ECE 445

SENIOR DESIGN LABORATORY

Design Document

New Generation Addiction Control and Recovery Device System with Absolute Safety and Privacy

An Addiction Treatment Device

Team 12

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13 Oct 2025

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Abstract: Our project aims at making a privacy-preserving, closed-loop nicotine-reduction device that senses user state and automatically titrates dose to taper dependence. The ESP32 control subsystem mixes nicotine, diluent, and an aversive additive via peristaltic pumps, adapting composition in real time from heart-rate/SpO_2 inputs, while fingerprint gating prevents misuse. Target performance is ±5% concentration accuracy with ~1 s control updates and mandatory inter-dose lockouts; safety monitors (leak/temperature/battery/sensor faults and abnormal vitals) trigger audible/visual alerts and software shutdown. To protect users, the system operates offline with SD-card data storage, and detailed histories require authentication.

1 Introduction

1.a Problem

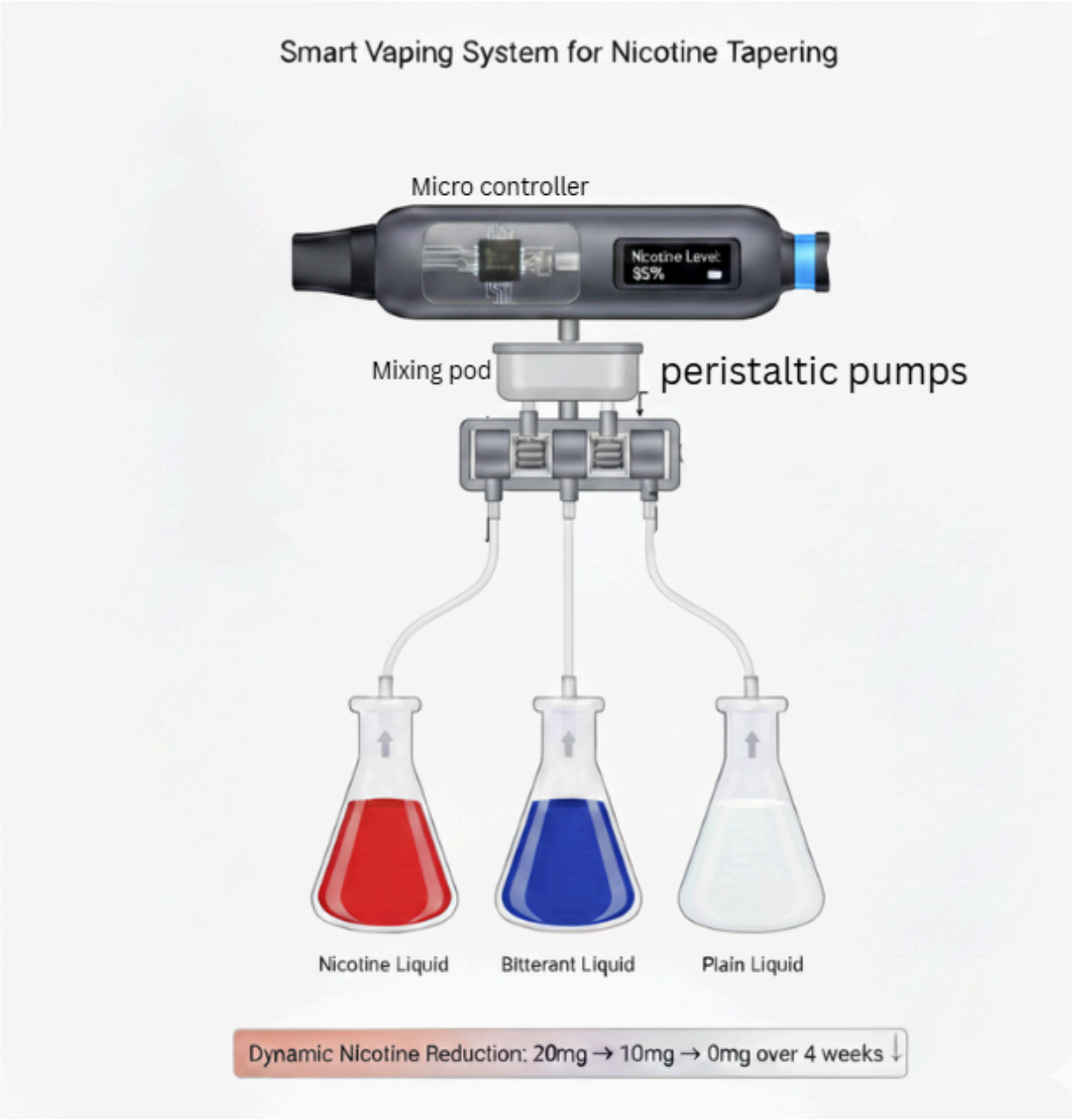
“First you take a drink, then the drink takes a drink, then the drink takes you.” – F. Scott Fitzgerald. As Fitzgerald says, unconscious Addiction is becoming a more and more common problem in modern society. By “unconscious,” I mean habits that sneak in slowly, built by small daily choices and cues, so people don’t notice the slide until it is strong. There’s many materials that can cause addiction in individuals' lives. Here I include both substances and behaviors. Some are relatively not impactful, like addiction to high sodium concentration, addiction to certain neuron impulses like music, even addiction to alcohol for most of the cases. I don’t mean these are harmless; only that for many people the day-to-day harm can be lower. Alcohol addiction can also be severe; I’m talking about mild use here. But some are much more horrifying, like addiction to smoking (more specifically nicotine), addiction to fentanyl, and addiction to cocaine. These often pull people in fast, with strong cravings, risky choices, and higher risk of death. All those substances deal a considerable amount of damage to the health of the addict and more or less influence the people around the user. Think heart and lung problems, changes in mood and thinking, money stress, and family strain. But this should not end here. Naming the harm is not enough; we need a clear plan to stop the slide. “It does not matter how slowly you go as long as you do not stop.” – Confucius. Like Confucius said, if there is no stop to the addiction then the addiction will eventually roll down the hill like a rock no matter faster or slower, a brake is needed for this process. The point is that steady effort matters more than speed, but pushes from stress and daily life keep the rock moving. Do we have a stop method for addiction? Certainly yes, there are many addictions known to be reversible and even the ones that are non-reversible, the symptom of the addiction can be controlled to be at least less severe. But there exists problems with the current method. Two big gaps stand out significantly in real life. The base logic for the addiction recovery is usually step-by-step. The steps are often fixed by a plan, not by how the person feels that day. Usually the addict needs to control the addiction level from severe step by step to nearly no impact, but if the process is too quick then the result can also be bad. It works like trying to reshape a Bouncy Ball, if we try to push too hard it will make a huge bounce back and eliminate most of the distance that has already gone through, in the worst case the addict might even be worse from the start because of the bounce. When that happens, the person loses trust and energy. They may even smoke more to calm the crash. All the

current methods rely heavily on the self-regulation ability of the addict: the addict has to lower the addiction level step by step with a highly organized daily routine. This assumes strong willpower every hour, which is not realistic for most people. Life is messy, work shifts, kids, money, and stress can break the routine. This sometimes works well but in most cases the result isn't optimal enough. There are mainly two problems: First, the self regulation ability of the addict is usually not well enough. Willpower rises and falls during the day, but cravings and desire don't wait. Sure there exist addicts that have a strong will to make a recovery from the addiction for reasons, but in most cases the addict only knows the current addiction phase is not healthy and have a relatively weak will for making a recovery, which in this case the addict may give up the process when feeling horrible. This drop-off point is the key failure we must design for. Second, the self control model is not optimal and scientific enough most of the time. Most plans don't measure anything in real time. Even if the addict tries one's best to regulate oneself, due to the fact that the human body is a huge chaotic system, there is no way that the addict will have a perfect endoscopic view to know what should be the correct dose for that specific moment. Nicotine fades fast, so strong desire can spike many times a day. People end up guessing dose and timing, which causes under-dosing (white-knuckle cravings) or over-dosing (nausea, dizziness). So what we are aiming for then, is to work out an optimal systemic solution for the addiction recovery for smoking (nicotine) addiction. In simple words, a system that senses, decides, and helps right when the urge hits. It should be easy to use, low cost, and private. We aim to solve the problem of smokers not being able to self-control accurately and regulate enough in a precise scientific responsive system. Today's tools are one-size-fits-all, slow to react, and too hard to follow under stress. We need a responsive loop: notice the trigger, then give the right aid, and then check the effect, then adjust and do it again in time.

1.b Solution

The solution is a smart nicotine reduction device that monitors and adjusts the amount of nicotine a user inhales with each use. This system will incorporate a programmable control unit that gradually decreases nicotine concentration over time. By lowering the dosage in careful steps, the device reduces the dependency and the "bounce back" effect of sudden withdrawal. To further discourage continued use, the system can introduce safe, conditioning the brain to associate vaping with reduced satisfaction. This combination of gradual reduction and negative reinforcement helps to break both the physical cravings and the psychological appeal. The implementation centers on a PCB that controls the vape's motor and mixing components. Sensory measures how many inhalations, while the PCB adjusts according to composition of the vapor in real time by mixing nicotine with an bitter compound.the device will progressively lower its nicotine levels and increases the substitution, allowing the user's to adapt without severe withdrawal symptoms.

1.c Visual Aid



1.d High Level Requirement List

1) Sensor:
    a) The Sensor should have proper functionality with the Micro Controller and immediate commands.
    b) The Sensor should be able to report the result within the range of 5% tolerance when dealing with data.
    c) Physical set up for the sensors should be arranged in a reasonable way to avoid unexpected movement in space or unexpected detection of the materials that are not in the design consideration

2) Control:
    a) The ESP32 Micro Controller should be properly working with the certainty of pins and power are adjusted in the correct set up, extreme cases should all be considered and handled
    b) The safety signal should be double handled in the Control Module with additional hardware to ensure it is working properly.
    c) The device calculates the requested content with 1s.
    d) When having the input with extremely abnormal combinations, the Analysis should handle all the cases that are not handled already by the other modules as the last move for response.

3) Mixing:
    a) The Control Signals for the motor are correctly sent to the Mixing System and correctly handled.
    b) The motor device is working correctly in the correct power supply and correct working frequency and power.
    c) The system delivers the commanded dose concentration (using a safe test liquid) within 5% up and down of target as measured on a scale, and enforces a minimum lockout time between doses every time.

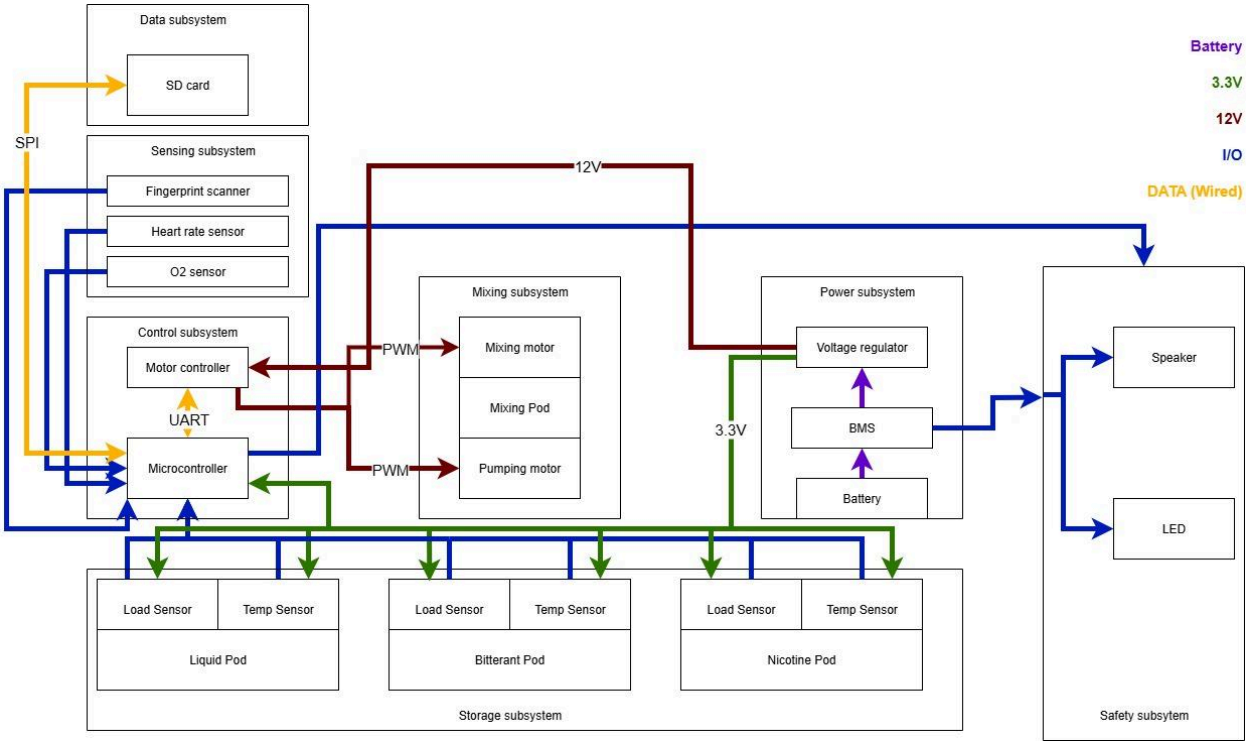
4) Safety:

a) All the Safety Systems in each module are connected correctly and sending signals to the Safety signal handler in the correct time.
b) If a red-flag condition appears (very high heart rate, high oxygen level, sensor fault, low battery, liquid leah, high liquid temp), a clear alert shows. The buzzer should ring and the LED should light up.

5) Privacy:
    a) The Device should not perform the operation of presenting detailed information about past usage without the password or safety check.
    b) The device works with no external network. All data is stored on a SD card and the user can erase all local data from the SD card.

2 Design

2.a Block Diagram



Block Diagram Breakdown:

1) Sensor Subsystem
    a) The sensor subsystem gets real-time user data like heart rate and oxygen levels. It also has a fingerprint sensor to record and read fingerprint data for secure operation of the device and to prevent misuse. These signals feed into the microcontroller, which uses them to adapt the dosage and detect unsafe conditions.
    b) RV Table

Requirement	Equipment	Test Procedure	Presentation
HR sensor shall report values within ±20% of a reference at rest and under light exertion.	Stopwatch and human counting	Place HR sensor on subject; count and start timer meanwhile. Record 2 min at rest, then 2 min	table of paired readings (device vs reference), mean error, max error; line plot over time.

		after 30 s of step-ups. Log ESP32 readings	
Fingerprint sensor shall gate all dosing; only enrolled prints unlock.	enrolled user, ≥2 non-enrolled users.	(1) Enroll one finger. (2) Attempt unlock 10× with enrolled, then 20× with non-enrolled. (3) Try to dose without unlock.	Record of success/failure; video or log excerpt.

2) Control subsystem
    a) The ESP32 serves as the central processor that receives the data, controls safety logic, and controls the dosing concentration. It enforces system timing, gradual nicotine reduction, and abnormal command overrides. It communicates with the mixing and tank systems to ensure safety cutoffs. The motor controller controls the pump and mixer to enable the transport of fluid from the tanks to the mixing pod and ensure the liquid concentration in the mixing pod.
    b) RVT

Requirement	Equipment	Test Procedure	Presentation
Safety overrides shall preempt dosing within ≤500 ms of a red-flag input (HR high, sensor fault, low battery).	Fault injection (software flag or signal line), scope	Induce each fault and measure time to pump-disable.	Table of fault with disabled times.
Commanded concentration should pump timing mapping shall achieve ±5% concentration when the Mixing/Storage are nominal.	Mixture ingredients	Request 10 setpoints, run dosing, measure actual concentration by gravimetric method. Mean error <8%	setpoint vs measured plot, error table.

3) Mixing/Pumping Subsystem
    a) The mixing subsystem controls the fluid reservoirs in the storage subsystem. Each reservoir feeds fluid into the Mixing pod through a peristaltic pump. The mixing pod incorporates a stir mechanism driven by a DC motor, which mixes the fluid to create a mixed solution prior to being vaporized. This subsystem serves as a main point for the dose control and interacts directly with the control subsystem.
    b) RVT

Requirement	Equipment	Test Procedure	Presentation
Delivered dose concentration shall be within ±10% of target.	0.01 g precision scale, beakers, dyed “nicotine surrogate” + diluent + aversive additive, stirrer	(1) Clean receiving cups. (2) Command dose at 10 targets. (3) Weigh each component pre/post to compute actual fractions.	Table of target vs actual %, bar/line plot.
No leaks: total unintended drip <0.1 g in 10 min after a dose.	Scale, absorbent pad check	Weigh pad under outlet before/after 10 min post-dose.	Mass difference table.

4) Power subsystem
    a) The power system supplies regulated DC voltage (3.3V, 12V, and 5V if needed) to sensors, motors and the ESP32 using regular batteries.
    b) The power system should also include an emergency backup system in the case that one of the batteries is not working because it is broken or out of charge. In this case when the switch is on, the power subsystem should directly use the 12V battery to supply everything through a voltage adaptor.
    c) RVT

Requirement	Equipment	Test Procedure	Presentation
Provide regulated rails: 3.3 V, 5 V,	Electronic load or resistors, DMM,	Load each rail to design max;	Table of Voltage in different trials.

12 V within ±15% at max load;	oscilloscope.	measure V (per schematic).	

5) Storage Subsystem
    a) This consists of three tanks, one stores the nicotine containing fluid, another stores a liquid to dilute the nicotine fluid and the third contains a bad tasting fluid to decrease addiction. Each tank has a temperature and load sensor to monitor the state of the liquid and detect issues in temperature and leakage.
    b) Each Tanks should be considered carefully for the device usage and also the material usage for it. Based on different requirements it can vary from a simple glass beaker to a 3D printed container.
    c) RVT

Requirement	Equipment	Test Procedure	Presentation
Tank temperature high (≥45 °C) shall trip alert and stop dosing.	Warm bath or heater.	Heat one tank slowly and observe	Log with temp and state.
Materials compatibility: tubing/tanks shall show no visible degradation after 24 h exposure to test liquids.	Visual inspection, mass check.	Soak samples 24 h; inspect and weigh.	Graph of photos, mass change in percentage.

6) Data subsystem
    a) This system is used to protect the users data and enforce data safety. Privacy is insured by the SD card, with no wireless network connections as all communications are through SPI.
    b) The Data Subsystem should not present the detail to anyone in most of the cases.
    c) RVT

Requirement	Equipment	Test Procedure	Presentation

Detailed history requires authentication (password or fingerprint).	Enrolled & non-enrolled users.	Open history UI without auth should expect deny; then with correct authentication should allow.	Statistical bar graph for correct trials.

7) Safety Subsystem
    a) Safety Subsystems include all the Safety modules in each subsystem, when any one of them triggers any warning signals, the safety subsystem should take an appropriate action.
    b) Safety Subsystem components include alarms, flashing red LED , software shutdown logic, and fingerprint authentication for secure access. It connects logically both the microcontroller software and the physical safety hardware.
    c) RVT

Requirement	Equipment	Test Procedure	Presentation
On any red-flag (HR high, sensor fault, battery low, tank leak, over-temp), system shall: (a) sound buzzer, (b) flash red LED	Human detection.	Trigger each red-flag one at a time. Then observe outputs of beep and red light.	Table of condition and responses and probably also correct trials.

8) Tolerance Analysis

The component most susceptible to risk in our system is the Adafruit 1150 peristaltic pump which is used to transport liquid from the liquid pods to the mixing pod for mixing according to the required concentration set by the microcontroller. The pump can get damaged or blocked while the tubing connected to the pump can leak affecting the flow rate of the liquid through the pump. A mathematical analysis of the Adafruit 1150 peristaltic pump can be modeled by breaking down its core components: the electric motor and the fluid dynamics of the peristaltic action. The overall performance depends on the relationship between the motor's power input

(voltage and current), its rotational speed, and the resulting volumetric flow rate and pressure generated within the tubing.

1. *Critical Performance Requirement*

The system is required to deliver fluid volumes with an accuracy of $\pm 1\%$, ensuring that the resulting fluid concentrations remain within the specified mixing tolerances. This tolerance analysis evaluates whether the $\mathrm{Adafruit\ 1150\ peristaltic\ pump\ subsystem}$ can meet that requirement, considering expected electrical, mechanical, and environmental variations.

This analysis focuses on key sources of error in the peristaltic pump system, including motor speed variation, tubing behavior, and backpressure effects, and their combined impact on flow accuracy.

2. *Nominal Model and Parameter Assumptions*

According to the datasheet, the Adafruit 1150 peristaltic pump has the following specifications:

- $\mathrm{Maximum\ flow\ rate}$:
  $V_0 = 100, \mathrm{mL/min} = 1.667, \mathrm{mL/s}$

- $\mathrm{Typical\ operating\ flow}$:
  $V_{\mathrm{op}} = 0.8 \cdot V_0 = 1.334, \mathrm{mL/s}$

The pump is modeled using the simplified linear relationship:

$$V = K \cdot \omega$$

Where:

- V is the volumetric flow rate (mL/s),

- ω is the pump's rotational speed (rev/s),

- K is an empirical constant based on tubing and pump head geometry.

Since the internal roller geometry is proprietary, K is assumed to be determined through calibration. For the purposes of this analysis, a conservative empirical approach is used.

Assumed Tolerances

The following tolerance values are used based on best engineering practices and estimations:

Parameter	Nominal	Assumed Tolerance (±)	Justification
Motor speed ω	ω_0	1%	PWM variation, supply voltage ripple
Pump constant K	K_0	1%	Tubing elasticity, wear, temperature
Backpressure variation ΔP	0	0.5%	Tubing layout, vertical fluid head

These tolerances are combined to estimate the overall error in flow delivery.

3. Error Propagation and Worst-Case Flow Deviation

The volumetric flow rate may vary due to perturbations in each contributing component. A first-order linear approximation estimates flow deviation:

$$\Delta V = \frac{\partial V}{\partial \omega}\Delta\omega + \frac{\partial V}{\partial K}\Delta K - L \cdot \Delta(\Delta P)$$

Where:

- ΔV is the variation in flow rate,

- L is an empirical constant representing the effect of pressure variation on flow.

Given the relationship $V = K \cdot \omega$, the partial derivatives are:

$$\frac{\partial V}{\partial \omega} = K_0, \quad \frac{\partial V}{\partial K} = \omega_0$$

The normalized, or fractional, deviation in flow is expressed as:

$$\frac{|\Delta V|}{V_0} = \left|\frac{\Delta \omega}{\omega_0}\right| + \left|\frac{\Delta K}{K_0}\right| + \left|\frac{L \cdot \Delta(\Delta P)}{K_0 \cdot \omega_0}\right|$$

Substituting the assumed tolerances:

$$\frac{|\Delta V|}{V_0} = 1\% + 1\% + 0.5\% = 2.5\%$$

Therefore, the worst-case flow error is 2.5%, which exceeds the target of $\pm 1\%$, indicating that modifications to the system are necessary.

4. Design Mitigation and Revised Error Estimate

To bring the system within specification, the following mitigation strategies can be applied:

- $\text{Motor speed stabilization}$: Implementing regulated power supplies and high-resolution PWM control is estimated to reduce $\frac{\Delta \omega}{\omega_0}$ to $\pm 0.3\%$.

- $\text{Improved tubing consistency}$: Using higher-quality silicone tubing and enforcing a maintenance schedule is expected to reduce $\frac{\Delta K}{K_0}$ to $\pm 0.3\%$.

- Minimized backpressure variation : Simplifying the tubing layout to reduce vertical lift and pressure differences can lower backpressure impact to $\pm 0.2\%$.

The new error estimate becomes:

$$\frac{|\Delta V|}{V_0} = 0.3\% + 0.3\% + 0.2\% = 0.8\%$$

With these adjustments, the system meets the $\pm 1\%$ requirement with margin.

5. Sensitivity and Prioritization

The contribution of each error source to the total variation is summarized in the following table:

Error Source	Contribution (Post-Mitigation)	Priority
Motor speed variation ω	0.3%	High
Pump constant variability K	0.3%	High
Backpressure effects ΔP	0.2%	Medium

This analysis indicates that motor speed stability and tubing reliability are the most influential factors in system performance.

6. Conclusion

The initial tolerance estimate for the Adafruit 1150 peristaltic pump subsystem shows that flow error could reach $\pm 2.5\%$ under worst-case assumptions, exceeding the allowable $\pm 1\%$. However, with realistic and implementable design improvements, the worst-case deviation can be reduced to 0.8%, which is within the specified tolerance range.

This analysis confirms that the pump subsystem is capable of supporting the required fluid mixing accuracy when appropriate measures are taken.

3 Cost and Schedule

3.a Cost Analysis

1) Labor: I need to give an approximate estimation on the hourly wage first, the Illinois minimum wage is 15$ per hour but I will suggest that we cannot follow this minimum since we are not exactly working on a minimum wage job. According to the Office of Student Financial Aid, in University of Illinois at Urbana-Champaign, the wage for a technical or professional job can be up to 19-22 dollars per hour. I will give a higher estimation, let's say 21.5 dollars per hour for each of us at technical work. But it is not just like this because we are not doing kicad or soldering PCBs every single second, so for example when doing some paper work I will set the wage at 16 dollars per hour and when we are doing some other works like finding parts I will set the wage at 18 dollars per hour.

   So with that being said, each person are expected to do 2 hours of paper work, 6 hours of random technical jobs, and around 18 hours of technical designing, which makes the total cost of labor being: 2*2.5*16+6*2.5*18+18*2.5*21.5=1317.5 per week. And we approximately have 12 weeks to work so it will be around 1317.5*12 = 15810 dollars per person. Thus 3 people will cost 15810*3 = 47430 dollars.

2) Parts:

Name	Description	Manufacturer	Part#	Quantity and Cost
Pyrex Glass Griffin Beaker, Low Form, Measuring, 100 Ml	Corning(R) 1000. Exceptional strength and stability Brilliant transparency Superior resistance to chemicals, contaminants, and drastic changes in temperature These are among the key properties that enable Pyrex(R) glass to endure even the toughest laboratory environments, making it the indispensable partner for education and research for over 100 years	Corning	None	4*5.45$
Watkins Assorted Food Coloring 4 - 1 fl oz Bottle(S)	Ingredients Red: Glycerin, invert sugar, water, vegetable juice, citric acid. Yellow: Glycerin, water, polysorbate 80, turmeric. Green: Glycerin, water, polysorbate 80, trehalose, spirulina extract,	Watkins	None	3*7.58$

	turmeric, sodium citrate. Blue: Glycerin, water, trehalose, spirulina extract, sodium citrate.			
Mainstays 6LB High Precision Digital Kitchen Scale with Blue Backlit, Black	Maximum weight capacity up to 3000 g/6.6 lbs. Display technology: digital display, large LCD screen with blue backlight. Advanced sensor technology delivers quick, accurate responses., Displays weight down to 0.005 oz /0.1 g increments. Switch between different units easily. Has both "manual off" and "auto off" to save power. Tare button subtracts container weight to zero out the scale so you only measure what you want. Remove the white clips on both sides of the weighing platform. Product net content uom: 313g. Helpful tips: Clean the scale with a slightly damp cloth. Do not immerse the scale in water or use chemical/abrasive cleaning agents. Helpful tips: All plastic parts should be cleaned immediately after contact with fats, spices, vinegar and strongly flavored/ colored foods.	Mainstays	None	1*12.53$
Strain Gauge Load Cell - 4 Wires - 1Kg	A strain gauge is a type of electronic sensor used to measure force or strain (big surprise there). They are made of an insulating flexible backing with a metallic foil pattern. The resistance of a strain gauge changes when force is applied and the object is deformed along with the foil and this change will give a different electrical output. However, these thin foils are very delicate and are easy to over-bend. In this product, the gauge is attached with epoxy to a chunk of strong aluminum. The metal keeps the strain gauge from being damaged, and constrains the amount of movement. Attach one side to a fixed enclosure or ground, using the mounting holes, to keep them from moving. Then apply weight to the other side in the direction indicated on the side, either by gravity (so arrow pointing down) or by pulling (arrow facing up). The output resistance will change with the amount of deflection, and is measured with a precision	Adafruit	TAL221	1*3.95$

	ADC or Wheatstone bridge. Strain gauges are useful for projects when you need to measure pressure, force, weight, and tension. Note that this is just the load cell, no ADC or converter is included! Also, like all load cells, the sensor must be calibrated with known weights once installed! This is a 1 Kg Strain Gauge.			
Adafruit HX711 24-bit ADC for Load Cells / Strain Gauges	If you are feeling the stress and strain of modern life on a Wheatstone bridge and you want to quantify it, this handy breakout will do the job, no sweat! The Adafruit HX711 Breakout contains a super-high-resolution 24-Bit differential ADC with extra gain circuitry that makes it perfect for measuring strain gauges / load cells or other sensors that have four wires that are connected in a Wheatstone bridge arrangement. Each breakout comes with a HX711 ADC chip, plus some support circuitry, and 6 port terminal blocks that can be used to connect one or two 4-wire sensors. The E- pad connects to ground (often a black wire), the E+ pad connects to the power voltage supplied to the HX711 (often a red wire). Then A- and A+ pads connect to the differential outputs from the bridge. For example, connecting to a strain gauge these tend to be the white and green wires. If you have a second gauge or voltage you want to measure, you can use the B- and B+ pads. On the A channel, you can select 64x or 128x gain. On the B channel, you have a fixed 32x gain. As the sensor is twisted and bent, the slight changes in resistance are converted to minuscule voltage changes that can be read by the HX711 ADC for converting into force or mass measurements. You can use our Arduino library to configure and read the ADC for fast interfacing. This sensor uses a two-wire protocol, similar to	Adafruit	HX711	1*9.95$

	SPI. If you want a similar sensor but I2C, check out the NAU7802 breakout we make. We based this design on the excellent Sparkfun HX711 breakout: incorporating their split analog/digital supply and digital supply filtering. We then made a few tweaks: pre-soldered terminal blocks, the second bridge exposed, and a slide switch to change between 10 SPS and 80 SPS rates.			
Temp Sensor	This is a waterproofed version of the DS18B20 Temperature sensor. Handy for when you need to measure something far away, or in wet conditions. While the sensor is good up to 125°C the cable is jacketed in PVC so we suggest keeping it under 100°C. Because they are digital, you don't get any signal degradation even over long distances! The DS18B20 provides 9 to 12-bit (configurable) temperature readings over a 1-Wire interface so that only one wire (and ground) needs to be connected from a central microprocessor. Usable with 3.0-5.5V systems.	DFRobot	DFR 0198	4*6.9$
Buzzer Piezo 12V 23.4mm Through Hole		Piezzo	MCP 320B 2 (MC P320 B2Q)	1*0.95$
3mm LED 3V Red		E-Shop Self Service	None	1*4$
Pulse Sensor Amped	Product Images and Video Pulse sensor with three long wires Component kit shot with sensor and attachment hardware Close up of pulse sensor detection side Back of sensor close up next to quarter Pulse sensor with three long wires Description Pulse Sensor Amped is a greatly improved version of the original Pulse Sensor, a plug-and-play heart-rate sensor for Arduino and Arduino compatibles. It can be used by students, artists,	Adafruit	None	1*25$

	athletes, makers, and game & mobile developers who want to easily incorporate live heart-rate data into their projects. Pulse Sensor Amped adds amplification and noise cancellation circuitry to the hardware. It's noticeably faster and easier to get reliable pulse readings. Pulse Sensor Amped works with either a 3V or 5V Arduino. Lastly, the Pulse Sensor creators have also streamlined and improved the Processing visualization software and Arduino code that comes with this hardware. The kit includes: A 24-inch Color-Coded Cable, with a standard male header connectors. Plug it straight into an Arduino or a Breadboard. No soldering is required. An Ear Clip, perfectly sized to the sensor. It can be hot-glued or epoxied to the back of the sensor to get reading from an ear lobe. Parts to make a handy Velcro finger strap. This is another great way to get heart-rate data. 4 Transparent Stickers, to insulate the front of the Pulse Sensor from oily fingers and sweaty earlobes. The Pulse Sensor has 3 holes around the outside edge which make it easy to sew it into almost anything. Visualization software (made in Processing) to instantly see output of the sensor and for troubleshooting.			
DC Motor Controller/Driver		E-Shop Self Service	L298 N	1*7$
MicroSD card breakout board+	Not just a simple breakout board, this microSD adapter goes the extra mile - designed for ease of use. Onboard 5v->3v regulator provides 150mA for	Adafruit	None	1*7.5$

	power-hungry cards 3v level shifting means you can use this with ease on either 3v or 5v systems Uses a proper level shifting chip, not resistors: less problems, and faster read/write access Use 3 or 4 digital pins to read and write 2Gb+ of storage! Activity LED lights up when the SD card is being read or written Four #2 mounting holes Push-push socket with card slightly over the edge of the PCB so its easy to insert and remove Comes with 0.1" header (unattached) so you can get it on a breadboard or use wires - your choice Tested and assembled here at the Adafruit factory Works great with Arduino, with tons of example code and wiring diagrams To use with an Arduino, connect GND to ground, 5V to 5V, CLK to pin 13, DO to pin 12, DI to pin 11, and CS to pin 10. Then you can use the Arduino IDE's SD library which supports FAT and FAT32 SD cards. For details on getting started, check out our detailed tutorial, it discusses microSD cards, wiring and how to use this breakout board with an Arduino or CircuitPython			
Adafruit Industries Ultra-Slim Round Fingerprint Sensor and 6-pin Cable	Ultra-Slim Round Fingerprint Sensor and 6-pin Cable Secure your project with biometrics - this adorably tiny, all-in-one, optical fingerprint sensor will make adding fingerprint detection and verification super simple. It's extremely slim, with a plastic casing that can be glued or panel mounted into any enclosure! There are some embedded blue LEDs that light up the outer casing when the sensor is waiting for finger touches.	Adafruit	None	1*19.95$
Linear Regulator		E-Shop Self Service	LP2950CZ	1*1.45$
12V 2400mAh AA NI-MH Battery Pack		ECE Supply Center	none	1*0.1$

DC motor		ECE Supply Center	ROB -11696	1*2.75$
L298 driver for DC/Stepper motors	Based on the ST L298N chip, this module is designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC motors, and stepper motors. It has the ability to reverse the motor rotation direction and features control inputs for stepper and DC motors, motor direction indication LEDs, power presence LEDs, and a base with 4 mounting holes. The control logic power supply voltage ranges from 4.5 to 5.5V, and the motor power supply voltage ranges from 6.5 to 30V DC, with a peak output current of 2A per channel.	Arduino	L298N	4*7$
Peristaltic Liquid Pump with Silicone Tubing - 12V DC Power	Move fluid safely from here to there with this very nice little pump. Unlike most liquid pumps, this is a peristaltic type - the pump squishes the silicone tubing that contains the liquid instead of impelling it directly. The upshot? The pump never touches the fluid which makes this an excellent choice for any food/drink/sterile based pumping such as for making drink-bots or gardening robots! The pump is basically a geared down DC motor, so it has a lot of torque. Inside the pump is a 'clover' pattern of rollers. As the motor turns, the clover presses on the tube to press the fluid though. The pump does not need to be primed and in fact can self-prime itself with water a half meter with ease. You can PWM the motor to speed up or slow down the flow rate and if you connect the motor the other way it will move fluid the other direction. Works great with either a power transistor (basic on/off) or a motor driver chip such as the L293D. We've also got a version that works well with 5V or 6V DC power. Please note The pump comes with a bit of silicone	Adafruit	None	3*24.95$

	tubing already installed and two 1/2 meter pieces attached on with barbed connectors. However, the silicone tubing is not sterile and might be dirty on its way to you. Before using, the tubing must be sterilized! The included tubing is also not rated FDA or USDA compliant and is only meant for basic testing of the pump. If you need to purchase FDA/USDA compliant tubing for use with your food-hacking project check out McMaster-Carr. They have many types of silicone tubing available by the foot! We also have a meter of silicone tubing you can pick up right now			
12V Battery Charger (NiCad/NiMH, Tamiya Connector)	This smart charger is able to charge 12VDC batteries with either NiCad or NiMH chemical makeup and capacity of 1000-5000mAh.	ServoCity	None	1*15$
Terminal Block		ECE Supply Center	None	1*2.17$
3Pairs Tamiya Battery Connectors Male & Female 14awg 10cm for RC Car Lipo Battery Charge	Wire length :10 cm Wire Gauge: 14AWG High performance and Quality components. Adaptors and leads to suit your RC model wiring needs. Package：3pcs male tamiya connector with wire+3pcs female tamiya connector with wire Can be used to fit onto lipo / NIMH Battery pack;	RLY RC	None	1*12.18$
Peristaltic Pump Adjustable Speed Easy to Use Reliable Micro Stepper Motor		None	None	1*11.74$

for				
ESP32-S3-WROOM-1-N4	ESP32-S3-WROOM-1 and ESP32-S3-WROOM-1U are two powerful, generic Wi-Fi + Bluetooth LE MCU modules that are built around the ESP32-S3 series of SoCs. On top of a rich set of peripherals, the acceleration for neural network computing and signal processing workloads provided by the SoC make the modules an ideal choice for a wide variety of application scenarios related to AI and Artificial Intelligence of Things (AIoT), such as wake word detection, speech commands recognition, face detection and recognition, smart home, smart appliances, smart control panel, smart speaker, etc.	DigiKey	ESP32-S3-WROOM-1-N4	1*5.06$
Total				351.48$

Note : Anything over 150$ will be bought with pitcher fund

3) Total Cost = Labor Cost + Material Cost = $351.48+ $47430 = $47781.48

3.b Schedule:

Week of	Main Task	Meetings
10/13	Ensure the MicroController Board works. Catch the second PCB ordering.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting Saturday 1PM: Pitcher Meeting
10/20	Focus on the first sensor system. General design for the powering system should finish.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting
10/27	Second Breadboard Demo. The Control Sub-system should be stabilized.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting Saturday 1PM: Pitcher Meeting
11/3	Third round of PCB order. Individual progress report.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting
11/10	Focus on the mixing sub-system. Fourth round of PCB order.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting Saturday 1PM: Pitcher Meeting
11/17	Mock Demo. Safety System first milestone. Team Contract Assessment.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting
11/24	Fall Break. Ensure the basic functionality has no logic errors, like powering system, control system.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting Saturday 1PM: Pitcher Meeting
12/1	Safety System Milestone 2. Final Milestone. Final demo.	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting

	Mock presentation.	
12/8	Final Presentation. Final Paper	Friday 3 PM: TA Meeting Saturday 12PM: Team Meeting Saturday 1PM: Pitcher Meeting (Final ones)

4 Ethics and Safety

We care about ethics more than anything else, we will mainly be focusing on these three aspects of ethics: privacy, care, academic integrity, and humanity. All of them have a different focus on different groups of people.

4.a Ethics

1) Privacy:

   Different people take different views on privacy, but we can estimate how people manage the privacy of themselves, especially for the parts that most people will agree on. Stoicism in Ancient Greece is one of the great examples. According to SEP, “The Stoics are determinists about causation, who regard the present as fully determined by past events, but who nonetheless want to preserve scope for moral responsibility by defending a version of compatibilism.” (Durand). Basically Stoics assume the world in a deterministic chain that contains so many minimal parts that can be determined for sure about what is going to happen in the future as long as we have sufficient information and correct models to make predictions. Furthermore, “They say that every cause is a body which becomes the cause to a body of something incorporeal. For instance, the scalpel, a body, becomes the cause to the flesh, a body, of the incorporeal predicate “being cut”” (Durand). Again, Stoics assume the whole world as a system of interrelated parts that act on each other and also get opposite act force when one part acts on the other parts, and from their definition a human individual is just a bag of those smaller parts or particles that get limited to a shell named like “Rajesh”. So the only thing about what a human is is then just a wall to separate the “inner” particles and “external” particles.

   Also, like many of the Greek ideology, “Stoic ethics is eudaimonist in structure, in the sense that it posits happiness (eudaimonia) – a well-lived, flourishing life – as the rational agent’s ultimate practical goal or end (telos).”(Durand) So, “Every human agent, it is assumed, wants nothing more than to live a flourishing, happy life and therefore arranges their own projects and efforts according to what they think will accomplish this goal.”(Durand) but the problem is “Unfortunately, however, most human beings are mistaken about what will in fact make them happy. Regardless of what they themselves might say about the value and success of their lives, most humans, according to the Stoics, hold false opinions about what their happiness consists in, i.e. false opinions about

what is good."(Durand). But then what is actually good? "Zeno represented the end as: 'living in agreement'. This is living in accordance with one concordant reason, since those who live in conflict are unhappy... Cleanthes, [Zeno's] first successor, added 'with nature', and represented it as follows: 'the end is living in agreement with nature'. (Stobaeus, 63B)"(Durand). So living well is thus living in agreement with nature. "the corporeal mind is present everywhere within it, structuring and shaping the underlying matter according to an all-encompassing, perfectly rational plan. For a human being to live "in agreement" (homologoumenôs) with cosmic nature therefore requires attuning her own reason (logos) with that of the whole, by thinking the same thoughts about her situation and circumstances as does Zeus in governing the portion of the world she occupies (Cooper 2012). In this way, the flourishing agent lives in conformity "with the will of the administrator as the whole" (Diogenes Laertius, 63C)."(Durand). So as a conclusion, in the Stoicism view, living in accordance with nature is a good way of life, it is one of the most important things to live in agreement with nature and probably is the most important thing.

But then you may ask, why do we care? Well, in short, we care because trying to get information about other people's privacy is not "in agreement with nature". The original "in agreement with nature" idea suggests one should make the internal "small parts" to act similar and ultimately the same as the external "small parts". And the fact that one trying to look into someone else' s edge is not "good" in three ways. First, trying to take a look at how other people have the interaction internally is not part of nature and will mess up even more the internal process of someone. Second, it is by "nature" that someone is not happy to be investigated how one's own interaction for small parts work and that "one" will then practice feisty acts back to the source. Third, it is also by nature, bad to look into the details of how another person's "internal parts" work together. That is immediately out of the natural order.

So with that being said, we will follow the thought to have the maximum respect toward privacy to make sure we are sufficiently respecting others, respecting other's "agreement with nature", and also respecting our own "agreement with nature".

2) Care:

I also would like to put a strong emphasis on caring about each other, both in the meaning

of caring about each other when working together as a team and caring about the product user that may use our design later.

“Drawing conceptually from a maternal perspective, Noddings understood caring relationships to be basic to human existence and consciousness. She identified two parties in a caring relationship—“one-caring” and the “cared-for”—and affirmed that both parties have some form of obligation to care reciprocally and meet the other morally, although not in the same manner.” (Sander-Staudt, “Nel Noddings”). As Noddings was talking about, caring relationships is as basic as mother loving children, meanwhile children loving back mother not for at least not just for the benefit. This should be an ethically true requirement and does not even be required to do so. It is a default method of every individual, not even like a moral law that needs to be developed later.

Furthermore, “She characterized caring as an act of “engrossment” whereby the one-caring receives the cared-for on their own terms, resisting projection of the self onto the cared-for, and displacing selfish motives in order to act on the behalf of the cared-for. Noddings located the origin of ethical action in two motives, the human affective response that is a natural caring sentiment, and the memory of being cared-for that gives rise to an ideal self.”(Sander-Staudt, “Nel Noddings”). In a more understandable sense, what she talked about here is the first type of motive, the natural caring, is from someone who feels “ought” to do something to care about others, like helping a drowning kid without even thinking about whether one should do it. The second type of motive, the ideal self, is a little more twisted but eventually comes with the same result. It means when one is indifferent about helping others on something or even just feeling opposed to helping someone on something, one still does a bit more thinking and then thinks that ideally, one should help. For example, if someone has diarrhea all over the place and fainted, someone walking by may just want to get away and ignore but feel still should morally take care of that individual and call 911.

With that being said, “Noddings rejected universal principles for prescribed action and judgment, arguing that care must always be contextually applied.” (Sander-Staudt, “Nel Noddings”). Basically she means there is never something by itself is ethically correct to act on someone, we should always work with the mind about the ideal self and think about what the care receiver may need for feeling good.

Why do I mention all these? What I want to say is as human individuals, we are fundamentally social creatures, and we all should care about each other by nature. This matters a lot in group activities because as a group we need to have a group contract and rules to ensure we function well as a group together. In the case when nothing goes wrong all the rules should be followed. But for example what if someone has a headache? Maybe that person should still work. What if someone has a cold? Maybe that person should still try one's best to catch up. But what if someone got hit by a car? I would suggest the other two people should then try to help that person to get over it as much as possible. In some sense rules are rules but we should then just get applied to total utilitarianism and treat each other like machines. When accidents happen we need to take into account everyone's reasons and use the care principle to "care" about each other to avoid more damage. This is why French people say "liberty, equality, fraternity", because extreme freedom causes extreme exploitation, extreme equality causes extreme tyranny, the fraternity is there to prevent the extremeness of both sides, so it always stays on a balance and never loses it. And here, "care" is our fraternity to keep a balance between rules and tolerance. On the other side we should also care about what may be the problems with the user of the product. There are many engineeringly successful products that get designed every single year but still are infamous because of bad design toward "care". We should put ourselves in the "ideal self" to do careful thinking about what users may need to be cared about, thus we never make the functionalities that are harmful for others.

3) Integrity:

Why do we care about academic integrity? It sounds that we have an obvious answer there that it is wrong by rules but it is not the full image. Saying it is wrong to not follow academic integrity by rule is correct, but also not just correct by itself. For example it is by rule one not supposed to swim in the boneyard creek, and it is correct, but what if Loomis Lab get destroyed by an earthquake and someone get buried down there with the only escape spot being swimming inside boneyard creek, is that then still wrong to swim in there? I assume not.

I want to start by explaining how Socrates defines the word "Virtue". If we list some virtues: brave, helpful, optimistic, they seem like totally different identities that are just

somehow “good”. But if we think about it, why, for example, being brave is a virtue? Someone who gets scared by a cricket is definitely not brave. Someone who fights a wolf to save a baby is brave. But what about someone just deciding to fist fight a bear for no reason? It doesn’t seem like the case to be brave here but rather just being stupid. It is the same case for helpful. If someone never helps others, that person is not helpful. If someone helps a granny get over a cross road, that person is indeed helpful. But what if someone says yes to anyone who needs any assistance(that may even be harmful)? That doesn’t sound like being helpful. Same for optimistic. If someone is sad and has low expectations on everything that happens, that person for sure is not optimistic. If someone always holds a happy view even when the worst case happens, that person is optimistic. But what if someone never even thinks bad things could happen and just assumes the world always should be the best case to self? This again does not sound optimistic but rather stupidity and arrogant. So, what if virtue? Virtues themselves may have different meanings and seem to be totally different identities but all of them eventually point to the same result: The wisdom to balance in the correct range.

Academic Integrity is undoubtedly one of the most important if not the most important Virtue for an Engineer. It matters in both ways. First we have to be responsible about others morally. Second, this is the class U of I created for us to practice in a real design and if we lack this exercise then in the future when nobody is doing the exact same thing as we do the harm will be directly back to us. So we need to be wise on the balance of Integrity. We need to seek help and information wisely, mindfully, and carefully.

(Below are the set of integrity code we need to follow)

a) https://studentcode.illinois.edu/article1/part4
b) https://www.ieee.org/about/corporate/governance/p7-8

4) Humanity:

“Humans can never be used as the way toward a goal. Humans can only be the goal.” (Philip Hillmer, ECE316)

As Professor.Hillmer said, every human individual can never be used as the way toward a goal, and a human can only be the goal for a better wish, for example fixing someone’s spinal cord should not come with the cost of cutting off someone else’s spinal cord.

As ECE445 students we are not that destructive yet for humanity(I hope so). But accidents always can happen and since this is our first practice toward the real world, I think we should treat it as if it is a real impactful project that might bring the influence like an industrial revolution.

My intention here is to be mindful about every single decision we will make about the project, to worry about each human individual that might get influenced by this project. I don't remember the details but there were a lot of engineering disasters that got caught later, like someone decided to add lead into the gas to make it more flammable and eventually it cost all the air on the earth to contain a bunch of lead.

But first of all why should we care about humanity as a whole and in more detail why should we care about all the human individuals? In my opinion there are three main reasons:

First, Like I mentioned before in the Care part, as humanity we all naturally and ideally care about each other, no need for more information

Second, We care about the people related to us, and follow Darwin's theory that we as humans more or less are closely related, so we should be mindful about humanity and each human individual because undoubtedly we belong to the same family.

Third, this is what I call "common descendent theory": Premise 1: As humans we love our descendents by nature. Premise 2: Every single human individual has a possibility to have a descendent with another human individual. Premise 3: The descendants will be sad if one of the ancestors harm another ancestor, even just unconsciously. Conclusion: Based on Premise 2 it is just a matter of time for two human individuals to have a common descendent, and if one harm another person unconsciously, one's descendants will feel sad and one should them also feel sad and do the best to be mindful about what could happen and then try best avoid it.

So we should follow what professor Hillmer said, we should always try our best to think about humanity and each human individual. We shall never use any human individual as ways of reaching a goal. We should always aim for the well being of every single human with the best wishes.

4.b Safety

Safety is also a big part that we need to ensure. Just as I mentioned before everyone's lives matter, life can never be used as a way, life can only be the ultimate goal, this common rule applies to everyone and in non-extreme cases should always be applied. We need to ensure the safety of the user, the society, and also for us the design team.

1) Safety for users: As a development team we value the safety of users more than anything. We need to make sure that users are totally safe when they use our product. We ensure that by doing careful design, including multiple levels of safety check systems in each system, and enforce emergency shutdown when significant danger is detected.
2) Safety for society: We should always care about the society and consider all kinds of influence our project can impact the society. We need to make sure that our project does not damage any single person's safety in the progress of development and distribution, again no one can be used as a way to reach the goal, people can only be goals. We also need to consider the case for the misusage of the device and set the appropriate strategy for avoiding anything like that.
3) Safety for development team: We as a team should also care about our own safety, we should care for ourselves and each other. We have to ensure a safe working environment to make sure that no one is hurt during the development process.
4) General Rules
    a) No one is allowed to work in the lab alone.
    b) Safety measures should be enforced while working in a dangerous environment like high voltage or high temperature. Always wear gloves and glasses when it is necessary.
    c) The maximum continuous working time for a person is 6 hours and the maximum working time in a day is 8 hours. This is necessary to avoid accidents caused by tiredness after continuous working.
    d) When feeling physically ill, someone is not suggested to come to the lab to ensure the safety of self and others.
    e) When feeling mentally exhausted or ill, one should consult a teammate or course member for help in order to always sustain a good efficiency when working on the project and personal wellbeing.

f) Dangerous devices that involve toxic or biohazard liquid, or high voltage, or possibility of flame or explosion, should not be taken out of the lab to work on. In the case of seriously dangerous conditions being involved(super high voltage or radiation), a special lab permit is needed for someone to work inside one of those labs with better protection.

5 Citations

"Wages." Office of Student Financial Aid, https://osfa.illinois.edu/types-of-aid/employment/regulations/wages/. Accessed 11 Oct. 2025.

Durand, Marion, Simon Shogry, and Dirk Baltzly. "Stoicism." The Stanford Encyclopedia of Philosophy, edited by Edward N. Zalta and Uri Nodelman, Spring 2023 ed., Metaphysics Research Lab, Stanford University, 2023, https://plato.stanford.edu/archives/spr2023/entries/stoicism/

Sander-Staudt, Maureen. "Care Ethics." Internet Encyclopedia of Philosophy, https://iep.utm.edu/care-ethics/