Teacher Toolkit - Vibrational Motion

Objectives:

1. To identify several examples of vibrating objects and to use terms such as equilibrium position, restoring force, fixed end, and damping to describe their motion.
2. To describe an object undergoing periodic motion using terms such as sinusoidal, cycle, period, amplitude, and damping and to relate these terms to the position-time graph.
3. To define period, frequency, and amplitude and to determine their values from verbal and graphical descriptions of a vibrating object's motion.
4. To describe and explain the motion of a simple pendulum using such representations as a free-body diagrams, position-time graphs, velocity-time graphs, energy tables, equations for period, and terms such as position, velocity, and acceleration.
5. To describe and explain the motion of a vibrating mass on a spring using such representations as a free-body diagrams, position-time graphs, velocity-time graphs, energy tables, energy bar charts, equations for period, and terms such as position, velocity, and acceleration.

Reading: The Physics Classroom Tutorial, Waves Chapter, Lesson 0

Interactive Simulations:

1. Mass on a Spring http://www.physicsclassroom.com/Physics-Interactives/Waves-and-Sound/Mass-on-a-Spring
   This simulation animates the vibrational motion of a mass on a spring. The position-time and velocity-time graph of the motion are represented in *real-time*. Bar charts showing the kinetic energy, gravitational potential energy, and elastic potential energy are also shown in *real-time*. Users can alter the mass that is hung on the spring, the stiffness of the spring, and the amount of damping. Two springs are included for conducting side-by-side comparative studies. This variable-rich environment allows students to explore a variety of relationships related to vibrating masses on springs.
2. Hooke's Law Simulation https://phet.colorado.edu/en/simulation/hookes-law
   This HTML5 simulation lets students stretch and compress springs to explore the relationships among force, spring constant, displacement, and potential energy. It will help them gain insight into the meaning of "restoring force" an area of documented student misconception. It also promotes understanding of the predictable mathematical relationships that underlie Hooke's Law.
3. Pendulum Lab https://phet.colorado.edu/en/simulation/legacy/pendulum-lab
   This simulation displays one or two pendulums to explore how the period of a simple pendulum depends on the length of the string, mass of the pendulum bob, and amplitude of the swing. Use the Photogate timer to easily measure the period! You can vary the friction or jump to Planet X to explore the effect of changing gravity on a pendulum.
4. Hooke's Law Digital Lab https://phet.colorado.edu/en/contributions/view/2939
   This two-hour digital lab for high school physics was created specifically to accompany the PhET simulation "Masses and Springs". In the first lesson, students explore how displacement of a spring is mathematically related to the load applied to it. In the next day's exploration, learners analyze the energy of a mass oscillating on a spring by observing distribution and transfer of kinetic, potential, and gravitational potential energy.

Video and Animation:

1. DMV: SHM with Motion Graphs https://serc.carleton.edu/dmvideos/videos/simple_harmonic.html
   This DVM (Direct Measurement Video) support s a conceptual understanding of the kinematics of simple harmonic motion (SHM). This video shows a low-friction glider moving on an air track. Springs on each side apply forces to the glider that produce SHM. Graphs of position, velocity, and acceleration vs. time are simultaneously displayed.
2. Simple Harmonic Motion http://www.animations.physics.unsw.edu.au/mechanics/chapter4_simpleharmonicmotion.html#4.1
   This PhysClips animation-based tutorial presents information in a non-textual way, but without sacrificing rigor. The animations are nicely constructed, blending video and diagrams.
3. DMV: Spring Force https://serc.carleton.edu/dmvideos/videos/spring_force.html
   This set of seven high-resolution Direct-Measurement Videos (DMV) that students to use digital rulers and frame-counters to analyze applied force on springs and make precise measurements of quantities such as position and time.

4. Veritasium: Bungee Jumper's Acceleration https://www.youtube.com/watch?v=FhmLBxyX8Dw
   At what point in a bungee jump is acceleration the greatest? Physics education researcher and YouTube icon Derek Muller brings us another cool "think problem" that lets you integrate concepts of kinematics, gravitational acceleration, spring tension, and the restoring force.
5. Circus Physics http://www.pbslearningmedia.org/resource/65508e65-74cc-40eb-aac9-6192b13a899a/65508e65-74cc-40eb-aac9-6192b13a899a/
   This video-based resource and accompnying activity guide provides a highly visual way to explore pendulum motion as a trapeze artist swings on a bar/rope system. The video examines factors that affect the amplitude and period of a pendulum.

Labs and Investigations: http://www.physicsclassroom.com/lab#waves

1. The Physics Classroom, The Laboratory, A Wiggle in Time
2. The Physics Classroom, The Laboratory, Period of a Pendulum

Interactive Digital Homework Problems

1. Mass on a Vertical Spring Problem http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/06/IE_mass_vertical_spring
   In this interactive problem, a mass hangs from a vertical spring. If the spring is stretched and then released, what is the speed of the block when it returns to its original position for the first time? Students will use the Conservation of Mechanical Energy method to solve the problem.
2. Block and Spring SHM Problem http://per.physics.illinois.edu/per/IE/ie.pl?phys111/ie/12/IE_block_and_spring
   This resource presents a similar, but not identical system to the previous problem. A block is attached to a massless spring on a friction-free surface. Students are given the initial velocity and distance from equilibrium. At what time will the block next pass through the x = 0 point?

Problem-Based Learning Activity: Real-World Applications

1. PBL: Bungee Jumping **See Complete Toolkit on website for more details.**
   http://pbl.ccdmd.qc.ca/resultat.php?action=clicFiche&he=1050&afficheRecherche=99&IDFiche=157&endroitRetour=99&lesMotsCles=bungee%20jumping

Classroom Learning Module: Periodic Motion **See Complete Toolkit on website for more details.**

1. Into the Swing of Things https://www.teachengineering.org/lessons/view/uno_swing_lesson01
2. Android Pendulums https://www.teachengineering.org/activities/view/uno_swing_lesson01_activity1

Problem-Solving Exercises: http://www.physicsclassroom.com/calcpad/waves/problems

1. Calculator Pad, Wave Basics, Problems #1 - #4

Science Reasoning Activities: http://www.physicsclassroom.com/reasoning/waves

1. The Period of a Pendulum
2. Mass on a Spring

Historical Context

1. The Story Behind the Science: Pendulum Motion https://www.storybehindthescience.org/pdf/pendulum.pdf
   This "Story" explores the humble pendulum and its significant role in the development of modern science.

Common Misconceptions **See Complete Toolkit on website for more details.**

1. Confusion of Amplitude and Period

Standards: **See Complete Toolkit on website for more details.**

A. Next Generation Science Standards (NGSS) – Grades 9-12

Performance Expectations - Energy: HS-PS3-2 Waves: HS-PS4-1

Disciplinary Core Ideas

Energy Conservation: HS-PS3.B.3

Wave Properties: HS-PS4.A.1

Crosscutting Concepts

Systems and System Models, Energy and Matter

Science and Engineering Practices

Analyzing Data; Constructing Explanations; Developing and Using Models; Obtaining, Evaluating, and Communicating Information; Planning and Carrying Out Investigations; Using Mathematics and Computational Thinking