Physics 30
Momentum and Impulse

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April 22, 2021

Unfinished!

Contents

Review

Scalar v/s Vector Quantity

- **Scalar** = Magnitude (size) only
- **Vector** = Magnitude (size) AND direction

Sig Digs

Multiplication & Division

Least number of sig digs in numbers provided by question.

Addition & Subtraction

p

Unit Analysis

km/h to m/s

$$100\,\text{km/h} \times \frac{1000\,\text{m}}{1\,\text{km}} \times \frac{1\,\text{h}}{3600\,\text{s}}$$

Proportional

$$a \propto b$$

If a variable is proportional to the other, increasing one will increase the other, same with decreasing.

$$a \propto \frac{1}{b}$$

If a variable is inversely proportional to the other, increasing one will decrease the other, and vice versa.

Proportionality Example

If the velocity of a car is doubled and the mass of the car is decreased by $\frac{1}{3}$ determine the new momentum and new Kinetic energy.

Momentum

$$\vec{p} = m\vec{v}$$

$$\left(\tfrac{1}{3}m\right)\left(2\vec{v}\right)$$

$$\tfrac{1}{3} \times 2 = 0.6666666667$$

The momentum of the car would be 0.667X greater.

Kinetic Energy

$$E_K = \tfrac{1}{2}mv^2$$

$$\left(\tfrac{1}{3}m\right)(2v)^2$$

We only include the variable values that have changed

$$\left(\tfrac{1}{3}\right) \times (2)^2 = 1.33\overline{3}$$

The Kinetic energy would be 1.33X greater.

A truck has a momentum of $2.00 \times 10^5\ \text{Kg}\cdot\frac{m}{s}$, E. Calculate the momentum the truck would have if it's velocity was tripled and it's mass was halved.

$$\vec{p} = m\vec{v}$$

$$\vec{p} = \left(\tfrac{1}{2}m\right)\left(3\vec{v}\right) \qquad \underline{\underline{1.5}}$$

$$\vec{P}_{new} = \vec{P}_{ORIGINAL} \times 1.5$$

$$\vec{P}_{new} = 2.00 \times 10^5\ \text{Kg}\cdot\frac{m}{s} \times 1.5 \ \text{E}$$

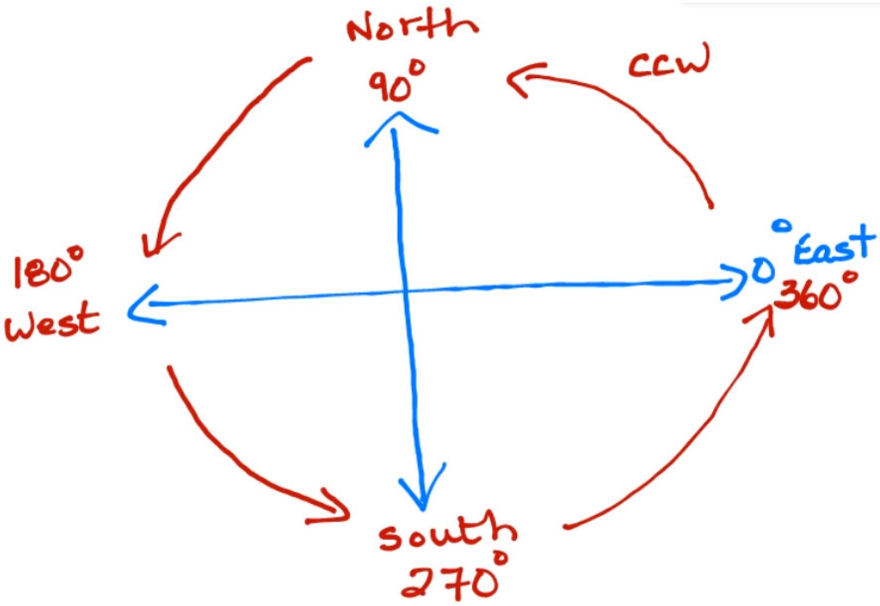
$$\vec{P}_{new} = 3.00 \times 10^5\ \text{Kg}\cdot\frac{m}{s}\ (E)$$

Conventions

Signs

- $+$ positive: right, up, north, east
- $-$ negative: left, down, south, west

Direction



Uniform Velocity

$$v = \frac{d}{t}$$

Uniform = constant: velocity does not change over time.

Formula Review

$$g = 9.81\,\mathrm{m/s^2}$$

$$\sum E_{top} = \sum E_{bottom}$$

$$E_p + E_k = E_p + E_k$$

$$\text{Newton's 2nd Law (Force, in N)} = \vec{F} = m\vec{a}$$

$$\text{Weight (N)} = \vec{F_g} = m\vec{g}$$

Momentum

$$\vec{p} = m\vec{v}$$

- $\vec{p}$ = momentum, product of mass and velocity
  vector quantity, kg · m/s
- m = mass
  scalar quantity, kg
- $\vec{v}$ = velocity
  vector quantity, m/s

$$\vec{p} \propto m$$

$$\vec{p} \propto \vec{v}$$

Examples

A bowling pin is dropped from 2.50 m above the ground. If the bowling pin has a mass of 1.50 kg find the momentum of the bowling pin as it strikes the ground.

$\vec{p} = m\vec{v}$

$v_1 = 0\,\frac{m}{s}$

$h = d = -2.50\,m$

$g = a = -9.81\,\frac{m}{s^2}$

$\Sigma E_{TOP} = \Sigma E_{BOTTOM}$

$E_p + \cancel{E_k} = \cancel{E_p} + E_k$

$mgh = \frac{1}{2}mv^2$

$v = \sqrt{\frac{2\cancel{m}gh}{\cancel{m}}}$

$\vec{p} = m\vec{v}$

$v_f^2 = v_1^2 + 2ad$

$v_f = \sqrt{2ad}$

$v_f = \sqrt{2 \times -2.50\,m \times -9.81\,\frac{m}{s^2}}$

$v_f = 7.003570518\,\frac{m}{s}$

$\vec{p} = 1.50\,kg \times 7.003570518\,\frac{m}{s}$ (down)

$\vec{p} = 10.5$ kg·m/s down

An object has a velocity of 5.00 m/s East and a momentum of 42.0 kg·m/s, East. What is the weight of the object.

$\vec{p} = m\vec{v}$ $\quad m = \frac{\vec{p}}{\vec{v}} = \frac{42.0\,kg\cdot\cancel{\frac{m}{s}},\cancel{E}}{5.00\,\cancel{\frac{m}{s}},\cancel{E}}$

$m = 8.40\,kg$

$\vec{F_g} = 8.40\,kg \times -9.81\,\frac{m}{s^2}$

$\vec{F_g} = -82.404\,N$

$\vec{F_g} = 82.4\,N$ towards the Earth

$\vec{g} = \frac{\vec{F_g}}{m}$

$\vec{F_g} = m\vec{g}$

WEIGHT (N)

A 12.0 kg object travels 8.76 m west in 2.12 s. Assuming uniform velocity, calculate the momentum of the object.

uniform velocity = $v = \frac{d}{t}$

constant

$\vec{v} = \frac{\vec{d}}{t} = \frac{8.76\,m\,(W)}{2.12\,s}$

$\vec{v} = 4.132075472\,\frac{m}{s}\,(W)$

$\vec{p} = m\vec{v} = 12.0\,kg \times 4.132075472\,\frac{m}{s}\,W$

$\vec{p} = 49.58490566\,kg\cdot\frac{m}{s}\,(W)$

$\vec{p} = 49.6\,kg\cdot\frac{m}{s}\,(W)$

Impulse

$$\Delta \vec{p} = \vec{p}_f - \vec{p}_i$$

Impulse is change in momentum; a force applied to an object will change its momentum.

Formula

$$\Delta \vec{p} = \vec{F} \Delta t = m \Delta \vec{v}$$

$$\text{kg} \cdot \text{m/s} = \text{N} \cdot \text{s} = \text{kg} \cdot \text{m/s}$$

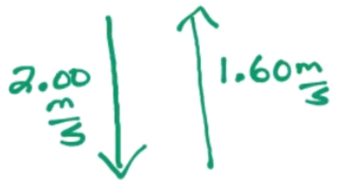
Can be reorganized into Newton's 2nd law.

$$\vec{F} = \frac{m \Delta \vec{v}}{\Delta t} = m \Delta a$$

$$\vec{F} \propto \frac{1}{\Delta t}$$

Force is inversely proportional to time; a large force will be in small time (swift execution), a small force will be over large time.

A 0.625 Kg basketball strikes the floor with a velocity of $2.00\ \frac{m}{s}$. If this basketball bounces up with a velocity of $1.60\ \frac{m}{s}$, what is the ball's change in momentum.



$$\Delta \vec{p} = m \Delta \vec{v}$$

$$\Delta \vec{p} = m (v_f - v_i)$$

$$\Delta \vec{p} = 0.625\,\text{Kg} \left(+1.60\,\frac{m}{s} - \left(-2.00\,\frac{m}{s}\right) \right)$$

$$\Delta \vec{p} = 2.25\ \text{Kg} \cdot \frac{m}{s},\ \text{up}$$

our answer in our calculator is positive so the direction is <u>up</u>

Figure 1: A frictionless disc of mass 0.500 kg is moving in a straight line across an air table top at a speed of 2.40 m/s when the disc bumps into an elastic band stretched between two fixed posts. If the elastic band exerts an opposing force of 1.40 N on the disc for 1.50 s, calculate the final velocity of the disc.

$$\vec{F}\Delta t = m\Delta\vec{v} \qquad \Delta v = v_f - v_i$$

$$\vec{F}\Delta t = m\vec{v}_f - m\vec{v}_i$$

$$\vec{v}_f = \frac{\vec{F}\Delta t + m v_i}{m}$$

$$\vec{v}_f = \frac{(-1.40\,\text{N} \times 1.50\,\text{s}) + (0.500\,\text{kg} \times 2.40\,\frac{\text{m}}{\text{s}})}{0.500\,\text{kg}}$$

$$\vec{v}_f = -1.80\,\frac{\text{m}}{\text{s}}$$

$\vec{v}_f = 1.80\,\frac{\text{m}}{\text{s}}$ in the direction of the force

or in the opposite direction to its original motion.