2020 Sec 3 Physics Chapter 5 Pressure

Answers to Notes and Exercises

5.1 Pressure

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

$P_5 = F \sin 30^o/A = F/2A$ or $P_5 = F \cos 60^o/A$

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 5.1.1

(a) Weight of block = mg = 1.25 x 10 = 12.5 N

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

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

Applications in Daily Life

Needle: small area at sharp tip sets up high pressure for needle to puncture skin with minimum force i.e. less painful

Bag strap: wide area reduces pressure on shoulder, less painful as it will not cut into the skin.

Knife: narrow edge allows high pressure with a small force applied, does not squash your food

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

Snow shoes: has wide area to reduce pressure on the snow when the person walks so that the person does not sink into the snow

Exercises

5.1 Pressure

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

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

2 Using P = F/A, 1.05 x 10^3 = (95.0 x 10) / area of legs

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

When the man stands on the table,

1.90 x 10^3 = [(95.0 x 10) + W] / [(95.0 x 10) / (1.05 x 10^3)]

where W is the weight of the man.

(95.0 x 10) + W = (1.90 x 10^3) x [(95.0 x 10) / (1.05 x 10^3)]

W = **769 N**

5.2 Pressure Differences

5.2.1 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 5.2.1

1 (a) T (b) F (c) F (d) F (e) T (f) F

2 (a) F is at a lower 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 x density x *g* = 2.0 x 1000 x 10 = 20 000 Pa

Exercises

5.2 Pressure Differences

1 Pressure in fresh water = pressure in seawater (since the amount of pressure safe for the diver must be the same in both waters)

$$h_{water} \times 1000 \times g = 30.0 \times 1025 \times g$$

$$h_{water} = 30.75 \text{ m}$$

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.)

5.2.2 Transmission of Pressure (Hydraulic System)

Example 5.2.2

(a)

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

(b) A hydraulic system can multiply the force applied.

Enrichment

(a) High boiling point; anti-corrosion, low compressibility or constant viscosity.

(b) Equal transmission of pressure in all directions ensures safety in stopping i.e. no skidding.

Exercises

1 Since pressure in a liquid is equally transmitted in all directions,
$P_1 = P_2 \Rightarrow F_1 / A_1 = F_2 / A_2$
$F / 2.0 = 80 / 40.0$, therefore F = **4.0 N**

2 $P_P = P_Q \Rightarrow F_P / A_P = F_Q / A_Q$
$F_P / 0.5^2 = 200 / 1.25^2$, therefore $F_P = 32$ N

5.3 Pressure Measurement

5.3.2 Barometer

Example 5.3.1

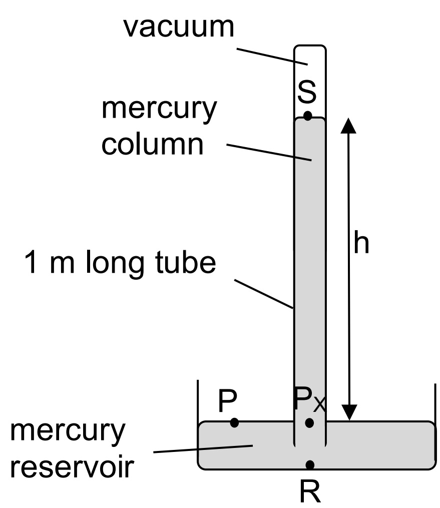
1(b) P experiences atmospheric pressure as it is exposed to the atmosphere.

(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)



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

(b) Perpendicular height of mercury column to the reservoir is unchanged as

(c) Mercury column height decreases. Lower atmospheric pressure at higher altitudes.

(d) Mercury column height decreases. Water vaporises and sets up vapour pressure in the space above the mercury column and presses downwards on the mercury column. Column indicates the pressure difference between atmosphere and the water vapour pressure.

(e) 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.

Exercises

1 $P = h \rho_A g = 76.0/100 \times 13\,600 \times 10 = 103\,360$ Pa $= 1.03 \times 10^5$ 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 x 1.3 kg m^{-3} x 10

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.

5.3.3 Manometer

Example 5.3.3

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

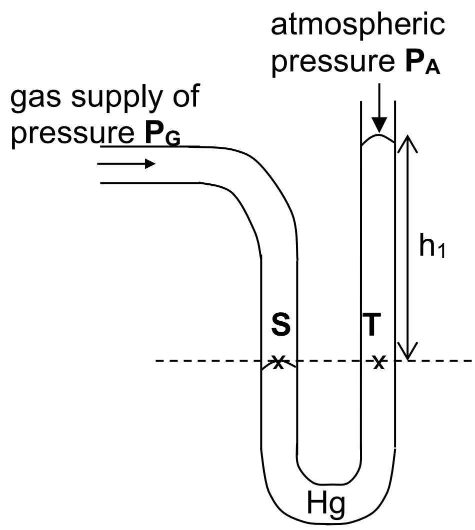
(ii) (Liquid at the same level have the same pressure)

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

(iv) The pressure at **T** = P_A + h_1 cm Hg

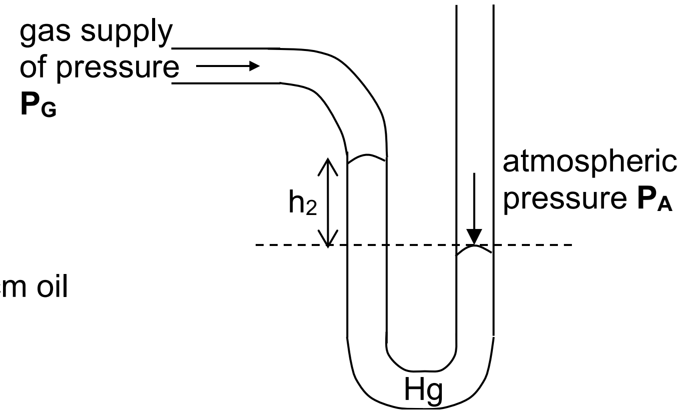
(v) Hence the gas pressure

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



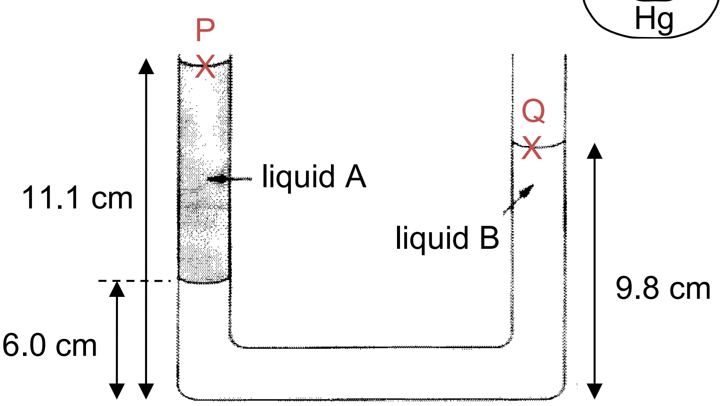
(b) $P_G + h_2 = P_A$

Hence, $P_G = P_A - h_2$



2 Excess Pressure = 16 – 6 = 10 cm oil

3 (a)



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

Using $h\rho g$, $(11.1 - 6.0) \times \rho_A g) + P_{atm} = (9.8 - 6.0) \times 1.0 \times g + P_{atm}$

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

Exercises

1

(a) P = 76.0 + (64.1 – 13.4) = 126.7 ≈ **127 cm Hg**

(b) **(i)** 64.1 + (13.4 – 11.4) = **66.1 cm**

(ii) P_{new} = 76.0 + (66.1 – 11.4) = 130.7 cm Hg ≈ **131 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.

5.3.4 Boyle's Law

Example 5.3.4

1 C

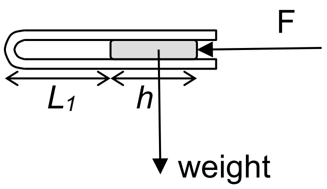
2**(a)** Using $P_iV_i = P_fV_f$, then 76.0 x 150 = P_f x 250

P_f = 45.6 cm Hg

(b) Using $P_iV_i = P_fV_f$, then 76.0 x 150 = 75.0 x V_f

V_f = 152 cm^3

3(a)



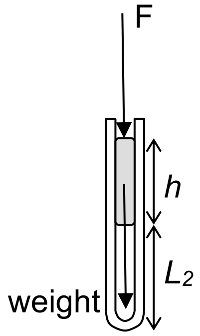
Freebody diagram of mercury column with cross-sectional area A

P_A = F/A

same F inside, so P_1 same as atmospheric pressure

Pressure $P_1 = P_A$

(b)



F_2: upward force on mercury column due to trapped air

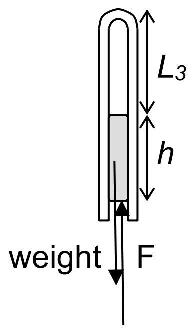
F_2 = F + weight of mercury

Dividing by area A,

F_2/A = F/A + pressure of mercury

$P_2 = P_A + h$ (cm Hg)

(c)



F_3: downward force on mercury column due to trapped air

F_3 + weight = F

F_3/A = F/A - pressure of mercury

$P_3 = P_A - h$ (cm Hg)

(b) Apply Boyle's law: $P_1 V_1 = P_2 V_2 = P_3 V_3$

$P_1 (L_1A) = P_2 (L_2A) = P_3 (L_3A)$

The relationship between the pressures is $P_1L_1 = P_2 L_2 = P_3 L_3$.

Exercises

1 When air is pumped in, the air pressure inside the bell jar (outside the balloon) increases, becoming greater than the air pressure inside the balloon. This will compress the balloon causing its volume to decrease as observed.

By Boyle's law, the pressure inside the balloon increases as its volume decreases. The balloon stops shrinking (a fixed volume) when the pressure inside is equal to the pressure outside the balloon (inside the bell jar), after the air pump is switched off.

2 Using $P_iV_i = P_fV_f$, $(60 + 10) \times 2.0 = 10 \times V_f$

$V_f = 14\ cm^3$

3 Using $P_iV_i = P_fV_f$, $A \times 30.0 = (A + 10.0) \times 26.5$

A = 75.7 cm Hg

4 Using $P_iV_i = P_fV_f$, $240 \times 2.00 = P_f \times 0.50$

$P_f = 960$ kPa