Guided Inquiry Activities using the Ideal Internal Combustion Engine Simulator

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The Engine Simulator models internal combustion engines using the Otto cycle for gasoline engines and the Diesel cycle for diesel engines. You can select an appropriate fuel for your engine selection, change the compression ratio, enter a cylinder volume, select an expansion ratio (for Diesel engines), and even compress the gas mixture entering the cylinder with a turbocharger. You can also select a real production vehicle and select your operational parameters to correspond to that vehicle.

These activities assume the user is familiar with the fundamentals of thermodynamic cycles and the basic operation of an internal combustion engine. A more detailed explanation of the input parameters is provided by clicking on the help icons. Information about real-world issues associated with each scenario is also presented for each simulation.

There are two activities suggested for students to complete prior to lecture. The first examines the impact of fuel choices for a given engine type, and the second looks at the tradeoffs in displacement volume design. The reflection questions and many of the activities can be combined at the discretion of the instructor.

Each activity has three parts. The first is intended to guide the student in thinking about what to expect from the simulation. The second guides the student through an investigation of properties of fuel selection and engine parameters. The third is intended as a deliverable for grading purposes. While your grading can be rigorous, the purpose is to compel students to make a reasonable effort and prepare them for a useful discussion during the subsequent class (remember the intent is for this to be assigned prior to lecture). The entire exercise is intended to be performed by a group of 2 to 4 students.

There are some parameters in this simulator not addressed in these activities and can be utilized at the discretion of the instructor or the initiative of the student. These parameters include additional alternative fuels (hydrogen, methanol, bio-butanol) and turbo/supercharging.

It should be noted that the MPG calculation is dependent on the weight of the vehicle selected under “Typical Vehicle Specifications”.

Ideal Internal Combustion Engine Simulator

Guided Inquiry Activity 1: Role of Fuel Composition

Directions: Open the "Engine Simulator.xlsm" file your instructor has provided. Complete the activity in a small group (2-4 students). Part I should be completed prior to using the simulator. Part II requires that you use the simulator to investigate the role of various fuels. You are welcome to also look at racing fuel (methanol), algae-produced bio-butanol, or hydrogen. Part III is intended for submission, but you should discuss your answers with your group.

Part I: Predictions

1. For a given IDEAL engine, is there a difference between performance (measured as gas mileage in mpg) when operating with gasoline compared to ethanol-gasoline mixtures? Petroleum-derived Diesel fuel (DinoDiesel) compared to biodiesel? Why would these be different?
2. For a given IDEAL engine, is there a difference in thermodynamic efficiency when operating with gasoline compared to ethanol-gasoline mixtures? Petroleum-derived Diesel fuel (DinoDiesel) compared to biodiesel?

Part II: Exploring

Select an Otto cycle engine running Unleaded Gas.

3. Set the engine to a configuration comparable to a real gasoline powered car either based on your research (most manufacturer website list engine specifications) or on a sample provided. Press "Start" and record the MPG and ideal thermodynamic efficiency.
4. Record MPG and efficiency after changing the fuel to E15 and then E85 and pressing "Start" after making the change. What changes? Why does that change? Why does what does not change not change?

Select a Diesel cycle engine running DinoDiesel at a fixed expansion ratio (r_e) of 8. Note that the labels for the expansion ratio will not darken until the engine is "started" with the Diesel cycle selected.

5. Set the engine to a configuration comparable to a real diesel powered vehicle either based on your research or on a provided sample in the "Typical Vehicle Specifications" section (like the Volkswagen Jetta with a compression ratio of about 16 and V_{max} of 0.750 L). Press "Start" and record the MPG and ideal thermodynamic efficiency.
6. Repeat step 5 for Biodiesel. Does biodiesel appears to be a good alternative to DinoDiesel based on mileage? What are some drawbacks to using Biodiesel?
7. Taking note of the simulator comments, compare MPG for an Otto engine and a Diesel engine of the same size (V_{max}) each running at a realistic compression ratio (based on your previous observations). In each case, run the simulation with the same "typical vehicle" selected so that the weight is the same for the mileage calculation. Which appears to be superior? Why might consumers not choose the "superior" engine type?

Part III: Reflection: To do outside of class and hand in. Your answers should be discussed with at least 2 other students and try to come to agreement on the answers and the reasons why.

8. How would you change your answers from Part 1 after using the simulator?
9. What are the strengths and weaknesses of the alternative fuels for each of the engines you investigated? Describe the characteristics of an ideal fuel by combining characteristics of fuels you've considered in this exercise.
10. What are some ethical considerations of using ethanol as a fuel? How do government incentives impact societal choices of fuels?
11. From a thermodynamic perspective, what is the intention of "hybrid" car designs (here, vehicles that use and store electricity generated onboard where a small combustion engine is the primary device for energy conversion).

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Guided Inquiry Activity 2: Role of engine operating parameters

Directions: Open the “Engine Simulator.xlsm” file your instructor has provided. Complete the activity in a small group (2-4 students). Part I should be completed prior to using the simulator. Part II requires that you use the simulator to investigate the role of selected engine design parameters. You are welcome to also look at racing fuel (methanol), algae-produced bio-butanol, or hydrogen. Part III is intended for submission, but you should discuss your answers with your group.

Part I: Predictions

1. How do you think compression ratio (ratio of the expanded volume of the cylinder to the compressed volume) impacts mileage? Thermodynamic efficiency?

Part II: Exploring

Select an Otto cycle engine running Unleaded Gas using other parameters for a typical vehicle.

2. Run the engine multiple times, increasing the compression ratio between runs. Record MPG and efficiency for each run. You can select the limits and spacing between points, but try to get a representative distribution.
3. Repeat this plot for E15 and E85. What changes? Why does that change? Why does what does not change not change?
4. How could you compensate in engine operation for the difference between fuels?
5. Select a reasonable compression ratio for an ideal Otto cycle engine and compare mileage for all of the available fuels. What appears to be the best alternative to gasoline based on mileage? What are the associated challenges with that fuel?
6. Note how the preignition temperature varies with compression ratio for gasoline and E85. What does that suggest about limitations on the operating parameters of an Otto cycle engine (remember the key difference between the Otto and Diesel cycles)?

Select a Diesel cycle engine running DinoDiesel at a fixed expansion ratio of 8 with natural aspiration.

7. Run the engine multiple times, increasing the compression ratio each time. Record MPG and efficiency for each run. Plot your results. You can select the limits and spacing between points, but try to get a representative distribution.
8. Repeat this plot for biodiesel. What changes? Why does that change? Why does what does not change not change?
9. Select a reasonable (based on a real vehicle) compression ratio and develop plots of MPG and efficiency as a function of **Expansion** ratio for DinoDiesel. What would be the optimal expansion ratio? What prevents real engines from achieving this optimum?

Part III: Reflection: To do outside of class and hand in. Your answers should be discussed with at least 2 other students and try to come to agreement on the answers and the reasons why.

10. How would you change your answer from Part 1 after using the simulator?
11. What are the strengths and weaknesses of the alternative fuels you investigated? Describe the characteristics of an ideal fuel by combining characteristics of fuels you've considered in this exercise.
12. One way of improving energy efficiency is reducing the weight of the vehicle. What are some constraints on reducing vehicle size?
13. What are limitations on other means of powering vehicles, including solar power, hydrogen, and electric cars? What are their strengths?