LSEF Physics Scheme of Work

Introduction

Dear colleagues,

This is the 'Physics Foundations' KS3 scheme of work. This scheme was written by a team of 23 experienced science teachers and two Canterbury Christ Church University science education researchers, with the support of six Imperial College physics professors. We have explored some of the vast 'conceptual change' literature together, and many insights from that research tradition have been incorporated into this scheme.

The scheme follows the 2014 National Curriculum Programme of Study and is therefore divided into 6 sections: Energy, Motion and Forces, Waves, Electricity & Electromagnetism, Matter and Space Physics. We have covered much of ‘working scientifically’, but there should be enough space within the scheme to develop more context-specific investigations based on pupil questions. If you are following a two year KS3 with 3 hours per week on science, then we anticipate spending around 12 hours on each of these sections of physics, with Space having some capacity for being shorter to accommodate overrunning. A three year KS3 with 3 hours per week will allow around 18 hours per section. The scheme differs from many in that we recommend moving through the earlier parts of each section at a pace determined by pupil understanding. Whilst all material in the National Curriculum Programme of Study is included, we advocate many pupils not getting to the later stages of each section, in order to support deeper understanding of key concepts. Although pupils following this scheme may not cover as much content as others, a firm conceptual understanding is likely to allow accelerated learning at KS4 (Gautreau and Novemsky, 1997).

The activities are labelled (e.g. W2b) so that we can work as a community to resource these. The project website (www.conceptualchange.org.uk) gives more information about the project and we will put links to resources there as they are shared. The website also provides a list of 526 physics 'misconceptions' which some of the teams have referenced in their sections. If you spot any sort of mistake in this scheme, we would be enormously grateful if you would let us know so that we can correct these in future editions (contact details are below). We welcome any feedback on the scheme (and Twitter users might like to use @MAHardman, @jpscience or #conceptualchange to talk with us and other colleagues about this).

Best wishes,

John-Paul and Mark

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N1	Big Questions:	Approximate time: 1 hour	Context:
Where do you find energy changes?			Glastonbury Festival or F1 racing track (Silverstone)

Activities:	Timing:	Resources:
Video a: Look at the videos or pictures of a festival or formula 1 Race. Q: What changes in energy do you see? Teacher to move around and listen to conversations/representations on whiteboards.	10 mins	Videos of festival, car racing, mini-whiteboards
Activity b: 'Zoom in' to specific parts of the festival (microphones, speakers, lights, dancing, burger van) and/or motor race (engines, lights, radio) and ask groups to describe processes, using a 3 step process (see guidance notes: observe, explain, analyse)	20 mins	Videos/images of specific parts of festival, car racing, mini-whiteboards
Experiment c: Follow the same process with a circus of objects/toys/plants. Ask pupils to describe what is happening, then explain, then think about the energy. Teacher circulates to challenge misconceptions.	20 mins	Circus of activities to allow students to identify energy changes; include living organisms such as fruit or plant
Discussion d: Ask pupils to define energy. Work towards it taking different forms but without those forms becoming a 'thing' in themselves.	10 mins	Mini-whiteboards or books
Interactive e: PhET 'energy forms and changes' http://phet.colorado.edu/en/simulation/energy-forms-and-changes	5 min	

Working Scientifically:
Explaining observations.
Numeracy and Literacy:
Homework: research filament and energy saving light bulbs; students need to present their findings to class and gain points for every valid argument made in favour of their light bulb; the team with the most points shall win and get an energy saving light bulb as a reward.
Differentiation:
↑ Work in mixed ability groups (peer support). ↓ Writing frame for circus and energy transfers. Use of simplified/translated/symbolised worksheets (see for example Widgit SymWriter software).

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ This session is designed to consider pupils' prior understanding of energy. Energy is an abstract notion and does not have an obvious physical model (such as the particle model does). There are a number of key misconceptions listed opposite that need to be challenged. There is much debate currently about how to teach energy, as detailed by Prof. Robin Millar http://esummit-msu.net/content/towards-research-informed-teaching-sequence-energy . The Institute of Physics are developing a specific way of teaching energy with reference to 'energy stores' which we have taken as inspiration here whilst not following it to the letter. A few key points have come out of this discussion: Reference to types of energy can often replace understanding of causal mechanisms. For example, saying a microphone converts kinetic (sound) energy into electrical energy explains it without any physical process, in a rather mystical way. A better description might be that it turns a sound wave (or vibrations) into an electrical signal. One proposal is that we engage pupils in a 3 step process: 1) explaining in everyday language, 2) Explaining the mechanisms, 3) an energy analysis. Energy is essentially a quantitative notion. We must ensure that KS3 prepares students for calculations by talking about 'amounts' of energy rather than 'types'.	Driver et al. (1994) identify a range of misconceptions in pupil thinking which need to be challenged: Only living things have energy (related to everyday language); energy is the same thing as a force; energy and power are often confused; energy as a substance which is 'in' things or energy sources being inside things; energy as a fluid which moves in some processes; energy being a fuel; energy being an ingredient (relates to how we write equations); energy as a by-product of a situation. For a full list please see www.conceptualchange.org.uk ('misconceptions'). Trumper et al (2000) support much of this and identified anthropocentric ideas about energy (the boy has a lot of energy today); energy as a depository - some objects have energy and spend it. Flow of energy was found to be a common notion. Igwebuike (2012) highlighted cultural aspects of pupil thinking, for example Nigerian students relate ideas to oil industry. Consider allowing pupils to set their own contexts to explore this. Lee & Liu (2009) propose that pupils learn by comparing and contrasting old ideas and new ideas and that making ideas explicit helps this process. However, Vosniadou (2001) argues that pupils often synthesise their old and new ideas to form different views in different contexts e.g. energy is a store but can also flow.

LSEF Physics Scheme of Work

Energy

N2	Big Questions:	Approximate time: 1 hour		Context:
How does energy change?				Glastonbury Festival or F1 racing track (Silverstone), pupils devise their own contexts from their lives.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Discussion a: Revisit a scenario from last lesson, or circus activities, or ask pupils to describe a situation in their own lives which involved energy changes. Describe and explain, then ask what different forms energy is taking. Compose a list (doesn't need to be all types)		10 mins	Video or scenario(s) from last lesson.	Present observations and data using appropriate methods, including tables and graphs Interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions Present reasoned explanations, including explaining data in relation to predictions and hypotheses
Activity b: Ask pupil to draw a representation of the amounts of different types of energy before and after in the scenario (with clear, start end points). Review the different interpretations of this (e.g. bar charts, blocks, number of units, flows etc.)		10 mins	Drawing materials.	**Numeracy and Literacy:**
Discussion c: Survey which pupils have the total amount of energy at the start of the scenario as the same as at the end. Ask for justifications. Explain that energy moves around and changes form but is not used, created, destroyed.		10 mins	Discussion, whiteboards/books for justification.	We are developing a quantitative understanding in this lesson and using representations and graphs. Conservation also requires numeracy skills.
Activity d: Apply the above approach to further scenarios: describe, explain, analyse forms of energy before and after. Careful to avoid energy becoming a 'thing' or a 'flow' in descriptions.		30 mins	Scenarios, drawing materials.	**Differentiation:**
				↑ Pupils devising their own scenarios will probably engage them, but beware that some situations may involve a number of stages and therefore energy changes. ↓ Have some simple scenarios prepared for weaker pupils.

Key Scientific Ideas and Guidance:	Links to Research:
This session is designed to move pupils on from thinking about where energy changes take place to considering what actually happens in terms of different forms of energy. For example, rather than thinking that a car engine makes noise and heat, consider how the petrol is burnt, which turns the engine, which makes a noise, gets hot and pushes the car forwards. Then consider how the chemical energy in the petrol is reduced and the internal/thermal energy of the engine increases, the kinetic energy of the car increases etc. Again, there is much debate about whether talking about 'types' of energy or energy stores can be misleading. The key point is that we don't want discussion of different forms of energy to replace actual mechanisms. We are building towards a quantitative understanding that different forms of energy increase and decrease (and eventually to conservation of energy). We therefore stick to the proposal that we engage pupils in a 3 step process: 1) explaining in everyday language, 2) Explaining the mechanisms, 3) an energy analysis. The energy analysis is develop in this lesson so that we think about which 'types of energy' increase and decrease. The Institute of Physics note the importance of defining start and end points so that pupils don't go beyond the immediate process. Diagrams of the amount of energy (e.g. bar charts) before and after might help support this. The different forms of energy or energy stores which teachers use may be determined by pupil ideas but we propose: chemical, gravitational, internal(or thermal), kinetic, elastic, nuclear and electric/magnetic. The idea of 'potential' is abstract so we propose avoiding it for now.	Driver et al. (1994) identify a range of misconceptions in pupil thinking which need to be challenged: Only living things have energy (related to everyday language); energy is the same thing as a force; energy and power are often confused; energy as a substance which is 'in' things or energy sources being inside things; energy as a fluid which moves in some processes; energy being a fuel; energy being an ingredient (relates to how we write equations); energy as a by-product of a situation. Trumper et al (2000) support much of this and identified anthropocentric ideas about energy (the boy has a lot of energy today); energy as a depository - some objects have energy and spend it. Flow of energy was found to be a common notion. Igwebuike (2012) highlighted cultural aspects of pupil thinking, for example Nigerian students relate ideas to oil industry. Consider allowing pupils to set their own contexts to explore this. Lee & Liu (2009) propose that pupils learn by comparing and contrasting old ideas and new ideas and that making ideas explicit helps this process. However, Vosniadou (2001) argues that pupils often synthesise their old and new ideas to form different views in different contexts e.g. energy is a store but can also flow.

N3	Big Questions:	Approximate time: 1 hour		Context:
Where does the energy go?				A nice cup of tea.
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Discussion a: As pupils enter be boiling a kettle and pretending to make tea/ talking about it. Pose problem of how the water gets hot and how cup of tea ultimately gets cold.	10 mins	Kettle, 'cup of tea'		Consider the historic context of Joule the scientist. Select, plan and carry out the most appropriate types of scientific enquiries to test predictions, including identifying independent, dependent and control variables, where appropriate. Use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety.
Demonstration b: Pose problem of how much energy is needed to boil water. Ideally put a flashing Joule-meter in line with a kettle or heater to show energy being measured. Introduce unit of Joule. Pupils plan investigation into energy needed to boil water.	15 mins	Demonstrate below equipment. Joule meter.		**Numeracy and Literacy:** Measurement and calculations (with some pupils)
Investigation c: Measuring energy input to heat specified amount of water with immersion heater. Ideally use joule meters but otherwise power ratings and timers (without introducing power yet). Discuss the energy changes beyond heating the water: some energy transferred as sound, some dissipates into surroundings. Stretch more capable with notion of specific heat capacity and or power vs energy.	25 mins	Immersion heaters and power supplies, beakers, water (100ml), joule meters, digital thermometers.		**Differentiation:** ↑ A range of concepts can be brought in here but ensure that pupils are not confused by doing so. E.g. energy per second = power, specific heat capacity vs heat capacity, energy vs temperature. ↓ To support those struggling, revert to representing amount and types of energy before and after.
Evaluation d: Ask the class about their results. Explain that 100ml of water takes 418 J of energy to heat 1 degree. Compare to their results, which should be much higher. Challenge pupils to explain why (now or as homework)	10 mins	Pupil results		

Key Scientific Ideas and Guidance:	**Links to Research:**
This lesson aims to further a quantitative understanding of energy and introduces the concept of joules. However, still note that energy is taking different forms. The investigation can be set up in a number of ways depending upon time and resources. Either energy or time taken to increase by 10 degrees will be quicker than trying to reach boiling point (and safer). In light of Luera, Otto & Zitzewitz's (2005) findings (opposite) consider whether pupils have already encountered particles or a scientific (not just everyday use) of temperature. This will influence what they think happens as water is heated.	Driver et al. (1994) found that many pupils confuse temperature and energy. Stick to talking about energy here initially, only introducing temperature if you are sure pupils won't be confused by it. They also report studies in which 40% of 12 year olds feel that water on a stove can be heated past 100 degrees, or that the temperature is determined by the setting on the stove. Heat and temperature are often confused. Boiling and evaporation are seen as different processes. Pupils consider solids to lose mass when they melt. Changes of state are not always related to specific temperatures by students (even for ice/water/vapour). See the Matter scheme for more misconceptions around changes of state. Trumper et al (2000, p699) saw that pupils think that there are no products or by-products of energy changes or that energy is not expended. Luera, Otto & Zitzewitz (2005) found that many primary teachers use non-specific language in relation to thermodynamics and that the order that concept are introduced is important. We propose that change in energy comes before a scientific understanding of temperature here.

N4	Big Questions:	Approximate time: 1 hour	Context:
	Why does the tea get colder? How can we stop this?		Cup of tea and teachers in the school not liking it cold. Dragons Den type competition to 'invent' a cup that stays hot.

Activities:	Timing:	Resources:
Discussion a: Review the problem posed at the end of the last lesson. Why does it take much more input to heat water than it should. Perhaps use a concept cartoon with different opinions to discuss.	10 mins	Concept cartoon
Discussion b: 1) a cup of tea getting 'cold', 2) ice in a drink melting. Explain with mechanisms of the air (or particles if covered already) getting warmer or cooler. Materials transferring thermal energy to reach equilibrium. Differences drive changes.	10 mins	Examples of ice melting; particle models/animations if appropriate
[Optional] Discussion c: Introduce temperature as the average vibrational/thermal energy of particles. Explain that a sparkler has higher temperature but a mug of tea has a higher total thermal energy.	5 mins	A sparkler and mug of tea.
Experiment d: Competition to see who can design the best insulating mug using a set amount of 'money' which can buy certain resources. Test through lowest temperature reduction in 10 minutes. Whilst testing, pupils give reasons/sales pitch for designs.	25-30 mins	Metal cans, selection of insulators and lids, tape etc. to be 'bought' by teams. Digital thermometers and stopcock.
Activity e: Each team draw a before and after representation of the types of energy in the water, 'cup' and surroundings (mostly thermal energy in each). Compare and discuss.	10 mins	Drawing materials

Working Scientifically:
Pay attention to objectivity and concern for accuracy, precision, repeatability and reproducibility. Make and record observations and measurements using a range of methods for different investigations; and evaluate the reliability of methods and suggest possible improvements.

Numeracy and Literacy:

Pupils will need to understand averages in order to fully grasp temperature. Quantitative representation of changes.

Differentiation:

↑ The focus on working scientifically skills will depend upon your group. Some will be able to determine variables and consider accuracy, reliability etc. Conduction, convection and radiation can be introduced to some pupil here.

↓ See guidance on introducing temperature for only some pupils.

Key Scientific Ideas and Guidance:	Links to Research:
This lesson will introduce the difference between energy and temperature but only do so if this will not confuse pupils. It is better to have a full understanding of energy changes first. If you decide to not introduce temperature, pupil can still engage with insulators to reduce the surroundings being heated up. In this case temperature is a proxy for thermal energy in the test. Note we are still trying to avoid seeing energy as something which flows.	Concept cartoons have been used to elicit pupil thinking and to challenge misconceptions (Keogh & Naylor, 1999; Stephenson & Warwick, 2003). As well as reporting confusion between temperature and energy, Driver et al (1994) explain that many pupil think insulation keeps us warm, rather than prevents transfer of energy. Pay attention to descriptions of why pupils think their insulation works.

N5	Big Questions:	Approximate time: 1 hour		Context:
How does energy change?				Energy changes in everyday life. Catapults in relation to Angry Birds or historic battles or fun fair rides.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Recap a: on how we represent energy before and after a process, focusing on describe, explain, then energy analysis. Consider introducing Sankey diagrams here if appropriate (see guidance).		5 mins	Example Sankey diagrams.	Evaluation and improvement of method; reproducibility; health and safety
Experiment b: circus of activities where students are asked to identify energy changes and processes.		20 mins	Scenarios: e.g. computer, iPad, mobile, bicycle, energy drinks, rollercoaster ride, elastic bands, pen that is clicked.	**Numeracy and Literacy:** Writing of the method/design; measuring the extension of elastic, measuring Y shaped hand grip and measuring distance of catapult achieved
Discussion c: which processes were not 'useful' within the scenarios. For example, processes which lead to heating of computers/phones. Focus in on one and make recommendation to the manufacturer on improving (making more efficient).		10 mins	Review of pupil representations of scenarios.	
Activity d: build catapults and compete with each other. Which catapult is best? Relate to processes of energy transfer. Testing should be done on sports field or other appropriate environment; use plasticine or Play-Doh as bullets; use Angry Birds as targets.		25 mins	Resources to make catapults e.g. clamp stands, or manufactured V frames, or chair legs. Elastic, goggles, gloves	**Differentiation:** ↑ Physics in the 'Angry Birds' game could give an opportunity to talk with pupils about the physics in more complicated games. For example, in one 'shoot them up' game, a bullet hitting a window at the top of the window means it shatters in a different way to when the bullet hits the bottom of the glass. Some pupils may know a lot about this! ↓ Some students may still need scaffolding in considering the types of energy before and after processes. This could be done through boxes representing different types/stores of energy that can be coloured in to represent the amount of each energy. PhET 'energy forms and changes' could be useful here: http://phet.colorado.edu/en/simulation/energy-forms-and-changes
Activity e: Sankey diagrams. Use cut out arrows and large pieces of paper to 'storyboard' the flow of energy in one of the scenarios. Note how a new phone may be different in the way it transfers energy to an older model by considering their diagrams.		25 mins	Large paper, scenario (e.g. different phones) arrows to represent change in energy amounts.	

Key Scientific Ideas and Guidance:	Links to Research:
This lesson is designed to revisit and reinforce lesson EN2 by considering real life situations and again focusing on energy change. However it extends it by bring more 'real life' examples in and by introducing Sankey diagrams. Introducing Sankey diagrams is risky in that it may reinforce the misconception that energy is something which flows. Only introduce such diagrams if you feel this can be avoided. We do not yet know whether Sankey diagrams will be included in KS4 specifications and this should also be a guiding factor. Energy efficiency but we take steps towards it here in considering useful energy transfers and those which we wish to reduce. High attaining pupils may be introduced to efficiency if the teacher is sure they understand processes and transfer of energy. As with lesson EN2: stick to the proposal that we engage pupils in a 3 step process: 1) explaining in everyday language, 2) Explaining the mechanisms, 3) an energy analysis. The energy analysis is develop in this lesson so that we think about which 'types of energy' increase and decrease. The Institute of Physics note the importance of defining start and end points so that pupils don't go beyond the immediate process. Diagrams of the amount of energy (e.g. bar charts) before and after might help support this. The different forms of energy or energy stores which teachers use may be determined by pupil ideas but we propose: chemical, gravitational, internal(or thermal), kinetic, elastic, nuclear and electric/magnetic. The idea of 'potential' is abstract so we propose avoiding it for now.	Inquiry based learning is suggested by Wenning (2005) as a way for pupils to work through their own ideas. This is in line with Vosniadou et al. (2001) who discuss designing learning environments to promote conceptual change: working in small groups and reviewing their own processes. Driver et al. (1994) identify a range of misconceptions in pupil thinking which need to be challenged: Only living things have energy (related to everyday language); energy is the same thing as a force; energy and power are often confused; energy as a substance which is 'in' things or energy sources being inside things; energy as a fluid which moves in some processes; energy being a fuel; energy being an ingredient (relates to how we write equations); energy as a by-product of a situation. Trumper et al (2000) support much of this and identified anthropocentric ideas about energy (the boy has a lot of energy today); energy as a depository - some objects have energy and spend it. Flow of energy was found to be a common notion. Igwebuike (2012) highlighted cultural aspects of pupil thinking, for example Nigerian students relate ideas to oil industry. Consider allowing pupils to set their own contexts to explore this. Lee & Liu (2009) propose that pupils learn by comparing and contrasting old ideas and new ideas and that making ideas explicit helps this process. However, Vosniadou (2001) argues that pupils often synthesise their old and new ideas to form different views in different contexts e.g. energy is a store but can also flow.

N6	Big Questions:	Approximate time: 1 hour		Context:
Are power and energy the same thing?				Duracell battery advert: Duracell batteries last longer vs. different brand

Activities:	Timing:	Resources:	
Discussion a: Say you have just run up/down stairs. Would you have used the same amount of energy if you had walked up/down slowly? Pupils discuss	5 mins		**Working Scientifically:** Planning an investigation in the form of a GCSE controlled assessment (or ISA), writing the method, identify variables and risks, writing of a conclusion and an evaluation.
Activity b: Develop concept of power as the amount of energy per second. Watts and Kilowatts. Voting game: which is more powerful? How do you know? Show different comparisons, e.g. electrical appliance and a sumo-wrestler.	10 mins	Images and voting cards (or hands up or interactive software votes)	**Numeracy and Literacy:** Students are gaining a quantitative understanding of energy = power x time. However, do not introduce this until they have this understanding (else they rely on equations). Relating W and kW, J and kJ
Activity c: Provide images/examples of animate and inanimate objects - students need to sort these according to how quickly they transfer/transform energy. Students need to justify why they have sequenced the images in a particular order.	10 mins	Various images of animate and inanimate objects e.g. Usain Bolt, bloodhound car, leaf photosynthesising	
Experiment d: power. Students measure personal power, by running up a flight of stairs (Nuffield Foundation): students then calculate how much energy from food they need to be able to climb up the stairs (which links power to energy); use of joule meter to measure appliance (phone charger). Ask pupils to describe to a Year 6 the difference between energy and power.	35 minutes	Resources from EDF, NPower or UPD8; Applied Sciences; Nuffield Foundation 'Student power'	**Differentiation:** ↑ Extend through the way they consider accuracy, reliability, controls, precision etc. ↓ The level of detail in their investigation will depend upon pupil ability.

Key Scientific Ideas and Guidance:	Links to Research:
Developing a notion of rates of change is challenging, on top of what we have already noted about the everyday confusion of power and energy (Driver et al, 1994). This will take considerable scaffolding. Talk to your maths colleagues about how they introduce rates of change or notions of 'per unit time' to ensure consistency, but do not assume they will have covered it in maths. Here gravitational energy may present another issue in that being higher up is not seen as having a greater store/potential of energy. This may need further support in relating it to falling objects. We introduce energy in food in a later lesson, but it relates to a range of misconceptions (see opposite).	Boulanger (1976) notes the difficulties of proportional reasoning and here we are attempting to relate rates of change. Driver et al (1994) report on food being seen in different ways in different contexts, e.g. as essential material, building material for the body or an energy source. Only 40% of 12-13 year olds in one study saw it as the latter. Energy associated within living things is also not necessarily related to energy in appliances and in the wider world. Furthermore, energy is linked to movement or 'excitement' and these everyday uses need to be related to science. For example, consider how your PE colleagues talk about power.

N7	Big Questions:	Approximate time: 1 hour		Context:
How much energy do we transfer in our homes?				Why should we unplug/turn off phone chargers?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Recap a: power vs energy. Show difference in Joule meter between phone charger with phone plugged in vs without. Or look at manufacturers descriptions of standby vs on power for appliances. Note that they still transfer energy in standby.		10 mins	Phone charger, phone, Joule meter (240V) or demo electric meter. Electricity suppliers often give out energy monitors.	Apply mathematical concepts and calculate results. Interpret data and observe patterns.
Activity b: Estimate which appliances use most power in standby/on. Look at appliances to note power ratings; add the classroom clock or any other battery operated appliance (batteries will provide power that incurs costs as well)		15 mins	Various appliances with ratings (or laptops to look up ratings)	**Numeracy and Literacy:** Application of the formula: energy = power x time; calculating unit costs; calculating costs of electricity using unit costs as offered by different energy companies
Discussion c: kWh (=3600kJ) used by energy companies. Ask pupils to calculate how much energy (in kJ and kWh) their appliances transfer in their rooms/lounges between 6pm-7pm each evening, and between 1am-2am (hopefully on standby!)		20 mins	Ratings for appliances is standby and on, calculators.	
Calculation d: Provide pupils with unit costs and ask them to calculate costs per day/week/year. Discuss household and global impact of this.		15 mins		**Differentiation:** ↑ A range of analogue and digital meters could be used. ↓ Some students will need support in the calculations. As an alternative, calculate hourly energy use/costs of appliances in advance, laminate these onto little cards and ask them to match the energy/costs with the correct appliance.

Key Scientific Ideas and Guidance:	Links to Research:
Pupils must be secure with energy vs power before adding in costs. Costs are per amount of energy and not related to power directly and this should be explained. Beware that pupils may see the costs as low (often pence) and this need to be put in context of energy bills for whole house (including heating etc.), as well as global context.	

N8	Big Questions:	Approximate time: 1 hour	Context:
How much does it cost?			Energy saving vs old style light bulbs (draw on homework earlier in topic)

Activities:	Timing:	Resources:	Working Scientifically:
Demonstration a: Show pupils an old style light bulb vs an energy saving bulb connected to a Joule-meter or demo energy meter. Ask pupils to represent the energy changes in an energy saving and old style light bulb.	10 mins	Light bulbs and Joule meter or electricity meter.	Apply mathematical concepts and calculate results. Interpret data and observe patterns.
Calculation b: Ask pupils to recall how many light bulbs they have in their house and their total power input if they were all turned on. Compare energy saving and none (usually 40w vs 12w). Calculate energy costs for one hour of this.	10 mins	Calculators.	**Numeracy and Literacy:**
Activity c: Provide pupils with copies of a range of electricity bills. Firstly, challenge them to see who has 'used' the most electricity (may not be same as bill total). Relate kWh to power x time again.	5 mins	Range of (anonymous) energy bills.	Application of the formula: energy = power x time; calculating unit costs; calculating costs of electricity using unit costs as offered by different energy companies
Activity d: Ask pupils to decide which power company they would go with from the different bills and websites (e.g. comparison sites). Justify their choices. Note that night and economy tariffs may be challenging initially.	20 mins	Bills, laptops and comparison / supplier websites.	**Differentiation:**
Calculations e: Consolidate their understanding of power, energy and cost in J and kWh through a range of problems. E.g. a laptop is left on standby for a year how much will it cost with a particular supplier.	15 mins	Problems sheet	↑ Pupils could look at a copy of the school electricity bill and discuss this (it will probably be quite shocking!). ↓ Again, scaffolding calculations will be important. Be aware of reading difficulties or dyscalculia as well.

Key Scientific Ideas and Guidance:	Links to Research:
In this session pay particular attention to correct usage of power and energy and pick students up on this. The use of kWh as a unit of energy but kW as a unit of power adds difficulty. introducing the equation energy = power x time may not help this as pupils need an understanding first. Many maths colleagues advise not using equation triangles as they do not develop an understanding of proportion and may limit equation manipulation later. A note on processes in light bulbs: old style light bulbs heat a filament in an inert gas/partial vacuum (so it does not burn). As such the transfer most of the electrical energy into heat (this is not always a bad thing in a cold house!). Energy-saving light bulbs excite gases (often containing mercury) which produces radiation in the ultraviolet part of the electromagnetic spectrum. The coating on the bulb then absorbs this but emits light in the visible spectrum. This does not involve as much heating so the same output of light can be achieved more efficiently.	Rates of change may consolidate notions of energy as a flow (Driver et al, 1994) by implying a rate of some kind. Try and recall pupil's earlier work on processes first and foremost with energy changes being a consequence of those, not a cause in themselves. Trumper et al (2000) notes pupils seeing energy as a depository - some objects have energy and spend it. This may be further confused by spending money on energy or everyday conversations about 'wasting' energy in the same way that food is 'wasted': thrown away.

N9	Big Questions:	Approximate time: 1 hour	Context:
	What are fuels? Is food a fuel?		Energy resources. Food vs dung comparison.

Activities:	Timing:	Resources:
Demo a: Have a range of fuels burning as pupils enter. Question pupils about how they would define 'fuel'. Explain/draw the energy changes associated with burning. In science is it usually something that has chemical energy (other than nuclear fuel).	10 mins	Fuels that can be burnt: candle, wood, oil burner, ethanol burner, Bunsen (gas), horse dung.
Activity b: Compare the use of fuels in history to today. What else do we use? Extend list/mind map to include other energy resources (fuels as a subset)	10 mins	Historic contexts to discuss: prehistoric, Roman, middle ages, Victorians, modern.
1. Pictures of stick man holding a bottle of Lucozade and toilet symbol: Q 'describe the energy changes when he/she drinks the Lucozade and when he/she goes to the toilet'. 2. Show peanuts, other types of food and horse dung: ask Q 'What do they all have in common?' Collate student responses.	10 mins	
Investigation d: Plan and conduct an investigation into calorific content in burning different foods and dung. The main focus is to consider the energy changes that are taking place. Comparison of the foods is secondary (calorimeters: heating water with fuels are very difficult to get valid results from as amount, combustibility, distance from tube of water, starting temp of water all effect it).	30 mins	Different food samples; dry cat/dog food, horse feed, beef jerky, different samples of animal dung CHECK CLEAPPS FOR DUNG/FOOD SAMPLES IN SCHOOL

Working Scientifically:

Planning and identifying variables, risk assessment, write conclusion and evaluation, making suggestions for improvements

Numeracy and Literacy:

Some pupils need only been given the problem and will design experiment, and select/justify the equipment used. There are lots of opportunities for improving the calorimeter set up and for spotting issues with it. Some students will need scaffolding in the set up and safety. Teacher demo may be required instead with pupils describing processes and energy changes

Differentiation:

↑ Planning and identifying variables, risk assessment, write conclusion and evaluation.

↓ Pupils make suggestions for improvements.

Key Scientific Ideas and Guidance:	Links to Research:
Be careful to use energy 'resources' rather than 'sources' as these are best seen as processes/stores which we can usefully transfer. Remind that energy is not created or destroyed. Some of the processes take a long time (e.g. fossilisation to coal/oil) but others are quicker (e.g. wind, solar, wood). Experience suggests that pupils often think that the sun is the source of all energy, which neglects that the sun has its own processes. Furthermore, geothermal processes, tides, radioactivity etc. are not neatly defined as being caused by the sun.	Driver et al (1994) suggest that students may have issues with the processes of digestion and everyday conversation leads them to focus on the stomach as the main (sometimes the only) organ involved. They see digestion as releasing energy from food (rather than it being breaking down). They also report on food being seen in different ways in different contexts, e.g. as essential material, building material for the body or an energy source. Only 40% of 12-13 year olds in one study saw it as the latter. Energy associated within living things is also not necessarily related to energy in appliances and in the wider world. Furthermore, energy is linked to movement or 'excitement' and these everyday uses need to be related to science. For example, consider how your PE colleagues talk about power.

N10	Big Questions:	Approximate time: 1 hour		Context:
How do simple machines conserve energy?				Making life easier. Tools on a building site.
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Demonstration a: Use a crowbar or claw hammer to pull a nail out of wood (pupils could do this too). What is the technique? Can you pull a nail straight out as easily as using the lever action? Why? Pupil discuss in pairs.	10 mins	Blocks of wood, nails, claw hammers/crow bars, safety goggles.		Planning an investigation, observing trends and patterns, drawing conclusions.
Investigation b: a lever. Set up two Newton meters at either end of a 'lever'. As the lever is turned note the forces and the displacement of each end. Move the pivot point and investigate the relationship between the forces and displacement at either end. Guide pupils towards a greater force relating to a shorter distance moved.	20 mins	Meter rulers as levers, using clamp boss which rotates as a pivot. Newton meter on each end. Goggles		**Numeracy and Literacy:** Opportunities for numeracy in spotting trends within data or plotting graphs. Proportional understanding being promoted.
Investigation c: a two wheel (2:1) pulley system. Use masses as the load (calculate/convert to weight) and a Newton meter to measure the force with which the rope is pulled. Again, investigate the relationship between the force and displacement at each end of the system.	20 mins	Two wheel pulley systems, masses, Newton meters, goggles.		**Differentiation:** ↑ This lesson will be challenging for many KS3 pupils and requires proportional reasoning. Support pupils through using the word weight (force) rather than mass. ↓ For some classes it would be worth doing just one investigation: pulleys are likely to give more useful results.
Discussion d: conclusions, starting with energy being conserved overall. So whilst you might increase force, the displacement is reduced.	10 mins	Pupil results.		

Key Scientific Ideas and Guidance:	**Links to Research:**
This lesson is stand alone in the unit and covers an aspect of the curriculum which says that pupils should be taught about: "simple machines give bigger force but at the expense of smaller movement (and vice versa): product of force and displacement unchanged." To be honest this is rather incongruous with the rest of the energy scheme but might be seen as a way to link energy and forces. The point is to introduce work done = force x displacement in a qualitative way to allow building on this in KS4. So if the total work done (energy transferred) by a machine such as a lever or pulley is conserved then displacement and force become inversely proportional.	Boulanger (1976) notes the difficulties of proportional reasoning and here we are attempting to relate rates of change.

F1	Big Questions:	Approximate time: 1 hour	Context:
What is a force?			Tug of war- what would happen if one team let go? Why aren't we falling through our chairs?

Activities:	Timing:	Resources:
Discussion a: 'Where have you heard the word 'force' before?' (1). Try and distinguish between everyday/anthropomorphic notions of force and scientific descriptions.	10 mins	Paper/whiteboard for groups to discuss (assess by moving around/listening)
Demonstration b: Hold a book in your hand. 'Why does it stay there?' [gravity pulls down, hand pushes up]. Put the book on a spring. Put the book on a sponge. Put the book on a desk and keep asking the same question (called a 'bridging analogy' Brown and Clement, 1989).	10 mins	A book, large spring, a large sponge. Paper/whiteboard for groups to discuss or class discussion
Activity c: 'A force is a push, a pull, a twist or a bend.' Students could push and pull chairs and tables. With a worksheet they could try and identify everything in the classroom where a force is needed (e.g. to turn a door handle...) and say if it needs a push, pull, twist or bend.	10 mins	Worksheet
Video d: Show a video of a tug of war and ask students to draw a diagram to show what is happening. What happens if someone lets go?	5 mins	E.g. Tug-of-war World Championships: https://www.youtube.com/watch?v=ZqjW8YkU65c [Google 'ClipGrab']
Activity e: List as many different examples of forces (push, pull, twist & bend) as you can. 'What effect does a force have on an object?' [Changes speed and/or direction]	15 mins	

Working Scientifically:

Predictions can be made around the track and sculpture activities as to what resultant force needs to be applied. These can then be modified after trials. Observation is a key focus throughout this section.

Numeracy and Literacy:

Literacy: recognising scientific terminology, i.e. force, to have more precise meaning than everyday usage. Written explanations of situations.

Numeracy: understanding direction and magnitude of forces and resultants.

Differentiation:

↑ Activity f: Zoom in to a specific part of a picture/situation and ask pupils to draw what is happening at the micro-scale (4) Repeat with more complex scenarios.

↓ Understanding that forces are of different sizes and representing these is challenging (Boulanger, 1976;, Driver et al, 1994). Pupils will likely start off being able to point and position arrows, then move on to considering magnitude, then on to considering balanced and unbalanced forces. This progression can be promoted across the activities suggested.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ National Curriculum 2014 Motion and Forces 2a. forces as pushes or pulls, arising from the interaction between two objects If students haven't been exposed to certain kinds of thinking in primary school, may be difficult to introduce successfully (Boulanger).	M30 [No research on pupils ideas about transmission of forces.] Driver, 1994, p. 148 M31 [Dispute about how consistent pupils are to particular frameworks] Driver, 1994, p. 148 M32 Force is anger. Osborne, 1980 and 1985 M33 Force is a feeling. Osborne, 1980 and 1985 M34 Forces get things going [but the idea that forces can slow things is missed]. Osborne, 1980 and 1985 M35 Force means to coerce. Watts, 1983; Osborne, Schollum and Hill, 1981; Shevlin, 1989 M36 Force means to resist. Watts, 1983; Osborne, Schollum and Hill, 1981; Shevlin, 1989 M37 Forces are associated with living things [not with non-living things]. Gunstone and Watts, 1985; Watts and Gilbert, 1985 M48 Force is a property of an object [as opposed to an interaction between two objects - introduce a qualitative intuitive understanding of momentum as a property?]. Brown and Clement, 1987 and 1989; Maloney, 1985; Minstrell and Stimpson, 1986; Watts, 1983. M49 An object's force depends on the object's weight/motion/activity/strength. Minstrell and Stimpson, 1986 M50 A kick is not a push. Shevlin, 1989 M51 A throw is not a push. Shevlin, 1989 M52 Forces which pull are different from forces which just hold. Erickson and Hobbs, 1978 (1) Driver et al (1994) found that many pupils associate forces with feeling and emotions (being forceful) or even authority (police force/armed forces). This further manifests as pupils suggesting that the bigger force 'wins' in a struggle, or that forces are 'trying to do things'.

F2	Big Questions:	Approximate time: 1 hour		Context:
How can forces be shown in diagrams?				Why is a mattress more comfortable than wood?
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Activity a: students build a ring shape out of plasticine. Ask them to draw step-by-step instructions for another student to make the same shape. 'How did you show the forces?' Hopefully the students themselves introduce the idea of force arrows [see differentiation].	15 mins	Plasticine. You could role play failing to follow their instructions.		Students make predictions, conduct and write up experiment.
Discussion b: 'Why do we use diagrams to represent forces?' Modify the drawings in activity a to add force arrows. Draw several examples of scenarios where force arrows help understand the situation (preferably onto real photos on an IWB).	15 mins			**Numeracy and Literacy:**
Experiment c: weight on a spring. Students predict what will happen when weights are added to a spring. The draw diagrams to represent the force being exerted before the weight is added and afterwards.	5 mins	Weights, springs, retort stands, ruler.		Numeracy: Students draw graph to show masses added against length of a spring. Students can calculate gradient for extension. Literacy: Students can write up the investigation formally.
Experiment d: Students continue experiment c recording length of a spring against weight added, and draw a graph to show their findings (Hooke's Law)	25 mins	Weights, springs, retort stands, ruler.		**Differentiation:**
				↑ Numeracy extension: Students can calculate gradient from graph. ↓ With force arrows take care to tell pupils that the base of the arrow is placed where the force acts, that the length of the arrow indicates how big the force is (the magnitude of the force), and that the arrow points in the correct direction. This is challenging for many learners and needs to be made explicit.

Key Scientific Ideas and Guidance:	Links to Research:
Motion and Forces 2b. using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces Driver - Misconceptions 1. Forces associated with physical strength/ feeling. 2. Coercion / opposing resistance - forces in a struggle (the stronger will win) 3. Pupils find it difficult to consider forces in terms of magnitude and direction. 4. Anthropomorphism 5. Forces trying to do things. 6. A force is a living thing. Ainsworth, Prain, Tytler (2011) + Tytler and Prain (2010): Drawing to learn - zooming in. Viennot (2010) - pupils reasoning through stories. There is no motion without force. Table in the way to stop falling. Book would float otherwise. Doesn't feel like chair is pushing you up. Take care to use the word 'weight' (measured in Newtons) when talking about forces. Mass is a measure of the amount of matter in an object (measured in kilograms). However, many teachers may choose not to correct some pupils about this at this stage, as there is a risk of discouraging pupils if we're too fussy about the language pupils use.	M53 [Arrows used ineffectively to represent force point of action] Terry et al., 1985 M54 [Arrows used ineffectively to represent force direction] Terry et al., 1985 M55 Force is a single entity [and a property of a single object]. Erickson and Hobbs, 1978 M56 A book does not fall when on a table because the table is in the way. Minstrell, 1982 M57 The downward force on a book on a table is bigger than the upward force, otherwise the book would float away. Clement, 1982 M58 Friction is the reaction force. Stead and Osborne, 1981 M59 Pulling and holding are different. Erickson and Hobbs, 1978 M60 If cars collide, the moving car exerts the [bigger] force. Brown and Clement, 1987 M61 If cars collide, the faster car exerts the bigger force. Brown and Clement, 1987 M62 Reaction [as in 'action and reaction'] means a sequence of events where one force leads to another. Terry et al., 1985 M63 Opposite [as in 'equal and opposite'] means the reaction force acts on the same object [rather than two forces involved in an interaction between two objects]. Terry et al., 1985 Clement (2008) used activity a. Rather than introduce force arrows from the start, they asked pupils to describe to another how they made rings of plasticine and pupils came up with the idea of adding arrows to explain stretching and squeezing. This approach builds on a 'natural' understanding of forces and can be extended by considering magnitude and direction of arrows.

F3	Big Questions:	Approximate time: 1 hour		Context:
How do we measure force? What happens if something experiences more than one force?				History of Science: Introduce students to the story of Isaac Newton. What did he think when the apple fell?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Video a: Show video about Isaac Newton. What was he thinking? Students fill in concept cartoon to demonstrate thinking before and after realisation.		15 mins	For example: http://www.bbc.co.uk/science/space/universe/scientists/isaac_newton#p009gynr	Students make predictions and test their findings.
Experiment b: Introduce students to the concept of the Newton, and demonstrate how a Newton meter works. Students should weigh objects around the room and record their results (to get in the habit of adding N for Newton after the number).		10 mins	Newton meters, a number of different objects.	**Numeracy and Literacy:** Numeracy: Students calculate resultant forces from free body force diagrams.
Activity c: Show a series of objects, and ask students to estimate what the reading will be when different objects are picked up. Students test out their predictions. Why do some require more force to lift than others?		10 mins	Newton meters, a number of different objects (including some trick ones - e.g. some pumice stone…).	
Activity d: Introduce students to free body force diagrams, including the numerical values. Show how to calculate resultant forces. Ask students what will happen in a series of scenarios.		15 mins	Invite students to suggest their own examples.	**Differentiation:** ↑ Extension: What happens when there are more than two forces acting, and they are not at 180 degrees to each other? Difficulty of scenarios can be tailored to class or individual students. ↓ In experiment b, if the Newton meters are the ones with Newtons on one side and grams on the other (aaghhh!), tape over the grams. Reading scales can be very challenging for many pupils. The following websites can be helpful: http://www.john-paul.org.uk/ then 'more', then 'websites', then 'measurement'.

Key Scientific Ideas and Guidance:	Links to Research:
Motion and Forces 2a. forces as pushes or pulls, arising from the interaction between two objects 2b. using force arrows in diagrams, adding forces in one dimension, balanced and unbalanced forces In the previous set of lessons you explored pupils intuitive understanding of forces, and students had been encouraged to represent forces diagrammatically. This part of the scheme aims to move them on to scientific approaches to drawing and labelling forces and considering situation in terms of balanced and unbalanced forces. Clement (2010) echoes other researchers in proposing that 'anchoring' is the way to develop models of forces: by looking at real life situations, ideally those that can be touched and manipulated by pupils. The idea of adding arrows after discussing a situation comes from this and repeated exposure to such activities is necessary to develop conceptual understanding. A note on force diagrams: pupils will often label forces where they apply e.g. at the foot of a footballer or from the ground pushing up. Higher up the school we adopt free-body diagrams in which every force is drawn coming from the centre of mass of an object. This has the advantage of allowing understanding of balanced and unbalanced forces and ensuring pupils focus upon the object in question, rather than mixing up which force act on which object (Driver et al, 1994). However, this is an abstraction that needs to be built up as it may not initially make sense for pupils to not put forces where they are acting.	M38 Only inanimate objects which can cause another object to move have forces associated with them (e.g. a spring). Watts, 1983 M39 An inanimate object which exerts a force is 'trying to' bring about a change. Gunstone and Watts, 1985 M40 Force is only associated with movement [c.f. 'passive' forces like those on an object in equilibrium]. Watts, 1983; Osborne, Schollum and Hill, 1981; Gunstone and Watts, 1985; Driver, 1984 M41 Moving objects contain a force which keeps the object moving. Moving objects stop when the force runs out [c.f. fuel]. Sjobert and Lie, 1981; Viennot, 1979; Watts and Zylbersztajn, 1981; Clement, 1982; McCloskey, 1983; Fischbein Stavey and Ma-Maim, 1988 M42 If there is motion, there is a force acting. Driver, 1994, p. 148 M43 If there is no motion, there is no force acting. Driver, 1994, p. 148 M44 There cannot be a force without motion. Driver, 1994, p. 148 M45 If there is motion, there is a force acting in the same direction as the object is moving in. Driver, 1994, p. 148 M46 Motion is proportional to the force acting. Driver, 1994, p. 148 M47 A constant speed results from a constant force. Driver, 1994, p. 148 M64 Equilibrium means several forces struggle together and the strongest wins. Erickson and Hobbs, 1978; Osborne, 1980 M65 Equilibrium means the resolution of several forces struggling together. After the struggle all forces stop. Erickson and Hobbs, 1978 M66 If a system in equilibrium is moved, it will not stay in the new position. Erickson and Hobbs, 1978

F4	Big Questions:	Approximate time: 1 hour	Context:
How are force and movement related?			How does a football change speed or direction? [the teacher could dribble a ball into the classroom at the start of the lesson, or ask a pupil to do this]

Activities:	Timing:	Resources:	Working Scientifically:
Activity a: Push a toy car. Ask students to draw a free body force diagram to show forces acting on the car at the point when it is pushed and then again once it is moving. 'Why does the car move?' [Answer: 'Because it does!' The more important question is why it slows down.]	10 mins	Toy cars	
			Numeracy and Literacy:
Activity b: Repeat the demonstration with the toy car. Ask students to draw a free body force diagram of the car when it has stopped moving. How is it different?	5 mins		Numeracy: students calculate resultant forces and use F = ma. Literacy: Students write stories involving balanced and unbalanced forces, and interpret others stories to represent diagrammatically, moving between two different forms of explanation, and requiring deep understanding of both.
Activity c: Ask students to draw a free body force diagram for a real car, stationary, accelerating, travelling at a constant speed & slowing down. Elicit the idea that for it to travel at a constant speed, forces must be balanced.	15 mins		
			Differentiation:
Discussion d: Elicit idea that unbalanced forces result in changes of speed or direction, and repeat with several examples- e.g. Using the toy car, give several different scenarios and ask whether forces are balanced or unbalanced, and ask students how they know.	15 mins	Extend questioning outside this context.	↑ The story task can be repeated in reverse, with students writing a story to illustrate other students' diagrams. Students may rearrange F = ma. ↓ Students with literacy difficulties might benefit from using software like Widgit SymWriter. This can be a very useful class dictionary on the IWB.
Activity e: Students write a story using descriptions involving balanced and unbalanced forces, and exchange them. Students must draw a series of free body force diagrams to illustrate the story.	15 mins		

Key Scientific Ideas and Guidance:	Links to Research:
A common misconception is that if forces are balanced, an object must be stationary. It should be emphasized to students that if forces are balanced an object will keep doing whatever it is doing: if it is stationary it will remain stationary, if it is moving, it will continue to move in the same direction at the same speed. Try to avoid pupils using a 'driving force' arrow when drawing a moving car. It is friction at the tyres that actually drive a car forwards.	Viennot (2010) found that pupils reason through stories: 'what happens next'. Whilst working with this, we suggest making it clear that physics isn't story-like in that forces are all acting at once. Driver et al (1994) found that pupils reason that the table is 'in the way' of an object falling, or that it could stay where it was if the table/water were removed, as no forces are acting. Ainsworth, Prain & Tyltler (2011) found that pupils think through their own understanding when asked to draw what is happening. For example, with a block moving on a table what is slowing it down? Try not to give a 'standardised' diagram of the situation later on, as they just believe this is correct rather than exploring their own ideas.

F5	Big Questions:	Approximate time: 1 hour	Context:
What is the 'moment' of a force?			The use of cranes in the construction industry. See-saws.

Activities:	Timing:	Resources:
Discussion a: Students think of as many examples of pivots as possible. E.g. door hinge, using a screwdriver to remove the lid of a paint pot, a piano key…	5 mins	Mini white boards so students can display their answers.
Video b: Students watch a moment crane collapsing while the World Cup Stadium was being built. Students must try to identify i) why it collapsed ii) what could have prevented it from collapsing. Reinforce the importance of moments in the real world.	10 mins	YouTube video: https://www.youtube.com/watch?v=Kjs8BSjW7vM
Experiment c: Moments. Students try to get the scales to balance (reach equilibrium) when a weight of 1N is put at different distances from the pivot. This data can be collected and used to introduce moment calculations.	20 mins	Scales that allows the distance from the pivot to be changed (e.g. http://www.timstar.co.uk/Item/Science_Supplies~SUBJECTS~Physics~
Calculations d: Moments. These begin easier and become more challenging. Harder questions involve the students rearranging the formula to find force and distance. These questions can be contextualised i.e. using a crane in the question.	15 mins	

Working Scientifically:
Experimental skills and investigations a (ask questions based on observations of the real world) use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety Apply mathematical concepts and calculate results Present observations and data using appropriate methods, including tables and
Numeracy and Literacy:
Numeracy: Calculating moments using the formula and changing the subject to find the force and distance. Literacy: Students could write a short risk analysis before they begin the practical.
Differentiation:
↑ Students could consider how things would be different if the examples of pivots they give did not exist. Lower ability students could be shown several examples of pivots and asked to label the pivot in the diagram. They could make predictions before the during the practical to see if they can identify a relationship between moment, force and distance. ↓ Pupils could create their own numeracy problems when carrying moments calculations or very basic calculations could be given with limited rearranging and several examples of modelling.

Key Scientific Ideas and Guidance:	Links to Research:
Motion and Forces 2c. moment as the turning effect of a force Moment as the turning effect of a force. - Students could be given a chance to play first before they are given instructions to the practical (Viennot, 2010). - Perhaps have a bank of contextual scenarios where moments are used so many different explanations can be given to further embed concepts (Viennot, 2010).	M75 [Most children appear to have an intuitive understanding of moments - e.g. how to balance a see-saw]. Inhelder and Piaget, 1958

F6	Big Questions:	Approximate time: 1 hour

How do different materials stretch?

What does elastic mean?

How are elastic and plastic materials different?

Context:

People who use pogo sticks to jump up in the air. The construction of any structure (bridges, buildings etc.).

Activities:	Timing:	Resources:
Experiment a: the stretchiness of a jelly sweet.	5 min	Jelly worm sweets / crocodile sweets, clamp stand, spring, various weights, ruler.
Experiment b: 'how stretchy is a spring?' - adding weights to a spring and record their results in a table (a prediction should be made beforehand). Students can then draw a conclusion.	25 mins	
Activity c: graph plotting of the results	15 min	Graph paper, pencil, ruler
Experiment d: Students test the extension of different materials (to see which would be best for making a force meter). A plastic material should be tested in this so students can compare to elastic materials.	15 min	Various materials, clamp stand, ruler, spring

Working Scientifically:

Students make predictions using scientific knowledge and understanding. Students plan and carry out the most appropriate types of scientific enquiries to test predictions. Students make and record observations and measurements.

Numeracy and Literacy:

Numeracy: Drawing a results table, drawing a labelled graph, estimating from a graph, interpreting graphs.

Differentiation:

↑ Extension activities could be used such as writing an evaluation of the spring extension experiment.

↓ The following video clip can be shown to demo experiment b first (http://www.youtube.com/watch?v=pVdGUTRI49E).

Key Scientific Ideas and Guidance:	Links to Research:
Motion and forces - 2: d. forces: associated with deforming objects; stretching and squashing – springs; with rubbing and friction between surfaces, with pushing things out of the way; resistance to motion of air and water e. forces measured in newtons, measurements of stretch or compression as force is changed This topic demonstrates how engineers use their knowledge of mathematics to investigate the properties of materials. Materials can be stretched or compressed. The type of material and the size of the force will determine the extent to which a material stretches or compresses.	M30 [No research on pupils ideas about transmission of forces.] Driver, 1994, p. 148 M31 [Dispute about how consistent pupils are to particular frameworks] Driver, 1994, p. 148 M32 Force is anger. Osborne, 1980 and 1985 M33 Force is a feeling. Osborne, 1980 and 1985 M34 Forces get things going [but the idea that forces can slow things is missed]. Osborne, 1980 and 1985 M35 Force means to coerce. Watts, 1983; Osborne, Schollum and Hill, 1981; Shevlin, 1989 M36 Force means to resist. Watts, 1983; Osborne, Schollum and Hill, 1981; Shevlin, 1989 M37 Forces are associated with living things [not with non-living things]. Gunstone and Watts, 1985; Watts and Gilbert, 1985 M38 Only inanimate objects which can cause another object to move have forces associated with them (e.g. a spring). Watts, 1983 M39 An inanimate object which exerts a force is 'trying to' bring about a change. Gunstone and Watts, 1985

F7	Big Questions:	Approximate time: 1 hour		Context:
How does the extension of a spring depend on the force applied?				Elastic behaviour is very important in car safety i.e. seatbelts.
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Calculations a: Students introduced to 'F=kx' (where F is the force, x is the extension and k is the proportionality constant) (1). Students work through calculations to find one of these.	10 min			Students apply mathematical concepts and calculate results, present observations and data using appropriate methods, including tables and graphs, interpret observations and data, including identifying patterns and using observations, measurements and data to draw conclusions. Students evaluate data and identify further questions.
Interactive b: weight on a spring http://phet.colorado.edu/en/simulation/mass-spring-lab	15 min			**Numeracy and Literacy:**
Activity b: Students use their graph to estimate the extension when various forces are applied (and vice versa).	10 min			Literacy: Writing scientific explanations to go alongside graph.
Activity c: Students analyse three force - extension graphs (stiff, soft, even softer springs) and write a paragraph comparing them (using scientific keywords).	10 min			**Differentiation:**
				↑ Can be introduced to the idea of a constant (k) in f = kx. Extension activities could be used such as writing a 'manual to work out how to use 'f=kx', or creating a list of ways in which Hooke's Law is useful to real life (with reasons). ↓ A fill in the gap exercise with keywords such as 'proportional' and 'extension' would be useful. These students will need help drawing the graph; provide them with the axis drawn and labelled and the first point plotted for them.

Key Scientific Ideas and Guidance:	Links to Research:
Motion and forces - 2: f. force-extension linear relation; Hooke's Law as a special case When students have drawn their graphs, introduce the word 'proportional' i.e. if the force is doubled, the extension is doubled. Every 1N increase in force results in the spring stretching by the same amount. Explain to students this is what we call Hooke's Law (named after Robert Hooke who studied how metals behave when stretched). After a certain point on the graph (point X), the spring reaches its elastic limit; this means it will no longer return to its original shape. Students will find 'F=kx' difficult; particularly the idea of a constant.	M40 Force is only associated with movement [c.f. 'passive' forces like those on an object in equilibrium]. Watts, 1983; Osborne, Schollum and Hill, 1981; Gunstone and Watts, 1985; Driver, 1984 M41 Moving objects contain a force which keeps the object moving. Moving objects stop when the force runs out [c.f. fuel]. Sjobert and Lie, 1981; Viennot, 1979; Watts and Zylbersztajn, 1981; Clement, 1982; McCloskey, 1983; Fischbein Stavey and Ma-Maim, 1988 M42 If there is motion, there is a force acting. Driver, 1994, p. 148 M43 If there is no motion, there is no force acting. Driver, 1994, p. 148 M44 There cannot be a force without motion. Driver, 1994, p. 148 M45 If there is motion, there is a force acting in the same direction as the object is moving in. Driver, 1994, p. 148 M46 Motion is proportional to the force acting. Driver, 1994, p. 148 M47 A constant speed results from a constant force. Driver, 1994, p. 148 M48 Force is a property of an object [as opposed to an interaction between two objects - introduce a qualitative intuitive understanding of momentum as a property?]. Brown and Clement, 1987 and 1989; Maloney, 1985; Minstrell and Stimpson, 1986; Watts, 1983. M49 An object's force depends on the object's weight/motion/activity/strength. Minstrell and Stimpson, 1986 M50 A kick is not a push. Shevlin, 1989 M51 A throw is not a push. Shevlin, 1989 M52 Forces which pull are different from forces which just hold. Erickson and Hobbs, 1978 M53 [Arrows used ineffectively to represent force point of action] Terry et al., 1985 M54 [Arrows used ineffectively to represent force direction] Terry et al., 1985

F8	Big Questions:	Approximate time: 1 hour	Context:
	What is work done? How are work done, force and distance related?		Bungee jumping.

Activities:	Timing:	Resources:
Interactive a: PhET 'The Ramp' http://phet.colorado.edu/en/simulation/the-ramp	5 min	
Discussion b: 4 pictures (man lifting a weight, aeroplane taking off, rocket taking off, man kicking a football) 'What have these pictures got in common?' (introduce concept of 'work done').	5 min	
Activity c: students carry out different exercises (squats, tricep dips, bicep curls, wrist curls, step-ups) & calculate the work done at each station (using the equation - use the upward distance).	35 min	Students can then decide which exercise does the most work and evaluate the experiment.
Discussion d: Jo says that 'work done and energy are the same as they are both measured in Joules'. Ben disagrees 'work done and energy are different even thought they are both measured in Joules'.	15 min	Students write down who they agree with and an explanation why. This can lead to a whole-class discussion.

Working Scientifically:
Students ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience. Students use appropriate techniques, apparatus, and materials during fieldwork and laboratory work, paying attention to health and safety. Students make and record observations and measurements.

Numeracy and Literacy:

Differentiation:
↑ Convert work done into calories (4.2J to every calorie) and work out how long you would have to do the circuit for to burn 500 calories. ↓ Provide some keywords alongside the 4 pictures. Circuit Training - fill in parts of their results table to help them calculate work done / show them a worked example.

Key Scientific Ideas and Guidance:	Links to Research:
Motion and forces - 2: g. work done and energy changes on deformation Students should now be starting to think as a force as a mechanism by which energy is transferred from one body to another. Work and energy are measured in the same unit (Joule). When an object is moved by a force, energy is transferred and work is done. It is important to emphasise that work is NOT a form of energy; it is one of the ways in which energy can be transferred. When introducing the equation, work done (Joules, J) = force (Newtons, N) × distance (metres, m), it is important to explain that the distance involved is the distance moved in the direction of the applied force. Elasticity is the property of a body which can be stretched or compressed or sheared and restored to its original shape. Elastic materials include rubber and steel (students will not think of steel as being elastic; explain that steel is actually stronger when stretched) - reference to the previous lesson on Hooke's Law will be useful here. Plastic materials, conversely, do not regain their original shape and therefore, do not obey Hooke's Law.	M10 The depository model: some objects have energy which is rechargeable, some need energy which they expend, and some are neutral. Watts and Gilbert, 1985 M11 Energy is doing. Watts and Gilbert, 1985 M12 Energy is force. Duit, 1981 M13 Energy is power. Ault et al., 1988 M18 Conservation of energy is unnecessary. Duit, 1981 M21 Energy is only associated with technical applications [rather than all processes]. Watts and Gilbert, 1985 M26 Energy is a physical substance. Stead, 1980 M27 Energy is linked with strength. Duit, 1984

F9	Big Questions:	Approximate time: 1 hour		Context:
How is work calculated?				Vehicle design.
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Experiment b: Hooke's Law	25 min	Elastic band, clamp stand, ruler, weights		Students apply mathematical concepts and calculate results and identify further questions. Students use and derive simple equations and carry out appropriate calculations.
Calculation c: 'work done = force x distance moved' to work through various calculations (1) (For example, a mass of 3 kg is lifted vertically through a distance of 5m. How much work has been done?).	15 min			**Numeracy and Literacy:**
Discussion d: Students read two paragraphs; one on elastic deformation and one on plastic deformation. Students discuss the differences in pairs and write their own explanation.	10 min	Paragraphs on elastic and plastic deformation		Numeracy: Using W = F x d equation, drawing table of results. Literacy: Reading and interpreting information on deformation. Writing own explanations.
				Differentiation:
				↑ After completing the 'does an elastic band follow Hooke's law?' investigation, students could plot a graph and compare it to the one drawn in lesson F1. ↓ Paragraphs could be symbolised using software like Widgit SymWriter for students with literacy difficulties.

Key Scientific Ideas and Guidance:	**Links to Research:**
Motion and forces - 2: g. work done and energy changes on deformation The area under a force-extension graph can tell us how much energy is stored in a stretched material. The stored energy is strain energy and is converted to elastic energy.	

F10	Big Questions:	Approximate time: 1 hour

Big Questions:

What is mass?

What is gravity?

How are weight, mass and gravity different?

Context:

Astronauts in Space. Video can be useful here. For example:
http://www.nasa.gov/externalflash/ISSRG/
or
http://www.nasa.gov/multimedia/hd/HDGalleryCollection_archive_4.html

Activities:	Timing:	Resources:
Activity a: 'Imagine you're an astronaut in space. Draw what the Earth would look like. Draw land. Draw people [stick people large enough to see]. Draw rain clouds.' [Adapted from Driver, 1994, p.169]		Afterwards [!] show a globe. Use blue tack to stick play mobile figures all over the globe.
Interactive b: find a local recognisable landmark on Google Earth, then zoom out until you can see the whole Earth from space. Then spin the Earth round 'one day' and then zoom back in.		
Video c: Felix free fall diving to Earth. Ask students to draw a picture on their mini-whiteboard of the forces acting on Felix as he jumps out of the balloon (3). http://www.youtube.com/watch?v=FHtvDA0W34I	10 min	
Experiment d: drop a marble from different heights on the ramp (1cm, 5cm, 8cm, 10cm, 12cm, 15cm, 20cm). Record the distance travelled by the marble. Write a conclusion explaining what the results showed.	30 min	Marbles, ramps, tape measures Listen to group discussions as they carry out the experiment

Working Scientifically:

Scientific attitudes
b. understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas

Numeracy and Literacy:

Numeracy: measuring heights and distances

Differentiation:

↑ Students could draw a graph for experiment b. Opportunity to discuss with pupils about how ideas about the Earth have changed. The old Salters' SOW had a lovely activity for this.

↓ Some children think the Earth is flat, or that we live inside the Earth, or that we only live in the Northern hemisphere of the Earth, or that 'down' is always the same direction (Driver, 1994, p.169). Hence activity a is very important. It may be wise to do it again during the space topic later in the year to see how thinking may have changed (or not!).

Key Scientific Ideas and Guidance:	Links to Research:
Motion and forces 2h. non-contact forces: gravity forces acting at a distance on Earth and in space, forces between magnets and forces due to static electricity.	M401 Forces only exist in a line [unilateral theory]. Selman et al. 1982 M402 Gravity pushes. Stead and Osborne, 1980 M403 Gravity holds. Stead and Osborne, 1980 M404 Gravity is caused by air pressure. Stead and Osborne, 1980 M405 Gravity is caused by air pressure which prevents things floating away. Stead and Osborne, 1980 M406 If there is no air, there is no gravity. Ruggiero et al. 1985 M407 Gravity lies outside objects [rather than being a property of all objects]. Driver, 1994 M408 Only some objects experience gravity. Stead and Osborne, 1980 M409 Gravity is caused by the Earth's magnetism. Stead and Osborne, 1980; Vicentini-Missoni, 1981 M410 Gravity is caused by the Earth's spin. Stead and Osborne, 1980; Vicentini-Missoni, 1981 M411 Artificial gravity' is caused by the Earth's spin. Vicentini-Missoni, 1981 M412 Gravity does not decrease with height. Stead and Osborne, 1980 M413 Gravity decreases with height extremely rapidly (rather than gradually). Stead and Osborne, 1980; Ruggiero et al., 1985 M414 Gravity increases with height [until outside the Earth's atmosphere]. Stead and Osborne, 1980; Ruggiero et al., 1985 M415 Gravity is the same as potential energy [hence higher gravity as height increases]. Watts, 1982 M416 Gravity is an upward force [which holds us vertical]. Stead and Osborne, 1980 M417 Gravity is a material which can be trapped [for example in aeroplanes, or which can flow up pylons to keep birds in place on wires]. Stead and Osborne, 1980 M418 Gravity only occurs at the surface of the Earth [which is why birds can fly]. Stead and Osborne, 1980 M419 Gravity is a very large force [because it affects so many things]. Watts, 1982 Weight M420 Weight is not 'the force of gravity'. Stead and Osborne, 1980; Ruggiero et al., 1985; Vicentini-Missoni, 1981; Watts, 1982 M421 Gravity only affects heavy things. Stead and Osborne, 1980 M422 It is possible to have weight without gravity [e.g. astronauts have moon boots to give them weight when there is no gravity]. Stead and Osborne, 1980 M423 Gravity keeps birds up when they fly. Stead and Osborne, 1980

F11	Big Questions:	Approximate time: 1 hour		Context:
What's pressure? What's the difference between atmospheric pressure and gravity?				Why is pressure in liquids important? Aerosols, camping stoves, fire hoses.
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Discussion a: Students recap KS2 particle theory by modelling the way particles move as a class. Students are asked which state has the most pressure. If students are unsure, recap definition of pressure.	10 mins	Possibly show students diagrams to illustrate the definition of pressure (e.g. https://www.google.co.uk/search?q=pressure		Experimental skills and investigations a (ask questions based on observations of the real world)
Experiment b: pressure in the three states of matter. Three syringes are filled with air, water and sand- the ends are blocked. Students write down the volume. Student then put pressure on the syringe and write down the volume.	15 mins	3 syringes, sand and water.		**Numeracy and Literacy:** Numeracy: Calculating pressure using the formula and changing the subject to find the force and area. Students are also required to plot data on a graph. Literacy: Students write a story about a balloon that wishes to go to the top of a mountain. They should explain the changes occurring to the particles inside the balloon. In contrast, students could also write a story about a fish that wants to travel to the bottom of the ocean. They can describe how pressure affects the fish as it swims deeper.
Experiment c: students weigh themselves on newton scales and then draw around their feet on graph paper to work out the area. They calculate pressure using the formula. Students draw conclusions about the relationship between P, A and F.	15 mins	Newton scales and graph paper.		
				Differentiation: ↑ Students could also be asked to recall characteristics of the three states of matter and describe how they can transform into each. Students could be asked to draw diagrams to represent how the particles are arranged in the three syringes. Students could come up with their own pressure problems and test each other. Students could be asked to draw particle diagrams to show what occurred in the demonstrations. Students could sketch a graph to show how pressure would change as the water depth increases. ↓ Students could be given unlabelled diagrams of the three states of matter to help them perform the modelling with other students. More calculations could be

Key Scientific Ideas and Guidance:	Links to Research:
Motion and Forces 3. Pressure in fluids a. atmospheric pressure, decreases with increase of height as weight of air above decreases with height b. pressure in liquids, increasing with depth; upthrust effects, floating and sinking c. pressure measured by ratio of force over area – acting normal to any surface. Students get confused between pressure and gravity.	M67 Only wind exerts pressure [not still air]. Séré, 1982 M68 Pressure does not act in all directions in air/water. Engel, Clough and Driver, 1985 M69 Pressure acts in all directions, but the pressure downwards is greater that the pressure in other directions. Engel, Clough and Driver, 1985 M70 A vacuum sucks [e.g. when someone sucks on a straw this creates a partial vacuum which 'sucks' up the liquid]. Engel, Clough and Driver, 1985 M71 Air sucks. Engel, Clough and Driver, 1985 M72 [Balanced pressures are not considered]. Engel, Clough and Driver, 1985 M73 The air pressure outside a football is the same/more than the air pressure inside the football. Séré, 1982 M74 Only moving air exerts pressure, and the pressure is in the direction of travel of the air. Séré, 1982 With a syphon where water comes out, pupils may think that there is only atmospheric pressure at one end (Viennot, 2010).

F12	Big Questions:	Approximate time: 1 hour		Context:
What's pressure? What's the difference between atmospheric pressure and gravity?				Why is pressure in liquids important? Aerosols, camping stoves, fire hoses.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Demonstration a: Pressure in liquids i) with a glass and card and ii) collapsing can. Students are asked to explain the phenomena.		10 mins	Videos can be used as an alternative- https://www.youtube.com/watch?v=65T4ReLkjCg and https://www.youtube.c	Experimental skills and investigations a (ask questions based on observations of the real world)
Calculations b: these begin easier and become more challenging. Harder questions involve the students rearranging the formula to find force and area. These questions can be contextualised i.e. using real life ideas.		20 mins		**Numeracy and Literacy:** Numeracy: Calculating pressure using the formula and changing the subject to find the force and area. Students are also required to plot data on a graph. Literacy: Students write a story about a balloon that wishes to go to the top of a mountain. They should explain the changes occurring to the particles inside the balloon. In contrast, students could also write a story about a fish that wants to travel to the bottom of the ocean. They can describe how pressure affects the fish as it swims deeper.
Experiment c: paper boats 'Why doesn't it sink?' Add weights. 'Why does the boat still float? Why does it sink? Students draw three diagrams - boat floating, boat floating with weights, boat sinking. Students label weight and upthrust with appropriately placed and sized arrows.		15 mins	Instructions to make a small paper boat, tub of water and some weights.	
Demonstration d: balloon/marshmallow/shaving foam in a vacuum. Get students to draw the item when there is atmospheric pressure, less atmospheric pressure and in a vacuum.		15 mins	Vacuum chamber, balloon.	**Differentiation:** ↑ Students could also be asked to recall characteristics of the three states of matter and describe how they can transform into each. Students could be asked to draw diagrams to represent how the particles are arranged in the three syringes. Students could come up with their own pressure problems and test each other. Students could be asked to draw particle diagrams to show what occurred in the demonstrations. Students could sketch a graph to show how pressure would change as the water depth increases. ↓ Students could be given unlabelled diagrams of the three states of matter to help them perform the modelling with other students. More calculations could be
Activity e: Students are given data relating altitude and atmospheric pressure. They can draw a graph to represent the data and be asked to draw a conclusion from the graph.		20 mins	Graph paper and rulers and data can be found and adapted from here: https://www.avs.org/AVS/files/c7/c7edaedb-	

Key Scientific Ideas and Guidance:	Links to Research:
Motion and Forces 3. Pressure in fluids a. atmospheric pressure, decreases with increase of height as weight of air above decreases with height b. pressure in liquids, increasing with depth; upthrust effects, floating and sinking c. pressure measured by ratio of force over area – acting normal to any surface. Students get confused between pressure and gravity.	"Viennot 2010: Syphon - where water comes out, there is only atmospheric pressure at one end -Forgetting the glass -Atmospheric supports weight of water - local view of forces"

W1	Big Questions:	Approximate time: 1 hour		Context:
What is a wave (ripple)? How can we 'draw' waves (ripples)?				Using a paddling pool (or a large bowl) and a rubber duck make ripples on the surface of the water. Ask pupils 'Tell me about waves or ripples?' or 'Who wants to go to the beach? Yes, well me too.' Then show live beach webcams (check they are working and suitable first!): E.g. http://explore.org/live-cams/player/santa-monica-sunset-cam
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Demonstration a: Slinky - show transverse & longitudinal waves. Ask pupils to describe what they see (they might spot reflection…). Show a single pulse and a continuous wave (both types).		5 mins	slinky (depending on teaching order, may want to show transverse wave)	Experimental skills and investigations a. ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience
Activity b: drawing waves. Without using the technical terms, demonstrate high freq., low freq., large amplitude, small amplitude, reflection, pulse & continuous waves in the pool & on the slinky. Pupils describe each of these using drawings. [M184]		20 min	If possible, using a visualiser (or digital camera), invite pupils to show their drawings to the class & explain them.	**Numeracy and Literacy:**
Investigation c: ripple tanks - pupils could explore deep and shallow water ripples, waves and edges, how fast water ripples travel or what happens as ripples spread out.		25 min	Ripple tanks, power supplies, Perspex sheets to make the water shallow. WARNING: see guidance.	Literacy: perhaps give pupils the opportunity to describe waves using their own language, before introducing the technical terms next lesson.
Role play d: pupils stand in a long line facing the same way with hands on shoulders of the person in front. Ask the person at the back to [CAREFULLY] rock from side to side, then to rock backwards and forwards.		5 mins	WARNING: this activity may not be suitable for pupils with challenging behaviour.	**Differentiation:** ↑ In the role play pupils could try and demonstrate other wave phenomena they have observed during the investigation. ↓ You may prefer to keep ripple tanks until KS4 and substitute investigation c for something else like playing sounds from the garden, kitchen, playground and supermarket where pupils must identify the sound and where it was made.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ National Curriculum 2014 Waves 1. Observed waves a. waves on water as undulations which travel through water with transverse motion; these waves can be reflected, and add or cancel – superposition. SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.17.	M179 Sound is not represented with diagrams. Watt and Russell 1990 M180 Sound is represented diagrammatically as a single thing that travels from a source to a receiver. Watt and Russell 1990 M181 Sound is represented diagrammatically as a continuous line that travels from a source to a receiver. Watt and Russell 1990 M182 Sound is represented diagrammatically as a line parallel to the direction the sound travels in. Watt and Russell 1990 M183 Sound travels only to the intended listener (it does not spread out). Watt and Russell 1990 M184 Sound can be represented (in science) using words, arrows, shading or musical notes. Watt and Russell 1990 M185 Vibrate means 'repeat'. Watt and Russell 1990 M186 Echo means 'repeat'. Watt and Russell 1990

W2	Big Questions:	Approximate time: 1 hour		Context:
What is sound? How is a high pitched sound different from a low pitched sound? What can sound move though? How might we 'draw' sound waves?				Stand at the back of the room. Ask pupils to look at the front and listen. The game is they need to identify what you've dropped. Try to make at least some of these objects 'funny' (say a rubber duck that makes a squeaky sound?). sound proof rooms
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Experiment a: making sounds with different objects - use a selection of objects and instruments, some of which where you can see something vibrating (e.g. a violin string) and some where you can't (the stones) M148		10 mins	30 cm plastic ruler (non shatter), two stones (which won't break),	Measurement a. understand and use SI units and IUPAC (International Union of Pure and Applied Chemistry) chemical nomenclature
Demonstration b: cathode ray oscilloscope (C.R.O.) on IWB if possible. Show the different waves forms as frequency (pitch) and amplitude are changed. Discuss what frequency in sound is (and the unit)		20 mins	CRO, microphone, signal generator. WARNING: see guidance	**Numeracy and Literacy:** Numeracy: Units (frequency, time) Literacy: introduce key words - frequency, longitudinal, transverse, etc.
Experiment c: tuning forks - pupils hit the end of the tuning fork on say a large rubber bung. They quickly put the end in the water. They could draw and describe in words what they find out.		10 mins	Tuning forks (at least one small and one big one each). Plastic petri dish filled with water, something to hit the tuning fork on.	
Demonstration d: use slinky to show how sound moves (longitudinal wave). Relate to images showing the arrangement of air particles as sound is moving (could show correct and incorrect versions and pupils could evaluate these).		20 mins	slinky (depending on teaching order, may want to show transverse wave)	**Differentiation:** ↑ Pupils could use a balloon, a water balloon (CAREFUL) and the desk; each with the ear touching it. Tap each object to explore how sound travels through a gas, liquid and solid. Virtual oscilloscopes can be useful: http://www.zeitnitz.eu/scms/scope_en https://itunes.apple.com/gb/app/oscope/id344345859?mt=8 ↓ Pupils could do a 'string telephone' experiment (crossing wires between two pairs, touching a tuning fork onto the wire, and hanging a large metal spoon on the string can all be interesting).

Key Scientific Ideas and Guidance:	Links to Research:
Waves 2. Sound waves a. frequencies of sound waves, measured in hertz (Hz); echoes, reflection and absorption of sound b. sound needs a medium to travel, the speed of sound in air, in water, in solids SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.14.	M138 Sound is made because the material making the sound is plastic/rubber. Watt and Russell 1990 and Asoko et al. 1991 M139 Sound is made because the material making the sound is thick/thin/taut/hard. Watt and Russell 1990 and Asoko et al. 1991 M140 Sound is part of an instrument released by a person. Asoko et al. 1991 M141 No mechanism for sound production is suggested. Watt and Russell 1990 M142 The sound from a drum is made inside the drum. Watt and Russell 1990 M143 The sound from a drum is made from both inside the drum and the surface of the drum. Watt and Russell 1990 M144 The mechanism for sound generation is context specific (e.g. a rubber band does not make sound like a drum). Watt and Russell 1990 M145 A force from a person makes sound (without any explanation of something vibrating). Watt and Russell 1990 M146 The sound is made by vibrations only in instruments where vibrations can be seen (guitar string, cymbal - not hooter or stones clashing). Asoko et al. 1991 M147 The instrument vibrates, but this vibration is not transferred to the air. Asoko et al. 1991 M148 Stones make sound when clashed because of some property of the stone. Asoko et al. 1991 M149 There is no general theory of sound production. Asoko et al. 1991 M150 Covering an object which is making sound is not explained. Asoko et al. 1991 M177 [No research into misconceptions about pitch, loudness or quality of sound] M178 Bigger vibrations are slower than small vibrations (so pitch and volume are difficult to understand). Driver 1994

<table>
<tr><th>W3</th><th>Big Questions:</th><th colspan="2">Approximate time: 1 hour</th><th>Context:</th></tr>
<tr><td colspan="4">How can sound be made?

How can sound be detected?

How do ears work?</td><td>Play the 'Little Red Riding Hood' story here:
http://www.britishcouncil.org/kids-stories-red-riding-hood-popup.htm

Why do some animals have big ears? [Wolves, earrings which stretch the ear and elephants might be interesting to talk about]</td></tr>
<tr><th colspan="2">Activities:</th><th>Timing:</th><th>Resources:</th><th>Working Scientifically:</th></tr>
<tr><td colspan="2">Demonstration a: plastic model of an ear</td><td>5 min</td><td></td><td>Experimental skills and investigations
a. observations of the real world</td></tr>
<tr><td colspan="2" rowspan="2">Interactive b: SmartBoard software has a nice interactive ear (search the gallery for 'ear')</td><td rowspan="2">5 min</td><td rowspan="2">Alternatively do a google search for 'interactive ear for kids' and there are several.</td><th>Numeracy and Literacy:</th></tr>
<tr><td rowspan="2">Literacy: planning and evaluation skills</td></tr>
<tr><td colspan="2">Experiment c: rice grains on a drum. Where is the drum vibrating? Pupils could plan out what they will do. E.g. How does the diameter of the drum affect the vibrations? How does where you hit the drum affect the vibrations?</td><td></td><td>Class set of drums!?</td></tr>
<tr><td colspan="2" rowspan="2">Investigation c: How far away can you hear a pin drop? Pupils could make a cone using paper to help them hear better (WARNING: take care that pupils do not put anything into their ears).</td><td rowspan="2">20 min</td><td rowspan="2">This experiment often goes badly, which provides a good opportunity for evaluation!</td><th>Differentiation:</th></tr>
<tr><td rowspan="2">↑ Pupils could investigate the technology people who are deaf (or hard of hearing) use in order to be able to hear. If possible, invite someone who is deaf to talk with the class about their experiences. Historical use of hearing trumpets could be included, as could how Beethoven used a stick held in his mouth to transmit vibrations from his piano (perhaps play some music for pupils?). Experiment c could lead to a demonstration of Chladni Plates (which are very cool). After showing this for real (!) the following could be useful:
http://www.pbslearningmedia.org/asset/lsps07_int_chladni/
↓ Images of 'loud' and 'quiet' things could be labelled by pupils. Some pupils could identify 'sounds I like' and 'sounds I don't like'</td></tr>
<tr><td colspan="2">Interactive d: animal hearing:
http://www.pbslearningmedia.org/resource/tdc02.sci.life.reg.animalhear/animal-hearing/</td><td></td><td></td></tr>
</table>

Key Scientific Ideas and Guidance:	Links to Research:
Waves 2. Sound waves c. sound produced by vibrations of objects, in loud speakers, detected by their effects on microphone diaphragm and the ear drum; sound waves are longitudinal d. auditory range of humans and animals.	M151 Sound 'goes' is misinterpreted. Asoko et al. 1991 M152 Sound travelling is not thought of at all (e.g. sound 'goes' can be easily misinterpreted). Watt and Russell 1990 and Asoko et al. 1991 M153 Sound needs an unobstructed path to travel at all (cf. walking through a crowd, rain stopped by an umbrella or a stream stopped by a dam). Watt and Russell 1990 M154 Sound is an invisible object with dimensions, which needs room to move. Watt and Russell 1990 M155 Air is not needed for sound to move (cf. children's ideas about air as an empty space). Watt and Russell 1990 M156 A clock ticking sound is made by the mechanism. Asoko et al. 1991 M157 A clock ticking sound is made by the person listening. Asoko et al. 1991 M158 Sound is carried by individual molecules through air. Linder and Erickson 1989 M159 Sound moves from on molecule to another molecule through air. Linder and Erickson 1989 M160 Sound travels usually in the form of flowing air. Linder and Erickson 1989 M161 Sound is a travelling pattern. Linder and Erickson 1989 M162 The ear is not associated with hearing. Watt and Russell 1990 M163 The ear drum/bones/nerve/brain is not mentioned when hearing is being explained. Watt and Russell 1990 M164 The need for sound to enter the ear is not mentioned when hearing is being explained. Watt and Russell 1990 M165 The most important factor in hearing is the listener concentrating on the source of the sound (the 'active ear'). Watt and Russell 1990 M166 I hear the clock ticking because it is ticking. [considered a sufficient explanation] Asoko, Leach and Scott 1992 M167 I hear the clock ticking I was listening. [considered a sufficient explanation] Asoko, Leach and Scott 1992 M168 The ear seeks the source of a sound [cf. active ear]. Boyes and Stanisstreet 1991 M169 A hearing ray goes from a radio to the ear and back. Boyes and Stanisstreet 1991

W4	Big Questions:	Approximate time: 1 hour		Context:
How can sound transfer energy? How can sound be useful? How does a microphone work?				Pictures (or perhaps Widgit symbols) of a submarine, a bat and someone having an ultrasound. 'What have all these got in common?'
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Demonstration a: echoes in the playground		5 min	If possible, demonstrate an echo in the playground using two planks & a large wall [CARE WITH FINGERS]	Experimental skills and investigations a. ask questions
Activity b: echo concept cartoon. Pupils draw a diagram/cartoon to show how an echo works (e.g. standing near a cliff side), discuss where else echoes are observed.		20 mins	Different characters in the drawing could explain the echo in different ways.	**Numeracy and Literacy:** Numeracy: speed of sound calculations (if appropriate)
Demonstration c: show ultrasound pictures (or a video of a 3D one if you can). 'How is high frequency sound used to make these pictures?'		5 min		
Interactive d: sound and light reflecting - http://www.acoustics.salford.ac.uk/schools/lesson3/lesson1p2.htm and Interactive e: guess the room - http://www.acoustics.salford.ac.uk/schools/lesson5/guess.swf		10 min		**Differentiation:** ↑ More able pupils (who have already studied about speed), could use a trundle wheel and stop watches to calculate the speed of sound. ↓ In activity d give the pupils a concept cartoon about echoes (google image search: 'concept cartoon echo') instead of them drawing one (or before they draw their own).
Activity f: matching exercise with pictures of bat/submarine/foetus with others of foetus/fly/enemy submarine		5 min		

Key Scientific Ideas and Guidance:	Links to Research:
Waves 3. Energy and waves a. pressure waves transferring energy; use for cleaning and physiotherapy by ultra-sound; waves transferring information for conversion to electrical signals by microphone.	M170 Sound absorption is not understood at all. Asoko et al. 1991 M171 If an object which makes sound is covered (causing a muffled sound), this is because the sound is trapped. Asoko et al. 1991 M172 If an object which makes sound is covered (causing a muffled sound), this is because the sound comes through more slowly. Asoko et al. 1991 M173 If an object which makes sound is covered (causing a muffled sound), this is because of the material the cover is made from. Asoko et al. 1991 M174 If an object which makes sound is covered (causing a muffled sound) can still be heard, this is because of leakage. Asoko et al. 1991 M175 Sound absorption is not explained using vibrations. Asoko et al. 1991 M176 Explanations of where a muffled sound has gone are different to those of how the sound gets out from under a cover. Asoko et al. 1991

W5	Big Questions:	Approximate time: 1 hour		Context:
What is light? In what ways are sound and light similar, and in what ways are they different? What happens when light meets something?				Why can we sometimes see lightening before we hear thunder? Or 'Can guns shoot round corners?' [Such guns do exist]
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Discussion a: Walk around the corner (with the door open, not too far!) and ask the class if they can see you. Then ask them if they can hear you. Pupils discuss why they could not see but could hear.		5 min	Take care to distinguish between 'a light' (as in a source of light) and 'light' (as in something which travels.	Scientific attitudes b. understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas
Activity b: sun, teddy and eye activity. Give pupils a sheet with pictures (or symbols) of each of these. Ask pupils, 'Show with drawing how you see the teddy.' Take care not to give the game away. Afterwards discuss the drawings.		10 min	Model of the sun (perhaps a blow up one), a teddy bear, ball of yellow wool, large arrows.	**Numeracy and Literacy:** Numeracy: speed of sound and light. Units.
Activity c: luminous and non-luminous things. With a page divided in two ask pupils to list things which make light, and things which don't. Take care with 'moon', 'eye', 'shadow' etc.		10 min	Selection of luminous and non-luminous things.	
Demonstration d: laser pen or laser [WARNING: see guidance] Introduce the idea of a 'light ray'. Take care to label this on a drawing.		10 min	Talc or dust [TAKE CARE: asthma attack hazard]	**Differentiation:** ↑ Pupils could investigate the history of how people measured the speed of light. This might be useful: http://www.colorado.edu/physics/2000/waves_particles/lightspeed_evidence.html ↓ The following interactive activity may be useful with low ability pupils: http://www.bbc.co.uk/schools/scienceclips/ages/5_6/light_dark_fs.shtml Taking photos of their own eyes might help pupils in the discussion about the nature of the pupil of the eye.
Activity e: slow or fast? Pupils should put a list of things in order from slowest to fastest [e.g. light, sound, bike, tortoise, me…]. Discuss with pupils the speed of sound and the speed of light.		10 min		

Key Scientific Ideas and Guidance:	Links to Research:
Waves 4. Light waves a. the similarities and differences between light waves and waves in matter b. light waves travelling through a vacuum; speed of light SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ 'PS52 lasers'. Never shine a laser directly into someone's eye, or allow reflections from surfaces like mirrors to go into the eye. In activity c, some teachers make the arrows out of those long floats you get in swimming pools.	M187 Students often have vague ideas about what light is and are not always given clear definitions Watts (1984) M188 Light is a source (e.g. a light bulb) (common for ages 10 - 11) Guesne (1985) and Andersson and Karrqvist (1981) M189 Light is an effect (e.g. a patch of light) (common for ages 10 - 11) Guesne (1985) M190 Light is a state (e.g. brightness) (common for ages 10 - 11) Guesne (1985) M191 Light is not recognised as a physical entity between a source and the effect it produces (age < 13) Guesne (1985) M192 Light rays are not considered to be the same as 'ordinary light' Ramadas and Driver (1989) M193 Light rays are associated with science fiction rather than fact Ramadas and Driver (1989) M194 The invisible path of a light ray causes problems in understanding Ramadas and Driver (1989) M195 Darkness considered as important a concept as light Ramadas and Driver (1989) M196 Darkness shaded in on white paper instead of the light Ramadas and Driver (1989) M197 Many examples of light sources known (by age 7), but predominately primary sources rather than secondary sources Osborne et al. (1990) M198 Children's knowledge of light sources does not seem to develop with age Osborne et al. (1990) M199 Light around sources shown with short lines Osborne et al. (1990) M200 Use of lines from source to object rare Osborne et al. (1990) M201 Everyday conception of light is psychological (e.g. 'the light is bad' or 'it is light') Andersson and Karrqvist (1981) M202 Direct light is distinguished from normal 'daylight' (scale from very bright to dark) Watts and Gilbert (1985)

W6	Big Questions:	Approximate time: hours	Context:
What happens when light touches materials? How do mirrors work?			Mirror mirror on the wall, who is the fairest of them all? [You could stick a picture of the latest heart throb on a mirror and pretend it is yourself if you're feeling silly] Or Fill a large clear circular cross section water bottle with water to the top. Hold it horizontally and allow the pupils to look at you through the water [you should appear upside-down 'The upside-down teacher trick']

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: ray boxes with mirrors to draw ray diagrams. Pupils describe relationship between incident and reflected ray.	20 mins	ray boxes and mirrors	Experimental skills and investigations a. ask questions and develop a line of enquiry based on observations of the real world, alongside prior knowledge and experience
			Numeracy and Literacy:
Experiment b: refraction of light in a rectangular Perspex block. Take care with how the diagrams are drawn for this.	30 min	ray boxes, Perspex blocks, paper, pencils.	An investigation of shadows might be more appropriate than experiment d. A video clip from Peter Pan could be nice here (the bit where Peter tries to sew his shadow back on). Pupils could do shadow puppets here.
Interactive c: bending light - http://phet.colorado.edu/en/simulation/bending-light	10 min		
			Differentiation:
			↑ ↓ Take care to show a picture of someone in a bathroom mirror, and label the person and the image. Ask 'Where is the image?' [i.e. on surface?]

Key Scientific Ideas and Guidance:	Links to Research:
Waves 4. Light waves c. the transmission of light through materials: absorption, diffuse scattering and specular reflection at a surface	M248 Light stays on a mirror during reflection (common ages 13 - 15) Fetherstonhaugh and Treagust (1990) M249 Images can be in two places Fetherstonhaugh and Treagust (1990) M252 Light bounces off mirrors, but not off other objects Anderson and Smith (1983) M253 Light doesn't bounce off anything (including mirrors) Anderson and Smith (1983) M254 Light bounces off things, but does not scatter Anderson and Smith (1983) M255 Light bounces off things, but this has no relevance to seeing Anderson and Smith (1983) M256 The image in a mirror is on the mirror (rather than behind it) Goldberg and McDermott (1986) M257 Moving the observers position will move the image Goldberg and McDermott (1986) M258 Moving back from a mirror will allow you to see more of yourself Goldberg and McDermott (1986) M259 A pencil in a beaker of water looks bent because the water makes it look broken Shapiro (1989) M260 A pencil in a beaker of water looks bent because the shape of the beaker makes it look broken Shapiro (1989) M261 A pencil in a beaker of water looks bigger because of the combination of water and beaker Shapiro (1989)

W7	Big Questions:	Approximate time: 1 hour		Context:
What is a 'pinhole camera', and how does it work? How do photographic film, and a digital camera, work? How does an eye work?				Story of the monk who showed his boss (the Abbot) the image inside a really dark room [which had a small hole in the wall], of someone outside the room. Ask the pupils why the Abbot had the monk burned as a witch. Don't say the answer! Return to this at the end of the lesson. Or a large picture of an eye. 'What is the pupil of your eye?' [Some pupils think this is a black thing, rather that a hole covered with something transparent through which light can pass into the eye ball].
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Investigation a: the pinhole camera [Take care not to tell pupils what they will see!]		extension	resources needed to make pinhole camera	Experimental skills and investigations b. make predictions using scientific knowledge and understanding c. select, plan and carry out the most appropriate types of scientific enquiries to test predictions
				Numeracy and Literacy:
Experiment b: lenses. What happens to parallel rays of light when they hit the surface of these lenses? [May need to explain the meaning of the word 'parallel']		20 minutes	convex and concave lenses	Numeracy: angles (reflection and incidence, and refraction) Literacy: use of key words (converge, diverge, concave, convex, focus etc.)
Demonstration c: How do we see? Discuss the different parts and how the lens can focus on near and far objects.		20 minutes	eye model	
				Differentiation:
				↑ Different power lenses could be used in experiment b. Interactive from PhET could be useful here: http://phet.colorado.edu/en/simulation/geometric-optics ↓ Mirror writing can be a nice activity here.

Key Scientific Ideas and Guidance:	Links to Research:
Waves 4. Light waves e. light transferring energy from source to absorber leading to chemical and electrical effects; photo-sensitive material in the retina and in cameras	M250 Lenses are not necessary to form images Fetherstonhaugh and Treagust (1990) M251 Lens needs to be whole to form an image Fetherstonhaugh and Treagust (1990)

W8	Big Questions:	Approximate time: hours		Context:
What is a shadow? What happens when light tries to go through materials? [i.e. transparent, opaque, translucent]				Shadow hand puppets. Pupils might know some. [A google image search will show how to do these]
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Video a: Peter Pan [the part where Peter tries to sew his shadow back on which has become detached]. Discussion.		5 min		Analysis and evaluation c. interpret observations
Experiment b: transparent, opaque and translucent objects. Pupils could accurately draw the rays onto paper underneath their equipment, and put arrows on to show which way the light is travelling.		15 min	Ray boxes; transparent, opaque, and translucent pieces of plastic; paper.	**Numeracy and Literacy:**
Demonstration c: guess the object from the shadow. This is an opportunity to discuss the shape of shadows (e.g. as an object gets further from the light source).		15 min		
				Differentiation:
				↑ There are traditions where intricate moving shadow puppets are made from leather. These could be investigated and made. Making shadow puppets with moving parts and putting on a show can be interesting. ↓ Pupils could make cut out shadow puppets.

Key Scientific Ideas and Guidance:	Links to Research:
Waves 4. Light waves e. light transferring energy from source to absorber leading to chemical and electrical effects; photo-sensitive material in the retina and in cameras	M203 Shadows only occur in bright light Watts and Gilbert (1985)

W9	Big Questions:	Approximate time: 1 hour		Context:
What is coloured light? How is coloured light related to white light? What happens when light meets different materials?				You could sing 'I can sing a rainbow', before pointing out that you clearly can't. Alternatively this might be useful: http://learnenglishkids.britishcouncil.org/en/songs/i-can-sing-rainbow What is a rainbow?

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: using a prism (dispersion of light). 'Where do the colours come from?'	20 mins	prism, ray box	Scientific attitudes b. understand that scientific methods and theories develop as earlier explanations are modified to take account of new evidence and ideas
			Numeracy and Literacy:
Discussion b: rainbows - what are the colours? order.	5 minutes	Good opportunity for some singing.	Literacy: key words - dispersion, prism, reflect, refract, dispersion and absorb
Recap c: light can be reflected, refracted, dispersed and absorbed. Why is a red card, red? Why is a yellow card yellow? Get students to discuss this and evaluate each others ideas.	10 minutes	different coloured cards	
			Differentiation:
Experiment d: filters - investigate the effect on coloured objects. Pupils could write a prediction first.	20 mins	filters of various colours, object of different colours	relate different colours to wavelengths - more able students could draw a visual representation of this.

Key Scientific Ideas and Guidance:	Links to Research:
Waves 4. Light waves f. colours and the different frequencies of light, white light and prisms (qualitative only); differential colour effects in absorption and diffuse reflection. Many children (and adults) have difficulty with the difference between the primary colours of light (red, green and blue), and the primary colours of paint (red, blue and yellow). The primary colours of light, when added together in equal amounts, make white light. The primary colours of pain, when added together in equal amounts, should make black paint. It might be wise to demonstrate both of these one after the other, as often pupils hear one thing from their science teacher (light) and another from their art teacher. It may be wise to always say, 'primary colours of light' as opposed to 'primary colours' to avoid this confusion.	M204 Light has parts of bits Watts and Gilbert (1985) M205 Light is separate from seeing (e.g. light needed to so room is lit up, but not to go into the eyes) Watts and Gilbert (1985) M206 Light is intentionally designed to allow us to see Watts and Gilbert (1985) M207 Different kinds of light in different circumstances give different effects Watts and Gilbert (1985) M208 Light is only a property of large conspicuous luminous objects Watts and Gilbert (1985) M209 Light is projected from a source Watts and Gilbert (1985) M210 Light transports colours Watts and Gilbert (1985) M211 Students often have no mechanism about how a lamp lit up a room Anderson and Smith (1983) M262 Few students (age 13) understand coloured filters Zylbersztajn and Watts (1982) M263 A red filter changes the white light in some way Zylbersztajn and Watts (1982) M264 A red filter dyes the white light Zylbersztajn and Watts (1982) M265 White light 'knocks-on' the colour of the filter Zylbersztajn and Watts (1982) M266 White light is not a mixture of colours of light Anderson and Smith (1983) M267 Students who do think white light is a mixture of colours of light usually don't know what colours are involved Anderson and Smith (1983) M268 Colour is an innate property of an object (eyes help us see this colour) Anderson and Smith (1983) M269 Light helps our eyes to see objects Anderson and Smith (1983)

E1	Big Questions:	Approximate time: 1 hours		Context:
How does electricity work? How do we draw an electric circuit? What is an electrical fault [broken and short circuits]?				What is the most important invention ever? [Take care to avoid gender bias] How many of these devices rely on electricity?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Experiment a: how do you turn on a bulb using a battery (FN1)? [M271-278]		20 min	IWB slide with a photo of a cell and a bulb [shown 5 times]. Pupils draw on their theories using arrows.	Experimental skills and investigations a (ask questions based on observations of the real world)
Activity b: drawing and making electric circuits [M318-324]		25 min	Pupils might make a series circuit (1 cell, 1 bulb), then draw the diagram next to a photo of the circuit.	**Numeracy and Literacy:** Pupils could write or blog about what they consider to be the most important invention ever.
				Differentiation: ↑ More able pupils might consider why they think the alternative theories the class have generated are wrong, and how they would prove this. Some pupils could draw more complicated circuits. ↓ FN1: A 'cell' in this context is a chemical source of electrical energy. A battery is two or more cells connected together in series. With some groups it may be wise to introduce this distinction once you're further into the topic, or even to leave it until KS4 [M270].

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. National Curriculum 2014 Electricity and Electromagnetism 1a: electric current in series circuits. Some pupils may consider experiment and activity b very simple, but establishing within the class that different people may have different theories about how electric circuits work is, we think, important. Pupils could be encouraged to generate theories, even if they actually think the theory is wrong. This might provide cover for pupils to express ideas they think might be embarrassing. This scheme of work will use the word 'battery' for a single cell at KS3 (please see foot note FN1 in the 'differentiation' box of lesson E1).	M270 A cell is something to do with biology, and has nothing to do with a battery. M271 [Given a bulb which is not in any holder, wires and a 'battery' see Driver, 1994, p. 118 for common attempts to light the bulb] Shipstone, 1985 M272 A single wire between a bulb and one end of a battery will light the bulb. Shipstone, 1985 M273 If the bulb is placed on the positive end of the battery, and a wire goes from the positive to the negative end [i.e. a short-circuit], then the bulb will light. Shipstone, 1985 M274 If a wire goes from the positive end of the battery to the bulb, and then from the same part of the bulb to the negative end of the battery, the bulb will light. Shipstone, 1985 M275 A bulb will light if one wire is connected from the bulb to one end of the battery [cell - the unipolar model]. Osborne and Freyberg, 1985; see Driver, 1994, p. 119 for more studies which confirm these findings. M276 In a complete circuit electricity comes out from both ends of the battery [the clashing currents model - light is made by the 'clash']. Osborne and Freyberg, 1985; see Driver, 1994, p. 119 for more studies which confirm these findings. M277 In a complete circuit electricity more current comes out from one end of the battery and less goes back into the other end of the battery [the current consumed model]. Osborne and Freyberg, 1985; see Driver, 1994, p. 119 for more studies which confirm these findings. M278 In a complete circuit only one wire is active. The other wire is a safety wire. Osborne and Freyberg, 1985; see Driver, 1994, p. 119 for more studies which confirm these findings. M318 [Pupils sometimes find it hard to associate a real circuit with a drawing]. Driver, 1994, p. 124 M319 [Pupils may retain an image, rather than the principles the image is intended to convey]. Caillot, 1984 M320 [Identical circuit diagrams which have been rotated are not considered by some pupils to be the same]. Duit, 1984 M321 Lines in a circuit diagram represent pipes. Johsua, 1984 M322 Resistances in a circuit are useful. Johsua, 1984 M323 [Non useful resistance are omitted from circuit diagrams]. Johsua, 1984 M324 Symmetrical circuit diagrams would 'work' in reality, non-symmetrical circuits would not. Niedderer, 1972

E2	Big Questions:	Approximate time: 1 hours	Context:
What happens inside a simple electric circuit? What happens to electric current as it flows around a series circuit? How is electric current measured?			What do you know about electric shocks? [WARNING: this may be a very sensitive subject for some pupils] Pictures of a pacemaker and a heart shock box.

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: using an ammeter	10 min	One cell, one bulb, one ammeter, three leads (of different colours).	Scientific attitudes c (evaluate risks) Measurement a (SI units)
Experiment b: measuring current (flow) around a series circuit. [M279-280, 282-284, 300-303]	20 min	Use two cells, two bulbs, four ammeters (or move one) and five leads.	**Numeracy and Literacy:**
Interactive c: PhET Circuit Construction Kit (DC only) [NB pupils use this only after they have had direct hands-on experience with the equipment]	10 min		
			Differentiation:
			↑ Experiment b could be extended with using three bulbs instead of two. Pupils could predict what difference they expect this to make before they do the experiment. ↓ Provide different coloured leads. Some children might think the colour of the leads makes a difference. They could investigate this.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. E & EM 1a: electric current, measured in amperes, in series circuits.	M279 Current is used up by bulbs. M280 [Using two ammeters (or more) in a series circuit may help pupils]. Osborne and Freyberg, 1985 M282 [Some pupils will 'remember incorrectly' ammeter readings to support the current consumed model]. Gauld, 1985 M283 Equal ammeter readings either side of a bulb in a circuit do not mean that current is conserved. Dupin and Johsua, 1984 M284 [Pupils who understood current conservation after a lesson, did not still hold this idea one year later]. Osborne, 1983 M300 Current is a series of happenings as electricity leaves the battery, travels through components and returns to the battery [the 'sequential view']. Shipstone, 1985 M301 [Some researchers advise introducing energy at the same time as current, to avoid the sequential view]. Shipstone, 1984; Tiberghein, 1983; Cohen, 1984; Arnold and Millar, 1988; Duit, 1984 M302 [Pupils sometimes do not consider the circuit as a complete system, where a change in one place can affect the whole circuit, and not just the parts 'downstream']. Tiberghein, 1983; Closset, 1983; Duit, 1984 M303 "A sequential model allows the idea of electricity standing, but not flowing, in unconnected wires and it does not account for the instantaneous lighting of a bulb when the circuit is completed." Driver, 1994, p. 123

E3	Big Questions:	Approximate time: 1 hours		Context:
What is a battery? What happens to energy in an electric circuit? How are electric current and electrical energy different? What is potential difference?				[Plonk (empty) car battery on the table]. My garage says my battery is flat, but it definitely looks like a cuboid to me. How does a battery * become flat?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Experiment a: using more batteries (FN1) [M287-299, 325-329]		15 min	One, two and then three cells with suitable bulb. One ammeter in the circuit.	Analysis and evaluation c (identify patterns)
Experiment b: using a voltmeter		15 min	Two cells, two bulbs, four leads in a series circuit. Two voltmeters if possible.	**Numeracy and Literacy:**
Interactive c: PhET Battery Voltage		15 min		
				Differentiation:
				↑ Experiment d: choosing the right battery. A selection of different batteries with devices (or pictures) which need them. If possible use devices which need a battery of the same size, but which require different voltages. ↓ Experiment b could be done as a demo, and experiment d used instead.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. E & EM 1b: potential difference, measured in volts, battery and bulb ratings	M287 A battery is a [unipolar] giver of electricity. Psillos, Koumaras and Tiberghein, 1988 M288 A battery is a store of electricity. Psillos, Koumaras and Tiberghein, 1988 M289 A battery is a store of energy [with energy understood as a 'thing']. Psillos, Koumaras and Tiberghein, 1988 M290 A battery delivers a constant current in a closed circuit [rather than maintaining a constant voltage]. Cohen, Eylon and Ganiel, 1983 M291 [Voltage and potential difference are often not understood at all by pupils]. Maichle, 1981 M292 Current, electricity and electrical energy are synonymous. Osborne and Freyberg, 1985 M293 Voltage is the strength of current. von Rhoneck, 1981 M294 Voltage is the force of current. von Rhoneck, 1981 M295 Voltage is a property of current [rather than a precondition for current to flow - often current is introduced to pupils first]. von Rhoneck, 1981 M296 Voltage is current [c.f. as voltage increases, current increases]. Maichle, 1981 M297 If no current flows, there cannot be a voltage. von Rhoneck, 1981 M298 [Some researchers advise avoiding teaching about potential difference or electromotive force, and only talking about voltage.] Psillos, Koumaras and Tiberghein, 1988 M299 [Some researchers advise avoiding measuring the voltage distribution in a circuit, as this may lead to the idea that voltage is 'consumed'.] Psillos, Koumaras and Tiberghein, 1988 M325 Current', 'energy' and 'electricity' are interchangeable concepts, having the properties of movement, storability and consumption. Shipston, 1984; Psillos et al., 1988 M326 [As current flowing in a circuit is reasonably intuitive, when voltage is introduced this is seen as a property of the current]. Driver et al., 1994 M327 [Some researchers advise introducing voltage initially as a property of the battery, a precondition for current to flow and present even when no current is flowing]. Driver, 1994, p. 124 and Psillos et al., 1988 M328 Voltage is a force. von Rhoneck, 1981 M329 Current is energy. von Rhoneck, 1981

E4	Big Questions:	Approximate time: 1 hours	Context:
What affects electric current flow? What is electrical resistance? What is resistance measured in? How do we calculate resistance?			[Dress up with bin and plunger, or video clip of a Dalek - note spelling?] Is resistance really useless?

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: electrical resistance [M322, M330]	15 min	a: One, two then three 10 Ohm resistors, one cell, one ammeter in a series circuit.	Experimental skills and investigations e (range of methods) Analysis and evaluation a and measurement b (maths)
Experiment b: measuring and then calculating electrical resistance	25 min	Pupils use the same circuit as in experiment a, but use an Ammeter and Voltmeter to measure current and voltage.	**Numeracy and Literacy:** FN2: Resistance is one of many words used in physics classrooms which have everyday as well as technical meanings. The context could be an opportunity to talk about this with pupils. Division calculations (check with Maths department how and when this is done)
Interactive c: PhET Ohm's Law	10 min		
			Differentiation: ↑↓ Multimeters available to use as an addition to, or alternative in experiment b.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. E & EM 1b: resistance, measured in ohms, as the ratio of potential difference (p.d.) to current	M322 Resistances in a circuit are useful. Johsua, 1984 M330 Resistance is a 'hindrance' [as in the word only refers to the physical barrier to the flow of charge]. Driver, 1994, p. 125

E5	Big Questions:	Approximate time: 1 hours		Context:
What is an electrical conductor? What is an electrical insulator?				[Class activity: whole class (if possible) in a circle holding hands)]. Pupil at each end touch each terminal of an 'energy ball'. How does that work?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Investigation a: electrical conductors and insulators.		45 min	A selection of different materials to test in the circuit.	Experimental skills and investigations c (fair test investigation)
Interactive b: PhET Battery-resistor circuit				**Numeracy and Literacy:**
				Differentiation:
				↑ Pupils could calculate the resistance of the conductors. ↓ Take care to distinguish from thermal conductors and insulators [M393-394]

Key Scientific Ideas and Guidance:	**Links to Research:**
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. E & EM 1c: differences in resistance between conducting and insulating components (quantitative).	[Though the following findings are about heat conduction and heat insulation, they may be of interest in the context of electrical conduction and insulation]. M393 Conductors and insulators seen as opposites Brook et al. (1984) M394 Insulators have no conductive ability at all Brook et al. (1984)

E6	Big Questions:	Approximate time: 1 hours	Context:
How do complicated electric circuits work? How does electric current flow in a parallel circuit? What is a scientific model? How might scientific models of electricity help?			What will happen if one of these Christmas tree light bulbs breaks? [if possible demo series and parallel versions]

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: measuring current (flow) around a parallel circuit [M285-286, 304-305, 306-317]	40 min	2 cells, 2 bulbs in the shorter branch, 1 bulb in the longer branch, 4 ammeters (or move one) and 7 leads.	Scientific attitudes b (modification or rejection of scientific theories) Experimental skills and investigations b (predictions)
			Numeracy and Literacy:
Interactive b: PhET Circuit Construction Kit (DC only) [After!]	10 min		
			Differentiation:
			↑ More able pupils could add a third branch to their circuit. They could predict how the current in each wire will compare with the currents in the circuit they used in experiment a. ↓ Many pupils find drawing circuits very challenging. Some identical circuits which have been rotated should be included. [M318-324]

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 6 and 12.2. E & EM 1a: electric current, measured in amperes, in parallel circuits.	M285 ['Cognitive conflict' is good, but not enough. Pupils also need a new model which has advantages over the one they hold.] Closset, 1983 and 1984 M286 [Teaching pupils what a model is, and that all models have limitations, can help]. Closset, 1983 and 1984 M304 [Some researchers advise treating series and parallel circuits separately and at different times, before going on to treat them in conjunction.] van Aalst, 1984 M305 [Some researchers advise separating sessions on electricity work with something else to allow ideas to become established before they have to be related.] van Aalst, 1984 M306 [Some researchers found that hydrodynamic, thermal and mechanical analogies can be useful to some extent.] Dupin and Johsua, 1984; Black and Solomon, 1987 M307 Rate of flow in a water circuit is velocity of the water. Schwedes, 1984 M308 Rate of flow in a water circuit is volume of the water. Schwedes, 1984 M309 The battery is analogous to the high point in a water circuit, with water running off both sides. Schwedes, 1984 M310 The water circuit is of no use in understanding electrical circuits. Russell, 1980 M311 [The water circuit is understood, but not used to explain electrical circuits.] Russell, 1980 M312 [The water circuit is understood, but used incorrectly to explain electrical circuits.] Russell, 1980 M313 [Some researchers advise against using heat and temperature analogies, as students have been found to have many 'misconceptions' about these fields.] Driver, 1994, p. 123 M314 [Some researchers advise against using blood circulation analogies, as students have been found to have many 'misconceptions' this.] Driver, 1994, p. 123 M315 [Some researchers found that mechanical analogies like the bike chain, a transportation belt or workers pushing a train around a track can be useful to some extent.] Duplin and Johsua, 1984; Hartel, 1984 M316 [Some researchers advise using multiple analogies]. Tenney, 1984 M317 [Some researchers advise using the stiff bike chain analogy as it emphasises that all points influence all others, thereby challenging the sequential model]. Hartel, 1984

E7	Big Questions:	Approximate time: 1 hours		Context:
What is static electricity? How can objects become electrically 'charged'? What happens when charged objects get close together? What is an electric field?				Demonstration: Plasma Ball No one can see the particles which flow in an electric circuit because they are much too small to see even using the best microscopes in the world. However, we can see the light given off when the tiny particles (called electrons) hit gas particles inside this ball.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Experiment a: balloons		10 min	A balloon each [WARNING: bursting can be a serious problem for some people]	Scientific attitudes b (take account of new evidence or ideas)
Interactive b: PhET Balloons and Static Electricity		10 min		**Numeracy and Literacy:**
Demonstration a: Van de Graaff generator - [spelling!] SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 12.9.		15 min	Fluorescent tube bulb, 10 metal cupcake tins, insulating stool [WARNING: follow CLEAPSS advice]	
Experiment c: Perspex and acetate rods (with one rod lying on one watch glass balanced on another or wooden stands to suspend one rod)		15 min	Two Perspex and two acetate rods, two watch glasses, cloths of different materials.	**Differentiation:**
				↓ It may well be wise to leave experiment c to KS4 (especially if it is already part of the KS4 course).

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook sections 12.9. E & EM 2a: separation of positive or negative charges when objects are rubbed together: transfer of electrons, forces between charged objects 2b: the idea of electric field, forces acting across the space between objects not in contact.	The following notes come from Başer and Geban (2007): M509 No clear understanding of the concept of charge (Eylon & Ganiel, 1990; Galili 1993; Guruswamy et al., 1997; Thacker et al., 1999). M510 ‘a neutral object has no charge’ (Calilot & Xuan, 1993; Thacker et al., 1999). M511 ‘a charged body contains only either electrons or protons’ (Siegel & Lee, 2001). M512 ‘friction is the cause of static electricity’(Calilot & Xuan, 1993; Siegel Lee, 2001). M513 No clear understanding of the concept of electric field. Difficulties about representation of electric field lines. (Eylon & Ganiel, 1990; McMillan & Swadener, 1991; Galili, 1993; Törnkovist et al., 1993; Rainson et al., 1994; Furio & Guisasla, 1998; Savelsberg et al., 2002) M514 Electric field lines are real (Galili, 1993). M515 Electric field lines can cross each other. (Törnkovist, 1993) M516 Electric field lines can make sharp boundaries. (Törnkovist, 1993) M517 Force exerted on a charge on the field line is along the field line. (Törnkovist, 1993) M518 ‘field lines can begin/and end anywhere’ (Rainson et al., 1994; Maloney et al., 2001). M519 ‘there are a finite number of field lines’ (Rainson et al., 1994; Maloney et al., 2001). M520 ‘there is no transfer of charge between two metal objects with charges of the same sign’ (Guruswamy et al., 1997) M521 ‘transfer between oppositely charged metal objects occurs until one of the objects is neutral’ (Guruswamy et al., 1997) M522 ‘there is no transfer between a charged metal object and a neutral metal object’ (Guruswamy et al., 1997) M523 ‘the charges on the two metal objects remain the same after touching regardless of the signs of the initial charges’ (Guruswamy et al., 1997) M524 ‘charges jump from one plate of the capacitor to the other’ (Thacker et al., 1999). M525 ‘parallel plate capacitors store a net charge’ (where students may not know what is meant by net charge. (Thacker et al., 1999; Jones & Childers, 1992, p. 474; Ohanian, 1989, p. 662). M526 ‘parallel plate capacitors store voltage’ where students may not know what a capacitor is (Beaty, 1996; Simanek, 2002).

E8	Big Questions:	Approximate time: 1 hours		Context:
What can a magnet do? How do magnets affect each other? What is the difference between a magnet and a magnetic material?				IWB and real fridge magnets (M343). Where have you come across magnets? It may be worth asking early on what pupils already know about magnets. One of my pupils mentioned gravity in response to this question recently [M331]. Also worth showing the class a piece of loadstone if possible, to demonstrate that magnetism is a natural phenomena.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Experiment a: magnet and iron/steel table leg. 'What will happen when you bring the North pole near the table leg?' 'What will happen when you bring the South pole near the table leg?' [M341-342]		5 min	Bar magnet each (one where the N & S poles are obvious). IMPORTANT: pupils don't say the answer before experiment!	Scientific attitudes b (take account of new evidence or ideas) Experimental skills and investigations b (predictions) Analysis and evaluation d (reasoned explanations)
Experiment b: magnetic and non-magnetic materials.			Selection of metals and non-metals (e.g. plastic, wood, fruit…). Large number of 1p coins is good (only some are magnetic).	**Numeracy and Literacy:**
Interactive c: IWB sorting activity - magnetic and non-magnetic materials (pictures or symbols for Iron, Steel, Nickel and Cobalt, lots of non-magnetic metals, plastic, wood, glass, fabric…).			Show an interactive periodic table like http://pse.merck.de/merck.php?lang=EN (show metals/non-metals/Fe,Ni,Co,C).	
				Differentiation:
				↑ Opportunity to investigate modern magnetic compounds ↓ Make your own fridge magnet activity from the BBC: http://www.bbc.co.uk/cbeebies/mister-maker/makes/mister-maker-funnyfridgemagnets/

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.22. E & EM 3a: magnetic poles, attraction and repulsion IWB fridge magnet websites for the start of the lesson: http://www.abcya.com/alphabet_number_magnets.htm [not bad, but you'll need to use Ctrl+ to zoom in, and the letters don't swivel round like real fridge magnets] [Unfortunately the brilliant Awen Media downloadable interactive fridge magnet software does not seem to be available on-line anymore. If you have a copy this would be a good moment to use it.]	M331 Gravity is caused by magnetism. Bar and Goldmuntz, 1987 M332 Magnetism is a type of gravity. Barrow, 1987 M333 Air is necessary for a magnet to have an effect [perhaps because it is believed that gravity is caused by air, or that air is necessary for gravity to act]. Barr and Zinn, 1989 M334 [Though many pupils are aware of magnetism, some offer no explanation of this phenomena]. Barrow, 1987 M335 Chemicals make magnets stick. Barrow, 1987 M336 Magnetism is caused by 'energies'. Barrow, 1987 M337 Magnetism is caused by electrons and protons. Barrow, 1987 M338 [Little awareness of magnetic poles]. Barrow, 1987 M339 Poles only occur at the ends of magnets. Barrow, 1987 M340 [Lack of experience of repulsion in comparison with attraction]. Barrow, 1987 M341 [Important to have experience with two magnets, and with a magnet and a magnetic material]. Barrow, 1987 M342 A North pole of a magnet will stick to a magnetic material, and the South pole of the magnet with repel the magnetic material. M343 [Teaching about magnets may dissociate pupils from their experiences of everyday magnets] Barrow, 1987 M344 Events involving magnets and/or magnetic materials are linked [without any conception of a magnetic force]. Selman et al., 1982 M346 All metals are magnetic. Finley, 1986

E9	Big Questions:	Approximate time: 1 hours	Context:
How can the area around a magnet be described? What is a magnetic field? How does a compass work? Can magnetic field lines act through materials?			IWB game - guide metal ball through maze: http://kent.skoool.co.uk/content/keystage3/Physics/pc/learningSimulations/USMSC/launch.html [M346]

Activities:	Timing:	Resources:	Working Scientifically:
Experiment a: make a compass	10 min	Bar magnet hanging from thread on a wooden clamp stand (if possible). When complete, give our real compasses.	Scientific attitudes b (scientific theories) Analysis and evaluation c (identify patterns)
Experiment b: make a bar magnet [http://www.magnet.fsu.edu/education/tutorials/java/domains/ can be useful]	10 min	Large Iron nails (with end blunted), bar magnets, small plotting compass. Stroke in same direction (demo).	**Numeracy and Literacy:** Experiment c is an opportunity to discuss scalar and vector quantities with more able pupils.
Experiment c: explore the area around a bar magnet using iron filings - draw the magnetic field pattern [IMPORTANT: don't show the pupils what field lines will look like first, let them draw what they see first]	15 min	SAFETY: Use sealed plastic boxes with the iron filings inside! Please see guidance on reverse side.	
Interactive d: magnets and electromagnets (only magnets at this stage): http://phet.colorado.edu/en/simulation/magnets-and-electromagnets [M409]	5 min	Show bar magnet but not Earth until next lesson (See guidance).	**Differentiation:** ↑ Pupils could explore the magnetic field around two magnets which attract, two which repel, and/or one magnet and a piece of magnetic material (say a piece of soft iron). ↓ There are nice magnetism resource on www.schoool.co.uk here: http://lgfl.skoool.co.uk/index.aspx
Experiment e: does magnetism act through materials	10 min	Bar magnet held in clamp stand, paper clip on thread suspended below. Range of sheet materials.	

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.22. E & EM 3b: magnetic fields by plotting with compass, representation by field lines Scientists call the area around a magnet a magnetic field. We draw field lines to describe this magnetic field. The closer the field lines, the stronger the magnetism. Field lines are not real, they are a way of describing magnetism (which is real). Experiment c: take a picture of the iron filing pattern and show on the IWB (or even better use a visualiser). Put see-through plotting compasses onto the iron filings box. Draw the field lines onto the iron filing pattern so the pupils can see how you do this. Put arrows onto the field lines while explaining that the compass shows us the direction the field lines point in. Then remove the picture of the iron filings from behind the drawing of the field lines. Many pupils find drawing magnetic field lines very difficult, and this slow approach may help understanding of this challenging concept.	M409 Gravity is caused by the Earth's magnetism. Stead and Osborne, 1980; Vicentini-Missoni, 1981

E10	Big Questions:	Approximate time: 1 hours		Context:
How can the magnetism of the Earth be described? Are magnetic fields flat? How is the magnetic field of the Earth useful?				In outer space there is no air and no gravity. If two magnets are placed next to each other what, if anything, will happen? (M331-333). This could be done using a concept cartoon (if you or one of your pupils is good at drawing - or Image Search 'Concept Cartoon magnets').
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Demonstration a: iron filings all around a bar magnet. [A magnetic field is a 3D 'thing']		5 min	Cylinder iron filing cases with hollow core for a magnet are available. Or cover a strong magnet in cling film (NB SAFETY)	Scientific attitudes b (take account of new evidence or ideas)
				Numeracy and Literacy:
Interactive b: magnets and electromagnets (only magnets at this stage): http://phet.colorado.edu/en/simulation/magnets-and-electromagnets [M331-333]		5 min	Show bar magnet and Earth (See guidance).	Mini project
Video c: magnets in space - https://www.youtube.com/watch?v=G_uKt2i2jvc [Google search: ClipGrab]		5 min		
				Differentiation:
Mini project d: Is magnetism useful? Useful starting point: http://msnucleus.org/membership/slideshows/historyelectricity.swf		35 min	Internet access? IPad? Presentations?	↑ Pupils could investigate the Northern and Southern lights. Great videos of this. For example http://www.theguardian.com/travel/video/2013/mar/25/northern-lights-footage-captured-in-iceland-video and http://helios.gsfc.nasa.gov/CME.mpg ↓ For the mini project you could set up a webpage (for example using a Google Document) with links to sites appropriate for your learners.
Demonstration e: small magnets and big magnets. 'Which is strongest? The small magnet, or the big magnet?' [M345, M347]		5 min	1 small & 1 large weak magnet, 1 small & 1 large neodymium magnet (SAFETY: see guidance)	

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.22. E & EM 3c: Earth's magnetism, compass and navigation Interactive b: You might like to ask pupils where the North magnetic pole of the Earth is before showing the Earth. The North geographical pole of the Earth is a South magnetic pole at the moment. This is an opportunity to discuss Paleo magnetism with the class if this is not too challenging a concept at this stage.	M331 Gravity is caused by magnetism. Bar and Goldmuntz, 1987 M332 Magnetism is a type of gravity. Barrow, 1987 M333 Air is necessary for a magnet to have an effect [perhaps because it is believed that gravity is caused by air, or that air is necessary for gravity to act]. Barr and Zinn, 1989 M345 Big magnets are stronger than little magnets. Finley, 1986 M347 [Having been shown a small strong magnet] Small magnets are stronger than big magnets. Finley, 1986

E11	Big Questions:	Approximate time: hours	Context:
How are electricity and magnetism related? What is an electromagnet? How might electromagnets be useful?			[Video of a scrap metal yard using electromagnets. For example https://www.youtube.com/watch?v=GXWr4h6YdHs or https://www.youtube.com/watch?v=BQA5VDXE7ts] How would you sort scrap metal at a recycle yard? [Demo trying to get off metal off a large neodymium magnet (WARNING: be careful not to get finders trapped, and don't bring it near any electronic equipment!)] [Perhaps don't use the word 'electromagnet' yet?]

Activities:	Timing:	Resources:	Working Scientifically:
Investigation a: exploring a coil of wire carrying electric current [SAFETY: see guidance]	25 min	Insulated wire, large soft & hard iron cylinder, paperclips, compass, power supply with trip switch.	Analysis and evaluation c (identify patterns)
Interactive b: magnets and electromagnets (both magnets and electromagnets at this stage): http://phet.colorado.edu/en/simulation/magnets-and-electromagnets [M331-333]	5 min	Careful not to give away the answer to experiment c.	**Numeracy and Literacy:**
Experiment c: making a stronger electromagnet	10 min	Get pupils to predict the answer and then to test their result.	
Demonstration d: a really strong electromagnet	5 min	Show the strongest electromagnet you have. Ideally the pupils should not be able to pull the metal off when it is on.	**Differentiation:** ↑↑ Very able pupils could be asked to explain how a loud speaker works (but probably best to leave this until KS4). http://electronics.howstuffworks.com/speaker5.htm ↑ Pupils could investigate how very strong electromagnets are used in hospitals, or magnetic levitation of trains. ↓ Pupils could use interactive b to make the predictions for experiment c.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook section 12.22. E & EM 3d: the magnetic effect of a current, electromagnets, D.C. motors (principles only).	M348 [Some pupils do not recognise the magnetic effect from the current flowing in a wire]. Barrow, 1987 M349 The magnetic effect when a current flows in a wire is caused by the wire. Selman et al., 1982 M350 A current carrying wire must be uninsulated for it to make an electromagnet. Andersson, 1985

E12	Big Questions:	Approximate time: hours	Context:
What have I learnt during this topic?			Video of frog levitation in a magnetic field (which gives an opportunity to discuss animal experimentation)? [YouTube search 'frog magnetic levitation'. For example

Activities:	Timing:	Resources:	Working Scientifically:
Video a: magnetism [best to pause and discuss this regularly as it can get a bit overwhelming otherwise] http://highered.mheducation.com/sites/dl/free/0078600499/161383/00050755.swf		Watch the video. Could do the quiz as a class activity	Analysis and evaluation b (present observations)
			Numeracy and Literacy:
Revision b: make a colourful mind map for this topic [Principles of mind maps here may be useful: http://www.mind-mapping.co.uk/mind-maps-examples/about-mind-maps.htm]		Paper, coloured pens and pencils.	Mind mapping
Demonstration c: magnetic levitation		Aluminium ring, iron core, large solenoid, ac supply.	
			Differentiation:
Video d: levitating bbq (or a similar video from YouTube) https://www.youtube.com/watch?v=txmKr69jGBk			↑ Able pupils could investigate how magnetic levitation works. Alternatively they could do a mini project on the work of Michael Faraday. ↓ Pupils could explain what they have learnt on a short video clip, which they or you could video edit to make a revision aid for pupils in this class next year. This could be done instead of, or as well as the revision b mind map.

Key Scientific Ideas and Guidance:	**Links to Research:**
Revision of topic	See our 'misconceptions' list at www.conceptualchange.org.uk (electricity and magnetism).

M1	Big Questions:	Approximate time: 1 hour		Context:
What is a particle?				Relate to the work at CERN to find out what the world is made of and/or the historic context of the ancient Greek 'atomists'
Activities:	**Timing:**	**Resources:**		**Working Scientifically:**
Discussion a: CERN and what it does, who has heard of it. Before CERN the ancient Greeks thought about 'atoms', which were particles that could not be divided.	5 mins	http://home.web.cern.ch/about		Present observations using appropriate methods, identify further questions arising from results. Also note the collaboration of international scientists at CERN.
Activity b: What is a particle? Hold up a piece of sulfur and iron filings. Ask students to draw (1) (2) the smallest particle of each. What properties do they have?	15 mins	Paper/mini whiteboards. Sulphur, Iron or materials such as wood and metal.		**Numeracy and Literacy:**
Demonstration c: iron and sulphur reaction. Highlight properties of both elements before and the different properties of the compound afterwards.	20 mins	http://www.nuffieldfoundation.org/practical-chemistry/iron-and-sulfur-reaction		Extended writing opportunities to describe and explain particles in reaction. Opportunities for considering how many atoms in a width of human hair (Approx. 1 million)
Discussion d: Ask pupils to revisit their drawings and consider what the particles look like before and after the reaction. Move around to engage with misconceptions (3)(4)(5)	20 mins	Drawing materials.		**Differentiation:**
				↑ Stretch pupils by considering particles vs atoms & molecules, or by explaining that atoms are made up of sub-atomic particles. ↓ www.john-paul.org.uk > more > websites > scale might be useful.

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ The use of the particle model has limitations. Students are often confused about the difference between a particle and an atom, once the structure of an atom has been introduced. We advise consistently using 'particles' within KS3 to avoid this, or explaining that an atom is a specific type of particle for now. Please be aware of what is happening in chemistry however. Common misconceptions are listed opposite. Brown & Hammer (2008) advocate pupils becoming aware of their own thinking and Bereiter & Scardamalia (2008) suggest that it is important for pupils to recognise that we are presenting models in science, and our models will continuously develop as we find new information. It is worth explaining that this is what professional scientists do also.	(1) Ainsworth, Tytler & Prain (2011) suggest drawing should be explicitly recognized as a key element in science education. Can be used especially to 'draw out' misconceptions and check conceptual change. Supported by earlier study by (2) Tytler and Prain (2009) where conceptual change is tracked with a number of pupils over a few grades. The study looks particularly at what happens to water particles when they evaporate and diagrams are used to test understanding. (3) Andersson (2010) 'Conceptions of Matter and its Transformations': Deals with changing perceptions of what happens to substances when they change state. Early misconceptions are that water disappears when it evaporates but this changes with age. (4) Beerenwinkel (2010) Lays out a structure for dealing with conceptual change: 1. Presentation of naive ideas 2. demonstrate limitations of those ideas 3. presentation of scientific concepts 4. Highlighting how concept addresses limitations. This requires skill and a focus on pupil thinking. (5) Driver et al. (1994) list a range of possible misconceptions around particles: pupils consider particles to have the same properties as the material (e.g. tiny blocks of wood); pupils know very few non-metals and may only give wood as an example; pupils may know the arrangement of particles in a solid from KS2 but not why such a structure should hold together.

M2	Big Questions:	Approximate time: 1 hour		Context:
How do particles behave in different states and between states? How does temperature affect density?				Why do we put ice in drinks? What happens when we boil a kettle? What would happen if we put ice in a kettle?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Activity a: How do particles move in different states? Students should have understanding from KS2 so use quick activity to assess, e.g. drawing particle diagrams.		10 mins	Paper/mini whiteboards.	Apply mathematical concepts and calculate results. Present observations using appropriate methods, identify further questions arising from results. Accuracy in measurement key if you are to see latent heat effects.
Role play b: Put students into groups to role play particles in solids, liquids and gases. Follow up by drawing diagrams to show movement. (3)(5)		10 mins	Paper/mini whiteboards.	**Numeracy and Literacy:**
Activity c: Using a trays of marbles, ask pupils to demonstrate the behaviour of particles in different states and between states. Alternatively use popcorn being heated to model state changes.(4)		10 mins	Trays of marbles / popcorn and frying pan.	Plot graph of heating curve.
Experiment d: Measure the temperature change of ice being heated and plot a heating curve. Label with changes of state and elicit explanation of the plateau sections. Pupils to add particle arrangement diagrams to their curve.		30 mins	Ice, beakers, digital thermometers	**Differentiation:**
				↑ More able students can be stretched by analysing the limitations of models in general and assessing the relative merits of the marbles or popcorn model, or the particle model itself. ↓ Understanding the motion and closeness of particles can be challenging so use the starter activities to pitch the rest of the lesson. Latent heat is a complicated process and not all pupils will be able to engage with it at this point.

Key Scientific Ideas and Guidance:	Links to Research:
Ice is a particular issue in terms of describing expansion, this will be dealt with in a later lesson. Common misconceptions are listed opposite.	(5) Driver et al (1994) found that pupils view liquids as a continuous substance and not made up of particles as a solid or gas is; others see it as a halfway state between solid and gas which often leads to greatly overestimating spacing of particles in liquids; random motion of particles is rarely understood so pupils think particles move away from each other as they gain energy in a simple way. Powders and soft solids (e.g. toothpaste) are seen as half-way between solid and liquid. It would be worth explaining that powders are small bits of solid. (3) Andersson (2010) 'Conceptions of Matter and its Transformations'. Deals with changing perceptions of what happens to substances when they change state. Early misconceptions are that water disappears when it evaporates but that changes with age. (4) Beerenwinkel (2010) lays out a structure for dealing with conceptual change: 1. Presentation of naive ideas 2. demonstrate limitations of those ideas 3. presentation of scientific concepts 4. Highlighting how concept addresses limitations. This is indeed challenging in a classroom and requires attention to how individual pupil are thinking.

M3	Big Questions:	Approximate time: 1 hour		Context:
How does temperature affect density?				Consider the Costa Concordia cruise ship which sank in April 2014. Why does a boat full of water sink but a heavy metal boat float otherwise? Alternatively use the Titanic.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Discussion a: show videos and/or explain what happened in a sinking. Pose the question as to why some things float and some sink.		5-10mins	http://www.bbc.co.uk/news/world-europe-16563562	Making predictions using scientific knowledge. Make and record observations.
Demonstration b: some objects floating or sinking and ask students to draw particle diagrams to explain each phenomena. Interactive c: PhET 'density' http://phet.colorado.edu/en/simulation/density		10 mins	1.5 litre measuring cylinder, oil, water, wooden blocks, metal blocks, marbles. Paper/whiteboards	**Numeracy and Literacy:**
Discussion d: Should more space between particles make an object more or less dense? Introduce density in qualitative way.		10 mins	IWB with particles that can be moved, or paper particles.	Extended writing opportunities to describe and explain each picture and its limitations. Higher attaining students may calculate density but they should have a qualitative understanding first.
Experiment e: Have a circus of demos that students have to draw particle diagrams of to explain the phenomena. 1. lava lamp 2. ice floating in water 3. mixing oil and water 4. 1cm3 blocks of different materials. (1)(2)		30 mins	lava lamp, ice, beaker, water, mixture of oil and water, density blocks	**Differentiation:**
Discussion f: What is the key difference with ice and water? Can it be explained?		Extension	Picture/demo of ice floating	↑ ↓ The anomaly of ice-water expansion is in the curriculum but may confuse pupils if introduced too early. Consider only using this to stretch higher attainers.

Key Scientific Ideas and Guidance:	Links to Research:
In defining density qualitatively, pupils may struggle with the notion of a 'unit volume', so it may be best to consider the same number of particles in a larger space as lower density initially.	As in Lesson M1, we here draw on (1) Ainsworth, Tytler & Prain (2011), who suggest drawing should be explicitly recognized as a key element in science education. Can be used especially to 'draw out' misconceptions and check conceptual change. This is supported by earlier study by (2) Tytler and Prain (2009) where conceptual change is tracked with a number of pupils over a few grades. (3) Andersson (2010) 'Conceptions of Matter and its Transformations'. Deals with changing perceptions of what happens to substances when they change state. Early misconceptions are that water disappears when it evaporates but that changes with age. (4) Beerenwinkel (2010) Lays out a structure for dealing with conceptual change: 1. Presentation of naive ideas 2. demonstrate limitations of those ideas 3. presentation of scientific concepts 4. Highlighting how concept addresses limitations. This requires skill and a focus on pupil thinking. (5) Driver et al. (1994) list a range of possible misconceptions around particles: pupils consider particles to have the same properties as the material (e.g. tiny blocks of wood); pupils know very few non-metals and may only give wood as an example; pupils may know the arrangement of particles in a solid from KS2 but not why such a structure should hold together.

M4	Big Questions:		Approximate time: 1 hour	Context:
How do particles change when they are heated? What happens when you heat a substance?				Carpenters and engineers need to know how materials change through the seasons. Paralympic physiotherapists need to know artificial limbs alter when their team goes to warmer climates.

Activities:	Timing:	Resources:	Working Scientifically:
Discussion a: 'Where do we notice changes to substances due to temperature?' E.g. window/door frames. Students then explain/discuss/act out what happens to the particles. Relate to carpenters or engineers: e.g. explaining to customers.	10 mins	Paper/whiteboard for groups to discuss (assess by moving around/listening)	Predictions can be made around the discuss/act out activities as to what happens when materials are heated/cooled. These can then be modified after trials. Observation is a key focus throughout this section.
Demo b: Heat the ball and ring up and get a student to safely disconnect them. Discuss what is observed (expansion). Refer back to previous learning, discuss limitations of previous behaviours of particles the students had acted /discussed. Cool the object (discuss).	10 mins	Ball and ring demo - ball just fits through ring until one is heated	**Numeracy and Literacy:** Literacy in recognising scientific terminology, i.e. particle, to have more precise meaning. Written explanations of situations.
Activity c: Tell the students that the Eiffel tower gets taller in the summer. Students must now draw how the particles behave in the summer and winter.	10 mins	Paper/whiteboard for groups to discuss	
Activity d: Zoom in to a specific part of a picture/situation and ask pupils to draw what is happening at the micro-scale.	5 mins	Paper/whiteboard for groups to discuss	**Differentiation:** ↑ To stretch, consider cooling as well as heating and/or make links between expanding materials and density. ↓ Interactive f: PhET 'States of matter: basics' http://phet.colorado.edu/en/simulation/states-of-matter-basics
Activity e: Ask groups to draw diagrams in relation to a range of situations e.g. rail way tracks. Then explain to other groups what is happening. Circulate and address misconceptions.	25 mins	Paper/whiteboard for groups to discuss	

Key Scientific Ideas and Guidance:	Links to Research:
In the previous set of lessons you explored pupils intuitive understanding of particles, states and density. This part of the scheme aims to move them on to scientific approaches to explaining expansion and contraction within the same state (solid).	(1) Ainsworth, Prain & Tytler (2011) found that pupils think through their own understanding when asked to draw what is happening. For example, with a substances are cooling and heating up. Try not to give a 'standardised' diagram of the situation later on, as they just believe this is correct rather than exploring their own ideas.

M5	Big Questions:	Approximate time: 1 hour		Context:
How do particles change when they are heated? What happens when you heat a substance?				Carpenters and engineers need to know how materials change through the seasons. Paralympic physiotherapists need to know artificial limbs alter when their team goes to warmer climates.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Video a: Show videos of Paralympic sprinters and ask what will happen to their artificial limbs as they go to different countries.		5 mins	Videos of Paralympic sprinters	Safe working in heating up the ice to evaporate it. Collecting data, using timers, plotting graphs during practical.
Experiment b: Heat ice up until it begins to evaporate, discuss the changes of state observed. Refer back to previous learning, discuss limitations of previous behaviours of particles the students had acted /discussed. (1) (5)		25 mins	Ice, beaker, Bunsen burner.	**Numeracy and Literacy:** Literacy opportunities in how they describe the transitions: could be a newspaper article, radio/TV interview, scientific journal etc. Literacy in recognising scientific terminology, i.e. diffusion to mean the movement of particles from high to low concentration. Written explanations of situations.
Activity c: In groups, draw and describe the 'journey' of particles as a solid is turned into a gas. Pupils may draw a flow diagram. Consider using ice cubes in a kettle as a context or dry ice (actual or videos of)		25 mins	Large sheets of paper or wallpaper rolls. Dry ice if possible.	
				Differentiation: ↑ Stretch pupils by relating density to the changes taking place. ↓ Different groups could be given different scenarios.

Key Scientific Ideas and Guidance:	Links to Research:
This session is designed to consolidate: thinking about the behaviour of particles as they are heated both within states and as they change states. The aim is for a coherent picture of expansion, density and state changes.	(1) Tytler & Prain (2010) found that some pupils have difficulty with evaporation taking place inside; they assume it needs wind or cannot account for where the water goes. They also found that pupils get fixed on a specific model, for example they studied a pupil who sustained an understanding based on the water cycle (from Geography) for a number of years as she considered evaporation. (5) Driver et al. (1994) report studies in which 40% of 12 year olds feel that water on a stove can be heated past 100 degrees, or that the temperature is determined by the setting on the stove. Heat and temperature are often confused. Boiling and evaporation are seen as different processes. Pupils consider solids to lose mass when they melt. Changes of state are not always related to specific temperatures by students (even for ice/water/vapour).

M6	Big Questions:	Approximate time: 1 hour	Context:
What is Brownian motion in gases?			How do we smell things? Why would a rubbish truck smell worse on a hot day?

Activities:	Timing:	Resources:	Working Scientifically:
Demonstration a: Ask students to stand up and close their eyes. Spray room freshener and tell them to call out when they can smell it. Ask the students how they think the smell travels.	10 mins	Air freshener.	Predictions can be made when students are thinking about how the particles will behave when inside the smoke chamber or with the pollen grain demo. They will then be able to make conclusions from their observations. Historic context of scientific discoveries should be emphasised.
Activity b: Ask students to try and draw/ mind map/ describe how particles move and what might cause it. Try and distinguish between everyday/anthropomorphic notions and scientific descriptions. (2)	15 mins	Paper/whiteboard/pics for groups to discuss (assess by moving around/listening)	**Numeracy and Literacy:** Literacy in recognising scientific terminology, i.e. diffusion to mean the movement of particles from high to low concentration. Written explanations of situations.
Discussion c: Introduce the scientist Robert Brown and his experiments. What do the students think he saw as he looked through the microscope at pollen happen? What do they think he might find out?	5 mins	Slides on historic context of Robert Brown.	
Demonstration d: Pollen Grains / smoke chamber. Use these demos to show students the particles moving. Get them to further how and why they now believe particles are moving. Ask them to make any amendments to their earlier work. Ask the students to write down what they think Robert Browns findings were.	30 mins	Smoke chamber/ pollen grain demo, ideally projected onto screen. Videos if not. Whiteboards/ paper.	**Differentiation:** ↑ This video might be useful for more able learners: http://www.brianjford.com/wbbrownb.htm ↓ Use the starter activities to pitch the lesson. Depending on the preconceptions of how particles move and the drawings students produce some extra scaffolding may be needed.

Key Scientific Ideas and Guidance:	Links to Research:
In the previous set of lessons you explored how particles behave. We here explore why this happens. Students also need to become familiar with new scientific language; concentration, diffusion.	(2) Tekkaya (2003) observed misconceptions in relation to diffusion: • Particles get smaller as a dye diffuses. • Dissolved particles sink (e.g. sugar) as heavier. • Less room in higher concentration solution. Be aware that the use of pollen in Brown's work could be confusing if pupils think it is to do with them being alive. Students will often see the particle as having the characteristics of a person and having intentions. Another common misconception is the fact that students will assume that external forces are moving the particles. Note the links between the way pressure is taught – colliding particles. (5) Gases are often seen as weightless (Driver et al, 1994)

M7	Big Questions:	Approximate time: 1 hour		Context:
What is diffusion in liquids and gases driven by?				How do we smell things? Why would a rubbish truck smell worse on a hot day?
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Recap a: the air freshener experiment from last lesson. Can they now describe how the particles get to them?		5 mins	Air freshener	Students can plan a full practical with the diffusion task; making predictions, collecting data making conclusions and evaluating their experiment.
Activity b: Students plan the practical and/or watch demo by teacher		15 mins	See below	**Numeracy and Literacy:**
Experiment c: Agar cubes containing alkali and cresol red indicator which are put in dilute HCl solution. Students carry this out at various temperatures to find out what impact heat has on diffusion.		40 mins	Pre-prepared agar cubes containing alkali & indicator. Dilute HCL in beakers. Heat baths to vary temperature.	Numeracy in collecting data, using timers, plotting graphs during practical.
Activity d: Students to write conclusions about their findings, referring to particles.		Homework	Results	**Differentiation:**
				↑ ↓ Level of scaffolding and inclusion of stages of a practical investigation will depend upon the class. A weaker group may need to just see and describe diffusion, whereas pupils can be stretched through full consideration of variables, accuracy, choosing measures etc.

Key Scientific Ideas and Guidance:	Links to Research:
Note the links between the way pressure is taught – colliding particles.	(5) Driver et al found that pupils consider particles to move in simple ways when heated or changing state, so considering random motion will challenge, but may need to be drawn attention to explicitly. (2) Tekkaya (2003) observed misconceptions in relation to diffusion: • Particles get smaller as a dye diffuses. • Dissolved particles sink (e.g. sugar) as heavier. • Less room in higher concentration solution. Be aware that the use of pollen in Brown's work could be confusing if pupils think it is to do with them being alive. Students will often see the particle as having the characteristics of a person and having intentions. Another common misconception is the fact that students will assume that external forces are moving the particles.

M8	Big Questions:	Approximate time: 1 hour	Context:
What is the difference between chemical and physical changes? Are some Changes Reversible?			Can we get a cooked egg to go runny? Can we get melted chocolate to go hard again? Relate to cooking or the manufacture of foodstuffs.

Activities:	Timing:	Resources:	Working Scientifically:
Interactive a: Show students a selection of potential changes both chemical and physical. Ask them to predict which ones are reversible and which ones are not. Refer to items in room or animation (without giving answers)	15 mins	http://www.sciencekids.co.nz/reversible_changes.swf	There are opportunities for students to plan and co write a method for a practical as well as make predictions throughout the theme.
			Numeracy and Literacy:
Experiment b: Get the students to move around in a circus style activity carrying out different activities and trying to reverse them. Students should record their observations. Let them know at the end which ones are chemical and which are physical and ask them to come up with definitions for these terms.	35 mins	Variety of demos, e.g. frying an egg, melting ice, melting chocolate, condensing steam from a kettle with a mirror, a slice of bread to toast.	Writing definitions from observations. Adapting ideas and explaining/justifying.
			Differentiation:
Activity c: Review what pupils have defined as chemical and what as physical. Revisit animation.	10 mins	Pupil definitions	↑ Stretch by challenging pupils to use the notion of particles to explain the difference between physical and chemical changes. They will need to develop an idea of bonding to do so. ↓ The 'melting chocolate' context could be developed into a practical activity for less able pupils.

Key Scientific Ideas and Guidance:	Links to Research:
Having considered particles in previous lessons, we now move on to considering how particles can be used to explain macroscopic changes.	(5) Driver et al (1994) found that pupils do not always understand what 'chemically combined' means despite its common use by teachers - pupils see it as a mix, or one type pf particle surrounding the other or as a lattice (when it is not). It may be necessary to show a particulate diagram of joined or bonded particles to distinguish chemical from physical changes.

M9	Big Questions:	Approximate time: 1 hour		Context:
What is the difference between chemical and physical changes? Are some Changes Reversible?				Survival on a desert island. Relate to films (e.g. Castaway or Life of Pi) or TV programmes (e.g. Bear Grylls' The Island)
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Discussion a: Pose the idea of being stuck on a desert island with no clean water. How will they know if water is safe to drink?		5 mins	Videos (see Context)	There are opportunities for students to plan and co write a method for a practical as well as make predictions throughout the theme.
				Numeracy and Literacy:
Demonstration b: Some students may express that we know water is clear when it is clear. Demo salt dissolving but with conservation of mass. Show the students that although they can not see the salt that the mass is increasing so something must be being added. (5)		10 mins	Salt, large beakers, water, accurate balance.	Literacy in recognising newly introduced scientific terminology. Literacy also in co-writing a method for cleaning the water. Numeracy in mass balance demo.
				Differentiation:
Investigation c: Give the students a beaker of salty and sand water and a variety of equipment "from their boat wreckage". Ask the students to use this to try and clean the water.		40 mins	Suggested equipment: filters, funnels, foil, beakers, Bunsen, metal sheeting, metal cans, matches, candles.	↑ Interactive e: PhET 'sugar and salt solutions' http://phet.colorado.edu/en/simulation/sugar-and-salt-solutions ↓ Some students or groups may find planning their own method difficult and may need extra scaffolding.
Demonstration d: Ask a successful group to explain, or If no group comes up with a system, demo how it works - with emphasis on the reversibility of each step.		5 mins	Demo version of above already set up (but hidden)?	

Key Scientific Ideas and Guidance:	Links to Research:
In the previous set of lessons you explored pupils intuitive understanding of what a particle is and what they might look like. This part of the scheme aims to move them on to how particles may behave when introduced to other particles or outside forces. Common misconceptions such as that when a substance has dissolved it has disappeared forever need to be addressed as well as that of clear substances being pure.	(5) Driver et al (1994) explain that pupils (and adults) have a range of misconceptions around dissolving: descriptions of the solute disappearing, melting away, dissolving away or turning into water. Around 2/3 of 8 year olds recognise that the solute is still there, but only 1/2 of those say it has weight. Pupils do not necessarily see solutions as homogenous mixtures. For example, they may assume there is more solute at the bottom of the solvent, or see the solute as being hidden.

M10	Big Questions:	Approximate time: 1-2 hours	Context:
What is conservation of material? What is conservation of mass?			Why does the volume of wood decrease as it burns? What is left behind and what has left?

Activities:	Timing:	Resources:
Demonstration a: Burn some wood (e.g. spills) or show a video of a bonfire/wicker man etc. Discuss where the wood goes or ask pupils to discuss in pairs.	5 mins	Wooden spills, matches or video
Experiment b: Get students to weigh a piece of copper on a mass balance and record the mass. Then ask them to heat it in a Bunsen flame. Ask the students to weigh it again. They should then discuss what they think has happened.	25 mins	Copper, crucibles with lids, Bunsen, tongs, heat proof mats, goggles etc.
Experiment c: Students can carry out a series of investigations where all products can be collected including gaseous ones and these can be quantified and compared with the masses of the reactants.	30 mins each	e.g. marble chippings and gas syringe; setting fire to iron wool

Working Scientifically:

Students will carry out investigations to address their particular misconception. this can then be used to make a new prediction which can be further tested. These activities involve heating so safety is paramount. Accurate and precise measurement is also required.

Numeracy and Literacy:

Literacy in recognising scientific terminology. Numeracy in collecting data, using timers, plotting graphs during practical.

Differentiation:

↑ It can be interesting asking pupils to explain how wood is made by trees. Some might think that the bulk of a block of wood is made from substances in soil (so for example they might predict that the soil level would go down noticeably in a pot where a tree is growing). Many have trouble with the idea that the tree 'makes itself' using predominantly carbon dioxide gas and water from the soil. Cf. children's 'misconceptions' about gases (Driver, 1994) [see www.conceptualchange.org.uk].

↓ Depending on the students ideas about what has initially happened, students could be grouped to carry out different investigations to help challenge their particular theory.

Key Scientific Ideas and Guidance:	Links to Research:
This lesson is stand alone in the series about matter but brings in ideas from previous threads about particles. Many students may feel that substances simply disappear.	(5) Gases are often seen as weightless (Driver et al, 1994) and this will prevent a full understanding of where mass 'goes'. Although most 11-12 year olds know that air is need for burning, its function is not clear and many do not see it as interacting with the combustible material. Burning of liquids (e.g. alcohol) might be confused with evaporation or simply be seen as irreversible destruction: it ceases to exist.

S1	Big Questions:	Approximate time: 1 hours		Context:
How do we know the Earth is round? How can we determine the size of the Earth? Something must be rotating from our observations?!				Moon, and shadows. Prep at end of subject before: keep a diary noting where in the sky the sun rises and where it sets, note the shape of the shadow on the moon, note in which direction the bright part of the moon is, requires a compass.
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Activity a: Draw the moon as we see it in the sky. Compare drawings with other students. Decide on the different types of moon.		5 min	Pencil and paper.	Activity A: Make careful observations of the real world, and check them against those of others. Activity B: Use a (neatly literal) model and test it to see which best matches the observations. Activity C: Build a model.
Activity b: Compare drawings to photographs. Discuss position of Sun relative to moon as observed in the sky. Shine a torch onto a table tennis ball and a piece of paper. Draw what you see. Is the moon round?		10 min	Pupils could be given a torch, ball and square piece of card and be invited to compare. Or demo.	**Numeracy and Literacy:**
Activity c: Use modelling clay to build a model of the Moon. Then in pairs one student illuminates while another holds the moon in front of their head and turns.		15 min	Torch, modelling clay.	Accurate drawing and annotation. Keeping diary.
Activity d: Video of balloon rising, balloon's POV.		10 min	Could use beginning of: https://www.youtube.com/watch?v=sorFIOMttFk - which is a clip from BBC 2's Orbit	**Differentiation:**
Activity e: Google Earth zoom out from cars driving to Earth in space.		5 min	Google Earth, computer room/tablets	↑ More able pupils might look up names of phases of moon and make a record on their drawings. They might consider whether it is reasonable to think the Earth is round if the Moon is. What other reasons might they come up with for a round Earth? A flat Earth? Why they think the alternative theories the class have generated are wrong, and how they would prove this. ↓ Able pupils to pair with less able in Activity C, larger groups where appropriate

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ Recommended Reading: "How far is up?" John & Mary Gribbin; note that Activity C will be the first stage of building a small solar system model that they will later use for video explanations.	Activities A, B & C: Combination of Activities D & E: Student must see camera held by student before launch, and later note the curvature of the limb appear, and the blue become black. M475 Two Earths; Activity B also addresses M490 for the Moon, and should help for Earth and Sun. M475 There are two Earths. Where we live, and the spherical one in space. Vosniadou and Brewer, 1990 M498 The phases of the Moon are caused by clouds covering part of the Moon. Baxter, 1989 M499 The phases of the Moon are caused by a planet casting a shadow on the Moon. Baxter, 1989 M500 The phases of the Moon are caused by the Sun casting a shadow on the Moon. Baxter, 1989 M501 The phases of the Moon are caused by the Earth casting a shadow on the Moon. [Most common idea] Baxter, 1989 M502 No understanding of the phases of the Moon. Targon, 1987

S2	Big Questions:	Approximate time: 1 hours		Context:
How do we know the Earth is round? How can we determine the size of the Earth? How do we know it is rotating?				Earth, and shadows. "My stick has a shadow, therefore I can measure the size of the Earth"
Activities:		**Timing:**	**Resources:**	**Working Scientifically:**
Activity a: Based on the Google Earth video make a plasticine model of the Earth, then make a new drawing including the Earth and the Moon. Assume the Sun is also round and make a Sun too.		5 -10 min	Plasticine	Model building from evidence. Simplifying without losing information.
				Numeracy and Literacy:
Activity b: Look at pictures of sundials. Compare to the situation in our 3D model.		5 min	Slides of sundials. Torch.	Conversion between 2D representations and 3D. Geometry and trigonometric calculations for those able.
Activity c: put a match stick into the Earth and think about the light coming from the Sun and hitting the stick. What happens to the shadow? Try to draw a 2D representation of this 3D situation.		10 min	Match stick and plasticine, pencil and paper	
				Differentiation:
Activity d: Simplify the 2D drawing into some triangles. Note now the reason why we might have less energy arriving at the poles. Recall S1 Act B		10 min	Pencil and paper, ruler and protractor.	↑ More able students challenged to complete the calculation without stepwise assistance. Exercise: Estimate the size (radius, circumference) of the Earth from a calculation of the type: a plane flies on a straight North-South path between two cities at latitudes A and B, at an altitude X, at a speed V, and takes time T... ↓ Add assistance with more steps as appropriate, by observing one on one.
Activity e: Hear about Eratosthenes from Carl Sagan. Then use the triangle diagram to do the calculation.		17 min	http://bit.ly/SaganEratosthenes	

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/	Important preparation in Activity D to deal with M503 to M507; M468 The Earth is flat. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M469 The Earth is flat and round like a pancake. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M470 The Earth is flat and round like a pancake and surrounded by water. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M471 The Earth is a sphere. We live inside the sphere. [The inside of the sphere might be blue explaining why the sky is blue]. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M472 The Earth is a sphere. We live on the outside of the sphere. People live on the top hemisphere. 'Down' is always the same direction. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M473 The Earth is a sphere. We live on the outside of the sphere. People live all over the sphere. 'Down' is always the same direction. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M474 The Earth is a sphere. We live on the outside of the sphere. People live all over the sphere. 'Down' is towards the surface of the sphere [rather than towards the centre]. Nussbaum, 1985; Baxter, 1989; Vosniadou and Brewer, 1990 M475 There are two Earths. Where we live, and the spherical one in space. Vosniadou and Brewer, 1990 M476 The Earth is round like a plate [with or without an edge]. Vosniadou and Brewer, 1990 M503 It is cold in the winter because a cold planet takes heat from the Sun. M504 It is cold in the winter because winter clouds stop heat getting to the Earth. M505 It is cold in the winter because the Sun is further away from the Earth at that time. M506 It is cold in the winter because the Sun is on the other side of the Earth at that time. M507 It is cold in the winter because of plants.

S3	Big Questions:	Approximate time: 1 hours	Context:
How does the Earth move in space? Why do we experience Summer and Winter? How long does it take to get to the Sun? How far away is the largest manmade thing?			Timescales of our Universe. Observations of our world over time. Consider the video of Carl Sagan. He was talking about length scales, and shapes, but he also mentioned time as important. What time? When the Sun was directly overhead. The tilt and orbit are required to explain the seasons, time is important to see this. We also have perihelion and aphelion.

Activities:	Timing:	Resources:	Working Scientifically:
Activity a: Discuss what do we see in the night sky? How does this connect with what we see in the day sky? A broad streak (milky way); twinkling points of light that rotate around a central one.	5 min	Slides of long exposure of night sky with pole star stationary.	Analysis and evaluation c (identify patterns)
Activity b or Pre-lesson Homework: Watch Orbit: Earth's Extraordinary Journey, selected episode. Also: Human Planet clips [http://www.bbc.co.uk/nature/humanplanetexplorer/seasons] such as Winter and "The most dangerous school run?".	10 min	Orbit: Earth's Extraordinary Journey, £1.89 per episode on iTunes. Suitable alternative: http://astro.unl.edu/na	**Numeracy and Literacy:**
Activity c: Take our model of the Earth, Sun, and Moon, and a torch, and make a video explaining the seasons. Show them, and pick the clearest explanation.	20 - 40 min	models made so far, iPods for videoing, or smart phones	
Activity d: Take a tour of the solar system with Google Android Solar System 3D or suitable alternative.	5 - 20 min	Google Android Solar System 3D App, or suitable alternative. Tablets or IWB	**Differentiation:** ↑ Why does the tilt point in a constant direction with respect to the rest of the Universe? Students encourage to learn how to identify stars, satellites, and asteroids. Video making: able students to add explanation of day length. Modelling, students invited to research actual length scales, directed to web research. ↓ Some of the links from www.john-paul.org.uk > more > websites > science might be useful here.
Discussion e: Sun as a source of energy, recall demonstration of light landing on Earth from Eratosthenes lesson, link to video explanations.	5 min		

Key Scientific Ideas and Guidance:	**Links to Research:**
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/	M485 The Earth is at the centre of the solar system. Vosniadou and Brewer, 1990 M486 The Earth is in the centre. The sun and moon move closer and further away. [Magic model] Jones et al., 1987 M487 The Earth spins in the centre. The Sun and Moon are either side. Jones et al., 1987

S4	Big Questions:	Approximate time: 1 hours	Context:
How do we know the stars are not fixed? How do we know they are not points of light affixed to some background at the same distance? How bright are they, and how far away? How do I know the distance to anything?			Interplanetary, interstellar, intergalactic travel - how long would it take to get to the nearest inhabitable planet? Astronomy & astrophysics. Parallax measurements, and standard candles. 3D movie technology, depth of field.

Activities:	Timing:	Resources:	Working Scientifically:
Activity a: Recap: What do we see in the night sky? A broad streak (milky way); twinkling points of light that rotate around a central one.	5 min		Activity A discuss the experience to be able to use it as a foundation for the next exercise.
Activity b: Watch clip about the model cow closeup and the real cow far away. Lead discussion on how do we know how big the cow is really? FT knows the other cow is far away, but he doesn't know how far. How could he work out how far? Parallax?	10 min	Father Ted video https://www.youtube.com/watch?v=GFTgkibl7DU	**Numeracy and Literacy:** Read Poul Anderson's 'Tau Zero'
Activity c: Two finger dominant eye example of parallax.	10 min	Pen and paper.	
Activity d: using a circus of lab equipment that might suffer from parallax error, students to work in pairs to identify how parallax error affects measurement.	15 min	Voltmeter with mirror behind needle. Height measurement. Anything involving reading from a scale. Diagram with parts left	**Differentiation:** ↑Exercise/Discussion: Actual numerical calculation of "How might relative distances between different stars be calculated from parallax measurements?". ↓ Showing a globe (or an Earth 'stress ball' which are useful), you could ask pupils to show you using their hands roughly how big the Sun would be on this scale (see M494-495 in 'links to research'). Also ask them to show you how big the moon is. A role play with groups of three pupils showing the relative motion of Sun, Earth and Moon can be useful here.
Activity e: Standard Candles, how bright does this torch appear? Consider a candle positioned in the room. Discuss how bright it is from different positions in the room. Pupils draw, and describe, their own observations, post discussion.	10 min	Torches with different brightness.	

Key Scientific Ideas and Guidance:	Links to Research:
"Trigonometric parallax measurement remains the fundamental method of determining distances to astronomical objects. The best ground-based parallax measurements can achieve accuracies of ~1 milliarcsecond, comparable with the typical accuracies achieved by the ESA Hipparcos astrometric satellite. This level of accuracy allows us to obtain reliable distances and luminosities for main sequence stars, subgiants, red giants and even a number of metal poor subdwarfs. However, with an effective distance limit of 100-150 parsecs, the sampling volume includes less than a handful of rarer, shorter-lived celestial objects. In particular, there are no RR Lyraes or Cepheids, two of the principal calibrators in the extragalactic distance scale. There is only one instrument currently available that can achieve astrometry of higher accuracy - the Fine Guidance Sensors (FGS) on HST." http://www.stsci.edu/~inr/thisweek1/2009/thisweek005.html Google "history of parallax": http://www.astro.virginia.edu/~rjp0i/museum/astrometry.html for instance.	M494 & M495 should be addressed when discussing the Father Ted clip. Awareness of common misconceptions around light (M187 -- M269) M494 The Earth, Sun and Moon are all the same size. Sadler, 1987 M495 The Earth, Sun and Moon are all a similar size. Sadler, 1987 M508 The Sun (or any other star) is a planet. Lightman et al., no date

S5	Big Questions:	Approximate time: 1 hours	Context:
What is a galaxy? How do scientists measure huge distances in space? [The Light Year]			[Class activity: whole class (if possible) in a circle holding hands)]. Pupil at each end touch each terminal of an 'energy ball'. How does that work?

Activities:	Timing:	Resources:	Working Scientifically:
Preparation or Activity a: Galaxy Zoo	20 min	http://www.galaxyzoo.org/	Experimental skills and investigations c (fair test investigation)
			Numeracy and Literacy:
Activity b: Discussion of Galaxy zoo and previous lessons as indicating a need for a very large unit to measure distances: m, km,... not enough	5 min	http://bit.ly/ScaleOfUniverseApplet	Calculations of distance travelled by light.
Calculation c: Recap speed: s = d / t Given d and t we can calculate s Rearranging: d = s t, so given s and t work out d.	10 min	Worksheet, calculations.	
			Differentiation:
Calculation d: For light, work this out... light-second, light-day, light-year Also: what is the distance to the Sun, given its light takes 8 minutes to reach the Earth?	10 min	Calculator, workbook, pens.	↑ Bright students to explain and teach to less able. ↓ Many pupils struggle with rearranging equations, even using the 'triangle method'. Research on this seems to be sparse as far as I can tell (Ed.). The following might be somewhere to start Owen and Sweller (1985) *'What do students learn while solving mathematics problems?'.*
Activity e: Video of scales in the Universe	10 min	http://bit.ly/PowersOfTen1977	

Key Scientific Ideas and Guidance:	**Links to Research:**
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/	cf. Horizontal Motion misconceptions: M86 [Training in 'proportional reasoning' (Piaget, 1979) leads to improved differentiation of speed, distance and time]. Boulanger, 1976 M133 [It may be helpful to introduce the relations between distance, time and speed earlier]. diSessa, 1982; Hewson, 1982; diSessa, 1989; Saltiel and Malgrange, 1980

S6	Big Questions:	Approximate time: 1 hours	Context:
Why is all this structure present? (Balance between gravitational and other forces) Why do tides occur? How do we stay stuck to the Earth's surface? What is freefall? What is a normal contact force? Why would I feel heavier on other planets? What is weight?			Satellites. Sailing. Weather. Orbital mechanics. Newton's apple. Syllabus point: gravity forces between Earth and Moon, and between Earth and Sun (qualitative only)

Activities:	Timing:	Resources:	Working Scientifically:
Activity a: Look at historical ideas about how this is all located, discuss how this is linked to how it is moving.	40 min	Blown & Bryce for storylines	Scientific attitudes b (modification or rejection of scientific theories) Experimental skills and investigations b (predictions)
			Numeracy and Literacy:
Activity b: Look at simulation of Ptolemaic model.	10 min	http://astro.unl.edu/naap/ssm/animations/ptolemaic.swf	
Activity c: Circular motion experiment. Bung on a string, string passed through a tube with spring. Spin to elongate spring. Compare tension in spring to gravity.	10 min	http://www.nuffieldfoundation.org/practical-physics/whirling-rubber-bung-string	
			Differentiation:
Activity d: Discuss freefall, planets around Sun, satellite around Earth.	5 min	Felix Baumgartner versus a satellite	↑ Bright students to explain and teach to less able. Activity B: more able class to use computers and investigate for themselves. Activity C: More able pupils to look at qualitative relation between force (extension of spring) and rotation speed. ↓ Partner choice made for less able pupils. More teacher guided experimentation.
Activity e: Discuss normal contact force, and why that is not present for astronauts. Teacher to sit on wheeled chair and bang into wall. Distinguish between inertial force and gravitational force.	5 min	Wheelie office chair.	

Key Scientific Ideas and Guidance:	Links to Research:
SAFETY: please follow CLEAPSS advice available on http://www.cleapss.org.uk/ in the Laboratory Handbook. How were the old models shown to be incorrect? The simplest explanation is usually true. The simple idea that the reason that things fall to Earth is the same as the reason that the Moon orbits the Earth, and likewise the Earth about the Sun. Science's view of things changes over time, models used to explain are not necessarily true (Blown & Bryce reading note on Ptolemy).	Awareness of common misconceptions around gravity, weight, mass and density, falling (M401 - M467 please see www.conceptualchange.org.uk 'misconceptions' tab for a full list). Recall freefall addressed in forces section. In addition: M285 ['Cognitive conflict' is good, but not enough. Pupils also need a new model which has advantages over the one they hold.] Closset, 1983 and 1984 M286 [Teaching pupils what a model is, and that all models have limitations, can help]. Closset, 1983 and 1984 M331 Gravity is caused by magnetism. Bar and Goldmuntz, 1987 M409 Gravity is caused by the Earth's magnetism. Stead and Osborne, 1980; Vicentini-Missoni, 1981