CHAPTER I
INTRODUCTION

1.1. Background

Water is a fundamental component of life; it maintains a productive environment and food supply for all animals and plants [1]. Due to the growth of the human population alongside industrial and agricultural activities, major threats arise to the quality of water. Water quality measures the physical, chemical, and biological standards of water and it is important to observe because of the direct impacts to the health of ecosystems [2]. Poor disposal, management, and treatment of waste result in polluted and declining water quality. In plants, degraded water quality affects biochemical activities, such as photosynthesis, nutrient intake, and water conductance [3]. Populations of animals can decline due to poor water quality, as it reduces chances of survival and rates of reproduction [4].

To effectively detect and combat water quality degradation, key parameters such as temperature, dissolved oxygen, pH, and turbidity must be continuously monitored. This critical need is exemplified by conditions in Iran's Sabalan Reservoir, where deeper water fails to mix with surface layers even during winter. Seasonal warming causes surface water to stratify over colder depths, trapping pollutants below. Consequently, surface temperatures rise significantly (exceeding deep layers by up to 18°C+); oxygen depletion below 20m creates hypoxic zones unsuitable for aquatic life; surface pH becomes alkaline from algal photosynthesis, while decomposing organic matter acidifies deep water; and turbidity peaks in mid-depths (algae accumulation) and near sediments (resuspended solids). These dynamics underscore the vital importance of depth-specific water quality monitoring [5].

Sampling is a traditional method of taking a small volume of material to be thoroughly analysed in a laboratory [6]. A method commonly used for sampling water on the surface is spot (bottle) sampling, but for deeper levels of water, special containers (samplers) are used to encapsulate the water (e.g., a Patterson grab sampler) [6]. When transporting samples of water from a body of water to a laboratory, a plethora of uncertainties are introduced, as it can undergo changes in temperature or become contaminated, thus, the measurement becomes inaccurate and unreliable [6]. Another underlying problem with the mentioned method relates with the efficiency and effectiveness. The time span of acquiring samples of water, transporting it to a laboratory, and then retrieving the data can be inconvenient for researchers.

The previous researchers of the topic developed a water monitoring system consisting of two subsystems, a floating and submersible unit. They work in unison to continuously monitor water quality at varying depths in a reservoir. The submersible unit's structure is composed of stainless steel, capable of traversing depths from one to four meters. The bulky weight of the submersible unit enables it to descend effortlessly through the water; however, problems arise when attempting to ascend back to the surface. To retrieve the submersible unit from such depths, the floating unit is equipped with a large stepper motor with steel cable that is attached to the submersible unit. The lack of a gearbox in the stepper motor contributes to the lack of torque generated to reel the submersible unit. Another drawback of the previous system was its lack of watertight integrity; long term use will further degrade the performance of the electronics of the system. These collections of problems contribute to an already poorly implemented basic control system.

Based on the problems given, the solution involves the development of an Autonomous Underwater Vehicle (AUV) as the submersible unit, capable of monitoring water conditions at varying depth, while being watertight and capable of user interaction. The submersible system achieves autonomous depth control through buoyancy adjustment, functioning like an underwater elevator without cables or propellers. By intaking water to increase density (enabling descent) or expelling water to decrease density (enabling ascent), it moves vertically between user-defined depths. Depth is continuously monitored by pressure sensors, while a closed-loop control system automatically adjusts buoyancy based on real-time error calculations, comparing target depth to actual depth, to maintain precise positioning.

This research will focus on the control system implemented during the ascending and descending process, specifically PID (Proportional, Integral and Derivative) control until it can reach and hold the desired depth.

1.2. Problem Statement

Based on the background of the problem, a list of problem statements needs to be resolved in this research.

1) How to design an optimal control system for an AUV alongside a buoyancy engine?
2) How is the performance of the PID control system when implemented in the AUV?

1.3. Purpose

Below is a list of purposes for the proposed research.

1) Designing and implementing a control system algorithm such as PID on a buoyancy engine.
2) Observe and analyse the performance of the implemented PID control system of the AUV.

1.4. Benefits of Research

1) Increasing the efficiency of monitoring water quality in reservoir environments.
2) Increasing the accuracy and reliability of water quality measurements by implementing a PID control system.
3) Developing underwater vehicle depth control with a buoyancy engine.
4) Providing insight in the performance of the PID control system for AUVs.

1.5. Constraint

In this research, several constraints of the problems applied are as follows.

1) The designed control system is only applicable to AUVs using buoyancy engines.
2) This study only covers AUV depth control (vertical z-axis), from one to four meters, in a swimming pool environment that can be obstructed by very light currents and other conditions to simulate a reservoir environment.
3) The control system observed and analysed is Proportional-Integral-Derivative (PID).

4) The monitored water quality parameters are limited to pH, temperature, dissolved oxygen, and turbidity.

1.6. Research Method

This research is conducted with an approach consisting of several stages, which include literature study, system design, and implementation. The following are details of the methods used in this research:

1) Literature Study

The first stage begins with a literature study to understand basic concepts related to underwater vehicles, such as the physical and mathematical aspects. This includes, but not limited to understanding weight force, buoyancy force, drag force, and many more. To create and design the buoyancy engine, a list of references from open-source projects and papers will need to be prepared and evaluated. References of code and literature will be collected and utilised to understand how a PID control system works and how to properly implement it in the AUV.

2) System Design

Based on the results of the literature study, a PID control system will be designed for the AUV with buoyancy engine. This design includes the selection and calculation of control parameters required to ensure the stability and efficiency of the AUV motion underwater.

3) Data analysis

The data collected during the testing period will be analysed to evaluate the performance of the control system. This analysis will include the performance and stability of AUV movement.

1.7. User Projections

The results of this research are expected to benefit various parties involved in marine environmental management and research, as well as the development of underwater vehicle technology. Some of the target users who can utilize the results of this research are as follows:

1) Industry

Companies engaged in monitoring water quality, such as those in the fisheries, aquaculture, and marine conservation sectors, can use AUVs equipped with this control system to conduct water quality monitoring more efficiently and accurately. The data obtained can help make decisions related to natural resource management and marine ecosystem protection.

2) Research Institutions and Universities

Universities and research institutions that focus on marine science and underwater vehicle technology can utilise the results of this research to improve their understanding of AUV design and operation, as well as further development in underwater vehicle control systems. This research can be an important reference for further studies or larger research projects in this field.

3) Government Agencies and Environmental Organizations

Government agencies that focus on marine environmental management and protection of conservation areas can use this AUV technology to conduct routine and continuous monitoring in marine conservation areas, as well as to detect potential pollution or damage to ecosystems early.

1.8. Implementation Schedule

Below is a table of events that will be implemented within a certain schedule and time frame.

Table 1. 1 Implementation Schedule

No.	Description	Duration	Deadline	Milestone
1	System Design	3 weeks	29 November 2024	Block Diagram and Specification
2	Choosing Components	2 weeks	20 December 2024	Component List
3	Implementation and analysis of research methods	4 months	23 June 2025	Data Collection and Analysis
4	Creation of Final Project book	1 month	15 July 2025	Final Project Book Finished