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OCR
Oxford Cambridge and RSA

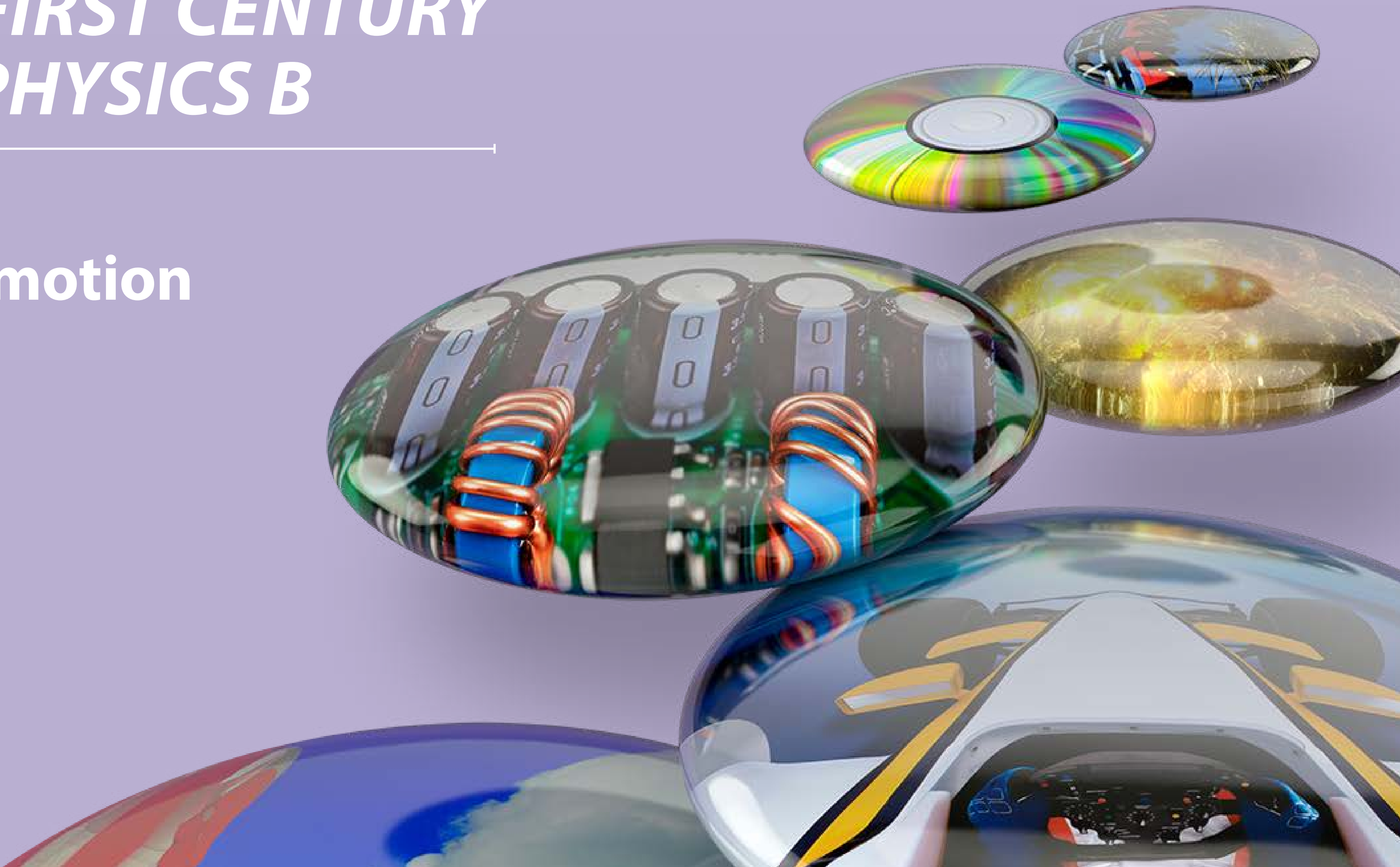
GCSE (9–1)
Delivery Guide

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J259
For first teaching in 2016

Explaining motion

Version 1



Can also be used for teaching:
GCSE (9–1)
TWENTY FIRST CENTURY COMBINED SCIENCE B

www.ocr.org.uk/physics

GCSE (9 –1)

TWENTY FIRST CENTURY SCIENCE PHYSICS B

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 students may have, approaches to teaching that can help students 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

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‘These draft qualifications have not yet been accredited by Ofqual. They are published (along with specimen assessment materials, summary brochures and sample resources) to enable teachers to have early sight of our proposed approach.

Further changes may be required and no assurance can be given at this time that the proposed qualifications will be made available in their current form, or that they will be accredited in time for first teaching in 2016 and first award in 2018.

Subtopic 3 – What is the connection between forces and motion?

Subtopic 4 – How do we describe motion in terms of energy transfers?

The images used throughout this guide have been provided to help aid learners' understanding and learning in this topic area.

A brief description is provided below each image.

P4.1.1	recall and apply Newton's Third Law
P4.1.2	recall examples of ways in which objects interact: by gravity, electrostatics, magnetism and by contact (including normal contact force and friction)
P4.1.3	describe how examples of gravitational, electrostatic, magnetic and contact forces involve interactions between pairs of objects which produce a force on each object
P4.1.4	represent interaction forces as vectors
P4.1.5	define weight
P4.1.6	describe how weight is measured
P4.1.7	recall and apply the relationship between the weight of an object, its mass and the gravitational field strength: weight (N) = mass (kg) × gravitational field strength (N/kg)

Forces balance in all directions and result in no change.

General approaches:

Since many of the basic concepts in this chapter – weight, speed, gravity, friction and so on – are phenomena that are familiar from everyday life, it is to some extent easier to communicate many of the main ideas to learners without having to use analogies, and even the slightly counter-intuitive idea of Newton's First Law is usually easy enough to communicate and demonstrate. The idea that a heavier object is harder to move than a lighter one probably won't need demonstrating at all. Because of this, it should be easier to get on with establishing the identities of the terms and their relationships, and practising their use with real examples. While new terms and units can sometimes be confusing, the units in which gravitational field strength is measured should actually help learners understand its meaning and how to derive it.

Some learners may already be aware that modern physics has rather changed the way we see many of the central aspects of Newton's laws. By now, learners should be fine with the idea that Newtonian physics itself is a very good analogy for what's going on in most ordinary situations but that, ultimately, more complicated physics underlies the processes involved.

Common misconceptions or difficulties learners may have:

In areas where many people already have a working understanding of the main concepts, the very familiarity of the subject can be the source of confusion; our habit of confusing mass with weight in common usage should be easy enough to deal with, but the profusion of closely-related terms – work, force, energy, power, distance, displacement, speed, velocity and so on – can cause problems if not clarified. It is important here to make sure that learners understand the relationships between the basic concepts. The concept of inertial mass is useful here, and can help with an explanation of how gravity cancels the greater inertia of more massive objects by attracting them more, which is why the net acceleration due to gravity is the same for all masses.

When dealing with Newton's Third Law, the wording "for every action, there is an equal and opposite reaction" can prove difficult for some learners, partly because it implies that there is an initial action and then an equal and opposite reaction follows as a consequence, whereas of course the action and the reaction are simultaneous and neither one "causes" the other. When we kick a football, it may seem like we are the cause and the ball is reacting to us, but that is to confuse intentional cause with physical cause. In fact, the ball and our foot are part of a dynamic system, as are all forces acting on anything. Paraphrasing it as "all forces are mutual" and pointing out that they all require at least two objects to exert force on each other (a single object exerts no force on itself) can help. Of course, these are difficult concepts, but skilful treatment of them can lay early foundations for an understanding of relativity.

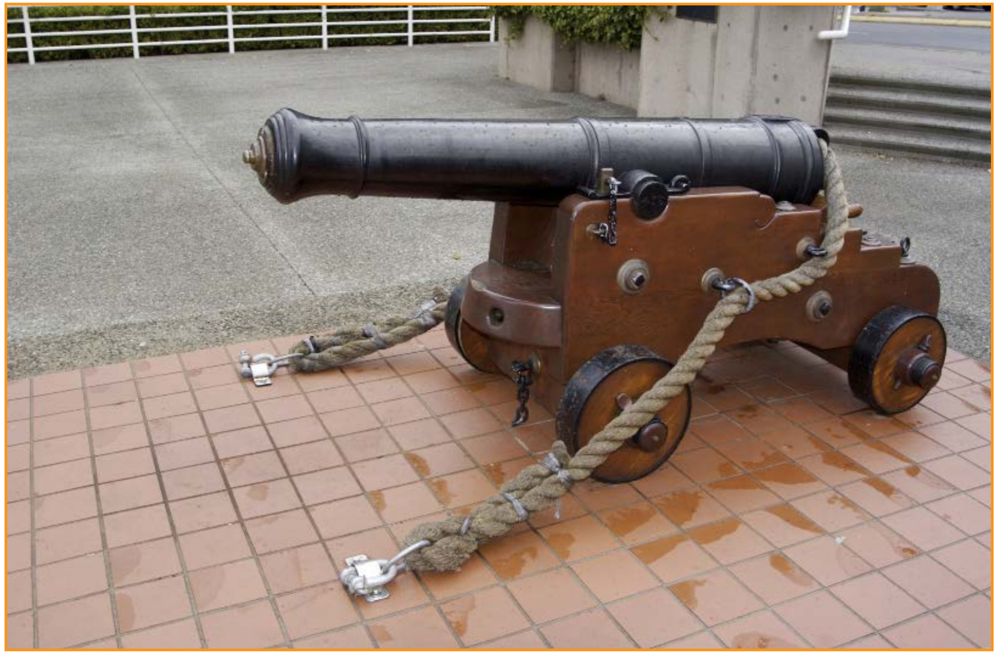
Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

Previous work with electromagnetism in P3 should have prepared learners for the idea of forces acting on objects and inducing motion, and for the idea that energy can be transferred from one form into another by interaction. Gravitational field strength per mass and electrical field strength per charge are of course very similar, except that gravitation is simpler in that it is exclusively attractive. More interested/able learners might be interested in the relationship between friction and electrostatics, or between kinetic and heat energy, a topic that also connects to P6 and P7, and of course in knowing that energy which is not transferred to matter by interaction can be released as electromagnetic radiation (P1). In general, these ideas can help learners to understand that the standard categorisation of types of energy is a helpful shorthand, but not in any way definitive. The most able might be amenable to the introduction of the idea that, for instance, all transfers of electromagnetic energy from particle to particle happen in theory through the exchange of photons.

Approaches to teaching the content

At this point, the concepts should be relatively straightforward to demonstrate and explain; plenty of popular and simple experiments can confirm most of the main concepts and relationships. When asking fundamental questions such as "What are forces?" and "How can we describe motion?", learners should be encouraged to remember that the questions are not about our basic concepts of these things but about how we can describe them reliably and meaningfully. We all have an intuitive understanding, for instance, of what distance and motion and time are, but part of the point of introducing different terms that relate to them is to avoid the confusion that using these words indiscriminately can cause. Examples such as "if you walk six feet North and six feet South again, you've moved, but you haven't moved" can be used to explain why, in physics, we need more specific terms.

Some of the questions asked in this chapter are among the very deepest in physics. Questions about the meaning of the terms "mass", "force", "motion", "distance", "time", etc. become more difficult to answer the more advanced the level at which you ask them, and their definitions are often interdependent. More advanced learners may well wish to ask questions about why you cannot accelerate beyond the speed of light, what energy is and how things "decide" what to do with it when it's imparted to them, and so on. The resulting discussions can help enthuse those learners who are interested in the more conceptual/theoretical side of physics.



Why does the cannon need to be fixed to the ground?

Activity 1

Forces and Motion: Basics

PHET, University of Colorado Boulder
https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html

A set of basic interactive demonstrations of forces acting on masses.

This can be a useful activity for introducing the idea of vectors by establishing simple linear resultants of forces acting in opposition.

Activity 2

Conceptual physics Mass Vs Weight

https://www.youtube.com/watch?v=aCqQzrPCcFM

A short video of a demonstration of the difference between inertial mass and weight. This demonstration is relatively easily reproducible, and is quite a neat example of the difference between weight and inertia due to mass, especially if objects of different masses are substituted and experimented with.

Activity 3

Newton's Laws of Motion and Forces

Tiros Educational
https://www.youtube.com/watch?v=NYVMlmL0BPQ

A video containing a précis of Newton's Laws of Motion, with CGI objects demonstrating the result of the application of forces under various conditions.

A useful medium-length (12 minutes) video in which the main concepts used in this chapter are introduced in idealised conditions, and the effects of forces on motion are addressed conceptually.

Activity 4

Feather in Vacuum

Backstage Science

http://hyperphysics.phy-astr.gsu.edu/hbase/mod3.html

A video featuring an experiment in which a feather and a large ball bearing are dropped in a vacuum.

This video also contains footage of the Apollo astronaut's experiment with equal acceleration due to gravity on the moon.

Activity 5

The Value of g Interactive

The Physics Classroom
http://www.physicsclassroom.com/Physics-Interactives/Circular-and-Satellite-Motion/The-Value-of-g/The-Value-of-g-Interactive

A simple web-based interactive graphic in which the values of g (the acceleration due to Earth's gravitational field strength) at various different locations on Earth can be compared.

Learners should be encouraged to speculate about the possible reasons for any patterns they observe.

Activity 6

Forces and Motion: Basics 1.1.0

PHET – University of Colorado Boulder
https://phet.colorado.edu/sims/html/forces-and-motion-basics/latest/forces-and-motion-basics_en.html
A set of interactives exploring forces and motion. The first, featuring a simple tug of war between participants exerting opposing forces, is directly relevant to this subtopic, while the others are relevant to topics explored later in the chapter.

Learners can be encouraged both to notice that the order in which the forces are added makes no difference to the outcome, and to explore the later interactives, which will introduce ideas dealt with in later subtopics, if they wish.

Activity 7

Gravitation: The Four Fundamental Forces of Physics

SciShow

https://www.youtube.com/watch?v=yhG_ArxmwRM

A video following on from the two about electromagnetism featured in the delivery guide for chapter 3.

More advanced learners may be interested in the references to relativity and quantum physics, while its style is still informal enough not to be intimidating for those for whom the more advanced concepts are difficult. Learners who are interested can find out about the other two fundamental forces by watching the companion videos on the strong and weak forces.

Activity 8

Fundamental Forces

xkcd

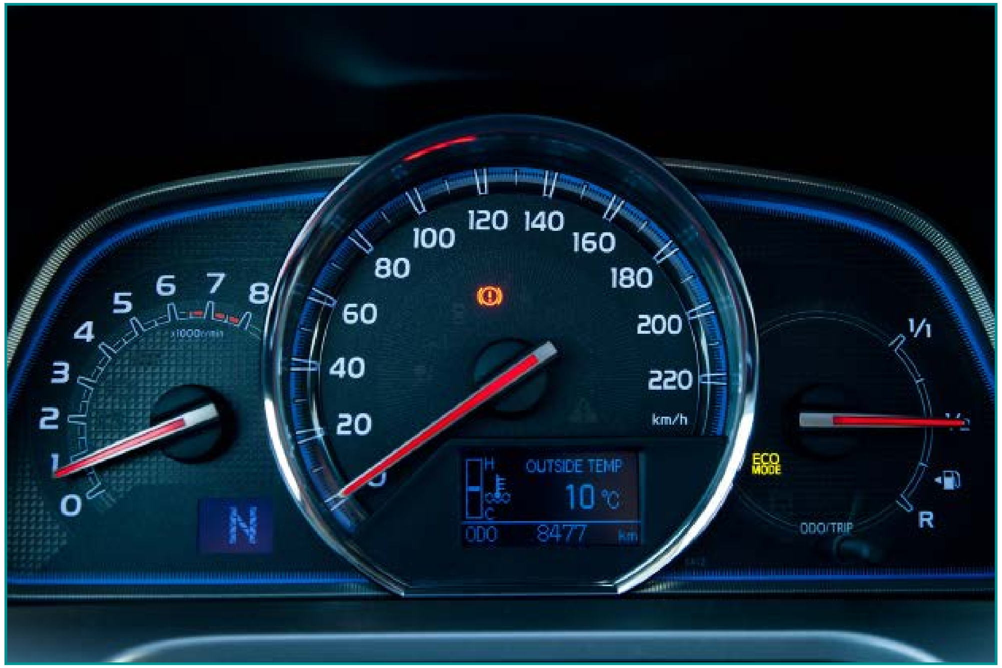
https://xkcd.com/1489/

A cartoon in which a stick figure explains the four fundamental forces of physics.

A fair representation of the difficulty of concisely describing complex ideas in physics.

Action and reaction

P4.2.1	recall and apply the relationship: average speed (m/s) = distance (m) ÷ time (s)
P4.2.2	recall typical speeds encountered in everyday experience for wind, and sound, and for walking, running, cycling and other transportation systems
P4.2.3	a) make measurements of distances and times, and calculate speeds b) describe how to use appropriate apparatus and techniques to investigate the speed of a trolley down a ramp
P4.2.4	make calculations using ratios and proportional reasoning to convert units, to include between m/s and km/h
P4.2.5	explain the vector-scalar distinction as it applies to displacement and distance, velocity and speed
P4.2.6	a) recall and apply the relationship: acceleration (m/s^2) = change in speed (m/s) ÷ time taken (s) b) explain how to use appropriate apparatus and techniques to investigate acceleration
P4.2.7	select and apply the relationship: (final speed (m/s))^2 - (initial speed(m/s))^2 = 2 x acceleration (m/s^2) x distance (m)
P4.2.8	draw and use graphs of distances and speeds against time to determine the speeds and accelerations involved
P4.2.9	interpret distance-time and velocity-time graphs, including relating the lines and slopes in such graphs to the motion represented
P4.2.10	interpret enclosed areas in velocity-time graphs
P4.2.11	recall the value of acceleration in free fall and calculate the magnitudes of everyday accelerations using suitable estimates of speed and time



A speedometer in km/h, such as would make it easier to convert common vehicle speeds into SI units.

General approaches:

As with gravitational field strength, it is helpful that the units in which velocity and acceleration are measured include their definition, so that learners who are having trouble remembering relationships can refer to the relevant units to help them. As with parts of Chapter 3, there is a lot of equation-manipulation here, but this time many of the results can be checked against common sense; where learners may have difficulty knowing what kinds of voltages and currents are reasonable to expect in various situations, speeds and distances are more intuitively easy to imagine.

Common misconceptions or difficulties learners may have:

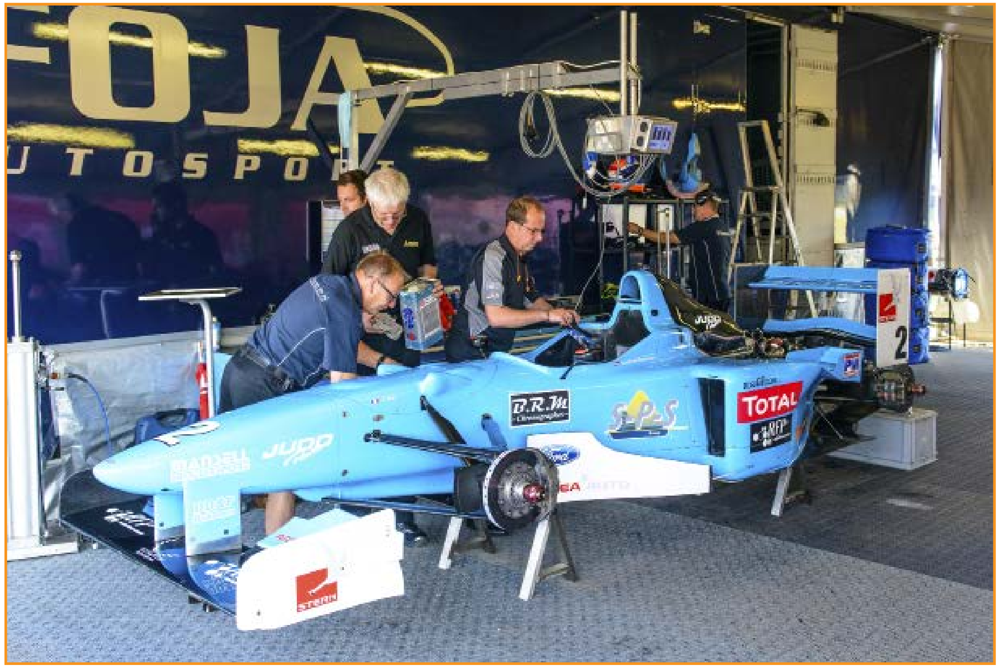
It is easy for learners to confuse the characteristics of distance/time graphs with those of velocity/time ones, but the idea that acceleration is to velocity as velocity is to distance is a useful one to drive home. Having said that the units used make the definitions easy to remember, it is true that the term "metres per second squared" can create some reasonable confusion; it's not possible to imagine a square second in the way it's possible to imagine a square metre. It might be useful to prefer the term "metres per second per second" until such time as learners are sufficiently used to it for a shorthand term to be understood without confusion. Learners should be reminded that you cannot derive acceleration by dividing distance travelled by the square of time taken, because objects moving at constant velocity can travel distances without being accelerated at all.

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 is the second part of the introduction of the main ideas that will inform the rest of the chapter. In particular, it is useful to get learners accustomed to understanding the important difference between velocity and acceleration, in order to solidify an understanding of the actions of forces in 4.3 and 4.4. The idea of what is essentially a relativistic viewpoint – that travelling with a constant velocity has the same signature on an acceleration graph as standing still – is essential in order to use Newton's first and second laws fluently.

Approaches to teaching the content

At this stage, hands-on experience is essential; the basic concepts need to be grasped before others can be added. Worked examples and real-world questions should be used wherever possible, particularly in cases where learners can have some intuitive idea of how feasible an answer might be so that they can adjust their working as they go until they are comfortable with the manipulations of terms. The difficulty in some of this subtopic is preventing the concepts from sounding dry, but the basics follow logically in such a way that learners can be encouraged to work out their own definitions while checking against practical and worked examples. For instance, the exploration of the characteristics of different types of motion on graphs with various related variables as axes can often be grasped best by interaction.



Interpreting velocity/time graphs can have exciting applications.

Activity 1

Dirk tackles 80 MPH Question
https://www.youtube.com/watch?v=2LKhHXeM1uE

One of the many examples of "The 80mph question", in which a staggering number of people turn out not to understand the meaning of the term "miles per hour".

This emphasises the importance of the understanding of the basic meanings of fundamental concepts and terms in science, as well as being amusing.

Activity 2

The Moving Man - Motion, Velocity, Acceleration
PHET – University of Colorado Boulder
https://phet.colorado.edu/en/simulation/moving-man

An interactive Java applet in which the relationship between motion and the terms distance, velocity and time is explored.

In this interactive, users can manipulate the motion of a runner either by dragging him along the track or by changing the values of his position, velocity and acceleration. The second tab of the applet then shows a graph of the motion, giving an excellent demonstration of the relationship between terms, graphs and observations.

Activity 3

Game Graphs

http://www.siminsights.com/Games/graphs.html

A simple game in which players have to move a slider to match a distance/time graph; attempts are scored.

This is a very basic game, but I found it became surprisingly addictive when the graphs became harder; it's as much a test of coordination as of understanding, but it can be an interesting second perspective on the distance/time graph.

Activity 4

Reproducing Galileo's Constant Acceleration Experiment

St. Mary's Physics Online

https://www.youtube.com/watch?v=7HUj7obvKpA

A version of Galileo's inclined plane experiment using rubber bands.

The idea is to get learners to position the rubber bands in such a way as to allow them to understand that, since speed can be measured from distance over time and acceleration can be measured from changing speed over time, acceleration can be measured from increasing distances travelled in equal time intervals.

Activity 5

Demonstration of Acceleration Inside the International Space Station During a Reboost
NASA
https://www.youtube.com/watch?v=8MR3daaWLXI

A demonstration of acceleration during a short period of velocity adjustment on the ISS.

It is interesting for learners to compare the effect of this acceleration with that of gravity.

Activity 6

Speed

Think Metric
http://thinkmetric.org.uk/speed.html

A list of speeds, in km/h, for reference.

Learners can be encouraged to convert between km/h and m/s, and to get used to doing so. More advanced learners may enjoy the information that, while all but one of these speeds are relative (eg. A cheetah running at 100km/h from back to front of a train going at 100km/h would be travelling at 200km/h relative to someone standing still on the ground), the speed of light is not, and will appear the same to all observers.

Activity 7

Scalars and Vectors

Bozeman Science

https://www.youtube.com/watch?v=EUrMI0DIh40

A mid-length (12 minutes) video about scalars and vectors and the differences between them.

This features some nice worked examples and demonstrations that can easily be adapted for a variety of situations.

Activity 8

Why Distance is Area under Velocity-Time Line

Khan Academy

https://www.youtube.com/watch?v=d-_eqgj5-K8

As the title suggests, this mid-length (9 minutes) video explains why distance is area under a velocity/time graph.

This video is a good example of the application of calculus in kinematics.

Activity 9

Rocket Sledder Interactive

The Physics Classroom

http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Rocket-Sledder/Rocket-Sledder-Interactive

A simple interactive applet which allows the user to accelerate a rocket sled under various conditions.

The idea that acceleration can be in the opposite direction from motion is very clearly demonstrated here.

P4.3.1	describe examples of the forces acting on an isolated solid object or system
P4.3.2	describe, using free body diagrams, examples where several forces lead to a resultant force on an object and the special case of balanced forces (equilibrium) when the resultant force is zero qualitative only
P4.3.3	**use scale drawings of vector diagrams to illustrate the addition of two or more forces, in situations when there is a net force, or equilibrium *Limited to parallel and perpendicular vectors only.***
P4.3.4	recall and apply the equation for momentum and describe examples of the conservation of momentum in collisions: momentum (kg m/s) = mass (kg) x velocity (m/s)
P4.3.5	recall and apply Newton's second law in calculations relating force, change in momentum and time: change of momentum (kg m/s) = **resultant force (N) × time for which it acts (s)**
P4.3.6	apply Newton's first law to explain the motion of objects moving with uniform velocity and also the motion of objects where the speed and/or direction changes
P4.3.7	**explain with examples that motion in a circular orbit involves constant speed but changing velocity *qualitative only***
P4.3.8	describe examples in which forces cause rotation
P4.3.9	define and calculate the moment of examples of rotational forces using the equation: moment of a force (N m) = force (N) x distance (m) (normal to direction of the force)
P4.3.10	explain, with examples, how levers and gears transmit the rotational effects of forces
P4.3.11	**explain that inertial mass is a measure of how difficult it is to change the velocity of an object and that it is defined as the ratio of force over acceleration**
P4.3.12	recall and apply the equation relating force, mass and acceleration: force (N) = mass (kg) × acceleration (m/s^2)
P4.3.13	show how the equations: force (N) = mass (kg) × acceleration (m/s^2) momentum (kg m/s) = mass (kg) x velocity (m/s) change of momentum (kg m/s) = resultant force (N) × time for which it acts (s) are inter-related
P4.3.14	explain methods of measuring human reaction times and recall typical results
P4.3.15	explain the factors which affect the distance required for road transport vehicles to come to rest in emergencies and the implications for safety
P4.3.16	explain the dangers caused by large decelerations and estimate the forces involved in typical situations on a public road
P4.3.17	given suitable data, estimate how the distance required for road vehicles to stop in an emergency, and describe how the distance varies over a range of typical speeds
P4.3.18	in the context of everyday road transport, use estimates of speeds, times and masses to calculate the accelerations and forces involved in events where large accelerations occur

Uniform circular motion feels like constant acceleration, which feels like gravity.

General approaches:

This is the point at which the chapter begins to get calculation-heavy, but the maths shouldn't be difficult so much as laborious and requiring care. Several new terms are added at this point, and they all need to be understood in terms of their relationships immediately as learners start using them in worked examples. Learners can be reminded that, when we refer to mass, we usually mean inertial mass, and that inertia is defined in terms of the amount of force required to produce a given acceleration.

Again, the units are useful reminders of the identities of the terms here, and will remain so into the last subtopic. Parallels between the relationships of related terms – distance, velocity and acceleration; moment, momentum and force – can be discussed as an aid to remembering the equations.

Common misconceptions or difficulties learners may have:

As with voltage in Chapter 3, the introduction of multiple terms measured in the same units can be confusing to some learners, and the similarity of the terms "moment" and "momentum" means their definitions simply need reinforcing and repeating, perhaps with a mnemonic device of some kind. In general, the main difficulty most learners will have is in becoming fluent and familiar with the relationships between the terms, so it is useful to get as much practice as possible translating any complex operations into intuitively understandable examples and reinforcing the basic meanings of the terms and their relationships with their identities and units in which they are measured.

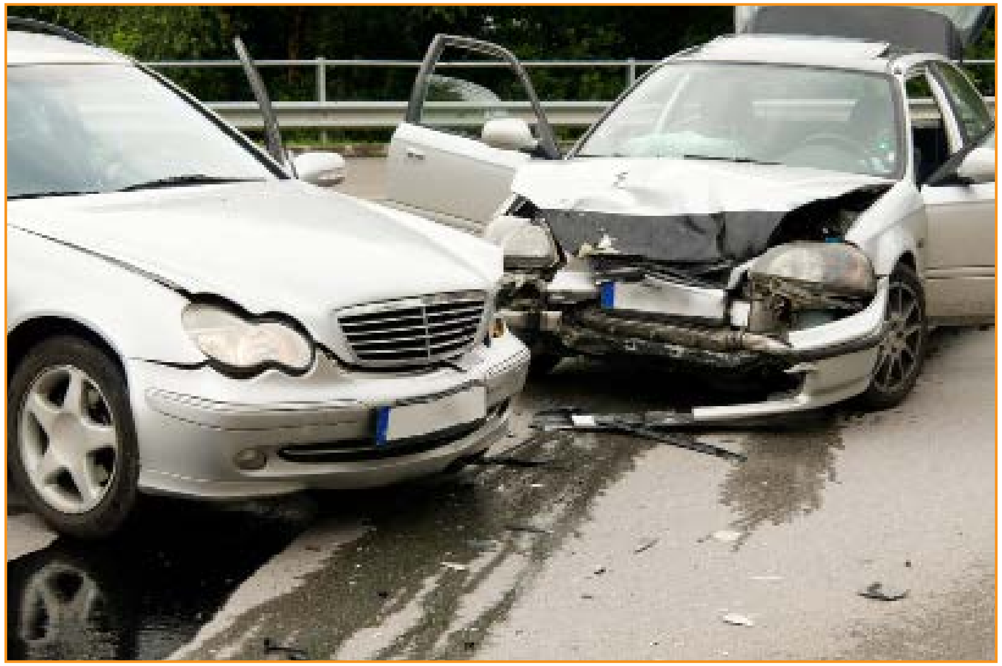
Conceptual links to other areas of the specification – useful ways to approach this topic to set learners up for topics later in the course:

We have already started talking about force and acceleration and field strength, and learners who remember thinking about voltage in Chapter 3 will by now be thinking about translating these terms into energy; indeed, in many cases, the energy relationships can be derived with reference to some of the identities established earlier in the course. This means that some learners should, by the end of this subtopic, be nearly ready to make the step to some of what comes in 4.4 on their own initiative, although others will still be uncertain with the large number of identities and equations being introduced.

Different arrangements of gears can do impressive things.

Approaches to teaching the content

A lot is covered in this subtopic; learners who are intimidated can be reassured that, although there are a lot of relationships and equations to remember, they are all interrelated and dependent on the meanings of the terms, many of which can be inferred from the units in which they are measured. As much as there is a large amount of brute force number crunching to be done when converting units and working through examples, there is on the positive side the fact that many of the examples used can come from realistic, even familiar, situations and can be tested easily. Learners with a more practical approach may enjoy putting theory into practice and designing systems with the object of producing certain kinds of motion.



Braking distance can be hard to judge.

Activity 1

Aristotle, Copernicus and Galileo on Motion

Shiny Happy Physics

https://www.youtube.com/watch?v=J79s7ggti7k

A short video about the history of our thinking about the nature of motion, from Aristotle to Galileo.

The sort of preconceptions brought by ancient thinkers to the description of motion can be a useful reminder of how our intuitive assumptions about the natural world can be wrong; discussions leading from this can be interesting when applied to more complex concepts in physics.

Activity 2

The mighty mathematics of the lever

Andy Peterson and Zack Patterson

https://www.youtube.com/watch?v=YIYEi0PgG1g

A short animated video about the mechanisms of levers.

Apart from introducing the idea that translating the equations we learn into real examples can help us in practical situations, this video mentions moving the Earth with a lever and using the moon as a pivot. The answer to the question of why that wouldn't work should be obvious enough, but it may provide amusement to list the various less obvious reasons why it would be impossible.

Activity 3

Free Body Diagram Interactive

The Physics Classroom

http://www.physicsclassroom.com/Physics-Interactives/Newtons-Laws/Free-Body-Diagrams/Free-Body-Diagram-Interactive

A short set of tests in which users construct a free-body diagram for a set of given situations, using only parallel, opposing and perpendicular forces.

This is quite a useful basic app, which can trip up learners who are not paying attention to the detail of the description.

Activity 4

Free-Body Diagrams

Bozeman Science

https://www.youtube.com/watch?v=nDis6HbXxjg

A medium-length video about the construction of free-body diagrams.

This is a useful précis, with worked examples, that may be a helpful revision aid as well as being a potentially helpful introduction.

Activity 5

Gears - How do they work? - Different types explained and compared

Explainthatstuff.com

http://www.explainthatstuff.com/gears.html

A page explaining the mechanism of gears and giving some examples of arrangements that will produce different effects on force and motion.

The idea of a gear creating motion in the opposite direction in the next gear is easy enough to understand intuitively, but the way that size, speed and force relate is not always immediately obvious.

Activity 6

Cars: engine power and transmission - 3D animation

https://www.youtube.com/watch?v=3-ilzxawUAs

A short CGI animation explaining why having a selection of gears is useful in vehicles.

This may be of interest to any learners with an interest in engineering or practical mechanics.

Activity 7

Measuring Your Dumbness With A Ruler in SLOW MOTION!
Distort
https://www.youtube.com/watch?v=3XM-4Qavh5k

A short video in which reaction times are tested and filmed in slow motion and the results discussed with a neurologist.

Of particular interest might be the large number of factors that can adversely affect reaction times. Learners should be encouraged to work out their reaction times from the distance a ruler falls before they catch it; this will be good practice for the manipulation of the relevant terms in real situations.

Activity 8

GCSE - Braking Distances - Distance-Time & Speed-Time Graphs

BBC

https://www.youtube.com/watch?v=NeIVKPjXFGE

A short video about braking distances at various speeds.

Learners should be encouraged to combine information from the experiment featured in the previous video with the figures in this one to arrive at conclusions about how much distance reaction times might add to the braking distance; they can also convert the units to ones they might be more familiar with in terms of vehicle speeds.

Activity 9

Intro to Circular Motion! (a tribute to Lou Reed)
Doc Physics
https://www.youtube.com/watch?v=qDbJyHOQKgQ

A medium-length (nine minutes) video introducing circular motion.

This is nicely presented, albeit basic and contains some useful references to dimensional analysis and the sense in which the term "metres per second squared" can reasonably be applied.

Activity 10

The Physics of Newton's Cradle
https://www.youtube.com/watch?v=kA2vjXHnySU

A short video explaining the patterns made by Newton's Cradle.

This is quite neat, in that it explains not only the conservation of momentum but also the symmetry of the reactions of the balls on the opposite side to the one initially collided with.

P4.4.1	describe the energy transfers involved when a system is changed by work done by forces including a) to raise an object above ground level b) to move an object along the line of action of the force
P4.4.2	recall and apply the relationship to calculate the work done (energy transferred) by a force: work done (Nm or J) = force (N) x distance (m) (along the line of action of the force)
P4.4.3	recall the equation and calculate the amount of energy associated with a moving object: kinetic energy (J) = 0.5 x mass (kg) x (speed (m/s))^2
P4.4.4	recall the equation and calculate the amount of energy associated with an object raised above ground level: gravitational potential energy (J) = mass (kg) x gravitational field strength (N/kg) x height (m)
P4.4.5	make calculations of the energy transfers associated with changes in a system, recalling relevant equations for mechanical processes
P4.4.6	calculate relevant values of stored energy and energy transfers; convert between newton-metres and joules
P4.4.7	describe all the changes involved in the way energy is stored when a system changes, for common situations: including an object projected upwards or up a slope, a moving object hitting an obstacle, an object being accelerated by a constant force, a vehicle slowing down
P4.4.8	explain, with reference to examples, the definition of power as the rate at which energy is transferred (work done) in a system
P4.4.9	recall and apply the relationship: power (W) = energy transferred (J) / time (s)

Charging a battery from the mains converts electrical energy into chemical energy. How many other conversions has this energy been through in its lifetime?

General approaches:

This is the point at which energy is introduced to the picture. Some learners may already have been thinking about its relationship with the terms introduced in previous parts of this chapter, and even remembering some of its relationships with other terms from Chapter 3's electrostatics equations. If the identities from previous subtopics have been grasped, the ideas introduced here should follow reasonably painlessly in most cases, but some of the more abstruse mathematical relationships may need to be explained carefully

Common misconceptions or difficulties learners may have:

Some learners have trouble with the idea that there are different types of energy and struggle to understand how and why one converts to another; why mechanical energy is lost as heat and sound, or why electrical energy can be converted to or from motion. How deep the explanation goes will obviously depend on the circumstances and the individuals, but the fact that all interaction of forces happens by energy transfer and that, in fact, systems where the type of energy is conserved (where mechanical energy is translated to more mechanical energy, for example) are no less miraculous than ones in which it is converted into heat, which is in a sense a measure of kinetic energy, although scalar instead of vector because, of course, it measures, in theory, the overall distance covered by the particles of the material concerned. In fact, some physicists would argue that matter itself is a form of potential energy. For learners who are more intimidated by such perplexing concepts, the idea that energy is constantly being transferred because all matter has energy should be enough.

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

When discussing the deeper nature of energy transfer, the particle model as discussed in IaS and P6.1 and P6.2 will inevitably arise. C1.2 also relates to the idea of energy transfer to heat, and this of course connects to the issue of conductivity, resistance and power transfer in Chapter 3.

Approaches to teaching the content

Now that this chapter has brought together the main concepts, establishing how they relate to and follow from each other is extremely useful. A solid base of conceptual confidence with the ideas should insure learners against confusion to some extent.

Learners should by now be getting used to the idea that interactions between matter and energy are central to physics, and that certain relationships involving time, space, mass and energy keep recurring. These should add to learners' cumulative understanding of the nature of the phenomena discussed; that it is in the nature of energy to maintain certain relationships with other measurable quantities and so on can eventually become more a part of a learner's understanding of the meaning of the terms than any theoretical definition.

When considering friction, forces of restoration, air resistance and so on, more able learners may be pleased to speculate on the interaction between electromagnetism and gravity that they represent.

The brakes glow as mechanical energy is converted into heat.

Activity 1

What is Potential Energy?

Whenthe appledrops

https://www.youtube.com/watch?v=4WQN-osljzg

A short video containing a slightly deeper exploration of the concept of potential energy.

The point that potential energy is an element of a system and not necessarily "stored" in any meaningful way within an object is worth making, and of course the fact that kinetic energy is a relative term (motion at a constant velocity requires no extra application of force) can be connected to this idea.

Activity 2

The Ramp - Force, Energy, Work

PHET – University of Colorado Boulder

https://phet.colorado.edu/en/simulation/legacy/the-ramp

A simple interactive applet in which objects can be pushed, pulled or allowed to slide up or down a ramp, with various adjustable parameters.

The ability of this applet to graph the forces acting on the object are particularly useful.

Activity 3

Pendulum Lab - Motion, Pendulum, Simple Harmonic Motion

PHET – University of Colorado Boulder

https://phet.colorado.edu/en/simulation/pendulum-lab

A simple interactive involving the relationship between a pendulum's motion and associated forces.

The ability to show the kinetic, potential and thermal energy (due to the adjustable friction parameter) of the pendulum as it swings is very useful in understanding how the system both conserves and loses energy.

Activity 4

Richard Garriott Space Video Blog: Conservation of Momentum

NASA

https://www.youtube.com/watch?v=nDis6HbXxjg

A short video in which the conservation of momentum is demonstrated in space using tennis balls.

Learners can be encouraged to speculate about what experiments would be interesting in the absence of gravity.

Activity 5

The Orbit Simulator

LASP Colorado

http://lasp.colorado.edu/education/outerplanets/orbit_simulator/

An interactive app in which the user can add a planet "X" to the existing solar system, adjust its average orbital distance and eccentricity and compare it to the existing planetary orbits.

This is a good opportunity for learners to gauge the true scale of the solar system; when zooming out to see the orbits of the outer planets, many may be surprised to discover how small the orbits of the inner planets appear.

Activity 6

When a physics teacher knows his stuff !!..

https://www.youtube.com/watch?v=7FfKaIgArJ8

A video of a physics teacher risking his life for science.

This should only be attempted if you are certain that the floor is level.

The small print

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