STEAM EDUCATION
H2 GRAND PRIX SPRINT

ENGINEERING AND RENEWABLE ENERGY CTE CURRICULUM

ESTIMATED TIME: 760 MINS.

UNIT OVERVIEW

760 MINUTES

This unit focuses on applying the engineering design process to assemble, redesign and optimize a hydrogen-powered sprint car. Students will engage in hands-on activities to construct, test, and refine their sprint car designs while exploring concepts like hydrogen fuel cells, energy efficiency, and mechanical systems. They will analyze performance data, identify design problems, brainstorm solutions, and implement modifications using tools and materials to enhance functionality. By integrating technical skills, teamwork, and creativity, students will gain practical experience in real-world engineering challenges and solutions.

OBJECTIVES

Build and assemble a hydrogen-powered sprint car using tools and materials to construct functional systems.

Analyze performance data using measures of central tendency and standard deviation to evaluate sprint car functionality.

Apply the engineering design process to identify problems, propose solutions, and implement modifications to improve sprint car performance.

Utilize tools and resources effectively to construct, test, and troubleshoot components of the sprint car.

Collaborate effectively to refine designs based on experimental data, trial outcomes, and observed challenges.

STANDARDS

COMMON CORE

LST.9-10.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

LST.9-10.3: Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.

LST.9-10.10: By the end of grade 10, read and comprehend science/technical texts in the grades 9–10 text complexity band independently and proficiently.

CONNECTED STANDARDS: NGSS

HS-PS1-2: Construct and revise an explanation for the outcome of a simple chemical reaction based on the outermost electron states of atoms, trends in the periodic table, and knowledge of the patterns of chemical properties.

HS-PS2-6: Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

HS-PS3-3: Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-LS2-7: Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

HS-ESS3-2: Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4: Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ETS1-1: Analyze a major global challenge to specify qualitative and quantitative criteria and constraints for solutions that account for societal needs and wants.

CONNECTED STANDARDS: ISTE

1.1.d: Students understand the fundamental concepts of technology operations, demonstrate the ability to choose, use and troubleshoot current technologies and are able to transfer their knowledge to explore emerging technologies.

1.3.a: Students plan and employ effective research strategies to locate information and other resources for their intellectual or creative pursuits.

1.3.d: Students build knowledge by actively exploring real-world issues and problems, developing ideas and theories and pursuing answers and solutions.

1.4.a: Students know and use a deliberate design process for generating ideas, testing theories, creating innovative artifacts or solving authentic problems.

1.5.b: Students collect data or identify relevant data sets, use digital tools to analyze them, and represent data in various ways to facilitate problem-solving and decision-making.

CONNECTED STANDARDS: STEL

1O: Assess how similarities and differences among scientific, mathematics, engineering, and technological knowledge and skills contributed to the design of a product or system.

1Q: Conduct research to inform intentional inventions and innovations that address specific needs and wants.

2T: Demonstrate the use of conceptual, graphical, virtual, mathematical, and physical modelling to identify conflicting considerations before the entire system is developed to aid in design decision making.

3I: Evaluate how technology enhances opportunities for new products and services through globalization.

4Q: Critique whether existing or proposed technologies use resources sustainably.

4R: Assess a technology that minimizes resource use and resulting waste to achieve a goal.

7X: Document trade-offs in the technology and engineering design process to produce the optimal design.

7Y: Optimize a design by addressing desired qualities within criteria and constraints.

SKILLS

- Technical Drawing Skills
- Understanding of Geometry and Mathematics
- Knowledge of Engineering Standards
- Attention to Detail
- Spatial Visualization
- Problem-Solving Skills
- Communication Skills
- Continuous Learning
- Collaboration Skills

STUDENT RESOURCES

- AA Batteries
- Small Philips Head Screw Driver
- Sprint Car kit
- Distilled Water
- Access to Google Sheets and Slides

INSTRUCTOR PREPARATION

Review:

Hydrogen Presentation- Sprint Car
Gears Presentation-Sprint Car
Kinematics Presentation- Sprint Car
Engineering Design Process- Sprint Car
Instructions for Think Pair Share.
Sprint Car Trial Data Log
Powering the Sprint Car Using a Fuel Cell
Producing Hydrogen with the Sprint Car Electrolyzer
Grand Prix Quick Assembly Guide

Print and review:

H2GP Sprint Quick Assembly Guide
Sprint Gear Practice
Kinematics Practice Sprint Car
Sprint Car Test Log
Pre and Post Assessment

In order to test the H2GP Sprint Car you will need a space roughly with a length of 10m and at least 5 m wide. You will also need a measuring tape and tape or cones to mark meter distances. Plan the timing of the lesson according to this availability.

SUPPLEMENTAL RESOURCES

https://plus.nasa.gov/video/how-we-know-what-we-know-about-climate-change/

Assembly Video

Fundamentals of hydrogen storage

Position, Displacement, and Distance - Nerdstudy Physics

Speed, Velocity, and Acceleration

Mode, Median, Mean, Range, and Standard Deviation (1.3)

VOCABULARY

COMMON CORE

Engineering Design Process: A systematic approach used by engineers to solve problems through creativity, testing, and iteration.

Iterative: A repetitive process of refining and improving a design or idea.

Criteria: The goals or features a design must achieve to be successful.

Constraints: Limitations or challenges, such as materials, time, or budget, that affect the design process.

Brainstorming: A group activity to generate creative ideas and solutions.

Prototype: An initial model or version of a design used for testing and improvement.

KINEMATICS

Kinematics: The study of motion without considering the forces that cause it.

Position: The location of an object in space, often described with coordinates.

Displacement: The change in position of an object, taking direction into account.

Distance: The total path traveled by an object, regardless of direction.

Velocity: The rate of change of displacement with time, including speed and direction.

Acceleration: The rate of change of velocity with time, including magnitude and direction.

Time: The duration over which motion occurs.

Vector: A quantity that has both magnitude and direction, such as velocity or displacement.

Scalar: A quantity that has only magnitude, such as speed or distance.

Graphical Analysis: The use of position vs. time or velocity vs. time graphs to analyze motion.

GEARS AND MECHANICS

Gear: A toothed mechanical device used to transfer motion and power between components.

Driver Gear: The gear connected to the power source that initiates motion.

Driven Gear: The gear that receives motion from the driver gear.

Gear Ratio: The relationship between the number of teeth on two meshing gears, determining speed and torque transmission.

Torque: A rotational force that causes an object to spin around an axis.

Rotational Speed: The rate at which an object spins, often measured in revolutions per minute (RPM).

Center Distance: The distance between the centers of two meshing gears, critical for smooth operation.

Alignment: Ensuring gears are properly positioned for smooth engagement and power transfer.

HYDROGEN AND HYDROGEN FUEL CELLS

Fuel Cell: A device that converts chemical energy from hydrogen into electricity through a chemical reaction with oxygen.

Electrolysis: A process that splits water into hydrogen and oxygen using electricity.

Proton Exchange Membrane (PEM): A component of a fuel cell that allows protons to pass through while blocking gases.

Green Hydrogen: Hydrogen produced using renewable energy through electrolysis, emitting no carbon dioxide during production.

Blue Hydrogen: Hydrogen produced from fossil fuels with carbon capture and storage (CCS) to reduce emissions.

Gray Hydrogen: Hydrogen made from fossil fuels, releasing carbon dioxide as a byproduct.

Catalyst: A substance that speeds up a chemical reaction without being consumed in the process.

Hydrogen Rainbow: A classification system for hydrogen based on its production method and environmental impact.

Energy Efficiency: The ratio of useful energy output to the total energy input in a system.

Energy Storage: Capturing energy for later use, such as storing electricity as hydrogen.

Sustainability: Meeting current energy needs without compromising future generations' ability to meet theirs.

LESSON PLAN

ENGAGE

Duration: 30 mins.

STEP 1	Pre-Assessment
STEP 2	Launch Hydrogen Presentation-Sprint Car. Show Slides 1-3.
STEP 3	Create student pairs for a Think Pair Share. Ask students “ What are some of the symptoms of Climate Change?” Lead a class discussion with student input. Answers to emphasize include: Experts point to effects like melting ice caps, rising sea levels, stronger storms, and changes to ecosystems as signs that this is one of the biggest challenges for our future.
STEP 4	Show video: https://plus.nasa.gov/video/how-we-know-what-we-know-about-climate-change/

EXPLORE

Duration: 90 mins.

STEP 1	Show slides 4-6
STEP 2	Show video: Fundamentals of hydrogen storage
STEP 3	Show slides 7-8.
STEP 4	Arrange students into groups and assign them a color of hydrogen to research.
STEP 5	Students should produce a slide explaining how that color of hydrogen is produced.
STEP 6	Students then share their slides with the class. Ensure students cite their source and produce slides that align with standard colors as shown below:

Gray Hydrogen: Produced primarily through steam methane reforming (SMR) or coal gasification, this method uses fossil fuels to extract hydrogen. It is the most common form of hydrogen production today, but it releases large amounts of carbon dioxide into the atmosphere, contributing significantly to greenhouse gas emissions. Gray hydrogen is often used because it is relatively inexpensive compared to other methods.

Blue Hydrogen: This is made using the same processes as gray hydrogen (like SMR), but with carbon capture and storage (CCS) technology to trap the carbon dioxide that would otherwise be released. While it is cleaner than gray hydrogen, it still relies on fossil fuels and has associated emissions from extraction and transportation of those fuels.

Green Hydrogen: Produced using renewable energy sources, such as wind, solar, or hydropower, to split water into hydrogen and oxygen through electrolysis. This method produces no carbon emissions, making it the cleanest form of hydrogen production. However, it is currently more expensive due to the costs of renewable energy and electrolysis infrastructure.

Brown Hydrogen: Made by gasifying coal to produce hydrogen. This method has a high environmental impact because it generates significant carbon dioxide emissions. Brown hydrogen is mostly used in regions where coal is abundant and cheap, but it is considered one of the least sustainable options.

Pink Hydrogen: Generated using electricity from nuclear power to split water into hydrogen and oxygen. Nuclear power does not emit greenhouse gases, so pink hydrogen is low in emissions. However, concerns about radioactive waste and the long-term sustainability of nuclear energy separate it from the broader category of green hydrogen.

Yellow Hydrogen: Refers specifically to hydrogen produced using solar power for electrolysis. While technically a subset of green hydrogen, the term "yellow" highlights its reliance solely on solar energy, distinguishing it from green hydrogen powered by a mix of renewable sources.

Turquoise Hydrogen: A less common type, made by breaking methane into hydrogen and solid carbon through a process called methane pyrolysis. This method does not produce carbon dioxide directly and is seen as a potential low-emission option, but it is not widely used yet due to its experimental status.

STEP 7

Review slide 9

EXPLAIN

Duration: 180 mins.

STEP 1

Review Slide 10-13

STEP 2

Provide students with materials to build electrolyzers. If needed provide groups copies of Producing Hydrogen with the Sprint Car Electrolyzer or show instructions on projector.

STEP 3

Review slides 14- 16

STEP 4

Provide students with materials to assemble fuel cell components. If needed provide groups copies of Powering the Sprint Car Motor Using a Fuel Cell.

STEP 5

Review slide 17 and support students as they troubleshoot.

STEP 6

Launch Gears Presentation Sprint Car.

Review Slides 1-2

STEP 7

Ask students "Can you think of common places where gears are used?"

Answers to encourage include:

Vehicles: Transmissions, bicycles, motorcycles.

Machinery: Conveyor systems, robots, tools.

Home Appliances: Washers, mixers, clocks.

Power Tools: Drills, saws.

Office Equipment: Printers, copiers.

Aerospace: Landing gear, spacecraft.

Medical Equipment: Surgical robots, MRI machines.

Agriculture: Tractors, harvesters.

Marine: Propulsion, steering.

Toys: RC cars, mechanical toys.

STEP 8

Review Slide 3

STEP 9

Ask students if they can tell which gear in the train shown is the driver gear.

In the gear train shown the small gear is the driver gear. According to the formula the gear ratio is determined by dividing the number of teeth of the output gear by the number of teeth of the input gear.

STEP 10	Review slides 4-7
STEP 11	Students complete Sprint Gear Practice
STEP 12	Review Slide 8
STEP 13	Provide students with the gears for their sprint car and allow them time to examine. Ask students what they think the numbers engraved on the wheel mean. They should recognize this as a gear ratio.
STEP 14	Review Slide 9-10
STEP 15	Show video: https://www.youtube.com/watch?v=RJirjpqIDrc
STEP 16	Provide H2GP Sprint Assembly Guide and/or have students follow along with video.
STEP 17	When students get to the point where they are aligning the gears, show slides 11-12.
STEP 18	After assembly, have students trouble shoot the connections in the car. Review Slides 13-14. Assist students in troubleshooting.
STEP 18	Review Slide 15

ELABORATE

Duration: 100 mins.

STEP 1	Launch Presentation Kinematics: Sprint Car. Review Slides 1-4

STEP 2	Show video: Position, Displacement, and Distance - Nerdstudy Physics
STEP 3	Review slides 5-7
STEP 4	Show video: Speed, Velocity, and Acceleration
STEP 5	Students complete Sprint Car Kinematics Practice
STEP 6	Review slide 8
STEP 7	Show video: Position/Velocity/Acceleration Part 2: Graphical Analysis
STEP 8	Review Slide 9

EVALUATE

Duration: 180 mins.

STEP 1

Ask students to design a trial run of their car. What will they need to test the functionality of the car?

Students should write down their ideas on paper or in their notebooks.

STEP 2

Teacher should walk around and listen and encourage students to consider:

What to Include in the Trial Run:

1. Track Setup:
    - Track Type: Decide on the type of track (e.g., straight, with curves, or varying surfaces) that will best simulate race conditions.
    - Length: Choose an appropriate track length that allows the car to reach top speed and test its full capabilities.

2. Environmental Conditions:
    - Surface: Test the car on different surfaces (e.g., asphalt, carpet, tile) to see how it performs in various conditions.
    - Weather: Consider how factors like temperature and humidity might affect the car's performance, especially if the race will be outdoors.

3. Data Collection Tools:
   - Stopwatch/Timers: Measure lap times to calculate speed and acceleration.
   - Distance Markers: Place markers at intervals along the track to track progress and measure specific segments of the run.

4. Trial Objectives:
   - Identify Weaknesses: Look for any weaknesses in the car's design, such as poor handling, insufficient power, or mechanical issues.
   - Optimize Strategy: Based on trial results, adjust your strategy for future races such as when to accelerate or conserve energy.

5. Safety Checks:
   - Inspection: Conduct a thorough inspection of the car before and after the trial run to ensure all components are functioning properly.
   - Safety Gear: Ensure that any necessary safety gear is worn during the trial to protect the car and the environment from damage.

STEP 3

Lead a class discussion recording the student's design ideas and guiding them to include all of the important aspects.

STEP 4

Develop a final plan as a class, suggestions include:

- Arrange a climate controlled indoor space such as basketball gym or a safe outdoor space on a dry day such as a marked off parking area with a minimum of 10 meters length of free space. Space should be at least 5 meters wide as the car will likely veer. Since the Sprint Car can not be steered a straight track is required.
- Use traffic cones or tape to mark, start, finish and 5m, 10m distance.
- Organize students to use stopwatches or timers on cell phones to record the time at each 5m marking and someone to be in charge of launching the car.
- Students should record their speed trial times and any notes on safety, weaknesses or strategy on their copy of the Sprint Car Trail Data Log.
- If car veers from the straight path have students measure the distance the car moved from the straight path and note on their Speed Log.
- Perform 10 runs for each car

STEP 5

Students help stage track for trail runs including measuring and marking:

Start
5 meters
10 meters (Finish)

STEP 6

Divide students into teams with their fully assembled cars.

Provide printed copies of Sprint Car Test Log.

Students perform speed trials and record their data on the Sprint Car Test Log.

STEP 7

Create a Spreadsheet Titled Sprint Car Trial Data Log

(Use provided example as a guide) Walk students through using Sheets to analyze their data from the Sprint Trail Data Log. Depending on the level of the students this can be given as independent work or performed as teacher demonstration.

STEP 8

Students create and format a table to record their data. Demonstrate how to shade cells and create averages for trials.

STEP 9

Generate a graph of position vs time*

STEP 10

Generate a graph of speed vs time*

*Notes for teachers on generating graphs in sheets.

Highlight the data you wish to graph. Select “Insert” and then “Chart”.

On the right hand side under Chart Editor select “ Line Chart”.

Click on “Add X Axis” and select Time.

Under “Series” Right click on Time (three dots) and select Remove.

You should now have a line chart that represents your data.

Go to “Customize” and “Chart and Axis Title”. Add a main title and X and Y Axis labels using the drop down menu.

EXTENSION

Duration: 180 mins.

STEP 1

Launch Presentation: Engineering Design Sprint Car

Review Slides 1-3

STEP 2	Show slide 4
STEP 3	Students work in teams to develop a problem statement based on the benchmark trial data for their car. The statement should cover each of the bullet points on slide 4. Common problems students will identify include: Car not driving straight Slower than average velocity Tires or Gears Slipping Car not completing 10 m runs
STEP 4	Review Slide 5 Students should brainstorm solutions with their groups. Provide sticky notes to write ideas or a section of a white board. Some solutions include: Changing gear ratio Using lubricants on axle Modifications to make car lighter Modifications to make tires grip better Balancing weight of car components Ensure students only change one variable at a time. Explain this is important for determining cause and effect.
STEP 5	Review Slide 6
STEP 6	Students should produce a plan for a final solution. Encourage sketches with labels and dimensions.
STEP 7	Review Slide 7
STEP 8	Allow students time to implement their redesigns. This could take several meetings. Instructors will need to help provide resources and remove obstacles for students.

STEP 9	Review Slide 8
STEP 10	Repeat the Sprint Trails. Provide students with a new log for data. After the trial, enter the new data in the "Redesign" Tab of the Sprint Car Trail Data Log.
STEP 11	Review Slide 9
STEP 12	Show video: Mode, Median, Mean, Range, and Standard Deviation (1.3)
STEP 13	Create a new tab on your Sprint Car Trial Data Log called Data analysis. Using the provided example as a guide, walk students through using sheets to calculate the measures of central tendency for each trial as well as the standard deviations.
STEP 14	Review Slide 10
STEP 15	Post Assessment

SOURCES

https://akotorque.com/resources/torque-101/

https://www.sciencedirect.com/science/article/pii/S0254058424008356

https://sketchplanations.com/isometric-projection