

Chapter 1

1. Two spheres are cut from a certain uniform rock. One has radius 4.50 cm. The mass of the other is five times greater. Find its radius.

Ans:

For either sphere the volume is $V = \frac{4}{3}\pi r^3$ and the mass is $m = \rho V = \rho \frac{4}{3}\pi r^3$.

We divide this equation for the larger sphere by the same equation for the smaller:

$$\frac{m_\ell}{m_s} = \frac{\rho(4/3)\pi r_\ell^3}{\rho(4/3)\pi r_s^3} = \frac{r_\ell^3}{r_s^3} = 5$$

$$\text{Then } r_\ell = r_s \sqrt[3]{5} = (4.50 \text{ cm}) \sqrt[3]{5} = \boxed{7.69 \text{ cm}}$$

2. A proton, which is the nucleus of a hydrogen atom, can be modeled as a sphere with a diameter of 2.4 fm and a mass of 1.67×10^{-27} kg. (a) Determine the density of the proton. (b) State how your answer to part (a) compares with the density of osmium, give in Table 14.1 in Chapter 14. (Hit: the density of osmium = $22.6 \times 10^3 \text{ kg/m}^3$)

Ans:

(a) $\rho = m/V$ and $V = (4/3)\pi r^3 = (4/3)\pi (d/2)^3 = \pi d^3/6$, where d is the diameter.

$$\text{Then } \rho = 6m / \pi d^3 = \frac{6(1.67 \times 10^{-27} \text{ kg})}{\pi (2.4 \times 10^{-15} \text{ m})^3} = \boxed{2.3 \times 10^{17} \text{ kg/m}^3}$$

$$(b) \quad \frac{2.3 \times 10^{17} \text{ kg/m}^3}{22.6 \times 10^3 \text{ kg/m}^3} = \boxed{1.0 \times 10^{13} \text{ times the density of osmium}}$$

Chapter 2.

1. A particle moves according to the equation $x = 10t^2$, where x is in meters and t is in seconds. (a) Find the average velocity for the time interval from 2.00 s to 3.00 s. (b) Find the average velocity of the time interval from 2.00 to 2.10 s.

Ans:

We substitute for t in $x = 10t^2$, then use the definition of average velocity:

t (s)	2.00	2.10	3.00
x (m)	40.0	44.1	90.0

$$(a) \quad v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{90.0 \text{ m} - 40.0 \text{ m}}{1.00 \text{ s}} = \frac{50.0 \text{ m}}{1.00 \text{ s}} = \boxed{50.0 \text{ m/s}}$$

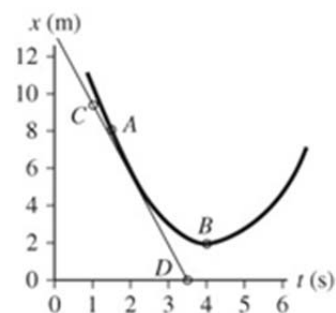
$$(b) \quad v_{\text{avg}} = \frac{\Delta x}{\Delta t} = \frac{44.1 \text{ m} - 40.0 \text{ m}}{0.100 \text{ s}} = \frac{4.10 \text{ m}}{0.100 \text{ s}} = \boxed{41.0 \text{ m/s}}$$

2. A position-time graph for a particle moving along the x axis is shown in Figure P2.7. (a) Find the average velocity in the time interval $t = 1.50 \text{ s}$ to $t = 4.00 \text{ s}$. (b) Determine the instantaneous velocity at $t = 2.00 \text{ s}$ by measuring the slope of the tangent line shown in the graph. (c) At what value of t is the velocity zero?

Ans:

For average velocity, we find the slope of a secant line running across the graph between the 1.5-s and 4-s points. Then for instantaneous velocities we think of slopes of tangent lines, which means the slope of the graph itself at a point.

We place two points on the curve: Point A, at $t = 1.5 \text{ s}$, and Point B, at $t = 4.0 \text{ s}$, and read the corresponding values of x .



(a) At $t_i = 1.5 \text{ s}$, $x_i = 8.0 \text{ m}$ (Point A)

At $t_f = 4.0 \text{ s}$, $x_f = 2.0 \text{ m}$ (Point B)

$$\begin{aligned} v_{\text{avg}} &= \frac{x_f - x_i}{t_f - t_i} = \frac{(2.0 - 8.0) \text{ m}}{(4.0 - 1.5) \text{ s}} \\ &= -\frac{6.0 \text{ m}}{2.5 \text{ s}} = \boxed{-2.4 \text{ m/s}} \end{aligned}$$

(b) The slope of the tangent line can be found from points C and D.

($t_C = 1.0 \text{ s}$, $x_C = 9.5 \text{ m}$) and ($t_D = 3.5 \text{ s}$, $x_D = 0$),

$$v \approx \boxed{-3.8 \text{ m/s}}$$

The negative sign shows that the **direction** of v_x is along the negative x direction.

(c) The velocity will be zero when the slope of the tangent line is zero.

This occurs for the point on the graph where x has its minimum value. This is at $t \approx \boxed{4.0 \text{ s}}$.

Chapter 3.

1. Two points in the xy plan have Cartesian coordinates (2.00, -4.00) m and (-3.00, 3.00) m. Determine (a) the distance between these points and (b) their polar coordinates.

Ans:

(a) The distance between the points is given by

$$\begin{aligned}d &= \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \\&= \sqrt{(2.00 - [-3.00])^2 + (-4.00 - 3.00)^2} \\d &= \sqrt{25.0 + 49.0} = \boxed{8.60 \text{ m}}\end{aligned}$$

(b) To find the polar coordinates of each point, we measure the radial distance to that point and the angle it makes with the +x axis:

$$r_1 = \sqrt{(2.00)^2 + (-4.00)^2} = \sqrt{20.0} = \boxed{4.47 \text{ m}}$$

$$\theta_1 = \tan^{-1}\left(-\frac{4.00}{2.00}\right) = \boxed{-63.4^\circ}$$

$$r_2 = \sqrt{(-3.00)^2 + (3.00)^2} = \sqrt{18.0} = \boxed{4.24 \text{ m}}$$

$$\theta_2 = \boxed{135^\circ} \text{ measured from the } +x \text{ axis.}$$

2. Given the displacement vectors $\vec{A} = (3\hat{i} - 4\hat{j} + 4\hat{k})$ m and $\vec{B} = (2\hat{i} + 3\hat{j} - 7\hat{k})$ m, find the magnitudes of the following vectors and express each in terms of its rectangular components. (a) $\vec{C} = \vec{A} + \vec{B}$ (b) $\vec{D} = 2\vec{A} - \vec{B}$

Ans:

We carry out the prescribed mathematical operations using unit vectors.

$$\begin{aligned}\vec{C} &= \vec{A} + \vec{B} = \boxed{(5.00\hat{i} - 1.00\hat{j} - 3.00\hat{k}) \text{ m}} \\(a) \quad |\vec{C}| &= \sqrt{(5.00 \text{ m})^2 + (-1.00 \text{ m})^2 + (-3.00 \text{ m})^2} = \boxed{5.92 \text{ m}}\end{aligned}$$

(b) $\vec{D} = 2\vec{A} - \vec{B} = \boxed{(4.00\hat{i} - 11.0\hat{j} + 15.0\hat{k})\text{ m}}$

$|\vec{D}| = \sqrt{(4.00\text{ m})^2 + (11.0\text{ m})^2 + (15.0\text{ m})^2} = \boxed{19.0\text{ m}}$

Chapter 4.

1. Suppose the position vector for a particle is given as a function of time by $\vec{r}(t) = x(t)\hat{i} + y(t)\hat{j}$, with $x(t) = at + b$ and $y(t) = ct^2 + d$, where $a = 1.00$ m/s, $b = 1.00$ m, $c = 0.125$ m/s², and $d = 1.00$ m. (a) Calculate the average velocity during the time interval from $t = 2.00$ s to $t = 4.00$ s. (b) Determine the velocity and the speed at $t = 2.00$ s.

Ans:

(a) For the average velocity, we have

$$\begin{aligned}\vec{v}_{\text{avg}} &= \left(\frac{x(4.00) - x(2.00)}{4.00 \text{ s} - 2.00 \text{ s}} \right) \hat{i} + \left(\frac{y(4.00) - y(2.00)}{4.00 \text{ s} - 2.00 \text{ s}} \right) \hat{j} \\ &= \left(\frac{5.00 \text{ m} - 3.00 \text{ m}}{2.00 \text{ s}} \right) \hat{i} + \left(\frac{3.00 \text{ m} - 1.50 \text{ m}}{2.00 \text{ s}} \right) \hat{j} \\ \vec{v}_{\text{avg}} &= \boxed{(1.00\hat{i} + 0.750\hat{j}) \text{ m/s}}\end{aligned}$$

(b) For the velocity components, we have

$$v_x = \frac{dx}{dt} = a = 1.00 \text{ m/s}$$

$$\text{and } v_y = \frac{dy}{dt} = 2ct = (0.250 \text{ m/s}^2)t$$

Therefore,

$$\vec{v} = v_x\hat{i} + v_y\hat{j} = (1.00 \text{ m/s})\hat{i} + (0.250 \text{ m/s}^2)t\hat{j}$$

$$\boxed{\vec{v}(t = 2.00 \text{ s}) = (1.00 \text{ m/s})\hat{i} + (0.500 \text{ m/s})\hat{j}}$$

and the speed is

$$|\vec{v}(t = 2.00 \text{ s})| = \sqrt{(1.00 \text{ m/s})^2 + (0.500 \text{ m/s})^2} = \boxed{1.12 \text{ m/s}}$$

2. The vector position of a particle varies in time according to the expression $\vec{r} = 3.00\hat{i} - 6.00\hat{j}$, where \vec{r} is in meter and t is in seconds. (a) Find an expression for the velocity of the particle as a function of time. (b) Determine the acceleration of the particle as a function of time. (c) Calculate the particle's position and velocity at $t = 1.00$ s.

Ans:

- (a) We differentiate the equation for the vector position of the particle with respect to time to obtain its velocity:

$$\vec{v} = \frac{d\vec{r}}{dt} = \left(\frac{d}{dt} \right) (3.00\hat{i} - 6.00t^2\hat{j}) = \boxed{-12.0t\hat{j} \text{ m/s}}$$

- (b) Differentiating the expression for velocity with respect to time gives the particle's acceleration:

$$\vec{a} = \frac{d\vec{v}}{dt} = \left(\frac{d}{dt} \right) (-12.0t\hat{j}) = \boxed{-12.0\hat{j} \text{ m/s}^2}$$

- (c) By substitution, when $t = 1.00$ s,

$$\boxed{\vec{r} = (3.00\hat{i} - 6.00\hat{j})\text{m}; \vec{v} = -12.0\hat{j} \text{ m/s}}$$

Chapter 5.

1. A 3.00 kg object undergoes an acceleration given by $\vec{a} = (2.00\hat{i} + 5.00\hat{j}) \text{ m/s}^2$. Find (a) the resultant force acting on the object and (b) the magnitude of the resultant force.

Ans:

We use Newton's second law to find the force as a vector and then the

Pythagorean theorem to find its magnitude. The givens are $m = 3.00$

kg and $\vec{a} = (2.00\hat{i} + 5.00\hat{j}) \text{ m/s}^2$.

(a) The total vector force is

$$\Sigma \vec{F} = m\vec{a} = (3.00 \text{ kg})(2.00\hat{i} + 5.00\hat{j}) \text{ m/s}^2 = \boxed{(6.00\hat{i} + 15.0\hat{j}) \text{ N}}$$

(b) Its magnitude is

$$|\vec{F}| = \sqrt{(F_x)^2 + (F_y)^2} = \sqrt{(6.00 \text{ N})^2 + (15.0 \text{ N})^2} = \boxed{16.2 \text{ N}}$$

2. The average speed of a nitrogen molecule in air is about $6.70 \times 10^2 \text{ m/s}$, and its mass is $4.68 \times 10^{-26} \text{ kg}$. (a) If it takes $3.00 \times 10^{-13} \text{ s}$ for a nitrogen molecule to hit a wall and rebound with the same speed but moving in the opposite direction, what is the average acceleration of the molecule during this time interval? (b) What average force does the molecule exert on the wall?

Ans:

(a) Let the x axis be in the original direction of the molecule's motion.

Then, from $v_f = v_i + at$, we have

$$a = \frac{v_f - v_i}{t} = \frac{-670 \text{ m/s} - 670 \text{ m/s}}{3.00 \times 10^{-13} \text{ s}} = \boxed{-4.47 \times 10^{15} \text{ m/s}^2}$$

(b) For the molecule, $\Sigma \vec{F} = m\vec{a}$. Its weight is negligible.

$$\begin{aligned}\vec{F}_{\text{wall on molecule}} &= (4.68 \times 10^{-26} \text{ kg})(-4.47 \times 10^{15} \text{ m/s}^2) \\ &= -2.09 \times 10^{-10} \text{ N}\end{aligned}$$

$$\vec{F}_{\text{molecule on wall}} = \boxed{+2.09 \times 10^{-10} \text{ N}}$$

Chapter 6.

1. In the Bohr model of the hydrogen atom, an electron moves in a circular path around a proton. The speed of the electron is approximately 2.20×10^6 m/s. Find (a) the force acting on the electron as it revolves in a circular orbit of radius 0.529×10^{-10} m and (b) the centripetal acceleration of the electron.

Ans:

- (a) The force acting on the electron in the Bohr model of the hydrogen atom is directed radially inward and is equal to

$$F = \frac{mv^2}{r} = \frac{(9.11 \times 10^{-31} \text{ kg})(2.20 \times 10^6 \text{ m/s})^2}{0.529 \times 10^{-10} \text{ m}} = \boxed{8.33 \times 10^{-8} \text{ N inward}}$$

- (b)

$$a = \frac{v^2}{r} = \frac{(2.20 \times 10^6 \text{ m/s})^2}{0.529 \times 10^{-10} \text{ m}} = \boxed{9.15 \times 10^{22} \text{ m/s}^2 \text{ inward}}$$

2. Whenever two *Apollo* astronauts were on the surface of the Moon, a third astronaut orbited the Moon. Assume the orbit to be circular and 100 km above the surface of Moon, where the acceleration due to gravity is 1.52 m/s^2 . The radius of the Moon is 1.70×10^6 m. Determine (a) the astronaut's orbital speed and (b) the period of the orbit.

Ans:

- (a) The astronaut's orbital speed is found from Newton's second law, with

$$\sum F_y = ma_y: \quad mg_{\text{moon}} \text{ down} = \frac{mv^2}{r} \text{ down}$$

solving for the velocity gives

$$v = \sqrt{g_{\text{moon}} r} = \sqrt{(1.52 \text{ m/s}^2)(1.7 \times 10^6 \text{ m} + 100 \times 10^3 \text{ m})}$$
$$v = \boxed{1.65 \times 10^3 \text{ m/s}}$$

(b) To find the period, we use $v = \frac{2\pi r}{T}$ and solve for T :

$$T = \frac{2\pi(1.8 \times 10^6 \text{ m})}{1.65 \times 10^3 \text{ m/s}} = \boxed{6.84 \times 10^3 \text{ s}} = 1.90 \text{ h}$$