Final Exam Review: Chapters 14 – 16

Physics 1425, Section 1 (Dr. Yost)

The final exam will cover chapters 1 - 20. You may use a calculator and a set of notes for this exam. You will be given any constants you need, as well as any required moments of inertia, unless the point of the problem is to derive it. You may bring *one page* (both sides) of notes to the exam. The page must be hand-written, and not photo-copied. This review covers the chapters since the third exam: 14 - 16. You should

Chapter 14: Oscillations

Concepts: vibration, oscillation, simple harmonic motion, amplitude, period, frequency, pendulums

Equations:

Simple harmonic motion is described by $x = A\cos(\omega t + \phi)$, where A is the amplitude, ω is the angular frequency, and ϕ is a phase.

Angular frequency is $\omega = 2\pi f$, where f is the frequency. Frequency is related to period by $f = 1/T$.

If an object of mass m oscillates under the force due to a spring of spring constant k, the angular frequency is $\omega = \sqrt{k/m}$.

The total energy is $E = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$.

The period of small oscillations of a pendulum with length L is $T = 2\pi\sqrt{L/g}$.

Chapter 15: Wave motion

Concepts: pulses, waves, amplitude, wavelength, frequency, period, longitudinal waves, transverse waves, wave velocity, energy transmitted by waves, the wave equation, principle of superposition, reflection and transmission, standing waves, resonance, harmonics

Equations:

The wave velocity is related to the frequency and wavelength by $v = f\lambda = \omega/k$, where the wave number is defined to be $k = 2\pi/\lambda$. A sine wave of amplitude D_M can be represented as $D(x,t) = D_M \sin(kx - \omega t)$. If F_T is the tension on a cord, and

μ is the linear mass density (kg/m), then the velocity of transverse waves on the cord is $v = \sqrt{F_T/\mu}$.

The velocity of longitudinal waves on a rod is $v = \sqrt{E/\rho}$, where E is Young's modulus and ρ is the mass density (kg/m^3) of the rod.

For longitudinal waves in a liquid or gas of density ρ and bulk modulus B, the velocity is $v = \sqrt{B/\rho}$.

The intensity of a spherical wave is the average power transmitted per unit area: $I = \overline{P}/A$. The power transmitted is proportional to f^2 and A^2, if f is the frequency and A is the amplitude. At two distances r_1 and r_2, the intensities are related by the inverse square law, $I_2/I_1 = (r_1/r_2)^2$.

If t and x are the time and position where a wave is measured, and y is the wave's displacement (in any units relevant for the wave), the wave equation says that

$$\frac{d^2y}{dt^2} - v^2\frac{d^2y}{dt^2} = 0, \tag{1}$$

where v is the wave velocity.

A wave is reflected from a free end without a phase change, but is reflected from a fixed end with a 180^o phase shift.

A standing wave vibrates in place. If the ends are fixed so that the displacement is $y = 0$ at $x = 0$ and $x = L$, then the vibrations can occur at wavelengths $\lambda_n = 2L/n$, $n = 1, 2, 3, \cdots$.

Chapter 16: Sound

Concepts: loudness, pitch, audible range, pressure waves, decibels, string instruments, wind instruments, overtones, harmonics, open pipes, closed pipes, interference, beats, Dopper effect

Equations:

The speed of sound in air is approximately $v \approx (331+0.60T)$ m/s, with T in Celcius degrees.

The sound level in decibels is given by

$$\beta(\text{in dB}) = 10\log_{10}\frac{I}{I_0} \tag{2}$$

where I is the intensity of the sound wave in W/m^2 and I_0 is a reference intensity, normally taken to be the threshold of human hearing, or 1.0×10^{-12} W/m^2. A doubling of power corresponds to about 3 dB, which is perceived as a small change in loudness.

The fundamental vibrational mode of a stringed instrument is $\lambda = 2L$, where L is the length of the string. The overtones or harmonics are at wavelengths $\lambda_n = 2L/n$, for $n = 1, 2, 3, \cdots$.

A tube open on both ends also produces wavelengths $\lambda_n = 2L/n$. A tube closed on one end produces wavelengths $\lambda_n = 4L/(2n-1)$. An open tube produces all integer multiples of the fundamental frequency $f_1 = v/\lambda_1$, while a tube closed on one end produces only the odd integer multiples of f_1. If two sounds are produced simultaneously with frequencies f_1 and f_2, they will interfere and produce "beats" with frequency $|f_1 - f_2|$.

Doppler effect:

If a source is moving at speed v_S and the speed of sound is v, then the frequency of sound heard by a stationary observer is shifted to a shorter wavelength and higher frequncy when the motion is *toward* the observer:

$$\lambda' - \lambda = -v_S \lambda / v, \qquad f' = f\left(1 - \frac{v_S}{v}\right)^{-1}, \tag{3}$$

where λ, f are what would be heard with no motion, and λ', f' are what is heard with the moving source. When the motion is *away from* the observer, the observed wavelength is longer, and the frequency is lower:

$$\lambda' - \lambda = v_S \lambda / v, \qquad f' = f\left(1 + \frac{v_S}{v}\right)^{-1}. \tag{4}$$

If the source is fixed but the observer is moving, the wavelength doesn't change, but the relative wave speed is shifted. When the motion is *toward* the source, the relative wave speed is higher, and so is the frequency:

$$v' - v = v_O, \qquad f' = f\left(1 + \frac{v_O}{v}\right). \tag{5}$$

When the motion is away from the source, the relative wave speed is lower, and so is the frequency:

$$v' - v = -v_O, \qquad f' = f\left(1 - \frac{v_O}{v}\right). \tag{6}$$

If the source and observer are both moving, these effects must be combined. In a common case, one object will emit a signal (as in sonar) which is reflected off a second, and then received and compared to the original signal. If the relative speed between the two objects is v_R, and v is the speed of sound, the received frequency f' will be related to the original frequency by

$$f' = f\left(\frac{v - v_R}{v + v_R}\right), \tag{7}$$

with v_R positive when the objects are moving apart.

Units:

Decibels (dB) are used to measure sound intensity logarithmically. They are dimensionless.