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| **Lesson Title :** Internal Combustion Engines | **Unit #:**  **1** | **Lesson #:**  **2** | **Activity #:**  **3** |
| **Activity Title:** How Do Engines Work? |

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| **Estimated Lesson Duration:** | 6 class periods of 47-minutes each |
| **Estimated Activity Duration:** | 2.5 class periods of 47-minutes each, including a double lab bell |

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| **Setting:** | The chemistry classroom, an outdoor field, and a large parking lot some distance away from the school building. |

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| **Activity Objectives:** |

Upon completion of the activity, students will be able to:

* identify the main parts of an internal combustion engine.
* explain what happens during each cycle of a 4-stroke engine.
* explain why the fuel/air (stoichiometric) ratio in an engine is important.
* explain what running “lean” or “rich” means in terms of fuel/air ratio.
* define engine RPM
* identify changes in RPM of an operating engine by listening to the pitch
* measure the RPMs and temperature of a model airplane engine as the fuel/air ratio is changed.
* relate the effect of an engine running “rich” or “lean” to engine temperature, RPMs, and exhaust pollutants.
* explain the similarities between the operation of a go-cart engine, a model airplane engine, and a Bunsen burner.
* compare advantages and disadvantages of using gasoline vs. methanol fuel for a race car driver.

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| **Activity Guiding Questions:** |

* How does an engine work?
* How exactly does burning fuel generate energy in a car?
* Do different fuels generate different amounts of energy?
* What does it mean for an engine to burn fuel more “efficiently?”
* How does fuel choice or engine operation affect a vehicle’s performance?
* How does fuel choice or engine operation affect the exhaust (including pollutants)?

| **Next Generation Science Standards (NGSS)** | |
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| **Science and Engineering Practices (Check all that apply)** | **Crosscutting Concepts (Check all that apply)** |
| ☒ Asking questions (for science) and defining problems (for engineering) | ☒ Patterns |
| ☒ Developing and using models | ☒ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☒ Analyzing and interpreting data | ☒ Systems and system models |
| ☐ Using mathematics and computational thinking | ☒ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function. |
| ☐ Engaging in argument from evidence | ☐ Stability and change. |
| ☒ Obtaining, evaluating, and communicating information |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☒ Demonstrating Science Knowledge **(D)** |
| ☒ Interpreting and Communicating Science Concepts **(C)** |
| ☐ Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** | |
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| **Standards for Mathematical Practice (Check all that apply)** | |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☒ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

AP Chemistry Curriculum Framework 2013-14

* Big Idea 3: Changes in matter involve the rearrangement and/or reorganization of atoms and/or the transfer of electrons.
  + Enduring Understanding 3.C: Chemical and physical transformations may be observed in several ways and typically involve a change in energy.
* Big Idea 5: The laws of thermodynamics describe the essential role of energy and explain and predict the direction of changes in matter.
  + Enduring Understanding 5.B: Energy is neither created nor destroyed, but only transformed from one form to another.
  + Essential Knowledge 5.B.1: Energy is transferred between systems either through heat transfer or through one system doing work on the other system.
  + Essential Knowledge 5.B.3: Chemical systems undergo three main processes that change their energy: heating/cooling, phase transitions, and chemical reactions.
* Science Practice 3: The student can engage in scientific questioning to extend thinking or to guide investigations within the context of the AP course.
* Science Practice 7: The student is able to connect and relate knowledge across various scales, concepts, representations in and across domains.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

* Student handout – “How Do Engines Work?”

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| **Teacher Advance Preparation:** |

* Scheduling our race car driver/guest speaker needed to be done in advance.
* A discussion with the guest speaker was important in order to plan what topics he would cover and what questions should be highlighted on the student handout.
* The student handout was designed to help students understand how internal combustion engines operate.
* The teacher needed to get help from an engineer who was also a model airplane enthusiast to get advice for the purchase of the model airplane engine (and related supplies) and to mount the engine on a stand for testing. Starting and adjusting the engine can be a very dangerous operation, and a good deal of practice needed to be done ahead of time with the engineer to increase the comfort level of the teacher.

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| **Activity Procedures:** |

* The guest speaker arrived with a couple of different engines that were partially disassembled so that students could get up close, look inside, and see how the parts move.
* The guest speaker described his love for race car driving and engines, and he explained some concepts relating to engines, fuels, and driving. He told the students about decisions that racecar drivers have to make before and during the race – regarding fuels, power, weight/handling of the vehicle (as fuel is consumed) and engine temperature. (High temperatures can lead to severe engine damage.)
* All of us then went outside to where the speaker had set up a go-cart in the parking lot. He revved up the engine and showed the students what happened when he changed the throttle and adjusted the fuel/air mix – running the engine “lean” or “rich.” The sound changed, the RPMs changed (as measured by his tachometer), and the temperature of the engine changed.
* The students had opportunities to ask questions that interested them regarding race car driving and engines.
* During the second part of the double lab, we investigated model airplane engines. Fortuitously, a student in the class had tinkered with model airplanes for many years, and he brought in several small engines. The other students were able to touch the engines, turn the propellers, and see how the piston in the engine goes up and down as the propeller turns (and vice versa).
* We then went outside and started up the model airplane engine mounted on a test stand. We tried to measure the RPMs with a tachometer and temperature with an IR thermometer, but it was a bright day and difficult to get reliable readings.
* The next day, we finished the third section of the activity by exploring how Bunsen burners work. The students were able to see the connections between a combustion reaction with which they were very familiar and the combustion reactions we studied in model airplane and car engines.

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

* Student knowledge and understanding was informally and continually assessed during both the demonstrations and the hands-on portions of the activity in the lab, by walking around, looking at individual student work, and asking directed questions to ensure that students understood what was happening.

**Summative Assessments:** These are optional; there may be summative assessments at the end of a set of Activities or only at the end of the entire Unit.

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.  Refer to Activity Template for details. |

* See section on formative assessment.
* I also made a particular effort to check on a couple of individuals/groups that had expressed concern on the first day of the unit about their limited knowledge regarding engines. I asked if they had unanswered questions and made sure they were feeling more confident after doing these activities.

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| **Reflection:** Reflect upon the successes and shortcomings of the lesson. |

* This series of three linked activities—two demonstrations and a short hands-on lab investigation—were extremely successful on many counts. The level of student engagement was *very* high, from the moment the speaker (a colleague in the math department) said, “Most of you already know that I really like teaching math, and I really like coaching sports, but I *LOVE* racing cars and working on engines.” You could have heard a pin drop for the next twenty minutes as he showed them the parts of an engine he had disassembled and let them look inside and ask questions.
* The students were also very excited to go outdoors on a beautiful day to study something in chemistry—a novel experience. From a practical standpoint, the two engines we started up were extremely loud, so we needed to distance ourselves from the building. But I think another more subtle and important message was also being conveyed to students that chemical principles are being applied all the time—often in places outside our chemistry classroom.
* The Bunsen burner activity generated a lot of “aha” moments as students understood that the barrel of their burner was essentially like a carburetor in a car – providing a space for the fuel and air to mix before combustion.
* I thought it might make better sense to do the Bunsen burner activity *before* the students looked at actual engines, but the availability of the speaker dictated the order of events. The students didn’t seem to mind, though, and in fact, they may have made better connections by doing the activities in this order.
* If I were doing this activity with the model airplane engine again, I would want to figure out a place to go outside (a partially covered area?) where we could take better RPM and temperature measurements of the spinning propeller and nearby metal. The bright sunshine made it difficult, along with my insecurity about managing the engine adjustments near the spinning propeller. It was too much to manage at one time safely in this first year. Perhaps next time…..
* I felt this three-part activity accomplished a major goal after speaking to a student who had been openly nervous about the whole unit on the first day. She commented, “You know, I was kind of surprised today. I found out that engines really aren’t that hard to understand!”