

OBJECTIVES --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: $\vec{P} = m\vec{V}$

specific linear momentum: \vec{V}

inertial reference frame

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

vector nature of linear momentum

Application of Accounting Principle for Linear Momentum

rate of accumulation of mass within the system

amount of linear momentum within the system: $\vec{P}_{sys} = \iiint_V \vec{V} \rho dV$

transport rate of linear momentum across the system boundaries

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

body forces

surface (contact) forces

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

generation/consumption rate of linear momentum within the system

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

Conservation of Linear Momentum Equation

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

Impulse: $\vec{I} = \int_1^2 \vec{F} dt$

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

Relationship of Conservation of Linear Momentum to Newton's Laws

Center of mass

Dry Friction (A useful constitutive relation)

friction coefficient

static vs kinetic (sliding) friction

Stress - normal vs. shear stress

Pressure

Dimensions - force / area

Units -- kPa, N/m², bar, lbf/in² or psi, lbf/ft², atm

Ways to report -- absolute vs. gage vs. vacuum

Hydrostatic pressure

Manometers

Hydrostatic Forces on submerged surfaces

Plane surfaces

Magnitude of the resultant force -- pressure at centroid of surface area times area of surface

Line of action of the force -- always normal to the surface

Point of application -- always on the surface

Moment of distributed hydrostatic force = moment of resultant hydrostatic force.

Area moment of inertia

~~Area product of inertia~~

Point of application = Center of pressure \neq Centroid of surface area

~~Curved surfaces~~

~~Magnitude of the force~~

~~Horizontal and vertical force components~~

~~Line of action of the force — vector sum of components~~

~~Point of application — vector sum of components (often times off of the surface)~~

Pressure Prism Approach

Magnitude of the force -- "volume of the pressure prism"

Line of action -- "passes through centroid of the pressure prism"

Plane surfaces -- line of action is perpendicular to surface

~~Curved surfaces — found using vertical and horizontal force components~~

Point of application

Plane surface -- "always on surface"

~~Curved surfaces — found using vertical and horizontal force components~~

Buoyancy Principle (Way to compute hydrostatic force)

Net hydrostatic force on an object.

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 important unknowns by 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

information in the problem plus your assumptions are used to develop the problem-specific equations from the general accounting and conservation principles.)

- (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 : $F=ma$.
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 manometer with one or more fluids, determine the pressure differences, absolute pressures, and gage pressures indicated by the manometer.
9. Given a pressure measurement reported as an absolute value convert it to either a gage or vacuum value, and given a pressure measurement reported as either a gage or vacuum value convert it to an absolute value.
10. Given a static body of fluid, determine the hydrostatic pressure at any point in the body.
11. Given a plane surface submerged in a fluid, determine the line of action, the magnitude, and the point of application of the resultant hydrostatic force.