Physics

Problem P1

In motorsports, engineers design cars to maximize downforce, enhancing tire grip and cornering performance. In contrast, manufacturers of road vehicles aim to minimize aerodynamic drag to improve energy efficiency and reduce fuel consumption. Investigate how different aerodynamic components — such as wings, ground-effect diffusers, and wheel covers — affect a vehicle's aerodynamic characteristics, particularly the balance between downforce and drag.

Problem P2

In internal combustion engines, oil plays a crucial role in maintaining efficiency and reliability. It minimizes friction between moving components and helps dissipate heat generated during operation. Without effective lubrication and cooling, excessive wear and overheating can significantly reduce engine performance. Investigate how oil contributes to both lubrication and cooling, and examine how its properties — such as viscosity, thermal stability, and flow characteristics — influence overall engine performance and durability.

Problem P3

Tires, as the only part of a vehicle in direct contact with the road, play a crucial role in determining performance, handling, and safety. Their effectiveness depends on multiple factors, including material composition, tread pattern, internal pressure, tire dimensions, as well as tire temperature and wear over time. Investigate how these factors influence a tire's grip on the road, cornering ability, and braking performance, and analyze how design variations can optimize overall vehicle stability and control.

Chemistry

Problem C1

Fruits, rich in electrolytes, can act as natural batteries when combined with appropriate metal electrodes, providing a simple way to explore alternative energy sources in resource-limited settings. Investigate how the choice of fruit, electrode pair, and circuit configuration influences the voltage and current output of a fruit-based electrochemical cell, and determine how to maximize its efficiency for powering a small device such as an LED.

Problem C2

Chemical gas production plays a central role in processes ranging from baking to industrial carbon capture. Carbon dioxide can be generated from the reaction between a carbonate salt and a weak acid. Investigate how the concentration, proportions, and mixing method of the reactants affect the total gas volume produced, and determine the optimal conditions for inflating a balloon to the maximum extent.

Problem C3

pH indicators display remarkable color transitions across the acidity-basicity scale, providing a visual map of chemical equilibria. By mixing indicators and adjusting solution pH, diverse color patterns can be achieved. Investigate how combining different pH indicators and adjusting solution acidity can produce the widest range and most intense sequence of visible colors, and determine the strategy that yields the largest volume of vividly colored solutions.