Locomotives at Work

YEAR 8
PHYSICAL SCIENCES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

Future Makers

Future Makers is an innovative partnership between Queensland Museum Network and Shell's QGC business aiming to increase awareness and understanding of the value of science, technology, engineering and maths (STEM) education and skills in Queensland.

This partnership aims to engage and inspire people with the wonder of science, and increase the participation and performance of students in STEM-related subjects and careers – creating a highly capable workforce for the future.

Cover image: A10 No.6 steam locomotive at The Workshops Rail Museum. QM, Peter Waddington.

QUEENSLAND MUSEUM NETWORK

Queensland Government

EXPLORE – EXPLAIN – ELABORATE

Locomotives at Work

Teacher Resource

The Workshops Rail Museum, located in Ipswich, Queensland, is a site steeped in history.

For decades, the site was the centre of rail construction, maintenance and technology for Queensland's burgeoning rail industry. Between 1865 to 1997, 217 locomotives, 871 carriages, 11,801 wagons, 2,016 vans, 96 railmotors and 143 trailers were constructed at the Ipswich Railways Workshops, and thousands of workers called the site home. During its peak in the Second World War, over 3,000 people worked on the site, making it Queensland's largest employer at the time. In the 1990s, the site ceased operations for most types of work, except for the maintenance of Queensland Rail's heritage fleet. They are now the oldest continually running railway workshops in Australia.

Ipswich Railway Workshops from the air, circa 1950.

In this activity, students use locomotives from The Workshops Rail Museum's collection to explore energy transfers and transformations. Students interpret Sankey diagrams and calculate the hypothetical energy efficiency of various locomotives. Students can view the locomotives used in this activity at The Workshops Rail Museum.

Following this activity, students could complete The Future of Rail: A Design Challenge.
In this resource, students design a 'clean' train and rail system for Queensland.

Curriculum Links

Science

YEAR 8

Science Understanding

Energy appears in different forms, including movement (kinetic energy), heat and potential energy, and energy transformations and transfers cause change within systems (ACSSU155)

Science Inquiry Skills

Communicate ideas, findings and evidence based solutions to problems using scientific language, and representations, using digital technologies as appropriate (ACSIS148)

Mathematics

YEAR 8

Number and Algebra

Solve problems involving the use of percentages, including percentage increases and decreases, with and without digital technologies (ACMNA187)

General Capabilities

Literacy

Comprehending texts through listening, reading and viewing

Composing texts through speaking, writing and creating

Locomotives at Work

Teacher Resource

Student Answers

In the *Student Activity: Locomotives at Work*, students are provided with a series of jumbled statements that describe how a steam and a diesel electric locomotive work. Students are required to read the statements and then write them in the correct order. The correct order for both locomotives can be seen below. You can use this information to check and correct students' responses.

Steam Locomotive

1. Fuel (usually coal) is burned in the firebox to make hot gases.
2. The gases pass through boiler tubes that run the length of the water-filled boiler.
3. The gases heat the surrounding water and turns it into steam.
4. The steam rises to the steam dome, where it is forced through a series of tubes into the cylinder.
5. The steam drives the piston in the cylinder, pushing it forward.
6. The steam escapes through a one way opening, and the piston can slide back again.
7. The pistons are connected to the driving wheels with rods. As the piston moves back and forth, it moves the rods, which then makes the wheels turn.

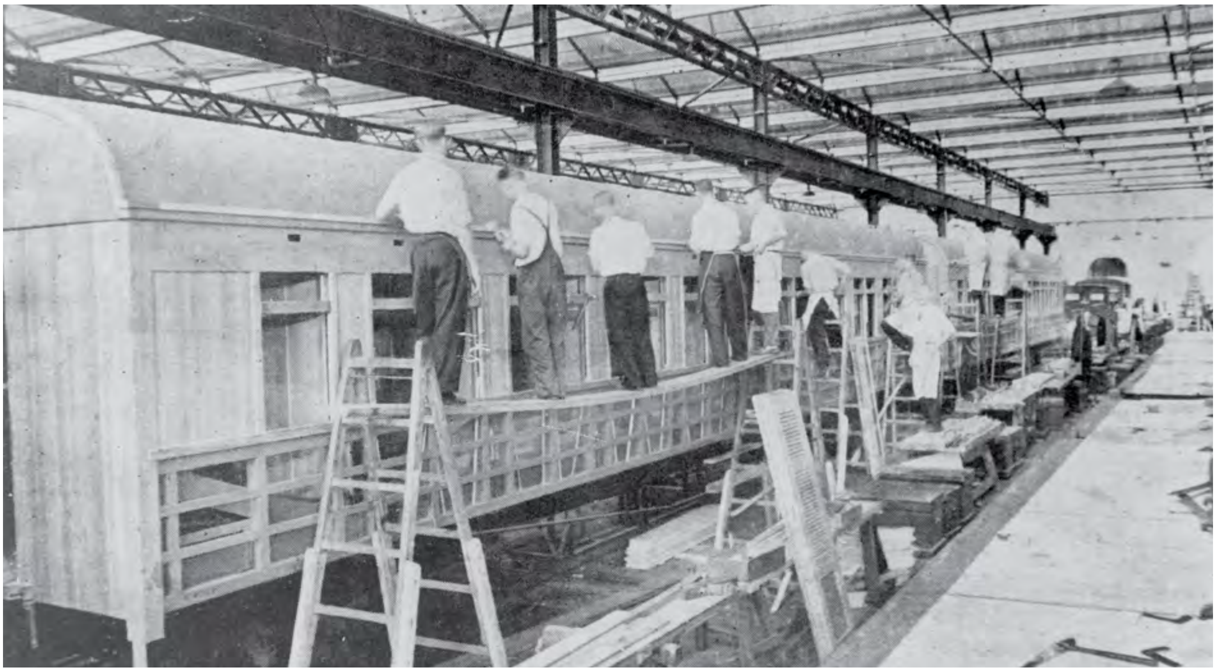
Diesel Electric Locomotive

1. The engine draws air into the cylinders.
2. Pistons are located inside the cylinders. This intake of air pushes the pistons down.
3. As the pistons move back up, they compress the air inside the cylinders.
4. Diesel fuel is injected directly into the cylinders. The fuel is delivered to the engine from the fuel tank by an electric pump.
5. The heat of the compressed air ignites the fuel. These explosive bursts push the pistons back down. This movement turns a crankshaft.
6. The movement of the crankshaft drives a generator, which makes electricity.
7. The electricity is distributed to the electric traction motors, which drive the wheels.

Locomotives at Work

Student Activity

Rail has been an integral industry in the development of Queensland, especially in Ipswich. The construction of the original Ipswich Railway Workshops began in 1864 at a site adjacent to the Bremer River in North Ipswich. As the railways expanded, a much larger site was needed, so the Workshops moved to its current location (The Workshops Rail Museum site) between 1884 and 1888. For decades, the site was the centre of rail construction, maintenance and technology for Queensland's burgeoning rail industry. The workshops still operate today, just on a far smaller scale!



Workmen constructing carriages in the carriage and wagon shop, circa 1925.

Ipswich Railway Workshops staff, circa 1910.

In this activity, you will use locomotives from The Workshops Rail Museum's collection to:

- Explore energy transfers and transformations;
- Interpret Sankey diagrams; and,
- Calculate the energy efficiency of various locomotives.

Locomotives vs Trains

Locomotives and trains are the same thing, right? Not quite. A locomotive refers to the power unit of a train. It is usually the first part of the train that you see. A locomotive does not carry passengers or freight; it usually pulls the coaches, rail cars or wagons that contain the passengers and freight. A train refers to the series of interconnected coaches, rail cars or wagons that are usually pulled by the locomotive.

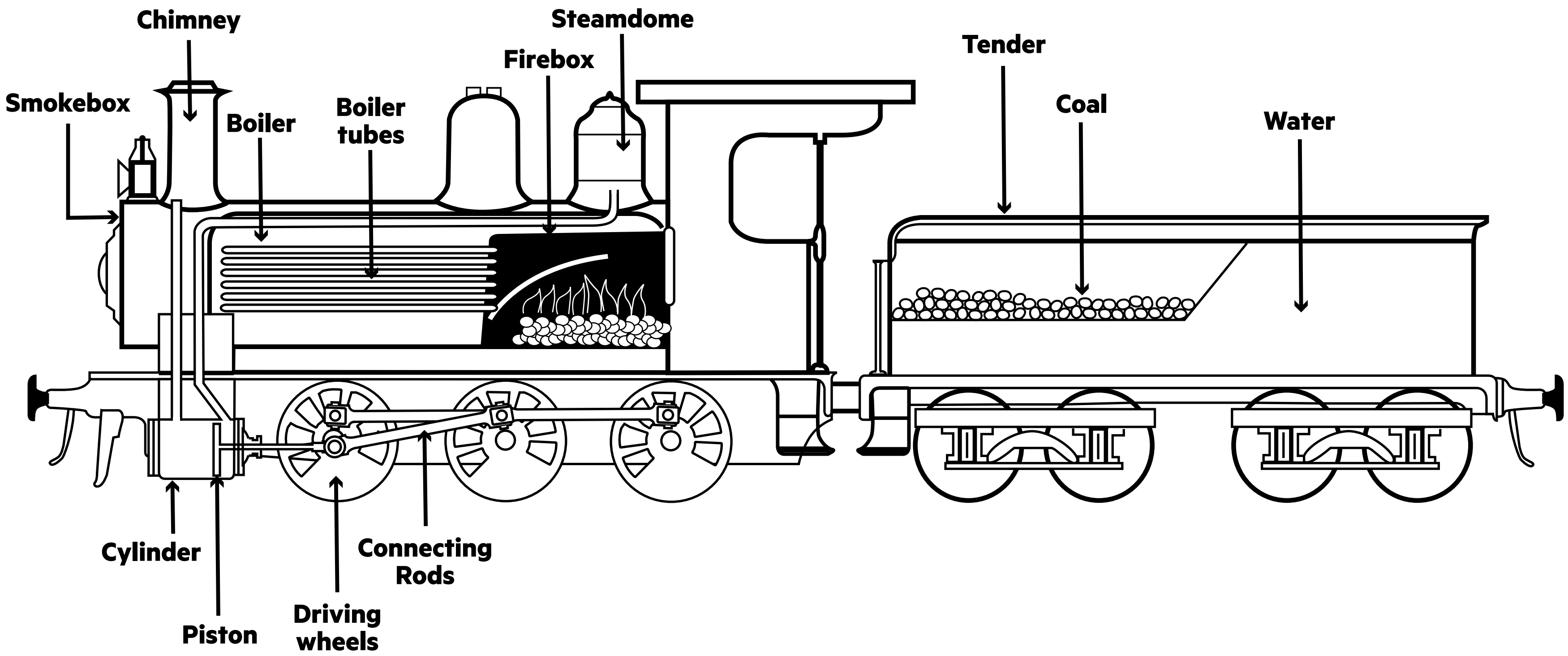
Steam Locomotives

A10 No.6 was one of twelve steam locomotives supplied to Queensland Railways (QR) in 1866. The locomotive was sold to the Bingera Sugar Mill in 1896, where it began a new life hauling sugar cane near Bundaberg. It remained in use until 1965, when the mill owner offered it back to QR as a 100th birthday present. The little locomotive was steamed all the way from Bundaberg to Brisbane and played a starring role in the centenary celebrations on 31 July 1965. A10 No.6 is the oldest working steam locomotive in Australia.

Image, left: A10 No.6 steam locomotive. QM, Peter Waddington.

Steam Locomotive

View the diagram of the steam locomotive below. This is a general diagram of a steam locomotive and does not specifically represent A10 No.6 locomotive.



Read the jumbled statements that describe how the steam locomotive works. Write the statements in the correct order in the flowchart below to show how energy moves through the system.
You could also cut out and rearrange the statements in the correct order.

Jumbled Statements

The pistons are connected to the driving wheels with rods. As the piston moves back and forth, it moves the rods, which then makes the wheels turn.
The steam rises to the steam dome, where it is forced through a series of tubes into the cylinder.
Fuel (usually coal) is burned in the firebox to make hot gases.
The gases heat the surrounding water and turns it into steam.
The steam drives the piston in the cylinder, pushing it forward.
The steam escapes through a one way opening, and the piston can slide back again.
The gases pass through boiler tubes that run the length of the water-filled boiler.

Flowchart – How a Steam Locomotive Works

Use your understanding of the states of matter to explain how the heating of water can drive an engine.

Draw a flow diagram to represent the energy transfers and transformations that occur in the steam locomotive.

Interpret the Sankey diagrams below. Justify which diagram best represents the transformation of energy in a steam locomotive.

Diagram 1

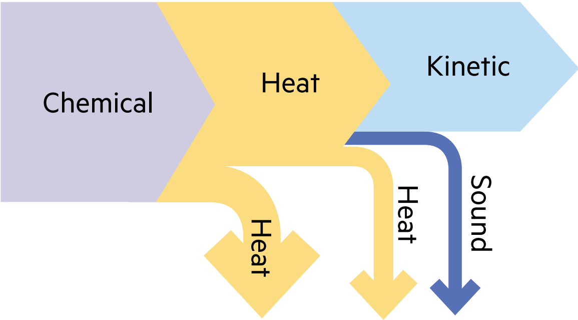


Diagram 2

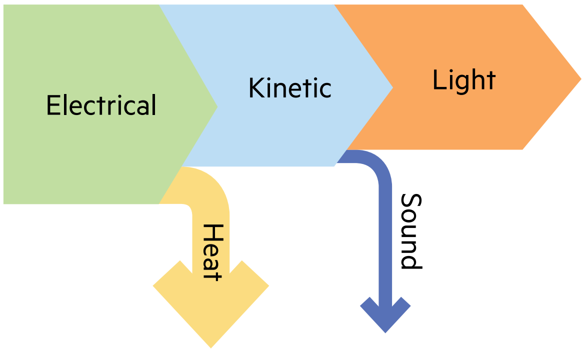
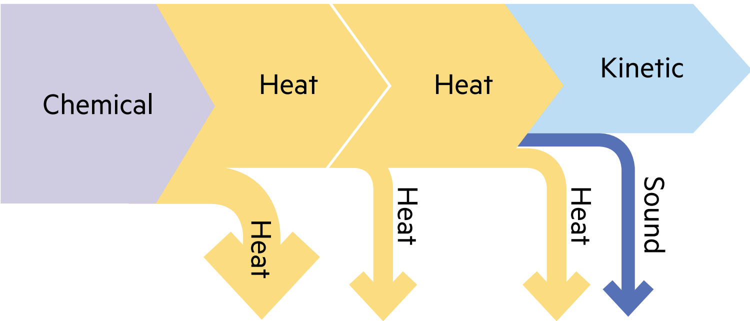


Diagram 3



The fireman's role on a steam locomotive was to stoke the fire and maintain steam pressure in the boiler. On average, a fireman could shift 4.53 kg of coal into the fire box in one shovel. If one gram of coal produces 34 kJ of energy, calculate much energy is in each shovel of coal.

For every shovel of coal that is burned in the fire box, 50,826 kJ is lost as heat energy to the surrounding air. The remaining energy is used to heat the water in the boiler. Calculate the energy efficiency of this process.

Calculate how much useful energy is used to heat the water in the boiler, per shovel of coal.

Of the remaining energy used to heat the water in the boiler, 20% is lost as heat and 10% is lost as sound. Calculate the amount of energy that is used to drive the wheels of the train per shovel of coal, and then the overall efficiency of this process.

Diesel Electric Locomotives

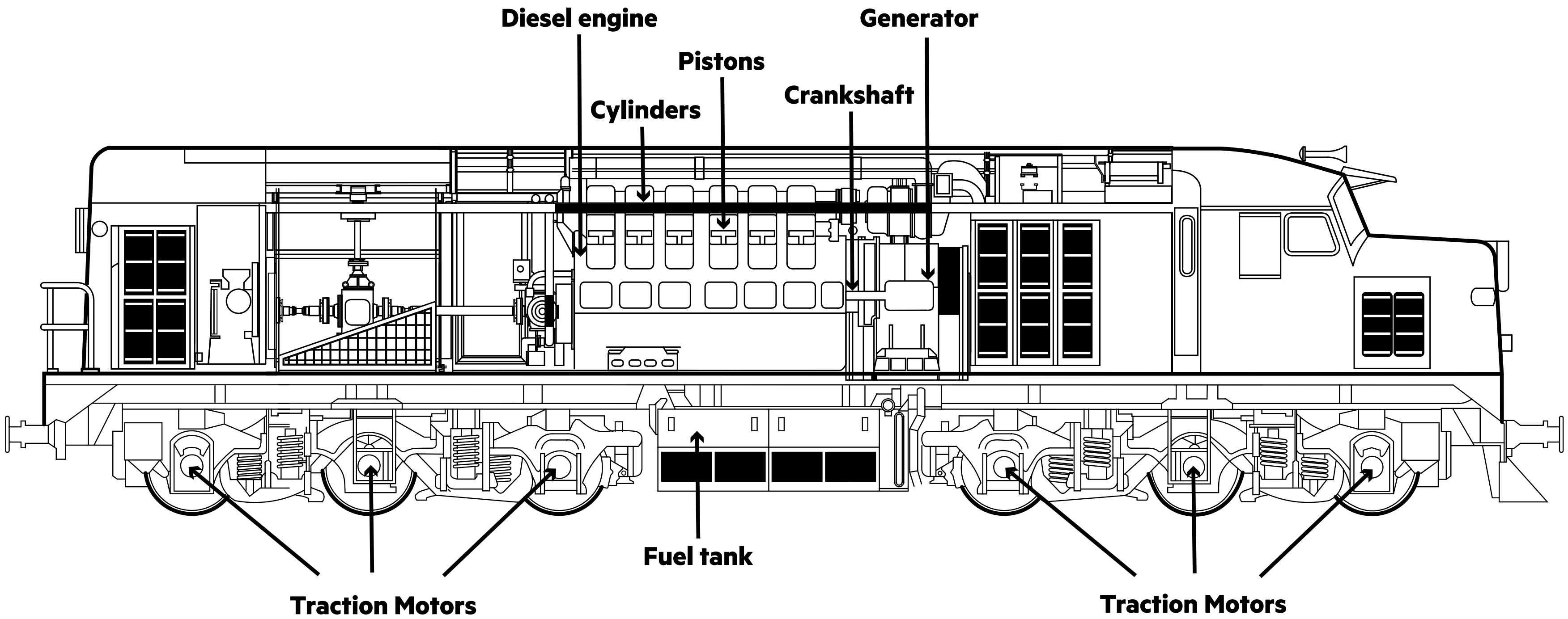
The age of the diesel electric locomotive in Queensland began in October 1952, with the arrival of 10 new locomotives from the United States of America. Diesel electric locomotives were stronger and more efficient than their steam-driven cousins; each diesel locomotive could effectively do the work of two to three steam locomotives. They also needed less servicing, as they did not require extra stops for water and coal. This meant diesel electric locomotives could venture further west where water supplies were poor. Furthermore, diesel electric locomotives were lighter than steam locomotives; this allowed them to haul longer passenger and freight cars over lightly laid tracks where steam locomotives were too heavy to travel.

The diesel electric 1250 Class: No.1262, now on display at The Workshops Rail Museum, entered service on 27 October 1961. Locomotives in the 1250 Class transported ore on the Great Northern Line (Townsville to Mount Isa) and freight on the North Coast Line (Brisbane to Cairns) and Southern Line (Toowoomba to Wallangarra). Locomotive No.1262 retired from service on 4 November 1988. It travelled 2.7 million kilometres during its service.

1250 Class: No.1262 diesel electric locomotive. QM, Peter Waddington.

Diesel Electric Locomotive

View the diagram of the diesel electric locomotive below. This diagram shows the diesel electric 1250 Class: No.1262.



Read the jumbled statements that describe how the diesel electric locomotive works. Write the statements in the correct order in the flowchart below to show how energy moves through the system.

Jumbled Statements

The electricity is distributed to the electric traction motors, which drive the wheels.
Pistons are located inside the cylinders. This intake of air pushes the pistons down.
The heat of the compressed air ignites the fuel. These explosive bursts push the pistons back down. This movement turns a crankshaft.
The engine draws air into the cylinders.
The movement of the crankshaft drives a generator, which makes electricity.
Diesel fuel is injected directly into the cylinders. The fuel is delivered to the engine from the fuel tank by an electric pump.
As the pistons move back up, they compress the air inside the cylinders.

Flowchart – How a Diesel Electric Locomotive Works

Draw a Sankey diagram to represent the energy transformations that occur in a diesel electric locomotive.

1250 Class: No.1262 could hold 3,200 L of fuel in its tank and was capable of travelling 800 km per tank of fuel. Calculate the fuel consumption of the locomotive per 100 km.

Compare the fuel efficiency of 1250 Class: No.1262 to other modes of transport and assess the fuel efficiency of the locomotive.

The kinetic energy of an object can be calculated using the equation:

$$KE = \frac{1}{2}mv^2$$

$$(\text{Kinetic Energy} = \frac{1}{2} \text{x mass x velocity}^2)$$

For example, if a 60 kg person is running at a velocity of 2 m/s (equivalent to 7.2 km/h) we could calculate their kinetic energy in the following steps:

$m = 60, v = 2$

$KE = \frac{1}{2} mv^2$

$KE = \frac{1}{2} \times 60 \times 2^2$

$KE = \frac{1}{2} \times 60 \times 4$

$KE = 30 \times 4$

KE = 120 J

Calculate the kinetic energy of one point during your trip to school. (If you travel via car or bus you may need to research the mass of your vehicle and choose to calculate the kinetic energy using the approximate maximum velocity of your trip.)

1250 Class: No.1262 had a mass of nearly 80,000 kilograms. Calculate the kinetic energy of the locomotive if it was travelling at 60 km/h. (You will need to convert the velocity to m/s.)

Explain how the kinetic energy of the train would change if the locomotive was pulling 10 carriages loaded with freight.

Calculate the kinetic energy of 1250 Class: No.1262 while it is in The Workshops Rail Museum.

If a car and a train are both travelling at 60 km/h, examine which would have the longest stopping distance. Justify your answer by giving multiple reasons for your decision.