Chapter 10: Force and motion 1

Knowledge organiser

Force and acceleration

If the velocity of an object changes it must be acted on by a **resultant force**. The acceleration is always in the same direction as the resultant force.

Gravity

The force of **gravity** close to the Earth is due to the planet's **gravitational field strength**.

Weight is the force acting on an object due to gravity.

The weight of an object

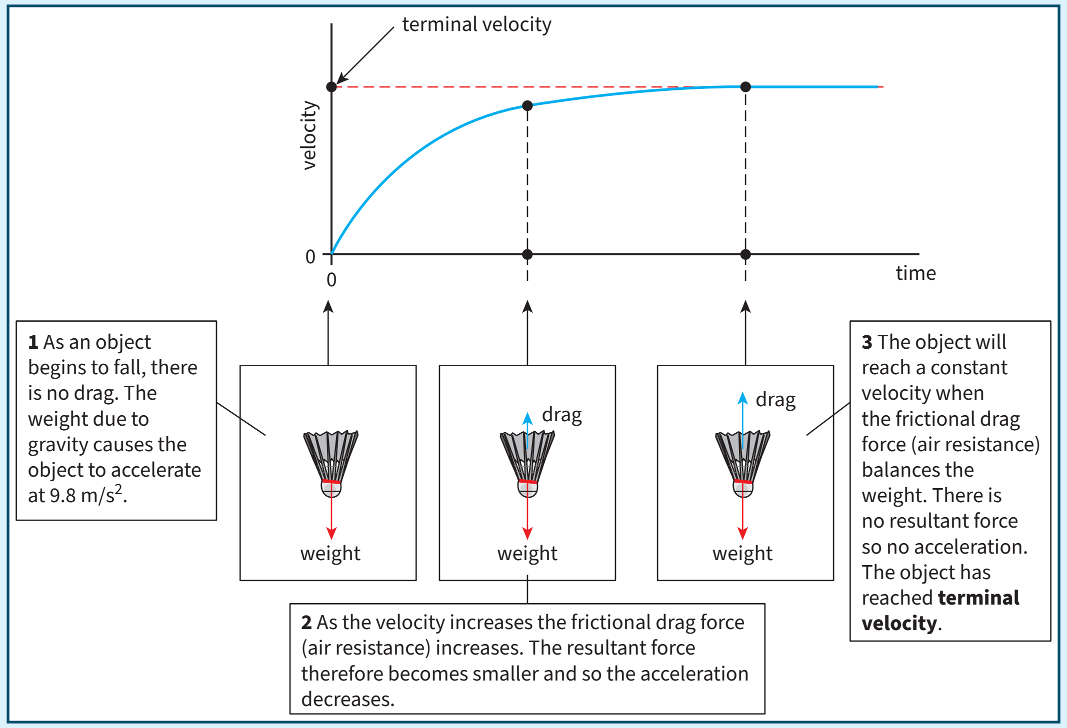
- can be considered to act at the object's **centre of mass**
- can be measured using a calibrated spring-balance (newtonmeter).

weight (N) = mass (kg) × gravitational field strength (N/kg)

$$W = m g$$

Weight and mass are directly proportional to each other, which can be written as $W \propto m$, so as the mass of an object doubles, its weight doubles.

Graph of terminal velocity



Newton's Second Law

Newton's Second Law says that the acceleration a of an object:

- is proportional to the resultant force on the object

$$a \propto F$$

- is inversely proportional to the mass of the object

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

Resultant force, mass and acceleration are linked by the equation:

resultant force (N) = mass (kg) × acceleration (m/s²)

$$F = ma$$

The **inertial mass** of an object is a measure of how difficult it is to change the velocity of an object. It can be found using:

$$\text{inertial mass (kg)} = \frac{\text{force (N)}}{\text{acceleration (m/s}^2\text{)}}$$

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

Terminal velocity

For an object falling through a fluid:

- there are two forces acting – its weight due to gravity and the drag force
- the weight remains constant
- the drag force is small at the beginning, but gets bigger as it speeds up
- the resultant force will get smaller as the drag force increases
- the acceleration will decrease as it falls
- if it falls for a long enough time, the object will reach a final steady speed.

Terminal velocity is the constant velocity a falling object reaches when the frictional force acting on it is equal to its weight.

If an object is only acted on by gravity the acceleration will be 9.8 m/s²

Momentum (HT only)

Momentum is a property of all moving objects. It is a vector quantity.

Momentum depends on the mass and velocity of an object and is defined by the equation:

mome (kg m/s) = mass (kg) × velocity (m/s)

$$p = mv$$

Law of Conversion Momentum (HT only)

The **Law of Conservation of Momentum** says that:

In a closed system, the total momentum before an event (a collision or an explosion) is *equal* to the total momentum after the event.

If two moving objects collide the law of conservation can be written as:

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

m_1 = mass of object 1 m_2 = mass of object 2

u_1 = initial velocity of object 1 u_2 = initial velocity of object 2

v_1 = final velocity of object 1 v_2 = final velocity of object 2

Momentum is conserved in explosions because:

- the total momentum before is zero
- the total momentum after is also zero because the different parts of the object travel in different directions and so the momentum of each part will cancel out with the momentum of another part.

If two moving objects **recoil** from each other, they start off with a total momentum of zero and end up moving away from each other with velocities v_1 and v_2. In this case, the law of conservation can be written as:

$$m_1v_1 + m_2v_2 = 0$$

Key terms

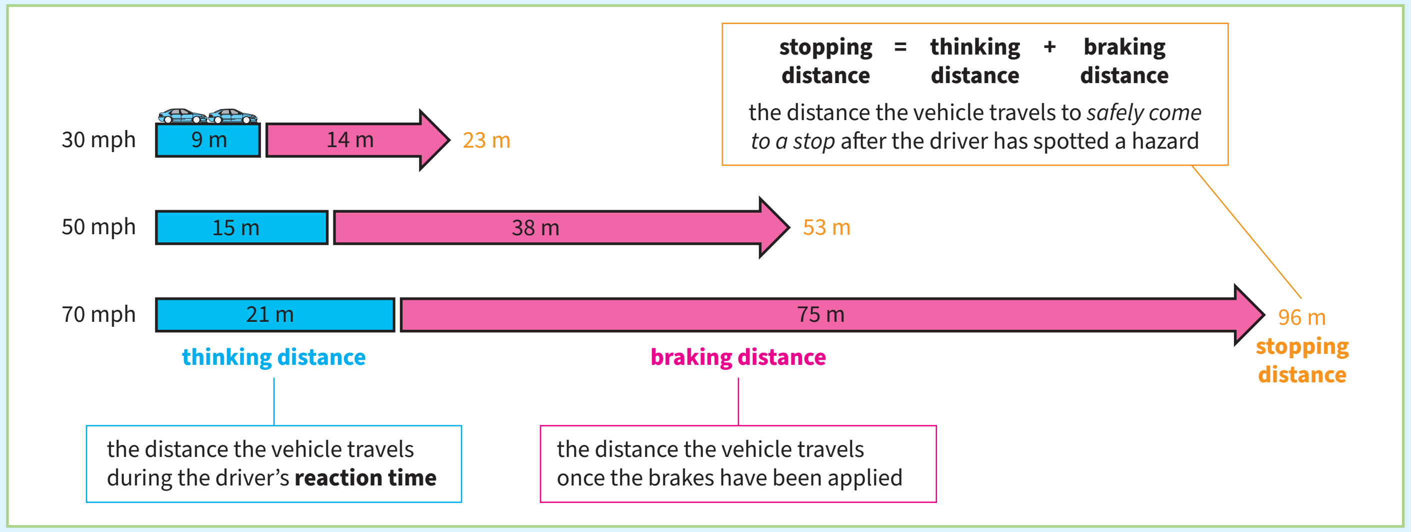
Make sure you can write a definition for these key terms.

acceleration   centre of mass   gravitational field strength   inertia   inertial mass   law of conservation of momentum   momentum   Newton's Second Law   recoil   resultant force   terminal velocity   weight

Chapter 10: Force and motion 2

Knowledge organiser

Forces and braking



Factors affecting braking distance:

- speed of the car
- road conditions
- conditions of the brakes and the tyres

Factors affecting thinking distance:

- speed of the car
- tiredness
- drugs
- alcohol
- distractions

Deceleration (HT only)

Deceleration of a vehicle can be calculated using the equation

$v^2 = u^2 + 2as$

where *s* is the distance travelled, *u* is the initial speed, and *v* is the final speed.

Deformation

Deformation is a change in the shape of an object caused by stretching, squashing (compressing), bending, or twisting.

More than one force has to act on a stationary object to deform it, otherwise the force would make it move.

Elastic deformation – the object can go back to its original shape and size when the forces are removed.

Inelastic deformation – the object does not go back to its original shape or size when the forces are removed.

Changes in momentum

If an object is moving or is able to move, an unbalanced force acting on it will change its momentum.

Since $F = ma$ and $a = \frac{\Delta v}{t}$, we can write:

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

where $m\Delta v$ is the change in momentum of an object.

The greater the time taken for the change in momentum of an object:

- the smaller the rate of change of momentum
- the smaller the force it experiences.

This means the force acting on an object is equal to the rate of change of momentum of the object.

Vehicle safety features increase the time taken for the change in momentum, e.g.:

- air bags, seat belts, and crumple zones in cars
- cycling helmets
- crash mats used for gymnastics

Impact forces (HT only)

The longer the impact time, the more the impact force is reduced.

When two vehicles collide, they exert equal and opposite impact forces on each other at the same time.

Therefore, the change of momentum of one vehicle is equal and opposite to the change of momentum to the other vehicle.

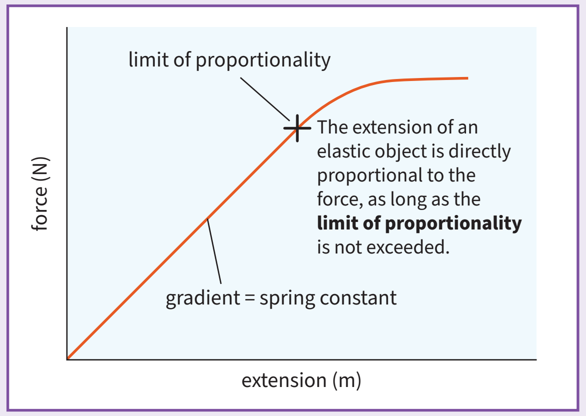
Graphs of force against extension for elastic objects

The spring constant can be calculated using the equation:

L force applied (N) = spring constant (N/m) × extension (m)

$$F = k\,e$$

This relationship also applies to compressing an object, where e would be compression instead of extension.



Key terms

Make sure you can write a definition for these key terms.

braking distance · deceleration · deformation · elastic · inelastic · limit of proportionality · reaction time · stopping distance · thinking distance

Chapter 10: Force and motion

Retrieval questions

Learn the answers to the questions below then cover the answers column with a piece of paper and write as many as you can. Check and repeat.

	P10 questions	Answers
1	What is the name given to the distance a vehicle travels to safely come to a stop after the driver has spotted a hazard?	stopping distance
2	What is thinking distance?	the distance vehicle travels during driver's reaction time
3	What is braking distance?	the distance vehicle travels once brakes have been applied
4	What is the relationship between stopping distance, thinking distance, and braking distance?	stopping distance = thinking distance + braking distance
5	Does the speed of a vehicle have a bigger effect on braking distance or thinking distance?	braking distance
6	Which distance is proportional to the speed of the vehicle?	thinking distance
7	What are three factors that can affect the braking distance of a vehicle?	speed, road conditions, condition of tyres and brakes
8	What can happen if the braking force used to stop a vehicle is very large?	brakes may overheat / the car may skid
9	What is the law of conservation of momentum?	in a closed system, the total momentum before an event is equal to the total momentum after it
10	What does $m\Delta v$ stand for?	change in momentum
11	How is the force acting on an object related to its momentum?	force acting on an object = rate of change of momentum
12	What are examples of everyday safety features which work by increasing the time taken for the change in momentum?	air bags, seat belts, crumple zones in cars, cycle helmets, crash mats in gyms, cushioned surfaces in children's playgrounds
13	What is elastic deformation?	an object can go back to its original shape and size when deforming forces are removed
14	What is inelastic deformation?	an object does not go back to its original shape and size when deforming forces are removed
15	How do you find the spring constant from a force-extension graph of a spring?	find the gradient of the straight line section

Put paper here