

Chapter 5 — Conservation of Linear Momentum

1. Define, explain, compare and contrast the following terms and concepts:

Particle vs. Extended Body

Rigid body

Kinematic Relationships: position, velocity, and acceleration

Linear Momentum

linear momentum of a particle: $\mathbf{P} = m\mathbf{V}$

specific linear momentum: \vec{V}

units of linear momentum (N · s ; lbf · s)

vector nature of linear momentum

inertial reference frame

Application of Accounting Principle for Linear Momentum

amount of linear momentum within the system: $\mathbf{P}_{sys} = \int_{\mathcal{V}_{sys}} \mathbf{V}\rho d\mathcal{V}$

transport rate of linear momentum across the system boundaries

external forces: $\sum \mathbf{F}_{external}$

body forces

surface (contact) forces

normal stress vs. shear stress

mass transport of linear momentum : $\sum_{in} \dot{m}_i \mathbf{V}_i - \sum_{out} \dot{m}_e \mathbf{V}_e$

generation/consumption rate of linear momentum within the system

Empirical result ----- Linear momentum is conserved!

Conservation of Linear Momentum Equation

rate form
$$\frac{d\mathbf{P}_{sys}}{dt} = \sum \mathbf{F}_{external} + \sum_{in} \dot{m}_i \mathbf{V}_i - \sum_{out} \dot{m}_e \mathbf{V}_e$$

Impulse:
$$\mathbf{I} = \int_{t_1}^{t_2} \mathbf{F} dt$$

Impulsive Force:
$$\mathbf{F}_{avg} = \frac{\mathbf{I}}{\Delta t} = \frac{1}{\Delta t} \int_t^{t+\Delta t} \mathbf{F} dt$$

Conservation of Linear Momentum and Newton's Laws

Center of mass

Dry Friction (A useful constitutive relation)

static friction coefficient

kinetic (sliding) friction

Relative velocity

2. Given a problem that can be solved using conservation of linear momentum, you should be able to do the following:
 - (1) Select an appropriate system that can be used to find the requested unknowns using the information given in the problem.
....Clearly identify the system and its boundaries on an appropriate drawing.
....Carefully label all transports of linear momentum with the surroundings. (This is commonly called a free-body diagram.)
 - (2) Indicate the time interval appropriate for the problem.
 - (3) Clearly identify and count the number of unknowns you are trying to find. Define and use a unique symbol for each unknown.
 - (4) Develop a set of INDEPENDENT equations that are equal in number to the number of unknowns and are sufficient to solve for the unknowns. These equations are developed using the conservation and accounting equations and the information given in the problem. Carefully indicate how the given information plus your assumptions are used to develop the problem-specific equations from the general accounting and conservation principles. (Recognize that in a two-dimensional problem, application of conservation of linear and angular momentum to a system can contribute at most three independent equations.)
 - (5) Solve for the unknown values.
3. Starting with the conservation of linear momentum equation, show what assumptions are necessary to develop the traditional result for a rigid body : $\mathbf{F} = m\mathbf{a}$
4. Given information about the acceleration of an object as a function of time, use elementary calculus to develop an equation for the velocity and as a function of time.
5. Given information about the velocity of an object as a function of time, use elementary calculus to develop an equation for the position as a function of time.
6. Use the concepts embodied in the conservation of momentum equation, including transport and storage of linear momentum, to explain the behavior of a device or system.
7. Given a problem that involves friction, use both sliding and static friction forces where appropriate to explain the motion and/or forces in the system.
8. Given a problem with impulsive forces or loads, evaluate the *impulse* applied to the system, and if the time interval is known, determine the average value of the impulsive force over the time interval.
9. Given a problem where relative velocities are given or required, correctly convert relative velocities to absolute velocities for use in the conservation of linear momentum equation.