

Study Guide for Test 4

Gravity on the large scale

You should know the gravitational force law and energy formula,

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

and be able to use these formulas in constrained motion problems and in energy conservation problems. You should understand the concept of escape speed.

Fluid statics

You should know how density is defined, how to convert units of density, and the approximate values of the density of air and water.

You should understand the definition of pressure ($P = F/A$) and why it depends on depth when gravity is present. Please memorize the approximate value of atmospheric pressure at sea level, 10^5 N/m^2 or 1 bar. You should be able to compute the pressure as a function of depth in a fluid of uniform density:

$$P(h) = P_0 + \rho gh.$$

You should understand the concept of buoyant force and Archimedes' principle.

Oscillations

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

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

You should know how the frequency ($f = \omega/2\pi$) and period ($T = 1/f$) related to the angular frequency (ω). You should be able to interpret 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; speed; superposition; interference.

Given a mathematical formula for a pulse or periodic wave traveling 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 sufficient number of these quantities, you should be able to write down a mathematical formula describing the pulse or wave.

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:

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

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 determine when two waves will cancel completely (“destructive interference”) and when they will add to a maximum resultant wave (“constructive interference”).

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).