problems:

1 Bending
2 Elastic section modulus
3 Change of a cross-section in pure bending

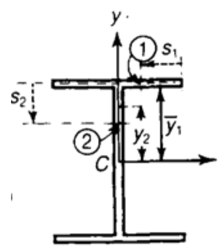
Use the following as phrase-openings:

1 I would like to tell/say/speak …
2 Let me say some/a few words/ideas about …
3 I need/have to point out that …
4 The problem(s) I want to tell about concern(s) …
5 As far as I know …
6 Finally/In the end I must/shall mention

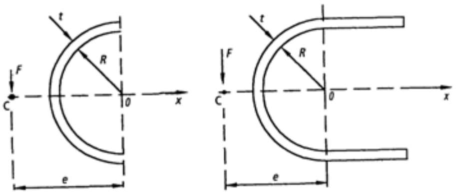


LISTENING

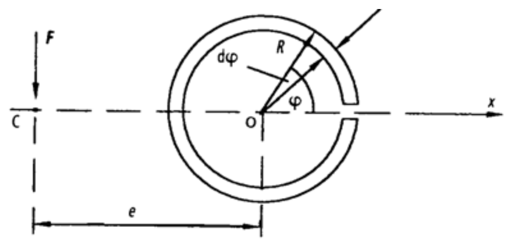
17. You are going to listen to three problem situations. Match them to the following figures. Which figure wasn't mentioned?



a)



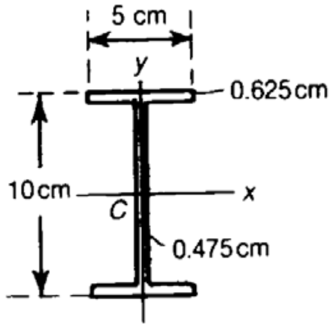
b)



c)

WRITING

18. Write the solution of the following problem situation.



A light-alloy I-beam of 10 cm overall depth has flanges of overall breadth 5 cm and thickness 0.625 cm, the thickness of the web is 0.475 cm. If the bending stresses are not to exceed 150 MN/m2 in tension and compression estimate the greatest moments which may be applied about the principal axes of the cross-section.

PRESENTATION

19. Make up a presentation "Bending" following the instructions:

Include these four parts into your presentation:

1 Introducing yourself
2 Preparing the audience
3 Delivering the message
4 Winding up

Use the following phrases:

- Good afternoon.
- First, let me introduce myself: I'm …….. from
- The problem(s) I want to tell about concern(s) …
- I'll begin by describing ………, and go on to ……….., and I'll end with………… .
- I would like to tell/say/speak …
- Feel free to interrupt if you have any questions.
- Let me say some/a few words/ideas about …
- I need/have to point out that …
- I'd like to talk about ………
- First of all ………… Next …………
- I'd like now to turn to ………..

- I want to stress ……..
- At this point we have to bear in mind ………..
- Now, to change a subject for a moment …
- To return to the point I made earlier …..
- Before I finish, I'd like to run through the main points again …
- In conclusion ………
- Finally/In the end I must/shall mention …
- That brings me to the end of my presentation.
- Thank you for your attention.
- If you have any questions, I'll be glad to answer them

Use visual aids such as chart, drawings and equations.

Be ready to answer the questions of the audience after your presentation.

APPENDIX 1

Glossary

Adherence - the extent to which a coating bonds to a substrate.
Adherence Index - measure of the adherence of porcelain enamel and ceramic coatings to sheet metal.
Axial Strain - the Strain in the direction that the load is applied, or on the same axis as the applied load.
Bend Test - method for measuring Ductility of certain materials. There are no standardized terms for reporting bend test results for broad classes of materials; rather, terms associated with bend tests apply to specific forms or types of materials. For example, materials specifications sometimes require that a specimen be bent to a specified inside diameter. Results of tests of fiberboard are reported by a description of the failure or photographs.
Bending Strength - alternate term for flexural strength. It is most commonly used to describe flexure properties of cast iron and wood products.
Bond Strength - stress (tensile load divided by area of bond) required to rupture a bond formed by an adhesive between two metal blocks.
Break Elongation - the elongation of the specimen to the break point.
Breaking Load - load which causes fracture in a tensile, compression, flexure or Torsion Test. In tensile tests of textiles and yarns, breaking load also is called breaking strength. In tensile tests of thin sheet materials or materials in form of small diameter wire it is difficult to distinguish between breaking load and the maximum load developed, so the latter is considered the breaking load.
Breaking Strength - tensile load or force required to rupture textiles (e.g., fibers, yarn) or leather. It is analogous to breaking load in a tension test. Ordinarily, breaking strength is reported as lb. or lb/in of width for sheet specimens.
Bulk Modulus of Elasticity - ratio of stress to change in volume of a material subjected to axial loading. Related to modulus of elasticity (E) and Poisson's Ratio (r) by the following equation: Bulk Modulus K=E/3(1-2r).
Coefficient of Elasticity - an alternate term for modulus of elasticity.
Cohesive Strength - theoretical stress that causes fracture in tensile test if material exhibits no plastic deformation.
Complex Modulus - measure of dynamic mechanical properties of a material, taking into account energy dissipated as heat during deformation and Recovery. It is equal to the sum of static modulus of

a material and its loss modulus. In the case of shear loading, it is called dynamic modulus.
Compressibility - extent to which a material is compressed in test for compressibility and recovery of gasket materials. It is usually reported with recovery.
Compression Fatigue - ability of rubber to sustain repeated fluctuating compressive loads.
Compression Set - the extent to which rubber is permanently deformed by a prolonged compressive load. Should not be confused with low temperature compression set.
Compressive Deformation - extent to which a material deforms under a crushing load.
Compressive Yield Strength - stress which causes a material to exhibit a specified deformation. Usually determined from the stress-strain diagram obtained in a compression test.
Creep - deformation that occurs over a period of time when a material is subjected to constant stress at constant temperature. In metals, creep usually occurs only at elevated temperatures. Creep at room temperature is more common in plastic materials and is called cold flow or deformation under load. Data obtained in a creep test usually is presented as a plot of creep vs. time with stress and temperature constant. Slope of the curve is creep rate and end point of the curve is time for rupture. As indicated in the accompanying diagram, the creep of a material can be divided into three stages. First stage, or primary creep, starts at a rapid rate and slows with time. Second stage (secondary) creep has a relatively uniform rate. Third stage (tertiary) creep has an accelerating creep rate and terminates by failure of material at time for rupture.
Creep Limit - alternate term for creep strength.
Creep Rupture Strength - stress required to cause fracture in a creep test within a specified time. Alternate term is stress rupture strength.
Creep Test - method for determining creep or stress relaxation behavior. To determine creep properties, material is subjected to prolonged constant tension or compression loading at constant temperature. Deformation is recorded at specified time intervals and a creep vs. time diagram is plotted. Slope of curve at any point is creep rate. If failure occurs, it terminates test and time for rupture is recorded. If specimen does not fracture within test period, creep recovery may be measured.

Deformation Under Load - measure of the ability of rigid plastics to withstand permanent deformation and the ability of nonrigid plastics to return to original shape after deformation. For rigid plastics, deformation (which can be flow or flow and shrinkage) is re-ported as % change in height of specimen after 24 hours under a specified load. For nonrigid plastics, results are reported as % change in height after 3 hours under load and recovery in the 1-1/2 hour period following removal of the load. Recovery is % increase in height calculated on basis of original height.

Ductility - extent to which a material can sustain plastic deformation without rupture. Elongation and reduction of area are common indices of ductility.

Dynamic Creep - creep that occurs under fluctuating load or temperature.

Elastic Limit - greatest stress that can be applied to a material without causing permanent deformation. For metals and other materials that have a significant straight line portion in their stress/strain diagram, elastic limit is approximately equal to proportional limit. For materials that do not exhibit a significant proportional limit, elastic limit is an arbitrary approximation (the apparent elastic limit).

Elasticity - ability of a material to return to its original shape when load causing deformation is removed.

Elongation - measure of the ductility of a material determined in a tensile test. It is the increase in gage length (measured after rupture) divided by original gage length. Higher elongation indicates higher ductility. Elongation cannot be used to predict behavior of materials subjected to sudden or repeated loading.

Embrittlement - reduction in ductility due to physical or chemical changes.

Endurance - alternate term for fatigue limit.

Engineering Stress - load applied to a specimen in a tension or compression test divided by the cross-sectional area of the specimen. The change in cross-sectional area that occurs with increases and decreases in applied load, is disregarded in computing engineering stress. It is also called conventional stress.

Fatigue - permanent structural change that occurs in a material subjected to fluctuating stress and strain. However, in the case of glass, fatigue is determined by long-term static testing and is analogous to stress rupture in other materials. In general, fatigue failure can occur with stress levels below the elastic limit.

Fatigue Limit - maximum fluctuating stress a material can endure for an infinite number of cycles. It is usually determined from an S-N diagram and is equal to the stress corresponding to the asymptote of the locus of points corresponding to the fatigue life of a number of fatigue test specimens. An alternate term is endurance limit.

Fatigue Ratio - ratio of fatigue strength or fatigue limit to tensile strength. For many materials, fatigue ratio may be used to estimate fatigue properties from data obtained in tension tests.

Fatigue Strength - magnitude of fluctuating stress required to cause failure in a fatigue test specimen after a specified number of cycles of loading. Usually determined directly from the S-N diagram.

Hardness - measure of a material's resistance to localized plastic deformation. Most hardness tests involve indentation, but hardness may be reported as resistance to scratching (file test), or rebound of a projectile bounced off the material (scleroscope hardness).

Hooke's Law - stress is directly proportional to strain Hooke's law assumes perfectly elastic behavior. It does not take into account plastic or dynamic loss properties.

Impact Energy - energy required to fracture a part subjected to shock loading as in an impact test. Alternate terms are impact value, impact strength, impact resistance, and energy absorption.

Impact Strength - energy required to fracture a specimen subjected to shock loading, as in an impact test. Alternate terms are impact energy, impact value, impact resistance and energy absorption. It is an indication of the toughness of the material.

Impact Test - a method for determining behavior of material subjected to shock loading in bending, tension, or torsion. The quantity usually measured is the energy absorbed in breaking the specimen in a single blow, as in the charpy impact test, Izod Impact test, and tension Impact test. Impact tests also are performed by subjecting specimens to multiple blows of increasing intensity, as in the drop ball impact test, and repeated blow impact test. Impact resilience and scleroscope hardness are determined in nondestructive impact tests.

Linear Density- mass per unit length.

Load-Deflection Diagram - plot of load versus corresponding deflection.

Maximum Fiber Stress - maximum tensile or compressive stress in a homogeneous flexure or torsion test specimen. For a specimen loaded as a simple beam at its midpoint, maximum fiber stress occurs at mid-span and may be calculated by the formula (for rectangular specimens):

$$S = \frac{3PL}{2bd^2}$$

where S is maximum fiber stress; P, load; L, span; b, width of the beam; and d, depth of the beam. For a circular cross section member loaded in torsion, maximum fiber stress may be calculated by the following formula:

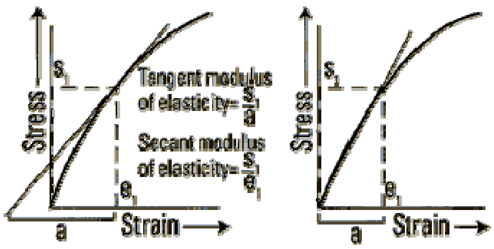
$$S = \frac{T \cdot R}{J}$$

where T is twisting moment; r, original outer radius and J, polar moment of inertia of original cross section.

Mean Stress - algebraic difference between maximum and minimum stress in one cycle of fluctuating loading, as in a fatigue test. Tensile stress is considered positive and compressive stress negative.

Modulus - alternate term for modulus of elasticity, often used in connection with rubber.

Modulus of Elasticity - rate of change of strain as a function of stress. The slope of the straight line portion of a stress-strain diagram. Tangent modulus of elasticity is the slope of the stress-strain diagram at any point. Secant modulus of elasticity is stress divided by strainat any given value of stress or strain. It also is called stress-strain ratio.



Tangent and secant modulus of elasticity are equal, up to the proportional limit of a material. Depending on the type of loading represented by the stress-strain diagram, modulus of elasticity may be reported as: compressive modulus of elasticity (or modulus of elasticity in compression); flexural modulus of elasticity (or modulus of elasticity in flexure); shear modulus of elasticity (or modulus of elasticity in shear); tensile modulus of elasticity (or modulus of elasticity in tension); or torsional modulus of elasticity (or modulus of elasticity in torsion). Modulus of elasticity may be determined by dynamic testing, where it can be derived from complex modulus. Modulus used alone generally refers to tensile modulus of elasticity. Shear modulus is almost always equal to torsional modulus and both are called modulus of rigidity. Modules of elasticity in tension and compression are approximately equal and are known as Young's

Modulus. Modulus of rigidity is related to Young's Modulus by the equation:

$$E = 2G(r + 1)$$

where E is Young's Modulus (psi), G is modulus of rigidity (psi) and r is Poisson's ratio. Modulus of elasticity also is called elastic modulus and coefficient of elasticity.

Modulus of Rigidity - rate of change of strain as a function of stress in a specimen subjected to shear or torsion loading. It is the modulus of elasticity determined in a torsion test. Alternate terms are modulus of elasticity in torsion and modulus of elasticity in shear. Apparent modulus of rigidity is a measure of the stiffness of plastics measured in a torsion test. It is "apparent" because the specimen may be deflected past its proportional limit and the value calculated may not represent the true modulus of elasticity within the elastic limit of the material.

Nominal Stress - stress calculated on the basis of the net cross section of a specimen without taking into account the effect of geometric discontinuities such as holes, grooves, fillets, etc.

Operating Stress - stress imposed on a part in service.

Plastic Deformation - deformation that remains after the load causing it is removed. It is the permanent part of the deformation beyond the elastic limit of a material. It also is called plastic strain and plastic flow.

Plastic Strain Ratio - plastic strain ratio, r, is the ratio of the true width strain to the true thickness strain.

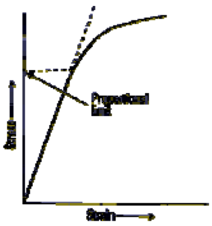
Plasticity - tendency of a material to remain deformed, after reduction of the deforming stress, to a value equal to or less than its yield strength.

Poisson's Ratio - ratio of lateral strain to axial strain in an axial loaded specimen. It is the constant that relates modulus of rigidity to Young's modulus in the equation:

$$E = 2G(r + 1)$$

where E is Young's modulus; G, modulus of rigidity; and r, Poisson's ratio. The formula is valid only within the elastic limit of a material.

Proportional Limit - highest stress at which stress is directly proportional to strain. It is the highest stress at which the curve in a stress-strain diagram is a straight line. Proportional limit is equal to elastic limit for many metals.



Residual Elongation - measure of ductility of plastics. It is the elongation of a plastic specimen measured 1 minute after rupture in a tensile test.

Relative Modulus - ratio of the modulus of a rubber at a given temperature to its modulus at 73° F. It is determined in the Gehman torsional test.

Shear Modulus of Elasticity - tangent or secant modulus of elasticity of a material subjected to shear loading. Alternate terms are modulus of rigidity and modulus of elasticity in shear. Also, shear modulus of elasticity usually is equal to torsional modulus of elasticity.

Shear Strength - maximum shear stress that can be sustained by a material before rupture. It is the ultimate strength of a material subjected to shear loading. It can be determined in a torsion test where it is equal to torsional strength. The shear strength of a plastic is the maximum load required to shear a specimen in such a manner that the resulting pieces are completely clear of each other.

Strain - change per unit length in a linear dimension of a part or specimen, usually expressed in % strain, as used with most mechanical tests, is based on original length of the specimen.

Stress - load on a specimen divided by the area through which it acts. As used with most mechanical tests, stress is based on original cross-sectional area without taking into account changes in area due to applied load. This sometimes is called conventional or engineering stress. True stress is equal to the load divided by the instantaneous cross-sectional area through which it acts.

Stress Ratio - ratio of minimum stress to maximum stress in one cycle of loading in a fatigue test. Tensile stresses are considered positive and compressive stresses negative.

Tensile Impact Test - method for determining energy required to fracture a specimen under shock tensile loading. Also known as tension impact test.

Tensile Modulus of Elasticity - tangent or secant modulus of elasticity of a material subjected to tensile loading. Alternate terms are Young's modulus and modulus of elasticity in tension. It can be measured in a tensile test or in a dynamic test where it is related to resonant frequency on a cylindrical rod by the equation:

$$E = \frac{4\pi^2 1^2 \rho f^2}{k^2 j^4}$$

where E is modulus of elasticity; 1, length of the rod; *p*, density; f, resonant frequency; k, radius of gyration of the rod about an axis normal to the rod axis and plane of motion (d/4 for cylindrical rods) and j, a constant dependent on the mode of vibration. Tensile modulus of elasticity is approximately equal to compressive modulus of elasticity within the proportional limit.

Tensile Strength - ultimate strength of a material subjected to tensile loading. It is the maximum stress developed in a material in a tensile test.

Tension Set - extent to which vulcanized rubber is permanently deformed after being stretched a specified amount for a short time. It is expressed as a % of the original length or distance between gage marks.

Torsional Deformation - angular displacement of specimen caused by a specified torque in torsion test. It is equal to the angular twist (radians) divided by the gage length.

Torsional Strength - measure of the ability of a material to withstand a twisting load. It is the ultimate strength of a material subjected to torsional loading, and is the maximum torsional stress that a material sustains before rupture. Alternate terms are modulus of rupture and shear strength.

Torsional Stress - Shear stress developed in a material subjected to a specified torque in torsion test. It is calculated by the equation:

$$S = \frac{T \cdot r}{J}$$

where T is torque, r is the distance from the axis of twist to the outermost fiber of the specimen, and J is the polar moment of inertia.

Ultimate Strength - Highest engineering stress developed in material before rupture. Normally, changes in area due to changing load and necking are disregarded in determining ultimate strength.

Yield Point - stress at which strain increases without accompanying increase in stress. Only a few materials (notably steel) have a yield point, and generally only under tension loading.

Yield Strength - indication of maximum stress that can be developed in a material without causing plastic deformation. It is the stress at which a material exhibits a specified permanent deformation and is a practical approximation of elastic limit. Offset yield strength is determined from a stress-strain diagram. It is the stress corresponding to the intersection of the stress-strain curve, and a line parallel to its straight line portion offset by a specified strain. Offset for metals is usually specified as 0.2%, i.e., the intersection of the offset line and the 0-stress axis is at 0.2% strain. Offset for plastics is usually 2%.

Young's Modulus - alternate term for modulus of elasticity in tension or compression.

APENDIX 2

Mathematical signs, symbols and abbreviations.

+	plus
—	minus
±	plus or minus
X	sign of multiplication, multiplication sign
:	sign of division, division sign
( )	round brackets; parentheses
{}	curly brackets; braces
[ ]	square brackets; brackets
~	approaches, equivalent, similar
≅	is approximately equal
a=b	a equals b; a is equal to b
a ≠ **b**	a is not equal to b; a is not b
a ≈ **b**	a approximately equals b
a ± b	a plus or minus b
a > b	a is greater than b
a » b	a is substantially greater than b
a<b	a is less than b
$a_2>a_d$	a second is greater than a d-th
$x \to \infty$	x tends to infinity
a ≥ **b**	a is greater than or equals b
p = q	p is identically equal to q
a'	a prime
a″	a double prime, a second prime
a'''	a triple prime

$\bar{a}$	a vector; the mean value of a
a_1	a) a first b) a sub one c) a suffix one
a_2	a) a second b) a sub two c) a suffix two
a_n	a) a n^{th} b) a sub n c) a suffix n
90°	ninety degrees
10//	ten seconds, also ten inches
$a + b=c$	a plus b is c a plus b equals c a plus b is equal to c a plus b makes c
$(a + b)^2$	a plus b all squared
4+7=11	four plus seven is eleven four plus seven equals eleven four plus seven is equal to eleven
12>5+5	twelve is greater than five plus five
5+5<12	five plus five is less than twelve
c— b=a	c minus b is a c minus b equals a c minus b is equal to a c minus b leaves a
(2x—y)	bracket two x minus y close the bracket

18—6=12 **1X1=1** **2X2=4** **5X5 =25**	eighteen minus six is equal to twelve eighteen minus six equals twelve eighteen minus six is twelve eighteen minus six leaves twelve once one is one twice two is four twice two makes four five times five is twenty five five multiplied by five equals twenty five five by five is equal to twenty five
a = $\frac{e}{1}$	a is equal to the ratio of e to 1
$\frac{ab^2}{b}$ **=ab**	ab square (divided) by b equals ab
$\frac{a}{\infty}$ **=0**	a) a divided by infinity is infinitely small
$\frac{x \pm \sqrt{x^2} - y^2}{y}$	X plus minus square root of x square minus y square all over y
16:4=4	sixteen divided by four is four sixteen by four equals four sixteen by four is equal to four the ratio of sixteen to four is four
20 : 5=16 : 4 $\frac{20}{5}$ **=** $\frac{16}{4}$	the ratio of twenty to five equals to the ratio of sixteen to four
1 :2	the ratio of one to two
51 : 1	the ratio of fifty one to one
2 : 3= 4:6	two to three is as four to six
1/2	a (one) half
1/3	a (one) third
1/4	a (one) quarter, a (one) fourth
2/3	two thirds

3/4	three quarters; three fourth
5/6	five sixths
25/57	twenty five fifty sevenths
2 1/2	two and a half
3 3/4	three and three quarters
1/273	one two hundred and seventy
0.5 **.5**	o [ou] point five zero point five nought point five point five one half
0.002 **.002**	o [ou] point o [ou] o [ou] two zero point zero zero two point two oes [ouz]two point two noughts two
0.0000001	o[ou]point six noughts one
1.1	one point one
2.1	two point one two
15.505	Fifteen point five nought five
2.12	Two point one two
x^2	a)x square; x squared b) the square of x c) the second power of x d) x raised to the second power e) x to the second power
$4^2=16$	a)the second power of four is sixteen b) four squared is sixteen
y^3	a) y cube, y cubed b) the cube of y c) the third power of y d) y raised to the third power e) y to the third power
$3^3=27$	the cube of three is twenty seven
a^5	a to the n-th power a raised to the fifth power
a^n	a to the n-th power a to the n-th power
y^{-10}	y to the minus tenth power
$\sqrt{16} = 4$	the square root of sixteen is four

$\sqrt{a}$	the square root of a
$\sqrt[3]{27}$ **=3**	the cube root of twenty seven is three
$\sqrt[3]{a}$	the cube root of a
$\sqrt[4]{16}$ **=2**	the fourth root of sixteen is two
$\sqrt[5]{a^2}$	the fifth root of a square
α **=** $\sqrt{R^2 + x^2}$	alpha equals the square root of capital R square plus x square
$\sqrt{\frac{7_{1_1} + A}{2xa''}}$	the square root of 7 first plus capital A ,divided by two xa double prime
$\frac{dz}{dx}$	a) dz over dx b) the first derivative of z with respect to x
$\frac{d^2y}{dx^2}$	a) the second derivative of y with respect to x b) d two y over d x square
$\int_n^m$	a) the integral from n to m b) integral between limits n and m
tan r	Tangent r
Log 2	The logarithm of two
log$_c$d	Logarithm of d to the base c
$\int \frac{dy}{\sqrt{c^2 - y^2}}$	The integral of dy divided by the square root out of c square minus y square

APPENDIX 3

Greek Alphabet

Αα	Alpha	[`life]
Ββ	Beta	[`bi:tə]
Γγ	Gamma	[`gæmə]
Δδ	Delta	[`deltə]
Εε	Epsilon	[`epsilən]
Ζζ	Zeta	[`zi:tə]
Ηη	Eta	[`i:tə]
Θθ	Theta	[`θi:tə]
Ιι	Iota	[ai`outə]
Κκ	Kappa	[`kæpə]
Λλ	Lambda	[`læmdə]
Μμ	Mu	[mju:]
Νν	Nu	[nju:]
Ξξ	Xi	[ksi:]
Οο	Omicron	[`omikrən]
Ππ	Pi	[pai]
Ρρ	Rho	[rɛu]
Σσ	Sigma	[`sigmə]
Ττ	Tau	[tau]
Υυ	Phi	[fai]
Φφ	Chi	[kai]

Χχ	Upsilon	[`Λpsilən]
Ψψ	Psi	[psai]
Ωω	Omega	[`əumigə]

<u>**APPENDIX 4**</u>

Summary Writing

GUIDELINES for summary writing

- Read the whole of the original text quickly to gain an impression of its content and its relevance to your work.
- Highlight the main points as you read.
- Make notes of your own on these points.
- Put away the original and rewrite your notes in your own words in complete sentences.
- Begin your summary with a statement of the main idea at the start.
- Using your notes, write out your subsidiary or supporting points in well-connected sentences.
- Re-read your work to check that you have included all the information that you need.

POINTS about the summary

1. about one third of the length of the (88 words, compared to 273 in the original)
2. number of sentences are reduced (from 16 to 4)
3. information is compressed into these 4 sentences by:

- cutting out less important information (examples)
- reducing a whole clause or sentence to a phrase
- using more subordinate clauses
- linking ideas by simple use of commas

STEPS in writing a summary

1. Read through the whole piece- carefully. Annotate as you read (underline, star, highlight, comment in the margins).
2. When you finish, look back for the 1-2 sentences that state the author's main point. Write it down. This is the article thesis statement. It may appear early (in the first paragraph), or at the end of the piece (as a conclusion).
3. Reread the selection, dividing it into sections of thought. Each section may be one paragraph (but, sometimes several paragraphs)

4. Write a sentence or two summarizing each section of thought. If you have trouble doing this, you might try writing a summary sentence for each paragraph and then revising where you see yourself repeating ideas.
5. Write a first draft of your summary, including the following items:

    A. In the first sentence or two- 1. the author's name
    2. the article's name
    3. the author's thesis statement

    B. Next, your summary sentences for each paragraph or section. Put them in the order that the author presents the essay because you are simply reporting back what he says.

    C. You should make every effort to put the author's ideas into your own words- to avoid plagiarism. You may occasionally quote a point directly from the author. In this case, be sure to place quotation marks and cite your page number.

    D. Occasional supporting details- only if they are significant ones.

6. Check your draft against the original piece for accuracy.
7. Revise the summary to smooth out its choppiness, link your section summary sentences together with good transitional words or phrases.
8. Proofread and spellcheck.

WORDS, EXPRESSIONS AND PATTERNS FOR SUMMARIES

1. The chief aim is … (to + V)

The central /key goal is …
The main purpose is ...

2. The present article /section is … devoted to the question of … considers.
3. The structure of the article is as follows:

- the first section describes/outlines …
- section 2 shows that …
- section 3 argues that … . Answer the following
- The final section summaries …

4. … is based on evidence

… focuses on
…involves observations of
… helps to investigate
… offers a clear (way)
… combines ____ with ____

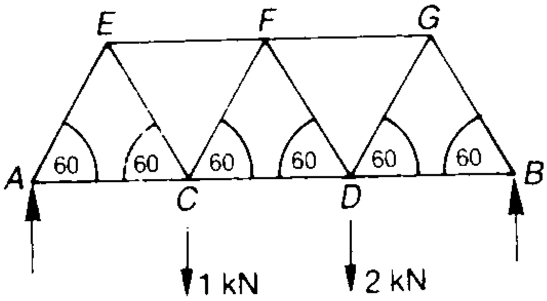
5. The following table/diagram shows that …

6. One important detail must be noted …
7. Here, we can add/mention/point out …

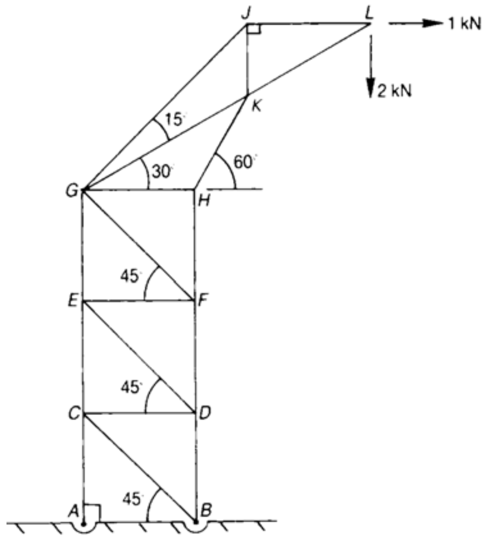
APPENDIX 5

Problems for Unit 1

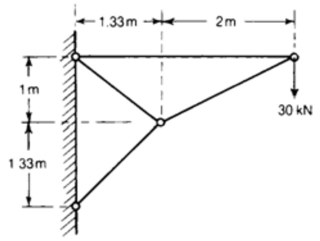
1 Determine the internal forces in the pin-jointed truss, below, which is known as a Warren girder.



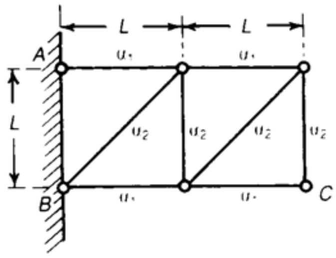
2 A plane pin-jointed truss is f m l y pinned at its base, as shown below.
Determine the forces in the members of this truss, stating whether they are in tension or compression.



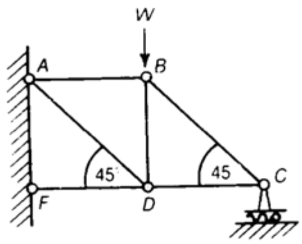
3 Determine the internal forces in the plane pin-jointed trusses shown below:



a)



b)



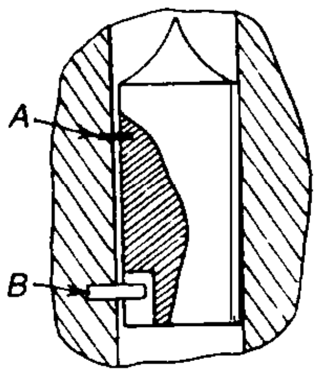
c)

Problems for Unit 2

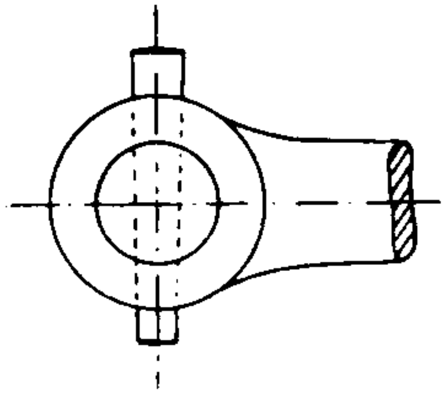
1 Rivet holes 2.5 cm diameter are punched in a steel plate 1 cm thick. The shearing strength of the plate is 300 hIN/m2. Find the average compressive stress in the punch at the time of punching.

2 The diameter of the bolt circle of a flanged coupling for a shaft 12.5 cm in diameter is 37.5 cm. There are six bolts 2.5 cm diameter. What power can be transmitted at 150 rev/min if the shearing stress in the bolts is not to exceed 60 MNIm2?

3 A pellet carrying the striking needle of a fuse has a mass of 0.1 kg; it is prevented from moving longitudinally relative to the body of the fuse by a copper pin *A* of diameter 0.05 cm. It is prevented from turning relative to the body of the fuse by a steel stud *B. A* fits loosely in the pellet so that no stress comes on *A* due to rotation. If the copper shears at150 MNIm2, find the retardation of the shell necessary to shear *A. (RNC)*



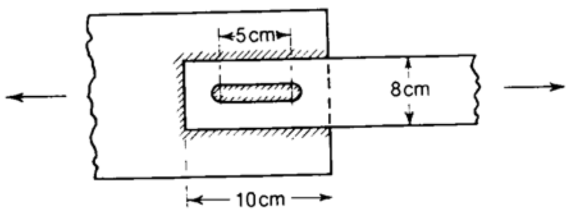
4 A lever is secured to a shaft by a taper pin through the boss of the lever. The shaft is 4 cm diameter and the mean diameter of the pin is 1 cm. What torque can be applied to the lever without causing the average shearing stress in the pin to exceed 60 MN/m2.



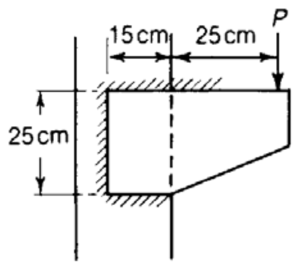
Problems for Unit 3

1 Two plates, each 1 cm thick are connected by riveting a single cover strap to the plates through two rows of rivets in each plate. The diameter of the rivets is 2 cm, and the distance between rivet centres along the breadth of the connection is 12.5 cm. Assuming the other unstated dimensions are adequate, calculate the strength of the joint per metre breadth, in tension, allowing 75 MN/m2 shearing stress in the rivets and a tensile stress of *90* MN/m2 in the plates.

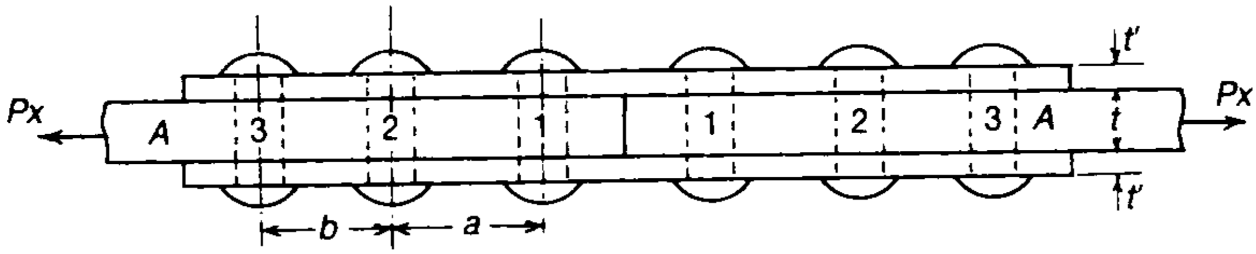
2 Two tie bars are connected together by 0.5 cm fillet welds around the end of one bar, and around the inside of a slot machined in the same bar. Estimate the strength of the connection in tension if the shearing stresses in the welds are limited to 75 MN/m^2.



3 A bracket plate is welded to the face of a column and carries a vertical load P. Determine the value of P such that the maximum shearing stress in the **1** cm weld is 75 MN/m^2.



4 Two flat bars are riveted together using cover plates, **x** being the pitch of the rivets in a direction at right angles to the plane of the figure. Assuming that the rivets themselves do not deform, show that the load taken by the rivets (1) is tPx / $(t + 2t^1)$ and that the rivets **(**2**)** are free from load.



Problems for Unit 4

1 A pipe has an internal diameter of 10 cm and is 0.5 cm thick. What is the maximum allowable internal pressure if the maximum shearing stress does not exceed *55* MN/m2? Assume a uniform distribution of stress over the cross-section.

2 A long boiler tube has to withstand an internal test pressure of 4 MN/m^2, when the mean circumferential stress must not exceed 120 MN/m^2. The internal diameter of the tube is *5* cm and the density is 7840 kg/m^3. Find the mass of the tube per metre run. *(RNEC)*

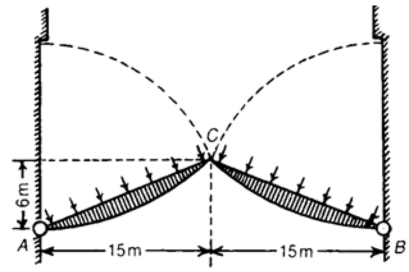
3 A long, steel tube, 7.5 cm internal diameter and 0.15 cm thick, is plugged at the ends and subjected to internal fluid pressure such that the maximum direct stress in the tube is 120 MN/m^2. Assuming v = 0.3 and *E* = 200 GN/m2, find the percentage increase in the capacity of the tube. *(RNC)*

4 A copper pipe 15 cm internal diameter and 0.3 cm thick is closely wound with a single layer of steel wire of diameter 0.18 cm, the initial tension of the wire being 10 N. If the pipe is subjected to an internal pressure of 3 MN/m^2 find the stress in the copper and in the wire (a) when the temperature is the same as when the tube was wound, (b) when the temperature throughout is raised 200°C. *E* for steel = 200 GN/m^2, *E* for copper = 100 GN/m^2, coefficient of linear expansion for steel = 11 x 1O^{-6}, for copper 18 x 1O^{-6} per 1° C.

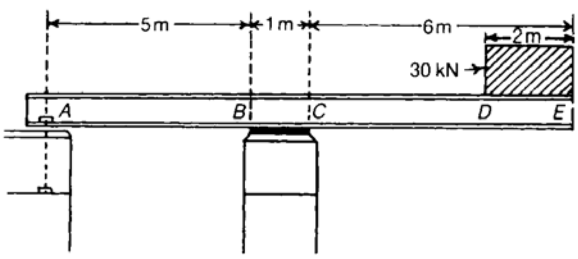
5 A spherical shell of 60 cm diameter is made of steel 0.6 cm thick. It is closed when just full of water at 15°C**,** and the temperature is raised to 35°C. For this range of temperature, water at atmospheric pressure increases 0.0059 per unit volume. Find the stress induced in the steel. The bulk modulus of water is 2 GN/m^2, *E* for steel is 200 GN/m^2, and the coefficient of linear expansion of steel is 12 x per 1° C, and Poisson's ratio = 0.3

Problems for Unit 5

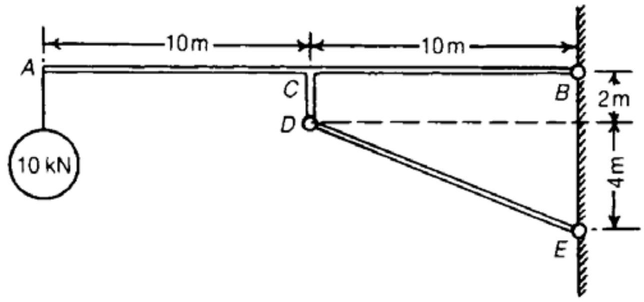
1 A pair of lock gates are strengthened by two girders *AC* and *BC.* If the load on each girder amounts to 15 kN per metre run, find the bending moment at the middle of each girder.



2 A girder *ABCDE* bears on a wall for a length *BC* and is prevented from overturning by a holding-down bolt at *A.* The packing under *BC* is *so* arranged that the pressure over the bearing is uniformly distributed and the 30 kN load may also be taken as a uniformly distributed load. Neglecting the mass of the beam, draw its bending moment and shearing force diagrams.

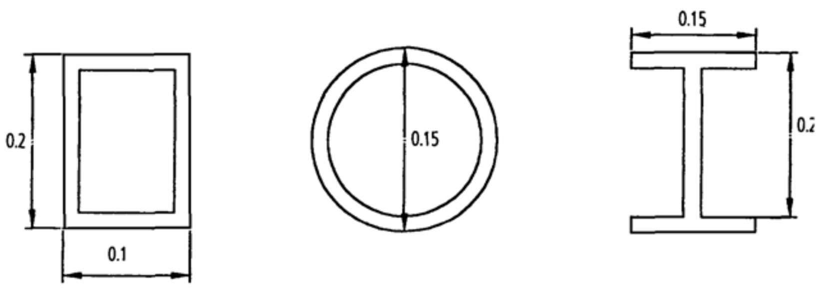


3 Draw the bending moment and shearing force diagrams for the beam shown. The beam is supported horizontally by the strut *DE,* hinged at one end to a wall, and at the other end to the projection *CD* which is firmly fixed at right angles to *AB.* The beam is freely hinged to the wall at *B.* The masses of the beam and strut can be neglected.



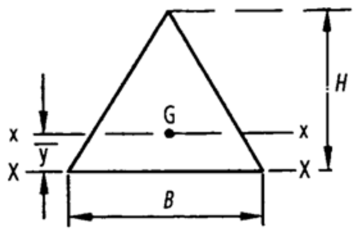
4 Determine **I**, for the thin-walled sections shown in Figures (a) to (c), where the wall thicknesses are 0.01 m.

NB Dimensions are in metres. I, = second moment of area about a horizontal axis passing through the centroid.

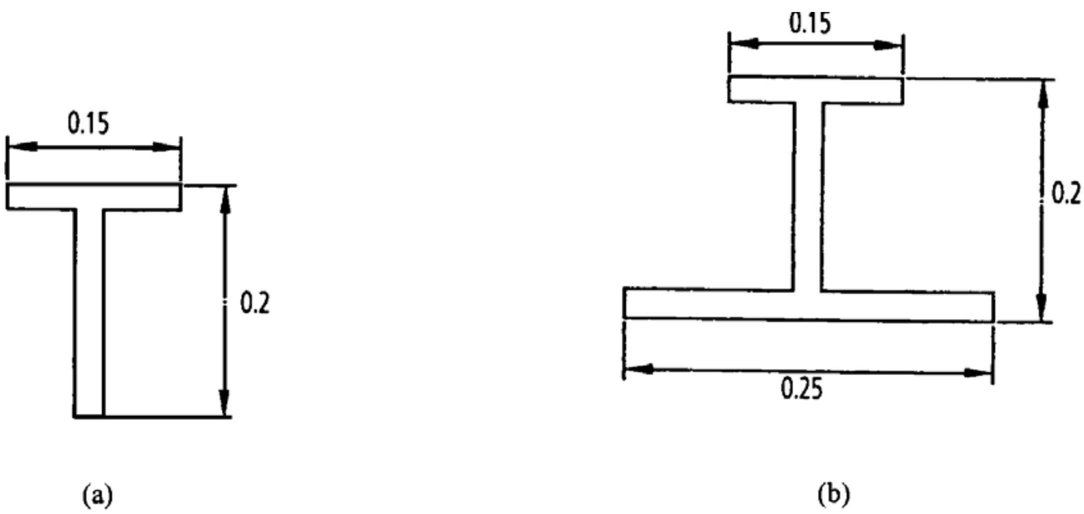


(a) (b) (c)

5 Determine the position of the centroid of the section shown in the Figure, namely *y*. Determine also *I,* for this section.

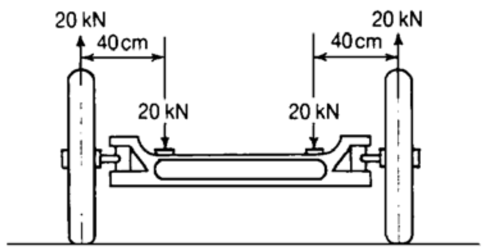


6 Determine *I,* for the thin-walled sections shown in the Figure, which have wall thicknesses of 0.01 m.

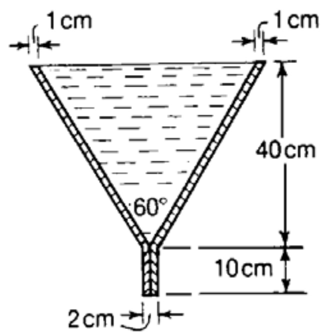


Problems for Unit 6

1 The front-axle beam of a motor vehicle carries the loads shown. The axle is of I-section: flanges 7.5 cm by 2.5 cm, web 5 cm by 2.5 cm. Calculate the tensile stress at the bottom of the axle beam.



2 A water trough 8 m long, is simply-supported at the ends. It is supported at its extremities and is filled with water. If the metal has a density 7840 kg/m^3, and the water a density 1000 kg/m^3, calculate the greatest longitudinal stress for the middle cross-section of the trough.



3 A built-up steel I-girder is 2 m deep over the flanges, each of which consists of four 1 cm plates, 1 m wide, riveted together. The web is 1 cm thick and is attached to the flanges by four 9 cm by 9 cm by 1 cm angle sections. The girder has a clear run of 30 m between the supports and carries a superimposed load of 60 kN per metre. Find the maximum longitudinal stress.

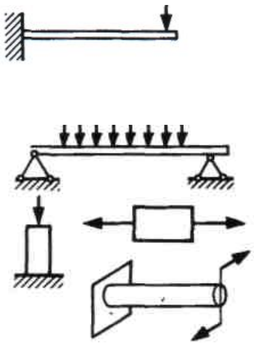
4 A beam rests on supports 3 m apart carries a load of 10 kN uniformly distributed. The beam is rectangular in section 7.5 cm deep. How wide should it be if the skin-stress must not exceed 60 MN/m^2? *(RNEC)*

5 A beam of I-section is 25 cm deep and has equal flanges 10 cm broad. The web is 0.75 cm thick and the flanges 1.25 cm thick. If the beam may be stressed in bending to 120 $MNIm^2$, what bending moment will it carry?

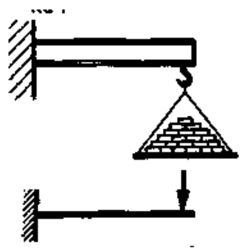
APPENDIX 6

Illustrated dictionary

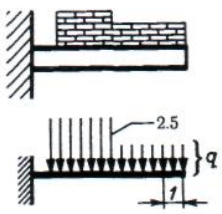
load



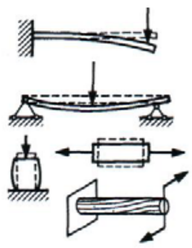
concentrated load



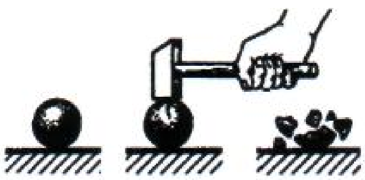
distributed load



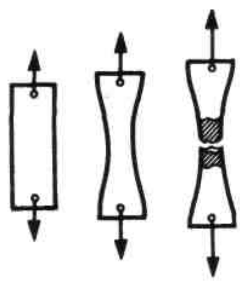
deformation



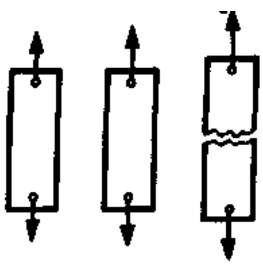
rapture, fracture



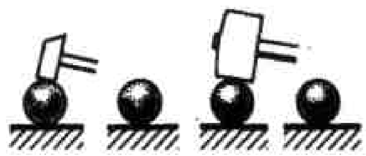
ductile rapture (fracture)



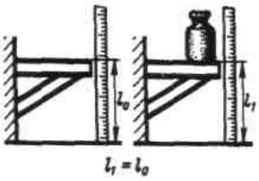
brittle fracture



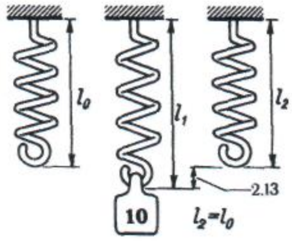
strength



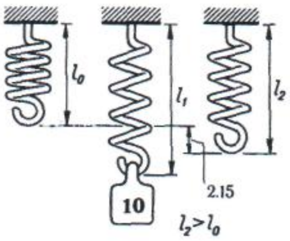
rigidity stiffness



elasticity

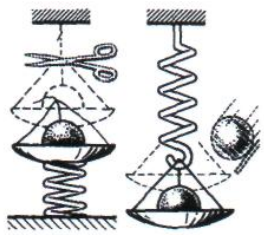


plasticity

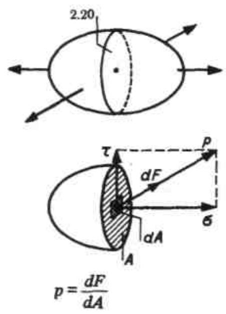


static loading

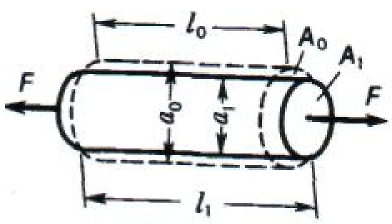
dynamic loading



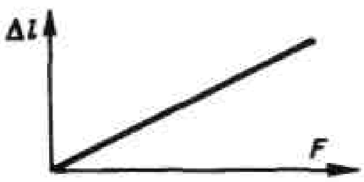
cross-section



tension

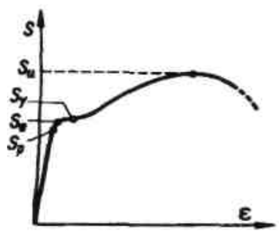


Hooke’s law

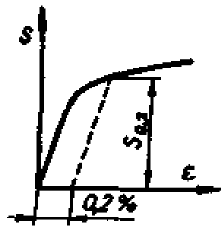


$\Delta l = k \cdot F$

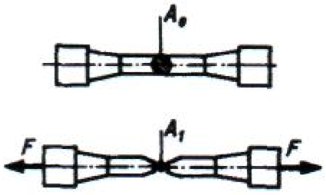
stress-strain diagram



yield strength

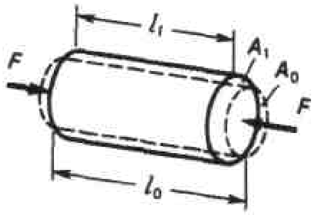


breaking strength

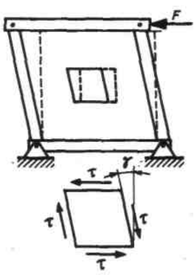


$$S = \frac{F}{A_1}$$

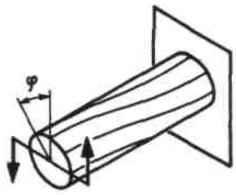
compression



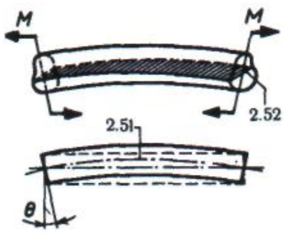
pure shear



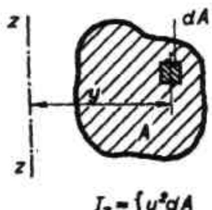
torsion



bending

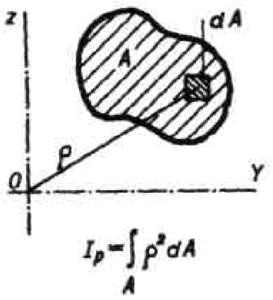


moment of inertia

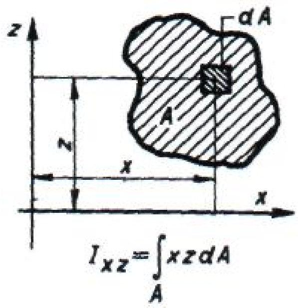


$$I_z = \int_A y^2 dA$$

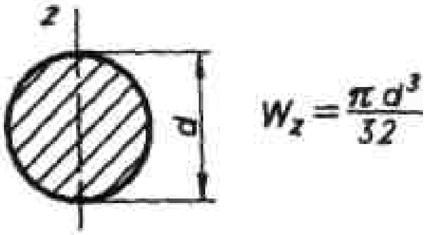
polar moment of inertia



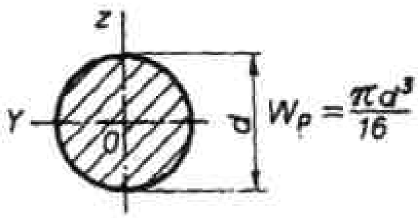
product of inertia



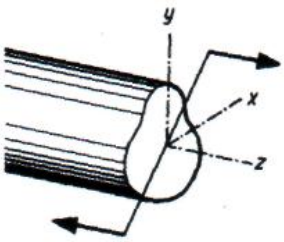
section modulus



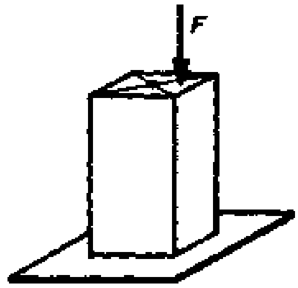
polar section modulus



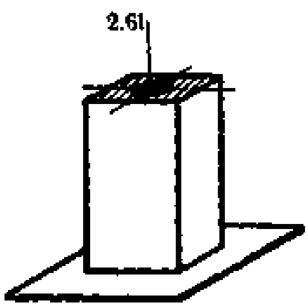
skew bending



eccentric load

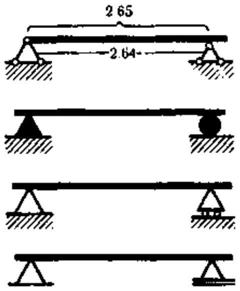


core of section

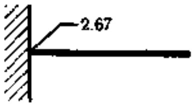


beam, girder

simply supported beam



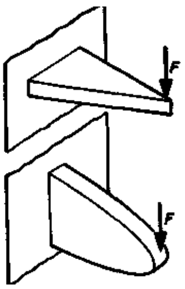
cantilever beam



continuous beam

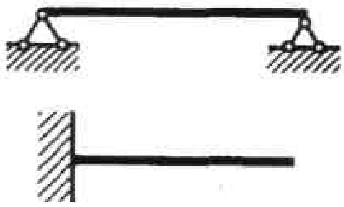
built-in beam

beam of uniform strength

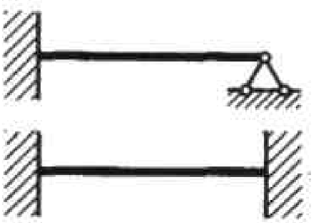


beam

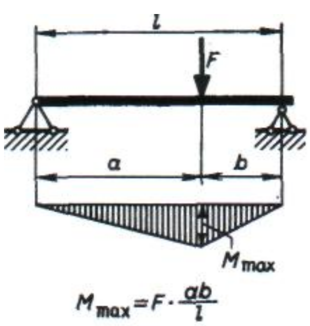
statically determinate



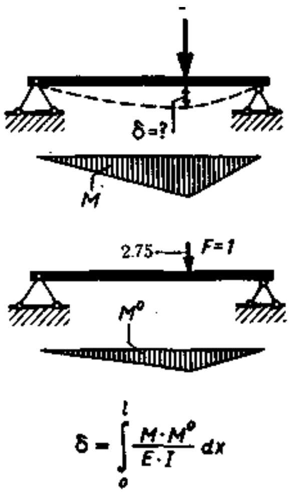
statically undeterminate beam
(curve)



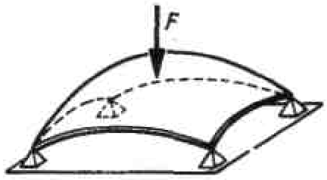
moments diagram



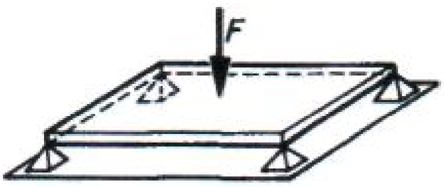
unit-load method



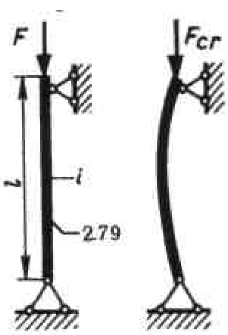
shell



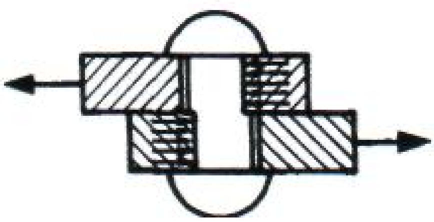
plate



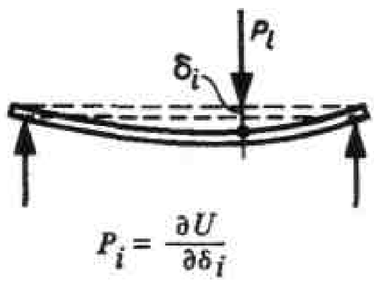
buckling



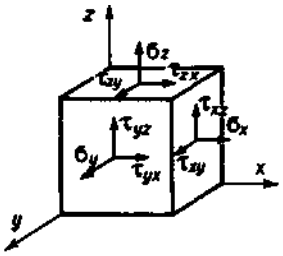
bearing strain
theorem



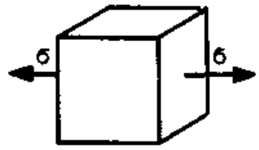
Castigliano's first



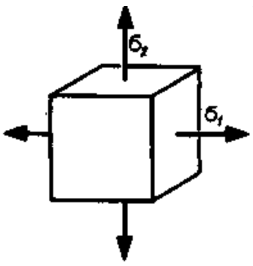
stress state



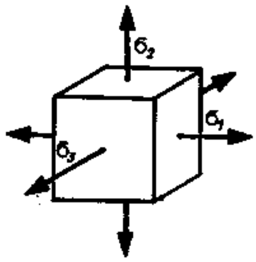
uniaxial state of stress



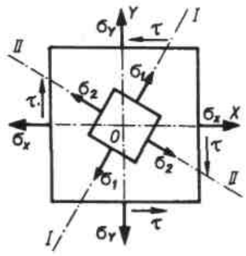
two-dimensional state of stress



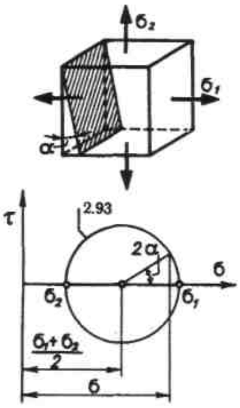
triaxial stress



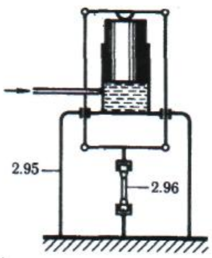
principal stress



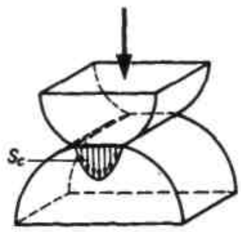
Mohr's circle



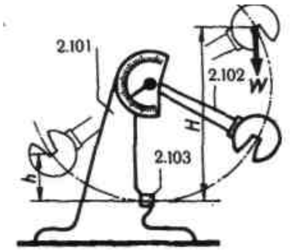
tensile test



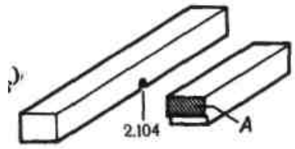
contact stress



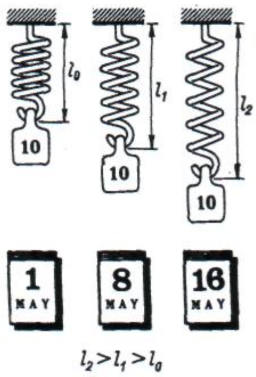
impact test



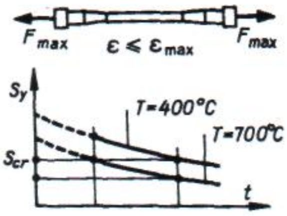
pendulum



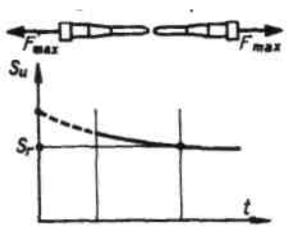
creep



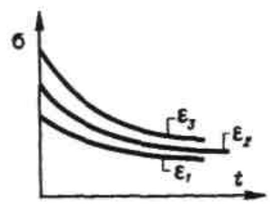
creep limit



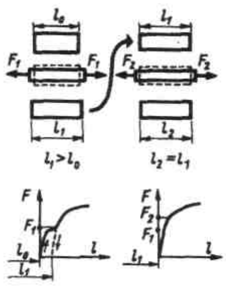
strength rapture



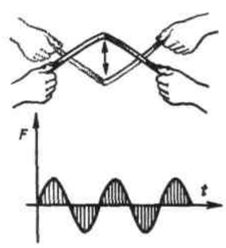
relaxation curve



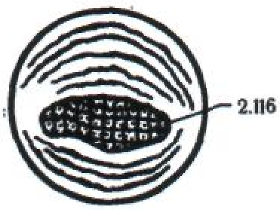
strain hardening



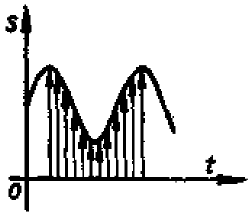
cycling loading



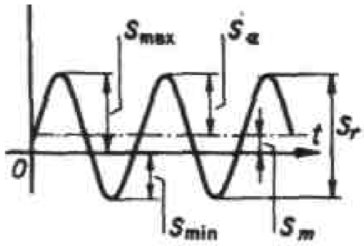
fatigue fracture



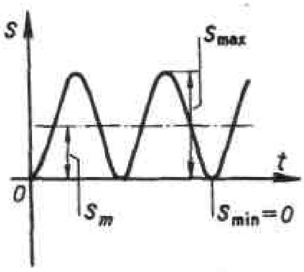
stress cycle



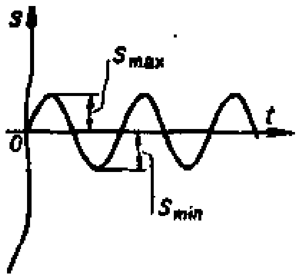
stress amplitude



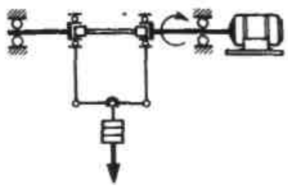
repeating stress cycle



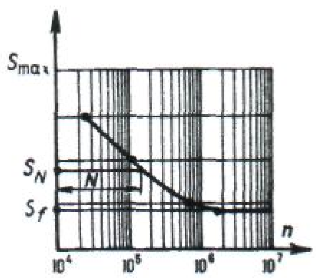
reversed stress cycle



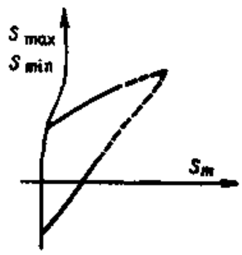
fatigue test



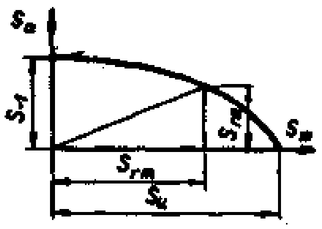
S-N curve, SN-diagram



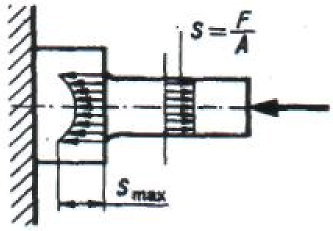
mean stress diagram



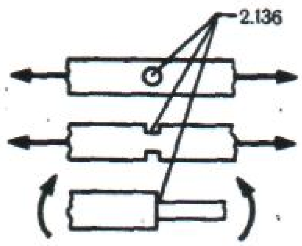
Haigh diagram



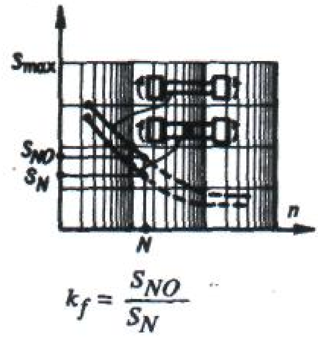
stress concentration



stress concentrator

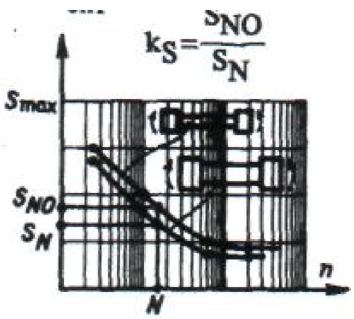


stress concentration

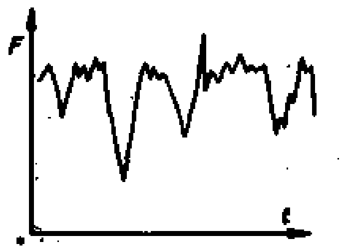


factor

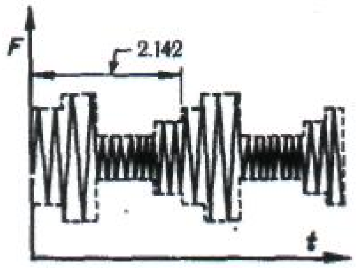
size factor



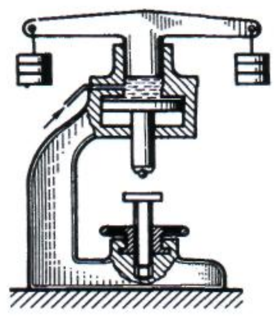
random loading



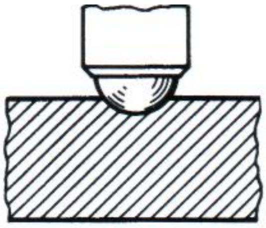
block loading



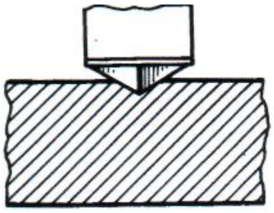
hardness tester



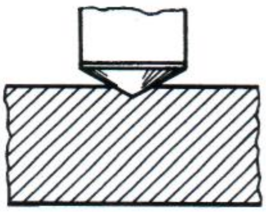
Brinell hardness



Rockwell hardness



Vickers hardness



Shore hardness