Chapters 11-24

Terms

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

1. relative velocity
2. reference frame
3. coefficient of restitution
4. elastic collision
5. inelastic collision
6. "super elastic" collision
7. friction
8. component of velocity parallel to surfaces in contact
9. component of velocity perpendicular to surfaces in contact
10. constant acceleration
11. speeding up
12. slowing down
13. direction of velocity, direction of acceleration, and how they can be used to determine whether an object will speed up or slow down
14. Newton's second law
15. net force
16. Iterative method to use Newton's second law to predict velocity and position of an object at later clock readings.
17. ideal projectile motion
18. gravitational field, g
19. free-fall acceleration
20. scaling factor
21. sliding friction (i.e. kinetic friction); rolling friction is similar
22. coefficient of kinetic friction
23. center of mass
24. center of mass velocity

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.

- relative motion (i.e. Galilean relativity)

  $\vec{v'}$: velocity of an object measured by an observer in the *Other* frame
  $\vec{v}$: velocity of an object measured by an observer in the *Home* frame
  $\vec{\beta}$: velocity of the *Other* frame as measured in the *Home* frame

  These three velocities are related by:

  $$\vec{v'} = \vec{v} - \vec{\beta}$$

  It is useful to describe in words the *object*, the *Home frame*, and the *Other frame* when you solve a given problem.

- coefficient of restitution

  $$C_R = \frac{v_{\perp,f}}{v_{\perp,i}}$$

- acceleration

  $$\text{acceleration} = \frac{\text{later velocity} - \text{earlier velocity}}{\text{time interval}}$$
  $$\vec{\mathrm{a}} = \frac{\vec{\mathrm{v}}_{\mathrm{f}} - \vec{\mathrm{v}}_{\mathrm{i}}}{\Delta t}$$
  $$\vec{\mathrm{a}} = \frac{\Delta \vec{v}}{\Delta t}$$

- Newton's second law

  $$\text{acceleration of an object} = \frac{\text{net force on the object}}{\text{mass of the object}}$$
  $$\vec{a} = \frac{\vec{F}_{net}}{m}$$

- Net force

  $$\vec{F}_{net} = \text{Sum of all forces acting on the object}$$

- Iterative form of Newton's second law (i.e. velocity update equation)

$$\vec{v}_f \quad \approx \quad \vec{v}_i + \frac{\vec{F}_{net}}{m}\Delta t \quad \text{for a non-constant force and small time interval}$$

- Position update equation

$$\text{new position} \quad \approx \quad \text{old position} + \text{new velocity} * \Delta t \qquad \text{position update equation}$$

- Gravitational field of Earth near Earth's surface.

$$\vec{g} \quad \approx \quad (0, -10, 0)\ \text{N/kg}$$

- Gravitational force by a body like Earth or Moon, for example, on an object of mass m.

$$\vec{F}_{grav} \quad = \quad m\vec{g}$$

- The location of the center of mass of a system of two particles is

$$\vec{r}_{cm} \quad = \quad \frac{m_1\vec{r}_1 + m_2\vec{r}_2}{m_1 + m_2}$$

  This is a vector equation that must be true for both the x and y directions (for two dimensions).

$$x_{cm} \quad = \quad \frac{m_1 x_1 + m_2 x_2}{m_1 + m_2}$$

$$y_{cm} \quad = \quad \frac{m_1 y_1 + m_2 y_2}{m_1 + m_2}$$

  Likewise, the center-of-mass velocity is

$$\vec{v}_{cm} \quad = \quad \frac{m_1\vec{v}_1 + m_2\vec{v}_2}{m_1 + m_2}$$

  Again, this equation must hold true for both the x and y components of the center-of-mass velocity.

$$v_{cm,x} \quad = \quad \frac{m_1 v_{1x} + m_2 v_{2x}}{m_1 + m_2}$$

$$v_{cm,y} \quad = \quad \frac{m_1 v_{1y} + m_2 v_{2y}}{m_1 + m_2}$$

Skills

You should be able to:

1. use the final velocity vector and initial velocity vector for an object after and before a collision with a rigid body to determine:
   (a) whether the collision was elastic or inelastic.
   (b) whether the surfaces were frictionless or not.
   (c) what direction the frictional force acted on the object,
2. know how the signs of velocity and acceleration are related to an object's direction of motion and whether it is speeding up or slowing down. (This is for one-dimensional motion.)
3. interpret an $x(t)$ graph and know whether the object has a constant x-velocity or whether the object is accelerating in the x-direction. If the x-velocity is constant, be able to use the slope to determine the x-velocity. (Be able to do the same for the y-direction if you have y-graphs.)
4. interpret a $v_x(t)$ graph and know whether the object has a constant x-velocity or whether the object is accelerating in the x-direction. If the object has a constant x-acceleration, be able to use the slope to determine the x-acceleration. (Be able to do the same for the y-direction if you have y-graphs.)
5. if given initial and final velocity vectors, sketch the vector for $\Delta\vec{v}$ and thus find the direction of acceleration and net force during the time interval.
6. add multiple force vectors acting on an object to find the net force on the object.
7. know that for projectile motion, the x-velocity of the projectile is constant and the y-velocity of the projectile decreases at a constant rate of -10m/s^2 for a projectile on Earth. Know what each of the graphs $x(t)$, $v_x(t)$, and $v_y(t)$ look like for a projectile (with no air resistance).
8. be able to use graphs of $x(t)$, $v_x(t)$, and $v_y(t)$ to get x-velocity, initial y-velocity, and y-acceleration for a projectile.
9. use the acceleration from a video game in arbitrary units to determine a scaling factor for distance in the video game.
10. analyze a video of a game to determine whether the projectile motion is "correct physics" or not, for ideal projectile motion.
11. calculate the magnitude and direction of the frictional force on a rolling ball or a sliding object.
12. compute the center of mass position and the center of mass velocity of a system of objects.
13. know that if the net force on a system of objects is zero, then the center of mass velocity of the system is constant.