Appendix 1: Research Paper Questions

Instructions

Choose two subjects of your choice, and from each subject, choose one topic of your choice to attend to as a team.

PHYSICS

Problem 1: The Art of Circuit Design: Creating Functional Circuits with Components

Explore the principles of circuit design by creating a functioning circuit using common electronic components (resistors, capacitors, LEDs, and transistors). Challenge participants to design a specific function, such as a simple alarm system or a light dimmer.

- How do different configurations of components (series vs. parallel) affect the overall performance of the circuit?

- Can you analyze the energy efficiency of the circuit and propose improvements to minimize power consumption?

Problem 2: The Lifecycle of Stars: Investigating Stellar Evolution

Stars undergo various stages throughout their lifecycle, from formation to their end as white dwarfs, neutron stars, or black holes. Investigate the factors influencing stellar evolution, such as mass, temperature, and chemical composition.

- How do different initial masses affect the lifecycle of a star, and what observational methods can be used to identify stars at different stages?

- Can you create a model or simulation that illustrates the lifecycle of a star and predicts the characteristics of a star based on its mass and composition?

Problem 3: Powering the Future: Investigating Energy Sources for Satellites

Satellites rely on energy sources to maintain communication and perform their functions in space. Investigate the effectiveness of different energy sources, such as solar panels or batteries, in powering satellites. Explore how solar radiation, temperature fluctuations, and distance from the Sun impact energy efficiency.

- How do the energy demands of different satellite functions (e.g., transmitting data, stabilizing orbit) affect the choice of energy sources?

   a. Can you design an experiment to simulate the efficiency of solar cells under different conditions, such as varying light intensity or temperature, and suggest improvements for energy sustainability in space?

CHEMISTRY

Problem 1: The Chemistry of Clean: Investigating the Effectiveness of Household Cleaning Agents

Cleaning products are designed to remove dirt, stains, and bacteria, but how effective are they under different conditions? Investigate the **chemical mechanisms** behind common cleaning agents (e.g., soaps, detergents, or disinfectants) and analyze their effectiveness on different surfaces or stains. Study how factors like pH, temperature, and concentration affect cleaning power.

- How do chemical additives, such as surfactants or enzymes, enhance the cleaning process?

- Can you develop an environmentally friendly cleaner that maintains or improves upon the efficiency of traditional chemicals?

Problem 2: The Power of the Atom: Investigating Nuclear Fission and Energy Production

Nuclear fission is a powerful process used in nuclear reactors to generate energy. Investigate the principles of **nuclear fission**, focusing on the conditions required for the reaction and its energy output. Conduct experiments using safe materials to simulate fission reactions, exploring factors such as **neutron absorption** and the impact of different isotopes on the fission process.

- How does the configuration of fissionable materials affect the efficiency of energy production?

- Can you model a simple system to demonstrate the chain reaction process and analyze how control mechanisms are implemented in real reactors?

Problem 3: The Strength of Bonds: Investigating the Factors Influencing Bond Strength

Chemical bonds vary in strength and stability, influenced by factors like bond type (ionic, covalent, or metallic) and molecular geometry. Investigate how different factors—such as electronegativity, atomic size, and molecular shape—affect the strength of bonds in various compounds. Conduct experiments comparing the melting or boiling points of substances with different types of bonds.

- How do the types of bonds present in a compound affect its physical properties, such as solubility or conductivity?

- Can you create a model to predict bond strength based on molecular structure and explain discrepancies observed in real compounds?

BIOLOGY

Problem 1: The Secret Language of Plants: Communication through Chemical Signals

Plants are not silent observers in nature; they communicate using chemicals. Investigate how plants use **chemical signals** to interact with each other and their environment. Explore how certain plants release chemicals to warn neighboring plants of pests or trigger defense mechanisms. Analyze the influence of these signals on plant growth, behavior, and survival.

- Can plants "sense" when their neighbors are under attack, and how does this affect their own growth or defense strategies?

- Investigate the phenomenon of "allelopathy"—how one plant inhibits the growth of another through chemical release.

Problem 3: The Battle of the Sexes: Investigating Plant Reproductive Strategies in Changing Environments

Some plants can switch between **self-pollination and cross-pollination** based on environmental conditions to ensure reproductive success. Investigate how environmental stressors, such as nutrient deficiency, drought, or crowding, influence a plant's choice of reproductive strategy.

- How does the balance between self-pollination and cross-pollination affect the genetic diversity of offspring?

- Can plants "sense" when cross-pollination is no longer viable and shift toward self-pollination as a survival mechanism?

Problem 3: The Struggle for Space: Investigating Competitive Exclusion in Ecosystems

In ecosystems, different species compete for limited resources like space, nutrients, and sunlight. Explore the phenomenon of **competitive exclusion**, where one species outcompetes another for a particular resource, often leading to local extinction. Study the dynamics of species competition in a controlled environment, such as aquatic plants competing for light or animals competing for nesting sites.

- How do environmental stressors (e.g., limited resources, pollution, or climate change) influence the outcome of competitive interactions?

- Can species coexist by partitioning resources, and if so, how does this affect the biodiversity and stability of the community?

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