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GNG5140

Design Project User and Product Manual

HYDROPONIC TOWER

Submitted by:

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1 ABSTRACT

A vertical hydroponic tower works on the principle of supplying the nutrients required for the growth of a plant by pumping and distributing to its subsidiary channels through a gravity-based trickling mechanism. The same nutrient incorporated water is transferred to a basin underneath, which is redirected back again; this mechanism is referred to as Nutrient Film Technique. The goal of this project is to rectify the existing technical problems, remodel the entire mechanism with a few additional technologies and design a new tower that will be significantly more reliable.

Table of Contents

List of Figures

List of Tables

2 Introduction

Welcome to the world of vertical hydroponic farming! This user manual will walk you through the process of assembling, installing, and operating a vertical hydroponic tower. This technique provides an economical and space-saving solution to cultivate plants without soil, whether you are a beginner or an experienced farmer. Hydroponics is the technique of raising plants without the usage of soil but just the nutrients and minerals supplied to their roots in a proportionate mix with water. There are various kinds of hydroponic systems available, and the one we worked on is a vertical hydroponic tower. The method of using hydroponics for the growth of plants in a vertical manner is technically called vertical hydroponics, and the nutrients fed into the module is by the conventional gravity-fed mechanism.

This manual provides a comprehensive overview of the improved design and user guide for seamless operations and functionalities of the hydroponic tower system.

The primary purpose of this document is to show the final version of the hydroponic tower after continuous revisions for improvement. By delineating the necessary steps and elements required for the design, material selection, standards, functions and operations, this report serves as a valuable resource for all users and stakeholders.

3 Overview

The structure of the system is mainly reflected in its external components, with the prototype consisting of a tower segment made of nine sections of cylindrical tubing. Each section has four growth channels embedded in it, and inside the growth channels cloning bins made of neoprene material will be installed to hold the plants without letting them fall into the tower. As shown in the picture below

Figure 3.1 Hydroponic Tower Growth Channel

Several issues were outlined from inspection and testing. The issue of the top opening in the hydroponics tower system poses a significant hurdle in maintaining the integrity and security of the entire hydroponics system. This opening, intended to provide natural ventilation inadvertently, becomes a potential entry point for pests that can wreak havoc on the crops and introduce harmful diseases.

- The consequences of pest infestation and disease outbreak can be devastating, leading to significant crop losses and compromised plant health. Moreover, there is a need to reduce drudgery, Automating the hydroponic tower system will alleviate the farmer's burden by implementing a control system for the water pump. This way, the farmer can avoid the inconvenience of manually operating the pump, thereby saving both time and energy. This automation will efficiently manage resources, reducing water waste and the risk of water oversaturation in the cloning pod, which, in turn, could lead to plant wilting and hindered growth.

- The product differs from major brands in its design. Inclusion of mesh to the light to protect the plant is a major consideration in the design. Additionally, Mesh covering is also not a common component in the hydroponic tower brands in the market.

This vertical hydroponic tower features include external and internal features. These features are as follows:

3.1 External Components

a) **Tower Segment:** This is a major external component of the hydroponic system. The component helps holding the plants, and helps in circulating and holding the pipe system, and water circulation system.

b) **Cloning Pods:** These are neoprene materials which hold the plants without letting them fall inside the tower.

c) **Frame:** This supports the entire integrity of the tower.

d) **Grow Lights:** For any autotrophs, light is essential for its growth. Hence an external light source, grow lights, are implemented at four corners of the system to provide enough light as a resource of photosynthesis. A mesh was added over the grow lights to avoid burning of plants touching them.

e) **Built-in screen (not in working condition):** The screen attached to the system is not functional, yet it can be replaced or programmed to give the user information like pH, temperature and electrical conductivity of the water.

f) Mesh cover: Mesh that covers the tower top to prevent insects from entering the tower. While mesh covering for light is to prevent the grown plant from getting burnt.

g) LCD Display: The display shows the real-time readings of temperature of the system and pH value of the nutrient solution.

h) Arduino Uno R3: Microcontroller that controls the sensors and the LCD display

i) PH Sensor: The sensor determines the nutrient composition in the tower, which helps to accurately determine the solution required for different plants.

j) Temperature sensor: When temperature is of importance during the plant growth process, the sensor determines the temperature of the inside and outside of the system.

Base: The base holds the internal components of the system like, the pumping system, reservoir tub etc.

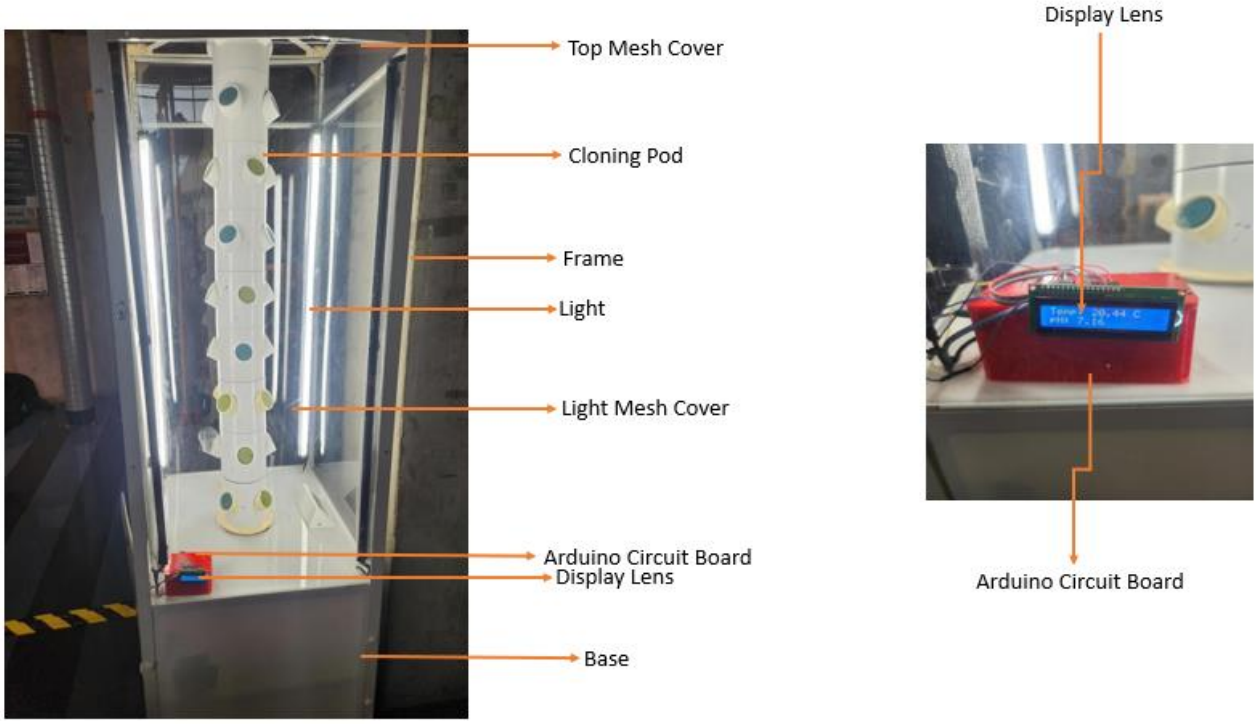


Figure 3.2 External Components

3.2 Internal Components

i. **Pump:** This is the major internal component of the hydroponic system. The pump functions to supply the water into the system and also helps in draining the reservoir tub during the time of cleaning.

ii. **Electronic Connectors:** These are used to connect the light, pump and other electrical equipment to the power source.

iii. **Reservoir Tub:** The tub acts as a reservoir unit in storing and supplying the nutrient water in to the tower system.

iv. **Tap for Inflow:** The inflow tap helps in regulating the flow rate that to be pumped into the hydroponic system. It can be adjusted based on the plant growth.

v. **Base Door:** Used to cover the entire internal components of the system.

vi. **Tap for Outflow (drainage):** As there is a tap to regulate the inflow, this tap helps in draining the reservoir tub during the time of cleaning. Once the inflow tap is closed and the outflow is opened, the entire waste water in the reservoir tub can be drained within a span of 7 minutes.

vii. **Splitter/Sprinkler**: Acts as a nutrient water distributer. This is placed at the top of the tower, and when the water reaches the top by pumping, the splitter with its 4 small openings will distribute the water in 4 directions. The splitter was placed at a new position. We found that if we keep the splitter on top of one of the top disks, it distributes the water more efficiently and uniformly.

viii. **Disk for uniform water distribution:** These are circular disks placed on each segment of the tower to evenly distribute the water to the plant roots.

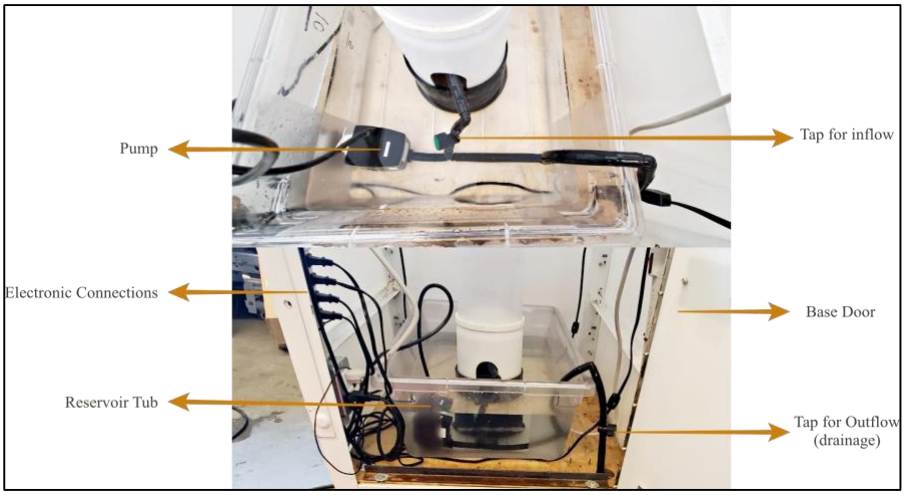


Figure 3.3 Internal Components-1

Figure 3.4 Internal Components-2

3.3 Cautions & Warnings

Electrical Safety: Since the system involves water and electricity (water pump, LED lights, Arduino, sensors, etc.), ensure all electrical components are properly insulated and waterproofed to prevent and risk of electric shocks.

Water Leakage: Regularly check the system for leaks. Water damage could affect the electronic components and poses a risk to surrounding areas.

Light Exposure: Avoid staring at the lights for extended periods of time to avoid any potential risks of vision damage.

Chemical Handling: Handle any nutrients or pH balancing chemicals used in the water with care. Use gloves and goggles and follow the manufacturer's safety guidelines.

4 Getting started

4.1 Set-up Considerations

Location: Choose a location with adequate light and temperature control for the system.

Safety: Ensure all electrical components are safely installed and water sources are secure to prevent leaks.

Access: Position the system for easy access to all components for maintenance and monitoring.

4.2 User Access Considerations

- **System Administrators/Owners:**

- Access Level: Full access to all system components, including the water tank, pump, LED lights, Arduino, sensors, and LCD display.
- Responsibilities: System setup, maintenance, troubleshooting, and updates.
- Restrictions: None but should be trained or knowledgeable about the system.

- **Maintenance Personnel:**

- Access Level: Limited to specific maintenance tasks such as checking the water level, nutrient balance, and sensor functionality.
- Responsibilities: Regular maintenance checks, reporting any issues to the administrators.
- Restrictions: Should not alter system settings or configurations without approval.

- **Educational Users (e.g., Students, Teachers):**

- Access Level: Access to observe and learn from the system, but not to alter its settings or components.
- Responsibilities: Use the system as a learning tool, follow safety guidelines.
- Restrictions: No access to the system's internal components or settings. Supervision required for younger users.

- **General Public (e.g., Visitors in a Public Setting):**

- Access Level: Visual access or guided tours.
- Responsibilities: Adhere to viewing guidelines, do not touch or interfere with the system.
- Restrictions: No physical or operational access to the system.

- **Researchers:**

- Access Level: Depends on the research scope; could range from observational to interactive.

- Responsibilities: Conduct research in a way that doesn't harm the system's functionality.
- Restrictions: Must obtain permission for any experimental modifications and should coordinate with the system administrators.

4.3 Accessing the System

4.3.1 Accessing the Tower Base

- **Key Replacement:** Since the original key is lost, you'll need to replace the lock or make a new key. A locksmith can help you either create a new key based on the lock or replace the lock entirely.
- **Unlocking Procedure:**

Once you have the new key, use it to unlock the base of the tower.

This will give you access to the electrical components, pump, light switches, sensors, and the water tank.

- **Adding Water to the Water Tank**
- **Opening the Base:**

After unlocking the base, open the panel to access the water tank.

Ensure the electrical components are secured and dry before proceeding.

- **Water Addition:**

Carefully add water to the tank, making sure not to spill or splash near electrical components.

Check for any leaks or issues during this process.

4.3.2 Accessing the Top of the Tower

- **Padlock System:**

The top of the tower is secured with a padlock on a mesh screen door.

Obtain a key for this padlock, or if unavailable, you may need to replace the padlock.

- **Opening the Mesh Screen Door:**

Use the key to unlock the padlock.

Carefully open the mesh screen door to access the top of the tower.

4.4 System Organization & Navigation

4.4.1 System Overview

The hydroponic tower system is organized around a central tower, with essential components including LED lights, a water tank, a pump, sensors (pH and temperature), an Arduino microcontroller, and an LCD display. The system is accessed physically, and manual operations are required for its functions.

4.4.2 Central Tower

Function: Houses the plants and serves as the main structure for the hydroponic system.

Navigation: Direct physical access to the tower through a screen door for planting, harvesting, and inspecting plants.

4.4.3 LED Lights

Function: Provide necessary lighting for plant growth.

Navigation: Lights are positioned around the central tower. Manual switches or controls for these lights are located at the base of the tower.

4.4.4 Water Tank with Pump

Function: Stores water and nutrients; the pump circulates water through the system.

Navigation: The water tank is located at the bottom of the tower. Access it by unlocking the base of the tower for refilling water, checking the pump, and performing maintenance.

4.4.5 Sensors (pH and Temperature)

Function: Monitor the water quality and temperature for optimal plant growth.

Navigation: Sensors are typically located in the water tank. Data from the sensors can be read directly from the LCD display connected to the Arduino.

4.4.6 Arduino and LCD Display

Function: Arduino microcontroller processes sensor data; the LCD display shows real-time readings.

Navigation: The Arduino and LCD display are likely housed near the base for easy access and protection from water. View the display for current pH levels and temperature reading

4.4.7 Mesh Screen (Top of the Tower)

Function: Protects the top part of the tower and provides aeration.

Navigation: Accessed by unlocking the padlock on the mesh screen door, allowing for inspection or maintenance of the upper part of the tower.

4.4.8 Maintenance Access

Function: Allows for regular check-ups, repairs, and adjustments to the system.

Navigation: Key access is required to open the base for maintenance tasks like inspecting electrical components, checking connections, and ensuring the functionality of the pump.

4.4.9 Water Refilling and Nutrient Addition

Function: Ensures plants receive adequate water and nutrients.

Navigation: Access the water tank through the base for refilling and adding nutrients.

4.4.10 Safety and Emergency Protocols

Function: Provides guidelines for safe operation and steps to follow in emergencies.

Navigation: Physical inspection and maintenance routines help identify potential issues. Emergency protocols should be documented and accessible near the system.

4.5 Exiting the System

When system is in used, it is powered through an electrical source. IT could be directly connected to the socket or to an extension cord. When system is out of use, the following procedures are required to exit the system:

- Close tower lid
- Open the base to turn off the pump.
- Turn of lighting component when not needed
- Unplug system from the light source.
- Make sure tower is clean and free from debris
- Then store where natural source of light could enter the system.

1. **Turning Off the LED Lights**

Action: Locate the switch or control for the LED lights.
Procedure: Turn off each LED light to ensure no unnecessary energy consumption occurs when the system is not in use.

2. **Checking the Water Pump**

Action: Inspect the water pump in the base of the tower.

Procedure: If the pump needs to be turned off (e.g., for maintenance or long-term shutdown), switch it off using its control mechanism. Ensure that turning off the pump does not adversely affect the plants, especially if the system will be off for an extended period.

3. **Inspecting the Water Tank**

Action: Check the water level in the tank.
Procedure: If you're shutting down the system for maintenance or other reasons, make sure the water tank is either adequately filled (if the system will be restarted soon) or properly drained (for long-term shutdowns).

4. **Arduino and LCD Display**

Action: Review the data on the LCD display connected to the Arduino.
Procedure: If necessary, log any final readings or information. If the Arduino system requires shutting down, disconnect it from the power source to shut it down.

5. **Securing the System**

Action: Ensure all components are secured.
Procedure: Close any open panels or doors. If the system has a locking mechanism (like the padlock on the mesh screen door or the lock at the base), ensure that these are securely locked.

6. **Cleaning and Clearing the Area**

Action: Tidy up the area around the hydroponic tower.
Procedure: Remove any tools, containers, or other items used during operation or maintenance. This helps prevent any tripping hazards or clutter.

7. **Final Inspection**

Action: Perform a visual inspection of the entire system.
Procedure: Check for any signs of leaks, electrical issues, or other potential problems that could arise while the system is turned off.

8. **Disconnecting Power (If Applicable)**

Action: Disconnect the system from its power source.

Procedure: If your system is connected to an external power source and needs to be completely powered down, safely disconnect it following the appropriate electrical safety procedures.

5 Using the System

The system is easy to operate by anyone with basic understanding of electrical appliances and use of English.

5.1 LED Lighting System

5.1.1 Function/Feature Description:

Input: Manual switch to turn on/off the LED lights.

Output: Adequate lighting for plant growth.

5.1.2 Step-by-Step Instructions:

Locate the switch for the LED lights.

Turn the switch to the 'On' position to activate the lights.

Observe the lights to ensure they are functioning correctly.

To turn off, switch back to the 'Off' position.

5.1.3 Caveats and Exceptions:

Be cautious of the heat produced by the lights.

Avoid operating with wet hands or in wet conditions.

5.2 Water Pump Operation

5.2.1 Function/Feature Description:

Input: Manual control to activate/deactivate the water pump.

Output: Circulation of water and nutrients to the plants.

5.2.2 Step-by-Step Instructions:

Access the water pump controls at the base of the tower.

Turn on the pump using the designated switch or knob.

Check for smooth water flow in the system.

To deactivate, reverse the control.

5.2.3 Caveats and Exceptions:

Ensure the water tank is sufficiently filled before activating the pump.

Regularly check for any leaks or blockages in the system.

5.3 Monitoring pH and Temperature

5.3.1 Function/Feature Description:

Input: Reading data from the sensors via the Arduino-connected LCD display.

Output: Real-time pH and temperature readings of the water.

5.3.2 Step-by-Step Instructions:

Locate the LCD display connected to the Arduino.

Read the displayed information for pH levels and temperature.

Note any readings that are outside the desired range for corrective action.

5.3.3 Caveats and Exceptions:

Sensor calibration may be required periodically for accurate readings.

5.4 Water Tank Refilling

5.4.1 Function/Feature Description:

Input: Manual addition of water and nutrients to the tank.

Output: Refilled water tank for the system's operation.

5.4.2 Step-by-Step Instructions:

Unlock and open the base of the tower.

Carefully add water and nutrients to the tank.

Ensure no spillage near electrical components.

Close and lock the base after refilling.

5.4.3 Caveats and Exceptions:

Avoid overfilling the tank.

Use only recommended nutrients for the system.

5.5 System Maintenance

5.5.1 Function/Feature Description:

Input: Regular inspections and servicing of the system's components.

Output: Optimal functioning and longevity of the system.

5.5.2 Step-by-Step Instructions:

Regularly inspect all physical components (lights, pump, sensors).

Clean and maintain components as necessary.

Record any maintenance activities in a log.

5.5.3 Caveats and Exceptions:

Disconnect power before performing any maintenance on electrical components.

6 Troubleshooting & Support

This section lists problems or issues that users may encounter when using the hydroponic tower. The Troubleshooting section provides a guide to help users identify and solve common problems themselves.

6.1 Error Messages or Behaviors

The following table illustrates the troubleshooting needed for an efficient working of the Hydroponic Tower.

Table 6.1 Troubleshooting and Support

ERROR MESSAGE/BEHAVIOR	LIKELY CAUSE(S)	POSSIBLE CORRECTIVE ACTIONS	SPECIFICATION
1. Water Pump Not Operating	- Power connection issue. - Faulty pump.	1. Check power connection. 2. Ensure the pump is not clogged. 3. Test with a known working pump if available.	Pump discharge: minimum 500L/hour
2. Insufficient Water Flow Through Tower	- Clogged divider disks. - Blockage in the tubing.	1. Inspect and clean divider disks. 2. Check tubing for any obstructions. 3. Adjust pump flow rate if necessary.	
3. pH Sensor Reading Inaccurate	- Sensor calibration issue. - Contaminated sensor.	1. Calibrate the pH sensor following the manual. 2. Clean the sensor according to maintenance guidelines.	
4. Unhealthy Plant Growth	- Inadequate nutrient concentration. - Poor water circulation.	1. Adjust nutrient concentration in the reservoir. 2. Confirm proper water circulation through the tower.	
5. Algae Growth in Water Tank	- Excessive exposure to light. - Nutrient imbalance.	1. Adjust lighting conditions. 2. Review and adjust nutrient solution composition.	
6. Leaks in the System	- Damaged tubing or connectors. - Loose fittings.	1. Inspect tubing and connectors for damage. 2. Tighten or replace fittings as needed.	

7. Unusual Sounds from Pump	- Air trapped in the pump. - Mechanical issues.	1. Bleed air from the pump system. 2. Check for visible mechanical issues; consult manual for pump maintenance.	
8. Lights Malfunction	- Electrical failure - Light tube fuse blown out - Disconnection from supply	1. Carry out Inspection and fix the miniature problems. 2. Change the light	Type of lights: fluorescent lights Minimum Kelvin value: 6500K

6.2 Special Considerations

The Special Considerations section will enumerate any special circumstances or exceptions that are critical to addressing any special circumstances or exceptions that the user needs to be aware of during the troubleshooting process.

Table 6.2 Table of Special Consideration During the Operation

SPECIAL CIRCUMSTANCE	ACTIONS OR CAVEATS
1. Power Outages	- In the event of a power outage, monitor the water levels in the tower and reservoir. Consider a backup power source for prolonged outages.
2. Extreme Temperatures	- High temperatures may affect nutrient absorption. Monitor plant health closely during heatwaves. Consider additional cooling measures.
3. Changes in Plant Types	- Different plant species may have varying nutrient requirements. Adjust the nutrient solution composition accordingly when changing plant types.
4. Water Quality	- Poor water quality can impact plant health. Use clean water sources and consider water quality testing if issues persist.

5. Seasonal Adjustments	- Adjust lighting schedules and nutrient concentrations based on seasonal changes and sunlight availability.
6. New Plant Introduction	- Gradually introduce new plants to the system to allow for acclimatization. Monitor closely for any signs of stress.
7. System Expansion	- If expanding the system, ensure the pump capacity is sufficient for the increased number of tower segments. Adjust nutrient concentration accordingly.

6.3 Maintenance

Regular maintenance is crucial for ensuring the continued efficiency and health of your vertical hydroponic tower. Follow the guidelines below to perform routine maintenance tasks:

Table 6.3 Regular Maintenance Guidelines

MAINTENANCE TASK	FREQUENCY	PROCEDURE
1. Cleaning Tower Segments	Weekly	1. Disconnect the water pump. 2. Remove plants and growing media from each segment. 3. Clean tower segments with a mild solution of water and non-toxic detergent. 4. Rinse thoroughly and let dry before reassembling.
2. Checking and Adjusting Nutrient Solution	Bi-weekly	1. Monitor nutrient solution levels in the reservoir tub. 2. Adjust nutrient concentration based on plant growth stage and requirements. Refer to the manual for recommended nutrient levels in the Appendix II-1.
3. Inspecting Divider Disks	Monthly	1. Check divider disks for any signs of wear, damage, or clogging. 2. Clean or replace divider disks as needed.
4. pH Sensor Calibration	Monthly	1. Calibrate the pH sensor according to the manual instructions. 2. Verify the accuracy of pH readings and adjust if necessary.

5. Cleaning Water Pump	Every 2-3 months	1. Turn off the pump and disconnect it from the power source. 2. Remove any debris or sediment from the pump. 3. Check impellers for damage and clean if necessary. 4. Reconnect and test the pump.
6. Checking Tubing and Fittings	Every 3 months	1. Inspect tubing for wear, cracks, or blockages. 2. Tighten loose fittings and replace any damaged tubing or connectors.
7. Inspecting Lights (if applicable)	Every 6 months	1. Check the condition of grow lights for any signs of wear or malfunction. 2. Replace bulbs or fixtures as needed.
8. Overall System Inspection	Annually	1. Conduct a comprehensive inspection of the entire system. 2. Replace any worn-out components and address any potential issues.

6.4 Support

General Support

For general system support, assistance, and inquiries, please contact our customer support team. We are here to help you make the most of your vertical hydroponic tower experience.

- Customer Support Email: support@VertiTechTitans.com.
- Customer Support Phone: 613-716-7786
- Customer Support Hours: 8:30 am to 8pm from Monday to Friday

Emergency Assistance

In the event of an emergency or urgent issue requiring immediate attention, please contact the following indiciduals:

- Emergency Contact:
    - Name: Shrey Vikramkumar Patel
    - Email: emergency@VertiTechTitans.com./spate287@uottawa.ca
    - Phone: 647-871-0821

Reporting Problems:

If you encounter any issues or problems with your vertical hydroponic tower, please follow these steps to report the problem:

1. Document the Issue:
    - Clearly describe the problem or error you are experiencing.
    - Note any error messages or unusual behaviors.
2. Collect Information:
    - Provide information such as the model/serial number, date of purchase, and any relevant details about your system setup.
3. Contact Customer Support:
    - Email our customer support team at support@VertiTechTitans.com.
    - Include a detailed description of the issue and any supporting information.
4. Include Photos or Videos (if applicable):
    - If the issue is visually evident, include clear photos or videos to assist in troubleshooting.

Security Incident Handling:

If you suspect a security incident or have security-related concerns, please follow these steps:

1. Isolate the System:

- If possible, isolate the hydroponic system from external networks to prevent further potential security risks.

2. Contact Security Incident Response:
    - Email our security incident response team at support@VertiTechTitans.com.
    - Provide a brief description of the incident and any relevant details.
3. Cooperate with Support:
    - Work closely with our support and security teams to address and resolve the incident.

Notes:

- **Customer Support Response Time:** Our team strives to respond to inquiries within 10-15 mins.
- **Emergency Response Time:** Emergency contacts will respond promptly to urgent issues.
- **Security Incident Response Time:** The security incident response team will assess and respond to security incidents in a timely manner.

For the most efficient support, please include as much detail as possible when reporting issues. Our dedicated support team is committed to assisting you promptly and effectively.

7 Product Documentation

7.1 Overall of The Prototype

7.1.1 Mechanical Components

- **Main Tower Structure**

Materials: PVC pipes were chosen for the main structure due to their durability, lightweight nature, and resistance to water damage. Plexiglass was used for the doors to allow visibility into the tower while maintaining a sealed environment. Wood frames provided structural support.

Design Considerations: The PVC pipes offer a balance between strength and ease of modification (e.g., drilling holes for plant sites). The plexiglass doors were selected for their clarity and durability, while the wooden frames added stability to the structure.

Alternative Materials: Metal, such as stainless steel, could be an alternative for the frames due to its strength and corrosion resistance. However, this was not tested due to higher costs and the potential for increased complexity in fabrication.

Analysis: The PVC pipes' strength was tested to ensure they could support the weight of the plants and water. Wood frames were treated to resist moisture and prevent decay.

7.1.2 Electrical Components

- **Lighting System**

Materials: LED lights were chosen for their energy efficiency and low heat emission.

Design Considerations: The placement and number of LED lights were determined based on the light requirements of the plants. The lights were positioned to ensure even light distribution.

Analysis: Light intensity and distribution were measured to ensure optimal plant growth conditions.

- **Water Pump and Sensors**

Materials: A standard water pump suitable for hydroponic systems was used. pH and temperature sensors were selected for their accuracy and compatibility with the Arduino microcontroller.

Design Considerations: The pump's flow rate was calculated to ensure adequate water circulation. Sensor placement was optimized for accurate readings.

Analysis: The system's water flow was modeled to confirm efficient nutrient distribution. Sensor calibration was regularly checked against standard readings.

7.1.3 Software Components

- **Arduino Microcontroller**

Functionality: The Arduino was programmed to read sensor data and display it on the LCD screen.

Design Considerations: Code simplicity and reliability were priorities. The user interface on the LCD was designed for ease of reading and interpretation.

Analysis: The software was tested for accuracy in reading and displaying sensor data. Error handling was incorporated to manage potential sensor malfunctions.

7.1.4 Material Substitutions and Considerations

PVC vs. Stainless Steel: While stainless steel offers better durability and corrosion resistance, PVC was chosen for its cost-effectiveness and ease of handling. In future designs, stainless steel could be considered for parts exposed to higher wear and tear.

Wood Frame Alternatives: Synthetic materials like high-density polyethylene (HDPE) could replace wood for greater moisture resistance but were not tested due to budget constraints.

7.1.5 Supporting Design Files and Diagrams

Software Code: See **Appendix II**

Conclusion

This documentation provides a detailed overview of the design and material choices made during the development of the hydroponic tower. Each choice was backed by practical considerations such as cost, availability, and suitability for the system's needs. Future designers may use this as a guide for material substitutions or improvements, taking into account the documented analyses and considerations.

7.1.6 BOM (Bill of Materials)

Item name	Description	Units of measure	Quantity	Unit cost (CAD)	Extended cost (CAD)	Link
Arduino UNO R3	Microcontroller board	Each	1	17	17	Arduino UNO R3 (Clone) (makerstore.ca)
Jumper cables	Different lengths for prototyping	Pack (of 10)	2	1	2	MakerStore
USB Type A/B Cable	Connect Arduino to PC (included with Arduino)	Each	1	0	0	Arduino UNO R3 (Clone) (makerstore.ca)
Breadboard	prototype with electronics and test circuit designs	Each	1	10	10	MakerStore
Dual Relay Module	Relay module optocoupler 2 channels 5V/12V	Each	1	3.5	3.5	MakerStore
Arduino Power Supply	9V 1A Power Supply	Each	1	10.99	10.99	DC 9V 1A AC to DC Switching Power Supply Adapter Input 100-240V, Output 9V DC 1A Transformer Charger : Amazon.ca: Electronics
Temperature sensor	DS18B20 Temperature Sensor with	Each	1	3.96	3.96	DS18B20 Temperature Sensor

	waterproof probe					Waterproof Probe Plugable Module with 1M Cable | eBay
Resistor	4.7kΩ	Each	5	0.01	0.05	Resistor | MakerLab (odoo.com)
3D printing filement	For 3D printing	Gram	500	0	0	N/A
Mesh	Fine mech net	Sq inch	795	13.45	0	N/A
pH sensor	pH sensor and module	Each	1	20	20	Liquid PH Value Detection detect Sensor Module Monitoring Control for Arduino BNC Electrode Probe : Amazon.ca: Industrial & Scientific
Total product cost (without taxes or shipping)	67.5					
Total product cost (with taxes and shipping)	76.3+ 11.65 shipping					

7.1.7 Equipment list

- **Reservoir Tub:**

- Plastic Storage Box with 11.4L Capacity
- Material: Durable plastic
- Dimensions: 25.5’’ X 17.75’’ X 9’’
- Features: Transparent for easy nutrient level monitoring

- **Water Pump:**

- Submersible Fountain Pump - Model PES-290-PW
- Flow Rate: 290 liters per hour
- Power: 5W
- Cord Length: 6 feet
- Additional Features: Adjustable flow control

- **Tower Segments:**

- PVC Vertical Tower Segments - Set of 9
- Material: PVC
- Length: 6.15 inch each
- Color: White

- **Growing Media:**

- Neoprene Grow Inserts - Set of 36
- Material: Neoprene
- Shape: Cylindrical inserts
- Size: Diameter-5.2cm
- Features: Durable and reusable, provides support for seedlings

- **PH0-14 pH Sensor:**

- Specification:

  Heating voltage: 5 ± 0.2V (AC · DC)
  Working current: 5-10mA
  Detectable concentration range: PH0-14
  Detection Temperature range: 0-80 °C

Response time: 5S

Settling Time: 60S

Component Power: ?0.5W

Working temperature: -10 ~ 50 °C (nominal temperature 20 °C)

Humidity: 95% RH (nominal humidity 65% RH)

Module Size: 42mm × 32mm × 20mm

Output: analog voltage signal output

With 4pcs M3 Mounting Holes

- Additional Features: Built for Arduino Uno for precise pH measurements, customizable for future upgrades

- **DS18B20 Temperature Sensor:**

- Specification:

Temperature sensor supply voltage: 3.0V ~ 5.5V

Temperature sensor resolution: 9 to 12 adjustable resolution

Temperature range: -55 ~ +125 ° (lead can only withstand the highest temperature of 85 degrees)

Temperature Sensor Output Lead: Yellow (DATA) Red (VCC) and Black (GND)

Adapter Cables: DATA, VCC, BLK,

- Calibration: Factory calibrated
- Additional Features: Built with Arduino Uno for precise temperature measurements, customizable for future upgrades.

- **Divider Disks:**

- Hydroponic Tower Splitter Disks - Set of 4
- Function: Acts as a nutrient water distributor.

- Placement: Positioned at the top of the tower.
- Water Distribution: The splitter, with its 4 small openings, efficiently distributes water in 4 directions.

- **Growth Channel Tubing:**

- PVC Tubing
- Size: 5.2cm inner diameter; 6.2cm outer diameter
- Colour: White

- **Grow Lights :**

- LED Plant Grow Light Strips
- Power: 36W
- Number of LEDs: 240
- Spectrum: Full Spectrum
- Features: Energy-efficient, suitable for promoting plant growth in hydroponic systems

- **Arduino Uno R3 (clone) :**

- Based on the ATmega328.
- 14 digital input/output pins (of which 6 can be used as PWM outputs),
- 6 analog inputs,
- A 16 MHz crystal oscillator,
- A USB connection,
- A power jack, an ICSP header,
- A reset button.

7.1.8 Instructions

- **Step 1: Prepare Components**

- Reservoir Tub:

Place the reservoir tub in a stable and accessible location.

- Water Pump:

Connect the water pump to the tower inside the tube.

- Control Valves:

Close the outlet flow valve on the tube. Open the inlet flow valve on the tube.

- **Step 2: Check Tower Segments**

  - Tower Segments:

  Check the tower segments， ensure a secure fit.

  - Divider Disks:

  Check the divider disks between each tower segment, ensuring even spacing.

- **Step 3: Install Growing Media**

  - Growing Media:

  Fill each tower segment with the provided growing media.

- **Step 4: Set Up Nutrient Solution**

  - Nutrient Solution:

  Prepare the nutrient solution according to the provided guidelines.

  Pour the nutrient solution into the reservoir tub.

- **Step 5: Turn on the Sensors and Lights**

  - pH Sensor and Temperature Sensor:

  Put the pH sensor and temperature sensor in the water.

  - Grow Lights:

  Turn on the four LED grow lights around the tower if needed.

- **Step 6: Final Checks**

  - System Connections:

  Double-check all pipes, electrical connections, and sensor placements.

- **Step 7: Put the Plants and Run the System**

  - Put the Plants:

  Insert the plant into the growing medium to make sure it is secure.

  - Run the System:

  Open the pump to make the system running.

7.2 Testing & Validation

To ensure the reliability and functionality of the hydroponic tower prototype, a series of tests were conducted.

Test 1: Water Distribution Efficiency

Objective: Evaluate the efficiency of water distribution through the tower segments using the divider disks.

Procedure: Monitor water distribution at different levels of the tower. Analyze the uniformity of water flow to each plant.

Results: The water supply seems to be strong and uniformly distributing within the entire system without any chances of clogging and bending of pipes, the newly added drainage system worked well in draining the reservoir tub within a span of 7 minutes.

Test 2: pH Sensor Calibration Accuracy

Objective: Calibrate and validate the accuracy of the pH sensor readings.

Procedure:

a. **Gather Calibration Solutions:** Obtain pH calibration solutions. Typically, one needs solutions at pH 4.00, pH 7.00, and pH 10.00 for a thorough calibration.
b. **Connect the Sensor:** Ensure the pH sensor is correctly connected to the Arduino as per sketch (connected to Analog pin A0 in this case).
c. Initial Reading: Immerse the pH sensor in the pH 7.00 solution. Allow it to stabilize for a few minutes.
d. **Adjust Software Offset:** Take a reading from the Arduino. If it's not reading 7.00, adjust the calibration variable in the code. This is an offset to bring the sensor's output in line with the known pH value.
e. Calibrate for Range: Repeat this process with the pH 4.00 and pH 10.00 solutions, adjusting the factor in the line `pH = 1.83 * voltage;`**(See Appendix II for detail)** in the code, where 1.83 is the conversion factor. The goal is to adjust this factor, so the sensor readings match the known pH values of the solutions.
f. **Rinse and Repeat :**Rinse the sensor with distilled water between tests in different solutions.
g. **Final Verification:** After calibration, verify the accuracy by immersing the sensor in a solution of known pH value and check if the reading is correct.

Results:

Table 7.1 PH Sensor Test Results

Known Value	Sensor Reading
0°C	0.3°C
25°C (Room Temperature)	24.7°C
50°C	50.5°C
75°C	74.8°C
100°C	99.6°C

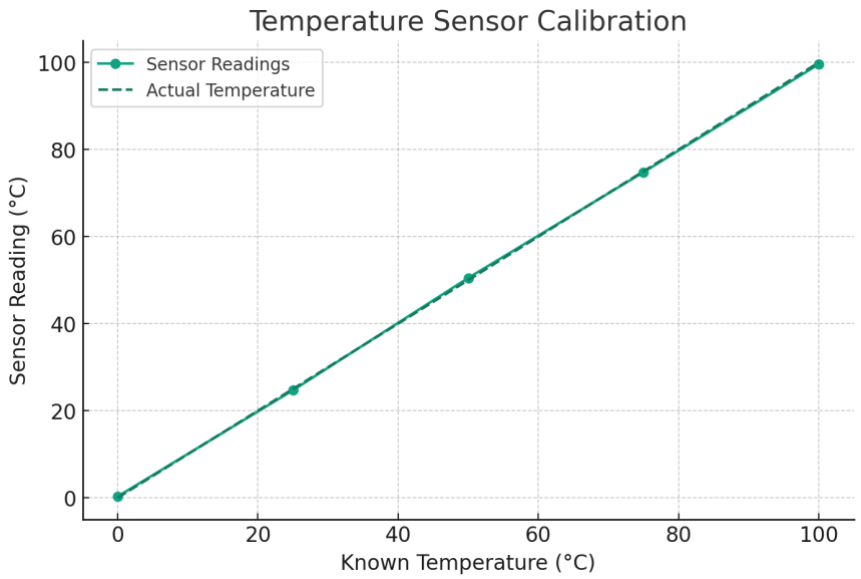


Figure 7.1 Temperature sensor calibration graph [3]

Test 3: Temperature Sensor Calibration Accuracy

Objective: Calibrate and validate the accuracy of the temperature sensor readings.

Procedure:

a. **Gather Reference Temperatures: Use** a known temperature reference, like ice water (0°C) or boiling water (100°C at sea level), depending on the range to be calibrated.
b. **Test and Record Readings: Immerse** the temperature sensor in the reference temperature. Wait for the sensor to stabilize and record the temperature reading from the Arduino.
c. **Adjust Software Calibration:**If there's a discrepancy between the known reference temperature and sensor's reading, adjust the conversion formula or add an offset in the code.
d. **Repeat if Necessary:** Repeat the process with other reference temperatures if required.
e. **Verification:** After calibration, verify the accuracy at various temperatures within sensor's operating range.

Results:

Table 7.2 PH Sensor Test Results

Sensor	Voltage
pH 4.00 Sensor	Voltage: Approximately 2.19V
pH 7.00 Sensor	Voltage: Approximately 3.83V
pH 10.00 Sensor	Voltage: Approximately 5.46V

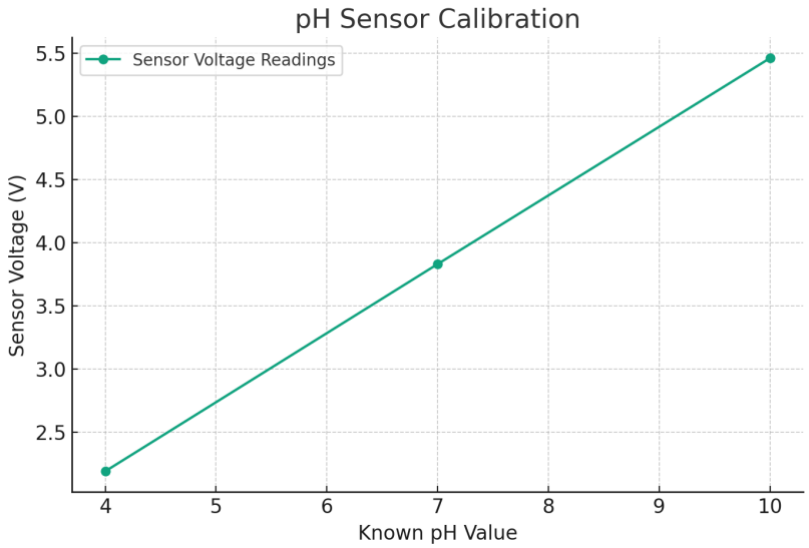


Figure 7.2 pH sensor Calibration graph [4]

Test 4: Isolation Mesh

Objective: Insulate the leaf so that it avoids contact with the light tube.

Procedure: Attach a fully grown plant in the system and checked whether they are getting burned touching the grow lights

Results: The stayed intact with the help of protective mesh provided over the grow lights.

Test 5: System Stability

Objective: Ensure the stability of the entire system during operation.

Procedure: Monitor for any vibrations, leaks, or irregularities. Observe system behavior over an extended period.

Results: The final product has been tested numerously to ensure its safety and efficiency in working. With regular final testing, all the redesigned prototypes were working flawlessly.

8 Conclusions and Recommendations for Future Work

The completed hydroponic tower prototype is now fully assembled and operational, meeting all the essential requirements. We have thoroughly discussed the modifications made with our client and provided her with a detailed video presentation outlining the updated functionalities. You can access the video, which includes an analysis of the system's improved performance and highlights the specific changes implemented in the hydroponic tower, through the attached link below:

https://youtu.be/OCXcjEFpgeQ?si=0k7UyRQwRKjAdWEE

In the course of developing and implementing our vertical hydroponic tower prototype, we have gained valuable insights and identified areas for improvement. Here are some key lessons learned and suggestions for future work to enhance the functionality and usability of the system.

Through the project, we learned how to build user-friendly prototypes and provide detailed user guides, troubleshooting instructions, and maintenance schedules to enhance the user's capabilities and experience. Working on the principle of customer centricity and customer needs, we clearly understood the problem statement and customer requirements. We also discussed the financial limitations and constraints of modifying the existing prototype. After continuous testing and improvement, the final prototype of the hydroponic tower was presented. Once again the process involved everyone on the team contributing special skills in their field. The project also demonstrated the spirit of teamwork.

For the future work, if we could be allowed a few extra months and enough financial support to complete the project, we would prioritize the following improvements:

1. EC sensor integration: Research, design, and integrate EC sensors into systems for real-time monitoring of nutrient concentrations.

2. Automated controls: Explore the development of additional automation control features such as automated pump and light on/off systems to conserve energy.

3. Mobile app/website development: Begin development of a user-friendly mobile application or website that will allow users to remotely monitor tower status, receive notifications, and control certain aspects of the system.

4. Water cleaning system implementation: Investigated and implemented water cleaning systems, such as filtration mechanisms, to improve water quality and extend the life of the water in the reservoir.

In summary, the work we have done on the vertical hydroponic tower prototype has laid the foundation for a sustainable and efficient growing system. Future work should focus on technological improvements, automation, and user accessibility to create a more advanced and user-friendly hydroponics experience. By addressing these areas, we believe the system can contribute to sustainable agricultural practices and enable users to grow healthy and thriving plants.

9 Bibliography

[1] Proactive. (n.d.). *FEEDCHART - Hydroponics & Coco Passive Systems*. proactive. https://www.growproactive.com/pages/hydroponics-coco-passive-systems

[2] Grady, A. (2023, January 30). *General hydroponics flora feed chart*. GroWell. https://www.growell.co.uk/blogs/feed-charts/general-hydroponics-flora-feed-chart

[3] Yanbing R. (2023, December 20). Command to ChatGPT to graph the relationship between temperature sensor readings and actual temperature. ChatGPT.

[4] Yanbing R. (2023, December 20). Command to ChatGPT to graph the relationship between

pH levels and sensor voltages. ChatGPT.

APPENDICES

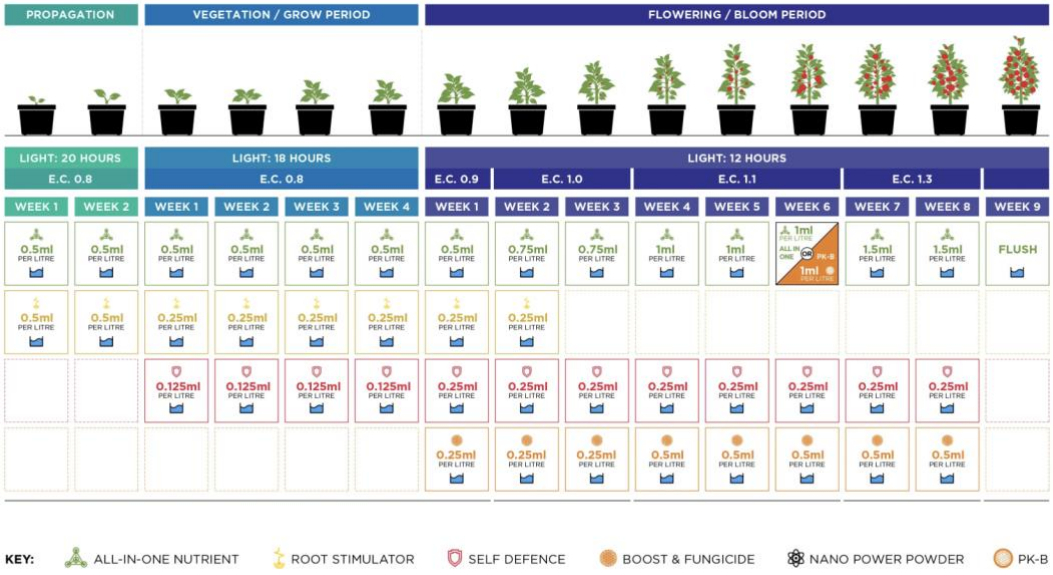
APPENDIX I: Design Files

Table 0.1. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
HYDROPONICS TOWER User Manual	Send by clients	Winter Term 2020

APPENDIX II: Other Appendices

Appendix 1: Basic Nutrient Application



General Hydroponics Flora Feed Chart

When using active hydroponics systems

WEEKS	-6	-5	-4	-3	-2	-1	1	2	3	4	5	6	7	8	FINAL WEEK
GROWTH STAGE	CUTTINGS / SEEDLINGS		VEGETATIVE GROWTH				FLOWERING / FRUITING GROWTH								
FLORA GRO	2.5ml	2.5ml	4ml	5ml	6ml	7ml	15ml	15ml	5ml	5ml	5ml	5ml			Just Water
FLORA MICRO	2.5ml	2.5ml	4ml	5ml	6ml	7ml	10ml	10ml	10ml	10ml	10ml	10ml	10ml	10ml	Just Water
FLORA BLOOM	2.5ml	2.5ml	4ml	5ml	6ml	7ml	5ml	5ml	15ml	15ml	15ml	15ml	15ml	15ml	Just Water
GHE BIO ROOTS		2ml	2ml	2ml	2ml	2ml									Just Water
GHE BIO BLOOM							2ml	2ml	2ml	2ml	2ml	2ml	2ml	2ml	Just Water
TARGET CONDUCTIVITY	3	3	5	5-6	6-9	9-10	10-14	12-16	14-18	14-18	14-18	14-18	9-16	9-16	Just Water

All applications are based on dilution in 10L of water unless otherwise stated

Appendix 2: Arduino code

```
#include <LiquidCrystal.h>

#include <OneWire.h>

#include <DallasTemperature.h>

#include <Wire.h>

// Code for interfacing E-201C pH sensor with Arduino Uno


const int PH_SENSOR_PIN = A0; // Connect sensor to Analog pin A0

float calibration = 28.34; // This value is subject to change

depending on your calibration process

float voltage = 0;

float pH = 0;


float readPH() {

  unsigned int analogValue = analogRead(PH_SENSOR_PIN);

  return (float)analogValue * 5.0 / 1023.0; // Convert analog

reading to voltage

}

const int TEMP_SENSOR_PIN = 10;


OneWire oneWire(TEMP_SENSOR_PIN);

DallasTemperature tempSensor(&oneWire);
```

```
float tempCelsius;
float tempFahrenheit;

LiquidCrystal lcd(13, 12, 5, 4, 3, 2);

//LiquidCrystal lcd(13,12,11,10,9,8,7,6,5,4,3);
void setup() {
  lcd.begin(16,2);

  Serial.begin(9600); // initialize serial
  tempSensor.begin();    // initialize the sensor
  pinMode(PH_SENSOR_PIN, INPUT); //initialize pH sensor

}

void loop() {
  lcd.setCursor(0,1);
//  lcd.print(millis()/1000);
tempSensor.requestTemperatures();             // send the command
to get temperatures
```

```
  tempCelsius = tempSensor.getTempCByIndex(0);  // read
temperature in Celsius
  tempFahrenheit = tempCelsius * 9 / 5 + 32; // convert Celsius
to Fahrenheit

  Serial.print("Temperature: ");
  Serial.print(tempCelsius);    // print the temperature in
Celsius
  Serial.print("°C");
  Serial.print("  ~  ");        // separator between Celsius and
Fahrenheit
  Serial.print(tempFahrenheit); // print the temperature in
Fahrenheit
  Serial.println("°F");

  tempSensor.requestTemperatures();             // send the
command to get temperatures
  tempCelsius = tempSensor.getTempCByIndex(0);  // read
temperature in Celsius
  tempFahrenheit = tempCelsius * 9 / 5 + 32; // convert Celsius
to Fahrenheit
  lcd.home();
```

```
  lcd.print("Temp: ");
  lcd.print(tempCelsius);    // print the temperature in Celsius
  lcd.print(" C");
    voltage = readPH();
  pH = 1.83 * voltage ; // Convert voltage to pH value. The
conversion factor and offset will need to be calibrated

  Serial.print("Sensor Voltage: ");
  Serial.print(voltage);
  Serial.print("V, pH value: ");
  Serial.println(pH);
  lcd.setCursor(0,1);
  lcd.print("pH: ");
  lcd.print(pH);
  delay(1000); // Delay for stability
}
```