DIVISIONS OF PHYSICS

- Classical Mechanics (Newtonian Physics)
  - Treats energy and matter as separate entities.
  - Uses Newton’s three Laws to predict motion.
  - Accurately predicts and describes the behavior of large scale objects.
  - Connects acceleration and forces.
- Quantum Mechanics
  - Attempts to explain the motion and energy of atoms and subatomic particles.
  - Studies microscopic objects that move at the speed of light ($c = 3.00 \times 10^8$ m/s$^2$).

NEWTON’S LAWS OF MOTION

- Newton uses three Laws to predict the interaction between force and motion for macroscopic objects.
- **Newton's First Law**
  - An object at rest or in uniform motion will remain at rest or in motion unless acted on by an external force.
  - The first law is often interpreted as saying that objects resist changes in motion. This resistance to motion changes is often given the name inertia. Objects with large inertia resist changes in motion better than objects with small inertia.
  - An external force is examined by looking at the vector sum of all the forces acting on an object. This is known as net force.
  - When the net force equals zero, and motion does not change, we say the body is in equilibrium.
- **Newton's Second Law**
  - The acceleration of a body is directly proportional to the net force acting on it and inversely proportional to its mass.
  - $F_{\text{NET}} = ma$
- **Newton's Third Law**
  - When an object exerts a force on a second object, the second object exerts a force on the first that is equal in magnitude but opposite in direction.
  - For every action there is an equal and opposite reaction.
  - Action – reaction pair
  - Example: Walking across the room you push the floor with your feet.
    - Newton’s second law: you are applying a force on the floor but it is not moving (net force =0).
    - Newton’s third law: the floor is exerting an equal and opposite frictional force on you. In reality, the floor pushes you, propelling you across the floor. That is why it is harder to walk on ice.

FORCES IN TWO DIMENSIONS

- Sometimes the direction of the net force is not clear. You must find the magnitude and direction of the net force by adding vectors. (Model problem – page 172)

MULTI-MASS PROBLEMS

- Tension in ropes and cables
  - When a force is exerted on one end of a cable, each particle in the cable exerts and equal force on the next particle in the cable, creating tension through the cable. Tension is the magnitude of the force exerted on and by a cable.
  - To avoid complicated mathematics we make several assumptions about cables and ropes:
    - The mass of the rope or cable is so much smaller than the mass of the load that it does not significantly affect the motion or forces involved.
    - The tension is the same at every point in the rope or cable.
    - If the rope or cable passes over a pulley, the direction of the tension forces changes, but the magnitude stays the same (so the pulley is frictionless and its mass is negligible).
  - Assigning direction to the motion of the connected objects:
    - When two objects are attached as in an Atwood machine, they are running in two different directions. However, connected objects move as a unit.
    - A system involves working with more than one object at a time
    - Internal forces are the forces exerted through the rope or the cable between any two objects in the system. Internal forces do not affect the motion of the system.
    - External forces are forces such as gravity or friction that affects the whole system. External forces do affect the motion of the system.
    - When you set up the system you must assign direction from one side of the cable to the other. Left is often negative and right is positive.
MOMENTUM
- In non-physics terms, momentum can be described as the amount of “oomph” an object has as it moves. A slowly moving bus and a speeding bullet are very different objects, but you wouldn’t want to be hit by either one! The momentum of an object is defined as the product of its mass and velocity.
  \[ p = mv \]
  - \( p \) is the object's momentum (kg\cdot m/s)
  - \( m \) is its mass (kg)
  - \( v \) is its velocity (m/s)
- The momentum discussed in this section is specifically linear momentum.

IMPULSE
- Impulse is the product of the force exerted on an object and the time interval over which the force acts.
  \[ J = F\Delta t \]
  - \( J \) – impulse (Ns)
  - \( F \) – force (N)
  - \( \Delta t \) – time interval (s)
- The changes in an object’s momentum could arise because its velocity changes (or its mass may change, but that will come at a later time). If the velocity of an object changes, there must be acceleration and, as Newton pointed out, acceleration is a result of a net force. If you put all of this together, you get the Impulse – Momentum Theorem.
  - We use the average force because when impulse is calculated over a very short time interval, force changes continually throughout the few milliseconds of contact of the two objects.
  - It is not always easy to calculate impulse in these situations so an alternate method involves analyzing the momentum both before and after an interaction between two objects.
  - \[ F\Delta t = \Delta p \]
  - \( F\Delta t = p_{\text{before}} - p_{\text{after}} \)
  - \[ F\Delta t = m(v_f - v_i) \]

IMPULSE AND AUTO SAFETY
- One of the most practical and important applications of impulse is the design of automobiles and their safety equipment.
- During collisions mass will remain the same while momentum goes to zero.
- Since the change in momentum can’t be reduced, impulse can’t be reduced either (\( F\Delta t = J \text{ [constant]} \)).
  - If you increase the time interval of the interaction, the average force exerted on the car occupants is reduced.
    - Crumple zones (diagram on page 203).
    - The lining of safety helmets (compresses relatively slowly).

COLLISIONS
- Inelastic collisions - only the momentum is conserved, not the kinetic energy (energy of motion).
- Elastic collisions - the momentum and kinetic energy are conserved.
  - Total momentum before collision = total momentum after collision
    \[ p_{\text{total}} \text{ (before)} = p_{\text{total}} \text{ (after)} \]
    \[ m_1v_i + m_2v_i = m_1v_f + m_2v_f \]
- Recoil - the interaction that occurs when two stationary objects push against each other and then move apart.
- Types of collisions:
  - Case 1 - when one moving mass collides head on with an identical stationary mass, the first mass stops. The second mass then moves with a velocity identical to the original velocity of the first mass.
  - Case 2 - when one moving mass collides head on with a much smaller stationary mass, the first mass continues at nearly the same speed. The second mass then moves with a velocity that is approximately twice the original velocity of the first mass.
  - Case 3 - when one moving mass collides head on with a much larger stationary mass, the first mass bounces backwards with a velocity opposite in direction and almost the same in magnitude as its original velocity. The motion of the second mass is almost imperceptible.