2026 Sec 4 Physics Chapter 9

Pressure

Name: _____ **( ) Class: 4 /** ___

9 Pressure

1. Pressure on a surface
2. Pressure differences
3. Pressure measurement

No.	Checklist of Learning Outcomes	Confidence Level 1 2 3
1.	I can define the term pressure in terms of force and area	
2.	I can recall and apply the relationship pressure = force / area to new situations or to solve related problems	
3.	I can recall and apply the relationship pressure due to a liquid column = height of column × density of the liquid × gravitational field strength to new situations or to solve related problems	
4.	I can describe how the height of a liquid column may be used to measure the atmospheric pressure	
5.	I can describe the use of a manometer in the measurement of pressure difference	
6.	I can describe and explain the transmission of pressure in hydraulic systems with particular reference to the hydraulic press	
7.	I can recall and explain using the kinetic model how a change in pressure of a fixed mass of gas at constant temperature is caused by a change in volume of the gas (to be covered in Thermal Physics)	

1. Pressure on a Surface

1.1 Pressure is defined as the ***force acting normally per unit area***.

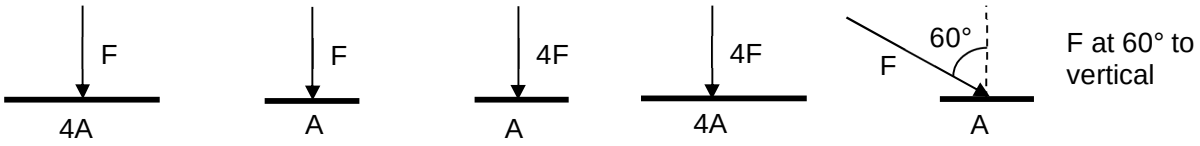
$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

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

- A pressure of 1 Pa is exerted when 1 N of force acts normally over an area of 1 m^2.
- The SI unit for pressure is **pascal**, named after the French mathematician and physicist Blaise Pascal. The symbol for the unit is Pa.
- 1 Pa = 1 N m^{-2}
- Pressure is a scalar quantity.

1.2 Factors Affecting Pressure on a Surface

The diagrams below show a force F and its multiples applied over tiles of different areas. Write down an expression for the pressure in each set-up.



P_1 = …… P_2 = …… P_3 = …… P_4 = …… P_5 = ……

The factors affecting the pressure set up on the tiles are:

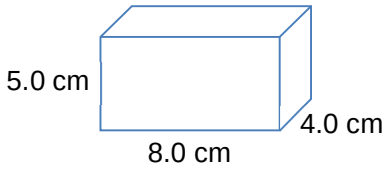
(i) …… on which force acts

(ii) magnitude of the …….. acting normally on the surface

Example 1

A block of dimensions 8.0 cm by 5.0 cm by 4.0 cm and mass of 1.25 kg is resting on a table.

(a) Calculate the maximum pressure exerted on the table.



maximum pressure = ……

(b) Calculate the minimum pressure exerted on the table.

minimum pressure = ……

1.3 Applications in Daily Life

For each of the objects listed, can you identify how the concept of pressure is applied to make it work?

- **Needle**: ..... area at sharp tip sets up high pressure for needle to puncture skin with ..... force.
- **Bag strap:** wide area ..... pressure on shoulder so the strap will not cut into the skin.
- **Knife:** ..... edge allows high pressure with a small force applied, so the food can be cut easily.
- **Ice skates:** sharp knife blade at the bottom sets up a ..... pressure which makes the ice under the skates melt easily, forming a film of water to reduce friction of the skates on the ice
- **Snowshoes:** have a wide area to reduce pressure on the snow when the person walks so that the person does not ..... into the snow

Exercise - Pressure on a Surface

1 The area of the head of a pin is 1.0 cm^2. A thumb exerts a force of 20 N on the head to push the pin into a board. The area of the tip of the pin is 0.0020 cm^2.

(a) Calculate the pressure exerted on the head of the pin by the thumb.

pressure = ……

(b) Calculate the pressure on a board when the pin is pressed onto it.

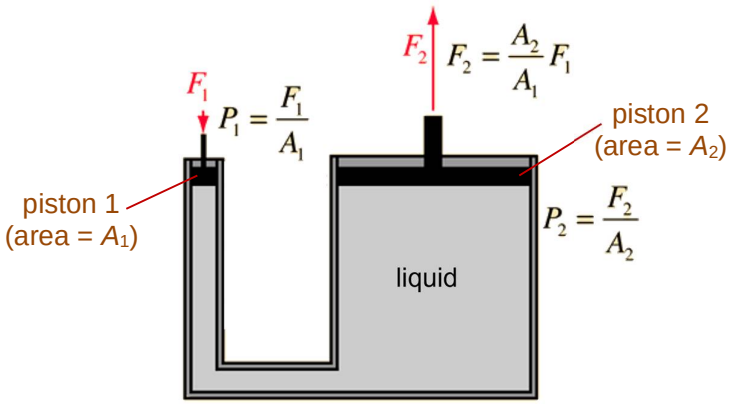
pressure = ……

2 A table of mass 95.0 kg exerts a total pressure of 1.05 kPa on its legs. When a man climbs on top of it, the total pressure exerted on its legs increased to 1.90 kPa. Calculate the weight of the man.

weight = ……

1.4 Transmission of pressure (Hydraulic system)

- A hydraulic press consists of a liquid in an enclosed space and two pistons at the two ends.



Source: http://hyperphysics.phy-astr.gsu.edu/hbase/pasc.html

- When a force F_1 is applied on piston 1 of surface area A_1, the pressure exerted on piston 1 and hence the liquid is $P_1 = F_1 / A_1$.

- By **Pascal's law**:

> If a pressure is applied to an enclosed liquid, the pressure is transmitted to other parts of the liquid undiminished.

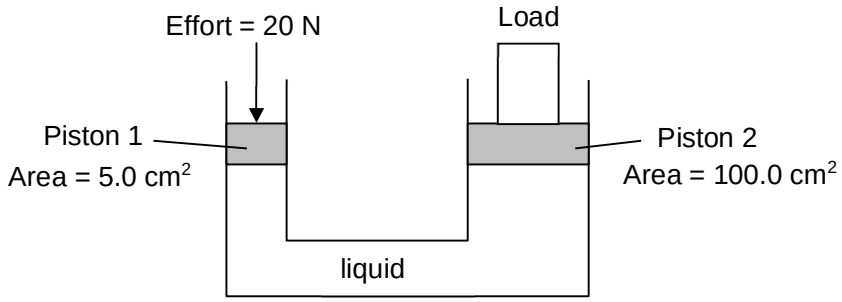
- As a liquid is almost incompressible, the pressure is transmitted equally to other parts of the liquid and to piston 2. The pressure transmitted to piston 2,

$$P_2 = P_1.$$
$$F_1 / A_1 = F_2 / A_2$$
$$F_2 = (A_2 / A_1) F_1$$

- If A_2 is very much larger than A_1, the force F_2 is very much larger than F_1.

Example 2

The diagram below shows a simple hydraulic system. An effort of 20 N is exerted on an area of 5.0 cm^2 on the left hand side to support a load placed on an area of 100.0 cm^2 on the right hand side of the system.



(a) Complete the following table.

	magnitude of force / N	area / cm^2	pressure / N cm^{-2}
On effort side (Piston 1)			
On load side (Piston 2)			
Ratio of load side versus effort side			

(b) Using the information from part **(a)**, what is the advantage in using a hydraulic system?

……..

(c) If Piston 2 moved through a distance of 2.0 cm, what distance did Piston 1 move through?

(d) Using ideas of conservation of energy, explain why the distance moved by Piston 1 must be larger than the distance moved by Piston 2.

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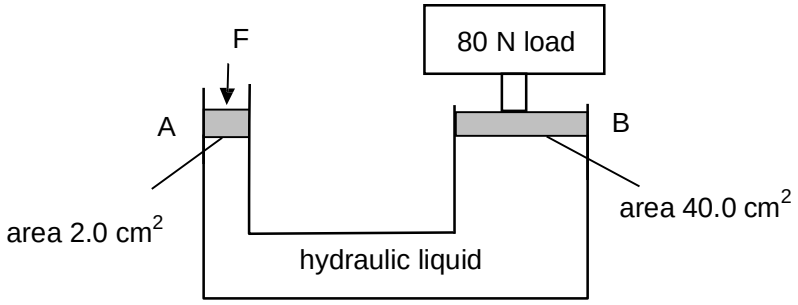
Exercise- Hydraulic system

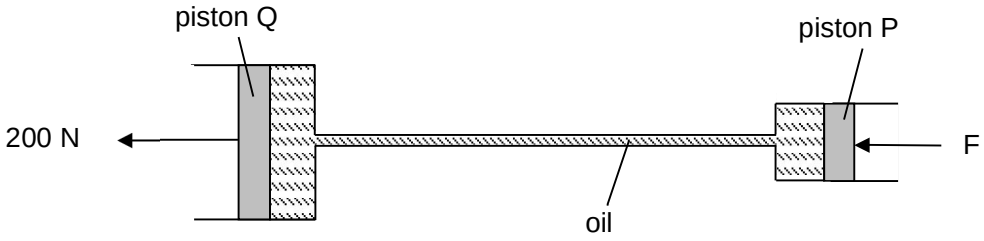
1 The diagram below shows the structure of a simple hydraulic lift. When a force F is applied at A, a force is set up at B to lift a load.



Calculate the magnitude of force F required to lift a load of 80 N at B.

force F = ……

2 The diagram below shows a simple hydraulic system.
Piston P has a diameter of 1.0 cm and piston Q has a diameter of 2.5 cm.

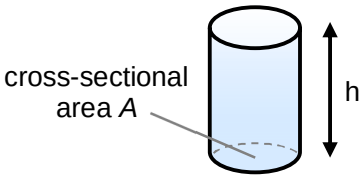


Calculate the magnitude of the force F on piston P to exert a force of 200 N on piston Q.

force F = ……

2. Hydrostatic Pressure

- Liquid pressure at the bottom of a liquid column due to the liquid above is given by $P = h\rho g$
  where
  h = height of liquid column,
  ρ = liquid density &
  g = gravitational acceleration.



- What are some assumptions when calculating hydrostatic pressure using $P = h\rho g$?

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  ……

- Can you derive $P = h\rho g$ from $P = F/A$?

Example 3

Circle true (**T**) or false (**F**) for each of the situations below.

(a) The liquid pressure at the bottom of a reservoir is greater than the liquid pressure at the top of a reservoir.

T / F

(b) The liquid pressure at the bottom of a swimming pool is the same whether it is filled with seawater or with fresh water.

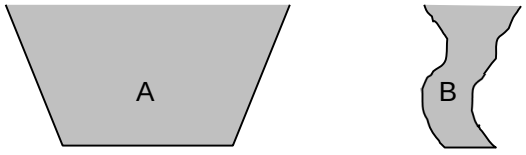
T / F

(c) The liquid pressure at the bottom of a swimming pool only acts downwards.

T / F

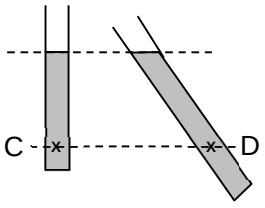
(d) The same liquid is placed inside containers A and B. The liquid pressure at the bottom of container A is the same as that at the bottom of container B.

T / F



(e) The same liquid is placed inside two containers. The liquid pressure at point C is less than the liquid pressure at point D.

T / F



Example 4

A box is held under water as shown in Fig. 4.1.
Fig. 4.2 shows the pressure acting on the six positions **A** to **F** of the box, the mid-points of the six faces of the box, as indicated by the arrows.

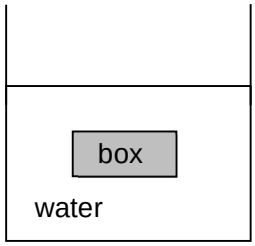


Fig. 4.1

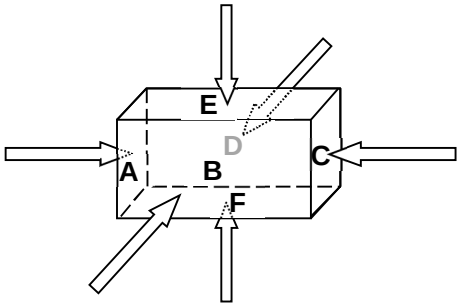


Fig. 4.2

(a) Why is the pressure at F greater than the pressure at E?

……

……

(b) Why are the pressures at A, B, C and D the same?

……

……

(c) Pressure at **E** is the **same all over the face** on which it acts. Can you say the same for the other pressures acting on the faces of positions **A**, **B**, **C**, **D** and **F**? Explain your answer.

……

……

……

(d) If the height of the box is 2.0 m and the density of the surrounding water is 1000 kg m^{-3}, what is the pressure difference between **F** and **E**?

Example 5

Below sea level, pressure increases with depth. The normal maximum safe depth a diver can go is 30.0 m in seawater.
Calculate the safe depth for a diver in fresh water.
(Assume $\rho_{seawater}$ = 1025 kg m^{-3} and $\rho_{freshwater}$ = is 1000 kg m^{-3}.)

3 Pressure Measurement

3.1 Atmospheric Pressure

- The atmospheric pressure is due to the force per unit area exerted against a surface by the weight of the air above that surface.
- Atmospheric pressure acts in all directions and all surfaces exposed to the atmosphere experience atmospheric pressure (just like pressure in a liquid).
- **Atmosphere** (atm) and **centimetres of mercury** (cm Hg) are common non-SI units for atmospheric pressure. At sea level, atmospheric pressure has an average value of one atmosphere (1 atm) or about 76 cm Hg.

3.2 Simple Mercury Barometer

Example 6

(a) Sketch a mercury barometer and label its parts in the box provided.

(b) Mark on the mercury reservoir, a point P, which experiences atmospheric pressure. State the reason for your choice.

……...

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(c) Mark in the mercury column, a point X, which is has the same pressure as P. State the reason for your choice.

……

(d) State the pressure due to the vacuum above the mercury column.

pressure = ...

(e) Express the pressure at X in terms of the height of the mercury column, h.

.....

(f) Mark on the diagram, h, the height reading to be taken to measure the atmospheric pressure.

(g) Mark the points R and S to indicate the positions of maximum and minimum pressures respectively in the mercury column.

Example 7

State and explain what happens to the mercury column in the barometer in the following situations.

(a) More mercury is poured into the reservoir.

As reservoir level rises, the mercury column level will rise by the ..... amount to maintain the ..... column height h since pressure, density and g remains constant.

(b) The glass tube is tilted.

..... of mercury column to the reservoir is .....as pressure is dependent on the ..... height and not on the length of the column.

(c) The barometer is taken to the top of a mountain.

Mercury column height ..... due to ..... atmospheric pressure at higher altitudes.

(d) Water is introduced into the space above the mercury column.

The pressure due to the mercury column and the pressure due to the water introduced ..... Since the atmospheric pressure is unchanged, the mercury column height .....

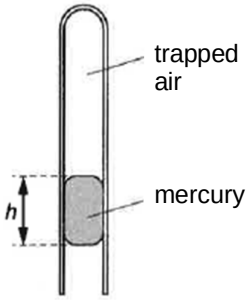
(e) There is a crack in the glass tube along the mercury column above the mercury reservoir.

Height of mercury ..... to the same level as the reservoir. Air outside the tube at the crack is at atmospheric pressure while the pressure at inside the tube is lower than atmospheric pressure.

The air will ..... from ..... pressure region to ..... pressure and so enters the column. The air only stops when pressure difference inside and outside the tube is ....., hence height difference will be zero.

Example 8 [Modified from 2019 P1 Q12]
A uniform tube, sealed at one end, is held vertically with the closed end at the top. It contains a thread of mercury which traps a column of air. The other end of the tube is open to the atmosphere.

The density of mercury is 13 600 kg m^{-3} and *h* is 0.13 m. Atmospheric pressure is 1.0×10^5 Pa. Calculate the pressure of the trapped air.



Exercise - Simple Mercury Barometer

1 Calculate the pressure due to 76.0 cm of mercury in **pascals** given that the density of mercury is 13 600 kg m^{-3}.

pressure = ……

2 For positions **(a)** to **(e)** marked on the simple mercury barometer below, write down their pressure in cm Hg**.**

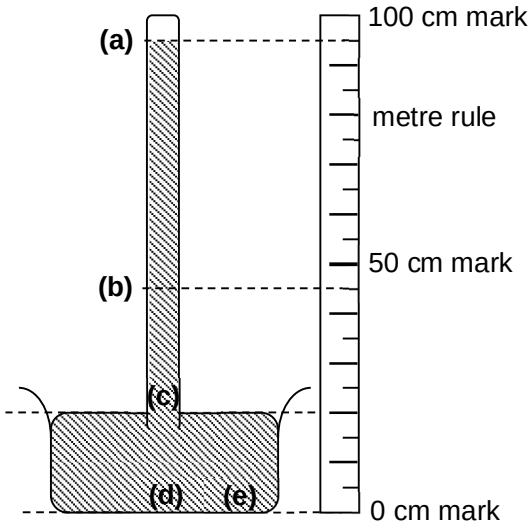
(a) ……..

(b) ……..

(c) ……..

(d) ……..

(e) ……..



3 **(a)** Given that the atmospheric pressure is 1.0 × 10^5 Pa and the density of air is 1.3 kg m^{-3}, calculate the height of the atmosphere.

(b) State one assumption made in your calculation.

……...

……...

(c) State and explain if the height of the atmosphere calculated in part (a) is larger or smaller than the true height of the atmosphere.

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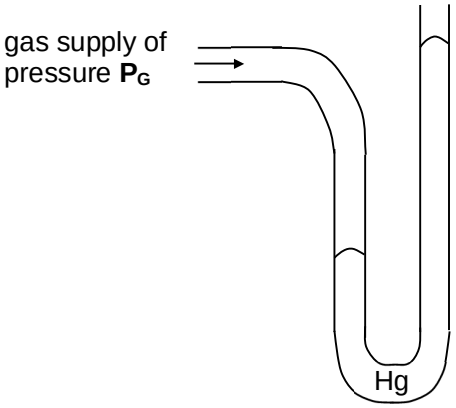
3.3 Manometer

- Gas pressure can be measured using a manometer or a Bourdon gauge.
- The pressure due to a sealed volume of gas will act on any surface exposed to the gas.
- The difference in the gas pressure and the atmospheric pressure is the **excess** pressure.

Example 9

A simple manometer with mercury inside is connected to a gas supply as shown below.
Let height difference of the mercury levels be $\mathbf{h_1}$ (in cm), the gas pressure be $\mathbf{P_G}$ and the atmospheric pressure be $\mathbf{P_A}$



(a) (i) Mark on the diagram a point **S** which represents the lower mercury level.

(ii) Mark a point **T** on the other mercury column which has the same pressure as **S**.

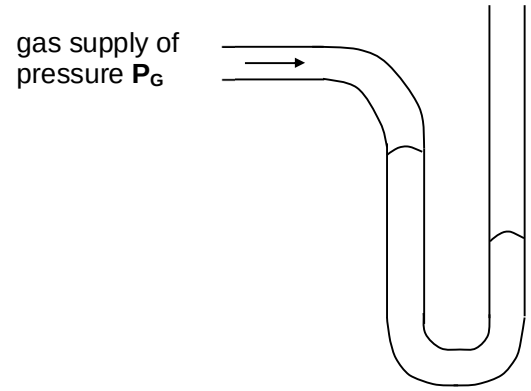
(iii) Pressure at **S** = ...

(iv) Pressure at **T** = ……. + ……. (in cm Hg)

(v) Hence gas pressure $\mathbf{P_G}$ = …….....

Note: *If both P_A and the pressure due to "h_1" are both in units of cm Hg, they can be added.*
If P_A has units of Pa, calculate the pressure due to "h_1" in Pa using $P = h_1 \rho g$

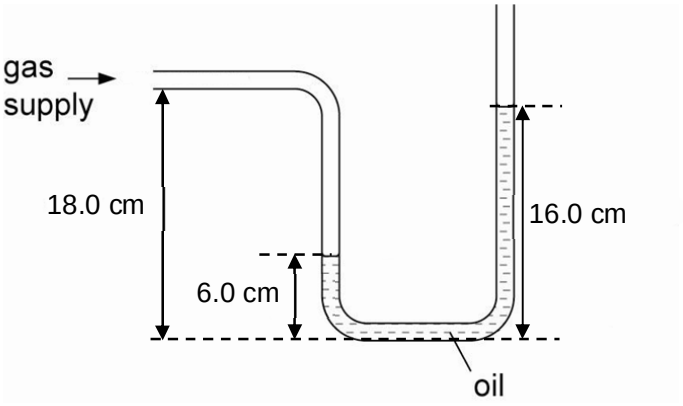
(b) The manometer is connected to another gas supply and the mercury levels are shown below. If the height difference of the mercury levels is denoted as $\mathbf{h_2}$, write an expression for the pressure of the gas supply.
[Hint: Apply a similar problem-solving approach as part (a)].



$\mathbf{P_G}$ = …….....

Example 10

A manometer is used to measure the pressure of a gas supply as shown in the diagram.

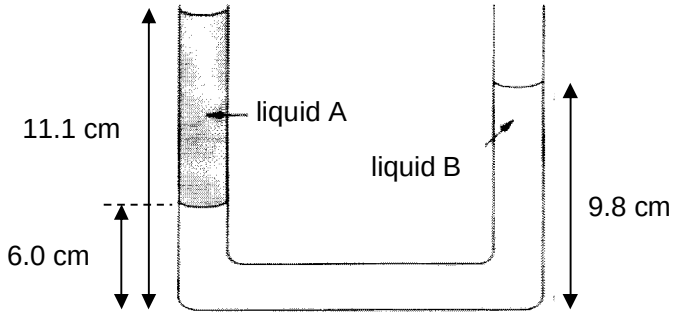


Determine the excess pressure of the gas supply.

excess pressure = ……..

Example 11

Two immiscible liquids A and B of different densities are in equilibrium in an open U-tube of uniform cross-section as shown below.

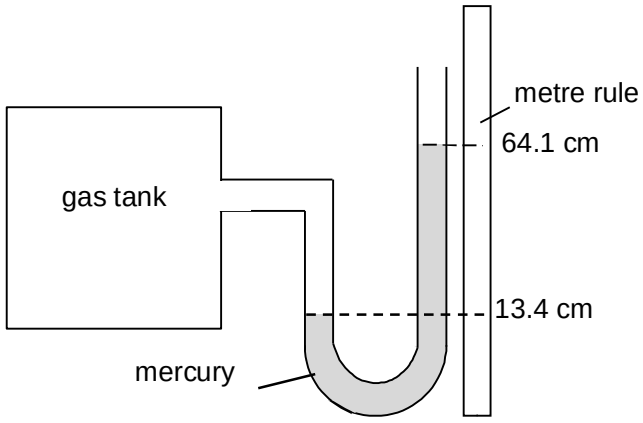


(a) On the diagram, clearly mark with a cross (without calculation) and label two points, P and Q, one in each side of the U-tube, where the pressure is equal to atmospheric pressure.

(b) If liquid B is water, calculate the density of liquid A. (Density of water = 1.0 g cm^{-3}.)

Exercise - Manometer

1 The diagram below shows a manometer that is used to measure the pressure in a gas pipe.



(a) Given that atmospheric pressure is 76.0 cm Hg, determine the pressure of the gas in the pipe.

(b) The pressure in the gas pipe is increased such that the reading of the left-hand column of the manometer changes to 11.4 cm. State

(i) the new reading on the right-hand side of the column,

(ii) the new pressure in the gas pipe in cm Hg.

(c) The mercury in the manometer is replaced by a liquid of the same volume, which has a density half that of the mercury. State and explain the effect on the **difference in height** of the level of the liquid in the left and right arm.
(No calculations required.)

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