2026 USA-North America AI Olympiad (USA-NA-AIO) Round 2 Problems Design and Rationale

USA AI Olympiad (USAAIO)

0. Design Principles of the Competition Problems

The problems in this competition are designed to reflect the core intellectual demands of modern AI, emphasizing depth, rigor, and creativity.

- **First-Principles Understanding**
  All problems emphasize deriving and building models from first principles. Black-box usage of AI models is significantly penalized.
- **Integration of Mathematics and Implementation**
  The competition evaluates both mathematical reasoning and practical coding ability, requiring students to translate theory into working systems.
- **Coverage of Foundational and Modern AI**
  Problems span both classical AI concepts and modern advances such as Transformers and generative models.
- **Model Design and Creativity**
  Students are expected to design and integrate models in a principled and creative manner, rather than applying standard templates.

1. Problem 1: Linear Attention with Relative Positional Encoding

1.1. Overview

Derive, analyze, and implement linear attention from first principles, and build a Transformer-based classifier.

1.2. Problem Description

- Derive linear attention from standard attention
- Analyze quadratic complexity of vanilla attention
- Implement linear attention with relative positional encoding
- Build multi-head attention with batching support
- Construct a Transformer classifier
- Apply to a binary classification task

1.3. Key Skills Assessed

Understanding of attention, complexity analysis, Transformer design, positional encoding integration, and tensor operations.

1.4. Rationale

Tests first-principles understanding, modern relevance (linear attention), system design ability, and theory-to-implementation skills.

2. Problem 2: Inverse Central Force Field Reconstruction

2.1. Overview

Recover the source and governing law of a central force field from observed data.

2.2. Problem Description

- Infer source location from a discretized vector field
- Recover unknown magnitude-distance relationship
- Develop a generalizable model

2.3. Key Skills Assessed

Inverse problem solving, physics-to-AI translation, vision abstraction, model selection, and training from scratch.

2.4. Rationale

Expands AI to scientific domains, tests abstraction ability, highlights limitations of pretrained models, and emphasizes global reasoning.

3. Problem 3: Derivation of Diffusion Model Loss Function

3.1. Overview

Derive the training objective of diffusion models from first principles.

3.2. Problem Description

- Derive the loss function step by step
- Analyze forward and reverse stochastic processes
- Apply Bayesian reasoning

3.3. Key Skills Assessed

Probabilistic modeling, stochastic processes, Bayes' rule, Gaussian distributions, and KL divergence.

3.4. Rationale

Highlights mathematical foundations of generative AI and reinforces the importance of deep theoretical understanding.

4. Problem 4: Semi-Supervised Shape Classification under Constraints

4.1. Overview

Build a classifier under limited supervision and strict constraints.

4.2. Problem Description

- Classify triangle, rectangle, or circle images
- Only 20% labeled data; 80% unlabeled
- No validation dataset provided
- Pretrained models are prohibited

4.3. Key Skills Assessed

Semi-supervised learning, CNN design, pseudo-labeling, clustering methods, and validation strategy design.

4.4. Rationale

Tests learning under constraints, encourages hybrid methods, and evaluates experimental rigor.

5. Problem 5: Latent Function Mixture and Parameter Inference

5.1. Overview

Recover latent structure and estimate parameters from mixed-function data.

5.2. Problem Description

- 400 data points from four function types (linear, logarithmic, exponential, sinusoidal)
- Unknown function type per point
- Unknown parameters per function
- Jointly perform clustering and parameter estimation

5.3. Key Skills Assessed

Latent variable modeling, clustering, function fitting, attention-based reasoning, and structured model design.

5.4. Rationale

Tests ability to discover hidden structure, leverage global relationships, and design multi-stage solutions.