Chapter 1

Terms

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

1. indications of an interaction
2. uniform motion
3. Newton's first law of motion
4. scalar
5. vector
6. vector magnitude
7. unit vector
8. vector components
9. coordinate system
10. direction cosines
11. SI units
12. position
13. change of position
14. time interval (or time elapsed)
15. average velocity
16. instantaneous velocity
17. direction of motion
18. speed
19. average speed
20. acceleration
21. momentum
22. approximate momentum at low speeds
23. relativistic speeds
24. change of momentum
25. principle of relativity
26. inertial reference frame
27. speed of light

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.

- A vector can be written as a product of its magnitude times its direction:

$$\vec{r} = |\vec{r}|\hat{r} \tag{1}$$

- Magnitude of a vector:

$$|\vec{r}| = \sqrt{r_x^2 + r_y^2 + r_z^2} \tag{2}$$

- Direction of a vector:

$$\hat{r} = \frac{\vec{r}}{|\vec{r}|} \tag{3}$$

- Direction cosines:

$$\cos\theta_x = \frac{r_x}{|\vec{r}|} = \hat{r}_x \tag{4}$$

$$\cos\theta_y = \frac{r_y}{|\vec{r}|} = \hat{r}_y \tag{5}$$

$$\cos\theta_z = \frac{r_z}{|\vec{r}|} = \hat{r}_z \tag{6}$$

- Average velocity:

$$\vec{v}_{avg} = \frac{\Delta\vec{r}}{\Delta t} = \frac{\vec{r}_f - \vec{r}_i}{t_f - t_i} = \left\langle \frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t}, \frac{\Delta z}{\Delta t} \right\rangle \tag{7}$$

- Update the position of the object for a given velocity:

$$\vec{r}_f = \vec{r}_i + \vec{v}_{avg}\Delta t \tag{8}$$

- Instantaneous velocity

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta\vec{r}}{\Delta t} = \frac{d\vec{r}}{dt} = \left\langle \frac{dx}{dt}, \frac{dy}{dt}, \frac{dz}{dt} \right\rangle = \langle v_x, v_y, v_z \rangle \tag{9}$$

- Momentum:

$$\vec{p} = \gamma m\vec{v} \tag{10}$$

- Gamma:

$$\gamma = \frac{1}{\sqrt{1 - \left(\frac{|\vec{v}|}{c}\right)^2}} \tag{11}$$

- Approximate momentum for speeds much less than the speed of light:

$$\vec{p} \approx m\vec{v} \qquad \text{if speed much less than c} \tag{12}$$

- Position update:

$$\vec{r}_f = \vec{r}_i + \Delta\vec{r} \tag{13}$$

$$\vec{r}_f = \vec{r}_i + \vec{v}_{avg}\Delta t \tag{14}$$

Skills

1. sketch a vector on a Cartesian coordinate system
2. add vectors algebraically
3. subtract vectors algebraically
4. add vectors pictorially
5. subtract vectors pictorially
6. multiply a vector by a scalar
7. know that multiplying a vector by a scalar changes the magnitude of the vector (i.e. length of the arrow)
8. interpret a motion diagram to determine whether the particle is in uniform motion or non-uniform motion
9. determine x-velocity using a x vs. t graph (similar for y and z)
10. determine x-displacement using a x vs. t graph (similar for y and z)
11. determine x-acceleration from a v_x vs. t graph (similar for y and z)
12. determine average x-velocity from a v_x vs. t graph (similar for y and z)
13. determine x-displacement using a v_x vs. t graph (similar for y and z)

Lab Skills

1. use video analysis to measure the position of an object as a function of time and calculate the velocity component(s) from the x vs. t graph (and/or y vs. t graph), for uniform motion
2. write a VPython program that simulates an object moving with uniform motion