Kinematics — Full Worked Session

Every skill in the unit, worked one problem at a time

Set up → solve → answer
87 problems

Lesson `ap1.kinematics.session`

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Distance vs displacement

K1

You walk 3 m east then 4 m west. Find the total distance and the displacement.

$$\text{distance} = 3 + 4 = 7 \text{ m} \quad \text{path length}$$

$$\text{displacement} = 1 \text{ m west} \quad \text{straight-line, with direction}$$

Answer

$$d = 7 \text{ m}, \ \Delta x = 1 \text{ m west}$$

Distance vs displacement

K1

You walk 6 m north then 4 m more north. Find the total distance and the displacement.

$$\text{distance} = 6 + 4 = 10 \text{ m} \quad \text{path length}$$

$$\text{displacement} = 10 \text{ m north} \quad \text{straight-line, with direction}$$

Answer

$$d = 10 \text{ m}, \ \Delta x = 10 \text{ m north}$$

Distance vs displacement

K1

You walk 5 m east then 5 m west. Find the total distance and the displacement.

$$\text{distance} = 5 + 5 = 10 \text{ m} \quad \text{path length}$$

$$\text{displacement} = 0 \quad \text{straight-line, with direction}$$

Answer

$$d = 10 \text{ m}, \ \Delta x = 0$$

Distance vs displacement

K1

You walk 8 m east, 2 m east, then 4 m west. Find the total distance and the displacement.

$$\text{distance} = 8 + 2 + 4 = 14 \text{ m} \qquad \text{path length}$$

$$\text{displacement} = 6 \text{ m east} \qquad \text{straight-line, with direction}$$

Answer

$$d = 14 \text{ m}, \ \Delta x = 6 \text{ m east}$$

Distance vs displacement

K1

You walk 10 m north then 3 m south. Find the total distance and the displacement.

$$\text{distance} = 10 + 3 = 13 \text{ m} \quad \text{path length}$$

$$\text{displacement} = 7 \text{ m north} \quad \text{straight-line, with direction}$$

Answer

$$d = 13 \text{ m}, \ \Delta x = 7 \text{ m north}$$

Avg speed & velocity, 100 s

K2

Over 100 *s you travel a path of* 400 *m with net displacement* 0 *m. Find average speed and average velocity.*

$$\text{avg speed} = \frac{400}{100} = 4.00 \text{ m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{0}{100} = 0.00 \text{ m/s} \qquad \text{displacement/time}$$

Answer

$$\bar{v}_{\text{spd}} = 4.00, \ \bar{v} = 0.00 \text{ m/s}$$

Avg speed & velocity, 20 s

K2

Over 20 s you travel a path of 100 m with net displacement 100 m. Find average speed and average velocity.

$$\text{avg speed} = \frac{100}{20} = 5.00\ \text{m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{100}{20} = 5.00\ \text{m/s} \qquad \text{displacement/time}$$

Answer

$\bar{v}_{\text{spd}} = 5.00,\ \bar{v} = 5.00\ \text{m/s}$

Avg speed & velocity, 120 s

K2

Over 120 s you travel a path of 600 m with net displacement 200 m. Find average speed and average velocity.

$$\text{avg speed} = \frac{600}{120} = 5.00 \text{ m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{200}{120} = 1.67 \text{ m/s} \qquad \text{displacement/time}$$

Answer

$\bar{v}_{\text{spd}} = 5.00, \ \bar{v} = 1.67 \text{ m/s}$

Avg speed & velocity, 10 s

K2

Over 10 *s you travel a path of* 50 *m with net displacement* 50 *m. Find average speed and average velocity.*

$$\text{avg speed} = \frac{50}{10} = 5.00 \text{ m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{50}{10} = 5.00 \text{ m/s} \qquad \text{displacement/time}$$

Answer

$\bar{v}_{\text{spd}} = 5.00, \ \bar{v} = 5.00 \text{ m/s}$

Avg speed & velocity, 60 s

K2

Over 60 s you travel a path of 300 m with net displacement 100 m. Find average speed and average velocity.

$$\text{avg speed} = \frac{300}{60} = 5.00 \text{ m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{100}{60} = 1.67 \text{ m/s} \qquad \text{displacement/time}$$

Answer

$$\bar{v}_{\text{spd}} = 5.00, \ \bar{v} = 1.67 \text{ m/s}$$

Avg speed & velocity, 30 s

K2

Over 30 s you travel a path of 240 m with net displacement 240 m. Find average speed and average velocity.

$$\text{avg speed} = \frac{240}{30} = 8.00\ \text{m/s} \qquad \text{distance/time}$$

$$\text{avg velocity} = \frac{240}{30} = 8.00\ \text{m/s} \qquad \text{displacement/time}$$

Answer

$\bar{v}_{\text{spd}} = 8.00,\ \bar{v} = 8.00\ \text{m/s}$

Acceleration, 0→20 m/s

K3

A car changes from 0 m/s to 20 m/s in 5 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{20 - 0}{5}$$ change in velocity per time

$$a = 4.00\ \text{m/s}^2$$ speeding up

Answer

$4.00\ \text{m/s}^2$

Acceleration, 30→0 m/s

K3

A car changes from 30 m/s to 0 m/s in 6 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{0 - 30}{6}$$ change in velocity per time

$$a = -5.00\ \text{m/s}^2$$ slowing down

Answer

$-5.00\ \text{m/s}^2$

Acceleration, 10→25 m/s

K3

A car changes from 10 m/s to 25 m/s in 3 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{25 - 10}{3}$$ change in velocity per time

$$a = 5.00\ \text{m/s}^2$$ speeding up

Answer

$5.00\ \text{m/s}^2$

Acceleration, $0 \to 100$ m/s

K3

A car changes from 0 m/s to 100 m/s in 8 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{100 - 0}{8}$$ change in velocity per time

$$a = 12.50 \text{ m/s}^2$$ speeding up

Answer

12.50 m/s^2

Acceleration, 40→10 m/s

K3

A car changes from 40 m/s to 10 m/s in 5 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{10 - 40}{5}$$ change in velocity per time

$$a = -6.00\ \text{m/s}^2$$ slowing down

Answer

$-6.00\ \text{m/s}^2$

Acceleration, 5→35 m/s

K3

A car changes from 5 m/s to 35 m/s in 2 s. Find its acceleration.

$$a = \frac{v_f - v_i}{t} = \frac{35 - 5}{2}$$ change in velocity per time

$$a = 15.00\ \text{m/s}^2$$ speeding up

Answer

$15.00\ \text{m/s}^2$

Read v from x-t slope

K4

On a position-time graph, position goes from 0 m to 30 m over 6 s (straight line). Velocity?

$$v = \text{slope} = \frac{30 - 0}{6} \qquad \text{slope of } x \text{ vs } t$$

$$v = 5.00 \text{ m/s} \qquad \text{moving forward}$$

Answer

5.00 m/s

Read v from x-t slope

K4

On a position-time graph, position goes from 10 m to 40 m over 5 s (straight line). Velocity?

$$v = \text{slope} = \frac{40 - 10}{5} \qquad \text{slope of } x \text{ vs } t$$

$$v = 6.00 \text{ m/s} \qquad \text{moving forward}$$

Answer

6.00 m/s

Read v from x-t slope

K4

On a position-time graph, position goes from 50 m to 20 m over 3 s (straight line). Velocity?

$$v = \text{slope} = \frac{20 - 50}{3} \qquad \text{slope of } x \text{ vs } t$$

$$v = -10.00 \text{ m/s} \qquad \text{moving backward}$$

Answer

-10.00 m/s

Read v from x-t slope

K4

On a position-time graph, position goes from 0 m to 100 m over 10 s (straight line). Velocity?

$$v = \text{slope} = \frac{100 - 0}{10} \qquad \text{slope of } x \text{ vs } t$$

$$v = 10.00 \text{ m/s} \qquad \text{moving forward}$$

Answer

10.00 m/s

Read v from x-t slope

K4

On a position-time graph, position goes from 20 m to 20 m over 4 s (straight line). Velocity?

$$v = \text{slope} = \frac{20 - 20}{4} \qquad \text{slope of } x \text{ vs } t$$

$$v = 0.00 \text{ m/s} \qquad \text{at rest}$$

Answer

0.00 m/s

v-t graph, $0 \to 20$ m/s

A velocity-time graph rises straight from 0 m/s to 20 m/s over 4 s. Find the acceleration and the displacement.

$$a = \text{slope} = \frac{20 - 0}{4} = 5.00 \text{ m/s}^2 \qquad \text{slope}$$

$$\Delta x = \text{area} = \tfrac{1}{2}(0 + 20)(4) = 40.0 \text{ m} \qquad \text{area under curve}$$

Answer

$$a = 5.00 \text{ m/s}^2, \ \Delta x = 40.0 \text{ m}$$

v-t graph, 10→30 m/s

K5

A velocity-time graph rises straight from 10 m/s to 30 m/s over 5 s. Find the acceleration and the displacement.

$$a = \text{slope} = \frac{30 - 10}{5} = 4.00 \text{ m/s}^2 \quad \text{slope}$$

$$\Delta x = \text{area} = \tfrac{1}{2}(10 + 30)(5) = 100.0 \text{ m} \quad \text{area under curve}$$

Answer

$$a = 4.00 \text{ m/s}^2, \ \Delta x = 100.0 \text{ m}$$

v-t graph, 40→0 m/s

K5

A velocity-time graph rises straight from 40 m/s to 0 m/s over 8 s. Find the acceleration and the displacement.

$$a = \text{slope} = \frac{0 - 40}{8} = -5.00\ \text{m/s}^2 \qquad \text{slope}$$

$$\Delta x = \text{area} = \tfrac{1}{2}(40 + 0)(8) = 160.0\ \text{m} \qquad \text{area under curve}$$

Answer

$$a = -5.00\ \text{m/s}^2,\ \Delta x = 160.0\ \text{m}$$

v-t graph, $5 \to 5$ m/s

K5

A velocity-time graph rises straight from 5 m/s to 5 m/s over 6 s. Find the acceleration and the displacement.

$$a = \text{slope} = \frac{5-5}{6} = 0.00 \text{ m/s}^2 \quad \text{slope}$$

$$\Delta x = \text{area} = \tfrac{1}{2}(5+5)(6) = 30.0 \text{ m} \quad \text{area under curve}$$

Answer

$$a = 0.00 \text{ m/s}^2, \ \Delta x = 30.0 \text{ m}$$

An object starts at 0 m/s and accelerates at 3 m/s^2 for 5 s. Find v_f.

$$v_f = v_i + at = 0 + (3)(5) \quad \text{first kinematic equation}$$
$$v_f = 15.0 \text{ m/s}$$

Answer
15.0 m/s

An object starts at 10 m/s and accelerates at 2 m/s^2 for 4 s. Find v_f.

$$v_f = v_i + at = 10 + (2)(4) \quad \text{first kinematic equation}$$
$$v_f = 18.0 \text{ m/s}$$

Answer
18.0 m/s

An object starts at 20 m/s and accelerates at -4 m/s^2 for 3 s. Find v_f.

$$v_f = v_i + at = 20 + (-4)(3) \quad \text{first kinematic equation}$$
$$v_f = 8.0 \text{ m/s}$$

Answer
8.0 m/s

An object starts at 5 m/s and accelerates at 6 m/s^2 for 2 s. Find v_f.

$$v_f = v_i + at = 5 + (6)(2) \quad \text{first kinematic equation}$$
$$v_f = 17.0 \text{ m/s}$$

Answer
17.0 m/s

Starting at 0 m/s with $a = 3.0\ m/s^2$, how far does it go in 5 s?

$$x = v_i t + \frac{1}{2}at^2 = 0(5) + \frac{1}{2}(3.0)(5)^2 \quad \text{second kinematic equation}$$

$$x = 37.5\ \text{m}$$

Answer

37.5 m

Starting at 8 m/s with $a = 2.0\ m/s^2$, how far does it go in 4 s?

$$x = v_i t + \frac{1}{2}at^2 = 8(4) + \frac{1}{2}(2.0)(4)^2 \quad \text{second kinematic equation}$$

$$x = 48.0\ \text{m}$$

Answer

48.0 m

Starting at 0 m/s with $a = 9.8$ m/s^2, how far does it go in 3 s?

$$x = v_i t + \frac{1}{2}at^2 = 0(3) + \frac{1}{2}(9.8)(3)^2 \quad \text{second kinematic equation}$$

$$x = 44.1 \text{ m}$$

Answer

44.1 m

Starting at 12 m/s with $a = -2.0$ m/s^2, how far does it go in 5 s?

$$x = v_i t + \frac{1}{2}at^2 = 12(5) + \frac{1}{2}(-2.0)(5)^2 \quad \text{second kinematic equation}$$

$$x = 35.0 \text{ m}$$

Answer

35.0 m

An object at 0 m/s accelerates at 2 m/s^2 over 25 m. Find v_f.

$$v_f^2 = v_i^2 + 2ax = 0^2 + 2(2)(25) \quad \text{time-free equation}$$
$$v_f = 10.00 \text{ m/s}$$

Answer
10.00 m/s

An object at 10 m/s accelerates at 3 m/s^2 over 20 m. Find v_f.

$$v_f^2 = v_i^2 + 2ax = 10^2 + 2(3)(20) \quad \text{time-free equation}$$
$$v_f = 14.83 \text{ m/s}$$

Answer
14.83 m/s

An object at 0 m/s accelerates at 5 m/s^2 over 40 m. Find v_f.

$$v_f^2 = v_i^2 + 2ax = 0^2 + 2(5)(40) \quad \text{time-free equation}$$
$$v_f = 20.00 \text{ m/s}$$

Answer
20.00 m/s

An object at 20 m/s accelerates at -4 m/s^2 over 30 m. Find v_f.

$$v_f^2 = v_i^2 + 2ax = 20^2 + 2(-4)(30) \quad \text{time-free equation}$$
$$v_f = 12.65 \text{ m/s}$$

Answer
12.65 m/s

Drop from 20 m

K7

An object is dropped from rest from 20 m. Find the fall time and impact speed ($g = 9.8$).

$$t = \sqrt{2h/g} = \sqrt{2(20)/9.8} = 2.02 \text{ s} \qquad \text{from } h = \tfrac{1}{2}gt^2$$

$$v = \sqrt{2gh} = 19.8 \text{ m/s} \qquad \text{impact speed}$$

Answer

$$t = 2.02 \text{ s}, \; v = 19.8 \text{ m/s}$$

Drop from 45 m

An object is dropped from rest from 45 m. Find the fall time and impact speed ($g = 9.8$).

$$t = \sqrt{2h/g} = \sqrt{2(45)/9.8} = 3.03 \text{ s} \qquad \text{from } h = \tfrac{1}{2}gt^2$$

$$v = \sqrt{2gh} = 29.7 \text{ m/s} \qquad \text{impact speed}$$

Answer

$t = 3.03$ s, $v = 29.7$ m/s

Drop from 5 m

K7

An object is dropped from rest from 5 m. Find the fall time and impact speed ($g = 9.8$).

$$t = \sqrt{2h/g} = \sqrt{2(5)/9.8} = 1.01 \text{ s} \qquad \text{from } h = \tfrac{1}{2}gt^2$$

$$v = \sqrt{2gh} = 9.9 \text{ m/s} \qquad \text{impact speed}$$

Answer

$t = 1.01$ s, $v = 9.9$ m/s

Drop from 80 m

K7

An object is dropped from rest from 80 m. Find the fall time and impact speed ($g = 9.8$).

$$t = \sqrt{2h/g} = \sqrt{2(80)/9.8} = 4.04 \text{ s} \qquad \text{from } h = \tfrac{1}{2}gt^2$$

$$v = \sqrt{2gh} = 39.6 \text{ m/s} \qquad \text{impact speed}$$

Answer

$t = 4.04$ s, $v = 39.6$ m/s

Drop from 100 m

K7

An object is dropped from rest from 100 *m. Find the fall time and impact speed* ($g = 9.8$).

$$t = \sqrt{2h/g} = \sqrt{2(100)/9.8} = 4.52 \text{ s} \qquad \text{from } h = \tfrac{1}{2}gt^2$$

$$v = \sqrt{2gh} = 44.3 \text{ m/s} \qquad \text{impact speed}$$

Answer

$t = 4.52$ s, $v = 44.3$ m/s

Thrown up at 20 m/s

K7

A ball is thrown straight up at 20 m/s. Find its maximum height and time to the top ($g = 9.8$).

$$h_{\max} = \frac{v_0^2}{2g} = \frac{20^2}{19.6} = 20.4 \text{ m} \qquad v = 0 \text{ at top}$$

$$t_{\text{up}} = \frac{v_0}{g} = 2.04 \text{ s}$$

Answer

$h_{\max} = 20.4$ m, $t = 2.04$ s

Thrown up at 30 m/s

K7

A ball is thrown straight up at 30 m/s. Find its maximum height and time to the top ($g = 9.8$).

$$h_{\max} = \frac{v_0^2}{2g} = \frac{30^2}{19.6} = 45.9 \text{ m} \qquad v = 0 \text{ at top}$$

$$t_{\text{up}} = \frac{v_0}{g} = 3.06 \text{ s}$$

Answer

$h_{\max} = 45.9$ m, $t = 3.06$ s

Thrown up at 15 m/s

K7

A ball is thrown straight up at 15 m/s. Find its maximum height and time to the top ($g = 9.8$).

$$h_{\max} = \frac{v_0^2}{2g} = \frac{15^2}{19.6} = 11.5 \text{ m} \qquad v = 0 \text{ at top}$$

$$t_{\text{up}} = \frac{v_0}{g} = 1.53 \text{ s}$$

Answer

$h_{\max} = 11.5$ m, $t = 1.53$ s

Two-stage trip

K8

A train accelerates from rest to 20 m/s over 5 s, then cruises at 20 m/s for 8 s. Total distance?

$$
\begin{aligned}
d_1 &= \tfrac{1}{2} v t_1 = \tfrac{1}{2}(20)(5) = 50.0 \text{ m} && \text{speeding-up leg} \\
d_2 &= v t_2 = 20(8) = 160.0 \text{ m} && \text{cruising leg} \\
d &= 50.0 + 160.0 = 210.0 \text{ m} && \text{add the stages}
\end{aligned}
$$

Answer

210.0 m

Two-stage trip

K8

A train accelerates from rest to 15 *m/s over* 4 *s, then cruises at* 15 *m/s for* 10 *s. Total distance?*

$$
\begin{aligned}
d_1 &= \tfrac{1}{2} v t_1 = \tfrac{1}{2}(15)(4) = 30.0 \text{ m} && \text{speeding-up leg} \\
d_2 &= v t_2 = 15(10) = 150.0 \text{ m} && \text{cruising leg} \\
d &= 30.0 + 150.0 = 180.0 \text{ m} && \text{add the stages}
\end{aligned}
$$

Answer

180.0 m

Two-stage trip

K8

A train accelerates from rest to 30 m/s over 3 s, then cruises at 30 m/s for 6 s. Total distance?

$$
\begin{aligned}
d_1 &= \tfrac{1}{2}vt_1 = \tfrac{1}{2}(30)(3) = 45.0\ \text{m} && \text{speeding-up leg} \\
d_2 &= vt_2 = 30(6) = 180.0\ \text{m} && \text{cruising leg} \\
d &= 45.0 + 180.0 = 225.0\ \text{m} && \text{add the stages}
\end{aligned}
$$

Answer

225.0 m

Scalar or vector?

Is temperature a scalar or a vector?

answer = scalar direction? then vector

Answer

scalar

Scalar or vector?

Is velocity a scalar or a vector?

answer = vector direction? then vector

Answer

vector

Scalar or vector?

Distance vs displacement: which is the vector?

answer = displacement direction? then vector

Answer

displacement

Components, 10 at 30°

A vector of magnitude 10 *points* 30° *above the* $+x$ *axis. Find its* x *and* y *components.*

$$A_x = A\cos\theta = 10\cos 30^\circ = 8.66 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 10\sin 30^\circ = 5.00 \quad \text{opposite}$$

Answer

$$A_x = 8.66,\ A_y = 5.00$$

Components, 20 at 60°

V2

A vector of magnitude 20 points 60° above the $+x$ axis. Find its x and y components.

$$A_x = A\cos\theta = 20\cos 60^\circ = 10.00 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 20\sin 60^\circ = 17.32 \quad \text{opposite}$$

Answer

$$A_x = 10.00,\ A_y = 17.32$$

Components, 15 at 45°

V2

A vector of magnitude 15 *points* 45° *above the* $+x$ *axis. Find its* x *and* y *components.*

$$A_x = A\cos\theta = 15\cos 45^\circ = 10.61 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 15\sin 45^\circ = 10.61 \quad \text{opposite}$$

Answer

$$A_x = 10.61,\ A_y = 10.61$$

Components, 50 at 37°

V2

A vector of magnitude 50 *points* 37° *above the* $+x$ *axis. Find its* x *and* y *components.*

$$A_x = A\cos\theta = 50\cos 37^\circ = 39.93 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 50\sin 37^\circ = 30.09 \quad \text{opposite}$$

Answer

$$A_x = 39.93,\ A_y = 30.09$$

Components, 8 at 53°

V2

A vector of magnitude 8 points 53° above the $+x$ axis. Find its x and y components.

$$A_x = A\cos\theta = 8\cos 53^\circ = 4.81 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 8\sin 53^\circ = 6.39 \quad \text{opposite}$$

Answer

$$A_x = 4.81,\ A_y = 6.39$$

Components, 25 at 20°

V2

A vector of magnitude 25 points 20° above the $+x$ axis. Find its x and y components.

$$A_x = A\cos\theta = 25\cos 20^\circ = 23.49 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 25\sin 20^\circ = 8.55 \quad \text{opposite}$$

Answer

$$A_x = 23.49,\ A_y = 8.55$$

Components, 12 at 90°

A vector of magnitude 12 points 90° above the $+x$ axis. Find its x and y components.

$$A_x = A\cos\theta = 12\cos 90^\circ = 0.00 \quad \text{adjacent}$$

$$A_y = A\sin\theta = 12\sin 90^\circ = 12.00 \quad \text{opposite}$$

Answer

$$A_x = 0.00,\ A_y = 12.00$$

Add 6 east + 8 north

V3

Walk 6 m east then 8 m north. Find the resultant magnitude and direction.

$$R = \sqrt{a^2 + b^2} = \sqrt{6^2 + 8^2} = 10.00 \text{ m} \qquad \text{Pythagoras}$$

$$\theta = \tan^{-1}\frac{8}{6} = 53^\circ \qquad \text{north of east}$$

Answer

$R = 10.00$ m at 53°

Add 3 east + 4 north

V3

Walk 3 m east then 4 m north. Find the resultant magnitude and direction.

$$R = \sqrt{a^2 + b^2} = \sqrt{3^2 + 4^2} = 5.00 \text{ m} \qquad \text{Pythagoras}$$

$$\theta = \tan^{-1}\frac{4}{3} = 53^\circ \qquad \text{north of east}$$

Answer

$R = 5.00$ m at 53°

Add 5 east + 12 north

V3

Walk 5 m east then 12 m north. Find the resultant magnitude and direction.

$$R = \sqrt{a^2 + b^2} = \sqrt{5^2 + 12^2} = 13.00 \text{ m} \qquad \text{Pythagoras}$$

$$\theta = \tan^{-1}\frac{12}{5} = 67^\circ \qquad \text{north of east}$$

Answer

$R = 13.00$ m at 67°

Add 9 east + 12 north

V3

Walk 9 m east then 12 m north. Find the resultant magnitude and direction.

$$R = \sqrt{a^2 + b^2} = \sqrt{9^2 + 12^2} = 15.00 \text{ m} \qquad \text{Pythagoras}$$

$$\theta = \tan^{-1}\frac{12}{9} = 53^\circ \qquad \text{north of east}$$

Answer

$R = 15.00$ m at 53°

Add 7 east + 24 north

V3

Walk 7 m east then 24 m north. Find the resultant magnitude and direction.

$$R = \sqrt{a^2 + b^2} = \sqrt{7^2 + 24^2} = 25.00 \text{ m} \qquad \text{Pythagoras}$$

$$\theta = \tan^{-1}\frac{24}{7} = 74^\circ \qquad \text{north of east}$$

Answer

$R = 25.00$ m at 74°

Add 10 east + 10 north

V3

Walk 10 *m east then* 10 *m north. Find the resultant magnitude and direction.*

$$R = \sqrt{a^2 + b^2} = \sqrt{10^2 + 10^2} = 14.14 \text{ m}$$ Pythagoras

$$\theta = \tan^{-1}\frac{10}{10} = 45^\circ$$ north of east

Answer

$R = 14.14$ m at 45°

Change in velocity

V4

Along one line, a ball hits a wall at 12 m/s and rebounds at 12 m/s. Find the change in velocity Δv.

$$\Delta v = v_f - v_i = (-12) - (12) \qquad \text{final minus initial}$$

$$\Delta v = -24.0 \text{ m/s} \qquad \text{sign gives direction}$$

Answer

-24.0 m/s

Change in velocity

V4

Along one line, a car slows from 20 m/s to a stop. Find the change in velocity Δv.

$$\Delta v = v_f - v_i = (0) - (20) \qquad \text{final minus initial}$$

$$\Delta v = -20.0 \text{ m/s} \qquad \text{sign gives direction}$$

Answer

-20.0 m/s

Change in velocity

Along one line, a puck speeds up from rest to 15 m/s. Find the change in velocity Δv.

$$\Delta v = v_f - v_i = (15) - (0) \qquad \text{final minus initial}$$

$$\Delta v = 15.0 \text{ m/s} \qquad \text{sign gives direction}$$

Answer

15.0 m/s

Change in velocity

Along one line, a cart reverses from +8 m/s to -6 m/s. Find the change in velocity Δv.

$$\Delta v = v_f - v_i = (-6) - (8) \qquad \text{final minus initial}$$

$$\Delta v = -14.0 \text{ m/s} \qquad \text{sign gives direction}$$

Answer

-14.0 m/s

Horizontal launch, 15 m/s, 20 m

V5

A ball is launched horizontally at 15 *m/s from* 20 *m high. Find the time to land and the range* ($g = 9.8$).

$$t = \sqrt{2h/g} = 2.02 \text{ s} \qquad \text{vertical drop sets the time}$$

$$x = v_0 t = 15(2.02) = 30.30 \text{ m} \qquad \text{horizontal: constant } v_0$$

Answer

$t = 2.02$ s, $x = 30.30$ m

Horizontal launch, 10 m/s, 45 m

V5

A ball is launched horizontally at 10 *m/s from* 45 *m high. Find the time to land and the range* ($g = 9.8$).

$$t = \sqrt{2h/g} = 3.03 \text{ s} \qquad \text{vertical drop sets the time}$$

$$x = v_0 t = 10(3.03) = 30.30 \text{ m} \qquad \text{horizontal: constant } v_0$$

Answer

$t = 3.03$ s, $x = 30.30$ m

Horizontal launch, 20 m/s, 5 m

V5

A ball is launched horizontally at 20 m/s from 5 m high. Find the time to land and the range ($g = 9.8$).

$$t = \sqrt{2h/g} = 1.01 \text{ s} \qquad \text{vertical drop sets the time}$$

$$x = v_0 t = 20(1.01) = 20.20 \text{ m} \qquad \text{horizontal: constant } v_0$$

Answer

$t = 1.01$ s, $x = 20.20$ m

Horizontal launch, 8 m/s, 80 m

V5

A ball is launched horizontally at 8 m/s from 80 m high. Find the time to land and the range ($g = 9.8$).

$$t = \sqrt{2h/g} = 4.04 \text{ s} \qquad \text{vertical drop sets the time}$$

$$x = v_0 t = 8(4.04) = 32.32 \text{ m} \qquad \text{horizontal: constant } v_0$$

Answer

$t = 4.04$ s, $x = 32.32$ m

Horizontal launch, 25 m/s, 30 m

V5

A ball is launched horizontally at 25 m/s from 30 m high. Find the time to land and the range ($g = 9.8$).

$$t = \sqrt{2h/g} = 2.47 \text{ s} \qquad \text{vertical drop sets the time}$$

$$x = v_0 t = 25(2.47) = 61.86 \text{ m} \qquad \text{horizontal: constant } v_0$$

Answer

$$t = 2.47 \text{ s}, \; x = 61.86 \text{ m}$$

Projectile reasoning

V6

A ball rolls off a table and another is dropped at the same instant. Which lands first?

idea = same time x and y are independent

Answer

same time

Projectile reasoning

V6

At the top of a projectile's arc, what is its vertical velocity?

idea $=$ $v_y = 0$ x and y are independent

Answer

$v_y \quad = \quad 0$

Projectile reasoning

What is the horizontal acceleration of a projectile (no air)?

idea $=$ $a_x = 0$ x and y are independent

Answer

$a_x \quad = \quad 0$

Angled launch, 20 m/s at 30°

V7

A projectile is launched at 20 m/s, 30° above horizontal (level ground). Find hang time, max height, and range ($g = 9.8$).

$$v_y = v_0 \sin\theta = 10.00 \text{ m/s} \quad \text{vertical part}$$

$$t = \frac{2v_y}{g} = 2.04 \text{ s} \quad \text{up and back down}$$

$$h,\ R = 5.1 \text{ m},\ 35.3 \text{ m} \quad \text{peak \& range}$$

Answer

$$t = 2.04 \text{ s},\ h = 5.1 \text{ m},\ R = 35.3 \text{ m}$$

Angled launch, 25 m/s at 53°

V7

A projectile is launched at 25 m/s, 53° above horizontal (level ground). Find hang time, max height, and range ($g = 9.8$).

$$v_y = v_0 \sin\theta = 19.97 \text{ m/s} \quad \text{vertical part}$$

$$t = \frac{2v_y}{g} = 4.07 \text{ s} \quad \text{up and back down}$$

$$h,\ R = 20.3 \text{ m},\ 61.3 \text{ m} \quad \text{peak \& range}$$

Answer

$$t = 4.07 \text{ s},\ h = 20.3 \text{ m},\ R = 61.3 \text{ m}$$

Angled launch, 30 m/s at 45°

V7

A projectile is launched at 30 m/s, 45° above horizontal (level ground). Find hang time, max height, and range ($g = 9.8$).

$$v_y = v_0 \sin\theta = 21.21 \text{ m/s} \quad \text{vertical part}$$

$$t = \frac{2v_y}{g} = 4.33 \text{ s} \quad \text{up and back down}$$

$$h,\ R = 23.0 \text{ m},\ 91.8 \text{ m} \quad \text{peak \& range}$$

Answer

$$t = 4.33 \text{ s},\ h = 23.0 \text{ m},\ R = 91.8 \text{ m}$$

Angled launch, 15 m/s at 60°

V7

A projectile is launched at 15 m/s, 60° above horizontal (level ground). Find hang time, max height, and range ($g = 9.8$).

$$v_y = v_0 \sin\theta = 12.99 \text{ m/s} \quad \text{vertical part}$$

$$t = \frac{2v_y}{g} = 2.65 \text{ s} \quad \text{up and back down}$$

$$h,\ R = 8.6 \text{ m},\ 19.9 \text{ m} \quad \text{peak \& range}$$

Answer

$$t = 2.65 \text{ s},\ h = 8.6 \text{ m},\ R = 19.9 \text{ m}$$

Angled launch, 40 m/s at 37°

V7

A projectile is launched at 40 m/s, 37° above horizontal (level ground). Find hang time, max height, and range ($g = 9.8$).

$$v_y = v_0 \sin\theta = 24.07 \text{ m/s} \quad \text{vertical part}$$

$$t = \frac{2v_y}{g} = 4.91 \text{ s} \quad \text{up and back down}$$

$$h,\ R = 29.6 \text{ m},\ 156.9 \text{ m} \quad \text{peak \& range}$$

Answer

$$t = 4.91 \text{ s},\ h = 29.6 \text{ m},\ R = 156.9 \text{ m}$$

River crossing, boat 4, current 3

V8

A boat heads straight across a river at 4 m/s; the current runs 3 m/s downstream. The river is 100 m wide. Find the ground speed, crossing time, and downstream drift.

$$v = \sqrt{v_b^2 + v_r^2} = 5.00 \text{ m/s} \quad \text{vectors add at right angles}$$

$$t = \frac{w}{v_b} = 25.0 \text{ s} \quad \text{cross-stream sets the time}$$

$$\text{drift} = v_r t = 75.0 \text{ m} \quad \text{carried downstream}$$

Answer

$v = 5.00$ m/s, $t = 25.0$ s, drift 75.0 m

River crossing, boat 5, current 12

V8

A boat heads straight across a river at 5 m/s; the current runs 12 m/s downstream. The river is 200 m wide. Find the ground speed, crossing time, and downstream drift.

$$v = \sqrt{v_b^2 + v_r^2} = 13.00 \text{ m/s} \quad \text{vectors add at right angles}$$

$$t = \frac{w}{v_b} = 40.0 \text{ s} \quad \text{cross-stream sets the time}$$

$$\text{drift} = v_r t = 480.0 \text{ m} \quad \text{carried downstream}$$

Answer

$v = 13.00$ m/s, $t = 40.0$ s, drift 480.0 m

River crossing, boat 6, current 8

V8

A boat heads straight across a river at 6 m/s; the current runs 8 m/s downstream. The river is 120 m wide. Find the ground speed, crossing time, and downstream drift.

$$v = \sqrt{v_b^2 + v_r^2} = 10.00 \text{ m/s} \quad \text{vectors add at right angles}$$

$$t = \frac{w}{v_b} = 20.0 \text{ s} \quad \text{cross-stream sets the time}$$

$$\text{drift} = v_r t = 160.0 \text{ m} \quad \text{carried downstream}$$

Answer

$v = 10.00$ m/s, $t = 20.0$ s, drift 160.0 m

River crossing, boat 3, current 4

V8

A boat heads straight across a river at 3 m/s; the current runs 4 m/s downstream. The river is 60 m wide. Find the ground speed, crossing time, and downstream drift.

$$v = \sqrt{v_b^2 + v_r^2} = 5.00 \text{ m/s}$$ vectors add at right angles

$$t = \frac{w}{v_b} = 20.0 \text{ s}$$ cross-stream sets the time

$$\text{drift} = v_r t = 80.0 \text{ m}$$ carried downstream

Answer

$v = 5.00$ m/s, $t = 20.0$ s, drift 80.0 m

River crossing, boat 8, current 6

V8

A boat heads straight across a river at 8 m/s; the current runs 6 m/s downstream. The river is 160 m wide. Find the ground speed, crossing time, and downstream drift.

$$v = \sqrt{v_b^2 + v_r^2} = 10.00 \text{ m/s} \quad \text{vectors add at right angles}$$

$$t = \frac{w}{v_b} = 20.0 \text{ s} \quad \text{cross-stream sets the time}$$

$$\text{drift} = v_r t = 120.0 \text{ m} \quad \text{carried downstream}$$

Answer

$v = 10.00$ m/s, $t = 20.0$ s, drift 120.0 m

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Identifying forces

A kicked ball has just left your foot. What horizontal force pushes it forward?

answer = none

Answer

none

Identifying forces

F1

A book rests on a table. Name the two forces on it.

answer $=$ gravity down, normal up

Answer

gravity down, normal up

Identifying forces

F1

Which is a contact force: gravity or friction?

answer = friction

Answer
friction

Inertia (Newton's 1st law)

A car brakes hard and loose groceries slide forward. What pushed them?

idea = nothing — inertia

Answer

nothing — inertia

Inertia (Newton's 1st law)

An object moves at constant velocity. What is the net force on it?

idea $=$ $F_{\text{net}} = 0$

Answer

$F_{\text{net}} \quad = \quad 0$

Inertia (Newton's 1st law)

Which object has more inertia: a 2 kg or a 10 kg block?

idea = the 10 kg

Answer

the 10 kg

$F = ma$, 5 kg, 2.0 m/s^2

What net force accelerates a 5 kg object at 2.0 m/s^2?

$$F = ma = 5(2.0) \qquad \text{Newton's second law}$$
$$F = 10.0 \text{ N}$$

Answer

10.0 N

$F = ma$, 10 kg, 3.0 m/s^2

What net force accelerates a 10 *kg object at* 3.0 *m/s*^{2}*?*

$$F = ma = 10(3.0) \qquad \text{Newton's second law}$$
$$F = 30.0 \text{ N}$$

Answer

30.0 N

$F = ma$, 2 kg, 6.0 m/s^2

What net force accelerates a 2 kg object at 6.0 m/s^2?

$$F = ma = 2(6.0) \qquad \text{Newton's second law}$$
$$F = 12.0 \text{ N}$$

Answer

12.0 N

$F = ma$, 20 kg, 0.5 m/s^2

What net force accelerates a 20 kg object at 0.5 m/s^2?

$$F = ma = 20(0.5) \qquad \text{Newton's second law}$$
$$F = 10.0 \text{ N}$$

Answer

10.0 N

$F = ma$, 0.5 kg, 8.0 m/s^2

What net force accelerates a 0.5 *kg object at* 8.0 *m/s*^{2}*?*

$$F = ma = 0.5(8.0) \qquad \text{Newton's second law}$$

$$F = 4.0 \text{ N}$$

Answer

4.0 N

Accel from $F = ma$, 50 N

A net force of 50 *N acts on a* 10 *kg object. Find its acceleration.*

$$a = \frac{F}{m} = \frac{50}{10}$$

solve $F = ma$ for a

$$a = 5.00 \text{ m/s}^2$$

Answer

5.00 m/s^2

Accel from $F = ma$, 30 N

A net force of 30 N acts on a 6 kg object. Find its acceleration.

$$a = \frac{F}{m} = \frac{30}{6} \qquad \text{solve } F = ma \text{ for } a$$

$$a = 5.00 \text{ m/s}^2$$

Answer

5.00 m/s^2

Accel from $F = ma$, 100 N

F3

A net force of 100 *N acts on a* 4 *kg object. Find its acceleration.*

$$a = \frac{F}{m} = \frac{100}{4} \qquad \text{solve } F = ma \text{ for } a$$

$$a = 25.00 \text{ m/s}^2$$

Answer

25.00 m/s^2

Mass from $F = ma$, 60 N

F3

A 60 N net force gives an object 3.0 m/s^2. Find its mass.

$$m = \frac{F}{a} = \frac{60}{3.0} \qquad \text{solve } F = ma \text{ for } m$$

$$m = 20.0 \text{ kg}$$

Answer

20.0 kg

Mass from $F = ma$, 24 N

F3

A 24 N net force gives an object 4.0 m/s^2. Find its mass.

$$m = \frac{F}{a} = \frac{24}{4.0} \qquad \text{solve } F = ma \text{ for } m$$

$$m = 6.0 \text{ kg}$$

Answer

6.0 kg

Weight of 10 kg

Find the weight of a 10 kg object on Earth ($g = 9.8$) and on the Moon ($g = 1.6$).

$$W_E = mg = 10(9.8) = 98.0 \text{ N} \quad \text{Earth}$$

$$W_M = 10(1.6) = 16.0 \text{ N} \quad \text{Moon: same mass}$$

Answer

$$W_E = 98.0 \text{ N}, \; W_M = 16.0 \text{ N}$$

Weight of 5 kg

F4

Find the weight of a 5 kg object on Earth ($g = 9.8$) and on the Moon ($g = 1.6$).

$$W_E = mg = 5(9.8) = 49.0 \text{ N} \quad \text{Earth}$$

$$W_M = 5(1.6) = 8.0 \text{ N} \quad \text{Moon: same mass}$$

Answer

$W_E = 49.0$ N, $W_M = 8.0$ N

Weight of 70 kg

Find the weight of a 70 kg object on Earth ($g = 9.8$) and on the Moon ($g = 1.6$).

$$W_E = mg = 70(9.8) = 686.0 \text{ N} \quad \text{Earth}$$

$$W_M = 70(1.6) = 112.0 \text{ N} \quad \text{Moon: same mass}$$

Answer

$$W_E = 686.0 \text{ N}, \; W_M = 112.0 \text{ N}$$

Weight of 2 kg

Find the weight of a 2 kg object on Earth ($g = 9.8$) and on the Moon ($g = 1.6$).

$$W_E = mg = 2(9.8) = 19.6 \text{ N} \quad \text{Earth}$$

$$W_M = 2(1.6) = 3.2 \text{ N} \quad \text{Moon: same mass}$$

Answer

$$W_E = 19.6 \text{ N}, \; W_M = 3.2 \text{ N}$$

Weight of 50 kg

Find the weight of a 50 kg object on Earth ($g = 9.8$) and on the Moon ($g = 1.6$).

$$W_E = mg = 50(9.8) = 490.0 \text{ N} \quad \text{Earth}$$

$$W_M = 50(1.6) = 80.0 \text{ N} \quad \text{Moon: same mass}$$

Answer

$$W_E = 490.0 \text{ N}, \; W_M = 80.0 \text{ N}$$

Mass from 98 N weight

F4

An object weighs 98 N on Earth. Find its mass ($g = 9.8$).

$$m = \frac{W}{g} = \frac{98}{9.8} \qquad \text{rearrange } W = mg$$

$$m = 10.0 \text{ kg}$$

Answer

10.0 kg

Mass from 490 N weight

F4

An object weighs 490 *N on Earth. Find its mass* ($g = 9.8$).

$$m = \frac{W}{g} = \frac{490}{9.8} \qquad \text{rearrange } W = mg$$

$$m = 50.0 \text{ kg}$$

Answer

50.0 kg

Newton's third law

You step off a small boat and it shoots backward. Why?

$$\text{rule} = \text{equal \& opposite}$$

Answer

equal & opposite

Newton's third law

A book pushes down on a table with 20 N. What does the table do?

$$\text{rule} = \text{pushes up 20 N}$$

Answer

pushes up 20 N

Newton's third law

Do action-reaction forces act on the same object?

$$\text{rule} = \text{no — different objects}$$

Answer

no — different objects

Friction, $\mu = 0.3$, 10 kg

F6

A 10 kg block sits on level ground, $\mu = 0.3$. Find the friction force when it slides ($g = 9.8$).

$$N = mg = 10(9.8) = 98.0 \text{ N} \qquad \text{normal} = \text{weight here}$$

$$f = \mu N = 0.3(98.0) = 29.4 \text{ N} \qquad \text{kinetic friction}$$

Answer

29.4 N

Friction, $\mu = 0.5$, 4 kg

A 4 kg block sits on level ground, $\mu = 0.5$. Find the friction force when it slides ($g = 9.8$).

$$N = mg = 4(9.8) = 39.2 \text{ N} \qquad \text{normal} = \text{weight here}$$

$$f = \mu N = 0.5(39.2) = 19.6 \text{ N} \qquad \text{kinetic friction}$$

Answer

19.6 N

Friction, $\mu = 0.2$, 20 kg

F6

A 20 kg block sits on level ground, $\mu = 0.2$. Find the friction force when it slides ($g = 9.8$).

$$N = mg = 20(9.8) = 196.0 \text{ N} \quad \text{normal = weight here}$$

$$f = \mu N = 0.2(196.0) = 39.2 \text{ N} \quad \text{kinetic friction}$$

Answer

39.2 N

Friction, $\mu = 0.4$, 5 kg

A 5 kg block sits on level ground, $\mu = 0.4$. Find the friction force when it slides ($g = 9.8$).

$$N = mg = 5(9.8) = 49.0 \text{ N} \qquad \text{normal} = \text{weight here}$$

$$f = \mu N = 0.4(49.0) = 19.6 \text{ N} \qquad \text{kinetic friction}$$

Answer

19.6 N

Friction, $\mu = 0.6$, 2 kg

A 2 kg block sits on level ground, $\mu = 0.6$. Find the friction force when it slides ($g = 9.8$).

$$N = mg = 2(9.8) = 19.6 \text{ N} \qquad \text{normal} = \text{weight here}$$

$$f = \mu N = 0.6(19.6) = 11.8 \text{ N} \qquad \text{kinetic friction}$$

Answer

11.8 N

Net force with friction, 40 N

You push a 10 *kg block with* 40 *N;* $\mu = 0.2$. *Find the acceleration* ($g = 9.8$).

$$f = \mu mg = 19.6 \text{ N} \qquad \text{opposes motion}$$

$$F_{\text{net}} = 40 - 19.6 = 20.4 \text{ N} \qquad \text{push minus friction}$$

$$a = \frac{F_{\text{net}}}{m} = 2.04 \text{ m/s}^2$$

Answer

2.04 m/s^2

Net force with friction, 30 N

F6

You push a 5 kg block with 30 N; $\mu = 0.3$. Find the acceleration ($g = 9.8$).

$$f = \mu mg = 14.7 \text{ N} \quad \text{opposes motion}$$

$$F_{\text{net}} = 30 - 14.7 = 15.3 \text{ N} \quad \text{push minus friction}$$

$$a = \frac{F_{\text{net}}}{m} = 3.06 \text{ m/s}^2$$

Answer

3.06 m/s^2

Net force with friction, 60 N

You push a 20 kg block with 60 N; $\mu = 0.1$. Find the acceleration ($g = 9.8$).

$$f = \mu mg = 19.6 \text{ N} \quad \text{opposes motion}$$

$$F_{\text{net}} = 60 - 19.6 = 40.4 \text{ N} \quad \text{push minus friction}$$

$$a = \frac{F_{\text{net}}}{m} = 2.02 \text{ m/s}^2$$

Answer

2.02 m/s^2

Elevator, 60 kg, a=2.0

A 60 kg person is in an elevator accelerating upward at 2.0 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g + a) = 60(9.8 + 2.0)$$ Newton's 2nd law, vertical

$$N = 708.0 \text{ N}$$ feels heavier

Answer

708.0 N

Elevator, 70 kg, a=3.0

A 70 kg person is in an elevator accelerating upward at 3.0 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g + a) = 70(9.8 + 3.0)$$ Newton's 2nd law, vertical

$$N = 896.0 \text{ N}$$ feels heavier

Answer

896.0 N

Elevator, 50 kg, a=2.0

A 50 kg person is in an elevator accelerating downward at 2.0 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g - a) = 50(9.8 - 2.0)$$ Newton's 2nd law, vertical

$$N = 390.0 \text{ N}$$ feels lighter

Answer

390.0 N

Elevator, 80 kg, a=1.5

A 80 kg person is in an elevator accelerating downward at 1.5 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g - a) = 80(9.8 - 1.5) \quad \text{Newton's 2nd law, vertical}$$

$$N = 664.0 \text{ N} \quad \text{feels lighter}$$

Answer

664.0 N

Elevator, 60 kg, a=0.0

A 60 kg person is in an elevator accelerating upward at 0.0 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g + a) = 60(9.8 + 0.0)$$ Newton's 2nd law, vertical

$$N = 588.0 \text{ N}$$ feels heavier

Answer

588.0 N

Elevator, 65 kg, a=2.5

A 65 kg person is in an elevator accelerating upward at 2.5 m/s^2. Find the apparent weight (normal force, $g = 9.8$).

$$N = m(g + a) = 65(9.8 + 2.5)$$ Newton's 2nd law, vertical

$$N = 799.5 \text{ N}$$ feels heavier

Answer

799.5 N

Incline, 5 kg at 30°

A 5 kg block rests on a frictionless 30° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 5(9.8)\sin 30^\circ = 24.5\ \text{N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 42.4\ \text{N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 4.90\ \text{m/s}^2 \quad \text{mass cancels}$$

Answer

$F_{\parallel} = 24.5$ N, $N = 42.4$ N, $a = 4.90$

Incline, 10 kg at 20°

A 10 kg block rests on a frictionless 20° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 10(9.8)\sin 20^\circ = 33.5 \text{ N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 92.1 \text{ N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 3.35 \text{ m/s}^2 \quad \text{mass cancels}$$

Answer

$F_{\parallel} = 33.5$ N, $N = 92.1$ N, $a = 3.35$

Incline, 2 kg at 45°

A 2 kg block rests on a frictionless 45° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 2(9.8)\sin 45^\circ = 13.9\ \text{N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 13.9\ \text{N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 6.93\ \text{m/s}^2 \quad \text{mass cancels}$$

Answer

$$F_{\parallel} = 13.9\ \text{N},\ N = 13.9\ \text{N},\ a = 6.93$$

Incline, 8 kg at 37°

A 8 kg block rests on a frictionless 37° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 8(9.8)\sin 37^\circ = 47.2\ \text{N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 62.6\ \text{N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 5.90\ \text{m/s}^2 \quad \text{mass cancels}$$

Answer

$F_{\parallel} = 47.2$ N, $N = 62.6$ N, $a = 5.90$

Incline, 4 kg at 53°

F8

A 4 kg block rests on a frictionless 53° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 4(9.8)\sin 53^\circ = 31.3\ \text{N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 23.6\ \text{N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 7.83\ \text{m/s}^2 \quad \text{mass cancels}$$

Answer

$F_{\parallel} = 31.3$ N, $N = 23.6$ N, $a = 7.83$

Incline, 6 kg at 25°

F8

A 6 kg block rests on a frictionless 25° incline. Find the force along the incline, the normal force, and the acceleration ($g = 9.8$).

$$F_{\parallel} = mg\sin\theta = 6(9.8)\sin 25^\circ = 24.8\ \text{N} \quad \text{drives it down}$$

$$N = mg\cos\theta = 53.3\ \text{N} \quad \text{perpendicular}$$

$$a = g\sin\theta = 4.14\ \text{m/s}^2 \quad \text{mass cancels}$$

Answer

$F_{\parallel} = 24.8$ N, $N = 53.3$ N, $a = 4.14$

Orbital speed, r=2.0 m, T=4.0 s

C1

An object circles at radius 2.0 m with period 4.0 s. Find its speed.

$$v = \frac{2\pi r}{T} = \frac{2\pi(2.0)}{4.0}$$

circumference per period

$$v = 3.14 \text{ m/s}$$

Answer

3.14 m/s

Orbital speed, r=0.5 m, T=1.0 s

C1

An object circles at radius 0.5 *m with period* 1.0 *s. Find its speed.*

$$v = \frac{2\pi r}{T} = \frac{2\pi(0.5)}{1.0}$$

circumference per period

$$v = 3.14 \text{ m/s}$$

Answer

3.14 m/s

Orbital speed, r=10.0 m, T=5.0 s

An object circles at radius 10.0 *m with period* 5.0 *s. Find its speed.*

$$v = \frac{2\pi r}{T} = \frac{2\pi(10.0)}{5.0}$$

circumference per period

$$v = 12.57 \text{ m/s}$$

Answer

12.57 m/s

Orbital speed, r=3.0 m, T=6.0 s

C1

An object circles at radius 3.0 *m with period* 6.0 *s. Find its speed.*

$$v = \frac{2\pi r}{T} = \frac{2\pi(3.0)}{6.0}$$

circumference per period

$$v = 3.14 \text{ m/s}$$

Answer

3.14 m/s

Orbital speed, r=1.5 m, T=2.0 s

C1

An object circles at radius 1.5 *m with period* 2.0 *s. Find its speed.*

$$v = \frac{2\pi r}{T} = \frac{2\pi(1.5)}{2.0}$$

circumference per period

$$v = 4.71 \text{ m/s}$$

Answer

4.71 m/s

Centripetal accel, 10 m/s, r=5 m

C2

An object moves at 10 *m/s in a circle of radius* 5 *m. Find its centripetal acceleration.*

$$a_c = \frac{v^2}{r} = \frac{10^2}{5}$$ toward the center

$$a_c = 20.00\ \text{m/s}^2$$

Answer

$20.00\ \text{m/s}^2$

Centripetal accel, 20 m/s, r=8 m

C2

An object moves at 20 m/s in a circle of radius 8 m. Find its centripetal acceleration.

$$a_c = \frac{v^2}{r} = \frac{20^2}{8}$$ toward the center

$$a_c = 50.00 \text{ m/s}^2$$

Answer

50.00 m/s^2

Centripetal accel, 4 m/s, r=2 m

An object moves at 4 m/s in a circle of radius 2 m. Find its centripetal acceleration.

$$a_c = \frac{v^2}{r} = \frac{4^2}{2} \qquad \text{toward the center}$$

$$a_c = 8.00\ \text{m/s}^2$$

Answer

$8.00\ \text{m/s}^2$

Centripetal accel, 15 m/s, r=45 m

An object moves at 15 m/s in a circle of radius 45 m. Find its centripetal acceleration.

$$a_c = \frac{v^2}{r} = \frac{15^2}{45}$$ toward the center

$$a_c = 5.00 \text{ m/s}^2$$

Answer

5.00 m/s^2

Centripetal accel, 30 m/s, r=90 m

An object moves at 30 m/s in a circle of radius 90 m. Find its centripetal acceleration.

$$a_c = \frac{v^2}{r} = \frac{30^2}{90} \qquad \text{toward the center}$$

$$a_c = 10.00 \text{ m/s}^2$$

Answer

10.00 m/s^2

Centripetal accel, 6 m/s, r=3 m

An object moves at 6 m/s in a circle of radius 3 m. Find its centripetal acceleration.

$$a_c = \frac{v^2}{r} = \frac{6^2}{3} \qquad \text{toward the center}$$

$$a_c = 12.00\ \text{m/s}^2$$

Answer

$12.00\ \text{m/s}^2$

Centripetal force, 2.0 kg

Find the centripetal force on a 2.0 kg object moving 10 m/s in a circle of radius 5 m.

$$F_c = \frac{mv^2}{r} = \frac{2.0(10)^2}{5}$$

net inward force

$$F_c = 40.0 \text{ N}$$

Answer

40.0 N

Centripetal force, 0.5 kg

Find the centripetal force on a 0.5 kg object moving 8 m/s in a circle of radius 2 m.

$$F_c = \frac{mv^2}{r} = \frac{0.5(8)^2}{2}$$ net inward force

$$F_c = 16.0 \text{ N}$$

Answer

16.0 N

Centripetal force, 1000.0 kg

Find the centripetal force on a 1000.0 *kg object moving* 20 *m/s in a circle of radius* 50 *m.*

$$F_c = \frac{mv^2}{r} = \frac{1000.0(20)^2}{50} \qquad \text{net inward force}$$

$$F_c = 8000.0 \text{ N}$$

Answer

8000.0 N

Centripetal force, 0.2 kg

Find the centripetal force on a 0.2 kg object moving 4 m/s in a circle of radius 1 m.

$$F_c = \frac{mv^2}{r} = \frac{0.2(4)^2}{1}$$ net inward force

$$F_c = 3.2 \text{ N}$$

Answer

3.2 N

Centripetal force, 5.0 kg

Find the centripetal force on a 5.0 kg object moving 6 m/s in a circle of radius 3 m.

$$F_c = \frac{mv^2}{r} = \frac{5.0(6)^2}{3}$$ net inward force

$$F_c = 60.0 \text{ N}$$

Answer

60.0 N

Centripetal force, 70.0 kg

Find the centripetal force on a 70.0 *kg object moving* 5 *m/s in a circle of radius* 10 *m.*

$$F_c = \frac{mv^2}{r} = \frac{70.0(5)^2}{10} \qquad \text{net inward force}$$

$$F_c = 175.0 \text{ N}$$

Answer

175.0 N

Loop top min speed, r=1.0 m

At the top of a vertical loop of radius 1.0 *m, what is the minimum speed to stay on track* ($g = 9.8$)*?*

$$mg = \frac{mv^2}{r}$$ gravity alone is centripetal

$$v_{\text{min}} = \sqrt{gr} = \sqrt{9.8(1.0)} = 3.13 \text{ m/s}$$ mass cancels

Answer

3.13 m/s

Loop top min speed, r=2.0 m

At the top of a vertical loop of radius 2.0 m, what is the minimum speed to stay on track ($g = 9.8$)?

$$mg = \frac{mv^2}{r}$$ gravity alone is centripetal

$$v_{\text{min}} = \sqrt{gr} = \sqrt{9.8(2.0)} = 4.43 \text{ m/s}$$ mass cancels

Answer

4.43 m/s

Loop top min speed, r=0.5 m

C4

At the top of a vertical loop of radius 0.5 *m, what is the minimum speed to stay on track* ($g = 9.8$)*?*

$$mg = \frac{mv^2}{r}$$ gravity alone is centripetal

$$v_{\text{min}} = \sqrt{gr} = \sqrt{9.8(0.5)} = 2.21 \text{ m/s}$$ mass cancels

Answer

2.21 m/s

Loop top min speed, r=5.0 m

C4

At the top of a vertical loop of radius 5.0 *m, what is the minimum speed to stay on track* ($g = 9.8$)*?*

$$mg = \frac{mv^2}{r}$$ gravity alone is centripetal

$$v_{\text{min}} = \sqrt{gr} = \sqrt{9.8(5.0)} = 7.00 \text{ m/s}$$ mass cancels

Answer

7.00 m/s

Gravitation (Earth-satellite)

Find the gravitational attraction between masses 5.97×10^{24} *kg and* 1.00×10^{3} *kg a distance* 6.37×10^{6} *m apart (Earth-satellite) (*$G = 6.67 \times 10^{-11}$*).*

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11}(5.97 \times 10^{24})(1.00 \times 10^{3})}{(6.37 \times 10^{6})^2}$$

universal gravitation

$$F = 9.81 \times 10^{3}\ \text{N}$$

Answer

9.81×10^{3} N

Gravitation (Earth-Moon)

Find the gravitational attraction between masses 5.97×10^{24} *kg and* 7.35×10^{22} *kg a distance* 3.84×10^{8} *m apart (Earth-Moon) (*$G = 6.67 \times 10^{-11}$*).*

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11}(5.97 \times 10^{24})(7.35 \times 10^{22})}{(3.84 \times 10^{8})^2}$$

universal gravitation

$$F = 1.98 \times 10^{20}\ \text{N}$$

Answer

1.98×10^{20} N

Gravitation (Sun-Earth)

Find the gravitational attraction between masses 2.00×10^{30} *kg and* 5.97×10^{24} *kg a distance* 1.50×10^{11} *m apart (Sun-Earth) (*$G = 6.67 \times 10^{-11}$*).*

$$F = \frac{Gm_1m_2}{r^2} = \frac{6.67 \times 10^{-11}(2.00 \times 10^{30})(5.97 \times 10^{24})}{(1.50 \times 10^{11})^2}$$

universal gravitation

$$F = 3.54 \times 10^{22} \text{ N}$$

Answer

3.54×10^{22} N

Surface gravity, Earth

Find the surface gravity of Earth: mass 5.97×10^{24} *kg, radius* 6.37×10^{6} *m* $(G = 6.67 \times 10^{-11})$.

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}(5.97 \times 10^{24})}{(6.37 \times 10^{6})^2}$$

field at the surface

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

Answer

9.81 m/s^2

Surface gravity, the Moon

Find the surface gravity of the Moon: mass 7.35×10^{22} *kg, radius* 1.74×10^{6} *m* $(G = 6.67 \times 10^{-11})$.

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}(7.35 \times 10^{22})}{(1.74 \times 10^{6})^2}$$

field at the surface

$$g = 1.62 \text{ m/s}^2$$

Answer

1.62 m/s^2

Surface gravity, Mars

Find the surface gravity of Mars: mass 6.42×10^{23} *kg, radius* 3.39×10^{6} *m* ($G = 6.67 \times 10^{-11}$).

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}(6.42 \times 10^{23})}{(3.39 \times 10^{6})^2}$$

field at the surface

$$g = 3.73 \text{ m/s}^2$$

Answer

3.73 m/s^2

Surface gravity, Jupiter

C6

Find the surface gravity of Jupiter: mass 1.90×10^{27} kg, radius 7.15×10^{7} m ($G = 6.67 \times 10^{-11}$).

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}(1.90 \times 10^{27})}{(7.15 \times 10^{7})^2}$$

field at the surface

$$g = 24.79 \text{ m/s}^2$$

Answer

24.79 m/s^2

Surface gravity, Mercury

C6

Find the surface gravity of Mercury: mass 3.30×10^{23} *kg, radius* 2.44×10^{6} *m* $(G = 6.67 \times 10^{-11})$.

$$g = \frac{GM}{r^2} = \frac{6.67 \times 10^{-11}(3.30 \times 10^{23})}{(2.44 \times 10^{6})^2}$$

field at the surface

$$g = 3.70 \text{ m/s}^2$$

Answer

3.70 m/s^2

Orbital speed, low Earth orbit

C7

Find the orbital speed around Earth ($M = 5.97 \times 10^{24}$ kg) at radius 6.77×10^{6} m (low Earth orbit).

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}(5.97\times10^{24})}{6.77\times10^{6}}}$$

gravity is centripetal

$$v = 7.67 \times 10^{3} \text{ m/s}$$

Answer

7.67×10^{3} m/s

Orbital speed, a high orbit

Find the orbital speed around Earth ($M = 5.97 \times 10^{24}$ kg) at radius 2.64×10^{7} m (a high orbit).

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}(5.97\times10^{24})}{2.64\times10^{7}}}$$

gravity is centripetal

$$v = 3.89 \times 10^{3}\ \text{m/s}$$

Answer

3.89×10^{3} m/s

Orbital speed, geostationary

C7

Find the orbital speed around Earth ($M = 5.97 \times 10^{24}$ kg) at radius 4.22×10^{7} m (geostationary).

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}(5.97\times10^{24})}{4.22\times10^{7}}}$$

gravity is centripetal

$$v = 3.07 \times 10^{3} \text{ m/s}$$

Answer

3.07×10^{3} m/s

Orbital speed, the Moon's orbit

C7

Find the orbital speed around Earth ($M = 5.97 \times 10^{24}$ kg) at radius 3.84×10^{8} m (the Moon's orbit).

$$v = \sqrt{\frac{GM}{r}} = \sqrt{\frac{6.67\times10^{-11}(5.97\times10^{24})}{3.84\times10^{8}}}$$

gravity is centripetal

$$v = 1.02 \times 10^{3} \text{ m/s}$$

Answer

1.02×10^{3} m/s

Kepler, r×4

C8

A planet orbits at 4 times Earth's orbital radius. How many Earth-years is its period ($T^2 \propto r^3$)?

$$\left(\frac{T}{T_E}\right)^2 = \left(\frac{r}{r_E}\right)^3 = 4^3 \qquad \text{Kepler's third law}$$

$$T = 4^{3/2} = 8.00 \text{ yr}$$

Answer

8.00 yr

Kepler, r×9

A planet orbits at 9 times Earth's orbital radius. How many Earth-years is its period ($T^2 \propto r^3$)?

$$\left(\frac{T}{T_E}\right)^2 = \left(\frac{r}{r_E}\right)^3 = 9^3 \qquad \text{Kepler's third law}$$

$$T = 9^{3/2} = 27.00 \text{ yr}$$

Answer

27.00 yr

Kepler, r×2

A planet orbits at 2 times Earth's orbital radius. How many Earth-years is its period ($T^2 \propto r^3$)?

$$\left(\frac{T}{T_E}\right)^2 = \left(\frac{r}{r_E}\right)^3 = 2^3 \qquad \text{Kepler's third law}$$

$$T = 2^{3/2} = 2.83 \text{ yr}$$

Answer

2.83 yr

Kepler, r×8

C8

A planet orbits at 8 times Earth's orbital radius. How many Earth-years is its period ($T^2 \propto r^3$)?

$$\left(\frac{T}{T_E}\right)^2 = \left(\frac{r}{r_E}\right)^3 = 8^3 \qquad \text{Kepler's third law}$$

$$T = 8^{3/2} = 22.63 \text{ yr}$$

Answer

22.63 yr

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Work, 50 N, 3 m, 0°

E1

A 50 N force acts over 3 m at 0° to the motion. Work done?

$$W = Fd\cos\theta = 50(3)\cos 0^\circ \qquad \text{work definition}$$

$$W = 150.0\ \text{J}$$

Answer

150.0 J

Work, 100 N, 5 m, 0°

E1

A 100 N force acts over 5 m at 0° to the motion. Work done?

$$W = Fd\cos\theta = 100(5)\cos 0^\circ \qquad \text{work definition}$$

$$W = 500.0\ \text{J}$$

Answer

500.0 J

Work, 40 N, 10 m, 60°

A 40 N force acts over 10 m at 60° to the motion. Work done?

$$W = Fd\cos\theta = 40(10)\cos 60^\circ \qquad \text{work definition}$$

$$W = 200.0\ \text{J}$$

Answer

200.0 J

Work, 200 N, 2 m, 30°

E1

A 200 N force acts over 2 m at 30° to the motion. Work done?

$$W = Fd\cos\theta = 200(2)\cos 30^\circ \qquad \text{work definition}$$

$$W = 346.4\ \text{J}$$

Answer

346.4 J

Work, 30 N, 4 m, 90°

E1

A 30 N force acts over 4 m at 90° to the motion. Work done?

$$W = Fd\cos\theta = 30(4)\cos 90^\circ \qquad \text{work definition}$$

$$W = 0.0\ \text{J}(\textit{perpendicular : nowork})$$

Answer

0.0 J

Work, 80 N, 6 m, 45°

E1

A 80 N force acts over 6 m at 45° to the motion. Work done?

$$W = Fd\cos\theta = 80(6)\cos 45^\circ \qquad \text{work definition}$$

$$W = 339.4\ \text{J}$$

Answer

339.4 J

Work, 150 N, 3 m, 0°

E1

A 150 N force acts over 3 m at 0° to the motion. Work done?

$$W = Fd\cos\theta = 150(3)\cos 0^\circ \qquad \text{work definition}$$

$$W = 450.0\ \text{J}$$

Answer

450.0 J

Work, 60 N, 8 m, 60°

A 60 N force acts over 8 m at 60° to the motion. Work done?

$$W = Fd\cos\theta = 60(8)\cos 60^\circ \qquad \text{work definition}$$

$$W = 240.0\ \text{J}$$

Answer

240.0 J

Work, 25 N, 12 m, 0°

E1

A 25 N force acts over 12 m at 0° to the motion. Work done?

$$W = Fd\cos\theta = 25(12)\cos 0^\circ \qquad \text{work definition}$$

$$W = 300.0\ \text{J}$$

Answer

300.0 J

Work, 500 N, 1 m, 90°

E1

A 500 N force acts over 1 m at 90° to the motion. Work done?

$$W = Fd\cos\theta = 500(1)\cos 90^\circ \qquad \text{work definition}$$

$$W = 0.0\ \text{J}(\textit{perpendicular} : \textit{nowork})$$

Answer

0.0 J

Kinetic energy, 2.000 kg, 10 m/s

E2

Find the kinetic energy of a 2.000 *kg object moving at* 10 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(2.000)(10)^2 \qquad \text{energy of motion}$$

$$KE = 100.0 \text{ J}$$

Answer

100.0 J

Kinetic energy, 1000.000 kg, 20 m/s

E2

Find the kinetic energy of a 1000.000 *kg object moving at* 20 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(1000.000)(20)^2 \qquad \text{energy of motion}$$

$$KE = 2.00 \times 10^5 \text{ J}$$

Answer

2.00×10^5 J

Kinetic energy, 0.500 kg, 8 m/s

E2

Find the kinetic energy of a 0.500 *kg object moving at* 8 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.500)(8)^2 \qquad \text{energy of motion}$$

$$KE = 16.0 \text{ J}$$

Answer

16.0 J

Kinetic energy, 70.000 kg, 5 m/s

E2

Find the kinetic energy of a 70.000 *kg object moving at* 5 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(70.000)(5)^2 \qquad \text{energy of motion}$$

$$KE = 875.0 \text{ J}$$

Answer

875.0 J

Kinetic energy, 4.000 kg, 15 m/s

E2

Find the kinetic energy of a 4.000 *kg object moving at* 15 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(4.000)(15)^2 \qquad \text{energy of motion}$$

$$KE = 450.0 \text{ J}$$

Answer

450.0 J

Kinetic energy, 0.145 kg, 40 m/s

E2

Find the kinetic energy of a 0.145 *kg object moving at* 40 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(0.145)(40)^2 \qquad \text{energy of motion}$$

$$KE = 116.0 \text{ J}$$

Answer

116.0 J

Kinetic energy, 10.000 kg, 3 m/s

E2

Find the kinetic energy of a 10.000 *kg object moving at* 3 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(10.000)(3)^2 \qquad \text{energy of motion}$$

$$KE = 45.0 \text{ J}$$

Answer

45.0 J

Kinetic energy, 1500.000 kg, 30 m/s

E2

Find the kinetic energy of a 1500.000 *kg object moving at* 30 *m/s.*

$$KE = \tfrac{1}{2}mv^2 = \tfrac{1}{2}(1500.000)(30)^2 \qquad \text{energy of motion}$$

$$KE = 6.75 \times 10^5 \text{ J}$$

Answer

6.75×10^5 J

Speed from 400 J KE

E2

A 2 kg object has 400 J of kinetic energy. Find its speed.

$$v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{2(400)}{2}} \qquad \text{solve for } v$$

$$v = 20.00 \text{ m/s}$$

Answer

20.00 m/s

Speed from 90 J KE

E2

A 5 kg object has 90 J of kinetic energy. Find its speed.

$$v = \sqrt{\frac{2\,KE}{m}} = \sqrt{\frac{2(90)}{5}} \qquad \text{solve for } v$$

$$v = 6.00 \text{ m/s}$$

Answer

6.00 m/s

Grav. PE, 2.0 kg, 5 m

E3

Find the gravitational potential energy of a 2.0 *kg object* 5 *m high* ($g = 9.8$).

$$PE = mgh = 2.0(9.8)(5) \qquad \text{height energy}$$

$$PE = 98.0 \text{ J}$$

Answer

98.0 J

Grav. PE, 10.0 kg, 3 m

E3

Find the gravitational potential energy of a 10.0 *kg object* 3 *m high* ($g = 9.8$).

$$PE = mgh = 10.0(9.8)(3) \qquad \text{height energy}$$

$$PE = 294.0 \text{ J}$$

Answer

294.0 J

Grav. PE, 0.5 kg, 20 m

E3

Find the gravitational potential energy of a 0.5 *kg object* 20 *m high* ($g = 9.8$).

$$PE = mgh = 0.5(9.8)(20) \qquad \text{height energy}$$

$$PE = 98.0 \text{ J}$$

Answer

98.0 J

Grav. PE, 70.0 kg, 10 m

E3

Find the gravitational potential energy of a 70.0 kg object 10 m high ($g = 9.8$).

$$PE = mgh = 70.0(9.8)(10) \quad \text{height energy}$$

$$PE = 6860.0 \text{ J}$$

Answer

6860.0 J

Grav. PE, 5.0 kg, 8 m

E3

Find the gravitational potential energy of a 5.0 *kg object* 8 *m high* ($g = 9.8$).

$$PE = mgh = 5.0(9.8)(8) \qquad \text{height energy}$$

$$PE = 392.0 \text{ J}$$

Answer

392.0 J

Grav. PE, 1000.0 kg, 2 m

E3

Find the gravitational potential energy of a 1000.0 *kg object* 2 *m high* ($g = 9.8$).

$$PE = mgh = 1000.0(9.8)(2) \qquad \text{height energy}$$

$$PE = 1.96 \times 10^4 \text{ J}$$

Answer

1.96×10^4 J

Grav. PE, 3.0 kg, 12 m

E3

Find the gravitational potential energy of a 3.0 *kg object* 12 *m high* ($g = 9.8$).

$$PE = mgh = 3.0(9.8)(12) \qquad \text{height energy}$$

$$PE = 352.8 \text{ J}$$

Answer

352.8 J

Grav. PE, 0.2 kg, 50 m

E3

Find the gravitational potential energy of a 0.2 *kg object* 50 *m high* ($g = 9.8$).

$$PE = mgh = 0.2(9.8)(50) \qquad \text{height energy}$$

$$PE = 98.0 \text{ J}$$

Answer

98.0 J

Height from 490 J PE

E3

A 5 kg object has 490 J of gravitational PE. How high is it ($g = 9.8$)?

$$h = \frac{PE}{mg} = \frac{490}{49.0} \qquad \text{solve } PE = mgh$$

$$h = 10.0 \text{ m}$$

Answer

10.0 m

Height from 196 J PE

E3

A 2 kg object has 196 J of gravitational PE. How high is it ($g = 9.8$)?

$$h = \frac{PE}{mg} = \frac{196}{19.6} \qquad \text{solve } PE = mgh$$

$$h = 10.0 \text{ m}$$

Answer

10.0 m

Drop from 5.0 m

An object falls from rest from 5.0 *m. Use energy conservation to find its speed at the bottom* ($g = 9.8$).

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

PE $\rightarrow$ KE, mass cancels

$$v = \sqrt{2gh} = \sqrt{2(9.8)(5.0)} = 9.90 \text{ m/s}$$

Answer

9.90 m/s

Drop from 20.0 m

E4

An object falls from rest from 20.0 m. Use energy conservation to find its speed at the bottom ($g = 9.8$).

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

PE $\rightarrow$ KE, mass cancels

$$v = \sqrt{2gh} = \sqrt{2(9.8)(20.0)} = 19.80 \text{ m/s}$$

Answer

19.80 m/s

Drop from 1.8 m

An object falls from rest from 1.8 *m. Use energy conservation to find its speed at the bottom* ($g = 9.8$).

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

PE $\rightarrow$ KE, mass cancels

$$v = \sqrt{2gh} = \sqrt{2(9.8)(1.8)} = 5.94 \text{ m/s}$$

Answer

5.94 m/s

Drop from 45.0 m

An object falls from rest from 45.0 *m. Use energy conservation to find its speed at the bottom* ($g = 9.8$).

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

PE $\rightarrow$ KE, mass cancels

$$v = \sqrt{2gh} = \sqrt{2(9.8)(45.0)} = 29.70 \text{ m/s}$$

Answer

29.70 m/s

Drop from 10.0 m

E4

An object falls from rest from 10.0 *m. Use energy conservation to find its speed at the bottom* ($g = 9.8$).

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

PE $\rightarrow$ KE, mass cancels

$$v = \sqrt{2gh} = \sqrt{2(9.8)(10.0)} = 14.00 \text{ m/s}$$

Answer

14.00 m/s

Drop from 80.0 m

An object falls from rest from 80.0 *m. Use energy conservation to find its speed at the bottom* ($g = 9.8$).

$$mgh = \tfrac{1}{2}mv^2 \qquad \text{PE} \to \text{KE, mass cancels}$$

$$v = \sqrt{2gh} = \sqrt{2(9.8)(80.0)} = 39.60 \text{ m/s}$$

Answer

39.60 m/s

Pendulum from 2.00 m

E4

A pendulum bob is released from rest 2.00 m above its lowest point. Find its speed at the bottom ($g = 9.8$).

$$\tfrac{1}{2}mv^2 = mgh \qquad \text{energy conserved on the swing}$$

$$v = \sqrt{2gh} = 6.26 \text{ m/s} \qquad \text{same as a free drop}$$

Answer

6.26 m/s

Pendulum from 5.00 m

A pendulum bob is released from rest 5.00 *m above its lowest point. Find its speed at the bottom* ($g = 9.8$).

$$\begin{aligned} \tfrac{1}{2}mv^2 &= mgh && \text{energy conserved on the swing} \\ v &= \sqrt{2gh} = 9.90\ \text{m/s} && \text{same as a free drop} \end{aligned}$$

Answer

9.90 m/s

Pendulum from 1.25 m

A pendulum bob is released from rest 1.25 *m above its lowest point. Find its speed at the bottom* ($g = 9.8$).

$$\tfrac{1}{2}mv^2 = mgh \qquad \text{energy conserved on the swing}$$

$$v = \sqrt{2gh} = 4.95 \text{ m/s} \qquad \text{same as a free drop}$$

Answer

4.95 m/s

Pendulum from 3.20 m

E4

A pendulum bob is released from rest 3.20 m above its lowest point. Find its speed at the bottom ($g = 9.8$).

$$\tfrac{1}{2}mv^2 = mgh \qquad \text{energy conserved on the swing}$$

$$v = \sqrt{2gh} = 7.92\ \text{m/s} \qquad \text{same as a free drop}$$

Answer

7.92 m/s

Spring, k=200 N/m, x=0.10 m

E5

A spring ($k = 200$ N/m) is stretched 0.10 m. Find the force and the stored energy.

$$F = kx = 200(0.10) = 20.0 \text{ N} \qquad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(200)(0.10)^2 = 1.00 \text{ J} \qquad \text{elastic energy}$$

Answer

$F = 20.0$ N, $PE = 1.00$ J

Spring, k=500 N/m, x=0.05 m

E5

A spring ($k = 500$ N/m) is stretched 0.05 m. Find the force and the stored energy.

$$F = kx = 500(0.05) = 25.0 \text{ N} \quad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(500)(0.05)^2 = 0.63 \text{ J} \quad \text{elastic energy}$$

Answer

$F = 25.0$ N, $PE = 0.63$ J

Spring, k=1000 N/m, x=0.20 m

E5

A spring ($k = 1000$ N/m) is stretched 0.20 m. Find the force and the stored energy.

$$F = kx = 1000(0.20) = 200.0 \text{ N} \quad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(1000)(0.20)^2 = 20.00 \text{ J} \quad \text{elastic energy}$$

Answer

$F = 200.0$ N, $PE = 20.00$ J

Spring, k=50 N/m, x=0.30 m

E5

A spring ($k = 50$ N/m) is stretched 0.30 m. Find the force and the stored energy.

$$F = kx = 50(0.30) = 15.0 \text{ N} \quad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(50)(0.30)^2 = 2.25 \text{ J} \quad \text{elastic energy}$$

Answer

$F = 15.0$ N, $PE = 2.25$ J

Spring, k=800 N/m, x=0.15 m

E5

A spring ($k = 800$ N/m) is stretched 0.15 m. Find the force and the stored energy.

$$F = kx = 800(0.15) = 120.0 \text{ N} \quad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(800)(0.15)^2 = 9.00 \text{ J} \quad \text{elastic energy}$$

Answer

$F = 120.0$ N, $PE = 9.00$ J

Spring, k=300 N/m, x=0.25 m

E5

A spring ($k = 300$ N/m) is stretched 0.25 m. Find the force and the stored energy.

$$F = kx = 300(0.25) = 75.0 \text{ N} \quad \text{Hooke's law}$$

$$PE = \tfrac{1}{2}kx^2 = \tfrac{1}{2}(300)(0.25)^2 = 9.38 \text{ J} \quad \text{elastic energy}$$

Answer

$F = 75.0$ N, $PE = 9.38$ J

Stretch for 8 J, k=400

How far must a 400 N/m spring be stretched to store 8 J?

$$x = \sqrt{\frac{2\,PE}{k}} = \sqrt{\frac{2(8)}{400}} \qquad \text{solve } PE = \tfrac{1}{2}kx^2$$

$$x = 0.200 \text{ m}$$

Answer

0.200 m

Stretch for 4 J, k=200

How far must a 200 N/m spring be stretched to store 4 J?

$$x = \sqrt{\frac{2\,PE}{k}} = \sqrt{\frac{2(4)}{200}} \qquad \text{solve } PE = \tfrac{1}{2}kx^2$$

$$x = 0.200 \text{ m}$$

Answer

0.200 m

Power, 600 J in 3 s

E6

A machine does 600 J of work in 3 s. Find its power.

$$P = \frac{W}{t} = \frac{600}{3}$$

work per time

$$P = 200.0 \text{ W}$$

Answer

200.0 W

Power, 1000 J in 10 s

E6

A machine does 1000 *J of work in* 10 *s. Find its power.*

$$P = \frac{W}{t} = \frac{1000}{10} \qquad \text{work per time}$$

$$P = 100.0\ \text{W}$$

Answer

100.0 W

Power, 450 J in 5 s

E6

A machine does 450 J of work in 5 s. Find its power.

$$P = \frac{W}{t} = \frac{450}{5} \qquad \text{work per time}$$

$$P = 90.0\ \text{W}$$

Answer

90.0 W

Power, 2400 J in 60 s

E6

A machine does 2400 J of work in 60 s. Find its power.

$$P = \frac{W}{t} = \frac{2400}{60} \qquad \text{work per time}$$

$$P = 40.0\ \text{W}$$

Answer

40.0 W

Power, 150 J in 2 s

E6

A machine does 150 *J of work in* 2 *s. Find its power.*

$$P = \frac{W}{t} = \frac{150}{2} \qquad \text{work per time}$$

$$P = 75.0\ \text{W}$$

Answer

75.0 W

Power, 200 N at 5 m/s

E6

A motor pushes with 200 N while moving at 5 m/s. Find the power delivered.

$$P = Fv = 200(5) \qquad \text{power} = \text{force} \times \text{speed}$$

$$P = 1000.0 \text{ W}$$

Answer

1000.0 W

Power, 50 N at 20 m/s

E6

A motor pushes with 50 N while moving at 20 m/s. Find the power delivered.

$$P = Fv = 50(20) \qquad \text{power} = \text{force} \times \text{speed}$$

$$P = 1000.0 \text{ W}$$

Answer

1000.0 W

Power, 800 N at 2 m/s

E6

A motor pushes with 800 N while moving at 2 m/s. Find the power delivered.

$$P = Fv = 800(2) \qquad \text{power} = \text{force} \times \text{speed}$$
$$P = 1600.0 \text{ W}$$

Answer

1600.0 W

Power, 30 N at 12 m/s

E6

A motor pushes with 30 N while moving at 12 m/s. Find the power delivered.

$$P = Fv = 30(12) \qquad \text{power} = \text{force} \times \text{speed}$$

$$P = 360.0 \text{ W}$$

Answer

360.0 W

Power, 500 N at 6 m/s

E6

A motor pushes with 500 N while moving at 6 m/s. Find the power delivered.

$$P = Fv = 500(6) \qquad \text{power} = \text{force} \times \text{speed}$$

$$P = 3000.0 \text{ W}$$

Answer

3000.0 W

Stopping distance, 2 kg, 6 m/s

E7

A 2 kg block slides at 6 m/s onto a rough floor, $\mu = 0.3$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 36.0\ \text{J} \qquad \text{energy to remove}$$

$$f = \mu mg = 5.9\ \text{N} \qquad \text{friction force}$$

$$d = \frac{KE}{f} = 6.12\ \text{m} \qquad \text{friction work} = \text{KE}$$

Answer

6.12 m

Stopping distance, 5 kg, 10 m/s

E7

A 5 kg block slides at 10 m/s onto a rough floor, $\mu = 0.4$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 250.0 \text{ J} \quad \text{energy to remove}$$

$$f = \mu mg = 19.6 \text{ N} \quad \text{friction force}$$

$$d = \frac{KE}{f} = 12.76 \text{ m} \quad \text{friction work} = \text{KE}$$

Answer

12.76 m

Stopping distance, 1 kg, 8 m/s

E7

A 1 kg block slides at 8 m/s onto a rough floor, $\mu = 0.2$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 32.0\ \text{J} \qquad \text{energy to remove}$$

$$f = \mu mg = 2.0\ \text{N} \qquad \text{friction force}$$

$$d = \frac{KE}{f} = 16.33\ \text{m} \qquad \text{friction work} = \text{KE}$$

Answer

16.33 m

Stopping distance, 10 kg, 4 m/s

A 10 kg block slides at 4 m/s onto a rough floor, $\mu = 0.5$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 80.0\ \text{J} \qquad \text{energy to remove}$$

$$f = \mu mg = 49.0\ \text{N} \qquad \text{friction force}$$

$$d = \frac{KE}{f} = 1.63\ \text{m} \qquad \text{friction work} = \text{KE}$$

Answer

1.63 m

Stopping distance, 3 kg, 12 m/s

E7

A 3 kg block slides at 12 m/s onto a rough floor, $\mu = 0.3$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 216.0 \text{ J} \quad \text{energy to remove}$$

$$f = \mu mg = 10.3 \text{ N} \quad \text{friction force}$$

$$d = \frac{KE}{f} = 20.99 \text{ m} \quad \text{friction work} = \text{KE}$$

Answer

20.99 m

Stopping distance, 0.5 kg, 20 m/s

E7

A 0.5 kg block slides at 20 m/s onto a rough floor, $\mu = 0.2$. How far until it stops ($g = 9.8$)?

$$KE = \tfrac{1}{2}mv^2 = 100.0 \text{ J} \quad \text{energy to remove}$$

$$f = \mu mg = 1.2 \text{ N} \quad \text{friction force}$$

$$d = \frac{KE}{f} = 81.63 \text{ m} \quad \text{friction work} = \text{KE}$$

Answer

81.63 m

Speed after friction, 2 kg

A 2 kg block at 10 m/s crosses 8 m against 5 N of friction. Find its final speed.

$$KE_i = \tfrac{1}{2}mv^2 = 100.0 \text{ J} \quad \text{start}$$

$$KE_f = 100.0 - 5(8) = 60.0 \text{ J} \quad \text{minus friction work}$$

$$v_f = \sqrt{2KE_f/m} = 7.75 \text{ m/s}$$

Answer

7.75 m/s

Speed after friction, 3 kg

E7

A 3 kg block at 6 m/s crosses 5 m against 4 N of friction. Find its final speed.

$$KE_i = \tfrac{1}{2}mv^2 = 54.0 \text{ J} \quad \text{start}$$

$$KE_f = 54.0 - 4(5) = 34.0 \text{ J} \quad \text{minus friction work}$$

$$v_f = \sqrt{2KE_f/m} = 4.76 \text{ m/s}$$

Answer

4.76 m/s

Speed after friction, 4 kg

E7

A 4 kg block at 8 m/s crosses 6 m against 6 N of friction. Find its final speed.

$$KE_i = \tfrac{1}{2}mv^2 = 128.0 \text{ J} \quad \text{start}$$

$$KE_f = 128.0 - 6(6) = 92.0 \text{ J} \quad \text{minus friction work}$$

$$v_f = \sqrt{2KE_f/m} = 6.78 \text{ m/s}$$

Answer

6.78 m/s

Speed after friction, 1 kg

E7

A 1 kg block at 15 m/s crosses 10 m against 3 N of friction. Find its final speed.

$$KE_i = \tfrac{1}{2}mv^2 = 112.5 \text{ J} \quad \text{start}$$

$$KE_f = 112.5 - 3(10) = 82.5 \text{ J} \quad \text{minus friction work}$$

$$v_f = \sqrt{2KE_f/m} = 12.85 \text{ m/s}$$

Answer

12.85 m/s

Energy method, 10 m ramp

Starting from rest, an object descends 10 *m along a frictionless ramp (frictionless). Use energy to find the bottom speed* ($g = 9.8$).

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

shape doesn't matter, only height

$$v = \sqrt{2gh} = \sqrt{2(9.8)(10)} = 14.00 \text{ m/s}$$

no need for forces

Answer

14.00 m/s

Energy method, 25 m hill

E8

Starting from rest, an object descends 25 m along a hill (frictionless). Use energy to find the bottom speed ($g = 9.8$).

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

shape doesn't matter, only height

$$v = \sqrt{2gh} = \sqrt{2(9.8)(25)} = 22.14 \text{ m/s}$$

no need for forces

Answer

22.14 m/s

Energy method, 4 m slide

Starting from rest, an object descends 4 m along a slide (frictionless). Use energy to find the bottom speed ($g = 9.8$).

$$mgh = \tfrac{1}{2}mv^2 \qquad \text{shape doesn't matter, only height}$$

$$v = \sqrt{2gh} = \sqrt{2(9.8)(4)} = 8.85 \text{ m/s} \qquad \text{no need for forces}$$

Answer

8.85 m/s

Energy method, 40 m drop

Starting from rest, an object descends 40 *m along a roller-coaster drop (frictionless). Use energy to find the bottom speed* ($g = 9.8$).

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

shape doesn't matter, only height

$$v = \sqrt{2gh} = \sqrt{2(9.8)(40)} = 28.00 \text{ m/s}$$

no need for forces

Answer

28.00 m/s

Energy method, 15 m slope

Starting from rest, an object descends 15 *m along a ski slope (frictionless). Use energy to find the bottom speed* ($g = 9.8$).

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

shape doesn't matter, only height

$$v = \sqrt{2gh} = \sqrt{2(9.8)(15)} = 17.15 \text{ m/s}$$

no need for forces

Answer

17.15 m/s

Energy method, 60 m slide

Starting from rest, an object descends 60 *m along a water slide (frictionless). Use energy to find the bottom speed* ($g = 9.8$).

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

shape doesn't matter, only height

$$v = \sqrt{2gh} = \sqrt{2(9.8)(60)} = 34.29 \text{ m/s}$$

no need for forces

Answer

34.29 m/s

Spring launch, k=500, 1.0 kg

E8

A 500 *N/m spring compressed* 0.20 *m launches a* 1.0 *kg cart. Find the launch speed (frictionless).*

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2 \qquad \text{spring energy} \to \text{kinetic}$$

$$v = \sqrt{\frac{kx^2}{m}} = 4.47 \text{ m/s}$$

Answer

4.47 m/s

Spring launch, k=800, 0.5 kg

E8

A 800 N/m spring compressed 0.10 m launches a 0.5 kg cart. Find the launch speed (frictionless).

$$\tfrac{1}{2}kx^2 = \tfrac{1}{2}mv^2 \qquad \text{spring energy} \to \text{kinetic}$$

$$v = \sqrt{\frac{kx^2}{m}} = 4.00 \text{ m/s}$$

Answer

4.00 m/s

Practice more, then watch the walk-through

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Linear Momentum — Full Worked Session

Every skill in the unit, worked one problem at a time

Set up → solve → answer
80 problems

Lesson `ap1.momentum.session`

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Momentum, 1000.000 kg, 10 m/s

Find the momentum of a 1000.000 *kg object moving at* 10 *m/s.*

$$p = mv = 1000.000(10) \qquad \text{mass} \times \text{velocity}$$

$$p = 1.00 \times 10^4 \ \text{kg} \cdot \text{m/s}$$

Answer

$1.00 \times 10^4 \ \text{kg} \cdot \text{m/s}$

Momentum, 2.000 kg, 15 m/s

P1

Find the momentum of a 2.000 *kg object moving at* 15 *m/s.*

$$p = mv = 2.000(15) \qquad \text{mass} \times \text{velocity}$$

$$p = 30.0\ \text{kg} \cdot \text{m/s}$$

Answer

30.0 kg · m/s

Momentum, 0.145 kg, 40 m/s

P1

Find the momentum of a 0.145 *kg object moving at* 40 *m/s.*

$$p = mv = 0.145(40) \qquad \text{mass} \times \text{velocity}$$

$$p = 5.8\ \text{kg} \cdot \text{m/s}$$

Answer

5.8 kg · m/s

Momentum, 70.000 kg, 5 m/s

P1

Find the momentum of a 70.000 *kg object moving at* 5 *m/s.*

$$p = mv = 70.000(5) \qquad \text{mass} \times \text{velocity}$$
$$p = 350.0\ \text{kg} \cdot \text{m/s}$$

Answer

350.0 kg · m/s

Momentum, 0.500 kg, 20 m/s

P1

Find the momentum of a 0.500 *kg object moving at* 20 *m/s.*

$$p = mv = 0.500(20) \qquad \text{mass} \times \text{velocity}$$

$$p = 10.0\ \text{kg} \cdot \text{m/s}$$

Answer

10.0 kg · m/s

Momentum, 5000.000 kg, 2 m/s

P1

Find the momentum of a 5000.000 *kg object moving at* 2 *m/s.*

$$p = mv = 5000.000(2) \qquad \text{mass} \times \text{velocity}$$

$$p = 1.00 \times 10^4 \ \text{kg} \cdot \text{m/s}$$

Answer

1.00×10^4 kg · m/s

Momentum, 0.020 kg, 300 m/s

P1

Find the momentum of a 0.020 *kg object moving at* 300 *m/s.*

$$p = mv = 0.020(300) \qquad \text{mass} \times \text{velocity}$$

$$p = 6.0\ \text{kg} \cdot \text{m/s}$$

Answer

6.0 kg · m/s

Speed from 300 momentum

An object of mass 6 kg has momentum 300 kg·m/s. Find its speed.

$$v = \frac{p}{m} = \frac{300}{6} \qquad \text{solve } p = mv$$
$$v = 50.00 \text{ m/s}$$

Answer

50.00 m/s

Speed from 50 momentum

P1

An object of mass 2 kg has momentum 50 kg·m/s. Find its speed.

$$v = \frac{p}{m} = \frac{50}{2} \qquad \text{solve } p = mv$$
$$v = 25.00 \text{ m/s}$$

Answer

25.00 m/s

Mass from 120 momentum

P1

An object moving 8 m/s carries 120 kg·m/s of momentum. Find its mass.

$$m = \frac{p}{v} = \frac{120}{8} \qquad \text{solve } p = mv$$

$$m = 15.00 \text{ kg}$$

Answer

15.00 kg

Mass from 600 momentum

An object moving 30 *m/s carries* 600 *kg·m/s of momentum. Find its mass.*

$$m = \frac{p}{v} = \frac{600}{30} \qquad \text{solve } p = mv$$

$$m = 20.00 \text{ kg}$$

Answer

20.00 kg

Impulse, 200 N for 0.50 s

A force of 200 *N acts for* 0.50 *s. Find the impulse.*

$$J = F\Delta t = 200(0.50) \qquad \text{impulse} = \text{force} \times \text{time}$$

$$J = 100.00\ \text{N}\cdot\text{s} \qquad = \text{change in momentum}$$

Answer

100.00 N · s

Impulse, 50 N for 2.00 s

P2

A force of 50 *N acts for* 2.00 *s. Find the impulse.*

$$J = F\Delta t = 50(2.00) \qquad \text{impulse} = \text{force} \times \text{time}$$

$$J = 100.00\ \text{N}\cdot\text{s} \qquad = \text{change in momentum}$$

Answer

100.00 N · s

Impulse, 1000 N for 0.01 s

A force of 1000 *N acts for* 0.01 *s. Find the impulse.*

$$J = F\Delta t = 1000(0.01) \qquad \text{impulse} = \text{force} \times \text{time}$$

$$J = 10.00\ \text{N}\cdot\text{s} \qquad = \text{change in momentum}$$

Answer

10.00 N · s

Impulse, 30 N for 4.00 s

P2

A force of 30 *N acts for* 4.00 *s. Find the impulse.*

$$J = F\Delta t = 30(4.00) \qquad \text{impulse} = \text{force} \times \text{time}$$

$$J = 120.00\ \text{N}\cdot\text{s} \qquad = \text{change in momentum}$$

Answer

120.00 N · s

Impulse, 500 N for 0.20 s

A force of 500 *N acts for* 0.20 *s. Find the impulse.*

$$J = F\Delta t = 500(0.20) \qquad \text{impulse} = \text{force} \times \text{time}$$

$$J = 100.00\ \text{N}\cdot\text{s} \qquad = \text{change in momentum}$$

Answer

100.00 N · s

Momentum change, 0.500 kg

P2

A 0.500 kg object goes from 0 m/s to 20 m/s. Find the impulse it received.

$$J = \Delta p = m(v_f - v_i) = 0.500(20 - 0) \qquad \text{impulse-momentum theorem}$$

$$J = 10.00\ \text{N} \cdot \text{s}$$

Answer

10.00 N · s

Momentum change, 2.000 kg

P2

A 2.000 kg object goes from 10 m/s to −5 m/s. Find the impulse it received.

$$J = \Delta p = m(v_f - v_i) = 2.000(-5 - 10)$$ impulse-momentum theorem

$$J = -30.00\ \text{N}\cdot\text{s}$$

Answer

-30.00 N · s

Momentum change, 1000.000 kg

P2

A 1000.000 *kg object goes from* 30 *m/s to* 0 *m/s. Find the impulse it received.*

$$J = \Delta p = m(v_f - v_i) = 1000.000(0 - 30) \qquad \text{impulse-momentum theorem}$$

$$J = -30000.00\ \text{N} \cdot \text{s}$$

Answer

-30000.00 N $\cdot$ s

Momentum change, 0.145 kg

A 0.145 kg object goes from 40 m/s to −40 m/s. Find the impulse it received.

$$J = \Delta p = m(v_f - v_i) = 0.145(-40 - 40) \qquad \text{impulse-momentum theorem}$$

$$J = -11.60\ \text{N}\cdot\text{s}$$

Answer

-11.60 N · s

Force from stopping, 0.145 kg

P2

A 0.145 kg object changes from 40 m/s to −40 m/s in 0.002 s. Find the average force.

$$F = \frac{m(v_f - v_i)}{\Delta t} = \frac{0.145(-40 - 40)}{0.002} \qquad F = \Delta p/\Delta t$$

$$F = -5800.0 \text{ N}$$

Answer

−5800.0 N

Force from stopping, 2.000 kg

A 2.000 kg object changes from 8 m/s to 0 m/s in 0.500 s. Find the average force.

$$F = \frac{m(v_f - v_i)}{\Delta t} = \frac{2.000(0 - 8)}{0.500} \qquad F = \Delta p/\Delta t$$

$$F = -32.0 \text{ N}$$

Answer

-32.0 N

Force from stopping, 60.000 kg

A 60.000 kg object changes from 5 m/s to 0 m/s in 0.100 s. Find the average force.

$$F = \frac{m(v_f - v_i)}{\Delta t} = \frac{60.000(0 - 5)}{0.100} \qquad F = \Delta p/\Delta t$$

$$F = -3000.0 \text{ N}$$

Answer

-3000.0 N

Recoil, 50.000 & 100 kg

Initially at rest, a 50.000 kg mass moves off at 2 m/s. How fast does the 100 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{50.000(2)}{100} = 1.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

1.00 m/s

Recoil, 0.020 & 4 kg

P3

Initially at rest, a 0.020 kg mass moves off at 400 m/s. How fast does the 4 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{0.020(400)}{4} = 2.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

2.00 m/s

Recoil, 60.000 & 40 kg

Initially at rest, a 60.000 kg mass moves off at 3 m/s. How fast does the 40 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{60.000(3)}{40} = 4.50 \text{ m/s} \qquad \text{opposite direction}$$

Answer

4.50 m/s

Recoil, 2.000 & 8 kg

Initially at rest, a 2.000 kg mass moves off at 5 m/s. How fast does the 8 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{2.000(5)}{8} = 1.25 \text{ m/s} \qquad \text{opposite direction}$$

Answer

1.25 m/s

Recoil, 1000.000 & 250 kg

Initially at rest, a 1000.000 kg mass moves off at 1 m/s. How fast does the 250 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{1000.000(1)}{250} = 4.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

4.00 m/s

Recoil, 5.000 & 20 kg

Initially at rest, a 5.000 kg mass moves off at 4 m/s. How fast does the 20 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{5.000(4)}{20} = 1.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

1.00 m/s

Recoil, 0.500 & 3 kg

Initially at rest, a 0.500 kg mass moves off at 12 m/s. How fast does the 3 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{0.500(12)}{3} = 2.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

2.00 m/s

Recoil, 80.000 & 60 kg

Initially at rest, a 80.000 kg mass moves off at 2 m/s. How fast does the 60 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{80.000(2)}{60} = 2.67 \text{ m/s} \qquad \text{opposite direction}$$

Answer

2.67 m/s

Recoil, 40.000 & 50 kg

Initially at rest, a 40.000 kg mass moves off at 3 m/s. How fast does the 50 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{40.000(3)}{50} = 2.40 \text{ m/s} \qquad \text{opposite direction}$$

Answer

2.40 m/s

Recoil, 1.000 & 5 kg

Initially at rest, a 1.000 kg mass moves off at 10 m/s. How fast does the 5 kg mass recoil the other way?

$$0 = m_1 v_1 - m_2 v_2 \qquad \text{total momentum stays zero}$$

$$v_2 = \frac{m_1 v_1}{m_2} = \frac{1.000(10)}{5} = 2.00 \text{ m/s} \qquad \text{opposite direction}$$

Answer

2.00 m/s

Find final velocity, 2&3 kg

Cart 2 kg at 6 m/s and cart 3 kg at 0 m/s collide. Afterward the first moves at 2 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 12.0 \text{ kg} \cdot \text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 2.67 \text{ m/s} \qquad \text{solve the balance}$$

Answer

2.67 m/s

Find final velocity, 1&1 kg

Cart 1 kg at 10 m/s and cart 1 kg at 0 m/s collide. Afterward the first moves at 4 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 10.0 \text{ kg} \cdot \text{m/s} \quad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 6.00 \text{ m/s} \quad \text{solve the balance}$$

Answer

6.00 m/s

Find final velocity, 4&2 kg

Cart 4 kg at 5 m/s and cart 2 kg at −3 m/s collide. Afterward the first moves at 3 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 14.0\ \text{kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 1.00\ \text{m/s} \qquad \text{solve the balance}$$

Answer

1.00 m/s

Find final velocity, 5&5 kg

Cart 5 kg at 4 m/s and cart 5 kg at 0 m/s collide. Afterward the first moves at 1 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 20.0 \text{ kg} \cdot \text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 3.00 \text{ m/s} \qquad \text{solve the balance}$$

Answer

3.00 m/s

Find final velocity, 3&2 kg

Cart 3 kg at 8 m/s and cart 2 kg at 0 m/s collide. Afterward the first moves at 4 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 24.0\ \text{kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 6.00\ \text{m/s} \qquad \text{solve the balance}$$

Answer

6.00 m/s

Find final velocity, 2&6 kg

Cart 2 kg at 12 m/s and cart 6 kg at 0 m/s collide. Afterward the first moves at 3 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 24.0 \text{ kg} \cdot \text{m/s} \quad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 3.00 \text{ m/s} \quad \text{solve the balance}$$

Answer

3.00 m/s

Find final velocity, 1&4 kg

Cart 1 kg at 20 m/s and cart 4 kg at −2 m/s collide. Afterward the first moves at 6 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 12.0\ \text{kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 1.50\ \text{m/s} \qquad \text{solve the balance}$$

Answer

1.50 m/s

Find final velocity, 10&5 kg

Cart 10 *kg at* 3 *m/s and cart* 5 *kg at* 1 *m/s collide. Afterward the first moves at* 2 *m/s. Find the second's velocity.*

$$p_i = m_1 u_1 + m_2 u_2 = 35.0 \text{ kg} \cdot \text{m/s} \qquad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 3.00 \text{ m/s} \qquad \text{solve the balance}$$

Answer

3.00 m/s

Find final velocity, 2&3 kg

Cart 2 kg at 9 m/s and cart 3 kg at 2 m/s collide. Afterward the first moves at 5 m/s. Find the second's velocity.

$$p_i = m_1 u_1 + m_2 u_2 = 24.0 \text{ kg} \cdot \text{m/s} \quad \text{momentum conserved}$$

$$v_2' = \frac{p_i - m_1 v_1'}{m_2} = 4.67 \text{ m/s} \quad \text{solve the balance}$$

Answer

4.67 m/s

Equal-mass elastic, 6 m/s

An elastic head-on collision: a 2 kg ball at 6 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$

$$v_2' = 6 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 6 \text{ m/s}$$

Equal-mass elastic, 10 m/s

An elastic head-on collision: a 1 kg ball at 10 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$

$$v_2' = 10 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 10 \text{ m/s}$$

Equal-mass elastic, 8 m/s

An elastic head-on collision: a 0.5 kg ball at 8 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \quad \text{moving ball stops}$$
$$v_2' = 8 \text{ m/s} \quad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 8 \text{ m/s}$$

Equal-mass elastic, 4 m/s

An elastic head-on collision: a 3 kg ball at 4 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$
$$v_2' = 4 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 4 \text{ m/s}$$

Equal-mass elastic, 12 m/s

An elastic head-on collision: a 2 kg ball at 12 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$

$$v_2' = 12 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 12 \text{ m/s}$$

Equal-mass elastic, 7 m/s

An elastic head-on collision: a 1 kg ball at 7 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$
$$v_2' = 7 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 7 \text{ m/s}$$

Equal-mass elastic, 3 m/s

An elastic head-on collision: a 5 kg ball at 3 m/s strikes an identical ball at rest. Find both final velocities.

$$v_1' = 0 \text{ m/s} \qquad \text{moving ball stops}$$
$$v_2' = 3 \text{ m/s} \qquad \text{target takes the full speed}$$

Answer

$$v_1' = 0,\ v_2' = 3 \text{ m/s}$$

1D elastic, 3→1 kg

Elastic collision: 3 kg at 8 m/s hits 1 kg at rest. Find both final velocities.

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} u_1 = 4.00 \text{ m/s} \qquad \text{elastic formula}$$

$$v_2' = \frac{2m_1}{m_1 + m_2} u_1 = 12.00 \text{ m/s}$$

Answer

$$v_1' = 4.00, \; v_2' = 12.00 \text{ m/s}$$

1D elastic, 1→3 kg

Elastic collision: 1 kg at 8 m/s hits 3 kg at rest. Find both final velocities.

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} u_1 = -4.00 \text{ m/s} \qquad \text{elastic formula}$$

$$v_2' = \frac{2m_1}{m_1 + m_2} u_1 = 4.00 \text{ m/s}$$

Answer

$$v_1' = -4.00, \; v_2' = 4.00 \text{ m/s}$$

1D elastic, 4→2 kg

Elastic collision: 4 kg at 6 m/s hits 2 kg at rest. Find both final velocities.

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} u_1 = 2.00 \text{ m/s} \qquad \text{elastic formula}$$

$$v_2' = \frac{2m_1}{m_1 + m_2} u_1 = 8.00 \text{ m/s}$$

Answer

$$v_1' = 2.00, \; v_2' = 8.00 \text{ m/s}$$

1D elastic, 2→6 kg

Elastic collision: 2 kg at 9 m/s hits 6 kg at rest. Find both final velocities.

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} u_1 = -4.50 \text{ m/s} \qquad \text{elastic formula}$$

$$v_2' = \frac{2m_1}{m_1 + m_2} u_1 = 4.50 \text{ m/s}$$

Answer

$$v_1' = -4.50, \; v_2' = 4.50 \text{ m/s}$$

1D elastic, 5→1 kg

Elastic collision: 5 *kg at* 10 *m/s hits* 1 *kg at rest. Find both final velocities.*

$$v_1' = \frac{m_1 - m_2}{m_1 + m_2} u_1 = 6.67 \text{ m/s} \qquad \text{elastic formula}$$

$$v_2' = \frac{2m_1}{m_1 + m_2} u_1 = 16.67 \text{ m/s}$$

Answer

$$v_1' = 6.67, \; v_2' = 16.67 \text{ m/s}$$

Inelastic, 2.000&3 kg stick

A 2.000 kg object at 6 m/s and a 3 kg object at 0 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 12.0 \text{ kg}\cdot\text{m/s} \quad \text{momentum conserved}$$

$$v_f = \frac{12.0}{5} = 2.40 \text{ m/s} \quad \text{they move as one}$$

Answer

2.40 m/s

Inelastic, 1.000&4 kg stick

A 1.000 kg object at 10 m/s and a 4 kg object at 0 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 10.0\ \text{kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_f = \frac{10.0}{5} = 2.00\ \text{m/s} \qquad \text{they move as one}$$

Answer

2.00 m/s

Inelastic, 1000.000&1500 kg stick

A 1000.000 kg object at 20 m/s and a 1500 kg object at 0 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 20000.0 \text{ kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_f = \frac{20000.0}{2500} = 8.00 \text{ m/s} \qquad \text{they move as one}$$

Answer

8.00 m/s

Inelastic, 2.000&2 kg stick

A 2.000 kg object at 5 m/s and a 2 kg object at −3 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 4.0 \text{ kg}\cdot\text{m/s} \quad \text{momentum conserved}$$

$$v_f = \frac{4.0}{4} = 1.00 \text{ m/s} \quad \text{they move as one}$$

Answer

1.00 m/s

Inelastic, 0.500&0.5 kg stick

A 0.500 kg object at 8 m/s and a 0.5 kg object at −4 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 2.0\ \text{kg}\cdot\text{m/s} \quad \text{momentum conserved}$$

$$v_f = \frac{2.0}{1.0} = 2.00\ \text{m/s} \quad \text{they move as one}$$

Answer

2.00 m/s

Inelastic, 60.000&40 kg stick

A 60.000 kg object at 4 m/s and a 40 kg object at 0 m/s collide and stick together. Find their common velocity.

$$(m_1+m_2)v_f = m_1u_1 + m_2u_2 = 240.0\ \text{kg}\cdot\text{m/s} \qquad \text{momentum conserved}$$

$$v_f = \frac{240.0}{100} = 2.40\ \text{m/s} \qquad \text{they move as one}$$

Answer

2.40 m/s

KE lost, 2&3 kg

A 2 kg object at 6 m/s sticks to a stationary 3 kg object. How much kinetic energy is lost?

$$v_f = \frac{m_1 u_1}{m_1 + m_2} = 2.40 \text{ m/s} \quad \text{common velocity}$$

$$\Delta KE = 36.0 - 14.4 = 21.6 \text{ J} \quad \text{lost to heat/sound}$$

Answer

21.6 J

KE lost, 1000&1500 kg

A 1000 kg object at 20 m/s sticks to a stationary 1500 kg object. How much kinetic energy is lost?

$$v_f = \frac{m_1 u_1}{m_1 + m_2} = 8.00 \text{ m/s} \quad \text{common velocity}$$

$$\Delta KE = 200000.0 - 80000.0 = 1.20 \times 10^5 \text{ J} \quad \text{lost to heat/sound}$$

Answer

1.20×10^5 J

Recoil, 4 kg gun

A 4 kg rifle fires a 0.020 kg bullet at 400 m/s. Find the recoil speed.

$$0 = m_b v_b - MV \qquad \text{total momentum zero}$$

$$V = \frac{m_b v_b}{M} = \frac{0.020(400)}{4} = 2.00 \text{ m/s} \qquad \text{backward}$$

Answer

2.00 m/s

Recoil, 3 kg gun

A 3 kg rifle fires a 0.010 kg bullet at 600 m/s. Find the recoil speed.

$$0 = m_b v_b - MV \qquad \text{total momentum zero}$$

$$V = \frac{m_b v_b}{M} = \frac{0.010(600)}{3} = 2.00 \text{ m/s} \qquad \text{backward}$$

Answer

2.00 m/s

Recoil, 5 kg gun

A 5 kg rifle fires a 0.050 kg bullet at 300 m/s. Find the recoil speed.

$$0 = m_b v_b - MV \qquad \text{total momentum zero}$$

$$V = \frac{m_b v_b}{M} = \frac{0.050(300)}{5} = 3.00 \text{ m/s} \qquad \text{backward}$$

Answer

3.00 m/s

Recoil, 4.5 kg gun

A 4.5 kg rifle fires a 0.008 kg bullet at 800 m/s. Find the recoil speed.

$$0 = m_b v_b - MV \qquad \text{total momentum zero}$$

$$V = \frac{m_b v_b}{M} = \frac{0.008(800)}{4.5} = 1.42 \text{ m/s} \qquad \text{backward}$$

Answer

1.42 m/s

Recoil, 6 kg gun

A 6 kg rifle fires a 0.030 kg bullet at 500 m/s. Find the recoil speed.

$$0 = m_b v_b - MV \qquad \text{total momentum zero}$$

$$V = \frac{m_b v_b}{M} = \frac{0.030(500)}{6} = 2.50 \text{ m/s} \qquad \text{backward}$$

Answer

2.50 m/s

Explosion, 1.0&2.0 kg

An object at rest bursts into a 1.0 kg piece moving 6 m/s and a 2.0 kg piece. Find the second piece's speed.

$$m_1 v_1 = m_2 v_2 \qquad \text{equal and opposite}$$

$$v_2 = \frac{m_1 v_1}{m_2} = 3.00\ \text{m/s} \qquad \text{other direction}$$

Answer

3.00 m/s

Explosion, 3.0&1.0 kg

An object at rest bursts into a 3.0 kg piece moving 4 m/s and a 1.0 kg piece. Find the second piece's speed.

$$m_1 v_1 = m_2 v_2 \qquad \text{equal and opposite}$$

$$v_2 = \frac{m_1 v_1}{m_2} = 12.00\ \text{m/s} \qquad \text{other direction}$$

Answer

12.00 m/s

Explosion, 0.5&1.5 kg

An object at rest bursts into a 0.5 kg piece moving 9 m/s and a 1.5 kg piece. Find the second piece's speed.

$$m_1 v_1 = m_2 v_2 \qquad \text{equal and opposite}$$

$$v_2 = \frac{m_1 v_1}{m_2} = 3.00\ \text{m/s} \qquad \text{other direction}$$

Answer

3.00 m/s

Explosion, 2.0&4.0 kg

An object at rest bursts into a 2.0 kg piece moving 10 m/s and a 4.0 kg piece. Find the second piece's speed.

$$m_1 v_1 = m_2 v_2 \qquad \text{equal and opposite}$$

$$v_2 = \frac{m_1 v_1}{m_2} = 5.00\ \text{m/s} \qquad \text{other direction}$$

Answer

5.00 m/s

Explosion, 1.0&5.0 kg

An object at rest bursts into a 1.0 *kg piece moving* 15 *m/s and a* 5.0 *kg piece. Find the second piece's speed.*

$$m_1 v_1 = m_2 v_2 \qquad \text{equal and opposite}$$

$$v_2 = \frac{m_1 v_1}{m_2} = 3.00\ \text{m/s} \qquad \text{other direction}$$

Answer

3.00 m/s

2D stick, east+north

A 2 kg object moving 3 m/s east strikes a 2 kg object moving 4 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 6.0,\ 8.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 10.00\ \text{kg}\cdot\text{m/s at } 53^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 2.50\ \text{m/s}$$

Answer

$$p = 10.00 \text{ at } 53^\circ,\ v_f = 2.50\ \text{m/s}$$

2D stick, east+north

A 1 kg object moving 6 m/s east strikes a 1 kg object moving 8 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 6.0,\ 8.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 10.00\ \text{kg}\cdot\text{m/s at } 53^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 5.00\ \text{m/s}$$

Answer

$$p = 10.00 \text{ at } 53^\circ,\ v_f = 5.00\ \text{m/s}$$

2D stick, east+north

A 3 kg object moving 4 m/s east strikes a 3 kg object moving 3 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 12.0,\ 9.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 15.00\ \text{kg}\cdot\text{m/s at } 37^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 2.50\ \text{m/s}$$

Answer

$$p = 15.00 \text{ at } 37^\circ,\ v_f = 2.50\ \text{m/s}$$

2D stick, east+north

A 1 kg object moving 5 m/s east strikes a 1 kg object moving 12 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 5.0,\ 12.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 13.00\ \text{kg}\cdot\text{m/s at } 67^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 6.50\ \text{m/s}$$

Answer

$$p = 13.00 \text{ at } 67^\circ,\ v_f = 6.50\ \text{m/s}$$

2D stick, east+north

A 2 kg object moving 5 m/s east strikes a 3 kg object moving 4 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 10.0,\ 12.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 15.62\ \text{kg}\cdot\text{m/s at } 50^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 3.12\ \text{m/s}$$

Answer

$$p = 15.62 \text{ at } 50^\circ,\ v_f = 3.12\ \text{m/s}$$

2D stick, east+north

A 4 kg object moving 2 m/s east strikes a 2 kg object moving 6 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 8.0,\ 12.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 14.42\ \text{kg}\cdot\text{m/s at } 56^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 2.40\ \text{m/s}$$

Answer

$$p = 14.42 \text{ at } 56^\circ,\ v_f = 2.40\ \text{m/s}$$

2D stick, east+north

A 1 kg object moving 9 m/s east strikes a 2 kg object moving 6 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 9.0,\ 12.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 15.00\ \text{kg}\cdot\text{m/s at } 53^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 5.00\ \text{m/s}$$

Answer

$$p = 15.00 \text{ at } 53^\circ,\ v_f = 5.00\ \text{m/s}$$

2D stick, east+north

A 5 kg object moving 2 m/s east strikes a 5 kg object moving 2 m/s north; they stick. Find the combined momentum, direction, and speed.

$$p_x, p_y = 10.0,\ 10.0\ \text{kg}\cdot\text{m/s} \qquad \text{conserve each axis}$$

$$p = \sqrt{p_x^2 + p_y^2} = 14.14\ \text{kg}\cdot\text{m/s at } 45^\circ \qquad \text{resultant}$$

$$v_f = \frac{p}{m_1 + m_2} = 1.41\ \text{m/s}$$

Answer

$$p = 14.14 \text{ at } 45^\circ,\ v_f = 1.41\ \text{m/s}$$

Practice more, then watch the walk-through

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Watch the walk-through

Rotation — Full Worked Session

Every skill in the unit, worked one problem at a time

Set up → solve → answer
78 problems

Lesson `ap1.rotation.session`

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$v = r\omega$, r=2.00 m

A point 2.00 m from the axis rotates at 3 rad/s. Find its linear (tangential) speed.

$$v = r\omega = 2.00(3) \qquad \text{tangential speed}$$

$$v = 6.00 \text{ m/s} \qquad \text{farther out = faster}$$

Answer

6.00 m/s

$v = r\omega$, r=0.50 m

A point 0.50 *m from the axis rotates at* 10 *rad/s. Find its linear (tangential) speed.*

$$v = r\omega = 0.50(10) \qquad \text{tangential speed}$$

$$v = 5.00 \text{ m/s} \qquad \text{farther out = faster}$$

Answer

5.00 m/s

$v = r\omega$, r=0.30 m

A point 0.30 *m from the axis rotates at* 20 *rad/s. Find its linear (tangential) speed.*

$$v = r\omega = 0.30(20) \qquad \text{tangential speed}$$

$$v = 6.00 \text{ m/s} \qquad \text{farther out = faster}$$

Answer

6.00 m/s

$v = r\omega$, r=1.50 m

A point 1.50 m from the axis rotates at 4 rad/s. Find its linear (tangential) speed.

$$v = r\omega = 1.50(4) \qquad \text{tangential speed}$$

$$v = 6.00 \text{ m/s} \qquad \text{farther out = faster}$$

Answer

6.00 m/s

$v = r\omega$, r=0.25 m

A point 0.25 m from the axis rotates at 40 rad/s. Find its linear (tangential) speed.

$$v = r\omega = 0.25(40) \quad \text{tangential speed}$$

$$v = 10.00 \text{ m/s} \quad \text{farther out = faster}$$

Answer

10.00 m/s

rpm to rad/s, 60

R1

Convert 60 rpm to angular speed in rad/s.

$$\omega = \frac{2\pi \text{ rpm}}{60} = \frac{2\pi(60)}{60} \qquad \text{one rev} = 2\pi \text{ rad}$$

$$\omega = 6.28 \text{ rad/s}$$

Answer

6.28 rad/s

rpm to rad/s, 120

R1

Convert 120 rpm to angular speed in rad/s.

$$\omega = \frac{2\pi\,\text{rpm}}{60} = \frac{2\pi(120)}{60} \qquad \text{one rev} = 2\pi \text{ rad}$$

$$\omega = 12.57 \text{ rad/s}$$

Answer

12.57 rad/s

rpm to rad/s, 33

R1

Convert 33 rpm to angular speed in rad/s.

$$\omega = \frac{2\pi \text{ rpm}}{60} = \frac{2\pi(33)}{60} \qquad \text{one rev} = 2\pi \text{ rad}$$

$$\omega = 3.46 \text{ rad/s}$$

Answer

3.46 rad/s

rpm to rad/s, 300

Convert 300 rpm to angular speed in rad/s.

$$\omega = \frac{2\pi\,\text{rpm}}{60} = \frac{2\pi(300)}{60} \qquad \text{one rev} = 2\pi \text{ rad}$$

$$\omega = 31.42 \text{ rad/s}$$

Answer

31.42 rad/s

A wheel at 0 rad/s has angular acceleration 2 rad/s^2 for 5 s. Find the final angular speed.

$$\omega_f = \omega_0 + \alpha t = 0 + (2)(5)$$ rotational analog of $v = v_0 + at$

$$\omega_f = 10.0 \text{ rad/s}$$

Answer

10.0 rad/s

A wheel at 10 rad/s has angular acceleration -2 rad/s^2 for 4 s. Find the final angular speed.

$$\omega_f = \omega_0 + \alpha t = 10 + (-2)(4) \qquad \text{rotational analog of } v = v_0 + at$$
$$\omega_f = 2.0 \text{ rad/s}$$

Answer
2.0 rad/s

A wheel at 5 rad/s has angular acceleration 3 rad/s^2 for 3 s. Find the final angular speed.

$$\omega_f = \omega_0 + \alpha t = 5 + (3)(3) \qquad \text{rotational analog of } v = v_0 + at$$
$$\omega_f = 14.0 \text{ rad/s}$$

Answer

14.0 rad/s

Starting at 0 rad/s with $\alpha = 4$ rad/s^2, through what angle does it turn in 3 s?

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 = 0(3) + \tfrac{1}{2}(4)(3)^2 \quad \text{angular displacement}$$

$$\theta = 18.0 \text{ rad}$$

Answer

18.0 rad

Starting at 2 rad/s with $\alpha = 2$ rad/s^2, through what angle does it turn in 5 s?

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 = 2(5) + \tfrac{1}{2}(2)(5)^2 \quad \text{angular displacement}$$

$$\theta = 35.0 \text{ rad}$$

Answer

35.0 rad

Starting at 0 rad/s with $\alpha = 6$ rad/s^2, through what angle does it turn in 2 s?

$$\theta = \omega_0 t + \tfrac{1}{2}\alpha t^2 = 0(2) + \tfrac{1}{2}(6)(2)^2 \quad \text{angular displacement}$$

$$\theta = 12.0 \text{ rad}$$

Answer

12.0 rad

$\omega_f^2 = \omega_0^2 + 2\alpha\theta$ R2

A disk at 0 rad/s accelerates at 2 rad/s^2 through 16 rad. Find the final angular speed.

$$\omega_f^2 = \omega_0^2 + 2\alpha\theta = 0^2 + 2(2)(16) \quad \text{time-free}$$
$$\omega_f = 8.00 \text{ rad/s}$$

Answer
8.00 rad/s

A disk at 4 rad/s accelerates at 3 rad/s^2 through 10 rad. Find the final angular speed.

$$\omega_f^2 = \omega_0^2 + 2\alpha\theta = 4^2 + 2(3)(10) \quad \text{time-free}$$
$$\omega_f = 8.72 \text{ rad/s}$$

Answer
8.72 rad/s

$\omega_f^2 = \omega_0^2 + 2\alpha\theta$ R2

A disk at 0 rad/s accelerates at 5 rad/s^2 through 40 rad. Find the final angular speed.

$$\omega_f^2 = \omega_0^2 + 2\alpha\theta = 0^2 + 2(5)(40) \quad \text{time-free}$$
$$\omega_f = 20.00 \text{ rad/s}$$

Answer
20.00 rad/s

Torque, r=0.80 m, 90°

A 50 N force is applied 0.80 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.80(50)\sin 90° \qquad \text{torque}$$

$$\tau = 40.00\ \text{N}\cdot\text{m}$$

Answer

40.00 N · m

Torque, r=1.00 m, 90°

A 20 N force is applied 1.00 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 1.00(20)\sin 90° \qquad \text{torque}$$

$$\tau = 20.00\ \text{N}\cdot\text{m}$$

Answer

20.00 N · m

Torque, r=0.50 m, 60°

A 100 N force is applied 0.50 m from the axis at 60° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.50(100)\sin 60° \qquad \text{torque}$$

$$\tau = 43.30\ \text{N}\cdot\text{m}$$

Answer

43.30 N · m

Torque, r=0.90 m, 90°

A 30 N force is applied 0.90 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.90(30)\sin 90° \qquad \text{torque}$$

$$\tau = 27.00\ \text{N}\cdot\text{m}$$

Answer

27.00 N · m

Torque, r=0.05 m, 90°

A 200 N force is applied 0.05 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.05(200)\sin 90° \qquad \text{torque}$$

$$\tau = 10.00\ \text{N}\cdot\text{m}$$

Answer

10.00 N · m

Torque, r=0.60 m, 30°

A 40 N force is applied 0.60 m from the axis at 30° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.60(40)\sin 30° \qquad \text{torque}$$

$$\tau = 12.00\ \text{N}\cdot\text{m}$$

Answer

12.00 N · m

Torque, r=0.80 m, 0°

A 50 N force is applied 0.80 m from the axis at 0° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.80(50)\sin 0^\circ \qquad \text{torque}$$

$$\tau = 0.00\ \text{N}\cdot\text{m}(\textit{alongthearm} : \textit{notorque})$$

Answer

0.00 N · m

Torque, r=1.20 m, 90°

A 25 N force is applied 1.20 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 1.20(25)\sin 90° \qquad \text{torque}$$

$$\tau = 30.00\ \text{N}\cdot\text{m}$$

Answer

30.00 N · m

Torque, r=0.40 m, 45°

A 60 N force is applied 0.40 m from the axis at 45° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.40(60)\sin 45° \qquad \text{torque}$$

$$\tau = 16.97\ \text{N}\cdot\text{m}$$

Answer

16.97 N · m

Torque, r=0.70 m, 90°

R3

A 80 N force is applied 0.70 m from the axis at 90° to the arm. Find the torque.

$$\tau = rF\sin\theta = 0.70(80)\sin 90^\circ \qquad \text{torque}$$

$$\tau = 56.00\ \text{N}\cdot\text{m}$$

Answer

56.00 N · m

Inertia of a solid disk

Find the moment of inertia of a solid disk: $M = 2$ kg, $R = 0.50$ m ($I = \frac{1}{2}MR^2$).

$$I = \frac{1}{2}MR^2 = \frac{1}{2}2(0.50)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.25\ \text{kg} \cdot \text{m}^2$$

Answer

0.25 kg $\cdot$ m^2

Inertia of a hoop

Find the moment of inertia of a hoop: $M = 3$ kg, $R = 0.40$ m ($I = MR^2$).

$$I = MR^2 = 3(0.40)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.48 \text{ kg} \cdot \text{m}^2$$

Answer

0.48 kg · m^2

Inertia of a solid sphere

Find the moment of inertia of a solid sphere: $M = 5$ kg, $R = 0.20$ m ($I = \frac{2}{5}MR^2$).

$$I = \frac{2}{5}MR^2 = \frac{2}{5}5(0.20)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.08\ \text{kg} \cdot \text{m}^2$$

Answer

0.08 kg $\cdot$ m^2

Inertia of a point mass

Find the moment of inertia of a point mass: $M = 1$ kg, $R = 1.00$ m ($I = MR^2$).

$$I = MR^2 = 1(1.00)^2 \qquad \text{depends on shape \& axis}$$

$$I = 1.00\ \text{kg} \cdot \text{m}^2$$

Answer

$1.00\ \text{kg} \cdot \text{m}^2$

Inertia of a solid disk

Find the moment of inertia of a solid disk: $M = 4$ kg, $R = 0.30$ m ($I = \frac{1}{2}MR^2$).

$$I = \frac{1}{2}MR^2 = \frac{1}{2}4(0.30)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.18\ \text{kg} \cdot \text{m}^2$$

Answer

0.18 kg $\cdot$ m^2

Inertia of a hoop

R4

Find the moment of inertia of a hoop: $M = 2$ kg, $R = 0.60$ m ($I = MR^2$).

$$I = MR^2 = 2(0.60)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.72 \text{ kg} \cdot \text{m}^2$$

Answer

0.72 kg · m^2

Inertia of a solid sphere

R4

Find the moment of inertia of a solid sphere: $M = 10\ kg$, $R = 0.10\ m$ ($I = \frac{2}{5}MR^2$).

$$I = \frac{2}{5}MR^2 = \frac{2}{5}10(0.10)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.04\ \text{kg} \cdot \text{m}^2$$

Answer

$0.04\ \text{kg} \cdot \text{m}^2$

Inertia of a point mass

Find the moment of inertia of a point mass: $M = 0.5$ kg, $R = 0.80$ m ($I = MR^2$).

$$I = MR^2 = 0.5(0.80)^2 \qquad \text{depends on shape \& axis}$$

$$I = 0.32 \text{ kg} \cdot \text{m}^2$$

Answer

0.32 kg $\cdot$ m^2

Rod, two axes, L=2.0 m

A uniform rod ($M = 3$ kg, $L = 2.0$ m) find I about its center vs its end.

$$I_{\text{center}} = \tfrac{1}{12}ML^2 = 1.000\ \text{kg}\cdot\text{m}^2 \qquad \text{axis at middle}$$

$$I_{\text{end}} = \tfrac{1}{3}ML^2 = 4.000\ \text{kg}\cdot\text{m}^2 \qquad \text{harder to spin}$$

Answer

$$I_c = 1.000,\ I_e = 4.000\ \text{kg}\cdot\text{m}^2$$

Rod, two axes, L=1.5 m

R4

A uniform rod ($M = 2$ kg, $L = 1.5$ m) find I about its center vs its end.

$$I_{\text{center}} = \tfrac{1}{12}ML^2 = 0.375 \text{ kg} \cdot \text{m}^2 \quad \text{axis at middle}$$

$$I_{\text{end}} = \tfrac{1}{3}ML^2 = 1.500 \text{ kg} \cdot \text{m}^2 \quad \text{harder to spin}$$

Answer

$$I_c = 0.375,\ I_e = 1.500 \text{ kg} \cdot \text{m}^2$$

$\tau = I\alpha$, I=2.00

A rigid body with $I = 2.00$ kg·m^2 has angular acceleration 3.0 rad/s^2. Find the net torque.

$$\tau = I\alpha = 2.00(3.0) \qquad \text{rotational } F = ma$$
$$\tau = 6.00 \text{ N} \cdot \text{m}$$

Answer

6.00 N · m

$\tau = I\alpha$, I=0.50

A rigid body with $I = 0.50$ kg·m^2 has angular acceleration 8.0 rad/s^2. Find the net torque.

$$\tau = I\alpha = 0.50(8.0) \qquad \text{rotational } F = ma$$
$$\tau = 4.00 \text{ N} \cdot \text{m}$$

Answer

4.00 N · m

$\tau = I\alpha$, I=4.00

A rigid body with $I = 4.00$ kg·m^2 has angular acceleration 1.5 rad/s^2. Find the net torque.

$$\tau = I\alpha = 4.00(1.5) \qquad \text{rotational } F = ma$$
$$\tau = 6.00 \text{ N} \cdot \text{m}$$

Answer

6.00 N · m

$\tau = I\alpha$, I=10.00

A rigid body with $I = 10.00$ kg·m^2 has angular acceleration 0.5 rad/s^2. Find the net torque.

$$\tau = I\alpha = 10.00(0.5) \qquad \text{rotational } F = ma$$

$$\tau = 5.00 \text{ N} \cdot \text{m}$$

Answer

5.00 N · m

$\tau = I\alpha$, I=0.20

A rigid body with $I = 0.20$ kg·m^2 has angular acceleration 20.0 rad/s^2. Find the net torque.

$$\tau = I\alpha = 0.20(20.0) \qquad \text{rotational } F = ma$$
$$\tau = 4.00 \text{ N} \cdot \text{m}$$

Answer

4.00 N · m

$\tau = I\alpha$, I=1.50

A rigid body with $I = 1.50$ kg·m^2 has angular acceleration 4.0 rad/s^2. Find the net torque.

$$\tau = I\alpha = 1.50(4.0) \qquad \text{rotational } F = ma$$
$$\tau = 6.00 \text{ N} \cdot \text{m}$$

Answer

6.00 N · m

$\tau = I\alpha$, I=6.00

A rigid body with $I = 6.00$ kg·m^2 has angular acceleration 2.0 rad/s^2. Find the net torque.

$$\tau = I\alpha = 6.00(2.0) \qquad \text{rotational } F = ma$$
$$\tau = 12.00 \text{ N} \cdot \text{m}$$

Answer

12.00 N · m

Angular accel, 12 N·m

R5

A torque of 12 *N·m acts on* $I = 3.00$ *kg·m*^{2}*. Find the angular acceleration.*

$$\alpha = \frac{\tau}{I} = \frac{12}{3.00} \qquad \text{solve } \tau = I\alpha$$

$$\alpha = 4.00 \text{ rad/s}^2$$

Answer

4.00 rad/s^2

Angular accel, 5 N·m

A torque of 5 *N·m acts on* $I = 0.50$ *kg·m*^{2}*. Find the angular acceleration.*

$$\alpha = \frac{\tau}{I} = \frac{5}{0.50} \qquad \text{solve } \tau = I\alpha$$

$$\alpha = 10.00 \text{ rad/s}^2$$

Answer

10.00 rad/s^2

Angular accel, 40 N·m

R5

A torque of 40 N·m acts on $I = 8.00$ kg·m^2. Find the angular acceleration.

$$\alpha = \frac{\tau}{I} = \frac{40}{8.00} \qquad \text{solve } \tau = I\alpha$$

$$\alpha = 5.00 \text{ rad/s}^2$$

Answer

5.00 rad/s^2

Angular accel, 20 N·m

R5

A torque of 20 N·m acts on $I = 4.00$ kg·m^2. Find the angular acceleration.

$$\alpha = \frac{\tau}{I} = \frac{20}{4.00} \qquad \text{solve } \tau = I\alpha$$

$$\alpha = 5.00 \text{ rad/s}^2$$

Answer

5.00 rad/s^2

Angular accel, 3 N·m

A torque of 3 N·m acts on $I = 1.50$ kg·m^2. Find the angular acceleration.

$$\alpha = \frac{\tau}{I} = \frac{3}{1.50} \qquad \text{solve } \tau = I\alpha$$

$$\alpha = 2.00 \text{ rad/s}^2$$

Answer

2.00 rad/s^2

Rotational KE, I=2.00

Find the rotational kinetic energy of $I = 2.00$ kg·m^2 spinning at 5 rad/s.

$$KE_{\text{rot}} = \tfrac{1}{2} I\omega^2 = \tfrac{1}{2}(2.00)(5)^2 \qquad \text{energy of spin}$$

$$KE_{\text{rot}} = 25.0 \text{ J}$$

Answer

25.0 J

Rotational KE, I=0.50

Find the rotational kinetic energy of $I = 0.50$ kg·m^2 spinning at 10 rad/s.

$$KE_{\text{rot}} = \tfrac{1}{2} I\omega^2 = \tfrac{1}{2}(0.50)(10)^2 \qquad \text{energy of spin}$$

$$KE_{\text{rot}} = 25.0 \text{ J}$$

Answer

25.0 J

Rotational KE, I=4.00

Find the rotational kinetic energy of $I = 4.00$ kg·m^2 spinning at 3 rad/s.

$$KE_{\text{rot}} = \tfrac{1}{2} I\omega^2 = \tfrac{1}{2}(4.00)(3)^2 \qquad \text{energy of spin}$$

$$KE_{\text{rot}} = 18.0 \text{ J}$$

Answer

18.0 J

Rotational KE, I=0.20

Find the rotational kinetic energy of $I = 0.20$ kg·m^2 spinning at 20 rad/s.

$$KE_{\text{rot}} = \tfrac{1}{2} I\omega^2 = \tfrac{1}{2}(0.20)(20)^2 \qquad \text{energy of spin}$$

$$KE_{\text{rot}} = 40.0 \text{ J}$$

Answer

40.0 J

Rotational KE, I=10.00

Find the rotational kinetic energy of $I = 10.00$ kg·m^2 spinning at 2 rad/s.

$$KE_{\text{rot}} = \tfrac{1}{2} I\omega^2 = \tfrac{1}{2}(10.00)(2)^2 \qquad \text{energy of spin}$$

$$KE_{\text{rot}} = 20.0 \text{ J}$$

Answer

20.0 J

Rolling solid sphere, 4 m/s

A solid sphere ($m = 2$ kg) rolls without slipping at 4 m/s. Find its total kinetic energy ($I = 0.4mR^2$).

$$KE = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2(1 + 0.4) \qquad \text{translation + rotation, } \omega = v/R$$

$$KE = 22.40 \text{ J}$$

Answer

22.40 J

Rolling solid disk, 3 m/s

R6

A solid disk ($m = 3$ kg) rolls without slipping at 3 m/s. Find its total kinetic energy ($I = 0.5mR^2$).

$$KE = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2(1 + 0.5) \qquad \text{translation + rotation, } \omega = v/R$$

$$KE = 20.25 \text{ J}$$

Answer

20.25 J

Rolling hoop, 6 m/s

A hoop ($m = 1$ kg) rolls without slipping at 6 m/s. Find its total kinetic energy ($I = 1.0mR^2$).

$$KE = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2(1 + 1.0) \qquad \text{translation + rotation, } \omega = v/R$$

$$KE = 36.00 \text{ J}$$

Answer

36.00 J

Rolling solid sphere, 2 m/s

R6

A solid sphere ($m = 5$ kg) rolls without slipping at 2 m/s. Find its total kinetic energy ($I = 0.4mR^2$).

$$KE = \tfrac{1}{2}mv^2 + \tfrac{1}{2}I\omega^2 = \tfrac{1}{2}mv^2(1 + 0.4) \qquad \text{translation + rotation, } \omega = v/R$$

$$KE = 14.00 \text{ J}$$

Answer

14.00 J

Angular momentum, I=2.00

Find the angular momentum of $I = 2.00$ kg·m^2 spinning at 5 rad/s.

$$L = I\omega = 2.00(5) \qquad \text{rotational momentum}$$
$$L = 10.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

10.00 kg · m^2/s

Angular momentum, I=0.50

Find the angular momentum of $I = 0.50$ kg·m^2 spinning at 12 rad/s.

$$L = I\omega = 0.50(12) \qquad \text{rotational momentum}$$
$$L = 6.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

6.00 kg · m^2/s

Angular momentum, I=4.00

Find the angular momentum of $I = 4.00$ kg·m^2 spinning at 3 rad/s.

$$L = I\omega = 4.00(3) \qquad \text{rotational momentum}$$
$$L = 12.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

12.00 kg · m^2/s

Angular momentum, I=10.00

Find the angular momentum of $I = 10.00$ kg·m^2 spinning at 1.5 rad/s.

$$L = I\omega = 10.00(1.5) \qquad \text{rotational momentum}$$
$$L = 15.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

15.00 kg · m^2/s

Angular momentum, I=0.20

Find the angular momentum of $I = 0.20$ kg·m^2 spinning at 30 rad/s.

$$L = I\omega = 0.20(30) \qquad \text{rotational momentum}$$

$$L = 6.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

6.00 kg · m^2/s

Angular momentum, I=3.00

Find the angular momentum of $I = 3.00$ kg·m^2 spinning at 8 rad/s.

$$L = I\omega = 3.00(8) \qquad \text{rotational momentum}$$
$$L = 24.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

24.00 kg · m^2/s

Angular momentum, I=1.00

Find the angular momentum of $I = 1.00$ kg·m^2 spinning at 15 rad/s.

$$L = I\omega = 1.00(15) \qquad \text{rotational momentum}$$
$$L = 15.00 \text{ kg} \cdot \text{m}^2/\text{s}$$

Answer

15.00 kg · m^2/s

Point-mass $L = mvr$

A 0.50 kg mass moves 4 m/s in a circle of radius 2.0 m. Find its angular momentum.

$$L = mvr = 0.50(4)(2.0) \quad \text{for a point mass}$$

$$L = 4.00\ \text{kg} \cdot \text{m}^2/\text{s}$$

Answer

4.00 kg · m^2/s

Point-mass $L = mvr$

A 2.00 kg mass moves 3 m/s in a circle of radius 1.5 m. Find its angular momentum.

$$L = mvr = 2.00(3)(1.5) \quad \text{for a point mass}$$
$$L = 9.00\ \text{kg} \cdot \text{m}^2/\text{s}$$

Answer

9.00 kg · m^2/s

Point-mass $L = mvr$

A 0.20 kg mass moves 10 m/s in a circle of radius 0.5 m. Find its angular momentum.

$$L = mvr = 0.20(10)(0.5) \quad \text{for a point mass}$$

$$L = 1.00\ \text{kg} \cdot \text{m}^2/\text{s}$$

Answer

1.00 kg · m^2/s

Skater, I:6→2

A skater with $I_1 = 6$ kg·m^2 spins at 2 rad/s, then pulls in to $I_2 = 2$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{6(2)}{2} = 6.00 \text{ rad/s} \qquad \text{spins faster}$$

Answer

6.00 rad/s

Skater, I:4→1

A skater with $I_1 = 4$ kg·m^2 spins at 3 rad/s, then pulls in to $I_2 = 1$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{4(3)}{1} = 12.00 \text{ rad/s} \qquad \text{spins faster}$$

Answer

12.00 rad/s

Skater, I:8→3

A skater with $I_1 = 8$ kg·m^2 spins at 1.5 rad/s, then pulls in to $I_2 = 3$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2$$ no external torque: L conserved

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{8(1.5)}{3} = 4.00 \text{ rad/s}$$ spins faster

Answer

4.00 rad/s

Skater, I:5→2

R8

A skater with $I_1 = 5$ kg·m^2 spins at 4 rad/s, then pulls in to $I_2 = 2$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2$$ — no external torque: L conserved

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{5(4)}{2} = 10.00 \text{ rad/s}$$ — spins faster

Answer

10.00 rad/s

Skater, I:10→4

A skater with $I_1 = 10$ kg·m^2 spins at 1 rad/s, then pulls in to $I_2 = 4$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{10(1)}{4} = 2.50 \text{ rad/s} \qquad \text{spins faster}$$

Answer

2.50 rad/s

Skater, I:3→1

A skater with $I_1 = 3$ kg·m^2 spins at 6 rad/s, then pulls in to $I_2 = 1$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{3(6)}{1} = 18.00 \text{ rad/s} \qquad \text{spins faster}$$

Answer

18.00 rad/s

Skater, I:12→4

R8

A skater with $I_1 = 12$ kg·m^2 spins at 2 rad/s, then pulls in to $I_2 = 4$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2$$ — no external torque: L conserved

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{12(2)}{4} = 6.00 \text{ rad/s}$$ — spins faster

Answer

6.00 rad/s

Skater, I:7→2

A skater with $I_1 = 7$ kg·m^2 spins at 3 rad/s, then pulls in to $I_2 = 2$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{7(3)}{2} = 10.50 \text{ rad/s} \qquad \text{spins faster}$$

Answer

10.50 rad/s

Skater, I:2→5

A skater with $I_1 = 2$ kg·m^2 spins at 10 rad/s, then pulls in to $I_2 = 5$ kg·m^2. Find the new angular speed.

$$I_1\omega_1 = I_2\omega_2 \qquad \text{no external torque: } L \text{ conserved}$$

$$\omega_2 = \frac{I_1\omega_1}{I_2} = \frac{2(10)}{5} = 4.00 \text{ rad/s} \qquad \text{spins faster}$$

Answer

4.00 rad/s

Practice more, then watch the walk-through

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Every skill in the unit, worked one problem at a time

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75 problems

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Restoring force, k=200, x=0.10

A spring ($k = 200$ N/m) is displaced 0.10 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 200(0.10) \qquad \text{restoring: points back to center}$$

$$|F| = 20.0 \text{ N}$$

Answer

20.0 N

Restoring force, k=500, x=0.05

A spring ($k = 500$ N/m) is displaced 0.05 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 500(0.05) \qquad \text{restoring: points back to center}$$

$$|F| = 25.0 \text{ N}$$

Answer

25.0 N

Restoring force, k=50, x=0.20

A spring ($k = 50$ N/m) is displaced 0.20 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 50(0.20) \qquad \text{restoring: points back to center}$$
$$|F| = 10.0 \text{ N}$$

Answer

10.0 N

Restoring force, k=800, x=0.15

A spring ($k = 800$ N/m) is displaced 0.15 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 800(0.15) \qquad \text{restoring: points back to center}$$

$$|F| = 120.0 \text{ N}$$

Answer

120.0 N

Restoring force, k=300, x=0.25

A spring ($k = 300$ N/m) is displaced 0.25 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 300(0.25) \qquad \text{restoring: points back to center}$$

$$|F| = 75.0 \text{ N}$$

Answer

75.0 N

Restoring force, k=1000, x=0.08

A spring ($k = 1000$ N/m) is displaced 0.08 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 1000(0.08) \qquad \text{restoring: points back to center}$$

$$|F| = 80.0 \text{ N}$$

Answer

80.0 N

Restoring force, k=120, x=0.30

A spring ($k = 120$ N/m) is displaced 0.30 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 120(0.30) \qquad \text{restoring: points back to center}$$

$$|F| = 36.0 \text{ N}$$

Answer

36.0 N

Restoring force, k=400, x=0.12

A spring ($k = 400$ N/m) is displaced 0.12 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 400(0.12) \qquad \text{restoring: points back to center}$$

$$|F| = 48.0 \text{ N}$$

Answer

48.0 N

Restoring force, k=250, x=0.16

A spring ($k = 250$ N/m) is displaced 0.16 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 250(0.16) \qquad \text{restoring: points back to center}$$

$$|F| = 40.0 \text{ N}$$

Answer

40.0 N

Restoring force, k=700, x=0.09

A spring ($k = 700$ N/m) is displaced 0.09 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 700(0.09)$$

restoring: points back to center

$$|F| = 63.0 \text{ N}$$

Answer

63.0 N

Restoring force, k=150, x=0.22

A spring ($k = 150$ N/m) is displaced 0.22 m from equilibrium. Find the magnitude of the restoring force.

$$|F| = kx = 150(0.22) \qquad \text{restoring: points back to center}$$

$$|F| = 33.0 \text{ N}$$

Answer

33.0 N

Accel at displacement, 0.5 kg

A 0.5 kg mass on a 200 N/m spring is 0.10 m from equilibrium. Find its acceleration there.

$$a = \frac{kx}{m} = \frac{200(0.10)}{0.5} \qquad a = F/m, \text{ greatest at the ends}$$

$$a = 40.00 \text{ m/s}^2$$

Answer

40.00 m/s^2

Accel at displacement, 2 kg

A 2 kg mass on a 400 N/m spring is 0.20 m from equilibrium. Find its acceleration there.

$$a = \frac{kx}{m} = \frac{400(0.20)}{2}$$

$a = F/m$, greatest at the ends

$$a = 40.00 \text{ m/s}^2$$

Answer

40.00 m/s^2

Accel at displacement, 1 kg

S1

A 1 *kg mass on a* 300 *N/m spring is* 0.15 *m from equilibrium. Find its acceleration there.*

$$a = \frac{kx}{m} = \frac{300(0.15)}{1}$$

$a = F/m$, greatest at the ends

$$a = 45.00 \text{ m/s}^2$$

Answer

45.00 m/s^2

Accel at displacement, 0.3 kg

A 0.3 kg mass on a 600 N/m spring is 0.05 m from equilibrium. Find its acceleration there.

$$a = \frac{kx}{m} = \frac{600(0.05)}{0.3}$$

$a = F/m$, greatest at the ends

$$a = 100.00 \text{ m/s}^2$$

Answer

100.00 m/s^2

SHM reasoning

Where in an oscillation is the speed greatest?

idea = at equilibrium energy trades KE and PE

Answer

at equilibrium

SHM reasoning

Where is the restoring force (and acceleration) greatest?

idea = at the extremes energy trades KE and PE

Answer

at the extremes

SHM reasoning

At the turning points of an oscillation, what is the speed?

idea $=$ $v = 0$ energy trades KE and PE

Answer

$v = 0$

Spring period, 2.00 kg, 200 N/m

Find the period of a 2.00 kg mass on a 200 N/m spring.

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{2.00/200}$$ mass-spring period

$$T = 0.628 \text{ s}$$ amplitude doesn't matter

Answer

0.628 s

Spring period, 0.50 kg, 50 N/m

S2

Find the period of a 0.50 *kg mass on a* 50 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.50/50} \qquad \text{mass-spring period}$$

$$T = 0.628\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 1.00 kg, 100 N/m

Find the period of a 1.00 *kg mass on a* 100 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{1.00/100} \qquad \text{mass-spring period}$$

$$T = 0.628 \text{ s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 4.00 kg, 400 N/m

Find the period of a 4.00 kg mass on a 400 N/m spring.

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{4.00/400} \qquad \text{mass-spring period}$$

$$T = 0.628\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 0.25 kg, 100 N/m

Find the period of a 0.25 *kg mass on a* 100 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.25/100} \qquad \text{mass-spring period}$$

$$T = 0.314 \text{ s} \qquad \text{amplitude doesn't matter}$$

Answer

0.314 s

Spring period, 3.00 kg, 300 N/m

Find the period of a 3.00 *kg mass on a* 300 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{3.00/300} \qquad \text{mass-spring period}$$

$$T = 0.628\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 0.10 kg, 40 N/m

S2

Find the period of a 0.10 *kg mass on a* 40 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.10/40} \qquad \text{mass-spring period}$$

$$T = 0.314\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.314 s

Spring period, 5.00 kg, 500 N/m

Find the period of a 5.00 *kg mass on a* 500 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{5.00/500} \qquad \text{mass-spring period}$$

$$T = 0.628\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 0.80 kg, 320 N/m

Find the period of a 0.80 *kg mass on a* 320 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{0.80/320} \qquad \text{mass-spring period}$$

$$T = 0.314\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.314 s

Spring period, 1.50 kg, 150 N/m

Find the period of a 1.50 *kg mass on a* 150 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{1.50/150} \qquad \text{mass-spring period}$$

$$T = 0.628\ \text{s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Spring period, 2.50 kg, 250 N/m

Find the period of a 2.50 *kg mass on a* 250 *N/m spring.*

$$T = 2\pi\sqrt{m/k} = 2\pi\sqrt{2.50/250} \qquad \text{mass-spring period}$$

$$T = 0.628 \text{ s} \qquad \text{amplitude doesn't matter}$$

Answer

0.628 s

Frequency, 2.00 kg, 200 N/m

S2

Find the frequency of a 2.00 kg mass on a 200 N/m spring.

$$T = 2\pi\sqrt{m/k} = 0.628 \text{ s} \qquad \text{period first}$$

$$f = \frac{1}{T} = 1.59 \text{ Hz} \qquad \text{cycles per second}$$

Answer

1.59 Hz

Frequency, 0.50 kg, 50 N/m

Find the frequency of a 0.50 kg mass on a 50 N/m spring.

$$T = 2\pi\sqrt{m/k} = 0.628 \text{ s} \qquad \text{period first}$$

$$f = \frac{1}{T} = 1.59 \text{ Hz} \qquad \text{cycles per second}$$

Answer

1.59 Hz

Frequency, 1.00 kg, 400 N/m

S2

Find the frequency of a 1.00 kg mass on a 400 N/m spring.

$$T = 2\pi\sqrt{m/k} = 0.314 \text{ s} \qquad \text{period first}$$

$$f = \frac{1}{T} = 3.18 \text{ Hz} \qquad \text{cycles per second}$$

Answer

3.18 Hz

Angular freq, 2.00 kg, 200 N/m

Find the angular frequency ω of a 2.00 kg mass on a 200 N/m spring.

$$\omega = \sqrt{k/m} = \sqrt{200/2.00} \qquad \omega = 2\pi f$$

$$\omega = 10.00 \text{ rad/s}$$

Answer

10.00 rad/s

Angular freq, 1.00 kg, 100 N/m

Find the angular frequency ω of a 1.00 kg mass on a 100 N/m spring.

$$\omega = \sqrt{k/m} = \sqrt{100/1.00} \qquad \omega = 2\pi f$$

$$\omega = 10.00 \text{ rad/s}$$

Answer

10.00 rad/s

Angular freq, 0.50 kg, 800 N/m

Find the angular frequency ω of a 0.50 kg mass on a 800 N/m spring.

$$\omega = \sqrt{k/m} = \sqrt{800/0.50} \qquad \omega = 2\pi f$$

$$\omega = 40.00 \text{ rad/s}$$

Answer

40.00 rad/s

Angular freq, 4.00 kg, 100 N/m

Find the angular frequency ω of a 4.00 kg mass on a 100 N/m spring.

$$\omega = \sqrt{k/m} = \sqrt{100/4.00} \qquad \omega = 2\pi f$$

$$\omega = 5.00 \text{ rad/s}$$

Answer

5.00 rad/s

Find k from T=1.0 s

A 2 kg mass oscillates with period 1.0 s. Find the spring constant.

$$k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2(2)}{(1.0)^2} \qquad \text{solve } T = 2\pi\sqrt{m/k}$$

$$k = 79.0 \text{ N/m}$$

Answer

79.0 N/m

Find k from T=0.5 s

A 0.5 kg mass oscillates with period 0.5 s. Find the spring constant.

$$k = \frac{4\pi^2 m}{T^2} = \frac{4\pi^2(0.5)}{(0.5)^2} \qquad \text{solve } T = 2\pi\sqrt{m/k}$$

$$k = 79.0 \text{ N/m}$$

Answer

79.0 N/m

Pendulum period, L=1.00 m

Find the period of a simple pendulum 1.00 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.00/9.8}$$ depends on length, not mass

$$T = 2.007 \text{ s}$$

Answer

2.007 s

Pendulum period, L=0.50 m

Find the period of a simple pendulum 0.50 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{0.50/9.8}$$ depends on length, not mass

$$T = 1.419 \text{ s}$$

Answer

1.419 s

Pendulum period, L=2.00 m

Find the period of a simple pendulum 2.00 m long ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{2.00/9.8}$$ depends on length, not mass

$$T = 2.838 \text{ s}$$

Answer

2.838 s

Pendulum period, L=0.25 m

Find the period of a simple pendulum 0.25 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{0.25/9.8}$$ depends on length, not mass

$$T = 1.004 \text{ s}$$

Answer

1.004 s

Pendulum period, L=1.50 m

Find the period of a simple pendulum 1.50 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.50/9.8}$$ depends on length, not mass

$$T = 2.458 \text{ s}$$

Answer

2.458 s

Pendulum period, L=0.80 m

Find the period of a simple pendulum 0.80 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{0.80/9.8}$$ depends on length, not mass

$$T = 1.795 \text{ s}$$

Answer

1.795 s

Pendulum period, L=3.00 m

Find the period of a simple pendulum 3.00 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{3.00/9.8}$$ depends on length, not mass

$$T = 3.476 \text{ s}$$

Answer

3.476 s

Pendulum period, L=0.10 m

Find the period of a simple pendulum 0.10 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{0.10/9.8}$$ depends on length, not mass

$$T = 0.635 \text{ s}$$

Answer

0.635 s

Pendulum period, L=0.40 m

Find the period of a simple pendulum 0.40 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{0.40/9.8}$$ depends on length, not mass

$$T = 1.269 \text{ s}$$

Answer

1.269 s

Pendulum period, L=1.20 m

Find the period of a simple pendulum 1.20 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.20/9.8}$$ depends on length, not mass

$$T = 2.199 \text{ s}$$

Answer

2.199 s

Pendulum period, L=2.50 m

Find the period of a simple pendulum 2.50 *m long* ($g = 9.8$).

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{2.50/9.8}$$ depends on length, not mass

$$T = 3.173 \text{ s}$$

Answer

3.173 s

Length for T=2.0 s

How long is a pendulum with period 2.0 s ($g = 9.8$)?

$$L = \frac{gT^2}{4\pi^2} = \frac{9.8(2.0)^2}{4\pi^2} \qquad \text{solve } T = 2\pi\sqrt{L/g}$$

$$L = 0.993 \text{ m}$$

Answer

0.993 m

Length for T=1.0 s

How long is a pendulum with period 1.0 s ($g = 9.8$)?

$$L = \frac{gT^2}{4\pi^2} = \frac{9.8(1.0)^2}{4\pi^2} \qquad \text{solve } T = 2\pi\sqrt{L/g}$$

$$L = 0.248 \text{ m}$$

Answer

0.248 m

Length for T=3.0 s

How long is a pendulum with period 3.0 s ($g = 9.8$)?

$$L = \frac{gT^2}{4\pi^2} = \frac{9.8(3.0)^2}{4\pi^2} \qquad \text{solve } T = 2\pi\sqrt{L/g}$$

$$L = 2.234 \text{ m}$$

Answer

2.234 m

Pendulum on the Moon

A 1.0 m pendulum swings on the Moon ($g = 1.6$). Find its period.

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.0/1.6}$$ weaker/stronger gravity

$$T = 4.967 \text{ s}$$

Answer

4.967 s

Pendulum on Mars

A 1.0 m pendulum swings on Mars ($g = 3.7$). Find its period.

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.0/3.7}$$ weaker/stronger gravity

$$T = 3.266 \text{ s}$$

Answer

3.266 s

Pendulum on Jupiter

A 1.0 m pendulum swings on Jupiter ($g = 24.8$). Find its period.

$$T = 2\pi\sqrt{L/g} = 2\pi\sqrt{1.0/24.8}$$ weaker/stronger gravity

$$T = 1.262 \text{ s}$$

Answer

1.262 s

Total energy, k=200, A=0.10

A spring ($k = 200$ N/m) oscillates with amplitude 0.10 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(200)(0.10)^2 \qquad \text{all PE at the extreme}$$

$$E = 1.000 \text{ J} \qquad \text{constant throughout}$$

Answer

1.000 J

Total energy, k=500, A=0.20

A spring ($k = 500$ N/m) oscillates with amplitude 0.20 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(500)(0.20)^2 \qquad \text{all PE at the extreme}$$

$$E = 10.000 \text{ J} \qquad \text{constant throughout}$$

Answer

10.000 J

Total energy, k=100, A=0.15

A spring ($k = 100$ N/m) oscillates with amplitude 0.15 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(100)(0.15)^2 \qquad \text{all PE at the extreme}$$

$$E = 1.125 \text{ J} \qquad \text{constant throughout}$$

Answer

1.125 J

Total energy, k=800, A=0.05

A spring ($k = 800$ N/m) oscillates with amplitude 0.05 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(800)(0.05)^2 \qquad \text{all PE at the extreme}$$

$$E = 1.000 \text{ J} \qquad \text{constant throughout}$$

Answer

1.000 J

Total energy, k=300, A=0.25

A spring ($k = 300$ N/m) oscillates with amplitude 0.25 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(300)(0.25)^2 \qquad \text{all PE at the extreme}$$

$$E = 9.375 \text{ J} \qquad \text{constant throughout}$$

Answer

9.375 J

Total energy, k=400, A=0.10

A spring ($k = 400$ N/m) oscillates with amplitude 0.10 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(400)(0.10)^2 \qquad \text{all PE at the extreme}$$

$$E = 2.000 \text{ J} \qquad \text{constant throughout}$$

Answer

2.000 J

Total energy, k=250, A=0.18

A spring ($k = 250$ N/m) oscillates with amplitude 0.18 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(250)(0.18)^2 \qquad \text{all PE at the extreme}$$

$$E = 4.050 \text{ J} \qquad \text{constant throughout}$$

Answer

4.050 J

Total energy, k=600, A=0.12

A spring ($k = 600$ N/m) oscillates with amplitude 0.12 m. Find the total mechanical energy.

$$E = \tfrac{1}{2}kA^2 = \tfrac{1}{2}(600)(0.12)^2 \qquad \text{all PE at the extreme}$$

$$E = 4.320 \text{ J} \qquad \text{constant throughout}$$

Answer

4.320 J

Max speed, 0.50 kg, A=0.10

A 0.50 kg mass on a 200 N/m spring oscillates with amplitude 0.10 m. Find its maximum speed.

$$v_{\max} = A\sqrt{k/m} = 0.10\sqrt{200/0.50} \qquad \text{at equilibrium: all KE}$$

$$v_{\max} = 2.000 \text{ m/s}$$

Answer

2.000 m/s

Max speed, 2.00 kg, A=0.20

A 2.00 kg mass on a 400 N/m spring oscillates with amplitude 0.20 m. Find its maximum speed.

$$v_{max} = A\sqrt{k/m} = 0.20\sqrt{400/2.00} \qquad \text{at equilibrium: all KE}$$

$$v_{max} = 2.828 \text{ m/s}$$

Answer

2.828 m/s

Max speed, 1.00 kg, A=0.15

A 1.00 kg mass on a 100 N/m spring oscillates with amplitude 0.15 m. Find its maximum speed.

$$v_{\max} = A\sqrt{k/m} = 0.15\sqrt{100/1.00} \qquad \text{at equilibrium: all KE}$$

$$v_{\max} = 1.500 \text{ m/s}$$

Answer

1.500 m/s

Max speed, 0.25 kg, A=0.05

A 0.25 kg mass on a 100 N/m spring oscillates with amplitude 0.05 m. Find its maximum speed.

$$v_{max} = A\sqrt{k/m} = 0.05\sqrt{100/0.25} \qquad \text{at equilibrium: all KE}$$

$$v_{max} = 1.000 \text{ m/s}$$

Answer

1.000 m/s

Max speed, 4.00 kg, A=0.10

A 4.00 kg mass on a 400 N/m spring oscillates with amplitude 0.10 m. Find its maximum speed.

$$v_{max} = A\sqrt{k/m} = 0.10\sqrt{400/4.00} \qquad \text{at equilibrium: all KE}$$

$$v_{max} = 1.000 \text{ m/s}$$

Answer

1.000 m/s

Max speed, 0.50 kg, A=0.20

A 0.50 kg mass on a 800 N/m spring oscillates with amplitude 0.20 m. Find its maximum speed.

$$v_{max} = A\sqrt{k/m} = 0.20\sqrt{800/0.50} \qquad \text{at equilibrium: all KE}$$

$$v_{max} = 8.000 \text{ m/s}$$

Answer

8.000 m/s

KE at x=0.10, A=0.20

A 200 N/m spring with amplitude 0.20 m is at displacement 0.10 m. Find the potential and kinetic energy there.

$$E = \tfrac{1}{2}kA^2 = 4.000 \text{ J} \quad \text{total}$$

$$PE = \tfrac{1}{2}kx^2 = 1.000 \text{ J} \quad \text{stored in the spring}$$

$$KE = E - PE = 3.000 \text{ J} \quad \text{the rest is motion}$$

Answer

$PE = 1.000$, $KE = 3.000$ J

KE at x=0.05, A=0.15

A 400 N/m spring with amplitude 0.15 m is at displacement 0.05 m. Find the potential and kinetic energy there.

$$E = \tfrac{1}{2}kA^2 = 4.500 \text{ J} \quad \text{total}$$

$$PE = \tfrac{1}{2}kx^2 = 0.500 \text{ J} \quad \text{stored in the spring}$$

$$KE = E - PE = 4.000 \text{ J} \quad \text{the rest is motion}$$

Answer

$$PE = 0.500,\ KE = 4.000 \text{ J}$$

KE at x=0.20, A=0.30

A 100 N/m spring with amplitude 0.30 m is at displacement 0.20 m. Find the potential and kinetic energy there.

$$E = \tfrac{1}{2}kA^2 = 4.500 \text{ J} \quad \text{total}$$

$$PE = \tfrac{1}{2}kx^2 = 2.000 \text{ J} \quad \text{stored in the spring}$$

$$KE = E - PE = 2.500 \text{ J} \quad \text{the rest is motion}$$

Answer

$$PE = 2.000,\ KE = 2.500 \text{ J}$$

KE at x=0.06, A=0.10

A 500 N/m spring with amplitude 0.10 m is at displacement 0.06 m. Find the potential and kinetic energy there.

$$E = \tfrac{1}{2}kA^2 = 2.500 \text{ J} \quad \text{total}$$

$$PE = \tfrac{1}{2}kx^2 = 0.900 \text{ J} \quad \text{stored in the spring}$$

$$KE = E - PE = 1.600 \text{ J} \quad \text{the rest is motion}$$

Answer

$$PE = 0.900,\ KE = 1.600 \text{ J}$$

Amplitude from 4 J

An oscillator on a 200 N/m spring has 4 J of energy. Find its amplitude.

$$A = \sqrt{2E/k} = \sqrt{2(4)/200} \qquad \text{solve } E = \tfrac{1}{2}kA^2$$

$$A = 0.200 \text{ m}$$

Answer

0.200 m

Amplitude from 10 J

An oscillator on a 500 N/m spring has 10 J of energy. Find its amplitude.

$$A = \sqrt{2E/k} = \sqrt{2(10)/500} \qquad \text{solve } E = \tfrac{1}{2}kA^2$$

$$A = 0.200 \text{ m}$$

Answer

0.200 m

Practice more, then watch the walk-through

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Fluids — Full Worked Session

Every skill in the unit, worked one problem at a time

Set up → solve → answer
77 problems

Lesson `ap1.fluids.session`

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Density, 2.00 kg / 0.0010 m^3

Find the density of a 2.00 *kg object with volume* 0.0010 m^3.

$$\rho = \frac{m}{V} = \frac{2.00}{0.0010}$$

mass per volume

$$\rho = 2000.0 \text{ kg/m}^3$$

Answer

2000.0 kg/m^3

Density, 5.00 kg / 0.0020 m^3

Find the density of a 5.00 *kg object with volume* 0.0020 m^3.

$$\rho = \frac{m}{V} = \frac{5.00}{0.0020}$$

mass per volume

$$\rho = 2500.0 \text{ kg/m}^3$$

Answer

2500.0 kg/m^3

Density, 19.30 kg / 0.0010 m^3

Find the density of a 19.30 *kg object with volume* 0.0010 m^3 *(gold).*

$$\rho = \frac{m}{V} = \frac{19.30}{0.0010}$$ mass per volume

$$\rho = 1.93 \times 10^4 \text{ kg/m}^3$$

Answer

1.93×10^4 kg/m^3

Density, 0.50 kg / 0.0005 m^3

Find the density of a 0.50 *kg object with volume* 0.0005 m^3.

$$\rho = \frac{m}{V} = \frac{0.50}{0.0005}$$

mass per volume

$$\rho = 1000.0 \text{ kg/m}^3$$

Answer

1000.0 kg/m^3

Density, 100.00 kg / 0.0500 m^3

Find the density of a 100.00 *kg object with volume* 0.0500 m^3.

$$\rho = \frac{m}{V} = \frac{100.00}{0.0500}$$

mass per volume

$$\rho = 2000.0 \text{ kg/m}^3$$

Answer

2000.0 kg/m^3

Density, 8.90 kg / 0.0010 m^3

Find the density of a 8.90 *kg object with volume* 0.0010 m^3 *(copper).*

$$\rho = \frac{m}{V} = \frac{8.90}{0.0010}$$ mass per volume

$$\rho = 8900.0 \text{ kg/m}^3$$

Answer

8900.0 kg/m^3

Mass from density, 1000

A volume of 0.0030 m^3 *has density* 1000 kg/m^3. *Find its mass.*

$$m = \rho V = 1000(0.0030) \qquad \text{rearrange } \rho = m/V$$
$$m = 3.00 \text{ kg}$$

Answer
3.00 kg

Mass from density, 800

A volume of $0.0050\ m^3$ *has density* $800\ kg/m^3$*. Find its mass.*

$$m = \rho V = 800(0.0050) \qquad \text{rearrange } \rho = m/V$$

$$m = 4.00\ \text{kg}$$

Answer

4.00 kg

Mass from density, 13600

A volume of $0.0001\ m^3$ *has density* $13600\ kg/m^3$*. Find its mass.*

$$m = \rho V = 13600(0.0001) \qquad \text{rearrange } \rho = m/V$$

$$m = 1.36\ \text{kg}$$

Answer

1.36 kg

Volume from 6 kg

A 6 kg object has density 2000 kg/m³. Find its volume.

$$V = \frac{m}{\rho} = \frac{6}{2000} \qquad \text{rearrange } \rho = m/V$$

$$V = 3.00 \times 10^{-3}\ \text{m}^3$$

Answer

$3.00 \times 10^{-3}\ \text{m}^3$

Volume from 10 kg

A 10 kg object has density 500 kg/m³. Find its volume.

$$V = \frac{m}{\rho} = \frac{10}{500}$$

rearrange $\rho = m/V$

$$V = 2.00 \times 10^{-2}\ \text{m}^3$$

Answer

$2.00 \times 10^{-2}\ \text{m}^3$

Pressure, 200 N / 0.50 m^2

A force of 200 *N presses on* 0.50 m^2. *Find the pressure.*

$$P = \frac{F}{A} = \frac{200}{0.50}$$

force per area

$$P = 400.0 \text{ Pa}$$

Answer

400.0 Pa

Pressure, 1000 N / 0.01 m^2

A force of 1000 *N presses on* 0.01 m^2. *Find the pressure.*

$$P = \frac{F}{A} = \frac{1000}{0.01}$$

force per area

$$P = 1.00 \times 10^5 \text{ Pa}$$

Answer

1.00×10^5 Pa

Pressure, 50 N / 2.00 m^2

A force of 50 *N presses on* 2.00 m^2. *Find the pressure.*

$$P = \frac{F}{A} = \frac{50}{2.00}$$

force per area

$$P = 25.0 \text{ Pa}$$

Answer

25.0 Pa

Pressure, 500 N / 0.05 m^2

A force of 500 *N presses on* 0.05 m^2. *Find the pressure.*

$$P = \frac{F}{A} = \frac{500}{0.05}$$

force per area

$$P = 1.00 \times 10^4 \text{ Pa}$$

Answer

1.00×10^4 Pa

Pressure, 300 N / 0.10 m^2

A force of 300 *N presses on* 0.10 m^2. *Find the pressure.*

$$P = \frac{F}{A} = \frac{300}{0.10}$$

force per area

$$P = 3000.0 \text{ Pa}$$

Answer

3000.0 Pa

Gauge pressure, 10 m water

Find the gauge pressure 10 *m below the surface of water* ($\rho = 1000\ kg/m^3$, $g = 9.8$).

$$P = \rho gh = 1000(9.8)(10) \qquad \text{weight of fluid above}$$

$$P = 9.80 \times 10^4 \text{ Pa}$$

Answer

9.80×10^4 Pa

Gauge pressure, 5 m water

Find the gauge pressure 5 *m below the surface of water* ($\rho = 1000\ kg/m^3$, $g = 9.8$).

$$P = \rho g h = 1000(9.8)(5) \qquad \text{weight of fluid above}$$

$$P = 4.90 \times 10^4\ \text{Pa}$$

Answer

4.90×10^4 Pa

Gauge pressure, 20 m water

Find the gauge pressure 20 m below the surface of water ($\rho = 1000\ kg/m^3$, $g = 9.8$).

$$P = \rho gh = 1000(9.8)(20) \qquad \text{weight of fluid above}$$

$$P = 1.96 \times 10^5 \text{ Pa}$$

Answer

1.96×10^5 Pa

Gauge pressure, 2 m mercury

Find the gauge pressure 2 m below the surface of mercury ($\rho = 13600\ kg/m^3$, $g = 9.8$).

$$P = \rho g h = 13600(9.8)(2) \qquad \text{weight of fluid above}$$

$$P = 2.67 \times 10^5\ \text{Pa}$$

Answer

2.67×10^5 Pa

Gauge pressure, 30 m seawater

Find the gauge pressure 30 m below the surface of seawater ($\rho = 1025\ kg/m^3$, $g = 9.8$).

$$P = \rho g h = 1025(9.8)(30) \qquad \text{weight of fluid above}$$

$$P = 3.01 \times 10^5\ \text{Pa}$$

Answer

3.01×10^5 Pa

Gauge pressure, 8 m oil

Find the gauge pressure 8 m below the surface of oil ($\rho = 800$ kg/m^3, $g = 9.8$).

$$P = \rho g h = 800(9.8)(8) \qquad \text{weight of fluid above}$$

$$P = 6.27 \times 10^4 \text{ Pa}$$

Answer

6.27×10^4 Pa

Absolute pressure, 10 m deep

Find the absolute pressure 10 *m underwater (*$P_{atm} = 1.01 \times 10^5$ *Pa).*

$$P_{\text{gauge}} = \rho g h = 9.80 \times 10^4 \text{ Pa} \quad \text{fluid column}$$

$$P_{\text{abs}} = P_{\text{atm}} + P_{\text{gauge}} = 1.99 \times 10^5 \text{ Pa} \quad \text{add the atmosphere}$$

Answer

1.99×10^5 Pa

Absolute pressure, 20 m deep

Find the absolute pressure 20 m underwater ($P_{atm} = 1.01 \times 10^5$ Pa).

$$P_{\text{gauge}} = \rho g h = 1.96 \times 10^5 \text{ Pa} \quad \text{fluid column}$$

$$P_{\text{abs}} = P_{\text{atm}} + P_{\text{gauge}} = 2.97 \times 10^5 \text{ Pa} \quad \text{add the atmosphere}$$

Answer

2.97×10^5 Pa

Hydraulic, 100 N in

A hydraulic lift: 100 N pushes on a 0.010 m^2 piston; the output piston is 0.50 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 100\frac{0.50}{0.010} = 5000.0 \text{ N}$$

force multiplied

Answer

5000.0 N

Hydraulic, 50 N in

A hydraulic lift: 50 N pushes on a 0.005 m^2 piston; the output piston is 0.20 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 50\frac{0.20}{0.005} = 2000.0 \text{ N}$$

force multiplied

Answer

2000.0 N

Hydraulic, 200 N in

A hydraulic lift: 200 N pushes on a 0.020 m^2 piston; the output piston is 1.00 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 200\frac{1.00}{0.020} = 1.00 \times 10^4 \text{ N}$$

force multiplied

Answer

1.00×10^4 N

Hydraulic, 80 N in

A hydraulic lift: 80 N pushes on a 0.010 m^2 piston; the output piston is 0.40 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 80\frac{0.40}{0.010} = 3200.0 \text{ N}$$

force multiplied

Answer

3200.0 N

Hydraulic, 150 N in

A hydraulic lift: 150 *N pushes on a* 0.030 m^2 *piston; the output piston is* 0.60 m^2. *Find the output force.*

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 150\frac{0.60}{0.030} = 3000.0 \text{ N}$$

force multiplied

Answer

3000.0 N

Hydraulic, 120 N in

A hydraulic lift: 120 *N pushes on a* 0.020 m^2 *piston; the output piston is* 0.80 m^2. *Find the output force.*

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1 \frac{A_2}{A_1} = 120 \frac{0.80}{0.020} = 4800.0 \text{ N}$$

force multiplied

Answer

4800.0 N

Hydraulic, 60 N in

A hydraulic lift: 60 N pushes on a 0.004 m^2 piston; the output piston is 0.16 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1 \frac{A_2}{A_1} = 60 \frac{0.16}{0.004} = 2400.0 \text{ N}$$

force multiplied

Answer

2400.0 N

Hydraulic, 250 N in

A hydraulic lift: 250 N pushes on a 0.050 m^2 piston; the output piston is 1.00 m^2. Find the output force.

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

Pascal: pressure equal

$$F_2 = F_1\frac{A_2}{A_1} = 250\frac{1.00}{0.050} = 5000.0 \text{ N}$$

force multiplied

Answer

5000.0 N

Buoyant force, V=0.0020 m^3

Find the buoyant force on a $0.0020\ m^3$ *object fully submerged in water (*$\rho = 1000$, $g = 9.8$*).*

$$F_b = \rho_f V g = 1000(0.0020)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 19.60\ \text{N} \quad \text{up}$$

Answer

19.60 N

Buoyant force, V=0.0050 m^3

Find the buoyant force on a 0.0050 m^3 *object fully submerged in water (*$\rho = 1000$, $g = 9.8$*).*

$$F_b = \rho_f V g = 1000(0.0050)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 49.00 \text{ N} \quad \text{up}$$

Answer

49.00 N

Buoyant force, V=0.0100 m^3

Find the buoyant force on a 0.0100 m^3 *object fully submerged in water (*$\rho = 1000$, $g = 9.8$*).*

$$F_b = \rho_f V g = 1000(0.0100)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 98.00 \text{ N} \quad \text{up}$$

Answer

98.00 N

Buoyant force, V=0.0010 m^3

Find the buoyant force on a 0.0010 m^3 *object fully submerged in seawater* ($\rho = 1025$, $g = 9.8$).

$$F_b = \rho_f V g = 1025(0.0010)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 10.04 \text{ N} \quad \text{up}$$

Answer

10.04 N

Buoyant force, V=0.0030 m^3

Find the buoyant force on a 0.0030 m^3 *object fully submerged in water (*$\rho = 1000$, $g = 9.8$*).*

$$F_b = \rho_f V g = 1000(0.0030)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 29.40 \text{ N} \quad \text{up}$$

Answer

29.40 N

Buoyant force, V=0.0005 m^3

Find the buoyant force on a $0.0005\ m^3$ *object fully submerged in mercury* ($\rho = 13600$, $g = 9.8$).

$$F_b = \rho_f V g = 13600(0.0005)(9.8) \quad \text{weight of displaced fluid}$$

$$F_b = 66.64\ \text{N} \quad \text{up}$$

Answer

66.64 N

Float or sink? $\rho = 500$

An object of density 500 kg/m^3 *is placed in water* ($\rho = 1000$). *Does it float or sink?*

$$\rho_{\text{obj}} = < \rho_{\text{water}} \qquad \text{compare densities}$$

$$\text{result} = \text{floats}$$

Answer

floats

Float or sink? $\rho = 800$

An object of density 800 kg/m^3 is placed in water ($\rho = 1000$). Does it float or sink?

$$\rho_{\text{obj}} = < \rho_{\text{water}} \qquad \text{compare densities}$$

$$\text{result} = \text{floats}$$

Answer

floats

Float or sink? $\rho = 2700$

An object of density 2700 kg/m^3 is placed in water ($\rho = 1000$). Does it float or sink?

$$\rho_{\text{obj}} \; = \; > \; \rho_{\text{water}} \qquad \text{compare densities}$$

$$\text{result} \; = \; \text{sinks}$$

Answer

sinks

Float or sink? $\rho = 920$

An object of density 920 kg/m^3 is placed in water ($\rho = 1000$). Does it float or sink?

$$\rho_{\text{obj}} = < \rho_{\text{water}} \qquad \text{compare densities}$$

$$\text{result} = \text{floats}$$

Answer

floats

Float or sink? $\rho = 1200$

An object of density 1200 kg/m^3 *is placed in water* ($\rho = 1000$). *Does it float or sink?*

$\rho_{obj} = > \rho_{water}$ compare densities

result $=$ sinks

Answer

sinks

Floating fraction, $\rho = 600$

An object of density 600 kg/m^3 floats in water. What fraction is submerged?

$$f = \frac{\rho_{\text{obj}}}{\rho_{\text{water}}} = \frac{600}{1000}$$ float equilibrium

$$f = 60\%$$ rest sticks out

Answer

60%

Floating fraction, $\rho = 800$

An object of density 800 kg/m^3 floats in water. What fraction is submerged?

$$f = \frac{\rho_{\text{obj}}}{\rho_{\text{water}}} = \frac{800}{1000} \qquad \text{float equilibrium}$$

$$f = 80\% \qquad \text{rest sticks out}$$

Answer

80%

Floating fraction, $\rho = 250$

An object of density 250 kg/m^3 floats in water. What fraction is submerged?

$$f = \frac{\rho_{\text{obj}}}{\rho_{\text{water}}} = \frac{250}{1000}$$ float equilibrium

$$f = 25\%$$ rest sticks out

Answer

25%

Continuity, $0.010 \to 0.005$ m^2

Fluid flows at 2 m/s through a 0.010 m^2 pipe that narrows to 0.005 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.010(2)}{0.005} = 4.00 \text{ m/s}$$ narrower = faster

Answer

4.00 m/s

Continuity, $0.020 \to 0.004$ m^2

Fluid flows at 3 m/s through a 0.020 m^2 pipe that narrows to 0.004 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.020(3)}{0.004} = 15.00 \text{ m/s}$$ narrower = faster

Answer

15.00 m/s

Continuity, 0.005→0.001 m^2

Fluid flows at 4 m/s through a 0.005 m^2 pipe that narrows to 0.001 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.005(4)}{0.001} = 20.00 \text{ m/s}$$ narrower = faster

Answer

20.00 m/s

Continuity, $0.100 \to 0.020$ m^2

Fluid flows at 1 m/s through a 0.100 m^2 pipe that narrows to 0.020 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.100(1)}{0.020} = 5.00 \text{ m/s}$$ narrower = faster

Answer

5.00 m/s

Continuity, $0.008 \to 0.002$ m^2

Fluid flows at 5 m/s through a 0.008 m^2 pipe that narrows to 0.002 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.008(5)}{0.002} = 20.00 \text{ m/s}$$ narrower = faster

Answer

20.00 m/s

Continuity, $0.040 \to 0.010$ m^2

Fluid flows at 2 m/s through a 0.040 m^2 pipe that narrows to 0.010 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.040(2)}{0.010} = 8.00 \text{ m/s}$$ narrower = faster

Answer

8.00 m/s

Continuity, 0.015→0.005 m^2

Fluid flows at 3 m/s through a 0.015 m^2 pipe that narrows to 0.005 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.015(3)}{0.005} = 9.00 \text{ m/s}$$ narrower = faster

Answer

9.00 m/s

Continuity, $0.060 \to 0.020$ m^2

Fluid flows at 1.5 m/s through a 0.060 m^2 pipe that narrows to 0.020 m^2. Find the new speed.

$$A_1 v_1 = A_2 v_2$$ what flows in flows out

$$v_2 = \frac{A_1 v_1}{A_2} = \frac{0.060(1.5)}{0.020} = 4.50 \text{ m/s}$$ narrower = faster

Answer

4.50 m/s

Continuity by diameter, 0.10→0.05 m

Water at 2 m/s flows through a 0.10 m diameter pipe narrowing to 0.05 m. Find the new speed.

$$v_2 = v_1\left(\frac{d_1}{d_2}\right)^2 = 2\left(\frac{0.10}{0.05}\right)^2 \qquad \text{area} \propto d^2$$

$$v_2 = 8.00 \text{ m/s}$$

Answer

8.00 m/s

Continuity by diameter, 0.20→0.10 m

Water at 1 m/s flows through a 0.20 m diameter pipe narrowing to 0.10 m. Find the new speed.

$$v_2 = v_1\left(\frac{d_1}{d_2}\right)^2 = 1\left(\frac{0.20}{0.10}\right)^2 \qquad \text{area} \propto d^2$$

$$v_2 = 4.00 \text{ m/s}$$

Answer

4.00 m/s

Bernoulli reasoning

Air moves faster over the top of an airplane wing than beneath it. Where is the pressure lower?

idea = on top fast fluid = low pressure

Answer

on top

Bernoulli reasoning

Water speeds up through a pipe constriction. What happens to its pressure there?

idea = drops fast fluid = low pressure

Answer

drops

Bernoulli reasoning

Two ships moving side by side are drawn together. Why?

idea = fast water, low pressure between

fast fluid = low pressure

Answer

fast water, low pressure between

Bernoulli pressure drop, 2→8 m/s

Along a horizontal pipe, fluid ($\rho = 1000$) speeds from 2 m/s to 8 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(1000)(8^2 - 2^2)$$ Bernoulli, level pipe

$$\Delta P = 3.00 \times 10^4 \text{ Pa}$$ pressure falls where it's faster

Answer

3.00×10^4 Pa

Bernoulli pressure drop, 1→5 m/s

Along a horizontal pipe, fluid ($\rho = 1000$) speeds from 1 m/s to 5 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(1000)(5^2 - 1^2)$$ Bernoulli, level pipe

$$\Delta P = 1.20 \times 10^4 \text{ Pa}$$ pressure falls where it's faster

Answer

1.20×10^4 Pa

Bernoulli pressure drop, 3→6 m/s

Along a horizontal pipe, fluid ($\rho = 800$) speeds from 3 m/s to 6 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(800)(6^2 - 3^2)$$

Bernoulli, level pipe

$$\Delta P = 1.08 \times 10^4 \text{ Pa}$$

pressure falls where it's faster

Answer

1.08×10^4 Pa

Bernoulli pressure drop, 2→10 m/s

Along a horizontal pipe, fluid ($\rho = 1000$) speeds from 2 m/s to 10 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(1000)(10^2 - 2^2)$$

Bernoulli, level pipe

$$\Delta P = 4.80 \times 10^4 \text{ Pa}$$

pressure falls where it's faster

Answer

4.80×10^4 Pa

Bernoulli pressure drop, 4→12 m/s

Along a horizontal pipe, fluid ($\rho = 1025$) speeds from 4 m/s to 12 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(1025)(12^2 - 4^2)$$

Bernoulli, level pipe

$$\Delta P = 6.56 \times 10^4 \text{ Pa}$$

pressure falls where it's faster

Answer

6.56×10^4 Pa

Bernoulli pressure drop, 1→7 m/s

Along a horizontal pipe, fluid ($\rho = 800$) speeds from 1 m/s to 7 m/s. Find the pressure drop.

$$P_1 - P_2 = \tfrac{1}{2}\rho(v_2^2 - v_1^2) = \tfrac{1}{2}(800)(7^2 - 1^2)$$

Bernoulli, level pipe

$$\Delta P = 1.92 \times 10^4 \text{ Pa}$$

pressure falls where it's faster

Answer

1.92×10^4 Pa

Viscosity

Which flows faster through the same pipe under the same pressure: water or honey?

idea = water internal friction

Answer

water

Viscosity

Why does honey pour more slowly than water?

idea = higher viscosity internal friction

Answer

higher viscosity

Viscosity

Does viscosity increase or decrease a fluid's resistance to flow?

idea = increase internal friction

Answer

increase

Viscosity

For most liquids, what happens to viscosity as temperature rises?

idea = decreases internal friction

Answer

decreases

Ship displacement, 50000 kg

A 50000 kg ship floats. What volume of water ($\rho = 1000$) must it displace ($g = 9.8$)?

$$F_b = W \qquad \text{float: buoyancy} = \text{weight}$$

$$\rho_f V g = m_{\text{ship}} g \qquad \text{the } g\text{'s cancel}$$

$$V = \frac{m}{\rho_f} = \frac{50000}{1000} = 50.00 \text{ m}^3 \qquad \text{displaced water}$$

Answer

50.00 m^3

Ship displacement, 200000 kg

A 200000 kg ship floats. What volume of water ($\rho = 1025$) must it displace ($g = 9.8$)?

$$F_b = W \qquad \text{float: buoyancy} = \text{weight}$$

$$\rho_f V g = m_{\text{ship}} g \qquad \text{the } g\text{'s cancel}$$

$$V = \frac{m}{\rho_f} = \frac{200000}{1025} = 195.12 \text{ m}^3 \qquad \text{displaced water}$$

Answer

195.12 m^3

Ship displacement, 10000 kg

A 10000 kg ship floats. What volume of water ($\rho = 1000$) must it displace ($g = 9.8$)?

$$F_b = W \qquad \text{float: buoyancy} = \text{weight}$$

$$\rho_f V g = m_{\text{ship}} g \qquad \text{the } g\text{'s cancel}$$

$$V = \frac{m}{\rho_f} = \frac{10000}{1000} = 10.00 \text{ m}^3 \qquad \text{displaced water}$$

Answer

10.00 m^3

Ship displacement, 100000 kg

A 100000 kg ship floats. What volume of water ($\rho = 1000$) must it displace ($g = 9.8$)?

$$F_b = W \qquad \text{float: buoyancy} = \text{weight}$$

$$\rho_f V g = m_{\text{ship}} g \qquad \text{the } g\text{'s cancel}$$

$$V = \frac{m}{\rho_f} = \frac{100000}{1000} = 100.00 \text{ m}^3 \qquad \text{displaced water}$$

Answer

100.00 m^3

Ship displacement, 75000 kg

A 75000 kg ship floats. What volume of water ($\rho = 1025$) must it displace ($g = 9.8$)?

$$F_b = W \qquad \text{float: buoyancy} = \text{weight}$$

$$\rho_f V g = m_{\text{ship}} g \qquad \text{the } g\text{'s cancel}$$

$$V = \frac{m}{\rho_f} = \frac{75000}{1025} = 73.17 \text{ m}^3 \qquad \text{displaced water}$$

Answer

73.17 m^3

Hydraulic by radius, 100 N

A hydraulic press has piston radii 0.02 *m and* 0.10 *m. What output force does* 100 *N produce?*

$$F_2 = F_1 \frac{A_2}{A_1} = F_1 \left(\frac{r_2}{r_1}\right)^2 \qquad \text{area} \propto r^2$$

$$F_2 = 100 \left(\frac{0.10}{0.02}\right)^2 = 2500.0 \text{ N} \qquad \text{force multiplied}$$

Answer

2500.0 N

Hydraulic by radius, 200 N

A hydraulic press has piston radii 0.05 *m and* 0.25 *m. What output force does* 200 *N produce?*

$$F_2 = F_1 \frac{A_2}{A_1} = F_1 \left(\frac{r_2}{r_1}\right)^2 \qquad \text{area} \propto r^2$$

$$F_2 = 200 \left(\frac{0.25}{0.05}\right)^2 = 5000.0 \text{ N} \qquad \text{force multiplied}$$

Answer

5000.0 N

Hydraulic by radius, 50 N

A hydraulic press has piston radii 0.01 *m and* 0.08 *m. What output force does* 50 *N produce?*

$$F_2 = F_1 \frac{A_2}{A_1} = F_1 \left(\frac{r_2}{r_1}\right)^2 \qquad \text{area} \propto r^2$$

$$F_2 = 50 \left(\frac{0.08}{0.01}\right)^2 = 3200.0 \text{ N} \qquad \text{force multiplied}$$

Answer

3200.0 N

Practice more, then watch the walk-through

Explore this live

Watch the walk-through