Section Summary

8.1 Linear Momentum and Force

- Linear momentum (*momentum* for brevity) is defined as the product of a system's mass multiplied by its velocity.
- In symbols, linear momentum p is defined to be
- $p = mv$,

  where m is the mass of the system and v is its velocity.
- The SI unit for momentum is $\mathrm{kg} \cdot \mathrm{m/s}$.
- Newton's second law of motion in terms of momentum states that the net external force equals the change in momentum of a system divided by the time over which it changes.
- In symbols, Newton's second law of motion is defined to be
- $F_{\mathrm{net}} = \frac{\Delta p}{\Delta t}$,

  F_{net} is the net external force, Δp is the change in momentum, and Δt is the change time.

8.2 Impulse

- Impulse, or change in momentum, equals the average net external force multiplied by the time this force acts:
- $\Delta p = F_{\mathrm{net}} \Delta t$.
- Forces are usually not constant over a period of time.

8.3 Conservation of Momentum

- The conservation of momentum principle is written
- $p_{\mathrm{tot}} = \mathrm{constant}$

  or

  $\mathrm{p}_{\mathrm{tot}} = \mathrm{p'}_{\mathrm{tot}}$ (isolated system),

  p_{tot} is the initial total momentum and $\mathrm{p'}_{\mathrm{tot}}$ is the total momentum some time later.
- An isolated system is defined to be one for which the net external force is zero $\left(\mathrm{F}_{\mathrm{net}} = 0\right)$.
- During projectile motion and where air resistance is negligible, momentum is conserved in the horizontal direction because horizontal forces are zero.
- Conservation of momentum applies only when the net external force is zero.
- The conservation of momentum principle is valid when considering systems of particles.

8.4 Elastic Collisions in One Dimension

- An elastic collision is one that conserves internal kinetic energy.
- Conservation of kinetic energy and momentum together allow the final velocities to be calculated in terms of initial velocities and masses in one dimensional two-body collisions.

8.5 Inelastic Collisions in One Dimension

- An inelastic collision is one in which the internal kinetic energy changes (it is not conserved).
- A collision in which the objects stick together is sometimes called perfectly inelastic because it reduces internal kinetic energy more than does any other type of inelastic collision.
- Sports science and technologies also use physics concepts such as momentum and rotational motion and vibrations.

8.6 Collisions of Point Masses in Two Dimensions

- The approach to two-dimensional collisions is to choose a convenient coordinate system and break the motion into components along perpendicular axes. Choose a coordinate system with the x-axis parallel to the velocity of the incoming particle.
- Two-dimensional collisions of point masses where mass 2 is initially at rest conserve momentum along the initial direction of mass 1 (the x-axis), stated by $m_1 v_1 = m_1 {v'}_1 \cos\,\theta_1 + m_2 {v'}_2 \cos\,\theta_2$ and along the direction perpendicular to the initial direction (the y-axis) stated by $0 = m_1 {v'}_{1y} + m_2 {v'}_{2y}$.
- The internal kinetic before and after the collision of two objects that have equal masses is
- $\frac{1}{2}\mathrm{m}{\mathrm{v}_1}^2 = \frac{1}{2}\mathrm{m}{\mathrm{v}'_1}^2 + \frac{1}{2}\mathrm{m}{\mathrm{v}'_2}^2 + \mathrm{m}{\mathrm{v}'}_1 {v'}_2 \cos\left(\theta_1 - \theta_2\right).$
- Point masses are structureless particles that cannot spin.

8.7 Introduction to Rocket Propulsion

- Newton's third law of motion states that to every action, there is an equal and opposite reaction.
- Acceleration of a rocket is $a = \frac{v_e}{m}\frac{\Delta m}{\Delta t} - g$.
- A rocket's acceleration depends on three main factors. They are
  1. The greater the exhaust velocity of the gases, the greater the acceleration.
  2. The faster the rocket burns its fuel, the greater its acceleration.
  3. The smaller the rocket's mass, the greater the acceleration.