Exam 2 Review

Chapter 6: Conservation of Energy

Introduce and apply one of the most important principles in physics.

- **The Law of Conservation of Energy**
  One of the few universal laws of physics.
  Energy can be in many different forms.
  - Kinetic energy is due to motion.
  - Potential energy is due to interactions.
  - Rest energy from Einstein's $E = mc^2$.

- **Work Done by a Constant Force**

$$W = F\Delta r\cos\theta$$

  Work can be positive, negative, or zero.

- **Kinetic Energy**
  For translational motion

$$K = \tfrac{1}{2}mv^2$$

  The total work done changes the kinetic energy

$$W_{total} = \Delta K$$

- **Gravitational Potential Energy (1)**

$$U_{grav} = mgy$$

  Choose the zero of potential energy at some convenient height.
  The all important conservation of energy theorem is

$$W_{nc} = \Delta K + \Delta U$$

  or

$$(K_i + U_i) + W_{nc} = (K_f + U_f)$$

  The mechanical energy is

$$E_{mech} = K + U$$

- **Gravitational Potential Energy (2)**
  Found from Newton's law of gravity.

$$U = -\frac{Gm_1 m_2}{r}$$

- **Work Done by Variable Forces: Hooke's Law**
  Hooke's law for the force due to an ideal spring

$$F_x = -kx$$

- **Elastic Potential Energy**

$$U_{elastic} = \tfrac{1}{2}kx^2$$

- **Power**

$$P_{av} = \frac{\Delta E}{\Delta t}$$

  Instantaneous power

$$P = Fv\cos\theta$$

Chapter 7: Linear Momentum

A conservation theorem that involves vectors.

- **A Conservation Law for a Vector Quantity**
  We take components of vectors.

- **Momentum**

$$\vec{\mathbf{p}} = m\vec{\mathbf{v}}$$

- **The Impulse-Momentum Theorem**
  The change in momentum is caused by the impulse

$$\Delta\vec{\mathbf{p}} = \sum \vec{\mathbf{F}}\Delta t$$

  Newton's second law can be reformulated

$$\sum \vec{\mathbf{F}} = \lim_{\Delta t \to 0} \frac{\Delta\vec{\mathbf{p}}}{\Delta t}$$

- **Conservation of Momentum**
  If the net external force acting on a system is zero, momentum is conserved.

- **Center of Mass**

$$x_{CM} = \frac{\sum m_i x_i}{M} \qquad y_{CM} = \frac{\sum m_i y_i}{M}$$

- **Motion of the Center of Mass**
  Newton's second law holds for extended objects

$$\sum \vec{\mathbf{F}}_{ext} = M\vec{\mathbf{a}}_{CM}$$

- **Collisions in One Dimension**
  - Elastic.

$$v_{1f} = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)v_{1i} + \left(\frac{2m_2}{m_1 + m_2}\right)v_{2i}$$

$$v_{2f} = \left(\frac{2m_1}{m_1 + m_2}\right)v_{1i} + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)v_{2i}$$

  - Inelastic
  - Perfectly inelastic.

$$v_{1f} = v_{2f}$$

- **Collisions in Two Dimensions**
  Draw pictures of initial and final situation. Use components of momenta.

Chapter 8: Torque and Angular Momentum

Discuss the dynamics of rotational motion and its similarity to translational motion.

- **Rotational Kinetic Energy and Rotational Inertia**

$$K_{rot} = \tfrac{1}{2} I\omega^2$$

$$I = \sum_{i=1}^{N} m_i r_i^2$$

  The rotational inertia of many uniform shapes has been determined.

- **Torque**

$$\tau = \pm rF_{\perp} = \pm r_{\perp} F$$

The sign is determined by counterclockwise (+) or clockwise (-).

- **Calculating Work Done From the Torque**

$$W = \tau \Delta \theta$$

- **Rotational Equilibrium**

$$\sum \vec{\mathbf{F}} = 0 \text{ and } \sum \tau = 0$$

A clever choice of the axis for the torque equation can simplify the problem.

- **Equilibrium in the Human Body**
  The forces in the body are surprisingly large.

- **Rotational Form of Newton's Second Law**

$$\sum \tau = I\alpha$$

- **The Motion of Rolling Objects**

$$\begin{aligned} K &= K_{trans} + K_{rot} \\ &= \tfrac{1}{2} m v_{CM}{}^2 + \tfrac{1}{2} I_{CM} \omega^2 \end{aligned}$$

- **Angular Momentum**

$$L = I\omega$$

$$\sum \tau = \frac{dL}{dt}$$

If the torque is zero, angular momentum is conserved.

- **The Vector Nature of Angular Momentum**
  The direction is given by the right-hand rule.