2026 Sec 4 Physics Chapter 9 Pressure

Answers to Notes and Exercises

1.2 Factors Affecting Pressure on a Surface

P_1 = ¼ F/A P_2 = F/A P_3 = 4 F/A P_4 = 4F/4A = F/A

P_5 = F sin 30°/A = F/2A or P_5 = F cos 60°/A

Three factors affecting the pressure:

(i) Area on which force acts

(ii) Magnitude of the force acting on the surface

(iii) Direction of the force acting on the surface

Example 1

(a) Weight of block = mg = 1.25 kg x 10 N kg^{-1} = 12.5 N

Maximum pressure = weight / minimum area = 12.5 N/ (5.0 x 4.0) cm^2 = 0.63 N cm^{-2}

(b) Minimum pressure = weight / maximum area = 12.5 N/ (5.0 x 8.0) cm^2 = 0.31 N cm^{-2}

1.3 Applications in Daily Life

<u>Needle</u>: <u>small</u> area at sharp tip sets up high pressure for needle to puncture skin with <u>minimum</u> force.

<u>Bag strap</u>: wide area <u>reduces</u> pressure on shoulder so the strap will not cut into the skin.

<u>Knife</u>: <u>narrow</u> edge allows high pressure with a small force applied, so the food can be cut easily.

<u>Ice skates</u>: sharp knife blade at the bottom sets up a <u>high</u> pressure which makes the ice under the skates melt easily, forming a film of water to reduce friction of the skates on the ice.

<u>Snow shoes</u>: have a wide area to reduce pressure on the snow when the person walks so that the person does not <u>sink</u> into the snow

Exercise - Pressure on a Surface

1 (a) P = 20 N / 1.0 cm^2 = **20 N / cm^2**

(b) P = 20 N / 0.0020 cm^2 = **10 000 N / cm^2**

2 Using P = F/A, 1.05 x 10^3 Pa = (95.0 kg x 10 N kg^{-1}) / area of legs

Area of legs = (95.0 x 10) N / (1.05 x 10^3) Pa

When the man stands on the table,

1.90 x 10^3 Pa = [(95.0 x 10) + W] N / [(95.0 x 10) / (1.05 x 10^3)] m^2

where W is the weight of the man.

(95.0 x 10) N + W = (1.90 x 10^3) Pa x [(95.0 x 10) / (1.05 x 10^3)] m^2

W = **769 N**

1.4 Transmission of Pressure (Hydraulic System)

Example 2

(a)

	magnitude of force / N	area / cm^2	pressure / N cm^{-2}
On effort side (Piston 1)	**20**	**5.0**	**4.0**
On load side (Piston 2)	**400**	**100**	**4.0**
Ratio of load side versus effort side	**20**	**20**	**1.0**

(b) A hydraulic system has a multiplier effect on the force applied.

(c) Since the liquid is incompressible, the volume of liquid displacing Piston 2 must be the same as the volume of liquid displaced by Piston 1

$5.0\ cm^2 \times d_{piston1} = 100.0\ cm^2 \times d_{piston2}$

$d_{piston1} = (100.0\ cm^2 \times 2.0\ cm) / 5.0\ cm^2 = 40\ cm$

(d) Since energy is conserved, work done by Piston 1 equals to work done by Piston 2.

Since work done is force applied multiplied by the distance moved in the direction of the force, a smaller effort would require Piston 1 to move through a larger distance in order to lift a larger load at Piston 2.

Exercise - Hydraulic system

1 Since pressure in a liquid is equally transmitted in all directions,

$P_1 = P_2 \Rightarrow F_1 / A_1 = F_2 / A_2$

$F / 2.0\ cm^2 = 80\ N / 40.0\ cm^2$, therefore F = **4.0 N**

2 $P_P = P_Q \Rightarrow F_P / A_P = F_Q / A_Q$

$F_P / 0.5^2\ cm^2 = 200\ N / 1.25^2\ cm^2$, therefore $F_P = 32\ N$

2 Hydrostatic Pressure

- Assume density ρ and g are constant.
- $P = F / A = mg / A = (V\rho)g / A = hA\rho g / A = h\rho g$
  where V is volume of liquid column

Example 3
(a) T (b) F (c) F (d) T (e) F

Example 4
(a) F is at a greater depth in the water compared to E.

(b) **A**, **B**, **C** and **D** are the same as they are all at the same depth under the water.

(c) Pressure at F is also the same all over the face on which it because all points on the face are at the same depth under the water. For the other faces, only the points along the same depth will have the same pressure but other points on the face at different depths will have different pressure.

(d) Pressure difference = ht diff × density × g = 2.0 m × 1000 kg m^{-3} × 10 N kg^{-1} = 20 000 Pa

Example 5
Pressure in fresh water = pressure in seawater (since the amount of pressure safe for the diver must be the same in both waters)
$h_{water} \times 1000 \text{ kg m}^{-3} \times g = 30.0 \text{ m} \times 1025 \text{ kg m}^{-3} \times g$
$h_{water} = 30.75 \text{ m}$
Hence the diver can dive 30.8 m (3 s.f.) in fresh water.
(The diver can dive 0.75 m deeper in fresh water.)

3. Pressure Measurement

3.2 Simple Barometer

Example 6

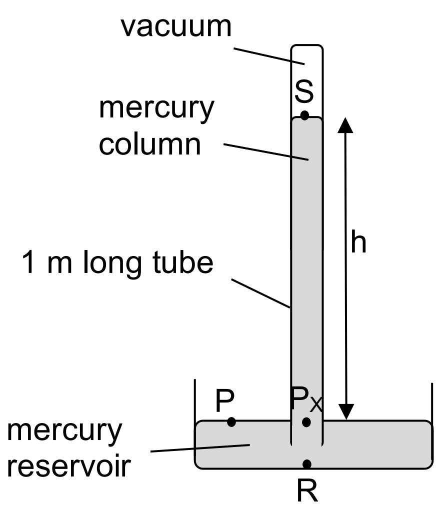
1(b) P experiences atmospheric pressure as it is exposed to the atmosphere.

(c) P_x has the same pressure as P as it is at the same level of the Hg as P.

(d) Pressure due to vacuum is 0 cm Hg

(e) P_x = h cm Hg

(a)



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 same amount to maintain the same column height h since pressure, density and g remains constant.

(b) The glass tube is tilted.

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

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

Mercury column height decreases. Lower 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 add up to equal to the atmospheric pressure. Since the atmospheric pressure is unchanged, the mercury column height decreases.

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

Height of mercury decreases 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 move from higher pressure region to lower pressure and so enters the column. The air only stops when pressure difference inside and outside the tube is zero, hence height difference will be zero.

Example 8

Pressure of trapped air + $P_{mercury} = P_{atm}$

Pressure of trapped air = $P_{atm} - \rho gh$

$= 1.0 \times 10^5 - 13600\ (10)\ (0.13)$

$= 8.2 \times 10^4$ Pa

Exercise - Simple Mercury Barometer

1 $P = h\, \rho_A\, g = 76.0/100 \text{ m} \times 13\,600 \text{ kg m}^{-3} \times 10 \text{ N kg}^{-1} = 103\,360 \text{ Pa} = 1.03 \times 10^5 \text{ Pa}$

2 **(a)** 0 cm Hg **(b)** 50 cm Hg **(c)** 75 cm Hg **(d)** 95 cm Hg **(e)** 95 cm Hg

3 **(a)** 1.0×10^5 Pa = height × 1.3 kg m^{-3} × 10 N kg^{-1}

height = 7700 m

(b) The assumption is that the density of the atmosphere is uniform, when it actually decreases with increasing altitude.

(c) The height of the atmosphere calculated in part **(a)** is smaller than the true height of the atmosphere. At higher altitudes, the density decreases.

3.3 Manometer

Example 9

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

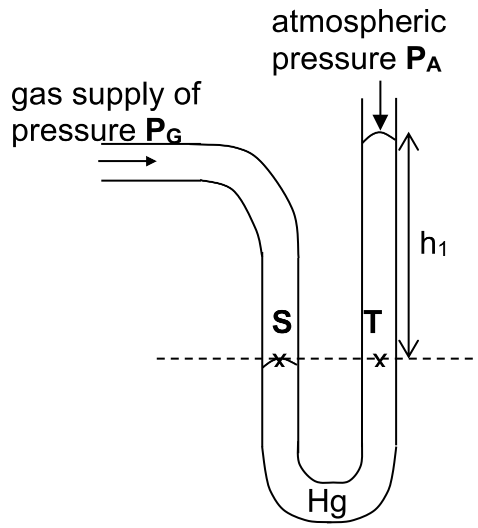
(ii) (Liquid at the same level have the same pressure)

(iii) The pressure at **S** = **$\underline{P_G}$**

(iv) The pressure at **T** = $\underline{P_A + h_1}$ cm Hg

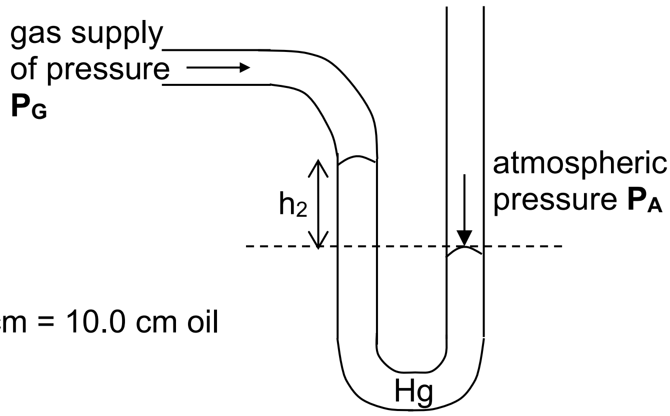
(v) Hence the gas pressure

P_G = $\underline{P_A + h_1}$ cm Hg



(b) $P_G + h_2 = P_A$

Hence, $P_G = P_A - h_2$

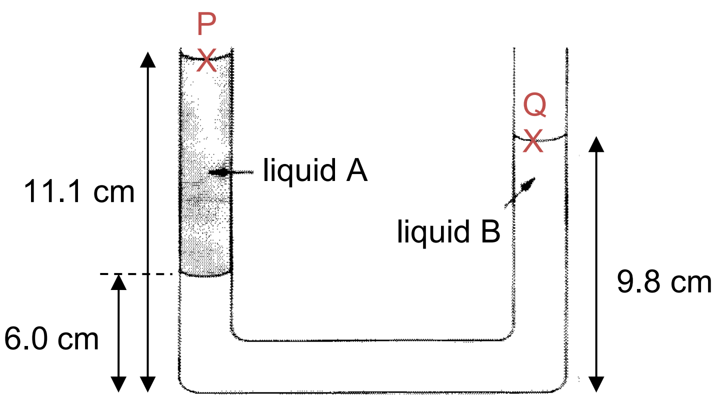


Example 10

Excess Pressure = 16.0 cm – 6.0 cm = 10.0 cm oil

Example 11

(a)



(b) Consider point R & S with equal pressures: $P_R = P_S$

Using $h\rho g$,

$(11.1\text{ cm} - 6.0\text{ cm}) \times \rho_A\, g) + P_{atm} = (9.8\text{ cm} - 6.0\text{ cm}) \times 1.0\text{ g cm}^{-3} \times g + P_{atm}$

$\rho_A = 0.75\text{ g cm}^{-3}$

Exercise - Manometer

1 **(a)** P = 76.0 cm + (64.1 cm – 13.4 cm) Hg = 126.7 cm Hg

(b) **(i)** 64.1 cm + (13.4 cm – 11.4 cm) = 66.1 cm
(ii) P_{new} = 76.0 cm + (66.1 cm – 11.4 cm) = 130.7 cm Hg

(c) The pressure difference between the gas and the atmosphere, which is the excess pressure of the gas, will remain the same. Since this pressure is equal to $h \rho g$, the height difference must double to compensate the reduction in the density of the liquid to half.