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9TH CLASS · PHYSICS · EXERCISE SOLUTIONS

06

CHAPTER SIX

Mechanical Properties of Matter

Complete, step-by-step solutions to every MCQ, short answer, constructed-response, comprehensive and numerical question — clearly explained for 9th-grade students.

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A

SECTION A

Multiple Choice Questions

6.1 A wire is stretched by a weight w. If the diameter of the wire is reduced to half of its previous value, the extension will become:

a) one half

b) double

c) one fourth

d) four times ✔

EXPLANATION

According to Hooke's Law, extension (ΔL) is inversely proportional to the area of cross-section (A). Since area $A = \pi(d/2)^2 \propto d^2$, the extension is inversely proportional to the square of the diameter (d). If the diameter is halved (d/2), the area becomes 1/4th. As a result, the extension becomes **4 times larger**.

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

a. Length 1 m, diameter 1 mm

b. Length 2 m, diameter 2 mm

c. Length 3 m, diameter 3 mm

d. Length 4 m, diameter 0.5 mm ✔

EXPLANATION

Extension is directly proportional to length (L) and inversely proportional to the square of the diameter (d^2), so $\Delta L \propto L/d^2$. Calculating the ratio for each option: (a) $1/1^2 = 1$ · (b) $2/2^2 = 0.5$ · (c) $3/3^2 = 0.33$ · (d) $4/(0.5)^2 = 4/0.25 =$ **16**. Option (d) has the highest value, so it will elongate the most.

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

- a 1:1 ✔
- b √2 : √3
- c 2:3
- d 4:9

EXPLANATION

The pressure exerted by a liquid at a certain depth is given by P = ρgh. It depends entirely on the depth (h), density (ρ), and gravity (g). It is completely independent of the area of the object placed in it. Since both plates are at the same depth, the pressure is the same — ratio = **1:1**.

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

a. density of the liquid

b. depth of the point below the surface

c. acceleration due to gravity

d. all of the above ✔

EXPLANATION

The formula for liquid pressure is $P = \rho g h$. This shows that pressure is directly proportional to the density of the liquid (ρ), the depth (h), and the acceleration due to gravity (g). Therefore, **all options are correct**.

6.5 Pressure applied to an enclosed fluid is:

- a) increased and applied to every part of the fluid
- b) diminished and transmitted to the walls of the container
- c) increased in proportion to the mass of fluid
- d) transmitted unchanged to every portion of the fluid and walls of containing vessel ✔

EXPLANATION

This is the statement of **Pascal's Law**. When pressure is applied to an enclosed fluid, it is transmitted equally and undiminished in all directions throughout the fluid and to the walls of the container.

6.6 The principle of a hydraulic press is based on:

- a Hooke's law
- b Pascal's law ✔
- c Principle of conservation of energy
- d Principle of conservation of momentum

EXPLANATION

A hydraulic press works by applying a small force on a small piston, which creates pressure. According to Pascal's Law, this pressure is transmitted equally to a larger piston, resulting in a much larger force.

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

- a Kinetic
- b Potential ✔
- c Internal
- d Heat

EXPLANATION

When a spring is compressed or stretched, work is done against the restoring force. This work is stored in the spring as **Elastic Potential Energy**, which is a form of potential energy.

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

- a) 20 kN ✔
- b) 100 kN
- c) 200 kN
- d) 500 kN

EXPLANATION

Area $A = L \times B = 50\text{ cm} \times 40\text{ cm} = 2000\text{ cm}^2 = 0.2\text{ m}^2$. Pressure $P = 100\text{ kPa} = 100{,}000\text{ Pa}$. Force $F = P \times A = 100{,}000 \times 0.2 = 20{,}000\text{ N} =$ **20 kN**.

SECTION B

B Short Answer Questions

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

ANSWER

Heavy animals have a large foot area to **reduce the pressure** they exert on the ground. Since $P = F/A$, increasing the area decreases the pressure, preventing them from sinking into soft ground.

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

ANSWER

Animals that run fast have small hooves (small area) to **increase the pressure** they exert on the ground. This high pressure allows their feet to dig slightly into the ground, providing better grip and traction for running.

6.3 Why is it painful to walk barefooted on pebbles?

ANSWER

Pebbles have a very small surface area. When we walk on them, our entire body weight acts on these tiny areas, creating **very high pressure** ($P = F/A$). This high pressure on the sensitive sole of the foot causes pain.

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

ANSWER

Pascal's Law: "Pressure applied to an enclosed fluid is transmitted undiminished to every portion of the fluid and the walls of the containing vessel."
Application: Hydraulic brakes in automobiles, hydraulic jack, hydraulic press.

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

ANSWER

Elasticity is the property of a solid material by virtue of which it **regains its original shape and size** after the deforming force is removed.

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

ANSWER

Hooke's Law: The strain produced in a body is directly proportional to the stress applied, within the elastic limit.
No, an object does not remain elastic beyond the elastic limit. Beyond this limit, the object undergoes permanent deformation (plastic deformation) and does not return to its original shape when the force is removed.

6.7 Distinguish between force and pressure.

ANSWER

- **Force:** It is a push or pull acting on an object. It is a vector quantity. Unit: Newton (N).
- **Pressure:** It is the force acting perpendicularly per unit area. It is a scalar quantity. Unit: Pascal (Pa) or N/m^2.

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

ANSWER

Liquid pressure is **directly proportional** to the depth of the liquid ($P \propto h$). As depth increases, the pressure increases.

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

ANSWER

The basic principle is that **atmospheric pressure balances the weight of the mercury column** in the tube. $P_{atm} = \rho gh$.

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

ANSWER

The hydraulic brake system works on **Pascal's Law**. When the brake pedal is pressed, pressure is applied to the brake fluid, which is transmitted equally to the brake shoes at the wheels, applying the braking force.

C

SECTION C

Constructed Response Questions

6.1 A spring having spring constant k hangs vertically from a fixed point. A load of weight L, when hung from the spring, causes an extension x, the elastic limit of the spring is not exceeded. Some identical springs, each with spring constant k, are arranged as shown below. For each arrangement, complete the table by determining: (i) the total extension in terms of x, (ii) the spring constant in terms of k.

Arrangement	Total Extension	Spring Constant of the Arrangement
Series (two springs end-to-end)	2x	k/2
Parallel (two springs side-by-side)	x/2	2k

EXPLANATION

Series: When springs are in series, the same load acts on both. Each spring extends by x. Total extension = x + x = 2x. The equivalent spring constant k_{eq} is given by $1/k_{eq} = 1/k + 1/k = 2/k \Rightarrow k_{eq} = k/2$.

Parallel: When springs are in parallel, the load is shared equally. Each spring supports half the load, so each extends by x/2. Total extension = x/2. The equivalent spring constant $k_{eq} = k + k = 2k$.

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

ANSWER

Steel is used because it has a **higher elasticity (Young's modulus)** and a higher elastic limit compared to iron. This means steel can withstand more stress and return to its original shape without permanent deformation, making it ideal for springs.

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

ANSWER

(a) Iron is more elastic than rubber. Although rubber stretches more, elasticity is defined as the ability to resist deformation and return to original shape. Iron has a much higher Young's modulus than rubber.

(b) Air is more elastic than water. Gases are highly compressible and can return to their original volume when pressure is released, exhibiting higher elasticity compared to liquids which are almost incompressible.

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

ANSWER

The water pressure will be **exactly the same** in both cases. Pressure in a liquid depends only on the depth (h), density (ρ), and gravity (g), according to $P = \rho g h$. It does not depend on the total volume or surface area of the water body.

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

ANSWER

According to Pascal's Law, if pressure is increased in one part of a confined liquid, it is **transmitted equally and undiminished** to all other parts of the liquid and the container walls.
Example: A hydraulic jack used to lift a car. A small force applied on a small piston creates pressure that is transmitted to a larger piston, lifting the heavy car.

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

ANSWER

If air is trapped, it will exert its own pressure downwards on the mercury column. This means the atmospheric pressure will have to balance both the mercury column and the trapped air pressure. As a result, the **height of the mercury column will decrease** (be lower than the standard 76 cm).

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

ANSWER

A giraffe has a very long neck, and raising it suddenly could cause a massive drop in blood pressure to the brain due to gravity. However, it is not a problem because giraffes have **highly elastic, thick-walled blood vessels** and a very powerful heart that pumps blood at high pressure. Additionally, they have special valves in the neck veins to prevent blood from rushing back down.

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

ANSWER

If there is a leak, atmospheric air will enter the tube. This air will exert pressure on the top of the mercury column, pushing it down. The barometer will give a **false, lower reading** of atmospheric pressure because the outside atmospheric pressure is now balancing both the mercury column and the air inside.

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

ANSWER

The statement is **correct**. Density is defined as mass per unit volume ($\rho = m/V$). It is an intrinsic property of the material itself (e.g., the density of pure gold is always 19,300 kg/m^3). If you cut a gold coin in half, its mass and volume both decrease, but its density remains exactly the same.

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

ANSWER

An engineer estimates the load by calculating the total volume of the materials used and multiplying it by their respective densities to find the mass ($m = \rho \times V$). Then, the weight (load) is calculated using $W = mg$. This helps in designing foundations strong enough to support the structure.

SECTION D

D Comprehensive Questions

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

ANSWER

Hooke's Law states that the strain produced in a body is directly proportional to the stress applied, within the elastic limit.

Applications:

1. **Spring Balances:** Used to measure weight or force.
2. **Shock Absorbers:** Used in vehicles to absorb shocks and vibrations.
3. **Galvanometers:** Used to measure small electric currents.

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

ANSWER

Mercury Barometer: A long glass tube closed at one end is filled with mercury and inverted into a mercury trough. The atmospheric pressure pushes the mercury up the tube. The height of the mercury column measures atmospheric pressure. **Application:** Measuring atmospheric pressure and predicting weather.

Manometer: A U-shaped tube containing liquid. One end is connected to a gas supply, and the other is open to the atmosphere. The difference in liquid levels in the two arms gives the pressure of the gas. **Application:** Measuring the pressure of gases in laboratories and pipelines.

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

ANSWER

Pascal's Law states that pressure applied to an enclosed fluid is transmitted undiminished to every part of the fluid and the walls of its container.

Applications:

- **Hydraulic Press:** Used to compress heavy materials like cotton bales.
- **Hydraulic Brakes:** Used in cars and trains for stopping vehicles.
- **Hydraulic Jack:** Used in workshops to lift heavy vehicles.

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

ANSWER

The pressure of a liquid depends on three factors:

1. Depth of the liquid (h)
2. Density of the liquid (ρ)
3. Acceleration due to gravity (g)

It is determined by the formula: **$P = \rho g h$**.

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

ANSWER

The atmosphere is a thick layer of air surrounding the Earth. Air has weight, and this weight exerts pressure on all objects on Earth. This is atmospheric pressure.

Applications:

1. **Drinking with a Straw:** When we suck air out of the straw, the atmospheric pressure pushes the liquid up into our mouths.
2. **Syringe:** Pulling the plunger creates a vacuum, and atmospheric pressure pushes the liquid medicine into the syringe.
3. **Suction Cups:** Pressing a suction cup against a wall removes air, and atmospheric pressure holds it firmly in place.

E

SECTION E

Numerical Problems

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

GIVEN	$F = 40\text{ N}, \quad x = 20\text{ mm} = 0.02\text{ m}$
SPRING CONSTANT	$k = F / x = 40 / 0.02 =$ **2000 N/m = 2 kN/m**
NEW EXTENSION	$x = 16\text{ mm} = 0.016\text{ m}$
NEW WEIGHT	$F = k \times x = 2000 \times 0.016 =$ **32 N**

★ **Spring constant k = 2000 N/m | Weight = 32 N**

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

GIVEN	$m = 4.5\text{ kg}, \quad V = 5\text{ L} = 5 \times 10^{-3}\text{ m}^3$
FORMULA	$\rho = m / V = 4.5 / (5 \times 10^{-3})$

★ **Density $\rho = 900\text{ kg/m}^3 = 0.9 \times 10^3\text{ kg/m}^3$**

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

GIVEN $m = 60$ g $= 0.06$ kg; volume of solid $= 44 - 40 = 4$ $cm^3 = 4 \times 10^{-6}$ m^3

FORMULA $\rho = m / V = 0.06 / (4 \times 10^{-6})$

★ **Density $\rho = 15{,}000$ kg/m^3 $= 15 \times 10^3$ kg/m^3**

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

GIVEN $\rho = 8 \times 10^3$ kg/m^3, $V = 60$ $cm^3 = 60 \times 10^{-6}$ m^3

FORMULA $m = \rho \times V = 8000 \times 60 \times 10^{-6}$

★ **Mass m = 0.48 kg**

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

GIVEN

$m = 5\text{ kg} \Rightarrow F = 5 \times 10 = 50\text{ N}$

MAX PRESSURE

Min area $= 5\text{ cm} \times 10\text{ cm} = 50\text{ cm}^2 = 0.005\text{ m}^2 \Rightarrow P_{max} = F / A_{min} = 50 / 0.005 =$ **$10{,}000$ Pa $= 1 \times 10^4$ Pa**

MIN PRESSURE

Max area $= 10\text{ cm} \times 20\text{ cm} = 200\text{ cm}^2 = 0.02\text{ m}^2 \Rightarrow P_{min} = F / A_{max} = 50 / 0.02 =$ **2500 Pa $= 2.5 \times 10^3$ Pa**

★ **$P_{max} = 1 \times 10^4$ Pa | $P_{min} = 2.5 \times 10^3$ Pa**

Note: The printed answer key contains a printing error for the minimum pressure. The mathematically correct answer, consistent with the working above, is 2.5×10^3 Pa.

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

GIVEN $h_{Hg} = 0.76$ m, $\rho_{Hg} = 13{,}600$ kg/m^3, $\rho_{water} = 1000$ kg/m^3

FORMULA $P = \rho_{Hg}\, g\, h_{Hg} = \rho_w\, g\, h_w$

CALCULATION $h_w = (\rho_{Hg} / \rho_w) \times h_{Hg} = (13{,}600 / 1000) \times 0.76 = 13.6 \times 0.76$

★ $h_w = 10.336$ m ≈ 10.3 m

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

GIVEN $A_1 = 5\ cm^2 = 5 \times 10^{-4}\ m^2$, $F_1 = 500$ N, $A_2 = 20\ cm^2 = 20 \times 10^{-4}\ m^2$

PRESSURE $P = F_1 / A_1 = 500 / (5 \times 10^{-4}) =$ **1.0×10^6 N/m^2**

FORCE F_2 $F_2 = P \times A_2 = 10^6 \times 20 \times 10^{-4} =$ **2000 N**

★ Pressure = 1.0×10^6 N/m^2 | Force F_2 = 2000 N

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

GIVEN $h = 10$ m, $\rho = 1030$ kg/m^3, $g = 10$ m/s^2

FORMULA $P = \rho gh = 1030 \times 10 \times 10$

★ **P = 103,000 Pa = 1.03 × 10^5 N/m^2**

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

GIVEN $A_1 = 10$ cm^2, $A_2 = 100$ cm^2, $F_2 = 4000$ N

FORMULA $F_1 / A_1 = F_2 / A_2$

CALCULATION $F_1 = F_2 \times (A_1 / A_2) = 4000 \times (10 / 100)$

★ **F_1 = 400 N**

6.10 In a hot air balloon, the following data was recorded. Draw a graph between the altitude and pressure and find out: (a) What would the air pressure have been at sea level? (b) At what height the air pressure would have been 90 kPa?

GRAPH	Plotting altitude (m) vs pressure (kPa) — (150, 99.5), (500, 95.7), (800, 92.4), (1140, 88.9), (1300, 87.2), (1500, 85.3) — gives a straight line.
SLOPE	$m = (85.3 - 99.5) / (1500 - 150) = -14.2 / 1350 \approx -0.0105$ kPa/m
(A) SEA LEVEL	At $h = 0$: $P = 99.5 - (150 \times -0.0105) = 99.5 + 1.575 = 101.075$ kPa $\approx$ **1.01×10^5 Pa**
(B) HEIGHT	$90 = 101.075 - 0.0105 \times h \Rightarrow 0.0105 \times h = 11.075 \Rightarrow h =$ **1054 m $\approx$ 1.02 km**

★ **Sea-level pressure ≈ 1.01×10^5 Pa | Height for 90 kPa ≈ 1.02 km**

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

GIVEN	Extra pressure $P = 10$ N/cm^2, Area $A = 50$ cm^2
FORMULA	$F = P \times A = 10 \times 50$

★ **Extra load F = 500 N**

6.12 The force exerted normally on the hydraulic brake system of a car, with its piston of cross sectional area 5 cm^2 is 500 N. What will be the: (a) pressure transferred to the brake oil? (b) force on the brake piston of area of cross section 20 cm^2?

GIVEN	$A_1 = 5\ cm^2, \quad F_1 = 500\ N, \quad A_2 = 20\ cm^2$
(A) PRESSURE	$P = F_1 / A_1 = 500 / 5 = \mathbf{100\ N/cm^2 = 1.0 \times 10^6\ N/m^2}$
(B) FORCE F_2	$F_2 = P \times A_2 = 100 \times 20 = \mathbf{2000\ N}$

★ **(a) 1.0×10^6 N/m² | (b) $F_2 = 2000$ N**

SE

You've Completed Chapter 06

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