# Chapter 2

## Terms

Be able to define or discuss the following terms and ideas, with their SI units if appropriate.

1. system
2. surroundings
3. change in momentum
4. force
5. external force
6. internal force
7. net force
8. the momentum principle (Newton's second law)
9. small time interval
10. impulse
11. constant net force
12. non-constant force
13. average force
14. update form of the momentum principle
15. arithmetic average (used as an approximation for average velocity)
16. gravitational field
17. ideal projectile motion near the surface of Earth

## Equations

Understand the meaning and know the SI units of all symbols in these equations; know how to perform each mathematical operation, such as trig functions; know how to solve for any unknown quantity; understand how changing one quantity affects another quantity (if all other quantities remain constant); be able to apply one or more equations to solve a problem.

- Momentum principle for a particle (Newton's second law):

$$\vec{F}_{net} = \frac{d\vec{p}}{dt} \tag{1}$$

- For a constant net force:

$$\vec{F}_{net} = \frac{\Delta\vec{p}}{\Delta t} \tag{2}$$

- Update form of the momentum principle:

$$\vec{p}_f = \vec{p}_i + \vec{F}_{net}\Delta t \tag{3}$$

- For constant net force and $v << c$:

$$\vec{v}_f = \vec{v}_i + \frac{\vec{F}_{net}}{m}\Delta t \tag{4}$$

- Net force on a system:

$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ... \qquad \text{the sum of all external forces acting on the system} \tag{5}$$

- Arithmetic average velocity:

$$\vec{v}_{avg} = \frac{\vec{v}_i + \vec{v}_f}{2} \qquad \text{this is exact if the net force on the system is constant} \tag{6}$$

- Position update for constant net force:

$$\vec{r}_f = \vec{r}_i + \vec{v}_{avg}\Delta t \tag{7}$$

- Gravitational force by Earth on an object of mass $m$ near Earth's surface.

$$|\vec{F}grav| = mg \qquad \text{where } g = 9.8 \text{ N/kg} \tag{8}$$

## Skills

1. identify all external forces on a system and calculate (or write an expression for) the net external force on the system.
2. sketch the final momentum of a system if given the initial momentum vector and the change in momentum.
3. sketch the change in momentum of a system if given its initial momentum vector and final momentum vector.
4. sketch the final velocity of a system if given the initial velocity vector and the change in velocity.
5. sketch the change in velocity of a system if given its initial velocity vector and final velocity vector.
6. sketch the path of a system if given the initial momentum (or velocity) and the constant net force.
7. sketch a graph of x vs. t and $v_x$ vs. t if given $F_{net,x}$ vs. t for a system.
8. apply the momentum principle and solve for the momentum, velocity, and position of a system at any clock reading t if given the net external force, the time interval that the net force acts on the particle or system, and the mass, initial position, and initial momentum (or velocity) of the system.
9. apply the momentum principle analytically to ideal projectile motion and constant net force problems
10. apply the momentum principle numerically to phenomena with non-constant forces such as projectile motion with air resistance

## Lab Skills

1. write a computer program that simulates motion due to a constant net force.
2. use video analysis to measure and graph x vs. t, y vs. t, $v_x$ vs. t, and $v_y$ vs. t and use the curve fits to determine acceleration and initial velocity components in the x and y directions.
3. from a curve fit of a velocity (component) vs. time graph for constant net force, determine the acceleration and displacement during a given time interval.
4. use a velocity (component) vs. time graph to calculate the net force on an object for one-dimensional motion.