UNIT 06

Mechanical Properties of Matter

Q1. Define following basic terms in concept of deformation of solids. 09106001

(i) Deforming force (ii) Elasticity (iii) Elastic Limit

Ans: (1) Deforming force: *An external force applied on an object can change its size or shape. Such a force is* ***known as deforming force.***

(2) Elasticity:

An object is said to be elastic, if after removal of the deforming force, it restores to its original size and shape. This property of the material is **known as elasticity.** Due to this property, we can determine the strength of a material and the deformation produced under the action of a force.

Example:

(i) An appropriate force applied to a spring can increase its length called extension or cause compression thus reducing its length. If this force is removed, the spring will restore its original size and shape.

(ii) Similarly, stretched rubber strip or band comes to its original shape and size on removing the applied force.

(iii) When a tennis ball is hit by a racket, the shapes of tennis ball and also racket strings are distorted or deformed (Fig. 6.1). They regain their original shape after bouncing of the ball by the racket.

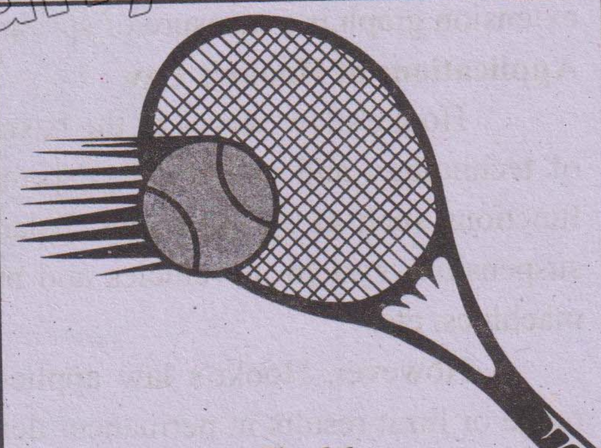


Fig.6.1

(3) Elastic limit:

Most of the materials are elastic up to a certain limit **known as elastic limit.** Beyond the elastic limit, the change becomes permanent. The object or material does not regain its original shape or size even after the removal of the deforming force.

Q2. What is Hooke's law? Give its three applications. 09106002

Ans: Statement of Hooke's law

"If force F is applied on a spring to stretch or compress it, the extension or compression x has been found directly proportional to the applied force within the elastic limit." Thus,

Mathematically,

$$F \propto x$$

Or

$$F = kx \qquad \text{or} \qquad k = \frac{F}{x} \quad ....(6.1)$$

Spring Constant: Where k is the constant of proportionality and is known as spring constant. In fact, it is a measure of stiffness of the spring. The greater the value of spring constant, the greater will be the stiffness or strength of the spring. Its unit is Nm^{-1}.

Graphical representation: A graph of force against extension is a straight line passing through the origin. If the applied force or load exceeds the elastic limit of the spring, it is permanently deformed and its graph will no longer remain linear. The gradient or slope of force-extension graph is a measure of spring constant k.

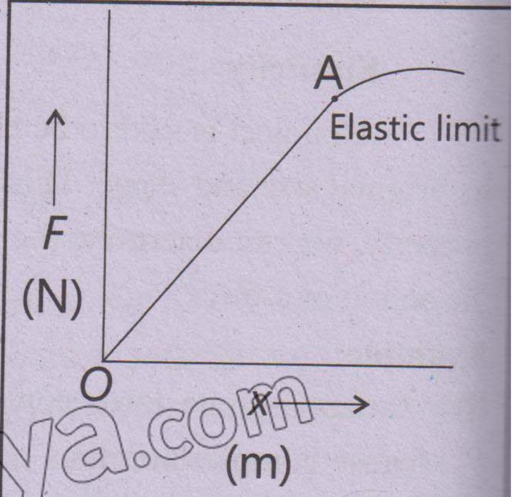


Fig.6.2

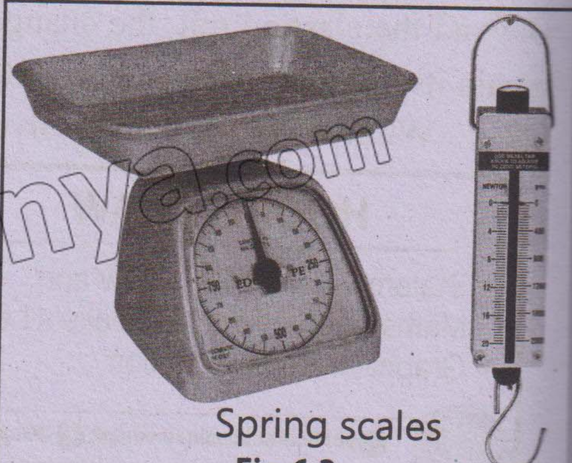
Applications of Hooke's Law

Hooke's law serves as the basic principle in wide range of applications. In the field of technology and engineering, springs in many devices rely on Hooke's low for their functions such as spring scales, balance wheel of the mechanical clocks, galvanometer, suspensions system in vehicles and motorbikes, door hinges, mattresses, material testing machines. etc.

However, Hooke's law applies within a specific range of forces. Exceeding the range or limit results in permanent deformation and no longer follows Hooke's law. Some of the uses are elaborated below:

(i) Spring scales

Spring scales use the extension or compression of a spring to determine the weight of objects. In a common spring balance the extension or elongation produced is a measure of the weight. In compression balance, the spring is compressed by the load (force) and the compression produced is measured by means of a pointer moving over a scale. Weighing machine usually use this type of balance.


Spring scales
Fig.6.3

(ii) Balance wheel of mechanical clocks

The balance wheel in mechanical clocks use spring to control the back and forth motion that regulates the speed of the hands of a clock (Fig. 6.4).

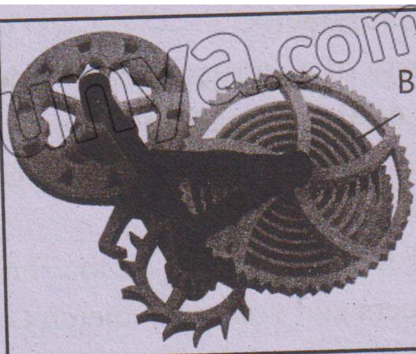
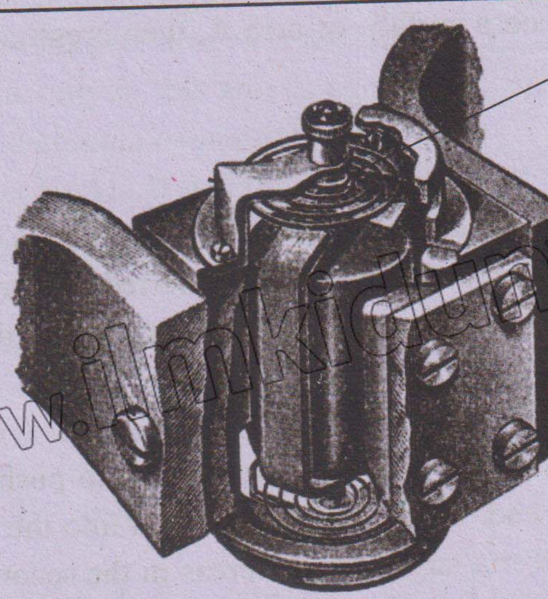


Fig.6.4

(iii) Galvanometer

Galvanometer is a current detecting device. It makes use of a tiny spring called hair spring (Fig. 6.5) which provides electrical connections to the galvanometer coil and also restores the pointer back to zero position. The deflection of the pointer is proportional to the current flowing through it within the range.



Inside of a Galvanometer

Fig. 6.5

Q3. Define and explain concept of Density. 09106003

Ans: Definition: Density of a substance is defined as its mass per unit volume.

Mathematically,

$$\text{Density} = \frac{\text{Mass}}{\text{volume}} \quad ....(6.2)$$

Unit: The Sl unit of density is kgm^{-3}. Other unit also in use is gcm^{-3}. Table shows the density of some substances.

Importance: The architects and engineers take special care of the density of the building material to be used in designing and constructing roads, bridges and buildings. The density of building material is essential for estimating the strength required in foundations and supporting pillars.

Table 7.1

Substance	Density (kgm^{-3})
Air	1.3
Patrol	800
Water	1000
Concrete	2400
Aluminum	2700
Steel	7800
Lead	11400
Gold	19300
Osmium	22600

Density measurement:

Density of a substance can be determined by measuring its mass and volume. The mass can be easily measured by a physical balance.

If the substance is solid and has a regular shape, its volume can be found by measuring its dimensions.

Example: If the substance is in the form of a sphere, its diameter can be measured by a Vernier Calipers and volume is thereby calculated. Knowing mass and volume, the density can be found out.

Q4. Define and explain term pressure. 09106004

Ans: Definition: Pressure is defined as the force exerted normally on unit area of an object.

Mathematically,

If F is the force acting normally on a surface of area A, then pressure P on the surface is given by

$$P = \frac{F}{A} \quad \text{................(6.3)}$$

Unit: In the system international, the unit of pressure is Nm^{-2} and is called pascal (Pa).

The area A on which the force acts is usually referred as contact area. Equation (6.3) shows that for a certain force, the pressure can be very large if the contact area A is small.

Explanation:

If a wooden rod has a flat end, it will be very difficult to push it into ground. On the other hand, if it has a pointed end, it can be easily pushed into the ground. In the first case, the applied force is spread over a large area, whereas in the second case, the force is concentrated on a small area. The force applied on the rod will exert greater pressure in the second case than in the first one.

Daily Life Examples

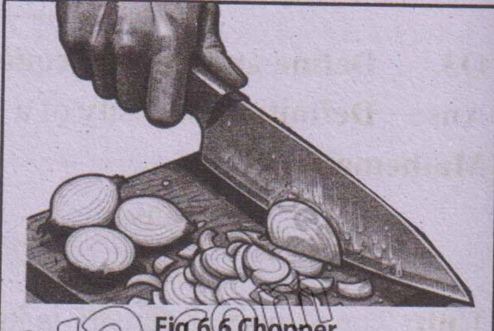


Fig.6.6 Chopper

(i) **Chopper:** The edge of the blade of a chopper is made very sharp. When we apply force on the handle of the chopper to cut an object, the pressure on the object, at the contact surface, due to its small area becomes very high and the object is easily cut (Fig. 6.6).

Fig.6.7 Thumb pin

(ii) **Thumb Pin:** The top of a thumb pin is flat but the end of the pin is very sharp. So, the contact area is very small. When we apply a force at the top, the pressure at the end of pin is so high that it pierces into the wooden board (Fig. 6.7).

(iii) Walking on ground: When we walk on ground, we exert a force on it due to which we experience a reaction force. When the ground is flat, this reaction force is spread over the whole area of the foot and the pressure due to reaction force is not painful. But when we walk on pebbles, the contact area is reduced. Then the pressure due to reaction force becomes so high that it becomes painful.

(iv) Elephant feet: Heavy animals like elephant have thick legs and large flat feet so that due to large contact area, pressure becomes less otherwise, their bones would not tolerate the pressure.

Q5. Derive an expression for pressure of a liquid in a container. On what factors it depends.

09106005

Ans: Explanation: Let us determine the pressure at a certain depth of a liquid. Figure: 6.8 shows a container of liquid. Consider an area A in the liquid at depth h. The force acting on this area is equal to the weight of the liquid column over surface A. The volume of this liquid is V=Ah. If p is the density of liquid, then mass m of the liquid column will be:

$$m = \rho V = \rho Ah$$

Therefore, force acting on area A will be

$F = mg = \rho Ahg$

The pressure P at area A will be,

$$P = \frac{F}{A} = \frac{\rho Ahg}{A}$$

Or $$p = \rho gh \qquad \text{............(6.4)}$$

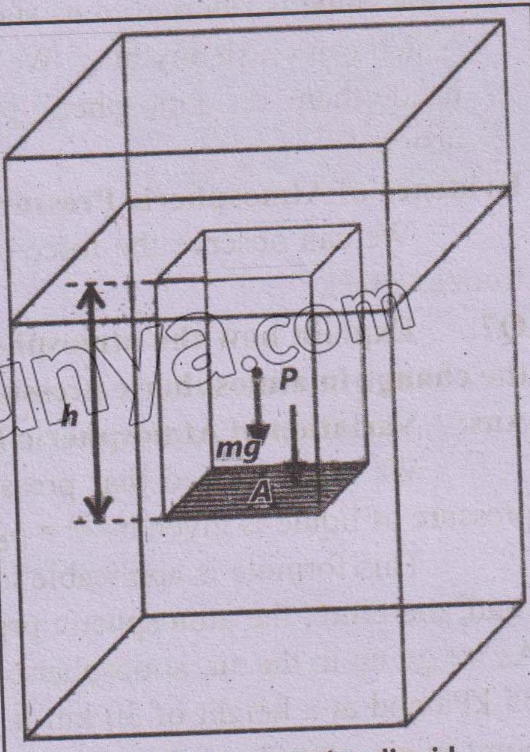


Fig. 6.8 Pressure in a liquid

Equation 6.4 shows that pressure in a liquid increases with depth.

Dependence:

The value of pressure depends on the depth and density of the liquid. Pressure produces force at right angle to the surface. A force or its component that is parallel to the surface, does not contribute to pressure. The pressure, by definition, is only contributed by the normal component of the force. That is, the force in a liquid that push directly against the surface and add up to a net force is perpendicular to the surface. It there is a hole in the surface of the liquid container, the liquid spurts at right angle to the surface before curving downward due to gravity.

Q6. Define and Explain Atmospheric Pressure.

09106006

Ans: Definition:

The atmosphere exerts pressure on the surface of the Earth and on everything on the Earth. This pressure is called atmospheric pressure.

Explanation:

(i) The Earth is surrounded by a layer of air which we call atmosphere. We know that air is a mixture of gases. Their molecules are always in motion. They collide with one another and with all other objects coming in their way. Thus, they exert force on the objects. This force per unit area is the atmospheric pressure. Since the molecules of air have random motion, therefore, atmospheric pressure acts equally in all direction.

(ii) Atmospheric pressure extends up to a height of about 100 kilometers. The density of air is not the same in the atmosphere. It decreases continuously with altitude.

(iii) We live at the bottom of the Earth's atmosphere which is a fluid that exerts pressure on our bodies. At sea level, the value of atmospheric pressure is about 1.013×10^5 Pa. This value is referred to as standard atmospheric pressure. It is an enormous pressure which can crush anything. We do not feel it because practically all the bodies have air inside them. As atmospheric pressure acts in all direction, so it balances the pressure inside.

Evidence of Atmospheric Pressure:

We can observe the force of the atmospheric pressure if we remove the inside air from a vessel.

Q7. Explain how the atmospheric pressure changes with height. Also explain how the change in atmospheric pressure represent expected weather. 09106007

Ans: Variation of Atmospheric Pressure with Height

We have studied that pressure in a liquid increases with depth. At depth h, the pressure of liquid is given by $P = \rho gh$

This formula is applicable to all the fluids. As the gases of the atmosphere are also fluid, therefore, the atmospheric pressure should be maximum on the ground at sea level. As we go up in the air, atmospheric pressure decreases. At a height of about 5km it falls to 55 kPa and at a height of 30 km it to 1 kPa. By measuring the atmospheric pressure at a point in air, altitude of that point can be determined. The lower the atmospheric pressure, the greater is the altitude.

Changes in Atmospheric Pressure as Weather Indicator

The atmospheric pressure does not always remain uniform but fluctuates. By observing the variation, the meteorologists can forecast the weather condition. Atmospheric pressure depends upon the density of air. At height altitudes, where the air is less dense, the atmospheric pressure falls down. Similarly, increase in the quantity of water vapours also decreases the density. Thus, atmospheric pressure becomes low in cloudy region. Weather casters use this knowledge to predict rains. A fall in pressure often means that rain clouds are on the way and the rain is to follow.

Q8. Describe the workings and application of a simple mercury barometer. 09106008

Ans: Measurement of Atmospheric Pressure by barometer:

Atmospheric pressure is usually measured by the height of mercury column which it can support. Instruments which measure the atmospheric pressure are called **barometers**.

Construction:

A simple mercury barometer consists of a glass tube about one metre long that is closed at one end. It is completely filled with mercury, then it is inverted vertically in a dish of mercury. A metre scale is placed by the side of the tube to measure the height of mercury column. The space in glass tube over the top of the mercury is completely empty. The pressure is almost zero.

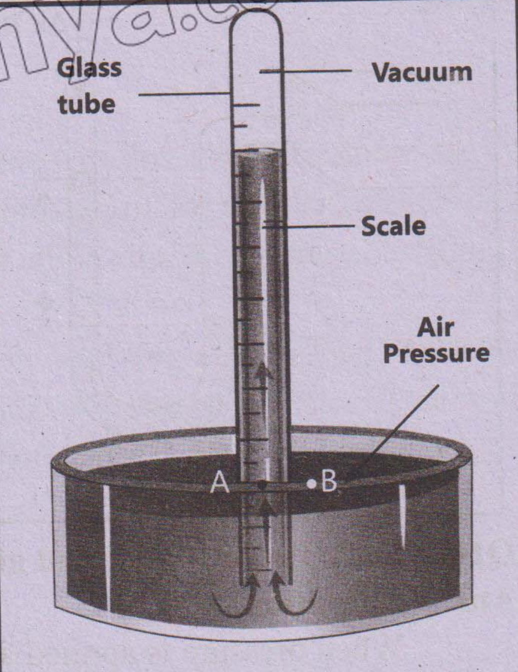


Fig 6.9 Barometer

Working:

The pressure P, at point A in the mercury column is the same as at point B at the surface of mercury column is the same as at point B at the surface of mercury in the dish because both the points are at the same level. This is equal to the atmospheric pressure $P = \rho gh$ acting at the surface of mercury in the dish. If we put $P = 1.013 \times 10^5$ Pa at sea level, $\rho = 13.6 \times 10^{-3}\text{kg m}^{-3}$ for mercury, the height of mercury column comes out to be 760 mm. By using this instrument atmospheric pressure at any altitude in the air can be measured in terms of height of mercury column.

Q9. How can you measure pressure by using manometer? 09106009

Measurement of Pressure by Manometer:

Ans: Construction:

A simple manometer consists of a U shaped glass tube which contain mercury. In the beginning, the atmospheric pressure at the two open ends of the tube is the same and hence, mercury level in the two arms remains same.

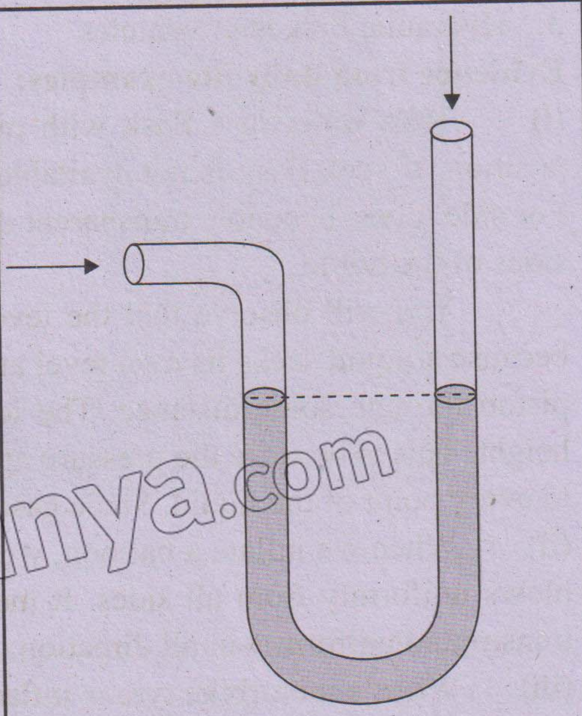


Fig. 6.10 manometer

Working:

If on connecting a gas cylinder with short arm keeping the longer arm of the tube open, the mercury level in short arm is lower than that in the long arm, then the unknown pressure is more than the atmospheric pressure. If the mercury level in the short arm is more than the long arm, then the unknown pressure is less that atmospheric pressure.

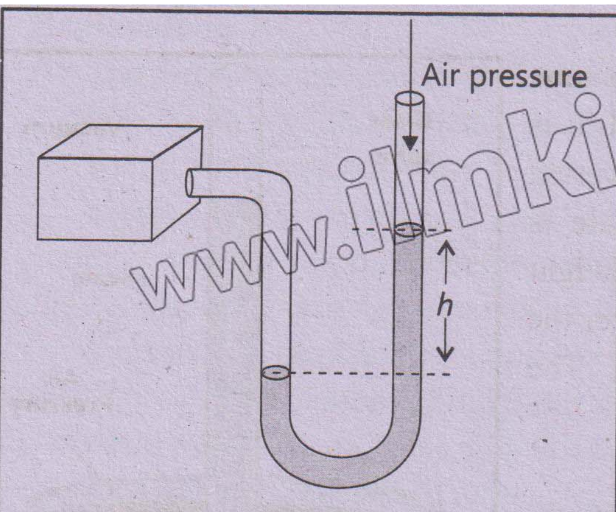


Fig. 6.11

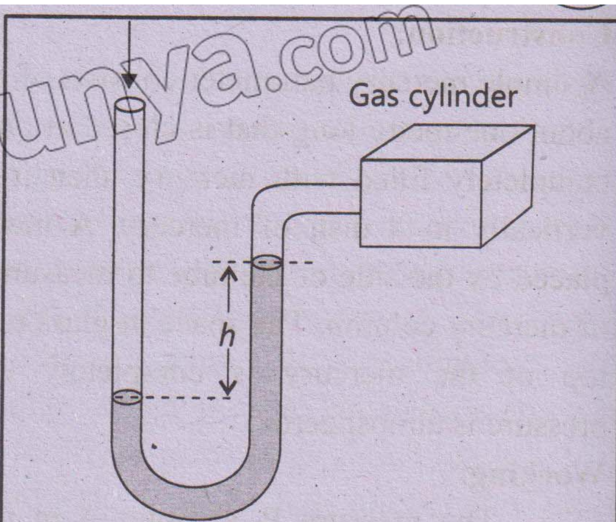


Fig. 6.12

Q10. State Pascal's Law and give daily life evidence of Pascal's Law. 09106010

Ans: Definition:

When pressure is applied at one point in an enclosed fluid, it is transmitted equally to all parts of liquid without loss.

Application:

The technology of hydraulic systems is bases on Pascal's law. Its main advantages are:

i. Liquids does not absorb any of the supplied energy.
ii. They are capable of moving much heavy loads and providing great forces due to incompressibility.

Some useful hydraulic systems are:

1. Hydraulic press
2. Car lift at service stations
3. Hydraulic brakes of vehicles

Evidence from daily life examples:

(i) Take water in a flask with piston and having a few side tubes fixed at different position. If such flask is not available, you can join a syringe at the mouth of a pet bottle. For side tubes, bendable transparent drinking straws can be glued on the holes punched on sides of the bottle.

You will observe that the level of water in all the side tubes is the same. This is because a liquid seeks its own level and rises to the same height at all points Now push the piston through some distance. The level of water in all the side tubes rises to the same height. This is because the pressure applied at one point of the liquid is transmitted equally to every point of the liquid. Since gases (air) and liquids are termed as fluid.

(ii) When we inflate a balloon, we blow air in it with a certain pressure but the balloon blows uniformly from all sides. It means that the pressure applied at its mouth has been transmitted uniformly in all direction.

(iii) When a motorbike tyre is inflated, air pressure is applied at one point but the tyre is uniformly inflated from all sides. This indicates that pressure is transmitted to each part of the tyre.

Q11. Describe Hydraulic press and Hydraulic brakes as an application of Pascal's Law. **09106011**

Ans: (i) Hydraulic press:

Construction:

Hydraulic press is a specially designed container. In this container there are two cylinders joined by means of a pipe. The cross-sectional area of the smaller cylinder is A_1 and that of the larger one is A_2. The cylinders are filled with some incompressible liquid.

Workings:

Suppose that the small piston is pressed down by applying a force F_1. The pressure $P_1 = F_1/A_1$ produced by small piston is transmitted equally to the large piston. Due to this pressure P_1 a force F_2, will act on A_2, which is given by $F_2 = PA_2$

Putting the value of P_1

$$F_2 = \frac{F_1}{A_1} A_2 \text{ .... (i)}$$

Since $A_2 > A_1$, therefore, $F_2 > F_1$. The result indicates that a small force applied on the smaller piston, results into a large force on the larger piston. Such a system is known as **force multiplier.**

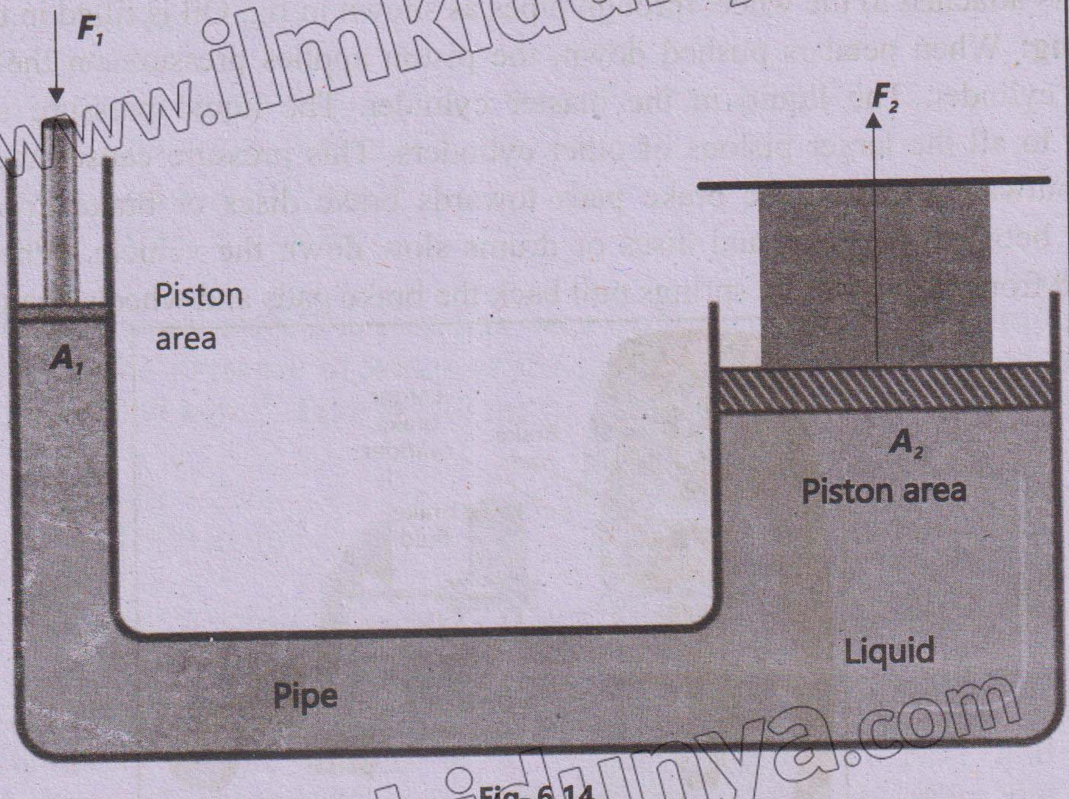


Fig. 6.14

Applications:

(i) Cotton bale or any other object to be compressed is placed over the larger piston. A force F_1 is applied on the smaller piston. The pressure P produced by smaller piston is transmitted equally to the larger piston. A much greater force F_2 acts on it. This force lifts the larger piston. A much greater force F_2 acts on it. This force lifts the larger piston and compresses the cotton bale.

(ii) This principle is also used at service stations to lift cars for washing.

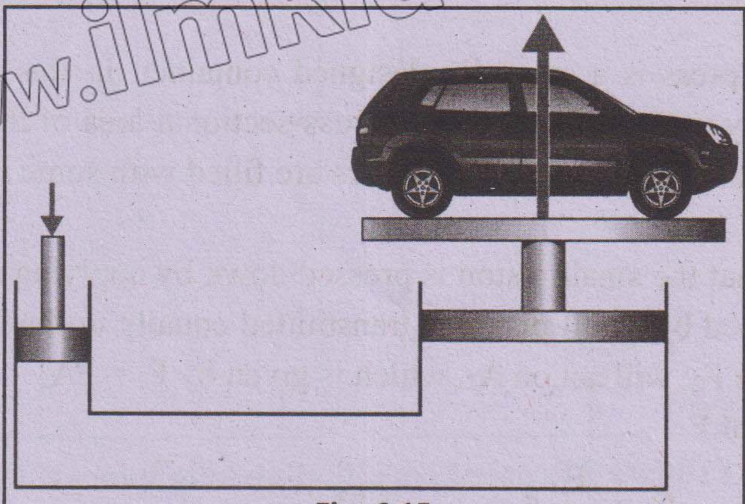


Fig. 6.15

(ii) Hydraulic Brakes

Construction: The brakes of some vehicles work on Pascal's law. In such type of brakes, cylinders with pistons are attached to the wheels. The brake pedal is attached to a master cylinder having smaller area of cross-section. Master cylinder is connected to all the larger cylinders attached to the wheel through pipes as shown in fig. Oil is filled in this system.

Working: When petal is pushed down, the piston applies pressure on the liquid in the master cylinder. The liquid in the master cylinder. The liquid pressure is transmitted equally to all the larger pistons of other cylinders. This pressure causes these pistons to move outward pressing the brake pads towards brake discs or brake drums. Force of friction between the pads and discs or drums slow down the vehicle. When pressure is released from the pedal, the springs pull back the brake pads and wheels again turn freely.

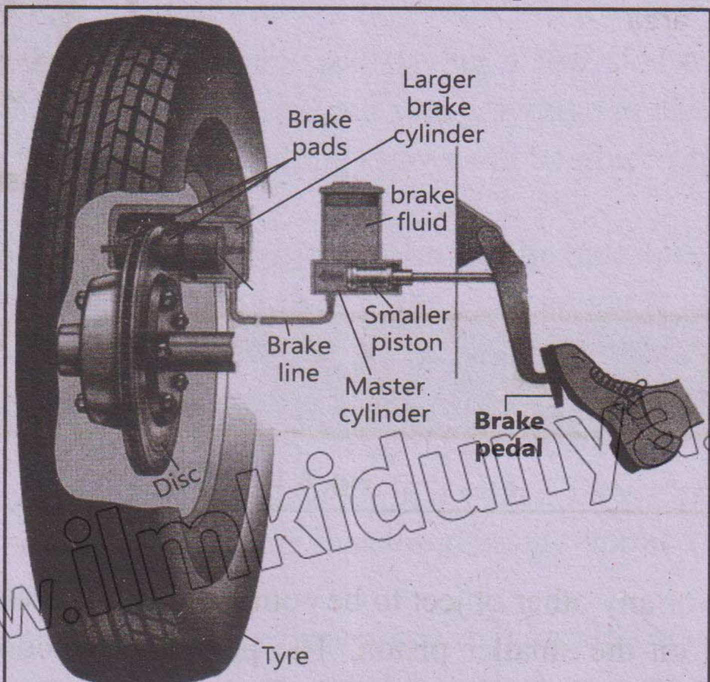


Fig. 6.16 Hydraulic brake system

Examples

Example 6.1: 09106012

The length, breath and thickness of an iron block are 3cm, 2cm, 2cm respectively. Calculate the density of iron if the mass of block is 94g.

Solution

Given Length = 3cm, Breadth = 2cm, Thickness = 2cm,
Mass = 94g, Density = ?

Using equation $\text{Density} = \dfrac{\text{Mass}}{\text{Volume}}$

where volume = Length × Breadth × Thickness

$= 3\text{ cm} \times 2\text{cm} \times 2\text{cm} = 12\text{cm}^3$

Hence, $\text{Density} = \dfrac{94\text{g}}{12\text{cm}^3} = 7.8\text{ g cm}^{-3}$

Thus, density of iron $= 7800\text{kg m}^{-3}$

Example 6.2 09106013

Calculate the pressure of column of mercury 76 cm high. Density of mercury is 13.6×10^{-3} kgm^{-3}

Solution:

Density $\rho = 13.6 \times 10^{-3}\text{kgm}^{-3}$

Height $h = 76\text{cm} = 76 \times 10^{-2}\text{m}$

$g = 10\text{ ms}^{-2}$

Pressure $P = \rho gh$

$P = 13.6 \times 10^{-3}\text{ kg m}^{-3} \times 10\text{ ms}^{-2} \times 76 \times 10^{-2}\text{m}$

$P = 1.034 \times 10^5\text{ kgm}^{-3} \times \text{ms}^{-2} \times \text{m}$

$P = 1.034 \times 10^5\text{ Nm}^{-2}$

$P = 1.034 \times 10^5\text{ Pa}$

Example 6.3 09106014

A cylindrical water tank 2m deep has been built on the top of a building 20m high. What will be the pressure of water at the ground floor when the tank is full? Density of water is 1000 kgm^{-3}. Take g = 10 ms^{-2}.

Solution:

Height h = 2 + 20 = 22m

Density $\rho = 1000\text{ kgm}^{-3}$

$g = 10\text{ ms}^{-2}$

$P = \rho gh = 22\text{m} \times 1000\text{ kg m s}^{-3} \times 10\text{ ms}^{-2}$

$P = 220000\text{ Pa} = 2.2 \times 10^5\text{ Pa}$

Examples 6.4 09106015

The diameters of the pistons of a hydraulic press are 5cm and 25cm respectively. A normal force of 160N is applied on the smaller piston, what will be the pressure exerted by this force on the bigger piston? How much weight can be lifted by the other piston?

Solution:

Let the areas of cross-sections of the pistons be A_1 and A_2 and their radii be r_1 and r_2 respectively.

Putting the values of $r_1 = \frac{5}{2}$ cm = 2.5×10^{-2}m , $r_2 = \frac{25}{2}$ cm = 12.5×10^{-2} m as $r = \frac{d}{2}$

$$A_1 = \pi r_1^2 \quad \text{and} \quad A_2 = \pi r_2^2$$

Force on the smaller piston $F_1 = 160$ N. Its pressure on the piston is

$$P = \frac{F_1}{A_1} = \frac{F_1}{\pi r_1^2}$$

If the weight lifted by the bigger piston is w, then according to the Pascal's law.

$$\frac{F_1}{A_1} = \frac{w}{A_2}$$

Or

$$w = \frac{F_1 A_2}{A_1} = \frac{F_1 \pi r_2^2}{\pi r_1^2} = \frac{F_1 \times r_2^2}{r_1^2}$$

Putting the values,

$w = 160\ N \times (12.5 \times 10^{-2}m)^2 / (2.5 \times 10^{-2}m) = 4000N = 4kN$

So, we can lift 4000 N weight by applying a force of 160 N on smaller piston.

Exercise

(A) Multiple Choice Questions

1. **A wire is stretched by a weight w. If the diameter of the wire is reduced to half of its previous value, the extension will become:** **09106016**
(a) one half
(b) double
(c) one fourth
(d) four times

2. **Four wires of the same material are stretched by the same load. Their dimensions are given below. Which of them will elongate most?** **09106017**
(a) Length 1m, diameter 1mm
(b) Length 2m, diameter 2mm
(c) Length 3m, diameter 3mm
(d) Length 4m, diameter 0.5mm

3. **Two metal plates of area 2 and 3 square meters are placed in a liquid at the same depth. The ratio of pressures on the two plates is:** **09106018**
(a) 1:1
(b) $\sqrt{2} : \sqrt{3}$
(c) 2:3
(d) 4:9

4. **The pressure at any point in a liquid is proportional to:** **09106019**
(a) density of liquid
(b) depth of the point below the surface of the liquid
(c) acceleration due to gravity
(d) all of the above

5. **Pressure applied to an enclosed fluid is:** **09106020**
(a) increased and applied to every part of the fluid
(b) diminished and transmitted to the walls of container
(c) increased in proportional to the mass of fluid and then transmitted to each part of the fluid
(d) transmitted unchanged to every portion of the fluid and walls of containing vessel

6. **The principle of a hydraulic press is based on:** 09106021
(a) Hooke's law
(b) Pascal's law
(c) Principle of conservation of energy
(d) Principle of conservation of momentum

7. **When a spring in compressed, what form of energy does it possess?** 09106022
(a) Kinetic
(b) Potential
(c) Internal
(d) Heat

8. **What is the force exerted by the atmosphere on a rectangular block surface of length 50cm and breadth 40 cm? The atmospheric pressure is 100 kPa.** 09106023
(a) 20kN
(b) 100 kN
(c) 200 kN
(d) 500 kN

Answer Key

1.	(d)	2.	(d)	3.	(a)	4.	(d)
5.	(d)	6.	(b)	7.	(b)	8.	(a)

SLO based Additional MCQs

Elastic Behavior of Material

1. **The most elastic material of the following is:** 09106024
(a) Rubber
(b) Wood
(c) Glass
(d) Steel

Hooke's Law

2. **Hooke's law hold good up to:** 09106025
(a) Proportional unit
(b) Yield limit
(c) Elastic limit
(d) Plastic

Spring Constant

3. **A mass of 2 kg is hung by spring, which displaces it through 5 cm. the spring constant is:** 09106026
(a) 400 N/m
(b) 40 N/m
(c) 4 N/m
(d) 4000 N/m

Deforming of Material

4. **Materials which does not regain its original shape after removal of the load producing deformation are termed as:** 09106027
(a) Elastic materials
(b) Plastic materials
(c) Rigid materials
(d) Hooke's materials

Pressure

5. **SI unit of pressure is:** 09106028
(a) Pascal
(b) Newton
(c) Zero
(d) Infinite

6. **Which will exert greater pressure?** 09106029

(a) 3 g needle of tip area 1mm^2

(b) 4000 kg elephant of total feed area 0.5 m^2

(c) A girl of mass 40 kg wearing high heel shoes of cross-sectional area 0.5 cm^2

(d) A loaded ship of mass 2.2×10^7 kg having area 600mm^2.

7. **Pressure of 1000 m bars is equivalent to:** 09106030

(a) 0.1 kPa

(b) 1 kPa

(c) 10 kPa

(d) 100kPa

8. **A girl of mass 50 kg wears heels with an area of 2 cm^2 in contact with the ground. The pressure she exerts on ground is:** 09106031

(a) 4×10^{-5} Pa

(b) 245×10^4 Pa

(c) 4×10^{-4} Pa

(d) 4×10^5 Pa

9. **Divers wear special suites in order to protect them from:** 09106032

(a) Low pressure

(b) High pressure

(c) Low temperature

(d) High temperature

10. **In a stationary fluid, the local pressure of the fluid vary:** 09106033

(a)With depth only

(b) Horizontally only

(c) Both with depth and along horizontal direction

(d) Neither with depth nor along horizontal direction

11. **The pressure exerted by a man on the surface of earth will be smaller when he:** 09106034

(a) Stands on both feet

(b) Sits on the ground

(c) Stands on one leg

(d) Sleeps on the ground

Atmospheric Pressure

12. **Pressure of 1 mm Hg is equal to:** 09106035

(a) 1.316×10^{-3} atm

(b) 1 atm

(c) 133.29 atm

(d) 1.316×10^{5} atm

13. **Atmospheric pressure is commonly measured using a:** 09106036

(a) Hygrometer

(b) Barometer

(c) Monometer

(d) Thermometer

14. **The atmospheric pressure will be smaller at:** 09106037

(a) Islambad (b) Peshawar

(c) Lahore (d) Murree

Pressure in Liquid

15. **Pressure of liquid in a container increase with:** 09106038

(a) Base (b) Volume

(c) Depth (d) Mass

Density

16. **Which amount of water has greater density at room temperature?** 09106039

(a) 100g

(b) 1 kg

(c) 1 ton

(d) All have same density

17. **What is mass of a liquid of density $50\ kg\,m^{-3}$ in a container of volume $5m^3$?** 09106040

(a) 200 kg (b) 225 kg

(c) 250 kg (d) 275 kg

Mercury Barometer

18. **Which of the following physical properties is used in a mercury thermometer?** 09106041

(a) Electrical resistance (b) Pressure

(c) Volume (d) Colour

Answer Key

1.	(d)	2.	(a)	3.	(a)	4.	(b)	5.	(d)
6.	(c)	7.	(d)	8.	(d)	9.	(b)	10.	(a)
11.	(d)	12.	(a)	13.	(b)	14.	(d)	15	(c)
16.	(c)	17.	(c)	18.	(c)				

(B) Short Answer Questions

6.1 Why heavy animals like an elephant have a large are of the foot? 09106042

Ans: Mathematically: $P = \frac{F}{A}$

Large area of feet to spread their weight over a bigger area, reduce air pressure on ground.

Thus, heavy animals like elephant have a large area of the foot to reduce pressure on ground.

6.2 Why animals like deer who run fast have a small area of the foot? 09106043

Ans: Deer have small feet to run faster by reduce air fraction with ground. This helps the deer escape predation easily.

6.3 Why is it painful to walk bare footed on pebbles? 09106044

Ans: $P = \frac{F}{A}$

When we walk on bare footed, the small contact area with high pressure, cause in pain. A large contact area would spread the force, reduce in pressure and discomfort.

6.4 State Pascal's law. Give an application of Pascal's law. 09106045

Ans: Pascal's Law:

When pressure is applied at one point in an enclosed fluid, it is transmitted equally to all parts of liquid without loss.

Applications:

(i) Hydraulic press

(ii) Car lift at service station

(iii) Hydraulic brakes of vehicles

6.5 State what do you mean by elasticity of a solid? 09106046

Ans: The property of an object to re-gain its original size and shape after removal of applied force is called elasticity.

6.6 What is Hooke' law? Does an object remain elastic beyond elastic limit? 09106047

Ans: Hooke's law states that extension or compression is directly proportional to force applied.

No, an object does not remain elastic beyond its elastic limit. Once the elastic limit is exceeded, the object undergoes plastic deformation and does not return to its original shape.

6.7 Distinguish between force and pressure. 09106048

Ans: Force: An agent which produces or tends to produce motion, stops or tends to stop the motion or deforms or tends to deform an object.

Pressure: The normal force per unit area is called pressure.

Mathematically:

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

6.8 What is the relationship between liquid pressure and the depth of the liquid? 09106049

Ans: The pressure of liquid given by relation

$$P = \rho g h$$

It is clear that pressure is directly proportional to depth of liquid ($P \propto h$).

6.9 What is basic principle to measure the atmospheric pressure by a simple mercury barometer? 09106050

Ans: The basic principle is hydrostatic pressure utilizing a liquid column in a barometer.

6.10 State the basic principle used in the hydraulic brake system of the automobiles. 09106051

Ans: See QNo.4.

SLO Based Additional Short Questions

Elasticity

6.1 Steel is more elastic than rubber. Why? 09106052

Ans. In steel more effort is required to change the shape as compared to rubber because the steel molecules retain their shape quickly as the deforming force ceases to act. That is why steel is more elastic than rubber.

6.2 What are inelastic materials? 09106053

Ans. Some materials such as clay dough or plasticine do not return to their original shape after the removal of the deforming force. They are known as inelastic materials.

Pressure

6.3 Why sports boots have studs on their soles? Explain. 09106054

Ans. Sports boots for football and hockey have studs on their soles. They reduce the area in contact between your feet and the ground. This increases the pressure and your feet grip the surface more firmly.

6.4 Why atmospheric pressure decreases with altitude? 09106055

Ans. Atmospheric pressure extends up to a height of about 100 kilometers. The density of air is not the same in the atmosphere. It decreases continuously with altitude and hence atmospheric pressure decreases with altitude.

We have studied that pressure in a liquid increases with depth. At depth h, the pressure of liquid is given by $P = \rho g h$

This formula is applicable to all the fluids. As the gases of the atmosphere are also fluid, therefore, the atmospheric pressure should be maximum on the ground at sea level. As we go up in the air, atmospheric pressure decreases. At a height of about 5km it falls to 55 kPa and at a height of 30 km it to 1 kPa.

6.5 How changes in atmospheric pressure is linked with weather? 09106056

Ans. The atmospheric pressure does not always remain uniform but fluctuates. By observing the variation, the meteorologists can forecast the weather condition. Atmospheric pressure depends upon the density of air. At height altitudes, where the air is less dense, the atmospheric pressure falls down. Similarly, increase in the quantity of water vapours also decreases the density. Thus, atmospheric pressure becomes low in cloudy region. Weather casters use this knowledge to predict rains. A fall in pressure often means that rain clouds are on the way and the rain is to follow.

6.6 A girl is walking on a carpet wearing high heel shoes, it leaves deep impressions on the carpet. Why? 09106057

Ans. Pressure is given by:

$$P = \frac{F}{A} = \frac{\text{constant}}{A} \Rightarrow P \propto \frac{1}{A}$$

For a constant force, pressure is inversely proportional to the area, i.e., if area is less then pressure is more and vice versa. In case of heels, the pressure is concentrated on a very small area thus pressure exerted by it is more and hence leaves a deeper marks on the carpet.

6.7 Why is the cutting edge of the knife mad very thin? 09106058

Ans. We know that the pressure is given by,

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

Equation (1) shows that pressure is inversely proportional to the area. That is greater the area, smaller will be the pressure and vice versa. Now the cutting edge of the knife is made very thin for getting smaller area and maximum pressure by increasing pressure, we can cut various objects with knife very easily.

6.8 Why water tanks are constructed at the highest level in our houses? 09106059

Ans. We know that the pressure of liquid in terms of height is given by,

$$P = \rho g h --- (1)$$

Equation (1) shows that the pressure of water pipe system increases with height. Thus for the easy flow of water in a pipe system, the water tanks are constructed at the highest level in our houses.

6.9 If you filled an airtight balloon at the top of a mountain, would the balloon expand or contract as you descend the mountain? Explain. 09106060

Ans. At the top of mountains, the air pressure is lower as compared to plane area. So low pressure air will be filled in a balloon at the top of mountains.

Now when moves from mountains towards plane areas, the air pressure increases. Thus the outside air pressure becomes higher than air pressure inside the balloon. The high atmospheric pressure stress the walls of the balloon inwards, due to which the balloon contracts and its volume decreases.

6.10 Explain how and why camels have adapted to allow them to walk more easily in desert conditions? 09106061

Ans. We know that,

$$P = \frac{F}{A} --- (1)$$

Equation (1) shows that pressure is inversely proportional to the contact area, i.e. larger the contact area smaller will be pressure exerted and vice versa. Since camels have feet with comparatively large surface area, therefore they exert little pressure. As a result of less pressure, their feet does not insert deep in the sand and remain on upper surface of the sand. Thus they can walk in desert easily due to less pressure exerted by their feet on sand surface.

6.11 Why dams are made thick at its bottom? 09106062

Ans. Pressure exerted by liquid is given by:

$$P = \rho g h \Rightarrow P = (\text{constant})\, h$$

$$\Rightarrow P \propto h$$

Since pressure in liquid is directly proportional to the height of the liquid, i.e., depth of the dam. Thus, as the depth increases, more and more pressure is exerted by water on the walls of the dam. A thicker wall can withstand greater pressure, therefore, the thickness of the dam increases towards the bottom.

Barometer

6.12 Can we use water instead of Hg to construct a barometer? Explain. 09106063

Ans. Water is not suitable in barometer because of its lower density. The density of mercury is 13.6 times than water. So the height of water column at sea-level in barometer will be

(0.76m) (13.6) = 10.335m, (760mm = 0.76m)

A glass tube with this length is not practicable, that's why water is not suitable use in barometer.

6.13 Why reading on barometer decreases when we travel to higher altitude areas? 09106064

Ans. Barometer is a device used for measuring atmospheric pressure. Atmospheric pressure decreases as we travel to high altitude areas. When atmospheric pressure decreases, the pressure on the mercury inside barometer also decreases. This decrease in pressure on the mercury leads to a decrease in the mercury level in column.

6.14 If you climbed a mountain carrying a mercury barometer, would the level of the mercury column in the glass tube of the barometer increase or decrease as you climb the mountain? Explain. 09106065

Ans. The level of mercury in the column depends upon the atmospheric pressure, i.e. greater the atmospheric pressure, high will be the level of mercury in the column and vice versa.

Now we know that the atmospheric pressure decreases at the top of mountains, so the level of mercury in glass tube of the barometer will fall down i.e. decreases.

Hooke's Law

6.15 Define elastic limit, Hooke's Law and Young's modulus. 09106066

Ans. **Elastic Limit:** It is a limit with in which a body recovers its original length, volume or shape after the deforming force is removed. When a stress crosses this limit, a body is permanently deformed and is unable to restore its original state after the stress is removed.

Hooke's Law: "The strain produced in a body by the stress applied to it is directly proportional to the stress within the elastic limit of the body".

Young's modulus: The ratio of stress to tensile strain is called young's modulus"

$$Y = \frac{\text{Stress}}{\text{Tensile Strain}}$$

(C) Constructed Response Questions

6.1 A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension x, the elastic limit of the spring is not exceeded. 09106067

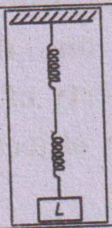
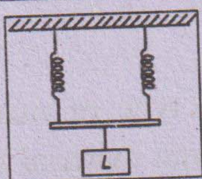
Ans: Some identical springs, each with spring constant k, are arranged as shown below:

For each arrangement, complete the table by determining:

i. The total extension in terms of x.

ii. The spring constant in terms of k.

Ans:

Arrangement	Total Extension x	Spring constant (k) of the arrangement
	x $L = kx$ $\Rightarrow x = \frac{L}{k}$	$K_{eff} = K$
	$L = kx_1 = kx_2$ $x_1 = x_2 = L/K$ $2x$	$\frac{1}{k} = \frac{1}{k} + \frac{1}{k} = \frac{2}{k}$ $K_{eff} = \frac{k}{2}$

For spring in sovier, the total extension is the sum of extension of each spring.

6.2 Spring are made of steel instead of iron. Why? 09106068

Ans:

i. Steel is more durable and can with stand higher pressure without deforming.

ii. Steel has greater strength and corrosion resistance.

6.3 Which of the following material is more elastic? (a) Iron and rubber (b) Air and water 09106069

Ans: **(a)** Iron is more elastic than rubber because iron returns to its original shape more completely after the deforming forces are removed.

Rubber, on the other hand, undergoes more permanent deformation.

(b) Air is more elastic than water because air can be compressed and expanded more easily than water, returning to its original volume and shape.

6.4 How does water pressure one metre below the surface of a swimming pool compare to water pressure one metre below the surface of a very large and deep lake? 09106070

Ans: The water pressure 1 meter below the surface is the same in both a swimming pool and a large lake, assuming both are freshwater. The pressure is given by formula:

$$P = \rho gh$$

Where P is the pressure, ρ is the water density, g is gravity and h is depth. At 1 meter the pressure is the same in both environment because depth and density

6.5 What will happen to the pressure in all parts of a confined liquid if pressure is increased in one part? Give an example from your daily life where such principle is applied. 09106071

Ans: According to Pascal's Principle, if pressure is increased in one part of a confined liquid, the pressure will increase equally in all other parts of the liquid.

Example from daily life: Hydraulic Brake System in vehicles.

When you press the brake pedal, it increases the pressure in the master cylinder, which is filled with brake fluid (a confined liquid). This increased pressure is transmitted equally to all parts of the brake system, including the brake calipers, which then apply the pressure to the brake pads to stop the vehicle.

6.6 If some air remains trapped within the top of the mercury column of the barometer which is supposed to be vacuum, how would it affect the height of the mercury column? 09106072

Ans: The trapped air in the barometer adds pressure, which lower the Hg height by opposing atmospheric pressure.

6.7 How does the long neck is not a problem to a giraffe while raising its neck suddenly? 09106073

Ans: The long neck of giraffe is not a problem when raised suddenly due to a special value called the "rete mirabile" which regulates blood pressure and flow to the brain.

6.8 The end of glass tube used in a simple barometer is not properly sealed, some leak is present what will be its effect? 09106074

Ans: It causes the reading lower than actual atmospheric pressure.

6.9 Comment on the statement, "Density is a property of a material not the property of an object made of that material." 09106075

Ans: $\rho = \frac{m}{v}$

It depends upon type of material and is constant for a given material regardless of size or shape of object.

6.10 How the load of a large structure is estimated by an engineer? 09106076

Ans:

An engineer estimates a large structure's load by calculating the weight of materials, occuptants and external forces like wind, snow and earthquakes.

(D) Comprehensive Questions

6.1 What is Hook's law? Give three applications of this law. 09106077

Ans: See QNo.2

6.2 Describe the working and applications of a simple mercury barometer and a manometer. 09106078

Ans: See QNo.8+9

6.3 Describe Pascal's Law. State its applications with examples. 09106079

Ans: See QNo.10

6.4 On what factors the pressure of a liquid in a container depend? How is it determined? 09106080

Ans: See QNo.5

6.5 Explain that atmosphere exerts pressure. What are its application? Give at least three examples. 09106081

Ans: See QNo.6

(E) Numerical Problems

6.1 A spring is stretched 20 mm by a load of 40N. Calculate the value of spring constant. What will be the weight of an object if it causes an extension of 16mm? 09106082

Solution:

Extension = $x = 20\text{mm} = 20 \times 10^{-3}\text{m}$

Load = F = 40 N

Spring constant = K = ?

$F = Kx$

$40 = K(20 \times 10^{-3})$

$$K = \frac{40}{20\times10^{-3}} = 2\times10^{3}\,\text{N/m}$$

$= 2\ \text{KN/m}$

$F = mg$

Also

$F = K\Delta x$

$mg = K\Delta x$, Here $\Delta x = 16\text{mm} = 16\times10^{-3}\text{m}$

$F = K\Delta x = 2 \times 10^{3} \times 16 \times 10^{-3}$

$F = 32\text{N}$

6.2 The mass of 5 litres of milk is 4.5kg. Find its density in SI units. 09106083

Solution:

Given data

Mass of milk = m = 4.5 kg

Volume of milk = v = 5 litres = $5 \times 10^{-3}\text{m}^{-3}$

To Find

Density = $\rho = \frac{m}{v}$

$$\rho = \frac{4.5}{5 \times 10^{-3}}$$

$$\rho = 900\ \text{kg m}^{-3}$$

OR

$\rho = 0.9 \times 10^{-3}\text{kg m}^{-3}$

6.3 When a solid of mass 60 g is lowered into a measuring cylinder, the level of water rises from $40\ \text{cm}^3$ to $44\ \text{cm}^3$. Calculate the density of the solid. 09106084

Solution:

Given Data:

Mass of solid (m) = 60 g = $\frac{60}{1000}$ = 0.060 kg

Initial water level = $40\ \text{cm}^3$

Final water level = $44\ \text{cm}^3$

Volume of solid = V =

Final water level − Initial water level

$V = 44\text{cm}^3 - 40\text{cm}^3$

$V = 4\text{cm}^3 = 4 \times (10^{-2})\text{m}^3$

$= 4 \times 10^{-6}\text{m}^3$

To Find:

Density = ρ = ?

Solution:

$$\rho = \frac{m}{v}$$

$$\rho = \frac{0.060}{4 \times 10^{-6}}$$

$\rho = 15 \times 10^{3}\text{kg m}^{-3}$

Result:

Hence the density of solid is $15 \times 10^{3}\text{kg m}^{-3}$.

6.4 A block of wood of density $8 \times 10^{3}\text{kg m}^{-3}$ has a volume $60\ cm^3$. Find its mass. 09106085

Solution:

Given Data

Density = $\rho = 80 \times 10^{3}\text{kg m}^{-3}$

Volume = $V = 60cm^3 = 60 \times (10^{-2})^3 m^3 = 60 \times 10^{-6} m^3$

To find:

Mass = m = ?

Solution:

$$\rho = \frac{m}{v}$$

$m = \rho \times v$

$m = 8 \times 10^3 \times 60 \times 10^{-6}$

$m = 480 \times 10^{-3}$

OR

$m = 0.48$ kg

Result:

The mass of block is 0.48 kg.

6.5 A brick measures $5\,cm \times 10\,cm \times 20\,cm$. If its mass is 5 kg, calculate the maximum and minimum pressure which the brick can exert on a horizontal surface. **09106086**

Solution:

Given Data:

Mass of brick = m = 5kg

Gravitational acceleration = g = $10ms^{-2}$

Dimension of the brick:

Length = 20cm = $\frac{20}{100}$ = 0.2 m

Width = 10 cm = $\frac{10}{100}$ = 0.1 m

Height = 5 cm = $\frac{5}{100}$ = 0.05 m

To Find:

Maximum pressure P_{max} =?

Minimum pressure P_{min} =?

Force is equal to weight of brick so,

F = w = mg = (5) (10) = 50 N

Now calculate areas:

Area 1 = A_1 = Length × width = 0.2 × 0.1 = $0.02\,m^2$

Area 2 = A_2 = width × height = 0.1 × 0.05 = $0.005\,m^2$

Area 3 = A_3 = Length × height = 0.2 × 0.05 = $0.01\,m^2$

Maximum Pressure exert when the brick rests on the smallest area ($A_2 = 0.005m^2$

$P_{max} = \frac{F}{A_2} = \frac{50}{0.005} = 10{,}000 Pa$

OR

$P_{max} = 1 \times 10^4 Pa$

Minimum pressure exert when the brick rests on the largest area ($A_1 = 0.02m^2$)

$P_{min} = \frac{F}{A_1} = \frac{50}{0.02} = 2500 Pa$

OR

$P_{min} = 25 \times 10^2 Pa$

Result:

The maximum and minimum pressure exert by brick on horizontal surface is 1×10^4 Pa and $25 \times 10^2 Pa$ Respectively.

6.6 What will be the height of the column if mercury is replaced by water of density $1000\ kgm^{-3}$, where density of mercury is $13.6 \times 10^3 kgm^{-3}$. **0910608**

Solution:

Given Data:

Density of water = $\rho_{water} = 1000 kgm^{-3}$

Density of mercury = $\rho_{mercury} = 13.6 \times 10^3 kgm^{-3}$

Height of mercury column at sea level = h_{hg} = 760 mm

$h_{Hg} = 760 \times 10^{-3} = \frac{760}{10000} = 0.76\,m$

To Find:

Height of water = h_{water}=?

Since the pressure exerted by both the mercury and water columns should be equal, we write.

$\rho_{Hg} \times g \times h_{Hg} = \rho_{water} \times g \times h_{water}$

$\rho_{Hg} \times h_{Hg} = \rho_{water} \times h_{water}$

$\frac{\rho hg \times hhg}{\rho water} = h_{water}$

$h_{water} = \frac{13.6 \times 10^3 \times 0.76}{1000}$

h_{water} = 10.336 m

Result:

The height of the water column will be 10.336m.

6.7 Suppose in the hydraulic brake system of a car, the force exerted normally on its piston of cross-sectional area of 5 cm^2 is 500 N. What will be the pressure transferred to the brake oil? What will be the force on the second piston of area of cross-section 20 cm^2.

09106088

Solution:

Given Data:

Force on small piston = $F_1 = 500\ N$

Cross-sectional area of the small piston = $A_1 = 5cm^2$

$= 5 \times (10^{-2})^2 m^2 = 5 \times 10^{-4} m^2$

Cross-sectional area of large piston = $A_2 = 20\ cm^2$

$= 20 \times (10^{-2})^2 = 20 \times 10^{-4} m^2$

To find:

Pressure on the oil = P = ?

Force on large piston = F_2 = ?

$$P = \frac{F_1}{A_1}$$

$$P = \frac{500}{5 \times 10^{-4}}$$

$$P = 1.0 \times 10^6\ Nm^{-2}$$

and

$$F_2 = P \times A_2$$

$$F_2 = 1.0 \times 10^6 \times 20 \times 10^{-4}$$

$$F_2 = 2000\ N$$

Result:

Pressure transferred to brake oil is $1.0 \times 10^6 Nm^{-2}$ and force on large piston is 2000 N.

6.8 Find the water pressure on a deep-sea diver at a depth of 10m, where the density of sea water is 1030 kg m^{-3}.

09106089

Ans: Given Data:

Depth = h = 10m

Density = ρ = 1030 kgm^{-3}

Gravitational acceleration = g = 10ms^{-2}

To find:

Water pressure = P = ?

Solution:

$$P = \rho \times g \times h$$

$$P = 1030 \times 10 \times 10$$

$$P = 10300$$

$$P = 1.03 \times 10^5 Nm^{-2}$$

Result:

The water pressure on the deep-sea water is $1.03 \times 10^5 Nm^{-2}$

6.9 The area of cross-section of the small and large pistons of a hydraulic press is respectively 10 cm^2. What force should be exerted on the small piston in order to lift a car of weight 4000 N?

09106090

Solution:

Given Data:

Cross-sectional are of small piston = $A_1 = 10cm^2 = 10 \times (10^{-2})^2 m^2 = 10 \times 10^{-4} m^2$

Force on large piston = F_2 = 4000 N

Cross-sectional area of large piston = $A_2 = 100cm^2 = 100 \times (10^{-2})^2 m^2 = 100 \times 10^{-4} m^2$

To Find:

Force applied on the small piston = F_1 = ?

By Pascal's law

$$\frac{F_1}{A_1} = \frac{F_2}{A_2}$$

$$F_1 = \frac{F_2}{A_2} \times A_1$$

$$F_1 = \frac{4000}{100 \times 10^{-4}} \times 10 \times 10^{-4}$$

$$F_1 = \frac{4000}{100} \times 4000$$

$$F_1 = 0.1 \times 4000 = 400\ N$$

Result:

The force that should be external on small piston is 400N.

6.10 In a hot air balloon, the following data was recorded. Draw a graph between the altitude and pressure and find out: 09106091

(a) What would the air pressure have been at sea level?

(b) At what height the air pressure would have been 90 kPa?

Altitude (m)	Pressure (kPa)
150	99.5
500	95.7
800	92.4
1140	88.9
1300	87.2
1500	85.3

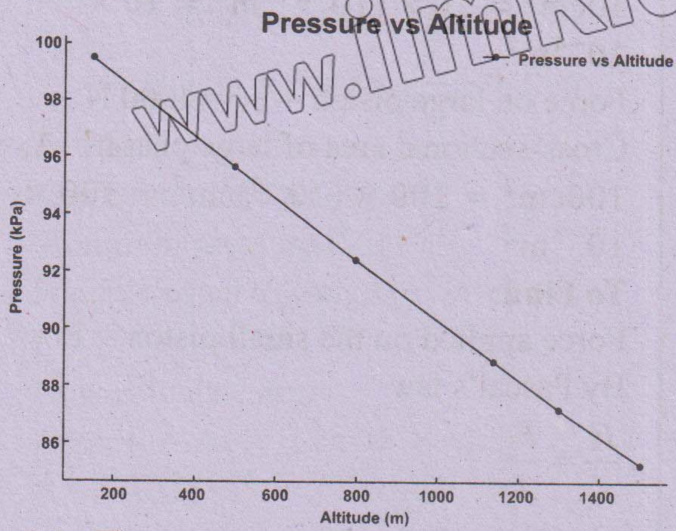
Solution:

To Find:

(a) Air pressure at sea level = P=?

(b) Height at the air pressure 90 Kpa

(c) Draw the graph b/w altitude and pressure



(a) The rate of pressure change with altitude is

$$\frac{P}{h}=\frac{95.7-99.5}{500-150}$$

$$=-\frac{3.8}{350}$$

$$\frac{P}{h}=-0.01086 \text{ kpa/m}$$

Now pressure at sea level h = 0m

P = 99.5 + (−0.01086)(0 − 150)

P= 99.5 + 1.629

P= 101.1 Kpa

$P = 1.01 \times 10^2 \times 10^3$Pa

$P = 1.01 \times 10^5$ Pa

(b)

Using the data points for 92.4 Kpa at 800m and 88.9 Kpa at 1140m.

The rate of pressure change.

$$\frac{P}{h}=\frac{88.9-92.4}{1140-800}=-\frac{3.5}{340}$$

$$\frac{P}{h}=-0.01029 \text{ Kpa/m}$$

Now,

90 = 92.4 + (−0.01029) (h − 800)

$$-\frac{2.4}{0.01029}=h-800$$

233.3 = h − 800

233.3 + 800 = h

H = 1033.3 m ≈ 1.02 km

6.11 If the pressure in a hydraulic press in increased by an additional 10 N cm^{-2}, how much extra load will the output platform support if its cross-sectional area is 50 cm^2. 09106092

Solution:

Given Data:

Additional pressure = P = 10 N/cm^2

Cross-sectional area of the output platform = A = 50cm^2

To Find:

Extra load: F =?

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

$$F=P\times A$$

$$F=10N/cm^2\times 50cm^2$$

$$F=500\ N$$

Result:

The extra load supported by the output platform is 500 N.

6.12 The force exerted normally on the hydraulic brake system of a car, with its piston of cross sectional area 5 cm^2 is 500 N. What will be the:

09106093

(a) pressure transferred to the brake oil?

(b) force on the brake piston of area of cross-section 20 cm^2?

Solution:

Given Data:

Force on small piston $= F_1 = 500\ N$

Cross-sectional area of the small piston $=$ $A_1 = 5cm^2$

$= 5 \times (10^{-2})^2 m^2 = 5 \times 10^{-4} m^2$

Cross-sectional area of large piston $= A_2 =$ $20\ cm^2$

$= 20 \times (10^{-2})^2 = 20 \times 10^{-4} m^2$

To find:

Pressure on the oil = P = ?

Force on large piston $= F_2 = ?$

$$P = \frac{F_1}{A_1}$$

$$P = \frac{500}{5 \times 10^{-4}}$$

$$P = 1.0 \times 10^6\ Nm^{-2}$$

and

$$F_2 = P \times A_2$$

$$F_2 = 1.0 \times 10^6 \times 20 \times 10^{-4}$$

$$F_2 = 2000\ N$$

Result:

Pressure transferred to brake oil is $1.0 \times 10^6 Nm^{-2}$ and force on large piston is 2000 N.

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