Lec. (4)

PHYSICS 1

1 ST LEVEL 2020 - 2021

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ENGINEERING CAMP

SCAN FOR FACEBOOK GROUP

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" CH.2 : Elasticity --- last "

11- The bulk modulus is a proportionality constant that relates the pressure acting on an object to:

A. the shear $\boxed{B}$ the fractional change in volume C. the fractional change in length D. Young's modulu sE. the spring constant

ans: B

12- A cube with edges exactly 2 cm long is made of material with a bulk modulus of 3.5×10^9 N/m^2. When it is subjected to a pressure of 3.0×10^5 Pa its volume is:

A. 7.31 cm^3 $\boxed{B}$ 7.99931 cm^3 C. 8.00069 cm^3 D. 8.69 cm^3 E. none of these

ans: B

13- A cube with 2.0-cm sides is made of material with a bulk modulus of 4.7×10^5 N/m^2. When it is subjected to a pressure of 2.0×10^5 Pa the length of its any of its sides is:

A. 0.85 cm B. 1.15 cm $\boxed{C}$ 1.66 cm D. 2.0 cm E. none of these

ans: C

14- To shear a cube-shaped object, forces of equal magnitude and opposite directions might be :

A. to opposite faces, perpendicular to the faces $\boxed{B}$ to opposite faces, parallel to the faces C. to adjacent faces, perpendicular to the faces. D. to adjacent faces, neither parallel or perpendicular to the faces E. to a single face, in any direction

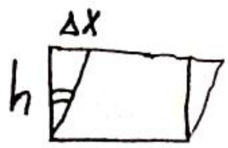
ans: B

15- A shearing force of 50 N is applied to an aluminum rod with a length of 10 m, a cross-sectional area of 1.0×10^{-5} m, and a shear modulus of 2.5×10^{10} N/m^2. As a result the rod is sheared through a distance of:

A. zero $\boxed{B}$ 1.9 mm C. 1.9 cm D. 19 cm E. 1.9 m

EX.2.1: a metal cube 10 cm side, shearing force 10^6 N calculate the modulus of rigidity (s), if $\Delta X = 0.02$ cm

answer: $S = \frac{F/A}{\Delta X/h} = \frac{Fh}{\Delta X A}$

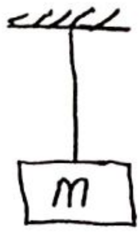


$= \frac{10^6 \times 0.1}{\ldots} = \boxed{5\times10^{10}\ N/m^2}$

$h = 10\,cm = 0.1\,m$

2-2 Calculate Young's modulus of a wire 100 cm long and 3 mm radius, which increase by 1 mm when pulled (الشد) with a mass 64.1 kg.

answer



$$Y = \frac{F/A}{\Delta L/L} = \frac{FL}{A\Delta L}$$

$F = mg = 64.1 \times 9.8 = 628.18 N$

$A = \pi r^2 = \pi (3 \times 10^{-3})^2 = 2.83 \times 10^{-5} m^2$

$$\therefore Y = \frac{(628.18) \times (100 \times 10^{-2})}{(2.83 \times 10^{-5}) \times (1 \times 10^{-3})}$$

$$= \boxed{2.22 \times 10^{10} N/m^2}$$

$L = 100 cm$
$r = 3 mm$
$\Delta L = 1 mm$
$m = 64.1 kg$
$Y = ??$

2-3 A steel rod (قضيب من الصلب) 2 m long has a cross-section area 0.30 cm^2, it is hung (معلق) by one end from a support (دعامة), and 550 kg milling (طحن) machine is hung from its other end

Determine the stress on the rod and the resulting strain elongation.

answer. $Y_{steel} = 20 \times 10^{10}$ Pa

$L = 2m$, $A = 0.30\ cm^2 = 0.30 \times 10^{-4}\ m^2$

$M = 550kg$, stress = ? , $\Delta L = ?$

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

$= \frac{550 \times 9.8}{0.30 \times 10^{-4}} = \boxed{1.8 \times 10^{8}\ N/m^2}$

* $\because Y = \frac{stress}{strain}$

$\therefore strain = \frac{stress}{Y} = \frac{1.8 \times 10^{8}}{20 \times 10^{10}}$

$= 9 \times 10^{-4}$

$\because strain = \frac{\Delta L}{L}$

$\therefore \Delta L = strain \times L = (9 \times 10^{-4}) \times (2)$

$= 18 \times 10^{-4}\ m = \boxed{1.8\ mm}$

2-4 A hydraulic press (مكبس هيدروليكي) Contains $0.25 m^3$ of oil, Find the decrease in the volume when it is subjected to $\Delta P = 1.6 \times 10^7$ Pa.

يحتوي

The bulk modulus of oil $B = 5 \times 10^9$ Pa, and its compressibility $K = \frac{1}{B} = 20 \times 10^{-6} \, atm^{-1}$

answer:

$$B = \frac{\text{stress}}{\text{strain}} = \frac{\Delta P}{-\Delta V / V} = -\frac{\Delta P \, V}{\Delta V}$$

$$\therefore \Delta V = \frac{-\Delta P \, V}{B} = \frac{-(1.6 \times 10^7) \times (0.25)}{5 \times 10^9}$$

$$= \boxed{-8 \times 10^{-4} \, m^3} = \boxed{-0.8 L}$$

Note: $1 m^3 = 1000$ Liter

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2-5 one end of a steel rod of radius $R = 9.5 mm$ is held in a vise مثبت بكماشة (منجلة) if $L = 81 cm$, $F = 62 KN$, $Y = 20 \times 10^{10}$

Find : stress, strain and elongation (ΔL)

answer

$\Rightarrow$ stress $= \dfrac{F}{A} = \dfrac{62 \times 10^{3}}{\pi (9.5 \times 10^{-3})^{2}} = \boxed{2.2 \times 10 \; N/m^2}$

$\Rightarrow$ strain $= \dfrac{stress}{Y} = \boxed{1.1 \times 10^{-3}}$

$\Rightarrow \Delta L = (strain) \times L = \boxed{8.9 \times 10^{-4} \, m}$

كرة صلبة من الرصاص

[2-6] A solid lead sphere of volume $0.5 \, m^3$, dropped in ocean, غرقت sinks to عمق depth $2 \times 10^{3} \, m$, where the pressure increases by 2×10^{7} Pa, lead has a bulk modulus of 4.2×10^{10} Pa, what is the change in the volume?

answer

$$B = -\frac{\Delta P}{\Delta V / V} = \frac{-V \cdot \Delta P}{\Delta V}$$

$$\therefore \Delta V = \frac{-V \Delta P}{B} = \frac{-0.5 \times (2 \times 10^{7})}{4.2 \times 10^{10}} = \boxed{-2.4 \times 10^{-4} \, m^3}$$

دعامة رأسية

2-7 A vertical steel beam in a building supports a load 6×10^4 N.

حمل

(a) If the length of the beam is 4 m and cross-section area $8\times10^{-3}\ m^2$, Find the distance the beam is compressed along its length ($Y_{steel} = 2\times10^{11}$ Pa)

ينضغط

(b) Find the maximum load in Newtons could the steel beam support, if the maximum stress is 5×10^8 Pa

answer

(a) $$Y = \frac{F/A}{\Delta L/L} = \frac{FL}{A\,\Delta L}$$

$$\therefore \Delta L = \frac{FL}{AY} = \frac{(6\times10^4)\times4}{(8\times10^{-3})\times(2\times10^{11})} = \boxed{1.5\times10^{-4}\ m}$$

(b) $$stress = \frac{F}{A}$$

$$\therefore F = (stress)\times A = (5\times10^8)\times(8\times10^{-3}) = \boxed{4\times10^6\ N}$$

Example 2.7

دعامة صلب عمودية

Problem A vertical steel beam in a building supports a load of 6.0×10^4 N. (a) If the length of the beam is 4.0 and its cross-sectional area is $8.0 \times 10^{-3}\ m^2$, find the distance the beam is compressed along its length. (b) Wh maximum load in newtons could the steel beam support before failing?

انضغطت

Solution

A) Find the amount of compression in the beam

$$\frac{F}{A} = Y \cdot \frac{\Delta L}{L_0}$$

$$\Delta L = \frac{FL_0}{YA} = \frac{(6.0 \times 10^4\ N)(4.0\ m)}{(2.0 \times 10^{11}\ Pa)(8.0 \times 10^{-3}\ m^2)}$$

$$= 1.5 \times 10^{-4}\ m$$

B) Find the maximum load that the beam can support.

$$\frac{F}{A} = \frac{F}{8.0 \times 10^{-3}\ m^2} = 5.0 \times 10^8\ Pa$$

$$F = 4.0 \times 10^6\ N$$

Example 2.8

Problem A solid lead sphere of volume $0.50\ m^3$, dropped in the ocean, sinks to a depth of 2.0×10^3 m (about 1 mile), where the pressure increases by 2.0×10^7 Pa. Lead has a bulk modulus of 4.2×10^{10} Pa. What is the change in volume of the sphere?

Solution

$$B = -\frac{\Delta P}{\Delta V / V}$$

$$\Delta V = -\frac{V \Delta P}{B}$$

$$\Delta V = -\frac{(0.50\ m^3)(2.0 \times 10^7\ Pa)}{4.2 \times 10^{10}\ Pa} = -2.4 \times 10^{-4}\ m^3$$

Example: 2.9 Calculate the change in length of the upper leg bone (the femur) when a 70.0 kg man supports 62.0 kg of his mass on it, assuming the bone to be equivalent to a uniform rod that is 40.0 cm long and 2.00 cm in radius.

Solution:

The force is equal to the weight supported, or

$$F = mg = (62.0\ \text{kg})(9.80\ \text{m/s}^2) = 607.6\ \text{N},$$

and the cross-sectional area is $\pi r^2 = 1.257\times10^{-3}\ \text{m}^2$. The equation $\Delta L = \frac{1}{Y}\frac{F}{A}L_0$ can be used to find the change in length.

3)

Solution

All quantities except ΔL are known. Note that the compression value for Young's modulus for bone must be used here. Thus,

$$\Delta L = \left(\frac{1}{9\times10^9\ \text{N/m}^2}\right)\left(\frac{607.6\ \text{N}}{1.257\times10^{-3}\ \text{m}^2}\right)(0.400\ \text{m}) = 2\times10^{-5}\ \text{m}.$$

Example:2.10

Calculate the fractional decrease in volume ($\frac{\Delta V}{V_0}$) for seawater at 5.00 km depth, where the force per unit area is $5.00\times10^7\ \text{N/m}^2$.

Equation $\Delta V = \frac{1}{B}\frac{F}{A}V_0$ is the correct physical relationship. All quantities in the equation except $\frac{\Delta V}{V_0}$ are known.

Solution

Solving for the unknown $\frac{\Delta V}{V_0}$ gives

$$\frac{\Delta V}{V_0} = \frac{1}{B}\frac{F}{A}.$$

Substituting known values with the value for the bulk modulus B from Table 5.3,

$$\frac{\Delta V}{V_0} = \frac{5.00\times10^7\ \text{N/m}^2}{2.2\times10^9\ \text{N/m}^2} = 0.023 = 2.3\%.$$

2.11

A metal wire 75.0 cm long and 0.130 cm in diameter stretches 0.0350 cm when a load of 8.00 kg is hung on its end. Find the stress, the strain, and the Young's modulus for the material of the wire.

$$\sigma = \frac{F}{A} = \frac{(8.00\ \text{kg})(9.81\ \text{m/s}^2)}{\pi(6.50\times10^{-4}\ \text{m})^2} = 5.91\times10^7\ \text{N/m}^2 = 5.91\times10^7\ \text{Pa}$$

$$\varepsilon = \frac{\Delta L}{L_0} = \frac{0.0350\ \text{cm}}{75.0\ \text{cm}} = 4.67\times10^{-4}$$

$$Y = \frac{\sigma}{\varepsilon} = \frac{5.91\times10^7\ \text{Pa}}{4.67\times10^{-4}} = 1.27\times10^{11}\ \text{Pa} = 127\ \text{GPa}$$

2.12

A solid cylindrical steel column is 4.0 m long and 9.0 cm in diameter. What will be its decrease in length when carrying a load of 80 000 kg? $Y = 1.9 \times 10^{11}$ Pa.

We first find

$$\text{Cross-sectional area of column} = \pi r^2 = \pi(0.045\ \text{m})^2 = 6.36 \times 10^{-3}\ \text{m}^2$$

Then, from $Y = (F/A)/(\Delta L/L_0)$ we have

$$\Delta L = \frac{FL_0}{AY} = \frac{[(8.00 \times 10^4)(9.81)\ \text{N}](4.0\ \text{m})}{(6.36 \times 10^{-3}\ \text{m}^2)(1.9 \times 10^{11}\ \text{Pa})} = 2.6 \times 10^{-3}\ \text{m} = 2.6\ \text{mm}$$

2.13

A box-shaped piece of gelatin dessert has a top area of 15 cm² and a height of 3.0 cm. When : shearing force of 0.50 N is applied to the upper surface, the upper surface displaces 4.0 mn relative to the bottom surface. What are the shearing stress, the shearing strain, and the shea modulus for the gelatin?

$$\sigma_s = \frac{\text{tangential force}}{\text{area of face}} = \frac{0.50\ \text{N}}{15 \times 10^{-4}\ \text{m}^2} = 0.33\ \text{kPa}$$

$$\varepsilon_s = \frac{\text{displacement}}{\text{height}} = \frac{0.40\ \text{cm}}{3.0\ \text{cm}} = 0.13$$

$$S = \frac{0.33\ \text{kPa}}{0.13} = 2.5\ \text{kPa}$$

Quick Quiz

1- A block of iron is sliding across a horizontal floor. The friction force between the block and the floor causes the block to deform. To describe the relationship between stress and strain for the block, you would use

(a) Young's modulus (b) shear modulus (c) bulk modulus (d) none of these.

2- A trapeze artist swings through a circular arc. At the bottom of the swing, the wires supporting the trapeze are longer than when the trapeze artist simply hangs from the trapeze, due to the increased tension in them. To describe the relationship between stress and strain for the wires, you would use

(a) Young's modulus (b) shear modulus (c) bulk modulus (d) none of these.

3- A spacecraft carries a steel sphere to a planet on which atmospheric pressure is much higher than on the Earth. The higher pressure causes the radius of the sphere to decrease. To describe the relationship between stress and strain for the sphere, you would use " BULK MODULUS "