Contents

Chapter 1

FORCE AND PRESSURE

INTRODUCTION

Forces can be defined and studied only through their effects. It is present in all parts of the universe. It was Aristotle who first studied the motion of an object. He believed that a force is required to keep an object moving. But Galileo proved that if an object once comes in motion, it continues its motion forever if there is no friction between the surfaces. This tendency of an object by which a moving object keeps on moving was named as "inertia" by him. Galileo's work set the stage for Isaac Newton, when he developed the three laws of motion. He put these three laws in his famous book, namely Philosophiae Naturalis Principia Mathematica (The Latin title means "Mathematical principles of natural philosophy"), often simply known as the principia.The first law is a restatement of Galileo's concept of inertia, the second law relates acceleration to its cause-force, and the third is the law of action and reaction.

The force acting normally per unit area is called pressure, Liquids and gases both flow when a force acts on them. Fluids-which include both liquids and gases play an important role in our day to day life. Life is not possible without them . We breathe them, drink them and cook our foods with their help. The force exerted by the atmosphere i.e., envelop of air surrounding the earth, per unit area on the surface of the earth is called atmospheric pressure.

FORCE

Force is an external agent which changes or tries to change the state of an object. It is a vector quantity and its S.I. **unit** is newton (N). Its **C.G.S unit** is dyne (1dyne = 10^{-5} newton).

Note that when we say "force", we imply the total force, or net force, acting on an object. Generally, more than one forces act on an object. For example, when a ball is sailing through the air, the force of gravity and air resistance both act on it. The net force on the ball is the combination of force.

It is the net force that changes an object's state. If the net force on a body is zero, it will remain in its original state. The foregoing figure will help in understanding what net force is .

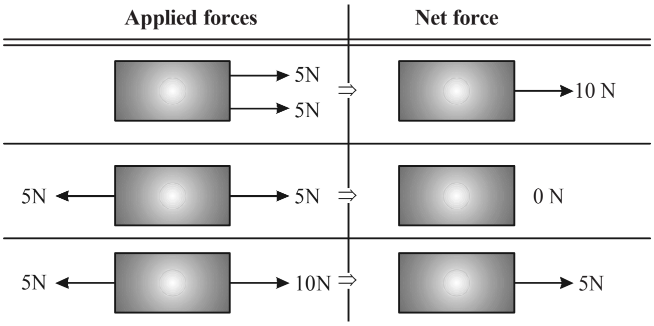
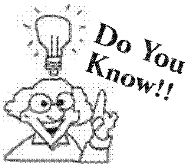


Fig. 1.1 : *Net force*

When the net of all the forces acting on a body is zero forces are called **balanced forces** and if net force is non-zero, forces acting on a body are called **unbalanced forces**.



A force produces or tries to produce motion in a body at rest, stops or tries to stop a moving body, changes or tries to change the direction of motion of a body and produces a change in the shape of a body.

Think it Over

Let the net force acting on an object be zero. Does it always mean that the body remain at rest ? If yes, why? If not, give one example.

THE RULE OF EQUILIBRIUM

When the net force acting on a system is zero, it is said to be in mechanical equilibrium. You will read in higher classes that is said to be in rotational equilibrium if net torque acting on it is zero.

Let us consider a mass M hanging from a support with a massless string. Its weight (=Mg) acts vertically downward and the tension (T) in the string acts vertically upwards as shown in the figure. Both forces are equal in magnitude but opposite in direction. Hence, the net force is zero. Therefore, the mass is in mechanical equilibrium.

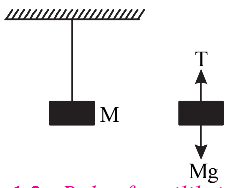
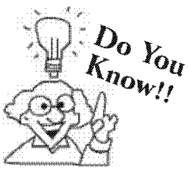


Fig. 1.2 : *Rule of equilibrium*



A number of forces acting at the same point are called concurrent forces. A number of concurrent forces are said to be in equilibrium if their resultant or net force is zero.

CHECK Point

1. **Consider a gymnast hanging from the rings. If the girl shown in figure 1.3 hangs with her weight evenly divided between the two rings, how would scale readings in both supporting ropes compare with her weight?**
2. **Suppose the girl hangs with slightly more of her weight supported by the left ring. How would a scale on the right read?**

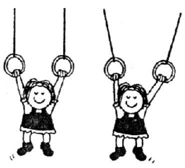


Fig. 1.3

SOLUTION

1. The reading on each scale will be **half her weight**. the sum of the reading on both scales then equals her weight.
2. When more of her weight is supported by the left ring, the reading on the right is **less than half her weight**. No matter how she hangs, the sum of the scale readings equals her weight

   For example, if one scale reads two-thirds her weight, the other scale will read one-third her weight.

FORCES ARE DUE TO AN INTERACTION

Consider a book lying at rest on a table. It is in equilibrium. What forces act on the book? One is the force due to gravity – the weight of the book. Since the book is in equilibrium, there must be another force acting on it to produce a net force of zero an upward force opposite to the force of gravity. The table exerts this upward force, called the support force. This upward support force, often called the normal force, must be equal to the weight of the book.

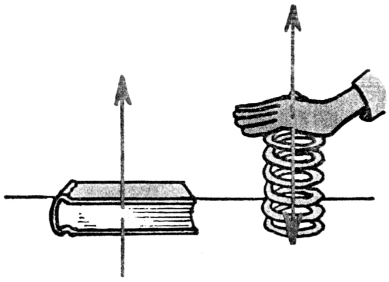
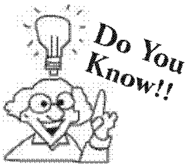


Fig. 1.4 : *The table pushes up on the book with as much force as the downward force of gravity on the book. The spring pushes up on your hand with as much force as you exert to push down on the spring.*

To better understand that the table pushes upon the book, compare the case of compressing a spring (figure) If you push the spring down, you can feel the spring pushing upon your hand. similarly, the book lying on the table compresses atoms in the table which behave like microscopic springs. The weight of the book squeezes downward on the atoms, and the squeeze upward on the book. In this way, the compressed atoms produce the support force.



The normal force is always acts in a direction perpendicular to the surface of contact. The number of normal forces acting on a body depends on the number of points or surfaces of contact.

Think it Over

A person of weight 50N is standing on the surface of the earth. What force does the person exert on the earth? What force does the earth exert on the person?

CONTACT AND NON-CONTACT FORCE

Frictional force, muscular force etc. are **contact force**. It is being applied by actually touching the body.

Non-contact force is the force being applied without touching the body e.g., gravitational force, electrostatic force, magnetic force etc.

FRICTON

When one object rubs against something else (which may be in any state such as solid, liquid or gas), a force acts on the surfaces in contact which opposes the relative motion between them. This force is called the force of friction. It always acts in a direction opposite to the direction of motion. If we pull a block of wood on a surface to the right, the force of friction on the block will be to the left.

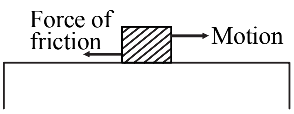


Fig. 1.5 : *Force of friction opposite to the applied force*

Similarly, a boat propelled to the east by its motor experiences water friction to the west. An object falling downward through the air, experiences air friction, called air resistance, in upward direction. The amount of friction between two surfaces depends on the kinds of material and how much they are pressed together. The force of friction between two rough surfaces is more than that between two smooth surfaces.

Friction is due to roughness of surfaces. All surfaces, on microscopic view, have tiny bumps as shown in the figure.

Due to these irregularities in the surfaces, friction appears in solid surfaces.

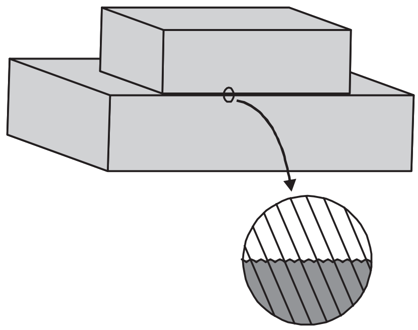
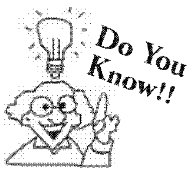


Fig. 1.6 : *Friction results from the mutual contact of irregularities in the surfaces of sliding objects. Even surfaces that appear to be smooth have irregular surfaces when viewed at the microscopic level.*



- *Frictional force does not oppose the motion in all cases, infact in some cases the body moves due to it.*
  In the fig. 1.7, book B moves to the right due to friction between A & B. If book A is totally smooth (i.e., frictionless) the book B does not move to the right. This is because of no force applied on the book B in the right direction.

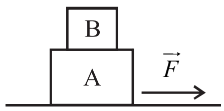


Fig. 1.7

- *The force of friction is independent of area of surfaces in contact & relative velocity between them (if it is not too high), but it depends on the nature of material of surfaces in contact (i.e., force of adhesion).*

Think it Over

A body on a rough surface is pushed by a force. But the body is still at rest. When the magnitude of force is increased slowly, the body comes in a state of "about to move". The frictional force acting at this state is called the force of limiting friction. Whether the force of limiting friction is less or more than the force of static friction?

CHECK Point

An aeroplane flies through the air at a constant velocity. In other words, it is in equilibrium. Two horizontal forces act on the plane. One is the thrust of the propeller that pushes it forward and the other is the force of air resistance that acts in the opposite direction. Which force is greater?

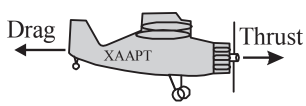


Fig. 1.8

SOLUTION

Both forces have the same magnitude. If you call the forward force exerted by the propeller positive, then the air resistance is negative. Since the plane is in equilibrium. the two forces combine to equal to zero.

NEWTON'S FIRST LAW OF MOTION

The first law of motion is generally called the **Law of inertia**. It is a restatement of Galileo's idea. It is stated as : *Every object continues in a state of rest or in a state of uniform motion in a straight line, unless it is compelled to change that state by external unbalanced forces exerted upon it.*

The key word "continues" in this law means an object continues to do whatever it happens to be doing unless a force is exerted upon it. This property of objects to resist changes in motion is called "inertia". If the object is at rest, it continues in a state of rest. This tendency of an object is called "the inertia of rest". This is nicely demonstrated when a bus starts moving, leaving the passengers leaning backward. Other examples are involved in the answers of the following illustrations.

(a) Why will the coin drop into the glass when a force accelerates the card?

(b) Why does the downward motion and sudden stop of the hammer tighten the hammer head?

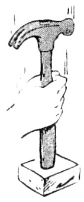
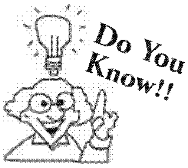


Fig. 1.9 : *Examples of inertia*

On the other hand, if an object is moving, it continues to move without changing its speed or direction. This tendency of the object is called "the inertia of motion". This is demonstrated when a moving bus comes to rest accidently, leaving the passengers leaning forward.



*Newton's first law gives the qualitative definition of force according to which 'force is that external cause which tends to change or actually changes the state of rest or of uniform motion of a body. Newton's first law of motion is the same as **law of inertia** given by Galileo.*

CHECK Point

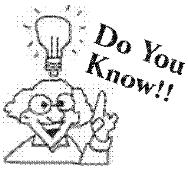
When a space shuttle travels in a nearly circular orbit around the earth, is a force required to maintain its high speed? If suddenly the force of gravity were cut off, what type of path would the shuttle follow?

SOLUTION

No force in the direction of the shuttle's motion exists. The shuttle coasts at a constant speed by its own inertia. The only force acting on it is the force of gravity, which acts at right angles to its motion (towards the earth's centre). We'll see later that this right-angled force holds the shuttle in a circular path. If it were cut off, the shuttle would move in a straight line at a constant speed (constant velocity).

Mass and Inertia

Inertia is directly related to the mass of an object. A heavier body has higher inertia than that of a lighter body. Mass in this context is called "inertial mass".



Inertia of direction is the property due to which a resistancy, change in its motion due to a change in direction.

NEWTON'S SECOND LAW OF MOTION

Newton formulated his second law, one of the most central rules of nature, which relates force to mass in producing acceleration, in the following way.

The acceleration produced by a net force on an object is directly proportional to it and is in the same direction as the net force but is inversely proportional to the mass of the object.

In shorter notation,

$$\text{Acceleration} = \frac{\text{net force}}{\text{mass}}$$

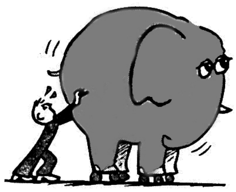


Fig. 1.10 : *Acceleration depends both on the amount of push and on the mass being pushed*

If we use consistent units such as newtons (N) for force, kilograms (kg) for mass and meter per second square (m/s^2) for acceleration, then mathematically,

$$a = \frac{F}{m}$$

where a = acceleration

F = net force

m = mass

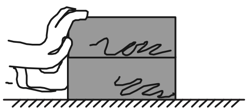
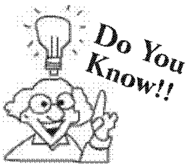


Fig. 1.11 : *Acceleration is directly proportional to force*



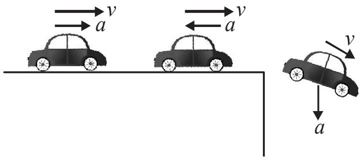


Fig. 1.12 : *When you accelerate in the direction of your velocity, you speed up; against your velocity, you slow down; at an angle to your velocity, your direction changes.*

Illustration : 1

Two blocks made of different metals identical in shape and size are acted upon by equal forces, which cause them to slide on a horizontal surface. The acceleration of the second block is found to be 5 times that of the first, what is the ratio of the mass of the second to first?

SOLUTION :

Let F be resultant force on each block.

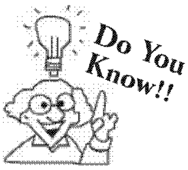
For 1st block, $F_1 = m_1a_1$

For 2nd block, $F_2 = m_2a_2$

or, $m_1a_1/m_2a_2 = 1$, i.e., $m_2/m_1 = a_1/a_2$ ….(i)

Here, $a_2 = 5a_1$ ….(ii)

From (i) and (ii), $m_2/m_1 = 1:5$



Newton's first law of motion follows from Newton's second law of motion. By second law $F = ma$

If $F = 0$, then $a = 0$, which means the body is either at rest or moves with a constant velocity.

Think it Over

Can Newton's laws of motion be applied for an object moving in an accelerated lift?

CHECK Point

1. **The net external force acting on an object is zero. Is it possible for the object to be travelling with a velocity that is not zero? If your answer is yes, state whether any conditions must be placed on the magnitude and direction of the velocity. If your answer is no, provide a reason for your answer.**
2. **Is it possible for an object to be at rest (have a velocity of zero) yet the net external force acting on the object is non-zero? Explain.**
3. **Newton's second law indicates that when a net force acts on an object, it must accelerate. Does this mean that when two or more forces are applied to an object simultaneously, it must accelerate? Explain.**

SOLUTION

1. If the net external force acting on an object is zero, it is possible for the object to be travelling with a non-zero velocity. According to Newton's second law, $F = ma$, if the net external force F is zero, the acceleration a is also zero. If the acceleration is zero, the velocity must be constant, both in magnitude and in direction. Thus, an object can move with a constant nonzero velocity when the net external force is zero.
2. An object at rest has a constant velocity (of zero), which means that it has an acceleration of zero (it is at rest!). Newton's first law indicates that the object will stay at rest only if the net force acting on the object is zero.
3. An object will not necessarily accelerate when two or more forces are applied to the object simultaneously. The applied forces may cancel so the net force is zero; in such a case, the object will not accelerate. The resultant of all the forces that act on the object must be nonzero in order for the object to accelerate.

CONNECTING TOPIC

FREE FALL

We know that a falling object accelerates towards the earth because of the gravitational force of attraction between the object and the earth. When the force of gravity is the only force – that is, when air resistance is negligible – we say that the object is in a state of **free fall**. An object in **free fall** accelerates towards the earth at 10 m/s^2 (or, more precisely, at 9.8 m/s^2).

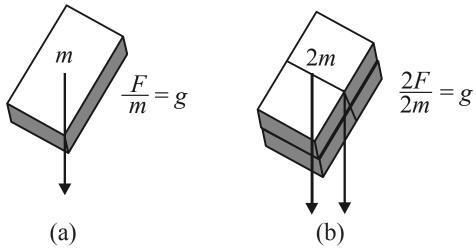
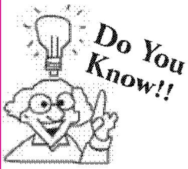


Fig. 1.13 : *The ratio of weight (F) to mass (m) is the same for all objects in the same locality; hence, their accelerations are the same in the absence of air resistance.*

The greater the mass of an object, the stronger is the gravitational pull between it and the earth. The double book in Fig. 1.13 (b) above, for example, has twice the gravitational attraction to earth as the single book. Why, then, doesn't the double book fall twice as fast (as Aristotle supposed it would)? The answer is evident in Newton's second law : the acceleration of an object depends not only on the force (weight, in this case), but on the object's resistance to motion – its inertia. Whereas a force produces an acceleration, inertia is a *resistance* to acceleration. So twice the force exerted on twice the inertia produces the same acceleration as half the force exerted on half the inertia. Both accelerate equally. The acceleration due to gravity is symbolised by g. We use the symbol g, rather than a, to denote acceleration due to gravity.



When an object is in a state of free fall, it experiences no weight. That is, it is in a state of "weightlessnes".

Think it Over

In a vacuum, a coin and a feather fall at an equal rate, side by side. Would it be correct to say that equal forces of gravity act on both the coin and the feather when in a vacuum?

NON-FREE FALL

In practice, air resistance is not negligible for falling objects. Then the acceleration of the object's fall is less. Air resistance depends on two things : speed and surface area. When a skydiver steps from a high-flying plane, the air resistance on the skydiver's body builds up as the falling speed increases. The result is reduced acceleration. The acceleration can be reduced further by increasing the surface area. A skydiver does this by orienting the body so that more air is encountered – by spreading out like a flying squirrel. So, air resistance depends both on speed and on the surface area encountered by the air.

For free fall, the downward net force is weight – only weight. But when air is present, the downward net force = weight – air resistance. Can you see that the presence of air resistance reduces net force? And that less net force means less acceleration? So, as a skydiver falls faster and faster, the acceleration of fall decreases. What happens to the net force if air resistance builds up to equal weight? The answer is, net force becomes zero. Then acceleration becomes zero. Does this mean the diver comes to a stop? No! What it means is that the diver no longer gains speed. Acceleration terminates – it no longer occurs. We say the diver has reached **terminal speed**. If we are concerned with direction – down, for falling objects, we say that the diver has reached **terminal velocity.**

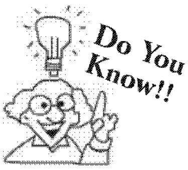
In mathematical notation,

$$a = \frac{F_{net}}{m} = \frac{mg - R}{m}$$

where mg is the weight and R is the air resistance. Note that, when $R = mg$, $a = 0$; then, with no acceleration, the object falls at a constant velocity. With elementary algebra, we can proceed another step and get

$$a = \frac{F_{net}}{m} = \frac{mg - R}{m} = g - \frac{R}{m}$$

We see that the acceleration a will always be less than g if air resistance R impedes falling. Only when $R = 0$ does $a = g$.



Any object falling through a resistive medium attains a constant velocity after some time which called the terminal velocity. This velocity depends on the nature and density of the medium and also on the shape of the object.

Think it Over

A skydiver jumps from a high-flying helicopter. As she falls faster and faster through the air, does her acceleration increase, decrease, or remain the same?

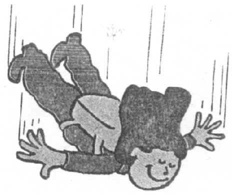


Fig. 1.14

CHECK Point

Consider two parachutists, a heavy person and a light person, who jump from the same altitude with parachutes of the same size.

1. **Which person reaches the terminal speed first?**
2. **Which person has the higher terminal speed?**
3. **Which person reaches the ground first?**
4. **If there were no air resistance, like on the moon, how would your answers to these questions differ?**

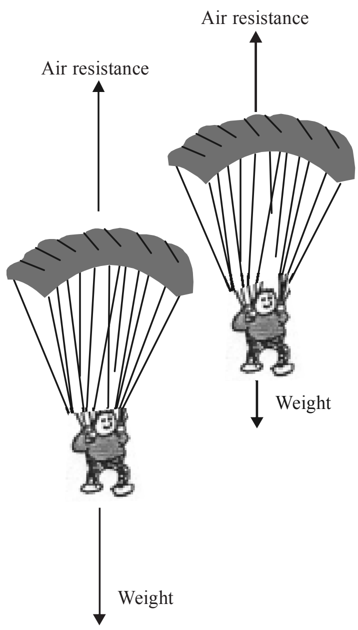


Fig. 1.15 : *The heavier parachutist must fall faster than the lighter parachutist for air resistance to cancel her greater weight.*

SOLUTION

To answer these questions correctly, think of a coin and a feather falling in air.

1. Just as a feather reaches terminal speed very quickly, the lighter person reaches terminal speed first.
2. Just as a coin falls faster than a feather through air, the heavy person falls faster and reaches a higher terminal speed.
3. Just as in the race between a falling coin and a falling feather, the heavier person falls faster and will reach the ground first.
4. If there were no air resistance, there would be no terminal speed at all. Both would be in free fall, and both would hit the ground at the same time.

Linear Momentum and The Newton's Second Law of Motion

Linear momentum of an object is the effect produced in it due to its mass and velocity. Quantitatively, it is product of the mass and the velocity of an object.

Mathematically, *Momentum = mass × velocity*

It is a vector having direction in the direction of velocity. Its S.I. unit is kilogram meter per second (kg m/s).

Symbolically, $p = mv$

where, p = momentum; m = mass and v = velocity

Newton's second law is related to linear momentum. It is stated as "*The force acting on an object is directly proportional to the rate of change of momentum with time*".

i.e., $\text{Force} = \dfrac{\text{change in momentum}}{\text{time}}$

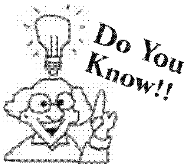
If an object of mass m moving with velocity v_1 changes its velocity to v_2 in time t then force acting on it

$$F = \frac{mv_2 - mv_1}{t} = \frac{m(v_2 - v_1)}{t}$$

Also, we know

$$\frac{v_2 - v_1}{t} = (a)\ \text{acceleration}$$

$\therefore \quad F = ma$ or $a = \dfrac{F}{m}$, which is the second law.



The change in the linear momenta is called 'impulse'. Therefore, impulse = force × time
A cricketer pulls his hands backward while catching a ball. He does so to maximise the time and hence to minimise the force on his hands due to the ball.

Illustration : 2

Two billiard ball, each of mass 0.05 kg, moving in opposite directions with speed of 6 ms^{-1}, collide and rebound with the same period. What is the impulse imparted to each ball due to the other?

SOLUTION :

Before collision, mass of each ball = 0.05 kg, speed of ball = 6 ms^{-1},

$\therefore$ momentum, $p = mv = 0.05 \times 6 = 0.3$ kg ms^{-1}.

After collision, mass of each ball = 0.05 kg, speed of ball = – 6 ms^{-1},

$\therefore$ momentum = 0.05 × (–6) = – 0.3 kg ms^{-1}.

(Change in momentum after collision = $p_2 - p_1$)

$\therefore$ change of momentum = impulse = – 0.3 – 0.3 = – 0.6 kg ms^{-1}

Hence an impulse of 0.6 kg ms^{-1} will be imported to each ball in opposite directions.

CONNECTING TOPIC

THE LAW OF CONSERVATION OF LINEAR MOMENTUM

It states that in absence of external force, the total linear momentum of a system remains conserved. During collision of two particles, for example, the total linear momenta before collision is equal to the total linear momenta after collision. Mathematically, if two objects of masses m_1 and m_2 moving with velocities u_1 and u_2 collide and moves with velocities v_1 and v_2 after collision, then

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

The principle of conservation of momentum is nicely involved in the process of firing a bullet by a gun. Let a bullet of mass m is fired with a velocity v from a gun of mass M. As gun exerts a forward force on bullet, by third law of motion (see next topic), the bullet also exerts an equal force in backward direction. Due to this force, gun recoil in backward direction with a velocity, say, v_{rec} known as recoil velocity.

Fig. 1.16

By conservation of momentum,
Total momenta before firing bullet = total momenta after firing bullet

$$\Rightarrow (M \times 0) + (m \times 0) = -M v_{rec} + mv$$

Negative sign in first term of R.H.S. is due to the fact that the gun recoils in opposite direction.

$$\therefore \quad Mv_{rec} = mv \Rightarrow v_{rec} = \frac{mv}{M}$$

Think it Over

The propulsion of rocket is an example of momentum conservation. In a rocket gases at high temperature and pressure are produced by the combustion of fuel. In a rocket fuel is consumed at the rate of 100 kgs^{-1}. The exhaust gases are ejected at speed of 4.5 × 10^{4} ms^{-1}. What is the thrust experience by the rocket?

Illustration : 3

A gun weighing 4 kg fires a bullet with a velocity 50ms^{-1}. If the weight of the bullet is 15g, find the velocity of recoil of the gun.

SOLUTION :

Here, M = 4 kg; m = 15 g = 0.015 kg; v = 50 ms^{-1}

$$v_{rec} = \frac{mv}{M} = \frac{0.015 \times 50}{4} = 0.17 \text{ ms}^{-1}$$

NEWTON'S THIRD LAW OF MOTION

According to this law, whenever an object exerts a force on another object, the latter object exerts an equal and opposite force on the first. We can call one force the action force, and the other the reaction force. In action-reaction form, the third law is stated as

To every action there is always an equal and opposite reaction.

Although action and reaction are equal and opposite but they never add to zero resultant force because both acts on two different objects which can't be added.

It doesn't matter which force we call the *action* and which we call the *reaction*. The important thing is that they are coequal parts of a single interaction and that neither force exists without the other. Action and reaction forces are equal in strength and opposite in direction. They occur in pairs and make up a single interaction between two things.

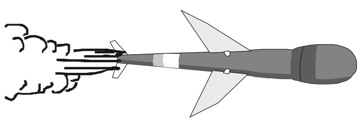
Simple Rule to Identify Action and Reaction

There is a simple rule for identifying action and reaction forces. First, identify the interaction – one thing (object A) interacts with another (object B). Then, action and reaction forces can be stated in the following form :

Action : *Object A exerts a force on object B.*

Reaction : *Object B exerts a force on object A.*

Action : Tyre pushes on road **Reaction :** Road pushes on tyre



Action : Rocket pushes on gas **Reaction :** Gas pushes on rocket

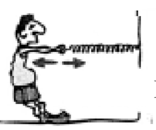
Action : Man pulls on spring  **Reaction :** Spring pulls on man

Fig. 1.17

CHECK Point

1. A car accelerates along a road. Identify the force that moves the car.

2. Identify the action and reaction forces for the case of an object in free fall (no air resistance).

SOLUTION

1. It is the road that pushes the car along. Except for air resistance, only the road provides a horizontal force on the car. How does it do this? The rotating tyres of the car push back on the road (action). The road simultaneously pushes forward on the tyres (reaction).
2. To identify a pair of action-reaction forces in any situation, first identify the pair of interacting objects. In this case, the earth interacts with the falling object via the force of gravity. So the earth pulls the falling object downward (call it action). Then reaction is the falling object pulling the earth upward. It is only because of the earth's enormous mass that you don't notice its upward acceleration.

CONNECTING TOPIC

FREE BODY DIAGRAM (FBD)

To apply Newton's laws of motion, first of all we choose our system and then indicate all the forces acting on it which we call the **free body diagram (FBD).**

Motion of a Mass on a Surface

Case (I) If friction is absent between the surfaces, the free body diagram is as shown in **Fig. 1.18**. The forces acting on mass are

(i) mg, the weight, vertically downward

(ii) N, the normal reaction, vertically upward

(iii) F, in right direction, due to external agent.

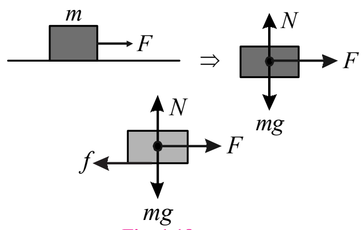


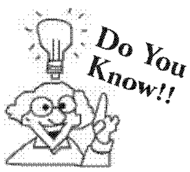
Fig. 1.18

Clearly, mg and N cancel each other, so, there is no motion in vertical direction. In horizontal direction, there is only force F, in right direction, hence the mass moves in this direction. If a be the acceleration of the mass, then

$$F = ma \Rightarrow a = \frac{F}{m}$$

Case (II) If friction is present between the surfaces, the acceleration of the mass will be

$$a = \frac{F - f}{m} \text{ where } f = \text{force of friction}$$

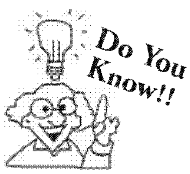


Two masses hanging on a massless pulley with massless, and inextensible string, move with same acceleration.

PRESSURE

Pressure is defined as the force or thrust exerted over a unit area.

$$\text{Pressure} = \frac{\text{force / thrust}}{\text{area}}$$



Pressure plays the same role in fluids as force plays in case of solids.
Force is a vector quantity but pressure is a scalar.

Think it Over

We see in our day-to-day life that paper pins and nails are made to have pointed ends. Think proper reasons behind it.

Thrust

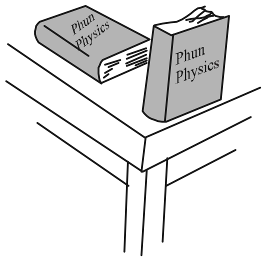


Fig. 1.19 : *Although the weight of both books is the same, the upright book exerts greater pressure against the table.*

The net force acting normal to a surface is called thrust. Thus, a body kept in any orientation exert equal thrust on the surface. It is the net force, so, its S.I. unit is newton (N). It is also expressed in kilogramme weight (kg wt)

1 kg wt = 9.8 N

The *pressure* of the book depends on the area over which the force is distributed.

Pressure may be measured in any unit of force divided by any unit of area. The standard international **(SI) unit** of pressure is newton per square metre called the *pascal* (Pa).

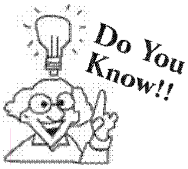
Huge pressure is measured in kilopascal (1 kPa = 1000 Pa).

Atmospheric Pressure

We live at the bottom of an ocean of air. The atmosphere, much like the water in a lake, exerts a pressure.

Just as water pressure is caused by the weight of water, **atmospheric pressure** is caused by the weight of air. We have adapted so completely to the invisible air that we sometimes forget it has weight. Perhaps a fish "forgets" about the weight of water in the same way. The reason we don't feel this weight crushing against our bodies is that the pressure (*blood pressure*) inside our bodies equals that of the surrounding air. There is no net force for us to sense.

The pressure of the atmosphere is not uniform. Atmospheric pressure is measured by **barometer**. Measurement of changing air pressure is important to meteorologists in predicting weather.



Atmospheric pressure is maximum at the surface of the earth and decreases as we move upwards. The value of the atmospheric pressure at sea level is 1.013 × 10^5 Nm^{-2} (or Pa) or 76 cm of Hg.

PRESSURE IN A LIQUID

When we swim in a river, we feel the water pressure acting against our eardrums. The deeper we swim, the greater the pressure. The cause of this pressure is the weight of the fluid, water plus air directly above us. As we swim deeper, there is more water above us. Therefore, there is more pressure. If we swim twice as deep, there is twice the weight of water above us, so the water's contribution to the pressure felt by us is doubled. The pressure due to a liquid also depends upon its density.

Mathematical expression for fluid pressure

Let us consider a liquid of density ρ in a beaker of base area 'A'. If 'h' be the height of the liquid column then

Volume of liquid in beaker, $V = A \times h$

Force (or thrust) acting at the bottom of the beaker is given by

F = Weight of liquid = mg

$= V\rho g \qquad (\because\ m = V\rho \text{ and } V = A \times h)$

$= (A \times h)\,\rho g = \rho g h A$

$\therefore$ Pressure at the bottom of the beaker $P = \dfrac{F}{A} = \dfrac{\rho g h A}{A} = \rho g h,$

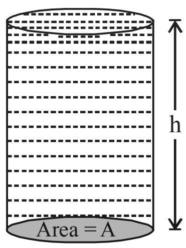


Fig. 1.20

Thus, we observe that pressure at a depth 'h' due to a liquid column is directly proportional to

(i) the density 'ρ' of the liquid.

(ii) the height 'h' of the liquid column and

(iii) the accelaration due to gravity 'g'

Total Pressure at a Point in a Liquid

Let us consider a point B at a depth 'x' from the surface of a liquid of density 'ρ'. Total pressure at the point B is the sum of the pressure due to atmosphere and the pressure due to the liquid column.

That is, total pressure at B

= atmospheric pressure (P_{atm}) + pressure due to liquid column $= P_{atm} + \rho g x$

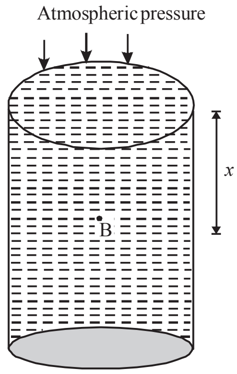
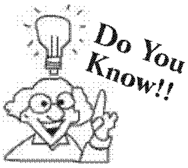


Fig. 1.21



A vessel filled with water exerts a pressure P on its bottom. Now the whole set-up is carried on the moon. What would be the pressure exerted by the water column on the bottom of the vessel now?

Water pressure acts perpendicular to the sides of its container, and it increases with increasing depth.

The relation P = rgh holds strictly only in case of an incompressible liquid.

Think it Over

The two vessels have water and oil inside there. Whether the pressure exerted by them on the bottoms of the vessels will be same, or different. Why?

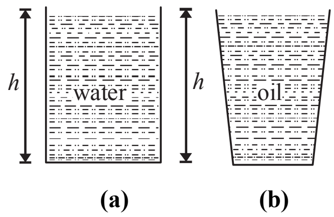


Fig. 1.22

Illustration : 4

Find the pressure at a point 5 cm inside the liquid column as shows in fig. 1.23. The atmospheric pressure is given to be 1.013×10^5 Nm^{-2}.

(The density of liquid = 1000 kg/m^3)

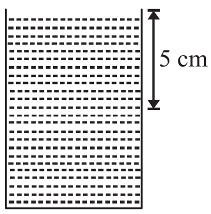


Fig. 1.23

SOLUTION :

Total pressure at given point

= Atmospheric pressure + Pressure due to liquid column

$= (1.013 \times 10^5) + h\rho g$

$= (1.013 \times 10^5) + (5 \times 10^{-2} \times 1000 \times 10)$

$= 1.018 \times 10^5$ Pa

CONNECTING TOPIC

PASCAL'S LAW

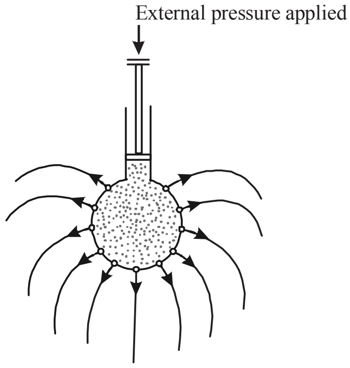


Fig. 1.24 : *Liquid exerts equal pressure*

Blaise Pascal formulated a law regarding the flow of liquid pressure. This law is stated as "*the pressure exerted by a liquid at rest is transmitted unchanged and equally in all directions, and acts at right angles to the surface of the container*".

The liquid has the property due to which its molecules exert great repulsive forces when they are pushed closer to each other than their normal distance. Due to this property it is difficult to compress a liquid by application of thrust on the surface. Thus any force applied on a liquid surface is immediately transmitted to every part of the liquid and the applied pressure at the surface is felt equally at every part of the liquid.

This may be demonstrated by filling a long necked bulb, having a number of holes, with water. When pressure is applied on the water by pushing the piston fitted in the neck of the bulb, water rushed out with equal pressure from all the holes.

Applications of Pascal's Law

Hydraulic Lever or Press : A hydraulic lever is used to magnify a force.

Let us consider two cylinders A_1 and A_2. Let the area of cross– section of A_1 be 'x' square units and that of A_2 be 'y' square units such that 'y' is n times 'x'.

The two cylinders are connected at the bottom by a horizontal connecting tube (T).

The apparatus is filled with a liquid. The cylinders A_1 and A_2 are fitted with air tight pistons P_1 and P_2. Let us apply an external force F_i (or input) on the piston P_1.

The pressure exerted on P_1 is F_i/x.

According to Pascal's law the pressure exerted on P_1 is transmitted unchanged equally by the liquid to piston P_2.

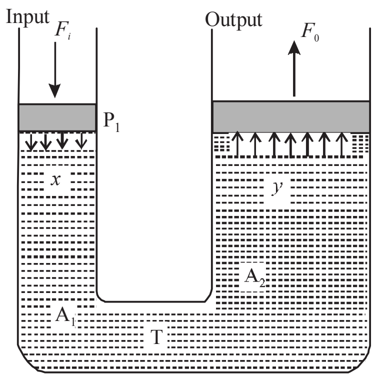


Fig. 1.25

The downward pressure exerted on $P_1 = \frac{F_i}{x}$

The upward force exerted on P_2

= pressure on P_2 × area of cross-section of A_2

For the piston P_2 to be in equilibrium, there must be a downward force of magnitude F_0 on the output piston from an external load (not shown).

Then, F_0 = (Pressure on P_2) y.

But according to Pascal's law, pressure on P_2 = pressure on $P_1 = \frac{F_i}{x}$ $\quad \therefore \quad F_0 = \left(\frac{F_i}{x}\right) y$, but $y = nx \Rightarrow F_0 = \frac{F_i}{x} \times nx = F_i n$

This shows $F_0 > F_i$. Therefore, a small force applied at a point can be used to exert a much larger force at another point.

A hydraulic press is also used

(i) to press the bales of cotton,

(ii) to extract oil from oil seeds, and

(iii) in hydraulic brakes that are used in brake systems of vehicles.

Think it Over

Air bubbles are dangerous to hydraulic brake. Why?

In the fig.1.26, if thrust F is applied on the piston of the side tube A, how much pressure will transmit through each of the tubes A, B and C ?

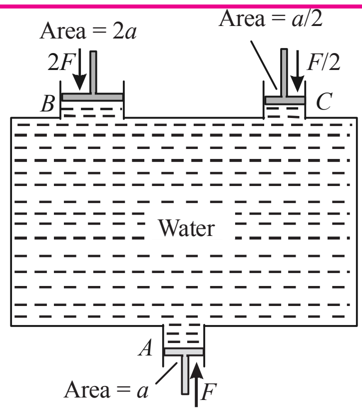


Fig. 1.26

BUOYANCY

When we lift a submerged object out of the water, the weight of the object felt by us is less than its actual weight. This loss in the weight of the object is due to a force called 'buoyant' force and the property of the liquid is called **buoyancy**. Buoyant force due to a fluid is the force acting upward on a submerged object exactly opposite in direction to gravity. This force arises due to the pressure difference at different depths.

Figure shows why the buoyant force acts upward. Pressure is exerted everywhere against the object in a direction perpendicular to its surface. The arrows represent the magnitude and the direction perpendicular to its surface. The arrows represent the magnitude and the direction of the forces at different locations. Forces that produce pressures against the sides due to equal depths cancel one another. Pressure is greatest against the bottom of the boulder because the bottom of the boulder is at a greater depth. Since the upward forces against the bottom are greater than the downward forces against the bottom are greater than the downward forces against the top, the forces do not cancel, and there is a net force upward. This net force is the byoyant force.

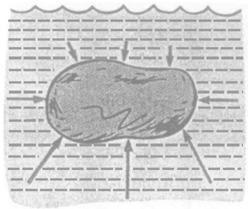


Fig. 1.27 : *The greater pressure against the bottom of a submerged object produces an upward buoyant force.*

If the weight of the submerged object is greater than the buoyant force, the object will sink. If the weight is equal to the buoyant force acting up on the submerged object, it will remain at any level, like a fish. If the buoyant force is greater than the weight of the completely submerged object, it will rise to the surface and float.

To understand buoyancy, the meaning of the term "volume of liquid displaced" should be clearly understood. If a stone is placed in a container that is full of water, some water will overflow as shown in fig. The volume of water overflown is alone equal to the volume of the stone. That is, *a completely submerged object always displaces a volume of liquid equal to its own volume.*

Buoyant force is also called *upthrust.*

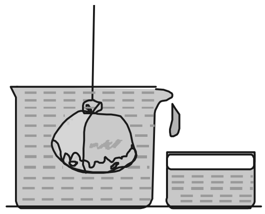


Fig. 1.28

Upthrust or buoyant force = $h\rho g A = V\rho g$ ($\because hA = V$, volume of the solid)

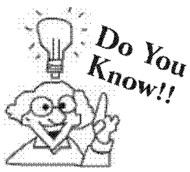
where, V = volume of the third displaced

ρ = density of fluid

$\therefore$ Upthrust = weight of the liquid displaced.

Thus, the upthrust or buoyant force is directly proportional to

1. the volume (V) of the fluid displaced by a solid.
2. the density (ρ) of the liquid in which the solid is immersed.



Upthrust depends on the density of the liquid, not on the density of the object.

Think it Over

It is easier to swim in a sea than that in a river. Why ?

CHECK Point

1. **Drop a stone in a tall water filled container. As it descends beneath the surface, pressure on it increases. Does this imply that buoyant force likewise increases?**
2. **Because buoyant force is the upward force that a fluid exerts on a body, and as we learned forces produce accelerations, why doesn't a submerged body accelerate?**

SOLUTION

1. No! Once the stone is beneath the water's surface, it has displaced all the water it can. This is evidenced by the initial rise of the water level in the container, which corresponds to the volume of the stone (and, hence, to the volume of water displaced by the stone). The level remains the same as the stone descends further, showing that the water displacement, and therefore the buoyant force on the stone, remains the same– even though water pressure on the stone increases with depth. Buoyancy and pressure are different concepts.
2. It does accelerate if the buoyant force is not balanced by other forces that act on it-the force of gravity and fluid resistance. The net force on a submerged body, is the result of the force the fluid exerts (buoyant force), the weight of the body and, if the body is moving, the force of fluid friction. When the net force is zero, the body is in equilibrium.

Illustration : 5

A piece of cork is embedded inside a block of ice which floats on water. What will happen to the level of water when all the ice melts?

SOLUTION :

Let, M = mass of the block of ice, m = mass of piece of cork and V = volume of water displaced.

Now $(M+m) = V \times 1 = V$ ...(1)

When the ice melts, let it be converted into V' c.c. of water.

Also $M = V' \times 1 = V'$

The piece of cork floats on the surface of water when all ice melts. Let the cork displaces a volume V'' c.c. of water.

Then $m = V'' \times 1 = V''$

If V_1 be the volume of water displaced by melted ice and cork, then

$(M+m) = V' + V'' = V_1$ ...(2)

From eqs. (1) and (2), $V = V_1$ (no change in the level)

Illustration : 6

A boat having a length of 3 metres and breadth 2 metres is floating on a lake. The boat sinks by one cm when a man gets on it. What is the mass of the man?

SOLUTION :

Weight of a man = Wt. of water displaced

$$= \text{volume} \times \text{density} = 3 \times 2 \times \frac{1}{100} \times 10^3 = 60 \text{ kg}$$

ARCHIMEDES' PRINCIPLE

The Greek scientist Archimedes' established a relationship between buoyancy and displaced liquid in the third century BC. It is stated as follows: *when an object is partially or wholly immersed in a fluid, it loses some of its weight which is equal to the weight of the displaced fluid.*

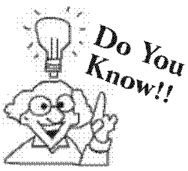
It applies to both liquids and gases. If an immersed object displaces 1 kg of fluid, the buoyant force acting on it is equal to the weight of 1 kg of the fluid.

Notice that unless the container is compressed, the buoyant force is equal to the weight of the displaced liquid at any depth, as long as it is completely submerged. This is because, at any depth, it can displace no greater volume of the liquid than its own volume.

Archimedes' (287 – 212 BC) and the Gold Crown

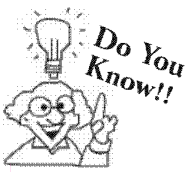
According to popular legend, Archimedes' had been given the task of determining whether a crown made for King Hiero II of Syracuse was of pure gold or whether it contained some less expensive metals, such as silver. Archimedes' problem was to find the density of the crown without destroying it. He could weigh the gold, but determining its volume was a problem. The story has it that Archimedes' came to the solution when he noted the rise in water level while immersing his body in the public baths of Syracuse. Legend reports that he excitedly rushed naked through the streets shouting " Eureka! Eureka!" ("I have found it! I have found it!").

What Archimedes' had discovered was a simple and accurate method of finding the volume of an irregular object – the displacement method of determining volumes. Once he knew both the weight and volume, he could calculate the density. Then the density of the crown could be compared to the density of gold. Archimedes' insight preceded Newton's laws of motion, from which Archimedes' principle can be derived, by almost 2000 years.



If the weight of a body submerged in a liquid is more than the weight of the liquid displaced, the body will sink in it.

If the weight of a body submerged in a liquid is equal or less than the weight of the liquid displaced, the body will float.



Only in the special case of floating does the buoyant force acting on an object equal the object's weight.

For a floating body, the weight of the body is balanced by the upthrust.

RELATIVE DENSITY

Relative density of a substance is defined as the ratio of its density to the density of water at 4°C. It is also called *specific gravity*. Mathematically,

$$\text{Relative density R.D.} = \frac{\text{density of substance}}{\text{density of water at } 4°\text{C}}$$

Since relative density is a ratio of same quantities, it has no unit.

Do You Know!!

If W_1 & W_2 represent the weight of a solid in air and water respectively, then the relative density of the solid R.D. $= \dfrac{W_1}{W_1 - W_2}$

Think it Over

People who can't float are, nine times out of ten, males. Most males are more muscular and slightly denser than most females. Also, cans of diet soda float whereas cans of regular soda sink in water. What does this tell you about their relative densities?

CHECK Point

1. **Does Archimedes' principle tell us that, if an immersed block displaces 10 N of fluid, the buoyant force on the block is 10 N?**
2. **A 1 litre container completely filled with lead has a mass of 11.3 kg and is submerged in water. What is the buoyant force acting on it?**
3. **A boulder is thrown into a deep lake. As it sinks deeper and deeper into the water, does the buoyant force on it increase? decrease?**

SOLUTION

1. Yes. If you look at this question with Newton's third law in mind, you can see that, when the immersed block pushes 10 N of fluid aside, the fluid reacts by pushing back on the block with a force of 10 N.
2. The buoyant force is equal to the weight of 1 kg (9.8 N) because the volume of water displaced is 1 L, which has a mass of 1 kg and a weight of 9.8 N. The 11.3 kg mass of the lead is irrelevent; 1 L of anything submerged in water will displace 1 L and be buoyed upward with a force of 9.8 N, the weight of 1 kg. (Get this straight before going further!)
3. Buoyant force does not change as the boulder sinks because the boulder displaces the same volume of water at any depth. Because water is practically incompressible, its density is very nearly the same at all depths; hence, the weight of water displaced, or the buoyant force, is practically the same at all depths.

FLOATATION

Iron is much denser than water and therefore iron needle sinks, but an iron ship floats. Why is this so? Consider a solid 1- ton block of iron. Iron is nearly eight times as dense as water. When it is submerged, it will displace only 1/8 ton of water, which is certainly not enough to prevent it from sinking. Suppose that we reshape the same iron block into a bowl, as shown in Figure. Although its surface area is increased, it still weighs 1 ton. When settling in water, it displaces a greater volume of water than before. The deeper it is immersed, the more water it displaces and the greater the buoyant force acting upon it. When the buoyant force equals 1 ton, it will sink no further.

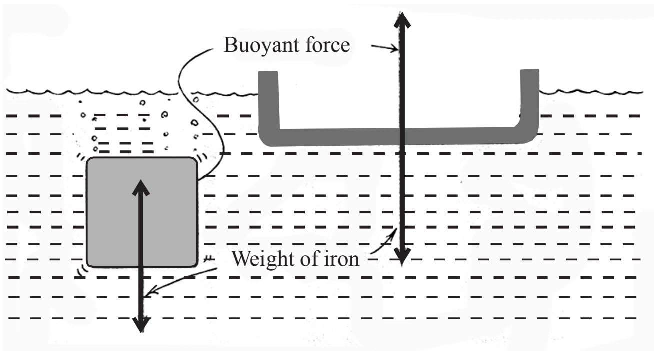


Fig. 1.29

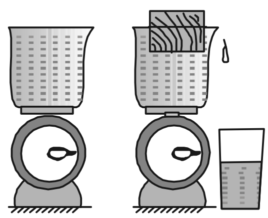


Fig. 1.30

A floating object displaces a weight of fluid equal to its own weight.

When the iron boat displaces a weight of water equal to its own weight, it floats. This is called the principle of flotation.

Every ship, submarine, and dirigible must be designed to displace a weight of fluid equal to its own weight. Thus, a 10,000 ton ship must be built wide enough to displace 10,000 tons of water before it sinks too deep in the water. The same applies to vessels in the air. A dirigible or a huge balloon that weighs 100 tons displaces at least 100 tons of air. If it displaces more, it rises; if it displaces less, it descends. If it displaces exactly its weight, it hovers at a constant altitude.

Since the buoyant force upon a body equals the weight of the fluid it displaces, denser fluids will exert a greater buoyant force upon a body than less dense fluids of the same volume. A ship, therefore, floats higher in salt water than in fresh water because salt water is slightly denser than fresh water. In the same way, a solid chunk of iron will float in mercury even though it sinks in water.

Think it Over

All bodies are buoyed up by a force equal to the weight of air they displace.

Why, then, don't all objects float like this balloon?

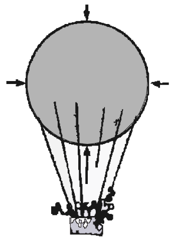


Fig. 1.31

CHECK Point

Figure shows four solid objects floating in corn syrup. Rank the objects according to their density, greatest first.

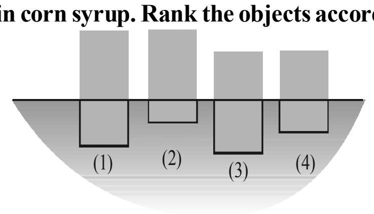


Fig.1.32

SOLUTION

The increasing portions of the objects submerged in the syrup are as below
$3 > 1 > 4 > 2$. Hence, the objects can be ranked as below
Rank 1 – object 3
Rank 2 – object 1
Rank 3 – object 4
Rank 4 – object 2

PRESSURE IN A GAS

The molecules in a gas are relatively farther placed with respect to a liquid. Therefore, their motions are less restricted. A gas expands, fills all space available to it, and exerts a pressure against its container.

Boyle's Law

Robert Boyle related the gas pressure with its volume in a container. It states that *if temperature of a gas remains constant then for a given mass of the gas, pressure is inversely proportional to its volume.*

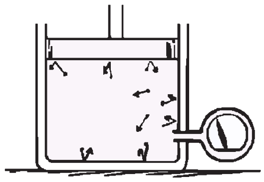
Mathematically, $P \propto \frac{1}{V}$ (T = constant) or, PV = constant

where, P = Pressure of gas
V = Volume of gas

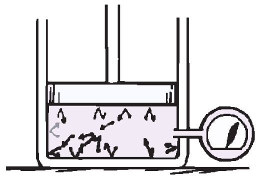
Therefore, if (P_1, V_1) and (P_2, V_2) be the pressure and volume in two states then

$$P_1 V_1 = P_2 V_2$$

When the volume of gas is decreased, the density, and therefore pressure, are increased.



(a)



(b)

Fig. 1.33

Buoyancy in a Gas

Buoyancy in gas acts in the same way as that in a liquid. Objects in a liquid are buoyed upward because the pressure acting up against the bottom of the object exceeds the pressure acting down against the top. Likewise air pressure acting up against an object immersed in air is greater than the pressure above pushing down. The buoyancy in both cases is numerically equal to the weight of fluid displaced. Archimedes' principle applies to air just as it does for liquid: *When an object is wholly or partially immersed in a gas, it loses some of its weight which is equal to the weight of the displaced gas.*

CHECK Point

1. **Is there a buoyant force acting on you? If there is, why are you not buoyed up by this force?**
2. **How does buoyancy change as a helium filled balloon ascends?**

SOLUTION

1. There is a buoyant force acting on you, and you are buoyed upward by it. You aren't aware of it only because your weight is so much greater.
2. If the balloon is free to expand as it rises, the increase in volume is counteracted by a decrease in the density of higher– altitude air. So, interestingly, the greater volume of displaced air doesn't weigh more, and buoyancy stays the same. If a balloon is not free to expand, buoyancy will decrease as the balloon rises because of the lesser density of the displaced air. Usually, balloons initially expand when they rise, and, if they don't eventually rupture, fabric stretching reaches a maximum and the balloons settle where buoyancy matches their weight.

CONNECTING TOPIC

MOTION OF FLUIDS

The motion of fluids are of following four types :

(i) **Streamline motion :** *In a fluid in motion, if fluid particles preceeding or succeeding a fluid particle follow the same path, then the path is called streamline; and then the motion of the fluid is called streamline motion*. This type of motion takes place in non-viscous fluids having very small speed.

Principle of continuity : When incompressible, non-viscous liquid flows in non-uniform tube then in streamline flow product of area and velocity at any section remains same. The mass of liquid flowing in equals the mass flowing out.

i.e., $m_1 = m_2$

or, $v_1 A_1 \rho_1 \, \Delta t = v_2 \, A_2 \rho_2 \Delta t$ ..... (1)

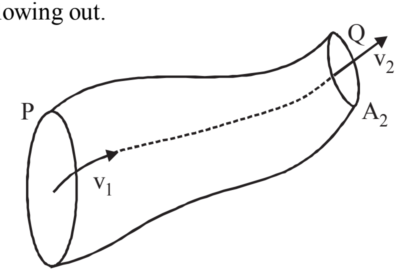


Fig. 1.34

As we have considered the fluid incompressible thus,

$v_1 A_1 = v_2 A_2$ or $Av = constant$ ....(2)

Since $\rho_1 = \rho_2$

Equations (1) and (2) are said to be as **equation of continuity**.

(ii) **Steady state motion :** *In a liquid in motion, when liquid particles, crossing a point, cross it with same velocity, then the motion of the liquid is called steady state motion*. This type of motion takes place in non-viscous liquids having very small speed.

(iii) **Laminar motion :** *Viscous liquids flow in bounded region or in a pipe, in layers and when viscous liquid is in motion, different layers have different velocities. The layers in contact with the fixed surface has least velocity and the velocity of other parallel layers increases uniformly and continuously with the distance from the fixed surface to the free surface of the liquid. This is called laminar motion of the liquid.*

(iv) **Turbulent motion :** *When the velocity of a liquid is irregular, haphazard and large, i.e. Beyond a limiting value called critical velocity the flow of liquid loses steadiness then the motion of the liquid is called turbulent motion*.

Critical velocity $V_c = \dfrac{K\eta}{\rho r}$

Here η is called coefficient of viscosity.

BERNOULLI'S PRINCIPLE

When incompressible, non-viscous, irrotational liquid i.e., ideal liquid flow from one position to other in streamline path then in its path at every point, the sum of pressure energy, kinetic energy and potential energy per unit volume remains constant.

i.e., $P_1 + \rho g h_1 + \frac{1}{2}\rho v_1^2 = P_2 + \rho g h_2 + \frac{1}{2}\rho v_2^2$ .... (1)

$\therefore \quad P + \rho g h + \frac{\rho v^2}{2} = constant$

where P = pressure energy per unit volume

ρgh = potential energy per unit volume and

$\frac{1}{2}\rho v^2$ = kinetic energy per unit volume.

The equation (1) is known as **Bernoulli's equation**.

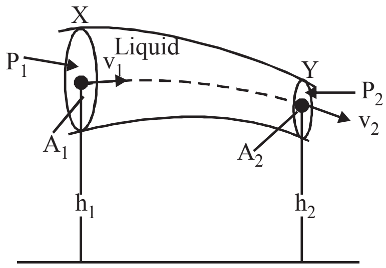
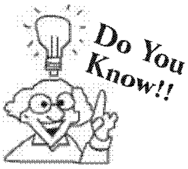


Fig. 1.35



- *A flowing fluid possesses three kinds of energies*
  - *(i) potential energy*
  - *(ii) kinetic energy and*
  - *(iii) pressure energy*
- *Wings of an aeroplane are shaped such that air travel faster over their top surfaces*
- *The curved shape of an umbrella can be disadvantageous on a windy day.*

Fig. 1.36

Applications of Bernoulli's Principle

Venturi-meter : It is a device used for the measurement of rate of flow of incompressible fluid through a tube. The working of venturi-meter is based on Bernoulli's principle.

The rate of flow of fluid

$$V = A_1 A_2 \sqrt{\frac{2gh}{A_1^2 - A_2^2}}$$

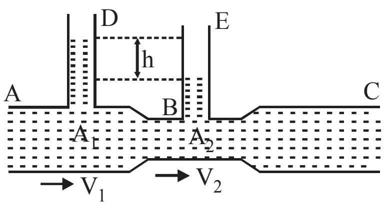


Fig. 1.37

Torricelli's law (speed of efflux) : The speed with which the liquid flows out of an orifice is equal to the speed of a freely falling body, would acquire in falling through a vertical distances equal to the depth of orifice below the free surface of liquid.

i.e., velocity of efflux, $v = \sqrt{2gh}$

Horizontal range, $R = 2\sqrt{hh'}$

The time after which liquid strikes the horizontal surface at the base level of the liquid,

$$t = \sqrt{\frac{2h'}{g}}$$

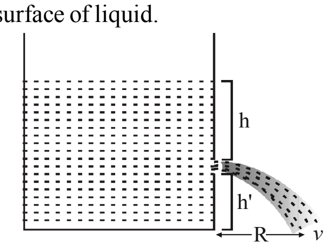
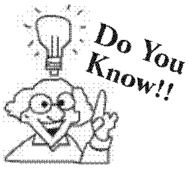


Fig. 1.38

VISCOSITY

If water in a tube is whirled and then left to itself, the motion of the water stops after some time. This is very common observation. What stops the motion? There is no external force to stop it. A natural conclusion is, therefore, that whenever there is relative motion between parts of a fluid, internal forces are set up in the fluid, which oppose the relative motion between the parts in the same way as forces of friction operate when a block of wood is dragged along the ground. To maintain relative motion between layers of a fluid an external force is needed.

"The property of a fluid by virtue of which it opposes the relative motion between its different layers is known as viscosity and the force that is into play is called the viscous force".



Viscous force plays the same role in fluids as the frictional force plays in case of solids. The viscosity of a liquid decreases with increase in temperature but the viscosity of a gas increases with increase in temperature.

SURFACE TENSION

If we place an iron needle slowly on the surface of water it floats on it. Rain drops are spherical in shape, soap water cleans clothes, these phenomena are due to the property of the liquid which is called surface tension. It is the property of a liquid at rest, due to which the top of a liquid contained in a vessel behaves like a stretched membrane occupying minimum surface area.

Examples of surface tension:

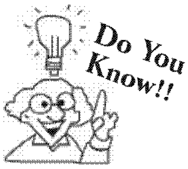
(i) After putting a glass rod in a burner flame its end becomes spherical.

(ii) Rain drops are spherical in shape.

(iii) Soap water cleans clothes well in comparison to impure water.

(iv) Filling the ink in the nib of a pen.

(v) The dancing of camphor on the water surface.



Liquids behave as if there is a skin on their surfaces.

Think it Over

Hair of a brush, when dipped in water spread out; but as soon as it is taken out, its hair cling together. Think of the physics behind it.

SUMMARY

- **Force :** It is an external agent (a push or a pull) which changes or tries to change the state of an object.
  It is a vector quantity and its S.I. unit is newton(N). Its C.G.S. unit is dyne (1 dyne = 10^{-5} newton).
- **The rule of equilibrium :** When the net force acting on a system is zero, it said to be in mechanical equilibrium.
- **Normal force :** The force exerted by the surface on the body placed on it which always acts in a direction perpendicular to the surface is called normal force.
- **Force of friction :** The force acting on two bodies in contact which always opposes their relative motion is called force of friction.
- **First law of motion :** Every object continues in a state of rest or in a state of uniform motion in a straight line, unless it is compelled to change that state by external forces exerted upon it.
- **Inertia :** The property of an object due to which it resist any change in its state of motion is called inertia. It is of three kinds (i) inertia of rest, (ii) inertia of motion and (iii) inertia of direction.
- **Second law of motion :** The acceleration produced by a net force on an object is directly proportional to it and is in the same direction as the net force but is inversely proportional to the mass of the object.
- **Linear momentum :** The product of mass and velocity of a body is called its momentum.
- **Conservation of linear momentum :** It states that in absence of external force, the total linear momentum of a system remains conserved.
- **Third law of motion :** This law states that to every action there is always an equal and opposite reaction.
- **Free fall :** A body falling under the action of gravity only is said to be in free fall.
- **Pressure :** The net force acting over a unit area is called pressure. Pressure $= \dfrac{\text{force or thrust}}{\text{area}}$.
- **Thrust :** The net force acting normal to a surface is called thrust.
- **Atmospheric pressure :** The pressure caused by the weight of air is called atmospheric pressure. It is generally measured in mm of Hg or cm of Hg by a barometer.
- **Liquid pressure :** The pressure exerted by a liquid column of height h is given by $P = h\rho g$ where, ρ = density of the liquid
- **Total pressure at a point in a liquid :** Total pressure at a point at a depth 'x' from the surface of a liquid is given by
  $P = P_{atm} + \rho g x$ where, P_{atm} = atmospheric pressure
- **Pascal's law:** "The pressure exerted by a liquid at rest is transmitted unchanged and equally in all directions, and acts at right angles to the surface of the container".
- **Buoyancy in a liquid:** When we lift a submerged object out of the water, the weight of the object felt by us is less than its actual weight. This loss in the weight of the object is due to a force called 'buoyant' force and the property of the liquid is called **buoyancy**.
- **Mathematical expression for upthrust :** Upthrust = Volume of object × density of liquid × acceleration due to gravity = $V\rho g$
- **Archimedes' principle:** When an object is partially or wholly immersed in a fluid, it loses some of its weight which is equal to the weight of the displaced fluid.
- **Relative density:** Relative density of a substance is defined as the ratio of its density to the density of water at 4°C.
- **Bernoulli's principle:** If an ideal i.e., non-viscous, incompressible liquid is flowing in a streamlined flow then total energy i.e., sum of pressure energy, kinetic energy and potential energy per unit volume of the liquid remain constant
- **Viscosity :** The property of a fluid by virtue of which it opposes the relative motion between its different layers.
- **Surface tension:** It is the property of a liquid at rest, due to which the top of a liquid contained in a vessel behaves like a stretched membrane occupying minimum surface area.

1 EXERCISE

Fill in the Blanks :

DIRECTIONS : *Complete the following statements with an appropriate word / term to be filled in the blank space(s).*

1. A change in the state of rest or of uniform motion is produced by....................
2. 1 newton = ... dyne
3. Frictional force is a .... force.
4. The change in momentum of a body has the same .... as that of force applied on it.
5. A car at rest can be moved or a moving car can be stopped by applying....................
6. A body is acted upon by a constant force then it will have a uniform ....
7. When we jump out a boat standing in water it moves ....
8. When a body is travelling at constant velocity, the force on it is ....
9. At constant temperature, the pressure of a gas is inversely proportional to its...........
10. The length of water column that can exert 1 atm pressure is ....
11. The property of a fluid to exert buoyant force on an object immersed in it is known as ....
12. The pressure exerted by mixture of atmospheric gases on its surroundings and on the surface of the earth is known as ....
13. As height of the liquid column increases, the pressure exerted by a liquid at a point ....

True/False :

DIRECTIONS : *Read the following statements and write your answer as true or false.*

1. Gravitational force and electrostatic force are non-contact forces.
2. If net force acting on a body is zero, it is said to be in equilibrium.
3. If a body is moving with a constant speed along a straight line then in order to change its direction of motion, an external force has to be applied in direction normal to the direction of motion.
4. The area under a force-time graph gives acceleration.
5. It is not advisable to tie any luggage kept on the roof of a bus with rope.
6. As the vertical height from mean sea level increases, the atmospheric pressure decreases.
7. Atmospheric pressure is 1.013×10^5 N/m^2.
8. Liquids exert pressure in all directions.
9. Archimedes' principle is a consequence of the conservation of energy.

Match the Following :

DIRECTIONS : *Each question contains statements given in two columns which have to be matched. Statements (A, B, C, D)in Column I have to be matched with statements (p, q, r, s) in Column II.*

1.

Column-I	Column-II
(A) Contact force	(p) Electrostatic
(B) Non-contact force	(q) Gravity
(C) Weight	(r) Max. at sea level
(D) Atmospheric pressure	(s) Friction

2.

Column I	Column II
(A) dyne/cm^2	(p) 760 mm of Hg
(B) 76 cm of Hg	(q) Nm^{-2}
(C) 1 Pa	(r) 1.013×10^{-5} Nm^{-2}
(D) 1 atm	(s) 10^{-1} Nm^{-2}

Very Short Answer Questions :

DIRECTIONS : *Give answer in one word or one sentence.*

1. Define force.
2. Is acceleration directly proportional to force, or is it inversely proportional to force?
3. Does a heavy object accelerate more than a light object when both are freely falling?
4. What is the net force that acts on a 10-N falling object with it encounters 4N of air resistance?
5. If body A and body B are both within a system, can forces between them affect the acceleration of the system?
6. Define atmospheric pressure.
7. Which instrument is used to measure atmospheric pressure?
8. Give two examples each of contact and non-contact force.
9. Give the expression for the pressure at a point inside a liquid.

Short Answer Questions :

DIRECTIONS : *Give answer in two to three sentences.*

1. State three effects that a force can produce.
2. When two horizontal forces are exerted on a cart, 600 N forward and 400N backward, the cart undergoes acceleration. What additional force is needed to produce non-accelerated motions?
3. If mass of 1 kg is accelerated 1 m/s^2 by a force of 1 N, what would be the acceleration of 2 kg acted on by a force of 2 N?
4. A boxer punches a sheet of paper in midair, and thereby brings it from rest upto a speed of 25 m/s in 0.5 second. If the mass of the paper is 0.003 kg, what force does the boxer exert on it?

5. Suppose that you are standing on a skateboard near a wall and that you push on the wall with a force of 30 N. How hard does the wall with a force of push you?
6. Forces of 3 N and 4 N act at right angles on a block of mass 5 kg. How much acceleration occurs?
7. Define force. Write its S.I. and C.G.. S. unit.
8. Define pressure. Write its S.I. unit.
9. A nail has 2 cm^2 at one end and $\frac{1}{100}$ cm^2 at the other end. A force of 1000 gwt is applied on the first end. Calculate the pressure acting on the wall?
10. A liquid of mass 200 g exerts a pressure of 0.1 Pa at a bottom of container. What pressure would it exert if the area of cross section of container is doubled?

Long Answer Questions :

DIRECTIONS : *Give answer in four to five sentences.*

1. State Newton's second law of motion. How does it help to measure force. Also state the units of force.
2. State Newton's third law of motion. Discuss its consequences.
3. A sphere of relative density σ and diameter d has concentric cavity of diameter D. What is the ratio of d/D if it just floats on water in a tank?
4. A truck of mass M is moved under a force F. If the truck is then loaded with an object equal to the mass of the truck and the driving force is halved, then how does the acceleration change?
5. Why gas filled balloons rise up, only to a certain height?

2 EXERCISE

Text-Book Exercise :

1. Give two examples each of situations in which you push or pull to change the state of motion of objects.
2. Give two examples of situations in which applied force causes a change in the shape of an object.
3. Fill in the blanks in the following statements:
   (a) To draw water from a well we have to _____ at the rope.
   (b) A charged body ______ an uncharged body towards it.
   (c) To move a loaded trolley we have to _______ it.
   (d) The north pole of a magnet ______ the north pole of another magnet.
4. An archer stretches her bow while taking aim at the target, She then releases the arrow, which begins to move towards the target. Based on this information fill up the gaps in the following statements using the following terms:
   Muscular, contact, non-contact, gravity, friction, shape, attraction
   (a) To stretch the bow, the archer applies a force that causes a change in its ______.
   (b) The force applied by the archer to stretch the bow is an example of ____ force.
   (c) The type of force responsible for a change in the state of motion of the arrow is an example of ______ force.
   (d) While the arrow moves towards its target, the forces acting on it are due to _______ and that due to _____ of air.
5. In the following situations, identify the agent exerting the force and the object on which it acts. State the effect of the force in each case.
   (a) Squeezing a piece of lemon between the fingers to extract its juice.
   (b) Taking out paste from a toothpaste tube.
   (c) A load suspended from a spring while its other end is on a hook fixed to a wall.
   (d) An athlete making a high jump to clear the bar at a certain height.
6. A blacksmith hammers a hot piece of iron while making a tool. How does the force due to hammering affect the piece of iron?
7. An inflated balloon was pressed against a wall after it has been rubbed with a piece of synthetic cloth. It was found that the balloon sticks to the wall. What force might be responsible for the attraction between the balloon and the wall?
8. Name the forces acting on a plastic bucket containing water held above ground level in your hand. Discuss why the forces acting on the bucket do not bring a change in its state of motion.
9. A rocket has been fired upwards to launch a satellite in its orbit. Name the two forces acting on the rocket immediately after leaving the launching pad.
10. When we press the bulb of a dropper with its nozzle kept in water, air in the dropper is seen to escape in the form of bubbles. Once we release the pressure on the bulb, water gets filled in the dropper. The rise of water in the dropper is due to
    (a) pressure of water (b) gravity of the earth
    (c) shape of rubber bulb (d) atmospheric pressure

Exemplar Questions :

1. Two persons are applying forces on two opposite sides of a moving cart. The cart still moves with the same speed in the same direction. What do you infer about the magnitudes and direction of the forces applied.

2. 

   Fig. shows a man with a parachute. Name the force which is responsible for his downward motion. Will he come down with the same speed without the parachute?

3. Fruits detached from a tree fall down due to force of gravity. We know that a force arises due to interaction between two objects. Name the objects interacting in this case.

4. An archer shoots an arrow in the air horizontally. However, after moving some distance, the arrow falls to the ground. Name the initial force that sets the arrow in motion. Explain why the arrow ultimately falls down.

5. Two women are of the same weight. One wears sandals with pointed heels while the other wears sandals with flat soles. Which one would feel more comfortable while walking on a sandy beach? Give reasons for your answer.

Hots Questions :

1. An athelete runs same distance before taking a jump. Explain why?

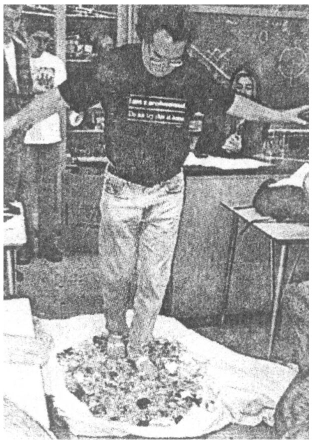
2. What is the angle between frictional force and instantaneous velocity of the body moving over a rough surface?

3. (a) According to Newton's third law of motion, every force is accompanied by an equal (in magnitude) and opposite (in direction) force called reaction, then how can a movement takes place?

   (b) You can move a brick easily by pushing it with your foot on a smooth floor, but, if you kick it, then your foot is hurt. Why?

4. Why is it easier to maintain the motion than to start it?

5. The photo shows the Physics teacher Mr. Chaurasiya walking barefoot on broken glass bottles in his class. What concept is he demonstrating, and why is he carefull that broken pieces are small and numerous?

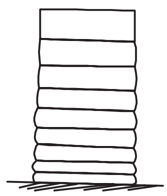
   

6. When a vessel containing a liquid is falling freely, does Archimedes's principle hold good in it?

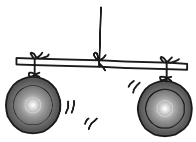
7. A block of wood floats in a bucket of water in a lift. Will there be any change in the equilibrium of wood if the lift starts accelerating upwards?

8. Why is the water reservoir of a dam thicker at the bottom?

9. We can understand how pressure in water depends on depth by considering a stack of bricks. The pressure below the bottom brick is determined by the weight of the entire stack. Halfway up the stack, the pressure is half because the weight of the bricks above is half. To explain atmospheric pressure, we should consider compressible bricks like foam rubber. Why is this so?

10. Two identical balloons of the same volumes are pumped up air to more than atmospheric pressure and suspended on the ends of a stick that is horizontally balanced. One of the balloons is then punctured. Is there a change in stick's balance? If so, which way does it trip?

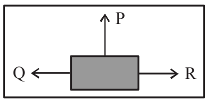
    

3 EXERCISE

Single Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

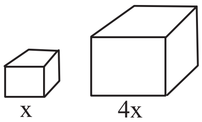
1. Three persons P, Q and R pull block with equal forces as shown in figure. Identify the direction of motion of the block?



(a) In horizontal direction towards left.
(b) In horizontal direction towards right.
(c) In vertically upward direction.
(d) The block remains stationary.

2. Which of the following is an example of a non-contact force?
(a) Muscular force (b) Frictional force
(c) Magnetic force (d) None of these

3. A cube of side 'x' rests on the floor as shown in the figure. Given that the pressure exerted by this cube on the floor is P, what is the pressure exerted by another cube of the same material of side 4x? (Take $g = 10\,N\,kg^{-1}$)



(a) P (b) 2P
(c) 4P (d) 16P

4. When a body is stationary, then
(a) there is no force acting on it
(b) the body is in vacuum
(c) the force acting on it is not in contact with it
(d) the net forces acting on it balances each other

5. An object will continue moving uniformly when
(a) the resultant force on it is increasing continuously
(b) the resultant force is at right angles to its rotation
(c) the resultant force on it is zero
(d) the resultant force on it begins to decrease

6. The force exerted by the floor of an elevator on the foot of a person standing there, is more than his weight, if the elevator is
(a) going down and slowing down
(b) going up and speeding up
(c) going up and slowing down
(d) either (a) and (b)

7. Pressure at a point inside a liquid does not depend on
(a) the depth of the point below the surface of the liquid
(b) the nature of the liquid
(c) the acceleration due to gravity at that point
(d) the shape of the containing vessel

8. Pressure varies with force (F) as (provided area is same)
(a) F (b) $\frac{1}{F}$ (c) F^2 (d) $\frac{1}{F^2}$

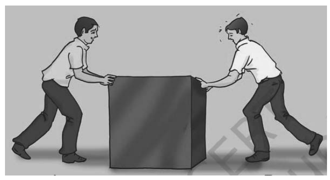
9. The pressure exerted by a women wearing shoes with pointed heels is .... than what an elephant with one foot can exert on ground
(a) much lesser (b) much greater
(c) both equal (d) none of these

10. Liquid pressure at a point in a liquid does not depend on the
(a) density of liquid
(b) shape of the vessel in which the liquid is kept
(c) depth of the point from the surface
(d) acceleration due to gravity

11. Pressure at a certain depth in river water is P_1 and at the same depth in sea water is P_2. Then (density of sea water is greater than that of river water)
(a) $P_1 = P_2$ (b) $P_1 > P_2$
(c) $P_1 < P_2$ (d) $P_1 - P_2$ = atmospheric pressure

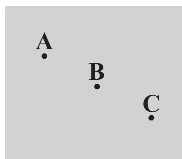
12. If the force on the surface is doubled and area is reduced to half, pressure will
(a) become 2 times (b) become 3 times
(c) become 4 times (d) remain unchanged

13. In Fig. two boys A and B are shown applying force on a block. If the block moves towards the right, which one of the following statements is correct?



(a) Magnitude of force applied by A is greater than that of B.
(b) Magnitude of force applied by A is smaller than that of B.
(c) Net force on the block is towards A.
(d) Magnitude of force applied by A is equal to that of B.

14. Fig. shows a container filled with water. Which of the following statements is correct about pressure of water?



(a) Pressure at A> Pressure at B> Pressure at C
(b) Pressure at A=Pressure at B=Pressure at C
(c) Pressure at A< Pressure at B>Pressure at C
(d) Pressure at A< Pressure at B<Pressure at C

15. A force of 100 N acts on a body of mass 2 kg for 10 s. The change in momentum of the body is

(a) 100 N–s (b) 250 N–s
(c) 500 N–s (d) 1000 N–s

16. A man is at rest in the middle of a pond of perfectly smooth ice. He can get himself to the shore by making use of Newton's

(a) First law (b) Second law
(c) Third law (d) All the laws

17. A cannon after firing recoils due to

(a) Conservation of energy
(b) Backward thrust of gases produced
(c) Newton's third law of motion
(d) Newton's first law of motion

18. A body of mass 4 kg moving on a horizontal surface with an initial velocity of 6 ms^{-1} comes to rest after 3 seconds. If one wants to keep the body moving on the same surface with the velocity of 6 ms^{-1}, the force required is

(a) Zero (b) 4 N
(c) 8 N (d) 16 N

19. A force of 10 N acts on a body of mass 20 kg for 10 seconds. Change in its momentum is

(a) 5 kg m/s (b) 100 kg m/s
(c) 200 kg m/s (d) 1000 kg m/s

20. When an object is made to float in two different liquids of density d_1 and d_2, the lenght of the object seen above the liquid surface are l_1 and l_2 respectevely. Which of the following is the correct alternative?

(a) $d_1 > d_2$ if $l_1 > l_2$ (b) $d_1 > d_2$ if $l_2 > l_1$
(c) $d_1 < d_2$ if $l_1 > l_2$ (d) $d_1 < d_2$ if $l_2 > l_1$

21. When an object of weight W is immersed in a liquid, its weight in the liquid is found to be W_1. When it is immersed in water, the weight of the water displaced is found to be W_2. The relative density of the liquid is

(a) $\frac{W_2}{W_1}$ (b) $\frac{W - W_1}{W_2}$

(c) $\frac{W_2}{W - W_1}$ (d) $\frac{W - W_2}{W_1}$

22. A solid cylinder of density 800 kg m^{-3} floats in water. The percentage volume of solid cylinder outside the water is

(a) 10 (b) 80
(c) 50 (d) 20

23. When a body of density ρ and volume V is floating in a liquid of density

(a) its true weight is $V\sigma g$
(b) loss in its weight is $V\sigma g$
(c) its apparent weight is zero
(d) its density ρ is greater than that of liquid σ

24. Two pieces of metal when immersed in a liquid have equal upthrust on them; then

(a) both pieces must have equal weights
(b) both pieces must have equal densities
(c) both pieces must have equal volumes
(d) both are floating to the same depth

25. The apparent weight of wood floating on water if it weighs 100 g in air is

(a) 400 g (b) 300 g
(c) 100 g (d) zero

26. An egg when placed in ordinary water sinks but floats when placed in brine. This is because

(a) density of brine is less than that of ordinary water
(b) density of brine is equal to that of ordinary water
(c) density of brine is greater than that of ordinary water
(d) None of these

27. Two pieces of metals are suspended from the arms of a balance and are found to be in equilibrium when kept immersed in water. The mass of one piece is 32 g and its density 8 g cm^{-3}. The density of the other is 5 g per cm^3. Then the mass of the other is

(a) 28 g (b) 35 g
(c) 21 g (d) 33.6 g

28. A man is sitting in a boat which is floating in pond. If the man drinks some water from the pond, the level of water in the pond will

(a) rise a little (b) fall a little
(c) remain stationary (d) none of these

29. A man is walking from east to west on a level rough surface. The frictional force on the man is directed

(a) from the west to east (b) from the east to west
(c) along the north (d) along the west

30. A spring balance is graduated on sea level. If a body is weighted at consecutively increased height from earth's surface, the weight indicated by the balance

(a) will go on increasing continuously
(b) will go on decreasing continuously
(c) will remain same
(d) will first increase and then decrease

31. A sample of metal weighs 210 g in air, 140 g in water and 120 g in an unknown liquid. Then

(a) the density of the metal is 3 g/cm^3
(b) the density of the metal is 7 g/cm^3
(c) density of the metal is 4 times the density of unknown liquid
(d) the metal still float in water

More than One Option Correct :

DIRECTIONS : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONE OR MORE may be correct.*

1. Two similar buses are moving with same velocity on a straight road. One of them is empty and the other is loaded with passengers
(a) Both buses are stopped by the application of same force
(b) Loaded bus will be stopped by applying large force
(c) Loaded bus will be stopped by applying less force
(d) Empty buses will be stopped by applying less force and loaded bus will be stopped by appplying large force.

2. Which of the following action cannot be describes as pushing by a body ?
(a) kicking (b) lifting
(c) picking (d) opening

3. Choose the correct options
(a) A force is applied to an object in the direction of its motion. The speed of object will increase
(b) If no force acts on a body it will either remain in rest or move in a straight line
(c) Friction force can change speed of an object
(d) None of these

4. Choose the correct options ?
(a) A body floats in water because the net force acting on this body is zero
(b) A mountain climber experiences a nose bleed due to increase in atmospheric pressure
(c) A body floats in water because the net force acting on this body is non-zero
(d) A mountain climber experiences a nose bleed due to decrease in atmospheric pressure

5. Pressure at a point in a fluid is directly proportional to
(a) depth of the point from the surface
(b) density of the fluid
(c) acceleration due to gravity
(d) the area of cross section

6. Which of the following factors affect pressure?
(a) Area (b) Acceleration
(c) Force (d) Current

7. Which of the following statements are true?
(a) When the mass of a body is doubled then the momentum of a body is also doubled, provided the body maintains the same velocity
(b) We feel pain in the hand on hitting the wall, this is a consequence of Newton's third law of motion.
(c) A table cloth can be pulled from the table without dislodging the dishes. This is due to inertia of rest.
(d) Momentum is a vector quantity.

8. A large truck and a car, both moving with a velocity of same magnitude have a head-on-collision. Car suffers more damage than the truck. This is because
(a) the material used in car is inferior than the material used in truck.
(b) car experience the greater force of impact than the truck.
(c) momentum transferred to the truck is greater than the momentum transferred to the car
(d) momentum transferred to the car is greater than the momentum transferred to the truck.

9. Choose the correct options
(a) An object of mass 10g acquires a speed of 100m/s after 1 second. If the force acting on the object is constant, its magnitude will be 1N.
(b) If a force of 2.5N acts on a body of mass 0.5 kg, then the acceleration produced in the body would be 5 m/s^2.
(c) An object of mass 10g acquires a speed of 100m/s after 1 second. If the force acting on the object is constant, its magnitude will be 2N.
(d) If a force of 2.5N acts on a body of mass 0.5 kg, then the acceleration produced in the body would be 2.5 m/s^2.

Multiple Matching Questions :

DIRECTIONS : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

1.

	Column-I		Column-II
A.	Force	(p)	non-contact force
B.	Change in object	(q)	contact force
C.	Magnet pulling iron pins	(r)	air pressure
D.	Pulling the window pane	(s)	effect
E.	Bloating of tube of cycle tyre	(t)	cause

2.

	Column-I		Column-II
A.	Going up an inclined plane is more tiring than walking on a horizontal plane	(p)	Magnetic force
B.	It is difficult to inflate balloon beyond a certain point	(q)	Pressure
C.	Waling on a sanday beach is more tiring than waling on a road	(r)	Gravitational Force
D.	A compass needle always point in the north-south direction	(s)	Friction

3.

	Column A		**Column B**
A.	Thrust	(p)	F/A
B.	Pressure	(q)	Force
C.	Atmospheric pressure	(r)	Pascal
D.	Fluid pressure acts	(s)	Decrease with altitude
		(t)	In downward direction

Passage Based Questions :

DIRECTIONS : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Liquid pressure in a container doesn't depend on the shape of the container but it only depends on the height of the liquid column.

1. A cylinderical container is full of water. The pressure will be maximum at

(a) top surface (b) mid of container

(c) bottom (d) None of these

2. If half of the water is taken out, what is the pressure at the bottom? (P = pressure when container full of liquid)

(a) P (b) $\frac{1}{2}P$

(c) $\frac{3}{2}P$ (d) $2P$

Assertion & Reason :

DIRECTIONS : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements.*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.

(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.

(c) If **Assertion** is **correct** but **Reason** is **incorrect**.

(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

1. **Assertion :** The acceleration produced by a force in the motion of a body depends only upon its mass.

Reason : Larger is the mass of the body, lesser will be the acceleration produced.

2. **Assertion :** If the net external force on the body is zero, then its acceleration is zero.

Reason : Acceleration does not depend on force.

3. **Assertion :** An object can move with constant velocity if no net force acts on it.

Reason : No net force is needed to move an object with constant velocity.

4. **Assertion :** The pressure at a point is the ratio of force to the area on which force is acting.

Reason : Pressure is the thrust acting per unit area.

Integer/Numeric type Questions :

DIRECTIONS : *Following are integer based/Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

1. A force produces an acceleration of 16 m/s^2 in a body of mass 0.5 kg, and an acceleration of 4 m/s^2 in another body. If both the bodies are fastened together, the acceleration produced by that force is (1.6)x m/s^2. Find the value of x.

2. A 20 gm bullet moving at 300 m/s stops after penetrating 3 cm of bone. The average force exerted by the bullet is $-x \times 10^4$ N. Find the value of x.

3. A rocket of initial mass 6000 kg ejects mass at a constant rate of 16 kg/s with constant relative speed of 11 km/s. What is the acceleration of the rocket one minute after blast?

4. If the water pressure gauge shows the pressure at ground floor to be 270 k Pa, 3x metre high would water rise in the pipes of a building. Find the value of x.

5. A water tank is 20 m deep. What is the pressure at the bottom of the tank in atmosphere?

4 ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

DIRECTIONS (Qs. 1–24) : *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which ONLY ONE is correct.*

1. China wares are wraped in straw of paper before packing. This is the application of concept of
(a) impulse (b) momentum
(c) acceleration (d) force

2. The impulse of a body is equal to
(a) rate of change of its momentum
(b) change in its momentum
(c) the product of force applied on it and the time of application of the force.
(d) both (b) and (c)

3. A bullet of mass 20 g is fired from a rifle of 8 kg with a velocity of 100 m s^{-1}. The velocity of recoil of the rifle is
(a) 0.25 m s^{-1} (b) 25 m s^{-1}
(c) 2.5 m s^{-1} (d) 250 m s^{-1}

4. Conservation of linear momentum is equivalent to
(a) Newton's first law of motion
(b) Newton's second law of motion
(c) Newton's third law of motion
(d) None of these

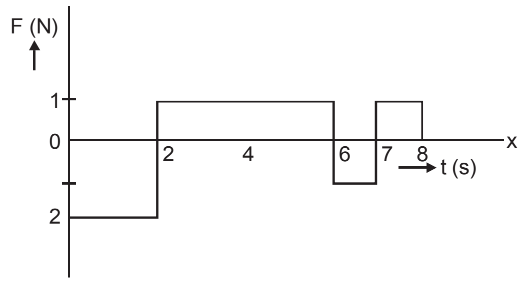
5. If two balls each of mass 0.06 kg moving in opposite direction with speed of 4 m s^{-1} collide and rebound with same speed, then the impulse imparted to each ball due to other is
(a) 0.48 kg m s^{-1} (b) 0.53 kg m s^{-1}
(c) 0.81 kg m s^{-1} (d) 0.92 kg m s^{-1}

6. When an elevator cabin falls down, the cabin and all the bodies fixed in the cabin are accelerated with respect to
(a) ceiling of elevator
(b) floor of elevator
(c) man standing on earth
(d) man standing in the cabin

7. The tension in the cable of 1000 kg elevator is 1000 kg wt, the elevator
(a) is ascending upwards
(b) is descending downwards
(c) may be at rest or accelerating
(d) may be at rest or in uniform motion

8. Consider an elevator moving downwards with an acceleration a, the force exerted by a passenger of mass m on the floor of the elevator is
(a) ma (b) $ma - mg$
(c) $mg - ma$ (d) $mg + ma$

9. A force time graph for the motion of a body is shown in Fig.. Change in linear momentum between 0 and 8s is



(a) zero (b) 4 N-s
(c) 8 Ns (d) None of these

10. Kerosene oil rises up in a wick of a lantern because of
(a) Diffusion of the oil through the wick
(b) Surface tension
(c) Buoyant force of air
(d) the gravitational pull of the wick

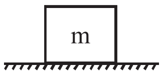
11. In a stream line (laminar flow) the velocity of flow at any point in the liquid
(a) does not vary with time
(b) may vary in direction but not in magnitude
(c) may vary in magnitude but not in direction
(d) may vary both in magnitude and direction

12. Water is flowing through a horizontal pipe in streamline flow. At the narrowest part of the pipe
(a) Velocity is maximum and pressure is minimum
(b) Pressure is maximum and velocity is minimum
(c) Both the pressure and velocity are maximum
(d) Both the velocity and pressure are minimum

13. The constant velocity attained by a body while falling through a viscous medium is termed as :
(a) critical velocity (b) terminal velocity
(c) threshold velocity (d) none of these

14. The difference between viscosity and solid friction is
(a) viscosity depends on area while solid friction does not.
(b) viscosity depends on nature of material but solid friction does not.
(c) both (a) and (b)
(d) neither (a) nor (b)

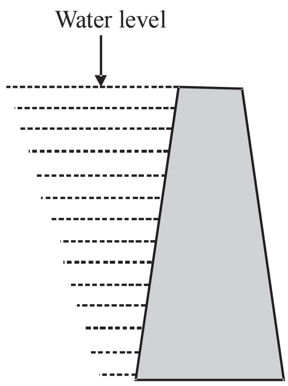
15. If r is the radius of influence of molecules of a certain liquid, then thickness of its surface film is
(a) r (b) $\frac{r}{2}$
(c) $2r$ (d) none of these
16. Bernoulli's theorems explains the phenomenon of
(a) blowing of roob's due to wind
(b) spinning of ball
(c) dynamic lift of aeroplane
(d) all of these
17. Toricelli's theorem is used to find :
(a) the velocity of efflux through an orifice.
(b) the velocity of flow of liquid through a pipe.
(c) terminal velocity
(d) critical velocity.
18. A block of mass m is placed on a smooth horizontal surface as shown. The weight (mg) of the block and normal reaction (N) exerted by the surface on the block



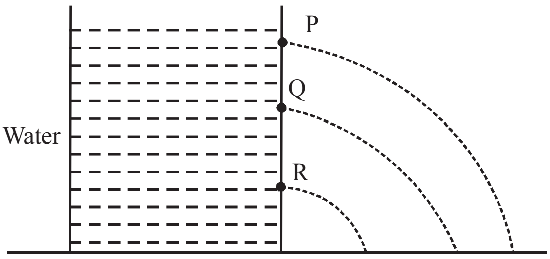
(a) form action-reaction pair
(b) balance each other
(c) act in same direction
(d) both (a) and (b)
19. A pin of density greater than that of water can float on the surface of water. It is due to :
(a) viscosity (b) buoyancy
(c) surface tension (d) none of these
20. With increase in temperature, the viscosity of gases :
(a) increases
(b) decrease
(c) remains same
(d) depends on the nature of the gas.
21. Paint-gun is based on :
(a) Bernoullis theorem
(b) Archimede's principle
(c) Boyle's law
(d) Pascal's law
22. Water is flowing through a horizontal pipe having a restriction, then
(a) Pressure will be greater at the restriction.
(b) Pressure will be greater in the wider portion.
(c) Pressure will be same through out the length of the pipe
(d) none of the above
23. The direction of impulse is
(a) same as that of the net force
(b) opposite to that of the net force
(c) same as that of the final velocity
(d) same as that of the initial velocity
24. A monkey is climbing up a rope, then the tension inthe rope.
(a) must be equal to the force applied by the monkey on the rope.
(b) must be less than the force applied by the monkey on the rope.
(c) must be greater than the force applied by the monkey on the rope.
(d) may be equal to, less than or greater the force applied by the monkey on the rope.

DIRECTIONS (Qs. 25–27): *This section contains multiple choice questions. Each question has 4 choices (a), (b), (c) and (d) out of which one or more may be correct.*

25. Which of the following statements are correct regarding linear momentum of a body?
(a) It is measure of quantity of motion contained by the body
(b) Change in momentum is the measurement of impulse
(c) Impulse and acceleration act in same direction to the change in momentum
(d) In case of uniform circular motion, the linear momentum is conserved
26. The given figure shows the cross section of a dam and its reservoir. Choose the correct options



(a) The widening of the wall, towards the bottom is because of increase in pressure with depth of water.
(b) The widening of the wall, towards the bottom is because of decrease in pressure with depth of water.
(c) Torque about the base tries to turn the dam.
(d) None of these
27. Choose the correct statements from the figure ?



(a) water flowing through hole P will move a smaller distance as compared to Q and R
(b) water flowing through hole Q will be maximum
(c) water flowing through R will be more than Q but less than p
(d) water flowing through all holes will travel same distance as pressure exerted by a liquid is equal in all direction

DIRECTIONS (Qs. 28-29) : *Following question has four statements (A, B, C and D) given in Column I and four statements (p, q, r , s) in Column II. Any given statement in Column I can have correct matching with one or more statement(s) given in Column II. Match the entries in Column I with entries in Column II.*

28.

Column I	Column II
(A) Action and reaction	(p) Rate in change of momentum
(B) Impulse	(q) Vector
(C) Force	(r) On two different bodies
(D) Momentum	(s) In opposite direction
	(t) Force for a very short time

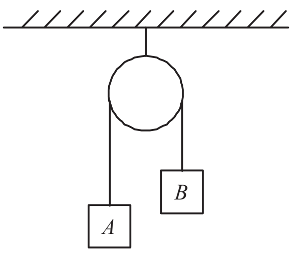
29.

Column A	Column B
(A) 1 atm	(p) newton
(B) Buoyant force	(q) 10^5 Pa
(C) Thrust	(r) bar
(D) Hydrometer	(s) upthrust
	(t) fluid pressure

DIRECTIONS (Qs. 30–32) : *Study the given paragraph(s) and answer the following questions.*

PARAGRAPH

Two blocks A and B of mass 2 kg and 3 kg respectively are connected with the help of a massless, inextensible string passing over a smooth pulley as shown, The system is released from rest at $t = 0$, then: (take $g = 10$ ms^{-2})



30. Acceleration of blocks is
(a) 5 ms^{-2} (b) 2 ms^{-2}
(c) 20/3 ms^{-2} (d) 6 ms^{-2}

31. If at t = 1s, block B is stopped momentarily and released, after how much time will the string become taut again?
(a) 0.2s (b) 0.4s
(c) 0.5s (d) 1s

32. What will be the velocity of the blocks, just after the string becomes taut?
(a) 0.2 ms^{-1} (b) 0.4 ms^{-1}
(c) 1 ms^{-1} (d) 2 ms^{-1}

DIRECTIONS (Qs. 33–37) : *Each of these questions contains an Assertion followed by Reason. Read them carefully and answer the question on the basis of following options. You have to select the one that best describes the two statements..*

(a) If both **Assertion** and **Reason** are **correct** and Reason is the **correct explanation** of Assertion.
(b) If both **Assertion** and **Reason** are correct, but Reason is **not the correct explanation** of Assertion.
(c) If **Assertion** is **correct** but **Reason** is **incorrect**.
(d) If **Assertion** is **incorrect** but **Reason** is **correct**.

33. Assertion : A rocket works on the principle of conservation of linear momentum.
Reason : Whenever there is change in momentum of one body, the same change occurs in the momentum of the second body of the same system but in the opposite direction.

34. Assertion : Inertia of an object of mass 10 kg is greater than the inertia of an object of mass 5 kg.
Reason : Inertia is inversely proportional to the mass of an object.

35. Assertion : Smaller the droplets of water, spherical they are.
Reason : Force of surface tension is equal, and opposite to force of gravity.

36. Assertion : The velocity of flow of a liquid is smaller when pressure is larger and vice-versa.
Reason : According to Bernoulli's theorem, for the stream line flow of an ideal liquid, the total energy per unit mass remains constant.

37. Assertion : Falling raindrops acquire a terminal velocity.
Reason : A constant force in the direction of motion and a velocity dependent force opposite to the direction of motion, always result in the acquisition of terminal velocity.

DIRECTIONS (Qs. 38 - 41) : *Following are integer based/ Numeric based questions. Each question, when worked out will result in one integer or numeric value.*

38. A body of mass 1 kg moving with a uniform velocity of $1\,\text{ms}^{-1}$. If the value of g is $5\,\text{ms}^{-2}$, then find the force acting on the frictionless horizontal surface on which the body is moving.

39. Two blocks of masses 2 kg and 1 kg are placed on a smooth horizontal table in contact with each other. A horizontal force of 3 newton is applied on the first so that the block moves with a constant acceleration. Find the force between the blocks would be

40. A cubical block is floating in a liquid with $\frac{3}{4}$ of its volume immersed in the liquid. When the whole system accelerates downwards with a net acceleration of g/4, the fraction of volume immersed in the liquid $\frac{3}{x}$. Find the value of x.

41. A cylindrical body of area of cross-section 100 cm^2 and length 4 cm is immersed in a liquid whose density is 1.5 g cm^{-3}. If the density of the solid is 2 g cm^{-3}, calculate the upthrust acting on the body.

SOLUTIONS

Brief Explanations of Selected Questions

1 EXERCISE

FILL IN THE BLANKS :

1.	net external force	**2.**	10^5
3.	contact	**4.**	direction
5.	external unbalanced force	**6.**	acceleration
7.	backwards	**8.**	zero
9.	volume	**10.**	10.336 m
11.	buoyancy	**12.**	atmospheric pressure
13.	increases		

TRUE/FALSE :

1.	True	**2.**	True	**3.**	True	**4.**	False
5.	False	**6.**	True	**7.**	True	**8.**	True
9.	False						

MATCH THE COLUMNS :

1. $A \rightarrow (s), B \rightarrow (p), C \rightarrow (q), D \rightarrow (r)$

2. $A \rightarrow (s), B \rightarrow (p), C \rightarrow (q), D \rightarrow (r)$

VERY SHORT ANSWER QUESTIONS :

1. Force is an external agent which changes or tries to change the state of an object

2. The acceleration is directly proportional to force and not inversely related.

3. No, both will accelerate with same acceleration, $g = 9.8\ m/s^2$

4. The net force will be $F_1 - F_2 = 10\ N - 4\ N = 6\ N$

5. No, if two bodies A and B are within a system, then their mutual forces are equal and opposite and cancel each other so that they do not affect the acceleration of the system.

6. The pressure exerted by air.

7. Barometer

8. **Contact force :** Frictional force and muscular force.

Non-contact force : Gravitational force and electrostatic force.

9. $P = \rho g h$

SHORT ANSWER QUESTIONS :

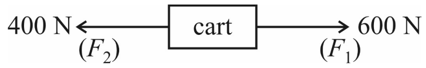
1. Effects produced by a force. :

(i) Force can change speed of an object.

(ii) Force can change the direction of motion of an object.

(iii) Force can change the shape of an object.

2. Two horizontal forces are acting on a cart in opposite directions as shown below



Thus the net force is, $F_1 - F_2 = 600 - 400$

$= 200\ N$

This net force is in the forward direction. This force produces acceleration in the forward direction. Hence to produce non-accelerated motion, an equal and opposite force must be applied to make the net force on the cart zero. Thus, required force = 200 N in the backward direction.

3. As we know,

$$\text{acceleration} = \frac{\text{force}}{\text{mass}}$$

A mass of 1 kg experiences an acceleration of 1 m/s^2 under a force of 1 N using above formula.

For a mass of 2 kg, under a force of 2 N, acceleration will be given by

$$\text{acceleration} = \frac{\text{force}}{\text{mass}} = \frac{2\ N}{2\ kg} = 1\ m/s^2$$

Thus the mass of 2 kg accelerates by 1 m/s^2 under a force of 2 N.

4. $a = \frac{25}{0.5}\ m/s^2 = 50\ m/s^2$ use formula F = ma = 0.15 N

5. We are standing on a skateboard and pushing the wall. The wall in turn pushes us back. These two forces form an action-reaction pair. By Newton's third law these two forces are equal and opposite of each other. This means that the wall pushes us with an equal amount of force = 30*N* in a direction away from the wall.

6. Let us assume that there is a mass '*m*' = 5 *kg* which is acted upon by two forces at right angles to each other as shown in figure.

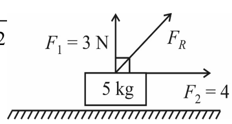
The first force is $F_1 = 3N$ acting in vertical direction.

The second force is $F_2 = 4N$ acting in horizontal direction.

These two force form two adjacent sides of a rectangle and their resultant force 'F_R' can be calculated using parallelogram law of vectors as

$$F_R = \sqrt{F_1^2 + F_2^2} = \sqrt{3^2 + 4^2}$$

$$\Rightarrow F_R = \sqrt{9 + 16} = 5\ N$$



A net force of 5 N acts on the mass at an angle inclined to it.
Now by Newton's second law

$$\text{acceleration of the mass} = \frac{\text{force on the mass}}{\text{mass of the body}}$$

$$= \frac{5\text{ N}}{5\text{ kg}} = 1\text{ m/s}^2$$

$\Rightarrow$ The mass will accelerate at a rate of 1 m/s^2.

10. $\text{Pressure} = \dfrac{\text{force}}{\text{area}}$

LONG ANSWER QUESTIONS :

1. Newton's second law of motion states that the rate of change of momentum of a rigid body is directly proportional to the applied force on it.

The law implies that when a bigger force is applied on a body of given mass, its linear momentum changes faster and vice-versa. The momentum will change in the direction of the applied force.

Let, m = mass of a body,

$\vec{v}$ = velocity of the body

$\therefore$ The linear momentum of the body

$$\vec{p} = m\vec{v} \qquad \text{...(i)}$$

Now, suppose $\vec{F}$ = external force applied on the body in the direction of motion of the body.

$\Delta\vec{p}$ = a small change in linear momentum of the body in a small time Δt.

Rate of change of linear momentum of the body

$$= \frac{\Delta\vec{p}}{\Delta t}$$

According to Newton's second law,

$$\frac{\Delta\vec{p}}{\Delta t} \alpha \vec{F} \quad \text{or} \quad \vec{F} \alpha \frac{\Delta\vec{p}}{\Delta t}$$

$$\text{or } \vec{F} = k\frac{\Delta\vec{p}}{\Delta t} \qquad \text{...(ii)}$$

where k is a constant of proportionality.

Taking the limit $\Delta T \to 0$, the term $\dfrac{\Delta\vec{p}}{\Delta t}$ becomes the derivative or differential coefficient of $\vec{p}$ w.r.t. time t. It is denoted by $\dfrac{d\vec{p}}{dt}$.

$$\therefore \vec{F} = k\frac{d\vec{p}}{dt}$$

Using eqn (i) $\vec{F} = k\dfrac{d}{dt}(m\vec{v}) = km\dfrac{d\vec{v}}{dt}$

$$\vec{F} = km\vec{a} \qquad \text{...(iii)}$$

where $\vec{a} = \dfrac{d\vec{v}}{dt}$ represents acceleration of the body.

The value of constant of proportionality k depends on the units adopted for measuring the force.

Now, putting $k = 1$

$\vec{F} = m\vec{a}$, This gives mean of measuring force.

Units of Force : Force in SI units is measured in 'Newton' or N. From the relation $\vec{F} = m\vec{a}$, we can see that a newton force is that force which produces 1 ms^{-2} acceleration in a body of mass 1 kg.

1 newton = 1 kilogram × 1 metre/second^2

$\Rightarrow$ 1 N = 1kg × 1 ms^{-2} = 1 kg ms^{-2}

In CGS system, force is measured in 'dyne'.

1 dyne = 1 gram × 1 cm s^{-2} = 1g cm s^{-2}

Since 1 N = 1kg ms^{-2} = 1000 g × 100 cm s^{-2}

= 10^5 g cm s^{-2} = 10^5 dyne.

$\Rightarrow$ 1 N = 10^5 dyne.

or 1 dyne = 10^{-5} N.

2. Newton's third law of motion states that for any action, there is equal and opposite reaction.

So, if a body applies a force F_{12} on body 2 (action), then body 2 also applies a force F_{21} on body 1 but in opposite direction, then

$$F_{21} = -F_{12}$$

In terms of magnitude

$$|F_{21}| = |F_{12}|$$

It is very important to note that F_{12} and F_{21} though are equal in magnitude and opposite in direction yet act on different point or else no motion will be possible.

For example, hands pull up a chest expander (spring) and spring in turn exerts force on the arms. A football pressed reacts on the foot with the same force and so on.

The most important consequence of the third law of motion is the law of conservation of linear momentum and its application in collision problems.

Since $F_{12} = -F_{21}$ and $F = m\dfrac{\Delta v}{\Delta t}$

$$\therefore m_1\frac{\Delta v_1}{\Delta t} = -m_2\frac{\Delta v_2}{\Delta t}$$

Here Δt is the time for which the bodies come in contact during impact. This is same for the two bodies of masses m_1 and m_2 and having velocity Δv_1 and Δv_2 respectively.

Therefore,

$m_1\,\Delta v_1 = m_2\,\Delta v_2$

or $m_1\,\Delta v_1 + m_2\,\Delta v_2 = 0$

Let u_1, u_2 and v_1, v_2 be the initial and final velocities of the two masses before and after collision, then,

$m_1(v_1 - u_1) = -m_2(v_2 - u_2)$

or $m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$

Momentum before impact = Momentum after impact.

(This is known as the law of conservation of momentum).

3. Let $\rho \rightarrow$ density of the sphere, $\rho' \rightarrow$ density of water.

The sphere will float if weight of the sphere = weight of the displaced water

$$\Rightarrow \frac{4}{3}\pi\left[\left(\frac{d}{2}\right)^3 - \left(\frac{D}{2}\right)^3\right]\rho g = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3 \rho' g$$

$$\Rightarrow (d^3 - D^3)\frac{\rho}{\rho^1} = d^3$$

$$\Rightarrow (d^3 - D^3)\,\sigma = d^3$$

$$\Rightarrow d^3(\sigma - 1) = \sigma D^3$$

$$\Rightarrow \frac{d}{D} = \left(\frac{\sigma}{\sigma - 1}\right)^{1/3}$$

2 EXERCISE

TEXT-BOOK EXERCISE :

1. (i) Applying the breaks to stop the vehicle

(ii) Opening or shutting the door.

2. (i) Applying the force to give shape to clay and make pots.

(ii) Bursting of a inflated balloon by pressing between the palms.

3. (a) apply the force of pull

(b) pulls or attracts

(c) either pull or push

(d) repels

4. (a) shape (b) muscular

(c) contact (d) gravity; friction

5. (a) Agent : Fingers Object : Lemon outer surface

Effect : shape of piece of lemon gets changed by squeezing and juice gets extracted.

(b) Agent : Fingers Object : Wall of tube and paste

Effect : Shape of the tube gets changed and paste is squeezed out.

(c) Agent : Weight of load Object : Spring

Effect : Spring will expand downward.

(d) Agent : Athlete Object : Athlete's body

Effect : The athlete will jump on the other side of the bar at a certain height.

6. When a blacksmith hammers a hot piece of iron, he uses his muscular force. This muscular force changes the shape of iron so that it can be given a desired shape.

7. When an inflated balloon is rubbed with a piece of synthetic cloth, it becomes charged. A charged body attracts an uncharged body so, when this charged balloon is pressed against a wall, it sticks to the wall. Electrostatic force is responsible for the attraction between the balloon and the wall.

8. The forces acting on the plastic bucket containing water held above the ground level are:

(a) Gravitational force (b) Muscular force

These forces donot change in the state of motion of bucket because they are balancing each other and as a result the net force becomes zero.

9. The forces acting on the rocket immediately after leaving the launching pad are:

(a) Force of gravitation in downward direction

(b) Friction force due to air

10. The rise of water in the dropper is due to atmospheric pressure. When all the air escapes from the nozzle, the atmospheric pressure, which is acting on the water, forces the water to fill the nozzle of the dropper.

EXEMPLAR QUESTIONS :

1. Both the forces are of equal magnitudes and applied in the opposite directions.

2. Force of gravity. No, without the parachute his speed will be higher.

3. Earth and fruits.

4. The archer stretches the string of the bow by applying muscular force. In the process the shape of the bow changes. When the string is released, it regains its original position that provides the initial force to set the arrow in motion. The force of gravity that acts on the arrow in the downward direction brings it to the ground.

5. The woman wearing sandals with flat soles will feel more comfortable while walking on the sandy beach. The flat soles have larger area compared to the sandals with pointed heels. Since the two women are of the same weight, they will apply same force on the ground. Therefore, the pressure exerted by the pointed heels will be more compared to that with sandals having flat soles. As a result the pointed heel sandals will sink more in the sand than the flat sole sandals. Hence, walking with flat sole sandals will be more comfortable.

HOTS QUESTIONS:

1. Running provides greater momentum which helps in jumping through a longer distance.

2. The angle is 180°, because force of friction always opposes the relative motion.

3. (a) As the action and reaction never act on the same body, so the motion is possible.

(b) As *Ft* remains constant, so if *t* is reduced, then F will be increased and hence hurt our foot.

4. As the dynamic friction is less than the force of limiting friction.

5. The teacher is demonstrating the concept of pressure.

The broken pieces of glass are having small cross-sectional area, so, the pressure on his feet increases and the glass pieces pierce through his skin. The relation between pressure and area is given by the formula, Pressure $= \dfrac{\text{Force}}{\text{Area}}$

So, for a constant force (body weight of the person) if the area decreases, pressure increases. The teacher is careful that the broken pieces are small and numerous because if the number of broken pieces is large, the combined surface area will be more, which results in a lesser pressure, and the glass pieces do not pierce through his skin.

6. No - because in free fall Buoyant force doesn't exist.
7. No - because equilibrium of floating bodies remain unaffected by variation of acceleration due to gravity.
8. Because the pressure of water increases with increase in depth.
9. Atmospheric pressure can be explained by using compressible bricks made up of foam rubber because larger the pressure, larger will be the compression on the surface of the bricks.
10. There will be a change in balance of the stick. It will tip on the side of the punched balloon. As the balloon is punched, air comes out through the hole, so the volume of the balloon decreases, so the buoyant force decreases. So due to its own weight the stick bends down on the side of the picked balloon.

3 EXERCISE

SINGLE OPTION CORRECT :

1. (c) It will move in vertically upward direction.
2. (c) Magnetic force is a non-contact force.
3. (c) The pressure exerted by another cube of the same material of side 4X is 4P.(P=F/A)

4. (d) **5.** (c) **6.** (b) **7.** (d)

8. (a) Pressure $= \dfrac{\text{Force}}{\text{area}}$ **9.** (b)

10. (b) Pressure , $P = \rho gh$ **11.** (b) **12.** (c)

13. (a) **14.** (d) **15.** (d) **16.** (c) **17.** (c)

18. (c)

19. (b) Change in momentum $= F \times t$

$= 10 \times 10 = 100$ Ns or 100 kg. m/s

20. (c) **21.** (b) **22.** (d) **23.** (c) **24.** (c)

25. (d)

26. (c) Brine due to its high density exerts an upthrust which can balance the weight of the egg.

27. (b) Volume of first piece of metal $= \dfrac{32}{8} = 4\,\text{cm}^3$

Upthrust = 4 gf

Effective weight = (32 – 4) gf = 28 gf

If m be the mass of second body, volume of second body is $\dfrac{m}{5}$

Now, $28 = m - \dfrac{m}{5} \Rightarrow m = 35$ g .

28. (c) **29.** (b) **30.** (b)

31. (a) $\dfrac{W_{air}}{W_{liq} - W_{water}} = \dfrac{210}{70} = 3\text{g/cm}^3$

MORE THAN ONE OPTION CORRECT :

1. (b, d) Inertia is $\propto$ mass
2. (b,c,d)
   Kicking is a pushing action while all others are pulling action.
3. (a,b,c)
   (a) Since the force is in the direction of motion, the speed of object will increase.
   (b) Force is required for a, b & d. In absence of a force an object will either remain at rest (static object) or move in a straight line (moving object).
   (c) Friction force between two surfaces tends to decrease the speed of a moving object.
4. (a,d) The weight of the body is balanced by the upthrust of water. Hence net force acting on the body is zero.
   The atmospheric pressure decreases with height due to thinning of atmosphere. Thus the internal body pressure becomes higher than atmospheric pressure causing a nose bleed.

5. (a, c) **6.** (a, c) **7.** (a, b, c, d) **8.** (b, d)

9. (a,b)

(a) Given : Mass $m = 10\text{ g} = 10^{-2}$ kg

Final speed, $v = 100$ m/s

Initial speed, $u = 0$, Time, $t = 1$ second

Acceleration, $a = \dfrac{v-u}{t} = 100\text{ m/s}^2$

Force, $F = ma = 10^{-2} \times 100 = 1\text{N}$

(b) Force = 2.5 N, mass of body = 0.5 kg.

Force = mass × acceleration

Acceleration $= \dfrac{\text{Force}}{\text{mass}} = \dfrac{2.5}{0.5} = 5\text{ m/s}^2$

MULTIPLE MATCHING QUESTIONS :

1. $A \to (s), B \to (t), C \to (p), D \to (q), E \to (r)$
2. $A \to (r), B \to (q), C \to (s), D \to (p)$
3. $A \to (q), B \to (p), C \to (s), D \to (r, t)$

PASSAGE BASED QUESTIONS :

1. (c) Pressure depends upon the length of air column.
2. (b) $P = \rho gh$

ASSERTION & REASON :

1. (a) **2.** (c) **3.** (a) **4.** (a)

INTEGER/NUMERIC TYPE QUSTIONS :

1. 2

Here, $a_1 = 16\ m/s^2$, $m_1 = 0.5$ kg,

$F = m_1 a_1 = 16 \times 0.5\ kg = 8\ N$

$$m_2 = \frac{F}{a_2} = \frac{8}{4} = 2\ kg\ ;\ m_1 + m_2 = 0.5 + 2 = 2.5\ kg,\ F = 8\ N;$$

$$a = \frac{F}{m_1 + m_2} = \frac{8}{2.5} = 3.2\ m/s^2 \quad \therefore \quad x = 2\ m/s^2$$

2. **3**

$$\text{Here, } m = \frac{20}{1000}\text{kg}, u = 300\ m/s, v = 0, s = 3\ cm = 3 \times 10^{-2}\ m$$

$$\therefore a = \frac{v^2 - u^2}{2s} = \frac{0 - (300)^2}{2 \times 3 \times 10^{-2}} = \frac{-300 \times 300}{2 \times 3 \times 10^{-2}}$$

$$= -1.5 \times 10^6\ m/s^2$$

$$\therefore \quad F = ma = \frac{20}{1000} \times (-1.5 \times 10^6) = -3 \times 10^4\ N$$

$\therefore$ x = 3

3. **34.92 m/s²**

Given, $m_0 = 6000$ kg, $\frac{dm}{dt} = 16$ kg/s, u = 11 km/s

= 11000 m/s, t = 1 min = 60 s, a = ?

$$\text{Mass left after 1 minute} = m_0 - \left(\frac{dm}{dt}\right)t$$

$$= 6000 - 16 \times 60 = 5040\ kg.$$

$$F = m\frac{du}{dt} = u\frac{dm}{dt}$$

$$\Rightarrow \quad a = \frac{du}{dt} = \frac{u(dm/dt)}{m}$$

$$\Rightarrow \quad a = \frac{1100 \times 16}{5040} = 34.92\ m/s^2$$

4. **9**

Here, P = 270 kPa = 270×10^3 Pa $\Rightarrow$ P = $h\rho g$

$$\Rightarrow h = \frac{P}{\rho g} = \frac{270 \times 10^3}{10^3 \times 9.8} = 27\ m$$

5. **3 atm**

Pressure at the bottom of the tank

= Atmospheric pressure + pressure due to the liquid column

$$P = P_0 + h\rho g = \left(1 + \frac{h\rho g}{P_0}\right)\text{atm}$$

$$= 1 + \frac{20\rho g}{10^5} = 3\ \text{atm}$$

4 ADVANCED EXERCISE
BASED ON CONNECTING TOPICS

1. (a) Impulse = Force × time

2. (d) Impulse = rate of change of momentum

3. (a) **4.** (c) **5.** (a) **6.** (c) **7.** (d)

8. (c) F = mg – ma when moving downward

9. (b) **10.** (b) **11.** (a) **12.** (a)

13. (b) When a body falls through a viscous medium, it attains a constant velocity called terminal velocity.

14. (a) Both friction and viscosity depend on nature of material but friction does not depend on area of contact.

15. (a) Thickness of the surface film is equal to the radius of influence.

16. (d) All the given phenomena can be explained by Bernoulli's theorem.

17. (a) Toricelli's theorem is used to find velocity of efflux of an ideal liquid through on orifice.

18. (b) Mg and N cannot form action-reaction pair as they are acting on same body.

19. (c) A pin of density greater than that of water can float on the surface of water due to surface tension.

20. (a) with increase in temperature, the viscosity of gases increases while those of liquids decreases.

21. (a) Paint gun is based on Bernoulli's theorem.

22. (b) By equation of continuity, the velocity of liquid will be more at narrower portion and less at wider portion, hence pressure will be more at the wider portion, as according to Bernoulli's theorem, pressure is more at a point where velocity is less.

23. (a) Direction of impulse is same as that of the net force.

24. (a) By Newton's third law of motion, the tension in the rope must be equal to the force applied by the monkey on the rope.

25. (a, b, d)

26. (a,c) The wall at bottom has to withstand higher pressure as compared to the top.

As force varies at the depth it produces torque about the base.

27. (a, b, d)

28. A – (r, s); B – (q, t); C – (p, q); D – (q)

29. A – (q, r); B – (s); C – (p); D – (t)

30. (b) *FBD* is of *A* and *B* are shown in figure, as $m_B > m_A$, *A* moves up and *B* moves down with same acceleration *Q*.

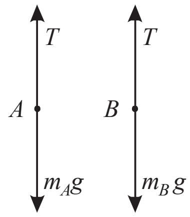
Here,

$m_B g - T = m_B a$ ...(1)

& $T - m_A g = m_A a$ ...(2)

On solving

$$a = \frac{m_B - m_A}{m_B + m_A} g = \frac{g}{5} = 2 \text{ ms}^{-2}$$



31. (a) Speed of A at $t = 1$s,

$v = u + \text{at} = 2$ ms–1

The string will become taut again when distance covered by both the blocks is equal, i.e.

$s_A = s_B$

$$2t - \frac{1}{2}gt^2 = \frac{1}{2}gt^2$$

or $t = 0.2$s.

32. (b) Let u_A and u_B be their velocities, just before the string become taut, then

$u_A = 2 - gt = 0, u_B = gt = 2 \text{ ms}^{-1}$

Let v be their common speed just after the string becomes taut, then

impulse of A on B = – impulse of B on A

$m_A(v - 0) = - m_B(v - 2)$

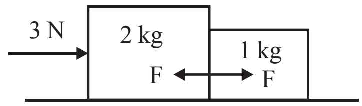
$2v = -3(v - 2)$

or $v = 0.4 \text{ ms}^{-1}$

33. (a) **34.** (c) **35.** (c) **36.** (a) **37.** (a)

38. **5** Weight of body = m g = 5 N

39. **1** See fig. Let F be the force between the blocks and a their common acceleration. Then for 2 kg block,



$3 - F = 2a$ ...(1)

for 1 kg block, $F = 1 \times a = a$ ....(2)

$\therefore 3 - F = 2F$ or $3F = 3$ or $F = 1$ newton

40. **4** The volume of liquid displaced, $v = \frac{m}{\rho}$, does not depend on a ceeleration due to grsletvity, so it remains as such.

41. **6**

Upthrust, F = vdg

$= 100 \times 4 \times 1.5 \times 10$ [$\because$ v = Al]

$= 600000$ dyne $\cong$ 6N