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GCSE (9–1)
Transition Guide

TWENTY FIRST CENTURY SCIENCE PHYSICS B

J249
For first teaching in 2016

KS3–KS4 Focus
Matter

Version 1

www.ocr.org.uk/physics

GCSE (9–1)
TWENTY FIRST CENTURY SCIENCE PHYSICS B

Key Stage 3 to 4 Transition guides focus on how a particular topic is covered at the different key stages and provide information on:

- Differences in the demand and approach at the different levels;
- Useful ways to think about the content at Key Stage 3 which will help prepare students for progression to Key Stage 4;
- Common student misconceptions in this topic.

Transition guides also contain links to a range of teaching activities that can be used to deliver the content at Key Stage 3 and 4 and are designed to be of use to teachers of both key stages. Central to the transition guide is a Checkpoint task which is specifically designed to help teachers determine whether students have developed deep conceptual understanding of the topic at Key Stage 3 and assess their 'readiness for progression' to Key Stage 4 content on this topic. This checkpoint task can be used as a summative assessment at the end of Key Stage 3 teaching of the topic or by Key Stage 4 teachers to establish their students' conceptual starting point.

Key Stage 3 to 4 Transition Guides are written by experts with experience of teaching at both key stages.

Key Stage 3 Content

From study at Key Stages 1 to 3, learners should:

- be able to use a particulate model of matter to explain states of matter and changes of state
- have investigated stretching and compressing materials and identifying those that obey Hooke's Law
- be able to describe how the extension or compression of an elastic material changes as a force is applied, and make a link between the work done and energy transfer during compression or extension
- have investigated pressure in liquids and related this to floating and sinking
- be able to relate atmospheric pressure to the weight of air overhead.

Key Stage 4 Content

Define density; recall and apply the relationship between density, mass and volume to changes where mass is conserved.

Describe the energy transfers involved when a system is changed by heating; define the term specific heat capacity and distinguish between it and the term specific latent heat. Select and apply the relationship between change in internal energy of a material and its mass, specific heat capacity and temperature; select and apply the relationship between energy needed to cause a change in state, specific latent heat and mass.

Describe all the changes involved in the way energy is stored when a system changes, and the temperature rises, for example: a moving object hitting an obstacle, an object slowing down, water brought to a boil in an electric kettle; make calculations of the energy transfers associated with changes in a system when the temperature changes, recalling or selecting the relevant equations for mechanical, electrical, and thermal processes.

Explain the differences in density between the different states of matter in terms of the arrangements of the atoms or molecules; use the particle model of matter to describe how mass is conserved, when substances melt, freeze, evaporate, condense or sublimate, but that these physical changes differ from chemical changes and the material recovers its original properties if the change is reversed.

Explain how the motion of the molecules in a gas is related both to its temperature and its pressure: hence explain the relationship between the temperature of a gas and its pressure at constant volume.

Explain, with examples, that to stretch, bend or compress an object, more than one force has to be applied; describe and use the particle model to explain the difference between elastic and plastic deformation caused by stretching forces.

Describe the relationship between force and extension for a spring and other simple systems; describe how to measure and observe the effect of forces on the extension of a spring; describe the difference between the force-extension relationship for linear systems and for non-linear systems.

Comment

This topic has the advantage that many of the basic concepts have already been introduced at KS3, and the new ideas learners will deal with at KS4 largely involve exploring in greater depth the details of the phenomena that these concepts underlie. While learners have already encountered the essentials of the particle theory of matter and many of its implications for qualitative observations and explanations of states of matter and related phenomena, one potential issue at KS4 is that there will be times when it is hard to retain a sense of how the specifics in each new area relate to the original model. To some extent, it is not essential for learners always to be able to intuitively relate everything they learn to the activity of particles. For the purposes of many KS4-level calculations, the differences between the ways that different kinds of matter respond to energy transfers relate to their properties on atomic and molecular levels in ways that are often either beyond GCSE level or more directly related to the syllabus of chemistry than that of physics, or indeed both.

For instance, the fact that water (at normal atmospheric pressure) is denser as a liquid than as a solid may seem at first sight to contradict the particle model's predictions. For instance the fact that some substances (such as carbon dioxide and iodine) sublime from solid to gas instead of going through a liquid phase may also seem puzzling. There is clearly not time to explore all the various different reasons for the occasionally surprising behaviour of different substances under the same conditions. It should be observed that, while there are exceptions to rules about density and large variations in specific heat capacity and specific latent heat, the basic predictions of the particle model – that increasing kinetic energy (or heat) in particles leads to an increasing tendency for particles to separate – are correct in all cases. If there is time, explaining one or two of these more unusual phenomena can help more able and curious learners.

Simplifications and generalisations are useful in order to communicate broad principles and avoid getting bogged down in detail. It is important to remember that, while many sources will glibly state that solids and liquids cannot be compressed, in fact they can. It is just that it's very much harder to compress them than it is to compress gases, because of the far greater forces involved in resisting the electrostatic forces operating between particles at very small distances. As so often in physics, these simplified rules are useful assumptions to make about the sort of phenomena we are likely to encounter in everyday situations, but will not always apply in more extreme circumstances.

In the case of the behaviour of materials under stress, important questions are why some materials obey Hooke's Law and some do not, and why those that do stop doing so after a point. It is difficult to answer these questions without going into some detail about the very fine structure of materials. Again the judicious explanation of a small number of examples and/or analogies (stretching a net until certain parts break as an analogy for exceeding the elastic limit of a substance, and so on) can be very useful. Learners can often have trouble with the general concept of potential energy. While electrical potential energy and gravitational potential energy can both be explained in terms of fields, other forms can be harder to conceptualise, especially elastic potential energy. At this point, the general principle that systems will tend to adopt the lowest available energy state – a principle that will remain pertinent throughout much of the progression to higher levels in this subject - can be emphasised here.

The suggested resources focus on aspects of the particle model, electric fields and conservation of energy and momentum. The particle model of matter, and the continuous model of matter, are both considered in the checkpoint task.

Activities

Hooke's Law - Springs | Force | Potential Energy

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/hookes-law

An interactive app in which users can experiment with the relationship between force and extension in springs and pairs of springs, with vector arrows included.

States of matter

Veritasium

https://www.youtube.com/watch?v=KCL8zqjXbME

A short video in which a brief explanation of the difference between the three main states of matter is interspersed with a vox pop in which members of the public display their knowledge (or lack thereof) of school-level science.

Balloons and Buoyancy - Gas | Buoyancy

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/legacy/balloons-and-buoyancy

An interactive app in which users experiment with different virtual gas-filled vessels in various atmospheres. Answers to the first two bonus questions might be found in this one.

KS3 Bitesize Science - The particle model : Activity

BBC

http://www.bbc.co.uk/bitesize/ks3/science/chemical_material_behaviour/particle_model/activity/

An interactive app that recaps the main points of the particle model at KS3, in clear simple stages.

Pressure

Sixty Symbols

https://www.youtube.com/watch?v=VB55RwvoPi4

A video featuring a very helpful analogy for the particle model in gases.

Overview

These tasks are designed particularly to reinforce in the minds of learners the connection between the particle model and the real behaviour of materials. As such, the questions are deliberately open-ended, allowing for more able and engaged learners to go into more detail if possible. Each task also has a 'bonus question', which should encourage learners to reason from their understanding of the concepts already introduced, as well as perhaps enabling a few to annoy other people with trick questions. In the cases of the main tasks, learners should be encouraged to use as much initiative as possible, and care should be taken to avoid 'spoonfeeding' the relevant information. However, learners are bound to need some degree of consultation and advice. While learners' original ideas are to be encouraged and preferred, it is more important that their answers display an understanding of the concepts, and emphasis has been placed on explanation.

Checkpoint task:

www.ocr.org.uk/Images/382383-matter-checkpoint-task.doc

Activities

Cool Pressure Trick!

Mist8k

https://www.youtube.com/watch?v=eLcyhT4Oly8

A brief demonstration of effects that can be achieved with a hot bottle and some cool liquid. Safety precautions are necessary for this experiment.

Friction - Thermodynamics | Heat

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/friction

A simple app in which users can see friction adding kinetic energy to particles and thus generating heat.

Feynman: Jiggling Atoms FUN TO IMAGINE 1

BBC

https://www.youtube.com/watch?v=v3pYRn5j7oI

An excerpt from Richard Feynman's 'Fun To Imagine' interview in which he explains the kinetic theory of matter.

Dislocations and Plastic Deformation

LearnChemE

https://www.youtube.com/watch?v=cpvTwYAUeA8

A short video which explains how inelastic deformation arises from defects – dislocations – in microscopic structures.

Vacuum Cannon

Sixty Symbols

https://www.youtube.com/watch?v=zwdo-2gOTyM

Another from the excellent Sixty Symbols series of physics videos, in which a university professor gets very excited about shooting a ping pong ball out of a vacuum cannon.

Activities

States of matter

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/states-of-matter

A more sophisticated simulation in which the characteristics of different particles and their relevance to phases transitions can be explored.

Gas Properties - Gas | Heat | Thermodynamics

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/en/simulation/legacy/gas-properties

Another more in-depth simulation in which the properties of gases can be explored with varying temperature and pressure.

Feynman: Rubber Bands FUN TO IMAGINE 3

BBC

https://www.youtube.com/watch?v=XRxAn2DRzgI

Another excerpt from Feynman's 'Fun To Imagine', in which he discusses the elasticity of rubber bands.

Carbon Dioxide (Parts I and II)

Periodic Table of Videos

https://www.youtube.com/watch?v=trhXiCxvzu4

https://www.youtube.com/watch?v=0dSMzg0UPPo

A small diversion into chemistry, featuring a rare look at carbon dioxide in its liquid form.

Atomic Interactions 1.0.1

PhET Interactive Simulations – University of Colorado, Boulder

https://phet.colorado.edu/sims/html/atomic-interactions/latest/atomic-interactions_en.html

An interactive app in which users can observe the effects of the various attractive and repulsive forces operating on atoms at very small distances.

Resources, links and support

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