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A Statistics

This section provides comprehensive quantitative and qualitative analyses of **SEEPHYS**’s composition. All data reflects the final curated version after expert validation and de-duplication. Table 5 presents the statistical summary of the dataset.

Our **SEEPHYS** comprises of 2,000 rigorously validated questions paired with 2,245 diagrams (averaging 1.12 images per question). The questions span 7 core physics fields and are stratified across 8 knowledge levels from middle school to PhD qualifying exams. Notably, 18.6% of problems target PhD-level reasoning, while 22.6% represent advanced Olympiad challenges. The benchmark emphasizes multimodal reasoning: 75% of questions are Vision-Essential, which necessarily requires diagram interpretation for solving (e.g., analyzing Feynman diagrams), while 25% are Vision-Optional, where visuals supplement text. Questions are language-balanced (1,039 English vs. 961 Chinese) and 88% have multi-step reasoning annotations, validated via expert annotation. Visual diversity is ensured through 21 diagram types (e.g., circuit schematics, free-body diagrams), curated by domain experts. The dataset’s composition supports granular evaluation of MLLMs’ physics understanding across textual, visual, and reasoning dimensions.

Figure 5: Statistics of our benchmark.

Statistics	Number
Total Questions	2,000
Total Images	2,245
Visual Enhanced Samples	2,000
Subjects	7
Diagram Types	21
EN: CN	1039: 961
Reasoning	88%
<i>Vision Enrichment Levels</i>	
Vision-essential	75%
Vision-optional	25%
<i>Knowledge Levels</i>	
Middle School	5.1%
High School	12.5%
Beginner Olympiad	5.4%
Advanced Olympiad	22.6%
Undergraduate	17.8%
Senior Undergraduate	11.0%
Master	7.3%
PhD	18.6%

A.1 Attributes

The following are the basic contents of the 7 covered **subjects**:

- **Classical Mechanics (CM)**: The study of motion and forces on macroscopic objects, from linear motion, circular motion, projectile to planetary orbits.
- **Electromagnetism (EM)**: Examines electric/magnetic fields and their interactions with matter, covering RC circuits to Maxwell’s equations.
- **Astrophysics, Cosmology & Gravitation (ACG)**: Investigates celestial phenomena, universe evolution, and gravitational interactions at all scales.
- **Optics (OPT)**: Focuses on light behavior (reflection/refraction) and its applications in lenses, lasers, and optical technologies, this section also covers wave-related physics of acoustics.
- **Atomic, Molecular, Nuclear & Particle Physics (AMONP)**: Studies fundamental particles and their interactions, spanning quarks to complex nuclei. It also contains emergent properties of solids/liquids and novel material design.
- **Quantum Mechanics, Information & Technology (QMIT)**: Explores quantum systems for computing and communication applications.
- **Thermodynamics & Statistical Mechanics (TSM)**: Analyzes energy transfer and microscopic behavior of particle ensembles.

The following are the basic contents of the 21 covered **diagram types**:

- **Charge Distribution**: Visualizes spatial arrangements of electric charges and their field effects.
- **Feynman Diagram**: Represents particle interactions through standardized symbolic notation in quantum field theory.
- **Relativity and Gravity**: Depicts spacetime curvature and relativistic effects near massive objects.
- **Atomic Physics**: Illustrates atomic energy levels, transitions, and spectral phenomena.

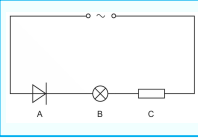
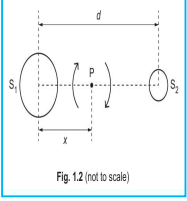
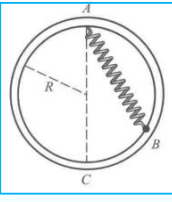
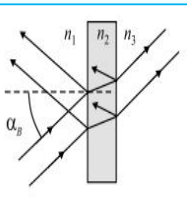
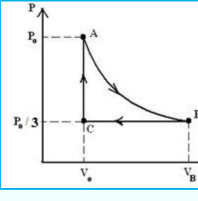
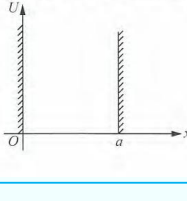
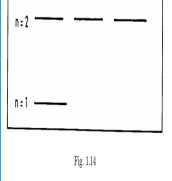
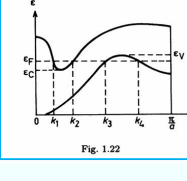
Image:  Subject: EM Level: Middle Vis: Essential	Question: The figure shows this power supply connected in a circuit. In each time period of the a.c., 1.5×10^{17} electrons pass through component A. The charge on an electron is $1.6 \times 10^{-19} \text{C}$. Calculate the average current in the circuit during one time period.	Image:  Subject: ACG Level: High Vis: Essential	Question: The stars S_1 and S_2 rotate with the same angular velocity ω about a point P, as illustrated in Fig. 1.2. Point P is at a distance x from the centre of star S_1. The period of rotation of the stars is 44.2 years. By considering the forces acting on the two stars, deduce an expression for the ratio of the masses of the stars.
Image:  Subject: CM Level: UG Vis: Essential	Question: 一根原长 l_0 的弹簧, 当下端悬挂质量为 m 的重物时, 弹簧长 $l = 2l_0$。现将弹簧一端悬挂在竖直放置的圆环上端 A 点, 设环的半径 $R = l_0$, 把弹簧另一端所挂重物放在光滑圆环的 B 点, 如图所示。已知 AB 长为 $1.6R$。当重物在 B 无初速地沿圆环滑动时, 试求重物在 B 点的加速度。	Image:  Subject: OPT Level: SUG Vis: Essential	Question: Determine the energy transmission coefficient T of a glass plane-parallel plate with $n_2 = 1.5$ in air ($n_1 = n_3 = 1.0$) when linearly polarized light with polarization azimuth $\theta_0 = 30^\circ$ is incident at the Brewster angle α_B.
Image:  Subject: TSM Level: BO Vis: Essential	Question: A monatomic ideal gas undergoes the reversible cyclic process (ABCA) shown in the PV diagram. Process $A \rightarrow B$ is adiabatic. What is the efficiency of this engine?	Image:  Subject: QMIT Level: AO Vis: Optional	Question: 势阱中的粒子不能到达 $x \leq 0, x \geq a$ 位置, 粒子的势能为零, 动能取为经典动能, 质量记为 m, 将氢原子中电子的能量取为经典动能与库仑势能之和, 试求电子的基态 (能量最低的定态) 轨道半径和能量。
Image:  Subject: AMONP Level: MA Vis: Optional	Question: Consider the ground state and $n = 2$ states of hydrogen atom. There are four corrections to the indicated level structure that must be considered to explain the various observed splitting of the levels. These corrections are: (a) Lamb shift, (b) fine structure, (c) hyperfine structure, (d) relativistic effects. Which of the above apply to the $n = 2, l = 1$ state? Answer in the name of the corrections.	Image:  Subject: AMONP Level: PhD Vis: Essential	Question: Figure shows an energy versus wave vector diagram for electrons in a one-dimensional solid. If n is the number density for electrons and p is that for holes, what can be inferred about p/n?

Figure 6: Cases of our SEEPHYS.

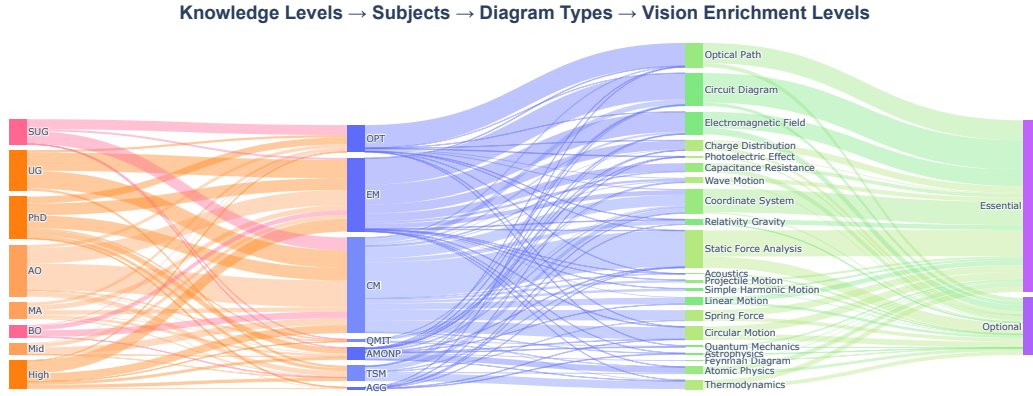


Figure 7: The Distribution of knowledge levels, subjects, diagram types, and vision enrichment levels.

- **Static Force Analysis:** Demonstrates equilibrium conditions through free-body diagrams and force vectors.
- **Photoelectric Effect:** Shows electron emission processes under photon irradiation with energy thresholds.
- **Linear Motion:** Characterizes one-dimensional kinematics with position-time/velocity-time graphs.
- **Coordinate System:** Provides reference frames for analyzing physical quantities in 2D/3D space.
- **Astrophysics:** Models celestial phenomena like stellar evolution or orbital mechanics.
- **Spring Force:** Displays Hooke’s law applications and oscillatory systems with restoring forces.
- **Optical Path:** Traces light propagation through media with reflection/refraction principles.
- **Simple Harmonic Motion:** Visualizes periodic motion through phase-space plots or pendulum dynamics.
- **Quantum Mechanics:** Represents wavefunctions, potential wells, and quantum superposition states.
- **Circular Motion:** Analyzes centripetal forces and angular kinematics in rotational systems.
- **Thermodynamics:** Charts thermodynamic cycles, heat engines, and entropy changes.
- **Acoustics:** Demonstrates sound wave propagation, interference, and standing wave patterns.
- **Circuit Diagram:** Standardized schematics for electrical networks with component symbols.
- **Projectile Motion:** Parabolic trajectories under uniform gravity with drag effects.
- **Wave Diagram:** Graphical representations of wavelength, frequency, and wave interference.
- **Electromagnetic Field:** Maps field lines and flux distributions in electric/magnetic systems.
- **Capacitance Resistance:** Characterizes RC circuits with charge/discharge time constants.

Figure 6 shows samples of our **SEEPHYS**. Moreover, we present the distributions of knowledge levels, subjects, diagram types, and vision enrichment levels in Figure 7.

A.2 Data Source

We comprehensively collect visual Physics problems from existing public question repositories:

Master’s and PhD. We select questions with Master’s and PhD qualifying exams level from Major American Universities Ph.D. Qualifying Questions and Solutions. This collection comprises problems from graduate-school entrance and qualifying examinations at seven major U.S. universities, spanning seven volumes: Mechanics, Electromagnetism, Optics, Atomic, Nuclear and Particle Physics, Thermodynamics and Statistical Physics, Quantum Mechanics, and Solid State Physics. The series is distinguished by its comprehensive coverage, with problems that span a wide spectrum of topics within each area and frequently overlap multiple areas. These problems are notable for their

versatility in applying physical laws and principles to up-to-date, realistic situations, while often requiring minimal complex mathematical manipulation. They effectively blend the objectives of enhancing the understanding of physical principles with the ability for practical application.

Undergraduate. This collection includes College Physics, General Physics, Theoretical Mechanics and Wave Optics. College Physics designs for students in science and engineering disciplines at general higher education institutions, offering broad coverage and a combination of varying difficulty levels. General Physics covering a wide spectrum of foundational university physics, this collection focuses on the analysis of problem-solving strategies and the application of fundamental methods, often presenting multiple solution approaches. Theoretical Mechanics covers all the teaching contents of theoretical mechanics and includes highly specific exercises, emphasizing the techniques for solving practical problems using general theorems and methods. Wave Optics presents problems related to a wide scope of wave phenomena in optics, studied within the framework of the university course of general physics. Largely associated with visual-spatial perception.

Olympiad competitions. The International Physics Olympiad (IPhO) is a premier global competition featuring problems of exceptional difficulty and innovative conceptual design, spanning mechanics, electromagnetism, thermodynamics, optics, and modern physics. Its challenges emphasize multidimensional problem-solving, requiring participants to synthesize physical principles in non-traditional contexts, such as astrophysical systems or nanotechnology. Problems often test advanced mathematical techniques, including tensor analysis in continuum mechanics, and demand critical modeling skills, such as dimensional analysis or symmetry-based simplifications. The Chinese Physics Olympiad (CPhO), renowned for its theoretical rigor and computational intensity, integrates calculus deeply into physics problem-solving, employing methods like variational principles in constrained dynamics. Its multi-stage problems frequently involve layered complexities, for instance, incorporating relativistic corrections in electromagnetic boundary-value problems, under strict time constraints. The CPhO’s quality aligns with the IPhO, with some problems exceeding its difficulty, making it one of Asia’s most demanding competitions.

Middle and high school. Past examination papers from the Cambridge Assessment International Education for IGCSE Physics and AS & A-Level Physics constitute this source. The data quality is high, reflecting a well-established and internationally recognized curriculum. These problems are characterized by their structured approach to assessing physics knowledge and understanding, ranging from fundamental concepts at the IGCSE level to more advanced topics in the AS & A-Level, with some questions incorporating elements of undergraduate-level content. The questions emphasize conceptual clarity, data interpretation, and the application of physics principles to varied contexts.

A.3 Annotators Information

For data annotation and evaluation, we recruit 7 annotators from engineering and physics programs, consisting of 4 undergraduates, 3 PhD candidates. All annotators demonstrated strong competencies in both secondary and tertiary-level physics through rigorous qualification assessments. One undergraduate student and one PhD candidate, both highly familiar with all knowledge levels covered by this benchmark, conduct a professional secondary review of the annotation results. Since all annotators are coauthors of this study, they are sufficiently motivated to participate in the annotation task and do not require additional compensation or benefits. Furthermore, this research is dedicated to academic AI evaluation and does not involve recruiting human subjects, making it exempt from Institutional Review Board (IRB) regulations. As part of the institutional research activities, all data used in this work were obtained from publicly available and legally permissible sources, with no collection of private or protected sensitive demographic information.

B Limitations

B.1 Process Reward

Many current models are capable of generating responses that include intermediate explanatory steps, which may reflect their internal logical reasoning patterns. This is a valuable, refined evaluation of LLM physics reasoning. However, due to the high cost of process annotation and the inherent uncertainty in evaluation (intermediate results can be expressed in multiple ways, and some problems may have multiple valid solutions), this study so far provides outcome-based reward signals. Future

work should focus on improving the reliability of process evaluation and integrating it with outcome accuracy to design a comprehensive metric for assessing reasoning capabilities.

B.2 Low-Resource Evaluation Method

Although SymPy is partially employed for quick result matching, the evaluation pipeline in this work still primarily relies on LLMs to provide reward signals. It is because **SEEPHYS** encompasses diverse open-ended question types (e.g., computation, derivation, case-based analysis) with inherent uncertainty in model output formats. Only a small fraction of responses could be directly verified using automated tools, resulting in a resource-intensive evaluation process that hinders broader adoption in the research community. Future work should focus on designing more efficient and accurate rules or tools for assessing open-ended question answers.

B.3 Connection between Theory and Real-World Scenarios

The questions used in this benchmark are sourced exclusively from existing theoretical physics databases, covering primarily high-level concepts and principles in the physics discipline, with minimal inclusion of engineering-related problems (e.g., architecture, mechanical engineering, and biomechanics) or cross-modal sensory problems that better approximate real-world applications. Future research should further examine the relationship between a model’s theoretical reasoning and its ability to model real-world phenomena—referred to as world modeling capability.

C Data Collection Pipeline

C.1 Collection

Our **SEEPHYS** benchmark aggregates educational materials (textbooks, exercises, exams, and contest problems) from globally distributed education systems, covering East Asian, European, North American, and other regional curricula. To preserve authentic multilingual evaluation, we retain all source languages without translation, maintaining a 961:1039 Chinese-English text ratio. The corpus comprises 7,000+ PDF pages processed through Mathpix’s OCR system to generate structured Markdown representations.

Each acquired question must satisfy the following criteria:

- **Vision Information Enrichment:** For Vision-Essential subset, selected images should contain essential information for problem-solving. Diagrams or illustrations should be non-decorative and directly support the question’s resolution. For Vision-Optional subset, images should not contain essential problem-solving information (e.g., numerical values) and should serve only as supplementary visual cues.
- **Knowledge Spectrum:** The content should cover topics ranging from middle school to PhD qualifying exam levels.
- **Without Ambiguity:** Only questions with definitive answers are included, while open-ended questions permitting multiple interpretations are excluded. Questions requiring explanatory answers longer than three sentences are discarded.

Since the collected questions may contain grammatical or formatting errors after OCR processing, we employ the prompt to guide GPT-4.1 in performing preliminary linguistic correction (Figure 9).

C.2 Standardization

Many source materials (particularly textbook exercises and competition problems) contain compound questions comprising multiple independent sub-questions (e.g., "Prove X and then calculate Y"). So we systematic decomposition of compound questions into atomic units and then reconstruct them with shared contextual elements when logically dependent. It ensures each question in our dataset represents a single, self-contained cognitive task while preserving original problem relationships through metadata tagging. To modify multi-choice questions to open-ended questions, we develop stem rewriting to remove choice-specific references (e.g., changing "Which of the following" to

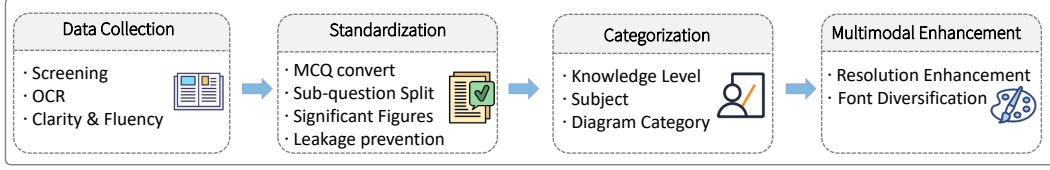


Figure 8: Overview of the data collection pipeline.

"Determine"). For computational problems, we address a significant figures annotation based on problem constraints. This approach reduces false negatives in automated scoring while accommodating legitimate solution variants.

To prevent data leakage, we implemented a dual-phase verification protocol: 1) Systematically use and disabling GPT-4o’s web search functionality via API parameters to eliminate questions exhibiting accuracy fluctuations. 2) Manual Google verification of all correctly answered items.

Our two-phase validation protocol ensures conceptual integrity:

- Primary annotation by domain experts.
- Cross-validation by secondary annotators.
- When the two annotators disagree in their judgment regarding physics concepts, a third arbitrator holding a PhD in physics is engaged to conduct the final review.
- Continuous validation sampling (10% of processed questions) throughout dataset development

C.3 Categorization

As all source materials originate from discipline-specific examinations, we initially classify questions into 7 broad thematic categories based on their subject matter. To analyze LLMs’ sensitivity to visual elements, we implement a fine-grained classification system comprising 21 distinct diagram types. Notably, coordinate systems are treated as composite categories, as they may incorporate multiple graphical components across different subject domains. Through comparative analysis of international curricula standards and expert deliberation, we establish an 8-tier knowledge hierarchy. Olympiad competition problems are split into beginner and advanced tiers based on average accuracy rates, while undergraduate-level questions are divided into undergraduate (non-mathematical physics) and senior undergraduate (mathematical physics) categories.

C.4 Multimodal Enhancement

We also provide a pure multimodal subset containing 2,000 composite image examples. Each example consists of a single image integrating both textual and graphical elements. We first generate detailed captions for each sample using o4-mini, which include comprehensive descriptions of geometric features and numerical data through the prompt template shown in Figure 10. Subsequently, we render each question with its corresponding diagram into a composite image under 4096×4096 pixels resolution. The rendering process incorporates varied font types and sizes, while dynamically adjusting text-to-diagram spacing based on each chart’s maximum dimensions to ensure optimal layout compactness. Cases are shown in Figure 11.

D Experimental Settings

D.1 Models

In our experiments, we evaluate the performance of several state-of-the-art and representative LLMs/MLLMs. For LLMs, we provide text-based prompts in the form of "question + caption" to guide the models in generating answers. For MLLMs, general-purpose models capable of processing interleaved image-text sequences are tested on the full benchmark. For most open-source models, we use the hyperparameter `torch.dtype=torch.float16`. We set `temperature=0`, with a maximum token limit of 8192 and a maximum image resolution of 4096×4096 pixels. Additionally, for other

Instruction for OCR Text Enhancement

You are a physicist, please enhance physics text with the following instructions:

1. STRUCTURE:

- Merge broken paragraphs
- Remove redundant line breaks
- Fix string omissions
- Preserve LaTeX math: $E=mc^2$
- Correct LaTeX syntax errors

2. TERMINOLOGY:

- Standardize terms ("Kirchoff" → "Kirchhoff")
- Keep glossary: {"电容": "capacitance"}

3. FLUENCY:

- Fix grammar/syntax errors
- Clarify ambiguous phrases

4. VALIDATION:

- Verify numbers/units unchanged
- Flag uncertain conversions

Example:

Input: "electric field $E=kq/r^2$ where k is Coulomb const"

Output: "Electric field $E=\frac{kq}{r^2}$ where k is Coulomb's constant"

Figure 9: Instruction for OCR Text Enhancement with GPT-4.1.

parameter configurations, we generally follow the settings provided in the original papers, their code repositories, or Hugging Face’s example configurations. The language models used in this study are briefly described as follows:

- **DeepSeek-R1:** It is based on a four-stage training process incorporating Supervised Fine-Tuning and Reinforcement Learning. Despite utilizing only minimal annotated data, it significantly enhances the model’s reasoning capabilities. In tasks such as mathematics, coding, and natural language reasoning, the model, with 670 billion parameters, achieves performance comparable to OpenAI’s o1 official version.
- **DeepSeek-V3:** It is a powerful Mixture of Experts (MoE) language model, activating approximately 37 billion parameters per token. DeepSeek-V3 pioneers an auxiliary-loss-free load balancing strategy and incorporates a multi-token prediction training objective to achieve enhanced performance.
- **Qwen3-235B-A22B:** The model has 235 billion parameters, activates 22 billion parameters per inference, and consists of 128 experts, with 8 activated during each forward pass. This design significantly enhances computational efficiency and scalability while maintaining high performance.
- **Qwen2.5-72B-Instruct:** This is a dense, decoder-only language model pre-trained on a dataset of up to 18 trillion tokens. Qwen2.5-72B-Instruct supports context lengths of up to 128K tokens and can generate content with a maximum length of 8K tokens.

Instruction for Diagram Caption

You are an expert physics analyst. Generate a detail, precise, and objective caption for the provided physics problem diagram.

Your caption must:

1. Identify Components & Labels:

Name all physical objects/entities and accurately include ALL their labels/variables (use LaTeX: e.g., ' m_1 ', ' θ ', ' $\vec{F}$ ').

2. Describe Setup & Interactions:

State their spatial arrangement, connections, and any depicted physical processes (e.g., forces acting, current flow, light paths, fields).

3. Specify Vectors:

Clearly indicate the direction of vectors shown.

Guidelines:

- Describe only what is visually presented. Do not add non-existent information.
- Do not solve the problem, infer unstated information, or add interpretations.
- Use standard physics terminology.
- The goal is a detail and complete summary of the physical setup shown.

Figure 10: Instruction for Diagram Caption with o4-mini.

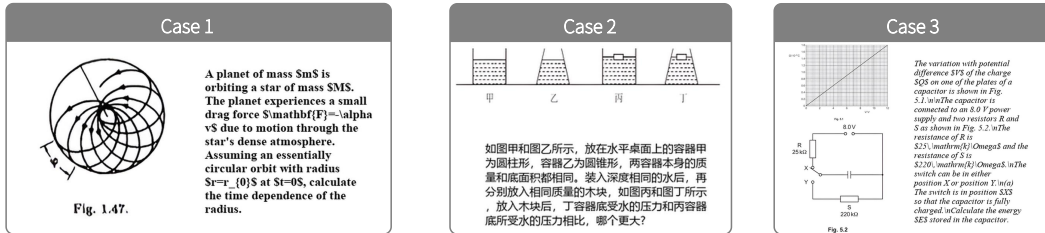


Figure 11: Cases of pure multimodal subset.

- **QwQ-32B:** QwQ-32B employs reinforcement learning techniques, supporting the visualization of the model's reasoning process and a context length of 131,072 tokens. It is capable of solving advanced mathematical problems, including algebra, geometry, calculus, and more.
- **R1-Distilled-Llama-70B:** Built upon the Llama-3.3-70B-Instruct model, it has been meticulously fine-tuned using DeepSeek R1's outputs, enabling outstanding performance across multiple benchmarks. While maintaining low costs, its capabilities rival those of larger, cutting-edge models.
- **Llama-4-Scout-17B:** This is the latest general-purpose multimodal model in the Llama series, featuring 16 expert modules, 17 billion active parameters, and a total of 109 billion parameters.
- **Gemma3-27B:** It is developed by the Google DeepMind team and incorporates several enhancements based on Gemma 2, including the addition of visual comprehension capabilities, support for more languages, and the ability to process contexts of up to 128K tokens.
- **Llama-3.1-8B:** The Llama 3.1 model features a 128K context length and is optimized for scenarios with limited computational resources.

The multimodal language models used in this study are briefly described as follows:

- **OpenAI o4-mini:** OpenAI o4-mini is a compact model optimized for fast, cost-efficient inference. Despite its reduced size and lower cost, it delivers exceptional performance in math, coding, and vision tasks, while maintaining high throughput.
- **OpenAI o3-mini:** The o3-mini demonstrates exceptional performance in STEM reasoning tasks. It achieves comparable results to the o1 model in mathematics, programming, and scientific tasks with significantly faster response times.
- **OpenAI o1:** o1 is a cutting-edge model released by OpenAI specifically designed for complex reasoning tasks, trained using reinforcement learning. The model is capable of engaging in prolonged deliberation before providing answers, and its performance empirically validates the existence of test-time scaling laws.
- **Gemini-2.5-Pro:** It is a hybrid reasoning model proposed by Google DeepMind, supporting native multimodal capabilities and a 1 million token context window, achieving significant advancements in coding, reasoning, and multimodal tasks. In this paper, we use Gemini-2.5-Pro-Exp-03-25.
- **Claude 3.7 Sonnet:** It is Anthropic’s most advanced large language model and the first to combine multiple reasoning approaches. Claude 3.7 Sonnet can both provide quick answers and engage in deeper, step-by-step thinking—with the entire reasoning process visible to users.
- **Doubao-1.5-pro:** It adapts a sparse MoE architecture, maintaining a training-inference co-design approach from the pre-training phase. With only a small fraction of activated parameters, it outperforms massive dense pre-trained models like Llama3.1-405B.
- **GPT-4.1:** The model comprehensively surpasses GPT-4o and GPT-4o mini in coding, instruction following, and long-context understanding, while being more cost-effective, faster, and capable of processing contexts up to 1 million tokens.
- **GPT-4o:** This model is trained on text, visual, and audio data. Its unified approach ensures that all inputs—whether text, images, or sound—can be processed simultaneously by a single neural network.
- **QvQ-72B-preview:** It is an open-source multimodal reasoning model developed by Qwen team, with a special focus on enhancing visual reasoning capabilities. It supports extracting precise information (e.g., object height, quantity) from images and can interpret the deeper meaning behind pictures.
- **Qwen-VL series:** The Qwen2-VL series models employ a three-stage fine-tuning approach to sequentially train different modules. It utilizes naive dynamic resolution mechanism and multimodal rotary position embedding to effectively fuse information from text, images, and videos of varying scales. Qwen2.5-VL series implements window attention, which boosts both training and inference speeds while significantly enhancing general image recognition capabilities.
- **Llama-3.2-Vision series:** Llama 3.2-Vision series is a collection of pre-trained and finetuning vision-language models that support text + image inputs with text-only outputs, featuring a 128K context length.
- **LLaVA-NeXT-7B:** This model is designed to improve image-text interaction capabilities, particularly in OCR (Optical Character Recognition) and commonsense reasoning. It employs Vicuna-7B as its language model and significantly boosts visual reasoning performance through dynamic high-resolution input processing and an optimized visual instruction-tuning dataset.
- **Phi-4-multimodal:** Phi-4-Multimodal is a 5.6B-parameter multimodal model that integrates text, visual, and speech/audio input modalities. It employs a modality expansion approach, utilizing LoRA adapters and modality-specific routers to enable interference-free combination of diverse modalities during inference.
- **InternVL2.5-8B:** InternVL2.5-8B integrates the pre-trained InternViT-300M vision backbone with large language models (InternLM 2.5) through a randomly initialized 2-layer MLP projector. The model additionally introduces native support for high-resolution multi-image inputs.
- **LLaVA-OneVision-7B:** It adopts Qwen-2 as its LLM backbone and SigLIP as the visual encoder, with the two modules connected via a parameterized 2-layer MLP. This architecture achieves state-of-the-art performance for open-source multimodal large models across single-image, multi-image, and video tasks.

D.2 Environment

We deploy advanced reasoning models with a computational infrastructure. we use a Linux-based environment equipped with CUDA-enabled GPUs (8 * 80G NVIDIA A800) to accelerate tensor operations. The software stack includes PyTorch 2.5.1 with CUDA 12.4 support, alongside Python 3.10 for compatibility with modern machine learning libraries. For all the models, half-precision (FP16) quantization is enabled to optimize runtime.

D.3 Inference Template

During the experiments, we design efficient Chain-of-Thought (CoT) templates to enhance the model’s reasoning capabilities. Given that physics problems often involve approximate calculations, we incorporate significant figure hints in the input. As shown in the Figure 12, we provide customized prompts in both English and Chinese to accommodate different linguistic contexts.

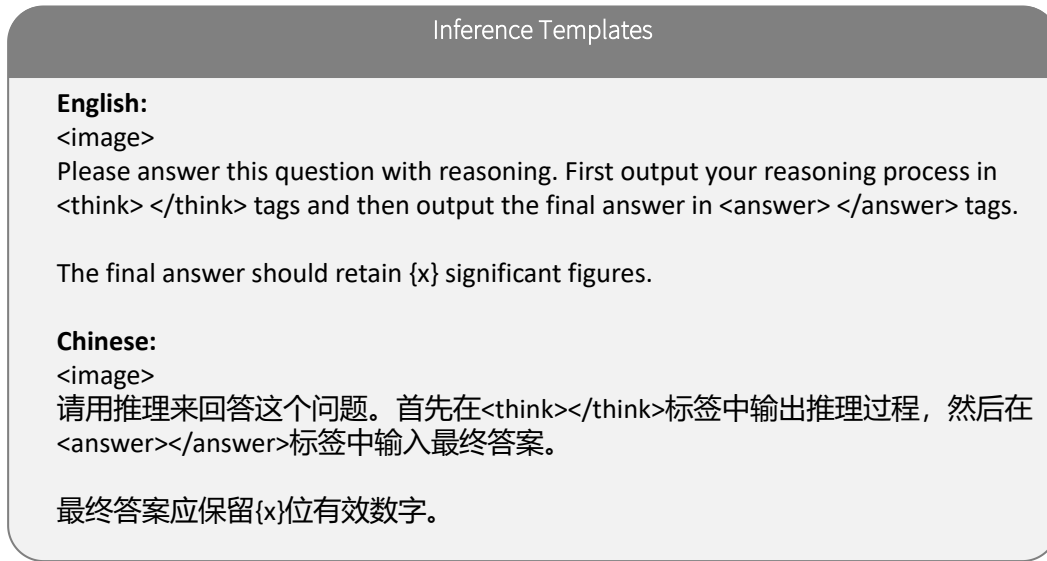


Figure 12: English/Chinese template for inference.

D.4 Evaluation

During the evaluation phase, we integrate automated verification with LLM-as-judge method to generate comprehensive reward signals. The assessment pipeline first leverages SymPy for rapid mathematical matching between model responses and ground truth. Samples failing this validation are then subjected to secondary scoring by LLM, ensuring robust evaluation coverage across all response types. Given the inherent complexity of physics reasoning tasks, the LLM’s judging process is implemented as a two-stage pipeline consisting of answer extraction followed by scoring. The first stage involves guiding the model to extract clean answers by removing extraneous characters, identifying numerical values and units, and handling cases with multiple valid answers. The second stage requires model to perform precise unit conversions and recognize various mathematically equivalent expressions when applying the scoring criteria. We calibrate these pipeline using carefully designed few-shot prompts as illustrated in Figure 13 and Figure 14. Through manual verification of 200 samples, the DeepSeek-V3 model demonstrates reliable judging capability with an error rate below 5%, validating the robustness of this evaluation methodology for complex physics reasoning tasks.

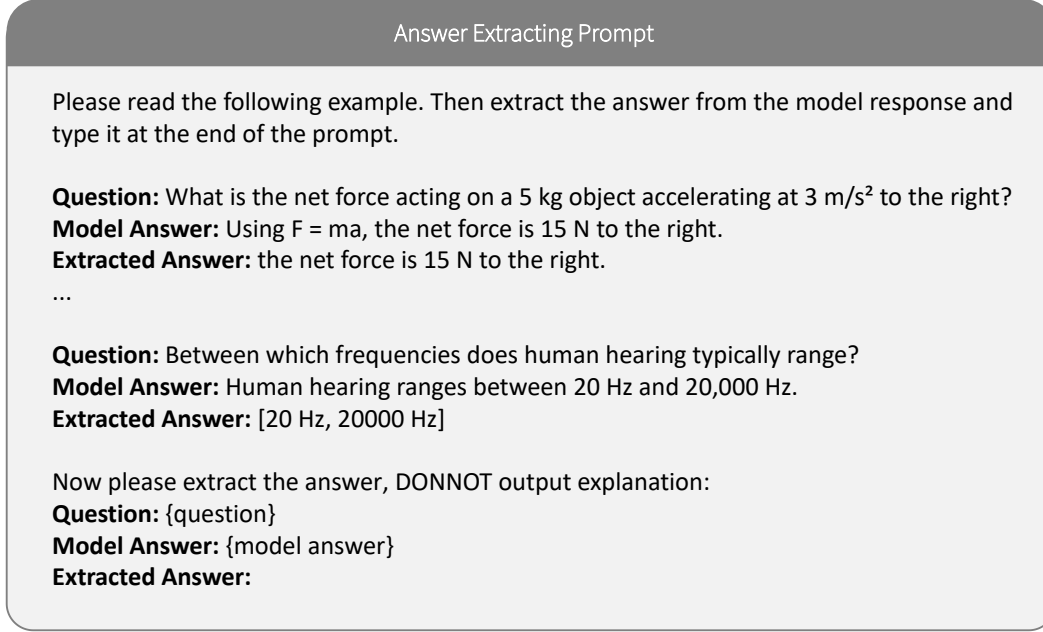


Figure 13: Prompt for answer extracting.

E More Experiments

E.1 Comparison of Theory Memorization and Problem-Solving Skills

Since the difficulty level labeling can be easily influenced by the subjective judgment of human annotators, SeePhys does not directly provide related tags (i.e., problem-solving skills level). We categorize the questions into 8 levels based on the knowledge content involved (i.e., conceptual level of theory needed as classified by incremental grades). Their order corresponds to the knowledge content (by grade distribution) rather than the actual difficulty. We placed Olympiad competitions between high school and undergrad since competitions like the IMO usually touch broader coverage than high school but does not require higher mathematics skills such as Calculus.

However, in order to further compare the **Theory Memorization** and **Problem-solving Skills** of SOTA models, we first reclassified the knowledge levels and the aggregated evaluation results are shown in Table 4. To minimize annotators’ subjective bias regarding difficulty levels as much as possible, we also applied majority voting in Table 5 to recalculate the accuracy of problems with different difficulty levels. It is found that models like Gemini-2.5-Pro excel in problem-solving tasks but show weaker high-level theory retention (44.2% in PhD, less than o4-mini). It proves knowledge depth does not guarantee strong problem-solving. In Table 2, we observe a significant imbalance in Doubao-1.5-pro’s theoretical memorization capabilities. While it demonstrates outstanding performance in memorizing middle school level knowledge (70.6%), it exhibits clear deficiencies in mastering higher-level concepts.

Table 4: Comparison of Theory Memorization and Problem-solving Skills across different difficulty levels.

Models	Theory Memorization				Problem-solving Skill			
	UG	SUG	MA	PhD	Mid	High	BO	AO
Gemini-2.5-Pro	64.2	50.2	53.8	44.2	69.6	66.7	64.5	46.7
o4-mini	53.8	45.7	51.0	53.4	66.7	61.8	56.1	41.8
Doubao-1.5-pro	56.6	34.7	40.7	37.5	70.6	58.2	49.5	29.2

Scoring Prompt

You are a physics professor, please determine if the Ground Truth and Model Answer are equivalent. Note that the significant figures in the answer must meet the requirements. Your judgment should be 0 (non-equivalent) or 1 (equivalent).

Question: An engine performs 1.2×10^5 J of work in 2 minutes. What is its average power output in watts?

Ground Truth: 1 kW

Model Answer: Power = Work / Time = 1.2×10^5 J / (2 min * 60 s/min) = 1.2×10^5 J / 120 s = 1000 W.

Judgement: 1

...

Question: The displacement of an object in Simple Harmonic Motion (SHM) is given by $x(t) = A \sin(\omega t)$. Determine the equation for its acceleration, $a(t)$.

Ground Truth: $a(t) = -A\omega^2 \sin(\omega t)$

Model Answer: The acceleration is the second derivative of displacement. $v(t) = A\omega \cos(\omega t)$. $a(t) = A\omega^2 \cos(\omega t + \frac{\pi}{2})$.

Judgement: 1

Now please provide your judgement (0 or 1), DONNOT output explanation:

Question: {question}

Ground Truth: {ground truth}

Model Answer: {model answer}

Judgement:

Figure 14: Prompt for answer scoring.

Table 5: Extended comparison of Theory Memorization and Problem-solving Skills across different knowledge and difficulty levels. We use majority voting approach across five models (Gemini-2.5-Pro, o4-mini, Doubao-1.5-pro, Qwen2.5-VL-72B-Inst and QVQ-72b-preview) to determine difficulty labeling, resulting in six difficulty level tags.

Theory Memorization	Mid	High+BO+AO	UG	SUG	MA	PhD
Gemini-2.5-Pro	69.6	52.1	64.2	50.2	53.8	44.2
o4-mini	66.7	48.4	53.8	45.7	51.0	53.4
Doubao-1.5-pro	70.6	42.8	56.6	34.7	40.7	37.5
Problem-solving Skill	100% (125)	80% (247)	60% (342)	40% (346)	20% (362)	0% (578)
Gemini-2.5-Pro	100	96.0	90.4	67.1	39.5	0
o4-mini	100	96.8	92.1	65.6	34.5	0
Doubao-1.5-pro	100	97.2	90.1	49.4	16.0	0

E.2 Statistical Analysis of Failure Reasonings

To provide the community with quantitative error analysis results, we conduct manual inspection of 100 error samples common to o4-mini, Gemini-2.5-Pro, and Qwen2.5-VL-3B. We shows 9 different error patterns in Table 6. First, all three models exhibit significant Modeling Flaws (e.g., incorrect theorem applications and formula misuse), while demonstrating relatively fewer Text Misinterpretation and Numerical Miscalculation errors. This suggests that even weaker models have acquired fundamental text recognition and numerical computation capabilities, yet still show

Table 6: Error patterns comparison of o4-mini, Gemini-2.5-Pro and Qwen2.5-VL-3B. We identify the following error patterns in the models’ outputs: VM: Visual Misinterpretation; TM: Text Misinterpretation; MF: Modeling Flaws; FA: False Assumption; NM: Numerical Miscalculations; OS: Oversimplification; SM: Summarization Mistakes; OT: Overthinking; RO: Repetitive Output

Models	VM	TM	MF	FA	NM	OS	SM	OT	RO
o4-mini [30]	15	1	61	8	3	6	3	3	0
Gemini-2.5-Pro [9]	17	2	49	13	3	0	4	12	0
Qwen2.5-VL-3B [3]	11	0	48	8	0	4	3	5	21

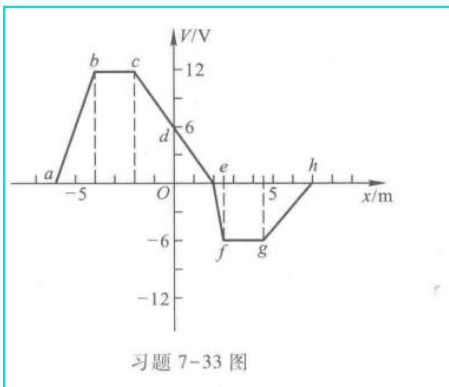
substantial gap in applying principles of physics. Second, Visual Misinterpretation emerged as the second most frequent error pattern, indicating persistent weaknesses in multimodal comprehension. Error frequencies for Overthinking and Oversimplification show notable variation across models. Particularly noteworthy is Qwen2.5-VL-3B’s high rate of Repetitive Output (21%), which is absent in the cutting-edge proprietary models. We attribute this to the model’s limited 3B parameter scale, which likely constrains its instruction-following capacity.

E.3 Case Studies of Failure Patterns

We also present concrete case studies illustrating common error patterns observed in outputs of o4-mini and Gemini-2.5-Pro:

Visual Misinterpretation

Question: The potential varies along the Ox axis as shown in the figure. Determine the x -component of the electric field intensity for the potential distribution in the interval a - b (neglecting the situation at the endpoints of the interval).



Response:

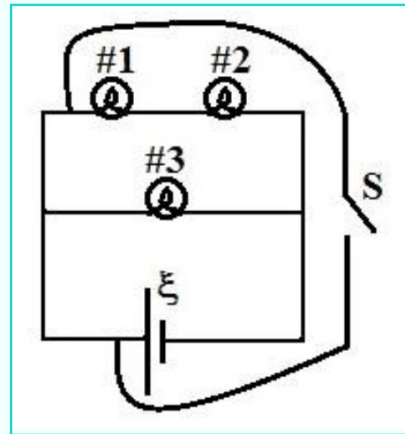
...potential from 0 linearly rises to 12 V, in the x direction correspondingly changes from $x \approx -10$ m to $x \approx -5$ m, distance $\Delta x = 5$ m, therefore in this interval $dV/dx \approx (12 - 0)/5 = 2.4$ V/m...

Error: It misreads the x -axis scale, incorrectly taking $\Delta x = 5$ m instead of the actual $\Delta x = 2$ m (-6 m to -4 m). This leads to an underestimated potential gradient and thus a wrong E_x value.

Figure 15: Visual Misinterpretation on o4-mini.

Visual Misinterpretation

Question: For the circuit shown, the three light bulbs have identical resistance R , the battery is ideal, and all wires have no resistance. Which light bulbs become dimmer or go out completely when the switch S in the circuit is closed?



Response:

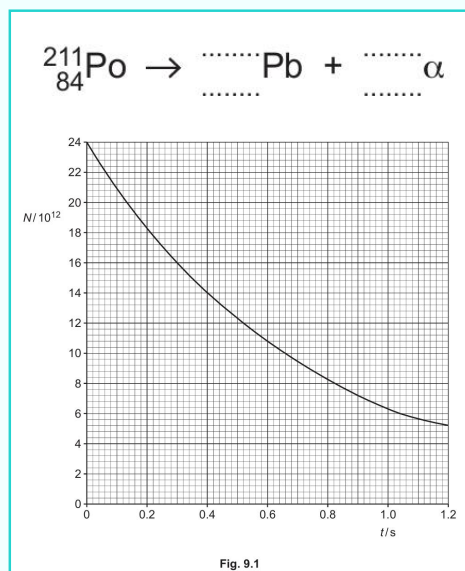
...once S is closed... The mid-rail bulb #3 is now shunted on its right side by a zero-ohm path (the right-rail). In effect, the voltage difference across #3 collapses to zero and all of the current chooses the short rather than flowing through #3. $\rightarrow$ #3 goes out completely.

Error: It **misinterprets the circuit diagram** and thinks that bulb #3 is shorted when S closes. In fact the new wire doesn't connect to the negative terminal, so bulb #3 remains lit with full voltage.

Figure 16: Visual Misinterpretation on o4-mini.

Visual Misinterpretation

Question: Polonium-211 decays by alpha emission to form a stable isotope of lead **Pb**. The variation with time t of the number of unstable nuclei N in a sample of polonium-211 is shown in Fig. 9.1. At time $t = 0$, the sample contains only polonium-211. Use the figure to determine the decay constant λ of polonium-211. Give a unit with your answer.



Response:

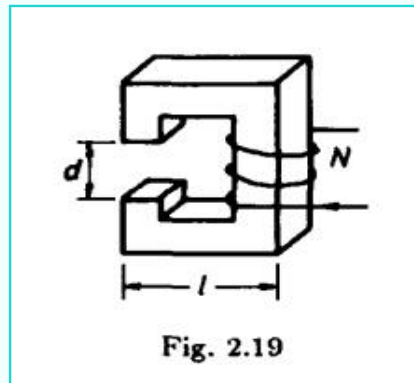
At $N = 12 \times 10^{12}$ the time t is approximately 0.51s. So, $T_{0.5} \approx 0.51\text{s}$.

Error: The actual half-life shown in the diagram is 0.52 s, while Gemini identified it as 0.51 s.

Figure 17: Visual Misinterpretation on Gemini-2.5-Pro.

Visual Misinterpretation

Question: On a frictionless horizontal surface, two bodies make a head-on collision and stick together. Body 1 has a mass of 3.50 kg and initially moves to the right with speed 7.0 m/s. Body 2 initially is at rest. What is the mass of Body 2?



Response:

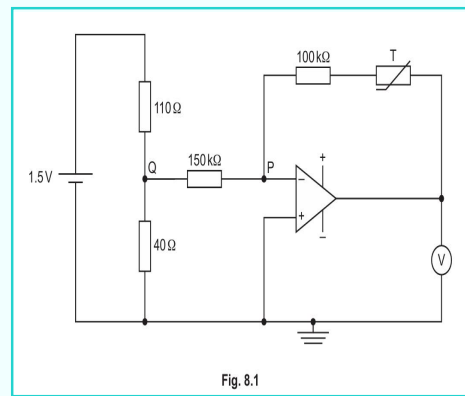
Now we need to determine the mean path length in the iron, l_{iron} . The problem states that "the length of each side of the 'C' is l ". A C-shape can be considered to have three main segments: a back segment and two arm segments. If the mean length of each of these three segments is l , then the total mean path length in the iron is: $l_{iron} = 3l$.

Error: It incorrectly models the total core path length as $3l$ when it should actually be $4l - d$.

Figure 18: Visual Misinterpretation on Gemini-2.5-Pro.

Visual Misinterpretation

Question: A student designs the circuit shown in the figure in order to indicate changes in temperature of the thermistor T. At a temperature of 13°C, the resistance of the thermistor T is 230kΩ. Calculate the potential difference measured with the voltmeter.



Response:

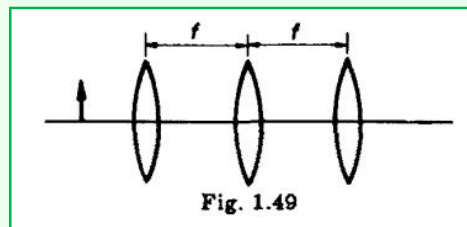
For an inverting amplifier, the output voltage is given by $V_{out} = -\frac{R_f}{R_{in}} V_{in}$, where $V_{in} = V_Q$ and $R_{in} = 150k\Omega$. $V_{out} = -2.2 \times 0.40V = -0.88V$.

Error: Misidentifying a non-inverting amplifier as an inverting amplifier when determining the circuit type, resulting in incorrect formula signs.

Figure 19: Visual Misinterpretation on Gemini-2.5-Pro.

Modeling Flaws

Question: If your eyes are near-sighted and can focus an object 20 cm away without using any glasses, estimate the required diameter of the hole through which you would have good sight for objects far away.



Response:

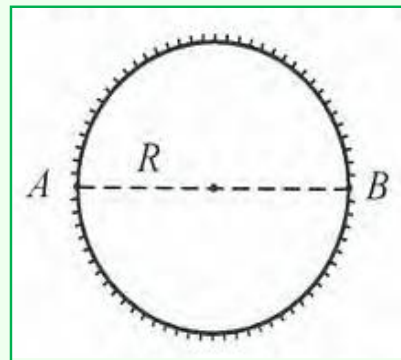
.....From the person's far point of 20 cm we can deduce that the unaccommodated focal length f_{∞} must satisfy ... $s_o = 0.20$ m and $s_i \approx$ the lens-retina spacing s_r . A typical $s_r \approx 17$ mm. hence $1/f_{\infty} = 1/0.20 - 1/0.017 \Rightarrow f_{\infty} \approx 18.6$ mm.

Error: It incorrectly uses subtraction when calculating the eye's unaccommodated focal length (f_{∞}). For the near-sighted eye's far point (object at 20 cm, image on the retina at ≈ 17 mm), the lens formula $1/f_{\infty} = 1/s_o + 1/s_i$ requires addition ($1/0.20 + 1/0.017$), not the subtraction ($1/0.20 - 1/0.017$) used in the text.

Figure 20: Modeling Flaws on o4-mini.

Modeling Flaws

Question: As shown in the figure, a transparent material sphere with radius R has diameter AB . Only the regions near points A and B on the sphere's surface are transparent. Inside the sphere at point B , there is a small luminous bulb. If the refractive index of the sphere is n , and the image is formed on the right side of the sphere, what is the lateral magnification of the image?



Response:

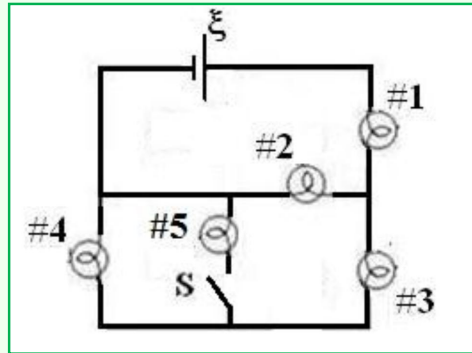
Using the spherical imaging formula $\frac{n_1}{u} + \frac{n_2}{v} = \frac{n_2 - n_1}{R}$. Substituting gives $\frac{n}{2R} + \frac{1}{v} = \frac{1-n}{R}$ (Object distance $u = 2R$ is also stated and used as a positive value).

Error: It incorrectly treats the object distance $u = 2R$ as positive and the radius of curvature R_{surf} as positive. It leads to an expression for image position v that differs from standard derivations using conventions like the Cartesian one.

Figure 21: Modeling Flaws on o4-mini.

Modeling Flaws

Question: Five identical light bulbs are connected into a circuit as shown. All wires are ideal with no resistance, and the ideal battery has emf ξ . When the switch S in the circuit is closed, aside from bulb #5, which bulbs brighten?



Response:

Bulbs #2 and #3 are in series, $R_{23} = 2R$. The combination of (#2 and #3) is in parallel with the combination of (#4 and #5). The equivalent resistance of this parallel part is $R'_{parallel} = \frac{R_{23} \cdot R_{45}}{R_{23} + R_{45}} = \frac{2R}{5}$Current through the series combination of #2 and #3 is

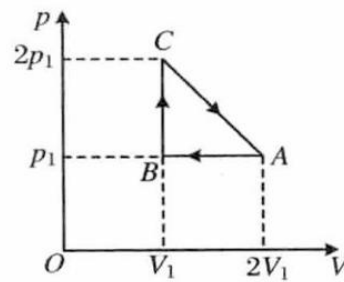
$$I_{23_{closed}} = \frac{V'_{parallel}}{R_{23}} = \frac{\xi}{7R}. \text{ So, } I_{2_{closed}} = I_{3_{closed}} = I_{23_{closed}} = \frac{\xi}{7R}.$$

Error: It incorrectly assumes that the branches containing Bulb 2 and Bulb 3 would maintain a series connection after the switch is closed during circuit analysis.

Figure 22: Modeling Flaws on Gemini-2.5-Pro.

Modeling Flaws

Question: 1 mole of helium (ideal gas) undergoes the cyclic process shown in the thermal diagram. In the diagram, AB , BC , and CA are all straight lines, and the relevant parameters have been indicated. Find the cycle efficiency η .



热图 2.19.1

Response:

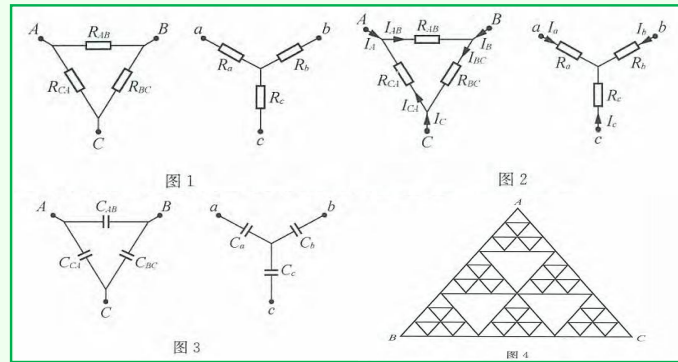
... Process $C \rightarrow A$ (straight line process): $W_{CA} = 1.5p_1V_1$. Since $T_A = T_C$, the change in internal energy $\Delta U_{CA} = n C_V (T_A - T_C) = 0$. $Q_{CA} = \Delta U_{CA} + W_{CA} = 1.5p_1V_1$. Since $Q_{CA} > 0$, heat is absorbed.

Error: It incorrectly assumes the entire process $C \rightarrow A$ in the cycle is endothermic during prediction, failing to correctly identify the turning point where the process transitions between endothermic and exothermic phases.

Figure 23: Modeling Flaws on Gemini-2.5-Pro.

Modeling Flaws

Question: The resistance network composed of resistors forms an equilateral triangle as shown in the figure. Given that the resistance of each small segment of the resistor is r_0 , find the equivalent resistance R_{BC} between points B and C .



Response:

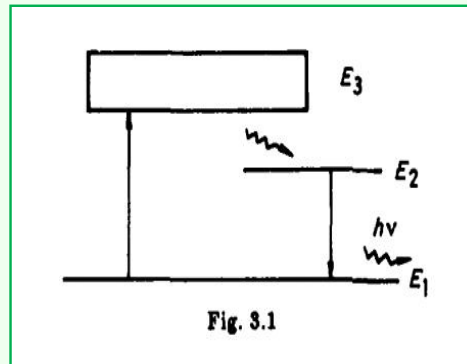
A three-terminal device where the resistance between any pair of terminals (say, 1, 2, 3) is X (i.e., $R_{12} = R_{23} = R_{31} = X$) is equivalent to a Y-network with three identical arms, each of resistance r . For this equivalence, $r + r = X$, so $r = X/2$. Thus, each $(k - 1)$ -th level gasket can be replaced by an equivalent Y-network with arms of resistance $r' = \frac{X_{k-1}}{2}$. Let O_1, O_2, O_3 be the central nodes of the Y-networks corresponding to $G_{k-1}^1, G_{k-1}^2, G_{k-1}^3$ respectively.

Error: It incorrectly applies the Y- Δ transformation relationship during prediction, leading to errors in both the recursive formula and the final equivalent resistance calculation.

Figure 24: Modeling Flaws on Gemini-2.5-Pro.

Modeling Flaws

Question: A ruby laser emits light with a wavelength of $6943\text{\AA}$, which to a very good approximation is a plane wave. What are the amplitudes of the electric and magnetic field vectors of this plane wave propagating through water, if the time-averaged power of the beam in the water is $100\text{ milliwatts/cm}^2$?



Response:

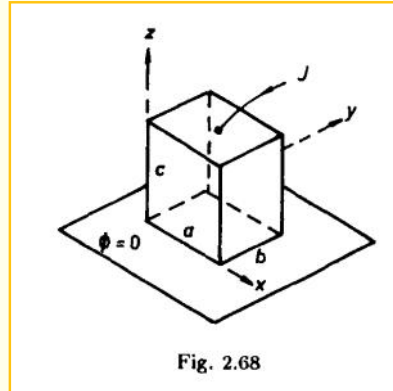
The light propagates through water. The refractive index of water is $n \approx 1.33$. The relationship between the intensity I and the amplitude of the electric field E_0 in a medium with refractive index n is: $I = \frac{n\epsilon_0 c E_0^2}{2}$, where ϵ_0 is the permittivity of free space ($\epsilon_0 \approx 8.85 \times 10^{-12} \text{ F/m}$) and c is the speed of light in vacuum. From this, we can find the amplitude of the electric field $E_0 = \sqrt{2I/n\epsilon_0 c}$.

Error: In the electric field amplitude calculation procedure, it incorrectly applies the intensity formula for vacuum without properly adjusting for the permittivity in the medium.

Figure 25: Modeling Flaws on Gemini-2.5-Pro.

Oversimplification

Question: A semiconductor block (conductivity σ) has its bottom face ($z=0$) grounded and top face ($z=c$) insulated except for a central current-injecting wire. Find the potential ϕ inside.



Response:

The general solution provided is:

$$\phi(x, y, z) = (A \cos \alpha x + B \sin \alpha x)(C \cos \beta y + D \sin \beta y) [E \exp(\sqrt{\alpha^2 + \beta^2} z) + F \exp(-\sqrt{\alpha^2 + \beta^2} z)],$$

Error: In presenting the general solution for the potential, the provided formula using separated variables fails to correctly apply the problem's **specific boundary conditions**. It erroneously includes sine function components for the spatial dependencies along x and y , which are incompatible with the insulated side conditions of the block. Additionally, its exponential form for the z -dependency is unadapted, as it neither directly reflects the zero potential requirement at the base of the block nor properly accounts for the distinct linear z -dependence essential for the current-carrying mode that arises when the separation constants for both x and y are zero.

Figure 26: Oversimplification on o4-mini.

Oversimplification

Question: A Three bodies of equal mass m and indicated by $i = 1, 2, 3$ are constrained to perform small oscillations along different coplanar axes forming 120° angles at their common intersection, as shown in Fig. 1.94. Verify that one normal mode is totally symmetric: $x_1(t) = x_2(t) = x_3(t)$, and determine its frequency.

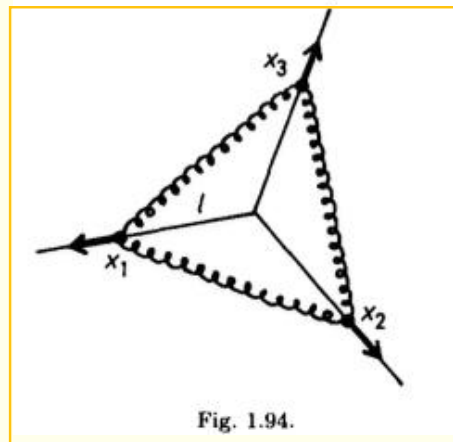


Fig. 1.94.

Response:

Each pair (i, j) is joined by a spring of spring-constant k and equilibrium length $|R_i - R_j| = \sqrt{3}l$ Summing over the three springs gives $V = \sum_{i < j} \frac{3k(x_i + x_j)^2}{8}$.

Error: The model builds **incomplete physical model for the potential energy**. It only considers the potential energy from the "coupling springs" (constant k) between the pairs of masses.

Figure 27: Oversimplification on o4-mini.

Oversimplification

Question: In the electrical circuit shown in the figure, ω , R_1 , R_2 and L are fixed; C and M can be varied. Find values of M and C which maximize the power dissipated in resistor R_2 . What is the maximum power? You may assume, if needed, $R_2 > R_1$, $\frac{\omega L}{R_2} > 10$.

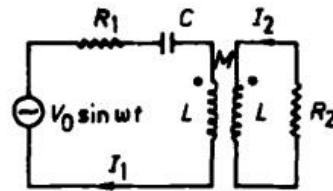


Fig. 3.36

Response:

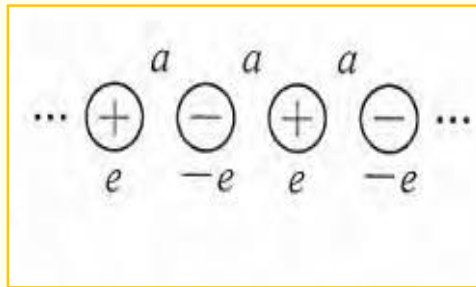
... Secondary: $Z_2 = R_2 + j\omega L$ At resonance in the primary...
 $C = \frac{1}{\omega^2 L}$ The primary “sees” an extra reflected resistance $R' = (\omega M)^2 / R_2$.

Error: The model **oversimplifies of the secondary circuit's** impedance when calculating the reflected impedance. It incorrectly assumes the secondary impedance is purely resistive (R_2) and ignores the significant reactance $j\omega L$ of the secondary inductor.

Figure 28: Oversimplification on o4-mini.

Oversimplification

Question: In An infinite chain of alternating $\pm e$ charges with spacing a . Find the potential energy W_- of one negative ion due to all others.
($e = \text{elementary charge}$, $N \rightarrow \infty$, Coulomb interaction)



Response:

... Other ions are located at distances n_a ($n = 1, 2, 3, \dots$) from q_0 ...
Summing all $n = 1$ to ∞ gives $W_- = \sum_{n=1}^{\infty} U_n$

Error: The model only sums for positive n (or in one direction), the calculation omits the interactions with half of the ions in the chain, resulting in a potential energy value that is half of the correct total.

Figure 29: Oversimplification on o4-mini.

Oversimplification

Question: To determine the specific latent heat of fusion of ice, L : an electric heater melts ice at 0°C . The mass of melted water versus time is recorded at a constant melting rate (see Fig. 3.2). The experiment has two phases: heating at an initial power for 10 minutes, then at an increased power for another 12 minutes. Electrical power is determined from ammeter and voltmeter readings (Fig. 3.3). Calculate L .

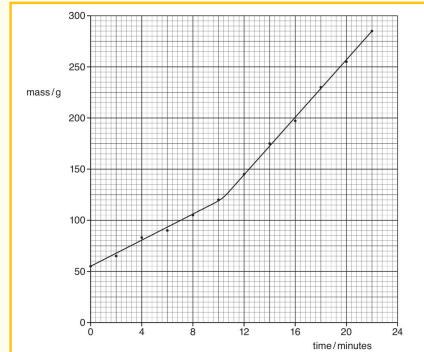


Fig. 3.2

	ammeter reading /A	voltmeter reading /V
from time 0 to time 10 minutes	1.8	7.3
after time 10 minutes	3.6	15.1

Fig. 3.3

Response:

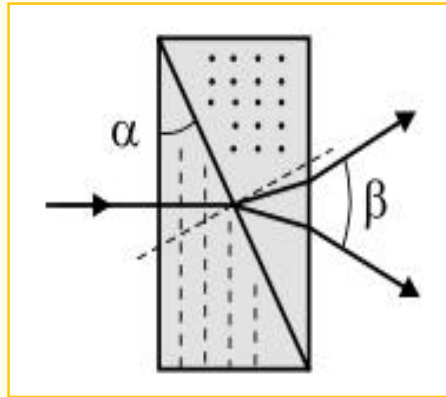
... $L = \frac{VI}{dm/dt} \dots \Rightarrow L_1 = \frac{P_1}{dm/dt} \approx 1.13 \times 10^5 \text{ J/kg} \dots \Rightarrow L_2 = \frac{P_2}{dm/dt} \approx 2.45 \times 10^5 \text{ J/kg} \dots$ The higher-power run is less affected by losses, so we take $L_2 \approx 2.5 \times 10^5 \text{ J/kg}$.

Error: It simply calculates L independently for each heating phase using the formula $L = P/(dm/dt)$ and then selects the value from the higher-power experiment, arguing it's less affected by losses. This method does not properly account for a constant rate of heat exchange (loss or gain) with the surroundings.

Figure 30: Oversimplification on o4-mini.

Oversimplification

Question: A Wollaston prism is made of Iceland spar $n_o = 1.658$, $n_e = 1.486$ with angle $\alpha = 20^\circ$ between the leg and hypotenuse faces of the prism. Determine angle β between the linearly polarized rays output from the prism if a ray of natural light is normally incident on the prism.



Response:

In the first prism, the optic axis is parallel to the entrance face and in the plane of the diagram (e.g., vertical). The incident light propagates horizontally. The ordinary ray (o-ray) is polarized perpendicular to the optic axis and the direction of propagation (e.g., out of the plane of the diagram). Its refractive index is n_o . The extraordinary ray (e-ray) is polarized parallel to the optic axis (e.g., vertical). Its refractive index is n_e . Both rays travel horizontally and are incident on the interface between the two prisms. The angle of incidence on this interface is α , measured from the normal to the interface.

Error: In the refraction analysis, model fails to correctly apply the angular formula for Wollaston prisms, erroneously considering **only single** refraction without properly calculating the cumulative effect of double refraction.

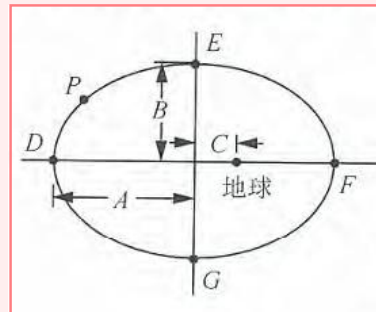
Figure 31: Oversimplification on Gemini-2.5-Pro.

False Assumption

Question: A The space shuttle P moves in an elliptical orbit ($e = \frac{\sqrt{3}}{2}$) around Earth. At point D , it ejects a probe backward, causing the shuttle to enter a circular orbit while the probe escapes on a parabolic trajectory. Find the mass ratio $= \frac{v}{2} = \frac{m_1}{m_2}$ (shuttle to probe).

Response:

By momentum conservation: $(m_1 + m_2)v_1 = m_1v_c + m_2v_p$ (Here, v_1 is initial speed, v_c is shuttle's final speed, v_p is probe's final lab speed, all implicitly positive in the same direction.)



Error: It incorrectly assumes the probe moves forward in the lab frame after being "fired backward." For the shuttle to speed up significantly (from apogee to circular orbit speed) and the probe to achieve an even higher escape speed, the probe must end up moving backward in the lab frame.

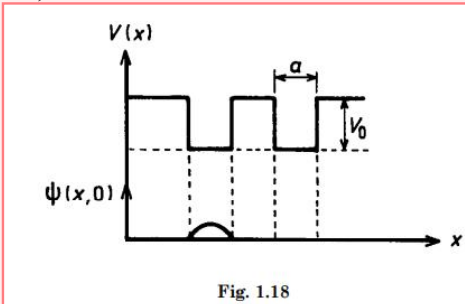
Figure 32: False Assumption on o4-mini.

False Assumption

Question: A particle of mass m is released at $t=0$ in the one-dimensional double square well shown in the figure in such a way that its wave function at $t = 0$ is just one sinusoidal loop (half a sine wave with nodes just at the edges of the left half of the potential as shown). Find the average value of the energy at $t = 0$ (in terms of symbols defined above).

Response:

each well of width a sits at $V=0$. Since $V=0$ everywhere ψ is nonzero, the expectation value of the potential is $\langle V \rangle = 0$

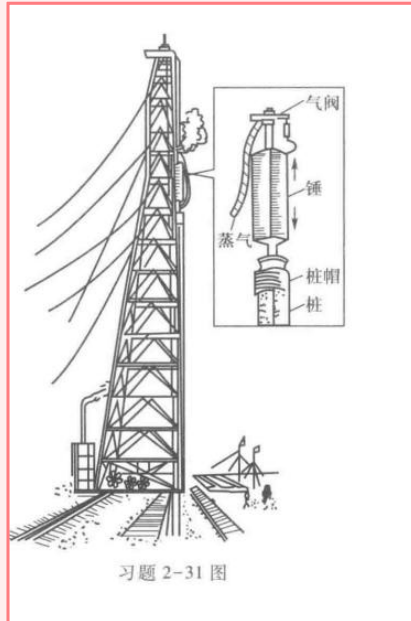


Error: The provided figure shows the bottom of the potential wells at a level V_0 below a dashed line, which typically represents $V=0$. Thus, inside the well, the potential energy is $-V_0$. However, due to the **incorrect assumption that $V(x)=0$ inside the well**, it erroneously concludes that the expectation value of the potential energy $\langle V \rangle = 0$.

Figure 33: False Assumption on o4-mini.

False Assumption

Question: The figure shows a schematic diagram of a large steam pile driver. The iron tower is 40 m high, and the hammer has a mass of 10 t. A reinforced concrete pile with a length of 38.5 m is now being driven into the ground. The mass of the pile is 24 t, and its cross-section is a square with an area of 0.25 m^2 . The resistance per unit area on the side of the pile due to soil is $k = 2.65 \times 10^4 \text{ N/m}^2$.



Response:

The pile sinks until its weight is balanced by the total frictional force, i.e., $W = F_f$. $235200 = (5.30 \times 10^4) \times h$.
 $h \approx 4.437735849 \text{ m}$.

Error: It incorrectly treats the resistance as a constant force and directly applies force equilibrium in the prediction, neglecting the fact that the resistance increases linearly with depth.

Figure 34: False Assumption on Gemini-2.5-Pro.