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Washington State Science Olympiad Pilot Event

Sustainable Energy

2024 - 25

Introduction

Helping prepare today's young people to address tomorrow's challenges is the linchpin of educators' work. Thus, the urgent and multifaceted challenges of climate change merit our attention. Finding alternatives to fossil fuels is one important response to addressing climate change as is finding energy storage solutions from intermittent renewable sources like solar and wind. In this year's Sustainable Energy event, teams will design, build, and test a chemical energy storage solution (battery) and demonstrate their knowledge of the chemistry, history, and advances in battery technology.

Participants will be evaluated in three areas:

1. Design log
2. Battery testing
3. Written test

As with other Science Olympiad events, the criteria for success require that the event be engaging (i.e., in the participants' zone of development), fair (the event is accessible to a wide range of teams, and the testing experience for all participants is the same), and inspiring. Participants and organizers alike will take reasonable precautions to ensure the safety of all involved.

Sustainable Energy: Storage

1. **DESCRIPTION:** Teams construct and calibrate a battery, a device that converts chemical energy to electrical energy. Teams will adjust their battery to output a supervisor-specified voltage across a supervisor-specified load. Additionally, teams complete a written test on the principles of energy storage.

   A TEAM OF UP TO: 2 **EYE PROTECTION:** C (chemical-splash goggles) **IMPOUND**: YES
   APPROX TIME: 50 min

2. **EVENT PARAMETERS**
   a. Each team may bring one three-ring binder of any size containing information in any form and from any source, attached using the available rings. Pages that are not attached may not be used. Sheet protectors, lamination, tabs and labels are permitted. Participants may remove information or pages for their use during any part of the event.
   b. Each team may also bring tools, supplies, writing utensils, and two stand-alone calculators of any type for use during any part of the event. Each team must bring their device and a Design Log for scoring.
   c. The event supervisor will provide the testing materials listed in the COMPETITION section.
   d. Participants must be able to answer questions regarding the design, construction, and operation of the battery per the Building Policy.

3. **CONSTRUCTION PARAMETERS**
   a. Participants will construct a battery.
      i. Electrodes shall be made from the following materials: copper, zinc, aluminum, iron, nickel, steel, or tin.
      ii. Participants may choose to use 5% distilled white vinegar or salt water as the electrolyte for their battery [see 5.II.f.i]
      iii. The portion(s) of the battery containing electrolyte must remain vented to room air. Batteries not meeting this parameter will not be tested.
   b. The battery shall be able to provide a target voltage across **a supervisor supplied load** for 60+ seconds **[see 5.II.e.2].**
   c. Prior to the start of the competition, participants will impound::
      i. All non-liquid components needed to finish assembling their battery onsite including cathode, anode, conductors, external casing, optional internal casing, etc.
         1. The components are sufficiently unassembled so that supervisors can confirm the cathode and anodes used visually match the supplied samples. [3.c.iii]
      ii. Any assembly tools needed to assemble the battery, including funnels or other tools needed to transfer the electrolyte to the battery.
      iii. Samples of the cathode and anode material used. These samples must be at least 2 cm by 2 cm, are not considered part of the battery, and may not be returned to the team. Teams not including samples will not be allowed to test their battery.
      iv. Labeled, leak-proof bin for testing and for transporting battery at conclusion of testing.

v. A written request for quantity and type of electrolyte to be provided by the supervisor (see 5.f.i).
vi. The samples required in part ii and written request in part v must be enclosed in a sealed, transparent plastic bag labeled with the team number.

d. Device output leads
   i. One wire (labeled +) and a second wire (labeled -) extending from device
   ii. Length of 20 - 30 cm
   iii. Insulated except where it will connect to **supervisor-provided load and volt meter.**
   iv. Terminated with alligator clips or approximately 1 cm of uninsulated 22 AWG wire (suitable for inserting into a standard breadboard).

e. In the ready-to-test configuration,
   i. The battery must be self contained
      1. It must NOT mark the testing environment
      2. It must NOT leak
      3. **It must be self-supporting and able to be weighed on a supervisor-provided scale**
   ii. The total molarity of the solution in the battery is provided by the distilled white vinegar or salt water which shall be provided by the supervisor and NOT be deliberately influenced by participants' materials
   iii. The battery must have a maximum voltage potential between the output leads less than 12 volts.

f. The battery output may be modified by changing the collector physically (concentration of electrolyte, size and shape and orientation of cathode or anode, etc.) or electronically (connecting cells in series or parallel)

g. Pre-assembled circuit boards are not permitted. Participants must be able to demonstrate that no pre-assembled circuit boards are present, including disassembling the device if requested.

h. The device may include passive electronic components such as: resistors, capacitors, switches, etc. Integrated circuits, buck/boost converters, active components, etc. are not permitted.

4. **DESIGN LOG**: Participants' design log will document the steps participants took to optimize their battery. The log will include
   a. Title page: A front cover labeled with the Team Name and the Team Number for the current tournament.
   b. Battery chemistry, **BC**: A brief (250 words or less) description of the specific battery chemistry participants chose to build, using their own words and appropriately-cited sources
      i. Citations do not count toward word count
   c. Safety, **S**: Safety precautions during battery construction, testing, and disposal
   d. Output 1, $\mathbf{O_1}$: Output of test of initial configuration:
      i. Data table and graph of voltage vs. time: 10 or more points
      ii. Two or more relevant qualitative observations
   e. Output 2+, $\mathbf{O_{2\text{-}3}}$: Output of two or more additional iterations
      i. Rationale for changes to initial battery configuration
      ii. Composition, size, and shape of cathode, anode, electrolyte
      iii. Circuit type (series vs. parallel)
      iv. Etc.

f. If a 3-D printer, laser cutter, CNC machine or similar device was used by the team as a tool to build the team's device, or any component thereof, the following information must also be supplied in the log. Any such parts purchased as an end item or as part of a kit do NOT require this information.
   i. Information about the tool hardware, software, materials, and supplies used.
   ii. Details of the source of any digital files (e.g., CAD, STL, OBJ) utilized by the tool, including but not limited to when and where the file was obtained, including the web address if downloaded from the internet.
   iii. Descriptions of how the team constructed the final device from the tool created components.

g. Participants are encouraged to submit a copy of their design log; its return is not guaranteed.

5. THE COMPETITION

Part I: Knowledge Test

a. Teams will be given a minimum of 20 minutes to complete a written test consisting of some combination of multiple choice, true-false, completion, and calculation questions/problems.
b. Topics:
   i. Big ideas and key inventors in history of development of batteries
   ii. Factors that affect rate and strength of reactions in typical batteries
   iii. Limitations of current batteries: energy density, safety, disposal, environmental impact
   iv. Current advances in battery chemistry
   v. C division only: summary of recent published research
      1. Two or more weeks prior to the tournament, supervisors will identify two important scientific papers, and communicate with teams about how to access those papers
      2. Participants will be asked to summarize key ideas, method(s) for generating data, and larger implication(s) of results.
   vi. Non-chemical methods to store energy
c. Overall point value of written test will be approximately evenly distributed among topics
d. Computational questions will be appropriate for the audience

Part II: Battery test:

e. After the impound period is complete, the supervisor will announce the target voltage and electrical load.
   i. Voltage:
      1. Between 1 and 5 V
         a. Invitationals / Regionals: 1 V intervals
         b. State: 0.5 V intervals
   ii. Load:
      1. **The battery load will be a 1000 ohm resistor or resistor network supplied by the supervisor.**
f. During their competition block, each team will present their impounded materials for inspection. The team will be given **5 minutes** to finish assembling their battery.
   i. Supervisor will provide each team with participants' pre-identified choice of

1. Up to 100 mL of 5% distilled white vinegar
2. Up to 100 mL of deionized (preferred) or distilled water
3. Up to 20 g of NaCl
4. Some combination of the above

g. When participants are ready or at the conclusion of the 5-minute build session, participants will quantify their battery's performance at one or more testing stations, identical to the extent feasible.

ii. Participants place their device on a supervisor-provided scale. Supervisors record the mass of the completed dry battery, including electrodes, casings, interconnecting conductors, leads, and any other components that are part of the completed battery. **This weighing does not include liquid electrolyte.**

iii. Supervisors record the mass of the electrolyte(s) participants requested.

iv. Participants remove their device from the scale, place it in their leak-proof bin for testing and connect the leads to the electrical load and supervisor-supplied multimeter. The reading on the multimeter must not be visible to the participants before they declare their battery ready in step vi below. At the supervisor's discretion, the readings may be made visible to the participants after this point.

v. Participants add the liquid electrolyte.

vi. **Sometime between 0 and 60 seconds after beginning to add electrolyte to the battery,** participants declare that the battery is ready for testing and the timer starts.

1. After the battery is declared ready, participants may not touch or otherwise modify their battery.
2. If participants do not declare that their battery is ready, the timer will start automatically **60 sec after the start of electrolyte addition** and the team will receive a competition violation.

vii. The supervisor will record the voltage drop across the battery terminals at 20, 30, 40, and 60 seconds after the battery has been declared ready **or the 60 second period has elapsed [5.vi].**

viii. At the conclusion of the battery test, supervisors will share recorded scores (and penalties, if any) with participants.

ix. Teams may take their device or, if they wish to file an appeal, leave it.

6. SCORING

a. Final Score (FS) = Design Log (DL) + Battery (B) + Knowledge Test (K). The maximum possible FS is 100 points. High score wins.

b. Design Log **DL**: 15 points possible

i. BC [0 - 4 points possible] + S [0-2] + O_1 [0-4] + $O_{2\text{-}3}$ [0-5]

c. Battery, **B**: 45 points possible

i. Target voltage score, **TVS**

a. If $V_{actual} < V_{target}$: V_{actual} / V_{target}

b. If $V_{actual} > V_{target}$: V_{target} / V_{actual}

c. If $V_{actual} = V_{target}$: 1

d. V_{target} is always positive. If V_{actual} is negative, the absolute value of V_{actual} shall be used in the above formulas but the resulting TVS value shall be multiplied by 0.80.

ii. $TVS_{total} = TVS_{@20s} + TVS_{@30s} + TVS_{@40s} + (TVS_{@60s} * 1.5)$

iii. Efficiency, **E**: $TVS_{total} * \sqrt{\frac{lowest\ mass}{team\ mass}}$

iv. Overall battery score, **B**: $[\mathbf{E_{team}} / \mathbf{E_{highest}}] * 45$

v. Tiers and penalties:

1. Participants whose devices have no construction violations will be placed in Tier 1.
2. Participants whose devices have construction violations will be placed in Tier 2, behind all Tier 1 teams.
3. Participants who have competition violations or who do not impound their devices on time will be placed in Tier 3, behind all Tier 2 teams.

d. Knowledge test, **K**: 40 points possible

i. K = (team score on written test / highest score on written test) * 40

e. Ties will be broken using pre-identified questions on the written test.

Recommended resources:

Clean Energy Institute: https://www.cei.washington.edu/lesson-plans/aluminum-air-battery/

American Chemical Society:
https://www.acs.org/education/whatischemistry/landmarks/drycellbattery.html