Lesson 6: 7th grade
Investigating Transportation
Step #3: Small Group Presentations

Lesson Overview: Exploring how transportation has changed over time.
Lesson Concept: People have been transporting materials for many years in many different ways around the world.

Materials:
- Note-taking journals
- Small group created project
- Student Hand-out: Organization and Ground Rules

Standards
- Science:
  - I.1.MS.1 (Construct new Scientific and personal Knowledge: Generate scientific questions about the world based on observation).
  - II.1.MS.3 (Reflect on the Nature, Adequacy and Connections Across Scientific Knowledge: Show how common themes of science, mathematics, and technology apply in real-world contexts).
- Social Studies:
  - II.5.MS.1 (Geographic Perspective: Describe how social and scientific changes in regions may have global consequences).
  - IV.2.MS.4 (Economic Perspective: Examine the historical and contemporary role an industry has played and continues to play in a community).
  - VI.1.MS.3 (Public Discourse and Decision Making: Explain how culture and experiences shape positions that people take on an issue).

Timeline: 1 - 2 class periods (50 - 60 minutes each) depending on the length of each presentation

Class Structure: small group presentations and class discussion

Assessment Strategy: EEK! Daily Assessment
General Assessment Strategy #1
General Assessment Strategy #2
General Assessment Strategy #3

Lesson 6: 7th grade
Investigating Transportation
Step #3: Small Group Presentations

Lesson Overview: Exploring how transportation has changed over time.
Lesson Concept: People have been transporting materials for many years in many different ways around the world.

Materials:
- Note-taking journals
- Small group created project
- Student Hand-out: Organization and Ground Rules

CLASS EXERCISES:

I. Culmination of the Project

The day has arrived–the culmination of the small group research project! Even if students have become deeply engaged in the research project, have developed positive, reflective, trusting relationships within their small group, and have created an insightful project, the public presentation may still be very difficult for many students.

In order to help facilitate a continued trusting environment where the students feel comfortable standing in front of the class and discussing their project, there are two specific issues we have found important to discuss with the class prior to the presentations: presentation organization and class ground rules.

II. Presentation Organization

Presentation organization is specifically how the group arrives at who will do what during the small group presentation. In order for their hard work to be understood and acknowledged, the group needs to be clear about what each member will be discussing. Below is a general outline of one way to help the groups organize their presentation materials.

A. Timed Presentations: Provide the groups with the presentation time maximum and minimum–for example, all group presentations need to be between 3 – 5 minutes.

B. Taking Turns: Even if one group member may feel inherently more comfortable speaking in front of the class than another group member, it is important to encourage all group members to directly participate in the presentation.

C. Get to the Point: Given that the presentations will have time limits, the groups need to develop a clear plan of how they will answer the target questions and present the visuals.

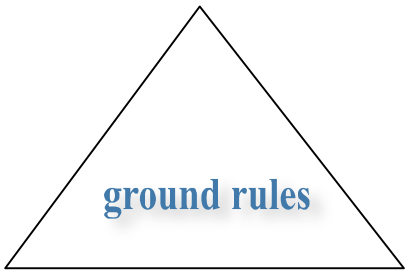
D. Stay on Track: Oftentimes, when middle school aged students become nervous, they begin laughing. Laughter, no matter the cause, can become infectious. Let students know ahead of time that the clock is ticking–if they waste their time they won't have an effective presentation.

E. Be Respectful: As an audience member, it is important to treat the presenters as you hope to be treated. Listen attentively, ask informed questions, do not interrupt, and be mindful of time constraints.

III. Presentation Ground Rules

These ground rules apply for the whole class during presentations–the presenters and the audience.

Trust
‡Respect each others' personal style
‡Don't make fun of anyone
‡Keep an open mind



Communication
‡Speak clearly
‡Stay focused
‡Answer questions at the end of the presentation
‡Wait your turn

Responsibility
‡Pay close attention
‡Ask informed questions
‡Include all group members

IV. Continuing the Transportation Timeline

Once each group presents their finished research project, add the new information on 18" x 24" pieces of colored cardstock or construction paper to the original Transportation Timeline. This can then place each research project into a larger context and provide a visual cue. We suggest using light colored pieces of cardstock to provide a visual signal to the spans of time that were more deeply researched.

Student Hand-out: Presentation Ground Rules

Small Group Organization

A. Timed Presentations: Provide the groups with the presentation time maximum and minimum–for example, all group presentations need to be between 3 – 5 minutes.

B. Taking Turns: Even if one group member may feel inherently more comfortable speaking in front of the class than another group member, it is important to encourage all group members to directly participate in the presentation.

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E. Be Respectful: As an audience member, it is important to treat the presenters as you hope to be treated. Listen attentively, ask informed questions, do not interrupt, and be mindful of time constraints.

Small Group Presentation Ground Rules

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‡Respect each others' personal style
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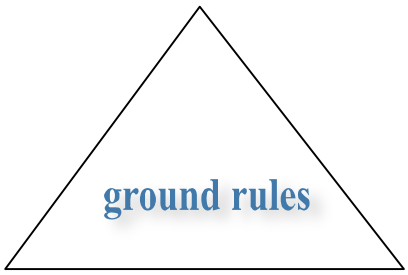
‡Keep an open mind



Communication
‡Speak clearly
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‡Answer questions at the end of the presentation
‡Wait your turn

Responsibility
‡Pay close attention
‡Ask informed questions
‡Include all group members

Lesson 7: 7th grade
A Cursory Glance: Gasoline Production

Lesson Overview: Exploring how gasoline is located, mined, and made.
Lesson Concept: To better understand the process of how gasoline is made and gain a working knowledge of the level of resources necessary to turn crude oil into useable fuel.

Materials:
- Note-taking journals
- Gasoline Production Primer: How Gasoline is Made
- Student Hand-out: Question Set

Standards:
- English:
  - IX.11.MS.1 (Inquiry and Research: Define and investigate important issues and problems using a variety of resources).
- Mathematics:
  - III.1.MS.1 (Data Analysis & Statistics: Collect and explore data through observation, measurements, surveys, sampling techniques and simulations).
  - III.1.MS.4 (Data Analysis & Statistics: Identify what data are needed to answer a particular question or solve a given problem, and design and implement strategies to obtain, organize and present those data).
- Science:
  - I.1.MS.1 (Construct new Scientific and personal Knowledge: Generate scientific questions about the world based on observation).
  - II.1.MS.3 (Reflect on the Nature, Adequacy and Connections Across Scientific Knowledge: Show how common themes of science, mathematics, and technology apply in real-world contexts).
- Social Studies:
  - II.3.MS.4 (Geographic Perspective: Describe the major economic and political connections between the United States and different world regions and explain their causes and consequences).
  - II.5.MS.1 (Geographic Perspective: Describe how social and scientific changes in regions may have global consequences).
  - IV.2.MS.4 (Economic Perspective: Examine the historical and contemporary role an industry has played and continues to play in a community).
  - VI.1.MS.3 (Public Discourse and Decision Making: Explain how culture and experiences shape positions that people take on an issue).

Timeline: 1 class period (50 - 60 minutes) depending on the length of each presentation

Class Structure: reading assignment with class discussion

Assessment Strategy: EEK! Daily Assessment

Lesson 7: 7th grade
A Cursory Glance: Gasoline Production

Lesson Overview: Exploring how gasoline is located, mined, and made.
Lesson Concept: To better understand the process of how gasoline is made and gain a working knowledge of the level of resources necessary to turn crude oil into useable fuel.

Materials:
- Note-taking journals
- Gasoline Production Primer: *Gasoline Production: A Cursory Glance–from crude oil to gasoline*
- Student Hand-out: Question Set

CLASS EXERCISES:

I. Gasoline Production

This lesson requires the students to read the Primer– *Gasoline Production: A Cursory Glance–from crude oil to gasoline*–and brainstorm, either in small groups or individually, the review questions at the end of the Primer. In answering these questions, the students will be asked to create flow-charts to explain in a condensed format the basic gasoline production process and illustrate their answers.

II. Reading the Primer

The student hand-out can be found at the end of the lesson.

III. Interpreting the Reading

After the students have completed the reading, have them create gasoline production flow-charts based on the following set of 10 questions (the answers follow in red). Encourage the students to read through the entire set of questions before beginning.

Question Set:

1. What is gasoline created from?

Fossil remains–plants and animals that died 10 – 100 million years ago.

2. What is a definition of crude oil?

Unprocessed oil

3. What must happen to fossil remains in order for them to become crude oil or gas?

Extreme pressure and heat must be exerted on the source rock where the organic material reside.

4. Using your own ideas (do not copy from the reading hand-out), draw the process of how fossil remains become crude oil.

Various interpretations of the given illustrations and text

5. How might trapped crude oil be found?

Methods / tools that scientists may use to locate trapped oil are satellite imaging of surface terrain, gravity meters, magnetometers, core sample drilling, seismology, or sniffers.

6. What are three considerations that must be taken into account before an oil rig can be set up at a selected site?

Accessibility, water supply, and waste disposal

7. Illustrate what an identified site for drilling and an oilrig might look like.

Various interpretations of the Preparing to Drill for Oil section in images

8. Summarize through illustrations and captions (words) the oil refining process.

Through using their own images and language, distilling the information of the 3 Basic Steps: Separation, Conversion, and Treatment.

9. What is cracking and why is it important?

Cracking is the process of breaking larger hydrocarbons into smaller, lighter hydrocarbons. If the larger hydrocarbons are not broken into smaller hydrocarbons gasoline cannot be made. The boiling point of larger hydrocarbons is much higher than smaller ones. The boiling point of gasoline is fairly low–between 104° F and 401° F which requires smaller hydrocarbons.

10. What are 3 ways gasoline might be transported from the refinery.

Pipelines, ships, trains

Gasoline Production: A Cursory Glance–from crude oil to gasoline

Gasoline has been a focal point of conversation, policy decisions, and international relationships in the world for the past three decades. Our dependence on gasoline (and other petroleum products) may ultimately, be the deciding factor in changing the scope and character of our international relationships and quality of life across the United States. What is this substance that holds such vast power over American society and how is it created? This section provides a cursory glance at how crude oil is formed, found, mined, and transformed into gasoline.

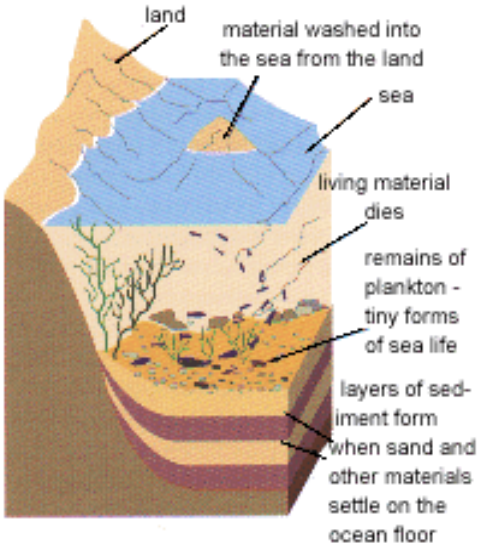
FOSSIL REMAINS

In order to create gasoline, crude oil–or unprocessed oil–must be located and extracted from deep inside the Earth. Crude oil is a non-renewable, natural resource called a fossil fuel. As the name suggests, it is formed from the remains of tiny plants and animals (plankton) that died millions of years ago–anywhere from 10 million to 600 million years ago.

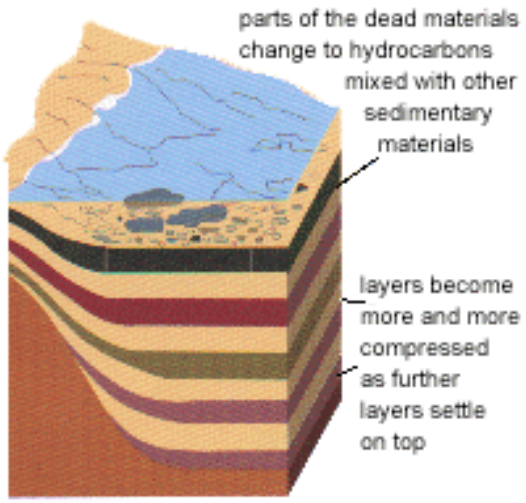
In this time period, much of the earth was covered with water (the ancient seas). Over millions of years, many layers of plankton remains, sand, and mud were formed on the ancient seabeds. Given there was little or no oxygen present in these layers, the plankton remains decayed into carbon-rich compounds. These compounds mixed with other sediment in the sea and formed fine-grained shale sedimentary layers. The early sedimentary layers are called source rock.

Over time, new sedimentary layers were formed and exerted pressure and heat onto the source rock layers below. Under extreme heat and pressure, the organic material found in the source rock became crude oil and natural gas. The crude oil then seeped from the source rock and accumulated in more porous limestone (shale + heat + pressure = limestone). The limestone layers are called reservoir rock. Movements in the Earth trapped the oil and natural gas in the reservoir rock between layers of very hard rock such as granite or marble. These layers are called cap rock.

Forming the Layers

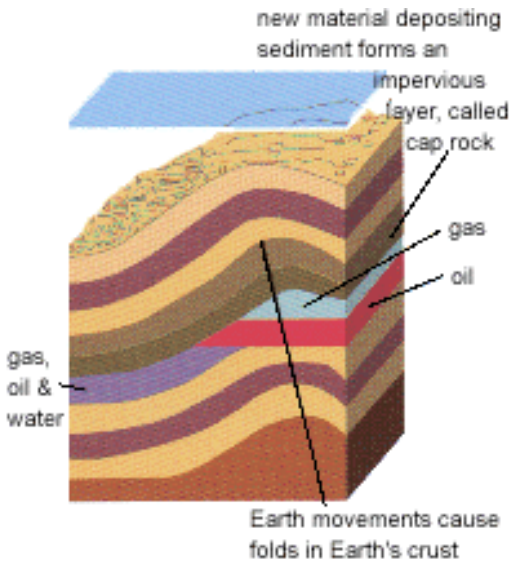


Compressing the Layers



images from School Science UK (www.schoolscience.co.uk/content/4/chemistry/fossils/p3.html)

Trapped Oil



LOCATING THE TRAPPED CRUDE OIL

Geologists are usually the scientists given the task of finding oil trapped deep within the Earth. Many methods are used to find the pockets of crude oil reservoirs. Today, satellite images help scientists to examine surface rocks and terrain. Scientists also use gravity meters that measure changes in the Earth's gravitational field possibly indicating flowing crude. Magnetometers that measure changes in the Earth's magnetic field are also used. Other methods / tools that scientists may use to locate trapped oil are core sample drilling, seismology, and sniffers.

Though modern oil exploration technology has become more sophisticated, there is still approximately a 10% success rate for locating new oil fields.

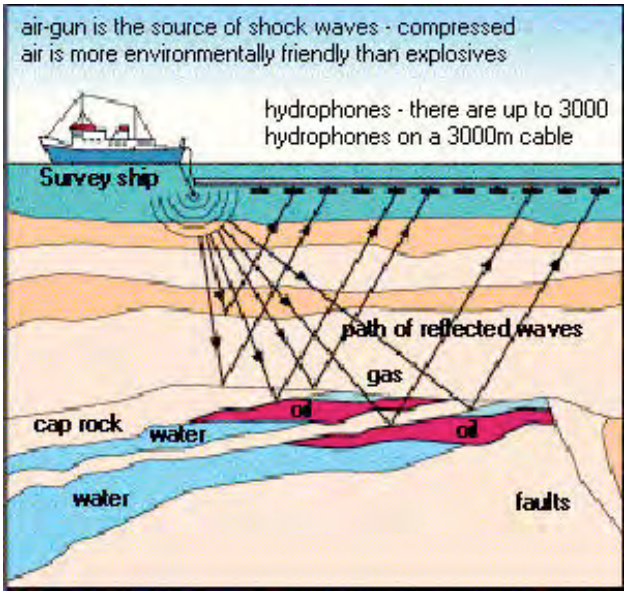


image courtesy from the article *How Oil Drilling Works* written by Craig C. Freudenrich, Ph.D

PREPARING TO DRILL FOR THE TRAPPED CRUDE OIL

Once a site has been selected for oil exploration, environmental impact studies and surveys must be completed. Land rights issues, access, and legal jurisdiction must also be settled before the actual drilling may begin.

Once these issues have been settled, the oil company begins preparing the site. These preparations may include:

- Clearing the land and building access roads;
- Drilling a water well if there is no water nearby;
- Digging a reserve pit where the drilling wastes (rock cuttings and drilling mud) are to be deposited; and,
- Building access roads and digging an off-site reserve pit if the drilling takes place in an ecologically sensitive area.

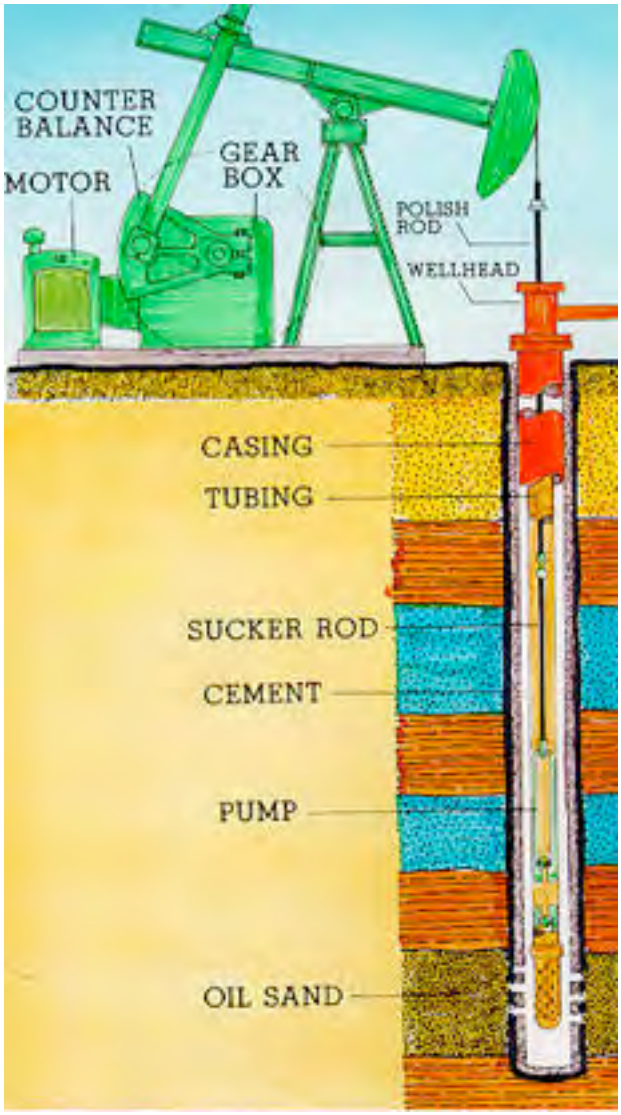
Once the site is prepared, the oil drilling rig must be built and several holes dug for the work crews and drilling apparatus. The drilling rig equipment and materials are then brought to the site by truck, helicopter, or barge-ship depending on the site location. Once the materials are in place, the oilrig is set-up.

Digging for oil is a large-scale operation and oilrig sites often resemble small cities. The oilrig not only contains all of the tools necessary for oil drilling and extraction, but it is also often the home for the crew. In most cases, oilrigs are in place for many years of drilling. Below is an image of a deepwater semi-submersible oilrig:

Sedco Energy & Sedco Express IHImage from:
www.btinternet.com/~derek.mackay/offshore/images/rigs/Twa_rigs_again.jpg

AN EXTREMELY SIMPLIFIED EXPLANATION OF CRUDE OIL EXTRACTION

Extracting the crude oil from inside the earth involves powering electrical generators from diesel engines to run the mechanical systems (drilling and hoisting systems). Deep shafts (wells) are drilled through the cap rock into the sedimentary layers containing the oil. A pump is moved up and down though the shaft creating a suction that draws oil up through the well. Below is an example of a pump on an oil well.



This detailed image is courtesy of the California Department of Conservation.

Photo courtesy of Phillips Petroleum Company

FROM CRUDE OIL TO GASOLINE: OIL REFINING

As we've learned thus far, crude oil that is pumped directly out of the ground is not the same thing as the oil used in a car's engine. Crude oil is a mixture of thousands of individual chemical compounds. In order to separate these compounds into useful materials (substances), the crude oil must be refined. There are three basic steps common to all oil refining operations: separation, conversion, and treatment.

But, before we discuss oil refining, it is important to note that the amount of gasoline–or kerosene, diesel oil, or other petroleum products–made from each barrel of crude oil depends on many factors and is not consistent from barrel to barrel of crude oil. Throughout the world, crude oil is sold by a 42-gallon barrel (barrel of crude oil equals 42 gallons). The conversion of crude oil to gasoline depends upon several factors such as: oil refinery production (it is not consistent from month to month); the quality of the crude oil; the type of gasoline (octane level) desired by the refinery; the international price per barrel (economic factors); and, the political stability of the region where the oil is being extracted. Therefore, it is difficult to gauge exactly how much gasoline can be made from each barrel of crude oil, though some experts will loosely estimate 40% of each barrel of crude is turned into gasoline. But, given the variety of factors determining gasoline production, please refer to the Energy Information Administration's website–eia.doe.gov–for up-to-date conversion percentages.

3 BASIC STEPS OF OIL REFINING: SEPARATION, CONVERSION, TREATMENT

FRACTIONAL DISTILLATION

One of the oldest and most common ways to separate molecules in liquid materials is through their boiling points. This method of distillation is also applied to separating crude oil. Crude oil contains many different chemical compounds that possess different boiling points. By heating the crude, the liquids and vapors can be separated into fractions according to their boiling points. Once the fractions reach their boiling point, the fractions will vaporize. Fractional distillation condenses the vapor.

FRACTIONAL DISTILLATION AND DISTILLATION TOWERS

Fractional distillation takes place in the distillation towers of an oil refinery. These are the tall, narrow columns that often give an oil refinery its distinctive appearance. Inside the towers, the liquids and vapors separate into fractions according to their density and boiling point. The lightest fractions rise to the top of the tower where they condense back to liquids, the medium weight liquids remain in the middle, the heavier liquids separate below, while the heaviest fractions with the highest boiling points settle at the bottom of the distillation towers.

www.sjgs.com/refinery.html

PRODUCTS PRODUCED FROM REFINED OIL FRACTIONS

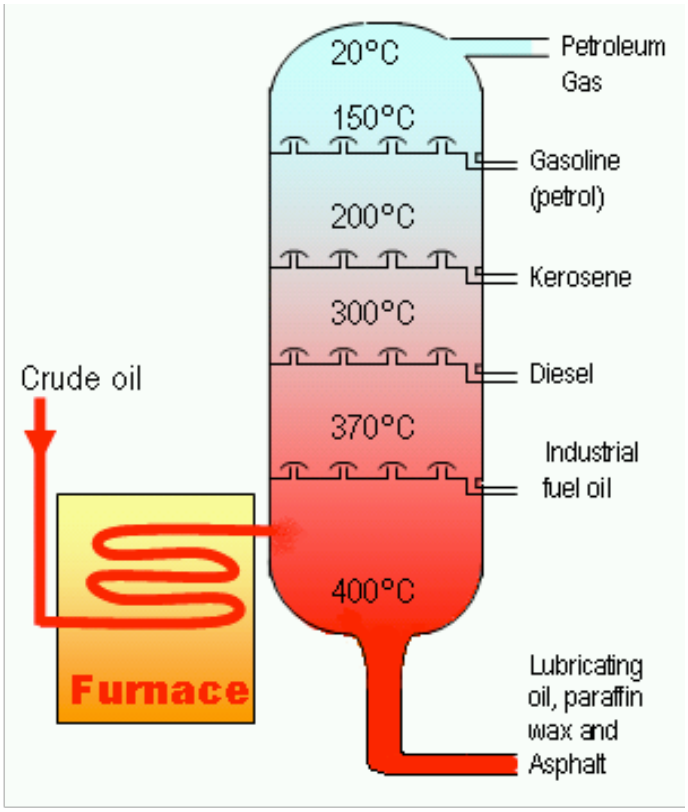


Image taken from Wikipedia from an article on Oil refinery
www.wikipedia.org

- Petroleum gas (used for heating, cooking, making plastics
  - Boiling range: less than 104°F
- Naptha or Ligroin (intermediate that will be further processed to make gasoline)
  - Boiling range: 140°F to 212°F
- Gasoline (motor fuel)
  - Boiling range: 104°F to 401°F
- Kerosene (jet / tractor fuel, starting material for other products)
  - Boiling range: 350°F to 617°F
- Diesel distillate (diesel fuel and heating oil, starting material for other products)
  - Boiling range: 484°F to 662°F
- Lubricating oil (motor oil, grease, other lubricants)
- Boiling range: 572° F to 700°F
- Fuel oil
  - Boiling range: 700°F to 1112°F
- Residuals (coke, asphalt, tar, waxes, starting material for other products)
  - Boiling range: greater than 1112°F

The listing of products was compiled from information from *How Oil Drilling Works* written by Craig C. Freudenrich, Ph.D. His article can be found at: www.science.howstuffworks.com/oil-refining.htm/printable. Also, please refer to the How Stuff Works website to view an animated drawing of a fractional distilling column.

CONVERSION

The various fractions are then piped to different stations within the refinery. Very few fractions leave the fractional distillation towers ready for market and many of them require chemical processing to transform them into other fractions. Conversion is where fractions are transformed into intermediate components that will eventually become the final products. The desired final product of the different fractions dictates the amount of additional processing that will be required. A fraction can be changed into another fraction by three different methods: cracking, unification, or alteration. But, we will focus on the 'gasoline-making' process of cracking.

Cracking is the general term for breaking larger hydrocarbons into smaller hydrocarbons. The larger hydrocarbons also have the highest boiling points. Therefore, in order to make gasoline, larger hydrocarbons must be transformed into smaller ones. (Gasoline molecules have from seven to eleven carbons in each hydrocarbon chain). The basic gasoline cracking process requires high heat, low pressure, and a catalyst. Depending on the octane level desired for the gasoline also dictates the amount of additional processing.

TREATMENT

This is the final stage of transforming crude oil into gasoline before it is loaded onto railroad cars and into tanker trucks to be delivered to gas stations across the nation. Impurities (such as sulfur, dissolved metals, nitrogen, water, and inorganic salts) are first removed and then refinery technicians blend fractions to make various grade gasolines–with or without performance additives–that meet governmental specifications.

The fractions that are not destined for becoming gasoline are also blended according to their desired product–lubricating oils of different weights (10W-40, 5W-30), various grades of kerosene, jet fuel, diesel fuel, heating oil, and various grade chemicals for plastics production.

Resources and Credits

The image used in the Conversion section is from the article *What is a Refinery? A Lesson in How to Make Gasoline*, www.sjgs.com/refinery.html

The image use in the Treatment section is from the book chapter, "Chemistry: Matter and Change", www.glencoe.com/sec/science/chemistry/mc/pow/chapter22.shtml

Excellent website resources for information on oil refinery are

- www.wpbschoolhouse.btinternet.co.uk/page04/OilProducts.htm#crude
- www.science.howstuffworks.com/oil-refining.htm/printable

Student Hand-out

Question Set:

1. What is gasoline created from?

2. What is a definition of crude oil?

3. What must happen to fossil remains in order for them to become crude oil or gas?

4. Using your own ideas (do not copy from the reading hand-out), draw the process of how fossil remains become crude oil.

5. How might trapped crude oil be found?

6. What are three considerations that must be taken into account before an oil rig can be set up at a selected site?

7. Illustrate what an identified site for drilling and an oilrig might look like.

8. Summarize through illustrations and captions (words) the oil refining process.

9. What is cracking and why is it important?

10. What are 3 ways gasoline might be transported from the refinery.

Lesson 8: 7th grade
A Cursory Glance: The Four-Stroke Internal Combustion Engine

Lesson Overview: Learning the basic components of a four-stroke internal combustion engine.

Lesson Concept: Understanding basic combustion theory in order to develop a deeper understanding of how automobile emissions are created.

Materials:
- Student hand-out or overhead: Internal Combustion Engine Primer
- Note-taking journal
- Parent Information Letter

Standards:
- English:
  - IX.11.MS.1 (Inquiry and Research: Define and investigate important issues and problems using a variety of resources).
- Mathematics:
  - III.1.MS.1 (Data Analysis & Statistics: Collect and explore data through observation, measurements, surveys, sampling techniques and simulations).
  - III.1.MS.4 (Data Analysis & Statistics: Identify what data are needed to answer a particular question or solve a given problem, and design and implement strategies to obtain, organize and present those data).
- Science:
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  - II.1.MS.3 (Reflect on the Nature, Adequacy and Connections Across Scientific Knowledge: Show how common themes of science, mathematics, and technology apply in real-world contexts).
- Social Studies:
  - IV.2.MS.4 (Economic Perspective: Examine the historical and contemporary role an industry has played and continues to play in a community).

Timeline: 2 – 5 class periods (40 – 50 minutes each)

Class Structure: reading assignment, small group project, and optional teacher-led demonstration

Assessment Strategy: EEK! Daily Assessment
General Assessment Strategy #2
General Assessment Strategy #3

Lesson 8: 7th grade
A Cursory Glance: The Four-Stroke Internal Combustion Engine

Lesson Overview: Learning the basic components of a four-stroke internal combustion engine.
Lesson Concept: Understanding basic combustion theory in order to develop a deeper understanding of how automobile emissions are created.

Materials:
- Student hand-outs or overheads: Internal Combustion Engine Primer
- Note-taking journal
- Parent Information letter (optional potato rocket teacher led demonstration)

CLASS EXERCISES:

I. Four-Stroke Internal Combustion Engines

For the first part of the lesson refer to the Internal Combustion Engine Primer (*Internal Combustion Engines: a Primer*). If possible, introduce the components of the internal combustion engine to the students via an overhead. Also, if you have access to the technology resources, refer to the websites provided to watch animated drawings of four-stroke internal combustion engines.

II. Drawing the Engine: a small group project

A. After you have introduced the information in the Primer, have the students, individually, draw an image of a four-stroke combustion engine from memory.
B. Once everyone in the class has completed their drawings, divide the students into small groups.
C. Ask the group members to compare their drawings with each other.
D. Then, ask each small group to create one final image of a four-stroke combustion engine labeling as many parts of their engine drawing as possible.
E. Hopefully, with the combined knowledge of all the group members, each group will create a close approximation to the information they learned earlier (in the Primer). If the students express confusion, encourage them to discuss what they have learned from the earlier lesson to tease out the information for themselves (independently or collectively).

III. Compare the Drawings

After each group has completed one drawing, pass out the Primer to each student. If necessary, ask the groups to correct and / or modify their drawings to reflect the basic components of a four-stroke combustion engine. Then, have the students securely place the Internal Combustion Primer in their Transportation Journals.

IV. Combustion Explained: Combustion Chemistry

This section discusses the basic chemistry of combustion. This exercise is an introduction to basic chemistry and chemistry concepts that will be later discussed in Lesson 9 (emissions, pollutants, and global warming).

V. Potato (Tennis Balls / Syrofoam Balls) Rockets ***optional teacher led demonstration***

Creating potato rockets is a direct and engaging way to show students exactly how energy dense gasoline is as a fuel. Also, it provides a visual for the ignition and exhaust parts of combustion. But, THIS IS A POTENTIALLY DANGEROUS EXERCISE! We have constructed this exercise as a teacher-led demonstration only with added exercises for student involvement.

Also, included at the end of the lesson is a PARENT INFORMATION LETTER. We suggest treating this letter as a permission slip for specific student participation in the experiment.

Internal Combustion Engines: a Primer

photo courtesy of Daimler Chrysler, 2003 Jeep Grand Cherokee Engine

A Brief History

In 1867, 34-year old Nicolaus August Otto created an invention that changed the world. The German engineer developed the four-stroke cycle engine. Dubbed the Otto-cycle this invention remains one of the most common engines used in cars and trucks today.

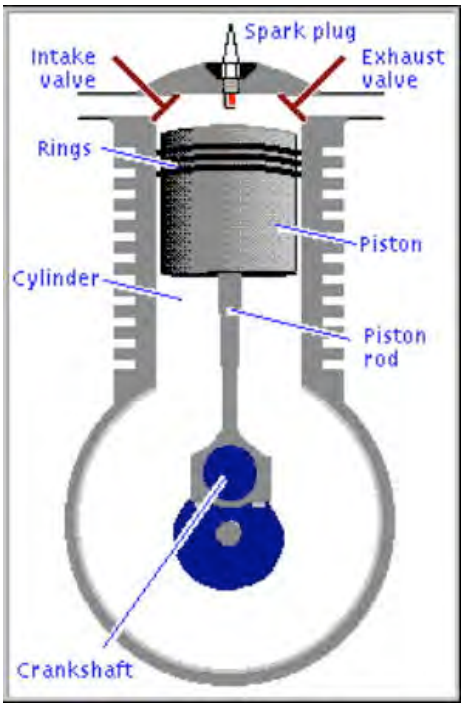
The Basics

The four-stroke engine is aptly named for it has four motions or “strokes”. The four strokes of the internal combustion engine occur in the following order:

- Intake
- Compression
- Power
- Exhaust

This process is continually repeated, always in this sequence, during the operation of the engine.

The Internal Parts

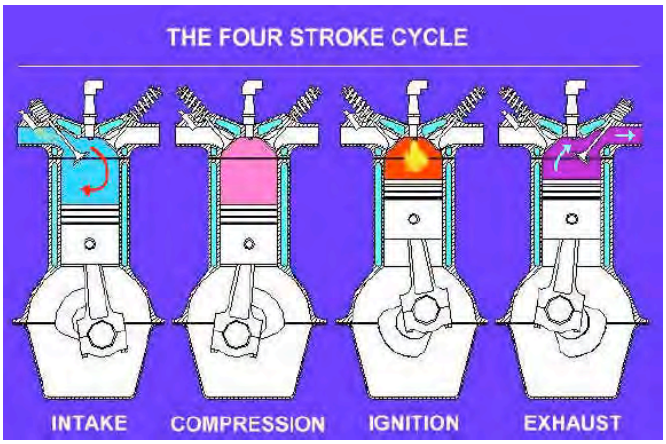


www.siu.edu/~autoclub/frange.html

Before explaining the operation of the four-stroke engine, some of the internal parts must be identified. Above is a drawing of the basic internal combustion engine. The description below is from *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University.

> The Intake Valve opens at a precise time to allow the air/fuel mixture to enter the cylinder. The Exhaust Valve opens at a precise time to allow the burned gases to leave the cylinder. The Spark Plug ignites the air/fuel mixture in the cylinder, which creates an explosion. The force of the explosion is transferred to the Piston. The piston travels up and down in a Reciprocation Motion. The force from the piston is then transferred to the Crankshaft through the Piston Rod (connecting rod). The piston rod converts the reciprocating motion of the piston, to the Rotating Motion of the crankshaft. The four engine strokes require two revolutions of the crankshaft to complete one full cycle.

The Cycle Explained



www.antonine-education.co.uk/physics_a2/options/Module_7/Topic_4/internal_combustion_engines.htm

Please refer to the above diagram to help describe each of the four engine strokes. Also, the following websites have excellent animated drawing of internal combustion engines that provide a graphic visual explanation of the cycle:

- www.siu.edu/~autoclub/frange.html
- www.howstuffworks.com/engine.htm
- www.keveney.com/Engines.html

The Intake Stroke

During this stroke, the piston starts at the top, the intake valve opens, and the piston moves down to let the engine take in a cylinder full of air and gasoline. Given that gasoline is a very energy dense chemical compound, only a small amount (a drop) of gasoline needs to be mixed with air for the cycle to work properly.

The Compression Stroke

The piston moves back up to compress the fuel / air mixture. As this happens, the intake valve closes and the exhaust valve is closed creating a sealed cylinder chamber. When this mixture is compressed, it increases in temperature, which in turn will make the explosion more powerful.

The Ignition Stroke

When the piston reaches the top of its' stroke, the spark plug emits an electric spark and ignites the gasoline. The gasoline / air mixture burns rapidly and the cylinder pressure increases. All of this pressure in the cylinder continues to increase until it explodes. The force of the explosion drives the piston down. As the piston moves downward, force is transmitted to the piston rod which is connected to the crankshaft. The crankshaft is rotated due to the force.

The Exhaust Stroke
Once the piston hits the bottom of the stroke, the exhaust valve opens. As the piston moves upward, it forces the burned gases out of the cylinder through the exhaust port (the tail pipe). When the piston reaches the top of its travel, the exhaust valve closes, and the intake valve opens. The crankshaft has now completed two full revolutions and the cycle is complete. The engine is ready for the intake stroke, so it intakes another charge of air and gasoline.

The above explanation is taken from two articles: *Back to the Basics: Fundamentals of the Four-Stroke Internal Combustion Engine* written by the Automotive Technology Organization at Southern Illinois University and *How Car Engines Work* written by Marshall Brain.

IV. Combustion Explained: Combustion Chemistry

What is the Air Made Of?
Begin this section with the lead question: What is air made of?

- Write down all of the students' responses.
- How quickly you can cover this part of the lesson will be determined on the students' prior knowledge of chemistry–the information may be review or an introduction of new concepts.

The air we breathe consists mostly of the following gases:

Nitrogen (N_2)	78%
Oxygen (O_2)	20%
Other (argon, helium, water vapor, carbon dioxide)	2%

Essentially, the air we breathe mainly consists of N_2 and O_2.

Gases: Phase-Change
Oxygen and nitrogen are chemical elements in the gaseous phase. All chemical elements can be found in one of three phases. The three phases are: solid, liquid, and gas. For example, let's take a look at water. Water is frozen when in the solid phase, wet when in the liquid phase, and steam when it is in the gaseous phase. When temperatures of an element increase, the molecules of a substance part (are further away from one another) causing the substance to become less visible (or generally considered gaseous in non-scientific terms). This phase change causes air to be invisible. When the temperature decreases, the molecules are closer together. If the temperature decreases enough the substance will become solid. Elements change phases (or phase-change) at different temperatures.

Combustion Chemistry (a simplified version)
Oxygen (O_2) is an extremely volatile chemical element. If oxygen were the only component in the air on earth, everything would be constantly blowing up (igniting). This is where nitrogen comes into play, the nitrogen in the air acts as a buffer. But, when you want to burn something (a combustion reaction), the nitrogen has to go along for the ride (in air). Therefore, the nitrogen has to be heated. When the nitrogen gets hot, it is susceptible to reacting. In the case of air, when nitrogen is heated it reacts with the oxygen and becomes nitrogen oxide.

If there was perfect combustion in automobile engines, nitrogen oxides would not be a result of the combustion reaction. Below is the most simple, idealized combustion reaction–methane. Most fuels have carbon, hydrogen, and oxygen, but methane is the only fuel without oxygen present. The combustion reaction looks like this:

$CH_4 + 2O_2 \;>\; 2H_2O + CO_2 + \text{energy}$

But, when driving a car, the combustion reaction takes place in the real world and oxygen is present.

Fossil fuels consist primarily of hydrocarbons. Hydrocarbons are atoms created from hydrogen and water. When hydrocarbons burn, the carbon combines with oxygen to produce carbon monoxide, carbon dioxide, nitrogen oxide, unburned hydrocarbons, and water.

Exhaust Pollutants
Hydrocarbons
Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone which is a major component of smog.

Nitrogen Oxides (NO_X)
Under the high temperature and pressure conditions of an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides. Nitrogen oxides must be present to the formation of ozone and contribute to the formation of acid rain.

Carbon Monoxide (CO)
CO is a product of incomplete combustion and occurs when the carbon in the fuel partially, rather than fully, oxidizes.

Carbon Dioxide (CO_2)
CO2 is a product of complete combustion and occurs when the carbon in the fuel is fully oxidized. CO2 is a greenhouse gas that traps the earth's heat and contributes to global warming. Most important is: gasoline is energy dense & the combustion reaction are not perfect because you are carrying along all this nitrogen. But, others things are also happening.

Why use fossil fuels (gasoline)
Even though the combustion reaction is not perfect and creates large amounts of toxic emissions, gasoline has been the fuel of choice because it is an energy dense fuel source which means it only takes a small amount to cause a large reaction.

Building a Potato Rocket: Basic Plans, Experiments

I. Gasoline is an Energy Dense Fuel

Gasoline has a high energy content which means it takes only a small amount of gasoline to cause a large reaction. Gasoline is also highly flammable and toxic. If strong concentrations of gasoline are inhaled, this can cause dizziness, vomiting, and even death.

Building a Potato Rocket is an excellent visual demonstration of exactly how energy dense of a fuel gasoline really is: it takes only a drop of gasoline to launch a potato or tennis ball potentially 100 (or more) feet through the air.

This exercise is being suggested as a strictly teacher-constructed and teacher-led demonstration. Specifically, this means that WE DO NOT RECOMMEND STUDENTS TAKING PART IN ANY ASPECT OF THE BUILDING OR FIRING OF THE POTATO ROCKET.

This, therefore, is an optional exercise for the teachers depending on their prep time, interest level, and classroom climate. This exercise does provide an excellent opportunity for the students to hypothesize on potential outcomes as well as gain a first hand understanding of what the term "energy dense fuel" means.

All of the building supplies can be purchased at your local hardware store and camping store. Once constructed, the potato rocket should last many years and provide multiple class demonstrations.

II. Class Involvement

The day before the Potato Rocket Demonstration, have the students make hypotheses about the distance the potato / tennis ball will be launched. Write down all of the responses and have each student write down their predictions in their Transportation Journal.

Question #1: How far away do you believe the potato / tennis ball will land from the launching rocket?

Question #2: Make predictions for three different launches.

Question #3: Which do you believe would travel further: a potato or a tennis ball? Explain why.

III. The Day of the Launch

Before going outside, go over the class behavior expectations for the experiment. Then, assign the roles for the student assistants.

Student Assistants' Tools

- 100' measuring tape
- clipboards
- note-taking journals
- pencils
- erasers

Student Assistants' Roles

- Students will assist in measuring the distance the objects are launched, recording each measurement, and retrieving all launched objects.
- Students may also assist in carrying supplies (other than the gasoline or the potato rocket) to the experiment site.

IV. Comparing Results with Initial Hypotheses

The following day, discuss the results from the experiment and compare the results with their original hypotheses.

- Were the students surprised by the experiment? Why or why not? Explain in detail.
- How close were their original hypotheses to the actual distance launched?
- Discuss briefly the concept of an energy dense fuel–consider the amount of energy it takes to move a vehicle the size and weight of an automobile. Ask the following question:

Question #1: What might affect gas mileage in different vehicles. Discuss this question with the class and have them record their answers in the Journal.