ELASTICITY

1. DEFINATION

Elasticity is that property of the material of a body by virtue of which the body opposes any change in its shape or size when deforming forces are applied to it, and recovers its original state as soon as the deforming forces are removed.

On the basis of defination bodies may be classified in two types :

(a) Perfectly Elastic (P.E.) : If body regains its original shape ans size completely after removal of force.

Nearest approach P.E. : quartz-fibre

(b) Perfectly Plastic (P.P.) : If body does not have tendency to recover its original shape and size.

Nearest Approach P.P. : Peetty

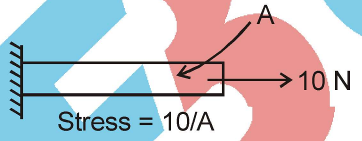
Limit of Elasticity : The maximum deforming force upto which a body retains its property of elasticity is called the limit of elasticity of the material of the body.

2. STRESS

When a deforming force is applied to a body, it reacts to the applied force by developing a reaction (or restoring force which, from Newton's third law, is equal in magnitude and opposite in direction to the applied force. *Thereaction force per unit area of the body which is called into play due to the action of the applied force is called stress.* Stress is measured in units of force per unit area, i.e. Nm^{-2}. Thus.

$$\text{Stress} = \frac{F}{A}$$

where F is the applied force and A is the area over which it acts.

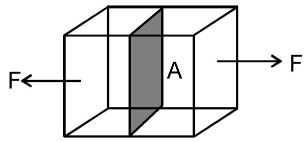


Unit of stress : N/m^2

Dimension of stress : $M^1L^{-1}T^{-2}$

2.1 Types of stress :

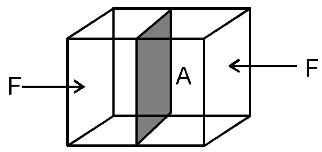
Three Types of Stress :



(A) Tensile Stress : Pulling force per unit area.

It is applied parallel to the length

It causes increase in length or volume



(B) Compressive Stress : Pushing force per unit area.

It is applied parallel to the length

It causes decrease in length or volume

(C) Tangential Stress : Tangential force per unit area. It causes shearing of bodies.

Note :

1. If the stress is normal to surface called normal stress.
2. Stress is always normal to surface in case of change in length of a wire or volume of body.
3. When external force compresses the body $\Rightarrow$ Nature of atomic force will be repulsive.
4. When external forces expanses the body $\Rightarrow$ Nature of atomic force will be attractive.

Difference between Pressure v/s Stress :

S. No.	Pressure	Stress
1	Pressure is always normal to the area.	Stress can be normal or tangential
2	Always compressive in nature	May be compressive or tensile in nature.
3	Scalar	Tensor

3. STRAIN

When a deforming force is applied to a body, it may suffer a change is size or shape. Strain is defined as the ratio of the change in size or shape to the original size or shape of the body. Strain is a number; it has no units or dimensions.

The ratio of the change in length to the original length is called *longitudinal strain.* The ratio of the change in volume to the original volume is called *volume strain.* The strain resulting from a change in shape is called shearing strain.

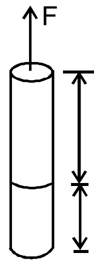
$$\text{Strain} = \frac{\Delta L}{L_0} = \frac{\text{final length} - \text{original length}}{\text{original length}} = \alpha \Delta T,$$

Note : Original and final length should be at same temperature.

3.1 Types of strain :

Three Types of Strain :

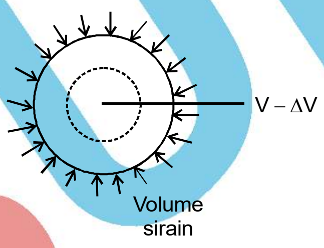
(A) Linear Strain : Change in length per unit length is called linear strain



$$\textbf{Linear Strain} = \frac{\text{Change in length}}{\text{Original length}}$$

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

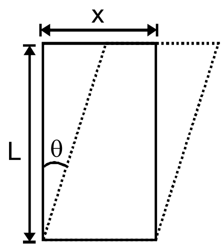
(B) Volume Strain : Change in volume per unit volume is called volume strain.



Volume Strain

$$= \frac{\text{Change in volume}}{\text{Original volume}} = \frac{\Delta V}{V}$$

(C) Shear Strain : Angle through which a line originally normal to fixed surface is turned.



Shear strain

$$\phi = \frac{x}{L}$$

Note : Strain is unitless.

4. WORK DONE IN STRETCHING A WIRE :

In stretching a wire work is done against internal restoring forces. This work is stored in body as elastic potential energy or strain energy.

If L = length of wire &

A = Cross-sectional Area.

$$Y = \frac{F/A}{x/L} \Rightarrow F = \frac{YA}{L}x$$

work done to increase dx length

$$dW = Fdx = \frac{YA}{L}xdx$$

$$\text{Total work done} = W = \int_0^{\Delta L} \frac{YA}{L} xdx = \frac{1}{2}\frac{YA}{L}(\Delta L)^2$$

$$\text{Work done per unit volume} = \frac{W}{V} = \frac{1}{2} Y \left(\frac{\Delta L}{L}\right)^2 \qquad [\because V = AL]$$

$$\frac{W}{V} = \frac{1}{2} Y\, (\text{strain})^2$$

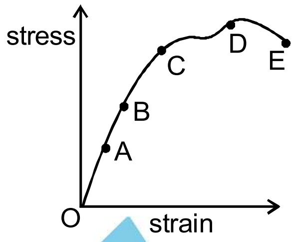
$$\frac{W}{V} = \frac{1}{2} \times \text{stress} \times \text{strain} \qquad \left[\because Y = \frac{\text{Stress}}{\text{Strain}}\right]$$

$$\frac{W}{V} = \frac{1}{2}\frac{(\text{stress})^2}{Y} \Rightarrow \frac{W}{AL} = \frac{1}{2}\frac{F}{A} \times \frac{\Delta L}{L}$$

$$W = \frac{1}{2} F \times \Delta L = \frac{1}{2} \text{ load x elongation}$$

5. STRESS-STAIN CURVE

If we increase the load gradually on a vertical suspended metal wire,



In Region OA :

Strain is small (< 2%)

Stress $\propto$ Strain $\Rightarrow$ Hook's law is valid.

Slope of line OA gives Young's modulus Y of the material.

In Region AB : Stress is not proportional to strain, but wire will still regain its original length after removing of stretching force.

In region BC : Wire yields $\Rightarrow$ strain increases rapidly with small change in stress. This behavior is shown up to point C known as yield point.

In region CD : Point D correspondes to maximum stress, which is called point of breaking or tensile strength.

In region DE : The wire literally flows. The maximum stress corresponding to D after which wire begin to flow.

In this region strain increase even if wire is unloaded and rupture at E.

6. HOOKES' LAW

Hookes' law states that, within the elastic limit, the stress developed in a bodyis proportional to the strain produced in it. Thus the ratio of stress to strain is a constant. This constant is called the modulus of elasticity. Thus

$$\text{Modulus of elasticity} = \frac{\text{stress}}{\text{strain}}$$

Since strain has no unit, the unit of the modulus of elasticity is the same as that of stress, namely, Nm^{-2}

7. YOUNG'S MODULUS

Suppose that a rod of length l and a uniform crossectional area a is subjected to a logitudinal pull. In other words, two equal and opposite forces are applied at its ends.

$$\text{Stress} = \frac{F}{A}$$

The stress in the present case is called linear stress, tensile stress, or extensional stress. If the direction of the force is reversed so that ΔL is negative, we speak of compressional strain and compressional stress. If the elastic limit is not exceeded, then from Hooke's law

Stress $\propto$ strain

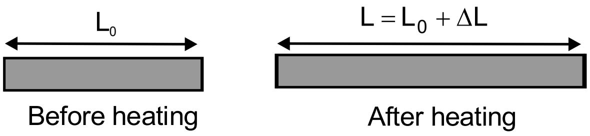
or Stress = Y $\times$ strain

or $$Y = \frac{\text{stress}}{\text{strain}} = \frac{F}{A} \cdot \frac{L}{\Delta L} \quad ...(1)$$

where Y, the constant of proportionality, is called the Young's modulus of the material of the rod and may be defined as the ratio of the linear stess to linear strain, provided the elastic limit is not exceeded. Since strain has no unit, the unit of Y is Nm^{-2}.

7.1 LINEAR EXPANSION

When the rod is heated, its increase in length ΔL is proportional to its original length L_0 and change in temperture ΔT where ΔT is in °C or K.



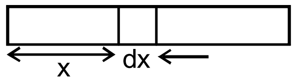
$dL = \alpha L_0 dT \quad \Rightarrow \quad \Delta L = \alpha L_0 \Delta T$ If a ΔT << 1

$\alpha = \dfrac{\Delta L}{L_0 \Delta T}$ where α is called the coefficient of linear expansion whose unit is $°C^{-1}$ or K^{-1}.

$L = L_0(1 + \alpha\Delta T)$. Where L is the length after heating the rod.

Variation of α with temperatue and distance

(a) If α varies with distance, α = ax + b



Then total expansion = $\int (ax+b)\Delta T dx$

(b) If α varies with temperature, α = f(T)

Then $\Delta L = \int \alpha L_0 dT$

Note :

- **Actually thermal expansion is always 3-D expansion. When other two dimensions of object are negligible with respect to one, then observations are significant only in one dimension and it is known as linear expansion.**
- **Avery linear dimenstions of the object changes in the same fashion**

7.2 Measurement of length by metallic scale :

Case (I)

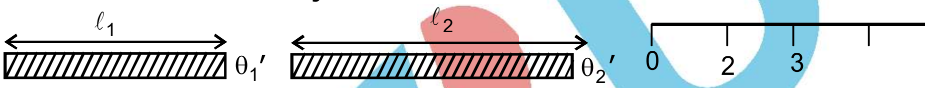
When object is expanded only

$\ell_2 = \ell_1\{1+\alpha_0(\theta_2 - \theta_1)\}$

ℓ_1 = actual length of object at θ_1°C = measure length of object at θ_1°C.

ℓ_2 = actual length of object at θ_2°C = measured length of object at θ_2°C

α_0 = linear expansion coefficient of object



Case (II)

When only measureal instrument is expaneded actual length of object will not change but measured value (MV) decreases.

MV = $\ell_1\{1-\alpha_s(\theta_2 - \theta_1)\}$

α_s = linear expansion coefficient of measuring instrument.

Case (III)

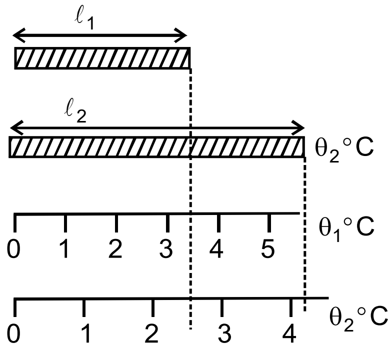
If both expanded simultaneously

MV = $l_1\{1 + (\alpha_0 - \alpha_s)(\theta_2 - \theta_1)\}$

(i) if $\alpha_0 > \alpha_s$, then measured value is more than actual value at θ_1°C

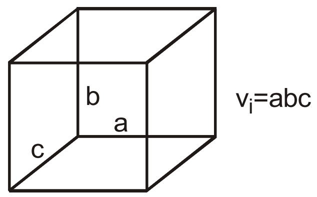
(ii) If $\alpha_0 < \alpha_s$, then measured value is less than actual value at θ_1°C

at θ_1 °C MV = 3.4, θ_2 °C MV = 4.1



7.3 VOLUME OR CUBICAL EXPANSION

When a solid is heated and its volume increases, then the expansion is called volume expansion or cubical expansion.



Note : Now after increase in temp by ΔT

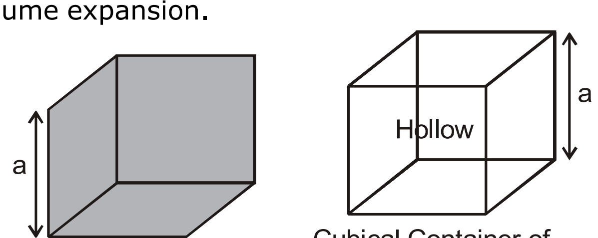
$V_f = a' b' c'$

$= a[1+\alpha\Delta T]^3 bc$

$= abc\,[1 + 3\,\alpha\,\Delta T]$ $\quad \therefore \alpha\Delta T << 1$

$v_f = v_i\,[1 + 3\alpha\Delta T]$

So $3\alpha = \gamma$ = coefficient of volume expansion.



Solid cube

Cubical Container of same material

1. When temperature changes the volume of the container and volume of the cube change in the same fashion because a changes in the same fashion.
2. In volume expansion of container we use γ of the container material.

SOLVED EXAMPLE

Ex.1 A structural steel rod has a radius of 10 mm and a length of 1.0 m. A 100 kN force stretches it along its length. Calculate (a) stress, (b) elongation, and (c) strain on the rod. Young's modulus, of structural steel is 2.0 × 10^{11} N m^{-2}.

Ans. We assume that the rod is held by a clamp at one end, and the force F is applied at the other end, parallel to the length of the rod. Then the stress on the rod is given by

$$\text{Stress} = \frac{F}{A} = \frac{F}{\pi r^2}$$

$$\frac{100 \times 10^3 N}{3.14 \times 10^2 m^2} = 3.18 \times 10^8 \text{ N m}^{-2}$$

The elongation,

$$\Delta L = \frac{(F/A)L}{Y} = \frac{3.18 \times 10^8 Nm^{-2} \times 1m}{2 \times 10^{11} Nm^{-2}}$$

$= 1.59 \times 10^{-3}$ m = 1.59 mm

The strain is given by Strain = ΔL/L

$= (1.59 \times 10^{-3} \text{ m})/(1\text{m}) = 1.59 \times 10^{-3} = 0.16$ %

Ex.2 A copper wire of length 2.2 m and a steel wire of length 1.6 m, both of diameter 3.0 mm, are connected end to end. When stretched by a load, the net elongation is found to be 0.70 mm. Obtain the load applied.

Ans. The copper and steel wires are under a tensile stress because they have the same tension (equal to the load W) and the same area of cross-section A. we have stress = strain × Young's modulus. Therefore $W/A = Y_c \times (\Delta L_c/L_c) = Y_s \times (\Delta L_s/L_s)$ where the subscripts c and s refer to copper and stainless steel respectively. Or, $\Delta L_c/\Delta L_s = (Y_s/Y_c) \times (L_c/L_s)$

Given $L_c = 2.2$ m, $L_s = 1.6$ m, $Y_c = 1.1 \times 10^{11}$ N.m^{-2}, and Y_s = 2.0 × 1011 N.m–2. $\Delta L_c/\Delta L_s$

$= (2.0 \times 10^{11}/1.1 \times 10^{11}) \times (2.2/1.6) = 2.5.$

The total elongation is given to be

$\Delta L_c + \Delta L_s = 7.0 \times 10^{-4}$ m

Solving the above equations,

$\Delta L_c = 5.0 \times 10^{-4}$ m, and $\Delta L_s = 2.0 \times 10^{-4}$ m.

Therefore $W = (A \times Y_c \times \Delta L_c)/L_c$

$= \pi(1.5 \times 10^{-3})^2 \times [(5.0\times10^{-4}\times1.1\times10^{11})/2.2]$

$= 1.8 \times 10^2$ N

Ex.3 In a human pyramid in a circus, the entire weight of the balanced group is supported by the legs of a performer who is lying on his back (as shown in Fig. 9.5). The combined mass of all the persons performing the act, and the tables, plaques etc. involved is 280 kg. The mass of the performer lying on his back at the bottom of the pyramid is 60 kg. Each thighbone (femur) of this performer has a length of 50 cm and an effective radius of 2.0 cm. Determine the amount by which each thighbone gets compressed under the extra load.

Ans. Total mass of all the performers, tables, plaques etc. = 280 kg Mass of the performer = 60 kg Mass supported by the legs of the performer at the bottom of the pyramid = 280 – 60 = 220 kg Weight of this supported mass = 220 kg wt. = 220 × 9.8 N = 2156 N. Weight supported by each thighbone of the performer = ½ (2156) N = 1078 N. the Young's modulus for bone is given by Y = 9.4 × 10^9 N m^{-2}.

Length of each thighbone L = 0.5 m the radius of thighbone = 2.0 cm Thus the cross-sectional area of the thighbone A =?× $(2 \times 10^{-2})^2$ m² = 1.26 × 10^{-3} m².

Using Eq. (9.8), the compression in each thighbone (?L) can be computed as ΔL = [(F × L)/(Y × A)]

$= [(1078 \times 0.5)/(9.4 \times 10^9 \times 1.26 \times 10^{-3})]$

$= 4.55 \times 10^{-5}$ m or 4.55×10^{-3} cm.

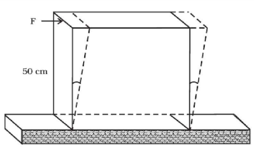
This is a very small change! The fractional decrease in the thighbone is ΔL/L = 0.000091 or 0.0091%.

Ex.4 A square lead slab of side 50 cm and thickness 10 cm is subject to a shearing force (on its narrow face) of 9.0 × 10^4 N. The lower edge is riveted to the floor. How much will the upper edge be displaced?

Ans. The lead slab is fixed and the force is applied parallel to the narrow face as shown in Fig. 9.7. The area of the face parallel to which this force is applied is A = 50 cm × 10 cm = 0.5 m × 0.1 m = 0.05 m²

Therefore, the stress applied is

$= (9.4 \times 10^4 \text{ N}/0.05 \text{ m}^2) = 1.80 \times 10^6 \text{ N.m}^{-2}$



We know that shearing strain = (Δx/L)= Stress /G.

Therefore the displacement Δx = (Stress XL)/G

$= (1.8 \times 10^6 \text{ N m}^{-2} \times 0.5\text{m})/(5.6 \times 10^9 \text{ N m}^{-2})$

$= 1.6 \times 10^{-4}$ m = 0.16 mm

Ex.5 The average depth of Indian Ocean is about 3000 m. Calculate the fractional compression, ΔV/V, of water at the bottom of the ocean, given that the bulk modulus of water is 2.2 ×10^9 N m^{-2}. (Take g = 10 m s^{-2})

Ans. The pressure exerted by a 3000 m column of water on the bottom layer

$p = h\rho g = 3000 \text{ m} \times 1000 \text{ kg m}^{-3} \times 10 \text{ m s}^{-2}$

$= 3 \times 10^7 \text{ kg m}^{-1} \text{ s}^{-2} = 3 \times 10^7 \text{ N m}^{-2}$

Fractional compression ΔV/V, is ΔV/V = stress/B

= (3 × 107 N m^{-2})/(2.2 × 10^9 N m^{-2})

$= 1.36 \times 10^{-2}$ or 1.36 %

Exercise - I UNSOLVED PROBLEMS

Q.1 The block oxide of copper is prepared in four different ways and the following observations noted:

Copper (in g)	Copper oxide (in g)
5.015	6.284
8.286	10.357
18.443	23.169
12.011	15.051

What do you infer form this data ?

Q.2 Given below are date on masses of two combining substances yielding more than one compound. Try to discover a striking feature hidden in these date.

Carbon	Oxygen (parts by mass)	Compound (parts by mass)
464.9	626.7	Carbon monoxide
9.3	2086.2	Carbon dioxide
Carbon	Hydrogen	Compound
334.6	111.2	Methane
854.5	146.4	Ethylene
Element	Sulphur	Compound
150.0	75.6	I
266.4	68.8	II

Q.3 Given the chemical formula for methane to be CH_4, obtain the ratio of mass of a carbon atom to the mass of a hydrogen atom from the data in Exercise 9.2, and predict some possible chemical formulae for ethylene.

Q.4 The following table gives observations on two gaseous reactions. In each set, the temperature and pressure conditions are kept fixed.

A. Nitrogen gas (cm^3)	Hydrogen gas (cm^3)	Ammonia gas (cm^3)
623.3	1830.0	1253.4
349.0	1051.2	685.6
84.7	251.9	170.7

B. Hydrogen gas (cm^3)	Oxygen gas (cm^3)	Water vapour (cm^3)
307.9	156.6	309.1
435.9	217.8	423.6
851.1	473.1	856.0

What do you infer from these data? Can you understand the law you have inferred empirically on the basis of the atomic picture and Avogardo's hypothesis?

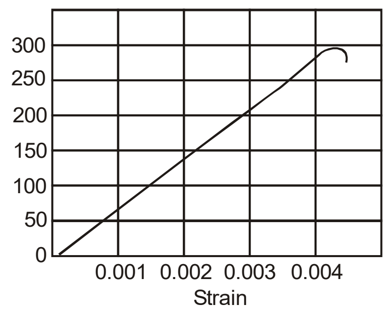
Q.5 (a) Avogadro's hypothesis is: "Equal volumes of all gases under the same conditions of temperature and pressure have the same number of molecules". Suppose we replaced 'molecules' by 'atoms' in this hypothesis. (By atoms we refer to indivisible entities in chemical reactions, unlike mol ecules, which can split into atoms). Would the modified hypothesis be correct ? Would it explain the data in 9.4?

(b) What is the atomicity of nitrogen, oxygen, and hydrogen suggested by the data in 9.4 ? (atomicity is the number of atoms in a molecule).

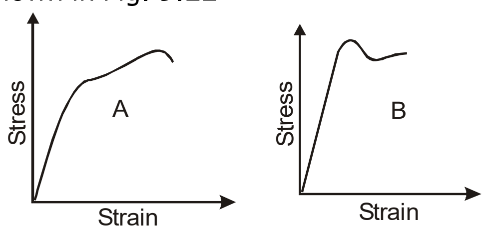
Q.6 A drop of olive oil of 1 mm diameter when transferred lightly over water dusted with lycopodium powder spreads out into a circular thin film of diameter 28.1 cm. Estimate the size of a molecule of the oil assuming that the film is only one molecule thick.

Q.7 A steel wire of length 4,7 m and cross-section 3.0×10^{-5} m^2 stretches by the same amount as a copper wire of length 3.5 m and cross-section 4.0×10^{-5} m^2 under a given load. What is the ratio of the Young's modulus of steel to that of copper ?

Q.8 Figure 9.21 shows the strain-stress curve for a given material. What are (a) Young's modulus and (b) approximate yield strength for this material ?



Q.9 The stress-strain graphs for martyries *A* and *B* are shown in Fig. 9.22



The graphs are drawn to the same scale.

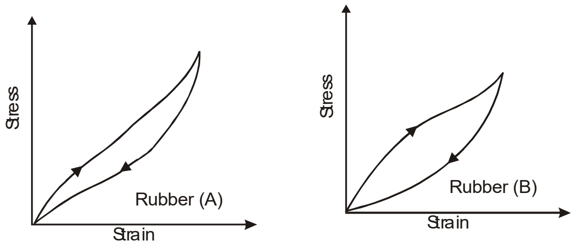
(a) Which of the material has greater Young's modulus

(b) Which material is more ductile ?

(c) Which is more brittle ?

(d) Which of the two is stronger material ?

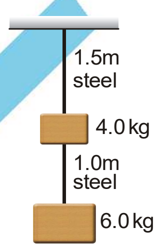
Q.10 Two different types of rubber are found to have the stress-strain curves as shown in Fig. 9.23.



(a) In which significant ways do these curves differ from the stress - strain curve of a metal wire shown in fig. 9.12 ?
(b) A heavy machine is to be installed in a factory. To absorb vibrations of the machine, a block of rubber is placed between the machinery and the floor. Which of the two rubbers A and B would you prefer to use for this purpose ? Why ?
(c) which of the tow rubber materials would you choose for a car tire ?

Q.11 Read each of the statements below carefully and state, with reasons, if it is true of false.
(a) The modulus of elasticity of rubber is greater than that of steel
(b) The stretching of a coil is determined by its shear modulus
(c) When a materials under tensile stress, the restoring force is due to inter -atomic repulsion
(d) A piece of rubber under an ordinary stress can display 1000% strain; yet when unloaded it returns to its original length. This shows that the restoring forces in a rubber piece are strictly conservative
(e) Elastic forces re strictly conservative when Hooks's law is obeyed

Q.12 Two wires of diameter 0.25 cm, one made of steel and other made of brass are loaded as shown in Figure. The unloaded length of steel wire is 1.5 m and that of brass wire is 1.0 m. Young's modulus of steel is 2.0 x 10^{11} Pa and that of brass is 0.91 x 10^{11} Pa. Compute the elongations of steel and brass wires. (1 Pa = 1 N n^{-2})



Q.13 The edges of an aluminium cube are 10 cm long. On face of the cube is firmly fixed to a vertical wall. A mass of 100 kg is then attached to the opposite face of the cube. The shear modulus of aluminium is 25 GPa. What is the vertical deflection of this face ? (1 Pa = 1 N m^{-2})

Q.14 A silica glass rod has a diameter of 1 cm and is 10 cm long. Using the data from table 9.1, estimate the largest mass that can be hung from it without breaking it.

Q.15 Compute the bulk modulus of water from the following data: initial volume =100.0 litre, Pressure increase = 100.0 atm. (1 atm=1.013 x 10^5), Final volume = 100.5 litre. Compare the bulk nodulus of water with that of air (at constant temperature). Explain in simple terms why the ratio is so large. (1 Pa = 1 N m^{-2})

Q.16 What is the density of water at a depth where pressure is 80.0 atm, given that its density at the surface is 1.03 x 10^3 kg m^{-3} ? (Compressibility of water is 45.8 x 10^{-11} Pa^{-1}; 1 Pa = 1 N m^{-2})

Q.17 You will appreciate from Exercise 9.3 that date on chemical combinations can at best yield ratios of atomic masses of different elements. This is why atomic masses are defined with respect to some 'reference atom'. In early chemistry, hydrogen was chosen to be the reference and assigned a unit mass. In the so called chemical scale, oxygen was assigned a mass of `6 units. By international agreement, the unified atomic mass unit (u) is defined to be such that the isotope ^{12}c has a mass exactly equal to 12 u. The difference between these different scales is slight but important for precision measurements. The mass of ^{137}Cs atom is 136.90707 u on the unified atomic scale. The mass of ^1H is 1.0078252 u on the same scale. What is the mass of ^{137}Cs atom with respect to the hydrogen reference scale ?

Q.18 Why are atomic masses (on say the unified scale) not exact integers ? Why is there a slight difference in the atomic mass of an element on different scales ?

Q.19 (a) If data on chemical combination give only relative atomic masses, how does one know the absolute mass of an atom of say oxygen ?
(b) Express 1 u in terms of Kg, given that the experimental value of Avogadro's number is N_A = 6.022045 x 10^{23} $mole^{-1}$

Q.20 Figure 9.1 in the text gives a plot of interatomic potential energy as function of the distance between two hydrogen atoms. Answer the following :
(a) if interatomic forces are electrical in nature, why do they not obey Coulomb's law; i.e. why do they fall of as 1 / r^7 for a large distance (instead of as 1 / r^7

expected on the basis of Coulomb's law).

(c) if the potential energy minimum is at $r = R_0 = 0.74$ Å, is the force attractive of repulsive at r = 0.5 Å, 1.9 Å and ∞ ?

Q.21 How much energy is needed to dissociate 0.05% of hydrogen gas occupying a volume of 5.6 liters under STP ? The binding energy of a hydrogen molecule is 4.75 eV.

Q.22 The interatomic separation in a neutral H_2 molecule is 0.74 Å and the binding energy is 4.75 eV. If an electron of the molecule is removed, the resulting molecular ion H_2^+ has a binding energy of 2.8 eV. Would you expect the separation between two protons in H_2^+ greater or less than 9.74 Å ?

Q.23 Explain (a) An energy of about 1.3 eV is need to create free Na^+ and Cl^- ions. [By this we mean that the Na^+ and Cl^- configuration at large distances has energy 1.3 eV. Higher than neutral Na and Cl atoms at large distances]. In spite of this initial investment the sodium chloride molecule prefers ionic binding. Why?

(b) A related question is why does H_2 prefer a covalent binding ? Why does it not prefer ionic binding H^+ H^- like Na^+ Cl^- ?

Q.24 The interatomic separation in an O_2 molecule is 1.2 Å and its binding energy is about 4.4 eV. The intermolecular potential energy between two oxygen molecules has a minimum at 2.9 Å. The two potential energy curves have roughly similar shapes. Would you expect the minimum of intermolecular potential energy in oxygen to be greater of less than 4.4 eV ? Check your expectation with the answer given in the text.

Q.25 In which principal aspects are intermolecular forces different from interatomic forces ? In which aspects are they similar ?

Q.26 Estimate the average intermolecular binding energy per molecular of (i) mercury, (ii) water if their latent heats of vaporization are 2.72×10^5 J kg^{-1} and 2.26×10^6 J kg^{-1} respectively. Is it correct to think that this substance apart from one another, i.e. the negative of the minimum of potential energy between two molecules ?

Q.27 Answer the following:

(a) If intermolecular potential energy has a minimum at some separation r = r, what is it that prevents all molecules of the given substance from collapsing to the condensed state where every pair has separation equal or r_0 ?

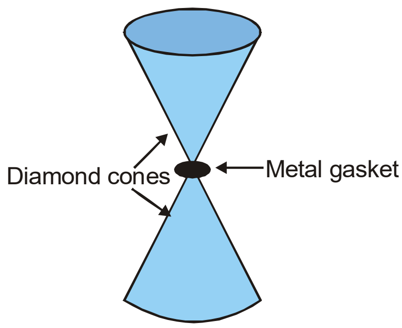
(b) Intermolecular attracting is the crucial thing for gas to liquid transition, while a repulsive potential energy at short distances is crucial for liquid to solid transition. Explain this important qualitative insight into the nature of phase transitions (Read section 9.3)

(c) give an example of an unusual phase of matter in nature, which arises due to the highly non- spherical shape of its molecules.

Q.28 Four in identical hollow cylindrical columns of steel support a big structure of mass 50,000 kg. The inner and outer radii of each column are 30 and 60 cm respectively. Assuming the to distribution to be uniform, calculate the compressional strain of each column. The Young's modulus of steel is 2.0×10^{11} Pa (1 Pa = 1 N m^{-2}).

Q.29 Anvils made of single crystals of diamond, with the shape as shown in Fig. 9.25, are used to investigate behavior of materials under very high pressures. Flat faces at the narrow end of the anvil have a diameter of 0.5 mm, and the wide ends are subjected to a compressional force of 50,000 N. What is the pressure at the tip of the anvil ?

Q.30 A composite wire of uniform diameter 3.0 mm consists of a copper wire of length 2.2 m and a steel wire of length 1.6 m stretches under a load by 0.7 mm. Calculate is 2.0×10^{11} Pa (1 Pa = 1 N m^{-2}).



Q.31 (a) You have discovered in Exercises 9.1 and 9.2 the 'law of constant proportions' and the 'low of multiple proportions'. Which of these two laws in your view suggests the atomic hypothesis ? Explain carefully.

(b) Would you regard Dalton's atomic hypothesis a fundamental improvement over the atomic views of ancient Indians and Greeks ? Justify your answer.