Materials Science

Division C

Georgia Tech Event Workshop Series
2024-25

Science Olympiad at Georgia Tech®

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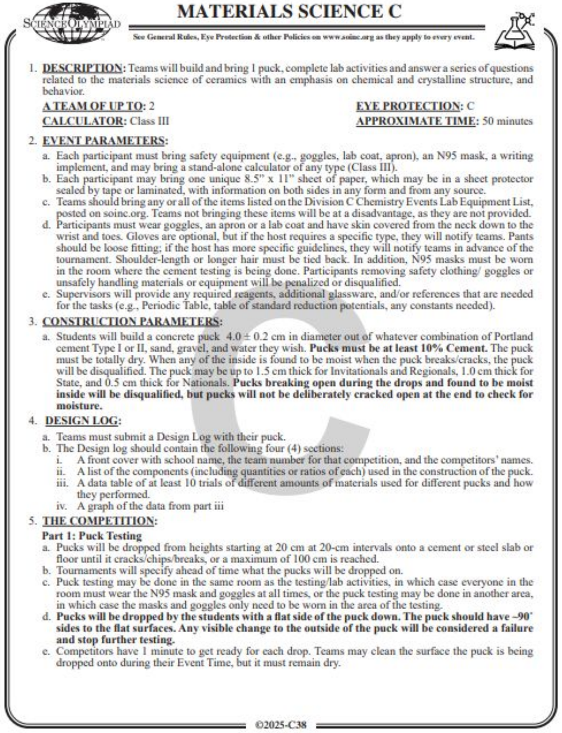
The Rules Sheet

Brief Description of Event:

- 3 parts: puck testing, written test, and lab activities
- Written test is weighted the heaviest, followed by lab activities (usually physics-based)and puck testing

What to Bring:

- Build (puck)
- Lab equipment (found on page 74 of the rules)
- N-95 mask
- Design log
- Pencils and calculator (can be graphing)
- 2 cheat sheets (one per participant)



MATERIALS SCIENCE C

See General Rules, Eye Protection & other Policies on www.soinc.org as they apply to every event.

1. **DESCRIPTION:** Teams will build and bring 1 puck, complete lab activities and answer a series of questions related to the materials science of ceramics with an emphasis on chemical and crystalline structure, and behavior.

   A TEAM OF UP TO: 2 **EYE PROTECTION:** C
   CALCULATOR: Class III **APPROXIMATE TIME:** 50 minutes

2. **EVENT PARAMETERS:**
   a. Each participant must bring safety equipment (e.g., goggles, lab coat, apron), an N95 mask, a writing implement, and may bring a stand-alone calculator of any type (Class III).
   b. Each participant may bring one unique 8.5" x 11" sheet of paper, which may be in a sheet protector sealed by tape or laminated, with information on both sides in any form and from any source.
   c. Teams should bring any or all of the items listed on the Division C Chemistry Events Lab Equipment List, posted on soinc.org. Teams not bringing these items will be at a disadvantage, as they are not provided.
   d. Participants must wear goggles, an apron or a lab coat and have skin covered from the neck down to the wrist and toes. Gloves are optional, but if the host requires a specific type, they will notify teams. Pants should be loose fitting; if the host has more specific guidelines, they will notify teams in advance of the tournament. Shoulder-length or longer hair must be tied back. In addition, N95 masks must be worn in the room where the cement testing is being done. Participants removing safety clothing/ goggles or unsafely handling materials or equipment will be penalized or disqualified.
   e. Supervisors will provide any required reagents, additional glassware, and/or references that are needed for the tasks (e.g., Periodic Table, table of standard reduction potentials, any constants needed).

3. **CONSTRUCTION PARAMETERS:**
   a. Students will build a concrete puck 4.0 ± 0.2 cm in diameter out of whatever combination of Portland cement Type I or II, sand, gravel, and water they wish. **Pucks must be at least 10% Cement.** The puck must be totally dry. When any of the inside is found to be moist when the puck breaks/cracks, the puck will be disqualified. The puck may be up to 1.5 cm thick for Invitationals and Regionals, 1.0 cm thick for State, and 0.5 cm thick for Nationals. **Pucks breaking open during the drops and found to be moist inside will be disqualified, but pucks will not be deliberately cracked open at the end to check for moisture.**

4. **DESIGN LOG:**
   a. Teams must submit a Design Log with their puck.
   b. The Design log should contain the following four (4) sections:
      i. A front cover with school name, the team number for that competition, and the competitors' names.
      ii. A list of the components (including quantities or ratios of each) used in the construction of the puck.
      iii. A data table of at least 10 trials of different amounts of materials used for different pucks and how they performed.
      iv. A graph of the data from part iii

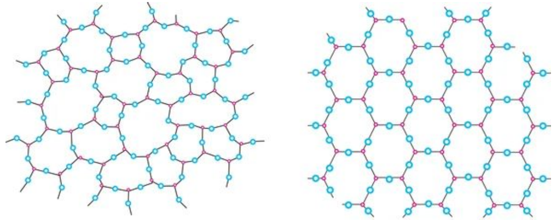
5. **THE COMPETITION:**
   Part 1: Puck Testing
   a. Pucks will be dropped from heights starting at 20 cm at 20-cm intervals onto a cement or steel slab or floor until it cracks/chips/breaks, or a maximum of 100 cm is reached.
   b. Tournaments will specify ahead of time what the pucks will be dropped on.
   c. Puck testing may be done in the same room as the testing/lab activities, in which case everyone in the room must wear the N95 mask and goggles at all times, or the puck testing may be done in another area, in which case the masks and goggles only need to be worn in the area of the testing.
   d. **Pucks will be dropped by the students with a flat side of the puck down. The puck should have ~90° sides to the flat surfaces. Any visible change to the outside of the puck will be considered a failure and stop further testing.**
   e. Competitors have 1 minute to get ready for each drop. Teams may clean the surface the puck is being dropped onto during their Event Time, but it must remain dry.

DIFFICULT TOPICS

Topic 1: Structure

Largely chemistry-based

- Amorphous Glasses: Randomly arranged atoms or molecules without long-range order.
- Crystalline Ceramics: Atoms or ions arranged in a repeating lattice structure.
- Defects: Imperfections in the structure that influence strength, conductivity, and durability.



The appearance of the amorphous glass   The appearance of crystalline glass

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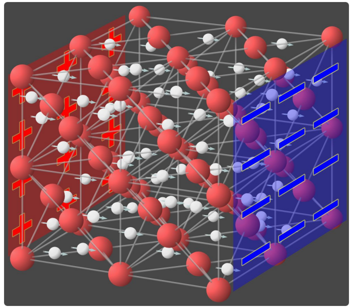
Topic 2: Characterization

- X-Ray Diffraction (XRD): Used for identifying crystalline phases, requiring an understanding of Bragg's law and diffraction patterns.
- Scanning Electron Microscopy (SEM): Provides detailed imaging of surface structures, but interpreting micrographs can be non-trivial.

- **Interpreting complex datasets and understanding instrument limitations.**

Topic 3: Thermal & Electrical Properties

- Thermal Properties: Include conductivity, expansion, and resistance to thermal shock.
- Electrical Properties: Dielectric strength, conductivity, piezoelectricity, and ionic conductivity.
- Complexity: Requires linking atomic-level phenomena to macroscopic behavior.



COMMON QUESTIONS

All of the following questions have been pulled from past YJI exams (which can be found on our website) or the Text Exchange on SciOly Wiki

Question 1

- Using Young's modulus and shear modulus, derive an equation that relates those two and produces Poisson's ratio. Then calculate Poisson's ratio with that equation

Young's Modulus (E): Relates stress (σ) to strain (ϵ) in a material under axial loading:

$$E = \frac{\text{Axial Stress}}{\text{Axial Strain}}$$

Shear Modulus (G): Relates shear stress (τ) to shear strain (γ):

$$G = \frac{\text{Shear Stress}}{\text{Shear Strain}}$$

Poisson's Ratio (ν): Ratio of lateral strain ($\epsilon_{\text{lateral}}$) to axial strain ($\epsilon_{\text{axial}}$):

$$\nu = -\frac{\epsilon_{\text{lateral}}}{\epsilon_{\text{axial}}}$$

$$G = \frac{E}{2(1+\nu)}$$

$$\nu = \frac{E}{2G} - 1$$

Question 2

34. (2.00 pts) A ceramic undergoes a crack propagation study, and it is observed that the crack deflects at grain boundaries. This toughening mechanism is most effective in:

- A) Fine-grained ceramics
- B) Coarse-grained ceramics
- C) Single crystals
- D) Amorphous ceramics

Question 3

During cold working of metals, the increase in strength and hardness is primarily due to:

A) Reduction in grain size
B) Increased dislocation density
C) Formation of a more ductile phase
D) Decrease in atomic packing factor

Tips from a Veteran

- Make sure you read over the entire rules sheet!
- Even if you're not confident with your build, make/bring a design log.
- If you don't have access to a lab for practice, look over previous tests' lab components and plan out how you would approach that specific type of lab.
- If you don't have a strong background in chemistry or physics, borrow a textbook from your school to learn some foundational knowledge.

Additional Resources

Previous tests through scioly wiki test exchange or websites of specific major invitationals

MIT- Intro to Solid State Chemistry Course

WebMO Online Molecular Modeling

NC State Scioly Resource Page

THANKS!