GIVE FEEDBACK

CONTINUE >

All around us, every day, motion is occurring.

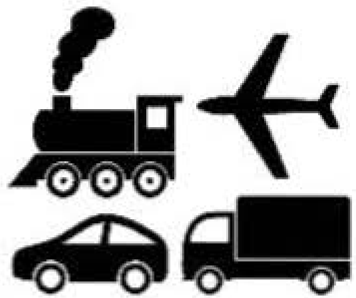
People, planes, animals, atoms and other objects are on the move.

We are able to use mathematical tools to understand and predict the motion of objects. These mathematical tools include equations, suitable units of measurement and free body diagrams.

This section discusses the fundamental concept of **motion**. Motion includes the concepts of position and change of position.

Sir Isaac Newton studied these concepts and formulated laws that are able to assist in the understanding of motion.

This section covers suitable techniques for the analysis and prediction of the motion of various objects.



< BACK GIVE FEEDBACK OK

Define motion

Motion refers to the movement of an object. One of the primary concerns of mechanical engineering is with motion.

Motion exists where there is a change in position or orientation of an object with reference to some other object or objects.

Aeroplanes, trains and automobiles are part of everyday life. A reciprocating piston in an internal-combustion engine, a rotating flywheel, water flowing inside a pipe and steam driving the rotor of a turbine are typical examples of different kinds of motion with which the science and practice of mechanical engineering are concerned.

GIVE FEEDBACK

OK

What is the formal definition of motion?

Click the correct answer.

- A change in position or orientation of an object with reference to some other object or objects
- The time rate of change in the position of an object
- A rotating flywheel
- Water flowing inside a pipe

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Define dynamics

The study of motion in mechanics is called **dynamics**.

Dynamics deals with moving objects. Historically, mechanics is the oldest of the physical sciences and it provided the foundation for the growth and development of all other areas of physics.

Unlike statics, which goes back to Archimedes and the Greek philosophers, serious study of dynamics only began with the experimental work of Galileo (1564–1642), which led to the mathematical formulation of the fundamental laws of motion by Newton in his famous publication known as the **Principia**.

GIVE FEEDBACK

OK

What is the study of motion in mechanics called?

Click the correct answer.

- Dynamics
- Kinematics
- Kinetics
- Statics

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Define kinematics and kinetics

The part of dynamics that describes the geometry of motion in terms of two elementary concepts, position and time, is called **kinematics.**

The part of dynamics that relates the motion to the forces causing it is called **kinetics.**

GIVE FEEDBACK

OK

Type your answer in the box.

The part of dynamics that describes the geometry of motion in terms of two elementary concepts, position and time, is called ________.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

The part of dynamics that relates the motion to the ______ causing it is called kinetics.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Define rectilinear translation or linear motion

The problems of dynamics can be classified and studied according to the type of motion that exists.

Motion along a straight line is known as **rectilinear translation.** We will simply refer to it as **linear motion**.

With some limitations our discussion also applies to motion along a curved path.

GIVE FEEDBACK

OK

What is motion along a straight line known as?

Check all that apply.

- [ ] Rectilinear translation
- [ ] Linear motion
- [ ] Kinetics
- [ ] Displacement
- [ ] Distance

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Linear displacement

The linear motion of an object, such as a motor car, can be described in terms of its position and time. More specifically, motion is usually described in terms of **linear displacement**, linear velocity and linear acceleration. If it is clear from the context that motion is in a straight line, the word linear is usually omitted from the terms linear displacement, linear velocity and linear acceleration.

Linear motion can generally be described as a change in the position of an object or as the passage of an object from one place to another along its path. Linear displacement, S, of an object is a measure of its change of position with respect to a fixed reference point.

Provided that displacement, velocity and acceleration are measured along the path of the motion at every point, e.g. road distances and not 'as the crow flies', the definitions and the formulae for linear motion are also applicable to curved paths.

GIVE FEEDBACK

OK

What is linear displacement?

Click the correct answer.

A measure of an object's change of position with respect to a fixed reference point

A measure of an object's change of position along the path of its motion

A measure of an object's change of position as a function of time

A measure of an object's change in velocity with respect to a fixed reference point

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The components of displacement

The magnitude of linear displacement can be measured in metres, kilometres or millimetres, depending on the actual distance measured. However, when relating displacement to velocity, acceleration and especially force, work and power, it is usually necessary to convert to base units, that is metres, before any further calculations are performed.

Displacement is a vector quantity, i.e. it has direction as well as magnitude.

It is usually convenient to measure displacement from the initial position of the object in the direction of motion, which is assumed to be positive, in which case displacement is also a measure of the distance travelled by the object.

If reversal in the direction of motion occurs, e.g. in reciprocating or oscillatory motion, the displacement from a fixed origin is not equivalent to the total distance travelled by the object.

GIVE FEEDBACK

OK

Type your answer in the box.

The SI unit for the magnitude of linear displacement is the ______.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Match the statements to show the difference between distance and displacement.

Drag statements on the right to match the left.

Displacement can be described as	how far an object has moved from a fixed reference point.
Distance can be described as	how far an object has travelled.
Distance is a	scalar quantity.
Displacement is a	vector quantity.
Displacement has	a magnitude and a direction.
Distance has	a magnitude only.

Linear velocity

Motion is a change in the position of an object which occurs in time. The time rate of change in the position of an object is known as its **linear velocity**, *v*.

Velocity is a vector quantity, implying a magnitude and direction.

For motion which occurs in one direction, the directional sense of velocity coincides with that of displacement and is taken to be positive.

Since velocity is a vector quantity, it must be described with a magnitude and a direction. If the magnitude only is given, this is known as speed. For example, 60 km/h north is a velocity, 60 km/h is a speed.

If reversal in the direction of motion occurs, such as when an object is thrown upwards, reaches a maximum altitude and starts falling, problems can easily be solved by considering the different stages of motion separately.

GIVE FEEDBACK

OK

Which of the following could be given as a measurement of velocity?

Check all that apply.

- [ ] 40 km/h east
- [ ] 15 m/s south-west
- [ ] 60 km/h
- [ ] 10 m/s
- [ ] 55 miles per hour west
- [ ] Walking pace towards the refrigerator

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The components of velocity

Even though the SI unit for velocity is the metre per second, the unit of measurement commonly used to express vehicle speeds is the kilometre per hour (km/h).

For linear motion in one direction, velocity at any point can best be understood as the distance travelled by an object per unit time in a specified direction along its linear path.

The base unit of velocity is the **metre per second (m/s).**

It is usually necessary to convert velocity from kilometres per hour to metres per second, particularly if calculations involve other related concepts, such as acceleration, power or momentum.

The conversion is achieved by dividing the km/h value by 3.6:

(1 km/h = 1000 m/3600 s = 1/3.6 m/s)

GIVE FEEDBACK

OK

Type your answer in the box.

72 km/h is equal to ________ m/s.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

54 km/h is equal to ______ m/s.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

10 m/s is equal to ______ km/h.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

In your car, the speedometer reading tells you how fast you are travelling at any instant of time without any regard to the direction of your travel. Although in many situations the meaning is obvious, you should not regard the terms speed and velocity as equivalent.

Differences between speed and velocity

Speed is not a synonym for **velocity**, but a scalar quantity which expresses the magnitude of velocity only, without any reference to its direction.

If distances travelled in successive intervals of time are the same, the speed is said to be constant. Otherwise the average speed can be calculated using total distance and the time taken to cover that distance.

GIVE FEEDBACK

OK

Match the statements that describe the differences between speed and velocity.

Drag statements on the right to match the left.

Speed is a	scalar quantity.
Velocity is a	vector quantity.
Speed can be described as	how fast an object is moving.
Velocity can be described as	how fast an object is moving in a given direction.
An example of speed is	10 m/s.
An example of velocity is	50 km/h north-west.

Conversion from metres per second to kilometres per hour requires multiplication by 3600, because there are 3600 seconds in an hour, and division by 1000, because there are 1000 metres in a kilometre. Therefore 1 m/s is equal to 3.6 km/h.

Example

In the last Grand Prix race of the series on his way to the World Drivers' Championship title in 1980, Australian Alan Jones established a new lap record for the 6 km road course at Watkins Glen, New York, by covering the distance in 1 minute 43.8 seconds.

What was his speed in metres per second?

What was his speed in kilometres per hour?

GIVE FEEDBACK

CONTINUE >

Solution

Distance and time:

$$\begin{aligned} S &= 6\,\text{km} \\ &= 6{,}000\ \text{m} \\ t &= 103.8\,s \end{aligned}$$

Speed:

$$\begin{aligned} \frac{S}{t} &= \frac{6{,}000\ \text{m}}{103.8\ \text{s}} \\ &= 57.8\ \text{m/s} \end{aligned}$$

Converting to kilometres per hour:

$$\begin{aligned} \text{Speed} &= 57.8\,\text{m/s} \cdot \frac{3{,}600}{1{,}000} \\ &= 208.1\ \text{km/h} \end{aligned}$$

< BACK GIVE FEEDBACK OK

Find the speed of a runner who covers a distance of 100 metres in 10 seconds (answer in m/s).

Clear

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

Type your answer in the box.

The speed of a runner who covers 100 metres in 10 seconds can be calculated using ______ divided by ______. (Use the actual quantities here.)

This calculation gives a speed of ______ m/s.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

How far will a truck travel in 90 minutes if it has an average speed of 40 km/h?

Check all that apply.

- [ ] 60 km
- [ ] 60000 m
- [ ] 3600 m
- [ ] 2.25 km
- [ ] 26.67 km
- [ ] 26667 m

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

What is the average speed of a car that travels 540 km in 6 hours?

Click the correct answer.

- 90 km/h
- 3240 km/h
- 90 m/s
- 25 km/h

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Since acceleration covers changes in velocity, the velocity could be increasing or decreasing under the action of acceleration. The numerical value of the acceleration is either positive or negative respectively.

Linear acceleration

If velocity is not constant but changes at a uniform rate, an object is said to move with a **uniformly accelerated motion.**

The rate at which linear velocity changes with time is called **linear acceleration**, a.

The base unit for acceleration is metres per second per second (m/s/s or m/s^2).

GIVE FEEDBACK

OK

What is the correct term that describes the rate at which linear velocity changes with time?

Click the correct answer.

- Linear acceleration
- Linear speed
- Average speed
- Average velocity
- Initial velocity
- Final velocity

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

To ensure that the answer to this calculation is given in metres per second squared, the values for velocity must be entered in metres per second.

The components of acceleration

If, over a period of time equal to t seconds, velocity of an object changes from its initial value v_0 to a final value v, it follows from the definition that acceleration a is the quotient of the increment of velocity $(v - v_0)$ and the time t:

$$a = \frac{(v - v_0)}{t}$$

It can readily be seen that the unit of acceleration must be the unit of velocity (m/s) divided by the unit of time (s), i.e. metre per second squared (m/s^2).

GIVE FEEDBACK

OK

Match each of the given quantities to the corresponding symbol for use in mathematical equations.

Drag statements on the right to match the left.

Acceleration	a
Initial velocity	v_0
Final velocity	v
Time	t

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

To ensure that the answer is in the correct units, it is necessary to ensure that appropriate units are used for each of the quantities in this equation.

The relationship between initial and final velocities, time and acceleration

The relationship between initial and final velocities, time and acceleration for uniformly accelerated motion is usually stated as a formula in which final velocity is the subject:

$$v = v_0 + a\,t$$

where:

v is the final velocity in m/s

v_0 is the initial velocity in m/s

a is the acceleration in m/s^2

t is the time taken in s

GIVE FEEDBACK

OK

Type your answer in the box.

Determine the magnitude of its velocity when a tree branch hits the ground after falling from rest for 2 seconds.

Final velocity = ______ + ______ x ______. (Use the actual values for each of these quantities.)

= ______ m/s. (Answer correct to two decimal places.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Mathematically, deceleration is indicated by a negative sign in front of the numerical value.

Differences between uniform acceleration and uniform deceleration

If, instead of increasing, the velocity is gradually decreasing, the motion is said to be **uniformly decelerated**.

Deceleration, or retardation, can be regarded as negative acceleration, i.e. acceleration acting in the direction opposite to the velocity.

GIVE FEEDBACK

OK

Match the statements to provide correct information regarding acceleration and deceleration.

Drag statements on the right to match the left.

Acceleration acts in the	same direction as the velocity.
Deceleration acts in the	opposite direction to the velocity.
Acceleration is denoted mathematically by a	positive number.
Deceleration is denoted mathematically by a	negative number.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the acceleration of a moving body—Example

Example

A car starts from rest and accelerates at the rate of $1.2\ \mathrm{m/s^2}$ for 15 seconds.
Determine the velocity reached after 15 seconds.

GIVE FEEDBACK

CONTINUE >

Calculate the acceleration of a moving body—Example

Example

A car starts from rest and accelerates at the rate of $1.2\ \mathrm{m/s^2}$ for 15 seconds. Determine the velocity reached after 15 seconds.

Solution

Initial velocity: $v_0 = 0$

Time: $t = 15\ \mathrm{s}$

Acceleration: $a = 1.2\ \mathrm{m/s^2}$

Substitute into $v = v_0 + a\,t$:

$$V = 0 + 1.2\ \mathrm{m/s^2} \cdot 15\ \mathrm{s}$$
$$= 18\ \mathrm{m/s}$$

Hence, the velocity after 15 seconds is $18\ \mathrm{m/s}$ (64.8 km/h).

< BACK GIVE FEEDBACK OK

Type your answer in the box.

Find the final velocity of a car that accelerates at 2 m/s/s for 12 seconds from an initial velocity of 5 m/s.

v = ______ + ______ x ______

= ______ m/s.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Determine the final velocity of a car that acclerates with an acceleration of 2 m/s/s from 10 m/s for 7.5 seconds (answer in m/s).

Clear

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

The equation could also have been transposed to make 't' the subject before the numerical values were substituted into it.

Example

If, after travelling for some distance at a constant velocity of 18 m/s, brakes are applied to a car producing a retardation of $2\ \mathrm{m/s^2}$, determine the time taken to reduce its velocity to 10 m/s (36 km/h).

GIVE FEEDBACK

CONTINUE >

Solution

Initial velocity:

$$v_0 = 18\ \text{m/s}$$

Final velocity:

$$v = 10\ \text{m/s}$$

Acceleration:

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

Substitute into $v = v_0 + a\,t$:

$$10 = 18 - 2t$$

$$\text{therefore } t = \frac{(10 - 18)}{-2} = 4s$$

Hence, time taken is 4 s.

< BACK GIVE FEEDBACK OK

Type your answer in the box.

Calculate the time taken for a truck to come to rest from 18 m/s if the brakes are able to apply a deceleration of 3.6 m/s^2.

time = ([ ] - [ ]) / [ ]

= [ ] seconds.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Four equations of linear motion

In the case of uniformly accelerated linear motion, the distance travelled from the starting point is the product of the time taken and the average velocity:

$$S = t \cdot v_{av}$$

Equations of linear motion	Average velocity	Changes in velocity	Distance	Distance, acceleration and velocity	Solving problems

GIVE FEEDBACK

OK

Four equations of linear motion

Where simple arithmetic averaging of velocities gives:

$$v_{av} = \frac{(v_0 + v)}{2}$$

Equations of linear motion	Average velocity	Changes in velocity	Distance	Distance, acceleration and velocity	Solving problems

GIVE FEEDBACK

OK

When these equations are combined, we have:

$$S = t\left(\frac{v_0 + v}{2}\right)$$

which is an additional independent equation to:

$$v = v_0 + a\,t$$

Four equations of linear motion

Eliminating final velocity *v* from these equations yields:

$$S = v_0 t + \frac{a t^2}{2}$$

Equations of linear motion	Average velocity	Changes in velocity	Distance	Distance, acceleration and velocity	Solving problems

GIVE FEEDBACK

OK

Four equations of linear motion

Similarly, if time t is eliminated, we get:

$$2aS = v^2 - v_0^2$$

Equations of linear motion	Average velocity	Changes in velocity	Distance	Distance, acceleration and velocity	Solving problems

Four equations of linear motion

Given any three of the five variables, i.e. displacement, time, acceleration and initial and final velocities, any problem involving uniformly accelerated linear motion can be solved using these equations.

Match the correct parts to show the four equations of motion.

Drag statements on the right to match the left.

$S =$	$t\left(\frac{(v_0 + v)}{2}\right)$
$v =$	$v_0 + a\,t$
$S = v_0 t +$	$a\frac{t^2}{2}$
$2aS =$	$v^2 - v_0^2$

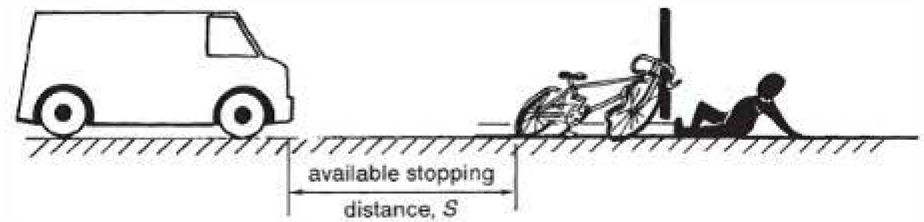
Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The results of this example provide instruction not only for the student of mechanics but also for those conscious of road safety.

Example

Find the total emergency stopping distance of a car and the total time taken from the point where the driver sights danger if the driver's reaction time before applying the brakes is 0.9 s, the initial velocity is 60 km/h and retardation due to the brakes is $7.5\ \mathrm{m/s^2}$.



GIVE FEEDBACK

CONTINUE >

Solution

There are two stages in this problem:
(a) Motion with uniform velocity before the brakes are applied
(b) Uniformly decelerated motion brings the car to rest

(a) *Uniform motion*
Velocity (constant):

$$v = 60\ \mathrm{km/h} \cdot \frac{1{,}000}{3{,}600}$$
$$= 16.67\ \mathrm{m/s}$$

Time: $t = 0.9\ \mathrm{s}$
Displacement: $S = t \cdot v_{a\,v}$
$= 0.9 \cdot 16.67\ \mathrm{m/s}$
$= 15\ \mathrm{m}$

< BACK GIVE FEEDBACK CONTINUE >

(b) *Decelerated motion*

Initial velocity: $v_0 = 16.67\ \mathrm{m/s}$

Final velocity: $v = 0$

Acceleration: $a = -7.5\ \mathrm{m/s^2}$

Note: retardation is negative acceleration.

Substitute into $v = v_0 + a\,t$ to find time taken to bring the car to rest:

$$0 = 16.67 + (-7.5) \times t$$

$$\therefore t = 2.22\ \mathrm{s}$$

< BACK GIVE FEEDBACK CONTINUE >

Substitute into $S = t\frac{(v_0 + v)}{2}$ to find the displacement during the period of decelerated motion:

$$S = 2.22 \cdot \left(\frac{(16.67 + 0)}{2}\right)$$
$$= 18.5\ \mathrm{m}$$

Combining the answers obtained in (a) and (b) yields:

Total stopping distance $= 15 + 18.5 = 33.5\ \mathrm{m}$

Total time taken $= 0.9 + 2.22 =$ 3.12 s

< BACK GIVE FEEDBACK OK

Determine the velocity of a car after it is subjected to an acceleration of 2 m/s^2 for 3 seconds if it was initially travelling at 72 km/h.

Check all that apply.

- [ ] 29 m/s
- [ ] 104.4 km/h
- [ ] 26 m/s
- [ ] 93.6 km/h
- [ ] 23.6 m/s
- [ ] 92 km/h

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

Calculate the maximum height that a ball will reach if it is kicked into the air with an initial velocity of 25 m/s. (Answer correct to two decimal places.)

Final velocity at maximum height = ______ m/s.

Acceleration = ______ m/s^2.

Maximum Height = ______ m.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the acceleration necessary to reduce a car's velocity from 100 km/h to 60 km/h within 100 m.

Click the correct answer.

- $-2.5\ m/s^2$
- $-64\ m/s^2$
- $0.2\ m/s^2$
- $0.06\ m/s^2$
- $6\ m/s^2$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Calculate the acceleration required to increase the velocity of a train from 10 m/s to 20 m/s in 5 seconds.

Click the correct answer.

- $2\ m/s^2$
- $-2\ m/s^2$
- $1.5\ m/s^2$
- $-1.5\ m/s^2$
- $70\ m/s^2$
- $-70\ m/s^2$

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

In ancient times, when people did not know about the effects of air resistance, an early Greek scientist-philosopher, Aristotle, had observed a leaf and a stone fall to the ground and had come to the general conclusion that a light body falls slower than a heavy one. It took almost two thousand years and the perseverance of Galileo to dispel this erroneous principle.

The history of experimenting freely falling bodies

Galileo suspected that if falling bodies were heavy enough to render air resistance negligible, Aristotle's idea was demonstrably wrong.

He undertook a series of experiments which led him to the correct conclusions that the maximum speed attained by a falling body, in the absence of air resistance, is proportional to the time taken, and that the distance travelled from rest is proportional to the square of the time.

This is consistent with the equations of linear motion if we take the initial velocity to be zero, i.e. $v_0 = 0$, and the acceleration due to gravity as a_g:

$$v = v_0 + a\,t \text{ gives } v = a_g\,t\,,$$

$$\text{and } S = v_0 t + \frac{a\,t^2}{2} \text{ gives } S = \frac{a_g\,t^2}{2}$$

GIVE FEEDBACK

OK

Match the idea to the person who stated it.

Drag statements on the right to match the left.

A light body falls slower than a heavy one.	Aristotle
The maximum speed attained by a falling body is proportional to the time taken.	Galileo
The distance travelled from rest by a falling body is proportional to the square of the time taken.	Galileo
Education is the best provision for the journey to old age.	Aristotle

Do you know the answer?

The exact numerical value of gravitational acceleration is subject to local variations. The value of 9.81 metres per second squared is generally accepted as a suitable approximation.

The value of gravitational acceleration (the acceleration of a body in free fall)

Experiments conducted since the time of Galileo, combined with the principles expounded by Newton, set the value of gravitational acceleration at:

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

This is more or less constant anywhere on or near the surface of the Earth.

GIVE FEEDBACK

OK

Type your answer in the box.

The symbol used to represent acceleration due to gravity in mathematical equations is
__________.

The accepted value of the magnitude of the acceleration due to gravity is __________ m/s^2.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Problems involving acceleration of bodies in free fall—Example 1

It should be noted that since several alternative equations are available, there is usually more than one way in which a particular problem can be solved. The choice of a suitable sequence of calculations depends not only on the given information, but also on the selection of particular equations, which to some extent is a matter of personal preference.

Example

A stone is dropped from the deck of a bridge and strikes the water below after 3.4 seconds of free fall. Neglecting air resistance, calculate the height of the bridge above the water and the velocity with which the stone strikes the water.

GIVE FEEDBACK

CONTINUE >

Solution

Since the initial velocity is zero, $v_0 = 0$, and $a_g = 9.81\ \mathrm{m/s^2}$, the distance of free fall is found from:

$$S = v_0 t + \frac{a t^2}{2}$$
$$= 0 + \frac{9.81 \cdot 3.4^2}{2}$$
$$= 56.7\ \mathrm{m}$$

The final velocity is found from:

$$v = v_0 + a t$$
$$= 0 + 9.81 \cdot 3.4$$
$$= 33.4\ \mathrm{m/s}$$

< BACK GIVE FEEDBACK CONTINUE >

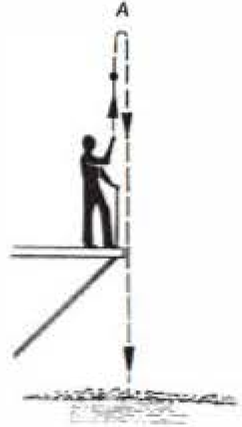
If a body such as a stone is projected vertically upwards with an initial velocity v_0, the acceleration due to gravity will be negative, i.e. it will be a retardation causing a decrease in velocity at the rate of $9.81\ \mathrm{m/s^2}$.

< BACK GIVE FEEDBACK OK

It should be noted that since several alternative equations are available, there is usually more than one way in which a particular problem can be solved. The choice of a suitable sequence of calculations depends not only on the given information, but also on the selection of particular equations, which to some extent is a matter of personal preference.

Example

If a stone is thrown upwards from the edge of a bridge with an initial velocity of 15.6 m/s, determine the maximum height reached above the deck of the bridge, the velocity with which it strikes the water below (56.7 metres below the deck of the bridge) and the total time taken.



GIVE FEEDBACK

CONTINUE >

Solution

(a) Consider the upward motion first.

Initial velocity: $v_0 = 15.6\ \text{m/s}$
Acceleration: $a_g = -9.81\ \text{m/s}^2$
Final velocity at point A: $v = 0$
Substitute into $2aS = v^2 \ \ v_0^2$:
$2 \cdot (-9.81) \cdot S = 0 - 15.6^2$ therefore S = 12.4 m

Therefore the maximum height above the deck is 12.4 m.

< BACK GIVE FEEDBACK CONTINUE >

Now using $v = v_0 + at$:

$$0 = 15.6 + (-9.81)t$$

therefore t = 1.59 s

Therefore, the time taken to reach this height is 1.59 seconds.

< BACK GIVE FEEDBACK CONTINUE >

(b) Consider free fall from the maximum height into the water below. Measured from point A as the origin:

Displacement: $S = 56.7\text{ m} + 12.4\text{ m} = 69.1\text{ m}$
Initial velocity: $v_0 = 0$
Acceleration: $a_g = 9.81\text{ m/s}^2$
Substitute into $S = v_0 t + \frac{a t^2}{2}$:

$$69.1 = 0 + \frac{9.81 t^2}{2}$$

therefore $t = \sqrt{\frac{69.1 \cdot 2}{9.81}} = 3.75\text{ s}$

Therefore, the time taken in free fall is 3.75 seconds.

< BACK GIVE FEEDBACK CONTINUE >

Now using $v = v_0 + a\,t$, the velocity when striking the water is equal to:

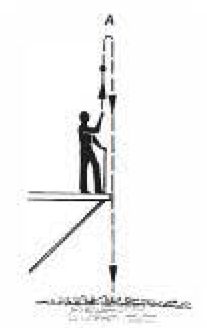
$v = 0 + 9.81 \cdot 3.75$
$= 36.8\ \mathrm{m/s}$

Combining the time taken for each part of this motion, total time from the moment the stone is thrown upwards to the moment it splashes into the water is:

total time = 1.59 s + 3.75 s
= 5.34 seconds

< BACK GIVE FEEDBACK OK

A stone is thrown upwards from the edge of a bridge with an initial velocity of 20 m/s. The bridge is 48 metres above the river below.



SMALL MEDIUM LARGE

Type your answer in the box.

(a) The maximum height reached above the deck of the bridge is ______ metres.

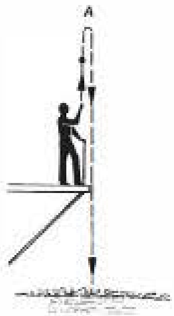
The time taken to reach this height is ______ seconds.

(Answer correct to two decimal places.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A stone is thrown upwards from the edge of a bridge with an initial velocity of 20 m/s. The bridge is 48 metres above the river below.



SMALL MEDIUM LARGE

Type your answer in the box.

(b) The distance that the stone must travel from point A to the water below the bridge is [ ] m.

The time taken in free fall from point A is [ ] seconds.

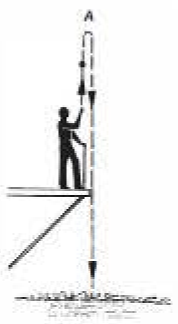
The velocity with which the stone strikes the water is [ ] m/s.

(Answer correct to two decimal places.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

A stone is thrown upwards from the edge of a bridge with an initial velocity of 20 m/s. The bridge is 48 metres above the river below.



SMALL MEDIUM LARGE

Type your answer in the box.

(c) The total time taken to hit the water after the stone is thrown is equal to ______ seconds.

(Answer correct to two decimal places.)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The fundamental relationship between force, mass and acceleration is the central concept of dynamics. It is embodied in the system of mechanics summarised by Isaac Newton in his three laws of motion.

Newton's three laws of motion

Slightly reworded, Isaac Newton's three **laws of motion** are as follows:

1. **First law.** If there is no unbalanced force acting on a body, the body will remain at rest or continue to move in a straight line with a constant linear velocity.

2. **Second law.** The acceleration of a body is proportional to the resultant force acting on it, inversely proportional to the mass of the body and is in the direction of the force.

3. **Third law.** The forces of action and reaction are equal in magnitude and opposite in direction.

GIVE FEEDBACK

CONTINUE >

In a different order, these laws take us through the basic principles of kinetics as follows.

The third law suggests that forces acting on a body always originate in other bodies, i.e. a push or pull experienced by an object is always a result of interaction with some other object. Single isolated forces do not exist.

The first law introduces the property of matter, often called **inertia**, which determines its resistance to a change in its state of rest or uniform motion. Mass of a body is then regarded as the quantitative measure of its **inertia**, which only a force can overcome.

The second law gives mathematical expression to the relationship between the mass of a body, the unbalanced force acting on it and the acceleration produced by the force:

$$F = m \cdot a$$

where:

F is the resultant of all forces acting on a body
m is the mass of the body
a is the acceleration

< BACK GIVE FEEDBACK OK

Match the title of each of Newton's three laws of motion with its description.

Drag statements on the right to match the left.

Newton's first law of motion	If there is no unbalanced force acting on a body, the body will remain at rest or continue to move in a straight line with a constant linear velocity.
Newton's second law of motion	The acceleration of a body is proportional to the resultant force acting on it, inversely proportional to the mass of the body and is in the direction of the force.
Newton's third law of motion	The forces of action and reaction are equal in magnitude and opposite in direction.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Consider inertia when next you are riding in a vehicle that turns a corner. Your body will try to continue travelling straight ahead due to inertia.

Define inertia

Newton's first law introduces the property of matter, often called **inertia**, which determines its resistance to a change in its state of rest or uniform motion.

Mass of a body is then regarded as the quantitative measure of its **inertia**, which only a force can overcome.

GIVE FEEDBACK

OK

Type your answer in the box.

The property of matter which determines its resistance to a change in its state of rest or uniform motion is called ______.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Newton's Second Law, expressed mathematically, is an essential tool for investigations in kinetics.

The mathematical relationship between the mass of a body, the unbalanced force acting on it and acceleration produced by the force

The second law gives mathematical expression to the relationship between the mass of a body, the unbalanced force acting on it and the acceleration produced by the force:

$$F = m \cdot a$$

where:

F is the resultant of all forces acting on a body
m is the mass of the body
a is the acceleration

GIVE FEEDBACK

OK

Match the symbol with the quantity that it represents.

Drag statements on the right to match the left.

F	Force in newtons
m	Mass in kilograms
a	Acceleration in metres per second squared

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Type your answer in the box.

Complete the missing words that describe the mathematical statement of Newton's second law of motion:

[ ] = mass x [ ]

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

It is very important to understand that the International System (SI) of units is a coherent system in which the product of any two unit quantities in the system is the unit of the resultant quantity.

The SI unit of force

Newton's second law of motion requires the product of the SI units of mass and acceleration, i.e. kilogram and metre per second squared.

The resultant unit is the SI unit of force, kg.m/s^2, which is given the special name **newton** (symbol N).

Thus the second law provides the definition of the unit of force:

$$F = m\,a$$

$$1\ \mathrm{N} = 1\ \mathrm{kg} \times 1\ \mathrm{m/s^2}$$

$$\mathrm{N} = \frac{\mathrm{kg.m}}{\mathrm{s}^2}$$

GIVE FEEDBACK

OK

Which of the following is the correct SI unit of force?

Click the correct answer.

- newton (symbol N)
- joule (symbol J)
- kilogram (symbol kg)
- kilogram metre per second (symbol kgm/s)
- pascal (symbol Pa)

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

The relationship between the newton and the kilogram

The newton is a derived unit. This slide shows the relationship between the newton and the fundamental SI units.

Newton's second law of motion requires the product of the SI units of mass and acceleration, i.e. kilogram and metre per second squared.

This equation describes the relationship between the two units, the newton (symbol N) and the kilogram (symbol kg).

From Newton's second law of motion:

$$F = m\,a$$

$$1\ \mathrm{N} = 1\ \mathrm{kg} \cdot 1\ \mathrm{m/s^2}$$

$$\mathrm{N} = \frac{\mathrm{kg.m}}{s^2}$$

GIVE FEEDBACK

OK

The relationship between the newton and the kilogram is that one newton = ______.

Click the correct answer.

- $1\ \mathrm{kg\,m/s^2}$
- $1\ \mathrm{kg\,m^2}$
- $1\ \mathrm{kg\,m/s}$
- $1\ \mathrm{kg}$
- $1\ \mathrm{kgm^2/s^2}$

Do you know the answer?

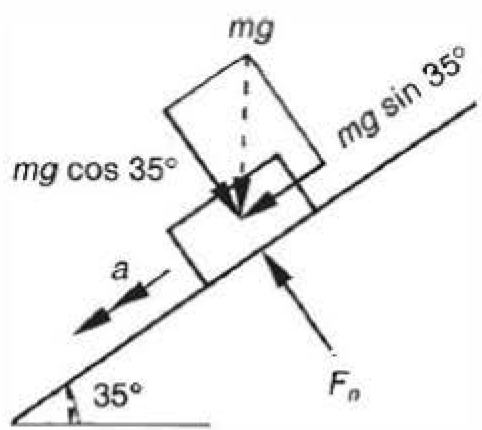
I KNOW IT | THINK SO | UNSURE | NO IDEA

Example 3

Determine the acceleration of a body sliding down a frictionless surface inclined to the horizontal at 35°.

Solution

It is necessary to consider components of weight acting along and at right angles to the surface. Let the weight be $F_w = m\,g$. The perpendicular component of weight is balanced by the normal reaction at the surface, as shown in the figure below.



< BACK GIVE FEEDBACK CONTINUE >

The parallel component, equal to *mg* sin 35°, is not balanced by any other force, assuming no frictional resistance, i.e. a smooth surface. Therefore, from F = ma:

$$
\begin{aligned}
a &= \frac{F}{m} \\
&= \frac{m\,g\,\sin 35^\circ}{m} \\
&= 9.81 \cdot \sin 35^\circ \\
&= 5.63\ \mathrm{m/s^2}
\end{aligned}
$$

The acceleration is in the direction of the net unbalanced force, i.e. parallel to the plane as shown.

Example 4

Determine the force required to accelerate a vehicle, of mass 1.5 tonne, from rest to 60 km/h in 12 s.

Example 4

Determine the force required to accelerate a vehicle, of mass 1.5 tonne, from rest to 60 km/h in 12 s.

Solution

The acceleration required is found from $v = v_0 + a\,t$, where $v = 60\,\text{km/h} = 16.67\,\text{m/s}$:

$$16.67 = 0 + a \cdot 12$$

$$\text{therefore } a = 1.389\,\text{m/s}^2$$

Applying Newton's law:

$$\begin{aligned} F &= m\,a \\ &= 1{,}500\,\text{kg} \cdot 1.389\,\text{m/s}^2 \\ &= 2{,}083\,\text{N} \\ &= 2.08\,\text{kN} \end{aligned}$$

< BACK GIVE FEEDBACK OK

Example 1

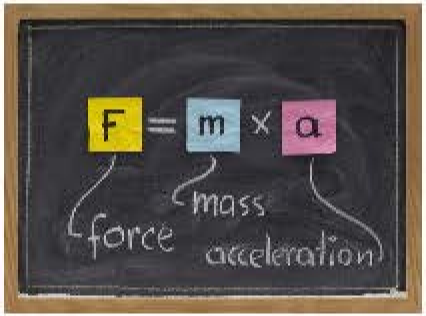
Determine the net force required to give a body, of mass 300 kg, a horizontal acceleration of $2.5\ \mathrm{m/s^2}$.

Example 1

Determine the net force required to give a body, of mass 300 kg, a horizontal acceleration of 2.5 m/s^2.

Solution

$$\begin{aligned} F &= m \cdot a \\ &= 300 \text{ kg} \cdot 2.5 \text{ m/s}^2 \\ &= 750 \text{ kg} \cdot \text{m/s}^2 \\ &= 750 \text{ N} \end{aligned}$$



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GIVE FEEDBACK
CONTINUE >

Example 2

Determine the acceleration of a body of mass 25 kg due entirely to its own weight.

Example 2

Determine the acceleration of a body of mass 25 kg due entirely to its own weight.

Solution

The weight of the body, i.e. the force of gravity acting on it, is:

$$\begin{aligned} F_w &= m\,g \\ &= 25\ \text{kg} \cdot 9.81\ \text{N/kg} \\ &= 245.3\ \text{N} \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >

Therefore, from $F = m\,a$, acceleration due to gravity is:

$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{245.3\ \mathrm{N}}{25\ \mathrm{kg}} \\ &= \frac{245.3\ \mathrm{kg} \cdot \mathrm{m/s^2}}{25\ \mathrm{kg}} \\ &= 9.81\ \mathrm{m/s^2} \end{aligned}$$

< BACK GIVE FEEDBACK OK

Calculate the acceleration of a 100 kg mass that is placed on a frictionless plane inclined at an angle of 30 degrees to the horizontal.

(Answer in metres per second squared correct to three decimal places.)

$\pm$ ▾ $\frac{\square}{\square}$ $\square^2$ $\sqrt{\square}$ $(\square)$ ▾ $\leq$ ▾ Clear

π m ▾ $\square^\circ$ $\overline{\square}$ $\sin\square$ θ Clear line

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↵

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Calculate the acceleration of the car.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Calculate the force in Newtons acting on a 1500 kg car that accelerates at 2 m/s/s.

Clear

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

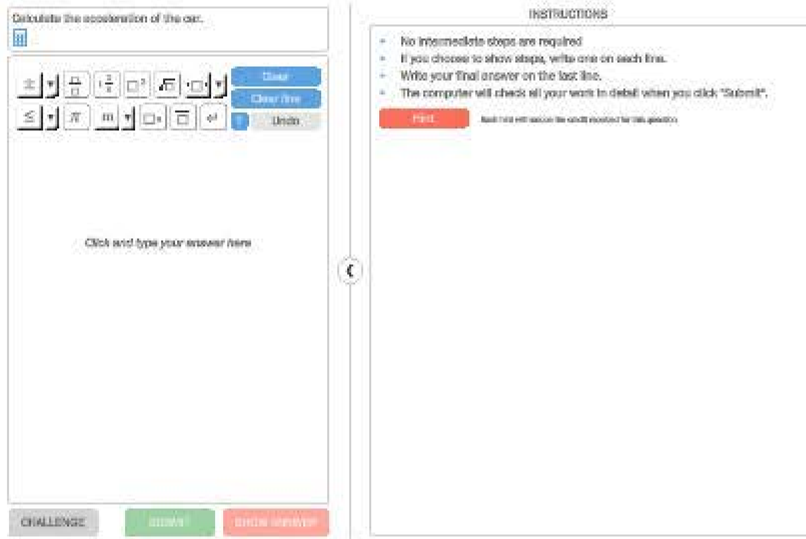
- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

An 800 kg car is able to travel 400 metres in 10 seconds from rest.

SMALL MEDIUM LARGE



An 800 kg car is able to travel 400 metres in 10 seconds from rest.

SMALL MEDIUM LARGE

Determine the force required to achieve the acceleration of $8\ \mathrm{m/s^2}$.

Clear

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

Determine the force required to achieve the acceleration of $8\ \mathrm{m/s^2}$.

Clear

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

Calculate the weight force pressing down on a chair when an 80 kg person is sitting on the chair.

(Answer correct to one decimal place.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

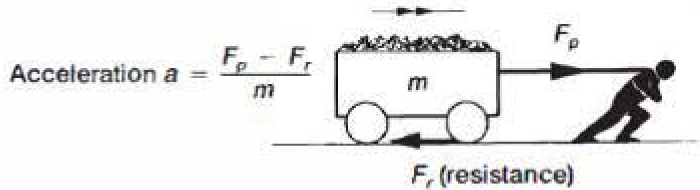
The acceleration of an object is dependent on the applied force, the tractive resistance and the object's mass.

Problems involving acceleration against resistance using Newton's second law of motion—Examples 1–2

In the equation $F = m\,a$, the force is the net accelerating force, i.e. the resultant of all forces applied to the body. The resultant unbalanced force, i.e. net accelerating force, is the difference between the applied push or pull F_p and the resistance force F_r.

$$F = F_p - F_r$$

The resistance is usually due to friction of some kind, which may include sliding friction, friction in bearings and air friction.



Using Newton's law to find acceleration against resistance

GIVE FEEDBACK

CONTINUE >

Acceleration produced by the resultant force is found from Newton's law:

$$
\begin{aligned}
a &= \frac{F}{m} \\
&= \frac{F_p - F_r}{m}
\end{aligned}
$$

It should be clear from this equation that if the applied force F_p is equal to the resistance force F_r, there will be no acceleration, i.e. the motion, if any, will continue at constant velocity.

Therefore, a vehicle moving on a level road at a constant speed requires a force equal to the tractive resistance to maintain uniform motion. Any force in excess of tractive resistance will accelerate the vehicle. On the other hand, a tractive effort which is less than the tractive resistance will result in retardation.

< BACK GIVE FEEDBACK CONTINUE >

Example 1

A train of total mass 120 tonne is travelling at 60 km/h on level track. The tractive resistance is 80 N/t. Calculate the tractive effort required to accelerate the train to 100 km/h in 30 s.

Example 1

A train of total mass 120 tonne is travelling at 60 km/h on level track. The tractive resistance is 80 N/t. Calculate the tractive effort required to accelerate the train to 100 km/h in 30 s.

Solution

Acceleration must be calculated using $v = v_0 + a\,t$, where $v = 100$ km/h = 27.78 m/s, and v_0 = 60 km/h = 16.67 m/s:

$$v = v_0 + a\,t$$
$$27.78 = 16.67 + a \cdot 30$$
$$\text{therefore } a = 0.37\ \text{m/s}^2$$

< BACK GIVE FEEDBACK CONTINUE >

The net accelerating force required to accelerate the mass is:

$$\begin{aligned} F &= m\,a \\ &= 120{,}000\ \text{kg} \cdot 0.37\ \text{m/s}^2 \\ &= 44{,}400\ \text{N} \\ &= 44.4\ \text{kN} \end{aligned}$$

Tractive resistance, which is often stated as resistance per unit mass of the vehicle, is equal to:

$$\begin{aligned} F_r &= 80\ \text{N/t} \cdot 120\ \text{t} \\ &= 9{,}600\ \text{N} \\ &= 9.6\ \text{kN} \end{aligned}$$

Therefore, from the balance of forces:

$$
\begin{aligned}
F &= F_p - F_r \\
44.4\ \text{kN} &= F_p - 9.6\ \text{kN} \\
\text{therefore } F_p &= 44.4 + 9.6 \\
&= 54\ \text{kN}
\end{aligned}
$$

The required tractive effort F_p is 54 kN.

Example 2

Determine the time taken and the distance travelled by the train in the previous example when it is brought to rest from 100 km/h by a braking force of 72.7 kN.

Solution

If tractive resistance F_r is unchanged:

$$F_r = 9.6 \text{ kN}$$

In this case, the resistance will assist the braking effort F_b in slowing the train down.

Therefore the total decelerating force will be:

$$\begin{aligned} F &= F_r + F_b \\ &= 9.6 + 72.7 \\ &= 82.3 \text{ kN} \end{aligned}$$

Deceleration is therefore equal to:

$$\begin{aligned} a &= \frac{F}{m} \\ &= \frac{82{,}300 \text{ N}}{120{,}000 \text{ kg}} \\ &= 0.686 \text{ m/s}^2 \end{aligned}$$

Remembering that deceleration is negative acceleration, we can substitute into $2aS = v^2 - v_0^2$ and solve for distance travelled during the period of retardation:

$$2aS = v^2 - v_0^2$$
$$2 \cdot (-0.686)S = 0 - 27.78^2$$
$$\text{therefore } S = 562 \text{ m}$$

The time taken can be found from:

$$S = t\left(\frac{v + v_0}{2}\right)$$
$$562 = t\left(\frac{0 + 27.78}{2}\right)$$
$$\text{therefore } t = 40.5 \text{ s}$$

< BACK GIVE FEEDBACK OK

Find the acceleration of the car (answer correct to two decimal places).

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint — Each hint will reduce the credit received for this question

Determine the resultant force on the car based on the acceleration of $2\ \mathrm{m/s^2}$.

(Answer in newtons.)

+ − · ÷ $\frac{\square}{\square}$ $\square^2$ $\sqrt{\square}$ Clear

Clear line

π m ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint

Each hint will reduce the credit received for this question

Calculate the acceleration required to bring the car to rest in a distance of 20 metres.

(Answer correct to three decimal places.)

+ − · ÷ $\frac{\square}{\square}$ $\square^2$ $\sqrt{\square}$ Clear

Clear line

π m Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint

Each hint will reduce the credit received for this question

A 1200 kg car travelling at 60 km/h on a level road slows to 42 km/h in 4 seconds when the driver shifts the car into neutral.

SMALL MEDIUM LARGE

Find the acceleration of the car (answer correct to two decimal places).

Done

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
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Hint

A 1200 kg car travelling at 60 km/h on a level road slows to 42 km/h in 4 seconds when the driver shifts the car into neutral.

SMALL MEDIUM LARGE

Now that you know the car's acceleration is $-1.25\ m/s^2$ find the total force resisting the car's motion.

(Answer in newtons.)

Clear
Clear line
Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

HELP

Determine the acceleration of the car.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
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- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

Now that you know the car's acceleration is $-1.25\ \mathrm{m/s^2}$ find the total force resisting the car's motion.

(Answer in newtons.)

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

The braking system of an 1100 kg car is required to bring it to rest from a speed of 40 km/h in a distance of 20 metres. Apart from the braking system, the car experiences a resisting force of 800 N.

SMALL | MEDIUM | LARGE

Calculate the acceleration required to bring the car to rest in a distance of 20 metres.

(Answer correct to three decimal places.)

Clear | Clear line | Undo

Click and type your answer here

CHALLENGE | SUBMIT | SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
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Hint

The braking system of an 1100 kg car is required to bring it to rest from a speed of 40 km/h in a distance of 20 metres. Apart from the braking system, the car experiences a resisting force of 800 N.

SMALL MEDIUM LARGE

Calculate the total force required to bring the car to rest in a distance of 20 metres.

(Answer correct to the nearest newton.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

The braking system of an 1100 kg car is required to bring it to rest from a speed of 40 km/h in a distance of 20 metres. Apart from the braking system, the car experiences a resisting force of 800 N.

SMALL MEDIUM LARGE

Determine the braking force that is provided by the car's braking system to bring the car to rest in a distance of 20 metres.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
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Hint

Calculate the total force required to bring the car to rest in a distance of 20 metres.

(Answer correct to the nearest newton.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

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Hint

Each hint will reduce the credit received for this question

Determine the braking force that is provided by the car's braking system to bring the car to rest in a distance of 20 metres.

Clear

Clear line

?

Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
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Hint

Each hint will reduce the credit received for this question

Determine the force provided by the car's engine.

(Answer in newtons.)

+ − · ÷ □² √□ Clear

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π N □ⁿ

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

A 1400 kg car accelerating from 74 km/h to 110 km/h in 5 seconds is subjected to a resisting force of 1 kN.

SMALL MEDIUM LARGE

Determine the acceleration of the car.

Clear
Clear line
Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

A 1400 kg car accelerating from 74 km/h to 110 km/h in 5 seconds is subjected to a resisting force of 1 kN.

SMALL MEDIUM LARGE

Determine the resultant force on the car based on the acceleration of 2 m/s^2.

(Answer in newtons.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
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- The computer will check all your work in detail when you click "Submit".

HINT

A 1400 kg car accelerating from 74 km/h to 110 km/h in 5 seconds is subjected to a resisting force of 1 kN.

SMALL MEDIUM LARGE

Determine the force provided by the car's engine.

(Answer in newtons.)

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Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Problems involving acceleration against gravity using Newton's second law of motion

When combining like quantities it is possible to use non-standard units, such as the forces in the example, which are combined in kilonewtons rather than newtons.

In the case of acceleration against gravity:

If the applied pull F_p is equal to the weight F_w, there will be no acceleration, i.e. the object will remain in a state of rest or, if moving, will continue to move with constant velocity.

A force F_p greater than the weight will produce an upward acceleration, while a force less than the weight will allow downward acceleration.

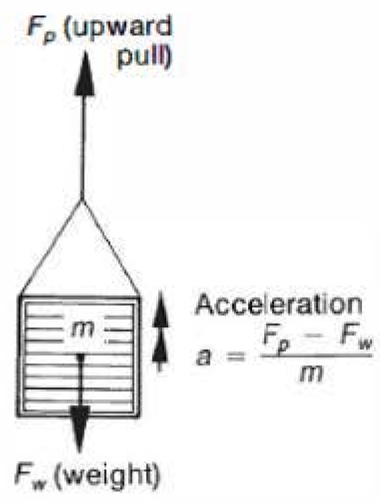
Problems involving acceleration against gravity using Newton's second law of motion

When motion occurs in a vertical direction, such as that of a lift, the force required to produce acceleration is influenced by the force of gravity, i.e. by the weight, F_w, of the object.

The resultant unbalanced force in this case is the difference between the applied force F_p, which is often provided by the pull in a cable, and the force of gravity F_w.

$$F = F_p - F_w$$

Problems involving acceleration against gravity using Newton's second law of motion



Acceleration against gravity	Vertical motion	Using Newton's law to find acceleration against gravity	Application of Newton's law	Example	Solution	Acceleration upwards	Acceleration downwards

GIVE FEEDBACK

OK

Problems involving acceleration against gravity using Newton's second law of motion

Gravity in this case can be regarded as the resistance to upward acceleration.

The acceleration produced by the resultant force is found from Newton's law:

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

$$= \frac{(F_p - F_w)}{m}$$

where:

$$F_w = m\,g$$

Acceleration against gravity	Vertical motion	Using Newton's law to find acceleration against gravity	Application of Newton's law	Example	Solution	Acceleration upwards	Acceleration downwards

GIVE FEEDBACK

OK

Problems involving acceleration against gravity using Newton's second law of motion

A loaded lift has a total mass of 1500 kg. Determine the force in the cables when:

(a) the acceleration of $2\ \mathrm{m/s^2}$ is upwards

(b) the acceleration of $2\ \mathrm{m/s^2}$ is downwards

Problems involving acceleration against gravity using Newton's second law of motion

Net accelerating force is:

$$\begin{aligned} F &= m\,a \\ &= 1{,}500 \text{ kg} \cdot 2 \text{ m/s}^2 \\ &= 3{,}000 \text{ N} \\ &= 3 \text{ kN} \end{aligned}$$

The force of gravity (weight of the lift) is:

$$\begin{aligned} F_w &= m\,g \\ &= 1{,}500 \text{ kg} \cdot 9.81 \text{ N/kg} \\ &= 14{,}715 \text{ N} \\ &= 14.7 \text{ kN} \end{aligned}$$

Acceleration against gravity	Vertical motion	Using Newton's law to find acceleration against gravity	Application of Newton's law	Example	Solution	Acceleration upwards	Acceleration downwards

GIVE FEEDBACK

OK

Problems involving acceleration against gravity using Newton's second law of motion

(a) When acceleration is upwards:

$$F = F_p - F_w$$
$$3\ \text{kN} = F_p - 14.7\ \text{kN}$$
$$\text{therefore } F_p = 17.7\ \text{kN}$$

Hence the force F_p in the cable is 17.7 kN.

Acceleration against gravity	Vertical motion	Using Newton's law to find acceleration against gravity	Application of Newton's law	Example	Solution	Acceleration upwards	Acceleration downwards

GIVE FEEDBACK

OK

Problems involving acceleration against gravity using Newton's second law of motion

(b) When acceleration is downwards, weight is greater than the force in the cable:

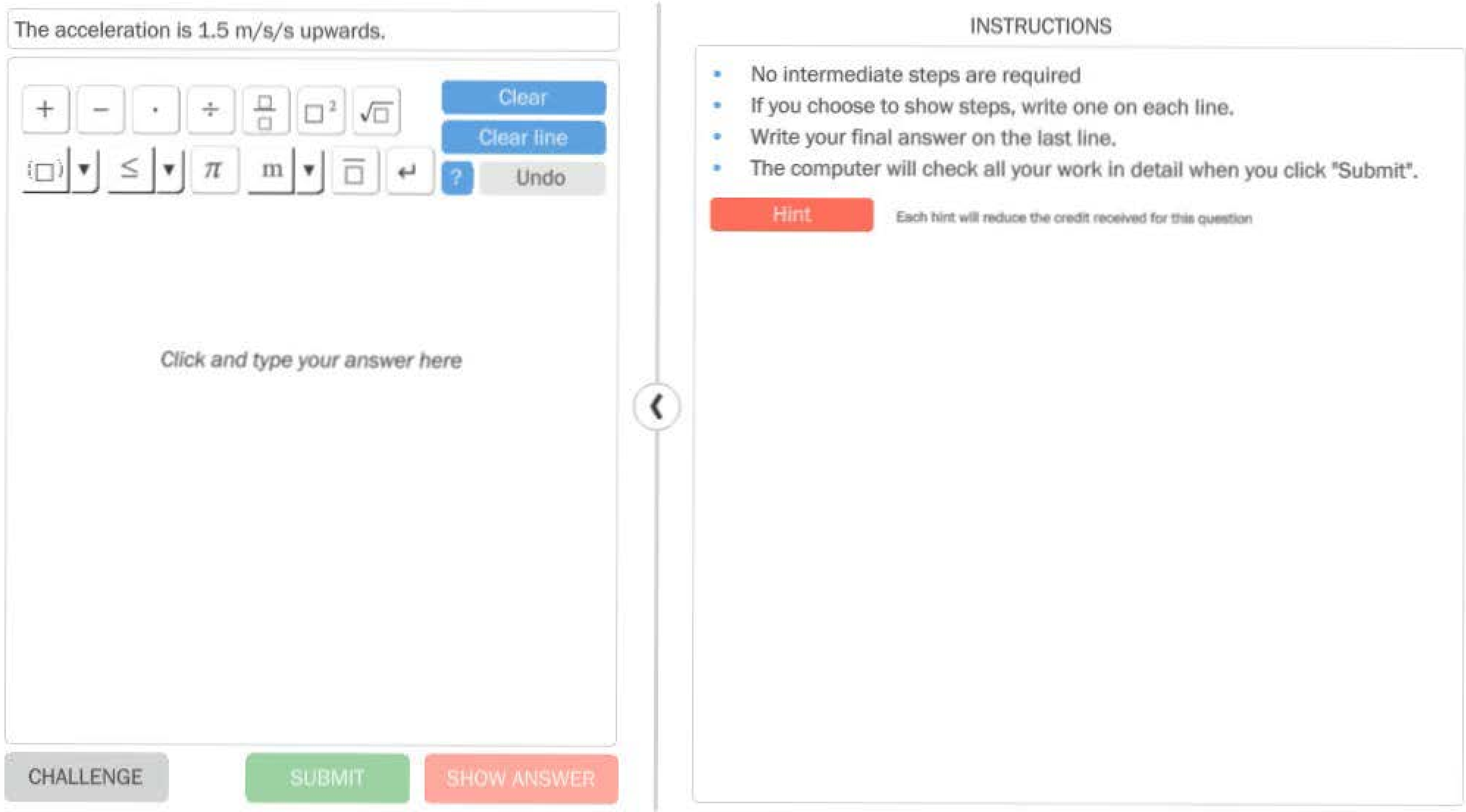
$$F = F_w - F_p$$
$$3\,\text{kN} = 14.7\,\text{kN} - F_p$$
$$\text{therefore } F_p = 11.7\,\text{kN}$$

Hence the force F_p in the cable is 11.7 kN.

Acceleration against gravity	Vertical motion	Using Newton's law to find acceleration against gravity	Application of Newton's law	Example	Solution	Acceleration upwards	Acceleration downwards

GIVE FEEDBACK

OK


The acceleration is 1.5 m/s/s upwards.
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Clear line
Undo
Click and type your answer here
CHALLENGE
SUBMIT
SHOW ANSWER
INSTRUCTIONS
No intermediate steps are required
If you choose to show steps, write one on each line.
Write your final answer on the last line.
The computer will check all your work in detail when you click "Submit".
Hint
Each hint will reduce the credit received for this question

The acceleration is zero, i.e. the elevator is at rest or moving with a constant velocity.

+ − · ÷ Clear

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
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- Write your final answer on the last line.
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Hint

Each hint will reduce the credit received for this question

The acceleration is 1.3 m/s/s downwards.

+ − · ÷ π m ↵

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Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

An elevator has a total mass of 1800 kg. Determine the force in the supporting cable for the given conditions.

SMALL MEDIUM LARGE

The acceleration is zero, i.e. the elevator is at rest or moving with a constant velocity.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
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- Write your final answer on the last line.
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HELP

An elevator has a total mass of 1800 kg. Determine the force in the supporting cable for the given conditions.

SMALL MEDIUM LARGE

The acceleration is 1.5 m/s/s upwards.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint

An elevator has a total mass of 1800 kg. Determine the force in the supporting cable for the given conditions.

SMALL MEDIUM LARGE

The acceleration is 1.3 m/s/s downwards.

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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HELP

Solving problems involving acceleration against friction on inclined planes

Acceleration against dry sliding friction

The underlying cause of resistance to continuous motion is usually found in some combination of different forms of friction. In this section we examine typical cases in which dry sliding friction between a body and a supporting surface is responsible for resistance to motion.

Draw a free body diagram resolving all forces into components along the plane (*x*-direction) and perpendicular to the plane (*y*-direction). Note that the force of friction F_f must always be shown in the direction opposite to that of motion.

Since there is no motion perpendicular to the plane, write the equation of equilibrium of forces in the *y*-direction, $\sigma F_y = 0$. Solve for the normal reaction F_n.

Using the law of dry sliding friction, $F_f = \mu F_n$, calculate the frictional resistance force F_f.

Since there is motion along the plane, write the expression for the net accelerating force *F*, i.e. add all forces assisting motion and subtract all forces opposing motion in the *x*-direction.

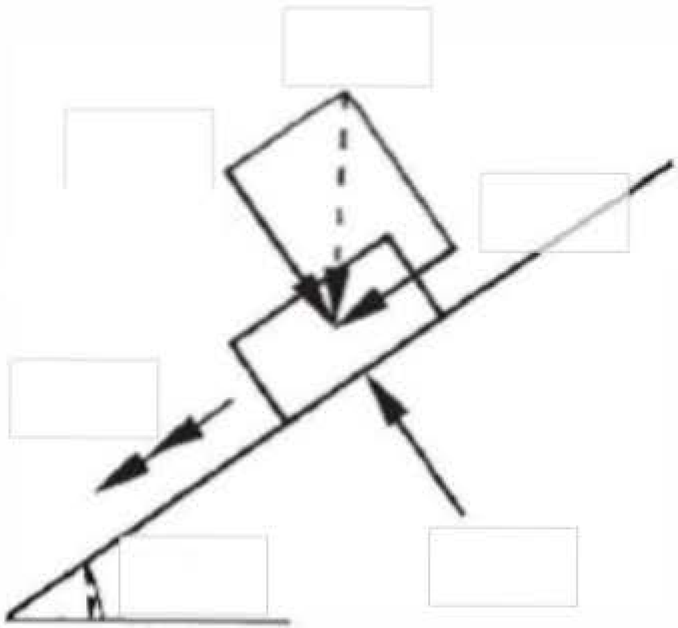
Substitute into Newton's law formula, *F* = *ma*, and then calculate the required unknown, which may be either the acceleration or the applied force F_p.

GIVE FEEDBACK

OK

Label the free body diagram.

$m\,g$	F_n	θ
a	$m\,g\cos\theta$	$m\,g\sin\theta$



Submit

Arrange the following steps for solving typical problems of acceleration against dry sliding friction into the correct sequence.

↑↓ Place these in the proper order.

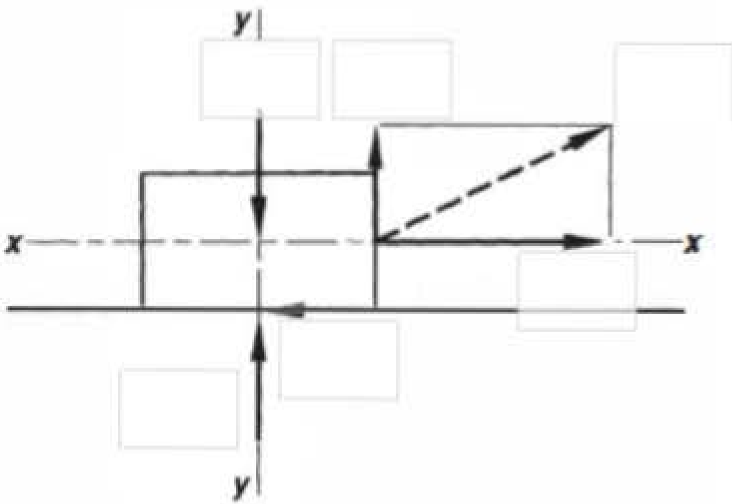
- Draw a free body diagram with forces resolved into x and y components.
- Write the equation of equilibrium of forces in the y direction and solve for the normal reaction.
- Calculate the dry sliding friction force.
- Write an expression for the net accelerating force in the x direction.
- Substitute into $F = m\,a$, and then calculate the required unknown quantity.

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Label the free body diagram.

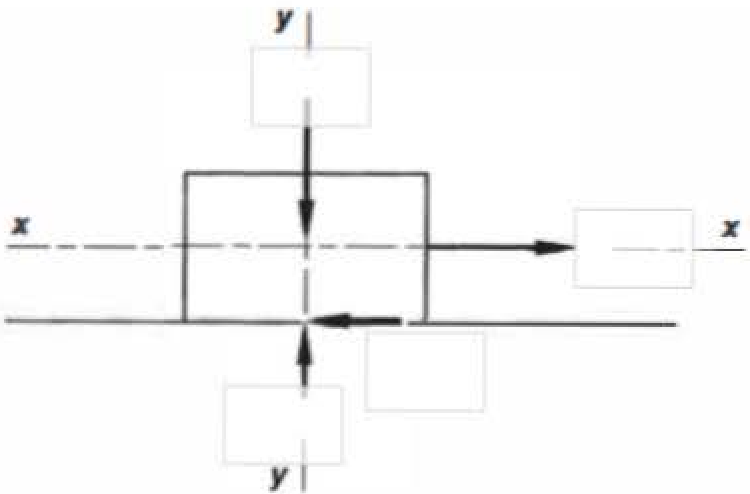
$F_{p\,y}$	$F_{p\,x}$	F_w
F_f	F_p	F_n



Submit

Label the free body diagram.

F_w	F_n	F_p	F_f



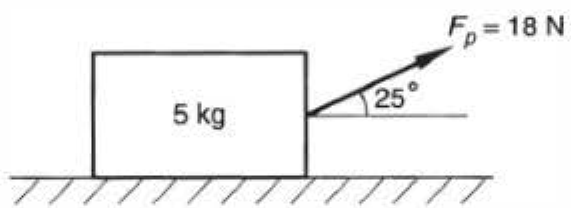
Submit

Do you know the answer?

I KNOW IT | THINK SO | UNSURE | NO IDEA

Example 2

The block shown below has a mass of 5 kg. The coefficient of friction between the block and the surface is 0.32. The force F_p of 18 N is applied at 25° to the horizontal as shown. Calculate the acceleration of the block, and hence the distance moved in 6 s, starting from rest.



GIVE FEEDBACK

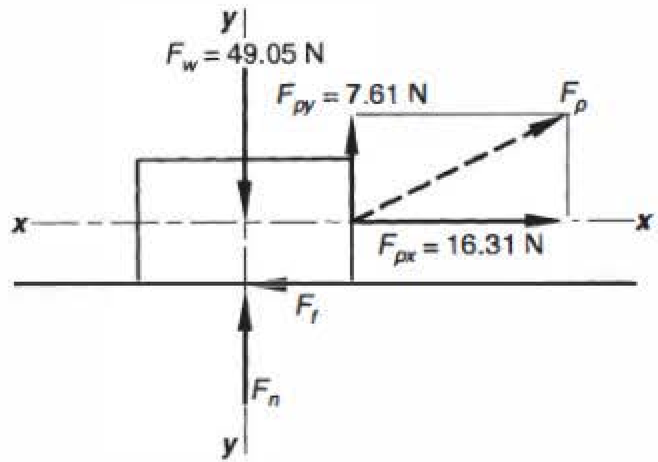
CONTINUE >

Solution

In this case, it is necessary to resolve the applied force into components:

$$
\begin{aligned}
F_{p\,x} &= 18\cos\ 25° \\
&= 16.31\ \text{N} \\
F_{p\,y} &= 18\sin\ 25° \\
&= 7.61\ \text{N}
\end{aligned}
$$

The free body diagram for the block is shown below.



< BACK
GIVE FEEDBACK
CONTINUE >

The weight of the block is:

$$\begin{aligned} F_w &= 5 \cdot 9.81 \\ &= 49.05 \text{ N} \end{aligned}$$

There is no motion perpendicular to the plane. Therefore, the forces must be balanced in the y-direction. The vertical component of the applied force is included in this equilibrium equation:

$$\begin{aligned} F_n + F_{p\,y} &= F_w \\ F_n + 7.61 &= 49.05 \\ \text{therefore } F_n &= 41.44 \text{ N} \end{aligned}$$

Hence, the normal reaction F_n is 41.44 N.

< BACK GIVE FEEDBACK CONTINUE >

Using the law of friction:

$$\begin{aligned} F_f &= \mu F_n \\ &= 0.32 \cdot 41.44 \\ &= 13.26\ \text{N} \end{aligned}$$

Hence, the frictional resistance force F_f is 13.26 N.

< BACK GIVE FEEDBACK CONTINUE >

The net accelerating force F in the x-direction is equal to the horizontal component of the unknown applied force $F_{p\,x}$ less frictional resistance F_f :

$$\begin{aligned} F &= F_{p\,x} - F_f \\ &= 16.31 - 13.26 \\ &= 3.05\ \mathrm{N} \end{aligned}$$

Substitute this into Newton's law formula:

$$\begin{aligned} F &= m\,a \\ 3.05 &= 5\,a \\ \text{therefore } a &= 0.61\ \mathrm{m/s^2} \end{aligned}$$

Hence, the acceleration along the plane is $0.61\ \mathrm{m/s^2}$.

< BACK GIVE FEEDBACK CONTINUE >

The distance moved in 6 s is now found using the appropriate equation of linear motion:

$$S = v_0 t + \frac{a t^2}{2}$$
$$= 0 + \frac{0.61 \cdot 6^2}{2}$$
$$= 11 \text{ m}$$

< BACK GIVE FEEDBACK OK

Example 1

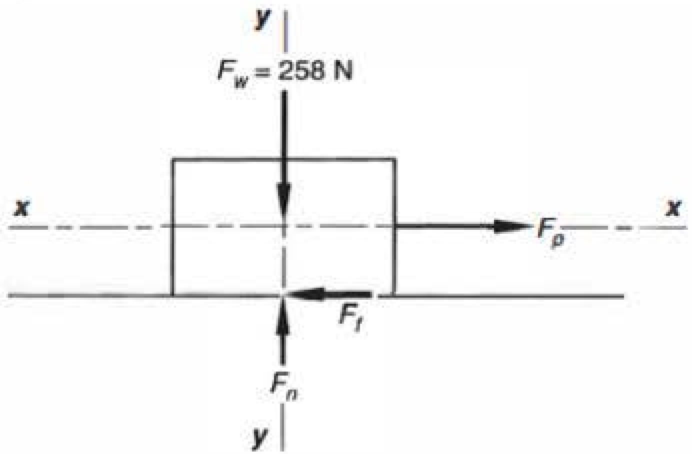
A block of mass 26.3 kg is sliding along a horizontal supporting surface with an acceleration of $1.7\ \mathrm{m/s^2}$ when pulled by a horizontal applied force F_p. If the coefficient of kinetic friction between the block and the surface is 0.35, what is the magnitude of the applied force?

GIVE FEEDBACK

CONTINUE >

Solution

Draw the free body diagram as shown below.



In this case all forces are either parallel or perpendicular to the plane. Therefore, there is no need to resolve them into components.

The weight of the block is:

$$\begin{aligned} F_w &= 26.3 \cdot 9.81 \\ &= 258 \text{ N} \end{aligned}$$

There is no motion perpendicular to the plane. Therefore, the forces must be balanced in the *y*-direction:

$$F_n = F_w$$

Normal reaction:

$$F_n = 258 \text{ N}$$

Using the law of friction:

$$\begin{aligned} F_f &= \mu F_n \\ &= 0.35 \cdot 258 \\ &= 90.3\ \mathrm{N} \end{aligned}$$

Therefore frictional resistance force F_f is 90.3 N.

The net accelerating force F in the x-direction is equal to the unknown applied force F_p less resistance F_f :

$$F = F_p - F_f$$

$$\text{therefore } F = F_p - 90.3$$

< BACK GIVE FEEDBACK CONTINUE >

Substitute this into Newton's second law formula:

$$F = m\,a$$
$$F_p - 90.3 = 26.3 \cdot 1.7$$
$$\text{therefore } F_p = 135\text{ N}$$

Hence the applied force F_p is 135 N.

< BACK GIVE FEEDBACK OK

Example 3

A box of mass 110 kg is accelerating downwards along a plane inclined at 35° to the horizontal against a restraining force of 185 N acting up along the plane. The coefficient of friction is 0.43. Calculate the acceleration of the box, and hence the time taken for it to slide 3 m along the plane.

GIVE FEEDBACK

CONTINUE >

Solution

The weight of the box is:

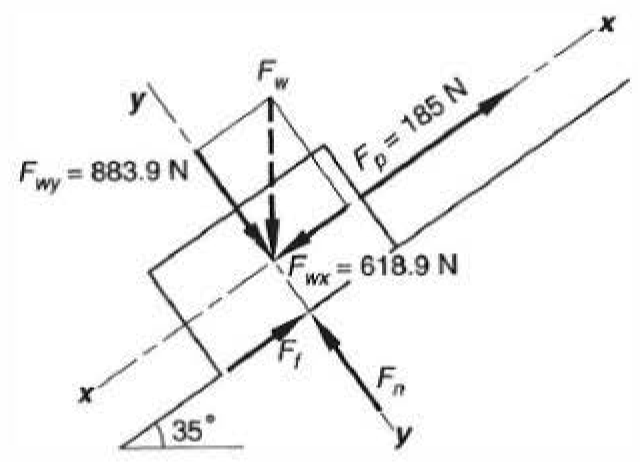
$$\begin{aligned} F_w &= 110 \cdot 9.81 \\ &= 1{,}079 \text{ N} \end{aligned}$$

In this case it is necessary to resolve the weight into components:

$$\begin{aligned} F_{w\,x} &= 1{,}079 \sin 35° \\ &= 618.9 \text{ N along the plane} \end{aligned}$$

$$\begin{aligned} F_{w\,y} &= 1{,}079 \cos 35° \\ &= 883.9 \text{ N perpendicular to the plane} \end{aligned}$$

< BACK GIVE FEEDBACK CONTINUE >



The free body diagram for this block

< BACK GIVE FEEDBACK CONTINUE >

Note carefully the direction of frictional resistance force F_f which is shown in opposition to motion, i.e. up the plane. There is no motion perpendicular to the plane. Therefore, the forces must be balanced in the y-direction. Only that component of weight which is perpendicular to the plane is relevant to this equilibrium equation:

$$\begin{aligned} F_n &= F_{w\,y} \\ &= 883.9 \text{ N} \end{aligned}$$

Thus, the normal reaction F_n is 883.9 N.

Using the law of friction:

$$\begin{aligned} F_f &= \mu F_n \\ &= 0.43 \cdot 883.9 \text{ N} \end{aligned}$$

Therefore, frictional resistance force F_f is 380.0 N.

< BACK GIVE FEEDBACK CONTINUE >

The net accelerating force F is equal to the algebraic sum of all forces acting in the x-direction along the plane. These include the applied force F_p, the force of frictional resistance F_f and the x-component of the weight F_{wx}.

Forces acting in the direction of acceleration are taken to be positive. Forces acting in the opposite direction are taken to be negative:

$$\begin{aligned} F &= F_{wx} - F_p - F_f \\ &= 618.9 - 185 - 380 \\ &= 53.9\ \mathrm{N} \end{aligned}$$

Therefore, the net accelerating force F is $53.9\ \mathrm{N}$.

< BACK GIVE FEEDBACK CONTINUE >

Substitute this into Newton's law formula:

$$\begin{aligned} F &= m\,a \\ 53.9 &= 110\,a \\ \therefore a &= 0.49\ \mathrm{m/s^2} \end{aligned}$$

Hence, the acceleration of the box along the plane is $0.49\ \mathrm{m/s^2}$.

< BACK GIVE FEEDBACK CONTINUE >

The time taken for the box to slide $3\ \mathrm{m}$ along the plane is now found by substituting values into the following equation of linear motion:

$$S = v_0 t + \frac{a t^2}{2}$$

$$3 = 0 + \frac{0.49 t^2}{2}$$

$$\therefore t = 3.5\ \mathrm{s}$$

Hence, the time taken is $3.5\ \mathrm{s}$.

< BACK GIVE FEEDBACK OK

Knowing the acceleration is 2.53 m/s^2 calculate the distance that the box will move from rest down the slope in 3.5 seconds.

(Answer correct to two decimal places.)

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Undo

Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
- If you choose to show steps, write one on each line.
- Write your final answer on the last line.
- The computer will check all your work in detail when you click "Submit".

Hint

Each hint will reduce the credit received for this question

A 50 kg box is pulled along a horizontal surface that has a friction coefficient of 0.39.

If a 300 N force is applied at an angle of 30 degrees to the horizontal, how long would it take for the box to move 4 m along the surface if it starts from rest?

(Answer correct to two decimal places.)

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$(\square)$ ▾ ≤ ▾ π m ▾ $\square_n$ $\overline{\square}$ Clear line

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CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required
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- Write your final answer on the last line.
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Hint

Each hint will reduce the credit received for this question

A 60 kg box accelerates from rest down a plane that is inclined at an angle of 40 degrees to the horizontal against a restraining force of 100 N. The surface has a friction coefficient of 0.28.

SMALL MEDIUM LARGE

Calculate the acceleration of the box down the inclined plane. (Answer to two decimal places.)

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint

A 60 kg box accelerates from rest down a plane that is inclined at an angle of 40 degrees to the horizontal against a restraining force of 100 N. The surface has a friction coefficient of 0.28.

SMALL MEDIUM LARGE

Knowing the acceleration is 2.53 m/s^2 calculate the distance that the box will move from rest down the slope in 3.5 seconds.

(Answer correct to two decimal places.)

Clear

Clear line

Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

- No intermediate steps are required.
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Hint

A 50 kg box is moved along a horizontal surface that has a friction coefficient of 0.39.

If the box accelerates at 1.5 m/s/s, what is the applied horizontal force? (Answer to one decimal place.)

+ − · ÷ ≤ π m

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Click and type your answer here

CHALLENGE

SUBMIT

SHOW ANSWER

INSTRUCTIONS

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Hint

Each hint will reduce the credit received for this question

A 50 kg box is pulled along a horizontal surface that has a friction coefficient of 0.39.

If the box accelerates at 1.5 m/s/s and the applied force acts at an angle of 30 degrees to the horizontal, what is the applied force?

(Answer correct to the nearest newton.)

+ − · ÷ π m

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Clear line

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint

Each hint will reduce the credit received for this question

A 50 kg box is pulled along a horizontal surface that has a friction coefficient of 0.39.

If a 300 N force is applied at an angle of 30 degrees to the horizontal, what is the acceleration?

(Answer in metres per second squared correct to two decimal places)

+ − · ÷ Clear

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Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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Hint Each hint will reduce the credit received for this question

Calculate the acceleration of the box down the inclined plane. (Answer to two decimal places.)

+ − · ÷ Clear

Clear line

π m ? Undo

Click and type your answer here

CHALLENGE SUBMIT SHOW ANSWER

INSTRUCTIONS

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