Harmonic Motion

A pendulum swings back and forth. The moon orbits the Earth every 28 days. These types of repetitive motions are called **harmonic motion**. Harmonic motion is motion that repeats in identical or nearly identical cycles. A **cycle** is a unit of motion that repeats. A system in harmonic motion is an **oscillator**. It oscillates.

Systems at rest are in **equilibrium**. Harmonic motion occurs in some systems when equilibrium is disturbed. A system at rest at relatively high potential energy, such as a marble at the top of a hill, is in **unstable equilibrium**. When disturbed, forces act to pull it away from equilibrium. The marble rolls away. A system at rest at relatively low potential energy, such as a marble at the bottom of a valley, is in **stable equilibrium**. When disturbed, forces act to pull it back toward equilibrium. The marble rolls back into the valley, but because of inertia it may move past the equilibrium point and begin oscillating back and forth. As a result, systems in stable equilibrium undergo harmonic motion when they are disturbed. During harmonic motion the system moves back and forth around the central or equilibrium position. Equilibrium is maintained by restoring forces. A **restoring force** is any force that acts to pull a system back toward equilibrium, much as gravity pulls a child on a swing back to the lowest point. The child moves past the equilibrium point despite the restoring force because the child has inertia.

Some systems oscillate faster than others. Some oscillators move further than others. The time it takes to complete a cycle is called the **period**. The number of cycles per second is the **frequency**. Frequency is the inverse of the period, and is measured in **Hertz** (**Hz**). The **amplitude** is the size of the cycle, or how far the system moves from its resting state. Larger amplitudes have higher energy. When kinetic energy of an oscillator is highest, potential energy is lowest. Think of a swing. It is moving fastest as it moves past the equilibrium point, but as it moves higher, gravity slows it down. Eventually the swing stops moving despite the fact that the restoring force, gravity, remains the same. This is because of friction. The gradual loss of amplitude by an oscillator due to friction is called **damping**.

The strings on a guitar all vibrate at different frequencies. The **natural frequency** is the frequency at which a system, such as a guitar string, tends to oscillate when disturbed. The natural frequency results from the interaction between the restoring force and inertia. Larger restoring forces, like those of tighter guitar strings, result in higher frequencies. Greater inertia, like that of thicker more massive guitar strings, results in lower frequencies. The natural frequency is proportional to the acceleration of the system because it depends on the restoring force and the mass.

When a child is on a swing, you keep pushing every so often. Your force is oscillating. A force that oscillates in strength and direction is a **periodic force**. When the frequency of a periodic force matches the natural frequency, the amplitude of the motion increases. This is called **resonance**. The swing will not end up moving so fast, however, that it flies into outer space. This is because resonance has limits. Resonance is limited by frequency changes associated with changing amplitude and by damping.

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Answer the questions below based on your reading on the previous page, and on your knowledge of physics.

1. Describe the cycle of the moon. Why is this an example of harmonic motion? _____

2. Wile E. Coyote is planning to balance an anvil at the top of a cliff to drop on the road runner. What type of equilibrium is he depending on? Will there be any harmonic motion? _____

3. A weight is hanging still on a spring. What type of equilibrium is this? What will happen if you pull down on the weight? _____

4. The period of a guitar string is about 0.00227 s. What is its frequency? _____

5. What are two ways to make a child on a swing keep moving higher? What aspects of harmonic motion are changing when this happens? _____

6. A man at a carnival swings a mallet hard enough that when he hits the lever of a high striker, it makes the puck hit the bell. Describe and explain the nature of the motion of the puck in the minutes after the lever is struck. _____