STEAMING SYSTEMS

LOCO-MOTION

LEVEL

Year 11

VCE: Systems Engineering

ACTIVITY DESCRIPTION

Puffing Billy Railway continues to run on its original mountain track from Belgrave to Gembrook through the magnificent Dandenong Ranges, 40 kilometres east of Melbourne. The journey takes visitors over hills, down valleys, around mountains and into the Mountain Ash forests surrounded by native ferns and Eucalyptus trees.

This iconic heritage steam train is hauled by a steam locomotive acting as a mechanical system, converting thermal energy into mechanical energy throughout the mountainous journey. Students are to analyse and investigate the steam engine, a machine using steam power to perform mechanical work. Students are to produce a multimedia presentation, using text, images and video that tracks motion and energy transformations of Puffing Billy Railway's steam locomotive throughout its operation on its journey through the Dandenong Ranges.

SUBJECT AREA

Systems Engineering Unit 1: Mechanical Systems

Area of Study 1 – Mechanical System Design

MATERIALS REQUIRED

- "Loco Motion" Worksheet
- Screen and whiteboard connected to the internet to showcase examples
- Devices with access to the internet to conduct research
- Devices with access to multimedia presentation programs

INSTRUCTIONS

1. Discuss the topic of energy with students. Continue these discussions to include types of energy eg. Heat energy, kinetic energy, potential energy. As a class write some definitions on the board. *See background information.*
2. Continue this conversation by discussing energy transformations. Use the *"Example of energy transfers"* in the background information. Show students the picture and describe what is happening. Have students complete the "Loco Motion" Worksheet.
3. Bring back students as a group and undertake "Energy changes of a rollercoaster" activity - https://userfiles-secure.educatorpages.com/userfiles/MsKlein/19P11SEch06.pdf. (Page 182) Students will observe how the energy of a roller coaster varies as it travels along a frictionless track.

HINT: Teachers can discuss friction with students.

4. As a class watch the animation linked here: https://media.pearsoncmg.com/intl/pec/school/synapse/physicssource/physics11/shell/resource.php?resource=act_ch06_c1_rollercoaster.htm

   Observe how a rollercoasters energy is constantly changing between potential energy and kinetic energy, each of which are represented by a bar. Analyse the data and discuss the relationship between potential and kinetic energy as the rollercoaster moves along.

   a. Consider the following questions with students:
      i. Which type of force pulls the rollercoaster to the top of the first hill?
      ii. What energy conversions are happening as the rollercoaster moves up the hill?
      iii. What energy conversions are happening as the rollercoaster moves down the hill?
5. Finally, as a class discuss Puffing Billy Railway. Highlight that the railway uses heritage steam locomotives to pull its trains.
6. Show students the video - https://www.youtube.com/watch?v=fsXpaPSVasQ and discuss the energy transformations occurring in a steam engine throughout its journey.
7. Set students their task: "In pairs, or groups, students are to produce a multimedia presentation, using text, images and video that tracks motion and energy transformations occurring in a Puffing Billy Railway steam locomotive throughout its operation on its journey through the Dandenong ranges." *Teachers to determine what multimedia programs students can use for their presentation.*
8. Give students time to produce their multimedia presentation. On completion have students present their work via a video viewing lesson.

HINT: Teachers can design the track for the locomotive to run on eg. Hills, valleys, turns, etc or have students design their own railway journey.
More information at Puffingbilly.com.au

EXTENSION: Use this resource to extend students knowledge of energy transfers and transformation by forces doing work.
https://userfiles-secure.educatorpages.com/userfiles/MsKlein/19P11SEch06.pdf

SUGGESTIONS FOR ASSESSMENT

Students' ability to analyse an existing mechanical system (a steam locomotive) and produce a multimedia presentation using text, images and video that tracks motion transformations throughout its operation.

CURRICULUM LINKS

SYSTEMS ENGINEERING

Unit 1: Mechanical Systems

Area of Study 1

Mechanical System Design

Outcome 1: Describe and apply basic engineering concepts and principles and use components to design and plan a mechanical system using the systems engineering process.

BACKGROUND INFORMATION

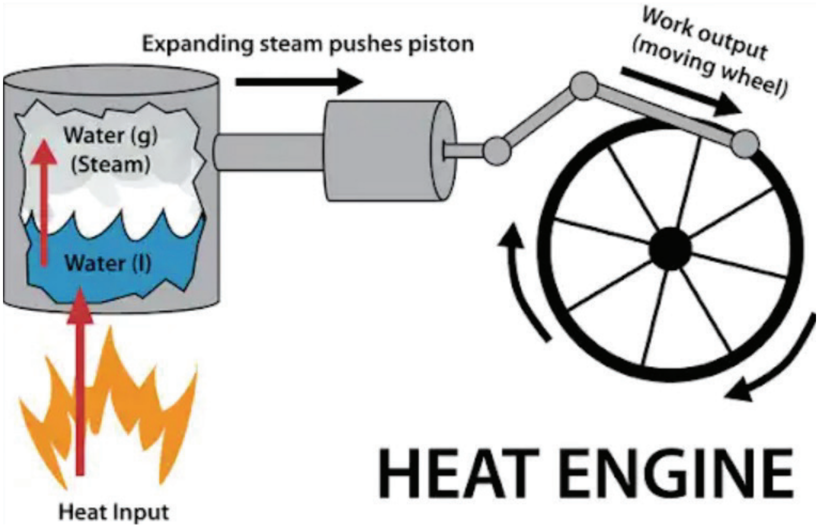
ENERGY TRANSFORMATIONS IN A STEAM ENGINE

Energy conversion, also termed as energy transformation, is the process of changing one form of energy into another.

When work is done, energy is transferred. From the Law of Conservation of Energy, it is not used up, but transferred from one form to another

In a steam engine, heat is used to boil water and obtain steam under high pressure to turn the shaft and drive the wheels.

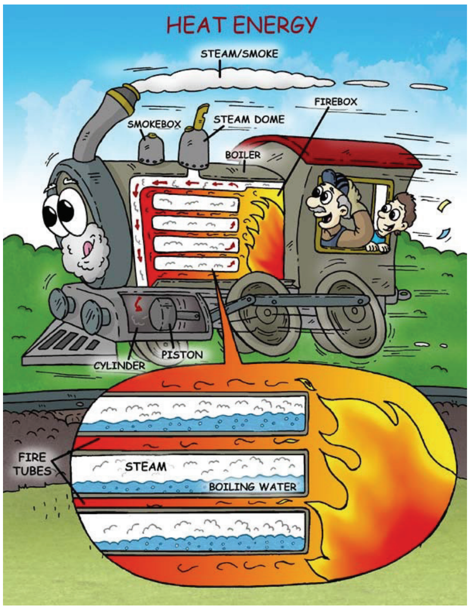
So, a steam engine converts heat energy into kinetic energy. Hence.



STEAM ENGINE ➡ HEAT ENERGY ➡ KINETIC ENERGY.

Reference: https://www.actuateminds.com/blog/physics/heat-engine/

Like steam engines, everything uses energy to function. For example, food that we eat gets digested, and then converted into fuel that our body needs to perform our daily tasks. Energy can be used and converted but can never disappear. It only passes from one state to another, and steam engines are the perfect example of seeing how it happens. For steam engines to work, energy is derived from four different kinds: chemical energy, heat energy, kinetic energy and then finally, potential energy.



Reference: https://www.sciencewithme.com/learn-about-steam-engines/

The basic elements of a steam engine are a source of steam (usually a boiler fired by wood, coal, or other combustible fuel), a device that is moved by the steam (such as a piston inside a cylinder or a turbine), and a means for converting the motion of the device into useful work. Steam engines of the 1800's had many more features that made them more efficient.

The source of energy for steam engines can be fossil fuels (which were originally produced by photosynthesis, since these fuels are the remains of once-living plants and animals), wood (also a product of photosynthesis), nuclear reactions, or sunlight (one type of solar generator uses a parabolic mirror to focus the sunlight onto a pipe containing water that is heated to produce steam).

Energy conversions typically involved in the operation of a steam engine are conversion of chemical energy (in fuels) to thermal energy, conversion of thermal energy to mechanical energy (by increasing the motion of water molecules), and sometimes conversion of mechanical energy into electrical energy (in the case of an electric generator).

CHEMICAL ENERGY.
To produce steam which a steam engine uses to operate, coal is loaded onto the firebox, which is essentially like an oven or wooden stove. Because coal is fuel which can transmit heat efficiently, it is used to increase the temperature for the boiler. The moment coal touches the fire and bursts into flame, it combusts. This kind of chemical reaction is called chemical energy.

HEAT ENERGY.
The conversion of energy begins in the firebox and ends in the boiler. In a steam engine, chemical energy is transformed to produce heat energy after the coals are set on fire. Heat energy is directed by a change in the temperature. Right after the coals ignites, that chemical energy gets converted to heat energy, which is used to boil the water and produce steam.

KINETIC ENERGY.
With steam, the engine can now use this energy to force motion into the gears or in a case of a steam locomotive, the wheels. The steam forces the cylinder and piston within the steam engine to shuffle and move, initiating the turning of the wheels and putting it in motion. This is called kinetic energy. Kinetic energy derived from heat energy (steam) gives power to the cylinder and piston to act forward and backward, triggering mechanical action towards the wheels.

POTENTIAL ENERGY.
Lastly, steam engines have potential energy when there is a need to function through a gravitational pull. When a steam locomotive goes up a hill, the kinetic energy that generates movement of the wheels suddenly becomes potential energy before the locomotive goes downhill. As the locomotive travels down the hill, this same potential energy converts back to kinetic energy, helping to bring the locomotive down.

Simply put, steam engines use fire and coal (chemical energy) to boil water and produce steam (heat energy), which in turn pushes the cylinder and piston to drive the movement of the wheels (kinetic). As the wheels turn and move towards a slope or a hill carrying a load (potential energy), it can also go faster when it goes downhill (kinetic energy). This gradual yet steady shift of energy forms makes it possible for a machine like the steam engine to work!

WHO INVENTED THE STEAM ENGINE?

James Watt is often credited with developing the first steam engine, but Hero of Alexandria (who lived more than 2,000 years ago) documented many of the principles upon which the steam engine is based. The first operating steam engine was built in 1712 by English engineer Thomas Newcomen (visit http: //technology.niagarac.on.ca/people/mcsele/newcomen.htm for a description of the Newcomen engine). Newcomen's engine was simpler than the systems described above.

EXAMPLE OF ENERGY TRANSFERS

Reference: https://www.cimt.org.uk/physics/B2/Text.pdf

Whenever work is done, an energy transfer process is initiated. For example, when a light bulb is switched on, electrical energy is converted to heat (thermal energy) and light (electromagnetic energy). When a car drives up hill, chemical energy (the fuel) is converted to heat, sound and kinetic energy driving the pistons in the engine. The kinetic energy is then transferred to the wheels, and from here converted to heat (friction between the tyres and the road), sound, and the kinetic energy of the car. Also, during this process, some of the kinetic energy of the car is transferred to heating the surroundings (the car does work on air molecules) and to the increasing potential energy of the car since it is driving up hill. From the example of the car driving up hill we see that energy transfer processes can get complicated, with one form of energy being transferred to many forms. It is therefore useful to keep track of the energy transfer processes using an energy transfer diagram. These pictorial representations show the flow of the original energy input to the useful energy output. Wasted energy (the energy produced that may not be in a useful form) may also (but not always) be represented. The diagrams below shows the energy transfer diagram for (a) the light bulb and (b) the car in the previous example.

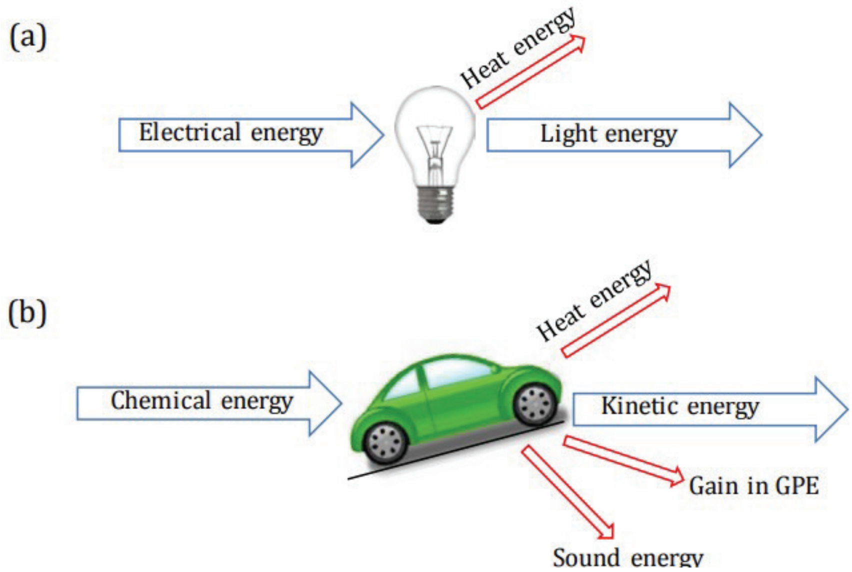


FIGURE 1. *Reference: https://www.cimt.org.uk/physics/B2/Text.pdf*

In figure 1, and in general for an energy transfer diagram, the input energy is shown on the left. The input energy is the original form of the energy within the process. The useful form of energy we get out of the process (the output) is shown to the right of the diagram and represented by the large arrow. The useful energy is the energy we require from the device. The energy transfer diagram therefore shows the flow of energy through the system, from the energy we put in, to the useful energy we get out. In the case of the light bulb, the useful energy is light. In the case of the car the useful energy is kinetic energy, enabling the occupants to get from A to B. Also shown (smaller arrows) are the main forms of wasted energy. Wasted energy is the energy transferred by the process that is not useful for the main purpose of the process. Sound from the car exhaust may be important to some people but it does not contribute to the forward momentum of the car and is therefore wasted energy!

https://www.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/
https://www.physicsclassroom.com/mmedia/energy/ce.cfm

ENERGY TRANSFERS IN A STEAM LOCOMOTIVE

- **CHEMICAL ENERGY**
  – Fuel is burnt to heat up water to turn it into steam.
- **POTENTIAL ENERGY**
  – Steam is stored inside the boiler in advance of it being used in a mechanical system
- **KINETIC ENERGY**
  – Steam is released into a piston to move it and piston is connected to wheels causing motion
- **MOMENTUM**
  – Enough velocity needs to be generated to get the steam engine and train up the hill.
- **POTENTIAL ENERGY**
  – The train is about to go down the hill. It is very heavy so gravity will pull it down the hill.
- **HEAT ENERGY**

– The brakes are applied to the wheels causing the train to slow down which converts kinetic energy into heat energy through friction

REFERENCES:

https://www.youtube.com/watch?v=9mhYnQGZJuM

https://www.youtube.com/watch?v=BYOlGYoM_cw

https://www.youtube.com/watch?v=fsXpaPSVasQ

https://www.youtube.com/watch?v=Imw8L5p7mOk

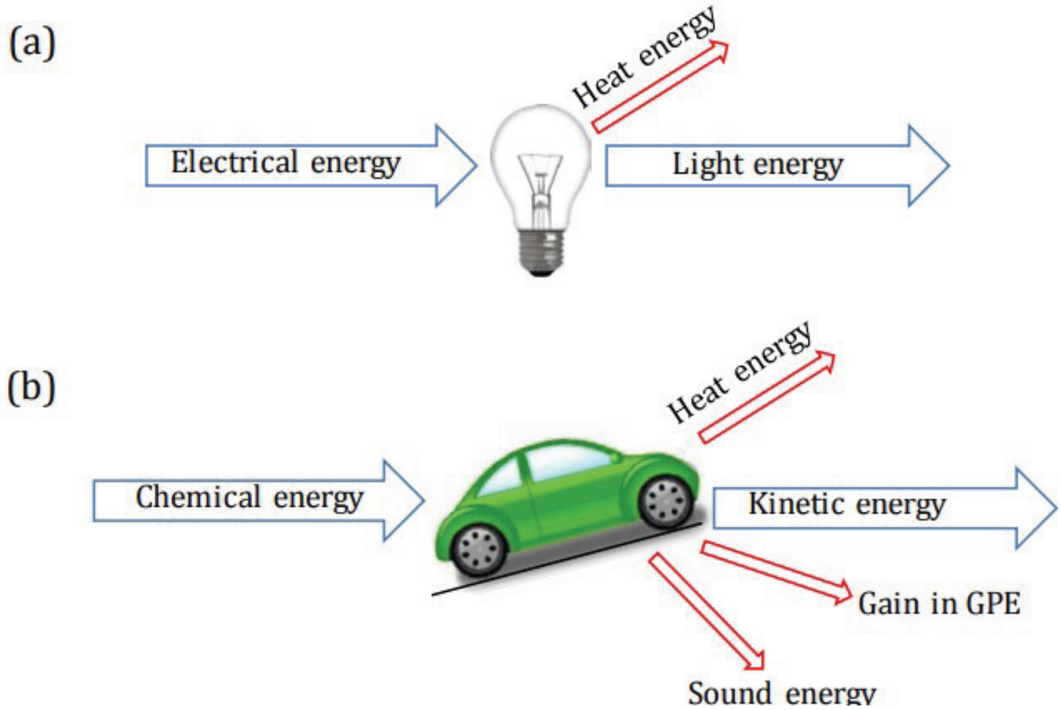
ROLLER COASTER ACTIVITY REFERENCES

https://www.pbslearningmedia.org/resource/hew06.sci.phys.maf.rollercoaster/energy-in-a-roller-coaster-ride/

https://www.physicsclassroom.com/mmedia/energy/ce.cfm

WORKSHEET – LOCO-MOTION

Energy conversion, also termed as energy transformation, is the process of changing one form of energy into another. See the example discussed below:



Reference: https://www.cimt.org.uk/physics/B2/Text.pdf

1. Outline the energy flow through the following devices and identify the input energy, useful energy, and wasted energy:

(a) Electric heater

(b) Personal stereo

(c) An archer firing an arrow from a bow

(d) A hair dryer

(e) A television

(f) A toy car

2. Construct an energy transfer diagram for the following.

(a) A person climbing a steep hill

(b) A propeller driven aeroplane

3. A dynamo is used to make a bicycle light work. The dynamo generates electrical energy by being driven by the bicycle wheel. Describe the energy transfer process beginning with chemical energy input.

4. Comment on the percentage of the output energy that is converted to useful energy for the bicycle light in question 3.