Riding on a Pendulum – Module Overview

Student challenge: Design a pendulum-type amusement park ride rated highly for its "thrill factor".

Module Intent: Design and conduct well-defined scientific investigations.

Module Science Concepts:
- Periodic force, harmonic motion
- Gravity

Module Maths Concepts:
- Independent vs. Dependent variables
- Types of graphs
- Formula for period of a pendulum
- Finding a variance

Module Engagement: Introduce module engagement.

Activity 1: Components of a Pendulum

Structured Inquiry – Design, construct and create scientific drawing of a pendulum
Concepts: Read to perform a task.

Activity 2: Amplitude of a Pendulum

Structured Inquiry – Students discover the concept of amplitude through observing the motions of a pendulum they built in Activity 1
Concepts: Amplitude, Independent vs. Dependent variables

Activity 3: Period of a Pendulum

Structured Inquiry: Data are collected on the period of the pendulum through individual and, then, repeated trials
Concepts: Calculated period of pendulum. What is variance and how do you calculate it?

Activity 4: How does Amplitude Affect Period?

Structured Inquiry – Introduces the students to the influence of amplitudes on the period of a pendulum.
Concepts: Well-structured investigation. Graphing.

Activity 5: How does Mass Affect the Period of a Pendulum?

Guided Inquiry – Students conduct repeated trials to validate their hypotheses about mass and the period of a pendulum.
Concepts: Well-structured investigation. Data table organisation.

Activity 6: How does Length Affect the Period of a Pendulum?

Guided Inquiry – Pendulums of varying lengths are investigated
Concepts: Well-structured investigation. Dependent vs. Independent variables. Formula for the period of a pendulum.

Activity 7: Engineering your Pendulum

Guided Inquiry: Design a Pendulum Thrill Ride
Concepts: Engineering Process

Activity 8: Galileo and the Pendulum

Guided Inquiry – Students compare their findings and confirm or refute Galileo's findings
Concepts: Effects of the force of gravity

Activity 9: Pendulum on the Moon

Structured Inquiry – Students explore how a pendulum would behave on the moon
Concepts: Force of gravity

Activity 10: Riding on a Pendulum

Guided Inquiry – Students explore what creates the "thrill factor" on amusement park rides
Concepts: Relate riding on a pendulum swing to microgravity

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Introduction to STEM-CIP

What is STEM-CIP?

Science, Technology, Engineering, Mathematics-Curriculum Integration Program (STEM-CIP) is an innovative approach to the design of curriculum and instructional materials in which the disciplines of science, technology, engineering and mathematics are taught as one, rather than being distinct and separate as in the past. The natural connections among the four disciplines, which have always been there in the past in research labs and professional work, have not traditionally been emphasised in the design and process of present day education. The (upper primary, middle and high school) modules of the STEM Curriculum Integration Program have been designed to engage students in stimulating, authentic and contemporary problem-based STEM scenarios involving the life, physical, environmental and earth/space sciences, technology and engineering, and mathematics. Drawing from the best in STEM pedagogy, the STEM-CIP modules provide students with the opportunity to learn age appropriate concepts, skills and processes, and to acquire STEM attitudes and "habits of mind".

Curriculum Design Template

All modules within STEM-CIP have been designed using principles of *Understanding by Design* (Wiggins and McTighe, 1998). *Understanding by Design (UbD)* is a well-known curriculum design process used to write units (modules of instruction) in a three-stage process — Desired Results, Assessment Evidence and the Learning Plan. Many departments of education, tertiary institutions and universities, and entire school systems advocate the use of *Understanding by Design* as a contemporary planning process for teaching and assessing applicable standards.

Many authors, among them Reeves (2003), Marzano, Pickering and McTighe (1993) and Lantz (2004) have been proponents of performance-based assessment in which students must demonstrate what they know and can do through the completion of meaningful performance tasks. All modules within STEM-CIP present opportunities for students to engage in performance-based tasks and assessments, along with more traditional forms of assessment, such as selected-response items.

5E Teaching, Learning and Assessing Cycle

A modified 5E teaching, learning and assessing cycle, incorporated into all STEM-CIP modules, is based upon research findings about how students learn science. These findings indicate that students learn best when they have an opportunity to engage in explorations in a hands-on/minds-on environment in which they make and pose explanations for their discoveries. Engagement, Exploration, Explanation, Elaboration and Evaluation are the recursive phases of the 5E teaching, learning and assessing cycle. A brief guide to the 5E model appears next.

The Original 5E Model – At-a-glance Guide (Trowbridge & Bybee, 1996)

Engage
This stage is designed to interest students in the learning, linking it with past learning and common background knowledge. It stimulates curiosity and promotes questioning, while linking the learning to real world experiences. This has a twofold purpose – it interests students in what is coming, while simultaneously showing them the purpose for the learning by situating it in their existing worldview. Teachers can guide this stage by asking specific questions to elicit prior knowledge from students.

Explore
This stage allows students to directly engage with key concepts by inciting them to probe, enquire and question, using their existing knowledge to connect it to new concepts and ideas. These connections may occur rapidly, or may need to be broken down several times before they are clear. The teacher is responsible for directing questioning appropriately and providing probing questions to push children in the right direction.
Explain
In this stage, students begin to logically sequence events and facts from their exploration, with a view to being able to communicate this information to others. The teacher can use this stage to act as a facilitator, offering further explanations and clarifying terms, etc, as necessary. This stage is useful in ascertaining the learner's development and grasp of the key ideas and concepts so far.
Elaborate
This stage allows students to expand what they've learned so far and to connect this directly with their prior knowledge and learning, hopefully reaching understanding. The teacher can therefore verify student understanding fully at this stage.
Evaluate
The process of evaluation should occur throughout the learning experience, allowing the teacher to determine whether the learner has reached the level of understanding needed at every stage. More formal evaluation, however, can now be conducted. If at any point the teacher decides that a student has not reached the desired level, they simply go back to the appropriate stage.

Breakdown of Activities by 5E

TITLE	TOPIC / CONTENT	5E
Module Engagement	Let's Soar: Launch a Rocket and Introduce Module Performance Task	Engage, Evaluate
Activity 1	Dissolving Materials	Explore, Explain, Evaluate
Activity 2	Alka-Seltzer and Water	Explore, Explain, Evaluate
Activity 3	Temperature and Dissolving Time	Explore, Explain, Evaluate
Activity 4	Particle Size and Dissolving Time	Explore, Explain, Evaluate
Activity 5	Different Liquids and Dissolving Time	Explore, Explain, Evaluate
Activity 6	What is Form and Function?	Explore, Explain, Evaluate
Activity 7	Engineering Your Rocket	Elaborate, Evaluate
Activity 8	Engineering Your Rocket: Redesign and Launch Day	Elaborate, Evaluate
Activity 9	What Goes Up Must Come Down	Elaborate, Evaluate
Activity 10	What Might Affect Gravity?	Elaborate, Evaluate
Activity 11	Rhythms of Gravity	Elaborate, Evaluate

Levels of Inquiry

All the example standards (derived from the US National Science Education Standards, the US National Council of Teachers of Mathematics Standards, the US National Education Technology Standards for Students and the Standards for Technological Literacy) utilised in STEM-CIP modules call for teaching, implementing and assessing student understanding of inquiry throughout the curriculum. As a result, four scaffolded levels of inquiry are included in most modules, starting with the most structured form — confirmatory inquiry,

Module Engagement: Understanding Amusement Park Rides

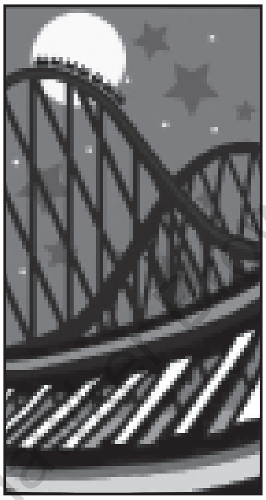
Mathematics Readiness Assessment

Mathematics and science go hand-in-hand. Many times mathematics is necessary to understand and work with science concepts. In order to fully understand the science and be successful with investigations and activities in this module, it is important for your teacher to know if you already know some mathematics computations and skills. On page 89 of the Student Data and Response section (SDR) is a mathematics readiness assessment designed for this module. Complete it to the best of your ability. It will not be marked, but it will be used to help your teacher create strategies so that you can successfully complete the activities.

What Are Your Prior Experiences of Amusement Park Rides?

He flies through the air with the greatest of ease, that daring young man on the flying trapeze …

Many people have seen trapeze artists fly high above the floor of a circus tent from one swing to another. The swings are not mechanically powered. The artists depend on a very fundamental law of motion – the motion of a pendulum.



The thrill of swinging high or free-falling is something many humans seek, and this thrill is why amusement park rides were created. The exhilaration and excitement of the sudden drop on a roller-coaster is like no other feeling. The rider goes from experiencing low g's ("g" refers to the force caused by the acceleration of gravity) to high g's in a split second. It feels as if the "bottom has dropped out".

Think about the most exciting and thrilling amusement park ride you have experienced. Which rides (if you know their names) have been the most exciting to you? Take a few minutes and recall the rides and think about why they were thrilling. Go to the Student Data and Response section (SDR) and write your thoughts on page 93.

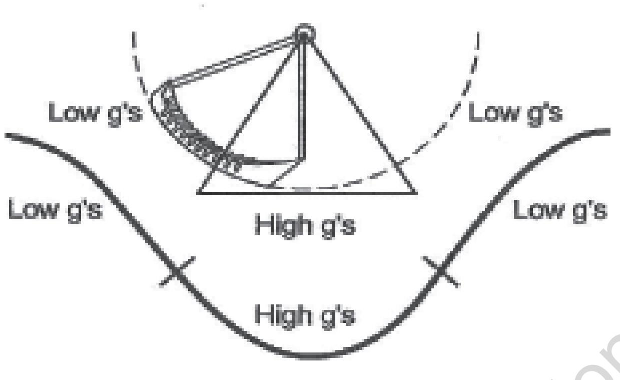
Pendulum rides (such as the Sea Dragon pictured to the left), unlike roller-coasters, are not rated highly on the "thrill factor" scale. Usually on a scale of 1–10, with 10 being the highest thrill factor, most teenagers rate pendulum rides as a "5". This is of concern to amusement park owners and operators. How would you increase the "thrill factor" for these rides? That is your challenge in this STEM (Science, Technology, Engineering and Mathematics) module. At the end of the module you will be asked to design and build a model "pendulum ride" that is more thrilling for teenagers.

You will act as an engineer, planning, researching, building, testing, redesigning and evaluating the final product. Your final product will be evaluated based on your use of accurate science and mathematics concepts as you apply them to engineer the model pendulum ride.

The Sea Dragon is a pendulum-like amusement park ride. The ride never completes 360 degrees (i.e. a complete circle), but may approach 180 degrees, as shown in the diagram. However, the rider does experience circular motion. Swinging back and forth on a curved path allows the rider to feel the sensations of high and low g (remember "g" refers to the force caused by the acceleration of gravity).

Typical Amusement Park Pendulum Ride

High and low "g" are shown in the diagram below.



High and Low "g's" Experienced During a Pendulum Ride

What You Need to Learn

In order to design your own pendulum ride, you will need to learn as much about pendulums as you can; therefore, you will conduct a series of investigations constructing and testing various pendulums. You will make observations and then make conclusions based on those observations.

What You Will Do

At the end of the module, you will have to apply the engineering process to the design of your pendulum ride by writing an engineering report and constructing a model of the ride. Your engineering report will contain the elements below. Also, the rubric "Engineering a Pendulum Ride" on page 129 of the SDR will be used to evaluate your work.

The **Engineering Report** will include:

- **Title Page –** Your teacher will specify items to include on this page.
- **Problem –** State the problem in your own words.
- **Materials –** List all the materials you used.
- **Problem-solving Process –** Describe the designing, producing, testing and analysing processes you used. List the science and mathematics concepts you are applying to your design.
- **Building –** Describe the building of your ride so that the reader could build your solution themselves.
- **Preliminary Testing –** Summarise the testing you performed prior to the due date. Be sure to describe any changes you made to your solution as a result of this testing.
- **Summary –** Explain what happened to your solution on the due date. State whether it was successful or unsuccessful, and why.
- **Drawings –** Include thumbnail sketches of preliminary ideas (brainstorming), and a formal scientific drawing of your final solution.

Activity 3: Check Your Understanding

1. Which one of the data sets below has the greatest variance?

Ⓐ 1.0; 2.0; 3.0; 4.0

Ⓑ 5.0; 6.0; 7.0; 8.0

Ⓒ 2.0; 4.0; 6.0; 8.0

Ⓓ 3.0; 6.0; 9.0; 12.0

2. Which one of the data sets below has the greatest standard deviation?

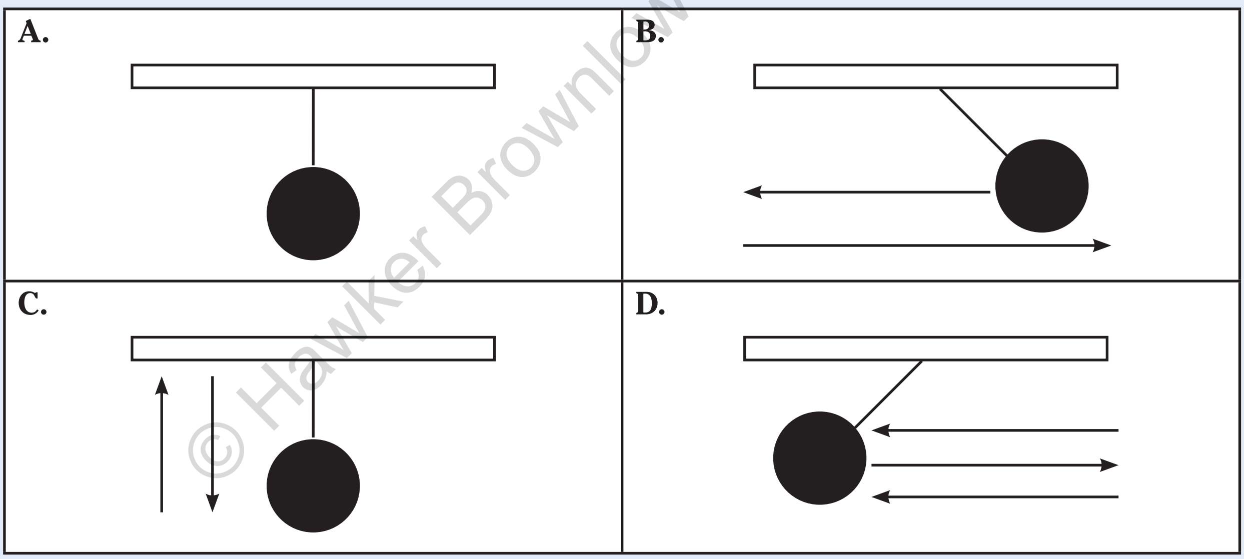
Ⓐ 1.0; 2.0; 3.0; 4.0

Ⓑ 5.0; 6.0; 7.0; 8.0

Ⓒ 2.0; 4.0; 6.0; 8.0

Ⓓ 3.0; 6.0; 9.0; 12.0

3. Which illustration below best shows the period of a pendulum?



4. What is x in the formula for variance shown below?

Ⓐ mean

Ⓑ standard deviation

Ⓒ one individual case

Ⓓ total number of cases

$$S^2 = \frac{\sum (x - \bar{x})^2}{n}$$