Study Guide for Test 2

Newton's first law: An isolated object (with no outside influences acting on it) moves in a straight line at constant speed.

Newton's second law: The acceleration of an object is determined by the vector sum of all the forces acting on it. More precisely,

$$\text{net } F_x = ma_x \qquad \text{net } F_y = ma_y \qquad \text{net } F_z = ma_z$$

Every force on an object arises from an interaction with some other nearby object (called the "agent" of the force).

Newton's third law: When two objects, A and B, interact, the forces they exert on each other are always of the same type, equal in magnitude, and opposite in direction:

$$\vec{F}_{\text{on } A \text{ from } B} = -\vec{F}_{\text{on } B \text{ from } A}$$

Newton's laws work only in an inertial reference frame, that is, when all measurements are made with respect to a reference frame that is not itself accelerating.

Types of forces:

- Contact forces
  1. compression (including "normal")
  2. tension (same at each end of an ideal string)
     (for a stretched or compressed spring, $F_x = -k_s x$)
  3. friction (gripping, $|\vec{F}_f| \leq \mu_s |\vec{F}_N|$; slipping, $|\vec{F}_f| = \mu_k |\vec{F}_N|$; also air resistance, etc.)
- Long-range forces
  1. gravity or "weight", $|\vec{F}_g| = mg$, where $g = 9.8$ N/kg near earth's surface
  2. electromagnetic

Torque and equilibrium: $\tau = |\vec{r}||\vec{F}|\sin\theta = r_\perp |\vec{F}| = |\vec{r}| F_\perp$. Counterclockwise torques are positive, clockwise torques are negative. To compute torque due to gravity, pretend that gravity acts at the center of mass. For an object in equilibrium, the net torque from all forces must be zero.

Work and energy:

$$W_{\text{by } \vec{F}} = |\vec{F}||\Delta\vec{r}|\cos\theta; \qquad \text{KE} = \tfrac{1}{2}m|\vec{v}|^2; \qquad \text{PE}_g = mgy; \qquad \text{PE}_s = \tfrac{1}{2}k_s x^2$$

The work-energy theorem states that during any time interval, the change in an object's energy equals the total work done on it by all forces:

$$E_f - E_i = \text{net } W.$$

If you include potential energy (from gravity, springs) in E on the left side of this equation, then you should *not* include the associated work from that force on the right side. If the only work-doing forces are gravity and springs, then the total mechanical energy is *conserved*: $E_f = E_i$.

Other (nonmechanical) types of energy include thermal, chemical, electrical, radiant, and nuclear. Units of energy include the joule, kilocalorie (4200 J), kilowatt-hour, and Btu. "Power" is the *rate* at which energy is converted (or transported):

$$\text{Power} = \frac{\text{Energy}}{\text{Time}}.$$

You should be able to do the following:

- Draw qualitatively accurate force diagrams, identify the type and agent of each force, identify third-law partners.
- Solve "constrained motion" problems involving straight-line motion of a single object or multiple interacting objects. Solve equilibrium problems involving both forces and torques.
- Recognize non-inertial reference frames (accelerating cars, elevators, etc.) and instead analyze problems from the viewpoint of an inertial reference frame.
- Calculate the work done by a force acting at any angle. Solve problems using the work-energy theorem and/or the principle of conservation of energy.
- Recognize and understand units of mass, force, torque, energy, and power. Convert from joules to kilocalories (or vice-versa).

Although this test will cover mainly the ideas listed here (Urone, Chapters 4–6), you are still responsible for material covered on the first test (Chapters 1–3). Note that the equations for constant acceleration tend to come up occasionally in constrained motion problems.

The formulas for the specific types of forces and specific types of energy will be provided on the test. You are responsible for knowing all the other formulas (definitions and fundamental principles) that appear on this study guide.