AP Physics C Review
Chapter 15: Oscillations

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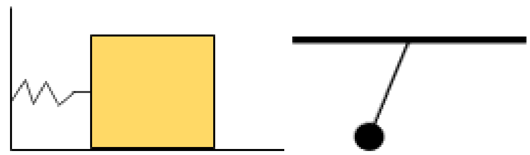
Background / Summary: The motion of some objects can be described as oscillatory as they move back-and-forth in a periodic fashion. In this unit, we look at simple systems that display this kind of motion including springs and pendulums. This kind of motion is called simple harmonic

Key Ideas:

- *Oscillatory motion* refers to the linear motion of an object whose movement is periodical and rotationally-based.
- From the idea of circular periodic motion, the expression for motion that moves with simple harmonic motion (SHM). SHM is derived as $x = Acos(\omega t + 2\pi)$, with *t* being the time after rotation begins.
- The period *T* of a simple harmonic system refers to the necessary time to complete one period and can be found with the equation $T = \frac{2\pi}{\omega}$.
- The frequency *f* of a simple harmonic system refers to the number of cycles per second, or the inverse of period. The corresponding formula is $f = \frac{\omega}{2\pi}$.
- Taking the derivative of an object in SHM's position yields its velocity. $v =- \omega Asin(\omega t + 2\pi)$. The maximum velocity occurs when the sine expression equals one, so $v_{max} =- \omega A$.
- Taking the second derivative of position yields acceleration. This formula can be simplified to $a =- \omega^2 x$.
- Spring systems exhibit SHM and have a ω value of $\sqrt{\frac{m}{k}}$.
- There are two types of pendulums: simple and physical. Simple pendulums consist of solely a point mass at the end of a massless string. Their ω value is $\sqrt{\frac{g}{d}}$. Physical pendulums, however, have mass distributed throughout their entire length. Their ω value is $\sqrt{\frac{mgd}{I}}$.



Spring and pendulum systems like the ones above exhibit simple harmonic motion.

Key Formulas:

$$x = Acos(\omega t + 2\pi)$$

$$T = \frac{2\pi}{\omega}$$

$$f = \frac{\omega}{2\pi}$$

$$v =- \omega Asin(\omega t + 2\pi)$$

$$a =- \omega^2 x$$

$$\omega_{spring} = \sqrt{\frac{k}{m}}$$

$$\omega_{pend} = \sqrt{\frac{g}{d}}$$

$$\omega_{phys\ pend} = \sqrt{\frac{mgd}{I}}$$

Some Key Vocabulary:

Simple harmonic motion - oscillatory motion in a system where the restoring force is proportional to the displacement
Amplitude - maximum displacement from the equilibrium position of an object oscillating around the equilibrium position

Problem Set:

Easy

28. A type of cuckoo clock keeps time by having a mass bouncing on a spring, usually something cute like a cherub in a chair. What force constant is needed to produce a period of 0.500 s for a 0.0150-kg mass?

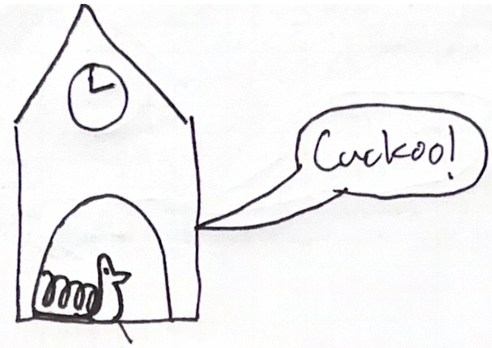
Medium

62. At what rate will a pendulum clock run on the Moon, where the acceleration due to gravity is $1.63\ \text{m/s}^2$, if it keeps time accurately on Earth? That is, find the time (in hours) it takes the clock's hour hand to make one revolution on the Moon.

Hard

69. Near the top of the Citigroup Center building in New York City, there is an object with mass of $4.00 \times 10^5\ \text{kg}$ on springs that have adjustable force constants. Its function is to dampen wind-driven oscillations of the building by oscillating at the same frequency as the building is being driven—the driving force is transferred to the object, which oscillates instead of the entire building. (a) What effective force constant should the springs have to make the object oscillate with a period of 2.00 s? (b) What energy is stored in the springs for a 2.00-m displacement from equilibrium?

28.



0.0150 Kg

$$T_{spring} = 2\pi\sqrt{\frac{m}{k}}$$

$$0.500s = 2\pi\sqrt{\frac{0.0150Kg}{k}}$$

$$0.42\,N/m = k$$

62.

Moon: $g = 1.63\,m/s^2$

Earth: $g = 9.81\,m/s^2$

$$T_{pendulum} = 2\pi\sqrt{\frac{d}{g}}$$

Moon: $T = 2\pi\sqrt{\frac{d}{1.63\,m/s^2}}$

$T = 4.92d$

Earth: $T = 2\pi\sqrt{\frac{d}{9.81\,m/s^2}}$

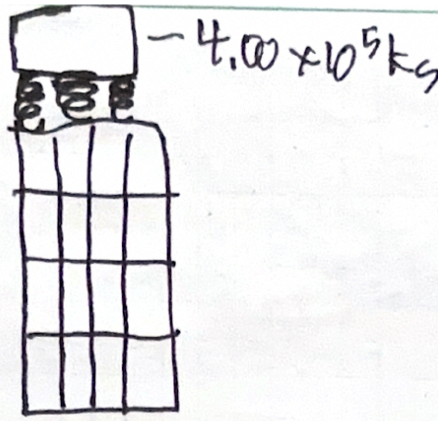
$T = 2.01d$

Solve for Ratio of periods on moon and earth

$$\frac{\text{Moon}}{\text{Earth}} = \frac{4.92d}{2.01d} = 2.45$$

$2.45 \cdot 1\,hr = 2.45\,hrs$ per rotation.

64.



(a) $T_{spring} = 2\pi\sqrt{\frac{m}{k}}$

$2.00\,s = 2\pi\sqrt{\frac{4.00e5\,kg}{k}}$

$3.95e6\,N/m = k$

(b) $U_s = \frac{1}{2}kx^2$

$U_s = \frac{1}{2}(3.95e6\,N/m)(2.00\,m)^2$

$U_s = 7.90e6\ J$