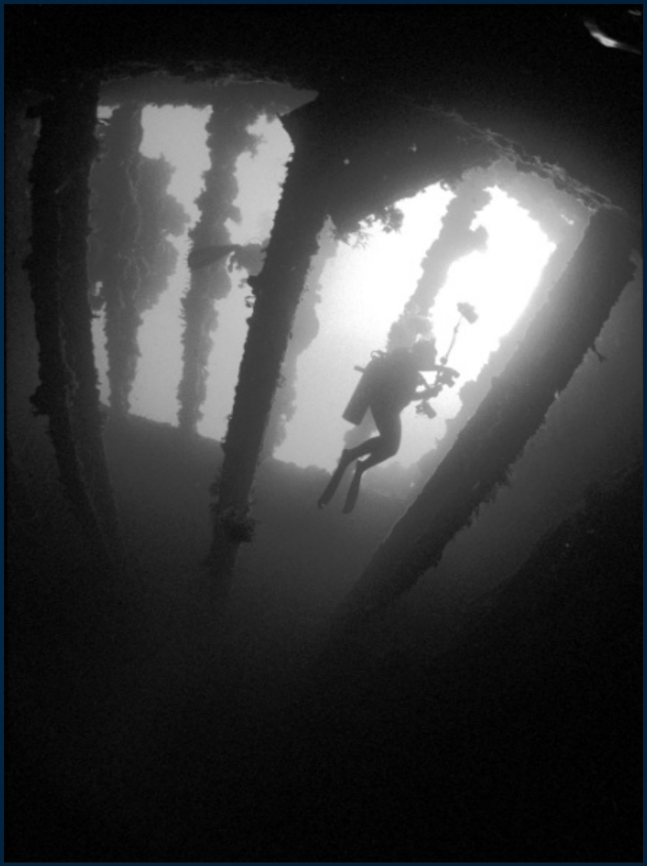


Chapter Six

# Diving Physics

# *Topics in this Chapter*

- ✓ Introduction
- ✓ Physical Properties of Water
- ✓ Archimedes' Principle
- ✓ Principles of Pressure
- ✓ Boyle's Law
- ✓ Charles' Law & Gay-Lussac's Law
- ✓ Combined & Ideal Gas Laws

# Topics in this Chapter

- ✓ Dalton's Law
- ✓ Henry's Law
- ✓ Haldane's Decompression Model
- ✓ Modern Dive Tables and Dive Computers
- ✓ Review Questions

# Introduction

The Laws of Physics were covered in detail in the SDI Divemaster course. Here they are covered briefly.

For more detailed information refer to the SDI Divemaster materials.

# Physical Properties of Water

- **Density of Water**
  - 800x denser than air
    - Greater resistance while moving underwater
      - Increased breathing and air consumption

# Physical Properties of Water

- **Refraction of Light in Water**
  - Light rays refract (bend) when passing from one medium to another of different densities
    - The human eye is designed to focus light entering from the air
      - The dive mask restores normal vision by adding an air space in front of the eyes
    - As light rays pass from water to the air space of the mask, it creates a magnifying effect
      - Objects appear 33% larger and 25% closer

# Physical Properties of Water

- **Diffraction of Light in Water**
  - Light rays normally travel in a straight line
    - Suspended particles in water can deflect the rays and cause a random divergence of light
      - An object may appear to be farther away that it actually is (visual reversal)

# Physical Properties of Water

- **Color Loss in Water**
  - The longest wavelengths are the first to be absorbed
    - Visible spectrum – “Roy G Biv”
      - Red
      - Orange
      - Yellow
      - Green
      - Blue
      - Indigo
      - Violet

*Longest Wavelength*

*Shortest Wavelength*

# Physical Properties of Water

- **Transmission of Sound in Water**
  - Sound waves travel faster and farther through a denser medium
    - About 4x faster in water than air

# Physical Properties of Water

- **Thermal Conductivity of Water**
  - Water conducts heat more efficiently than air
    - Whisks away body heat 25x faster
    - Plan for proper exposure protection

# Archimedes’ Principle

- **Buoyancy**
  - When immersed in a fluid, an object will experience a buoyant force equal to the weight of the displaced fluid

# Archimedes' Principle

- **How this Principle Relates to Diving**
  - Items used by a diver to control buoyancy
    - BCD
      - Inflation and deflation alters the volume of water which is displaced
    - Lead weights
      - To offset the overall positive buoyancy of a diver and his equipment
    - Lung volume
      - Fine tune buoyancy on a temporary basis

# Archimedes' Principle

- **Saltwater versus Freshwater**
  - Saltwater weighs more than freshwater, so an object will be more buoyant in saltwater that freshwater
    - Saltwater
      - 1 litre = 1.03 kilograms
      - 1 cubic foot = 64 pounds
    - Freshwater
      - 1 litre = 1 kilogram
      - 1 cubic foot = 62.4 pounds

# Archimedes' Principle

- **Buoyancy Calculations**
  - To determine the buoyancy of an object

*Metric*

buoyancy = weight of object – [ (litres displaced) x (kg per litre of water) ]

*Imperial*

buoyancy = weight of object – [ (cu ft displaced) x (lbs per cu ft of water) ]

# Archimedes' Principle

- **Buoyancy Calculations**
  - To achieve neutral buoyancy

*Metric*

litres required = [kg of negative buoyancy] / [kg per litre of water]

*Imperial*

cu ft required = [lbs of negative buoyancy] / [lbs per cu ft of water]

# Principles of Pressure

- **Pressure**
  - The force, or weight, pressing upon a surface
    - Units of measurement
      - 1 bar = 1 kilogram per square centimetre
      - 1 atm = 14.7 pounds per square inch
      - 1 bar = 1 atm

# Principles of Pressure

- **Ambient Pressure**
  - The absolute or total pressure
    - Includes the weight of the overhead atmosphere plus the weight of the water overhead
      - Atmosphere = 1 bar or 1 atm
      - 10 metres of seawater = 1 bar
      - 33 feet of seawater = 1 atm

# Principles of Pressure

- Ambient Pressure

| Depth in Seawater | | Ambient Pressure |
|---|---|---|
| 0 m | 0 ft | 1 bar / atm |
| 10 m | 33 ft | 2 bar / atm |
| 20 m | 66 ft | 3 bar / atm |
| 30 m | 99 ft | 4 bar / atm |
| 40 m | 132 ft | 5 bar / atm |
| 50 m | 165 ft | 6 bar / atm |

# Principles of Pressure

- **Gauge Pressure**
  - Effectively disregards atmospheric pressure, and only indicates the force exerted by another source of pressure
    - Used in two types of dive instruments
      - Submersible pressure gauge
      - Depth gauge


# Principles of Pressure

- **Pressure Calculations**
  - For different types of SPG readings

| *Imperial-to-Metric* |
| --- |
| bar = psi / 14.7 |

| *Metric-to-Imperial* |
| --- |
| psi = bar x 14.7 |

# Principles of Pressure

- **Pressure Calculations**
  - For different types of depth gauge readings

*Imperial-to-Metric*

metres = feet / 3.3

*Metric-to-Imperial*

feet = metres x 3.3

# Principles of Pressure

- **Pressure Calculations**
  - To covert depth to pressure

*Metric*

$P = [\ D / 10\ ] + 1$ *or* $P = [\ D + 10\ ] / 10$

*Imperial*

$P = [\ D / 33\ ] + 1$ *or* $P = [\ D + 33\ ] / 33$

# Principles of Pressure

- **Pressure Calculations**
  - To covert pressure to depth

*Metric*

D = [ P – 1 ] x 10 *or* D = [ P x 10 ] – 10

*Imperial*

D = [ P – 1 ] x 33 *or* D = [ P x 33 ] – 33

# Principles of Pressure

- **Freshwater versus Saltwater**
  - Freshwater weighs less than saltwater, and freshwater water exerts less pressure than saltwater
    - 1 bar = 10 metres of saltwater
    - 1 bar = 10.3 metres of freshwater
    - 1 atm = 33 feet of saltwater
    - 1 atm = 34 feet of freshwater

# Principles of Pressure

- **Freshwater versus Saltwater**
  - Most depth gauges and personal dive computers are calibrated for saltwater

# Principles of Pressure

- **Pressure Calculations**
  - To covert *freshwater* depth to pressure

*Metric*

P = [ D / 10.3 ] + 1 *or* P = [ D + 10.3 ] / 10.3

*Imperial*

P = [ D / 34 ] + 1 *or* P = [ D + 34 ] / 34

# Principles of Pressure

- **Pressure Calculations**
  - To covert pressure to *freshwater* depth

*Metric*

D = [ P – 1 ] x 10.3 *or* D = [ P x 10.3 ] – 10.3

*Imperial*

D = [ P – 1 ] x 34 *or* D = [ P x 34 ] – 34

# Principles of Pressure

- **Pressure Calculations**
  - To determine actual *freshwater* depth, from depth gauge

*Metric*

metres of freshwater = metres of saltwater x 1.03

*Imperial*

feet of freshwater = feet of saltwater x 1.03

# Principles of Pressure

- **Pressure Calculations**
  - What will be the depth gauge reading, at a specified *freshwater* depth

*Metric*

metres of saltwater = metres of freshwater / 1.03

*Imperial*

feet of saltwater = feet of freshwater / 1.03

# Boyle's Law

- **Pressure and Volume**
  - – Any change in pressure, applied upon a gas in a flexible container, will result in a corresponding and inversely proportional change in volume
    - Though not part of the original principle, in practice Boyle's Law has been expanded to also include the density of the gas

# Boyle’s Law

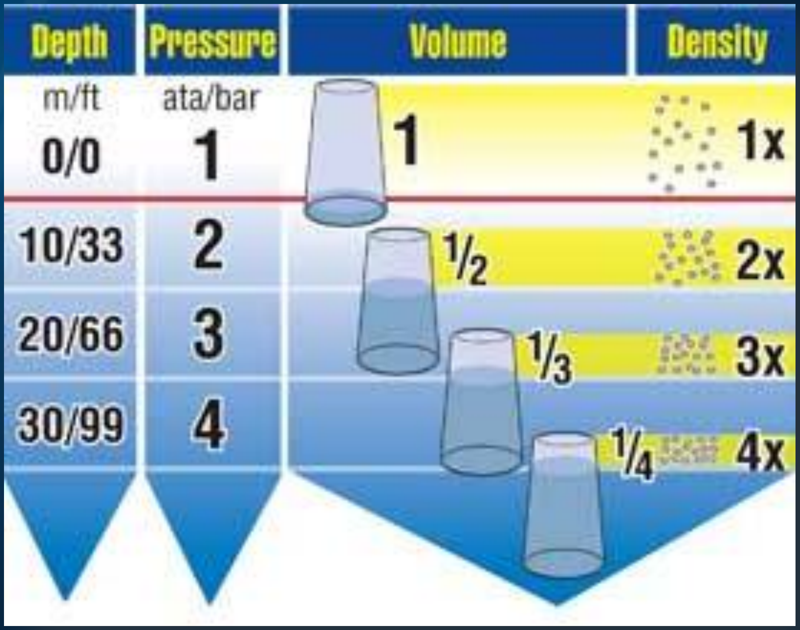
- Pressure and Volume

| Depth in Seawater | | Ambient Pressure | Volume | Density |
|---|---|---|---|---|
| 0 m | 0 ft | 1 bar / atm | x 1 | x 1 |
| 10 m | 33 ft | 2 bar / atm | x 1/2 | x 2 |
| 20 m | 66 ft | 3 bar / atm | x 1/3 | x 3 |
| 30 m | 99 ft | 4 bar / atm | x 1/4 | x 4 |
| 40 m | 132 ft | 5 bar / atm | x 1/5 | x 5 |
| 50 m | 165 ft | 6 bar / atm | x 1/6 | x 6 |

# Boyle’ s Law

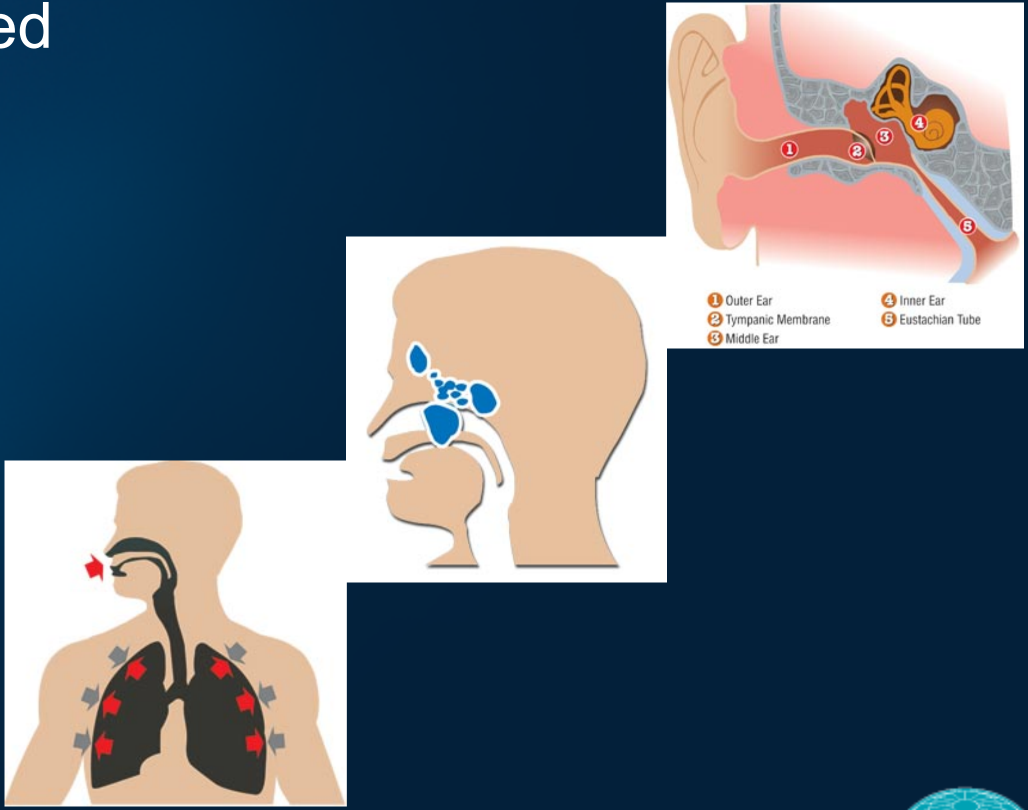
- **Pressure and Volume**
  - Inside a flexible container

Gas Pressure = Ambient Pressure



# Boyle’s Law

- **How this Principle Relates to Diving**
  - Air spaces affected
    - Middle Ear
    - Sinuses
    - Lungs
    - Mask
    - Suit
      - Neoprene
      - Dry suit
  - Equalize



# Boyle’s Law

- **How this Principle Relates to Diving**
  - Air consumption
    - It takes more molecules of air, drawn from the scuba cylinder with each inhaled breath, to fill a diver’s lungs at depth
      - A cylinder full of air, which lasts one hour at the surface, will last only 15 minutes at 30 m / 99 ft

# Boyle's Law

- **How this Principle Relates to Diving**
  - Breathing effort
    - The density of air, inhaled by a diver, increases with depth
      - Normally it is unnoticed by the diver, when a proper pattern of breathing is maintained
      - Over-exertion increases the breathing rate  and turbulence may occur in the airway

# Boyle's Law

- **How this Principle Relates to Diving**
  - Buoyancy
    - Air compresses in BCD as the diver descends and expands on ascent
    - Similarly the air inside dry suits and neoprene material compress and expands

# Boyle's Law

- **The Significance of Relative Changes**
  - Greater changes occur at shallower depths
    - Pressure doubles during a descent from the surface to 10 m / 33 ft
    - Then, from 10 m / 33 ft, it does not double again until 30 m / 99 ft

| Depth in Seawater | | Ambient Pressure | Volume | Density |
|---|---|---|---|---|
| 0 m | 0 ft | 1 bar / atm | x 1 | x 1 |
| 10 m | 33 ft | 2 bar / atm | x 1/2 | x 2 |
| 20 m | 66 ft | 3 bar / atm | x 1/3 | x 3 |
| 30 m | 99 ft | 4 bar / atm | x 1/4 | x 4 |
| 40 m | 132 ft | 5 bar / atm | x 1/5 | x 5 |
| 50 m | 165 ft | 6 bar / atm | x 1/6 | x 6 |

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# Boyle’ s Law

- **The Significance of Relative Changes**
  - Greater changes occur at shallower depths
    - Volume increases by only 25% during an ascent from 40 m / 132 ft to 30 m / 99 ft
    - It increases by 100% from during an ascent from 10 m / 33 ft to the surface

| Depth in Seawater | | Ambient Pressure | Volume | Density |
|---|---|---|---|---|
| 0 m | 0 ft | 1 bar / atm | x 1 | x 1 |
| 10 m | 33 ft | 2 bar / atm | x 1/2 | x 2 |
| 20 m | 66 ft | 3 bar / atm | x 1/3 | x 3 |
| 30 m | 99 ft | 4 bar / atm | x 1/4 | x 4 |
| 40 m | 132 ft | 5 bar / atm | x 1/5 | x 5 |
| 50 m | 165 ft | 6 bar / atm | x 1/6 | x 6 |

# Boyle’s Law

- **The Significance of Relative Changes**
  - Greater changes occur at shallower depths
    - Important to equalize early during a descent
    - A diver may have more difficulty maintaining buoyancy control at shallower depths
    - Need vigilance to maintain a slow rate of ascent throughout the entire ascent, especially as the diver nears the surface

# Boyle's Law

- **Pressure and Volume Calculations**
  - The general mathematical formula

*Metric and Imperial*

$$P_1 \times V_1 = P_2 \times V_2$$

# Boyle's Law

- **Pressure and Volume Calculations**
  - To determine the new volume, after a given change in pressure

*Metric and Imperial*

$$V_2 = [\ P_1 \times V_1\ ]\ /\ P_2$$

# Boyle's Law

- **Pressure and Volume Calculations**
  - To determine the new pressure, after a given change in volume

*Metric and Imperial*

$$P_2 = [\ P_1 \times V_1\ ] / V_2$$

# Boyle's Law

- **Pressure and Volume Calculations**
  - Knowing the time a certain supply of gas lasts at one depth, to determine the time at a new depth

*Metric and Imperial*

$$\text{minutes}_2 = [\, P_1 \times \text{minutes}_1 \,] \,/\, P_2$$

# Boyle's Law

- **Pressure and Volume Calculations**
  - Knowing the time a certain supply of gas lasts at one depth, to determine the new depth at which it will last a specific time

*Metric and Imperial*

$$P_2 = [\ P_1 \times \text{minutes}_1\ ]\ /\ \text{minutes}_2$$

# Boyle's Law

- **Pressure and Volume Calculations**
  - To determine the relative change in ambient pressure between two different depths

*Metric and Imperial*

relative change = $P_2 / P_1$

# Charles' Law & Gay-Lussac's Law

- **Temperature and Volume**
  - Charles' Law: The volume of a gas increases or decreases by the same factor as its temperature
- **Temperature and Pressure**
  - Gay-Lussac's Law: The pressure of a gas increases or decreases by the same factor as its temperature

*Both principles refer to absolute temperature (°Kelvin or °Rankin)*

# Charles' Law & Gay-Lussac's Law

- **How these Principles Relate to Diving**
  - Temperature affects both volume and pressure
    - Changes in volume occur only when the gas is confined in a flexible container
    - Changes in pressure occur in both flexible and rigid containers

# Charles' Law & Gay-Lussac's Law

- **How these Principles Relate to Diving**
  - Similarly
    - A change in pressure or volume also will affect the temperature

# Charles' Law & Gay-Lussac's Law

- **How these Principles Relate to Diving**
  - The most apparent effect involves the scuba cylinder
    - When a cylinder is heated, its pressure increases
    - When a cylinder is cooled, its pressure decreases
    - When a cylinder is filled, its temperature increases
    - When a cylinder is drained, its temperature decreases

# Charles' Law & Gay-Lussac's Law

- **Temperature and Volume Calculations**
  - To determine the new volume of a gas (in a flexible container) after a change in temperature

*Metric*

$$V_2 = V_1 \text{ x } [ ( {}^oC_2 + 273 ) / ( {}^oC_1 + 273 ) ]$$

*Imperial*

$$V_2 = V_1 \text{ x } [ ( {}^oF_2 + 460 ) / ( {}^oF_1 + 460 ) ]$$

*Each formula includes the conversion for absolute temperature*

# Charles' Law & Gay-Lussac's Law

- **Temperature and Pressure Calculations**
  - To determine the new pressure of a gas after a change in temperature

*Metric*

$$bar_2 = \{ ( bar_1 + 1 ) \times [ ( {}^{o}C_2 + 273 ) \ / \ ( {}^{o}C_1 + 273 ) ] \} - 1$$

*Imperial*

$$psi_2 = \{ ( psi_1 + 14.7 ) \times [ ( {}^{o}F_2 + 460 ) \ / \ ( {}^{o}F_1 + 460 ) ] \} - 14.7$$

*Each formula includes the conversion for absolute temperature*

# Charles' Law & Gay-Lussac's Law

- **Quick Estimate for Temperature and Pressure**
  - In the real world of diving

| *Metric* |
| --- |
| $1^{o}C = 0.6$ bar |

| *Imperial* |
| --- |
| $1^{o}F = 5$ psi |

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# Combined & Ideal Gas Laws

- **Pressure, Volume and Temperature**
  - Combined Gas Law: includes three variables in a single formula

*Metric and Imperial*

$$( P_1 \times V_1 ) / T_1 = ( P_2 \times V_2 ) / T_2$$

*T: absolute temperature (°Kelvin or °Rankin)*

# Combined & Ideal Gas Laws

- **Pressure, Volume, Temperature and Mass**
  - Ideal Gas Law: expanded concept beyond Combined Gas Law, also includes mass
    - Applies to a hypothetical "ideal" gas, but an actual gas might vary from this model

*Metric and Imperial*

$$P \times V = ( n \times R ) \times T$$

*T: absolute temperature (°Kelvin or °Rankin)*
*n: number of moles (atomic and sub-atomic particles)*
*R: universal gas constant*

# Dalton’ s Law

- **Partial Pressure**
  - The total pressure exerted by a mixture of gases is equal to the sum of the pressures of each of its component gases, with each component gas acting as if it alone was present and occupied the total volume
    - Each gas, within a mixture, has its own pressure (based upon its percentage in the mixture)
    - Each gas is unaffected by any other gas in the mixture

# Dalton’ s Law

- Partial Pressure

| Depth in Seawater | | Ambient Pressure | Partial Pressures in Air | |
|---|---|---|---|---|
| | | | Oxygen (21%) | Nitrogen (79%) |
| 0 m | 0 ft | 1 bar / atm | 0.21 bar / atm | 0.79 bar / atm |
| 10 m | 33 ft | 2 bar / atm | 0.42 bar / atm | 1.58 bar / atm |
| 20 m | 66 ft | 3 bar / atm | 0.63 bar / atm | 2.37 bar / atm |
| 30 m | 99 ft | 4 bar / atm | 0.84 bar / atm | 3.16 bar / atm |
| 40 m | 132 ft | 5 bar / atm | 1.05 bar / atm | 3.95 bar / atm |
| 50 m | 165 ft | 6 bar / atm | 1.26 bar / atm | 4.74 bar / atm |

# Dalton's Law

- **Partial Pressure**
  - As depth varies
    - Percentage of each gas remains constant
    - Partial pressure of each gas varies with depth

# Dalton's Law

- **How this Principle Relates to Diving**
  - Physiological impact of a gas depends upon its partial pressure
    - When breathing air at 40 m / 132 ft
      - The $PO_2$ is 1.05 bar / atm, which is about the same as breathing 100% oxygen at the surface
      - The $PN_2$ is 3.95 bar / atm, which is almost four times more than breathing 100% nitrogen at the surface

# Dalton’s Law

- **How this Principle Relates to Diving**
  - Ambient pressure, as well as the pressure of the breathing mixture inside a diver’s lungs, remains constant at a given depth
    - Altering the percentages of the gases in the mixture allows more effective control of the physiological impact of each gas
    - This is the foundational concept for nitrox and other breathing mixtures

# Dalton's Law

- **How this Principle Relates to Diving**
  - Partial pressures in air and nitrox

| Depth in Seawater | | Ambient Pressure | Partial Pressures in Air | | Partial Pressures in Nitrox | |
|---|---|---|---|---|---|---|
| | | | Oxygen (21%) | Nitrogen (79%) | Oxygen (40%) | Nitrogen (60%) |
| 0 m | 0 ft | 1 bar / atm | 0.21 bar / atm | 0.79 bar / atm | 0.40 bar / atm | 0.60 bar / atm |
| 10 m | 33 ft | 2 bar / atm | 0.42 bar / atm | 1.58 bar / atm | 0.80 bar / atm | 1.20 bar / atm |
| 20 m | 66 ft | 3 bar / atm | 0.63 bar / atm | 2.37 bar / atm | 1.20 bar / atm | 1.80 bar / atm |
| 30 m | 99 ft | 4 bar / atm | 0.84 bar / atm | 3.16 bar / atm | 1.60 bar / atm | 2.40 bar / atm |

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# Dalton's Law

- **Partial Pressure Calculations**
  - To determine the partial pressure of oxygen and nitrogen in air or a nitrox mixture

*Metric and Imperial*

$PO_2 = P \times FO_2$ *and* $PN_2 = P \times FN_2$

# Dalton’ s Law

- **Partial Pressure Calculations**
  - To determine which mixture provides a specific partial pressure at a given ambient pressure

*Metric and Imperial*

$FO_2 = PO_2 / P$ *and* $FN_2 = PN_2 / P$

# Dalton’ s Law

- **Partial Pressure Calculations**
  - To determine the maximum depth, with a given nitrox mixture, which does not exceed a specified partial pressure of oxygen

*Metric and Imperial*

$$P = PO_2 / FO_2$$

# Dalton’ s Law

- **Partial Pressure Calculations**
  - To determine the equivalent air depth for a given nitrox mixture

*Metric*

$$EAD = [\ (\ FN_2 / 0.79\ ) \times (\ D + 10\ )\ ] - 10$$

*Imperial*

$$EAD = [\ (\ FN_2 / 0.79\ ) \times (\ D + 33\ )\ ] - 33$$

# Henry's Law

- **Partial Pressure and Gas Solubility**
  - At a constant temperature, the quantity of gas which is dissolved in a given type and volume of liquid is directly proportional to the partial pressure of that gas in equilibrium with the liquid

# Henry’ s Law

- Partial Pressure and Gas Solubility

| Partial Pressure of Gas | Maximum Quantity of Dissolved Gas |
|---|---|
| 0.25 bar / atm | x .025 |
| 0.50 bar / atm | x 0.50 |
| 0.75 bar / atm | x 0.75 |
| 1 bar / atm | x 1 |
| 2 bar / atm | x 2 |
| 3 bar / atm | x 3 |
| 4 bar / atm | x 4 |
| 5 bar / atm | x 5 |

# Henry’ s Law

- **How this Principle Relates to Diving**
  - Helps to explain
    - Why a diver on-gasses nitrogen at depth
    - Why a diver off-gasses nitrogen during and after ascent
    - Why DCS can occur if a diver remains too long at depth, or ascends too quickly

# Henry's Law

- **Gas Solubility Calculations**
  - Impractical for general diving applications
    - Because of the variability of solubility coefficients and the widely divergent tissues of the human body

# Haldane's Decompression Model

- **Theoretical Tissue Compartments**
  - Recognizing the complexities of the human body, Haldane constructed a mathematical model with multiple theoretical tissue compartments
    - These compartments do not directly correspond to any actual tissues
    - Each compartment is defined by certain properties
    - Taken together these compartments mimic the overall process of nitrogen on-gassing and off-gassing within a diver's body

# Haldane’s Decompression Model

- **Half-Times**
  - Haldane assigned a half-time to each compartment
    - This is the time it takes for that compartment to go halfway, from its initial level of dissolved nitrogen at a certain depth, to its ultimate level of dissolved nitrogen at a new depth
    - Half-times accommodate the fact that on-gassing and off-gassing initially occur at faster rates, then slow as the pressure gradient narrows

# Haldane's Decompression Model

- Half-Times

| 60 Minute Compartment<br>Exposed to Increased Pressure | |
|---|---|
| Elapsed Time | On-Gassing Completed |
| **Start** | **0.0%** |
| **1 hour** | **50.0%** |
| **2 hours** | **75.0%** |
| **3 hours** | **87.5%** |
| **4 hours** | **93.8%** |
| **5 hours** | **96.9%** |
| **6 hours** | **98.5%** |

| 5 Minute Compartment<br>Exposed to Decreased Pressure | |
|---|---|
| Elapsed Time | Off-Gassing Completed |
| **Start** | **0.0%** |
| **5 minutes** | **50.0%** |
| **10 minutes** | **75.0%** |
| **15 minutes** | **87.5%** |
| **20 minutes** | **93.8%** |
| **25 minutes** | **96.9%** |
| **30 minutes** | **98.5%** |

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# Haldane's Decompression Model

- **M-Values**
  - Haldane conducted experiments to determine the maximum quantity of excess nitrogen that could be held in solution by each tissue compartment during ascent, after time at depth
    - It is expressed as a factor (or percent) above the normal amount of nitrogen present in a saturated tissue at the surface

# Haldane's Decompression Model

- **Haldane's Algorithm**
  - Complex mathematical computation
    - Haldane calculated the relevant information for each theoretical tissue compartment
    - Haldane found that different compartments would govern the time limits at different depths
    - Haldane projected a schedule of depth and time limits
      - First dive tables
      - Used by Royal Navy from 1907 to 1956

# Haldane’ s Decompression Model

- **Haldane’ s Algorithm**
  - Though highly theoretical in nature, time has proven Haldane’s methodology to be valid

# Modern Dive Tables and Computers

- **Over the years researchers have continued to refine and build upon Haldane's work**
  - Expanded the number of tissue compartments
  - Recalculated the applicable M-values
  - Altered the specified ascent rates
  - Assigned dissimilar rates for on-gassing and off-gassing
  - Made other modifications to the algorithm

# Haldane's Decompression Model

- **Modern Dive Tables and Dive Computers**
  - Today most dive tables and dive computers rely on an algorithm derived, directly or indirectly, from Haldane's decompression model

# Summary

- ✓ Introduction
- ✓ Physical Properties of Water
- ✓ Archimedes’ Principle
- ✓ Principles of Pressure
- ✓ Boyle’s Law
- ✓ Charles’ Law & Gay-Lussac’s Law
- ✓ Combined & Ideal Gas Laws

# Summary

- ✓ Dalton's Law
- ✓ Henry's Law
- ✓ Haldane's Decompression Model
- ✓ Modern Dive Tables and Computers

# Review Questions

# Review Questions

1. An object viewed underwater appears _________ than it actually is.

C. Larger and Closer

2. Sound travels approximately ______ times faster in water than in air.

A. Four (4)

3. An object that is neutrally buoyant displaces a volume of water that is:

B. Equal to the weight of the object.

# Review Questions

**4. To maintain neutral buoyancy during descent, a diver must:**

A. Add air to his BCD.

**5. An object that is neutrally buoyant in salt water will float in fresh water.**

B. False

**6. An object weighing 107kg/236lb is placed in salt water. The object displaces 127l/4.5cf of water. What is the buoyancy of this object?**

A. 23.8kg/52lb positively buoyant

# Review Questions

7. **Total force exerted by all sources of pressure is referred to as ________ or _________ pressure.**

B. Absolute, ambient

8. **Pressure increases by 1bar/atm for every _________________seawater.**

C. 10m/33ft

9. **A metric SPG displays a reading of 170bar. What would an imperial SPG read if attached to the same cylinder?**

A. 2499 psi

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# Review Questions

10. **A diver at a true depth of 36m / 119ft in fresh water would see what reading on his depth gauge?**

C. 35m / 115ft

11. **According to Boyle's Law, increasing pressure on a fixed volume of gas will result in an increase in that volume of gas.**

B. False

12. **A cylinder that lasts a diver 30 minutes at the surface will last him how long at 30m / 99ft?**

B. 7.5 minutes

# Review Questions

**13. A balloon is filled with 10L / .35ct of air at 3.7 bar / atm. If the balloon is taken to 4.3bar /atm what will the new volume be?**

D. 8.61L / .3cf

**14. What will be the approximate change in the pressure inside a scuba cylinder taken from a surface temperature of 35C/95F to an underwater temperature of 13C/55F? (Use the quick estimate method for temperature and pressure)**

A. 13.2bar / 200psi

# Review Questions

**15. A gas will move from an area of ________ concentration to an area of _______ concentration.**

C. Higher, lower

Any Questions ?