Phys 123

Thurs Jan 18: Exam 1 Prep

- Session 5:00 <u>Tonight</u>, Kane 210
  - Kane 220 for Overflow Only

"Preparation for Exam 1"

- What to Bring, What to Expect, Topics
- Review
- Includes Taking a Short "Trial" Exam
  - And Immediate Feedback on Your Performance

What to Bring & Expect

- BRING:
  - Standard Answer Form
    - Also Known as “Bubble Sheet” or “Scantron”
  - Pencils, Eraser, Plastic Ruler, Calculator
    - No USE of Graphics or Text Storage Features
  - Rested, Relaxed Mindset (Get Lots of Sleep)
- EXPECT:
  - No Time to Think, Must Move Fast
    - Approximately 2.6 Minutes Available per Question
  - Lecture, Lab (16%) and Tutorial (18%) Questions
    - Multiple Choice OR Hand-Graded
  - Compute Numbers, Draw Sketches, Explain Your Reasoning (OR <u>Choose</u> Number, Sketch, Explanation)

Exam 1 Topics

- Basically Everything in Chapters 15 – 17, Plus Perhaps a Bit of Chapter 33
  - Oscillations and Simple Harmonic Motion
    - Blocks & Springs, Pendula
  - Waves on Strings or Springs (1-D)
  - Waves in 2-D & 3-D (Water Surface, Sound)
  - Diffraction & Interference of Waves, Shock Waves
  - Fundamentals of the Ray Model of Light
- Plus First 3 Labs, First 3 Tutorials

Basic Principles

PHYS 121: Mechanics

- Relations Among $\vec{r}, \vec{v}$ and $\vec{a}$
- Principle of Relativity
- Newton's Three Laws of Motion
- Conservation of Energy:
  - The Work - Energy Principle
    - Special Case: Mechanical Energy is Constant
- Conservation of Linear Momentum
  - The Impulse – Momentum Principle
    - Special Case: Linear Momentum is Constant
- Conservation of Angular Momentum
  - The Angular Impulse – Angular Momentum Principle
    - Special Case: Angular Momentum is Constant

And Their Rotational Analogues

Review: Basic Principles

PHYS 122: Electromagnetism

- Conservation of Electric Charge
- Gauss' Law for Electric Fields
- Definition of Electric Potential Difference
- Ampere's Law *(Modified by Maxwell)
- Gauss' Law for Magnetic Fields
- Faraday's Law of Electromagnetic Induction

Other General Principles:

- Principle of Superposition
- Principle of Symmetry

Basic Principles:

PHYS 123: Waves, Optics & Thermal Physics

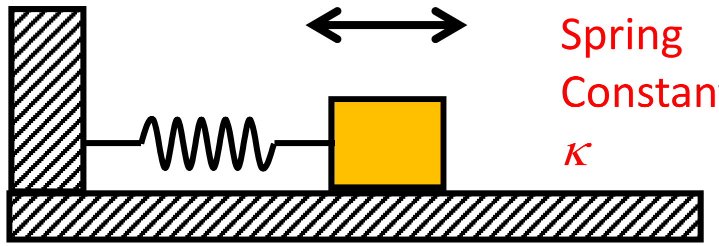
- Oscillations Produce Waves of the Same Frequency
- Superposed Sine Waves Can Represent Any Wave
- Waves Diffract & Interfere
- The Ray Model Works for Waves When Diffraction & Interference Are Negligible
- The Building Blocks of Nature Share Wave & Particle Properties
- The Values of Physical Quantities Are Quantized
- The Laws of Thermodynamics Arise from the Statistics of Large Systems, and Constrain the Transfer of Energy (and All Interactions) Within and Between Such Systems

Review: SHM of Mass on Spring

- SHM Always Follows This Form of Equation:

$$\frac{d^2x}{dt^2} = -\frac{\kappa}{m}x$$

Example:
Mass on Spring
No Friction



- Solution Has 3 Constants: $x(t) = A\cos\left(\omega t + \phi\right)$
  - *A*, ϕ Set By Initial Conditions (Amplitude, Phase)
  - ω Determined By Equation:

$$\omega\left[\text{rad/s}\right] \equiv \sqrt{\frac{\kappa}{m}} = 2\pi f \qquad T\left[\text{s}\right] = \frac{1}{f} = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{\kappa}}$$

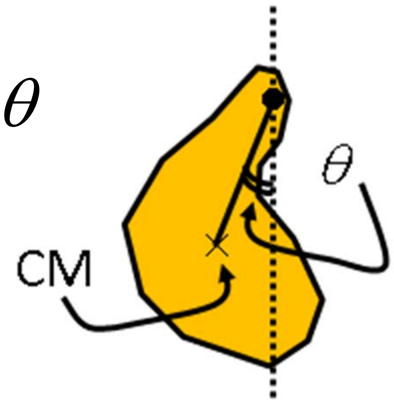
- Get Velocity & Acceleration by Derivatives:

$$v(t) = -\omega A\sin\left(\omega t + \phi\right) \qquad a(t) = -\omega^2 A\cos\left(\omega t + \phi\right)$$

Review SHM: Pendulum

- Can Obtain Equation From Net Torque $= I\ddot{\theta}$
  - Angle θ Replaces x
  - Small Angles ($\leq 30°$)

$$\frac{d^2\theta}{dt^2} = -\frac{mgR_{\mathrm{CM}}}{I_{\mathrm{pivot}}}\theta$$



- Solution:

$$\theta(t) = A\cos(\omega t + \phi) \qquad A = \theta_{\max} \quad \text{(radians)}$$

  - Again A, ϕ From Initial Conditions

SIMPLE PENDULUM

$$\boxed{\omega = \sqrt{\left(\frac{mgR_{\mathrm{CM}}}{I}\right)}} \quad \boxed{T = 2\pi\sqrt{\frac{I}{mgR_{\mathrm{CM}}}}} \quad \boxed{\omega \to \sqrt{\frac{g}{l}}} \quad \boxed{T \to 2\pi\sqrt{\frac{l}{g}}}$$

  - Again Derivatives for (Angular) Velocity, Accel. :

$$\Rightarrow \dot{\theta}(t) = -\omega A\sin(\omega t + \phi) \qquad \ddot{\theta}(t) = -\omega^2 A\cos(\omega t + \phi)$$

Review: Energy & Damping in S.H.M.

- With No Damping: $K_i + U_i = K_f + U_f$
  - Pick Convenient Initial & Final
  - Mass on Spring: $K = \frac{1}{2} m v^2 \qquad U = \frac{1}{2} \kappa x^2$

    May Have Gravity, Too: $U = mgh$
  - Pendulum: $K = \frac{1}{2} I \dot{\theta}^2 \qquad U = mgR_{\text{CM}} \left[1 - \cos\theta \right]$

- With Damping: Do Not Use Energy
  - Unless You Can Compute Energy Loss by Damping
  - For $\vec{F} = -b\vec{v}$ $\qquad x(t) = Ae^{-\alpha t} \cos\left(\omega_d t + \phi \right)$

$$\omega_d = \sqrt{\omega_0^2 - \alpha^2} \quad \text{where} \quad m\omega_0^2 = \kappa \quad \text{and} \quad 2m\alpha = b$$

Review: The Wave Equation

- Waves on Strings/Springs: $$\frac{\partial^2}{\partial x^2} y(x,t) = \frac{1}{v^2}\frac{\partial^2}{\partial t^2} y(x,t)$$
  - The Wave Equation
  - Satisfied by Any Function of the Form: $y(x \pm v\Delta t)$
  - Same Signs on (x, t) $\Rightarrow$ Travel to Decrease x
- Harmonic Waves: $y(x,t) = A\cos\left(kx \pm \omega t + \phi\right)$

$$\omega = 2\pi f, \qquad T = \frac{2\pi}{\omega}, \qquad k = \frac{2\pi}{\lambda}$$

Wave Number k

$$v = \frac{\omega}{k} = \lambda f = \sqrt{\frac{F_{\mathrm{T}}}{\mu}}$$

  - These Relationships Hold for All (Classical) Waves
    - The Details Change

Review: Power

- 1-D Waves Transport Energy As They Move
- The Energy Transported Per Second (Power) for a Wave on a String / Spring is:

Units = Watts = Energy / s

$$P = \frac{d\left(K+U\right)}{dt} = \tfrac{1}{2}\mu v \omega^2 A^2$$

  - With 1-D Waves, That is All There Is
    - The Energy Just Moves Along the String or Spring without Diminishing (if No Losses)
  - Derived Under the Small Wave Amplitude Approximation (Amplitude Much Smaller than Wavelength)

Review: Sound

- Sound Waves are Longitudinal (Compressional) 3-D Waves in Gases, Liquids or Solids.
  - We Treat as 1-D Except for Energy / Power Dependence on Distance.
  - Same Math as Waves on Springs / Strings

$$y(x,t) = A\cos(kx \pm \omega t + \phi) \quad k \equiv \frac{2\pi}{\lambda} \quad \omega \equiv \frac{2\pi}{T}$$

  - *A* Can Be Pressure, Density, Displacement of Molecules.
- – Speed of Sound:
  - Air = 343 m/s

$$v = \sqrt{\frac{B}{\rho}} \quad B = \text{ Bulk Modulus}$$

- – Coming Soon:

Doppler Effect:

- Observed Frequency Varies with Relative Motion of Source (S) Or Observer (O) to Medium

$$f' = f\left(\frac{v \pm v_{\mathrm{O}}}{v \mp v_{\mathrm{S}}}\right)$$

Review: Intensity & Sound Level

- Abandon 1-D Model for Energy Transport
  - Intensity = Power Transported per Detector Area :

$$I \equiv \frac{P}{\text{Area}} \quad \text{2-D Spread: } I = \frac{P}{2\pi r} \quad \text{3-D Spread: } I = \frac{P}{4\pi r^2}$$

  - Intensity of Sound: $I = \dfrac{P}{\text{Area}} = \tfrac{1}{2}\rho v \omega^2 A^2 \quad \text{(3-D)}$
  - Sound Level (Decibels)

$$\beta \equiv 10 \log_{10}\left(\frac{I}{I_0}\right), \quad I_0 = \text{"Threshold"} = 10^{-12}\ \text{W/m}^2$$

    - Log Scale, 100 dB Has 10^{10} Times Intensity of 0 dB
    - Doubling Intensity Increases Sound Level by $\approx$ 3 dB

Review: Standing Waves

- Similar Mathematical Description for Standing Waves: Strings and Tubes.
- Open Tube, Free String:

(Both Ends Open / Free)

$$L = n\frac{\lambda_n}{2} \qquad f_n = n\frac{v}{2L}$$

- Closed (1 End) Tube:

(or String 1 Free)

$$L = (2n-1)\frac{\lambda_{2n-1}}{4} \qquad f_{2n-1} = (2n-1)\frac{v}{4L}$$

- 2 Ends Fixed String:

(Both Ends Closed Tube)

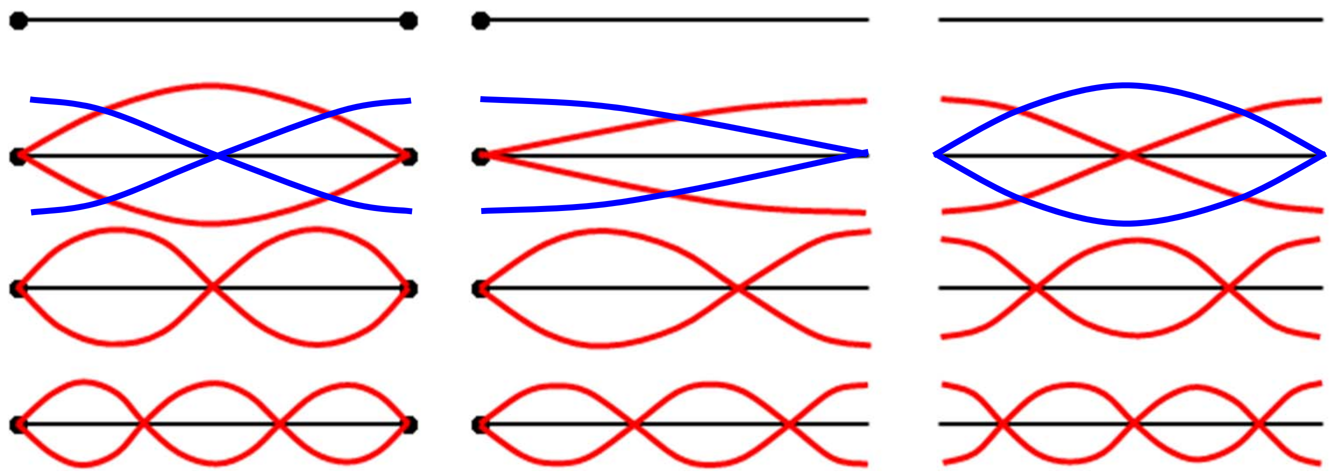
$$L = n\frac{\lambda_n}{2} \qquad f_n = n\frac{v}{2L}$$

- Need Formulae & Patterns…

Review: Standing Wave Patterns

STRINGS

2 Fixed   Fixed / Free   2 Free



ALSO TUBES*

2 Closed   1 Closed   2 Open

– *But <u>Only</u> if Amplitude = Molecular Displacement
  - Nodes & Antinodes Are REVERSED for Pressure…

More Exam Topics Coming

- Interference & Diffraction (This Week)
- Beats, a special case of interference for sound waves (Next Week)
- Doppler Effect, Motion Changes Frequency
- Shock Waves
- Possibly: Fundamentals of Ray Optics (Begins Late Next Week)

PRACTICE EXAM