Lungs and Breathing

Pouya Taghipour
Dr. Malikeh Nabaei
Winter 2024

Table of contents

01

Overview

Midterm Exam

01

Introduction

02

Statics and Dynamic of Human Body

03

Heat and Energy

04

Lungs and Breathing

Introduction

Our lungs serve several important functions. They interact with blood by exchanging carbon dioxide for oxygen and they maintain the blood pH. The lungs are involved in heat exchange and fluid balance in the body, because relatively dry and usually cooler air is inhaled and air at the body temperature saturated with water vapor is exhaled. They are also a key element in voice production. We will highlight the mechanics of breathing

“The lungs are the primary organs of respiration, and their function is to bring oxygen into the body and expel carbon dioxide.”

—Dr. William Foege

What does this system do?

Alveoli

The alveoli in the lungs facilitate gas exchange, allowing oxygen to enter the bloodstream and carbon dioxide to be removed from it.

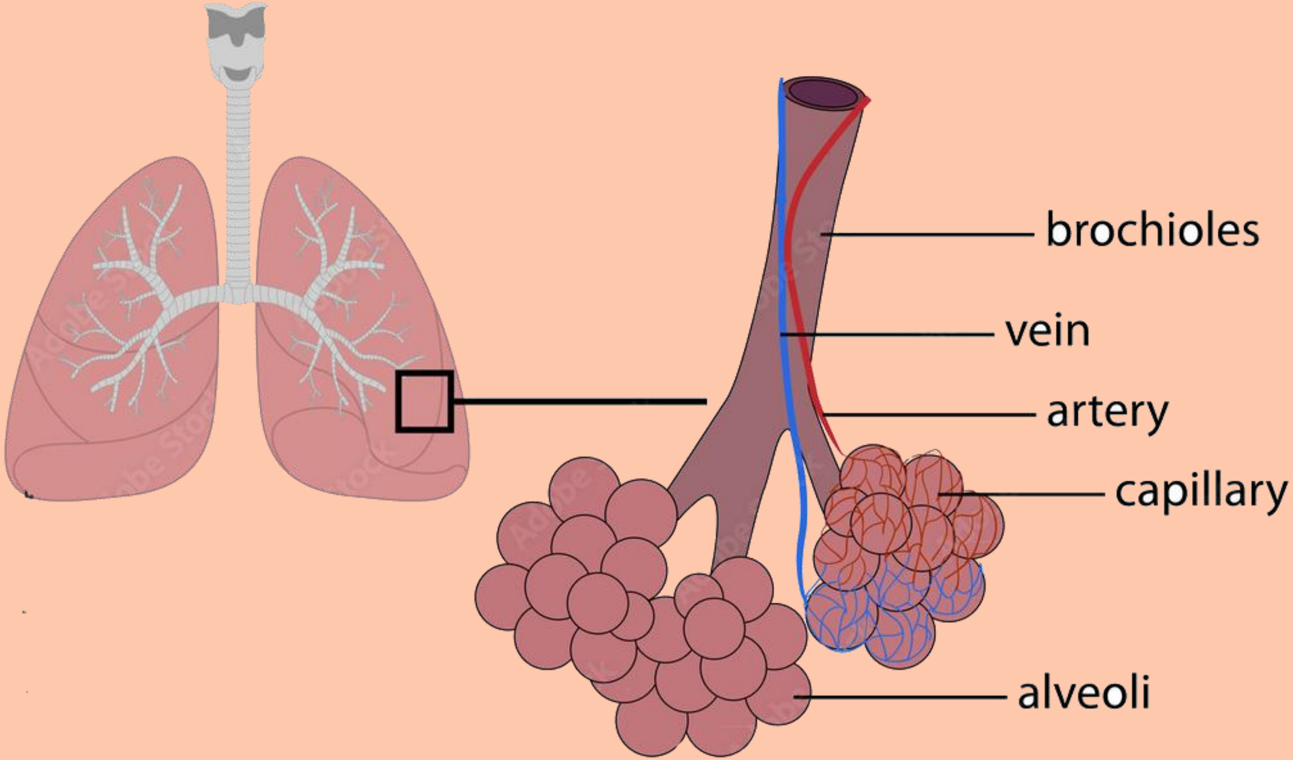
Lungs

The lungs facilitate respiration by exchanging oxygen from the air with carbon dioxide from the body, enabling oxygenation of the blood and removal of waste gases.

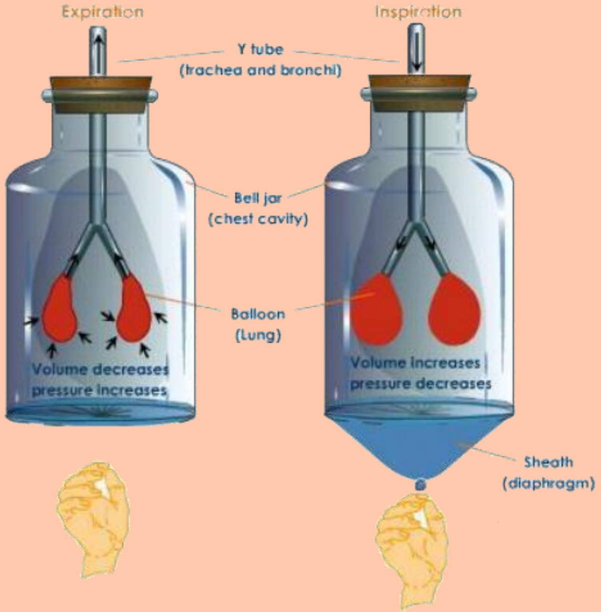
02

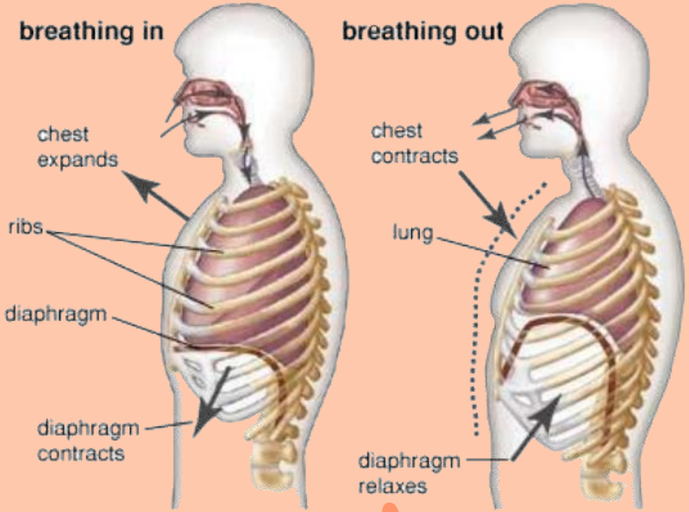
Generals

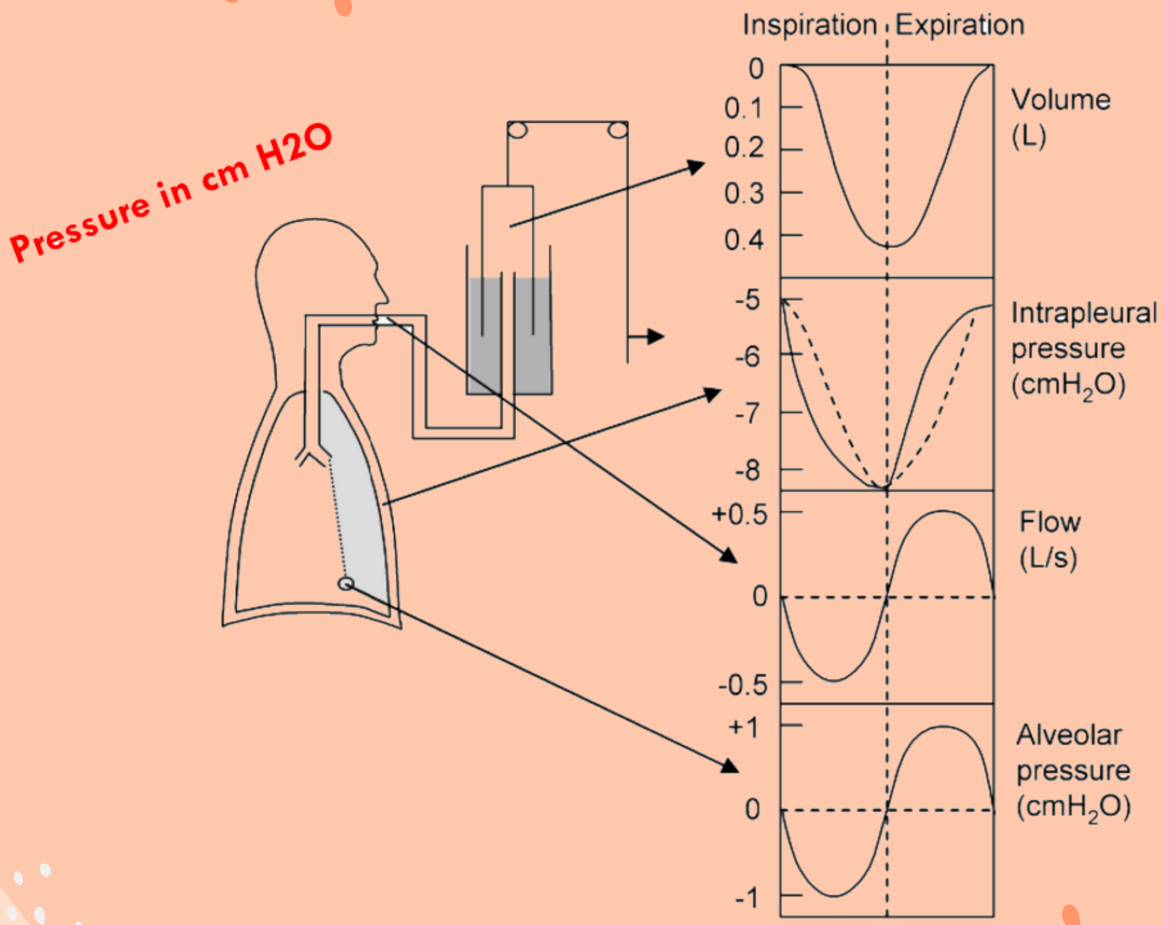
Alveoli Diagram

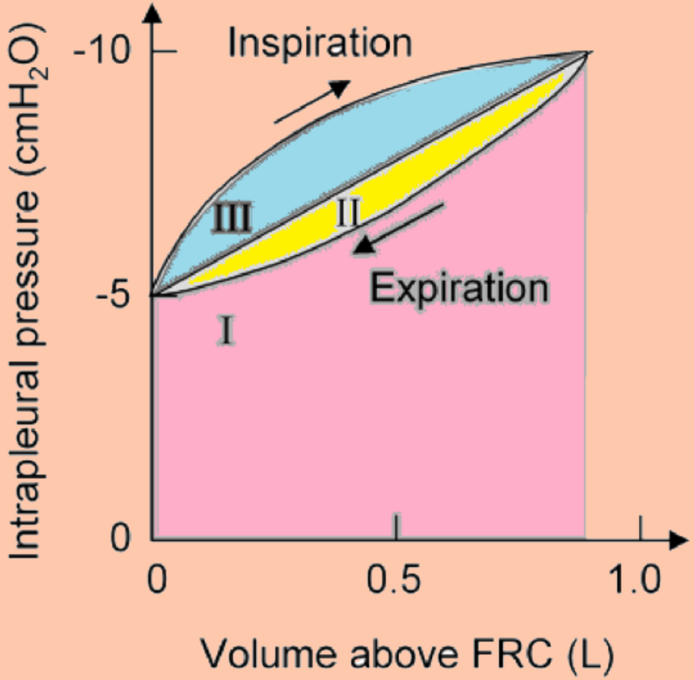


breathing mechanism





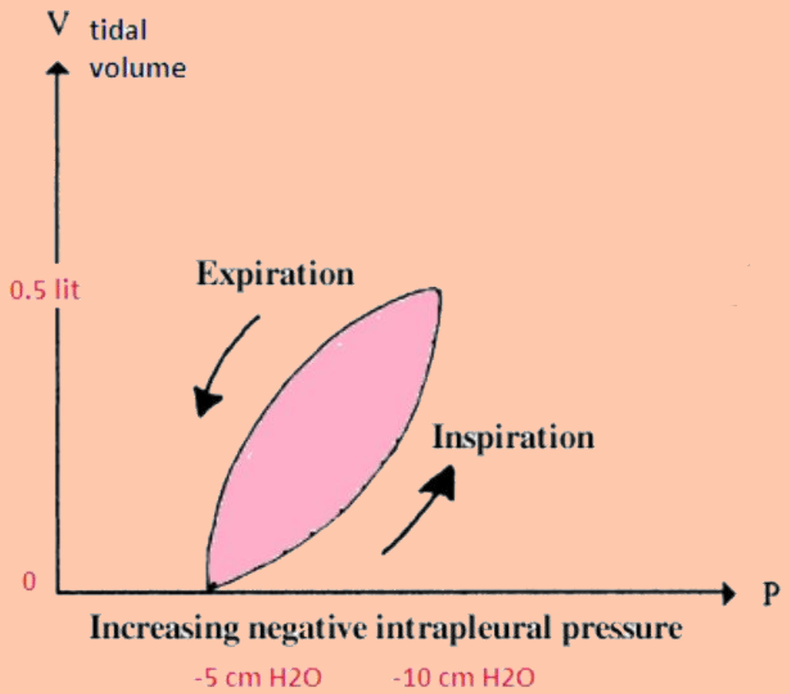

Pressure in cm H2O
Inspiration
Expiration
0
0.1
0.2
0.3
0.4
Volume
(L)
-5
-6
-7
-8
Intrapleural
pressure
(cmH2O)
+0.5
0
-0.5
Flow
(L/s)
+1
0
-1
Alveolar
pressure
(cmH2O)



Inspiration (work is done by the lung)

Expiration (work is done on the lung)

Work of cycle (clockwise)


V tidal volume
0.5 lit
0
Expiration
Inspiration
P
Increasing negative intrapleural pressure
-5 cm H2O
-10 cm H2O

Calculation of elastic work during exhalation

$$V(t) = V_{FRC} + C_{flow}P(t)$$
$$\Delta V(t) = V(t) - V_{FRC} = C_{flow}P(t)$$

Or

$$P(t) = \frac{\Delta V(t)}{C_{flow}}$$

$$W = \int_0^{V_t} Pd(\Delta V) = \int_0^{V_t} \frac{\Delta V}{C_{flow}} d\Delta V = \frac{V_t^2}{2C_{flow}}$$

$$\frac{dW}{dt} = f\frac{V_t^2}{2C_{flow}}$$

Definition of standard lung capacities and volumes

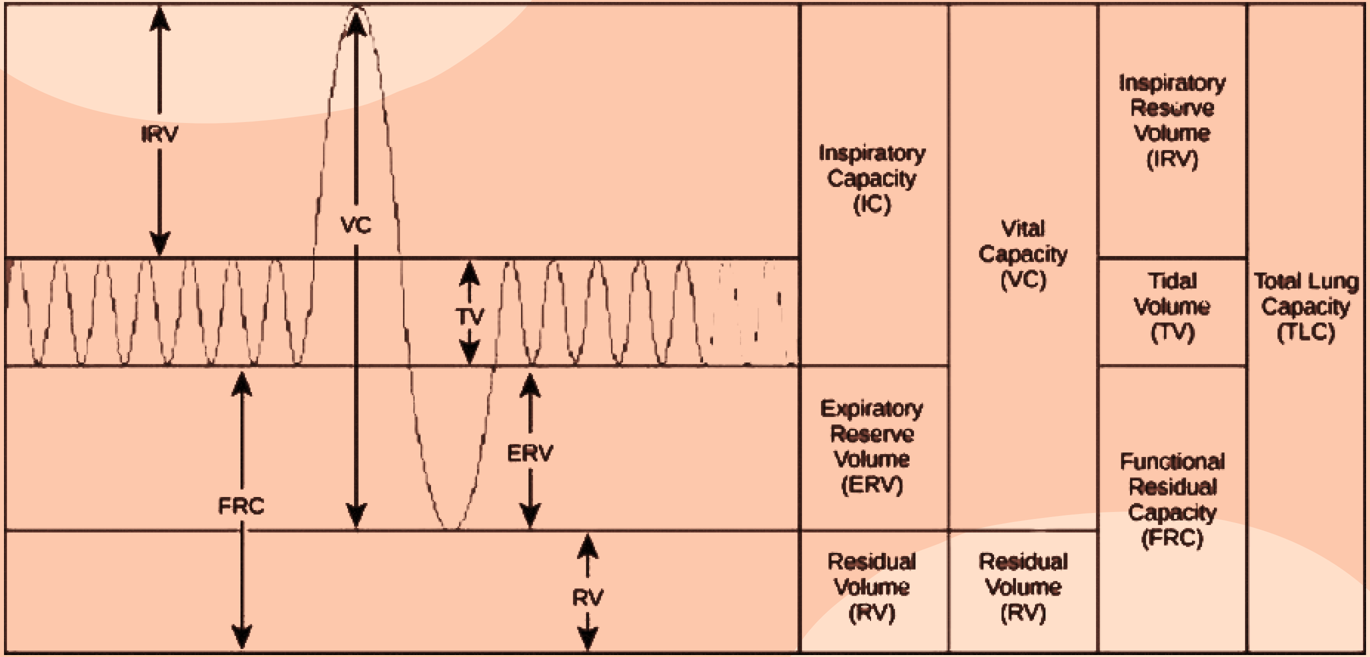
Volumes:

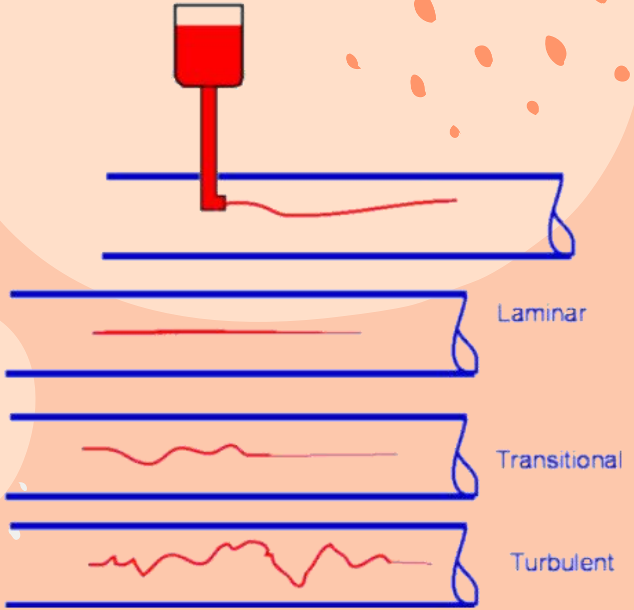
- **Tidal Volume (TV):** The volume of ambient air that enters or leaves the lungs during each normal breath. **0.5 lit**
- **Residual Volume (RV):** The volume of air that remains in the lungs after a deep exhalation. **1.5 lit**
- **Expiratory Reserve Volume (ERV):** The volume of air that is removed from the lungs in addition to a normal exhalation and then in a deep exhalation. **1-1.5 lit**
- **Inspiratory Reserve (IRV):** The volume of air that enters the lungs in addition to a normal breath and then in a deep breath. **2-2.5 lit**

Definition of standard lung capacities and volumes

Capacities:

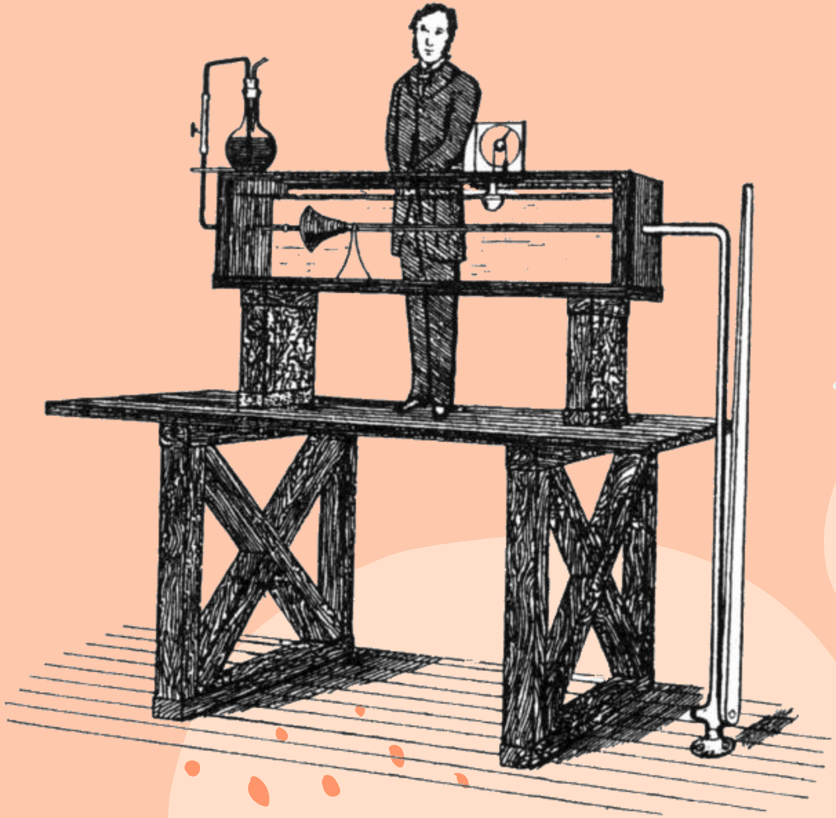
- **Functional Residual Capacity(FRC):** The volume of air remaining in the lungs at the end of a normal exhalation. $\mathbf{FRC} = \boldsymbol{RV} + \boldsymbol{ERV} \cong \mathbf{2.5{\sim}3}\ \boldsymbol{lit}$
- **Inspiratory Capacity (IC):** The volume of air that is drawn into the lungs at the end of a normal exhalation and during a deep breath. $\boldsymbol{IC} = \boldsymbol{IRV} + \boldsymbol{TV} \cong \mathbf{2.5{\sim}3}\ \boldsymbol{lit}$
- **Total Lung Capacity (TLC):** The volume of air left in the lungs after a deep breath. $\boldsymbol{TLC} = \boldsymbol{RV} + \boldsymbol{ERV} + \boldsymbol{TV} + \boldsymbol{IRV} \cong \mathbf{5{\sim}6}\ \boldsymbol{lit}$
- **Vital Capacity (VC):** The volume of air that leaves the lungs after a deep breath as a deep exhalation: the maximum amount of air passing through the lungs. $\boldsymbol{VC} = \boldsymbol{TLC} + \boldsymbol{RV} \cong \mathbf{4.5{\sim}5}\ \boldsymbol{lit}$


IRV
VC
TV
ERV
FRC
RV
Inspiratory Capacity (IC)
Expiratory Reserve Volume (ERV)
Residual Volume (RV)
Vital Capacity (VC)
Residual Volume (RV)
Inspiratory Reserve Volume (IRV)
Tidal Volume (TV)
Functional Residual Capacity (FRC)
Total Lung Capacity (TLC)

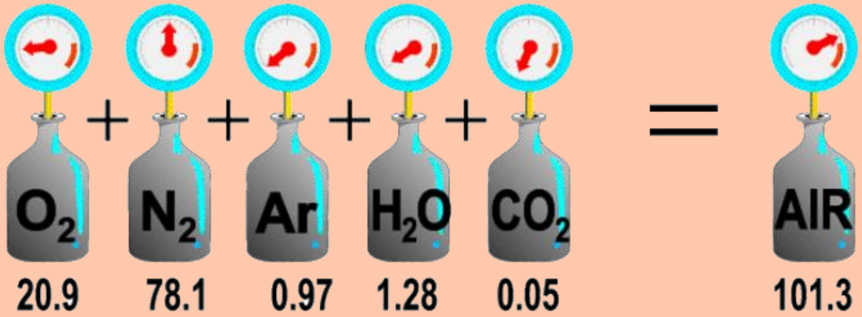


Reynolds number

$$Re = \frac{\rho V D}{\mu}$$



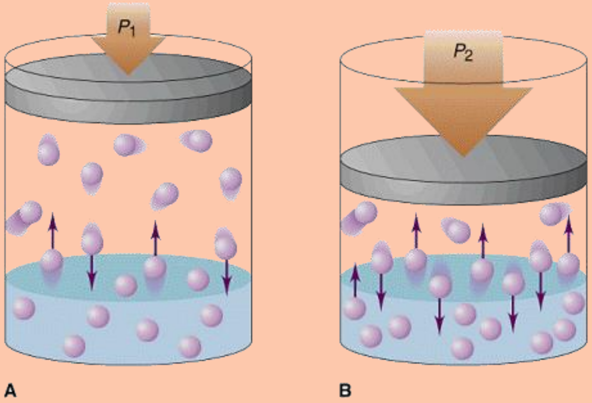
Dalton's Law



$$p_i = x_i p_t$$

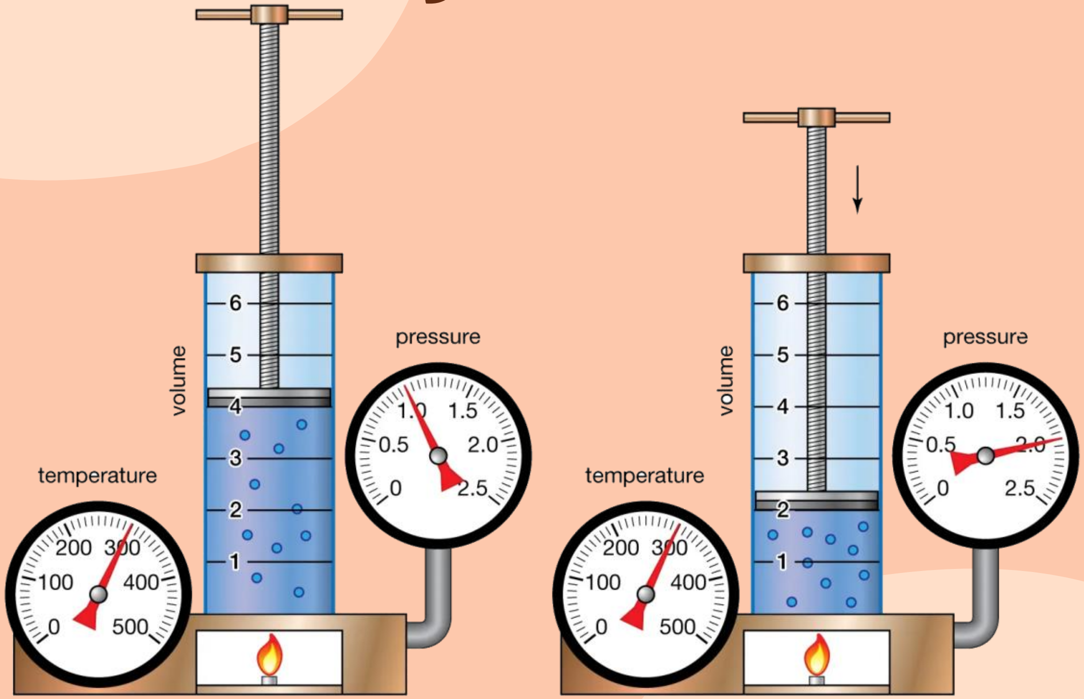
$$p_t = \sum p_i$$

Henry's Law



$$x_i = H \times p_i$$

Boyl's Law



$$pV = nRT$$

Fick's Law of Diffusion

$$N_a = A \times D_{ab} \times \frac{\Delta C_a}{\Delta x}$$

Laplace's Law

$$P_i - P_o = \frac{4\gamma}{r}$$

$$P_i - P_o = \frac{2\gamma}{r}$$

Calculation of surfactant effect

$$\Delta P_{alveoli} = P_{in} - P_{out} = \frac{2\gamma}{R}$$

03

Examples

Example 4–1

Find the work of breathing of a person who breathes 20 times per minute in one day. Current volume is $500\ cm^3$ and Compliance is $0.1\,\frac{lit}{cm}$

If muscle efficiency is 5%, find the metabolic rate.

Example 4–1

Answer:

A)

$$\frac{dW}{dt} = f\,\frac{V_t^2}{2C_{flow}} = \left(\frac{20}{min}\right)\frac{(500)^2}{2 \times 0.1} \xrightarrow{Considering\ scales} \frac{20\,(500\ \times 10^{-6})}{2\ \times 0.1\ \times 10^{-5}} \cong 3.6 \times 10^3\,\frac{J}{day}$$

$$3.6 \times 10^3\,\frac{J}{day} \xrightarrow{\div 4184} 0.86\,\frac{kcal}{day}$$

B)

$$\text{efficiency} = \frac{\frac{dW}{dt}}{MR} \to MR = \frac{\frac{dW}{dt}}{\text{efficiency}} = \frac{0.86}{0.5} = 17.2\,\frac{kcal}{day}$$

Example 4-2

In both inspiration and expiration, a pressure difference of 0.4cmH2O causes a flow of 0.15 L/s in the nose. Determine the flow resistance in it.

Answer:

$$R = \frac{\Delta P}{\Delta Q} \longrightarrow R = \frac{0.4}{0.15} \cong 2.6$$

Example 4–3

If the radius of the collapsed air bags is equal to 0.05 mm and its surface tension is equal to $7.2 \times 10^{-2} \frac{N}{m}$, what is the pressure change in the expansion of this bag set? If the area of the diaphragm muscle is $500\ cm^2$, what is the force required to expand these air sacs in one breath?

Example 4–3

Answer:

A)

$$\Delta P = \frac{2\gamma}{r} = \frac{2 \times 7.2 \times (10)^{-2}}{0.05 \times (10)^{-3}} \longrightarrow \Delta P = 2.9 \times 10^{3}\,\frac{N}{m^{2}} \cong 21.75\, mmHg$$

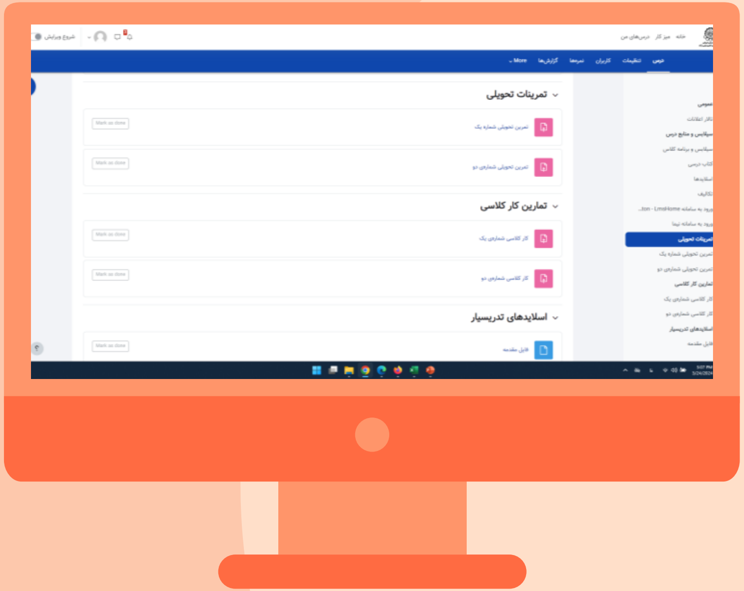
B)

$$F = P \times A = 2.9 \times 10^{3} \times 500 \times 10^{-4} = 145\, N$$

04

Assignment

HWh03



Class Activity

HWc03

1. The presence of surfactant in the air sacs plays two important and fundamental roles in breathing. Mention and explain these two items
2. Human consciousness and ability decreases in the depths of the sea. Why?

Resources

Dr. Malikeh Nabaei:

- Slides
- Classes

Faezeh Jahani:

- Slides

biological and medical physics, biomedical engineering

- The reference book

Thanks!

Do you have any questions?

Taghipourpouyaa@gmail.com

@PouyaTghpr

Pouya Taghipour

CREDITS: This presentation template was created by **Slidesgo**, including icons by **Flaticon** and infographics & images by **Freepik**

Additionally, Some Icons are taken from "Vector Icons and Stickers" and all the pictures are taken from the web

Have a good afternoon