Teacher's Notes	Physics in the Museum

Investigations for Upper Secondary students

Note to teachers:

*All students should initially **Engage** with the exhibits to gain an overview of the objects on display and some of the underlying physics concepts that can be explored.*

*It would be anticipated that students would then select ONE investigation based around a specific object or display to form a major project or Extended Experimental Investigation. The **Explore** section would be conducted while on location at the museum, whilst the **Explain** and **Elaborate** sections would be completed at school and at home.*

The investigations are suggested approaches only and do not include all details of constructions and procedures for testing. Design of testing procedures, collation and analysis of data is left for the student to do as part of EEI criteria.

Teachers will also need to develop appropriate documentation to accompany the investigation including marking criteria to suit the school's program.

Engage:

Explore the Museum exhibitions, looking for applications of physics in the objects on display. Look for applications that include:

- Forces
- Simple Machines
- Work and energy
- Energy transformation
- Linear and rotational motion

Physics Concepts

Identify examples in the Museum that illustrate these physics concepts:

Key Concept	Example
Mechanics	□ Pumper trolley □ Bogies
Heat and thermodynamics	□ Steam engine □ Cooling systems
Sound and Hearing	□ Whistles □ Horns
Light and Vision	□ Marker lamps □ Head lamps
Electricity and Magnetism	□ Electric motors □ Generators

Investigations:

On the following pages are some possible ideas for investigations at The Workshops Rail Museum. Each investigation constitutes a significant investigation of the physical principles underlying the museum object.

Queensland Government

1. Mechanics: Machine efficiency (EEI)

Exhibition: Might and Muscle

Research statement:

Pumper trolleys are an inefficient use of human energy resources that can be improved by simple design changes.

Physics Concepts:

Simple machines, mechanical advantage, displacement, velocity, speed, rotational motion, force, work, energy conversion and efficiency

Explore:

- Investigate the **advantages** of using hand tools.
    - Consider the application of principles of simple machines.
    - Collect data (including photos) about the operation of some of the hand tools on display for further investigation. Note any numerical data included in any display labels.
- Investigate **pumper trolleys** as **mechanical systems** involving multiple levers.
    - Sketch and photograph the lever systems that enable the action of the operators to translate to the rotation of the wheels. Mark all critical points such as points of rotation and fulcrums.
    - Infer the mechanical advantage achieved through the system by estimating dimensions of the components on the sketch.

Explain:

- Classify each hand tool as a simple machine type then determine the mechanical advantage. Use the data collected to estimate the MA.
- Draw a detailed diagram of the pumper trolley mechanical system. Identify the simple machines included in the system. Determine the mechanical advantage of the system.
- Make a list of assumptions and data that you will use in calculations that would predict the speed of the pump trolley for a possible effort by two operators.

    Estimate:
    - Mass of trolley and two operators
    - Displacements of one downstroke and corresponding forward movement
    - Time for one downstroke

    Perform the calculations and predict the speed.
- Determine the energy efficiency of the system.

Elaborate:

- Construct a model of the pumper trolley using Lego or similar construction systems.
- Use the model to gather data to verify the predictions made using estimated data.
- Test the model for energy efficiency and suggest improvements to the design that would improve its efficiency.

Evaluate:

- Use the evidence gained through the investigation to support or refute the claims of the research statement.

2. Energy Efficiency: Comparison of alternative engine configurations on efficiency (EEI)

Exhibitions: Diesel Revolution

Research statement: (choose one or construct your own)

- *Electric multiple units offer efficiency and operational advantages over push-pull configurations for passenger trains.*
- *Multi-header units placed at the head and centre of the train offer efficiency advantages over units placed solely at the head.*

Physics Concepts:

Work, force, displacement, energy conversion and efficiency

Explore:

- Investigate the various configurations of locomotives in trains within the museum. Find examples of:
  - Single pull
  - Push-pull
  - Electric multiple units (EMU)
  - Multi-header units at the front of the train
  - Multi-header units placed at different positions along the train
- Make notes on each configuration, gathering data on:
  - Type of locomotive
  - Purpose for train
  - Positioning of locomotive in train
  - Location of driver and method of control
  - Advantages
  - Disadvantages of configuration

Explain:

- For each example, determine the engineering and operational reasons for the configuration.
- For each example, suggest the engineering and operational difficulties for the configuration.

Elaborate:

[*Note: Access to a model train set with multiple locomotives and a means to record current and voltages while operating the system, is required for this part of the investigation***]**

- Construct a model of the configuration system using a suitable model train set.
- Design an experimental investigation that will gather data to support or refute your research statement. You will need to gather data that will allow calculation of energy efficiency of each locomotive configuration.
- Collate and analyse the data to make some conclusions about the efficiency of different locomotive configurations.
- Make recommendations, based on your research findings, for optimum configuration of locomotives for a more sustainable future.

Evaluate:

- Present your findings to a critical audience and invite feedback on your recommendations.

3. Energy Conversion Efficiency: Steam vs. Diesel-electric (Research Project)

Exhibitions: B13 Class & Pompey and Diesel Revolution

Research statement:

Use of steam-powered locomotives should be reconsidered as an energy efficient alternative to diesel-electric locomotives.

Physics Concepts:

Heat, thermal capacity, work, energy conversion and efficiency

Explore:

- Identify the energy conversions that occur in steam and diesel-electric engines in the Museum.
- Draw a block diagram that shows the energy conversion occurring and the energy converter in each part of the engine system.

Explain:

- Provide details on how each type of engine works. Gather data such as sketches, photos and notes from museum labels to support your explanation.
- Make a list of assumptions and data that you will use in calculations that would predict the energy consumption of each type of engine.
  Estimate:
  - Fuel consumption
  - Energy recovery (research required)

  Perform the calculations and predict the energy consumption.
- Make a list of assumptions and data that you will use in calculations that would predict the energy output of each type of engine.
  Estimate:
  - Mass of engine
  - Mass of load

  Perform the calculations and predict the energy output.
- Using the calculated values for energy consumption and output, determine the estimated energy efficiency of the system.

Elaborate:

- Research typical energy efficiencies, performance, maintenance costs and emissions for the following types of engines:
  - Steam
  - Diesel-electric

  Summarise results in a table.
- Identify any compromises that have to be made among efficiency, performance, and emissions for each type of engine.
- Use your results and comparisons to present an argument that supports or refutes the research statement.
- Make recommendations for the optimum engine system for a more sustainable future.

Evaluate:

- Present your findings to a critical audience and invite feedback on your recommendations.

4. Energy Conversion Efficiency: Hybrid Petrol-electric vs. Diesel-electric vehicles (Research Project)

Exhibitions: B13 Class & Pompey and Diesel Revolution

Research statement:

Use of diesel-electric hybrid vehicles provides efficiency, performance and emission advantages over petrol-electric vehicles.

Physics Concepts:

Heat, thermal capacity, work, energy conversion and efficiency

Explore:

- Identify the energy conversions that occur in diesel-electric engines in the Museum.
- Consider the efficiency advantage of not using a mechanical gear–box to drive the wheels directly from the diesel engine. Where are the efficiency gains made?
- What other advantages can you determine for using direct-drive electric motors on the wheels of the bogies?

Explain:

- Provide details on how the diesel-electric engine works. Gather data such as sketches, photos and notes from museum labels to support your explanation.
- Make a list of assumptions and data that you will use in calculations that would predict the energy consumption of this type of engine.
  Estimate:
  - Fuel consumption
  - Energy recovery (research required)

  Perform the calculations and predict the energy consumption.
- Make a list of assumptions and data that you will use in calculations that would predict the energy output of this type of engine.
  Estimate:
  - Mass of engine
  - Mass of load

  Perform the calculations and predict the energy output.
- Using the calculated values for energy consumption and output, determine the estimated energy efficiency of the system.

Elaborate:

- Research typical energy efficiencies, performance and emissions for the following types of engines: http://www.beyondfossilfuel.com/hybrid/
  - Diesel
  - Petrol
  - Diesel-electric
  - Petrol-electric

  Summarise results in a table.
- Identify any compromises that have to be made among efficiency, performance, and emissions for each type of engine.
- Use your results and comparisons to present an argument that supports or refutes the research statement.
- Make recommendations for the optimum vehicle engine system for a more sustainable future.

Evaluate:

- Present your findings to a critical audience and invite feedback on your recommendations.