Lesson Three

Friction and Momentum

Aims

By the end of this lesson you should be able to:

- understand friction as a force that opposes motion, and use this to explain why falling objects reach a terminal velocity
- know that the stopping distance of a vehicle equals the thinking distance plus the braking distance, and describe the factors affecting these

Context

This lesson covers sections 1.16, 1.19 – 1.21 and 1.25P – 1.28P of the Edexcel IGCSE Physics specification.

Edexcel International GCSE (9-1) Physics Student Book, pages 21-22, 32-33 and 35-36.

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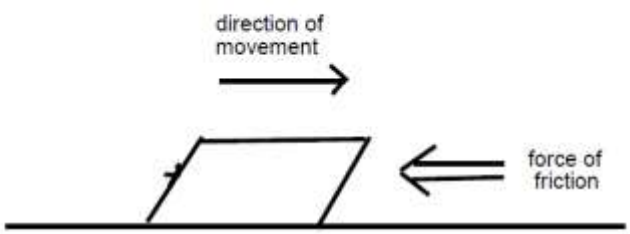
Introduction

In Lesson Two we studied forces as pushes or pulls and their effects on the motion of objects. In this lesson we study one particular force: friction. We then examine another tricky but very useful idea connected with motion: the momentum of objects.

Remember to review 'Using Numbers in Physics' while working through this lesson.

Friction

Friction is the force which tries to stop two surfaces sliding over each other. It therefore "opposes motion" when objects are in contact, pushing in the opposite direction to the direction of movement:



Log on to Twig and look at the film titled: **Friction**

www.ool.co.uk/1499my

Friction can be friend or foe. What is friction, how does it affect our lives and how can we alter it?

Sometimes friction is useful. For example:

- friction between your feet and the ground stops you slipping when walking or running;
- friction between the discs and the wheels of a car enable its brakes to slow the car down.

Often, however, friction is a nuisance, and we try to minimise it. For example:

- **air resistance**, or **drag**, is friction between a moving car and the air, which increases as the car speeds up; the car is streamlined to reduce the size of this friction;
- friction between the moving parts of a car engine tends to slow it down; oil is used as a **lubricant** to reduce this effect.

Activity 1

Think of two more instances where friction is useful, and two more where it is a nuisance.

Describe how you could use a newtonmeter to compare the force of friction between a sliding block and different surfaces.

Log on to Twig and look at the film titled: **Aerodynamics In Cycling**

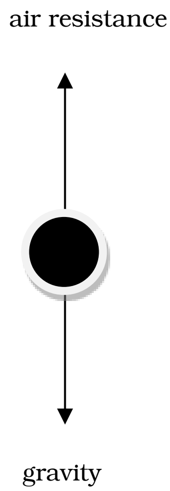
www.ool.co.uk/1502dy

The cutting edge bike and clothing designs that make cyclists more aerodynamic and can make the difference between winning and losing.

Terminal velocity

Imagine a man who has just jumped out of a hot air balloon high in the sky.

1. As he falls, there are two opposing forces acting on him: the force of gravity (his weight) pulling him downwards, and air resistance (friction between his surface and the air as he falls through it) pushing him up:



At first gravity is greater than air resistance. So there is a resultant force downwards which speeds him up: he accelerates, or falls faster.

2. As he falls faster:

- the force of gravity stays the same (it is never affected by speed of movement);
- but the air resistance increases.

so the resultant downwards force gets less and less. He still accelerates, but less and less than before.

3. Eventually he reaches a speed where the air resistance is equal and opposite to the force of gravity. The resultant force is now zero so he falls at a constant speed. This speed is known as his **terminal velocity**. He will fall at this speed until he either opens a parachute or hits the ground.

A "terminal velocity" is reached whenever some sort of driving force (the force of gravity in this case) is opposed more and more by friction as the movement speeds up.

Log on to Twig and look at the film titled: **Terminal Velocity**

www.ool.co.uk/1493gt

If a skydiver jumps out of a plane, when will they stop accelerating? Competing physical forces hold the answer.

Activity 2

Use what you now know about forces and motion to explain why:

(a) the man falls more slowly once his parachute opens

(b) all cars have a top speed

Vehicle stopping distances

Imagine a car driving along a road when a child runs out in front of it. The driver slams on the brakes and stops just before hitting the child. The distance covered by the car between when the driver first sees the child and when it comes to a halt is called the car's **stopping distance**.

Obviously, the faster the car is going the longer that stopping distance will be. You might think that doubling the speed would double the stopping distance, but in fact it *more than doubles it*. See the data on page 32 of the textbook, which you can also find by putting "highway code stopping distances chart" into the Google search engine.

The stopping distance is made up of two components:

1. The **thinking distance**. This is the distance covered by the car between the driver noticing the child and first applying the brakes. This *doubles* as the speed of the car doubles, because it is governed by the formula distance = speed × time (Lesson 1).

   The thinking distance increases if the **reaction time** of the driver gets longer (the time between her noticing the child and her foot starting to move towards the brake pedal). This will happen if the driver is tired, drunk, very old, or distracted (for example by using a mobile phone).

2. The **braking distance**. This is the distance covered by the car while actually braking. This *more than doubles* as the speed doubles, for a reason we will discover when we study kinetic energy in a later lesson.

   The braking distance increases if the road is wet, icy, covered in loose material or is downhill, or if the car is overloaded (its mass is greater), or if it has defective brakes or tyres.

Activity 3	1. Use the chart to find out how many times greater (i) the thinking distance and (ii) the stopping distance of a car is at 60 mph than at 30 mph.

2. Explain why the following increase the stopping distance of a car: (i) overloading it (ii) the driver being drunk (iii) an icy road. Use the formulae from Lessons 1 and 2 in your explanations wherever possible.

Now is the time to read through *Edexcel International GCSE (9-1) Physics Student Book*, pages 21-22, 32-33 and 35-36. This covers the same topics as the lesson, so will add to your understanding of the material.

Keywords

friction	**air resistance**
drag	**lubricant**
terminal velocity	**stopping distance**
thinking distance	**braking distance**

Summary

Friction - terminal velocity
- stopping distances

What you need to know

- the meanings of the terms printed in bold in the lesson
- why falling objects reach a terminal velocity
- the effects of driver, vehicle and road conditions upon stopping distances

Self-Assessment Test: Lesson Three

Remember to review the introductory lesson, 'Using Numbers in Physics' before attempting this test.

1. A speedboat accelerates from rest. At first it gets faster, but then its speed remains constant even though its engine is running flat out. Explain this.

Suggested Answers to Activities

Activity 1

Use a newtonmeter to push or pull the block along the surface at constant speed. (Some newtonmeters measure pushes and some measure pulls. In the second case, attach the newtonmeter to the block with string or an elastic band). Read the force in newtons while the block is moving. Repeat on different surfaces. The surface giving the highest reading on the newtonmeter has the greatest friction between it and the sliding block.

N.B. generally speaking, rough surfaces result in more friction than smooth ones, and wet or icy surfaces give less friction than dry ones.

Activity 2

(a) The increased surface area of the parachute dramatically increases the upwards air resistance. There is now a resultant upwards force, opposing his motion, which decelerates him.

(b) As a car goes faster, the air resistance opposing its motion increases. The friction in the engine may also increase. Eventually these frictional forces are equal and opposite to the thrust (driving force) from the engine. There is now no resultant forwards force, so the car moves at a constant speed.

Activity 3

(a) (i) The thinking distance is twice as great (18m compared to 9m).

(ii) The stopping distance is over three times as great (73m compared to 23m).

(b) (i) The mass is greater, but the frictional force from the brakes stays the same.

Acceleration = force / mass (Lesson 2), so the (negative) acceleration will be less. This increases the braking distance.

(ii) This increases the reaction time of the driver, and hence the thinking distance, because

distance = speed × time (Lesson 1)

(iii) This reduces the friction between the tyres and the road, and hence the force slowing the car.
Acceleration = force / mass (Lesson 2), so the (negative) acceleration is less. This increases the braking distance.

Suggested Answers to Self-Assessment Test: Lesson Three

1. At first the thrust from the engine is greater than the drag from the water. The resultant forwards force accelerates the boat. As the boat speeds up, the drag increases, but the thrust from the engine remains constant. When the boat reaches a speed at which the two are equal, the resultant force is zero, and the boat moves at constant speed.