MARYLAND

MESA CHALLENGE

LEVEL: Secondary

2023—2024

WEARABLE TECHNOLOGY

JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

23-00000

Wearable Technology Challenge

Level: Middle School and High School

Type of Contest: Team

Composition of Team: Two to four students per team (four team members is strongly encouraged)

Number of Entries: One entry per school

Next-Generation Science Standards: MS-ETS1-1, MS-ETS1-2, MS-ETS1-3, MS-ETS1-4, HS-ETS1-1, HS-ETS1-2, HS-ETS1-3, HS-ETS1-4

Background

Engineers solve problems. Some design bridges to cross rivers. Some design computer programs to help us with our daily tasks. Some work on ways to travel to Mars. Others design systems to keep people safe in cars or to make sure the food we eat is safe. Often, the problems engineers tackle are very complex and involve many ideas from different fields of study. As a result, engineers often work on multidisciplinary teams with biologists, chemists, mathematicians, and other scientists.

Because health care is a concern for all of us, many engineers work on solutions to help people live safer, healthier lives. Advances in technology are changing health care at a rapid pace, and engineers are playing an important role in finding new ways to keep people healthy. The use of *wearable technology* in medicine and health care is a great example. Think about the impact the wearable insulin pump has had on people with diabetes. This is just one example of the benefits wearable devices can have on the quality of people's lives. As engineers continue to develop new technologies, more and more wearable devices will be developed to promote healthy habits and help people stay healthy. In the not-so-distant future, wearable devices will be widely available and will have a huge impact on the health of many people. In fact, wearable devices will probably be a regular part of normal, everyday health care. Some of these devices may save many, many lives.

Many people realize the potential that wearable devices have to improve quality of life and even to save lives. For example, the Bill and Melinda Gates Foundation issued a Grand Challenge that involved using wearable technology to improve the health of mothers and babies in low-resource countries. More about the Gates Foundation Grand Challenge can be found here. According to the World Health Organization's Integrated Management of Neonatal and Childhood Illness (IMNCI) Guidelines, there are seven critical indicators of severe newborn illness: difficulty feeding, convulsions, movement only when stimulated, respiratory rate ≥60/minute, severe chest indrawing, body temperature >37.5°C, and body temperature <35.5°C. A wearable device that could detect these indicators in babies has the potential to save many lives. Drawing on the IMNCI criteria, engineers, biologists, and other scientists at the Johns Hopkins Applied Physics Laboratory (APL) teamed up with doctors and biomedical engineers at Johns Hopkins Medical School to develop wearable technology to improve the health of babies. More information about the NeMo (Neonatal Monitoring) group at the Johns Hopkins Center for Bioengineering Innovation and Design (CBID) can be found here and in this article.

Note about the 2023–2024 Competitions:

Regional Competitions will be virtually judged ahead of time, followed by an in-person showcase and awards ceremony. All files must be submitted no later than 11:59 p.m. on the due date specified by the MESA Regional Coordinator.

The teams that win the Regional Competition will progress to the 2024 Statewide MESA Competition. The Statewide MESA Competition will be virtually judged in advance, and an in-person MESA Day showcase and awards ceremony will take place in May on the campus of the Johns Hopkins Applied Physics Laboratory in Laurel, Maryland.

Overview

In this MESA challenge, students will use the engineering design process to design a wearable neonatal health monitoring system. Teams will design, build, and demonstrate a wearable device to monitor a specific indicator of potential neonatal illness (i.e., respiration rate). All MESA clubs will receive a starter kit with various components that can be used in the project. Other materials will be sourced and secured by students. As with all engineering projects, budget constraints will be imposed on the design team.

Judging

During this project, the team will focus on designing a device that can be used to monitor and *accurately* report the respiration rate of an infant.

The team will calculate and submit an Accuracy Score to indicate how accurately their device reports respiration rate compared to the actual observed respiration rate. Because each competing team will demonstrate their device in a different environment with different equipment (e.g., testing devices) and because judges will not be present, it is not possible to ensure that the Accuracy Scores submitted by teams are correct. Therefore, the Accuracy Score will *not* be used to rank entries in the competition. Instead, a video-recorded presentation and electronic poster about each team's design process and solution will be used to score projects.

Projects will be scored in the following categories:

Video-Recorded Presentation with Demonstration	40 points
Electronic Poster	36 points
Design of Device	24 points
Total Score	100 points

If a design/device does not perform as well as the team would like, the team is still encouraged to submit a video-recorded presentation and electronic poster. The presentation and poster can showcase the process the team used to develop a solution, even if the device does not work properly.

Please refer to the guidelines below and the scoring sheets at the end of this document for details about judging criteria.

Tiebreakers

Ties will be broken via the use of the highest score on the following:

1. Device Design Score
2. Video-Recorded Presentation Score
3. Electronic Poster Score

Continuing Projects

MD MESA recognizes that there is both an interest in and benefit for student teams to continue work on a project started in previous years. However, all projects must be new and original. Teams cannot continue working on a project previously submitted.

Plagiarism Policy

Academic honesty and personal integrity are essential to ensure future success as college students and STEM professionals. As such, the APL STEM Program Management Office expects that the work presented for this challenge will be solely the work of the students. If the work or ideas of another are used to further students' work, proper credit must be given to the owner. Failure to do so will be interpreted as an act of plagiarism. If it is determined that a student committed plagiarism, they will be disqualified from the competition and will be ineligible to receive any awards. They may also risk further sanctions from the APL STEM Program Management Office.

MESA USA Code of Sportsmanship

At all times during the course of the competition, MESA students, staff, advisers, and supporting family members should act in a professional and courteous manner. All judges' decisions are final.

General Design Requirements and Ergonomic Considerations

Teams must design and build a wearable device that can monitor the respiration rate of an infant. The device must be:

- capable of displaying respiration rate (i.e., breaths per minute) in a way that is intuitive for parents, childcare providers, and health care professionals to understand;
- suitable for use on an infant (i.e., would not cause discomfort or injury to an infant);
- easily placed on and removed from an infant;
- adjustable to allow appropriate fit on different sizes of infants;
- able to stay in place and continue monitoring respiration during normal infant movements like squirming, rolling, and being lifted by a caregiver; and
- durable, reusable, and aesthetically pleasing.

Technical Requirements

The final design of the wearable device must meet certain technical requirements. The device must:

- Use hardware (e.g., sensors, microprocessor, etc.) to sense chest movements in an infant

  There are no restrictions or specific requirements for the type of hardware that can be used. Teams can use the hardware included in the starter kit provided by MD MESA (e.g., Circuit Playground Express microprocessor) and/or source other hardware.

- Use software (i.e., code) written by the team

  There are no restrictions or specific requirements for the programming language. Teams can write code using the programming language of their choice.

- Output respiration rate on a display device (e.g., laptop, tablet, smartphone) located at least 27 inches (70 cm) from the infant

  There are no restrictions or specific requirements for the way the information is presented on the display device. Number or respirations or respiration rate could be represented by a single number, could be indicated on a graph, or could be shown some other way. It does need to be clear to the user how to determine the respiration rate.

- Be capable of being powered by a battery (users must be able to easily change or charge the battery/batteries)

Materials Requirements

When selecting materials for this project, teams should consider that the device is designed to be placed on an infant and to be used by parents, childcare providers, and medical professionals. The device must:

- Be made of materials that are appropriate for use on an infant's body

  There are no restrictions or specific materials requirements. However, materials used in the device should not have the potential to cause discomfort or injury to an infant. Teams are not required to use and are not limited to the materials in the starter kit provided by MD MESA.

- Cost no more than $50 to build

  Materials provided by MD MESA do not count toward the $50 spending limit. Likewise, the price of the display device does not count toward the $50 spending limit. All materials used should be recorded on an itemized budget sheet. For more information, please see the Expense Report Guidelines later in this document.

Design Bonus

Teams will receive bonus points for devices that:

- successfully transmit respiration data to the data display device (i.e., laptop or another device) *wirelessly*; and/or

- are exceptionally well designed and executed, show a high level of engineering prowess, and/or demonstrate excellent consideration of human factors (i.e., ergonomics).

Testing and Demonstrating the Device

Each MESA club has been provided with a NeoNatalie manikin. The chest of the infant-sized manikin moves in a way that mimics respiration. This makes it the ideal testing device for prototypes developed for this challenge. Ideally, the team should use a NeoNatalie manikin to test and demonstrate their prototype. However, if a team does not have access to a NeoNatalie manikin, they can use another object to test and demonstrate their prototype. A simple, low-cost test device can be created using items typically found in many homes. For instance, a football, balloon, or baby doll could be used to represent an infant's chest. Finger or hand movements could be used to simulate chest movements. The testing device does not need to be complicated. It simply needs to be able to help the team develop and demonstrate a device that fits on an infant's chest and senses motion of the chest.

The type of device used to test and demonstrate the prototype will not have an impact on scoring. In other words, the team will not be penalized if they do not have access to a NeoNatalie manikin and must create their own test device.

IMPORTANT NOTE ABOUT SAFETY: All testing should be conducted on NeoNatalie manikins or on other testing devices. ***No testing should be conducted on humans or animals.***

Calculating the Accuracy Score

The team must calculate an Accuracy Score to indicate how close the respiration rate determined when using the team's device is to the actual observed respiration rate.

The Accuracy Score is calculated using the following formula:

$$\textbf{Accuracy Score} = |\textbf{actual observed rate} - \textbf{reported rate}|$$

In other words, the Accuracy Score is calculated by taking the absolute value of how far the team's reported respiration rate is from the actual observed rate.

Presentation with Demonstration Requirements (Video Submission)

The team must deliver a video-recorded presentation that describes their design process and the solution they developed. The presentation, including the demonstration, can be a maximum of 10 minutes in duration. Teams should use appropriate visual aids to support the presentation. Creativity is encouraged. The team must address the following during the presentation:

Introduction of Team Members/Description of Roles

Background Information

- What background research did the team do related to the topic of the challenge?

- What did the team have to know to be successful at building an effective device?
- Did you contact experts and/or potential users? If so, whom did you contact? What did you learn?

Design and Development Process

- How did the team go about designing a device to monitor and report respiration rate? Describe the team's design process.
- How did the team test the design?
- What improvements or changes did the team make to the design during the development process? In other words, describe iterations of the design.
- What obstacles did the team face while working on this project? How did the team overcome those obstacles?

Description of Design

- What are the key elements of the final design? In other words, describe the final design.
- Does the team's solution meet all design requirements and constraints?
  - The video must clearly show that the device meets the requirements.
- How do the hardware, circuitry, sensors, and code used in the design work together to monitor and report respiration?
- How did human factors/ergonomics considerations impact the design (e.g., materials, design of device, fastening methods, aesthetics, etc.)

Demonstration

- Describe and demonstrate how the device is used. (Hint: Think about how you would teach a parent or caregiver to use the device.)
- Demonstrate how an adult would place the device on an infant.
- Describe and demonstrate how the parent, childcare provider, or health care professional knows the respiration rate based on the output.

Evaluation of Effectiveness of the Solution

- How well does the team's solution work, overall?
- How accurately does the device report respiration rate?
  - The video must show how the team calculated the Accuracy Score. Note: While the actual Accuracy Score will not be factored into scoring, the team must show that they *accurately calculated the Accuracy Score* using data from testing.
- What part(s) of the solution work well?
- What could have worked better?

Lessons Learned/Next Steps

- What did the team learn while working on this project?

- What would be next steps for the project? How could the team's solution be improved (i.e., what would the team do with more time/resources)?

Video-Recorded Presentation Submission Instructions

1. Upload the video to YouTube as an unlisted video.
2. Create a document containing the school name, team member names, MESA School Coordinator name(s), and a link to the video on YouTube.
3. Save the document as a PDF file, using the following format for the file name: **School name_Wearable Tech_Presentation**.
4. Submit the document as instructed **no later than 11:59 p.m. on the specified due date**.

Note about Videos:

Remember to watch the video and make sure all of the required elements are included and easily seen or heard. For example, viewers can't read a ruler, so say the length as you show the measurement.

If the judges can't clearly observe something that is scored, you will not get points for that item.

Electronic Poster Requirements

The team must create an electronic poster. Creating the layout in Microsoft PowerPoint is recommended but not required. The poster should be submitted as a PDF file. The size of the virtual display must be 36 inches × 24 inches (width × height). All information should be contained on **one single slide**. The electronic poster should help an observer quickly understand the problem, the solution, and the next steps of the project. As a visual aid during the presentation, the poster can be a powerful tool providing important graphics and highlights of the solution. The electronic poster must include the following:

1. **School Name**
2. **Names of Team Members and Their Roles**
   - Include all team members and their primary contributions to the project.
3. **Name(s) of MESA School Coordinator(s) and Adviser(s)**
4. **Name of the Device**
5. **Description of the Purpose of the Device**
6. **Description of Key Features of the Device**
   - Include information that will allow an observer to quickly understand the design of the device and how the device is used to monitor respiration.

7. **Images and/or Diagrams of the Device**
    - Include labeled images and/or graphics that show key parts of the design (e.g., fasteners, sensors, display device, etc.).
    - Include pictures and/or screenshots of information on the display device.
8. **Testing Data**
    - Include pictures of the device being tested.
    - Include data from testing the device.
9. **Design Iterations**
    - Include information about how testing led to improvements in the design (i.e., iterations).
10. **Code**
    - Excerpts from the code should be included on the poster. Selected code should increase an observer's knowledge of how the device monitors and displays respiration rate. It may be beneficial to add labels and/descriptions to help clarify the purpose of the selected code.
11. **Cost Information**
    - Include an expense report. See the Expense Report Guidelines later in this document.
12. **Next Steps**
    - Include information about how the team's solution could be improved (i.e., what would the team do with more time/resources)?
13. **Bibliography**
    - Include a list of sources for any third-party information used for the project.
14. **MESA Logo**
    - Include the APL MD MESA logo, no smaller than 3 inches × 3 inches.

Electronic Poster Submission Instructions

1. Complete a poster. We recommend creating the layout in PowerPoint.
2. Save the poster as a PDF file, using the following format for the file name: **School name_Wearable Tech_Poster**.
3. Submit the PDF file as instructed **no later than 11:59 p.m. on the specified due date**.

Expense Report Guidelines (Included on Electronic Poster)

An itemized expense report must be provided for all components and materials used in the construction of the device. The expense report must be included on the electronic poster.

- The expense report must include a list of every part (or materials used to construct the part) of the device and the corresponding unit dimensions, retail price, price per unit, quantity used, total cost, and retail source.
- All parts received through barter, trade, donation, recycling, etc., must be included in the itemized expense report. Reasonable estimated retail prices for these items must be determined through product research (online or in person).
- The total cost will be based only on the actual materials used in the construction of the device. Teams will need to calculate the cost per unit and use this figure to calculate the total cost of the item. For example, a 1.75 mm × 240-m-long roll of ABS Filament SmartReel (for 3D printing) costs $39.99. This breaks down to $0.167 per meter (i.e., $39.99/240 m). If a team uses 50 meters, the cost would be $8.33 (i.e., 50 × $0.167).
- The value of the display device does not need to be included in the expense report and does not count toward the $50 maximum expense limit.
- Costs should be calculated using pre-tax prices. Shipping and handling charges should not be included in the cost calculations.
- Note regarding materials provided by MD MESA: The expense report must include all components of the device, including materials provided my MD MESA. However, the value of materials provided by MD MESA should not be counted toward the maximum expense limit. Materials provided by MD MESA should be listed in the expense report with a cost of "N/A." This includes materials provided by MD MESA for other challenges (e.g., NEDC).

Sample Expense Report

Part	Unit Dimensions	Retail Price	Price per Unit	Quantity Used	Total Cost	Retail Source	Receipt #
Sparkfun RedBoard (Item #: Dev-13975 ROHS)	Approx. 55 mm × 72 mm × 15 mm	$19.95/unit	$19.95	1 unit	$19.95	Sparkfun.com	1
061 Aluminum Flat	1/8 inch × 1/2 inch × 24 inches	$1.98/flat	$0.0825/ linear inch	10 inches	$0.82	Metalsdepot.com	2
Masking Tape	1 inch × 60 yards	$4.02	$0.0019/ linear inch	12 inches	$0.02	TheSupplyTree.com	3
Wire with Alligator Clips	12 inches long	N/A	N/A	6	N/A	MD MESA	N/A
				Total Cost:	**$20.95**		

Scoring Sheet
Wearable Tech Challenge (Middle and High School)

School Name: _____ **Judge:** _____

Performance Area	Level of Mastery (Select One)					
Video-Recorded Presentation with Demonstration	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Background Information						
Description of background research the team did related to the topic of the challenge. Description of what the team had to know to be successful at building an effective device. Description of contact with experts and/or potential users and what was learned from those interactions.	(0)	(1)	(2)	(3)	(4)	____/4
Engineering Design Process						
Description of how the team tested the design of the device and made improvements to the design. Discussion of obstacles the team faced during the project and how they overcame those obstacles.	(0)	(1)	(2)	(3)	(4)	____/4
Description of Design						
Description of key elements of the final design and how the team's solution meets all design requirements and constraints. Description of how human factors/ergonomics considerations impacted the design (e.g., materials, design of device, fastening methods, aesthetics, etc.).	(0)	(1)	(2)	(3)	(4)	____ /4
Description of how the hardware, circuitry, sensors, and code work together to monitor and report respiration.	(0)	(1)	(2)	(3)	(4)	____ /4

Performance Area	Level of Mastery (Select One)					
Video-Recorded Presentation with Demonstration	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Demonstration						
The team provides a general description of how the device is used. The team demonstrates how an adult would place the device on an infant and demonstrates how a caregiver or health care provider uses the output to determine respiration rate.	(0)	(1)	(2)	(3)	(4)	____ /4
Team's Evaluation of the Effectiveness of the Solution						
Calculation of Accuracy Score. The project is not rated on the accuracy of the device. However, the team must demonstrate that they accurately calculated the Accuracy Score following the required procedure. See page 5.	(0)	(1)	(2)	(3)	(4)	____ /4
Lessons Learned/Next Steps						
Description of the parts of the final device that worked well and of what could have worked better. Discussion of what the team learned while working on this project and what the next steps for this project would be (i.e., what the team would do if they had more time/resources).	(0)	(1)	(2)	(3)	(4)	____ /4
Overall Quality of the Presentation						
The presentation is well organized and holds the audience's attention. It includes an engaging introduction (including an introduction of team members), an interesting body that conveys accurate information, and a compelling conclusion. The presentation includes effective and creative use of props, visual aids, sound effects, video editing, etc.	(0)	(1)	(2)	(3)	(4)	____ /4
The presentation demonstrates the team's deep understanding and knowledge of concepts related to the challenge. All team members participate appropriately in the presentation.	(0)	(1)	(2)	(3)	(4)	____ /4

Performance Area	Level of Mastery (Select One)					
Video-Recorded Presentation with Demonstration	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Overall, the team delivered a high-quality, engaging presentation that included all necessary information for the audience to fully understand the team's project and their final design.	(0)	(1)	(2)	(3)	(4)	____ /4
Penalties?						
Time – 10-point deduction if the presentation exceeds the allotted 10 minutes						Points deducted: _____
VIDEO-RECORDED PRESENTATION WITH DEMONSTRATION TOTAL SCORE: _____/40						

Performance Area	Level of Mastery (Select One)					
Device Design	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
The device appears to be suitable for use on an infant (i.e., would not cause discomfort or injury to an infant). It uses a "data transmitter" (i.e., an LED) located at least 70 cm (27 inches) from the infant to show when a breath is taken.	(0)	(1)	(2)	(3)	(4)	____/4
The device appears as though it can be easily placed on and removed from different-sized infants. The device appears to be durable and reusable. It is generally made of materials appropriate for use with an infant.	(0)	(1)	(2)	(3)	(4)	____/4
The device appears to be designed in a way that will allow it to continue to monitor respiration during normal infant movements like squirming, rolling, and being lifted by a caregiver.	(0)	(1)	(2)	(3)	(4)	____/4
The device appears to report a reasonably accurate respiration rate, and a caretaker or health care provider can determine respiration easily using the information on the display device.	(0)	(1)	(2)	(3)	(4)	____/4
It appears as though the team's use of software (i.e., the code they wrote) and hardware contributed to an effective design. It is capable of being powered by battery.	(0)	(1)	(2)	(3)	(4)	____/4
Overall quality of the design. The device is aesthetically pleasing.	(0)	(1)	(2)	(3)	(4)	____/4
Design Bonus?						
Wireless transmission – 10-point bonus if the device successfully transmits respiration data to the data display device (i.e., laptop or another device) *wirelessly*						Bonus points added: ____
Excellence in Design – 10-point bonus if the device is exceptionally well designed and executed, shows a high level of engineering prowess, and/or demonstrates excellent consideration of human factors (i.e., ergonomics)						Bonus points added: ____
DEVICE DESIGN TOTAL SCORE: _____/24						

Performance Area	Level of Mastery (Select One)					
Electronic Poster	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Poster Required Content						
All Required Content Was Included—Name of device, school name, team members' names and roles, name of adviser, MESA logo, bibliography (APA).	(0)	(1)	(2)	(3)	(4)	____/4
Expense Report—Expense report showing the cost to build the device was no more than $40.	(0)	(1)	(2)	(3)	(4)	____/4
Description of the Purpose of the Device (i.e., description of why the device might be used).	(0)	(1)	(2)	(3)	(4)	____/4
Description of the Key Features of the Device (i.e., information that will allow an observer to quickly understand the design of the device and how the device is used to monitor respiration).	(0)	(1)	(2)	(3)	(4)	____/4
Information about How Testing Led to Improvements in the design (i.e., iterations). Images of the device being tested. Labeled images and/or diagrams that show important parts of the design (e.g., fasteners, sensors, display device, etc.).	(0)	(1)	(2)	(3)	(4)	____/4
Code and Data—Team displays excerpts from the code and displays quantitative data, qualitative data, or both on poster.	(0)	(1)	(2)	(3)	(4)	____/4
Description of Next Steps—What improvements would the team make if they had more time/resources?	(0)	(1)	(2)	(3)	(4)	____/4
Overall Quality of Poster						
Poster Layout—The poster is organized in such a way that an observer can quickly understand the purpose of the device, the team's design process, and key aspects of the design	(0)	(1)	(2)	(3)	(4)	____/4
Design Elements (e.g., color, layout, spacing, diagrams, etc.) utilized result in an effective, user-friendly, aesthetically pleasing poster.	(0)	(1)	(2)	(3)	(4)	____/4

Performance Area	Level of Mastery (Select One)					
Electronic Poster	**Not Present (0 pts)**	**Poor (1 pt)**	**Fair (2 pts)**	**Met Criteria (3 pts)**	**Excellent (4 pts)**	
Penalties?						
Format – 10-point deduction if the electronic poster is not formatted correctly (i.e., one single slide that is 36 inches × 24 inches [width × height])					Points deducted: _____	
ELECTRONIC POSTER TOTAL SCORE: _____/36						

Wearable Technology Challenge Overall Score
VIDEO-RECORDED PRESENTATION WITH DEMONSTRATION SCORE: _____/40
DEVICE DESIGN SCORE: _____/24
ELECTRONIC POSTER SCORE: _____/36
OVERALL SCORE: _____/100