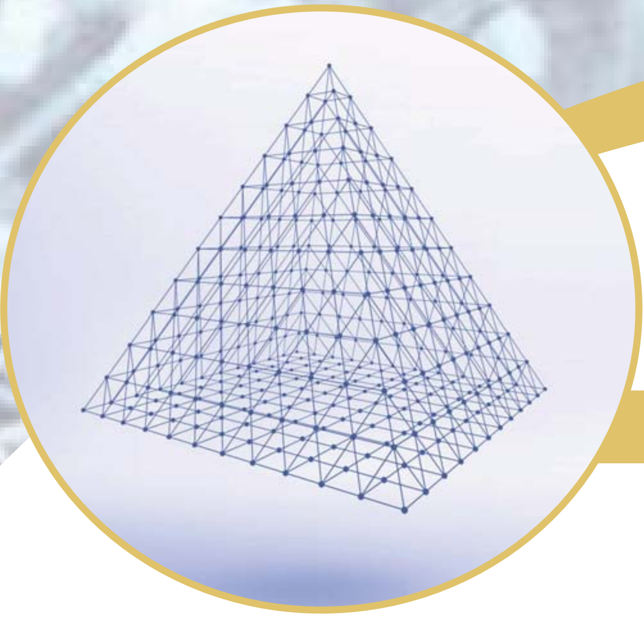


TECHNICAL SCIENCE

ELASTICITY

GRADE 12

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Read to Lead
A Reading Nation is a Leading Nation

2030 NDP

Table of Contents

Foreword

In order to improve learning outcomes the Department of Basic Education conducted research to determine the specific areas that learners struggle with in Grade 12 examinations. The research included a trend analysis by subject experts of learner performance over a period of five years as well as learner examination scripts in order to diagnose deficiencies or misconceptions in particular content areas. In addition, expert teachers were interviewed to determine the best practicesto ensure mastery of thetopic by learners and improve outcomes in terms of quality and quantity.

The results of the research formed the foundation and guiding principles for the development of the booklets. In each identified subject, key content areas were identified for the development of material that will significantly improve learner's conceptual understanding whilst leading to improved performance in the subject.

The booklets are developed as part of a series of booklets, with each bookletfocussing onlyon one specific challenging topic. The selected content is explained in detail and include relevant concepts from Grades 10 - 12 to ensure conceptual understanding.

The main purpose of these booklets is to assist learners to master the content starting from a basic conceptual level of understanding to the more advanced level. The content in each booklets is presented in an easy to understand manner including the use of mind maps, summaries and exercises to support understanding and conceptual progression. These booklets should ideally be used as part of a focussed revision or enrichment program by learners after the topics have been taught in class. The booklets encourage learners to take ownership of their own learning and focus on developing and mastery critical content and skills such as reading and higher order thinking skills.

Teachers are also encouraged to infuse the content into existing lesson preparation to ensure in-depth curriculum coverage of a particular topic. Due to the nature of the booklets covering only one topic, teachers are encouraged to ensure learners access to the booklets in either print or digital form if a particular topic is taught.

2. How to use this study guide

- This book in intended to assist and guide you through the topics. It is complimentary to your textbooks, worksheets and other learning materials you might have. Your efforts to practice and master concepts outlined will assist you to be confident in the learning and assessments you will do.
- Ensure you understand all the relevant concepts, formulae etc.
- Do extra research on your own to get more information on the topics in this booklet. It is important that you share and discuss with fellow learners on your understanding of your findings.
- Work through the examples given under each topic, master them and try to give yourself more examples. You must go through examples in your textbooks. At the end of Unit 5, there are exercises for you to do. Work through them on your own and compare with answers in Unit 6
- When doing calculations, take note of all the information given. It is intended to help you. Read the given information with the intention to understand what you must do with it. Always look for action verbs in order to answer correctly. Eg Determine, explain, discuss ,calculate, list, compare etc
- If you are given measurements in millimetres(mm),convert into meters.
- Familiarise yourself with Scientific notations used. Eg Kilo, Mega, Giga and write them as 10^x.
- It is important to show SI units on the final answer. This will earn you a mark.
- At the beginning of the topic(s), an extract from the Examination guidelines is included. You must use this to check what you are expected to master. Revise what you have not mastered and do more exercises.

3. Study and examination tips

3.1 Tips for Technical Sciences Paper One

Technical Science Paper 1

Content	Marks	%	Total	Duration
Mechanics	108	72	150 marks	3 hours
Electricity and Magnetism	42	28		

Mechanics include Elasticity and Viscosity as covered in this booklet. The percentage of marks as shown in the table above indicates how important this topics are.

3.2 Tips for Elasticity and Viscosity

- In doing Elasticity, Stress and Strain calculations, keep in mind Hooke's law as well as Newton's Laws of motion. Particular attention should be given to Newton's Third Law of motion; Internal resisting force is a reaction force equal to externally applied force.
- The Area (A) used in calculating stress is a cross-sectional are, you are expected to calculate area of round bars, square bars and tubes where applicable.
- Viscosity should be understood in the application of lubrication and friction in mechanisms and engines.

3. Overview of Elasticity

ELASTICITY

Key Definitions

Deforming force is a force that changes the shape and size of a body.

Restoring force is a force that is equal and opposite to the deforming force applied (to a body).

Elasticity of a body is a property of the body by virtue of the body regains its original shape and size when the deforming force is removed.

Perfectly elastic body is a body which regains its original shape and size completely when the deforming force is removed. Some of the examples of a perfectly elastic body are quartz fire in guitar strings and phosphorus bronze in springs and cables.

Perfectly plastic body is a body that does not show a tendency to regain its original shape and size when the deforming force is removed. Examples of a perfectly plastic body are wax, putty, etc.

Elastic limit is the maximum force that can be applied to the body so that the body regains its original form completely on removal of the force.

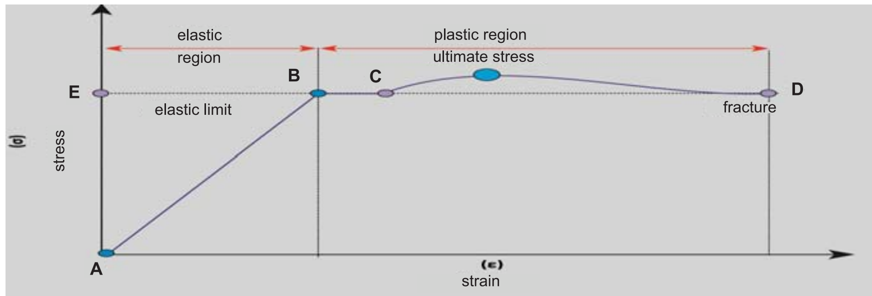
Stress is internal restoring force per unit area of a body

Strain is the ratio of change in dimension to the original dimension

Hooke's Law

Hooke's law states that, within the limit of elasticity, stress is **directly proportional to the strain.**

Stress α strain.



5. Elasticity and Viscosity: Summary

Elasticity and Viscosity
(This section must be read in conjunction with the CAPS, p. 43-44.)

Elasticity

- Define a deforming force as a force that changes the shape and size of a body.
- Define restoring force as a force that is equal and opposite to the deforming force applied (to a body).
- Explain that when a deforming force is applied to a body, the restoring force develops inside the body to oppose the effect of the deforming force, thus restoring its original size and shape of that body.
- Elasticity of a body is a property of the body by virtue of the body regains its original shape and size when the deforming force is removed.
- Define a perfectly elastic body as a body which regains its original shape and size completely when the deforming force is removed. Some of the examples of a perfectly elastic body are quartz fire in guitar strings and phosphorus bronze in springs and cables.
- Define a perfectly plastic body is a body that does not show a tendency to regain its original shape and size when the deforming force is removed. Examples of a perfectly plastic body are wax, putty, etc.
- Elastic limit is the maximum force that can be applied to the body so that the body regains its original form completely on removal of the force.
- Stress is internal restoring force per unit area of a body.
  Stress has the SI unit Pa or $N.m^{-2}$.
  $\sigma = \frac{F}{A}$, where σ is stress, F is force and A is area.
- Use the equation above to calculate stress, force and area or diameter.
- Strain is the ratio of change in dimension to the original dimension.
  $\varepsilon = \frac{\Delta L}{L}$, where ε is strain, ΔL is the change in length and L is the original length.
  Strain does not have a unit.
- Hooke's law states that, within the limit of elasticity, stress is directly proportional to the strain.
- Stress α strain.
  $\therefore \frac{\sigma}{\varepsilon} = K$, where K is a constant known as the modulus of elasticity of a material of a body.
  K has the unit $N.m^{-2}$ or Pa.
- Use the equation above to calculate stress, strain and modulus of elasticity.

Viscosity

- Define viscosity as the property of the fluid to oppose relative motion between the two adjacent layers.
- Discuss the effect of temperature in viscosity in the field of technology.
- Explain that, as the temperature of the fluid increases, its viscosity decreases. The liquids used as the lubrication fluid and for number of other applications should be selected properly considering the operating temperatures.
- Discuss motor oil grades.

5.1 Elasticity

It is advisable that the learners revise the grade 10 work:

- Units and measurements:
- Conversion: mm to m ; m to mm ; m to km ; etc
- Scientific notations : Kilo = 10^3
  Mega = 10^6
  Giga = 10^9

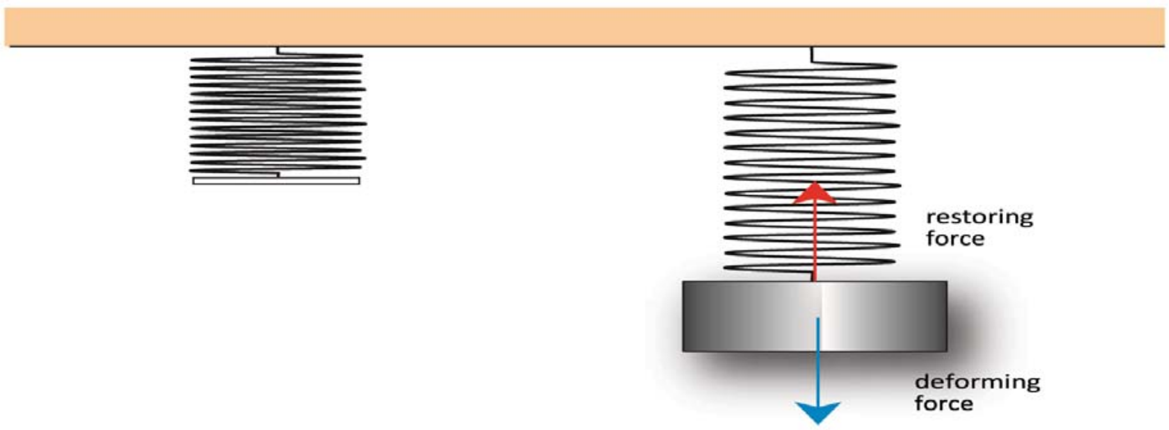
IMPORTANT

In all calculations in this section, all millimetres (mm) must be converted to meters(m) and all forces should be written as newtons (N). The following examples show how;

0.36 mm = 0,36 x 10^{-3}
16 kN = 16 x 10^3
3,7 MPa = 3,7 x 10^6

Elasticity

1. A **deforming force** is a force that changes the shape and size of a body.
2. A **restoring force** is a force that **is equal and opposite to the deforming force** applied (to a body).



3. When a deforming force is applied to a body, the restoring force develops inside the body to oppose the effect of the deforming force, thus restoring its original size and shape of that body.

4. Elasticity of a body is a property of the body by virtue of the body regains its original shape and size when the deforming force is removed
.
5. A perfectly elastic body is a body which regains its original shape and size completely when the deforming force is removed. Some of the examples of a perfectly elastic body are quartz fire in guitar strings and phosphorus bronze in springs and cables.

6. A perfectly plastic body is a body that does not show a tendency to regain its original shape and size when the deforming force is removed. Examples of a perfectly plastic body are wax, putty, etc.

7. **Elastic limit** is the **maximum force** that can be applied to the body so that the body regains its original form completely on removal of the force.

8. **Stress** is **internal restoring force** per unit area of a body.

9. Stress has the SI unit Pa or $N{\cdot}m^{-2}$.

$\boldsymbol{\sigma}=\frac{F}{A}$, where $\boldsymbol{\sigma}$ is stress, F is force and A is area. NB! Cross-sectional area

Use the equation above to calculate stress, force and area or diameter.

10. Strain is the ratio of change in dimension to the original dimension.

$\varepsilon = \frac{\Delta L}{L}$, where ε is strain, ΔLis the change in length and L is the original length.

Strain does not have a unit.

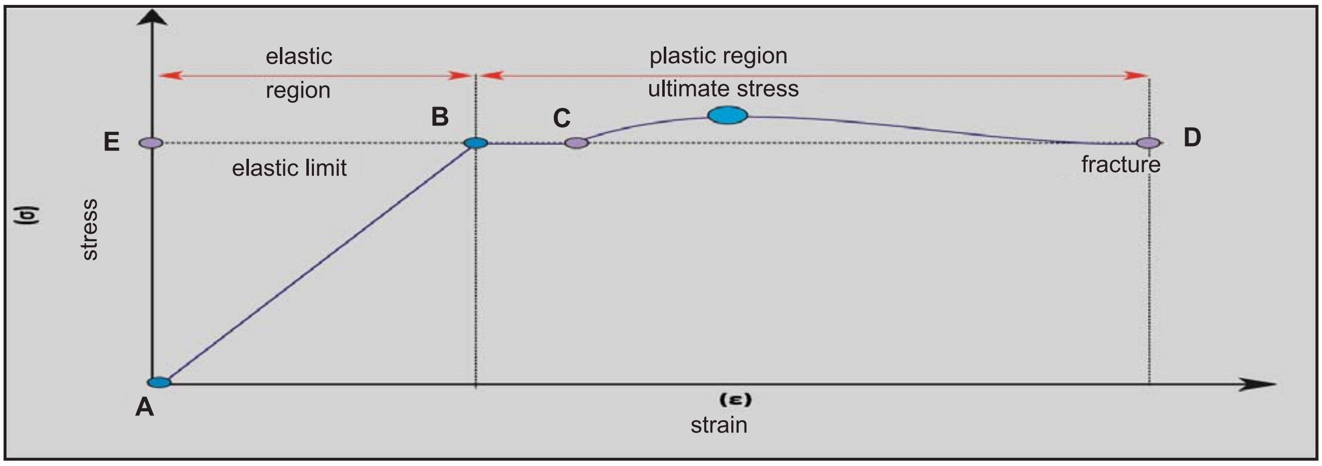
11. Hooke's law states that, **within the limit of elasticity**, **stress is directly proportional to the strain.**

    Stress α **strain**.

$K = \frac{\sigma}{\varepsilon}$, where K is a constant known as the modulus of elasticity of a material of a body.

K has the unit $N{\cdot}m^{-2}$ or Pa.

- Use the equation above to calculate stress, strain and modulus of elasticity.



Graph: Hooke's Law

WORKED EXAMPLES

Calculations on stress, strain and the Young modulus

1. A strip of rubber originally 75 mm long is stretched until it is 100 mm long.

   a) Calculate the tensile strain?

$$\text{Strain} = \frac{\textit{(change in length)}}{\textit{(original length)}}$$

$$= \frac{(100-75)}{75}$$

$$= 0.33$$

   b) Why does the answer have no units?

   Strain is the ratio of lengths and therefore units are not necessary

2. The greatest tensile stress which steel of a sort can withstand without breaking is about 109 $N{\cdot}m^{-2}$. A wire of cross-sectional area 0.01 mm^2 is made of this steel. What is the greatest force that it can withstand?

   A= 0.01mm^2 ;this must be converted to m^2 ∴ A = 0.01 X 10^{-6} m^2

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

$$109 = \frac{F}{0{,}01 \times 10^{-6}}$$

$$F = 109 \times 0.01 \times 10^{-6}$$

$$F = 1.09 \times 10^{-6}\ N$$

3. Find the minimum diameter of an alloy cable, tensile strength 75 MPa, needed to support a load of 15 kN.
   Tensile strength = 75 x 10^6
   Force = 15 x 10^3

$$\text{Force} = 15 \times 10^3$$

$$\boldsymbol{stress = \frac{F}{A}}$$

$$\mathbf{75 \times 10^6 = \frac{15 \times 10^3}{A}}$$

Area = 2 x 10^{-4} m^2

$$A = \frac{\pi d^2}{4}$$

so

$$d = \sqrt{\frac{\pi d^2}{4}}$$

$$d = \sqrt{\frac{4 \times 2 \times 10^{-4}\ m^2}{3.14}}$$

$d = 1.6 \times 10^{-2}$ m or 1.6 cm

4. Calculate the tensile stress in a suspension bridge supporting cable, of diameter of 50 mm, which pulls up on the roadway with a force of 4 kN.
   Diameter = 50×10^{-3}m

   Force = 4×10^{3}

$$stress = \frac{F}{A}$$

$$= \frac{4 \times 10^3}{A};$$

The area must be worked out first

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (50 \times 10^{-3} m)^2}{4}$$

$$= 1.96 \times 10^{-3}\ m^2$$

$$stress = \frac{force}{area}$$

$$= \frac{4 \times 10^3}{1.96 \times 10^{-3}}$$

Stress = 2.0 x 106 N m^{-2} or 2.0 MPa

5. Calculate the tensile stress in a nylon fishing line of diameter 0.36 mm which a fish is pulling with a force of 20 N
Diameter = _0,36 10^{-3}m

Property means the chemical characteristic
Fluid in this case refer to both lubricating liquids used in engines and high pressure fluids used in hydraulic machines
relative motion refers to action between surfaces in a mechanism
SAE: Society for Automotive Engineers

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

$$= \frac{20}{A} \text{ ; calculating the area}$$

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (0.36 \times 10^{-3} \text{m})^2}{4}$$

$$= 1.017 \times 10^{-7} \text{ m}^2$$

$$\text{stress} = \frac{\text{force}}{\text{area}}$$

$$= \frac{20 \text{ N}}{1.017 \times 10^{-7} \text{ m}^2}$$

Stress = 200 MPa

6. A large crane has a steel lifting cable of diameter 36 mm.
The steel used has a Young modulus of 200 GPa. When the crane is used to lift 20 kN, the unstretched cable length is 25.0 m. Calculate the extension of the cable.

diameter = 36 x 10^{-3}

$$A = \frac{\pi d^2}{4}$$

$$= \frac{3.14 \times (3.6 \times 10^{-2} \text{ m})^2}{4}$$

=1.02 x 10–3 m2

$$E = \frac{F/A}{\Delta l / l}$$

so

$$\Delta l = \frac{F \times l}{A \times E}$$

$$= \frac{20 \times 10^3 \text{ N} \times 25 \text{ m}}{1.02 \times 10^{-3} \text{ m}^2 \times 2 \times 10^{11} \text{ N m}^{-2}}$$

Δl = 2.45 x 10^{-3} m or 2.45 mm

5.2 Viscocity

- Viscosity as the property of the fluid to oppose relative motion between the two adjacent layers.
- Discuss the effect of temperature in viscosity in the field of technology.
- Explain that, as the temperature of the fluid increases, its viscosity decreases. The liquids used as the lubrication fluid and for number of other applications should be selected properly considering the operating temperatures.
- Discuss motor oil grades.

Important notes

1. Viscosity is the **property** of the fluid to oppose **relative motion** between the **two adjacent layers**.
2. Effects of temperatures in viscosity
    a. When the fluid temperature rises(heats up), the viscosity lowers, the fluid becomes thinner in density
    b. When the fluid temperature is low (cold), the viscosity is high, the fluid becomes thicker in density.
3. Fluids should be used according to intended purposes and conditions such as operating temperatures, lubrication and other applications. Eg hydraulic pumps use fluids differing from engine oils.
4. Oils are graded according to operating temperatures.
    a. **SAE 30** , **SAE 40**, **20W40** are some of the grading that are used to classify motor oils.
    b. There are **mono**-graded and ***multi***-graded motor oils, **SAE 30 is mono-graded** while **15W50 is multi-graded**. Petrol and Diesel motors use differently formulated oil

5. Numbers are indicating the readings obtained through a VISCOMETER as oil viscosity was measured at different temperatures.
   SAE 30 implies that the viscosity of motor oil is 30 at that temperature, however as in motor cars, temperatures rise and fall. In motor car engines the temperatures starts from cold (presumed 0^0 Celsius) to hot (100^0 Celsius and more) and therefore oils used should be able to lubricate under the extreme temperatures.
   e.g 20W50 implies that at cold temperatures the oil viscosity is 50 (SAE 50) and when temperatures are high the viscosity will be 20 (SAE 20).
6. Others types of engines, lawn mower for example will use only motor oils with a constant viscosity because they operate at a certain maximum temperature .e,g SAE 30

Test your knowledge on Elasticity

1. A steel railroad track is 1 000 m long. When its temperature is raised, it causes the length of the track to increase by 0, 01%. Young's modulus for steel is 2×10^{11} N·m^{-2}

1.1 Define the strain. (2)

1.2 Calculate the strain on the steel railroad track. (3)

1.3 Explain why the strain has no units. (3)

1.4 State Hooke's law in words. (3)

1.5 Determine the stress in the rail. (4)

2. A compressive force causes internal stress of 16 MPa in a bar made of an unknown metal. The resistance area of the round bar is 1,26 _ 10-3 m2 and the original length is 80 mm. The force causes the round bar to increase by√ $1,44 \times 10^{-3}$ mm.

Determine (by means of calculations) the:

2.1 Force that causes the bar to stretch. (3)

2.2 Strain in the metal caused by the force. (3)

2.3 Elasticity modulus for this metal. (3)

3. A wire that is 2 m long and has a diameter of 1 mm is suspended from the ceiling. Hanging a 4,5 kg mass from the wire stretches the wires length by 1 mm.

3.1 Define the term elasticity limit. (2)

3.2 Calculate the stress on the wire? (3)

3.3 Calculate the strain on the wire. (2)

3.4 What is Young's modulus for this wire? (3)

1. Test your knowledge on Viscosity

1.1 Define the term viscosity. (3)

1.2 Do temperatures affect the viscosity of lubricants?
Motivate your answer (3)

1.3 Explain the differences between mono-grade and multi-grade oils.
Give example of each grading (3)

1.4 Interpret the meaning of the grading 20 W 50 SAE
on the engine oil. (3)

5.3 Check your answers

5.3.1 Answers to test your knowledge questions on Elasticity

1.1. Strain is the **ratio of change** in dimension to the **original dimension**√√

1.2. $\Delta l = 0.01 \div 100 \ x \ 1\,000$ m

$\Delta l = 0,1$ m √

$\varepsilon = {}^{\Delta l}/_{l}$ √

$\varepsilon = \frac{0.1}{1000}$

$= 1 \times 10^{-4}$ √

1.3. Because the units of the change in length and the length are the same.

When calculating strain, which is the ratio between the change in length and the original length of the object, the √ units cancel out and the answer therefore has no units. √

1.4. Hooke's Law states that within the limit of elasticity, stress is directly proportional to strain.

1.5. $K = \frac{\sigma}{\varepsilon}$ √

$$2 \times 10^{11} = \frac{\sigma}{1 \times 10^{-4}} \quad \surd\surd$$

$$\sigma = 2 \times 10^{7} \text{ Pa} \quad \surd$$

$$\sigma = 20 \text{ MPa}$$

2.1.

$$\sigma = \frac{F}{A} \quad \surd$$

$$16 \times 10^{6} = \frac{F}{1.26 \times 10^{-3}} \surd$$

$$F = 2, \ x104N$$

$\surd$

2.2.

$$\varepsilon = \frac{\Delta L}{L} \quad \surd$$

$$\varepsilon = \frac{1.44 \times 10^{-3}}{80} \quad \surd$$

$$= 1,80 \times 10^{-5}$$

2.3.

$$K = \frac{stress}{strain} \quad \surd$$

$$K = \frac{16 \times 10^{6}}{180 \times 10^{-5}} \surd$$

$$K = 8.89 \times 10^{11} \text{ Pa} \surd$$

3.1 An elastic limit is the maximum force that can be applied to body so that the body regains its original form completely on removal of the force.

3.2 $\sigma = \frac{F}{A}$ $\surd$

$$\sigma = \frac{mg}{\pi (r)^2} \quad \surd$$

$$\sigma = \frac{4.5 \times 9.8}{\pi (\frac{1}{2} \times 10^{-3})^2} \quad \surd$$

$$\sigma = \frac{44.1}{\pi (2.5 \times 10^{-7})} \quad \surd$$

$$\sigma = 5,61 \times 10^{7} \text{ Pa}$$

$$\sigma = 56,1 \text{ MPa} \quad \surd$$

3.3

$$= \frac{\Delta l}{l} \quad \surd$$

$$\varepsilon = \frac{1 \text{ mm}}{2\,000 \text{ mm}} \quad \surd$$

$$= 5 \times 10^{-4} \quad \surd$$

3.4

$$K = \frac{\sigma}{\varepsilon} \quad \surd$$

$$K = \frac{5.61 \times 10^{7}}{5 \times 10^{-4}} \quad \surd$$

$$K = 1,122 \times 10^{11} \text{ Pa} \surd$$

5.3.2 Answers to test your knowledge questions on Viscosity

1. Viscosity is the property of the fluid to oppose relative motion between the two adjacent layers.

2. Yes. When the temperatures heats up the viscosity becomes low and in cold temperatures the viscosity is high

3. Monograde oil is the engine oil that is designed to function at either low temperatures or high temperatures √ and cannot be suitable for changing engine temperatures. √

For example, SAE 40 oil is a mono-grade oil. √
Multi-grade oil is an engine oil that is designed to cope with the increasing engine temperatures. √

It behaves as a low viscosity oil at lower temperatures and as a high viscosity oil at high temperatures. √

For example, 20W50 SAE is an engine oil that behaves as SAE 20 when the engine is cold, and as a SAE 50 when the engine heats up√

4. 20 W 50 SAE is the oil that behaves as an SAE 20 oil at low temperatures and behaves as an SAE 50 at high temperatures. √√

7. Message to the grade 12 learners

We trust that you will enjoy using this booklet as much as we enjoyed compiling it. Your success in the Technical Sciences depends on how hard you work. Knowledge is a treasure but practice is the key to it. Remember, Minds are like parachutes, they only work when open.
Good luck in your journey to success

8. Thank you and Acknowledgements

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TECHNICAL SCIENCE

ELASTICITY

GRADE 12

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