1. Kinematics and Dynamics

Units

- The SI units include meter, kilogram, second, ampère, mole, kelvin, and candela.

Vectors and Scalars

- **Vectors** are physical quantities that have both magnitude and direction. Vector quantities include displacement, velocity, acceleration, and force, among others.
- **Scalars** are quantities without direction. Scalar quantities may be the magnitude of vectors, like speed, or may be dimensionless, like coefficients of friction.
- Vector addition may be accomplished using the tip-to-tail method or by breaking a vector into its components and using the Pythagorean theorem.
- Vector subtraction is accomplished by changing the direction of the subtracted vector and then following the procedures for vector addition.
- Multiplying a vector by a scalar changes the magnitude and may reverse the direction.
- Multiplying two vectors using the **dot product** results in a scalar quantity. The dot product is the product of the vectors' magnitudes and the cosine of the angle between them.
- Multiplying two vectors using the **cross product** results in a vector quantity. The cross product is the product of the vectors' magnitudes and the sine of the angle between them. The right-hand rule is used to determine the resultant vector's direction.

Displacement and Velocity

- **Displacement** is the vector representation of a change in position. It is path independent and is equivalent to the straight line distance between the start and end locations.
- **Distance** is a scalar quantity that reflects the path traveled.
- **Velocity** is the vector representation of the change in displacement with respect to time.

- **Average velocity** is the total displacement divided by the total time.
- **Average speed** is the total distance traveled divided by the total time.
- **Instantaneous velocity** is the limit of the change in displacement over time as the change in time approaches zero.
- **Instantaneous speed** is the magnitude of the instantaneous velocity vector.

Forces and Acceleration

- A **force** is any push or pull that has the potential to result in an acceleration.
- **Gravity** is the attractive force between two objects as a result of their masses.
- **Friction** is a force that opposes motion as a function of electrostatic interactions at the surfaces of two objects.
- **Static friction** exists between two objects that are not in motion relative to each other.
- **Kinetic friction** exists between two objects that are in motion relative to each other.
- Whereas static friction can take on many values depending on the magnitude of an applied force, kinetic friction is a constant value.
- The **coefficient of friction** depends on the two materials in contact. The coefficient of static friction is always higher than the coefficient of kinetic friction.
- Mass and weight are not synonymous.
- **Mass** is a measure of the inertia of an object-its amount of material.
- **Weight** is the force experienced by a given mass due to its gravitational attraction to the Earth.
- **Acceleration** is the vector representation of the change in velocity over time. Average or instantaneous acceleration may both be considered, similar to velocity.

Newton's Laws

- **Newton's first law**, or the **law of inertia,** states that an object will remain at rest or move with a constant velocity if there is no net force on the object.

- **Newton's second law** states that any acceleration is the result of the sum of the forces acting on the object and its mass.
- **Newton's third law** states that any two objects interacting with one another experience equal and opposite forces as a result of their interaction.

Motion with Constant Acceleration

- **Linear motion** includes free fall and motion in which the velocity and acceleration vectors are parallel or antiparallel.
- **Projectile motion** contains both an x- and y-component. Assuming negligible air resistance, the only force acting on the object is gravity.
- **Inclined planes** are another example of two-dimensional movement. It is often easiest to consider the dimensions as being parallel and perpendicular to the surface of the plane.
- **Circular motion** is best thought of as having radial and tangential dimensions. In **uniform circular motion**, the only force is the centripetal force, pointing radially inward. The instantaneous velocity vector always points tangentially.

Mechanical Equilibrium

- **Free body diagrams** are representations of the forces acting on an object. They are useful for equilibrium and dynamics problems.
- **Translational equilibrium** occurs in the absence of any net forces acting on an object. An object in translational equilibrium has a constant velocity, and may or may not also be in rotational equilibrium.
- **Rotational equilibrium** occurs in the absence of any net **torques** acting on an object. Rotational motion may consider any pivot point, but the center of mass is most common. An object in rotational equilibrium has a constant angular velocity; on the MCAT, the angular velocity is usually zero.