Name: _____

Class: _____

Due Date: _____

C.1 Simple Harmonic Motion

Understandings

- Conditions that lead to simple harmonic motion.
- The defining equation of simple harmonic motion as given by $a = -\omega^2 x$.
- A particle undergoing simple harmonic motion can be described using time period *T*, frequency *f*, angular frequency ω, amplitude, equilibrium position, and displacement.
- The time period in terms of frequency of oscillation and angular frequency as given by $T = \frac{1}{f} = \frac{2\pi}{\omega}$.
- The time period of a mass-spring system as given by $T = 2\pi\sqrt{\frac{m}{k}}$.
- The time period of a simple pendulum as given by $T = 2\pi\sqrt{\frac{l}{g}}$.
- A qualitative approach to energy changes during one cycle of an oscillation.

Equations

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

$$T = \frac{1}{f} = \frac{2\pi}{\omega}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{l}{g}}$$

Additional HL Understandings

- A particle undergoing simple harmonic motion can be described using phase angle.
- Problems can be solved using the equations for simple harmonic motion as given by
  - $x = x_0 \sin(\omega t + \phi)$
  - $v = \omega x_0 \cos(\omega t + \phi)$
  - $v = \pm\omega\sqrt{{x_0}^2 - x^2}$
  - $E_\mathrm{T} = \frac{1}{2} m\omega^2 {x_0}^2$
  - $E_\mathrm{p} = \frac{1}{2} m\omega^2 x^2$

Additional HL Equations

$x = x_0 \sin(\omega t + \phi)$

$v = \omega x_0 \cos(\omega t + \phi)$

$v = \pm\omega\sqrt{{x_0}^2 - x^2}$

$E_\mathrm{T} = \frac{1}{2} m\omega^2 {x_0}^2$

$E_\mathrm{p} = \frac{1}{2} m\omega^2 x^2$

If you are interested in learning more about waves then please read the book *Vibrations and Waves* by George C. King.

The solutions can be found on the YouTube channel Go Physics Go:

https://www.youtube.com/@gophysicsgo/playlists

Part 1: Use your favorite sources to answer the following questions

1. Define *oscillation.*

2. Give three examples of oscillations.

3. Define *periodic.*

4. Define *period.* Units?

   The *period* is the time it takes for an oscillating object to complete one oscillation (or revolution). *Period* is given in seconds.

5. Define *amplitude.* Units?

6. Define *frequency*. Units?

7. What is the mathematical relationship between the *frequency* and *period* of a wave?

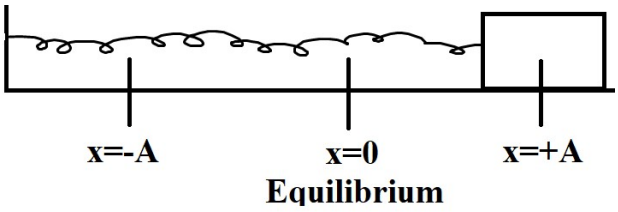
8. State the equation for the angular frequency for an object undergoing simple harmonic motion.

9. Topic A.1 Review: The slope of a displacement vs. time graph tells us the _____ of an object while the slope of a velocity vs. time graph tells us the _____ of an object.

10. Topic A.2 Review: Define *equilibrium.*

11. Give the name, define, and give the units of each variable from Hooke's Law $\vec{F} = -k \times \Delta\vec{x}$.

12. A mass lying on a smooth horizontal surface is attached to a spring and is stretched from its equilibrium position. It is then released. Label the forces on the mass.



13. **Use a pencil and ruler!** Draw and label an *acceleration vs. displacement* graph for simple harmonic motion.

14. Derive the defining equation of simple harmonic motion $a = -\omega^2 x$.

15. What are the main characteristics of simple harmonic motion?

16. Derive the equation for the time period of a mass-spring system $T = 2\pi\sqrt{\frac{m}{k}}$.

17. State the equation for the time period of a simple pendulum.

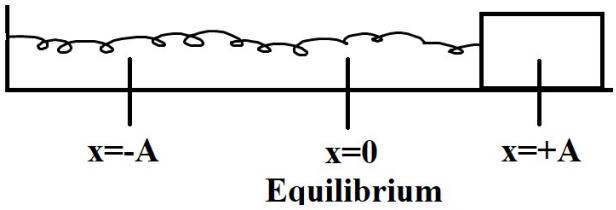
18. **Use a pencil and ruler!** Draw two waves which are *in phase*.

19. **Use a pencil and ruler!** Draw two waves which are *out of phase by 180°*.

20. **Use a pencil and ruler!** Draw two waves which are *out of phase by 90°*.

21. **Use a pencil!** The total energy of a simple harmonic oscillator is given by the equation $E_{\mathrm{T}} = E_{\mathrm{k}} + E_{\mathrm{p}} = \frac{1}{2}mv^2 + \frac{1}{2}k\Delta x^2 = \text{constant}$. In the figure below label the locations of

$E_{\mathrm{k,max}}$	$E_{\mathrm{k,min}} = 0\ \mathrm{J}$	$E_{\mathrm{p,max}}$	$E_{\mathrm{p,min}} = 0\ \mathrm{J}$
a_{max}	$a_{\mathrm{min}} = 0\ \frac{\mathrm{m}}{\mathrm{s}^2}$	v_{max}	$v_{\mathrm{min}} = 0\ \frac{\mathrm{m}}{\mathrm{s}}$



22. What is the mathematical relationship between the energy and amplitude of an object in simple harmonic motion?

23. **Use a pencil and ruler!** Draw an energy vs. displacement graph for a mass on a spring with three curves: a potential energy vs. displacement curve, a kinetic energy vs. displacement curve, and a total energy vs. displacement curve.

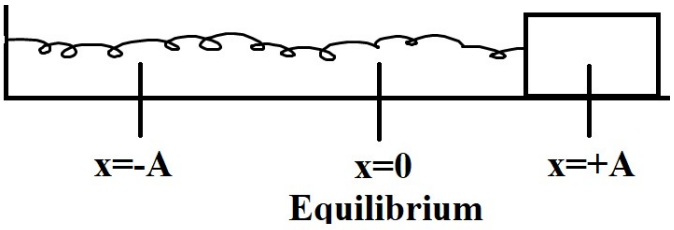
24. **Use a pencil and ruler!** Draw an energy vs. time graph during one oscillation for a mass on a spring with three curves: a potential energy vs. displacement curve, a kinetic energy vs. displacement curve, and a total energy vs. displacement curve.

Additional HL Understandings

25. Math review: Describe the significance of the variables A, B, C, and D in the equation $y = A\sin(Bx + C) + D$.

26. Derive the equations of motion, energy, and speed for simple harmonic motion.

For a mass on a spring:



Optional for math lovers

The small angle approximation ($\theta < 10°$) for the period of a pendulum is given in the physics data booklet: $T = 2\pi\sqrt{\frac{l}{g}}$

The exact solution is given from the video below:

Exact Solution of the Nonlinear Pendulum
Flammable Maths
https://www.youtube.com/watch?v=efvT2iUSjaA

Watch and take notes from the video above.