4.7 Acceleration

- Define acceleration.
- Give examples of acceleration.
- Describe how it feels to accelerate.

Defining Acceleration

Acceleration is a measure of the change in velocity of a moving object. It measures the rate at which velocity changes. Velocity, in turn, is a measure of the speed and direction of motion, so a change in velocity may reflect a change in speed, a change in direction, or both. Both velocity and acceleration are vectors. A vector is any measurement that has both size and direction. People commonly think of acceleration as in increase in speed, but a decrease in speed is also acceleration. In this case, acceleration is negative and called deceleration. A change in direction without a change in speed is acceleration as well.

4.8 Calculating Acceleration from Velocity and Time

- Explain how to calculate average acceleration when direction is constant.
- Identify the SI unit for acceleration.
- Solve simple acceleration problems.

Calculating Average Acceleration in One Direction

$$\vec{a} = \frac{\vec{v}_f - \vec{v}_o}{t}$$

Calculating acceleration is complicated if both speed and direction are changing or if you want to know acceleration at any given instant in time. However, it's relatively easy to calculate average acceleration over a period of time when only speed is changing. Then acceleration is the change in velocity (represented by Δv) divided by the change in time (represented by Δt):

$$acceleration = \frac{\Delta v}{\Delta t} \quad \Rightarrow \quad \vec{a} = \frac{\vec{v}_f - \vec{v}_o}{t}$$

Guidance

- Acceleration is the rate of change of velocity. So in other words, acceleration tells you how quickly the velocity is increasing or decreasing. An acceleration of 5 m/s^2 indicates that the velocity is increasing by $5m/s$ in the positive direction every second.
- Gravity near the Earth pulls an object downwards toward the surface of the Earth with an acceleration of 9.8 $m/s^2 (\approx 10\ m/s^2)$. In the absence of air resistance, all objects will fall with the same acceleration. The letter g is used as the symbol for the acceleration of gravity.
  - When talking about an object's acceleration, whether it is due to gravity or not, the acceleration of gravity is sometimes used as a unit of measurement where $1g = 9.8m/s^2$. So an object accelerating at 2g's is accelerating at $2 * 9.8m/s^2$ or $19.6m/s^2$
- *Deceleration* is the term used when an object's *speed* (i.e. magnitude of its velocity) is decreasing due to acceleration in the opposite direction of its velocity.

Problem Set

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1. A roller coaster car rapidly picks up velocity as it rolls down a slope. As it starts down the slope, its velocity is 4 m/s. But 3 seconds later, at the bottom of the slope, its velocity is 22 m/s. What is its average acceleration? (6.0 m/s^2)

$v_0 = 4 m/s$

$v_f = 22 m/s$

$t = 3 s$

$a = ?$

$$a = \frac{v_f - v_0}{t}$$

$$a = \frac{22 - 4}{3}$$

$$\boxed{a = 6 m/s^2}$$

2. A car accelerates at a rate of 3.0 m/s^2. If its original velocity is 8.0 m/s, how many seconds will it take the car to reach a final velocity of 25.0 m/s? (5.7 s)

$a = 3 m/s^2$

$v_0 = 8 m/s$

$v_f = 25 m/s$

$t = ?$

$$a = \frac{v_f - v_0}{t}$$

$$3 = \frac{25 - 8}{t}$$

$$\frac{3}{1} = \frac{17}{t}$$

$$3t = 17$$

$$t = 17/3$$

$$\boxed{t = 5.7 s}$$

The wind changes the velocity of a glider from 25 m/s [E] to 25 m/s [W] in 32 seconds. a) Calculate the average acceleration of the glider. b) Displacement for the 32 seconds.

a) $v_0 = 25\ m/s\ [E]$

$v_f = -25\ m/s\ [E]$

$t = 32\ s \quad a = \dfrac{v_f - v_0}{t}$

$$a = \frac{-25 - 25}{32}$$

$$a = \frac{-50}{32} = \boxed{-1.56\ m/s^2\ [E]}$$

or

$1.56\ m/s^2\ [W]$

b) $\vec{d} = ?$

$$d_f = \cancel{d_0}^{\,0} + v_0 t + \tfrac{1}{2} a t^2$$

$$d_f = (25)(32) + \tfrac{1}{2}(-1.56)(32)^2$$

$$= 800 - 799$$

$$\boxed{d_f = 1\ m}$$

How much time is necessary to change the velocity of a car from 12 m/s [W] to 8 m/s [E] if the acceleration is 2.5 m/s^2 [E]? What is the resulting displacement?

$v_f^2 = v_0^2 + 2\vec{a}\vec{d}$

$v_0 = -12\ m/s$

$v_f = 8\ m/s$

$a = 2.5\ m/s^2$

$t = ?$

$a = \frac{v_f - v_0}{t}$

$2.5 = \frac{8-(-12)}{t}$

$2.5t = 20$

$\boxed{t = 8.0\ s}$

b) $\vec{d} = ?$

$v_f^2 = v_0^2 + 2\vec{a}\vec{d}$ $\rightarrow d_f - d_0$

$d_0 = 0\ m$

$d_f = ?$

$(8)^2 = (-12)^2 + 2(2.5)d_f$

$64 = 144 + 5d_f$

$-80 = 5d_f$

$\boxed{-16\ m = d_f}$