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OCR
Oxford Cambridge and RSA

GCSE (9–1)
Delivery Guide

GATEWAY SCIENCE PHYSICS A

J249
For first teaching in 2016

Forces and Motion

Version 1

www.ocr.org.uk/physics

Introduction

GCSE (9–1) GATEWAY SCIENCE PHYSICS A

Delivery guides are designed to represent a body of knowledge about teaching a particular topic and contain:

- Content: A clear outline of the content covered by the delivery guide;
- Thinking Conceptually: Expert guidance on the key concepts involved, common difficulties learners may have, approaches to teaching that can help learners understand these concepts and how this topic links conceptually to other areas of the subject;
- Thinking Contextually: A range of suggested teaching activities using a variety of themes so that different activities can be selected which best suit particular classes, learning styles or teaching approaches.

If you have any feedback on this Delivery Guide or suggestions for other resources you would like OCR to develop, please email resources.feedback@ocr.org.uk

Mathematical learning outcomes: **PM2.1i Recall and apply distance travelled (m) = speed (m/s) x time (s).** **PM2.1ii Recall and apply acceleration (m/s²) = change in velocity (m/s) / time (s).** **PM2.1iii Apply (final velocity (m/s))² – (initial velocity (m/s))² = 2 x acceleration (m/s²) x distance (m).** **PM2.1iv Recall and apply kinetic energy (J) = 0.5 x mass (kg) x(speed (m/s))².**	
P2.1a	Describe how to measure distance and time in a range of scenarios.
P2.1b	Describe how to measure distance and time and use these to calculate speed.
P2.1c	Make calculations using ratios and proportional reasoning to convert units and compute rates.
P2.1d	Explain the vector-scalar distinction as it applies to displacement and distance, velocity and speed.
P2.1e	Relate changes and differences in motion to appropriate distance-time, and velocity-time graphs, and interpret lines, slopes and enclosed areas in such graphs.
P2.1f	**Interpret enclosed area in velocity-time graphs**
P2.1g	Calculate average speed for non-uniform motion.
P2.1h	Apply formulae relating distance, time and speed, for uniform motion, and for motion with uniform acceleration.

Approaches to teaching the content:

The basics tools to describe motion using graphs and the speed = distance x time formula should have been covered at Key Stage 3. Many of the concepts within in this topic, which can be demonstrated through practical work, depend upon conditions being perfect and presuming that friction is negligible. It is a good opportunity to develop graph skills and basic re-arrangement of formulae.

This subtopic may be a good opportunity to introduce exercises to develop the skill of selecting appropriate apparatus to measure to different levels of precision. Forces and motion covers concepts which are very visible in our everyday lives, providing us with many different contexts to teach them within, allowing us to tailor teaching to the audience.

Common misconceptions or difficulties learners may have:

The difference between vector and scalar quantities can pose difficulties in understanding. This can be addressed simply when looking at the difference between displacement-time and velocity-time graphs and what they actually show. Applying this to forces during the next part of this topic may help to reinforce this idea.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

This topic involves many calculations and interpretation of graphs. It is crucial that these opportunities are well utilised to develop these numeracy skills as learners will be required to use similar skills across many areas of physics.

Approaches to teaching the content:

A very simple demonstration to highlight the difference between distance and displacement could be to walk around the classroom and ask learners to consider how far you have walked, as well how far you are from where you started. The idea of displacement being the distance from the original start position and not just the distance travelled can be a little confusing.

Once distance-time, displacement-time and velocity-time graphs have been introduced, develop learners' literacy by asking them to 'write the story' of the journey shown by a graph or by challenging them to describe a journey by drawing a graph of their own. This could be a peer assessed activity and provides the opportunity to use maths.

Activity 1

Applying the speed distance time triangle

BBC Bitesize
http://www.bbc.co.uk/bitesize/standard/maths_i/numbers/dst/revision/1/

This page includes worked examples and opportunities for learners to practise applying the formulae with worked answers for them to self-assess.

Activity 2

Graph Shots

National STEM Centre
http://www.nationalstemcentre.org.uk/elibrary/resource/473/graph-shots

Learners watch clips of a football game, linking the movement of highlighted players to motion graphs. There is a corresponding worksheet and a quiz at the end to check understanding. (Subscription is required to access resources but it is free.)

Activity 3

Interpreting distance-time and speed-time graphs

Teachit Science
http://www.teachitscience.co.uk/index.php?CurrMenu=2184&resource=20854

A useful resource with different examples of distance-time and speed-time graphs which can be used as worked examples or as tasks for learners to complete. (Free subscription is required to access this resource, paid subscription allows access to further resources.)

Activity 4

Hare and the tortoise distance-time graph game

TES
https://www.tes.com/teaching-resource/hare-and-the-tortoise-distance-time-graphs-game-6061038

A resource that involves drawing different distance-time graphs and a card matching activity.

Activity 5

Graph shots

http://2901.stem.org.uk/Graph%20Shots/

A football match related video clip with questions based around the clip about distance-time graphs.

Activity 6

Skate boarders

Colman Web
http://www.colmanweb.co.uk/Assets/SWF/Skate_boarders.swf

An interactive distance-time graph creator with skate boarders.

Activity 7

Velocity-time graphs

Physics Lab
http://dev.physicslab.org/Document.aspx?doctype=3&filename=Kinematics_VelocityTimeGraphs.xml

A web page with a number of questions at the bottom to test learners on the interpretation of velocity-time graphs.

Activity 8

Describing velocity

The Concord Consortium
http://concord.org/stem-resources/describing-velocity

This online resources uses animations and activities to help learners understand velocity and motion graphs.

Mathematical learning outcomes: **PM2.2i Recall and apply force (N) = mass (kg) x acceleration (m/s²).** **PM2.2ii Recall and apply momentum (kgm/s) = mass (kg) x velocity (m/s).** **PM2.2iii Recall and apply work done (J) = force (N) x distance (m) (along the line of action of the force).** **PM2.2iv Recall and apply power (W) = work done (J) / time (s).**	
P2.2a	Recall examples of ways in which objects interact.
P2.2b	Describe how such examples involve interactions between pairs of objects which produce a force on each object.
P2.2c	Represent such forces as vectors
P2.2d	Apply Newton's First Law to explain the motion of an object moving with uniform velocity and also an object where the speed and/or direction change.
P2.2e	Use vector diagrams to illustrate resolution of forces, a net force, and equilibrium situations. (HT)
P2.2f	Describe examples of the forces acting on an isolated solid object or system. (HT)
P2.2g	Describe, using free body diagrams, examples where two or more forces lead to a resultant (net) force on an object (qualitative only). (HT)
P2.2h	Describe, using free body diagrams, examples of the special case where forces balance to produce a resultant force of zero. (HT)
P2.2i	Apply Newton's Second Law in calculations relating forces, masses and accelerations.
P2.2j	Explain that inertia is a measure of how difficult it is to change the velocity of an object and that the mass is defined as the ratio of force over acceleration. (HT)
P2.2k	Define momentum and describe examples of momentum in collisions.
P2.2l	Apply formulae relating force, mass, velocity and acceleration to explain how the changes involved are inter-related.
P2.2m	Use the relationship between work done, force and distance moved along the line of action of the force and describe the energy transfer involved.
P2.2n	Calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules.
P2.2o	Explain, with reference to examples, the definition of power as the rate at which energy is transferred.
P2.2p	Recall and apply Newton's Third Law.
P2.2q	Explain why an object moving in a circle with a constant speed has a changing velocity (qualitative only). (HT)

Approaches to teaching the content:

Forces are covered at Key Stage 3 so learners should have a good grasp of the basic concepts. However this subtopic covers a number of new areas that they may not be as familiar with. Forces acting as pairs and application of Newton's three laws will be new material. Alongside this the skill of drawing scale vector diagrams may have to be covered.

Momentum, inertia and vector diagrams alongside the concepts of inertia and circular motion could be taught with practical demonstrations or application to real life contexts. They rely on learners being skilled enough to make the vector-scalar distinction. Be aware that learners will already have come across many of the terms used in this topic in an everyday sense and the scientific meanings and uses of these terms will need to be reinforced.

Common misconceptions or difficulties learners may have:

Learners often have difficulty grasping the link between forces and motion, believing that no motion means that there is no force and also that no force leads to a lack of motion. Another concept that learners find difficult to understand is that of a reaction force e.g. the reason why the object doesn't fall is that the table is in the way, rather than that the table is exerting a force on the object. It can be difficult for learners to grasp elastic and inelastic collisions as, again, any demonstrations that we can perform are likely to be flawed by the presence of friction or air resistance. In these cases, simulations can be particularly helpful.

Approaches to teaching the content:

Contexts such as sports and moving vehicles are ones that many learners will be able to relate to and can be adapted to different groups of learners to match their interests. Events such as the Olympics provide many opportunities to analyse forces and motion in different situations. Activities such as rollerblading can be used to introduce situations with little or no friction and compare them to walking on a floor, as learners may find it difficult to grasp the fact that we require friction between the floor and our shoes to allow us to move.

It may be useful for learners to consider their own bodies when considering forces. For example, ask learners to consider how they can stay upright if someone was trying to push them over. This helps to reinforce the idea that objects can remain still, even when there are forces acting.

Activity 1

Forces Dance Mat

TES
https://www.tes.com/teaching-resource/forces-dance-mat-active-learning-6269067

This could be used as a plenary activity to summarise resultant forces and a good revitaliser during a lesson which could be quite calculation heavy. Learners jump in the direction of the resultant force.

Activity 2

Free body diagrams

The Physics Classroom
http://www.physicsclassroom.com/Class/newtlaws/U2L2c

This is a useful self study or group activity for learners, both as an introduction to and to practice drawing free body diagrams.

Activity 3

Collision Lab

PhET
https://phet.colorado.edu/sims/collision-lab/collision-lab_en.html

This simulation is particularly useful if an air track is not available to demonstrate elastic and inelastic collisions. Clicking on the 'more data' button allows you to see the velocity of each ball and carry out momentum calculations should you wish to do so.

Activity 4

Interaction Pairs

The Physics Classroom
http://www.physicsclassroom.com/Class/newtlaws/U2l4b.cfm

This could be used as a self-assessment tool or plenary quiz to check understanding of interaction pairs. Learners are challenged to identify the interaction pair in different situations. Answers are given on the page.

Activity 5

Circular motion

TES
https://www.tes.com/teaching-resource/circular-motion-questions-and-answers-11084677

A worksheet with answers to answer questions of circular motion. There is some context within the questions but some questions on stellar evolution that are not covered in this subtopic.

Activity 6

Space shuttle landing

NASA Education (TES)
https://www.tes.com/teaching-resource/space-shuttle-landing-6410515

A resource from NASA which allows learners to apply the laws of motion, force, work and energy to a space shuttle.

Activity 7

Force, mass and acceleration

TES
https://www.tes.com/teaching-resource/force-mass-acceleration-differeniated-activity-11185508

A resource that allows for differentiation where learners gain points by answering questions of increasing demand.

Activity 8

Forces

TES
https://www.tes.com/teaching-resource/forces-equals-m-x-a-ks4-physics-lesson-6341377

PowerPoint with worksheets on forces, mass and acceleration.

Mathematical learning outcomes:	
PM2.3i	**recall and apply: force exerted by a spring (N) = extension (m) x spring constant(N/m)**
PM2.3ii	**apply: energy transferred in stretching (J)= 0.5 x spring constant (N/m) x (extension(m))^2**
PM2.3iii	**recall and apply: gravity force (N) = mass (kg) x gravitational field strength, g (N/kg)**
PM2.3iv	**recall and apply: (in a gravity field:) potential energy (J) = mass (kg)x height (m) x gravitational field strength, g (N/kg)**
PM2.3v	**recall and apply: pressure (Pa) = force normal to a surface (N) / area of that surface(m^2)**
PM2.3vi	**recall and apply: moment of a force (Nm)= force (N) x distance (m) (normal to direction of the force)**
P2.3a	explain that to stretch, bend or compress an object, more than one force has to be applied
P2.3b	describe the difference between elastic and plastic deformation (distortions) caused by stretching forces
P2.3c	describe the relationship between force and extension for a spring and other simple systems (to include graphical representation of the extension of a spring)
P2.3d	describe the difference between linear and non-linear relationships between force and extension
P2.3e	calculate a spring constant in linear cases
P2.3f	calculate the work done in stretching
P2.3g	describe that all matter has a gravitational field that causes attraction, and the field strength is much greater for massive objects
P2.3h	define weight, describe how it is measured and describe the relationship between the weight of an object and the gravitational field strength (g)
P2.3i	recall the acceleration in free fall
P2.3j	apply formulae relating force, mass and relevant physical constants, including gravitational field strength (g), to explore how changes in these are inter-related (M1c, M3b, M3c)
P2.3k	describe examples in which forces cause rotation
P2.3l	define and calculate the moment of the force in such examples (to include the principle of moments for objects which are balanced
P2.3m	explain how levers and gears transmit the rotational effects of forces (to include ratios and how this enables gears and levers to work as force multipliers)
P2.3n	recall that the pressure in fluids (gases and liquids) causes a net force at right angles to any surface
P2.3o	use the relationship between the force, the pressure and the area in contact (to include simple hydraulic systems)

Approaches to teaching the content:

General approaches:

This subtopic focuses on the application of forces in stretching materials and force multipliers. A simple Key Stage 3 experiment of 'stretching a spring' using a range of different masses could be undertaken to recap the relationship between force and extension of a spring. Learners should be introduced to key ideas such as Hooke's law and energy related to stretched objects. Keywords such as elastic deformation, plastic deformation, linear, non-linear will need to be introduced. Through experiments related to Hooke's law learners could use graphs to share ideas with peers about what they could mean and analyse them mathematically. This could cover specification statements P2.3a–f.

Experiments relating to moments, hydraulics and gears will enable learners to understand how forces can be multiplied but many of these ideas will be new concepts. Turning forces can be simply related to see-saws for calculations whilst syringes full of liquid can be used to help learners to understand how hydraulic systems work and can be applied.

Common misconceptions or difficulties learners may have:

Learners may find new terminology difficult to understand such as plastic deformation. To overcome difficulty learners could be provided with keywords with their definitions and a labelled graph for different types of material. Alternatively they could try and predict the shape of graphs for materials that are, for instance, brittle.

Learners may find understanding the rotation effect of gears difficult. When one gear turns clockwise the second gear in contact turns anti clockwise. To overcome this difficulty, plastic cogs found in toys for younger children could be used to physically show learners how they work.

Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

The mathematical skills and understanding key concepts of Hooke's law is fundamental to topics including Energy (P7.1c, d, e) and Global challenges (subtopic P8.1). These include calculations of work done by a force. Acceleration when free falling is a good introduction to speed and everyday accelerations. Gravitational field strength and weight is a good introduction to orbits (P8.3f).

The knowledge and understanding of 'Forces in action' builds on the work covered previously in subtopic P2.1.

Approaches to teaching the content:

Learners are to be entered into a competition to compete for a position to become a car company's new scientific trainee engineer. In order to become successful they must first beat the rest by showing off their knowledge of Physics. Learners must research and complete the following areas:

1. Draw outline of a car and label position of gears and suspensions.
2. Explain how suspensions work using Hooke's law and spring constant (P2.3 a, b, c, d, e, f).
3. Explain how gears work and cause the car to run (P2.3 k, l, m, n, o).

Each group must present their research and knowledge to the rest of the group.

Activity 1

Gears

Explain that stuff
http://www.explainthatstuff.com/gears.html

A description of how gears and levers work with good and simplified illustrations.

Activity 2

Gears basics

YouTube
https://www.youtube.com/watch?v=odpsm3ybPsA

Video tutorial explaining gear rotation and ratio and how it can control speed.

Activity 3

Moments

YouTube
https://www.youtube.com/watch?v=AJGvBGmb6P8

Video tutorial explaining moments with example moment calculations applied to a see-saw scenario.

Activity 4

Stretching rubber

Nuffield foundation
http://www.nuffieldfoundation.org/practical-physics/stretching-rubber

Here is a selection of practical's that can be used to explain Hooke's law, and PM2.3i, PM2.3ii.

Activity 5

Revision

BBC Bitesize
http://www.bbc.co.uk/education/guides/zttfyrd/revision/7

A good starting point for Hooke's law and calculations of work done, spring constant. Includes quiz at the end.

Activity 6

Force, Pressure, Hydraulics revision

s-cool
http://www.s-cool.co.uk/gcse/physics/forces-moments-and-pressure/revise-it/forces-and-pressure

This website is a useful source of revision, it also includes an interactive program that gives a visual representation.

Activity 7

Acceleration due to gravity

Nuffield foundation
http://www.nuffieldfoundation.org/practical-physics/acceleration-due-gravity

Here is a selection of simple practicals that can be used to explain acceleration and gravity.

The small print

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