Engineering L2 – Motion and Newtons Laws

1 of 18 – Introduction

Welcome to this session on motion and Newton’s laws.

By the end of this session, you will be able to:

* Identify the four types of motion
* Explain Newton’s three laws of motion
* Know the effects of balanced and unbalanced forces on an object
* Define speed, velocity and acceleration​

2 of 18 – Types of motion​

There are four types of motion experienced by mechanical devices. Sometimes this motion is input, meaning it is done to the machine, and sometimes it is output, meaning the motion the machine moves as a result of the input motion.

The four types of motion are:

* Linear – in a straight line, such as opening a sliding door
* Rotary – around an axis or pivot point, such as a wheel
* Reciprocating – going backwards and forwards, such as a pump
* Oscillating – swinging from side to side around a pivot point, such as a pendulum.

3 of 18 – Speed and velocity​

Speed is how fast something is going. It is measured in metres per second (m/s) which means how many metres the object will travel in one second.

This relationship is shown in the equation:

speed equals distance divided by time

Velocity is speed with direction. Objects can be travelling at the same speed in different directions, however if one is going forwards and one is going backwards then they will each have a different velocity.

4 of 18 – Calculating speed​

We can use the equation speed equals distance divided by time to find out how fast an object is moving if we know how far it has travelled and how long it took to do so.

For example, a man is riding a bicycle along a road. He travels 100m in 10 seconds. How fast is he travelling? Have a go at working out the answer.

Answer:

speed equals distance divided by time

speed equals 100 divided by 10

speed equals 10m/s

5 of 18 – Acceleration

Acceleration is the rate of change of speed or velocity. It is measured in metres per second squared. It is defined as the final speed minus the initial speed, all divided by the time taken.

As an equation, that looks like this,

Acceleration equals, open brackets, final speed, minus, initial speed, close brackets, divided by time taken,

You will often see u to represent initial speed, v to represent final speed, a to represent acceleration and t to represent time.

Using these symbols, the equation looks like this,

a, equals, open brackets, v minus, u, close brackets, divided by t or v equals u plus a t,

If an object has a constant or uniform acceleration, then this means its speed will be increasing by the same about every second.

6 of 18 – Calculating with acceleration

As with other equations, we can use the equation relating speed, time and acceleration to find missing values when we know the others.

Remember the equation,

final speed equals initial speed plus open brackets acceleration multiplied by time taken close brackets,

Take a look at this example and have a go at working out the answer.

Consider an aeroplane taking off.

It leaves the ground moving at 80 metres per second.

It accelerates at a rate of 5 metres per second squared and takes 30 seconds to get into the air.

At the end of that time, what speed is it going?

**Answer**

final speed, equals, initial speed, plus, open brackets, acceleration multiplied by time taken, close brackets,

v equals u plus a t,

v equals 80 plus open brackets 5 multiplied by 30 close brackets,

v equals 80 plus 150,

v equals 230 metres per second​

7 of 18 – Uniform acceleration

When an object has a uniform acceleration, its speed will be increasing by the same about every second.

This can be defined in the equation:

s equals ut plus ½ at squared

Click on the terms in the equation to see what they represent.

s = the distance covered

u = the initial velocity of the object

t = the time interval

a = the acceleration of the object

This equation can be used to work out missing information, such as how long it will take for a constantly accelerating object will take to reach a point at a given distance away, or how far an object will travel in a given time if it accelerates constantly.

8 of 18 – Newton’s laws of motion

Sir Isaac Newton was a scientist who studied how objects move. In 1687, he created three laws of motion to describe what he had learnt about how forces affect the movement of things.

**Newton’s first law of motion** – An object will remain at rest or continue to move at a constant speed in a straight line unless another force acts upon it. In other words, if forces are balanced then the object will remain stationery or moving at a constant velocity.

**Newton’s second law of motion** – A resultant force is the single force acting on an object when all the individual forces have been combined. The equation force = mass x acceleration is often associated with this law, as it describes the fact that unbalanced forces cause a change in speed or direction.

**Newton’s third law of motion** – When forces act between two objects, they both experience an equal size force but in opposite directions. In other words, for every action there is an equal and opposite reaction.

9 of 18 – Friction

When objects move against one another, they create friction. Friction is a force that acts in the opposite direction to the forward motion, making it more difficult for objects to move.

Friction can be a useful force, such as when it allows tyres to grip to the road or allows a bicycle to brake and stop. However, it can also be unhelpful, particularly in machinery. Friction between machine parts causes wear and tear that can lead to malfunctions. It also slows down manufacture and can waste energy through heat. All these things cause extra costs which businesses do not want.

Friction can be reduced by using lubricants, such as oil or polish. Air resistance is also a type of friction, and this can be minimised through the design of the product to make it more aerodynamic.

10 of 18 – Balanced and unbalanced forces

When two forces acting upon the same object are equal in size but exactly opposite in direction, we call them balanced forces. If the forces are not the same size or are not exactly opposite in direction, we call them unbalanced forces.

Objects experiencing balanced forces are, as stated by Newton’s first law, either stationery or moving at a constant velocity. For example, a boat is floating on the water. Its weight is 30,000N pushing down into the water. The water pushes back up with an upthrust of 30,000N. These forces are equal and opposite, so the boat remains stationery and doesn’t sink or float up into the sky.

Objects experiencing unbalanced forces will be either accelerating or decelerating, which could involve a change of direction. For example, a truck is driving along the road. The wheels provide it with 95N of forward-moving force and the friction with the road is offering resistance of 50N against the direction of travel. As the forward-moving force is greater, the truck will be increasing in speed.

11 of 18 – Force, mass and acceleration

Newton’s second law of motion defines how an object’s acceleration is dependent on its mass and the forces acting on it. This can be shown using the equation force equals mass multiplied by acceleration or F equals m multiplied by a. Force is measured in newtons (N), mass in kg and acceleration in metres per second squared.

This equation can also be represented using an equation triangle, which makes it easy to rearrange the formula to find any one of the three values if it is unknown and you know the other two.

**Force**

Looking at the triangle; covering up force leaves mass multiplied by acceleration:

Force equals mass multiplied by acceleration,

or,

F equals m multiplied by a

**Mass**

Looking at the triangle; covering up mass leaves force over acceleration:

Mass equals force divided by acceleration,

or,

m equals F divided by a  
  
**Acceleration**

Looking at the triangle; covering up acceleration leaves force over mass:

Acceleration equals force divided by mass,

or,  
a equals F divided by m

12 of 18 – Acceleration Calculations

Acceleration can either be positive or negative.

Positive acceleration

When an object is speeding up it has positive acceleration.

Example:

Consider a car moving along a road. It is applying 3000N of force to move forward, but the friction of the road is applying 1000N of force to prevent it from doing so. The car weighs 1000kg.

What will its acceleration be?

acceleration equals force divided by mass

a equals F divided by m

a equals open brackets 3,000 minus 1,000 close brackets divided by 1,000

a equals 2,000 divided by 1,000

a equals 2 metres per second squared

Negative acceleration

When an object is slowing down it has negative acceleration also known as deceleration.

Example:

Consider the car moving along the road again. It is still applying 3,000N of force to move forward, but the combination of air resistance, friction of the road and braking force is now applying 6,000N of force to prevent it from moving forward. The car weighs 1,000kg.

What will its acceleration be?

acceleration equals force divided by mass

a equals F divided by m

a equals open brackets 3,000 minus 6,000 close brackets divided by 1,000

a equals minus 3,000 divided by 1,000

a equals minus 3 metres per second squared

13 of 18 – Mechanical devices

All moving parts are usually one or more simple mechanical machines, put together to convert one type of motion into another, or to make movement easier.

Key mechanical devices that can adjust the motion of an object include:

* Linkages – Levers can be joined together with moving and fixed pivots to form a linkage, which can change the direction of motion and amount of force.
* Cams – A follower creates linear motion from a shaped cam, changing the direction and period of movement from the consistently rotating camshaft.
* Gears – Wheels with teeth around the outside that interlock with each other to transfer motion to another place or change the direction or speed of movement.
* Belts – A loop of flexible material that goes around two or more pulley wheels, transferring movement from one rotating pulley to another, often to increase or decrease rotational velocity.

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14 of 18 - Question 1

What is acceleration measured in?

Choose one

* ms2
* m/s2
* ms
* m/s

**Answer:**

Acceleration is measured in metres per second squared (m/s2).

15 of 18 - Question 2

A woman is running along a road. She travels 400m in 50 seconds. How fast is she travelling?

Choose one:

* 5m/s
* 8m/s
* 12.5m/s
* 350m/s

**Answer:**

speed = distance / time

speed = 400 / 50

speed = 8m/s

16 of 18 - Question 3

The equation for uniform acceleration is s = ut + ½ at2

Match all the terms in the equation to the values they represent:

Terms

* t
* a
* s
* u

Values

* the distance covered
* the initial velocity of the object
* the time interval
* the acceleration of the object

**Answers:**

* s = the distance covered
* u = the initial velocity of the object
* t = the time interval
* a = the acceleration of the object

17 of 18 - Question 4

A car is moving along a road. It is applying 5000N of force to move forward, but the friction of the road is applying 1000N of force to prevent it from doing so. The car weighs 1000kg. What will its acceleration be?

Choose one:

* 4 m/s2
* 5 m/s2
* 2 m/s2
* 2.5 m/s2

**Answer:**

acceleration = force / mass

a = f / m

a = (5000 – 1000) / 1000

a = 4000 / 1000

a = 4 m/s2

18 of 18 - End

Well done. You have completed this session on motion and Newton’s laws. ​

You should now be able to: ​

* Identify the four types of motion
* Explain Newton’s three laws of motion
* Understand the effects of balanced and unbalanced forces on an object
* Define speed, velocity and acceleration

If you have any questions about anything covered in this session, speak to your tutor for more help. ​