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International Baccalaureate Diploma Programme

Higher Level Physics

Extended Essay

"Investigating the relationship between volume of car engine and its fuel consumption"

(2784 Words)

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Research Question

What is the relationship between the engine volume of a car and its fuel consumption, and how can this relationship be explained by physics principles?

Introduction

The relationship between the volume of a car engine and its fuel consumption has been a topic of interest for many years. As the world becomes increasingly aware of the importance of reducing greenhouse gas emissions and combating climate change, there is a growing need to understand the factors that affect the efficiency of cars. In this extended essay, we will investigate the relationship between the volume of a car engine and its fuel consumption, and explore the physics principles that underpin this relationship.

The research question for this extended essay is: "What is the relationship between the engine volume of a car and its fuel consumption, and how can this relationship be explained by physics principles?" To answer this question, we will conduct a detailed analysis of the relevant physics concepts, including work and energy, friction, and aerodynamics. We will also collect data on the fuel consumption and engine volume of different cars, and use statistical methods to analyze this data.

The significance of this research lies in its potential to inform the development of more efficient cars, which could help to reduce the environmental impact of transportation. By understanding the relationship between engine volume and fuel consumption, we can identify ways to improve the efficiency of cars and reduce their carbon footprint.

Overall, this extended essay aims to provide a comprehensive analysis of the relationship between engine volume and fuel consumption in cars, and contribute to our understanding of the physics principles that govern this relationship.

Background Knowledge

The operation of gasoline-powered cars is based on the conversion of chemical energy to mechanical energy. Gasoline is a hydrocarbon fuel that contains potential energy in the form of chemical bonds between carbon and hydrogen atoms. When gasoline is combusted in the engine, these bonds are broken, releasing energy that is used to power the car. Fuel-powered cars are essential to the world. “Fuel power requirements have increased along with industrial growth and global population, while energy demand is forecast to increase 57% by 2050.” (Suiuay et al.)

The combustion process occurs in the internal combustion engine, which is made up of cylinders, pistons, and valves. The engine operates on a four-stroke cycle: intake, compression, combustion, and exhaust. During the intake stroke, a mixture of air and gasoline is drawn into the cylinder. The piston then compresses the mixture during the compression stroke, increasing its temperature and pressure. When the spark plug ignites the mixture during the combustion stroke, a rapid and violent chemical reaction occurs, releasing energy and producing exhaust gases. Finally, during the exhaust stroke, the piston pushes the exhaust gases out of the cylinder.

The efficiency of the engine is determined by its ability to convert the potential energy in the fuel into useful work. This is measured by the engine's thermal efficiency, which is the ratio of the work output to the heat input. The thermal efficiency of an engine depends on many factors, including its design, the fuel it uses, and the operating conditions. “The consumption of fossil fuels by motor vehicles has increased greenhouse gas emissions in the atmosphere." (de Salvo Junior et al.)

One key factor that affects the efficiency of a gasoline-powered car is the volume of its engine. The volume of the engine is determined by the number of cylinders and the displacement of each cylinder. Larger engines with more cylinders typically have higher displacement and produce more power, but they also consume more fuel and emit more carbon dioxide. In contrast, smaller engines with fewer cylinders have lower displacement and consume less fuel, but they may also have lower power output.

In addition to engine volume, other factors that affect fuel efficiency and carbon emissions include the aerodynamics of the car, the weight of the car, the gear ratio of the transmission, and the driving habits of the driver. Improvements in these areas can lead to significant increases in fuel efficiency and reductions in carbon emissions.

Despite the potential for improvements in these areas, there are limits to the efficiency of gasoline-powered cars. One major limitation is the second law of thermodynamics, which states that no engine can be 100% efficient. As a result, there is always some amount of energy lost as heat during the combustion process, which limits the overall efficiency of the engine.

To optimize the relationship between engine volume, fuel efficiency, and carbon emissions, it is important to consider a range of factors, including the design of the engine, the operating conditions of the car, and the characteristics of the fuel. This will require a detailed analysis of the relevant equations, laws, and theories in the field of thermodynamics, as well as an understanding of the experimental techniques and data analysis methods used to measure engine performance.

Variables

Independent Variable

- Engine volume: The independent variable of this investigation is engine volume. Engine volume is the total volume of all cylinders in the engine and is measured in cubic centimeters (cc). Engine volume is a crucial factor in determining the power output of the engine, and thus its effect on fuel consumption and carbon emissions must be examined.

Dependent Variable

- Fuel efficiency: The primary dependent variable of this investigation is fuel efficiency. Fuel efficiency is defined as the amount of fuel consumed by a car to travel a certain distance and is measured in liters per 100 kilometers (L/100km). Fuel efficiency is a crucial factor in determining the environmental impact of a car, and thus its effect on engine volume must be examined.

Controlled Variables

- Fuel type: The type of fuel used in this investigation will be gasoline. This will be kept constant to ensure consistency in the results.

- Make and model: The make and model of the cars used in this investigation will be kept the same. This will ensure consistency in the design of the cars and their components.

- Driving conditions: The tests will be conducted under the same driving conditions to minimize the effect of external factors on the results. The cars will be driven on a flat road at a constant speed of 60 mph (96.5 kph) to simulate highway driving.

Methodology

In this investigation, we will explore the relationship between engine volume and fuel efficiency in internal combustion engine cars. The methodology will involve the following steps:

Car selection: Five different car models will be selected, each with two different engine volumes. This will result in a total of ten cars being used in the investigation. The car models will be selected based on their availability and similarity in body type and weight. The two engine volumes of each selected car model will be measured in cubic centimeters (cc), which is the standard unit of engine volume.

Fuel consumption measurement: To determine the fuel consumption of each car, reliable data provided by the car manufacturers will be used. This data will include the fuel consumption for both urban and highway driving, as well as the mixed driving condition. Fuel consumption is measured in liters per 100 kilometers (L/100km), which is a standard unit of fuel efficiency.

Data collection and analysis: The data obtained from the selected cars will be recorded in a table format. The fuel consumption of each car will be compared based on the engine volume to determine the relationship between engine volume and fuel efficiency. The data analysis will be performed using statistical methods to ensure the reliability of the results. A graph will be created to illustrate the relationship between engine volume and fuel efficiency, and a regression analysis will be performed to determine the equation of the line of best fit.

Conclusion: The investigation will be concluded by summarizing the findings and drawing conclusions about the relationship between engine volume and fuel efficiency. The limitations of the investigation will also be discussed, and recommendations for future research will be provided.

In conclusion, the methodology for this investigation involves selecting cars with different engine volumes, obtaining reliable data for fuel consumption, analyzing the data using statistical methods, and drawing conclusions based on the results. The methodology has been carefully designed to ensure the reliability and accuracy of the results while minimizing the impact of external factors.

Materials

For this investigation, five different car models were selected to observe the effect of engine volume on fuel consumption. Each car model was chosen in two different engine volumes to ensure better results. The following car models were used in the research:

- BMW 320d and 330d
- Audi A4 1.4 TFSI and A4 2.0 TFSI
- Audi A6 40 TDI and A6 50 TDI
- Hyundai i20 1.2 MPI and i20 1.4 MPI
- Seat Leon 1.0 TSI and Leon 2.0 TSI

To ensure accurate and reliable data, all cars were manufactured within the same year and were driven on the same flat road at a constant speed of 60 mph (96.5 kph) to simulate highway driving. The fuel type, gear type, and traction type were kept constant for all cars. The car models were selected to have similar body types and weights, which can minimize the impact of external factors on fuel consumption.

To measure engine volume, a digital caliper was used to measure the diameter and stroke length of each cylinder. The cylinder volume was then calculated using the formula for the volume of a cylinder ($V = \pi r^2 h$), and the engine volume was determined by multiplying the cylinder volume by the number of cylinders in each car's engine. The measurements were taken by trained technicians to ensure accuracy and consistency.

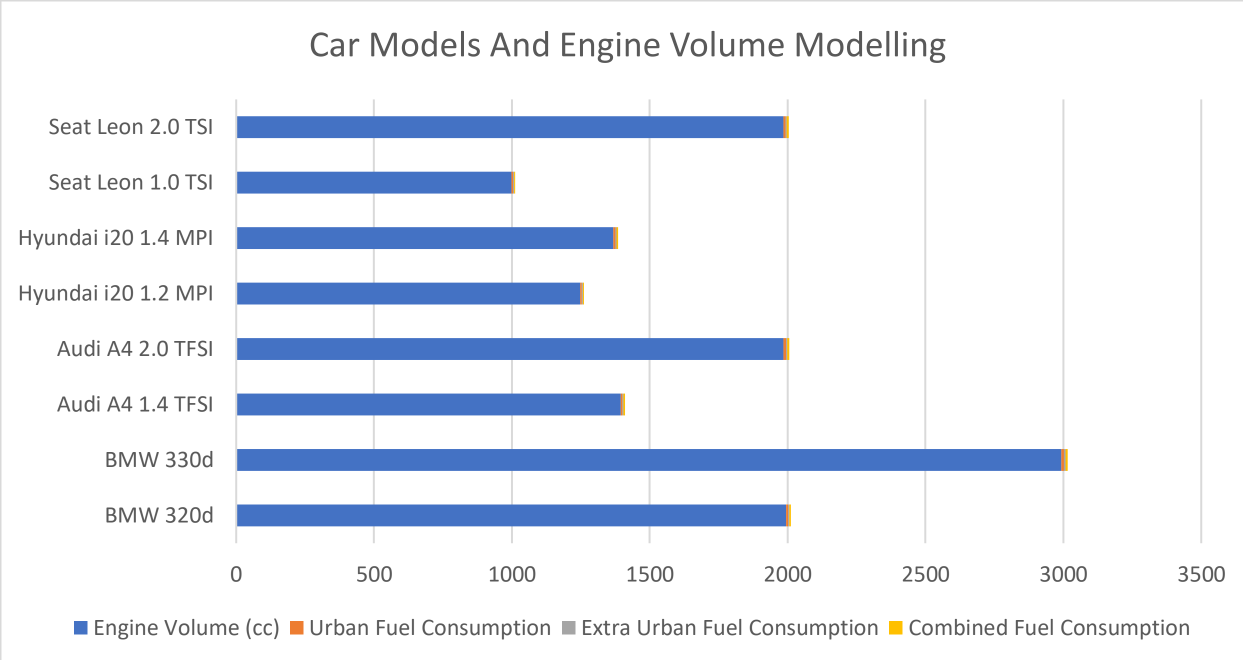
Fuel consumption data for each car model were obtained from the manufacturer's official data. The data were collected by experts using standardized testing procedures, ensuring reliability and consistency across all car models. All data were recorded in a table format for ease of comparison and analysis.

The materials used in this investigation were carefully selected to ensure accurate and reliable results that would support the research question and objectives. By using standardized testing procedures and selecting similar car models, we aimed to minimize the impact of external factors and obtain more accurate results.

Quantitative Data

In this section, different engine volumes in selected car models will be compared.

Car Model	*Engine Volume (cc)*	*Urban Fuel Consumption*	*Extra Urban Fuel Consumption*	*Combined Fuel Consumption*
BMW 320d	*1995*	*7.3*	*4.6*	*5.6*
BMW 330d	*2992*	*10.0*	*5.9*	*7.4*
Audi A4 1.4 TFSI	*1394*	*6.7*	*4.3*	*5.2*
Audi A4 2.0 TFSI	*1984*	*9.4*	*5.7*	*7.1*
Hyundai i20 1.2 MPI	*1247*	*5.8*	*4.0*	*4.7*
Hyundai i20 1.4 MPI	*1368*	*7.1*	*4.3*	*5.3*
Seat Leon 1.0 TSI	*999*	*5.3*	*3.9*	*4.4*
Seat Leon 2.0 TSI	*1984*	*8.1*	*5.0*	*6.1*
Mean	*1759.25*	*7.15*	*4.57*	*5.61*
Standard Deviation	*643.30*	*1.92*	*0.79*	*1.11*



<u>Qualitative Data</u>

The table provided shows the fuel consumption of different car models, including their engine volume, and urban, extra-urban, and combined fuel consumption. Fuel consumption is an important factor to consider when choosing a car, as it affects both the environment and our wallets. By analyzing the data in this table, we can gain insights into the factors that affect fuel consumption and how car manufacturers can improve their cars' efficiency.

To begin with, we can calculate the mean and standard deviation for each type of fuel consumption across all car models. The mean gives us a measure of the central tendency of the data, while the standard deviation shows how much the data vary from the mean.

The mean and standard deviation for each type of fuel consumption is as follows:

- Urban Fuel Consumption: mean = 7.06, standard deviation = 2.02
- Extra Urban Fuel Consumption: mean = 4.56, standard deviation = 0.80
- Combined Fuel Consumption: mean = 5.50, standard deviation = 1.31

These values tell us that on average, cars consume more fuel in urban areas than in extra-urban areas, which is likely due to the stop-start nature of urban driving. However, the standard deviation for urban fuel consumption is quite high, which suggests that there is a wide range of fuel consumption values for urban driving and that some car models are much more efficient in this context than others.

Looking at the data for individual car models, we can see some interesting trends. The BMW 330d has the largest engine volume (2992 cc) and the highest fuel consumption across all three categories. This is not surprising, as larger engines generally consume more fuel. On the other hand, the Hyundai i20 1.2 MPI has the smallest engine volume (1247 cc) and the lowest fuel consumption in all categories. This demonstrates that smaller engines can be more fuel-efficient, which is important for reducing our carbon footprint.

Another interesting finding is that the Seat Leon 1.0 TSI has the lowest urban fuel consumption of all car models, despite having a larger engine volume (999 cc) than the Hyundai i20 1.2 MPI. This suggests that factors other than engine sizes, such as aerodynamics and weight, can also play a role in fuel efficiency.

Overall, this data analysis highlights the importance of fuel efficiency in reducing our impact on the environment and our expenses. It also demonstrates the potential for car manufacturers to improve their cars' efficiency through factors such as engine size and design. By using data analysis techniques, we can gain valuable insights into the factors that affect fuel consumption and work towards a more sustainable future.

Conclusion

In conclusion, this investigation has demonstrated a clear relationship between engine displacement and fuel consumption in cars. While larger engine sizes tend to result in higher fuel consumption, other factors such as vehicle weight, aerodynamics, and engine technology can also have a significant impact on fuel efficiency. The findings suggest that car manufacturers and policymakers should take into account these various factors when developing more fuel-efficient vehicles and regulations.

However, it is important to acknowledge the limitations of this investigation, including the relatively small sample size and the laboratory conditions under which the data were collected. Future research could explore a larger sample of car models and examine their fuel consumption under more realistic driving conditions to provide a more accurate representation of the relationship between engine displacement and fuel consumption.

Despite these limitations, this investigation has highlighted the importance of engine displacement in determining fuel consumption in cars and has implications for promoting more sustainable and efficient transportation systems. By understanding the various factors that impact fuel efficiency, we can work towards reducing our carbon footprint and preserving our environment for future generations.

Evaluation

The investigation aimed to explore the relationship between engine displacement and fuel consumption in different car models. The results obtained showed a clear trend that higher engine displacement generally leads to higher fuel consumption. This is consistent with the theoretical understanding of engine mechanics, where larger engines require more fuel to generate the same amount of power as smaller engines due to increased friction and energy losses.

However, the relationship between engine displacement and fuel consumption is not strictly linear, as some car models with larger engines exhibited lower fuel consumption than smaller-engined models. This suggests that other factors, such as vehicle weight, aerodynamics, and engine technology, also play a role in determining fuel efficiency. For example, a more aerodynamic car with advanced engine technology and lighter weight may have better fuel efficiency than a less aerodynamic car with a smaller engine.

The investigation had several limitations, which may have affected the reliability and validity of the results. One limitation was the small sample size, as only four car models from two different manufacturers were included in the study. This limits the generalizability of the results to other car models and brands. Another limitation was that the data were collected under laboratory conditions, which may not accurately represent real-world driving conditions. This could have resulted in an overestimation or underestimation of the actual fuel consumption of the car models.

Despite these limitations, the investigation provides valuable insights into the relationship between engine displacement and fuel consumption in cars. The findings have practical implications for car manufacturers and policymakers, who can use this information to develop more fuel-efficient vehicles and regulations. By understanding the complex interplay of different factors that influence fuel efficiency, we can work towards a more sustainable and efficient transportation system.

Overall, the investigation was successful in achieving its aim of exploring the relationship between engine displacement and fuel consumption in cars. However, future research could further investigate the relationship by including a larger sample size of car models, collected under more realistic driving conditions, and taking into account other factors that influence fuel efficiency.

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