# UNDER WATER JETSKI MODEL

CSCI 100 (MWF 12:30-1:45) — FINAL PROJECT REPORT

## Introduction:

A key concern for underwater jetskis is the significant pressure they experience, which increases rapidly with depth. This pressure results from the combined weight of air and water per square centimeter. At sea level, atmospheric pressure is 1 atmosphere (atm), equivalent to approximately 760 millimeters of mercury (mmHg) or 10.1 newtons per square centimeter ($N/cm^2$). This means a column of air as tall as the atmosphere weighs about 10.1 N or 1 atm. However, underwater, the primary source of pressure is the weight of water, which is much heavier than air. For instance, at a temperature of 3.98°C, water has a density of 1.00000 grams per cubic centimeter ($g/cm^3$). A 10-meter column of water with a 1 $cm^2$ base weighs 9.81 N, roughly equal to the weight of the atmospheric column above it. As a result, at a depth of 10 meters, a machine or a product experiences 2 atm of pressure—1 atm from air and 1 atm from water. Consequently, for every additional 10 meters of depth, the pressure increases by approximately 1 atm.

The goal of this project is to create a mini-submarinelike model using Vensim PLE that incorporates the pressure and volume of air in the lungs. Once completed, comparison graphs will be produced for seawater at various coastal locations across the United States. The model will adjust for local temperature and water density based on current measurements from these locations (NOAA 2020). Each graph will illustrate two key stages of a jetski dive: descending to the desired depth and ascending back to the surface. The feasibility of each dive will be evaluated using a dive table, which calculates the amount of nitrogen absorbed by the diver during the dive. The dive table, approved by the National Association of Underwater Instructors (NAUI), assigns a letter group (ranging from A to L, with A indicating the lowest nitrogen level) to represent residual nitrogen in the body. These tables are derived from the U.S. Navy Decompression Tables and are specifically designed for recreational diving (NAUI 2019).

## The Construct of the UNDERWATER JETSKI MODEL:

For easier calculations, we will assume the air capacity in the machine and this gear behaves as an ideal gas. This implies that the volume of individual gas atoms is negligible compared to the overall gas volume, and interactions between atoms are insignificant except for the exchange of energy and momentum during collisions. Consequently, the behavior of the air in the lungs and submarine equipment can be analyzed using the ideal gas laws.

The primary function of breathing gear is to supply air to people piloting the submarine at the elevated pressures found in deeper waters. Air comprises approximately 21% oxygen ($O_2$), 78% nitrogen ($N_2$), and 1% other inert gases. When determining diving speeds and rest schedules, it is important to account for both nitrogen and inert gases. However, for simplicity, scuba calculations combine nitrogen and inert gases, allowing us to consider air as consisting of 21% $O_2$ and 79% $N_2$ (Shiflet & Shiflet, 244).

Divers breathe air from tanks using regulators that adjust the air pressure to match the surrounding water pressure. For instance, at a depth of 20 meters, divers inhale air equivalent to three surface breaths because the pressure at this depth is 3 atm. As a result, divers must calculate their surface air consumption (SAC) rate to estimate how long their air tanks will last at specific depths (Shiflet & Shiflet, 246). However, for this project, the effects of the tank and SAC will not be included in the overall model.

Another issue associated with air under high pressure is that, as divers ascend from deep waters, the gases in the machine air system, Let’s call it lungs expand due to the decreasing pressure. If the expansion occurs too quickly and significantly, it could cause damage to the lungs (Shiflet & Shiflet, 246). To evaluate how lung pressure and volume are affected, we will assume the lung pressure matches the total pressure acting on the machine, with an initial lung volume of 6 liters (ALA 2020). Additionally, deep dives over extended periods present another challenge: the amount of gas dissolved in a liquid at a constant temperature depends on the gas's partial pressure and its solubility coefficient in the liquid. As a result, divers must monitor the nitrogen content in their blood. Under higher pressures, blood can absorb more nitrogen gas, which the body cannot utilize. For this analysis, we assume the solubility coefficient of nitrogen in human blood is 0.012 and that the total blood volume in an adult is approximately 5 liters (Shiflet & Shiflet, 247).

It is crucial to understand that the partial pressure of nitrogen increases proportionally with higher pressures. Since nitrogen gas does not participate in cellular metabolism in divers, it accumulates in bodily fluids, depending on the dive's depth and duration. At greater depths, divers may experience nitrogen narcosis—a sudden euphoria that can impair judgment and potentially result in severe or fatal consequences—after inhaling high concentrations of nitrogen (Shiflet & Shiflet, 249).

Another risk divers face is decompression sickness, which occurs when they ascend to the surface too quickly. As water pressure decreases, nitrogen gas becomes less soluble in the blood, causing nitrogen bubbles to form. These bubbles expand during ascent, potentially leading to joint pain, blocked blood vessels, and serious conditions like heart attack, stroke, or lung damage due to ruptured blood vessels (Shiflet & Shiflet, 249).

For this project, the following assumptions will be made: the temperature remains constant, the descent rate does not exceed 75 ft/min (23 m/min or 0.38 m/s), and the ascent rate is limited to a maximum of 30 ft/min (9 m/min or 0.15 m/s) as per U.S. Navy standards (2008). The independent variable in this model will be time measured in seconds. In contrast, the dependent variables will include ocean depth in meters, water and lung pressure in atmospheres, lung volume in liters, and water temperature in Kelvin.

## Solving the Model:

After reviewing the information, it was determined that an unrestricted growth model would most accurately represent the realities of diving. This model calculates the diver's depth over time by integrating the descent rate. The resulting depth is then used to determine the total pressure exerted on the diver, based on the relationship between ocean depth and pressure outlined in the Introduction.

However, before calculating the total pressure, the water's density must be adjusted to reflect the temperature specific to each selected coastal location in the United States. The formula for determining the final water density is provided in Table 1. This calculation is based on the standard temperature (3.98°C) and density (1.00000 g/cm³) of water, along with the volumetric temperature expansion coefficient (VTEC) for water, which is 0.0002 (Hessong).

Once the values for water density and pressure are determined, Boyle's Law will be applied to calculate the diver's lung pressure and volume over time (see Table 1). According to Boyle's Law, the volume of an ideal gas is inversely proportional to its pressure at a constant temperature. In other words, as pressure increases at a constant temperature, the gas volume decreases, and vice versa. Given our assumptions, where total pressure equals lung pressure, the lung volume at any given time can be found by dividing the product of the initial lung pressure and volume by the current lung pressure.

To study the effects of nitrogen gas in the diver's blood, Dalton's Law will be used to calculate the total pressure of nitrogen (see Table 1). Dalton's Law states that the partial pressure of a gas is the product of its fraction in the mixture and the total pressure of the mixture. Assuming air is composed of 21% oxygen and 79% nitrogen, 1 atm of pressure at sea level consists of 0.21 atm of oxygen and 0.79 atm of nitrogen. Therefore, the nitrogen gas pressure can be calculated as a fraction of the total pressure.

Next, Henry's Law would be applied to determine the volume of nitrogen gas in the diver's lungs after a specific period (Table 1). According to Henry's Law, the amount of gas dissolved in a liquid at a constant temperature depends on the partial pressure of the gas and its solubility coefficient in that liquid. In other words, the product of the gas pressure and its solubility coefficient in a particular liquid equals the ratio of the gas volume to the liquid volume. Consequently, the volume of nitrogen can be computed using the nitrogen pressure, its solubility coefficient in blood, and the total blood volume in the human body.

After calculating the nitrogen pressure and volume, Charles's Law would be used to determine the total moles of nitrogen (Table 1). Charles's Law states that the product of gas pressure and volume is equal to the product of the gas temperature, the number of moles of gas, and a universal gas constant. However, the gas temperature must be expressed in.

The temperature of the water at each coastal location will be converted from Celsius to Kelvin by adding 273.15 to the Celsius temperature (see Table 1). Once the mass of nitrogen in moles is calculated, it can be converted to grams by multiplying by the molar mass of nitrogen, which is 28.0 g/mol (see Table 1). After determining the pressure of nitrogen gas, we can calculate the rate at which body tissues absorb nitrogen over time. This absorption rate is proportional to the difference in partial pressures between the gas in the lungs and the gas in the tissues. The instantaneous absorption rate is the product of this pressure difference and a proportionality constant (see Table 1). This constant can be calculated by dividing the natural logarithm of 2 by the time it takes for the tissue to absorb or release half of the pressure difference, which is approximately 40 minutes for several body tissues (Bjurstedt and Gustaf).

| **Table 1:** List of Equations, Variables, and Units | | |
|---|---|---|
| *Formula Name* | *Equation* | *Variables* |
| Density of Water | $\rho = \frac{\rho_i}{\alpha_V \Delta T + 1}$ | $\rho_i$ = Initial Density (g/cm$^3$)<br>$\alpha_V$ = VTEC = 0.0002 (°C$^{-1}$)<br>$\Delta T$ = Temp. Difference (°C) |
| Boyle's Law | $P_i V_i = P_f V_f$ | $P_i$ = Initial Pressure (atm)<br>$P_f$ = Final Pressure (atm)<br>$V_i$ = Initial Volume (L)<br>$V_f$ = Final Volume (L) |
| Dalton's Law | $P_G = F_G P$ | $P_G$ = Partial Pressure (atm)<br>$F_G$ = Fraction of Gas<br>$P$ = Total Pressure (atm) |
| Henry's Law | $\frac{V_G}{V_L} = sP_G$ | $V_G$ = Volume of Gas (L)<br>$V_L$ = Volume of Liquid (L)<br>$P_G$ = Pressure of Gas (atm)<br>$s$ = Solubility Coefficient |
| Charles's Law | $PV = nRT$ | $n$ = Number of Moles (mol)<br>$R$ = Universal Gas Constant<br>= 0.0821 (atm L)/(mol K)<br>$T$ = Temperature (K) |
| Temperature Conversion | $T_K = T_C + 273.15$ | $T_K$ = Temperature (K)<br>$T_C$ = Temperature (°C) |
| Number of Moles | $n = \frac{m}{M}$ | $m$ = Mass (g)<br>$M$ = Molar Mass (g/mol) |
| Rate of Absorption | $\frac{dP_{\text{tissue}}}{dt} = k(P_{\text{lungs}} - P_{\text{tissue}})$ | $P_{\text{lungs}}$ = Pressure in Lungs<br>$P_{\text{tissue}}$ = Pressure in Tissue |
| Proportionality Constant | $k = \frac{\ln 2}{t_{\text{half}}}$ | $k$ = Proportionality Constant<br>$t_{\text{half}}$ = Half-Time (s) |

## Result and Discussion:

Sixteen U.S. coastal locations were randomly selected, and the water temperature at each site was input into the diving model. The temperatures, originally in degrees Fahrenheit, were converted to degrees Celsius using a program provided by NOAA (2020). Each simulation lasted 30 seconds, and the desired outputs included final ocean depth, water pressure, nitrogen gas mass, and nitrogen absorption rate. Additionally, graphs showing changes over time in lung pressure, lung volume, nitrogen mass, and absorption rate were recorded. Results and graphs for each location are detailed in Tables 2 and 3.

Two distinct Vensim models were developed to illustrate a jetski ride: one for the descent (Figure 1) and one for the ascent (Figure 2). After completing both models and obtaining results from the descent model, the ascent model was adjusted based on the descent results to ensure continuity with the associated graphs. Documentation examples of how the models were implemented in the Vensim tool can be found in Appendices A and B.

The model effectively replicated a scuba dive from the start of the descent to the end of the ascent based on the results of each trial. The ocean depth correctly increased at a steady rate of 0.38 m/s during the descent and decreased at a rate of 0.15 m/s during the ascent. Both water and lung pressure rose as expected according to the Vensim model, and lung volume decreased as predicted by Boyle's Law. However, upon examining the data and graphs, the model was not entirely precise in tracking changes in lung volume over time. Despite each trial lasting thirty seconds, some final values and graphs were significantly exaggerated. For instance, lung volume dramatically decreases between zero and five seconds in each trial, and by ten seconds, the graphs indicate that the diver's lungs have collapsed.

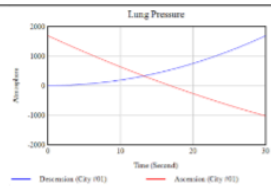
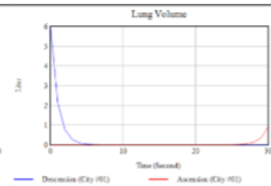
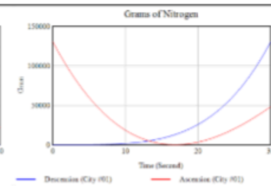
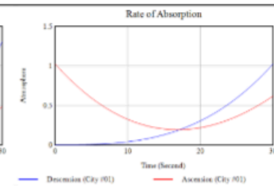
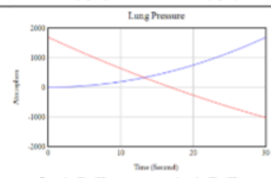
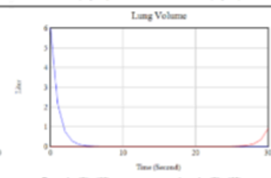
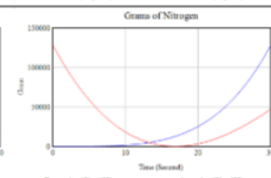
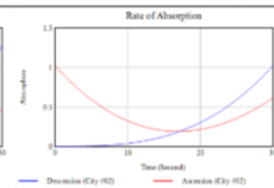
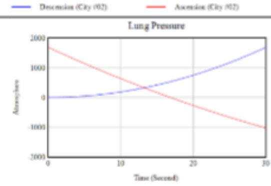
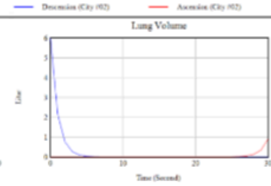
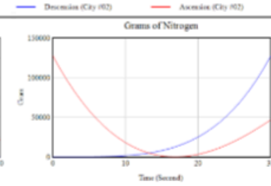
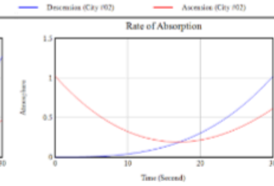
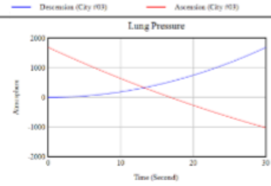
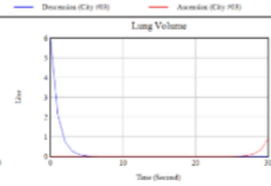
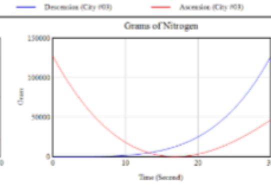
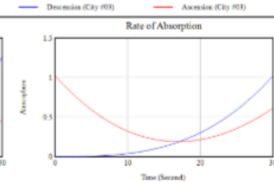
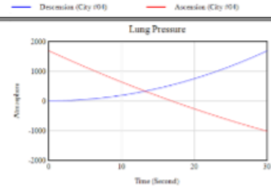
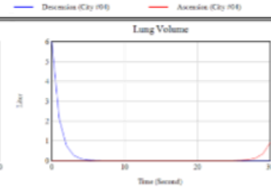
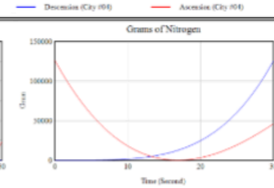
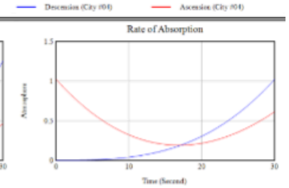
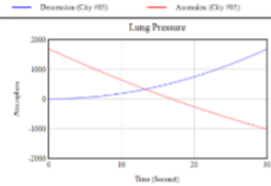
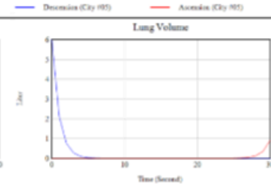
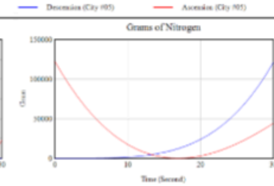
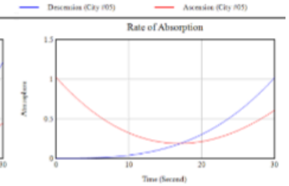
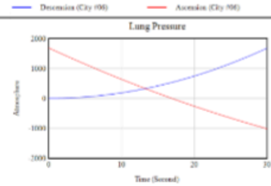
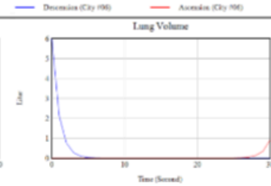
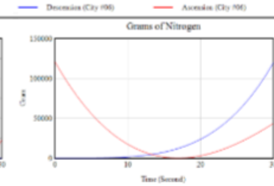
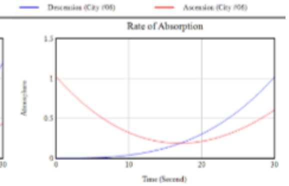
Table 2: Jetski's diving result per U.S. Coastal Location

| *Location* | *T* (°F)[1] | *T* (°C)[2] | *Depth* (m) | $P_{Water}$ (atm) | $P_{Lungs}$ (atm) | $V_{Lungs}$ (L) | $N_2$ *Mass* (kg) | *Absorption* (atm/s) |
|---|---|---|---|---|---|---|---|---|
| Portland, ME | 44.8 | 7.11 | 11.4 | 1691 | 1691 | 2.1e-13 | 130.3 | 1.022 |
| Fall River, MA | 53.6 | 12.0 | 11.4 | 1689 | 1689 | 2.1e-13 | 127.8 | 1.021 |
| Cape May, NJ | 56.5 | 13.6 | 11.4 | 1689 | 1689 | 2.1e-13 | 127.0 | 1.021 |
| Baltimore, MD | 58.5 | 14.7 | 11.4 | 1688 | 1688 | 2.1e-13 | 126.4 | 1.021 |
| Yorktown, VA | 62.8 | 17.1 | 11.4 | 1687 | 1687 | 2.1e-13 | 125.3 | 1.020 |
| Daytona Beach, FL | 78.4 | 25.8 | 11.4 | 1684 | 1684 | 2.1e-13 | 121.2 | 1.019 |
| Watson Place, FL | 84.7 | 29.3 | 11.4 | 1683 | 1683 | 2.1e-13 | 119.6 | 1.018 |
| Dauphin Island, AL | 75.2 | 24.0 | 11.4 | 1685 | 1685 | 2.1e-13 | 122.0 | 1.019 |
| Freeport, TX | 79.0 | 26.1 | 11.4 | 1684 | 1684 | 2.1e-13 | 121.1 | 1.018 |
| Newport, OR | 55.9 | 13.3 | 11.4 | 1689 | 1689 | 2.1e-13 | 127.1 | 1.021 |
| Tacoma, WA | 49.1 | 9.50 | 11.4 | 1690 | 1690 | 2.1e-13 | 129.0 | 1.022 |
| Redwood City, CA | 69.1 | 20.6 | 11.4 | 1686 | 1686 | 2.1e-13 | 123.6 | 1.020 |
| Buffalo, NY | 50.4 | 10.2 | 11.4 | 1690 | 1690 | 2.1e-13 | 128.7 | 1.022 |
| Rock Cut, MI | 41.4 | 5.22 | 11.4 | 1691 | 1691 | 2.1e-13 | 131.2 | 1.023 |
| Nikiski, AK | 37.6 | 3.11 | 11.4 | 1691 | 1691 | 2.1e-13 | 132.3 | 1.023 |
| Honolulu, HI | 78.1 | 25.6 | 11.4 | 1684 | 1684 | 2.1e-13 | 121.3 | 1.019 |

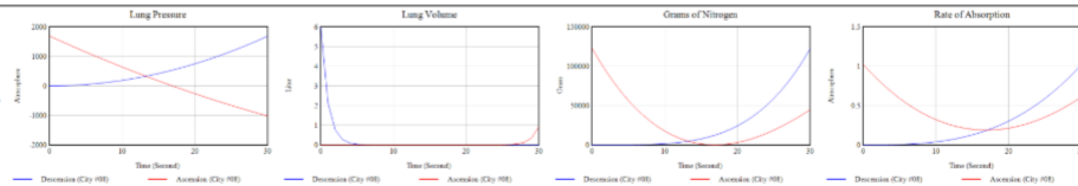
(1) The temperatures were obtained from the NCEI Coastal Water Temperature Guide on May 5, 2020.

(2) The temperatures were converted from Fahrenheit to Celsius using the NCEI Temperature Guide.

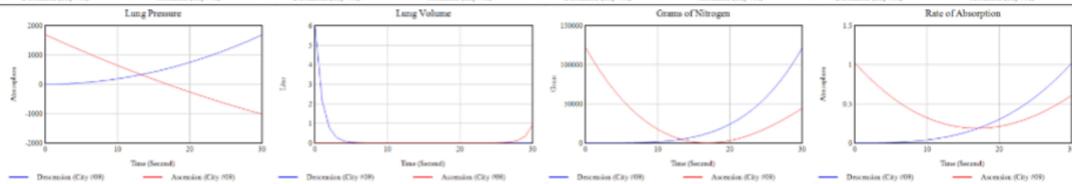
Table 3: Jetski's Diving Graph per U.S. Coastal Location

| *Location* | *Lung Pressure* | *Lung Volume* | *Mass of Nitrogen* | *Rate of Absorption* |
|---|---|---|---|---|
| Portland, ME |  |  |  |  |
| Fall River, MA |  |  |  |  |
| Cape May, NJ |  |  |  |  |
| Baltimore, MD |  |  |  |  |
| Yorktown, VA |  |  |  |  |
| Daytona Beach, FL |  |  |  |  |
| Watson Place, FL |  |  |  |  |

Dauphin Island, AL




Freeport, TX

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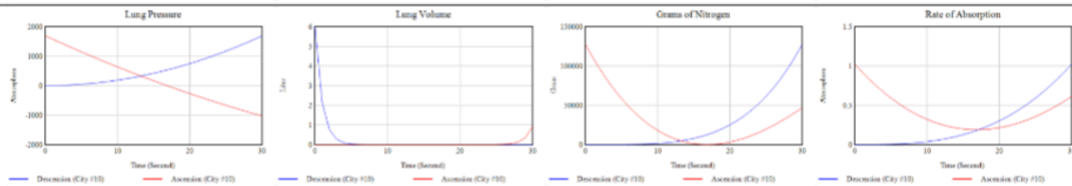


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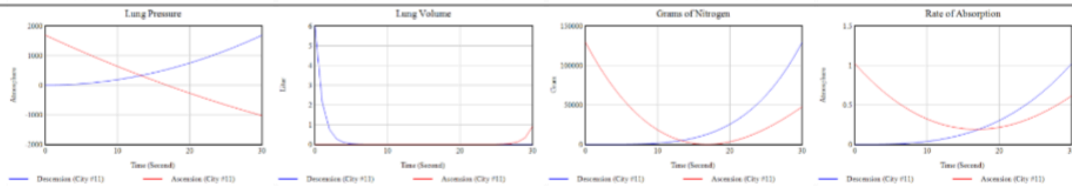
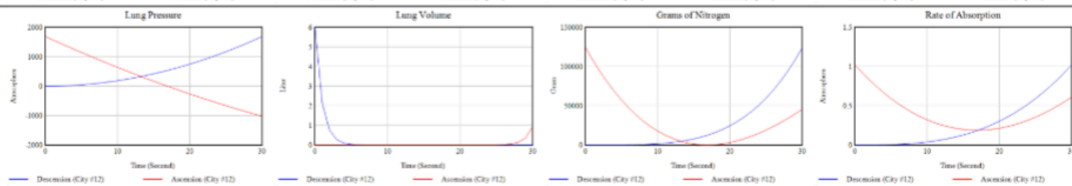
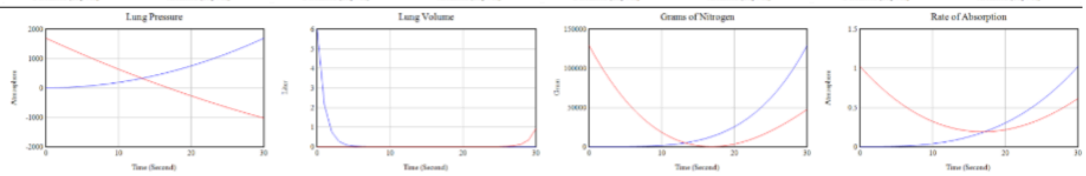


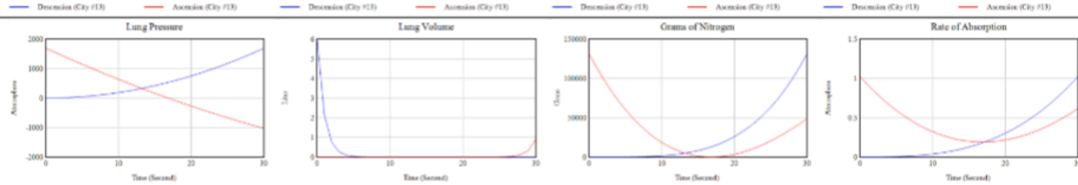

Redwood City, CA



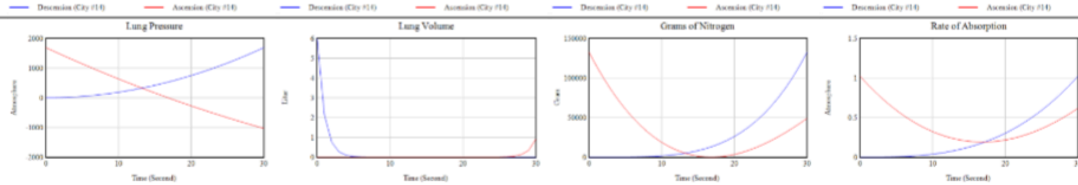

Buffalo, NY




Rock Cut, MI




Nikiski, AK




Honolulu, HI

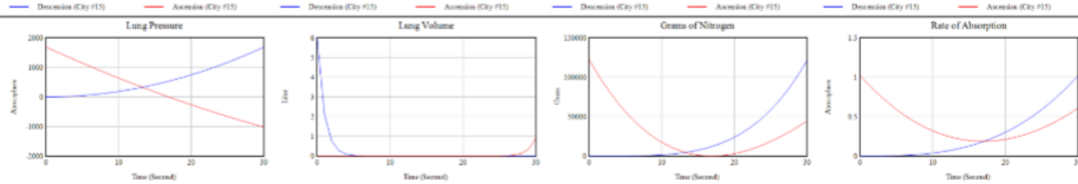


Figure 1: Final Vensim Model for the Descent Component of the underwater Jetskis Dive

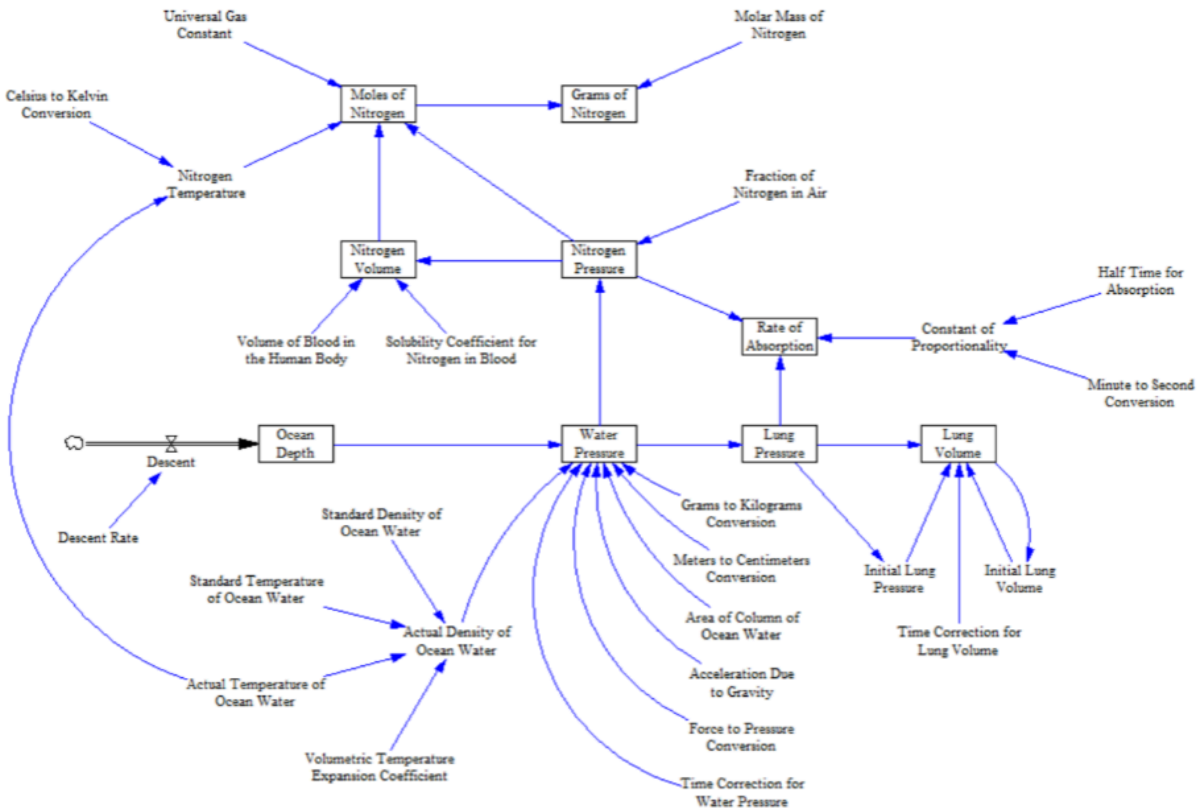
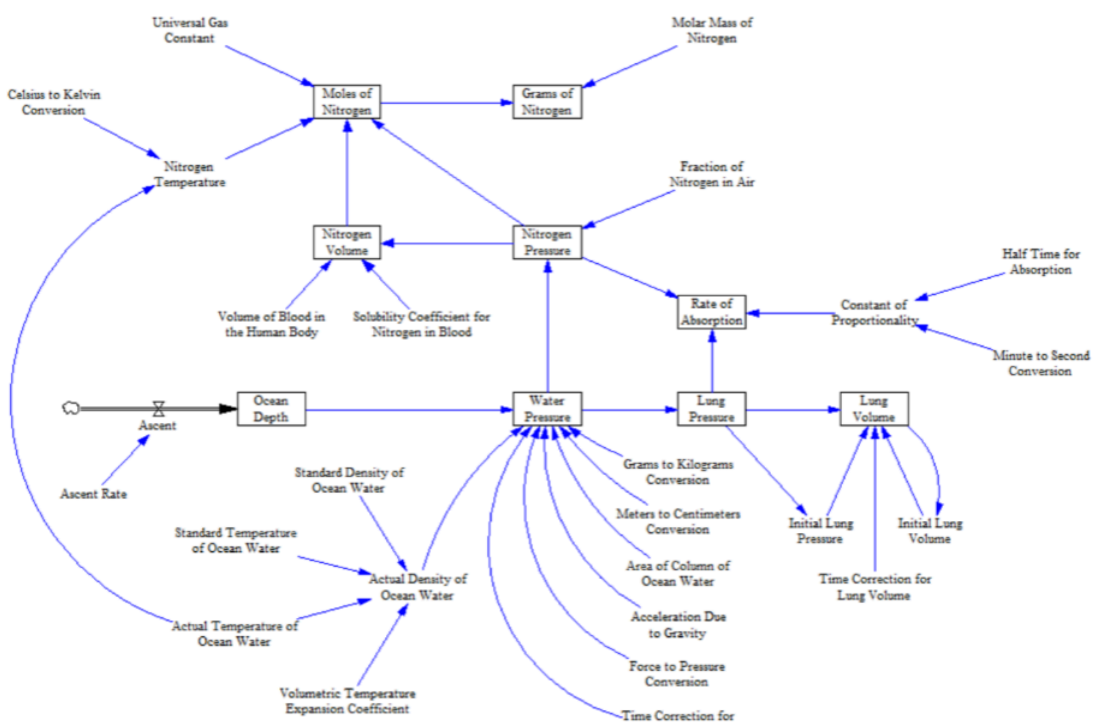



Figure 2: Final Vensim Model for the Ascent Component of the underwater Jetskis Dive



Another significant error in the model is in the section that calculates the ideal gas properties of nitrogen. While the graphs depicting the change in nitrogen mass over time are accurate during the descent, they are exaggerated near the end of the run. After thirty seconds, the final nitrogen mass in each system exceeds 100 kilograms according to the plots. Additionally, near the end of the ascent phase, the graph shows a minimum point before gradually increasing. Consequently, the NAUI dive table cannot be used to evaluate the practicality of each dive based on these results.

## Conclusion:

In summary, the objective of this project was to create a functional scuba diving model using the computational tool Vensim PLE. The model was divided into two submodels: one for the descent phase and one for the ascent phase. The four ideal gas laws were integrated into each submodel to describe the air behavior in the diver's lungs, and the nitrogen absorption rate in the diver's body tissues was calculated to assess the feasibility of the dive. Once the diving model was completed, it was tested by adjusting the standard water temperature used in the model to the values measured at sixteen coastal locations across the United States, with the results recorded and plotted. Overall, the model effectively simulated a scuba dive using descent rate, ascent rate, and ocean water temperature, though the results showed only minor differences between each run, and some properties appeared exaggerated.

## Future Work:

The comprehensive scuba diving model can be enhanced to include the impact of scuba equipment on the diver's lungs. Additionally, the model can be refined to more precisely represent the ideal gas properties of nitrogen compared to theoretical results. Moreover, the comparison graphs can be updated with new temperature data from the NOAA National Centers for Environmental Information. However, a more intriguing project would be to determine the distance a diver covers when traveling to a specific location using the available scuba equipment.

## Appendix A: Vensim Model Documentation ( Descension )

(01) Acceleration Due to Gravity= 9.81

Units: Meter/(Second*Second)

(02) Actual Density of Ocean Water= Standard Density of Ocean Water / (ABS(Standard Temperature of Ocean Water - Actual Temperature of Ocean Water) * Volumetric Temperature Expansion Coefficient + 1)

Units: Gram/(Centimeter*Centimeter*Centimeter)

(03) Actual Temperature of Ocean Water= 3.98

Units: Celsius

(04) Area of Column of Ocean Water= 1

Units: Centimeter*Centimeter

(05) Celsius to Kelvin Conversion= 1

Units: Kelvin/Celsius

(06) Constant of Proportionality= LN(2) / (Half Time for Absorption * Minute to Second Conversion)

Units: 1/Second Application of Proportionality Constant

(07) Descent= Descent Rate

Units: Meter/Second

(08) Descent Rate= 0.38

Units: Meter/Second

(09) FINAL TIME = 30

Units: Second The final time for the simulation.

(10) Force to Pressure Conversion= 10.1

Units: Atmosphere/(Kilogram*Meter/(Second*Second)

(11) Fraction of Nitrogen in Air= 0.79

Units: Dmnl

(12) Grams of Nitrogen= Moles of Nitrogen * Molar Mass of Nitrogen Units: Gram Application of Grams to Moles Conversion

(13) Grams to Kilograms Conversion= 0.001

Units: Kilogram/Gram

(14) Half Time for Absorption= 40

Units: Minute

(15) Initial Lung Pressure= Lung Pressure

Units: Atmosphere

(16) Initial Lung Volume= Lung Volume

Units: Liter

(17) INITIAL TIME = 0

Units: Second The initial time for the simulation.

(18) Lung Pressure= Water Pressure

Units: Atmosphere

(19) Lung Volume= INTEG ( -(Initial Lung Pressure / Lung Pressure) * Initial Lung Volume * Time Correction for Lung Volume, 6)

Units: Liter Application of Boyle's Law

(20) Meters to Centimeters Conversion= 100

Units: Centimeter/Meter

(21) Minute to Second Conversion= 60

Unit: Second/Minute

(22) Molar Mass of Nitrogen= 28

Units: Gram/Mole

(23) Moles of Nitrogen= (Nitrogen Pressure * Nitrogen Volume) / (Universal Gas Constant * Nitrogen Temperature )

Units: Mole Application of Charles's Law

(24) Nitrogen Pressure= Water Pressure * Fraction of Nitrogen in Air

Units: Atmosphere Application of Dalton's Law

(25) Nitrogen Temperature= (Actual Temperature of Ocean Water * Celsius to Kelvin Conversion) + 273.15

Units: Kelvin Application of Temperature Conversion

(26) Nitrogen Volume= Solubility Coefficient for Nitrogen in Blood * Nitrogen Pressure * Volume of Blood in the Human Body

Units: Liter Application of Henry's Law

(27) Ocean Depth= INTEG ( Descent, 0)

Units: Meter

(28) Rate of Absorption= INTEG ( Constant of Proportionality * (Lung Pressure - Nitrogen Pressure), 0)

Units: Atmosphere Application of Rate of Absorption

(29) SAVEPER = 1

Units: Second [0,?] The frequency with which output is stored.

(30) Solubility Coefficient for Nitrogen in Blood= 0.012

Unit: 1/Atmosphere

(31) standard Density of Ocean Water= 1

Units: Gram/(Centimeter*Centimeter*Centimeter)

(32) Standard Temperature of Ocean Water= 3.98

Units: Celsius

(33) Time Correction for Lung Volume= 1

Units: 1/Second

(34) Time Correction for Water Pressure= 1

Units: 1/Second

(35) TIME STEP = 0.0625

Units: Second [0,?] The time step for the simulation.

(36) Universal Gas Constant= 0.0821

Units: (Atmosphere*Liter)/(Mole*Kelvin)

(37) Volume of Blood in the Human Body= 5

Units: Liter

(38) Volumetric Temperature Expansion Coefficient= 0.0002

Units: 1/Celsius

(39) Water Pressure= INTEG ( Actual Density of Ocean Water * Grams to Kilograms Conversion * Ocean Depth * Meters to Centimeters Conversion * Area of Column of Ocean Water * Acceleration Due to Gravity * Force to Pressure Conversion * Time Correction for Water Pressure, 1)

Units: Atmosphere

## Appendix A: Vensim Model Documentation ( Ascension )

(01) Acceleration Due to Gravity= 9.81

Units: Meter/(Second*Second)

(02) Actual Density of Ocean Water= Standard Density of Ocean Water / (ABS(Standard Temperature of Ocean Water - Actual Temperature of Ocean Water) * Volumetric Temperature Expansion Coefficient + 1)

Units: Gram/(Centimeter*Centimeter*Centimeter)

(03) Actual Temperature of Ocean Water= 3.98

Units: Celsius

(04) Area of Column of Ocean Water= 1

Units: Centimeter*Centimeter

(05) Ascent= Ascent Rate

Units: Meter/Second

(06) Ascent Rate= -0.15

Units: Meter/Second

(07) Celsius to Kelvin Conversion= 1

Units: Kelvin/Celsius

(08) Constant of Proportionality= LN(2) / (Half Time for Absorption * Minute to Second Conversion)

Units: 1/Second Application of Proportionality Constant

(09) FINAL TIME = 30

Units: Second The final time for the simulation.

(10) Force to Pressure Conversion= 10.1

Units: Atmosphere/(Kilogram*Meter/(Second*Second))

(11) Fraction of Nitrogen in Air= 0.79

Units: Dmnl

(12) Grams of Nitrogen= Moles of Nitrogen * Molar Mass of Nitrogen

Units: Gram Application of Grams to Moles Conversion

(13) Grams to Kilograms Conversion= 0.001

Units: Kilogram/Gram

(14) Half Time for Absorption= 40

Units: Minute

(15) Initial Lung Pressure= Lung Pressure

Units: Atmosphere

(16) Initial Lung Volume= Lung Volume

Units: Liter

(17) INITIAL TIME = 0

Units: Second The initial time for the simulation.

(18) Lung Pressure= Water Pressure

Units: Atmosphere

(19) Lung Volume= INTEG ( (Initial Lung Pressure / Lung Pressure) * Initial Lung Volume * Time Correction for Lung Volume , 2.1e-13)

Units: Liter Application of Boyle's Law

(20) Meters to Centimeters Conversion= 100

Units: Centimeter/Meter

(21) Minute to Second Conversion= 60

Units: Second/Minute

(22) Molar Mass of Nitrogen= 28

Units: Gram/Mole

(23) Moles of Nitrogen= (Nitrogen Pressure * Nitrogen Volume) / (Universal Gas Constant * Nitrogen Temperature )

Units: Mole Application of Charles's Law

(24) Nitrogen Pressure= Water Pressure * Fraction of Nitrogen in Air Units: Atmosphere Application of Dalton's Law

(25) Nitrogen Temperature= (Actual Temperature of Ocean Water * Celsius to Kelvin Conversion) + 273.15

Units: Kelvin Application of Temperature Conversion

(26) Nitrogen Volume= Solubility Coefficient for Nitrogen in Blood * Nitrogen Pressure * Volume of Blood in the Human Body

Units: Liter Application of Henry's Law

(27) Ocean Depth= INTEG ( Ascent, 11.4)

Units: Meter

(28) Rate of Absorption= INTEG ( -Constant of Proportionality * (Lung Pressure - Nitrogen Pressure), 1.023)

Units: Atmosphere Application of Rate of Absorption

(29) SAVEPER = 1

Units: Second [0,?] The frequency with which output is stored.

(30) Solubility Coefficient for Nitrogen in Blood= 0.012

Units: 1/Atmosphere

(31) Standard Density of Ocean Water= 1

Units: Gram/(Centimeter*Centimeter*Centimeter)

(32) Standard Temperature of Ocean Water= 3.98

Units: Celsius

(33) Time Correction for Lung Volume= 1

Units: 1/Second

(34) Time Correction for Water Pressure= 1

Units: 1/Second

(35) TIME STEP = 0.0625

Units: Second [0,?] The time step for the simulation.

(36) Universal Gas Constant= 0.0821 U

nits: (Atmosphere*Liter)/(Mole*Kelvin)

(37) Volume of Blood in the Human Body= 5

Units: Liter

(38) Volumetric Temperature Expansion Coefficient= 0.0002

Units: 1/Celsius

(39) Water Pressure= INTEG ( -Actual Density of Ocean Water * Grams to Kilograms Conversion * Ocean Depth * Meters to Centimeters Conversion * Area of Column of Ocean Water * Acceleration Due to Gravity * Force to Pressure Conversion * Time Correction for Water Pressure, 1692)

Units: Atmosphere

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