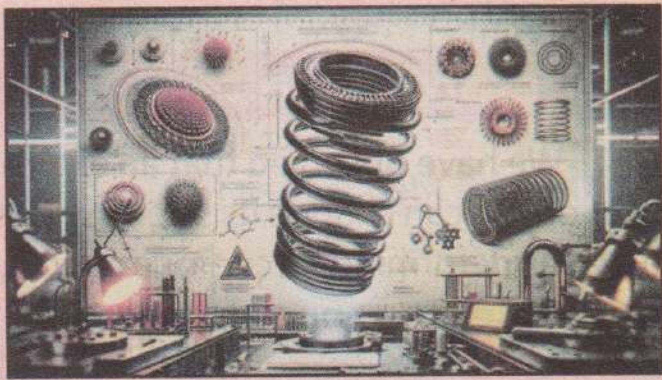
Chapter 6

Mechanical Properties of Matter

Student Learning Outcomes

After completing this chapter, students will be able to:



- Illustrate that forces may produce a change in size and shape of an object.
- Define and calculate the spring constant [apply the equation, spring constant = force/extension $k = F/x$ to solve problems involving simple springs]
- Sketch, plot and interpret load–extension graphs for an elastic solid and describe the associated experimental procedures.
- Define and use the term 'limit of proportionality' for a load-extension graph [Including identifying this point on the graph (an understanding of the elastic limit is not required)]
- Illustrate the applications of Hooke's law [Such as that it is the fundamental principle behind engineering many measurement instruments such as the spring scale, the galvanometer, and the balance wheel of the mechanical clock.]
- Define and calculate density.
- Define and calculate pressure [As force per unit area. Use the equation pressure = force/area $P = F/A$ to solve simple problems]
- Describe how pressure varies with force and area in the context of everyday examples
- Describe how pressure at a surface produces a force in a direction at right angles to the surface [can make reference to experiments to verify this principle]
- Justify that the atmosphere exerts a pressure.
- Describe that atmospheric pressure decreases with the increase in height above the Earth's surface.
- Explain that changes in atmospheric pressure in a region may indicate a change in the weather.
- Analyse the workings and applications of a liquid barometer
- Justify and analyse quantitatively how pressure varies with depth in a liquid
- Describe the working and applications of a manometer
- Define and apply Pascal's law [Apply Pascal's law to systems such as the transmission of pressure in hydraulic systems with particular reference to the hydraulic press and hydraulic brakes on vehicles]

You have learnt in lower classes that every thing around us is made up of matter. The matter normally exists in solid, liquid and gaseous states. These states are due to attractive force that exists between the atoms and molecules. We have already studied some basic properties of matter. In this chapter, we will discuss mechanical properties of matter that are of vital importance of a material for various useful purposes in technology and engineering. The main contents included in this chapter are: deformation of solids due to some applied force, density and pressure.

6.1 Deformation of Solids

We have observed that an external force applied on an object can change its size or shape. Such a force is known as deforming force. For example, 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. Similarly, stretched rubber strip or band comes to its original shape and size on removing the applied force.

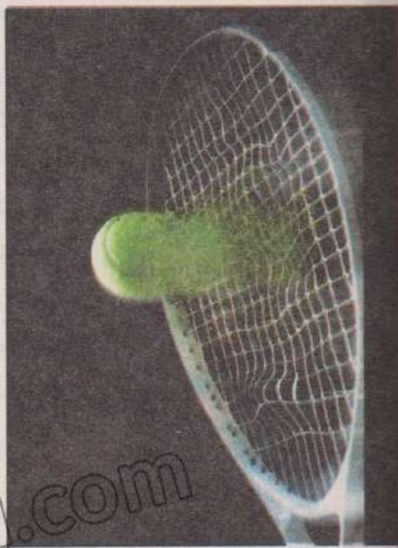


Fig. 6.1

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. 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.

For Your Information!

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.

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.

6.2 Hooke's Law

If a 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,

$$F \propto x$$

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

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 N m^{-1}.

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*.

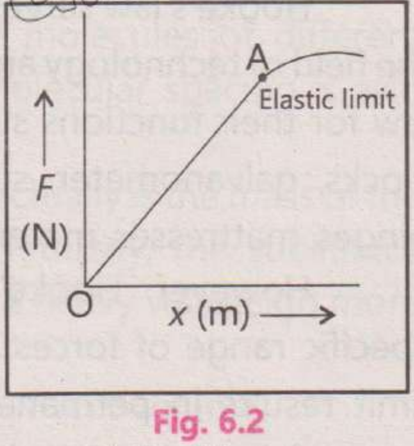


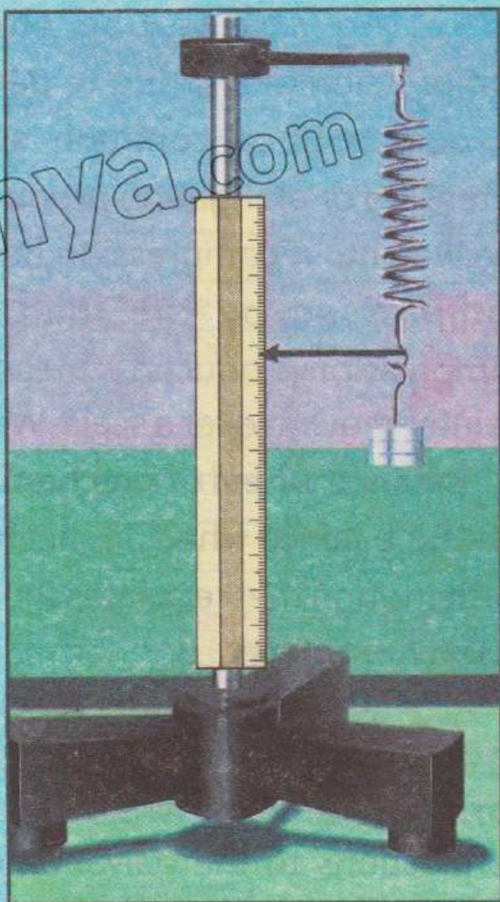
Fig. 6.2

Hooke's law also holds when a force is applied to a straight thin wire or a rubber band within its elastic limit.

Activity 6.1

The teacher will arrange a helical spring with an attached pointer, slotted weights, half metre rule or scale, iron stand and will facilitate to perform this activity as per instructions. Note that a spring of helical or spiral shape is called helical spring. Its length should be greater than its diameter.

(i) Suspend a helical spring with the stand.
(ii) Adjust the pointer so that it does not touch the scale but can move up and down freely along the scale.
(iii) Place a slotted weight say 50 g in the hanger and note the position of pointer on the scale.
(iv) Repeat this step for five times, each time increasing the load in equal amount.
(v) Draw a graph between force *F* along y-axis and extension x along x-axis.
(vi) What is the shape of the graph?
(vii) What does it show?
(viii) Find the slope of the straight line. What does it represent?



Quick Quiz

1. If the above experiment is repeated with a stiffer spring (high value of *k*), what will be the effect on the graph?
2. How can you find the value of unknown weight using this experiment?

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 law 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:

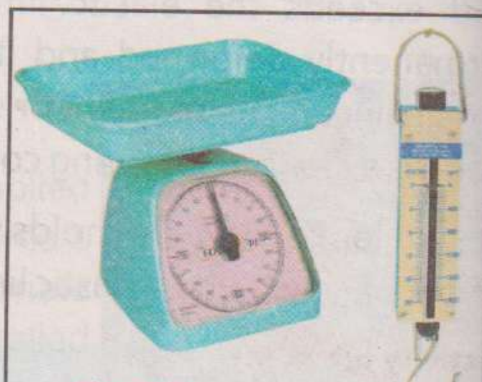


Fig. 6.3 Spring scales

1. 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.

Fig. 6.4

2. 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).

3. 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.

Fig. 6.5

6.3 Density

If you take equal volumes of different substances and weigh them by a balance, you will find that each of them has a different mass. That is, one centimetre cube of wood may weigh only 0.7 g but made of iron will weigh 8.0 g. Why is it so? You know that all substances are composed of molecules. The molecules of different substances are different in size and mass. The inter-molecular spacing is also different.

The mass of equal volume of various substances actually is the mass of the total number of molecules present in that volume. Naturally, the substance whose molecules are densely packed and also which are heavy will weigh more than others.

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

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

The SI unit of density is kg m^{-3}. Other unit also in use is g cm^{-3}. Table 7.1 shows the density of some substances.

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.

Example 6.1 The length, breath and thickness of an iron block are 3 cm, 2 cm, 2 cm respectively. Calculate the density of iron if the mass of block is 94 g.

Solution

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

Using Eq. 6.2 $\quad \text{Density} = \frac{\text{Mass}}{\text{Volume}}$

where Volume = Length × Breadth × Thickness
$= 3 \text{ cm} \times 2 \text{ cm} \times 2 \text{ cm} = 12 \text{ cm}^3$

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

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

For Your Information!

Packing foam or polythene has a very low density.

Table 7.1

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

For Your Information!

Immiscible liquids of different densities form layers when they are mixed.

Quick Quiz

How will you measure the volume if the object is lighter than the liquid?

For Your Information!

Density is a test to know the purity of a substance.

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.

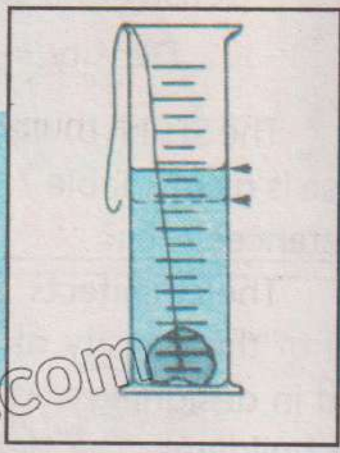
Quick Quiz

By which property can you identify a silver spoon and a stainless steel spoon?

If the substance is solid and has a regular shape, its volume can be found by measuring its dimensions. For example, if the substance is in the form of a sphere, its diameter can be measured by a Vernier Callipers and volume is thereby calculated. Knowing mass and volume, the density can be found out. If the solid has not a geometrical shape, its volume is determined by the following activity:

Activity: 6.2

Teacher should facilitate to help the groups to pour some water in a measuring cylinder. If the substance is soluble in water, then use a liquid in which the substance is insoluble. Note the level of the liquid in the cylinder. Now gently drop the substance into the cylinder. The rise in the level gives the volume of the substance.



6.4 Pressure

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.

For Your Information!

The force in both the pictures is same, equal to weight of the bag. In right hand picture, the area of contact is the greater than in the left hand picture. We say that the pressure is less in the right hand picture.

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

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

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

For Your Information!

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.

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.

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

Daily Life Examples

1. 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).
2. 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).
3. 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.
4. 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.

Fig. 6.6 Chopper

Fig. 6.7 Thumb pin

Brain Teaser!

Why a bulldozer has large pillar tracks instead of wheels?

6.5 Pressure in Liquids

We have learnt in the lower classes that liquids exert pressure in all directions. Moreover, liquid pressure increases with depth.

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 ρ 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 $$P = \rho gh \quad \text{.................. (6.4)}$$

Equation 6.4 shows that pressure in a liquid increases with depth. The value of pressure depends on the depth and density of the liquid.

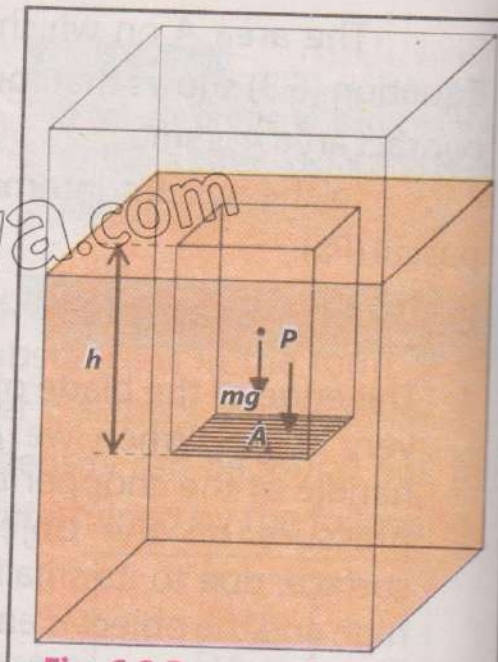


Fig. 6.8 Pressure in a liquid

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 forces in a liquid that push directly against the surface and add up to a net force is perpendicular to the surface. If 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.

Example 6.2

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

Solution

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

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

$g = 10 \text{ m s}^{-2}$

As Pressure $= \rho gh$

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

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

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

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

For Your Information!

Some liquids under pressure can dissolve more gas than a liquid at a lower pressure. When we open a bottle of soda water, the pressure in the bottle is decreased. The liquid can no longer hold as much gas. The dissolved gas comes out of the solution and rises to the surface of the liquid in the form of bubbles.

Example 6.3

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

Solution

Height $h = 2 + 20 = 22\,m$

Density $\rho = 1000\ kg\,m^{-3}$

$g = 10\,m\,s^{-2}$

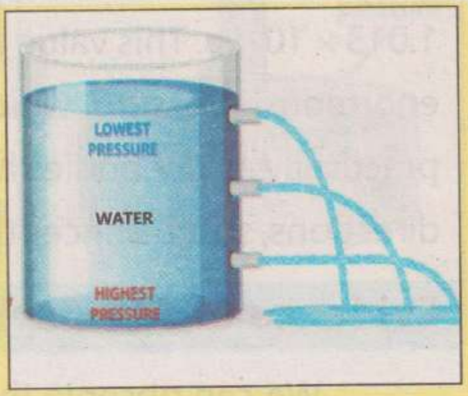
$P = \rho gh = 22\,m \times 1000\,kg\,m^{-3} \times 10\,m\,s^{-2}$

$= 220000\,Pa = 2.2 \times 10^5\,Pa$

Activity 6.3

Teacher should help the students to perform this activity and initiate discussion as per instructions:

i. Make three small holes at different heights in the side of a container as shown in the figure.
ii. Fill the container with water.
iii. Observe the water streams flowing out of the holes. It is initially normal to the surface.
iv. Which one of the streams hits the ground at larger distance?
v. At which position the liquid has more pressure?



You will observe that the stream from each hole, initially flows out normal to the surface before curving down due to gravity and the lowest hole has more pressure. It shows that liquid pressure increases with depth.

Activity 6.4

Teacher should demonstrate or help the students to perform by following the instructions given below:

(i) Fill a polythene shopping bag with water.
(ii) Poke several holes by using a pin on the bag.
(iii) Squeeze the bag gently.
(iv) What do you observe?

Squeezing the top of bag causes the water to squirt on in all directions. It means the pressure is transmitted equally throughout the liquid.

6.6 Atmospheric Pressure

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 directions.

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

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

Do You Know?

The pressure of 1 atmosphere is equivalent to placing a 1.0 kg mass (10 N weight) on an area of 1 cm^2.

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 directions, so it balances the pressure inside.

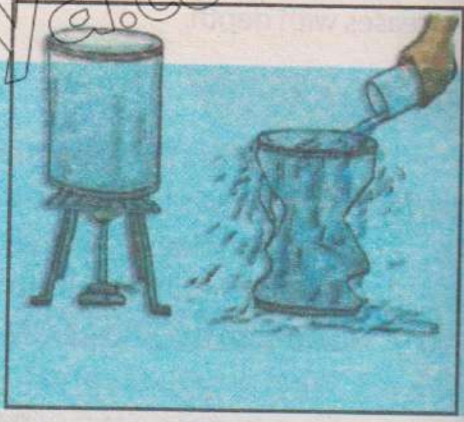
Evidence of Atmospheric Pressure

We can observe the force of the atmospheric pressure if we remove the inside air from a vessel as shown in the following activity.

Activity 6.5

The teacher should perform this activity in the class following the given instructions.

Boil some water in a tin can. When it is full of steam, remove it from the burner and close its mouth by an air tight cork. Then pour cold water over it. The can crumples as shown in the figure. Why does the tin crumples?



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

$$P = \rho g h$$

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 5 km, it falls to 55 kPa and at a height of 30 km, it falls 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.

6.7 Measurement of Atmospheric Pressure

Atmospheric pressure is usually measured by the height of mercury column which it can support. Instruments which measure the atmospheric pressure are called barometers. 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 (Fig. 6.9). The space in glass tube over the top of the mercury is completely empty. The pressure is almost zero.

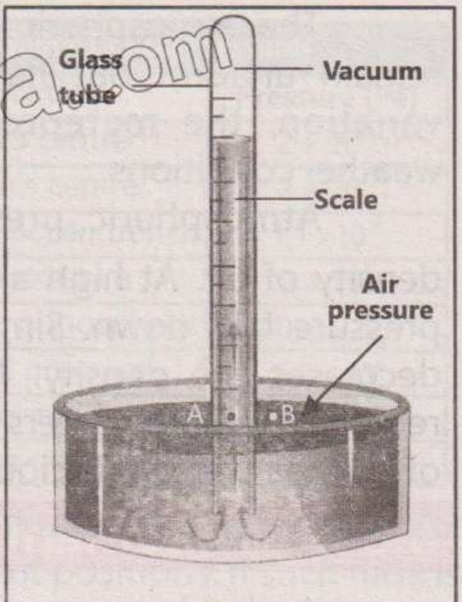


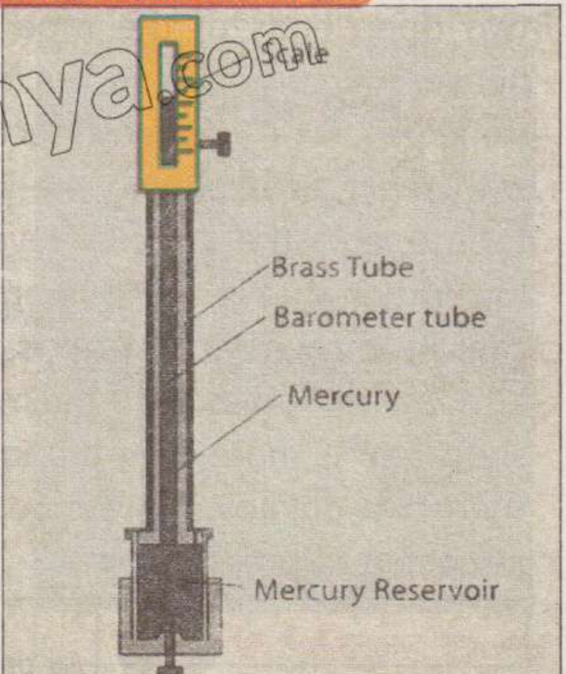
Fig 6.9 Barometer

The pressure P, at point A in the 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.

For Your Information!

Air pressure guage which is used to measure the pressure in motor car tyres.

For Your Information!



A Fortin's Barometer is used in laboratories to measure the atmospheric pressure.

If we put $P = 1.013 \times 10^5$ Pa at sea level, $\rho = 13.6 \times 10^3$ 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.

Quick Quiz

Would you exert more, same or less pressure on the ground if you stand on one foot instead of two feet?

Changes in Atmospheric Pressure as Weather Indicator

The atmospheric pressure does not always remain uniform but flactuates. By observing the variation, the meteorologists can forecast the weather conditions.

Quick Quiz

Can we use water in place of mercury to construct a barometer? Explain why.

Atmospheric pressure depends upon the density of air. At high 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 regions. 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.

6.8 Measurement of Pressure by Manometer

A simple manometer consists of a U-shaped glass tube which contains 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). 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 (Fig. 6.11), then the unknown pressure is more than the atmospheric pressure. If the mercury level in the short arm is more than the long arm (Fig.6.12), then the unknown pressure is less than the atmospheric pressure.

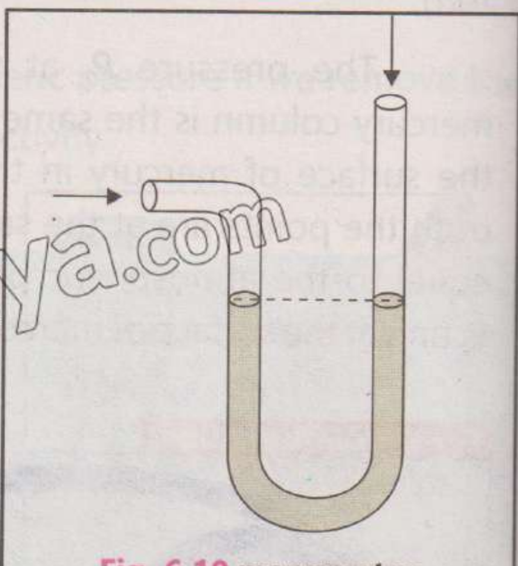


Fig. 6.10 **manometer**

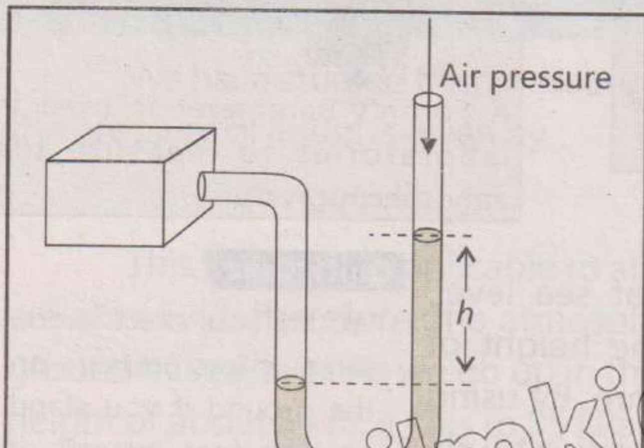


Fig. 6.11

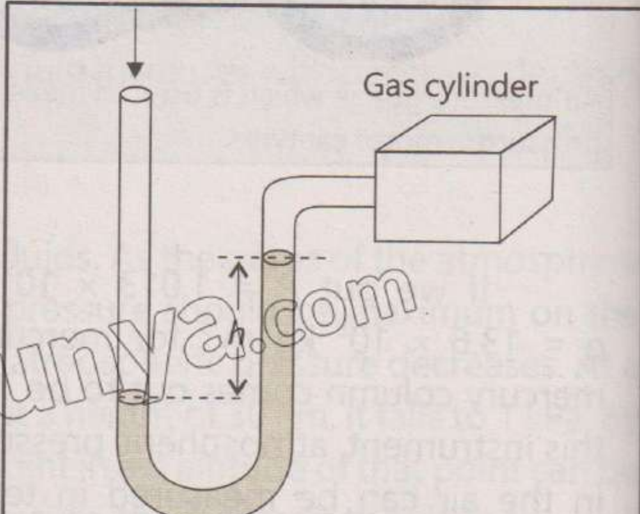


Fig. 6.12

6.9 Pascal's Law

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 directions. Similarly, 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.

Some Typical Pressures

Location	Pressure (Pa)
Sun's centre	2×10^{16}
Earth's centre	2×10^{11}
Deepest ocean trench	1.1×10^{18}
A motor tyre	2×10^{5}
Standard atmospheric	1.013×10^{5}
Blood pressure	1.6×10^{4}
On mount Everst	4×10^{4}
On mars	7×10^{2}

Let us perform a very interesting activity with a liquid. Take water in a flask with piston and having a few side tubes fixed at different positions. 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. Why does this happen? 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 fluids so the above activities prove that:

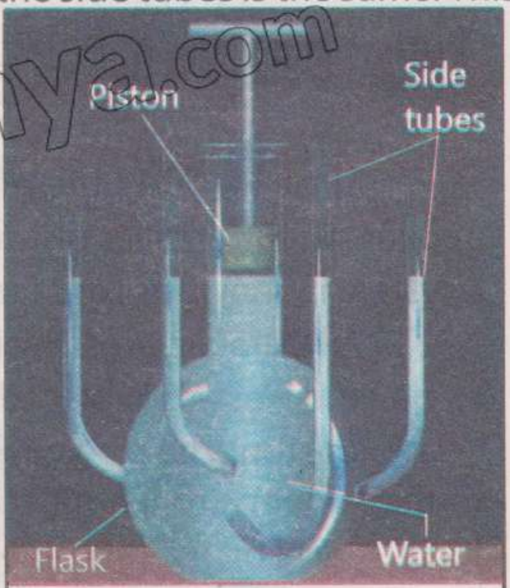


Fig. 6.13

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

This is the statement of Pascal's law.

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

(I) Liquids do 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

Hydraulic Press

Consider a specially designed container as shown in Fig. 6.14. 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.

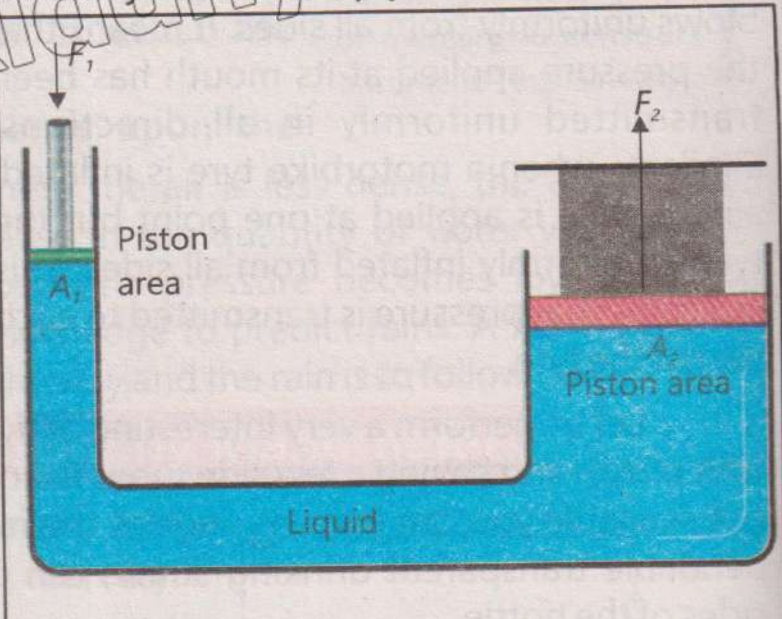


Fig. 6.14

Suppose that the small piston is pressed down by applying a force F_1. The pressure $P = F_1 / A_1$ produced by small piston is transmitted equally to the large piston.

Due to this pressure P, a force F_2, will act on A_2, which is given by

$$F_2 = PA_2$$

Putting the value of P,

$$F_2 = \frac{F_1}{A_1} A_2 \quad \text{.................... (6.5)}$$

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**.

A hydraulic press works on this principle. 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 and compresses the cotton bale.

This principle is also used at service stations to lift cars for washing (Fig. 6.15).


Fig. 6.15

Example 6.4

The diameters of the pistons of a hydraulic press are 5 cm and 25 cm respectively. A normal force of 160 N 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 $= 2.5 \times 10^{-2}$ m $r_2 = \frac{25}{2}$ cm $= 12.5 \times 10^{-2}$ m

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

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,

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

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

Hydraulic Brakes

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. 6.16. Oil is filled in this system. When pedal is pushed down, the piston applies pressure on the liquid in the master cylinder. The liquid pressure is transmitted

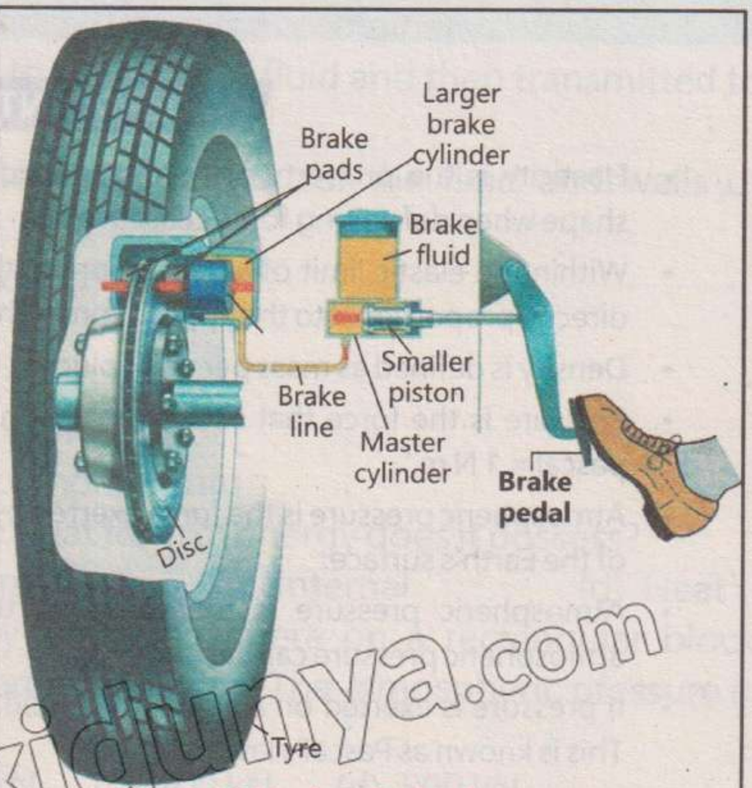


Fig. 6.16 Hydraulic brake system

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 slows down the vehicle. When pressure is released from the pedal, the springs pull back the brake pads and wheels again turn freely.

Activity 6.6

The teacher should facilitate the groups to follow the instructions given below.

i. Fill a syringe with water and insert its nozzle into a thin plastic tube.
ii. Press the syringe to fill the tube with water.
iii. Half fill the second syringe with water and insert its nozzle to the other end of the tube.
iv. Press one plunger in through some distance.
v. Is the second plunger pushed out through the same distance?
vi. Is the pressure transmitted to the second plunger by the liquid?
vii. What is your inference?

KEY POINTS

- Elasticity is the property of solids by which they come back to their original shape when deforming force ceases to act.
- Within the elastic limit of a helical spring, the extension or compression in it is directly proportional to the applied force. This is known as Hooke's law.
- Density is defined as mass per unit volume.
- Pressure is the force that acts normally on unit area of a surface. Its SI unit is pascal = 1 N m^{-2}.
- Atmospheric pressure is the force exerted by the atmosphere acting on unit area of the Earth's surface.
- Atmospheric pressure is measured by the column of mercury which the atmospheric pressure can support.
- If pressure is exerted on a liquid, the liquid transmits it equally in all directions. This is known as Pascal's law.

EXERCISE

A Multiple Choice Questions

Tick (✓) the correct answer.

6.1. 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:

(a) one half (b) double

(c) one fourth (d) four times

6.2. Four wires of the same material are stretched by the same load. Their dimensions are given below. Which of them will elongate most?

(a) Length 1 m, diameter 1 mm (b) Length 2 m, diameter 2 mm

(c) Length 3 m, diameter 3 mm (d) Length 4 m, diameter 0.5 mm

6.3. Two metal plates of area 2 and 3 square metres are placed in a liquid at the same depth. The ratio of pressures on the two plates is:

(a) 1:1 (b) $\sqrt{2} : \sqrt{3}$

(c) 2:3 (d) 4:9

6.4. The pressure at any point in a liquid is proportional to:

(a) density of the liquid

(b) depth of the point below the surface of the liquid

(c) acceleration due to gravity

(d) all of the above

6.5. Pressure applied to an enclosed fluid is:

(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

6.6. The principle of a hydraulic press is based on:

(a) Hooke's law

(b) Pascal's law

(c) Principle of conservation of energy

(d) Principle of conservation of momentum

6.7. When a spring is compressed, what form of energy does it possess?

(a) Kinetic (b) Potential (c) Internal (d) Heat

6.8. What is the force exerted by the atmosphere on a rectangular block surface of length 50 cm and breadth 40 cm? The atmospheric pressure is 100 kPa.

(a) 20 kN (b) 100 kN (c) 200 kN (d) 500 kN

B Short Answer Questions

6.1. Why heavy animals like an elephant have a large area of the foot?

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

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

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

6.5. State what do you mean by elasticity of a solid.

6.6. What is Hooke's law? Does an object remain elastic beyond elastic limit? Give reason.

6.7. Distinguish between force and pressure.

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

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

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

C Constructed Response Questions

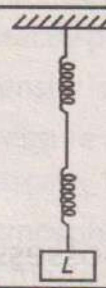
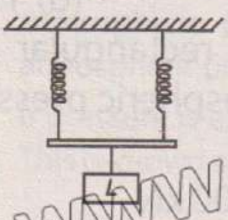
6.1. A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension x, the elastic limit of the spring is not exceeded.

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.

Arrangement	Total Extension x	Spring constant (k) of the arrangement
		
		

6.2. Springs are made of steel instead of iron. Why?

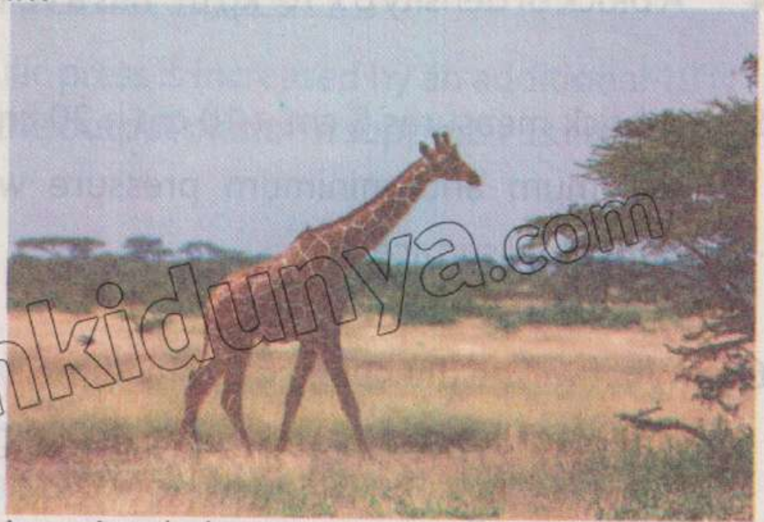
6.3. Which of the following material is more elastic?
(a) Iron or rubber (b) Air or water

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?

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.

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?

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



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?

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

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

D Comprehensive Questions

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

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

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

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

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

E Numerical Problems

6.1 A spring is stretched 20 mm by a load of 40 N. Calculate the value of spring constant. If an object causes an extension of 16 mm, what will be its weight?

($2\ kN\ m^{-1}$, 32 N)

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

($0.9 \times 10^3\ kg\ m^{-3}$)

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

($15 \times 10^3\ kg\ m^{-3}$)

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

(0.48 kg)

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

(1×10^4 Pa, 25×10^2 Pa)

6.6 What will be the height of the column in barometer at sea level if mercury is replaced by water of density $1000\ kg\ m^{-3}$, where density of mercury is $13.6 \times 10^3\ kg\ m^{-3}$

(10.3 m)

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 $20\ cm^2$?

[$1.0 \times 10^6\ N\ m^{-2}$, 2000 N]

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

($1.03 \times 10^5\ N\ m^{-2}$)

6.9 The area of cross-section of the small and large pistons of a hydraulic press is respectively $10\ cm^2$ and $100\ cm^2$. What force should be exerted on the small piston in order to lift a car of weight 4000 N?

(400 N)

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

(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**

(a) 1.01×10^5 Pa

(b) 1.02 km

6.11 If the pressure in a hydraulic press is 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?

(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:

(a) pressure transferred to the brake oil?

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

[(a) 1.0×10^6 N m^{-2}, (b) 2000 N)]