Study Guide for Test 4

Gravity

You should know the gravitational force law and energy formula,

$$|\vec{F}_g| = \frac{Gm_1m_2}{r^2}, \qquad U_g = -\frac{Gm_1m_2}{r}, \qquad G = 6.67 \times 10^{-11}\ \text{N-m}^2/\text{kg}^2,$$

and be able to use these formulas in constrained motion problems and in energy conservation problems. You should understand the concept of escape speed. Please memorize the exponent (-11) in the gravitational constant, and be able to figure out its units from the force law.

Fluids

Density is mass per unit volume: $\rho = m/V$. Its official SI unit is kg/m^3, but other common metric units are kg/liter and g/cm^3, and you need to be able to convert between these. You should know the approximate values of the densities of air (1 kg/m^3) and water (1000 kg/m^3).

Pressure is force per unit area: $P = F/A$. Its official SI unit is N/m^2, also called Pa (pascals). Please memorize the approximate value of atmospheric pressure at sea level, 1 atm $\approx 10^5$ N/m^2 = 1 bar.

In a static fluid with gravity present, the pressure increases with depth:

$$(P \text{ at depth } d) = (P \text{ at reference level}) + \rho g d.$$

Because fluid pressure increases with depth, the net ("buoyant") force exerted by a fluid on a submerged object is upward, and its magnitude equals the weight of the fluid displaced ("Archimedes' principle", $|\vec{F}_b| = mg = \rho V g$, where m and ρ refer to the *fluid*, not the submerged object).

Oscillations

You should understand how Newton's second law for a mass on a spring predicts oscillatory motion:

$$\frac{d^2x}{dt^2} = -\frac{k_s}{m}x \quad \Rightarrow \quad x(t) = A\cos\omega t, \quad \text{with} \quad \omega = \sqrt{\frac{k_s}{m}}.$$

You should know how the frequency ($f = \omega/2\pi$) and period ($T = 1/f$) are related to the angular frequency (ω). You should understand the correspondences to similar behavior in other oscillating systems such as a simple pendulum in the small-amplitude limit.

Waves

You should understand the following terms as applied to waves: transverse; longitudinal; amplitude; frequency; angular frequency; period; wavelength; angular wave number; wave velocity; superposition.

Given a formula for the shape of a pulse or periodic traveling wave or standing wave in one dimension (as on a string), you should be able to determine any of the relevant quantities (amplitude, frequency, etc.) in the preceding list. Given a sufficent number of these quantities, you should be able to write down a formula describing the pulse or wave shape.

You should know the formulas for the speed of a transverse wave on a taut string, or a sound wave, in terms of the elastic and inertial properties of the medium:

$$v_{\text{string}} = \sqrt{\frac{\text{tension}}{\text{mass/length}}}; \qquad v_{\text{sound}} = \sqrt{\frac{\text{bulk modulus}}{\text{density}}}.$$

You should also understand why these formulas make sense, qualitatively. You should memorize the approximate value of the speed of sound in air (340 m/s).

You should understand the principle of superposition, and be able to apply it to both pulses and sinusoidal waves.

You should understand what sound waves are, in terms of displacement of molecules and variations in density and pressure. In particular, you should know that where the displacement is large, the density variation is zero, and vice-versa.

You should be able to draw standing-wave patterns and determine the various standing-wave wavelengths and frequencies for strings and pipes (with open and/or closed ends).