FORCE AND PRESSURE

Learning outcomes

By the end of this theme, students will be able to:

- explain the turning effect of a force with examples from daily life
- define the moment of a force and express it in standard units
- solve numerical problems based on the moment of a force
- define pressure
- solve numerical problems based on pressure
- describe the pressure exerted by solids, liquids and gases
- describe atmospheric pressure and how it is measured

Warm-up

Encourage students to complete the *Get going* section given at the beginning of the chapter.

GUIDELINES TO TEACH

Introduction:

Ask students:

Can you list a few instances from our daily life where force is required?

- Help students recall the uses of force and its effects in everyday life/how objects move when force (push or pull) is applied.
- State that we are unable to see forces but we are able to see their results.
- List and explain all the effects of forces as listed in the book.
- Help students recall about the different types of contact and non-contact forces from '*Know more*'.

Units of force

- Define one newton and explain the significance of the name. Compare one newton with one kilogram force and define one newton in terms of gravitational force.

Turning effect of force

- Define translatory motion with example.
- Using the example of a door moving on its hinges, define rotational motion.

- Underline the fact that an object fixed at some point cannot undergo translatory motion. The motion of such bodies is rotatory.
- With the example of the door, demonstrate the fact that the same force applied at different points on an object that is fixed at one point produce different amounts of rotation.
- Point out that the same force applied near the hinges produces very little rotation while that applied near the free end produces a large rotation.
- Ask students to do it and find out for themselves on the classroom door.
- Bring out clearly that it is not just the force alone, but the distance of the force from the fixed point—known as the *pivot*—about which the body rotates also that determines the amount of rotation is produced.
- Point out that these two factors are combined into one physical quantity that decides the amount of rotation produced—known as the *torque*.
- Define torque as the turning effect of a force about a fixed point.
- Introduce the terminology '*moment of the force'* as an equivalent to torque.
- Using the figure, '*The relationship between the point at which force is applied and the moment of the force*', given in the coursebook, explain that for a given force, the moment of the force is larger when the distance from the pivot is larger.
- Distinguish between clockwise and anticlockwise moments of force.
- Point out how the direction of rotation can be changed using the information from 'Spotlight'.
- Demonstrate the activity '*To determine the factors affecting the moment of a force*', given in the coursebook, in class.
- List and explain the factors that affect moment of the force.

Unit of moment of a force

- State the mathematical definition of the moment of the force and its expression as $M = F \times d$.
- Point out that d is the perpendicular distance of the point of action of the force from the pivot.

Ask students:

Can you obtain the unit of torque from the above expression? You already know the unit of energy as joule. Is the unit of torque same as that of energy?

- Show students how the unit of torque is obtained.
- Using *Spotlight*, explain that torque is not same as energy and hence unit of torque is just N-m and not joule.
- Help students to work out the examples, given in the coursebook.

PRESSURE

Ask students:

Have you heard of low blood pressure, high blood pressure? So, what is pressure? Does it have any relation to the word press?

- Help students recall the different effects of force. Explain that force and pressure are not the same but they are related.
- Give a small introduction/demonstration using a shoebox, as given in the coursebook.
- Discuss the activity '*To observe how the effect of a force changes with the area on which it acts*', given in the coursebook, and analyse the observations.
- Explain with more examples how the effect of a force depends on the area over which it acts.
- Define pressure based on the conclusion of the activity.
- Define pressure as the force acting perpendicular to unit area of the given surface and write down its formula on the board as, $\text{pressure} = \frac{\text{force}}{\text{area}} = \frac{F}{A}$.
- Remind students of the word thrust (last unit they learned about upthrust) and define thrust as the force perpendicular to area. Hence, $\text{pressure} = \frac{\text{thrust}}{\text{area}}$
- Underline the fact that force has to act perpendicular to the surface. Make this clear using the example given.
- Point out that pressure is directly proportional to the magnitude of the force perpendicular to the area and hence increases with force. On the other hand, pressure decreases with increase in area over which the force acts.
- Tell students that people can lie over a bed of nails, but they cannot stand on it because in the first case, weight of the person acts over a larger area while in the latter case, the same force acts over a very small area.

Ask students:

How is pressure related to force and area of contact?

Unit of pressure

- Just as was done in the previous unit, ask students to determine the unit of pressure from its definition.
- Define a pascal as 1 newton of force acting perpendicular to an area of 1 m^2.
- Help students to work out all the examples given under this section.
- Discuss the activity '*Calculating pressure*', given in the coursebook.

Everyday examples of pressure

Ask students:

Can you say why is it difficult to ride a bicycle with a flat tyre?

Why is it difficult to cut with a blunt knife than a sharp one?

Why is it easier to run in sports shoes than in shoes with heels?

- Encourage students to come up with examples of pressure applied from everyday life.
- Explain why it is easier to cut with a sharp knife and push in sharp board pins.
- Point out to students why their school bags have broad straps and why it is healthier to wear flat shoes.
- Point out the reason why the wheels of vehicles have rubber tyres and heavy vehicles have as much as 18 wheels.
- Explain the use of caterpillar tracks in bulldozers and tanks.
- Explain the need of broad base for tall buildings and pillars of bridges and broad sleepers under rail tracks.
- Share the information from Sci Tech.
- Work out example 9 in the class.
- Use **Stop and check** for a quick recap. 

Pressure exerted by liquids

Ask students:

What will happen if you keep on blowing air into a balloon? Can you explain the reason behind your answer?

- To give students an idea about what caused the breach of dam, show the video available in the link— youtube.com/watch?v=RcNqv0dm2lA
- Demonstrate the activity '*To determine whether liquids exert pressure*', given in the coursebook, and ask students to explain the observation.
- Point out that water exerts pressure in all directions. Prove this using the activity '*To check whether liquids exert pressure in all directions*', given in the coursebook.
- Discuss all the observations in detail and establish the relation between the height of liquid column above the hole and the force of ejection of water.
- Explain that from kinetic theory of matter, liquid molecules have some degree of motiondue to which they hit the walls of the container exerting a force. This gives rise to pressure.

Factors that affect liquid pressure

- List and describe the factors that affect the pressure exerted by a liquid column.
  (i) Demonstrate the activity '*To determine how the height of the liquid column affects liquid pressure*', in class, and ask students to come up with one factor that affects the pressure

exerted by a liquid. Identify the **height of the liquid column** as one factor that affects the pressure exerted by a liquid.

(ii) Demonstrate the activity '*To determine how the density of a liquid affects liquid pressure*', and ask students to identify the second factor affecting the pressure exerted by a liquid column. Underline **density of the liquid** as the second factor.

Liquid pressure in real life

Ask students:

Have you noticed the fact that the base of dams is broader than its top region? Do you know that living things in the seabed are small in size and mostly have hard shells?

- Explain the reason for the broad bases of reservoirs and dams.
- Explain how deep sea divers and submarines survive deep under water.
- Discuss how the vacuum created inside the syringe and the pressure of blood let blood to be drawn from our blood vessels.

Manometer

Ask students:

We have studied that force and area can be measured. Can we measure liquid pressure? What is the instrument that measures liquid pressure like a thermometer measures temperature?

- Inform students that the device used to measure liquid pressure is known as manometer.
- Using the figure, given in the coursebook, describe the principle and working of a manometer.

Atmospheric pressure

Ask students:

In which state of matter the molecules have maximum freedom of movement? Can freedom of movement be related to the pressure exerted?

- Relate the freedom of movement of the molecules to the pressure exerted.
- Define atmospheric pressure and the reason for it.

Unit of atmospheric pressure

- Explain how standard atmospheric pressure is defined as the pressure exerted by a column of 760 mm (76 cm or 0.76 m) of mercury.
- Point out that this pressure is known as 1 atm and that this unit is just a convenient unit and not the SI unit of pressure.
- Give the value of 1 atm in terms of the SI unit of pressure, pascal as 1 atm = 101, 325 Pa.
- Describe the activity '*To study the effect of atmospheric pressure*' and discuss the observations.

Effects of atmospheric pressure

Ask students:

Can you think of some uses or effects of atmospheric pressure?

- List and explain the points given in the coursebook.
  - (i) Explain how vacuum is created inside the straw when we suck out the air which aids liquid to rise through the straw.
  - (ii) Explain the action of medicine/ink dropper works.
  - (iii) Explain the principle of the rubber sucker pressed against a wall.
  - (iv) Point out why nose bleeding occurs at higher altitudes and airplanes should remain airtight.

Ask students:

You may have seen pictures of astronauts. Why do they wear that special suit?

- Explain the reason for special suits for astronauts.

Barometer

Ask students:

You have learned that a manometer is used to measure liquid pressure. Can we use the same device to measure air pressure?

- Inform students that manometer cannot be used to measure air pressure. Instead, a barometer is used for that purpose.
- Tell them about Torricelli and his contribution to physics.
- Using the figure, given in the coursebook, explain the principle and working of a barometer.
- Inform students about aneroid barometer and its uses.
- Share the information from *Eco corner* and *Career watch*.

Give the following instruction to students/Write it on the board.

Activity: Make a chart on anemometer—What is an anemometer? Explain briefly, with the help of diagrams, how air pressure creates wind.

FORCE

Checkpoint

A. 1. c, pushing a moving revolving door to make it swing faster
2. b, B and C
3. a, a sledge sliding down a slope
4. b,
5. d, 2500 N m

B. 1. The bottom edge of the cardboard box is the pivot and the distance between the edge and the flap is the moment arm.
2. The central fixed point of the seesaw is the pivot and the distance between the child and the pivot is the moment arm.
3. The spine of the book is the pivot and the distance between the spine and the point at which the finger applies the force is the moment arm.
4. The pivot is the left extreme end and the moment arm is the distance between pivot and the hand that applies the force.

C. 1. A force is a push or pull applied to an object.
2. Newton is SI system unit of force.
3. Kilogram-force is the force with which the Earth attracts a 1 kg mass. It is nearly equal to 10 N.
4. Moment of a force is the turning power of a force. It is the product of the force and the perpendicular distance between the pivot and the point of application of the force.

D. 1. The motion of an object as a whole along a line is known as translatory motion.
2. An example of the turning effect of a force is a spanner screwing or unscrewing a nail. Another example is a force applied on the free end of a door panel.
3. The moment of a force depends on the magnitude of the force and the perpendicular distance between the pivot and the point of application of the force.

E. 1. The five effects of force are
(i) It can make a stationary object move. For example, a stationary pushcart can be made to move by pushing it.
(ii) It can stop a moving object. For example, a moving cricket ball can be stopped by fielder by exerting a force on it while catching it.
(iii) It can change the speed of a moving object. For example, a battery operated moving toy car will move faster if it is pushed from behind.
(iv) It can change the direction of motion of an object. For example, while a batsman hits the bowled ball, it moves in a different direction.
(v) It can change the shape of an object. For example, if a metal vessel is hit with a hammer, it produces denting.

2. If a force acting on a body of mass 1 kg produces a change in its velocity of 1 m/s in one second, the force is said to be one newton while one kilogram-force is the gravitational force acting on a mass of 1 kg. One kilogram-force is approximately equal to 10 N.

F. 1. The moment of the force $M = F \times d = 10\ \text{N} \times 0.2\ \text{m} = 2\ \text{Nm}$

2. The moment of the force $M = F \times d = 10\ \text{N} \times 0.05\ \text{m} = 0.5\ \text{Nm}$

3. The radius of the wheel $r = \frac{M}{F} = \frac{8}{20} = 0.4\ \text{m} = 40\ \text{cm}$

   Thus the diameter of the wheel $d = 2r = 2 \times 40\ \text{cm} = 80\ \text{cm}$.

4. The moment of the force $M = F \times d = 50\ \text{Nm}$

   The diameter of the wheel $d = 2r = 200\ \text{cm} = 2\ \text{m}$

   The radius of the wheel $r = 1\ \text{m}$

   The force acting on the wheel $F = \frac{M}{r} = \frac{50}{1}\ \text{N} = 50\ \text{N}$

PRESSURE

Stop and check

1. pressure, force 2. less than 3. sharp 4. harder 5. less

Checkpoint

A. 1. b, the area on which the thrust acts should be increased
2. a, pascal
3. d, i and ii
4. b, manometer
5. a, decreases
6. c, barometer
7. b, 76 cm

B. 1. True 2. True 3. False 4. True 5. False 6. True

C. 1. The force acting perpendicular to unit area of a surface is known as pressure. The standard unit of pressure is pascal.

2. If F is the force acting perpendicular to a surface of area A, then the pressure on the surface is $P = \frac{F}{A}$

3. For a sharp tipped pin, all the applied force is concentrated on a very small area. Hence the pressure acting would be very high while in a blunt pin, the pressure in lowered due to larger surface area. Hence it is easy to drive in a sharp in into a board than a blunt one.
4. The two factors affecting the liquid pressure are the height of the liquid column and the density of the liquid.
5. (i) Walls of dam are thicker at the bottom because it has to withstand more water pressure.
   (ii) Deep sea divers have to wear special protective gears to withstand the effects of water pressure.
6. (i) Medicine dropper is able to pull in medicine when there is reduced pressure inside the dropper due to atmospheric pressure.
   (ii) We are able to suck juice using a straw because of atmospheric pressure pushing liquid into the straw when we create a low pressure inside it by sucking out air.
7. Atmospheric pressure decreases with height from the surface of the Earth. Our bodies are made to balance the air pressure on the surface of the Earth. If we open the windows of airplane, our body maintaining a higher pressure cannot adjust to the low pressures at high altitudes. This would cause the blood vessels to burst.

D. 1. Thrust is nothing but a force perpendicular to a surface. Since pressure is perpendicular force divided by the area, larger the thrust, larger is the pressure. Since pressure is inversely proportional to the area, larger the area, smaller is the pressure.
2. The attaching of caterpillar tracks on wheels provides more area of contact to the wheels. This reduces the pressure exerted on the Earth and hence prevents sinking of the wheels into the soil.
3. Take a wide glass tube and attach a balloon firmly to one end of the tube using thread. Pour water through the other end. As the water collects on the balloon, it starts expanding. We can see that the expansion takes place in all directions. From this we can understand that a liquid exerts pressure in all directions.
   OR refer to the activity ' To check whether liquids exert pressure in all directions', given in the coursebook.
4. To test the pressure exerted by a liquid,the rubber tube with the funnel is dipped into the liquid. If the pressure in the liquidis more than the outside air pressure, the level of the liquid in arm A goes down and the level of the liquid in arm B goes up. The levels of the liquid in the two arms are read using the scale. The difference in the levels gives us the measure of the pressure in the liquid that the funnel is immersed in.
   Diagram: Refer to the coursebook.
5. Heat an empty metal can with a small lid over a flame with its lid open. When the can gets heated, the air inside it expands and escapes through the opening. When the can is sufficiently hot, close the lid and pour cold water over it immediately. We can see that the can gets crushed on all sides under atmospheric pressure because the pressure inside the can is very low as all the air has escaped on expansion.

6. A barometer is a 1 m long glass tube containing mercury, kept inverted in an open vessel containing a small amount of mercury such that the mercury is exposed to atmospheric pressure. The space above the mercury column in the tube is partial vacuum. When placed at sea level, the height of mercury column is 76 cm. When the barometer is taken higher in the atmosphere, the height of the mercury column decreases due to lower atmospheric pressure. When the atmospheric pressure is larger, it presses down mercury in the vessel and hence the height of mercury column increases.

E. 1. The force acting is $F = 20$ N

The area on which it acts $= 70\ \text{cm}^2 = 0.007\ \text{m}^2$

The pressure exerted on the surface $P = \frac{F}{A} = \frac{20}{0.007}\ \text{Pa} = 2857\ \text{Pa}$

2. The pressure on an area of 1 m^2 is $P = 100\ \text{N/m}^2$

The thrust on the surface is pressure $\times$ area $= 100\ \text{N/m}^2 \times 1\ \text{m}^2 = 100$ N.

3. The force acting is $F = 100$ N

The pressure produced $P = 1000$ Pa

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

$$\text{Therefore, area} = \frac{\text{force}}{\text{pressure}} = \text{area} = \frac{\text{force}}{\text{pressure}} = \frac{100}{1000} = 0.1\ \text{m}^2$$

4. The mass of the cuboid box $M = 10$ kg

The weight acting downward $F = 10\ \text{kg} \times 9.8\ \text{m/s}^2 = 98$ N

The pressure exerted by the 1st cuboid A with an area 10 cm $\times$ 5 cm over which the weight acts $P_A = \frac{98}{0.1 \times 0.05} = 19600$ Pa

The pressure exerted by the 2nd cuboid B with an area 5 cm $\times$ 2 cm over which the weight acts $P_B = \frac{98}{0.02 \times 0.05} = 98000$ Pa

(i) Box B will exert more pressure as its weight acts through a smaller area.

(ii) Box B will create a deeper impression on wet soil because it exerts a larger pressure on the soil.

5. The mass of the horse $M_h = 450$ kg

The weight of the horse $W_h = 450\ \text{kg} \times 10\ \text{m} - \text{s}^{-2} = 4500$ N

The area of a hoof $a_h = 40\ \text{cm}^2 = 0.004\ \text{m}^2$

The area of four hooves $A_h = 4 \times 0.004\ \text{m}^2 = 0.016\ \text{m}^2$

The pressure exerted by the horse on the ground $P_h = \frac{4500}{0.016}\ \text{Pa} = 281{,}250$ Pa

The mass of the elephant $M_e = 4000$ kg

The weight of the elephant $W_e = 4000\ \text{kg} \times 10\ \text{m} - \text{s}^{-2} = 40000$ N

The area of a foot $a_e = 1250\ \text{cm}^2 = 0.125\ \text{m}^2$

The area of four feet $A_e = 4 \times 0.125\ m^2 = 0.5\ m^2$

The pressure exerted by the elephant on the ground $P_e = \frac{40000}{0.5}\ Pa = 80{,}000\ Pa$

Thus the horse exerts a greater pressure on the ground.

6. The maximum pressure the elevator can withstand $P_{max} = 32{,}000\ Pa$

The total area of feet $A = 1500\ cm^2 = 0.15\ m^2$

The maximum weight it can carry is $W_{max} = P_{max} \times 0.15 = 32{,}000 \times 0.15 = 4800\ N$.

The maximum mass it can carry is $M_{max} = \frac{W_{max}}{10} = 480\ kg$

Think and answer

It is easier to open the cover of the book since when the perpendicular distance between the pivot and the point where the force is applied is more, the turning effect of force is also more.

FORCE AND PRESSURE

A. Fill in the blanks.

1. A force of 3 N acting at a distance 50 cm from the hinges will produce _____ turning than the same force acting at 75 cm.
2. One newton is the gravitational force acting on a _____ kg mass.
3. The two types of moments of force are _____ and _____ .
4. A force is directly applied at the pivot. The turning produced is _____ .
5. The unit of thrust is _____ .
6. 1 kg-f acts on an area of 1 m^2 is nearly equal to _____ pascal.
7. Two identical vessels have a hole at the same level from the bottom. If one is filled with water and the other with kerosene, the _____ jet will go more distance.

Ans: 1. less 2. 0.1 3. clockwise, anticlockwise 4. zero 5. newton 6. 10 7. water

B. Answer the questions.

1. How can you change the direction of rotational motion?

   Ans: The direction of rotational motion can be changed by changing either the direction of the force or by changing the point of application of the force.

2. Why do snow shoes have broad bases?

   Ans: Broad bases decrease the pressure exerted on the ground as pressure is inversely proportional to area. This prevents the person from sinking into loose snow.

3. Does a solid body exert pressure on the walls of its container? Justify your answer.

   Ans: A solid body does not exert pressure on the walls of its container as its molecules do not have the freedom to leave their equilibrium position. It only exerts its weight on the lower wall of its container.

4. Why does water from a hole near the bottom of a vessel ejected to a farther point than a hole near the top of the water level?

   Ans: Since the pressure exerted by a liquid depends upon the height of the liquid meniscus from the point considered, the liquid pressure near the bottom of the vessel is much larger than that near the top. So liquid near the bottom is ejected with more force.

FORCE AND PRESSURE

1. Name the following.

a. The SI unit of force: _____

b. The force that pulls an object of mass 1 kg towards the Earth: _____

c. The movement of the whole object from one point to another: _____

d. The rotation of an object around a fixed point when a force is applied at a suitable point: _____

e. The perpendicular distance from the pivot to the point where the force is applied: _____

f. The SI unit of pressure: _____

g. The instrument used to measure liquid pressure: _____

h. The instrument used to measure atmospheric pressure: _____

2. Calculate the moment of force for the following.

a. The handle of a door is 50 cm away from the hinge and you have to apply 20 N of force to open it. _____

b. The handle of a door is 40 cm away from the hinge and you have to apply 50 N of force to open it. _____

3. Complete the sentences with respect to pressure.

a. When the force exerted on an object increases, _____

b. When the area over which the force is exerted increases, _____

c. A pascal is equal to _____

d. As we go deeper into a liquid, _____

e. As the density of a liquid increases, _____

4. Describe the structure of a barometer.

_____

_____

WORKSHEET

ANSWER KEY FOR THE WORKSHEET

FORCE AND PRESSURE

1. a. newton b. gravitational force/weight c. translatory motion
d. turning effect of force e. moment arm f. pascal
g. manometer h. barometer

2. a. 10 N m b. 20 N m

3. a. the pressure increases.
b. the pressure decreases.
c. 1 newton per square metre.
d. the pressure exerted also increases.
e. the pressure exerted by the liquid also increases.

4. A barometer is a 1 m long glass tube containing mercury, inverted in a small amount of mercury in a container. The mercury in the container is open to the air.